Additively Manufactured Polymer Material Qualification Data Report for Onyx FR-A w/ Carbon Fiber FR-A and Markforged X7 System

NCAMP Project Number: NPN 032004

NCAMP Test Report Number: CAM-RP-2023-008 Rev -

Report Date: November 7, 2023

Testing Facility:

National Institute for Aviation Research
Wichita State University
1845 N. Fairmount
Wichita, KS 67260-0093

Test Coupon Fabrication Facility:

Markforged
85 School Street
Watertown, MA 02472

Prepared by:

Neville Tay
Digitally signed by Neville Tay
Date: 2023.11.20 12:14:26 -06'00'

Neville Tay

Cole Daharsh
Digitally signed by Cole Daharsh
Date: 2023.11.20 14:45:56 -06'00'

Cole Daharsh

Reviewed by:

Royal Lovingfoss
Digitally signed by Royal Lovingfoss
Date: 2023.11.20 12:50:09 -06'00'

Royal Lovingfoss

Vinsensius Tanoto
Digitally signed by Vinsensius Tanoto
Date: 2023.11.20 12:54:27 -06'00'

Vinsensius Tanoto

Evelyn Lian
Digitally signed by Evelyn Lian
Date: 2023.11.20 12:58:17 -06'00'

Evelyn Lian

Approved by:

Ed Hooper
Digitally signed by Ed Hooper
Date: 2023.11.20 12:55:28 -06'00'

Ed Hooper

REVISIONS:

Rev	By	Date	Pages Revised or Added
-	Neville Tay and Cole Daharsh	11/7/23	Document Initial Release

TABLE OF CONTENTS

List of Tables

List of Figures

1. Introduction

1.1 Scope

The scope of this Markforged Onyx FR-A and Carbon Fiber FR-A qualification was to establish a B basis allowable set for this Dual Material System (DMS). The second layer objectives include developing a Material Property Data Report (CAM, Material and Process Specification and Statistical Report of the Markforged DMS. The primary focus of this document is the Material Property Data which have been generated with National Center for Advanced Materials Performance (NCAMP) oversight. This dataset was developed in accordance with CMH-17-1G-1G (Composite Materials Handbook) and NCAMP Standard Operating Procedure (NSP-100). The Markforged material specimens have been inspected by NCAMP Authorized Inspection Representative (AIR) and testing has been witnessed by NCAMP Authorized Engineering Representative (AER).

The data reported was not intended for any specific material applications, further analysis may be required to fulfill specific properties, environments, build orientations and loading scenarios.
The use of NCAMP material and process specifications does not guarantee material or structural performance. Material users should be actively involved in evaluating material performance and quality including, but not limited to, performing regular purchaser quality control tests, performing periodic equivalency or additional testing, participating in material change management activities, conducting statistical process control, and conducting regular supplier audits.

The applicability of NCAMP material property data, material allowables, and specifications must be evaluated on a case-by-case basis by aircraft companies and certifying agencies. NCAMP assumes no liability whatsoever, expressed or implied, related to the use of the material property data, material allowables, and specifications.

This report contains the material property data only. The statistical analysis including the B basis allowables generation is detailed within the Markforged X7/Onyx Material Qualification Material Allowables Statistical Analysis Report, NCP-RP-2023-007- Rev N/C. The qualification material was procured to NCAMP Material Specification NMS 754/1 Rev A. The qualification test coupons were manufactured in accordance with NCAMP Process Specification NPS 86754 Rev B. The NCAMP Test Plan NTP AM-6754Q1 Rev B was used for this qualification program. Newer revisions of the material and process specification may contain more current information and process parameters but any deviation from the qualification standard must be carefully evaluated.

Part manufacturers that wish to use the Markforged material property data, allowables, and specifications may do so upon completion of an Equivalency study to demonstrate that they can reproduce the original material properties. More information on the Equivalency process, including limitations and test statistics can be found in Section 6 of DOT/FAA/AR-03/19 and Section 8.4.1 of CMH-17-1G. The applicability of equivalency process must be evaluated on program-by-program basis by the applicant and certifying agency. The applicant and certifying agency must agree that the equivalency test plan along with the equivalency process described in Section 6 of DOT/FAA/AR-03/19 and Section 8.4.1 of CMH-17-1G are adequate for the given

program.

Those that wish to use the data published in this report should not do so without specifying NCAMP Material Specification NMS 754/1. NMS 754/1 may have additional requirements that are listed in its material Process Control Document (PCD) and other raw material specifications and PCDs which impose essential quality controls on the raw materials and raw material manufacturing equipment and processes. *Aircraft companies and certifying agencies should assume that the material property data published in this report is not applicable when the material is not procured to NMS 754/1*. NMS 754/1 is a free, publicly available, non-proprietary aerospace industry material specification.

The data in this report is intended for general distribution to the public, either freely or at a price that does not exceed the cost of reproduction (e.g. printing) and distribution (e.g. postage).

1.2 Symbols Used

Acronyms and Definitions

B – Basis	95% lower confidence limit on the tenth population percentile
AER	Authorized Engineering Representative
AIR	Authorized Inspection Representative
AM	Additive Manufacturing
AMS	Aerospace Material Specification
ANOVA	Analysis of Variance
ASAP	Agate Statistical Analysis Program
ASME	American Society of Mechanical Engineers
ASTM	American Society for Testing and Materials
CFRA	Continuous Carbon Fiber with Fire Retardant Additive Filament
CMH-17-1G	Composite Materials Handbook 17 (formerly MIL-HDBK-17)
CTD	Cold Temperature Dry
CTE	Coefficient of Thermal Expansion
CV	Coefficient of Variation
DMA	Dynamic Mechanical Analysis
DSC	Differential Scanning Calorimetry
ETD	Elevated Temperature Dry
ETW	Elevated Temperature Wet
FAA	Federal Aviation Administration
FFF	Fused Filament Fabrication
FTIR	Fourier Transform Infrared Spectroscopy
HPLC	High Performance Liquid Chromatography
IAB	Industry Advisory Board (an NCAMP Board)
IR	Infrared spectroscopy
MAB	Manufacturers Advisory Board (an NCAMP Board)
NASA	National Aeronautics and Space Administration

NCAMP	National Center for Advanced Materials Performance
NDI	Non-Destructive Inspection
NIAR	National Institute for Aviation Research
NIST	National Institute of Standards and Technology
NMS	NCAMP Material Specification
NPS	NCAMP Process Specification
OFRA	Onyx with Fire Retardant Additive Filament
OEM	Original Equipment Manufacturer
PCD	Process Control Document
QA	Quality Assurance
QC	Quality Control
RH	Relative Humidity
RTD	Room Temperature Dry
SACMA	Suppliers of Advanced Composite Materials Association
SAE	Society of Automotive Engineers
SBS	Short Beam Strength
Tg	Glass Transition Temperature
TGA	Thermogravimetric Analyzer
TMA	Thermomechanical Analysis
WSU	Wichita State University

1.3 References

ASTM Standards

All testing was in accordance with nationally recognized standards, methods and procedures. Specific mechanical property test methods applicable to the test program in this document include:

- DO-160 Category A – Standard Humidity Environment
- DO-160 Category B - Severe Humidity Environment
- ASTM D256-10(2018) – Standard Test Methods for Determining the IZOD Pendulum Impact Resistance of Plastics
- ASTM D790-17 – Standard Test Method for Flexural Properties of Unreinforced and Reinforced Plastics and Electrical Insulating Materials
- ASTM D792- 20 – Standard Test Methods for Density and Specific Gravity (Relative Density) of Plastics by Displacement
- ASTM D2344/D2344M- 16 – Standard Test Method for Short-Beam Strength of Polymer Matrix Composite Materials and Their Laminates
- ASTM D3039/D3039M- 17 – Standard Test Method for Tensile Properties of Polymer Matrix Composite Materials

- ASTM D3171- 15 – Standard Test Methods for Constituent Content of Composite Materials
- ASTM D3518/D3518M- 18 – Standard Test Method for In-Plane Shear Response of Polymer Matrix Composite Materials by Tensile Test of a ±45° Laminate
- ASTM D3418-15 - Standard Test Method for Transition Temperatures and Enthalpies of Fusion and Crystallization of Polymers by Differential Scanning Calorimetry (DSC)
- ASTM D5766/D5766M-11(2018) – Standard Test Method for Open Hole Tensile Strength of Polymer Matrix Composite Laminates
- ASTM D5961/D5961M-17 – Standard Test Method for Bearing Response of Polymer Matrix Composite Laminates
- ASTM D6484/D6484M-20 – Standard Test Method for Open-Hole Compressive Strength of Polymer Matrix Composite Laminates
- ASTM D6641/D6641M- 16e1 – Standard Test Method for Compressive Properties of Polymer Matrix Composite Materials Using a Combined Loading Compression (CLC) Test Fixture
- ASTM D6742/D6742M-17 – Standard Practice for Filled-Hole Tension and Compression Testing of Polymer Matrix Composite Laminates
- ASTM E831- 19 – Standard Test Method for Linear Thermal Expansion of Solid Materials by Thermomechanical Analysis
- ASTM D7028-07(2015) – Standard Test Method for Glass Transition Temperature (DMA Tg) of Polymer Matrix Composites by Dynamic Mechanical Analysis (DMA)
- FAR 25.853 (A), Appendix F, Part I – Vertical Burn
- FAR 25.853 (D), Appendix F, Part IV – Heat Release
- FAR 25.853 (D), Appendix F, Part IV – Smoke Density

1.4 Methodology

1.4.1 Process Definition

The testing process was designed around four main categorical comparators. The material lot or batch (A, B and C), the machine used to print the parts (M1 or M2), the print orientation with the first character as the primary axis (XY, XZ and ZX) and the CFRA (CF30) fiber fill described by No Fiber (NF) Partial Fiber (PF) and Full Fiber (FF). The test specimens identified with NF are solely composed of OFRA, which are built with ± 45° infill raster at 100% fill. Specimens identified with PF and FF are fabricated with both the OFRA and CFRA material. The FF fill configuration fits as much CFRA in the test specimen as possible, while the PF fill configuration fits less than the maximum allowable amount of fiber within the test specimen. Infill strategy for the PF and FF are similar, and are dependent on specimen orientation. The infill strategy (fiber angles) are typically either all 0° fiber, ±45° fiber, or a quasi-isotropic stack. The specimen selection and coupon count design is pictorially depicted below in Figure 1-1.

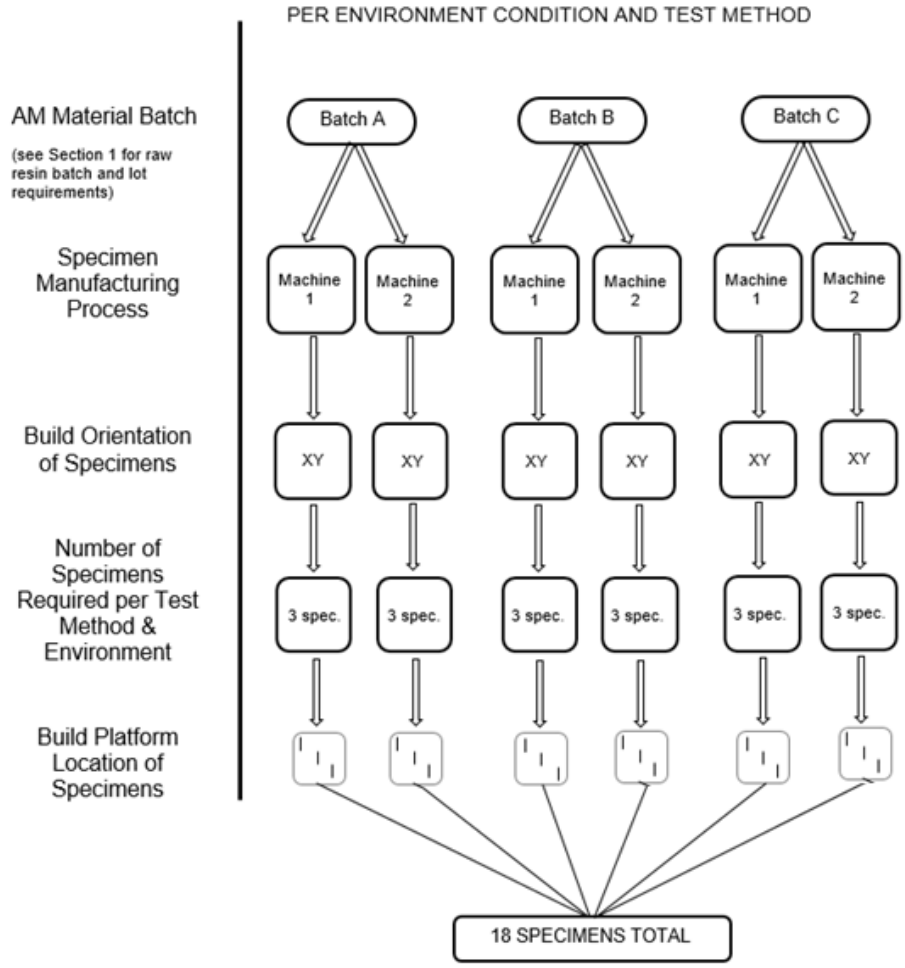


Figure 1-1: Specimen Selection Methodology

All specimens will be fabricated in accordance with NCAMP Process Specification NPS 86754.

In order to facilitate individual specimen traceability, each specimen will carry a unique specimen identifier as described in Section 1.4.2 of this document. To help in verifying build platform location of specimen, the following nomenclature will be used: 11- Top Left Corner, 12-Middle, 13-Bottom Right Corner.

1.4.2 **NIAR-Specimen Naming Format**

All specimens were uniquely identified using the following reference system: The Test Plan Document Number – AM Material Manufacturer ID – Material Code-Fabricator ID – Fabricator ID – Batch ID – Machine ID – Print Number – Build Orientation – Actual Test Types ID – Specimen Build Location ID – Test Condition – Fiber Volume – Specimen Number. Specimen Build Orientation is depicted in Figure 1-2 below.

NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M1-P10001-XY-OHT-11-RTD-FF-3												
Document Number	AM Material Manufacturer ID	Material Code	Fabricator ID	Batch ID	Machine ID	Print Number	Build Orientation	Test Type ID	Specimen Build Orientation	Test Condition	Fiber Placement	Specimen Number

Some coupons were printed to replace data points that have been omitted due to test anomalies. These specimens are distinguished with an (R) at the end of their string name; ie. following the specimen number.

For the purpose of plotting graphs and data analysis, an assigned Batch ID is referenced (i.e.: AM Batch A as # 1, AM Batch B as # 2, etc). This is used in section 4 of this report.

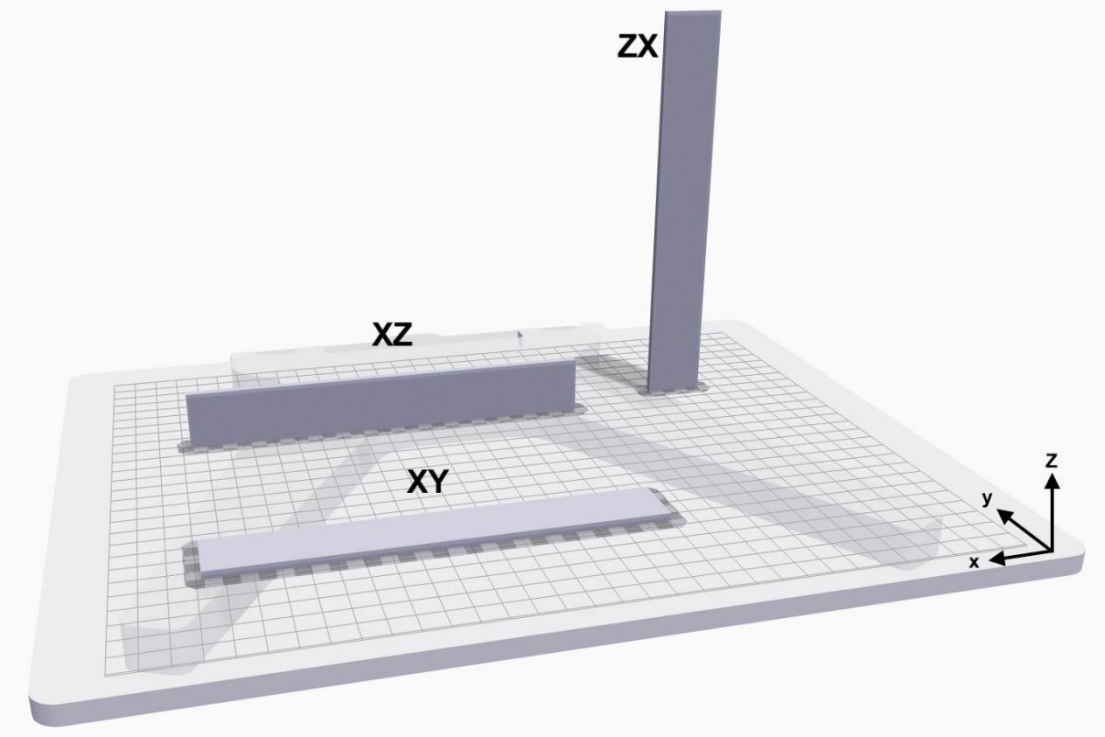


Figure 1-2: Specimen Build Orientation Diagram

1.4.3 Specimen & Testing Details

1.4.3.1 Tabbing

No tabs were used for this program.

1.4.3.2 Specimen Strain Device Used

Corresponding Gage ID can be obtained from Appendix 1 of NTP AM-6754Q1.

Biaxial gages were used on:

All conditions of Combined Loading Compression (CLC).

Biaxial Extensometers were used on:

All conditions of Tension and In-Plane Shear (IPS) Tension.

Clip Gage were used on:

All conditions of Single Shear Bearing

Deflectometers were used on:

All conditions of Flex.

1.4.3.3 Specimen Dimensions & Test Configuration

For filled-hole tension (FHT) and Single-shear bearing (SSB) tests, the fasteners were installed to 30±5 in-lb above the prevailing torque. Fasteners were installed after machining and before drying or moisture conditioning. For filled-hole and bearing tests, the hole diameter was 0.25 in -0.000 +0.003 in. The following fasteners were used:

NASM21297-04004 bolts with MS21084 nuts and MS21206 washers for FHT.
NASM21297-04016 bolts with MS21084 nuts and MS21206 washers for SSB.

Open and Filled-Hole Tension specimens were machined to 8.0” in length instead of 12.0”.

For all tension testing, 120 grit sand paper were used at the specimen grip area to reduce stress risers caused by wedge grips.

For all XY orientation flexural testing, the print bed face is tested facing up.

1.4.4 Mechanical Test Matrix

The tables below show the test matrices for each combination of test type and build orientation.

Table 1. AM Material Mechanical Test

				Number of Batches x Number of Machines x Number of Specimens			
				Test Temperature / Moisture Condition (7)			
Build Orientation	Test Type	Fiber Volume	Property	CTD (-65°F) (10)	RTD (70°F)	ETD (130°F) 11	ETW (130°F) (11)
XY(11)	Tension ASTM D3039 [0° Fiber]	PF (6)	Strength and Modulus and Poisson’s	3x2x3	3x2x3	3x2x3	3x2x3
XZ (4)	Tension ASTM D3039	PF (6)	Strength and Modulus and Poisson’s	3x2x3	3x2x3	3x2x3	3x2x3
ZX (12)	Tension ASTM D3039	PF (6)	Strength and Modulus and Poisson’s	-	6 Specimens (9)	-	-
ZX	Tension ASTM D3039	NF	Strength and Modulus and Poisson’s	3X2X3	3x2x3	3X2X3	3X2X3
XY(11)	Compression ASTM D6641 [0° Fiber] (1)	PF (6)	Offset Strength and Modulus and Poisson’s	3x2x3	3x2x3	3x2x3	3x2x3
XZ (4)	Compression ASTM D6641 (1)(5)	PF (6)	Offset Strength and Modulus and Poisson’s	3x2x3	3x2x3	3x2x3	3x2x3

ZX (12)	Compression ASTM D6641 (1)	PF (6)	Offset Strength and Modulus and Poisson's	-	6 Specimens (9)	-	-
ZX	Compression ASTM D6641 (1)(5)	NF	Offset Strength and Modulus and Poisson's	3X2X3	3x2x3	3X2X3	3X2X3
XY	Flex ASTM D790 [0° Fiber] (2)	PF (6)	Strength and Modulus	3x2x3	3x2x3	3x2x3	3x2x3
XZ (4)	Flex ASTM D790 (2)	PF (6)	Strength and Modulus	3x2x3	3x2x3	3x2x3	3x2x3
ZX (12)	Flex ASTM D790 (2)	PF (6)	Strength and Modulus	-	6 Specimens (9)	-	-
ZX	Flex ASTM D790 (2)	NF	Strength and Modulus	3X2X3	3x2x3	3X2X3	3X2X3
XY	In-Plane Shear ASTM D3518 [±45°Fiber] (3)	PF (6)	Strength and Modulus	3x2x3	3x2x3	3x2x3	3x2x3
XY	Short-Beam Strength ASTM D2344 [0° Fiber] (5)	PF (6)	Strength	3X2X3	3X2X3	3x2x3	3x2x3
XY(11)	Open-Hole Tension ASTM D5766 (7)(10)	PF (6)	Strength	3X2X3	3X2X3	3X2X3	3X2X3
XZ (4)	Open-Hole Tension ASTM D5766 (7)(10)	PF (6)	Strength	3X2X3	3X2X3	3X2X3	3X2X3
ZX (12)	Open-Hole Tension ASTM D5766 (7)(10)	PF (6)	Strength	-	6 Specimens (9)	-	-
ZX	Open-Hole Tension ASTM D5766 (7)(10)	NF	Strength	3X2X3	3X2X3	3X2X3	3X2X3
XY(11)	Filled-Hole Tension ASTM D6742 (8)(10)	PF (6)	Strength	3X2X3	3X2X3	3X2X3	3X2X3
XZ (4)	Filled-Hole Tension ASTM D6742 (8)(10)	PF (6)	Strength	3X2X3	3X2X3	3X2X3	3X2X3
ZX (12)	Filled-Hole Tension ASTM D6742 (8)(10)	PF (6)	Strength	-	6 Specimens (9)	-	-
ZX	Filled-Hole Tension ASTM D6742 (8)(10)	NF	Strength	3X2X3	3X2X3	3X2X3	3X2X3
XY(11)	Single Shear Bearing ASTM D5961 proc. C (9)(10)	PF (6)	Strength & Deformation	3X2X3	3X2X3	-	3X2X3

XZ (4)	Single Shear Bearing ASTM D5961 proc. C (9)(10)	PF (6)	Strength & Deformation	3X2X3	3X2X3	-	3X2X3
ZX (12)	Single Shear Bearing ASTM D5961 proc. C (9)(10)	PF (6)	Strength & Deformation	-	6 Specimens (9)	-	-
ZX	Single Shear Bearing ASTM D5961 proc. C (9)(10)	NF	Strength & Deformation	3X2X3	3X2X3	-	3X2X3
XY(11)	IZOD Pendulum Impact ASTM D256	PF (6)	Impact Resistance	-	1X2X3	-	-
XZ (4)	IZOD Pendulum Impact ASTM D256	PF (6)	Impact Resistance	-	1X2X3	-	-
ZX (12)	IZOD Pendulum Impact ASTM D256	PF (6)	Impact Resistance	-	1x2x3	-	-

Notes:

(1) Back-back strain gauges will be used on all specimens. An appropriate extensometer may be used in place of the strain gauges if the test fixture does not allow strain gauge use. Buckling may not be identifiable when using extensometer. Strength offset values shall be reported. If buckling occurs an extensometer will be used to determine modulus along with strain gages.

(2) ASTM D790 Flex Procedure B. Support Span to Depth ratio = 16:1.

(3) Initial layers of build need to be · 45° Raster as well

(4) All XZ Specimens printed with 0° Fiber due to specimen thickness and printer capabilities.

(5) All ZX Specimens with fiber are printed with 0° Fiber due to specimen thickness and printer capabilities. Due to orientation, 0° Fiber build direction in the ZX orientation will look like the specimen was printed with 90° fiber when laid flat.

(6) Test temperature and wet condition requirements necessitate flexibility with regards to material thermal properties, the standard operating conditions used for composites will not correlate directly with AM materials.

(7) Fiber Volume percentage is dependent on print orientation and will therefore vary between orientations of the same test geometry as stated in section 5.1.3 of the NTP AM-6754Q1.

(8) Gripping length of 2.5" required.

(9) Test for informational purposes (specimens may be from any material batch or machine combination)

(10) Cold temperature test conditions utilize external aircraft temperature requirements, this material is characterized for interior applications.

(11) Per Section 4 of DO-160 "Temperature and Altitude", the elevated test temperature utilized for this program follows the requirements defined for equipment under Category A1.

All specimens printed without tabs

Table 2 – AM Material Mechanical Tests [Full Fiber Sub-set]

				Number of Batches x Number of Machines x Number of Specimens			
				Test Temperature / Moisture Condition (5)			
Build Orientation	Test Type	Fiber Volume	Property	CTD (-65°F)	RTD (70°F)	ETD (130°F)	ETW (130°F)
XY	Tension ASTM D3039 [0° Fiber]	FF (6)	Strength and Modulus and Poisson's	-	1x2x3	-	-
XZ (4)	Tension ASTM D3039 [0° Fiber]	FF (6)	Strength and Modulus and Poisson's	-	1x2x3	-	-
XY	Compression ASTM D6641 [0° Fiber] (1)	FF (6)	Offset Strength and Modulus and Poisson's	-	1x2x3	-	-
XZ (4)	Compression ASTM D6641 [0° Fiber] (1)	FF (6)	Offset Strength and Modulus and Poisson's	-	1x2x3	-	-
XY	Flex ASTM D790 [0° Fiber] (2)	FF (6)	Strength and Modulus	-	1x2x3	-	-
XZ (4)	Flex ASTM D790 [0° Fiber] (2)	FF (6)	Strength and Modulus	-	1x2x3	-	-
XY	In-Plane Shear ASTM D3518 [±45°Fiber] (3)	FF (6)	Strength and Modulus	-	1x2x3	-	-

Notes:

(1) Back-back strain gauges will be used on all specimens. An appropriate extensometer may be used in place of the strain gauges if the test fixture does not allow strain gauge use. Buckling may not be identifiable when using extensometer. Strength offset values shall be reported. If buckling occurs an extensometer will be used to determine modulus along with strain gages.

(2) ASTM D790 Flex Procedure B. Support Span to Depth ratio = 16:1.

(3) Initial layers of build need to be ±45° Raster as well

(4) All XZ Specimens printed with 0° Fiber due to specimen thickness and printer capabilities.

(5) Test temperature and wet condition requirements necessitate flexibility with regards to material thermal properties, the standard operating conditions used for composites will not correlate directly with AM materials.

(12) Fiber Volume percentage is dependent on print orientation and will therefore vary between orientations of the same test geometry as stated in section 5.1.3 of the NTP AM-6754Q1.

All specimens are fabricated on printers that are not being used for the qualification, three batch test matrix utilizes Machine 1 & 2. Supplementary printers include Machines 3 & 4

All specimens printed without tabs

Table 3 summarizes the design guidance level tests to be carried out. The three build orientations are XY, XZ and ZX. The build orientations in this program are not specific to any design. Therefore, careful consideration should be given to the validity of properties derived from this program based on the design specific orientations in a structure to be certified.

Table 3 emphasizes those properties and test condition combinations believed to constitute the worst case, which in general is hot wet for polymer matrix material properties.

For the single shear bearing tests, the ASTM D5961 One-Piece Single-Shear Test Set-Up (Procedure C) will be used.

Table 3 – AM Material Mechanical Tests (Design Guidance Properties)

Build Orientation	Test Type	Fiber Content	Property	Number of Batches x Number of Machines x Number of Specimens			
				Test Temperature / Moisture Condition (8)			
				CTD (-65°F)	RTD (70°F)	ETD (130ºF)	ETW (130°F)
XY	Open-Hole Tension ASTM D5766 (1)(4)(10)	PF (5)(9)	Strength	3X2X3	3X2X3	3X2X3	3X2X3
XZ (6)	Open-Hole Tension ASTM D5766 (1)(4)(10)	PF (9)	Strength	3X2X3	3X2X3	3X2X3	3X2X3
ZX (7)	Open-Hole Tension ASTM D5766 (1)(4)(10)	PF (9)	Strength	-	6 Specimens (11)	-	-
ZX	Open-Hole Tension ASTM D5766 (1)(4)(10)	NF	Strength	3X2X3	3X2X3	3X2X3	3X2X3
XY	Filled-Hole Tension ASTM D6742 (2)(4)(10)	PF (5)(9)	Strength	3X2X3	3X2X3	3X2X3	3X2X3
XZ (6)	Filled-Hole Tension ASTM D6742 (2)(4)(10)	PF (9)	Strength	3X2X3	3X2X3	3X2X3	3X2X3
ZX (7)	Filled-Hole Tension ASTM D6742 (2)(4)(10)	PF (9)	Strength	-	6 Specimens (11)	-	-
ZX	Filled-Hole Tension ASTM D6742 (2)(4)(10)	NF	Strength	3X2X3	3X2X3	3X2X3	3X2X3
XY	Single Shear Bearing ASTM D5961 proc. C (3)(4)	PF (5)(9)	Strength & Deformation	3X2X3	3X2X3	-	3X2X3
XZ (6)	Single Shear Bearing ASTM D5961 proc. C (3)(4)	PF (9)	Strength & Deformation	3X2X3	3X2X3	-	3X2X3
ZX (7)	Single Shear Bearing ASTM D5961 proc. C (3)(4)	PF (9)	Strength & Deformation	-	6 Specimens (11)	-	-

ZX	Single Shear Bearing ASTM D5961 proc. C (3)(4)	NF	Strength & Deformation	3X2X3	3X2X3	-	3X2X3
XY	IZOD Pendulum Impact ASTM D256	PF (5)(9)	Impact Resistance	-	1X2X3	-	-
XZ (6)	IZOD Pendulum Impact ASTM D256	PF (9)	Impact Resistance	-	1X2X3	-	-
ZX (7)	IZOD Pendulum Impact ASTM D256	PF (9)	Impact Resistance	-	1x2x3	-	-

Notes:

(1) Open-hole test configuration: 0.25 inch hole diameter, 1.5 inch width.

(2) Filled-hole test configuration: 0.25 inch hole diameter, 1.5 inch width, see section 2 for fastener callout.

(3) Single shear bearing test configuration: 0.25 inch hole diameter, 1.5 inch width, e/D = 3, ASTM D5961 Procedure C, see section 2 for fastener callout.

(4) DO NOT PRINT HOLE. Specimen with hole will be drilled/ reamed by machine.

(5) Quasi fiber orientation for FF Fiber Content specimens of XY orientation. Fiber orientation will follow in this manner from build plate to top of specimen: [45/0/-45/90____90/-45/0/45]. Quasi fiber orientation for PF Fiber Content specimens of XY orientation will follow the same pattern but will be limited by the number of layers containing fiber due to Partial Fill.

(6) All XZ Specimens can only be printed with 0° Fiber due to specimen thickness and printer capabilities.

(7) All ZX Specimens with fiber are printed with 0° Fiber due to specimen thickness and printer capabilities. Due to orientation, 0° Fiber build direction in the ZX orientation will look like the specimen was printed with 90° fiber when laid flat.

(8) Test temperature and wet condition requirements necessitate flexibility with regards to material thermal properties, the standard operating conditions used for composites will not correlate directly with AM materials.

(9) Fiber Volume percentage is dependent on print orientation and will therefore vary between orientations of the same test geometry as stated in section 5.1.3 of the NTP AM-6754Q1 Rev B.

(10) Gripping length of 2.5" required.

(11) Test for informational purposes (specimens may be from any material batch or machine combination)

Table 4 – AM Material Mechanical Tests (Design Guidance Properties) [Full Fiber Sub-set]

Build Orientation	Test Type	Fiber Content	Property		Number of Batches x Number of Machines x Number of Specimens		
					Test Temperature / Moisture Condition (8)		
				CTD (-65°F)	RTD (70°F)	ETD (130°F)	ETW (130°F)
XY	Open-Hole Tension ASTM D5766 (1)(5)(10)	FF (6)(9)	Strength	-	1X2X3	-	-
XZ (7)	Open-Hole Tension ASTM D5766 (1)(5)(10)	FF (9)	Strength	-	1X2X3	-	-

XY	Filled-Hole Tension ASTM D6742 (2)(5)(10)	FF (6)(9)	Strength	-	1X2X3	-	-
XZ (7)	Filled-Hole Tension ASTM D6742 (2)(5)(10)	FF (9)	Strength	-	1X2X3	-	-
XY	Single Shear Bearing ASTM D5961 (4)(5)	FF (6)(9)	Strength & Deformation	-	1X2X3	-	-
XZ (7)	Single Shear Bearing ASTM D5961 (4)(5)	FF (9)	Strength & Deformation	-	1X2X3	-	-
XY	IZOD Pendulum Impact ASTM D256	FF (6)(9)	Impact Resistance	-	1X2X3	-	-
XZ (7)	IZOD Pendulum Impact ASTM D256	FF (9)	Impact Resistance	-	1X2X3	-	-

Notes:

(1) Open-hole test configuration: 0.25 inch hole diameter, 1.5 inch width.

(2) Filled-hole test configuration: 0.25 inch hole diameter, 1.5 inch width, see section 2 for fastener callout.

(3) Strength offset values shall be reported when improper failure mode at ultimate strength is observed.

(4) Single shear bearing test configuration: 0.25 inch hole diameter, 1.5 inch width, e/D = 3, ASTM D5961 Procedure C, see section 2 for fastener callout.

(5) DO NOT PRINT HOLE. Specimen with hole will be drilled/ reamed by machine.

(6) Quasi fiber orientation for FF Fiber Content specimens of XY orientation. Fiber orientation will follow in this manner from build plate to top of specimen: [45/0/-45/90____90/-45/0/45]. Quasi fiber orientation for PF Fiber Content specimens of XY orientation will follow the same pattern but will be limited by the number of layers containing fiber due to Partial Fill.

(7) All XZ Specimens can only be printed with 0° Fiber due to specimen thickness and printer capabilities.

(8) Test temperature and wet condition requirements necessitate flexibility with regards to material thermal properties, the standard operating conditions used for composites will not correlate directly with AM materials.

(9) Fiber Volume percentage is dependent on print orientation and will therefore vary between orientations of the same test geometry as stated in section 5.1.3 of the NTP AM-6754Q1 Rev B.

(10) Gripping length of 2.5" required.

All specimens are fabricated on printers that are not being used for the qualification, three batch test matrix utilizes Machine 1 & 2. Supplementary printers include Machines 3 & 4

1.4.5 Physical Testing

The properties in Table 5 shall be determined for each test type and build orientation. The tests will be performed by the National Institute for Aviation Research (NIAR) Composites Laboratory or an approved laboratory under the supervision of NCAMP. These tests may be repeated by the participating fabricators.

Table 5 – FFF AM Material Physical Test

				# of Batches x # of Machines x # of Specimens
Build Orientation	**Condition / Method**	**Fiber Content**	**Property**	**Specimen Count**
ZX	ASTM D3171-15/or applicable mechanical test method.	PF	Thickness	All data from mechanical test specimens
XZ	ASTM D3171-15/or applicable mechanical test method.	PF	Thickness	All data from mechanical test specimens
XY	ASTM D3171-15/or applicable mechanical test method.	PF	Thickness	All data from mechanical test specimens
ZX	ASTM D3171-15/or applicable mechanical test method.	FF	Thickness	All data from mechanical test specimens
XZ	ASTM D3171-15/or applicable mechanical test method.	FF	Thickness	All data from mechanical test specimens
XY	ASTM D3171-15/or applicable mechanical test method.	FF	Thickness	All data from mechanical test specimens
ZX	ASTM D792-13	PF	Density	3x2x5
ZX	ASTM D792-13	FF	Density	3x2x5
ZX	ASTM D792-13	NF	Density	3x2x5
ZX	CP6101 and CP6102 (Note 2)	N/A	Photomicrograph	Per Note 1
XZ	CP6101 and CP6102 (Note 2)	N/A	Photomicrograph	Per Note 1
XY	CP6101 and CP6102 (Note 2)	N/A	Photomicrograph	Per Note 1
ZX	ASTM E831-19	PF	CTE by TMA	3x2x1 (5)

XZ	ASTM E831-19	PF	CTE by TMA	3x2x1 (5)
XY	ASTM E831-19	PF	CTE by TMA	3x2x1 (5)
ZX	ASTM E831-19	FF	CTE by TMA	3x2x1 (5)
XZ	ASTM E831-19	FF	CTE by TMA	3x2x1 (5)
XY	ASTM E831-19	FF	CTE by TMA	3x2x1 (5)
ZX	ASTM E831-19	NF	CTE by TMA	3x2x1 (5)
XZ	ASTM E831-19	NF	CTE by TMA	3x2x1 (5)
XY	ASTM E831-19	NF	CTE by TMA	3x2x1 (5)
XY	ASTM E831-19	FF ±45	CTE by TMA	3x2x1 (5)
XY	ASTM E831-19	PF ±45	CTE by TMA	3x2x1 (5)
XY	ASTM E831-19	FF Quasi	CTE by TMA	3x2x1 (5)
XY	ASTM E831-19	PF Quasi	CTE by TMA	3x2x1 (5)
ZX	ASTM D7028-07 (DRY)	PF	Glass Transition Temperature	3x2x3
XZ	ASTM D7028-07 (DRY)	PF	Glass Transition Temperature	3x2x3
XY	ASTM D7028-07 (DRY)	PF	Glass Transition Temperature	3x2x3
XY	ASTM D7028-07 (DRY)	FF	Glass Transition Temperature	3x1x1 (5)
XY	ASTM D7028-07 (DRY)	NF	Glass Transition Temperature	3x1x1 (5)
XY	ASTM D7028-07 (DRY)	PF Quasi	Glass Transition Temperature	1x2x3
XY	ASTM D7028-07 (DRY)	FF Quasi	Glass Transition Temperature	1x2x3
ZX	ASTM D7028-07 (WET)	PF	Glass Transition Temperature	3x2x3
XZ	ASTM D7028-07 (WET)	PF	Glass Transition Temperature	3x2x3
XY	ASTM D7028-07 (WET)	PF	Glass Transition Temperature	3x2x3
XY	ASTM D7028-07 (WET)	FF	Glass Transition Temperature	3x1x1 (5)
XY	ASTM D7028-07 (WET)	NF	Glass Transition Temperature	3x1x1 (5)
XY	ASTM D7028-07 (WET)	PF Quasi	Glass Transition Temperature	1x2x3

XY	ASTM D7028-07 (WET)	FF Quasi	Glass Transition Temperature	1x2x3
N/A	ASTM D3418-15	FF	Glass Transition Temperature & Melt Temperature, Enthalpy	3x1x1 (5)
N/A	ASTM D3418-15	PF	Glass Transition Temperature & Melt Temperature, Enthalpy	3x1x1 (5)
N/A	ASTM D3418-15	NF	Glass Transition Temperature & Melt Temperature, Enthalpy	3x1x1 (5)
ZX	FAR 25.853 (D) Appendix F, Part IV	PF	Flammability: heat release peak, drip time	3x2x3 (4)
XZ	FAR 25.853 (D) Appendix F, Part IV	PF	Flammability: heat release peak, drip time	3x2x3 (4)
XY	FAR 25.853 (D) Appendix F, Part IV	PF	Flammability: heat release peak, drip time	3x2x3 (4)
ZX	FAR 25.853 (A), Appendix F, Part I, (a), 1, (i): 60 sec	PF	Flammability Vertical Burn: extinguishing time, burn length	3x2x3 (4)
XZ	FAR 25.853 (A), Appendix F, Part I, (a), 1, (i): 60 sec	PF	Flammability Vertical Burn: extinguishing time, burn length	3x2x3 (4)
XY	FAR 25.853 (A), Appendix F, Part I, (a), 1, (i): 60 sec	PF	Flammability Vertical Burn: extinguishing time, burn length	3x2x3 (4)
ZX	FAR 25.853 (D), Appendix F, PART V	PF	NBS Smoke and Density	3x2x3 (4)
XZ	FAR 25.853 (D), Appendix F, PART V	PF	NBS Smoke and Density	3x2x3 (4)
XY	FAR 25.853 (D), Appendix F, PART V	PF	NBS Smoke and Density	3x2x3 (4)
ZX	FAR 25.853 (D), Appendix F, PART V	NF	NBS Smoke and Density	1x1x3 (3)
ZX	FAR 25.853 (D), Appendix F, PART V	FF	NBS Smoke and Density	1x1x3 (3)

Notes:

(1) Test five specimens from each batch, machine, and build orientation, fiber volume. Example: Test five specimens of the XY orientation for Batch A, Machine 1 with PF fiber volume. Then test five specimens of the XY orientation for Batch A, Machine 2. Continue in this manner through all orientation, machine, batch, and fiber volume combinations.

(2) NIAR internal procedures.

(3) 3 specimens required. The printer does not have to be one of the printers from the qualification printer set.

(4) One qualification print machine must be used, the second machine does not have to be a qualified machine.

(5) All specimens fabricated in Build Location 13.

All specimens requiring fiber will be fabricated with a 0^{o} fiber orientation unless otherwise specified

1.4.6 **Environmental Conditioning**

The following tests were performed by the NIAR Composites Laboratory under the supervision of NCAMP.

CTD = -65±5°F, dry
RTD = 70±10°F, dry
ETD = 130±5°F, dry
ETW = 130±5°F, wet

Within each test method and test environment, the failure mode was evaluated immediately after each test by an NCAMP staff engineer or NCAMP AER. In cases where excessive deformation occurred (such as compression), an appropriate failure mode may not have been obtained. All tested specimens were digitally photographed after each test in order to pictorially document failure modes.

For dry testing, specimens were dried at 120°F±5°F for at least 7 days. During the drying process, specimens were oriented on its side (along the width edge). After drying, specimens were kept in a sealed plastic bag with a descant for a maximum of 14 days until mechanical testing. Room Temperature laboratory condition is defined as 70°F±10°F, since moisture absorption and desorption rate for polymer is very slow at ambient temperature, there was no requirement to maintain relative humidity levels.

For wet conditioning, specimens were dried at 120°F±5°F for a minimum of 7 days before being conditioned for a 48-hour cycle at 120°F±5°F and 95% ± 5% following DO-160 (Category A) Standard Humidity Environment, shown below. During the wet conditioning process, specimens were also oriented on its side (along the width edge).

Step 1: Install the test item in the test chamber, and ensure its configuration is representative of that used in actual service.

Step 2: Stabilize the test item at 38±2 °C and 85±4 % RH.

Step 3: Over a two-hour period, ±10 minutes, raise the chamber temperature to 50±2 °C and humidity to 95±4 % RH.

Step 4: Maintain the chamber temperature at 50±2 °C and humidity at 95±4 % RH for six hours minimum.

Step 5: During the next 16-hour period, ±15 minutes, decrease the temperature gradually to 38±2 °C or lower. During this period, keep the humidity as high as possible and do not allow it to fall below 85 % RH.

Step 6: Steps 3, 4 and 5 constitute a cycle. Repeat these steps until a total of two cycles (48 hours of exposure) have been completed.

Figure 1.4.6-1: Standard humidity conditioning per DO-160 section 6.3.1 (Category A)

The specimens were removed from the environmental chamber and placed in a sealed plastic bag along with a moist cotton towel for a maximum of 14 days until mechanical testing. Strain-gaged specimens were removed from the controlled environment for a maximum of 2 hours for application of gages in ambient laboratory conditions.

1.4.7 **Non-ambient Testing**

The chamber was of adequate size so that all test fixtures and load frame grips were contained within the chamber. For elevated temperature testing, the chamber, test fixture, and grips, for tension tests, were preheated to the specified temperature. Each specimen was heated to the required test temperature as verified by a thermocouple in direct contact with and taped to the specimen gage section. The heat-up time of the specimen did not exceed 5 minutes, unless otherwise specified in individual test summary sheets. The test was started 5^{+1}_{-0} minutes after the specimen reached the test temperature. During the test, the temperature, as measured on the specimen, was maintained within ±5°F of the required test temperature.

For subzero temperature testing, each specimen was cooled to the required test temperature as verified by a thermocouple in direct contact with and taped to the specimen gage section. The test started 5^{+1}_{-0} minutes after the specimen reached the test temperature. During the test, the temperature, as measured on the specimen, was maintained within ±5°F of the required test temperature.

1.4.8 **Fluid Sensitivity Screening**

Table 6 lists the requirements for fluid sensitivity screening, which requires ASTM D3039 tension testing on specimens dried at 120°F±5°F for 5-7 days before being subjected to the conditions indicated, five replicates per fluid from one AM material batch and only one machine. All specimens will be printed in the XY orientation and PF fiber volume with one specimen from the center build location (BL 12) and two specimens each from each of the corner locations (BL 11 & 13).

Specimens should be cleaned with a dry towel prior to the tests. In addition to tension strength, load versus displacement curves shall be plotted to aid in the identification of polymer softening. Since load versus displacement curves are influenced by test machine and fixture compliance, all the tests should be performed with the identical machine and fixture (if used), preferably through a single setup. It is intended that the fluid resistance testing be performed on a limited number of specimen types and that engineering judgment be used to determine the necessity of repetition for other configurations. Experience suggests that each AM material may have different solutions that are detrimental to its mechanical property capability. Should screening tests for fluid sensitivity indicate this to be the case, further testing of a particular solution may or may not be needed to confirm the detrimental effect.

Table 6 – Fluid Sensitivity Screening

Extended Contact:	Exposure	Test Condition	Code (1)
100 Low Lead Aviation Fuel (ASTM D910)	90 days min. @ 70°F±10°F	70°F	TFS11RT
	90 days min. @ 70°F±10°F	160°F (2)	TFS11ET
ASTM D1655 Jet A Fuel (other jet fuel may be used but its type must be reported)	90 days min. @ 70°F±10°F	70°F	TFS12RT
	90 days min. @ 70°F±10°F	160°F (2)	TFS12ET
MIL-PRF-5606 Hydraulic Oil	90 days min. @ 70°F±10°F	70°F	TFS13RT
	90 days min. @ 70°F±10°F	160°F (2)	TFS13ET
MIL-PRF-83282 Hydraulic Oil	90 days min. @ 70°F±10°F	70°F	TFS14RT
	90 days min. @ 70°F±10°F	160°F (2)	TFS14ET
MIL-PRF-7808 Engine Oil	90 days min. @ 70°F±10°F	70°F	TFS15RT
	90 days min. @ 70°F±10°F	160°F (2)	TFS15ET
MIL-PRF-23699, Class STD Engine Oil	90 days min. @ 70°F±10°F	70°F	TFS16RT
	90 days min. @ 70°F±10°F	160°F (2)	TFS16ET
Sea Water (ASTM D1141 or equiv.)	90 days min. @ 70°F±10°F	70°F	TFS17RT
	90 days min. @ 70°F±10°F	160°F (2)	TFS17ET
Skydrol LD-4 (SAE AS1241, Type IV, Class 1)	90 days min. @ 70°F±10°F	70°F	TFS18RT
	90 days min. @ 70°F±10°F	160°F (2)	TFS18ET
50% Water with 50% Skydrol LD-4 (SAE AS1241, Type IV, Class 1)	90 days min. @ 70°F±10°F	70°F	TFS19RT
	90 days min. @ 70°F±10°F	160°F (2)	TFS19ET
Short Duration Contact:			
MEK washing fluid. ASTM D740	90 minutes min. @ 70°F±10°F	70°F	TFS21RT
	90 minutes min. @ 70°F±10°F	160°F	TFS21ET
Polypropylene Glycol Deicer (Type I) SAE AMS 1424	90 minutes min. @ 70°F±10°F	70°F	TFS22RT
	90 minutes min. @ 70°F±10°F	160°F	TFS22ET
Isopropyl Alcohol Deicing Agent (TT-I-735)	48±4 hours @70°F±10°F	70°F	TFS23RT
	48±4 hours @70°F±10°F	160°F	TFS23ET
Control Tests:			
Distilled Water	90 days min. at 70°F±10°F	70°F	TFS31RT
	90 days min. at 70°F±10°F	160°F (2)	TFS31ET
Dry	Dry per section 5.2 of the NTP AM-6754Q1 Rev B	70°F	TFS32RT
	Dry per section 5.2 of the NTP AM-6754Q1 Rev B	160°F	TFS32ET

Notes:

(1) Specimens to be produced from material Batch A

(2) Gripping length of 2.5" required.

All specimens can be fabricated on a printer that is not being used for the qualification

1.4.9 **Inspection Verification**

The qualification test specimens have been fabricated according to the requirements of the test plan and conformed by an NCAMP AIR

Test setup and witnessing was delegated to an NCAMP AER. Mechanical testing was carried out at the National Institute for Aviation Research, Wichita State University. The inspection documentation, with required approval signatures are stored in hard copy as well as electronically.

1.4.10 **Material Pedigree Information**

The AMC Data Collection Template includes the material pedigree information required, such as material and batch/lot information, as well as specimen fabrication record, environmental conditioning, test equipment, and test procedures. This template is in Microsoft Excel file format.

2. Test Results for Additively Manufactured Polymer Material

2.1 Test Summary

Material:	Markforged Onyx FR-A™ - Carbon Fiber FR-A™	**Markforged OFRA-CFRA / Markforged X7 Properties Summaries**
Material Specification	NMS 754/1	
Process Specification	NPS 86754	
Tg (Dry): 217.37 °F	**Tm:** 393.51 °F	**Tg(wet):** 128.95°F
Date of raw material manufacture	2019, 2020	**Date of Testing:** Sep. 21 - June 2023
Date of filament manufacture	2020	**Date of data submittal:** July 2023 - Sep 2023
Date of coupon manufacture	Jan. 2021 - Mar. 2023	

Mean Values of Mechanical Property Summary Data
Data Was Not Normalized and Reported As-Measured Only

	XY					XZ					ZX			
	CTD	RTD		ETD	ETW	CTD	RTD		ETD	ETW	CTD	RTD	ETD	ETW
	PF	PF	FF	PF	PF	PF	PF	FF	PF	PF	NF	NF	NF	NF
	-65°F	70°F		130°F	130°F	-65°F	70°F		130°F	130°F	-65°F	70°F	130°F	130°F
Tensile Strength (ksi)	46.32	38.18	85.80	32.93	30.85	41.55	35.37	63.27	31.76	19.76	4.726	2.823	1.782	1.241
Tensile Modulus (Msi)	3.030	2.810	7.038	2.710	2.544	3.260	2.831	5.242	2.606	2.032	0.564	0.247	0.120	0.058
Tensile Poisson's	0.481	0.536	0.442	0.525	0.569	0.378	0.423	0.283	0.404	0.215	0.203	0.209	0.210	0.219
Compression Strength (ksi)	28.95	18.47	39.12	15.06	8.337	24.14	16.00	23.48	11.94	5.461	10.68	3.068	1.734	1.014
Average Compression Modulus (Msi)	2.853	2.674	6.589	2.795	2.838	2.630	2.097	5.174	1.620	1.000	0.625	0.323	0.189	0.125
Average Compression Poisson's	0.433	0.460	0.427	0.457	0.444	0.351	0.416	0.284	0.489	0.383	0.164	0.172	0.205	0.241
Flexural Strength - Procedure A (ksi)	59.89	37.44	51.78	26.87	12.05	45.42	26.48	36.57	16.41	7.679	10.97	6.937	3.640	1.856
Flexural 2% Offset strength - Procedure A (ksi)	68.05	35.13		23.91	10.00	34.77	18.91	33.98	14.25	5.934	12.02	4.771	2.236	0.795
Flexural Modulus - Procedure A (Msi)	2.715	2.126	2.979	1.831	1.172	1.898	1.343	1.851	0.964	0.509	0.561	0.310	0.121	0.057
In-Plane Shear Strength (ksi)	6.355	3.997	6.746	3.368	1.779									
In-Plane Shear 0.2% Offset Strength (ksi)	3.911	1.697	3.103	1.264	0.571									
In-Plane Shear 5% Offset Strength (ksi)		3.120	5.700	2.293	1.078									
In-Plane Shear Modulus (Msi)	0.248	0.134	0.251	0.103	0.048									
Short Beam Strength (ksi)	4.237	2.291	3.306	1.841	0.878									
Open Hole Tension Strength (ksi)	11.89	9.517	20.61	8.139	6.659	28.53	34.84	52.39	32.96	24.28	3.327	2.483	1.407	0.870
Filled Hole Tension Strength (ksi)	13.65	10.49	22.53	8.817	6.735	37.13	36.03	53.36	33.74	25.43	3.562	2.574	1.529	0.939
Single Shear Bearing Strength - Procedure C (ksi)	47.86	33.23	58.00		14.66	21.95	12.76	12.19		6.046	19.03	12.72		4.776
Single Shear Bearing 2% Offset Strength - Procedure C (ksi)	44.36	29.73	50.35		13.69		10.75	11.23		5.008	18.31	10.13		2.690
Single Shear Bearing Stiffness - Procedure C (Msi)	0.421	0.365	0.686		0.234	0.358	0.186	0.208		0.062	0.226	0.111		0.024
IZOD Energy (J)			1.058					1.028						
IZOD Impact Resistance (J/m)			130.1					126.09						

2.2 Individual Test Summaries

2.2.1 XY PF Tension Properties

Material:	Markforged Onyx FR-A™ - Carbon Fiber FR-A™			**Tension (T)** Markforged OFRA-CFRA / Markforged X7 Partial Fiber (PF) Fill Build Orientation: XY	
AM printer	Markforged X7				
Test method:	ASTM D3039/D3039M- 17	**Modulus calculation:** 1000-3000 microstrain			
		CTD	**RTD**	**ETD**	**ETW**
Test Temperature [°F]		-65	70	130	130
Moisture Conditioning		Dry	Dry	Dry	Equilibrium
Equilibrium at T, RH					120 F,95%
Source code: Prefixed by NTPAM6754Q1-MFD-OFRA-CFRA-MFD-		X-MX-PX-XY-T-1X-CTD-PF-X	X-MX-PX-XY-T-1X-RTD-PF-X	X-MX-PX-XY-T-1X-ETD-PF-X	X-MX-PX-XY-T-1X-ETW-PF-X
		Measured	**Measured**	**Measured**	**Measured**
XY PF Tensile Strength [ksi]	**Mean**	46.32	38.18	32.93	30.85
	Minimum	40.68	33.85	28.82	24.14
	Maximum	50.17	43.33	36.77	35.28
	C.V.(%)	6.369	7.005	7.123	8.695
	No. Specimens	20	19	18	19
	No. Material Batches	3	3	3	3
XY PF Tensile Strength [Msi]	**Mean**	3.030	2.810	2.710	2.544
	Minimum	2.884	2.690	2.521	2.257
	Maximum	3.174	2.942	2.827	2.707
	C.V.(%)	2.587	2.603	2.850	3.966
	No. Specimens	19	19	18	19
	No. Material Batches	3	3	3	3
XY PF Poisson's Ratio	**Mean**	0.481	0.536	0.525	0.569
	Minimum	0.208	0.508	0.474	0.532
	Maximum	0.608	0.570	0.557	0.611
	C.V.(%)	15.63	3.647	3.905	4.438
	No. Specimens	18	19	18	19
	No. Material Batches	3	3	3	3

2.2.2 XY FF Tension Properties – Reference Only

Material:	Markforged Onyx FR-A™ - Carbon Fiber FR-A™			**Tension (T)** Markforged OFRA-CFRA / Markforged X7 Full Fiber (FF) Fill Build Orientation: XY	
AM printer	Markforged X7				
Test method:	ASTM D3039/D3039M- 17	**Modulus calculation:** 1000-3000 microstrain			
			RTD		
Test Temperature [°F]			70		
Moisture Conditioning			Dry		
Equilibrium at T, RH					
Source code: Prefixed by NTPAM6754Q1-MFD-OFRA-CFRA-MFD-			X-MX-PX-XY-T-1X-RTD-FF-X		
			Measured		
XY FF Tensile Strength [ksi]	**Mean**		85.80		
	Minimum		79.54		
	Maximum		90.86		
	C.V.(%)		4.850		
	No. Specimens		6		
	No. Material Batches		3		
XY FF Tensile Strength [Msi]	**Mean**		7.038		
	Minimum		6.958		
	Maximum		7.114		
	C.V.(%)		0.899		
	No. Specimens		6		
	No. Material Batches		3		
XY FF Poisson's Ratio	**Mean**		0.442		
	Minimum		0.435		
	Maximum		0.460		
	C.V.(%)		2.169		
	No. Specimens		6		
	No. Material Batches		3		

2.2.3 XZ PF Tension Properties

Material:	Markforged Onyx FR-A™ - Carbon Fiber FR-A™			**Tension (T)** Markforged OFRA-CFRA / Markforged X7 Partial Fiber (PF) Fill Build Orientation: XZ	
AM printer	Markforged X7				
Test method:	ASTM D3039/D3039M- 17	**Modulus calculation:** 1000-3000 microstrain			
		CTD	**RTD**	**ETD**	**ETW**
Test Temperature [°F]		-65	70	130	130
Moisture Conditioning		Dry	Dry	Dry	Equilibrium
Equilibrium at T, RH					120 F,95%
Source code: Prefixed by NTPAM6754Q1-MFD-OFRA-CFRA-MFD-		X-MX-PX-XZ-T-1X-CTD-PF-X	X-MX-PX-XZ-T-1X-RTD-PF-X	X-MX-PX-XZ-T-1X-ETD-PF-X	X-MX-PX-XZ-T-1X-ETW-PF-X
		Measured	**Measured**	**Measured**	**Measured**
XZ PF Tensile Strength [ksi]	**Mean**	41.55	35.37	31.76	19.76
	Minimum	35.81	32.04	28.89	15.60
	Maximum	44.81	37.87	34.47	23.26
	C.V.(%)	5.744	5.106	5.379	12.58
	No. Specimens	21	18	18	20
	No. Material Batches	3	3	3	3
XZ PF Tensile Strength [Msi]	**Mean**	3.260	2.831	2.606	2.032
	Minimum	3.083	2.709	2.495	1.331
	Maximum	3.499	2.939	2.715	2.413
	C.V.(%)	3.877	2.094	2.624	14.63
	No. Specimens	19	18	18	20
	No. Material Batches	3	3	3	3
XZ PF Poisson's Ratio	**Mean**	0.378	0.423	0.404	0.215
	Minimum	0.325	0.370	0.374	0.132
	Maximum	0.453	0.445	0.426	0.300
	C.V.(%)	7.719	3.601	4.242	31.04
	No. Specimens	19	18	18	5
	No. Material Batches	3	3	3	3

2.2.4 **XZ FF Tension Properties – Reference Only**

Material:	Markforged Onyx FR-A™ - Carbon Fiber FR-A™			**Tension (T)** Markforged OFRA-CFRA / Markforged X7 Full Fiber (FF) Fill Build Orientation: XZ	
AM printer	Markforged X7				
Test method:	ASTM D3039/D3039M- 17	**Modulus calculation:** 1000-3000 microstrain			
			RTD		
Test Temperature [°F]			70		
Moisture Conditioning			Dry		
Equilibrium at T, RH					
Source code: Prefixed by NTPAM6754Q1-MFD-OFRA-CFRA-MFD-			X-MX-PX-XZ-T-1X-RTD-FF-X		
			Measured		
XZ FF Tensile Strength [ksi]	**Mean**		63.27		
	Minimum		56.43		
	Maximum		67.72		
	C.V.(%)		6.790		
	No. Specimens		6		
	No. Material Batches		3		
XZ FF Tensile Strength [Msi]	**Mean**		5.242		
	Minimum		4.927		
	Maximum		5.373		
	C.V.(%)		3.207		
	No. Specimens		6		
	No. Material Batches		3		
XZ FF Poisson's Ratio	**Mean**		0.283		
	Minimum		0.270		
	Maximum		0.299		
	C.V.(%)		3.784		
	No. Specimens		6		
	No. Material Batches		3		

2.2.5 ZX PF Tension Properties – Reference Only

Material:	Markforged Onyx FR-A™ - Carbon Fiber FR-A™			**Tension (T) - Reference Only** Markforged OFRA-CFRA / Markforged X7 Partial Fiber (PF) Fill Build Orientation: ZX	
AM printer	Markforged X7				
Test method:	ASTM D3039/D3039M- 17	**Modulus calculation:** 1000-3000 microstrain			
		CTD	**RTD**		
Test Temperature [°F]			70		
Moisture Conditioning			Dry		
Equilibrium at T, RH					
Source code: Prefixed by NTPAM6754Q1-MFD-OFRA-CFRA-MFD-			X-MX-PX-ZX-T-1X-RTD-PF-X		
			Measured		
ZX PF Tensile Strength [ksi]	**Mean**		1.309		
	Minimum		0.712		
	Maximum		1.927		
	C.V.(%)		21.129		
	No. Specimens		18		
	No. Material Batches		3		
ZX PF Tensile Strength [Msi]	**Mean**		0.258		
	Minimum		0.207		
	Maximum		0.386		
	C.V.(%)		19.111		
	No. Specimens		18		
	No. Material Batches		3		
ZX PF Poisson's Ratio	**Mean**		0.028		
	Minimum		0.007		
	Maximum		0.072		
	C.V.(%)		71.197		
	No. Specimens		17		
	No. Material Batches		3		

2.2.6 **ZX NF Tension Properties**

Material:	Markforged Onyx FR-A™			**Tension (T)** Markforged OFRA / Markforged X7 No Fiber (NF) Fill Build Orientation: ZX	
AM printer	Markforged X7				
Test method:	ASTM D3039/D3039M- 17	**Modulus calculation:** 1000-3000 microstrain			
		CTD	**RTD**	**ETD**	**ETW**
Test Temperature [°F]		-65	70	130	130
Moisture Conditioning		Dry	Dry	Dry	Equilibrium
Equilibrium at T, RH					120 F,95%
Source code: Prefixed by NTPAM6754Q1-MFD-OFRA-CFRA-MFD-		X-MX-PX-ZX-T-1X-CTD-NF-X	X-MX-PX-ZX-T-1X-RTD-NF-X	X-MX-PX-ZX-T-1X-ETD-NF-X	X-MX-PX-ZX-T-1X-ETW-NF-X
		Measured	**Measured**	**Measured**	**Measured**
ZX NF Tensile Strength [ksi]	**Mean**	4.726	2.823	1.782	1.241
	Minimum	4.076	2.421	1.527	1.089
	Maximum	5.369	3.226	1.926	1.412
	C.V.(%)	7.829	7.455	5.495	6.053
	No. Specimens	18	18	18	18
	No. Material Batches	3	3	3	3
ZX NF Tensile Strength [Msi]	**Mean**	0.564	0.247	0.120	0.058
	Minimum	0.515	0.199	0.101	0.043
	Maximum	0.601	0.297	0.134	0.072
	C.V.(%)	4.442	12.05	8.337	14.52
	No. Specimens	18	18	18	18
	No. Material Batches	3	3	3	3
ZX NF Poisson's Ratio	**Mean**	0.203	0.209	0.210	0.219
	Minimum	0.181	0.188	0.194	0.209
	Maximum	0.224	0.236	0.226	0.243
	C.V.(%)	5.397	8.345	4.643	3.858
	No. Specimens	18	18	18	18
	No. Material Batches	3	3	3	3

2.2.7 **XY PF Compression Properties**

Material:	Markforged Onyx FR-A™ - Carbon Fiber FR-A™			**Combined Loading Compression (CLC)**	
AM Printer:	Markforged X7			Markforged OFRA-CFRA / Markforged X7 Partial Fiber (PF) Fill Build Orientation: XY	
Test method:	ASTM D6641/D6641M- 16e1	**Modulus calculation:** 1000 to 3000 microstrain			
		CTD	**RTD**	**ETD**	**ETW**
Test Temperature [°F]		-65	70	130	130
Moisture Conditioning		Dry	Dry	Dry	Equilibrium
Equilibrium at T, RH					120 F,95%
Source code: Prefixed by NTPAM6754Q1-MFD-OFRA-CFRA-MFD-		X-MX-PX-XY-CLC-1X-CTD-PF-X	X-MX-PX-XY-CLC-1X-RTD-PF-X	X-MX-PX-XY-CLC-1X-ETD-PF-X	X-MX-PX-XY-CLC-1X-ETW-PF-X
		Measured	**Measured**	**Measured**	**Measured**
XY PF Compression Strength [ksi]	**Mean**	28.954	18.470	15.056	8.524
	Minimum	19.252	14.012	11.596	6.225
	Maximum	34.245	22.904	18.556	13.720
	C.V.(%)	12.292	12.249	12.869	23.114
	No. Specimens	21	22	18	22
	No. Material Batches	3	3	3	3
XY PF Compression Modulus [Msi]	**Mean**	2.853	2.674	2.795	2.838
	Minimum	2.718	2.514	2.703	2.542
	Maximum	3.004	2.883	2.979	3.228
	C.V.(%)	2.983	3.783	2.733	6.911
	No. Specimens	21	22	18	24
	No. Material Batches	3	3	3	3
XY PF Poisson's Ratio	**Mean**	0.433	0.460	0.457	0.445
	Minimum	0.396	0.422	0.426	0.323
	Maximum	0.470	0.503	0.517	0.626
	C.V.(%)	4.913	4.780	5.500	14.217
	No. Specimens	21	22	18	24
	No. Material Batches	3	3	3	3
XY PF Percent bending [%]	**Mean**	2.434	1.829	1.328	4.552
	Minimum	0.103	0.130	0.018	0.170
	Maximum	5.920	6.017	4.346	16.542
	C.V.(%)	68.477	79.971	94.587	102.866
	No. Specimens	21	22	18	23
	No. Material Batches	3	3	3	3

2.2.8 **XY FF Compression Properties – Reference Only**

Material:	Markforged Onyx FR-A™ - Carbon Fiber FR-A™			**Combined Loading Compression (CLC)** Markforged OFRA-CFRA / Markforged X7 Full Fiber (FF) Fill Build Orientation: XY	
AM Printer:	Markforged X7				
Test method:	ASTM D6641/D6641M- 16e1	**Modulus calculation:** 1000 to 3000 microstrain			
			RTD		
Test Temperature [°F]			70		
Moisture Conditioning			Dry		
Equilibrium at T, RH					
Source code: Prefixed by NTPAM6754Q1-MFD-OFRA-CFRA-MFD-			X-MX-PX-XY-CLC-1X-RTD-FF-X		
			Measured		
XY FF 0.2% Offset Strength [ksi]	**Mean**		39.12		
	Minimum		34.49		
	Maximum		43.39		
	C.V.(%)		8.067		
	No. Specimens		8		
	No. Material Batches		1		
XY FF Compression Modulus [Msi]	**Mean**		6.589		
	Minimum		6.307		
	Maximum		6.884		
	C.V.(%)		3.171		
	No. Specimens		8		
	No. Material Batches		1		
XY FF Poisson"s Ratio	**Mean**		0.427		
	Minimum		0.407		
	Maximum		0.448		
	C.V.(%)		3.149		
	No. Specimens		8		
	No. Material Batches		1		
XY FF Percent Bending (%)	**Mean**		2.385		
	Minimum		0.090		
	Maximum		5.026		
	C.V.(%)		81.58		
	No. Specimens		8		
	No. Material Batches		1		

2.2.9 **XZ PF Compression Properties**

Material:	Markforged Onyx FR-A™ - Carbon Fiber FR-A™			**Combined Loading Compression (CLC)** Markforged OFRA-CFRA / Markforged X7 Partial Fiber (PF) Fill Build Orientation: XZ	
AM Printer:	Markforged X7				
Test method:	ASTM D6641/D6641M- 16e1	**Modulus calculation:** 1000 to 3000 microstrain			
		CTD	**RTD**	**ETD**	**ETW**
Test Temperature [°F]		-65	70	130	130
Moisture Conditioning		Dry	Dry	Dry	Equilibrium
Equilibrium at T, RH					120 F,95%
Source code: Prefixed by NTPAM6754Q1-MFD-OFRA-CFRA-MFD-		X-MX-PX-XZ-CLC-1X-CTD-PF-X	X-MX-PX-XZ-CLC-1X-RTD-PF-X	X-MX-PX-XZ-CLC-1X-ETD-PF-X	X-MX-PX-XZ-CLC-1X-ETW-PF-X
		Measured	**Measured**	**Measured**	**Measured**
XZ PF Compression Strength [ksi]	**Mean**	24.14	16.00	11.94	5.548
	Minimum	20.60	13.55	9.905	3.338
	Maximum	28.40	23.00	14.17	9.621
	C.V.(%)	9.564	16.28	8.876	28.91
	No. Specimens	22	23	18	21
	No. Material Batches	3	3	3	3
XZ PF Compression Modulus [Msi]	**Mean**	2.630	2.097	1.620	1.000
	Minimum	2.353	1.595	1.425	0.824
	Maximum	2.895	2.693	1.994	1.539
	C.V.(%)	5.959	14.55	9.326	17.64
	No. Specimens	22	23	18	23
	No. Material Batches	3	3	3	3
XZ PF Poisson's Ratio	**Mean**	0.351	0.416	0.489	0.383
	Minimum	0.264	0.276	0.413	0.292
	Maximum	0.408	0.514	0.534	0.542
	C.V.(%)	10.126	15.02	7.045	16.46
	No. Specimens	22	23	18	23
	No. Material Batches	3	3	3	3
XZ PF Percent bending [%]	**Mean**	3.033	2.260	2.924	4.677
	Minimum	0.100	0.038	0.418	0.136
	Maximum	9.933	5.622	6.651	11.464
	C.V.(%)	92.31	73.00	74.32	72.53
	No. Specimens	22	23	18	22
	No. Material Batches	3	3	3	3

2.2.10 **XZ FF Compression Properties – Reference Only**

Material:	Markforged Onyx FR-A™ - Carbon Fiber FR-A™			**Combined Loading Compression (CLC)** Markforged OFRA-CFRA / Markforged X7 Full Fiber (FF) Fill Build Orientation: XZ	
AM Printer:	Markforged X7				
Test method:	ASTM D6641/D6641M- 16e1	**Modulus calculation:** 1000 to 3000 microstrain			
			RTD		
Test Temperature [°F]			70		
Moisture Conditioning			Dry		
Equilibrium at T, RH					
Source code: Prefixed by NTPAM6754Q1-MFD-OFRA-CFRA-MFD-			X-MX-PX-XZ-CLC-1X-RTD-FF-X		
			Measured		
XZ FF 0.2% Offset Strength [ksi]	**Mean**		23.48		
	Minimum		21.05		
	Maximum		25.51		
	C.V.(%)		7.192		
	No. Specimens		6		
	No. Material Batches		1		
XZ FF Compression Modulus [Msi]	**Mean**		5.174		
	Minimum		4.952		
	Maximum		5.501		
	C.V.(%)		3.716		
	No. Specimens		6		
	No. Material Batches		1		
XZ FF Poisson"s Ratio	**Mean**		0.284		
	Minimum		0.244		
	Maximum		0.366		
	C.V.(%)		18.37		
	No. Specimens		6		
	No. Material Batches		1		
XZ FF Percent Bending (%)	**Mean**		3.102		
	Minimum		1.117		
	Maximum		5.683		
	C.V.(%)		57.77		
	No. Specimens		6		
	No. Material Batches		1		

2.2.11 **ZX PF Compression Properties – Reference Only**

Material:	Markforged Onyx FR-A™ - Carbon Fiber FR-A™			**Combined Loading Compression (CLC) - Reference Only**	
AM Printer:	Markforged X7			Markforged OFRA-CFRA / Markforged X7 Partial Fiber (PF) Fill Build Orientation: ZX	
Test method:	ASTM D6641/D6641M- 16e1	**Modulus calculation:** 1000 to 3000 microstrain			
		CTD	**RTD**	**ETD**	
Test Temperature [°F]		-65	70	130	
Moisture Conditioning		Dry	Dry	Dry	
Equilibrium at T, RH					
Source code: Prefixed by NTPAM6754Q1-MFD-OFRA-CFRA-MFD-		X-MX-PX-ZX-CLC-1X-CTD-PF-X	X-MX-PX-ZX-CLC-1X-RTD-PF-X	X-MX-PX-ZX-CLC-1X-ETD-PF-X	
		Measured	**Measured**	**Measured**	
ZX PF Compression Strength [ksi]	**Mean**	20.001	11.828	9.212	
	Minimum	16.074	8.420	9.016	
	Maximum	23.326	15.690	9.601	
	C.V.(%)	12.833	18.699	3.654	
	No. Specimens	9	9	3	
	No. Material Batches	2	2	1	
ZX PF Compression Modulus [Msi]	**Mean**	0.440	0.296	0.217	
	Minimum	0.366	0.234	0.203	
	Maximum	0.549	0.357	0.236	
	C.V.(%)	14.188	17.439	7.645	
	No. Specimens	9	9	3	
	No. Material Batches	2	2	1	
ZX PF Poisson's Ratio	**Mean**	0.043	0.044	0.050	
	Minimum	0.023	0.021	0.039	
	Maximum	0.060	0.072	0.059	
	C.V.(%)	27.208	30.904	20.191	
	No. Specimens	9	9	3	
	No. Material Batches	2	2	1	
ZX PF Percent bending [%]	**Mean**	3.548	2.415	5.476	
	Minimum	0.118	0.111	1.320	
	Maximum	8.968	5.792	8.502	
	C.V.(%)	91.540	65.901	67.972	
	No. Specimens	9	9	3	
	No. Material Batches	2	2	1	

2.2.12 **ZX NF Compression Properties**

Material:	Markforged Onyx FR-A™ - Carbon Fiber FR-A™			**Combined Loading Compression (CLC)** Markforged OFRA-CFRA / Markforged X7 No Fiber (NF) Fill Build Orientation: ZX	
AM Printer:	Markforged X7				
Test method:	ASTM D6641/D6641M- 16e1	**Modulus calculation:** 1000 to 3000 microstrain			
		CTD	**RTD**	**ETD**	**ETW**
Test Temperature [°F]		-65	70	130	130
Moisture Conditioning		Dry	Dry	Dry	Equilibrium
Equilibrium at T, RH					120 F,95%
Source code: Prefixed by NTPAM6754Q1-MFD-OFRA-CFRA-MFD-		X-MX-PX-ZX-CLC-1X-CTD-NF-X	X-MX-PX-ZX-CLC-1X-RTD-NF-X	X-MX-PX-ZX-CLC-1X-ETD-NF-X	X-MX-PX-ZX-CLC-1X-ETW-NF-X
		Measured	**Measured**	**Measured**	**Measured**
ZX NF 0.2% Offset Strength [ksi]	**Mean**	10.68	3.068	1.734	1.014
	Minimum	7.656	2.419	1.538	0.901
	Maximum	13.70	3.948	1.895	1.129
	C.V.(%)	14.94	13.39	6.848	6.737
	No. Specimens	18	18	18	18
	No. Material Batches	3	3	3	3
ZX NF Compression Modulus [Msi]	**Mean**	0.625	0.323	0.189	0.125
	Minimum	0.576	0.259	0.169	0.114
	Maximum	0.695	0.387	0.202	0.137
	C.V.(%)	4.829	10.40	6.001	4.757
	No. Specimens	18	18	18	18
	No. Material Batches	3	3	3	3
ZX NF Poisson's Ratio	**Mean**	0.164	0.172	0.205	0.241
	Minimum	0.128	0.133	0.177	0.171
	Maximum	0.190	0.205	0.234	0.279
	C.V.(%)	9.141	9.948	7.138	9.701
	No. Specimens	18	18	18	18
	No. Material Batches	3	3	3	3
ZX NF Percent bending [%]	**Mean**	4.881	2.656	2.240	1.267
	Minimum	0.027	0.075	0.288	0.011
	Maximum	17.16	7.704	6.257	4.029
	C.V.(%)	96.30	87.32	79.58	87.55
	No. Specimens	18	18	18	18
	No. Material Batches	3	3	3	3

See section 4, paragraph 1 for discussion related to CLC Compression Strength properties.

2.2.13 **XY PF Flex Properties**

AM Printer:	Markforged X7			Markforged OFRA-CFRA / Markforged X7 Partial Fiber (PF) Fill Build Orientation: XY	
Test method:	ASTM D790-17 Procedure A	**Modulus calculation:** 1000-3000 microstrain			
		CTD	**RTD**	**ETD**	**ETW**
Test Temperature [°F]		-65	70	130	130
Moisture Conditioning		Dry	Dry	Dry	Equilibrium
Equilibrium at T, RH					120 F,95%
Source code: Prefixed by NTPAM6754Q1-MFD-OFRA-CFRA-MFD-		X-MX-PX-XY-F-1X-CTD-PF-X	X-MX-PX-XY-F-1X-RTD-PF-X	X-MX-PX-XY-F-1X-ETD-PF-X	X-MX-PX-XY-F-1X-ETW-PF-X
		Measured	**Measured**	**Measured**	**Measured**
XY PF Flexural Strength [ksi]	**Mean**	59.89	38.07	26.87	12.05
	Minimum	49.32	33.02	21.37	5.299
	Maximum	69.85	46.16	29.62	19.63
	C.V.(%)	9.911	10.76	7.344	32.08
	No. Specimens	19	17	18	22
	No. Material Batches	3	3	3	3
XY PF Flexural 2% Offset Yield Strength [ksi]	**Mean**	68.05	35.13	23.91	10.00
	Minimum	68.05	25.79	11.14	4.008
	Maximum	68.05	40.53	26.52	18.01
	C.V.(%)		23.12	17.11	37.96
	No. Specimens	1	3	14	21
	No. Material Batches	3	3	3	3
XY PF Flexural Modulus [Msi]	**Mean**	2.715	2.126	1.831	1.172
	Minimum	2.462	1.954	1.590	0.459
	Maximum	2.991	2.508	1.914	1.565
	C.V.(%)	4.818	6.192	4.059	25.99
	No. Specimens	19	19	18	22
	No. Material Batches	3	3	3	3

2.2.14 **XY FF Flex Properties – Reference Only**

Material:	Markforged Onyx FR-A™ - Carbon Fiber FR-A™			**Flexural (F) Procedure A** Markforged OFRA-CFRA / Markforged X7 Full Fiber (FF) Fill Build Orientation: XY	
AM Printer:	Markforged X7				
Test method:	ASTM D790-17 Procedure A	**Modulus calculation:**	1000-3000 microstrain		
			RTD		
Test Temperature [°F]			70		
Moisture Conditioning			Dry		
Equilibrium at T, RH					
Source code: Prefixed by NTPAM6754Q1-MFD-OFRA-CFRA-MFD-			X-MX-PX-XY-F-1X-RTD-FF-X		
			Measured		
XY FF Flexural Strength [ksi]	**Mean**		51.78		
	Minimum		46.07		
	Maximum		56.15		
	C.V.(%)		8.283		
	No. Specimens		8		
	No. Material Batches		1		
XY FF 2% Offset Yield Strength [ksi]	**Mean**				
	Minimum				
	Maximum				
	C.V.(%)				
	No. Specimens		0		
	No. Material Batches		1		
XY FF Flexural Modulus [Msi]	**Mean**		2.979		
	Minimum		2.863		
	Maximum		3.100		
	C.V.(%)		3.051		
	No. Specimens		8		
	No. Material Batches		1		

2.2.15 **XZ PF Flex Properties**

Material:	Markforged Onyx FR-A™ - Carbon Fiber FR-A™			**Flexural (F) Procedure A**	
AM Printer:	Markforged X7			Markforged OFRA-CFRA / Markforged X7 Partial Fiber (PF) Fill Build Orientation: XZ	
Test method:	ASTM D790-17 Procedure A	**Modulus calculation:** 1000-3000 microstrain			
		CTD	**RTD**	**ETD**	**ETW**
Test Temperature [°F]		-65	70	130	130
Moisture Conditioning		Dry	Dry	Dry	Equilibrium
Equilibrium at T, RH					120 F,95%
Source code: Prefixed by NTPAM6754Q1-MFD-OFRA-CFRA-MFD-		X-MX-PX-XZ-F-1X-CTD-PF-X	X-MX-PX-XZ-F-1X-RTD-PF-X	X-MX-PX-XZ-F-1X-ETD-PF-X	X-MX-PX-XZ-F-1X-ETW-PF-X
		Measured	**Measured**	**Measured**	**Measured**
XZ PF Flexural Strength [ksi]	**Mean**	45.42	26.48	16.41	7.679
	Minimum	41.98	22.66	15.03	4.796
	Maximum	49.52	29.12	17.42	12.44
	C.V.(%)	4.775	7.667	4.287	36.51
	No. Specimens	19	18	18	18
	No. Material Batches	3	3	3	3
XZ PF Flexural 2% Offset Yield Strength [ksi]	**Mean**	34.77	18.91	14.25	5.934
	Minimum	32.56	15.54	13.26	2.662
	Maximum	38.98	24.15	15.87	12.27
	C.V.(%)	4.623	12.77	4.430	58.59
	No. Specimens	16	18	18	18
	No. Material Batches	3	3	3	3
XZ PF Flexural Modulus [Msi]	**Mean**	1.898	1.343	0.964	0.509
	Minimum	1.670	1.144	0.794	0.231
	Maximum	2.128	1.493	1.052	0.793
	C.V.(%)	6.560	8.594	7.484	42.36
	No. Specimens	19	18	18	18
	No. Material Batches	3	3	3	3

See section 4, paragraph 2 for discussion related to Flexural Strength properties.

2.2.16 **XZ FF Flex Properties – Reference Only**

Material:	Markforged Onyx FR-A™ - Carbon Fiber FR-A™			**Flexural (F) Procedure A** Markforged OFRA-CFRA / Markforged X7 Full Fiber (FF) Fill Build Orientation: XZ	
AM Printer:	Markforged X7				
Test method:	ASTM D790-17 Procedure A	**Modulus calculation:**	1000-3000 microstrain		
			RTD		
Test Temperature [°F]			70		
Moisture Conditioning			Dry		
Equilibrium at T, RH					
Source code: Prefixed by NTPAM6754Q1-MFD-OFRA-CFRA-MFD-			X-MX-PX-XZ-F-1X-RTD-FF-X		
			Measured		
XZ FF Flexural Strength [ksi]	**Mean**		36.57		
	Minimum		32.50		
	Maximum		40.00		
	C.V.(%)		7.328		
	No. Specimens		6		
	No. Material Batches		1		
XZ FF 2% Offset Yield Strength [ksi]	**Mean**		33.98		
	Minimum		31.05		
	Maximum		36.40		
	C.V.(%)		5.351		
	No. Specimens		6		
	No. Material Batches		1		
XZ FF Flexural Modulus [Msi]	**Mean**		1.851		
	Minimum		1.707		
	Maximum		2.047		
	C.V.(%)		7.892		
	No. Specimens		6		
	No. Material Batches		1		

2.2.17 **ZX PF Flex Properties – Reference Only**

Material:	Markforged Onyx FR-A™ - Carbon Fiber FR-A™			**Flexural (F) Procedure A - Reference Only** Markforged OFRA-CFRA / Markforged X7 Partial Fiber (PF) Fill Build Orientation: ZX
AM Printer:	Markforged X7			
Test method:	ASTM D790-17 Procedure A	**Modulus calculation:** 1000-3000 microstrain		
		CTD	**RTD**	
Test Temperature [°F]		-65	70	
Moisture Conditioning		Dry	Dry	
Equilibrium at T, RH				
Source code: Prefixed by NTPAM6754Q1-MFD-OFRA-CFRA-MFD-		X-MX-PX-ZX-F-1X-CTD-PF-X	X-MX-PX-ZX-F-1X-RTD-PF-X	
		Measured	**Measured**	
ZX PF Flexural Strength [ksi]	**Mean**	4.450	4.097	
	Minimum	2.312	3.013	
	Maximum	6.758	4.906	
	C.V.(%)	29.87	16.29	
	No. Specimens	18	18	
	No. Material Batches	3	3	
ZX PF Flexural 2% Offset Yield Strength [ksi]	**Mean**		3.699	
	Minimum		2.313	
	Maximum		4.616	
	C.V.(%)		25.26	
	No. Specimens	0	9	
	No. Material Batches	3	3	
ZX PF Flexural Modulus [Msi]	**Mean**	0.458	0.356	
	Minimum	0.413	0.247	
	Maximum	0.501	0.409	
	C.V.(%)	5.138	11.67	
	No. Specimens	20	18	
	No. Material Batches	3	3	

2.2.18 **ZX NF Flex Properties**

Material:	Markforged Onyx FR-A™ - Carbon Fiber FR-A™			**Flexural (F) Procedure A** Markforged OFRA-CFRA / Markforged X7 No Fiber (NF) Fill Build Orientation: ZX	
AM Printer:	Markforged X7				
Test method:	ASTM D790-17 Procedure A	**Modulus calculation:** 1000-3000 microstrain			
		CTD	**RTD**	**ETD**	**ETW**
Test Temperature [°F]		-65	70	130	130
Moisture Conditioning		Dry	Dry	Dry	Equilibrium
Equilibrium at T, RH					120 F,95%
Source code: Prefixed by NTPAM6754Q1-MFD-OFRA-CFRA-MFD-		X-MX-PX-ZX-F-1X-CTD-NF-X	X-MX-PX-ZX-F-1X-RTD-NF-X	X-MX-PX-ZX-F-1X-ETD-NF-X	X-MX-PX-ZX-F-1X-ETW-NF-X
		Measured	**Measured**	**Measured**	**Measured**
ZX NF Flexural Strength [ksi]	**Mean**	10.97	6.937	3.640	1.856
	Minimum	7.355	5.951	3.290	1.585
	Maximum	14.55	8.647	4.069	2.074
	C.V.(%)	17.12	10.55	6.327	7.931
	No. Specimens	18	18	18	18
	No. Material Batches	3	3	3	3
ZX NF Flexural 2% Offset Yield Strength [ksi]	**Mean**	12.02	4.771	2.236	0.795
	Minimum	11.10	4.217	1.880	0.556
	Maximum	13.36	5.465	2.650	1.027
	C.V.(%)	7.147	8.453	7.706	15.94
	No. Specimens	6	18	18	18
	No. Material Batches	3	3	3	3
ZX NF Flexural Modulus [Msi]	**Mean**	0.561	0.310	0.121	0.057
	Minimum	0.519	0.275	0.105	0.047
	Maximum	0.636	0.361	0.131	0.062
	C.V.(%)	6.202	8.470	6.971	6.822
	No. Specimens	18	18	18	18
	No. Material Batches	3	3	3	3

See section 4, paragraph 2 for discussion related to Flexural Strength properties.

2.2.19 **XY PF In-Plane Shear Properties**

Material:	Markforged Onyx FR-A™ - Carbon Fiber FR-A™			**In-Plane Shear (IPS)** Markforged OFRA-CFRA / Markforged X7 Partial Fiber (PF) Fill Build Orientation: XY	
AM Printer:	Markforged X7				
Test method:	ASTM D3518/D3518M- 18	**Modulus calculation:** 2000 to 6000 microstrain			
		CTD	**RTD**	**ETD**	**ETW**
Test Temperature [°F]		-65	70	130	130
Moisture Conditioning		Dry	Dry	Dry	Equilibrium
Equilibrium at T, RH					120 F,95%
Source code: Prefixed by NTPAM6754Q1-MFD-OFRA-CFRA-MFD-		X-MX-PX-XY-IPS-1X-CTD-PF-X	X-MX-PX-XY-IPS-1X-RTD-PF-X	X-MX-PX-XY-IPS-1X-ETD-PF-X	X-MX-PX-XY-IPS-1X-ETW-PF-X
		Measured	**Measured**	**Measured**	**Measured**
XY PF 0.2% Offset Shear Strength [ksi]	**Mean**	3.911	1.697	1.264	0.571
	Minimum	3.401	1.544	1.154	0.244
	Maximum	4.447	1.842	1.393	0.767
	C.V.(%)	6.050	5.800	5.991	19.76
	No. Specimens	18	20	18	21
	No. Material Batches	3	3	3	3
XY PF 5% Offset Shear Strength [ksi]	**Mean**		3.120	2.293	1.078
	Minimum		2.801	2.109	0.523
	Maximum		3.403	2.519	1.353
	C.V.(%)		6.047	5.512	16.55
	No. Specimens	0	20	18	21
	No. Material Batches	3	3	3	3
XY PF Maximum Shear Strength [ksi]	**Mean**	6.355	3.997	3.368	1.779
	Minimum	5.747	3.224	2.538	1.394
	Maximum	6.794	4.678	4.517	2.158
	C.V.(%)	4.664	11.67	14.01	11.78
	No. Specimens	18	20	18	21
	No. Material Batches	3	3	3	3
XY PF Shear Modulus [Msi]	**Mean**	0.248	0.134	0.103	0.048
	Minimum	0.219	0.123	0.095	0.019
	Maximum	0.269	0.143	0.114	0.059
	C.V.(%)	4.316	5.133	5.083	18.63
	No. Specimens	18	20	18	21
	No. Material Batches	3	3	3	3

2.2.20 XY FF In-Plane Shear Properties – Reference Only

Material:	Markforged Onyx FR-A™ - Carbon Fiber FR-A™			**In-Plane Shear (IPS)** Markforged OFRA-CFRA Qualification Full Fiber (FF) Fill Build Orientation: XY	
AM Printer:	Markforged X7				
Test method:	ASTM D3518/D3518M- 18	**Modulus calculation:** 2000 to 6000 microstrain			
			RTD		
Test Temperature [°F]			70		
Moisture Conditioning			Dry		
Equilibrium at T, RH					
Source code: Prefixed by NTPAM6754Q1-MFD-OFRA-CFRA-MFD-			X-MX-PX-XY-IPS-1X-RTD-FF-X		
			Measured		
XY FF 0.2% Offset Shear Strength [ksi]	**Mean**		3.103		
	Minimum		2.826		
	Maximum		3.288		
	C.V.(%)		5.771		
	No. Specimens		6		
	No. Material Batches		3		
XY FF 5% Offset Shear Strength [ksi]	**Mean**		5.700		
	Minimum		4.999		
	Maximum		6.063		
	C.V.(%)		6.939		
	No. Specimens		6		
	No. Material Batches		3		
XY FF Maximum Shear Strength [ksi]	**Mean**		6.746		
	Minimum		5.464		
	Maximum		7.493		
	C.V.(%)		10.97		
	No. Specimens		6		
	No. Material Batches		3		
XY FF Shear Modulus [Msi]	**Mean**		0.251		
	Minimum		0.234		
	Maximum		0.269		
	C.V.(%)		5.630		
	No. Specimens		6		
	No. Material Batches		3		

2.2.21 XY PF Short-Beam Strength Strength Properties

Material:	Markforged Onyx FR-A™ - Carbon Fiber FR-A™			**Short Beam Strength (SBS)**	
AM Printer:	Markforged X7			Markforged OFRA-CFRA / Markforged X7 Partial Fiber (PF) Fill	
Test method:	ASTM D2344/D2344M- 16			Build Orientation: XY	
		CTD	**RTD**	**ETD**	**ETW**
Test Temperature [°F]		-65	70	130	130
Moisture Conditioning		Dry	Dry	Dry	Equilibrium
Equilibrium at T, RH					120 F,95%
Source code: Prefixed by NTPAM6754Q1-MFD-OFRA-CFRA-MFD-		X-MX-PX-XY-SBS-1X-CTD-PF-X	X-MX-PX-XY-SBS-1X-RTD-PF-X	X-MX-PX-XY-SBS-1X-ETD-PF-X	X-MX-PX-XY-SBS-1X-ETW-PF-X
		Measured	**Measured**	**Measured**	**Measured**
XY PF Short Beam Strength [ksi]	**Mean**	4.237	2.291	1.841	0.878
	Minimum	2.837	1.766	1.514	0.563
	Maximum	5.179	2.790	2.111	1.214
	C.V.(%)	13.384	11.293	9.231	19.115
	No. Specimens	18	18	20	18
	No. Material Batches	3	3	3	3

See section 4, paragraph 2 for discussion related to Short Beam Strength properties.

2.2.22 XY FF Short Beam Strength Properties – Reference Only

Material:	Markforged Onyx FR-A™ - Carbon Fiber FR-A™			**Short Beam Strength (SBS)** Markforged OFRA-CFRA / Markforged X7 Full Fiber (FF) Fill Build Orientation: XY	
AM Printer:	Markforged X7				
Test method:	ASTM D2344/D2344M- 16				
			RTD		
Test Temperature [°F]			70		
Moisture Conditioning			Dry		
Equilibrium at T, RH					
Source code: Prefixed by NTPAM6754Q1-MFD-OFRA-CFRA-MFD-			X-MX-PX-XY-SBS-1X-RTD-FF-X		
			Measured		
XY FF Short Beam Strength [ksi]	**Mean**		3.306		
	Minimum		3.024		
	Maximum		3.659		
	C.V.(%)		7.038		
	No. Specimens		6		
	No. Material Batches		3		

2.2.23 XY PF Open-Hole Tension Properties

Material:	Markforged Onyx FR-A™ - Carbon Fiber FR-A™			**Open-Hole Tension (OHT)**	
AM Material:	Markforged X7			Markforged OFRA-CFRA / Markforged X7 Partial Fiber (PF) Fill	
Test method:	ASTM D5766/D5766M-11(2018)			Build Orientation: XY	
		CTD	**RTD**	**ETD**	**ETW**
Test Temperature [°F]		-65	70	130	130
Moisture Conditioning		Dry	Dry	Dry	Equilibrium
Equilibrium at T, RH					120 F,95%
Source code: Prefixed by NTPAM6754Q1-MFD-OFRA-CFRA-MFD-		X-MX-PX-XY-OHT-1X-CTD-PF-X	X-MX-PX-XY-OHT-1X-RTD-PF-X	X-MX-PX-XY-OHT-1X-ETD-PF-X	X-MX-PX-XY-OHT-1X-ETW-PF-X
		Measured	**Measured**	**Measured**	**Measured**
XY PF Open-Hole Tensile Strength [ksi]	**Mean**	11.89	9.517	8.139	6.659
	Minimum	10.04	8.467	7.575	5.658
	Maximum	14.62	10.41	8.880	7.675
	C.V.(%)	9.747	5.549	4.496	9.717
	No. Specimens	18	18	18	18
	No. Material Batches	3	3	3	3

2.2.24 XY FF Open-Hole Tension Properties – Reference Only

Material:	Markforged Onyx FR-A™ - Carbon Fiber FR-A™ / Markforged X7			**Open-Hole Tension (OHT)** Markforged OFRA-CFRA / X7 -45/45 Build Orientation: XY	
AM Material:	Markforged X7				
Test method:	ASTM D5766/D5766M-11(2018)				
			RTD		
Test Temperature [°F]			70		
Moisture Conditioning			Dry		
Equilibrium at T, RH					
Source code: Prefixed by NTPAM6754Q1-MFD-OFRA-CFRA-MFD-			X-MX-PX-XY-OHT-1X-RTD-FF-X		
			Measured		
XY FF Open-Hole Tensile Strength [ksi]	**Mean**		20.61		
	Minimum		19.29		
	Maximum		22.11		
	C.V.(%)		4.964		
	No. Specimens		6		
	No. Material Batches		3		

2.2.25 **XZ PF Open-Hole Tension Properties**

Material:	Markforged Onyx FR-A™ - Carbon Fiber FR-A™ / Markforged X7			**Open-Hole Tension (OHT)** Markforged OFRA-CFRA / Markforged X7 -45/45 Build Orientation: XZ	
AM Printer:	Markforged X7				
Test method:	ASTM D5766/D5766M-11(2018)				
		CTD	**RTD**	**ETD**	**ETW**
Test Temperature [°F]		-65	70	130	130
Moisture Conditioning		Dry	Dry	Dry	Equilibrium
Equilibrium at T, RH					120 F,95%
Source code: Prefixed by NTPAM6754Q1-MFD-OFRA-CFRA-MFD-		X-MX-PX-XZ-OHT-1X-CTD-PF-X	X-MX-PX-XZ-OHT-1X-RTD-PF-X	X-MX-PX-XZ-OHT-1X-ETD-PF-X	X-MX-PX-XZ-OHT-1X-ETW-PF-X
		Measured	**Measured**	**Measured**	**Measured**
XZ PF Open-Hole Tensile Strength [ksi]	**Mean**	28.53	34.84	32.96	24.28
	Minimum	20.48	18.38	30.43	16.84
	Maximum	35.75	40.57	36.02	33.03
	C.V.(%)	18.73	17.05	4.592	15.78
	No. Specimens	22	19	18	20
	No. Material Batches	3	3	3	3

See section 4, paragraph 3 for discussion related to Open-Hole Tensile Strength properties.

2.2.26 **XZ FF Open-Hole Tension Properties – Reference Only**

Material:	Markforged Onyx FR-A™ - Carbon Fiber FR-A™ / Markforged X7			**Open-Hole Tension (OHT)** Markforged OFRA-CFRA / X7 -45/45 Build Orientation: XZ	
AM Material:	Markforged X7				
Test method:	ASTM D5766/D5766M-11(2018)				
			RTD		
Test Temperature [°F]			70		
Moisture Conditioning			Dry		
Equilibrium at T, RH					
Source code: Prefixed by NTPAM6754Q1-MFD-OFRA-CFRA-MFD-			X-MX-PX-XZ-OHT-1X-RTD-FF-X		
			Measured		
XZ FF Open-Hole Tensile Strength [ksi]	**Mean**		52.39		
	Minimum		48.86		
	Maximum		55.26		
	C.V.(%)		4.670		
	No. Specimens		7		
	No. Material Batches		3		

See section 4, paragraph 3 for discussion related to Open-Hole Tensile Strength properties.

2.2.27 ZX PF Open-Hole Tension Properties – Reference Only

Material:	Markforged Onyx FR-A™ - Carbon Fiber FR-A™ / Markforged X7			**Open-Hole Tension (OHT) - Reference Only**	
AM Printer:	Markforged X7			Markforged OFRA-CFRA / Markforged X7 -45/45 Build Orientation: ZX	
Test method:	ASTM D5766/D5766M-11(2018)				
		CTD	**RTD**		
Test Temperature [°F]		-65	70		
Moisture Conditioning		Dry	Dry		
Equilibrium at T, RH					
Source code: Prefixed by NTPAM6754Q1-MFD-OFRA-CFRA-MFD-		X-MX-PX-ZX-OHT-1X-CTD-PF-X	X-MX-PX-ZX-OHT-1X-RTD-PF-X		
		Measured	**Measured**		
ZX PF Open-Hole Tensile Strength [ksi]	**Mean**	1.106	1.030		
	Minimum	0.721	0.678		
	Maximum	1.354	1.219		
	C.V.(%)	20.45	16.63		
	No. Specimens	6	9		
	No. Material Batches	1	2		

2.2.28 ZX NF Open-Hole Tension Properties

Material:	Markforged Onyx FR-A™ - Carbon Fiber FR-A™ / Markforged X7			**Open-Hole Tension (OHT)** Markforged OFRA-CFRA / Markforged X7 -45/45 Build Orientation: ZX	
AM Printer:	Markforged X7				
Test method:	ASTM D5766/D5766M-11(2018)				
		CTD	**RTD**	**ETD**	**ETW**
Test Temperature [°F]		-65	70	130	130
Moisture Conditioning		Dry	Dry	Dry	Equilibrium
Equilibrium at T, RH					120 F,95%
Source code: Prefixed by NTPAM6754Q1-MFD-OFRA-CFRA-MFD-		X-MX-PX-ZX-OHT-1X-CTD-NF-X	X-MX-PX-ZX-OHT-1X-RTD-NF-X	X-MX-PX-ZX-OHT-1X-ETD-NF-X	X-MX-PX-ZX-OHT-1X-ETW-NF-X
		Measured	**Measured**	**Measured**	**Measured**
ZX NF Open-Hole Tensile Strength [ksi]	**Mean**	3.327	2.502	1.407	0.870
	Minimum	2.605	1.974	1.192	0.741
	Maximum	3.959	2.970	1.584	1.016
	C.V.(%)	11.44	11.71	7.613	8.766
	No. Specimens	18	18	18	18
	No. Material Batches	3	3	3	3

2.2.29 XY PF Filled-Hole Tension Properties

Material:	Markforged Onyx FR-A™ - Carbon Fiber FR-A™			**Filled-Hole Tension (FHT)**	
AM Printer:	Markforged X7			Markforged OFRA-CFRA / Markforged X7 Partial Fiber (PF) Fill	
Test method:	ASTM D6742/D6742M-17			Build Orientation: XY	
		CTD	**RTD**	**ETD**	**ETW**
Test Temperature [°F]		-65	70	130	130
Moisture Conditioning		Dry	Dry	Dry	Equilibrium
Equilibrium at T, RH					120 F,95%
Source code: Prefixed by NTPAM6754Q1-MFD-OFRA-CFRA-MFD-		X-MX-PX-XY-FHT-1X-CTD-PF-X	X-MX-PX-XY-FHT-1X-RTD-PF-X	X-MX-PX-XY-FHT-1X-ETD-PF-X	X-MX-PX-XY-FHT-1X-ETW-PF-X
		Measured	**Measured**	**Measured**	**Measured**
XY PF Filled-Hole Tensile Strength [ksi]	**Mean**	13.65	10.49	8.817	6.735
	Minimum	12.77	9.474	7.976	5.948
	Maximum	14.50	12.11	9.480	7.876
	C.V.(%)	3.778	6.780	4.708	8.085
	No. Specimens	18	21	18	19
	No. Material Batches	3	3	3	3

2.2.30 XY FF Filled-Hole Tension Properties – Reference Only

Material:	Markforged Onyx FR-A™ - Carbon Fiber FR-A™			**Filled-Hole Tension (FHT)** Markforged OFRA-CFRA / Markforged X7 Full Fiber (FF) Fill Build Orientation: XY	
AM Printer:	Markforged X7				
Test method:	ASTM D6742/D6742M-17				
			RTD		
Test Temperature [°F]			70		
Moisture Conditioning			Dry		
Equilibrium at T, RH					
Source code: Prefixed by NTPAM6754Q1-MFD-OFRA-CFRA-MFD-			X-MX-PX-XY-FHT-1X-RTD-FF-X		
			Measured		
XY FF Filled-Hole Tensile Strength [ksi]	**Mean**		22.53		
	Minimum		21.37		
	Maximum		24.90		
	C.V.(%)		6.043		
	No. Specimens		6		
	No. Material Batches		3		

2.2.31 XZ PF Filled-Hole Tension Properties

Material:	Markforged Onyx FR-A™ - Carbon Fiber FR-A™			**Filled-Hole Tension (FHT)**	
AM printer:	Markforged X7			Markforged OFRA-CFRA / Markforged X7 Partial Fiber (PF) Fill	
Test method:	ASTM D6742/D6742M-17			Build Orientation: XZ	
		CTD	**RTD**	**ETD**	**ETW**
Test Temperature [°F]		-65	70	130	130
Moisture Conditioning		Dry	Dry	Dry	Equilibrium
Equilibrium at T, RH					120 F,95%
Source code: Prefixed by NTPAM6754Q1-MFD-OFRA-CFRA-MFD-		X-MX-PX-XZ-FHT-1X-CTD-PF-X	X-MX-PX-XZ-FHT-1X-RTD-PF-X	X-MX-PX-XZ-FHT-1X-ETD-PF-X	X-MX-PX-XZ-FHT-1X-ETW-PF-X
		Measured	**Measured**	**Measured**	**Measured**
XZ PF Filled-Hole Tensile Strength [ksi]	**Mean**	37.13	36.54	33.74	25.43
	Minimum	31.37	28.04	30.45	17.81
	Maximum	41.39	40.42	36.36	29.40
	C.V.(%)	7.137	7.853	4.806	14.18
	No. Specimens	18	18	18	18
	No. Material Batches	3	3	3	3

See section 4, paragraph 3 for discussion related to Filled-Hole Tensile Strength properties.

2.2.32 XZ FF Filled-Hole Tension Properties – Reference Only

Material:	Markforged Onyx FR-A™ - Carbon Fiber FR-A™			**Filled-Hole Tension (FHT)** Markforged OFRA-CFRA / Markforged X7 Full Fiber (FF) Fill Build Orientation: XZ	
AM Printer:	Markforged X7				
Test method:	ASTM D6742/D6742M-17				
			RTD		
Test Temperature [°F]			70		
Moisture Conditioning			Dry		
Equilibrium at T, RH					
Source code: Prefixed by NTPAM6754Q1-MFD-OFRA-CFRA-MFD-			X-MX-PX-XZ-FHT-1X-RTD-FF-X		
			Measured		
XZ FF Filled-Hole Tensile Strength [ksi]	**Mean**		53.36		
	Minimum		50.38		
	Maximum		59.13		
	C.V.(%)		6.117		
	No. Specimens		6		
	No. Material Batches		3		

See section 4, paragraph 3 for discussion related to Filled-Hole Tensile Strength properties.

2.2.33 ZX PF Filled-Hole Tension Properties – Reference Only

Material:	Markforged Onyx FR-A™ - Carbon Fiber FR-A™			**Filled-Hole Tension (FHT) - Reference Only** Markforged OFRA-CFRA / Markforged X7 Partial Fiber (PF) Fill Build Orientation: ZX	
AM Printer:	Markforged X7				
Test method:	ASTM D6742/D6742M-17				
			RTD		
Test Temperature [°F]			70		
Moisture Conditioning			Dry		
Equilibrium at T, RH					
Source code: Prefixed by NTPAM6754Q1-MFD-OFRA-CFRA-MFD-			X-MX-PX-ZX-FHT-1X-RTD-PF-X		
			Measured		
ZX PF Filled-Hole Tensile Strength [ksi]	**Mean**		1.005		
	Minimum		0.871		
	Maximum		1.130		
	C.V.(%)		13.50		
	No. Specimens		4		
	No. Material Batches		3		

2.2.34 **ZX NF Filled-Hole Tension Properties**

Material:	Markforged Onyx FR-A™ - Carbon Fiber FR-A™			**Filled-Hole Tension (FHT)**	
AM Printer:	Markforged X7			Markforged OFRA-CFRA / Markforged X7 No Fiber (NF) Fill	
Test method:	ASTM D6742/D6742M-17			Build Orientation: ZX	
		CTD	**RTD**	**ETD**	**ETW**
Test Temperature [°F]		-65	70	130	130
Moisture Conditioning		Dry	Dry	Dry	Equilibrium
Equilibrium at T, RH					120 F,95%
Source code: Prefixed by NTPAM6754Q1-MFD-OFRA-CFRA-MFD-		X-MX-PX-ZX-FHT-1X-CTD-NF-X	X-MX-PX-ZX-FHT-1X-RTD-NF-X	X-MX-PX-ZX-FHT-1X-ETD-NF-X	X-MX-PX-ZX-FHT-1X-ETW-NF-X
		Measured	**Measured**	**Measured**	**Measured**
ZX NF Filled-Hole Tensile Strength [ksi]	**Mean**	3.562	2.574	1.529	0.939
	Minimum	2.870	2.352	1.430	0.823
	Maximum	4.093	2.896	1.631	1.075
	C.V.(%)	11.54	6.992	4.352	7.240
	No. Specimens	18	18	18	18
	No. Material Batches	3	3	3	3

See section 4, paragraph 3 for discussion related to Filled-Hole Tensile Strength properties.

2.2.35 XY PF Single Shear Bearing Properties

Material:	Markforged Onyx FR-A™ - Carbon Fiber FR-A™
AM Printer:	Markforged X7
Test method:	ASTM D5961/D5961M-17 Procedure C

Single Shear Bearing (SSB) Proc. C
Markforged OFRA-CFRA / Markforged X7
Partial Fiber (PF) Fill
Build Orientation: XY

		CTD	RTD		ETW
Test Temperature [°F]		-65	70		130
Moisture Conditioning		Dry	Dry		Equilibrium
Equilibrium at T, RH					120 F,95%
Source code: Prefixed by NTPAM6754Q1-MFD-OFRA-CFRA-MFD-		X-MX-PX-XY-SSB-1X-CTD-PF-X	X-MX-PX-XY-SSB-1X-RTD-PF-X		X-MX-PX-XY-SSB-1X-ETW-PF-X
		Measured	**Measured**		**Measured**
XY PF Ultimate Bearing Strength [ksi]	**Mean**	47.86	33.37		14.66
	Minimum	42.71	25.73		11.37
	Maximum	54.52	40.68		19.18
	C.V.(%)	7.426	10.27		14.05
	No. Specimens	18	18		19
	No. Material Batches	3	3		3
XY PF 2% Offset Bearing Strength [ksi]	**Mean**	44.36	29.73		13.69
	Minimum	39.19	24.53		10.37
	Maximum	50.92	35.34		19.09
	C.V.(%)	7.849	9.515		16.90
	No. Specimens	18	18		16
	No. Material Batches	3	3		3
XY PF Bearing Stiffness [Msi]	**Mean**	0.421	0.365		0.234
	Minimum	0.348	0.294		0.156
	Maximum	0.485	0.446		0.310
	C.V.(%)	10.99	13.29		18.92
	No. Specimens	18	18		19
	No. Material Batches	3	3		3

2.2.36 XY FF Single Shear Bearing Properties – Reference Only

Material:	Markforged Onyx FR-A™ - Carbon Fiber FR-A™			**Single Shear Bearing (SSB) Proc. C** Markforged OFRA-CFRA / Markforged X7 Full Fiber (FF) Fill Build Orientation: XY	
AM printer:	Markforged X7				
Test method:	**ASTM D5961/D5961M-17 Procedure C**				
			RTD		
Test Temperature [°F]			70		
Moisture Conditioning			Dry		
Equilibrium at T, RH					
Source code: Prefixed by NTPAM6754Q1-MFD-OFRA-CFRA-MFD-			X-MX-PX-XY-SSB-1X-RTD-FF-X		
			Measured		
XY FF Ultimate Bearing Strength [ksi]	**Mean**		58.00		
	Minimum		47.22		
	Maximum		62.35		
	C.V.(%)		9.877		
	No. Specimens		6		
	No. Material Batches		1		
XY FF 2% Offset Bearing Strength [ksi]	**Mean**		50.35		
	Minimum		44.86		
	Maximum		53.44		
	C.V.(%)		6.064		
	No. Specimens		6		
	No. Material Batches		1		
XY FF Bearing Stiffness [Msi]	**Mean**		0.686		
	Minimum		0.648		
	Maximum		0.709		
	C.V.(%)		3.357		
	No. Specimens		6		
	No. Material Batches		1		

2.2.37 **XZ PF Single Shear Bearing Properties**

Material:	Markforged Onyx FR-A™ - Carbon Fiber FR-A™			**Single Shear Bearing (SSB) Proc. C**	
AM Printer:	Markforged X7			Markforged OFRA-CFRA / Markforged X7 Partial Fiber (PF) Fill	
Test method:	ASTM D5961/D5961M-17 Procedure C			Build Orientation: XZ	
		CTD	**RTD**		**ETW**
Test Temperature [°F]		-65	70		130
Moisture Conditioning		Dry	Dry		Equilibrium
Equilibrium at T, RH					120 F,95%
Source code: Prefixed by NTPAM6754Q1-MFD-OFRA-CFRA-MFD-		X-MX-PX-XZ-SSB-1X-CTD-PF-X	X-MX-PX-XZ-SSB-1X-RTD-PF-X		X-MX-PX-XZ-SSB-1X-ETW-PF-X
		Measured	**Measured**		**Measured**
XZ PF Ultimate Bearing Strength [ksi]	**Mean**	21.95	12.76		6.046
	Minimum	17.66	10.27		5.347
	Maximum	25.29	16.57		6.908
	C.V.(%)	9.354	13.18		6.362
	No. Specimens	18	18		18
	No. Material Batches	3	3		3
XZ PF 2% Offset Bearing Strength [ksi]	**Mean**		10.75		5.008
	Minimum		9.246		3.950
	Maximum		12.67		6.538
	C.V.(%)		12.29		13.021
	No. Specimens	0	11		18
	No. Material Batches	3	3		3
XZ PF Bearing Stiffness [Msi]	**Mean**	0.358	0.186		0.062
	Minimum	0.298	0.095		0.029
	Maximum	0.482	0.319		0.102
	C.V.(%)	12.47	36.80		40.79
	No. Specimens	18	18		18
	No. Material Batches	3	3		3

See section 4, paragraph 3 for discussion related to Single Shear Bearing Strength properties.

2.2.38 XZ FF Single Shear Bearing Properties – Reference Only

Material:	Markforged Onyx FR-A™ - Carbon Fiber FR-A™			**Single Shear Bearing (SSB) Proc. C** Markforged OFRA-CFRA / Markforged X7 Full Fiber (FF) Fill Build Orientation: XZ	
AM printer:	Markforged X7				
Test method:	**ASTM D5961/D5961M-17 Procedure C**				
			RTD		
Test Temperature [°F]			70		
Moisture Conditioning			Dry		
Equilibrium at T, RH					
Source code: Prefixed by NTPAM6754Q1-MFD-OFRA-CFRA-MFD-			X-MX-PX-XZ-SSB-1X-RTD-FF-X		
			Measured		
XZ FF Ultimate Bearing Strength [ksi]	**Mean**		12.19		
	Minimum		11.30		
	Maximum		13.08		
	C.V.(%)		5.779		
	No. Specimens		6		
	No. Material Batches		1		
XZ FF 2% Offset Bearing Strength [ksi]	**Mean**		11.23		
	Minimum		8.740		
	Maximum		12.77		
	C.V.(%)		12.93		
	No. Specimens		6		
	No. Material Batches		1		
XZ FF Bearing Stiffness [Msi]	**Mean**		0.208		
	Minimum		0.087		
	Maximum		0.283		
	C.V.(%)		35.00		
	No. Specimens		6		
	No. Material Batches		1		

See section 4, paragraph 3 for discussion related to Single Shear Bearing Strength properties.

2.2.39 ZX PF Single Shear Bearing Properties – Reference Only

Material:	Markforged Onyx FR-A™ - Carbon Fiber FR-A™			**Single Shear Bearing (SSB) Proc. C - Reference Only** Markforged OFRA-CFRA / Markforged X7 Partial Fiber (PF) Fill Build Orientation: ZX	
AM Printer:	Markforged X7				
Test method:	ASTM D5961/D5961M-17 Procedure C				
			RTD		
Test Temperature [°F]			70		
Moisture Conditioning			Dry		
Equilibrium at T, RH					
Source code: Prefixed by NTPAM6754Q1-MFD-OFRA-CFRA-MFD-			X-MX-PX-ZX-SSB-1X-RTD-PF-X		
			Measured		
ZX PF Ultimate Bearing Strength [ksi]	**Mean**		6.703		
	Minimum		5.914		
	Maximum		7.587		
	C.V.(%)		8.320		
	No. Specimens		9		
	No. Material Batches		1		
ZX PF 2% Offset Bearing Strength [ksi]	**Mean**		4.572		
	Minimum		3.710		
	Maximum		5.414		
	C.V.(%)		12.87		
	No. Specimens		9		
	No. Material Batches		1		
ZX PF Bearing Stiffness [Msi]	**Mean**		0.125		
	Minimum		0.103		
	Maximum		0.153		
	C.V.(%)		14.09		
	No. Specimens		9		
	No. Material Batches		1		

2.2.40 **ZX NF Single Shear Bearing Properties**

Material:	Markforged Onyx FR-A™ - Carbon Fiber FR-A™			**Single Shear Bearing (SSB) Proc. C**	
AM Printer:	Markforged X7			Markforged OFRA-CFRA / Markforged X7 No Fiber (NF) Fill	
Test method:	**ASTM D5961/D5961M-17 Procedure C**			Build Orientation: ZX	
		CTD	**RTD**		**ETW**
Test Temperature [°F]		-65	70		130
Moisture Conditioning		Dry	Dry		Equilibrium
Equilibrium at T, RH					120 F,95%
Source code: Prefixed by NTPAM6754Q1-MFD-OFRA-CFRA-MFD-		X-MX-PX-ZX-SSB-1X-CTD-NF-X	X-MX-PX-ZX-SSB-1X-RTD-NF-X		X-MX-PX-ZX-SSB-1X-ETW-NF-X
		Measured	**Measured**		**Measured**
ZX NF Ultimate Bearing Strength [ksi]	**Mean**	19.03	12.72		4.776
	Minimum	16.30	10.39		3.772
	Maximum	22.65	15.00		5.283
	C.V.(%)	9.955	9.247		7.721
	No. Specimens	18	18		18
	No. Material Batches	3	3		3
ZX NF 2% Offset Bearing Strength [ksi]	**Mean**	18.31	10.13		2.690
	Minimum	16.26	7.812		2.238
	Maximum	19.74	13.67		3.336
	C.V.(%)	6.721	14.86		12.94
	No. Specimens	8	18		18
	No. Material Batches	3	3		3
ZX NF Bearing Stiffness [Msi]	**Mean**	0.226	0.111		0.024
	Minimum	0.181	0.070		0.015
	Maximum	0.291	0.166		0.032
	C.V.(%)	16.13	26.40		17.92
	No. Specimens	18	18		18
	No. Material Batches	3	3		3

See section 4, paragraph 3 for discussion related to Single Shear Bearing Strength properties.

2.2.41 **XY PF IZOD Pendulum Impact Properties – Reference Only**

Material:	Markforged Onyx FR-A™ - Carbon Fiber FR-A™			**IZOD Pendulum Impact (I)** Markforged OFRA-CFRA / Markforged X7 Partial Fiber (PF) Fill Build Orientation: XY	
AM printer:	Markforged X7				
Test method:	ASTM D256-10(2018)				
			RTD		
Test Temperature [°F]			70		
Moisture Conditioning			Dry		
Equilibrium at T, RH					
Source code: Prefixed by NTPAM6754Q1-MFD-OFRA-CFRA-MFD-			X-MX-PX-XY-I-1X-RTD-PF-X		
			Measured		
XY PF IZOD Impact Energy [Joules]	**Mean**		1.058		
	Minimum		0.977		
	Maximum		1.207		
	C.V.(%)		7.621		
	No. Specimens		8		
	No. Material Batches		3		
XY PF IZOD Imapct Resisitance [Joules/meter]	**Mean**		130.119		
	Minimum		119.414		
	Maximum		150.311		
	C.V.(%)		8.126		
	No. Specimens		8		
	No. Material Batches		3		

2.2.42 XY FF IZOD Pendulum Impact Properties – Reference Only

Material:	Markforged Onyx FR-A™ - Carbon Fiber FR-A™			**IZOD Pendulum Impact (I)** Markforged OFRA-CFRA / Markforged X7 Fulll Fiber (FF) Fill Build Orientation: XY	
AM printer:	Markforged X7				
Test method:	ASTM D256-10(2018)				
			RTD		
Test Temperature [°F]			70		
Moisture Conditioning			Dry		
Equilibrium at T, RH					
Source code: Prefixed by NTPAM6754Q1-MFD-OFRA-CFRA-MFD-			X-MX-PX-XY-I-1X-RTD-FF-X		
			Measured		
XY FF IZOD Impact Energy [Joules]	**Mean**		2.454		
	Minimum		2.229		
	Maximum		2.767		
	C.V.(%)		8.043		
	No. Specimens		8		
	No. Material Batches		3		
XY FF IZOD Imapct Resisitance [Joules/meter]	**Mean**		301.3		
	Minimum		274.5		
	Maximum		340.8		
	C.V.(%)		8.013		
	No. Specimens		8		
	No. Material Batches		3		

2.2.43 XZ PF IZOD Pendulum Impact Properties – Reference Only

Material:	Markforged Onyx FR-A™ - Carbon Fiber FR-A™			**IZOD Pendulum Impact (I)** Markforged OFRA-CFRA / Markforged X7 Partial Fiber (PF) Fill Build Orientation: XZ	
AM printer:	Markforged X7				
Test method:	ASTM D256-10(2018)				
			RTD		
Test Temperature [°F]			70		
Moisture Conditioning			Dry		
Equilibrium at T, RH					
Source code: Prefixed by NTPAM6754Q1-MFD-OFRA-CFRA-MFD-			X-MX-PX-XZ-I-1X-RTD-PF-X		
			Measured		
XZ PF IZOD Impact Energy [Joules]	**Mean**		1.028		
	Minimum		0.908		
	Maximum		1.160		
	C.V.(%)		7.386		
	No. Specimens		8		
	No. Material Batches		3		
XZ PF IZOD Imapct Resisitance [Joules/meter]	**Mean**		126.1		
	Minimum		111.5		
	Maximum		143.0		
	C.V.(%)		7.311		
	No. Specimens		8		
	No. Material Batches		3		

2.2.44 **XZ FF IZOD Pendulum Impact Properties – Reference Only**

Material:	Markforged Onyx FR-A™ - Carbon Fiber FR-A™			**IZOD Pendulum Impact (I)** Markforged OFRA-CFRA / Markforged X7 Fulll Fiber (FF) Fill Build Orientation: XZ	
AM printer:	Markforged X7				
Test method:	ASTM D256-10(2018)				
			RTD		
Test Temperature [°F]			70		
Moisture Conditioning			Dry		
Equilibrium at T, RH					
Source code: Prefixed by NTPAM6754Q1-MFD-OFRA-CFRA-MFD-			X-MX-PX-XZ-I-1X-RTD-FF-X		
			Measured		
XZ FF IZOD Impact Energy [Joules]	**Mean**		4.656		
	Minimum		4.254		
	Maximum		5.514		
	C.V.(%)		8.995		
	No. Specimens		8		
	No. Material Batches		3		
XZ FF IZOD Imapct Resisitance [Joules/meter]	**Mean**		551.6		
	Minimum		521.3		
	Maximum		606.6		
	C.V.(%)		5.242		
	No. Specimens		7		
	No. Material Batches		3		

2.2.45 **ZX PF IZOD Pendulum Impact Properties – Reference Only**

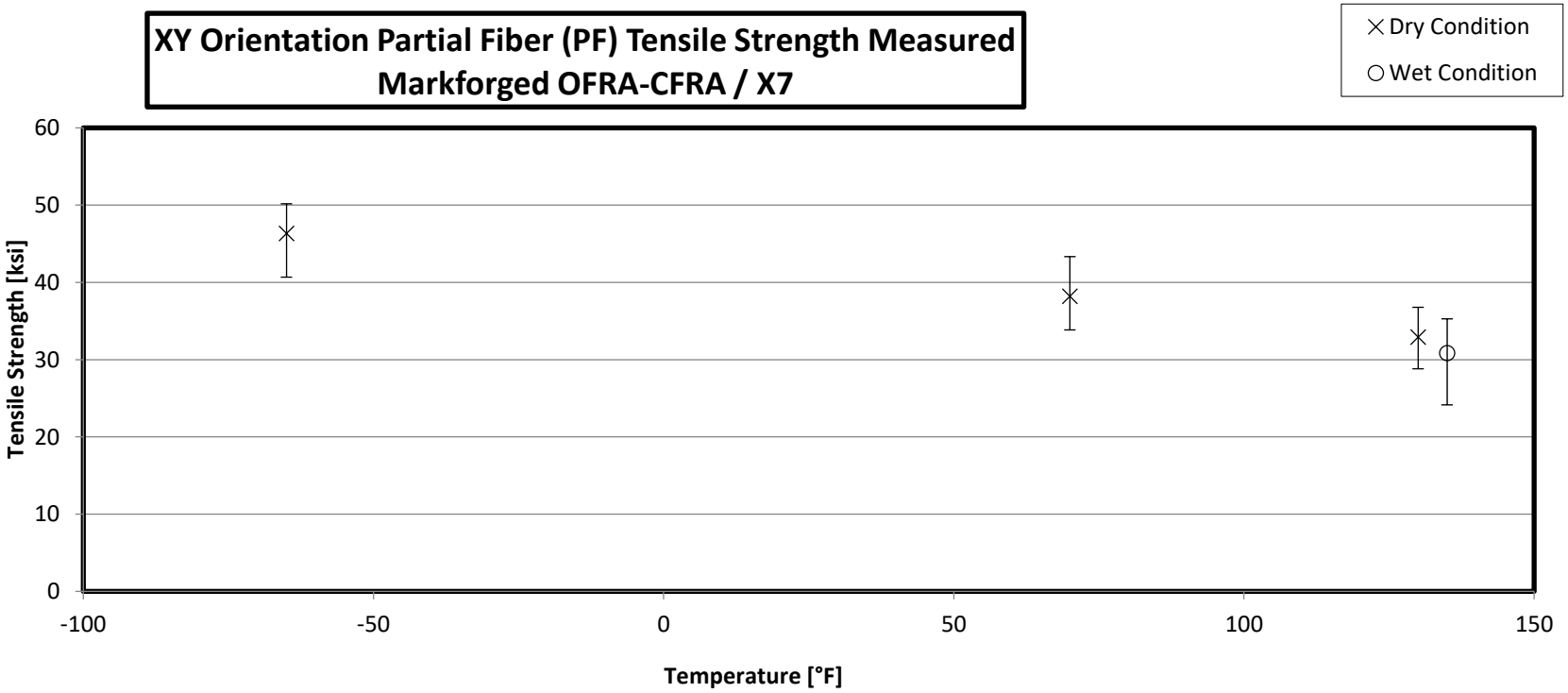
Material:	Markforged Onyx FR-A™ - Carbon Fiber FR-A™			**IZOD Pendulum Impact (I)**	
AM printer:	Markforged X7			Markforged OFRA-CFRA / Markforged X7 Partial Fiber (PF) Fill Build Orientation: ZX	
Test method:	ASTM D256-10(2018)				
			RTD		
Test Temperature [°F]			70		
Moisture Conditioning			Dry		
Equilibrium at T, RH					
Source code: Prefixed by NTPAM6754Q1-MFD-OFRA-CFRA-MFD-			X-MX-PX-ZX-I-1X-RTD-PF-X		
			Measured		
ZX PF IZOD Impact Energy [Joules]	**Mean**		0.200		
	Minimum		0.161		
	Maximum		0.235		
	C.V.(%)		15.01		
	No. Specimens		6		
	No. Material Batches		3		
ZX PF IZOD Imapct Resisitance [Joules/meter]	**Mean**		24.36		
	Minimum		19.61		
	Maximum		28.66		
	C.V.(%)		14.97		
	No. Specimens		6		
	No. Material Batches		3		

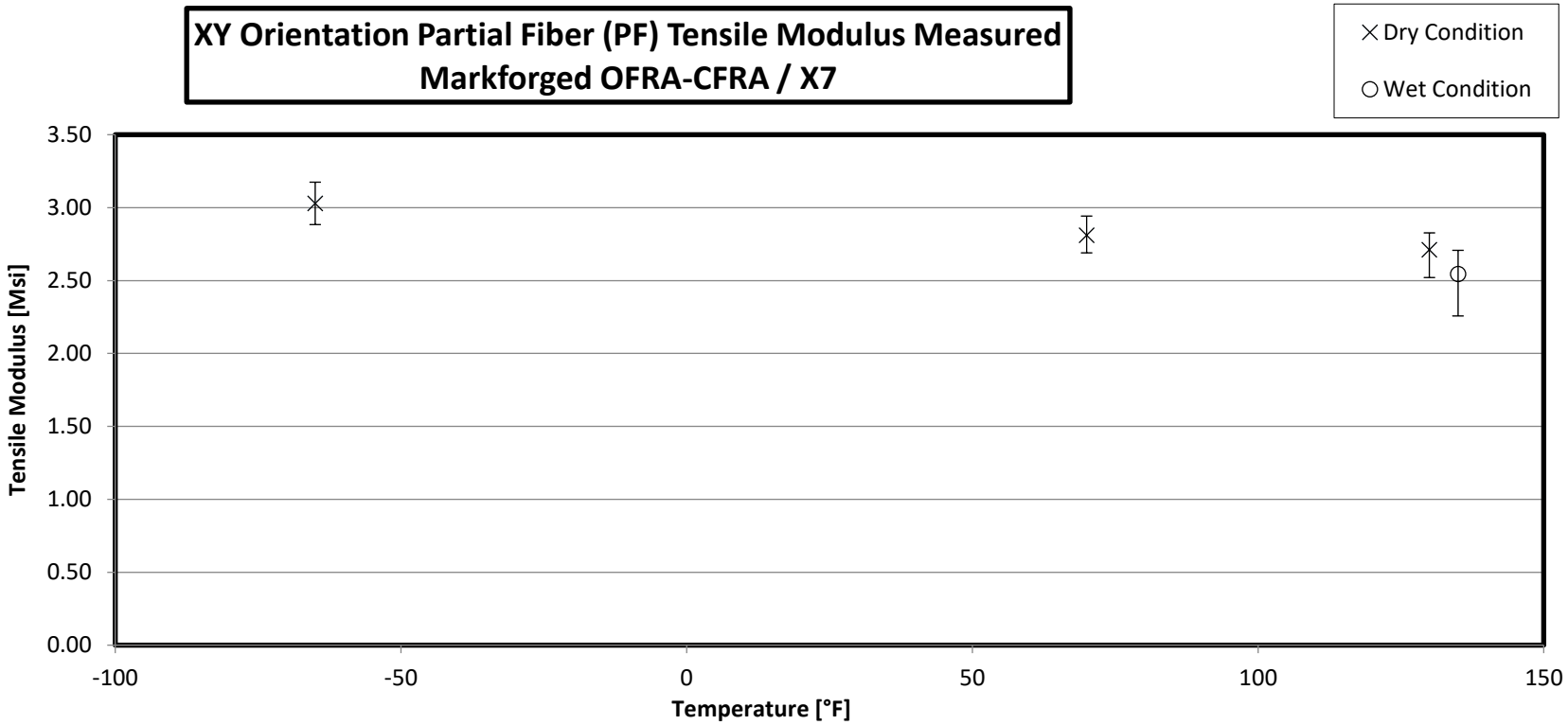
3. Individual Test Charts

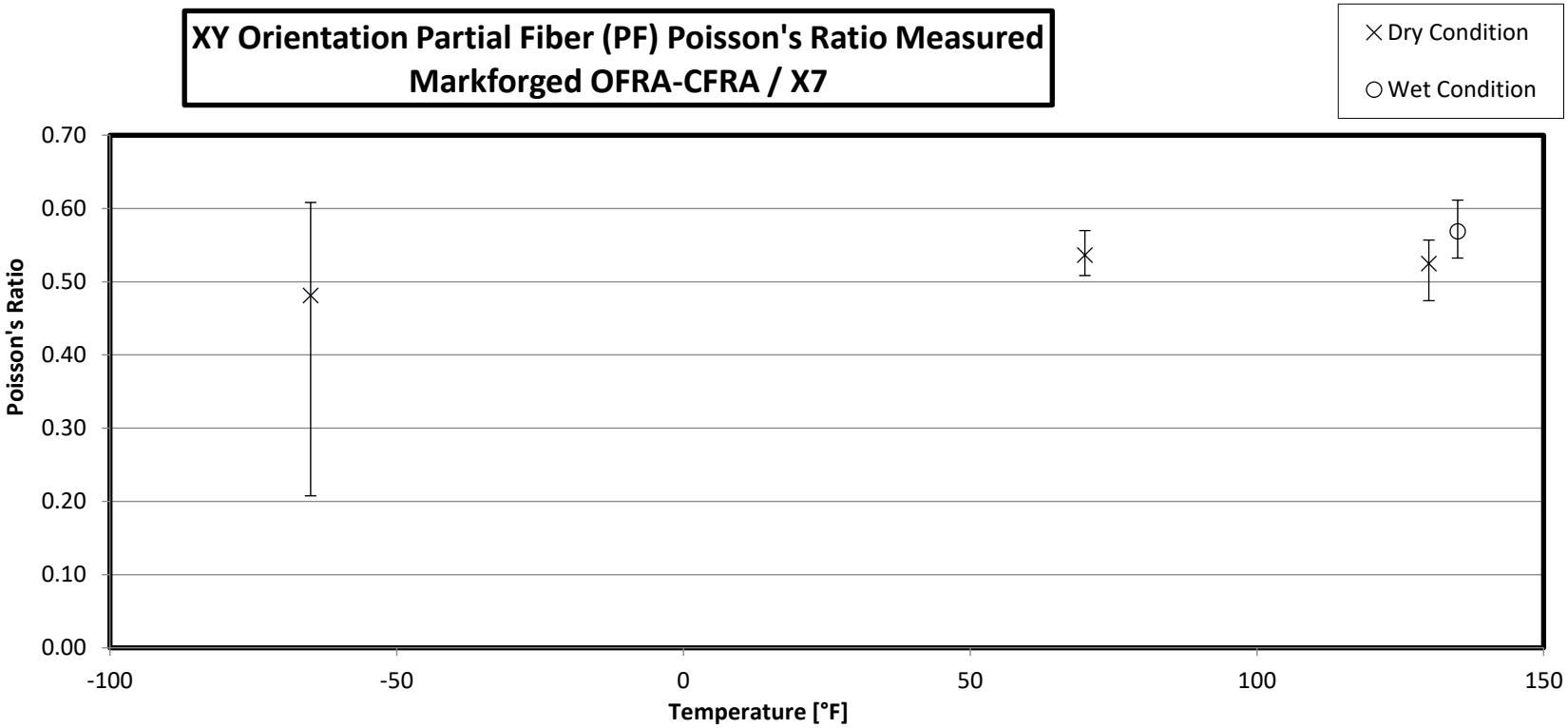
These charts combine all batches of data per test type and orientation. The charts plot the minimum and maximum modulus and strength range based on the test temperature.

Plots for ETW have been offset to 135°F (from 130°F) to improve clarity and readability.

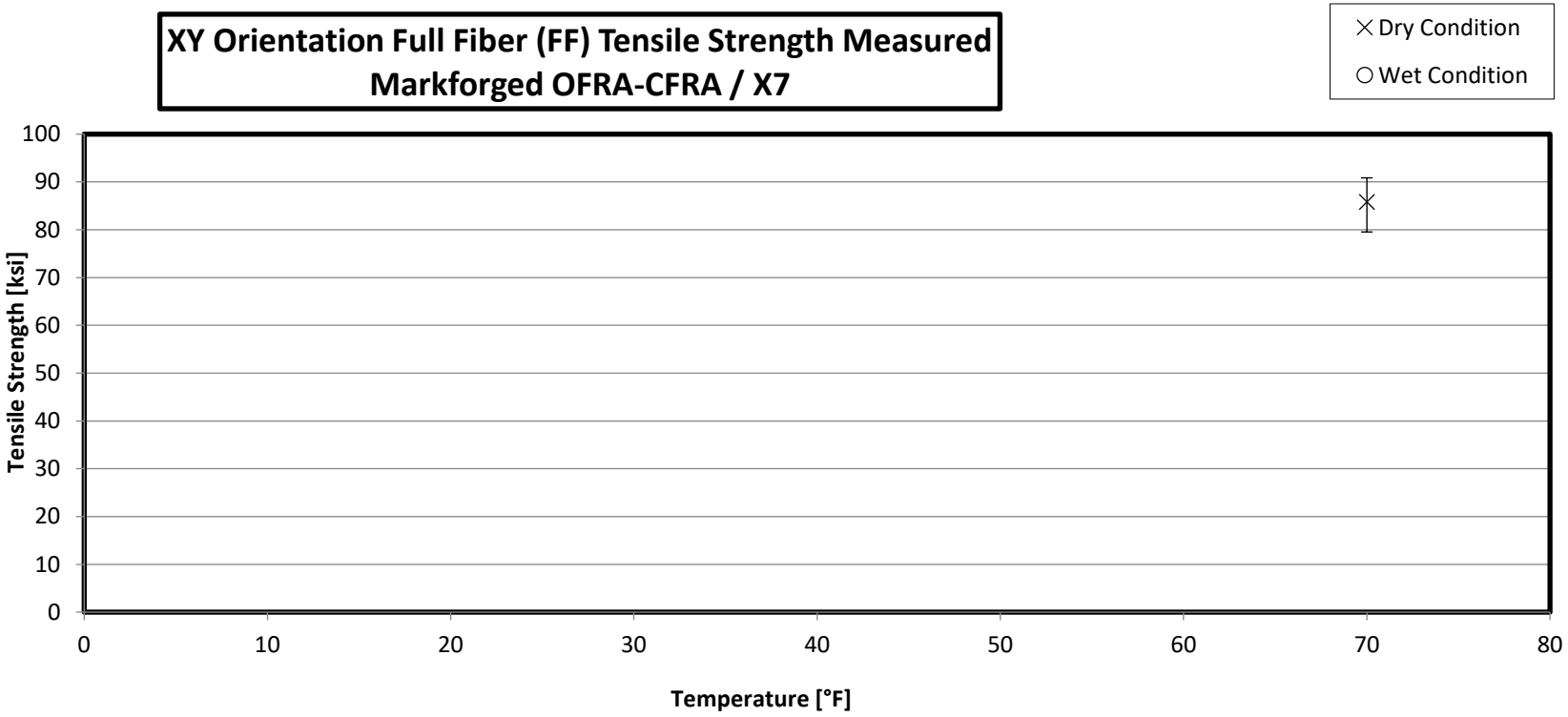
3.1 XY PF Tension Properties

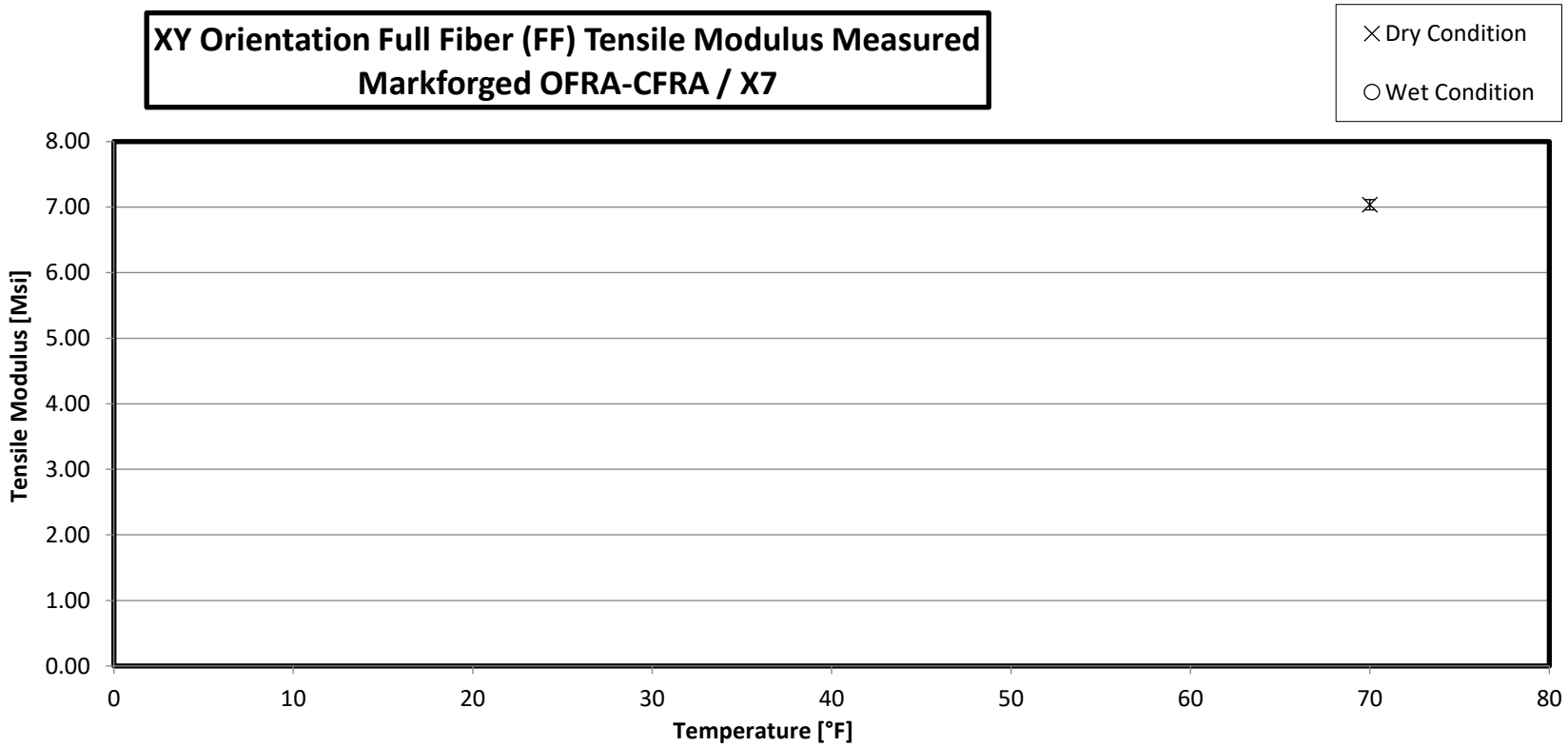


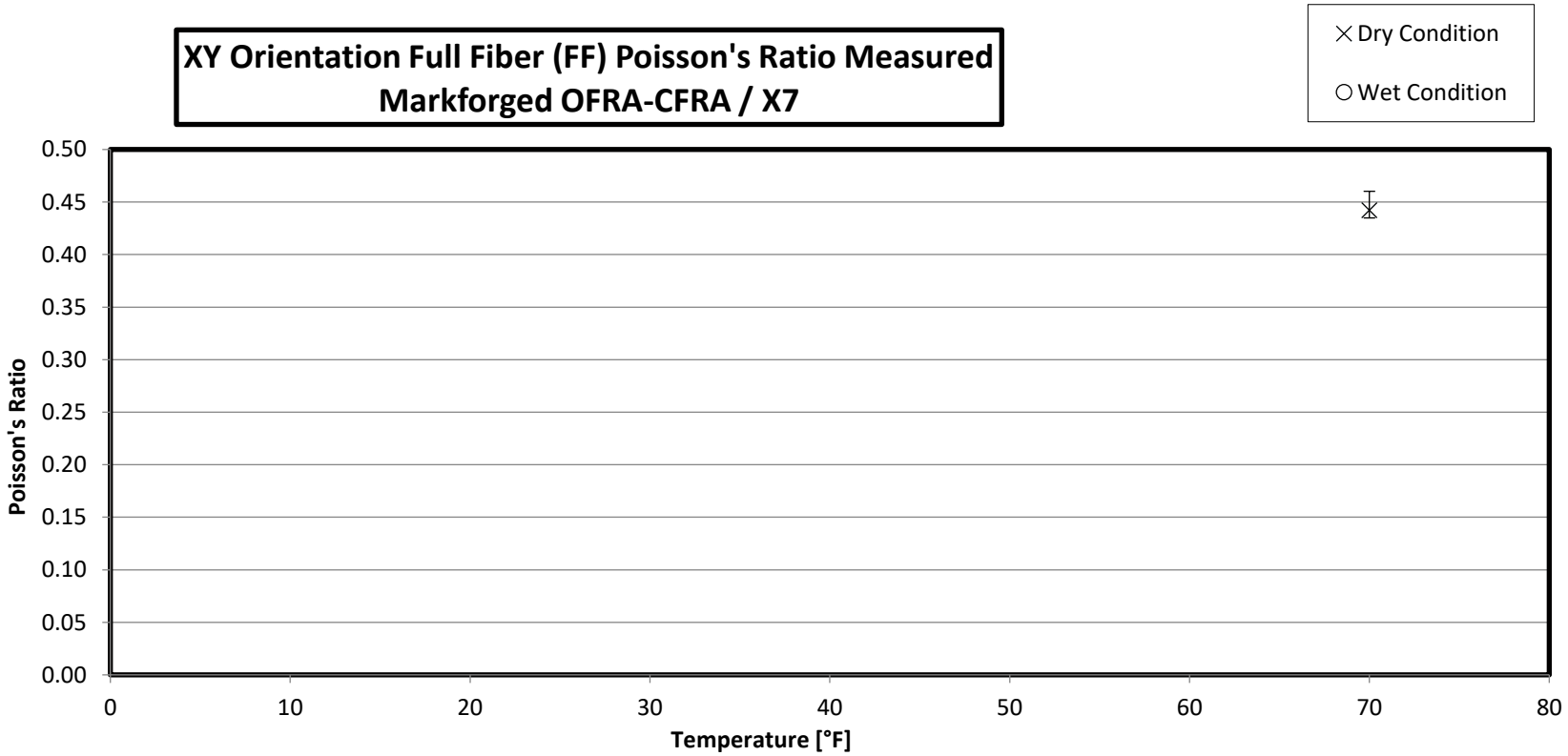

XY Orientation Partial Fiber (PF) Tensile Modulus Measured
Markforged OFRA-CFRA / X7
Dry Condition
Wet Condition
Tensile Modulus [Msi]
3.50
3.00
2.50
2.00
1.50
1.00
0.50
0.00
-100
-50
0
50
100
150
Temperature [°F]



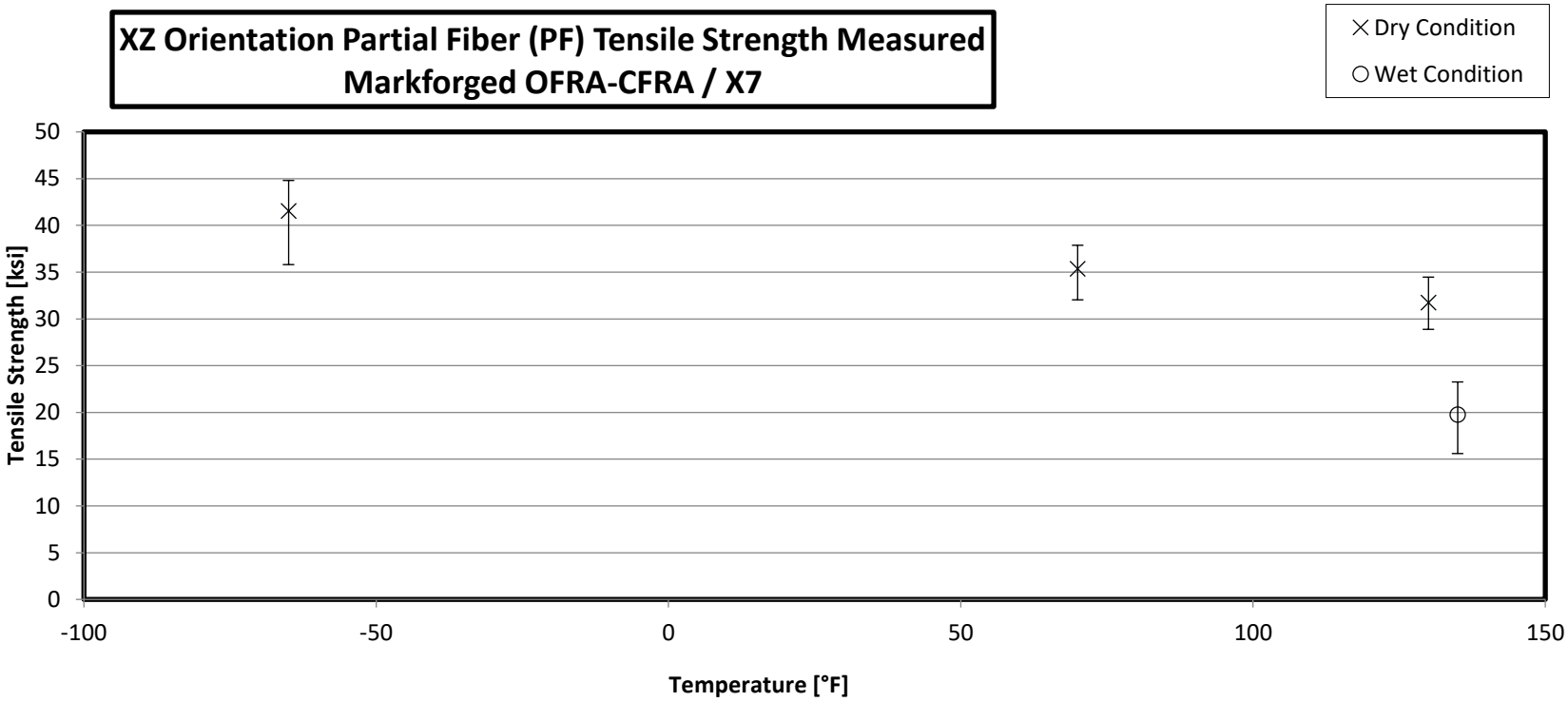
3.2 XY FF Tension Properties – Reference Only

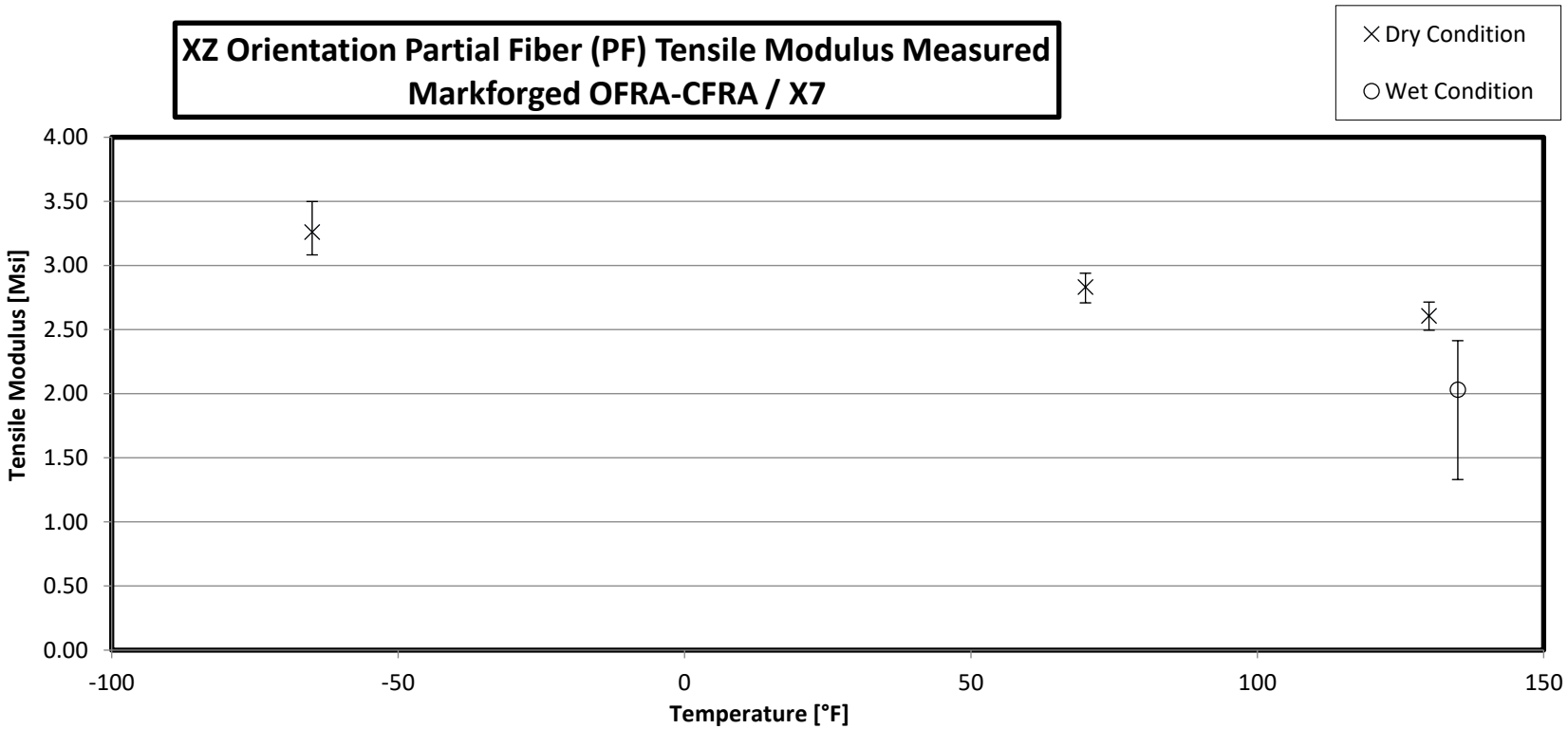

XY Orientation Full Fiber (FF) Tensile Strength Measured
Markforged OFRA-CFRA / X7
Dry Condition
Wet Condition
Tensile Strength [ksi]
100
90
80
70
60
50
40
30
20
10
0
0
10
20
30
40
50
60
70
80
Temperature [°F]

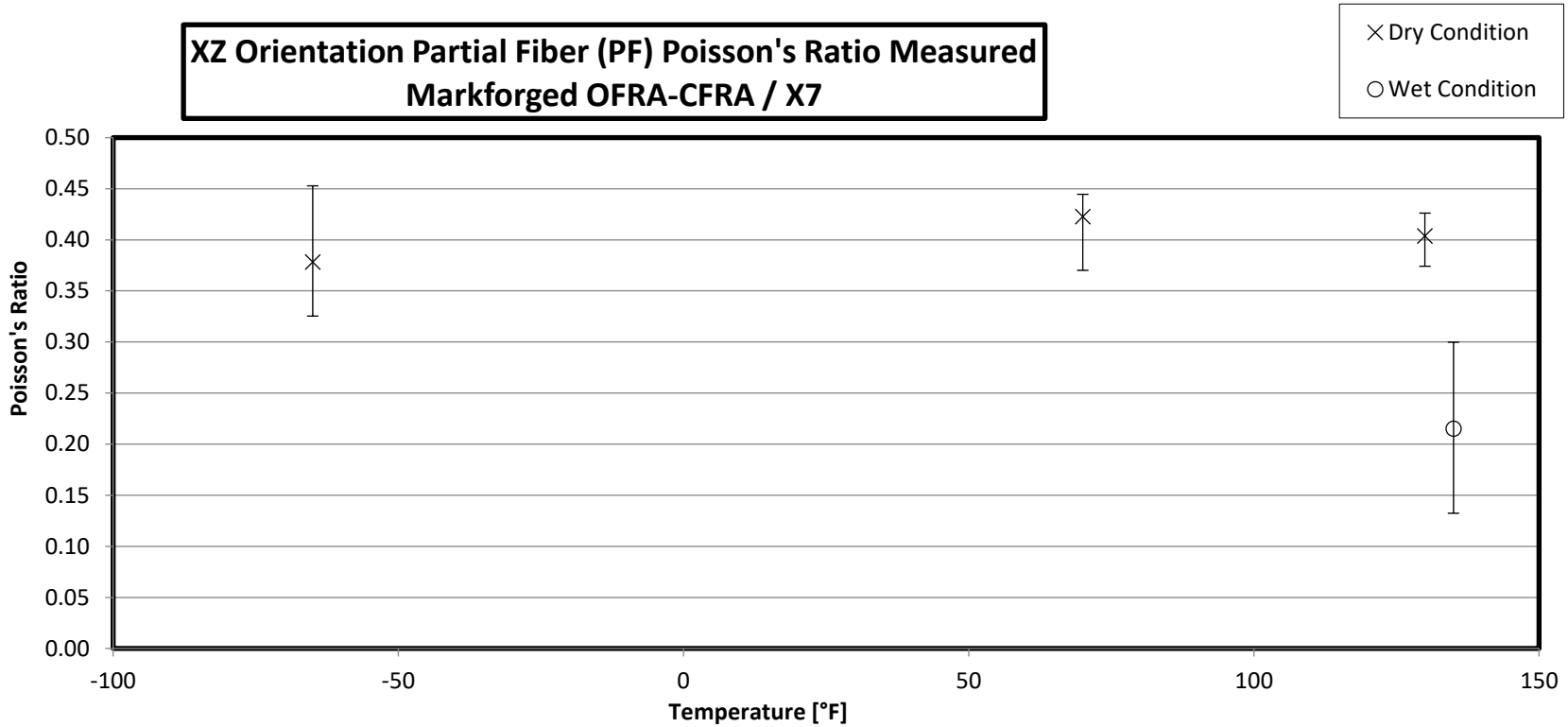

XY Orientation Full Fiber (FF) Tensile Modulus Measured
Markforged OFRA-CFRA / X7
Dry Condition
Wet Condition
Tensile Modulus [Msi]
8.00
7.00
6.00
5.00
4.00
3.00
2.00
1.00
0.00
0
10
20
30
40
50
60
70
80
Temperature [°F]


XY Orientation Full Fiber (FF) Poisson's Ratio Measured
Markforged OFRA-CFRA / X7
Dry Condition
Wet Condition
Poisson's Ratio
0.50
0.45
0.40
0.35
0.30
0.25
0.20
0.15
0.10
0.05
0.00
0
10
20
30
40
50
60
70
80
Temperature [°F]

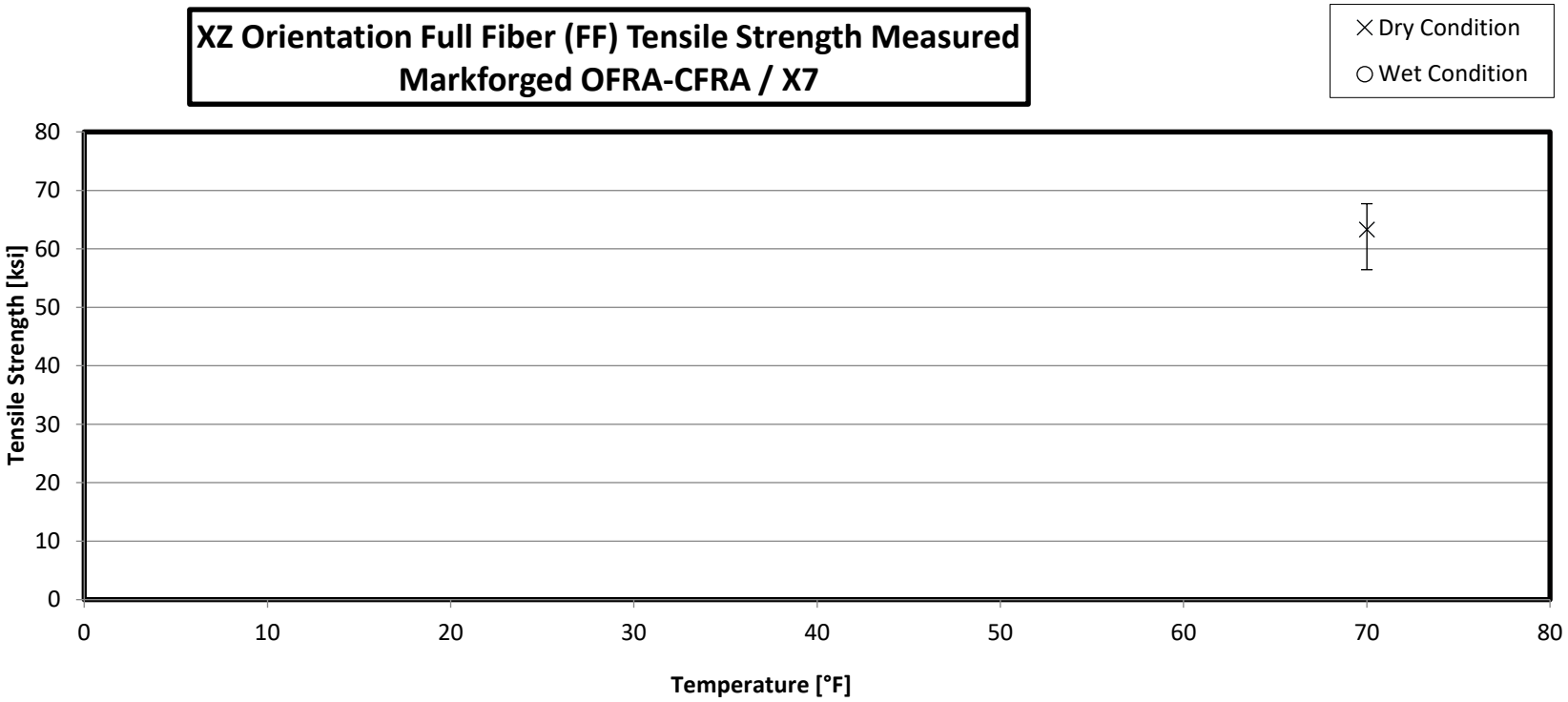
3.3 XZ PF Tension Properties

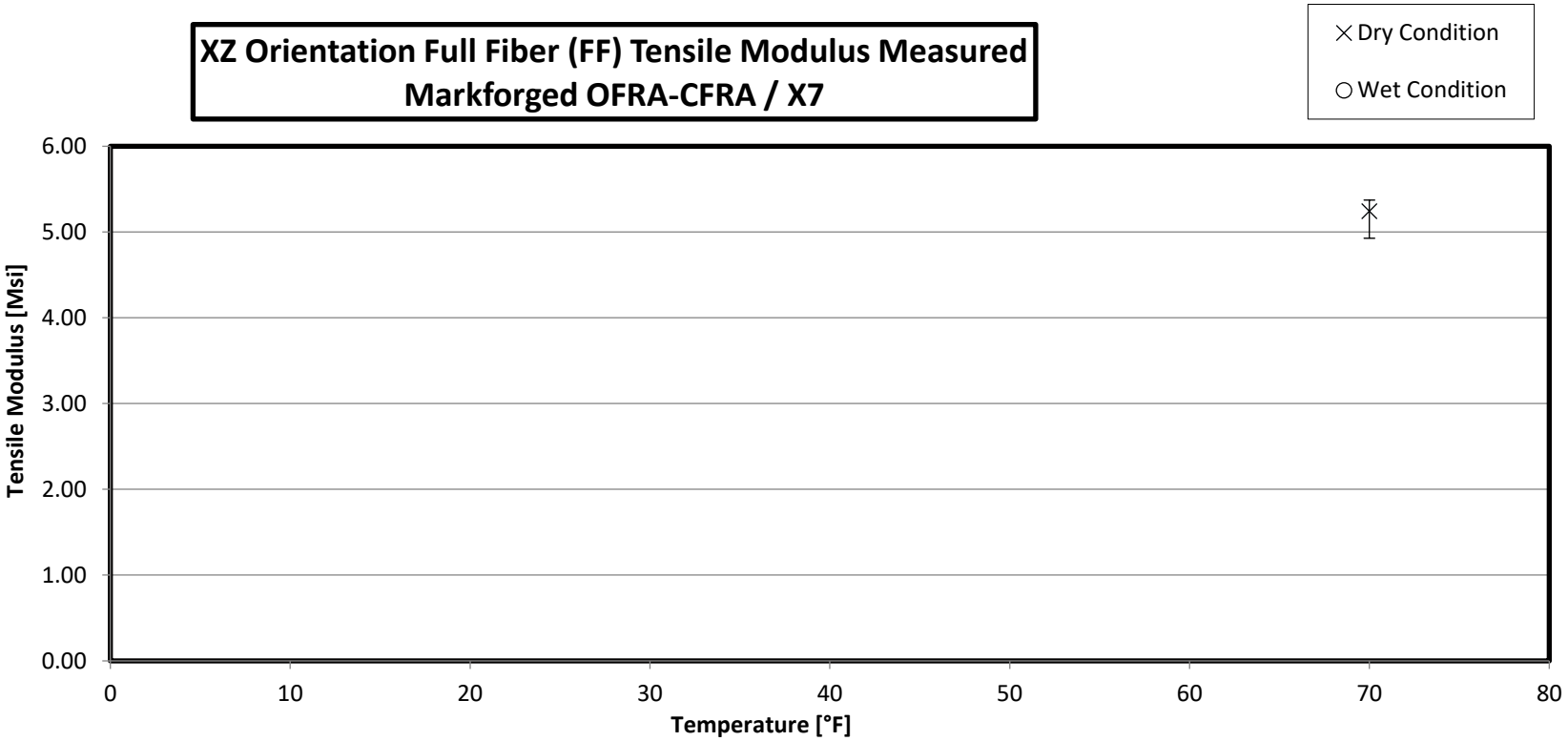


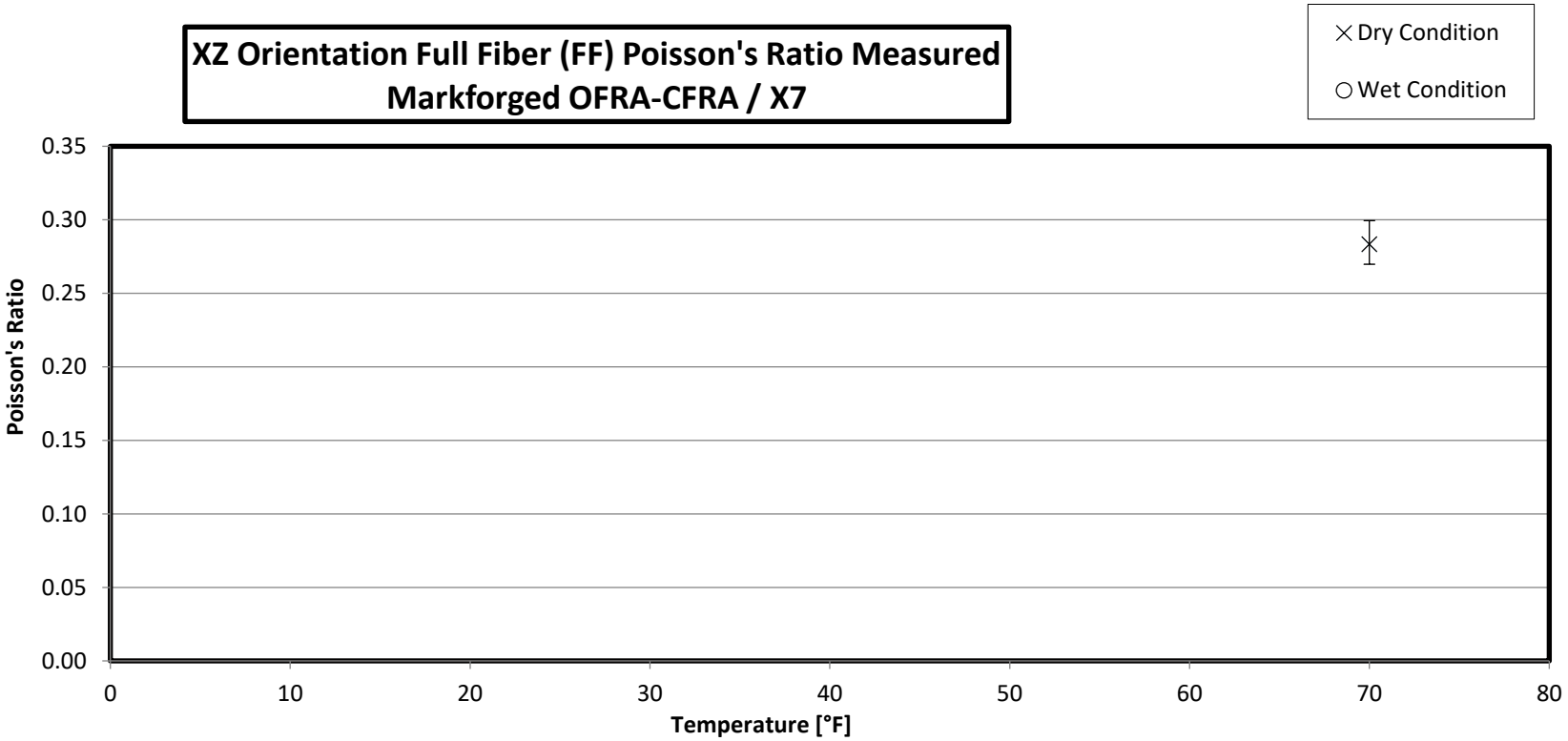

XZ Orientation Partial Fiber (PF) Tensile Modulus Measured
Markforged OFRA-CFRA / X7
Dry Condition
Wet Condition
Tensile Modulus [Msi]
4.00
3.50
3.00
2.50
2.00
1.50
1.00
0.50
0.00
-100
-50
0
50
100
150
Temperature [°F]


XZ Orientation Partial Fiber (PF) Poisson's Ratio Measured
Markforged OFRA-CFRA / X7
Dry Condition
Wet Condition
Poisson's Ratio
0.50
0.45
0.40
0.35
0.30
0.25
0.20
0.15
0.10
0.05
0.00
-100
-50
0
50
100
150
Temperature [°F]

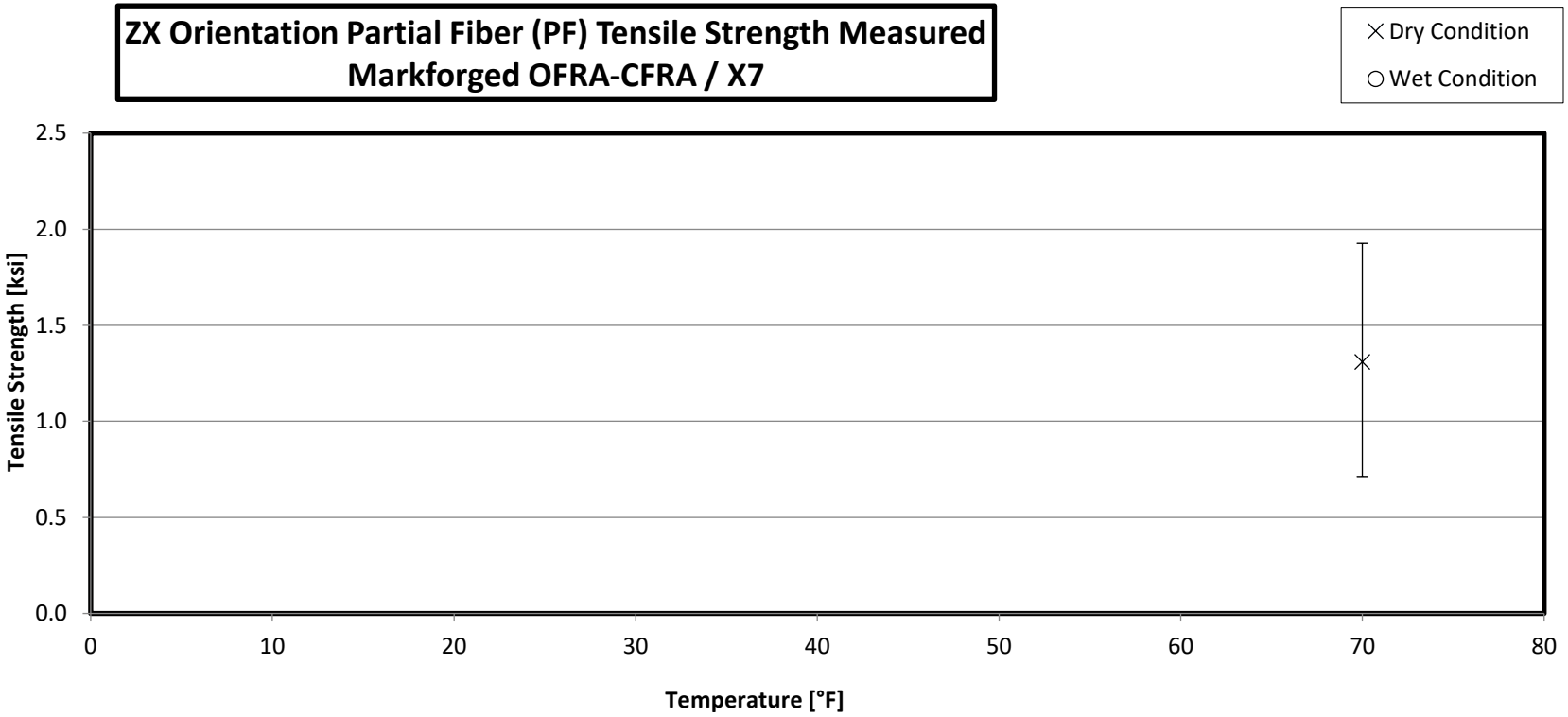
3.4 XZ FF Tension Properties – Reference Only

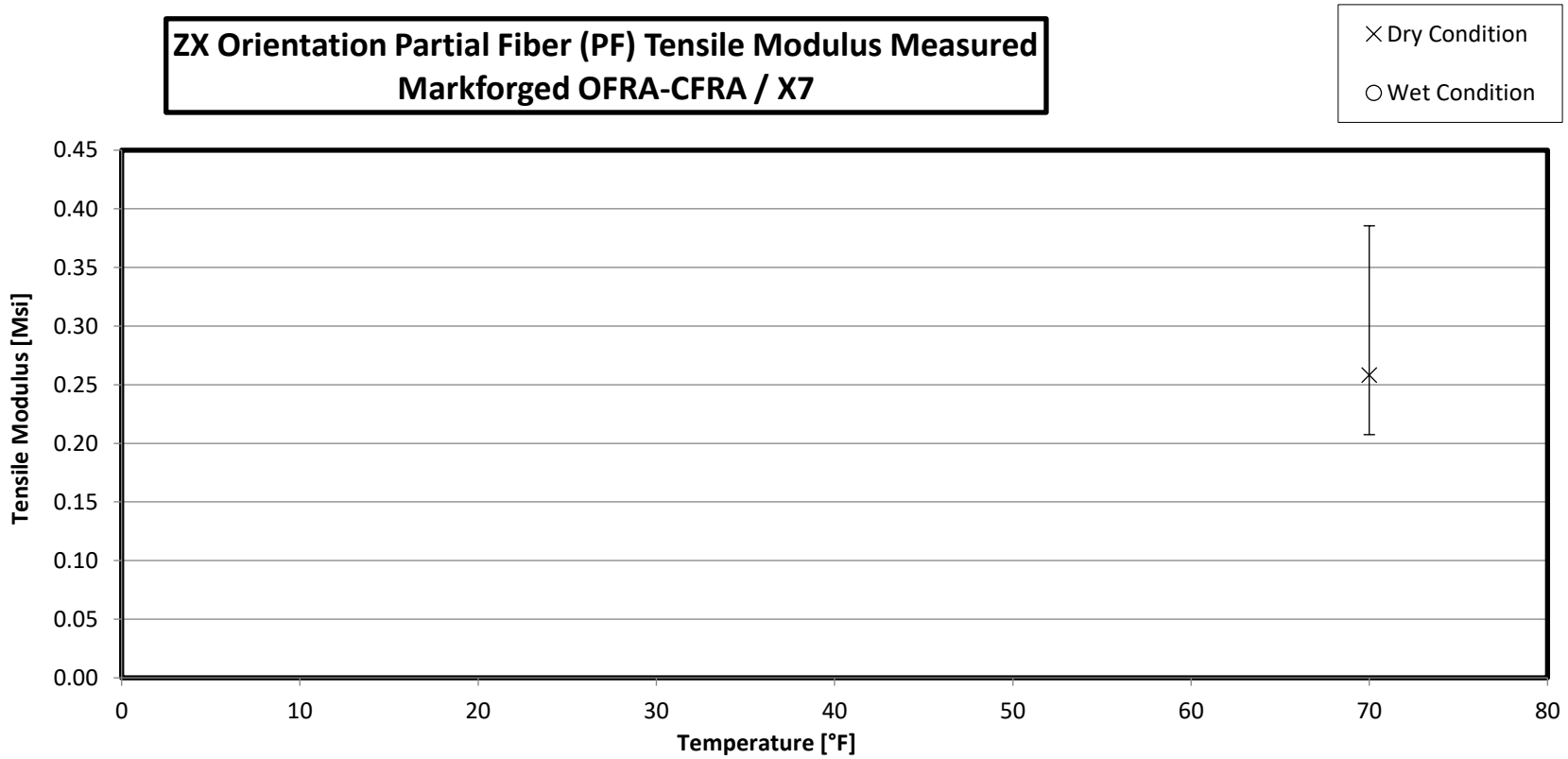


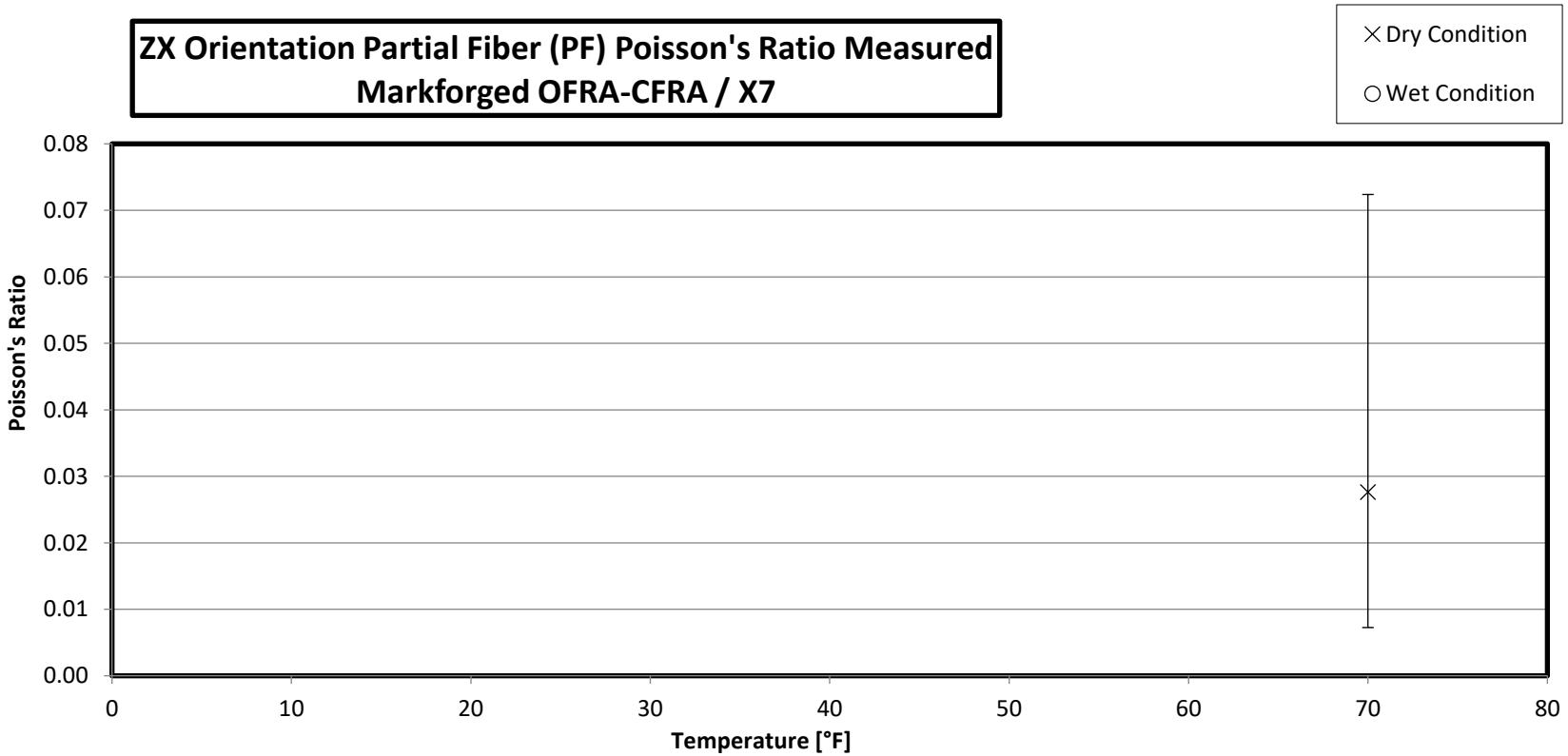

XZ Orientation Full Fiber (FF) Tensile Modulus Measured
Markforged OFRA-CFRA / X7
Dry Condition
Wet Condition
Tensile Modulus [Msi]
6.00
5.00
4.00
3.00
2.00
1.00
0.00
0
10
20
30
40
50
60
70
80
Temperature [°F]


XZ Orientation Full Fiber (FF) Poisson's Ratio Measured
Markforged OFRA-CFRA / X7
Dry Condition
Wet Condition
Poisson's Ratio
0.35
0.30
0.25
0.20
0.15
0.10
0.05
0.00
0
10
20
30
40
50
60
70
80
Temperature [°F]

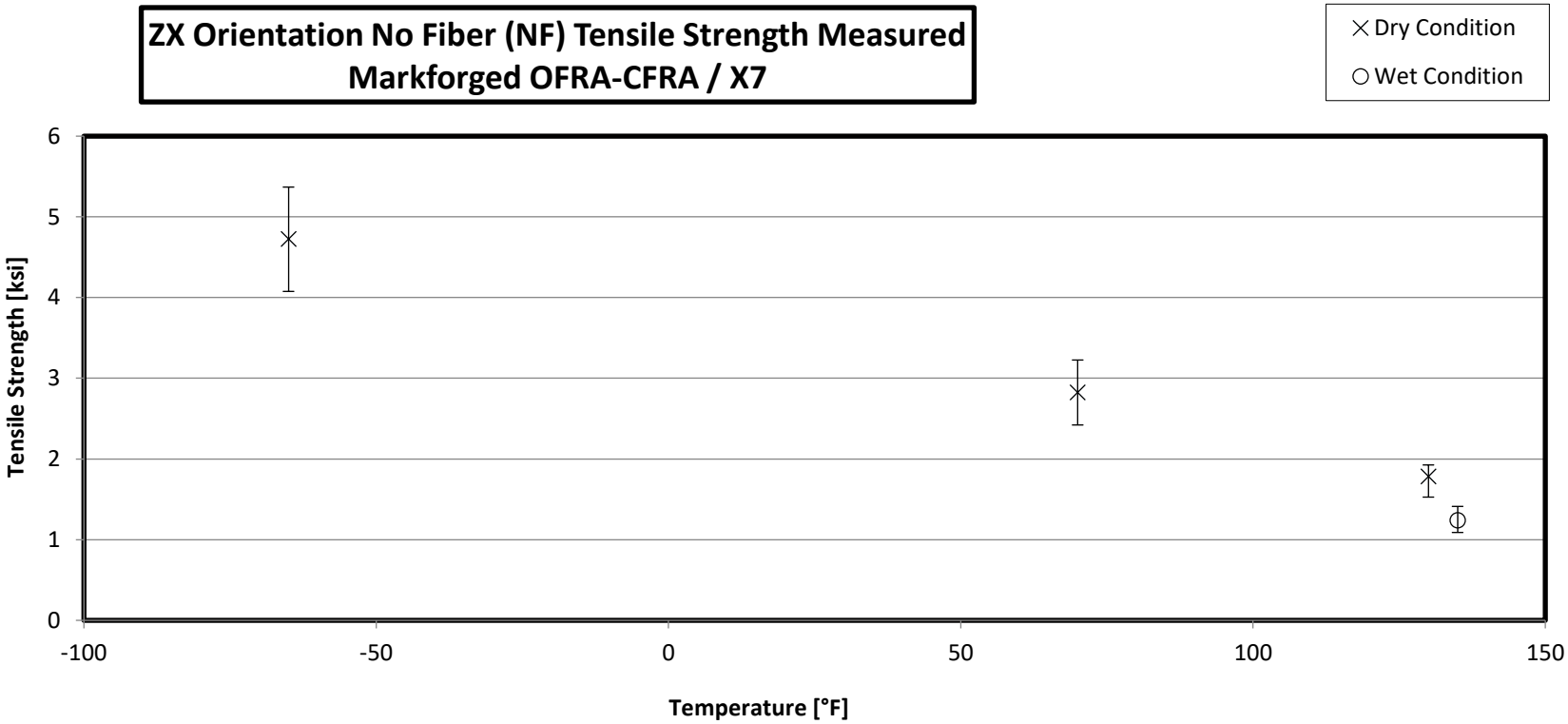
3.5 ZX PF Tension Properties – Reference Only

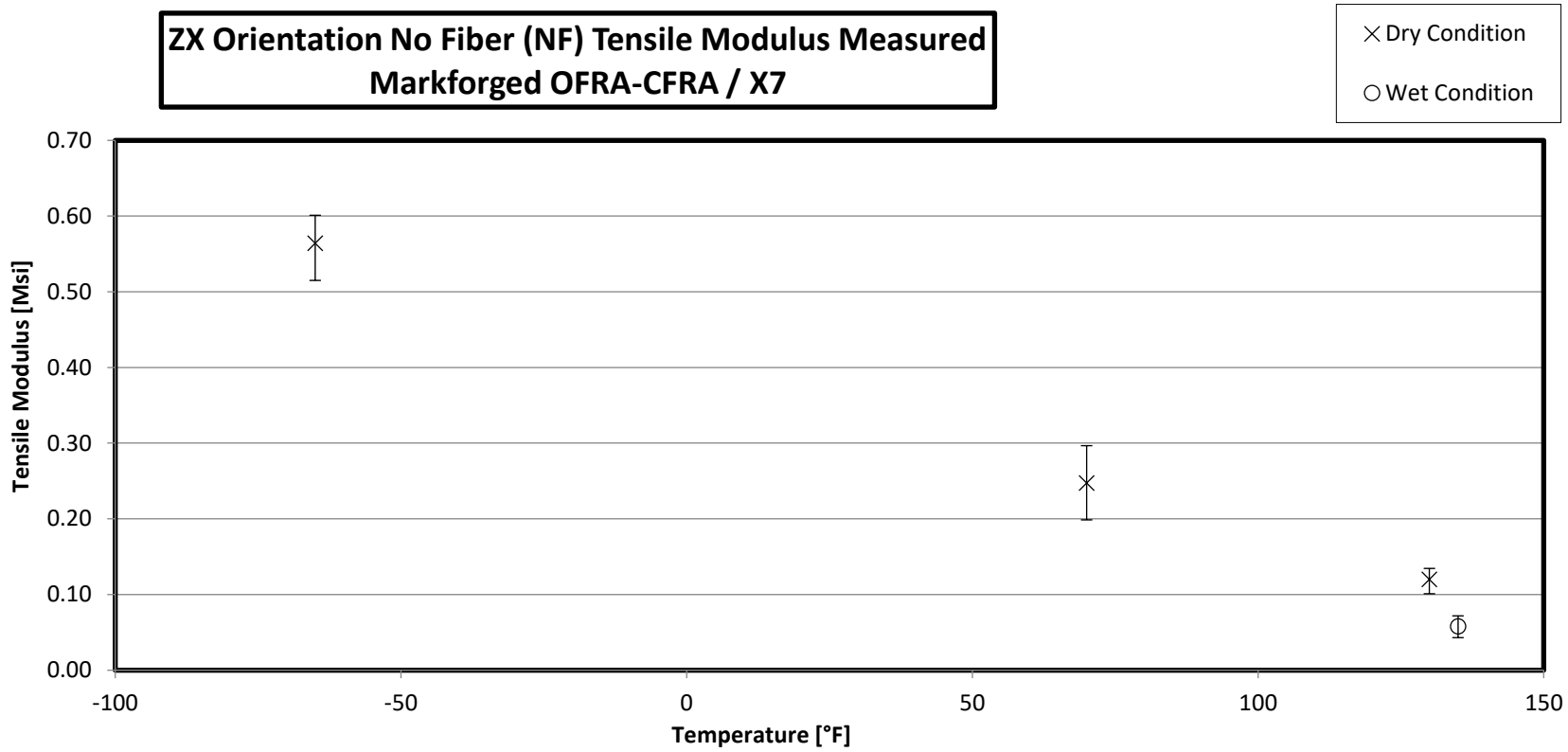


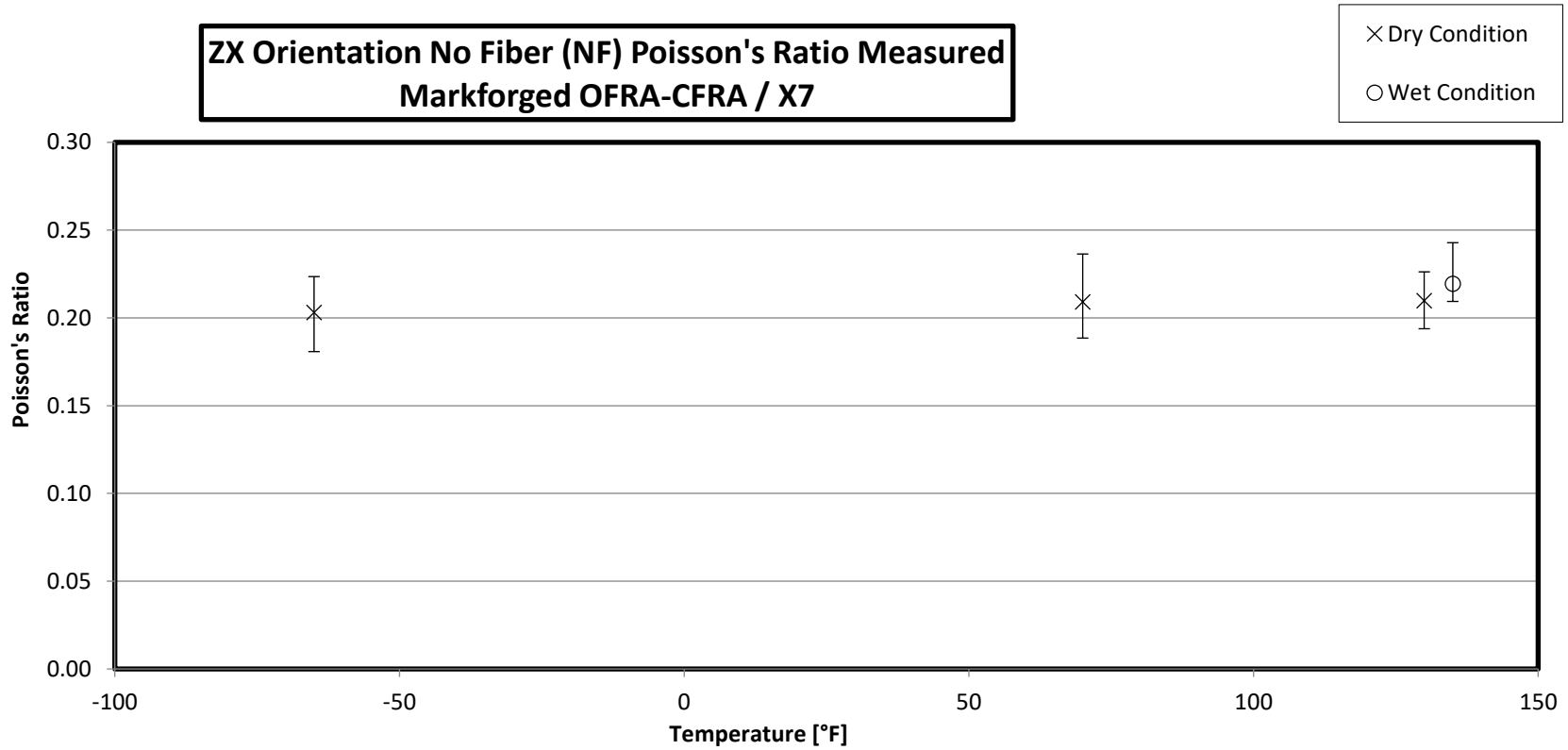

ZX Orientation Partial Fiber (PF) Tensile Modulus Measured
Markforged OFRA-CFRA / X7
× Dry Condition
○ Wet Condition
Tensile Modulus [Msi]
0.45
0.40
0.35
0.30
0.25
0.20
0.15
0.10
0.05
0.00
0
10
20
30
40
50
60
70
80
Temperature [°F]



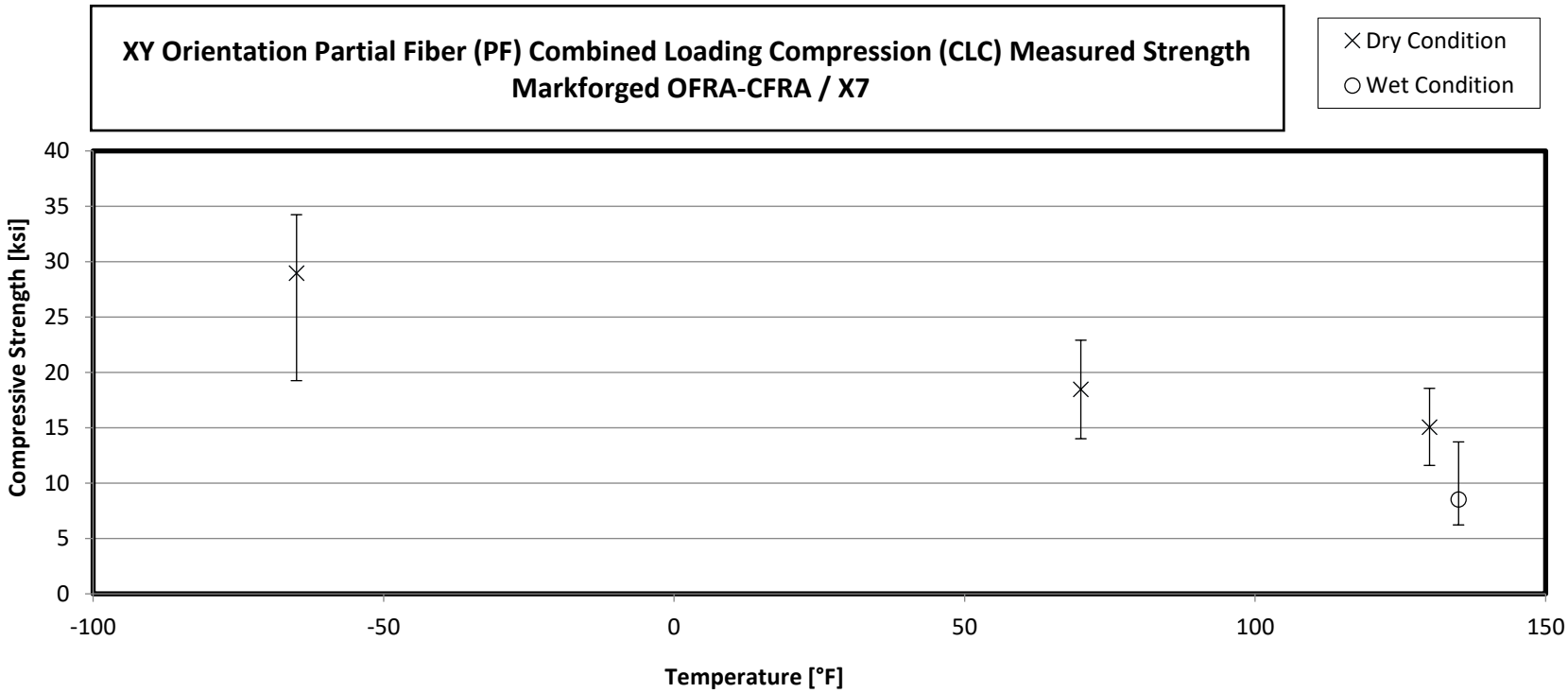
3.6 ZX NF Tension Properties

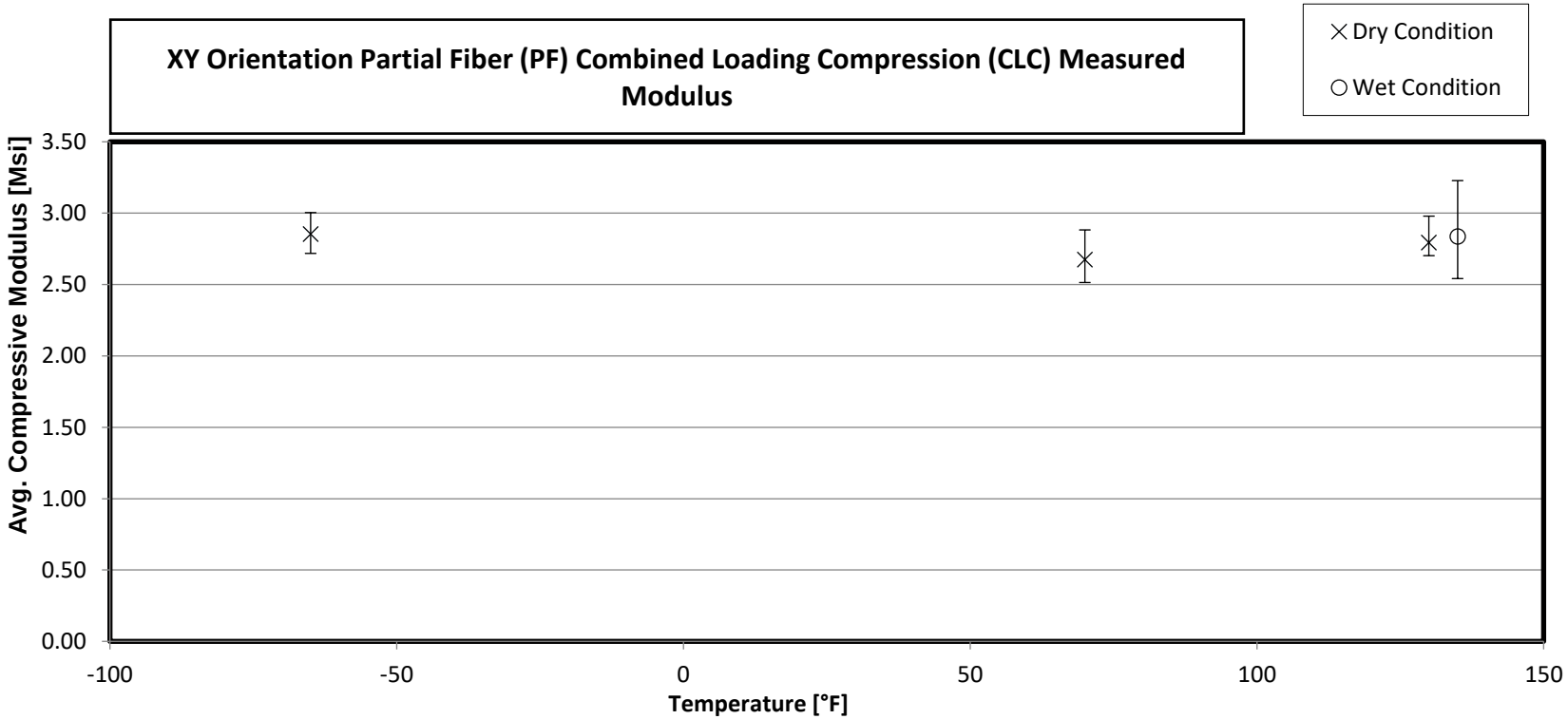

ZX Orientation No Fiber (NF) Tensile Strength Measured
Markforged OFRA-CFRA / X7
Dry Condition
Wet Condition
Tensile Strength [ksi]
0
1
2
3
4
5
6
-100
-50
0
50
100
150
Temperature [°F]

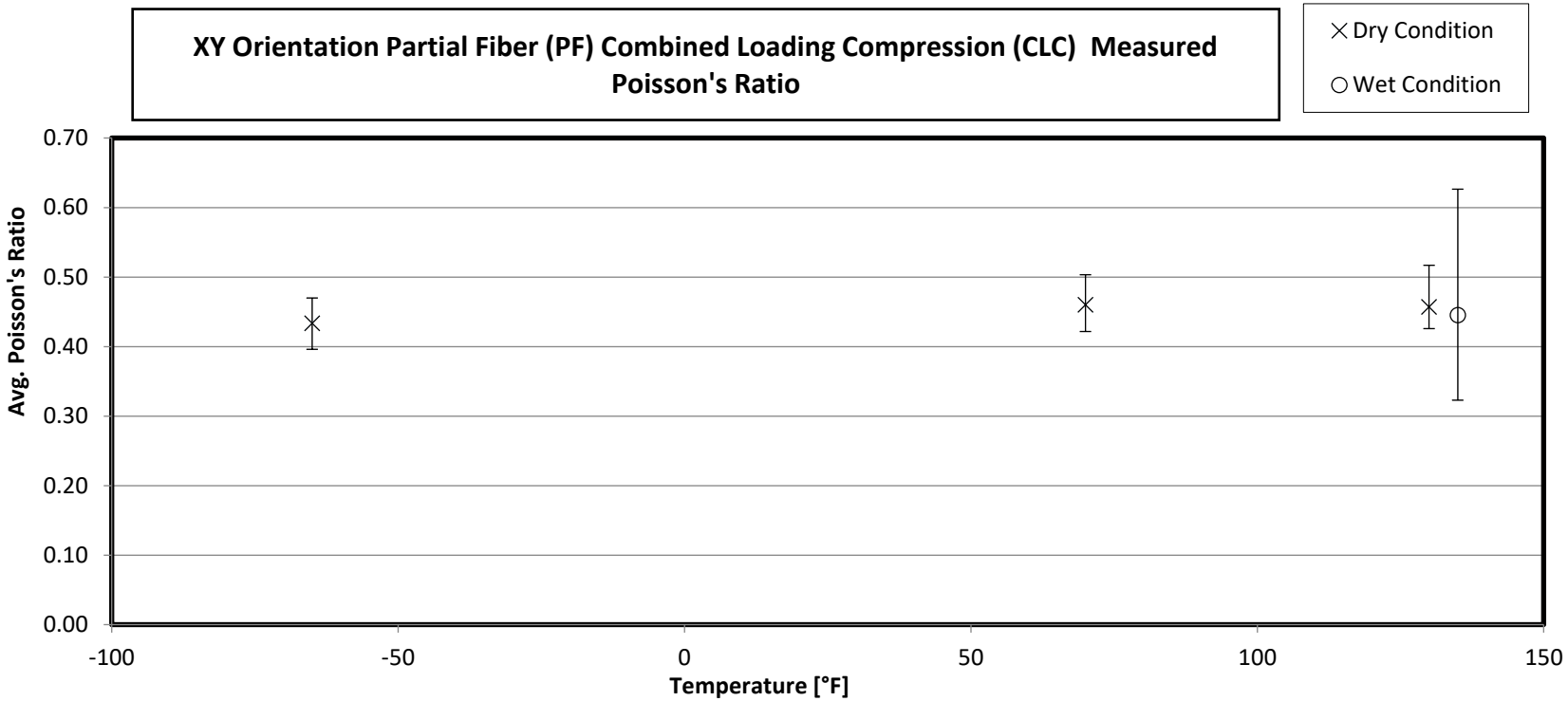

ZX Orientation No Fiber (NF) Tensile Modulus Measured
Markforged OFRA-CFRA / X7
Dry Condition
Wet Condition
Tensile Modulus [Msi]
0.70
0.60
0.50
0.40
0.30
0.20
0.10
0.00
-100
-50
0
50
100
150
Temperature [°F]

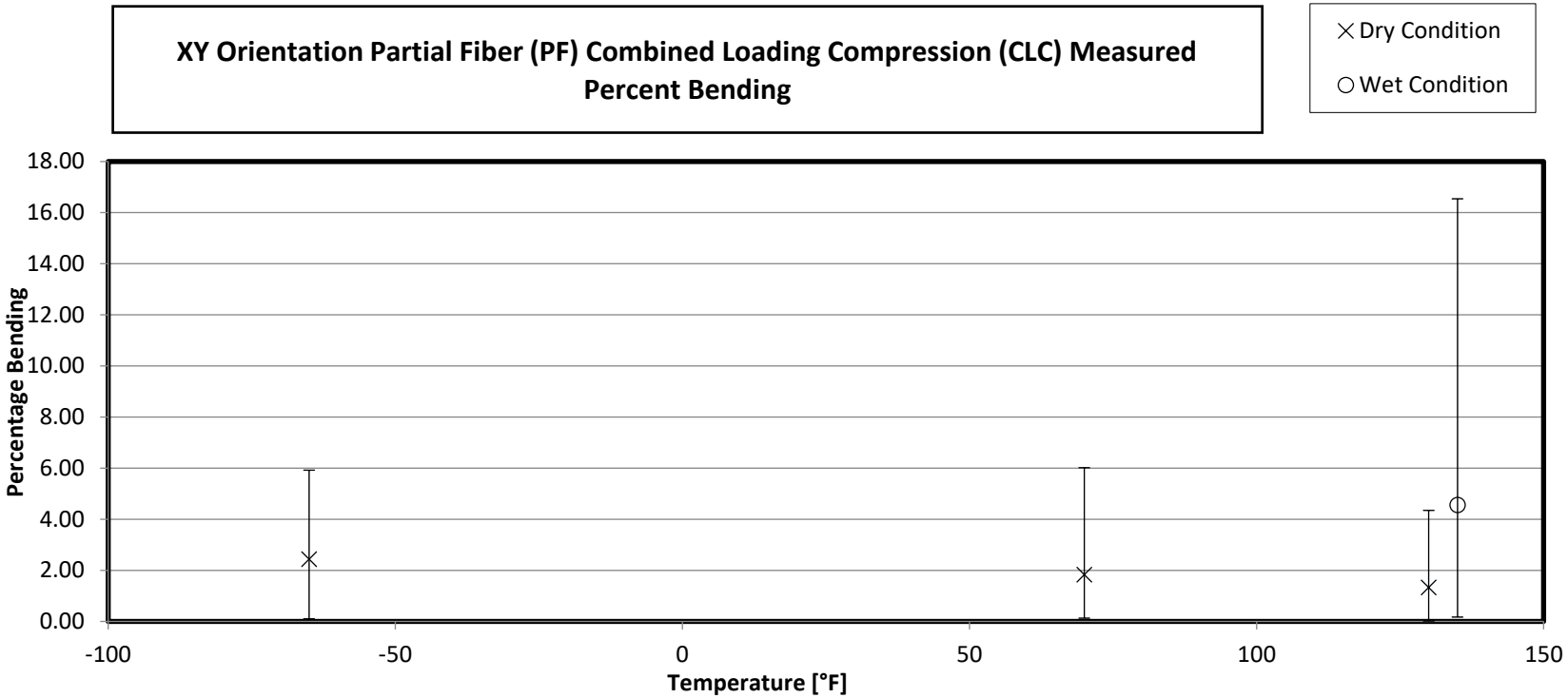

ZX Orientation No Fiber (NF) Poisson's Ratio Measured
Markforged OFRA-CFRA / X7
Dry Condition
Wet Condition
Poisson's Ratio
0.30
0.25
0.20
0.15
0.10
0.05
0.00
-100
-50
0
50
100
150
Temperature [°F]

3.7 XY PF Compression Properties

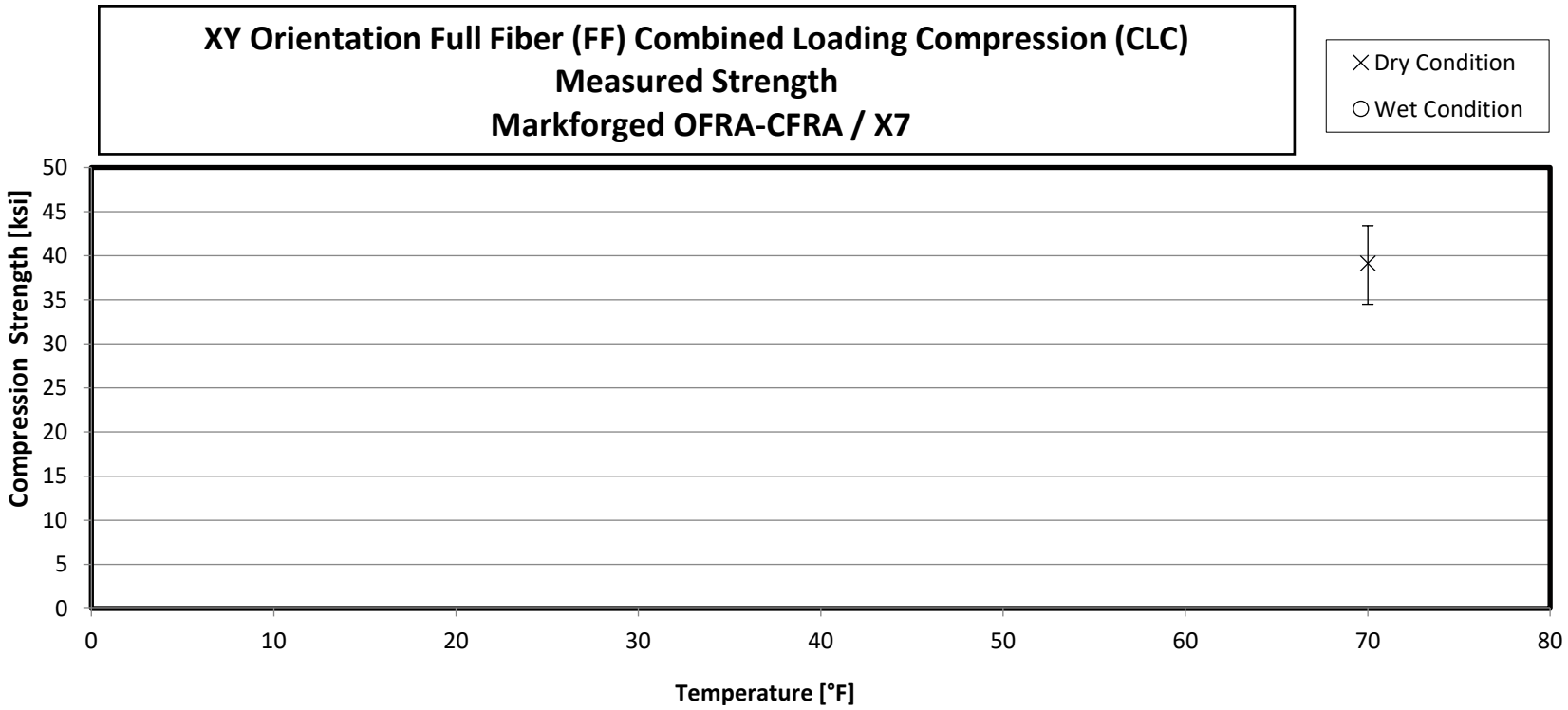


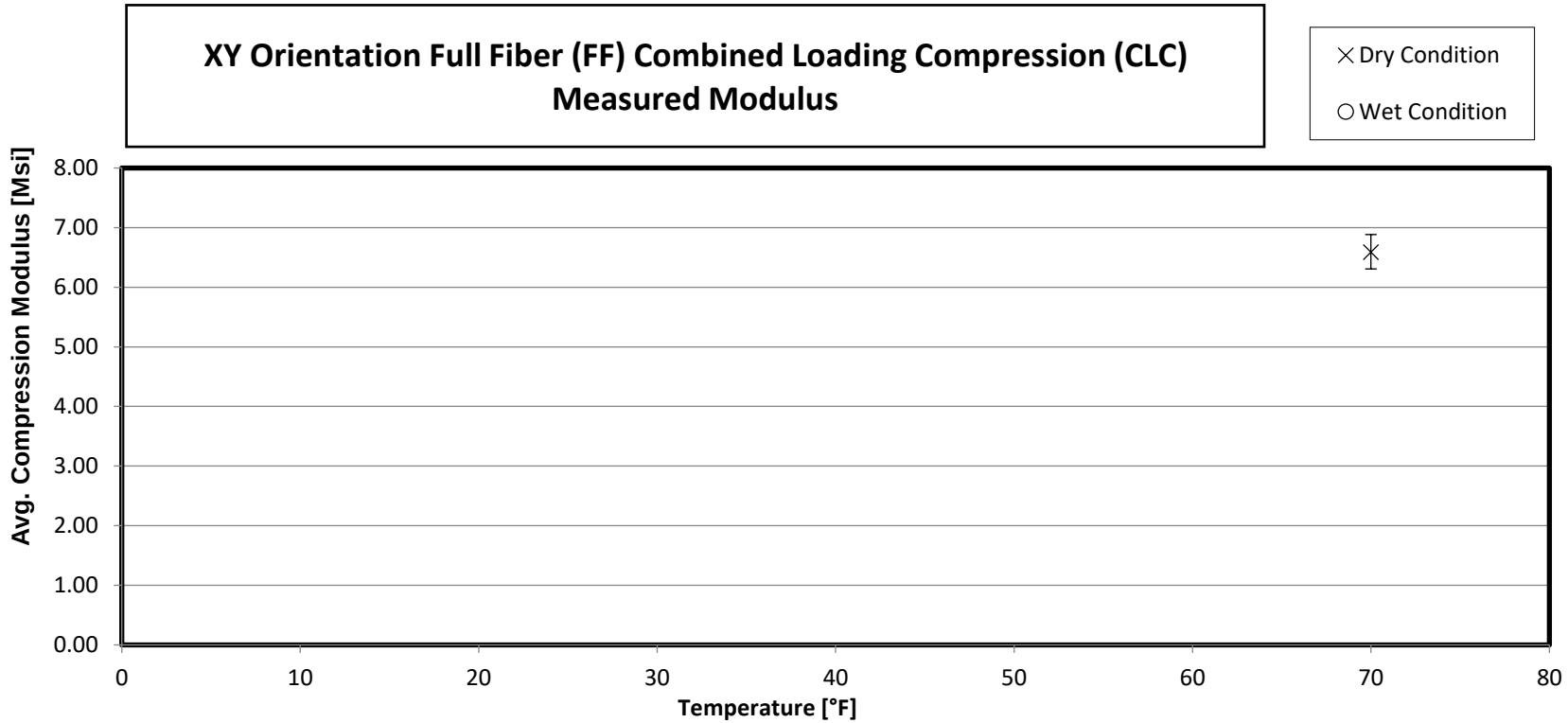

XY Orientation Partial Fiber (PF) Combined Loading Compression (CLC) Measured Modulus
Dry Condition
Wet Condition
Avg. Compressive Modulus [Msi]
3.50
3.00
2.50
2.00
1.50
1.00
0.50
0.00
-100
-50
0
50
100
150
Temperature [°F]

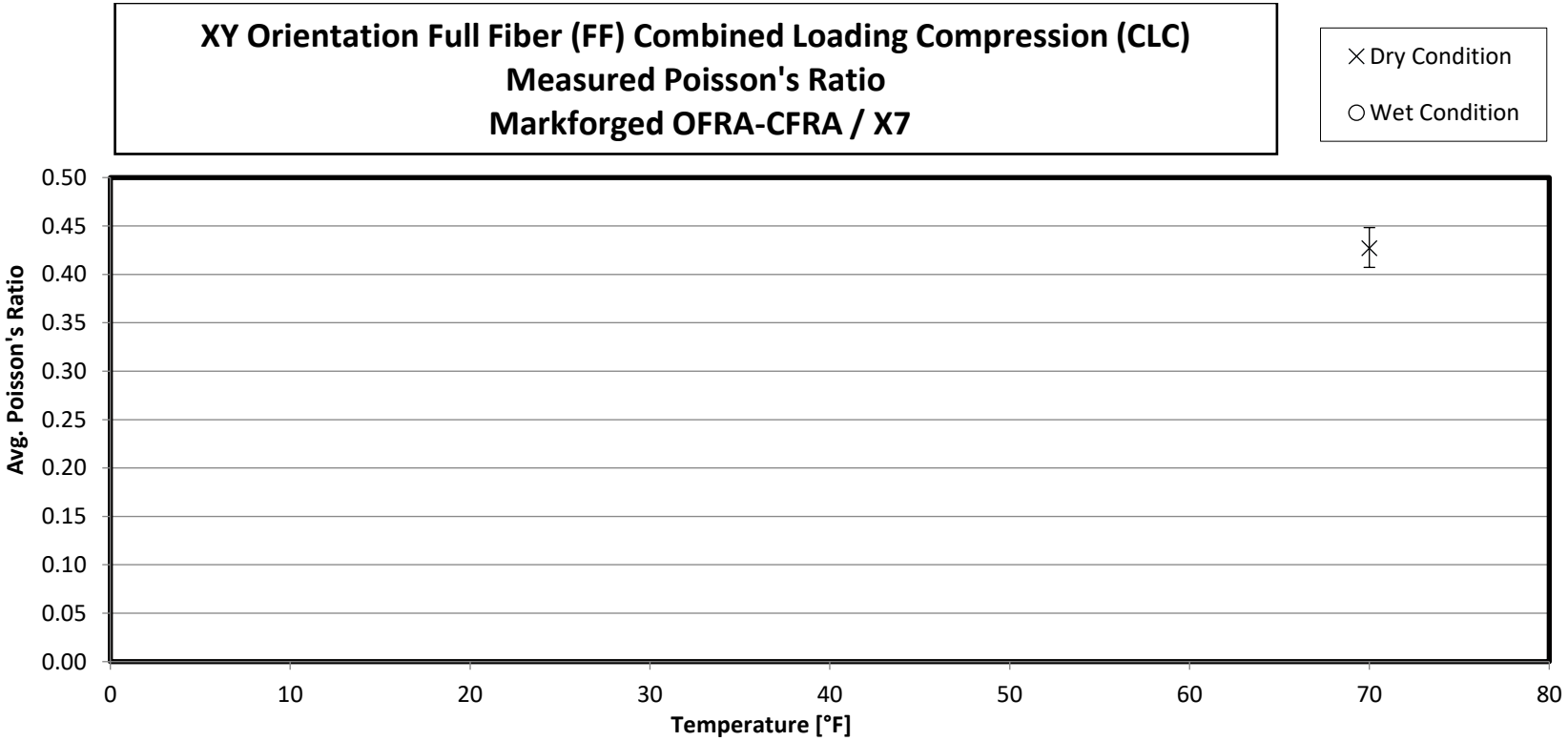

XY Orientation Partial Fiber (PF) Combined Loading Compression (CLC) Measured Poisson's Ratio
Dry Condition
Wet Condition
Avg. Poisson's Ratio
0.70
0.60
0.50
0.40
0.30
0.20
0.10
0.00
-100
-50
0
50
100
150
Temperature [°F]

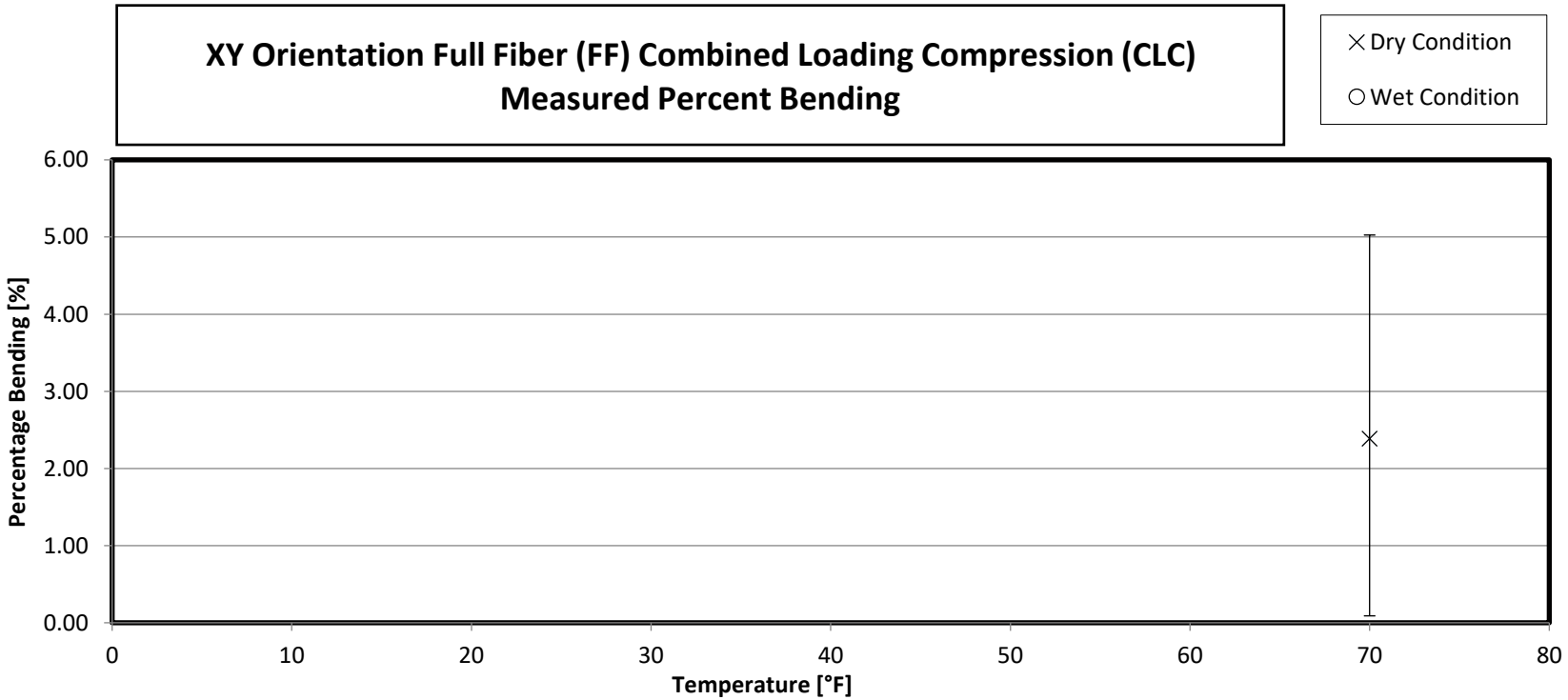

XY Orientation Partial Fiber (PF) Combined Loading Compression (CLC) Measured Percent Bending
Dry Condition
Wet Condition
18.00
16.00
14.00
12.00
10.00
8.00
6.00
4.00
2.00
0.00
Percentage Bending
-100
-50
0
50
100
150
Temperature [°F]

3.8 XY FF Compression Properties – Reference Only

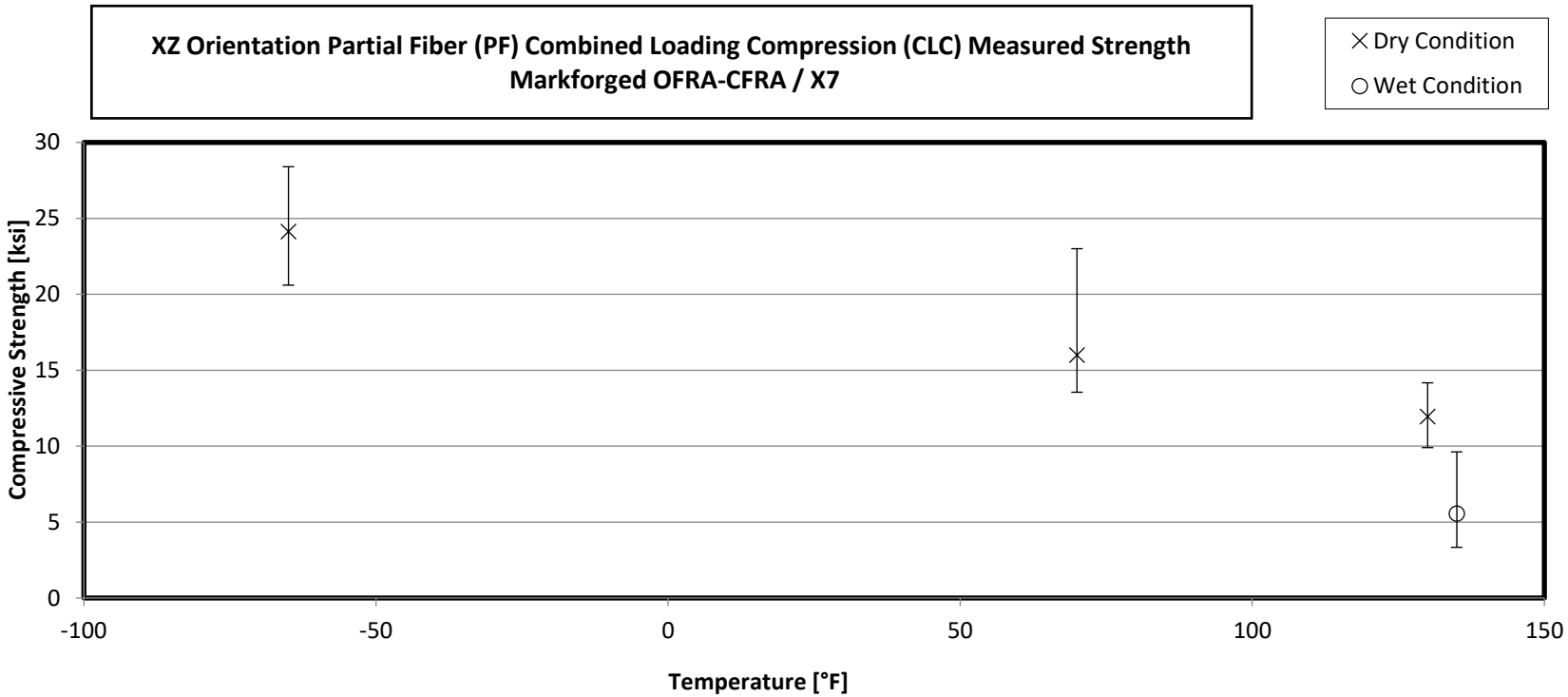


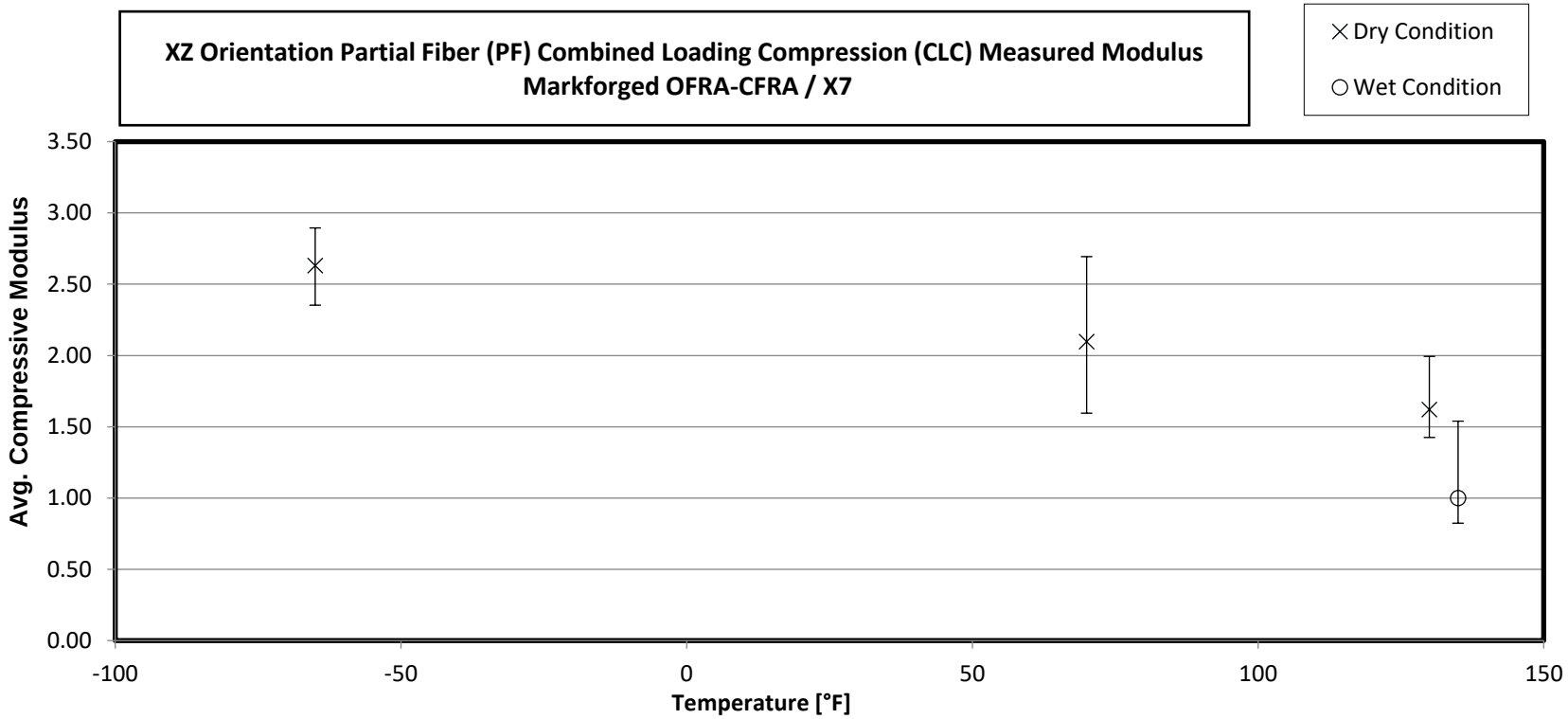

XY Orientation Full Fiber (FF) Combined Loading Compression (CLC)
Measured Modulus
Dry Condition
Wet Condition
Avg. Compression Modulus [Msi]
8.00
7.00
6.00
5.00
4.00
3.00
2.00
1.00
0.00
0
10
20
30
40
50
60
70
80
Temperature [°F]

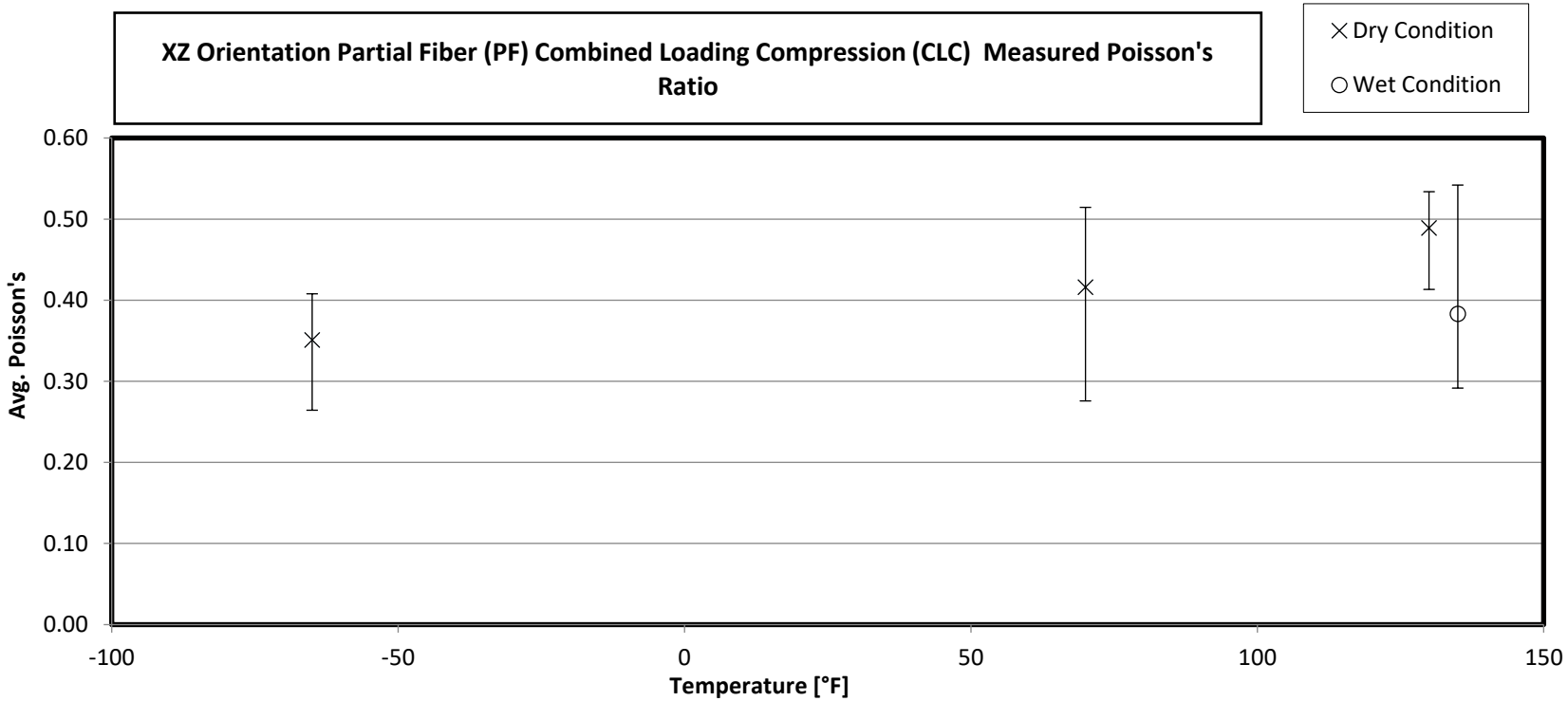

XY Orientation Full Fiber (FF) Combined Loading Compression (CLC)
Measured Poisson's Ratio
Markforged OFRA-CFRA / X7
Dry Condition
Wet Condition
Avg. Poisson's Ratio
0.50
0.45
0.40
0.35
0.30
0.25
0.20
0.15
0.10
0.05
0.00
0
10
20
30
40
50
60
70
80
Temperature [°F]

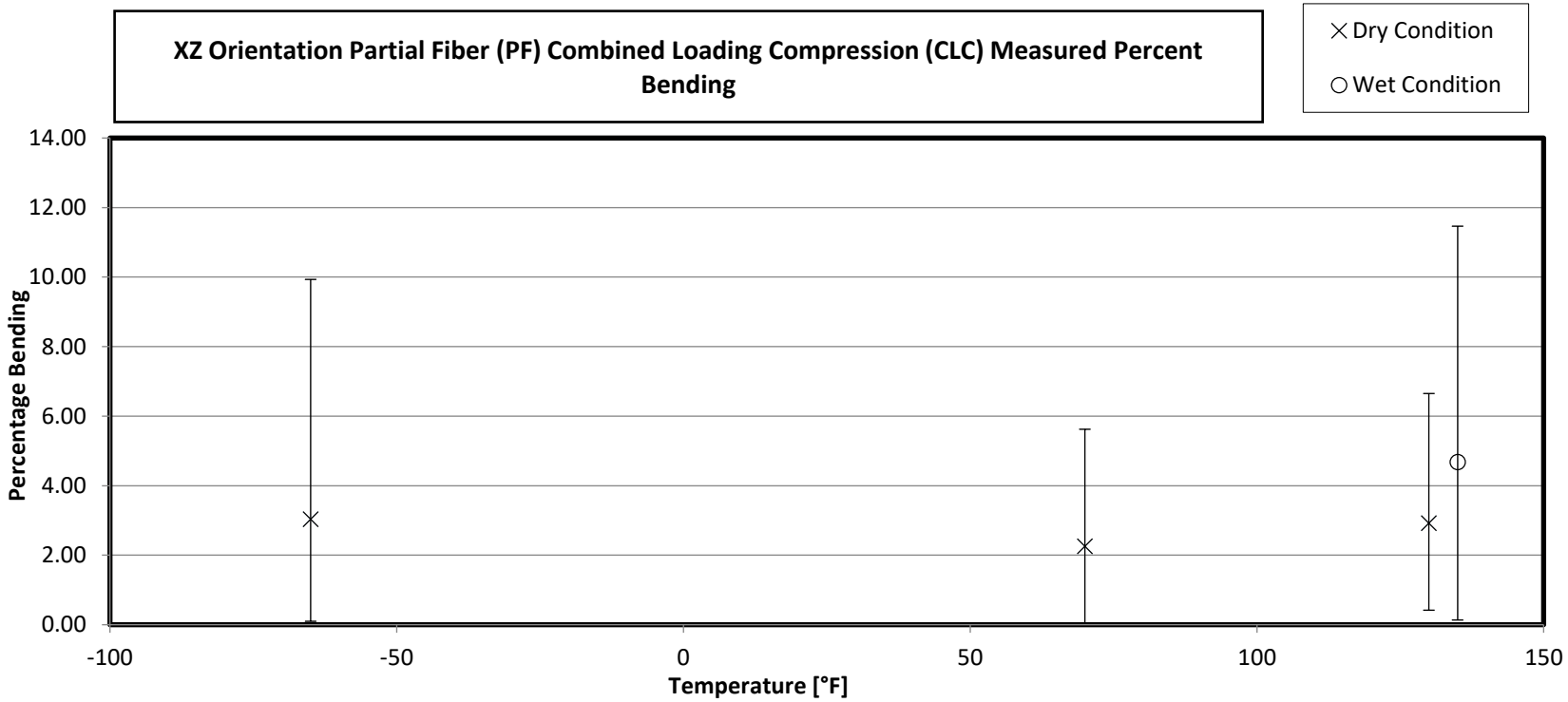

XY Orientation Full Fiber (FF) Combined Loading Compression (CLC)
Measured Percent Bending
Dry Condition
Wet Condition
Percentage Bending [%]
6.00
5.00
4.00
3.00
2.00
1.00
0.00
0
10
20
30
40
50
60
70
80
Temperature [°F]

3.9 XZ PF Compression Properties

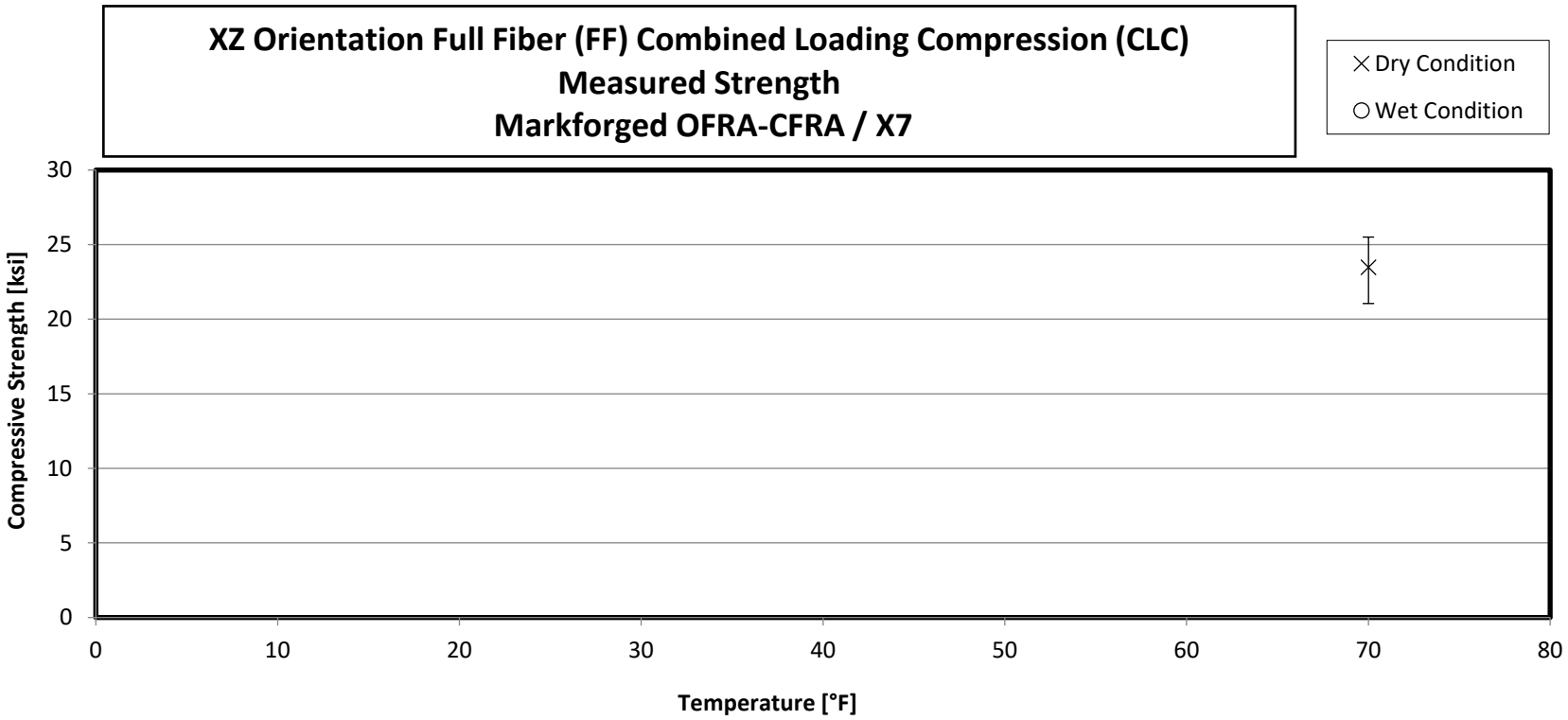


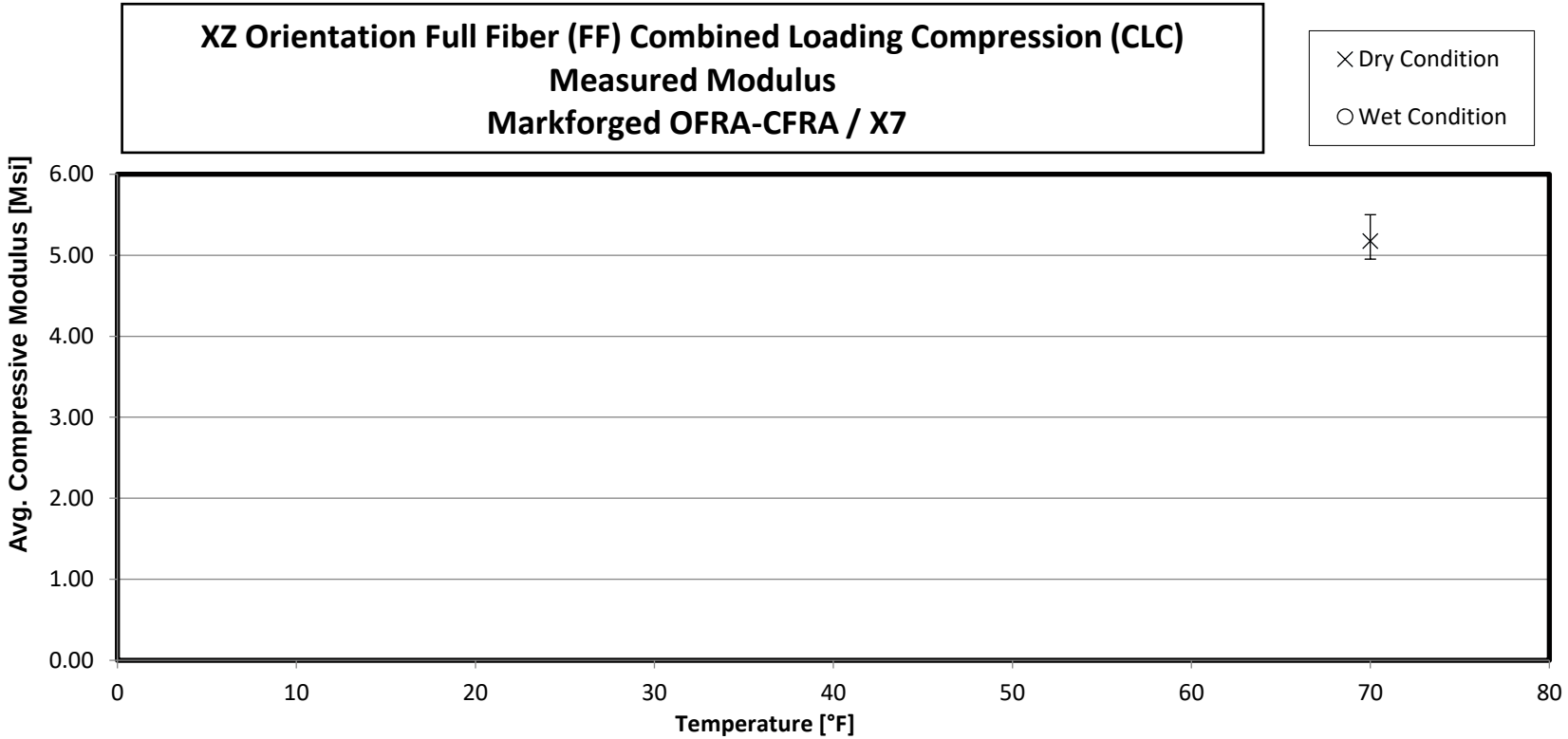

XZ Orientation Partial Fiber (PF) Combined Loading Compression (CLC) Measured Modulus
Markforged OFRA-CFRA / X7
Dry Condition
Wet Condition
Avg. Compressive Modulus
3.50
3.00
2.50
2.00
1.50
1.00
0.50
0.00
-100
-50
0
50
100
150
Temperature [°F]

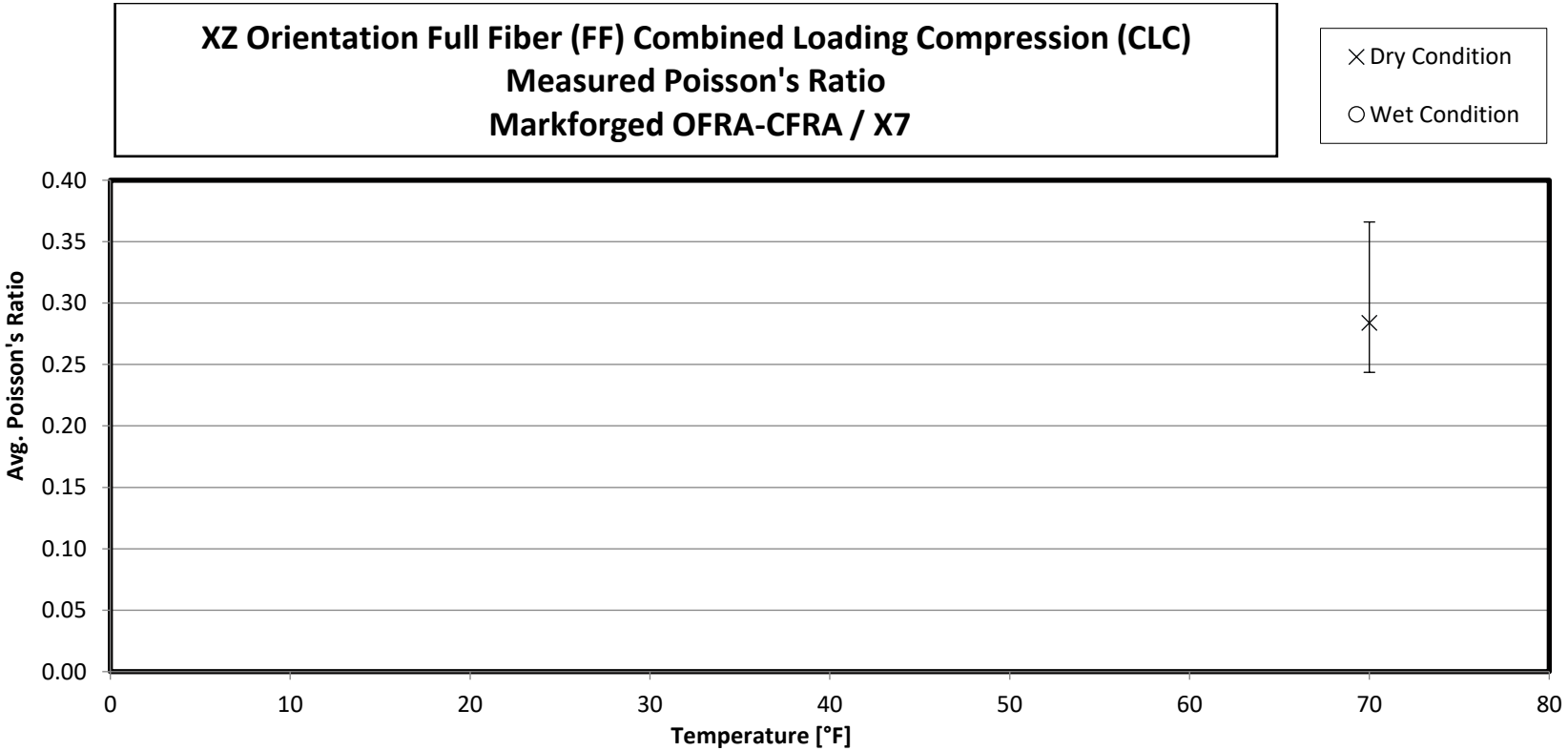

XZ Orientation Partial Fiber (PF) Combined Loading Compression (CLC) Measured Poisson's Ratio
Dry Condition
Wet Condition
Avg. Poisson's
0.60
0.50
0.40
0.30
0.20
0.10
0.00
-100
-50
0
50
100
150
Temperature [°F]

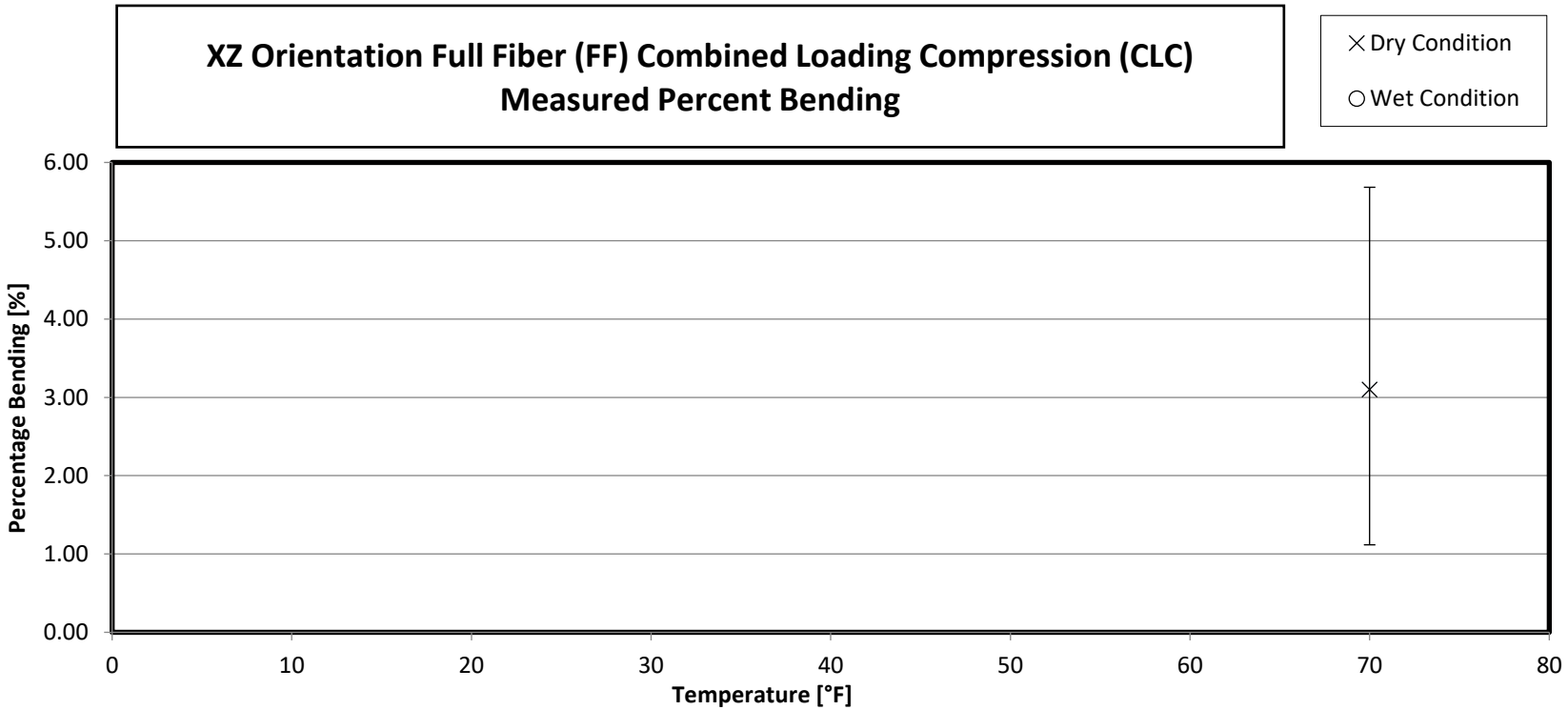

XZ Orientation Partial Fiber (PF) Combined Loading Compression (CLC) Measured Percent Bending
Dry Condition
Wet Condition
14.00
12.00
10.00
8.00
6.00
4.00
2.00
0.00
Percentage Bending
-100
-50
0
50
100
150
Temperature [°F]

3.10 XZ FF Compression Properties – Reference Only

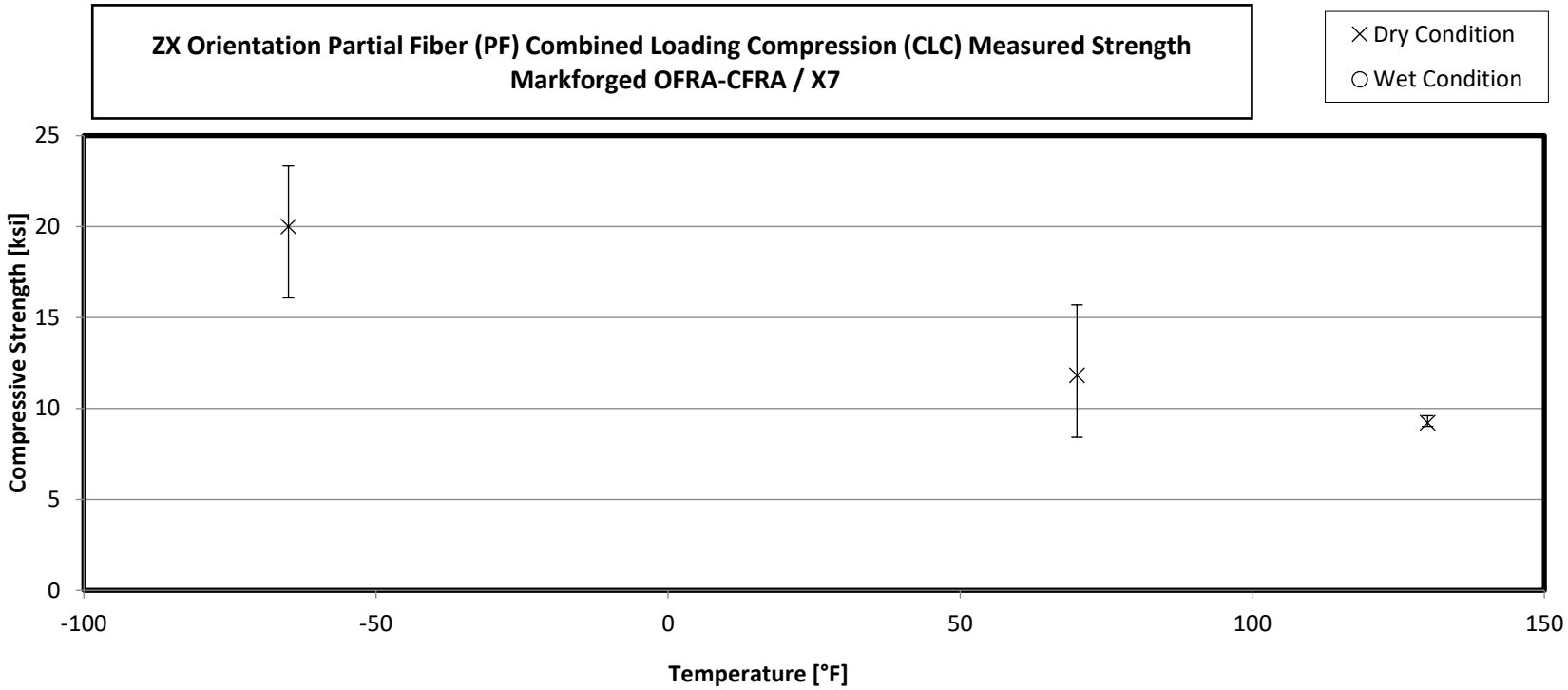


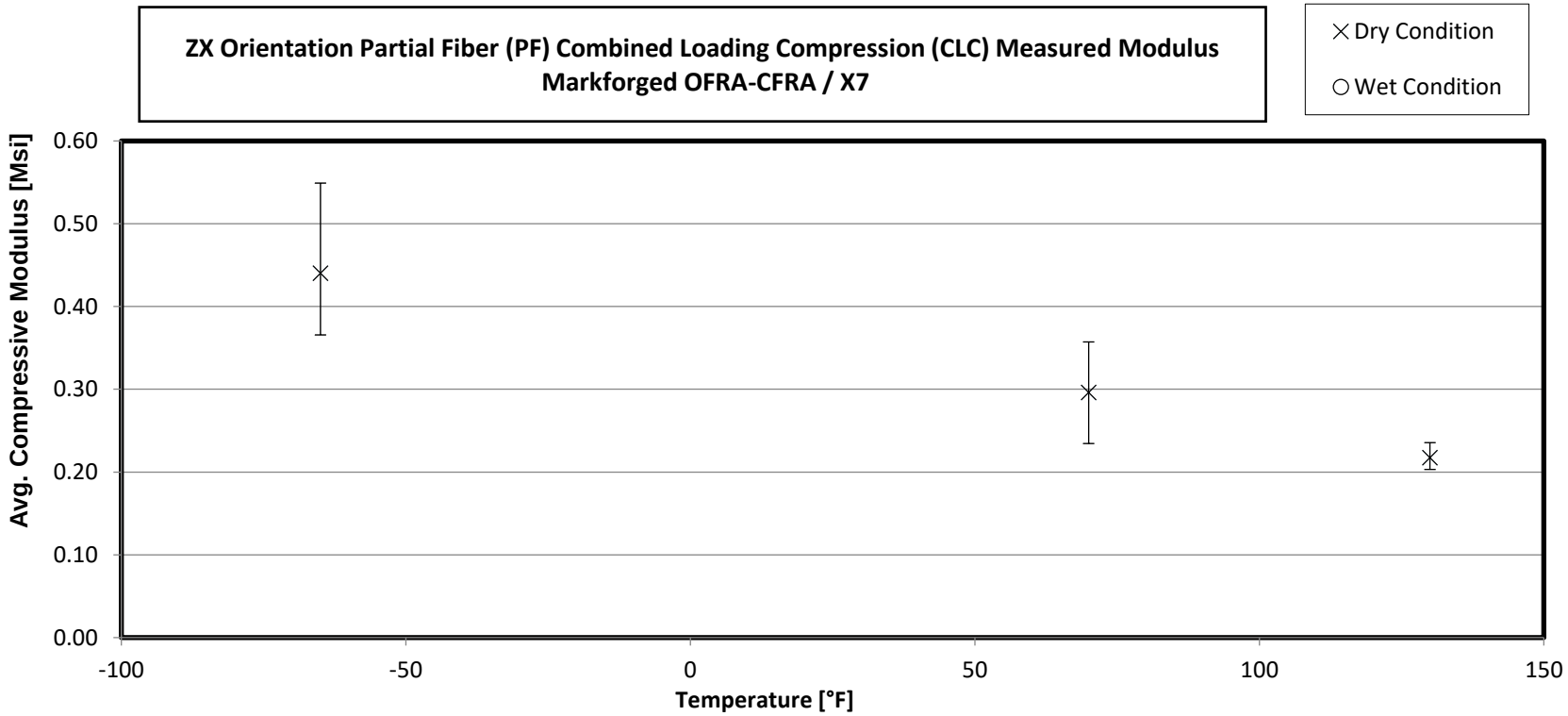

XZ Orientation Full Fiber (FF) Combined Loading Compression (CLC)
Measured Modulus
Markforged OFRA-CFRA / X7
Dry Condition
Wet Condition
Avg. Compressive Modulus [Msi]
6.00
5.00
4.00
3.00
2.00
1.00
0.00
0
10
20
30
40
50
60
70
80
Temperature [°F]

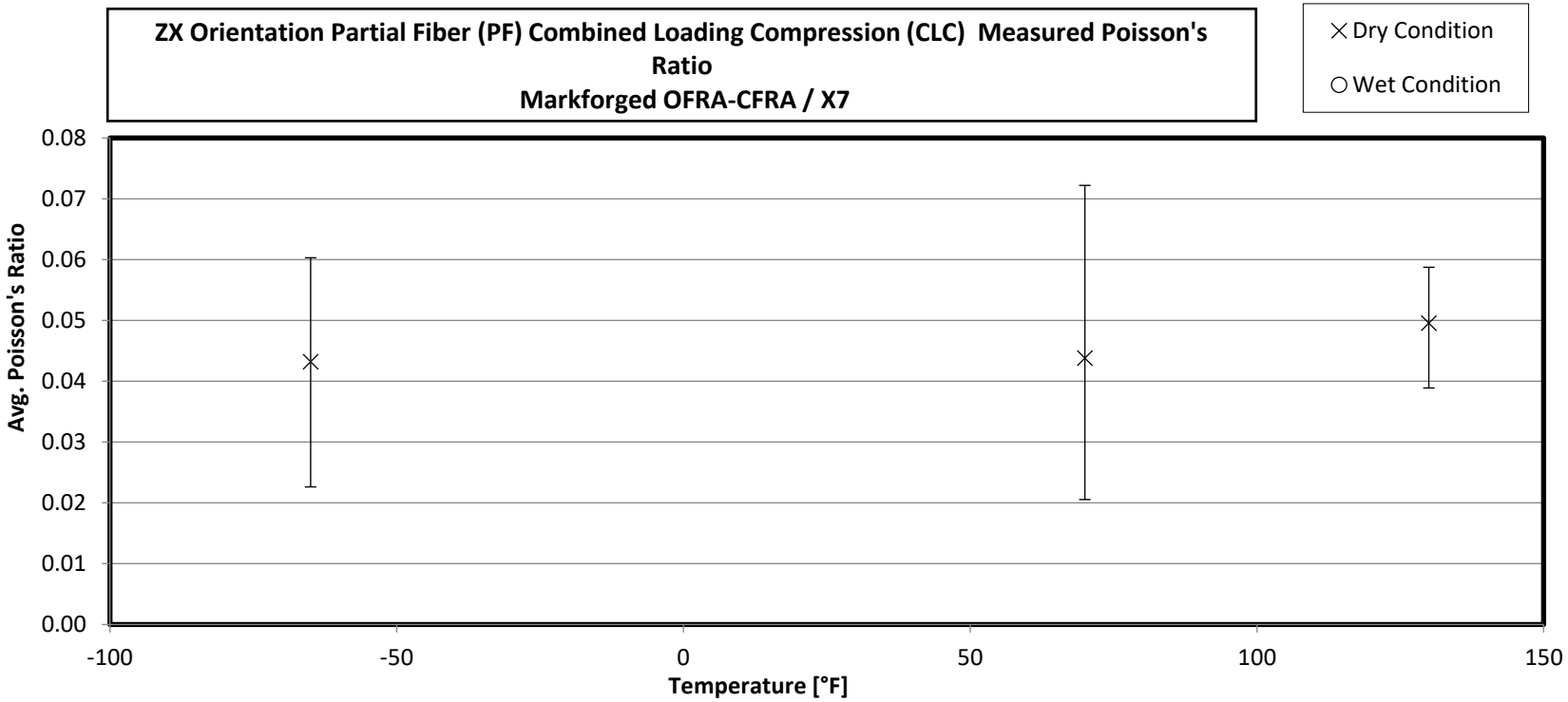

XZ Orientation Full Fiber (FF) Combined Loading Compression (CLC)
Measured Poisson's Ratio
Markforged OFRA-CFRA / X7
Dry Condition
Wet Condition
Avg. Poisson's Ratio
0.40
0.35
0.30
0.25
0.20
0.15
0.10
0.05
0.00
0
10
20
30
40
50
60
70
80
Temperature [°F]

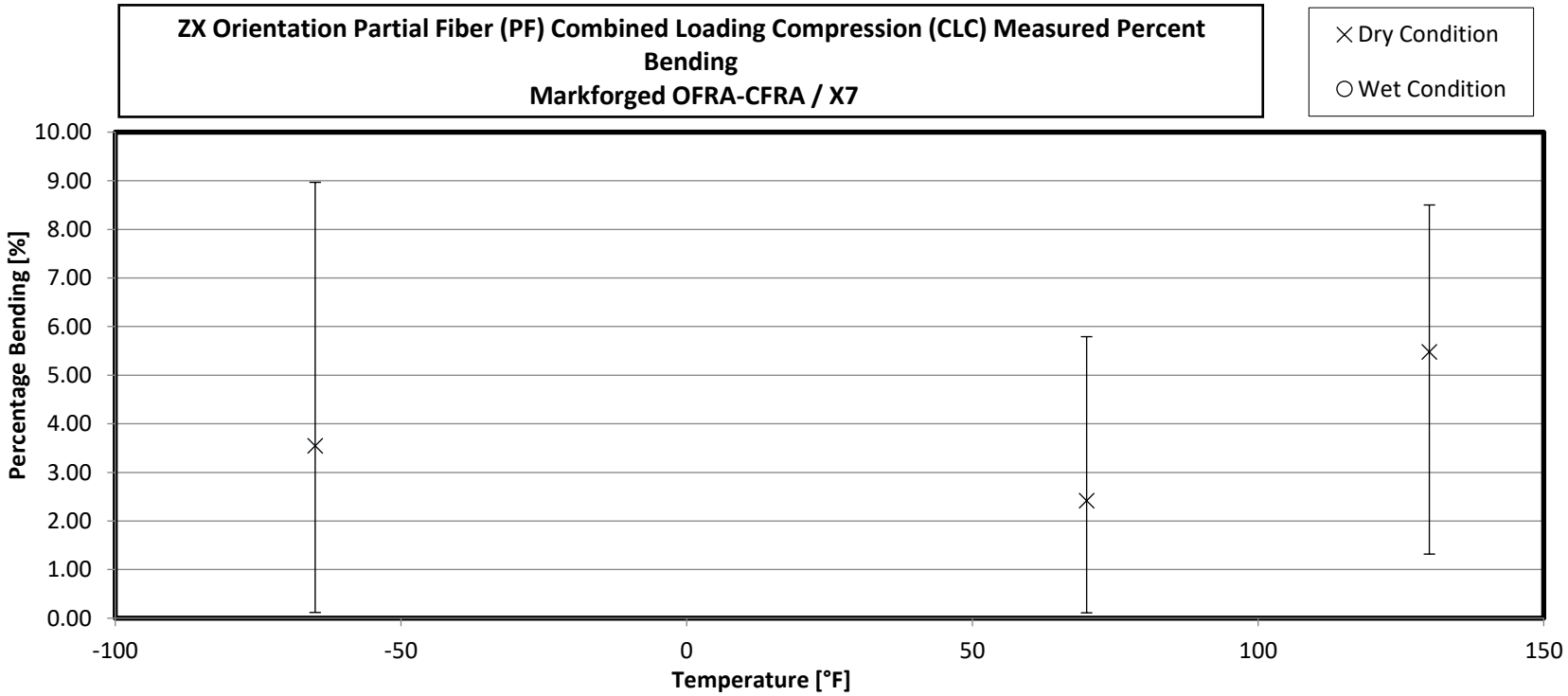

XZ Orientation Full Fiber (FF) Combined Loading Compression (CLC)
Measured Percent Bending
Dry Condition
Wet Condition
Percentage Bending [%]
6.00
5.00
4.00
3.00
2.00
1.00
0.00
0
10
20
30
40
50
60
70
80
Temperature [°F]

3.11 ZX PF Compression Properties – Reference Only

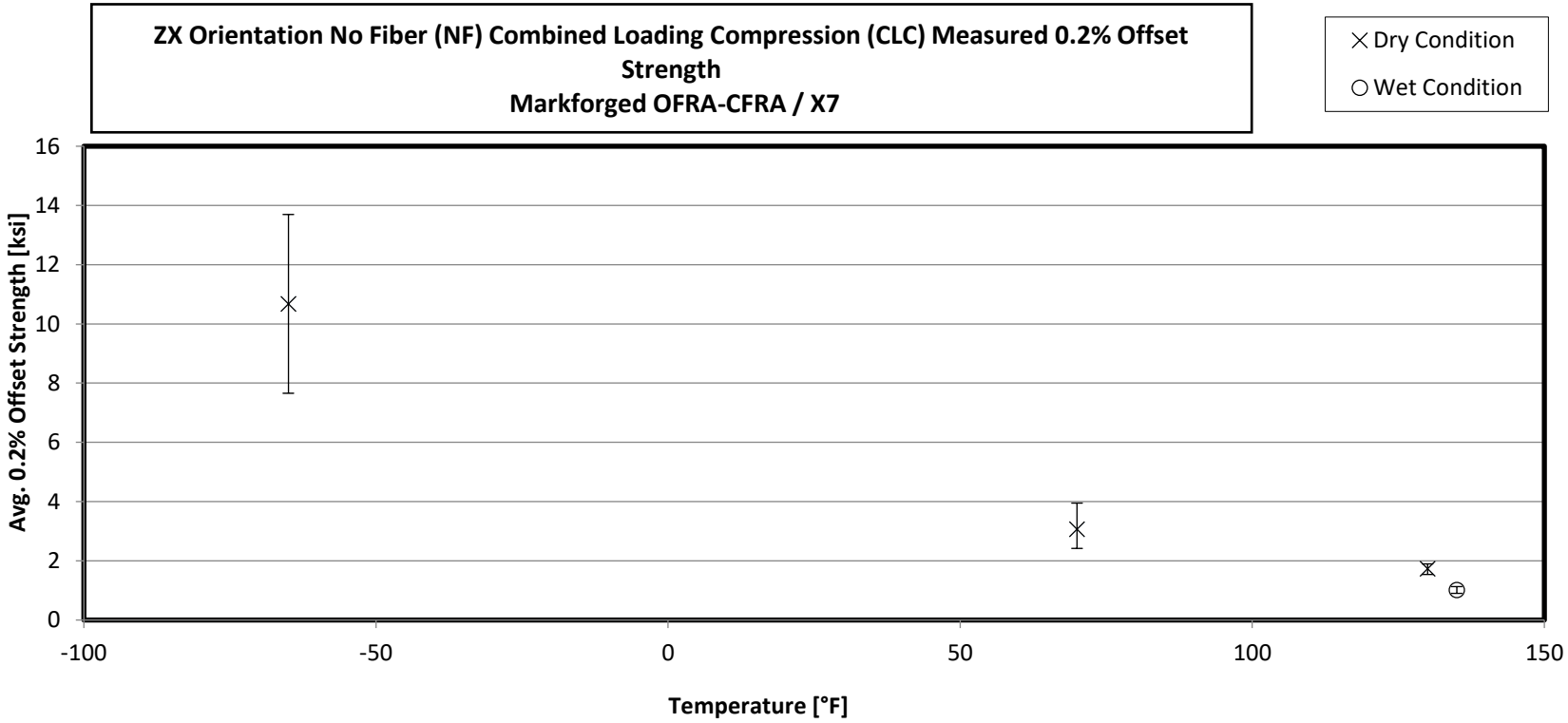


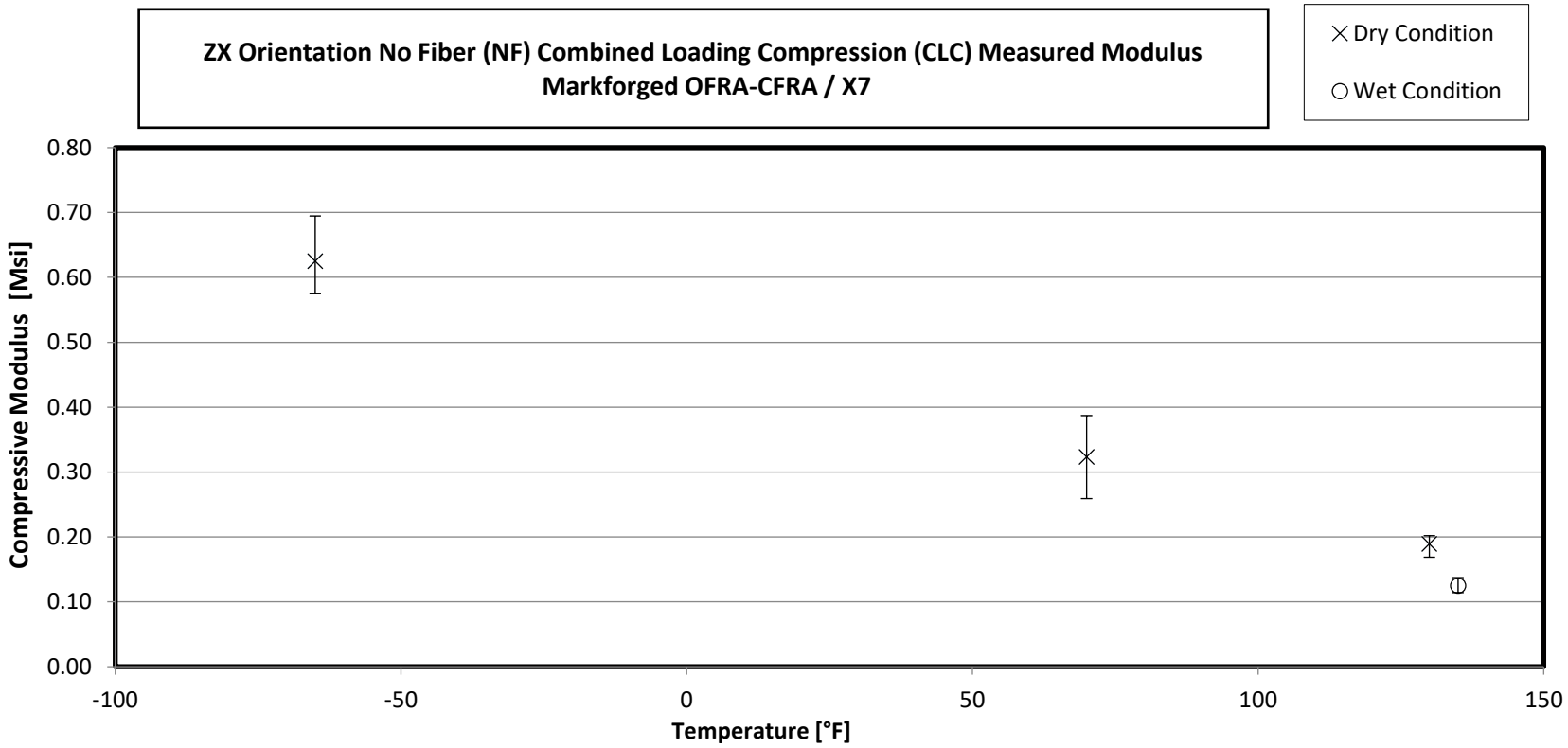

ZX Orientation Partial Fiber (PF) Combined Loading Compression (CLC) Measured Modulus
Markforged OFRA-CFRA / X7
Dry Condition
Wet Condition
Avg. Compressive Modulus [Msi]
0.60
0.50
0.40
0.30
0.20
0.10
0.00
-100
-50
0
50
100
150
Temperature [°F]

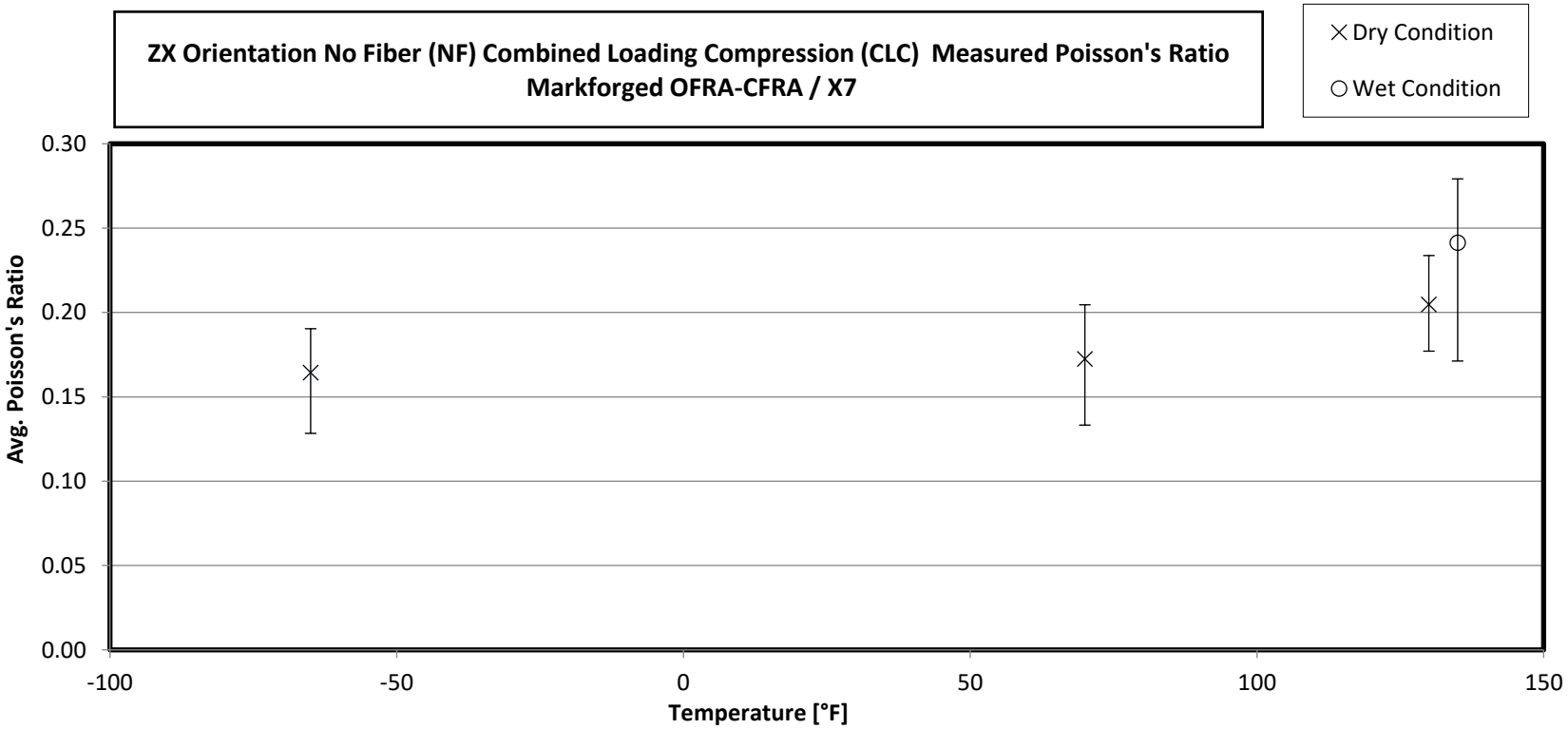

ZX Orientation Partial Fiber (PF) Combined Loading Compression (CLC) Measured Poisson's Ratio
Markforged OFRA-CFRA / X7
Dry Condition
Wet Condition
Avg. Poisson's Ratio
0.08
0.07
0.06
0.05
0.04
0.03
0.02
0.01
0.00
-100
-50
0
50
100
150
Temperature [°F]

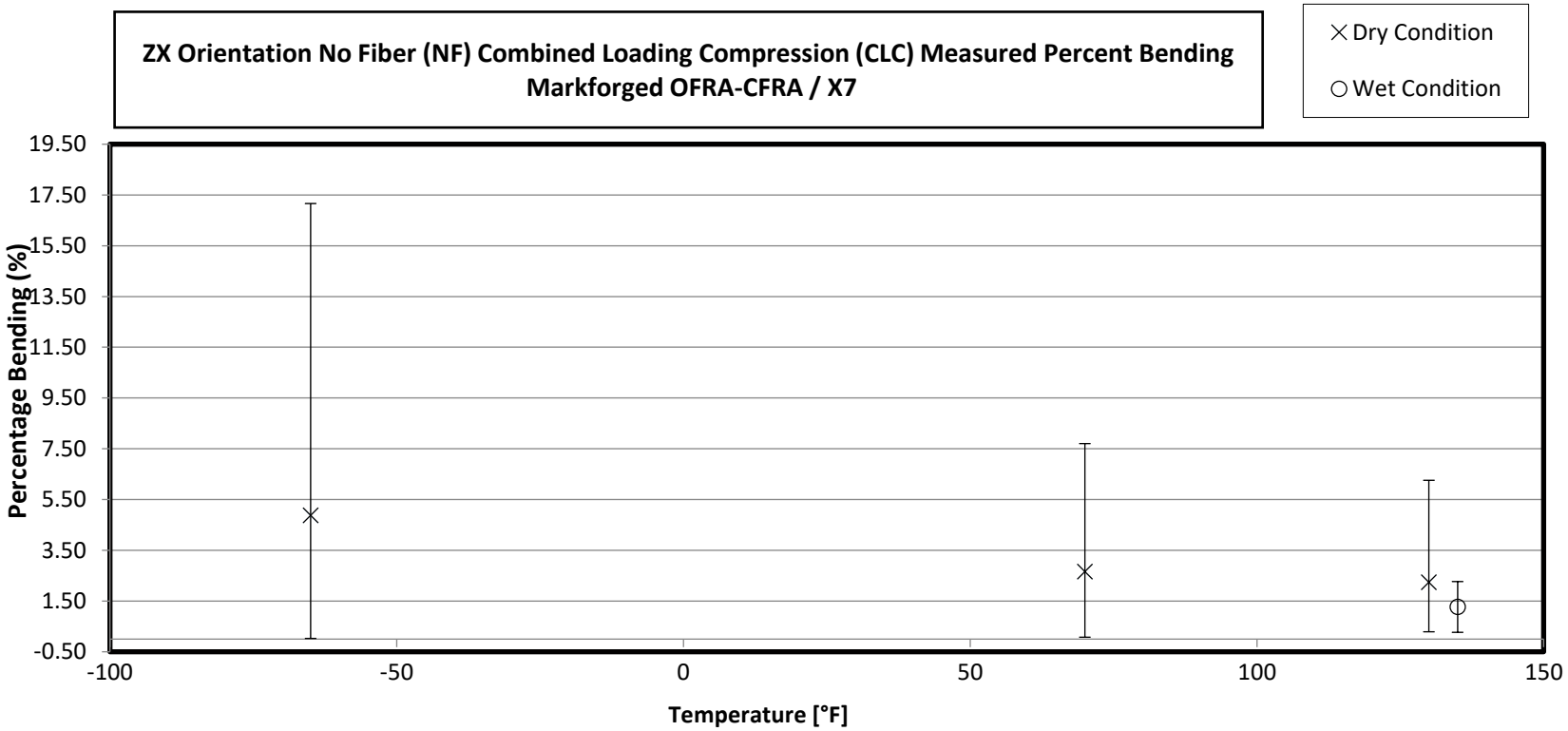

ZX Orientation Partial Fiber (PF) Combined Loading Compression (CLC) Measured Percent Bending
Markforged OFRA-CFRA / X7
Dry Condition
Wet Condition
Percentage Bending [%]
10.00
9.00
8.00
7.00
6.00
5.00
4.00
3.00
2.00
1.00
0.00
-100
-50
0
50
100
150
Temperature [°F]

3.12 ZX NF Compression Properties

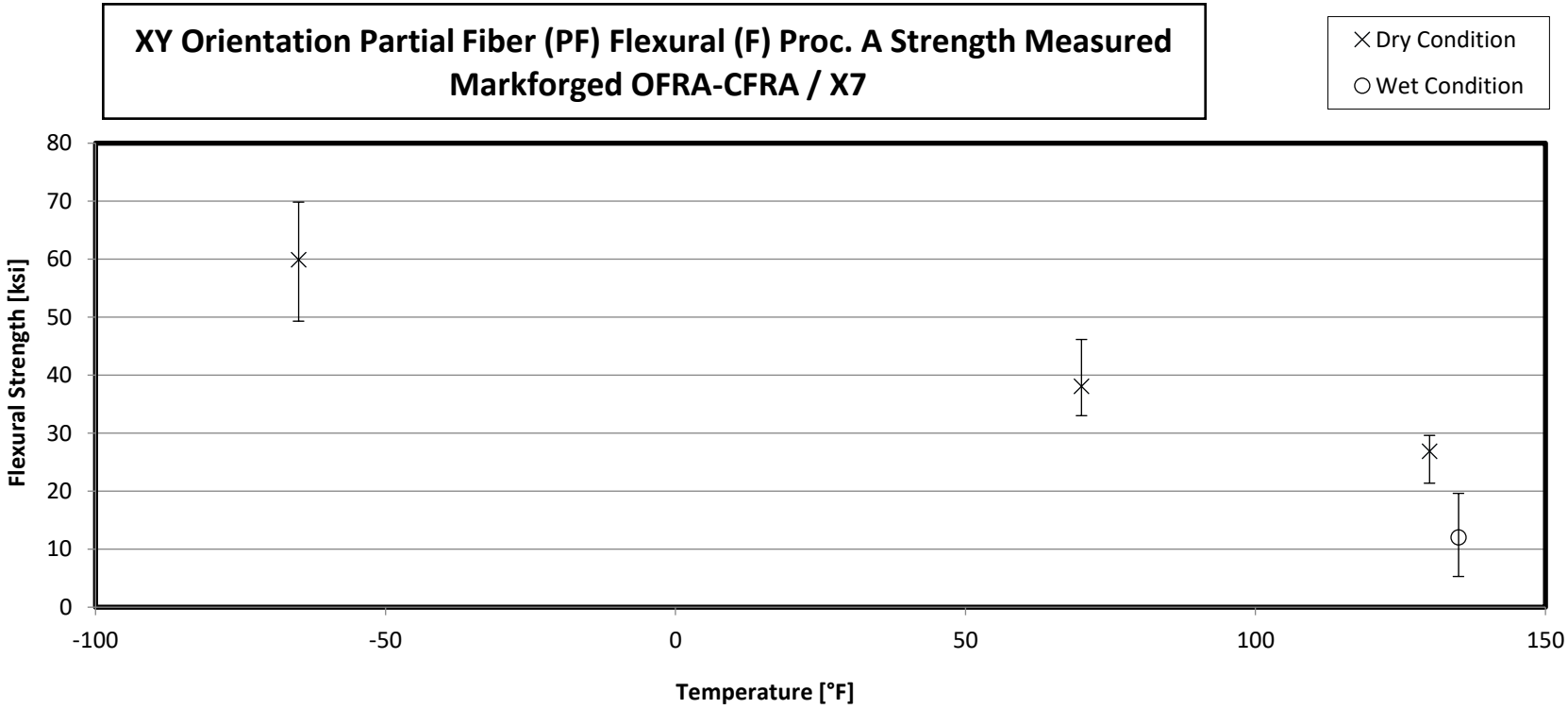


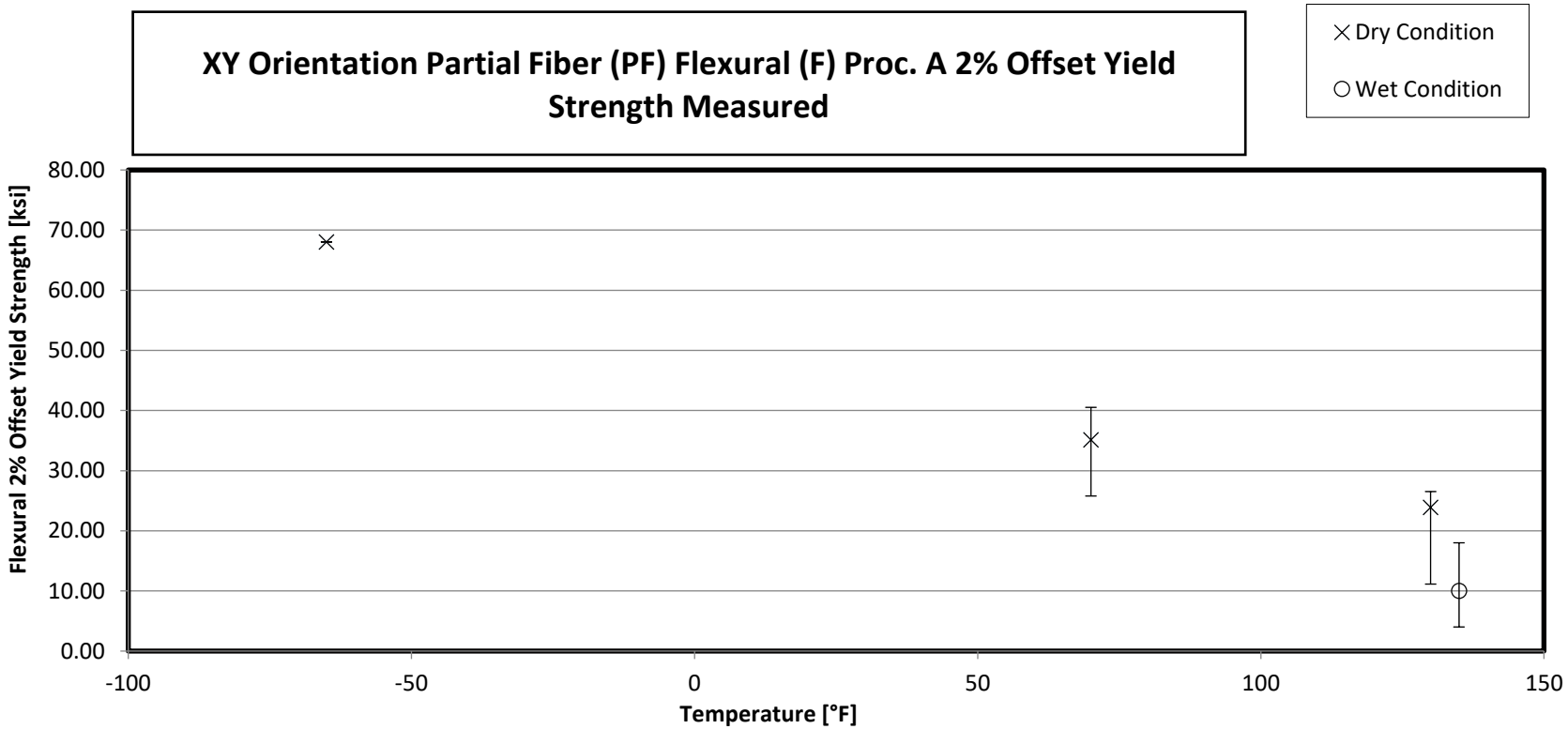

ZX Orientation No Fiber (NF) Combined Loading Compression (CLC) Measured Modulus
Markforged OFRA-CFRA / X7
Dry Condition
Wet Condition
Compressive Modulus [Msi]
0.80
0.70
0.60
0.50
0.40
0.30
0.20
0.10
0.00
-100
-50
0
50
100
150
Temperature [°F]

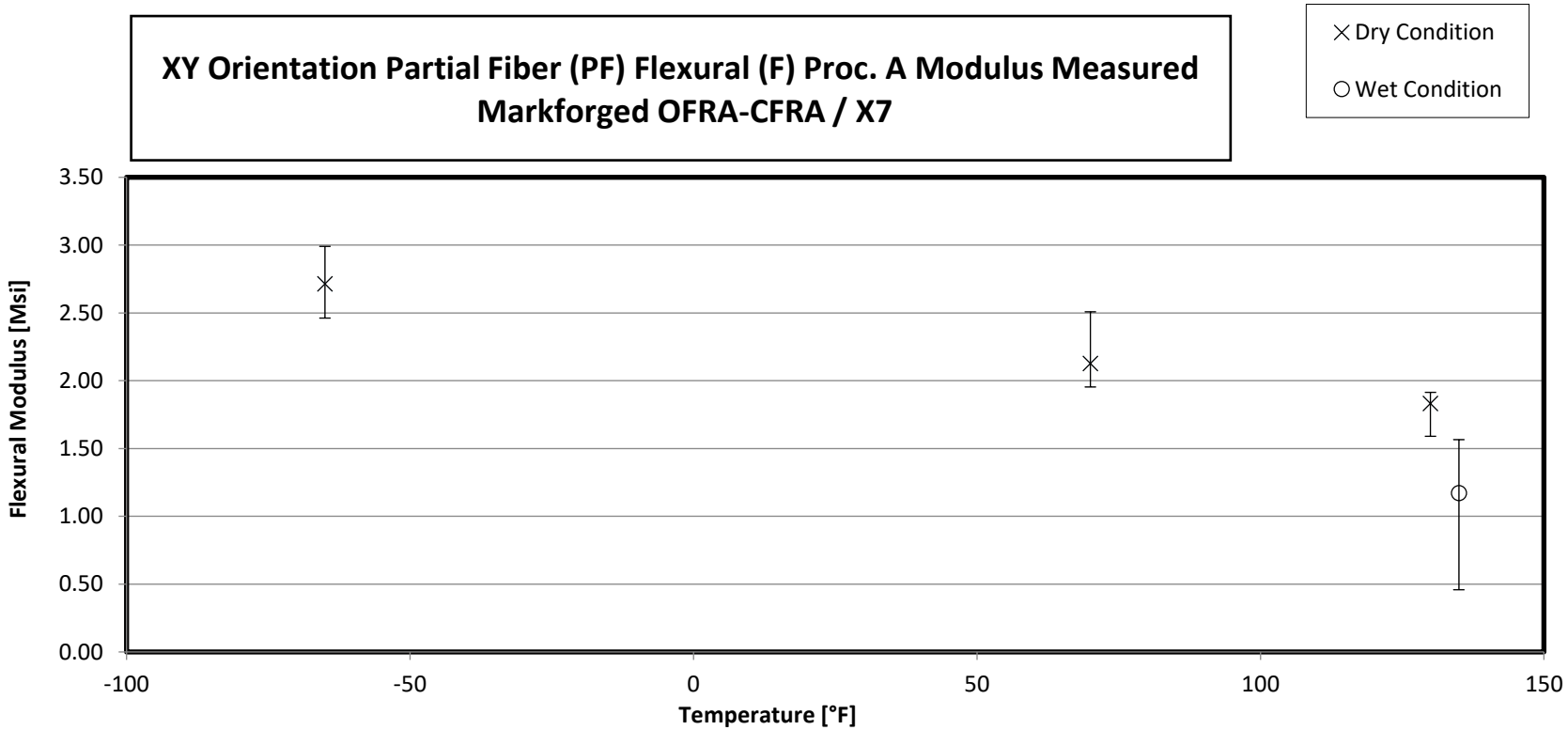

ZX Orientation No Fiber (NF) Combined Loading Compression (CLC) Measured Poisson's Ratio
Markforged OFRA-CFRA / X7
Dry Condition
Wet Condition
Avg. Poisson's Ratio
0.30
0.25
0.20
0.15
0.10
0.05
0.00
-100
-50
0
50
100
150
Temperature [°F]


ZX Orientation No Fiber (NF) Combined Loading Compression (CLC) Measured Percent Bending
Markforged OFRA-CFRA / X7
Dry Condition
Wet Condition
Percentage Bending (%)
19.50
17.50
15.50
13.50
11.50
9.50
7.50
5.50
3.50
1.50
-0.50
-100
-50
0
50
100
150
Temperature [°F]

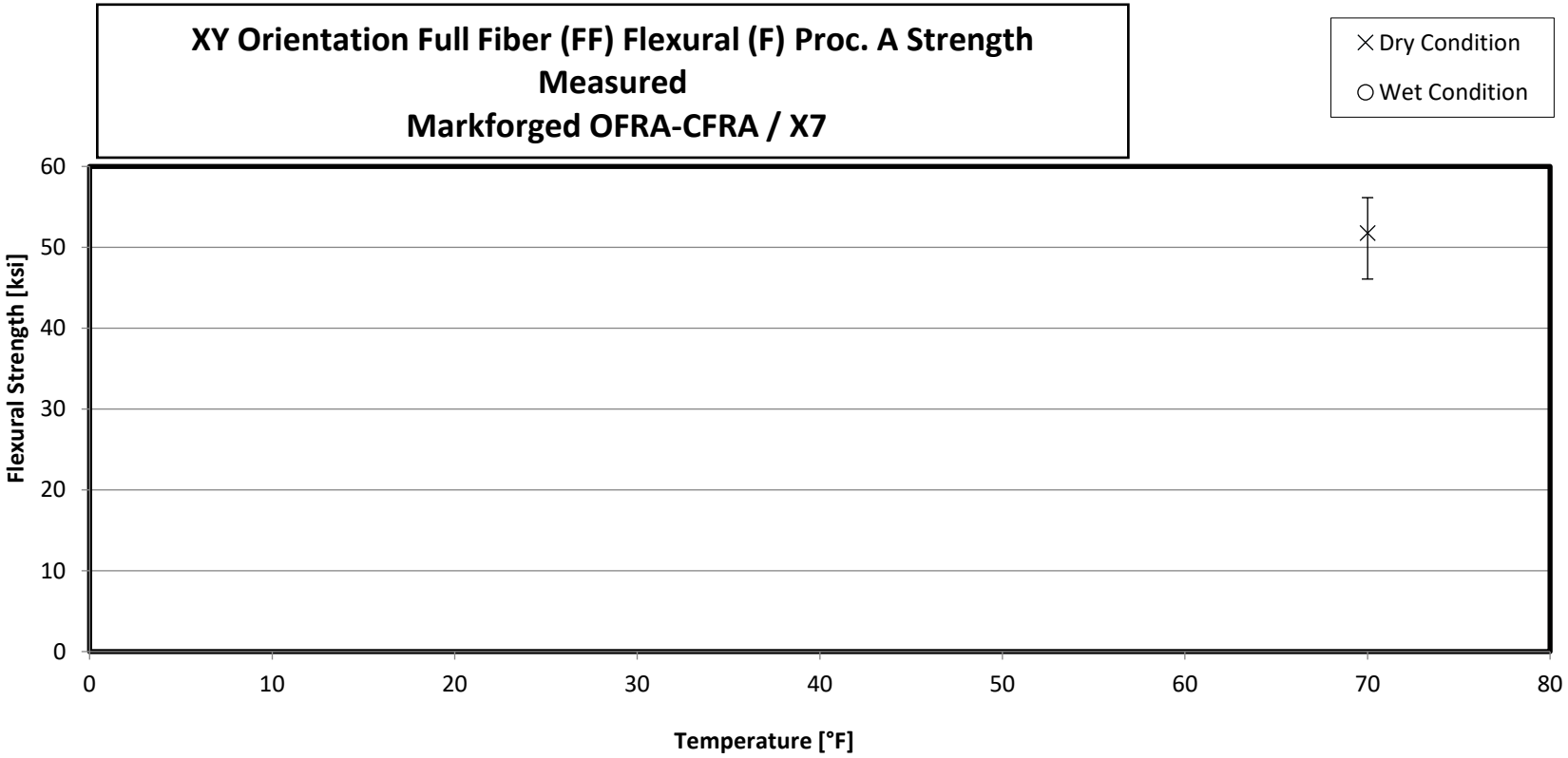
3.13 XY PF Flex Properties

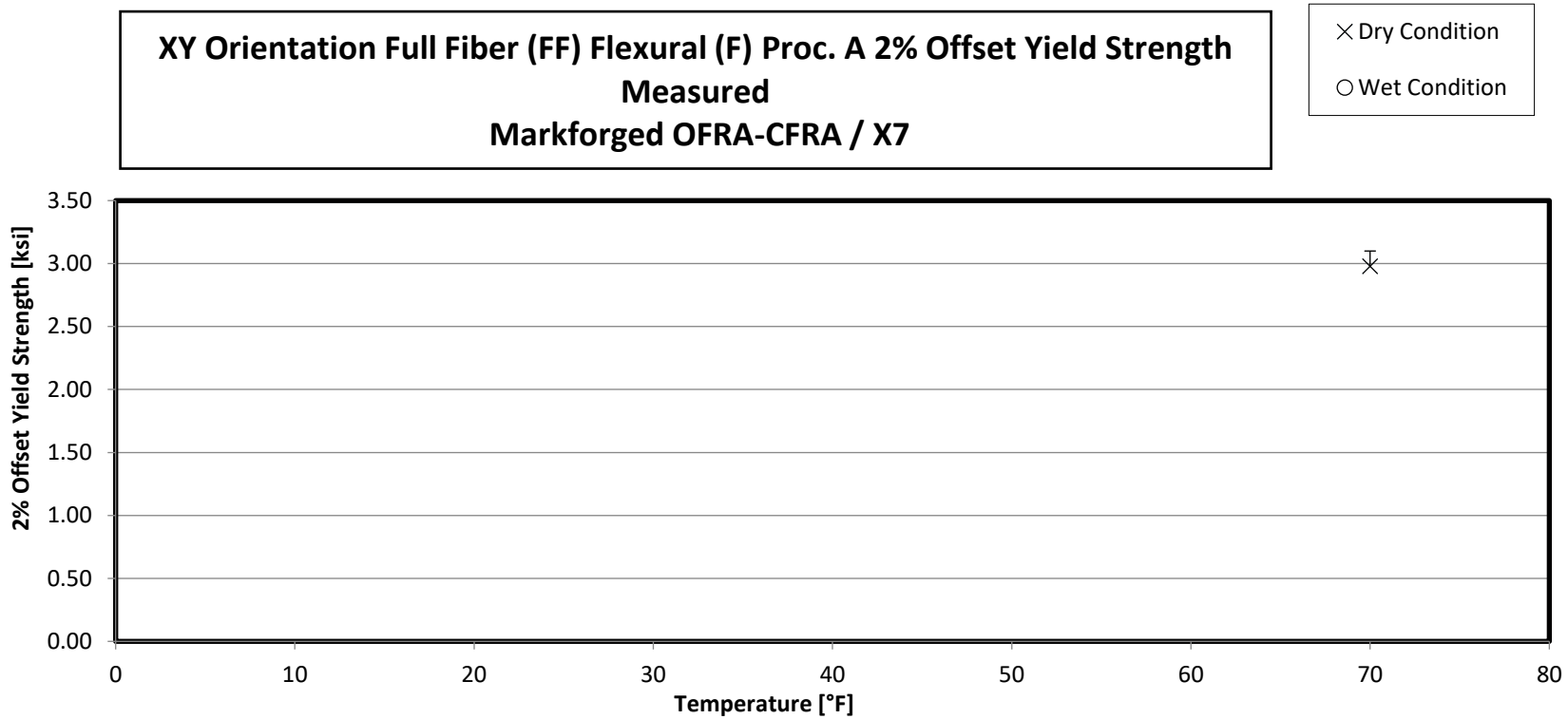


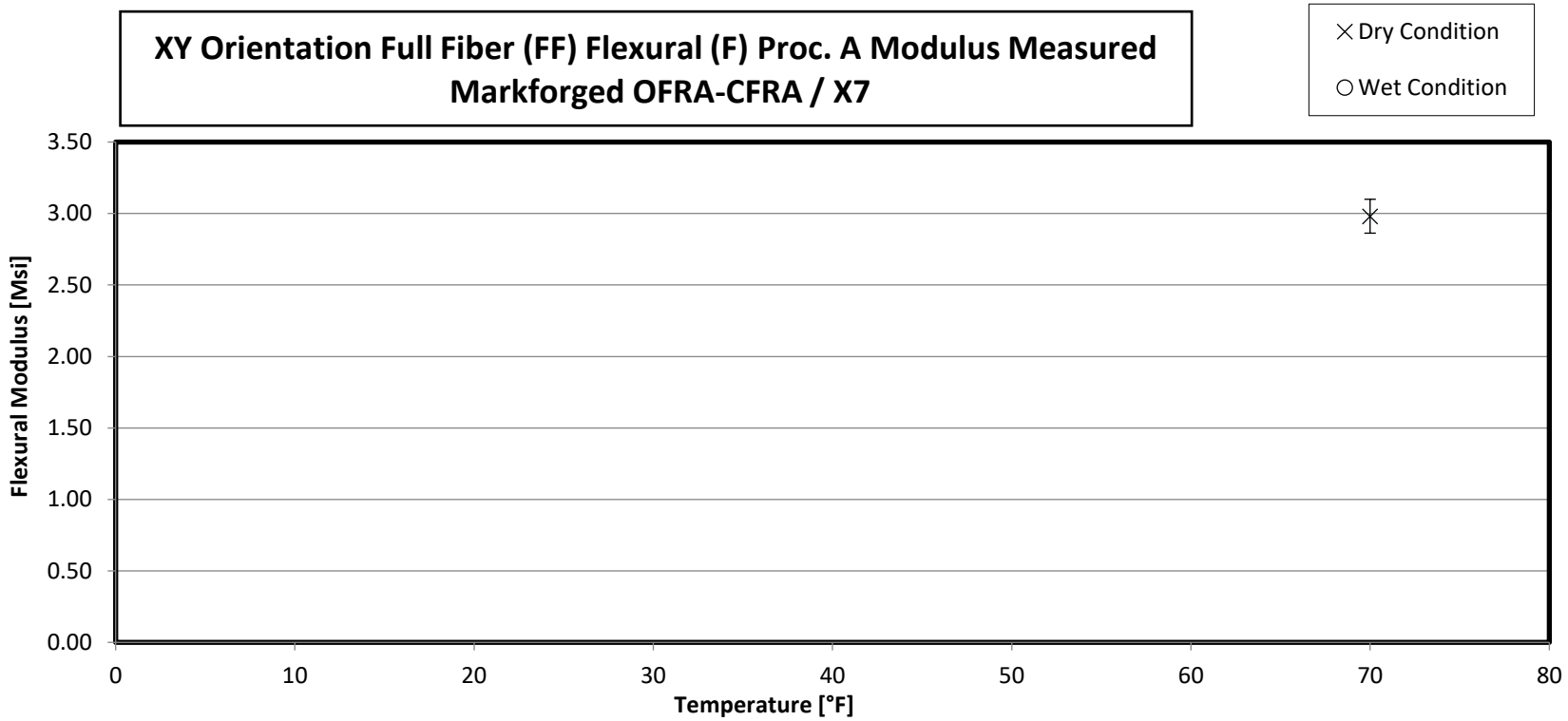

XY Orientation Partial Fiber (PF) Flexural (F) Proc. A 2% Offset Yield Strength Measured
Dry Condition
Wet Condition
Flexural 2% Offset Yield Strength [ksi]
80.00
70.00
60.00
50.00
40.00
30.00
20.00
10.00
0.00
-100
-50
0
50
100
150
Temperature [°F]


XY Orientation Partial Fiber (PF) Flexural (F) Proc. A Modulus Measured
Markforged OFRA-CFRA / X7
Dry Condition
Wet Condition
Flexural Modulus [Msi]
3.50
3.00
2.50
2.00
1.50
1.00
0.50
0.00
-100
-50
0
50
100
150
Temperature [°F]

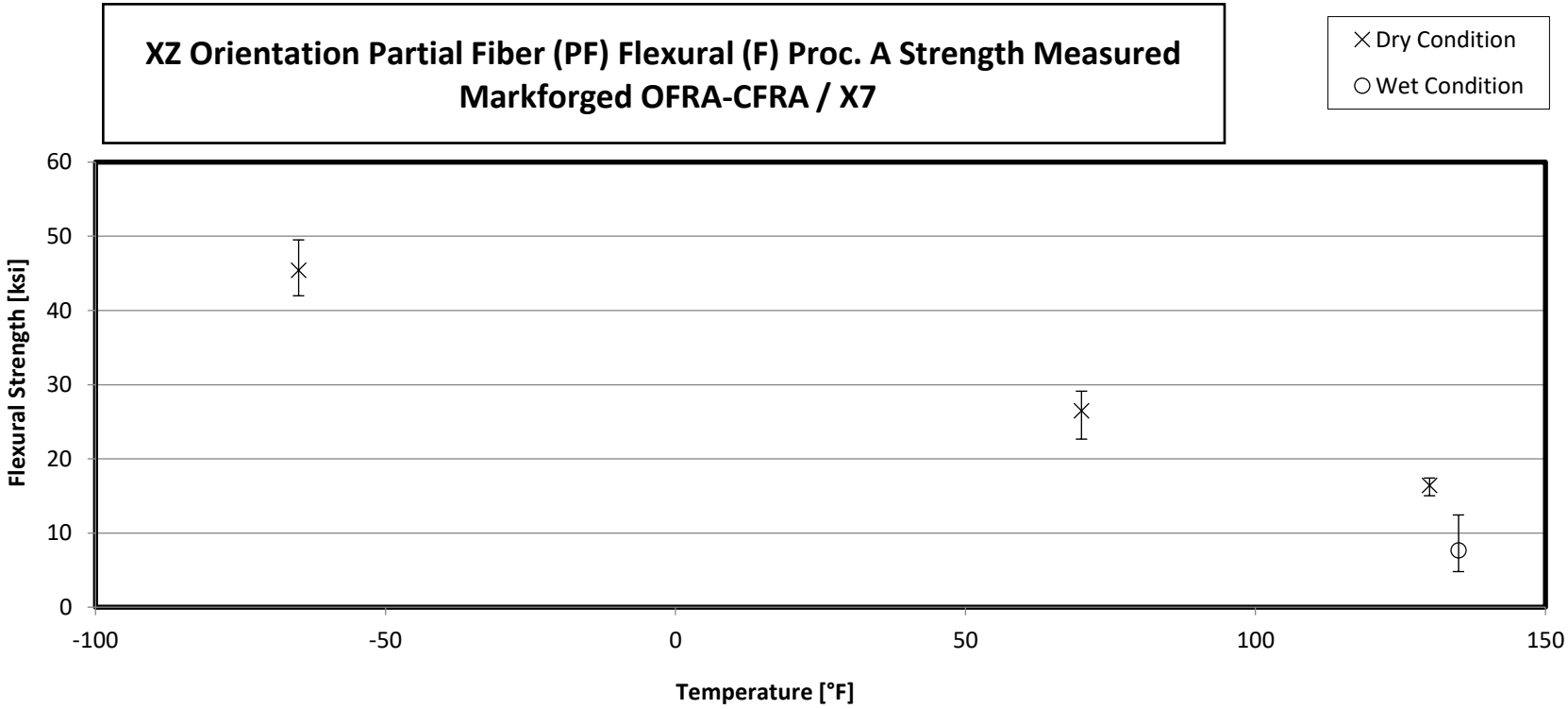
3.14 XY FF Flex Properties – Reference Only

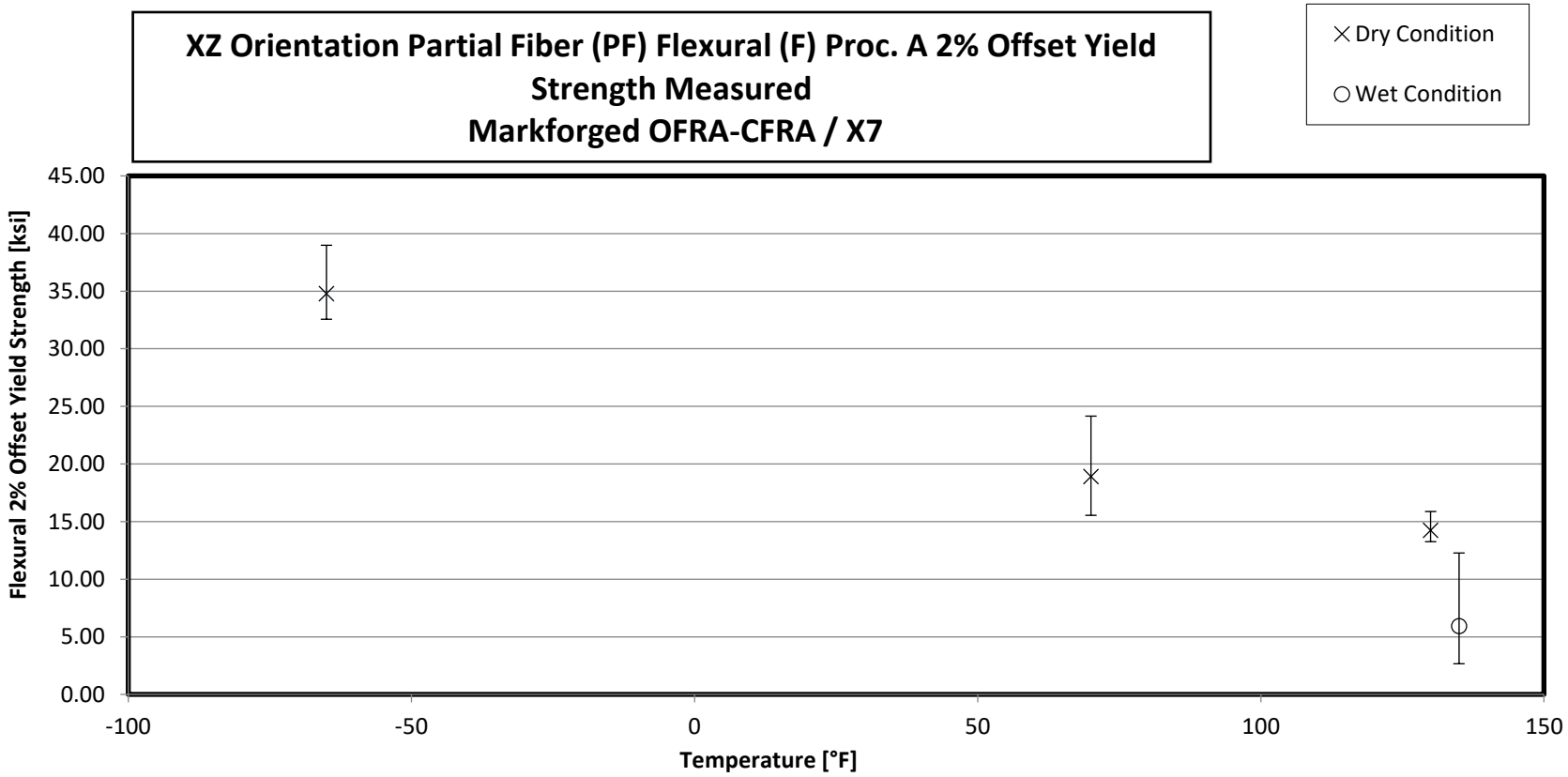


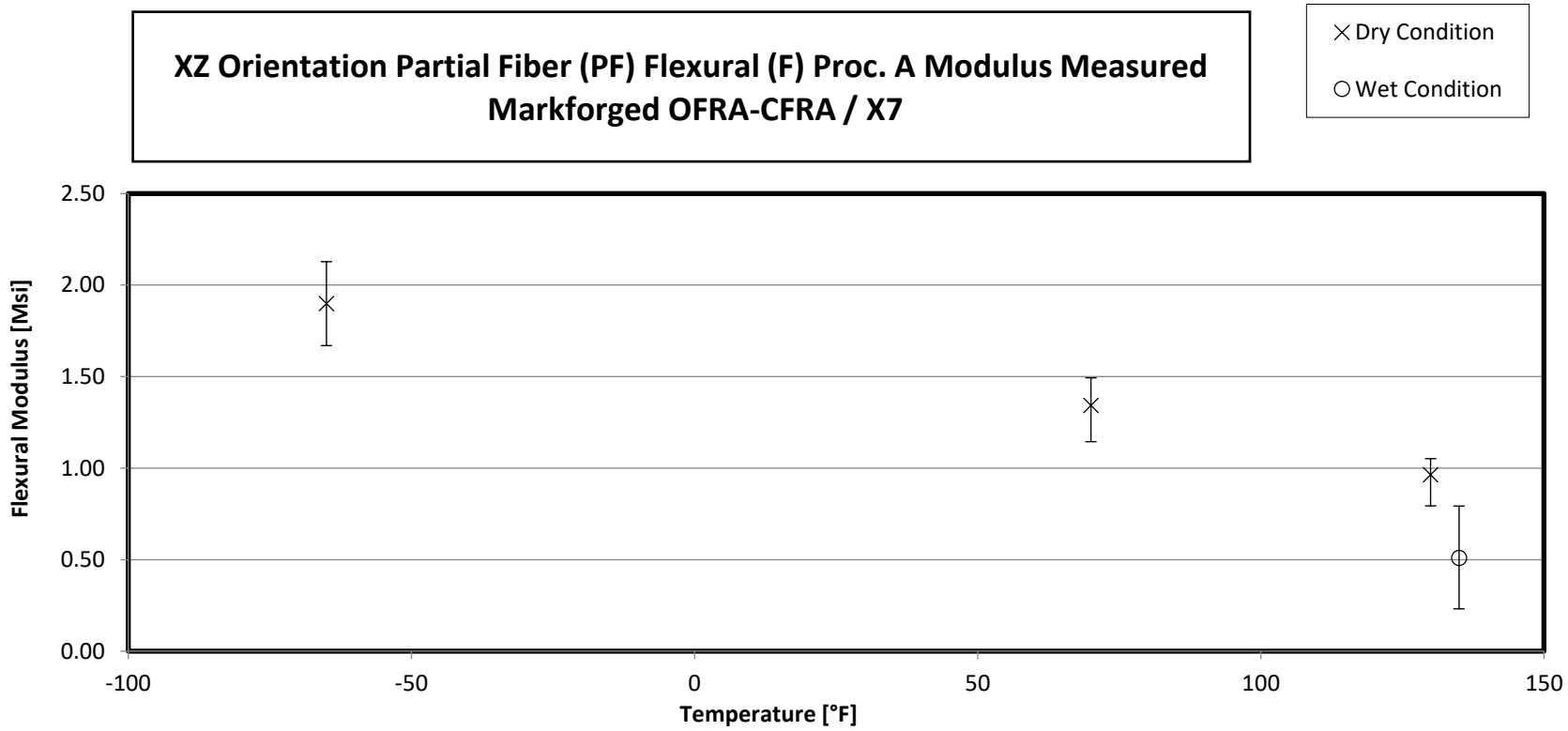

XY Orientation Full Fiber (FF) Flexural (F) Proc. A 2% Offset Yield Strength
Measured
Markforged OFRA-CFRA / X7
Dry Condition
Wet Condition
2% Offset Yield Strength [ksi]
3.50
3.00
2.50
2.00
1.50
1.00
0.50
0.00
0
10
20
30
40
50
60
70
80
Temperature [°F]


XY Orientation Full Fiber (FF) Flexural (F) Proc. A Modulus Measured
Markforged OFRA-CFRA / X7
Dry Condition
Wet Condition
Flexural Modulus [Msi]
3.50
3.00
2.50
2.00
1.50
1.00
0.50
0.00
0
10
20
30
40
50
60
70
80
Temperature [°F]

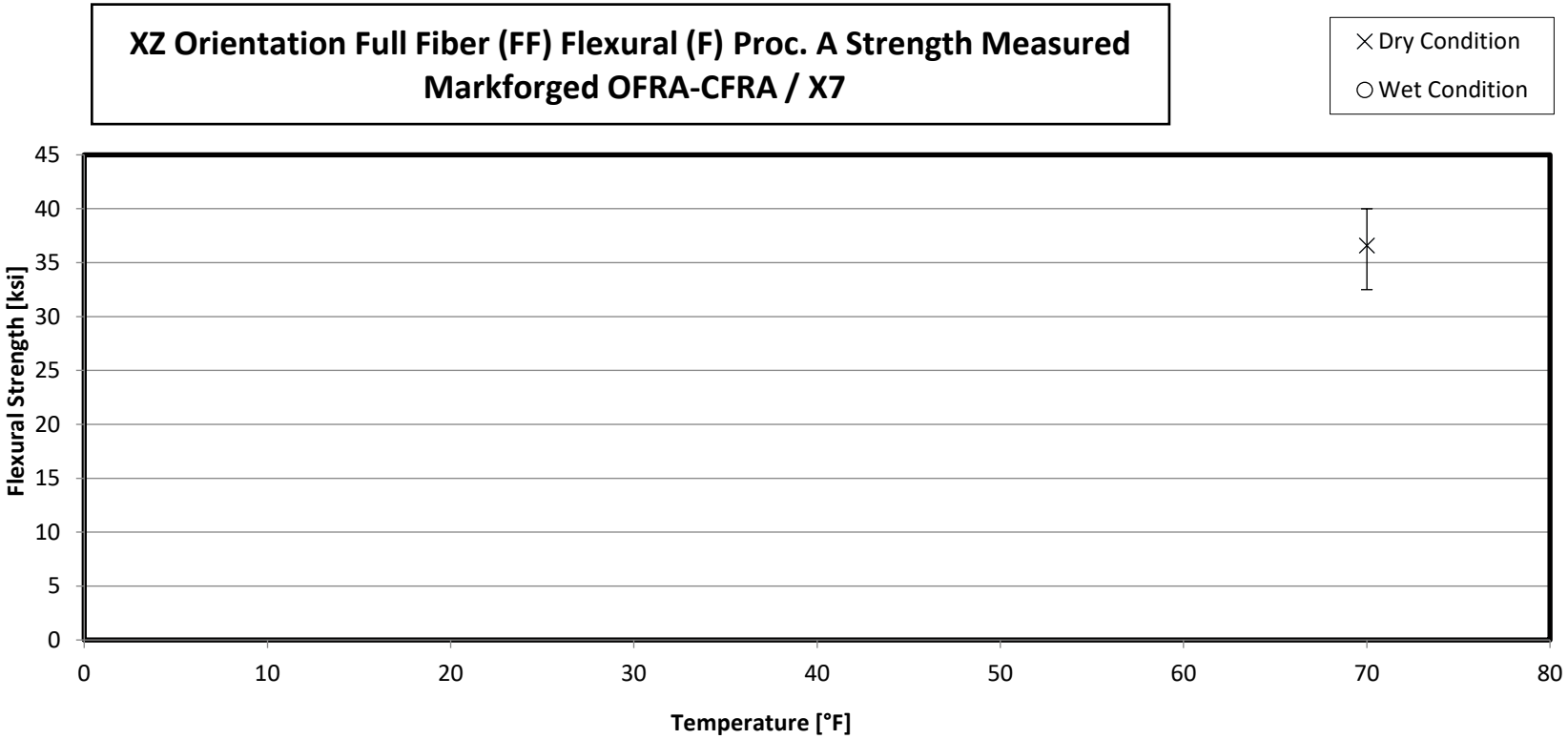
3.15 XZ PF Flex Properties

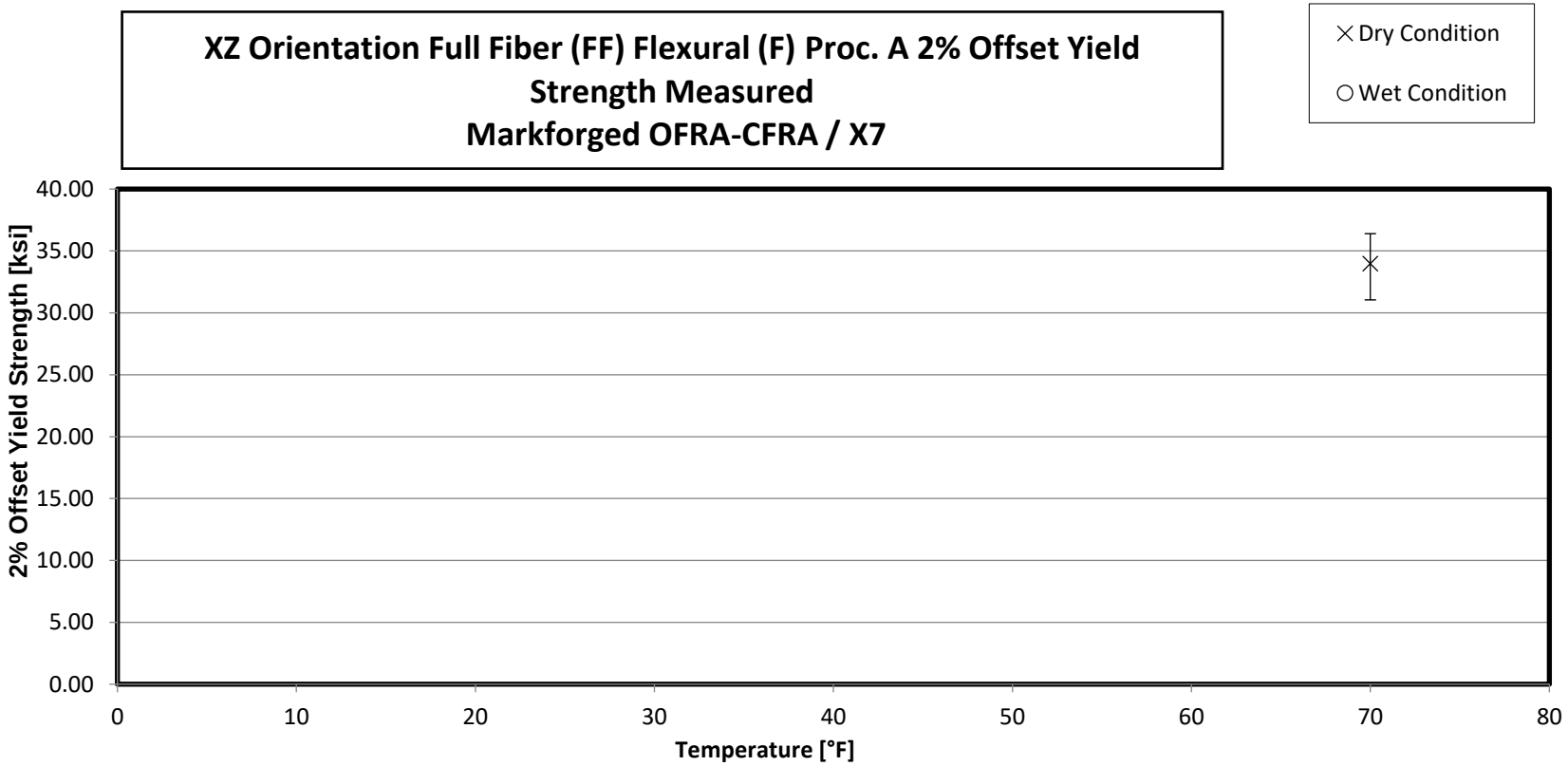


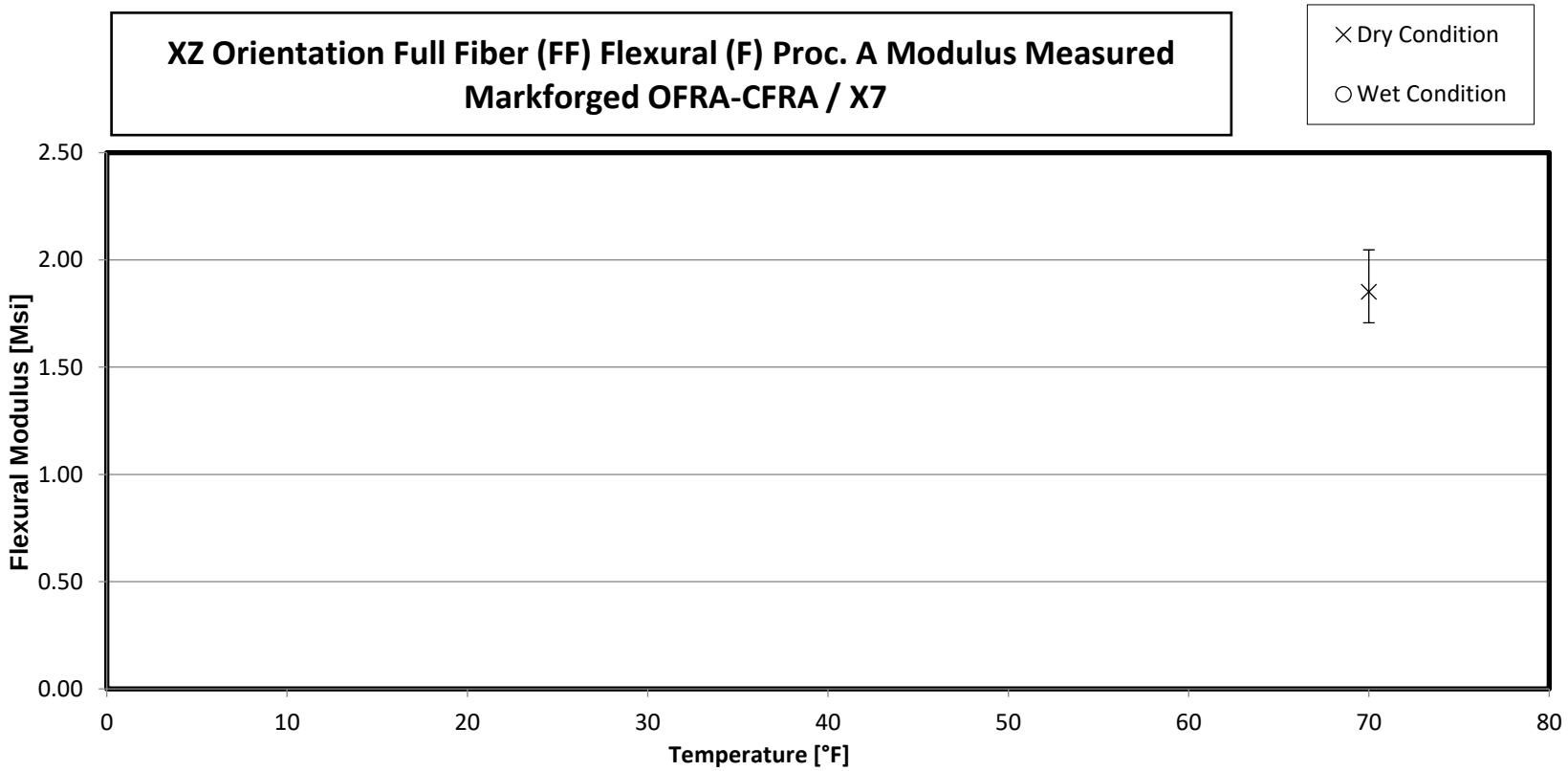

XZ Orientation Partial Fiber (PF) Flexural (F) Proc. A 2% Offset Yield Strength Measured
Markforged OFRA-CFRA / X7
Dry Condition
Wet Condition
Flexural 2% Offset Yield Strength [ksi]
45.00
40.00
35.00
30.00
25.00
20.00
15.00
10.00
5.00
0.00
-100
-50
0
50
100
150
Temperature [°F]


XZ Orientation Partial Fiber (PF) Flexural (F) Proc. A Modulus Measured
Markforged OFRA-CFRA / X7
Dry Condition
Wet Condition
Flexural Modulus [Msi]
2.50
2.00
1.50
1.00
0.50
0.00
-100
-50
0
50
100
150
Temperature [°F]

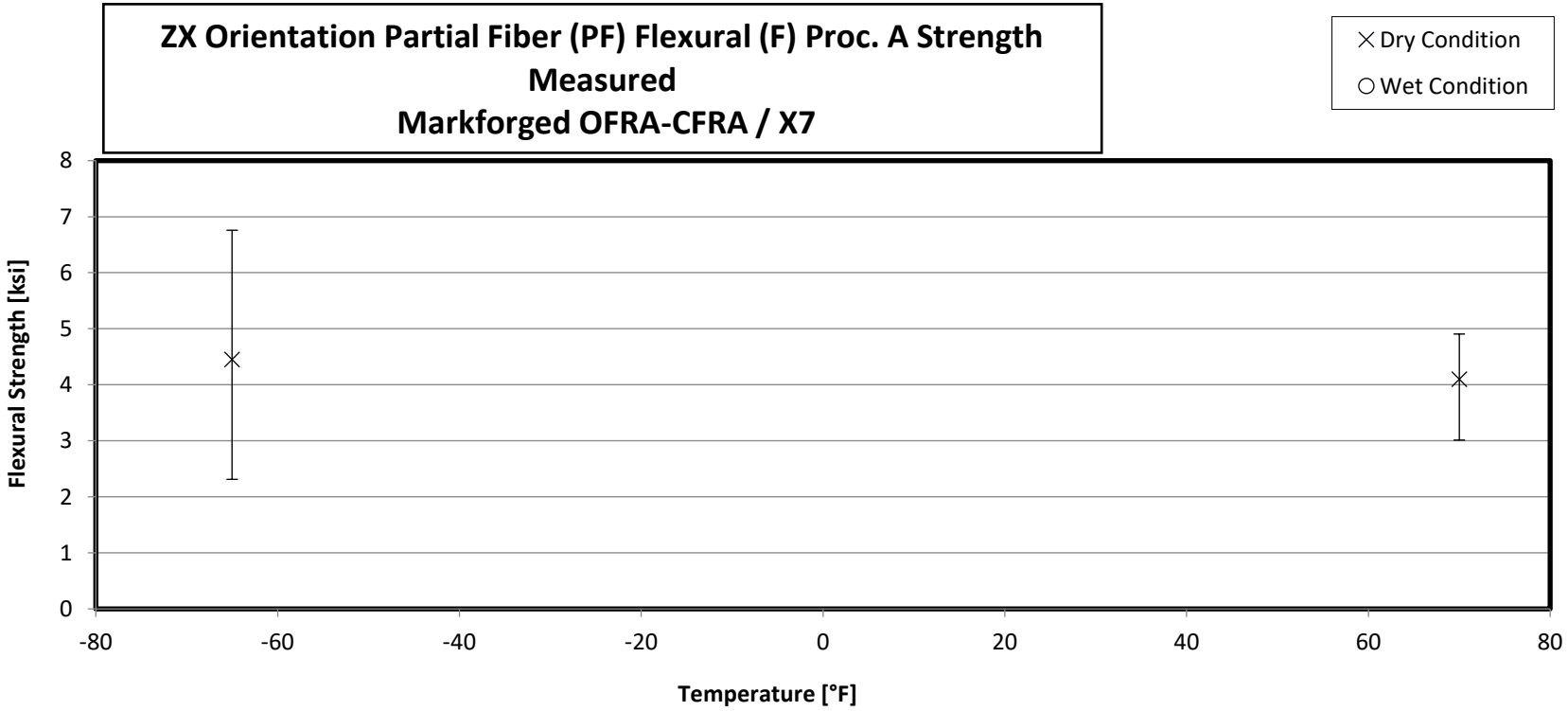
3.16 **XZ FF Flex Properties – Reference Only**

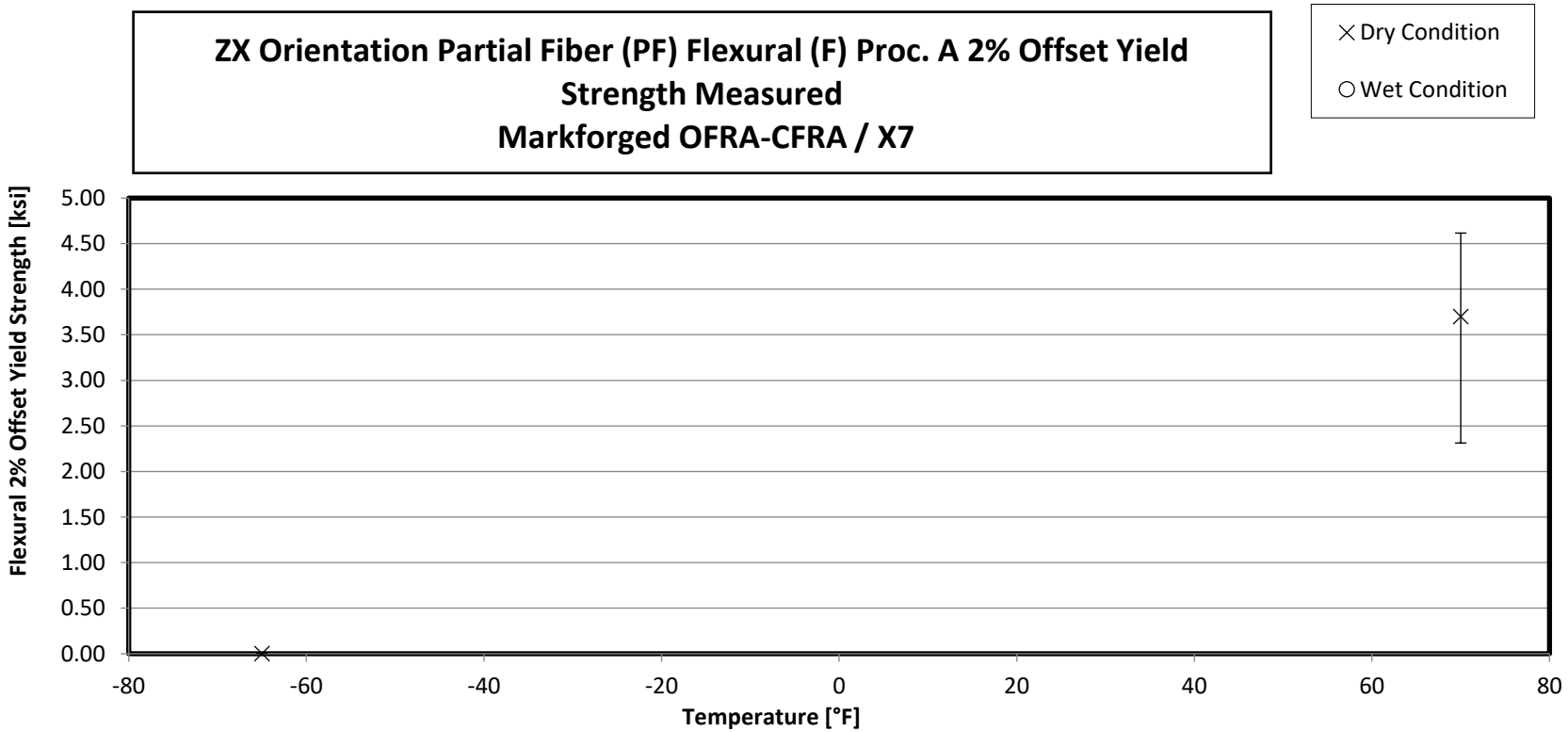


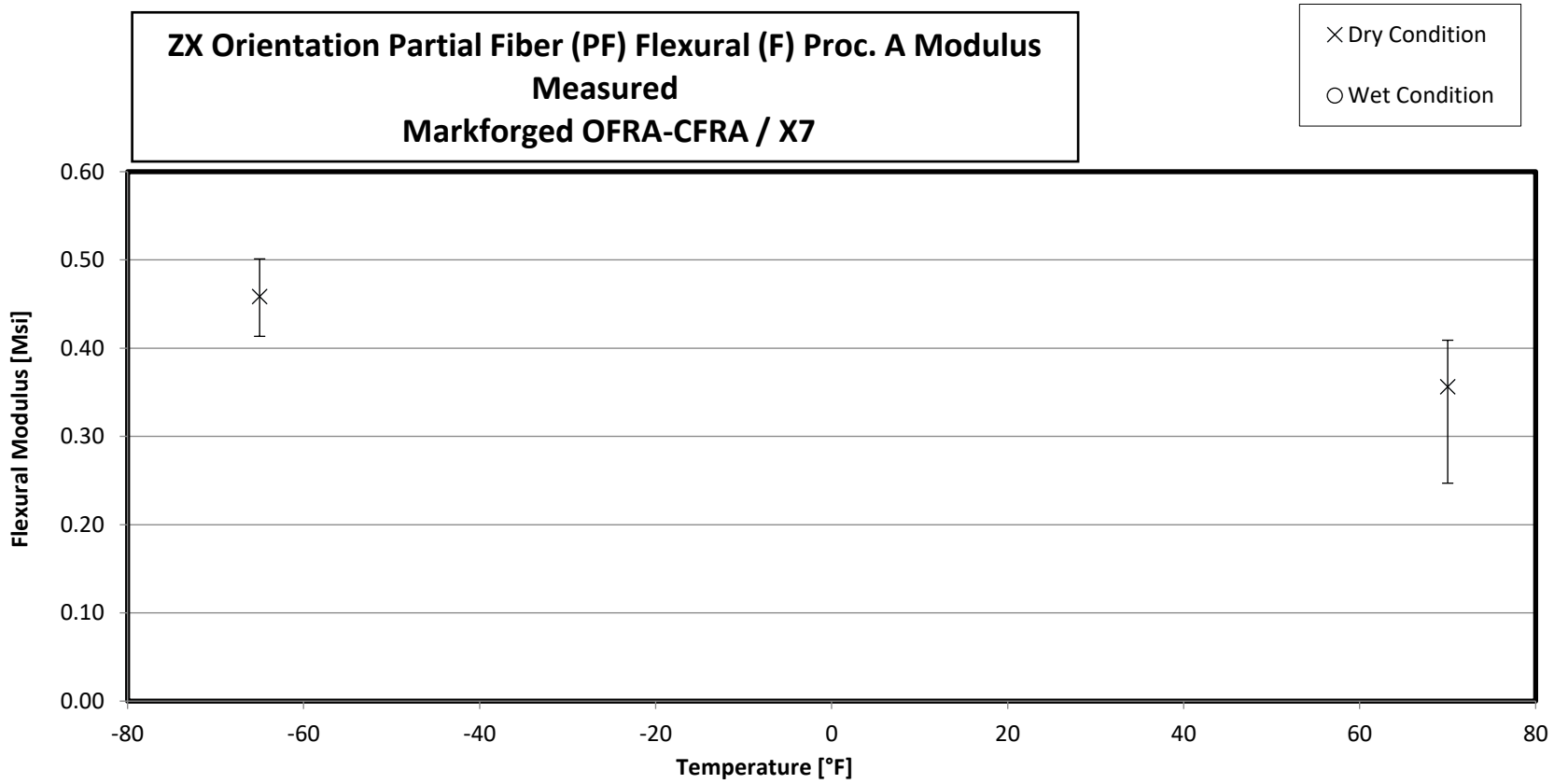

XZ Orientation Full Fiber (FF) Flexural (F) Proc. A 2% Offset Yield Strength Measured
Markforged OFRA-CFRA / X7
Dry Condition
Wet Condition
2% Offset Yield Strength [ksi]
40.00
35.00
30.00
25.00
20.00
15.00
10.00
5.00
0.00
0
10
20
30
40
50
60
70
80
Temperature [°F]


XZ Orientation Full Fiber (FF) Flexural (F) Proc. A Modulus Measured
Markforged OFRA-CFRA / X7
Dry Condition
Wet Condition
Flexural Modulus [Msi]
2.50
2.00
1.50
1.00
0.50
0.00
0
10
20
30
40
50
60
70
80
Temperature [°F]

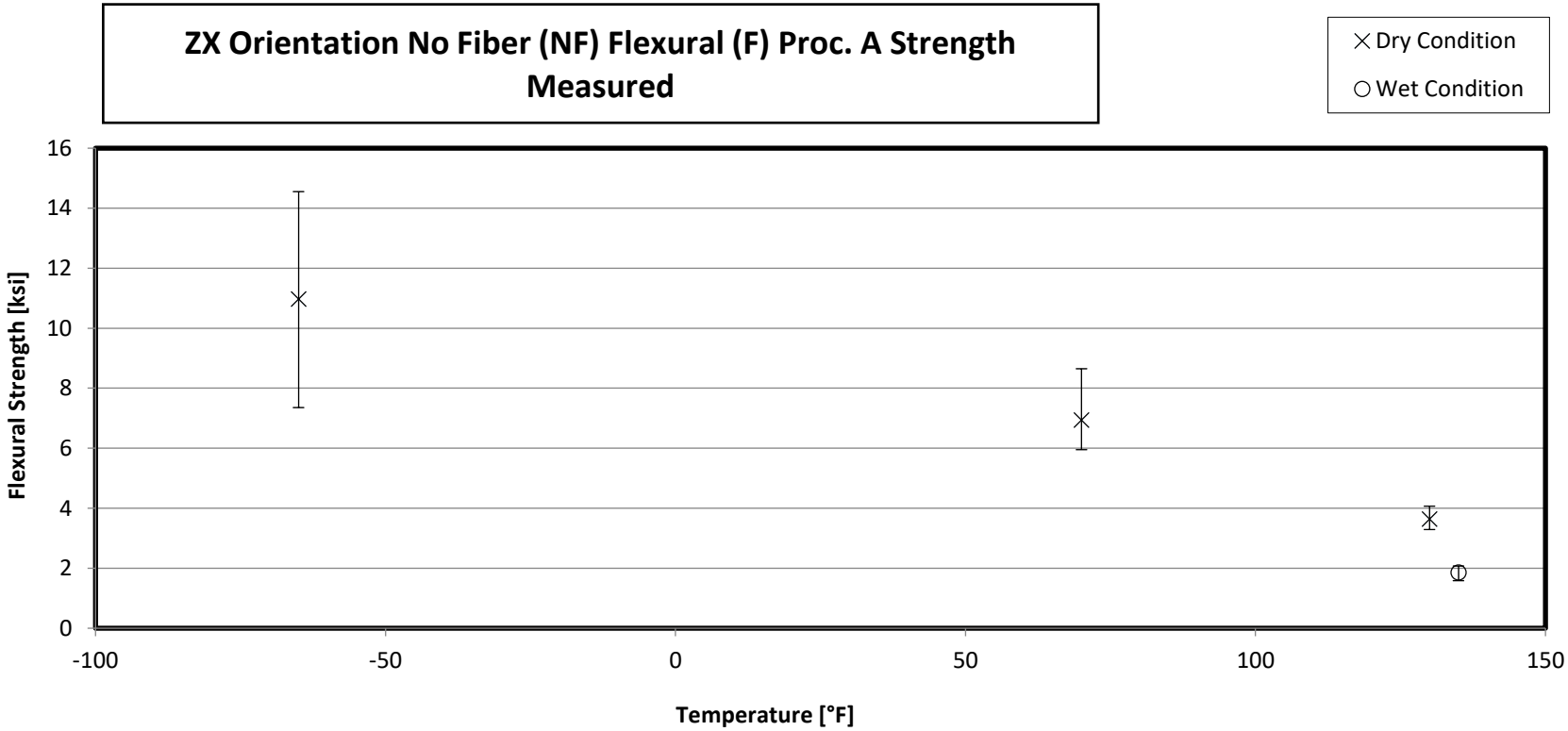
3.17 ZX PF Flex Properties – Reference Only

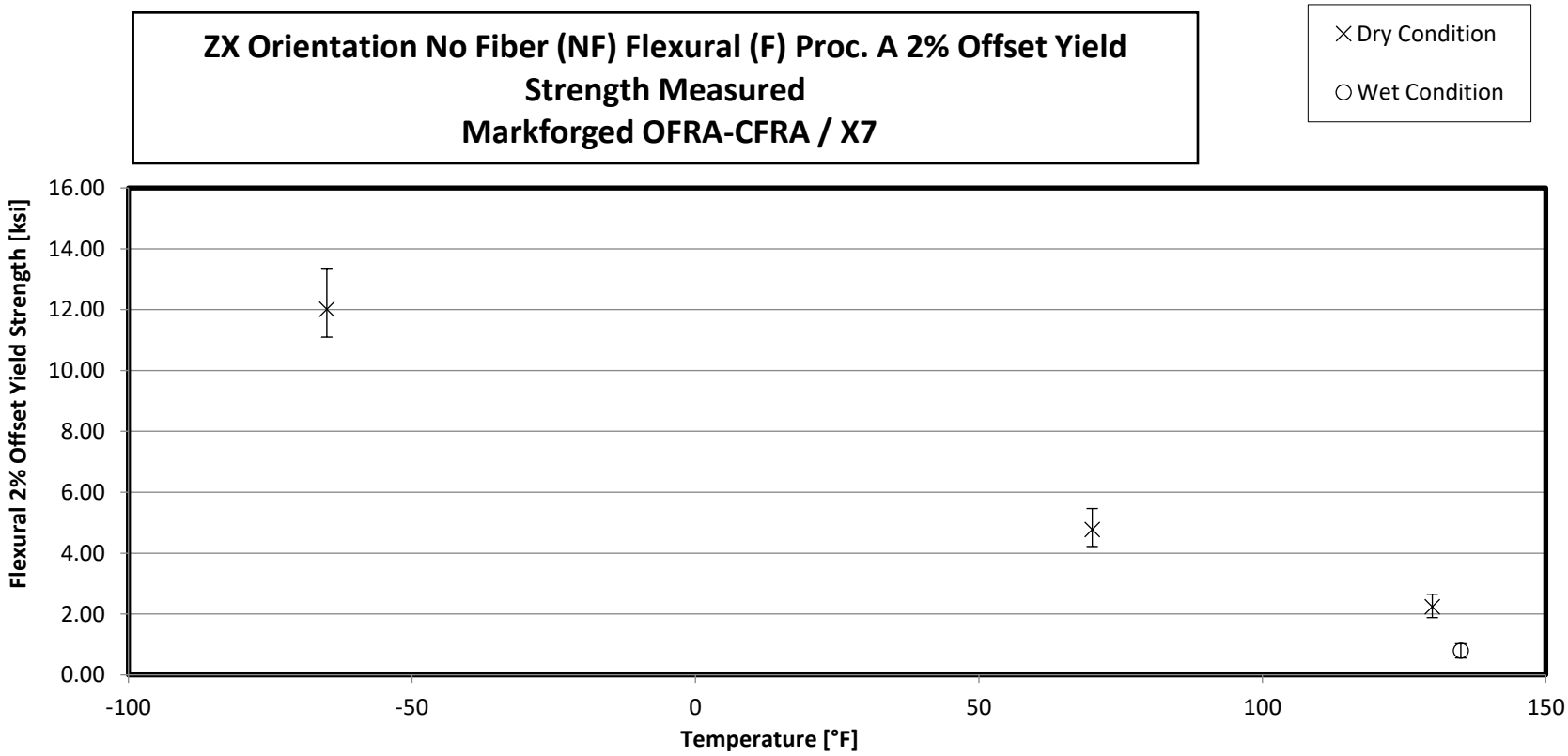


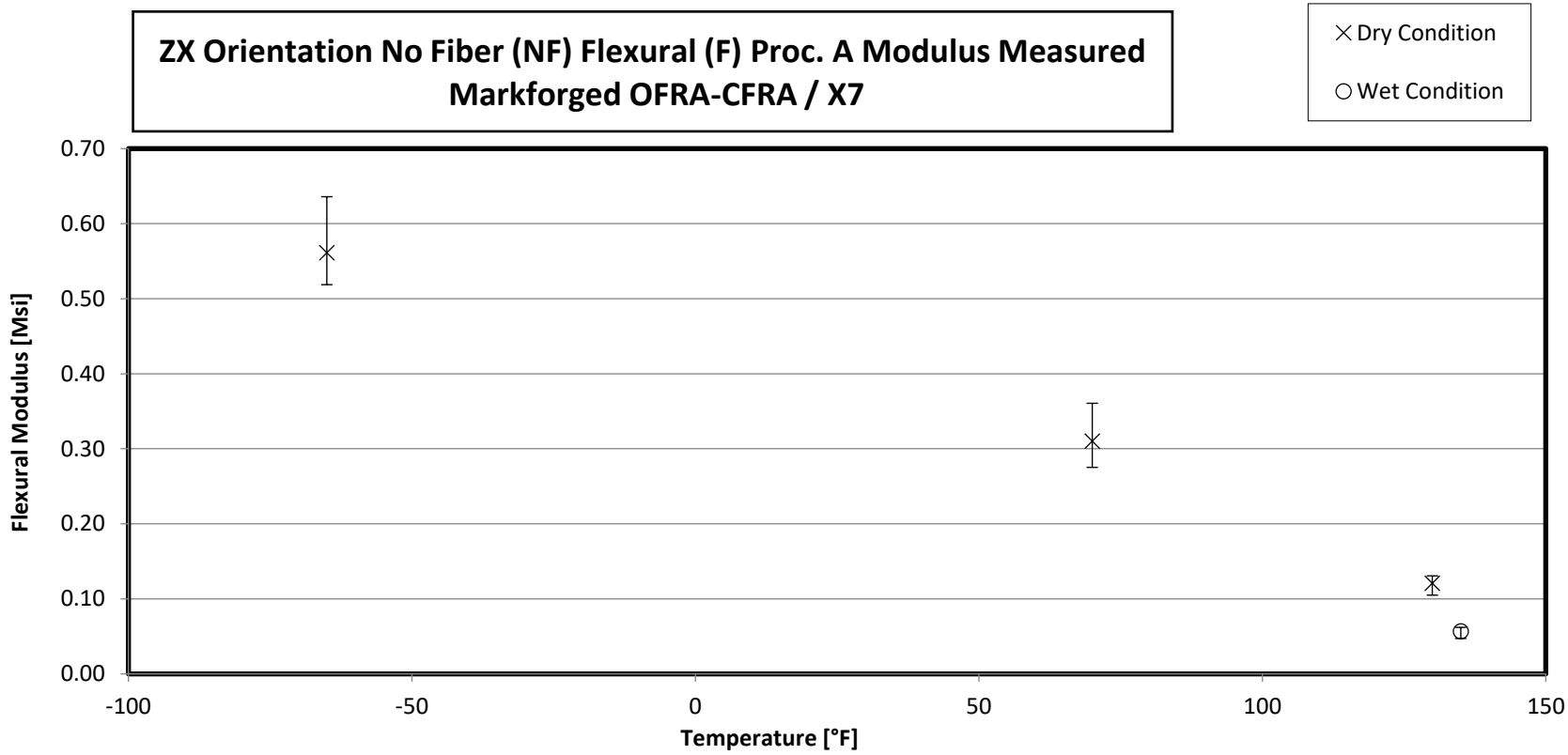

ZX Orientation Partial Fiber (PF) Flexural (F) Proc. A 2% Offset Yield Strength Measured
Markforged OFRA-CFRA / X7
Dry Condition
Wet Condition
Flexural 2% Offset Yield Strength [ksi]
5.00
4.50
4.00
3.50
3.00
2.50
2.00
1.50
1.00
0.50
0.00
-80
-60
-40
-20
0
20
40
60
80
Temperature [°F]


ZX Orientation Partial Fiber (PF) Flexural (F) Proc. A Modulus Measured
Markforged OFRA-CFRA / X7
Dry Condition
Wet Condition
Flexural Modulus [Msi]
0.60
0.50
0.40
0.30
0.20
0.10
0.00
-80
-60
-40
-20
0
20
40
60
80
Temperature [°F]

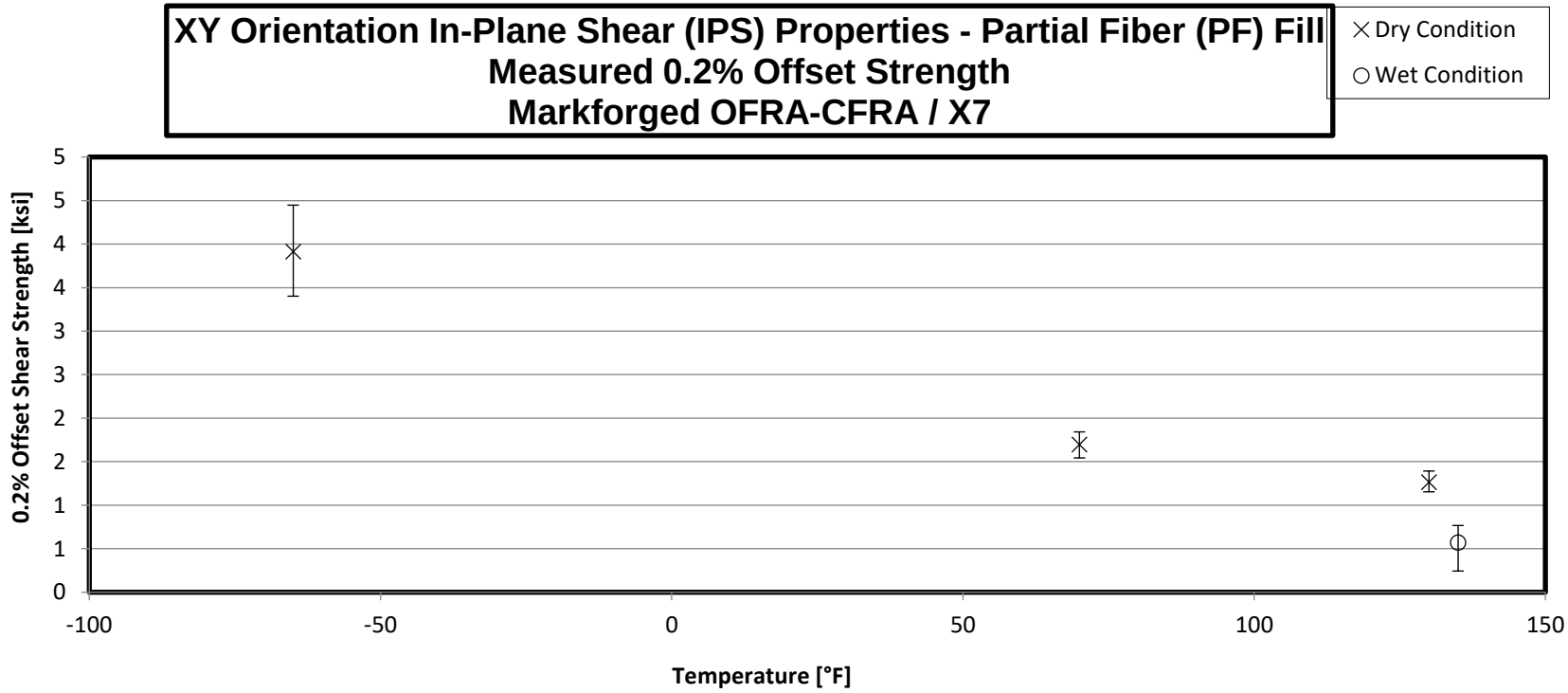
3.18 ZX NF Flex Properties

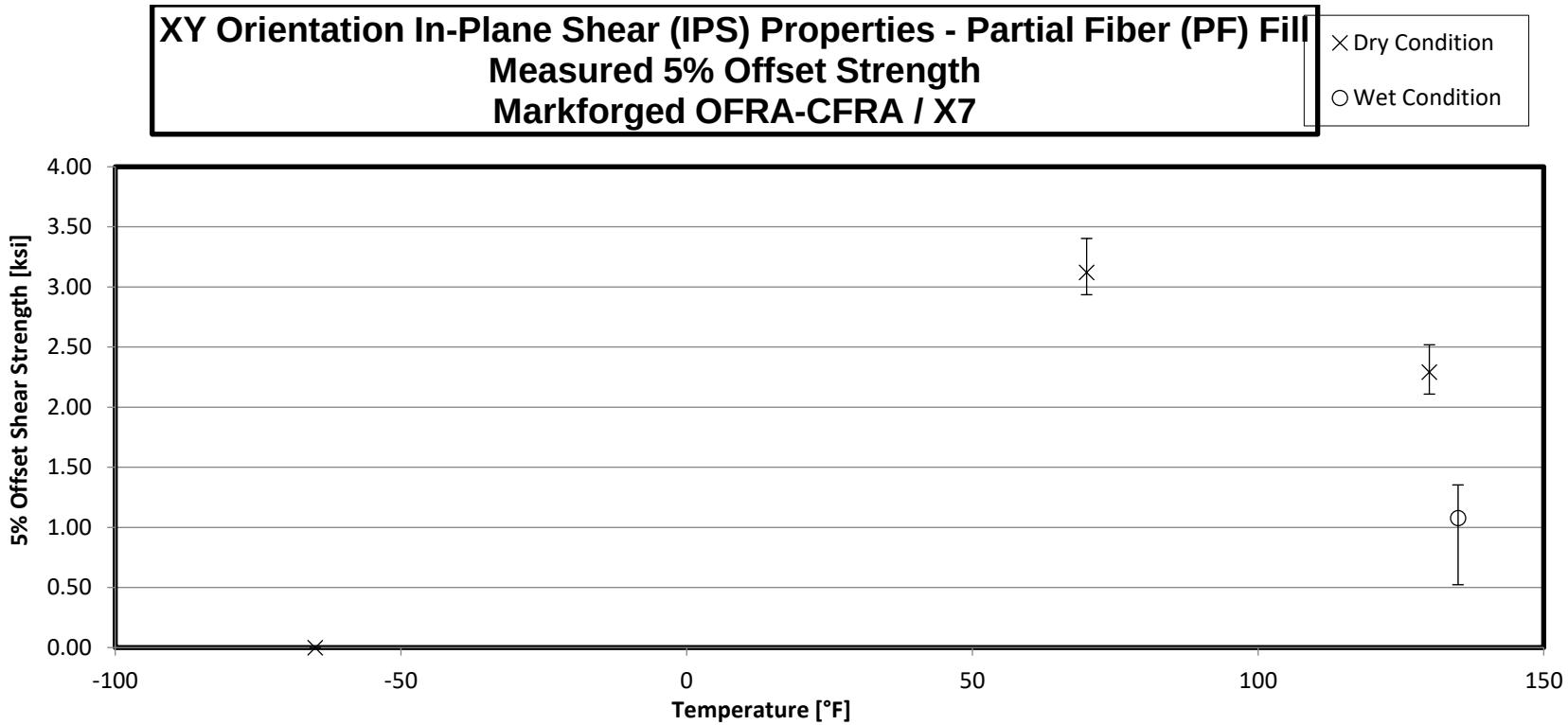


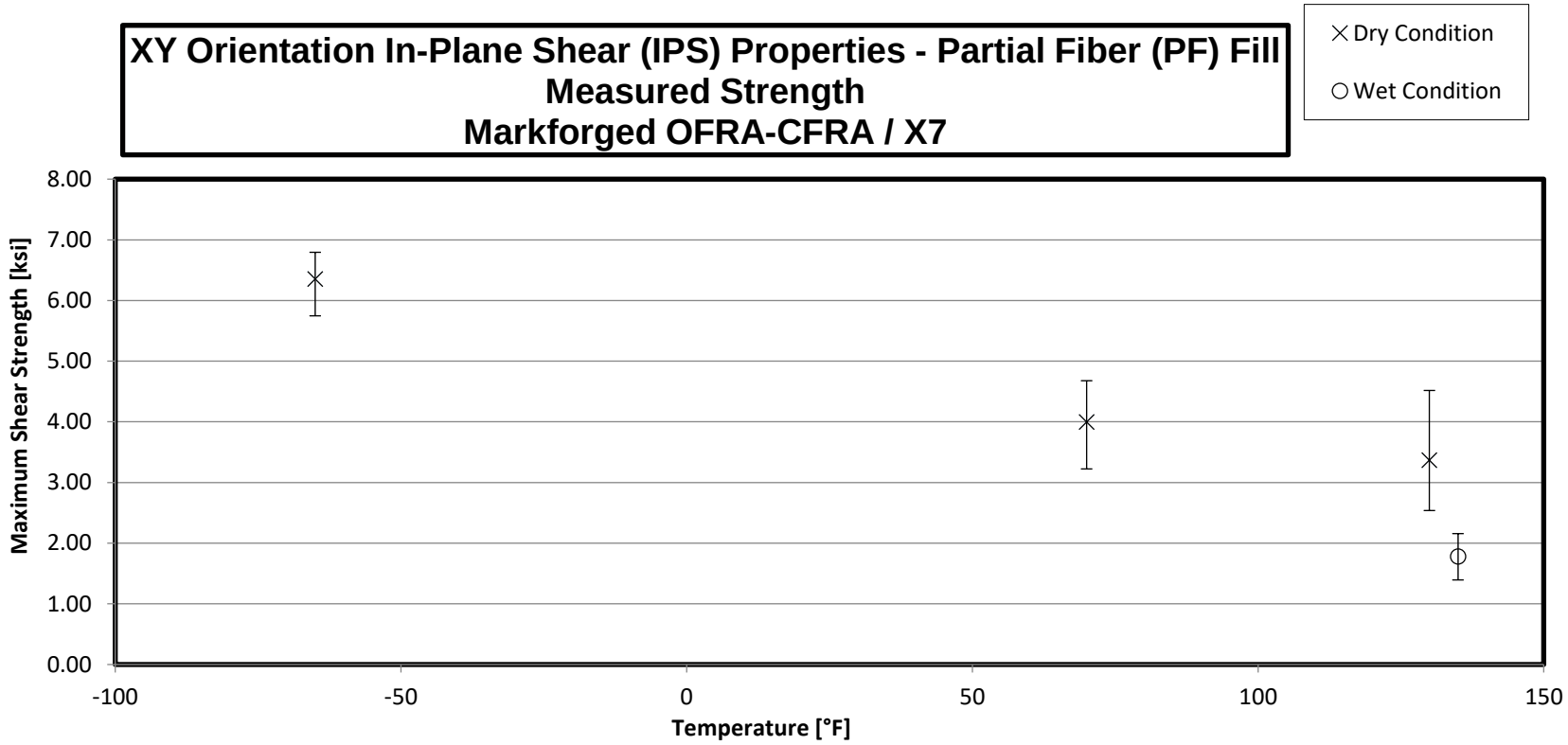

ZX Orientation No Fiber (NF) Flexural (F) Proc. A 2% Offset Yield Strength Measured
Markforged OFRA-CFRA / X7
Dry Condition
Wet Condition
Flexural 2% Offset Yield Strength [ksi]
16.00
14.00
12.00
10.00
8.00
6.00
4.00
2.00
0.00
-100
-50
0
50
100
150
Temperature [°F]

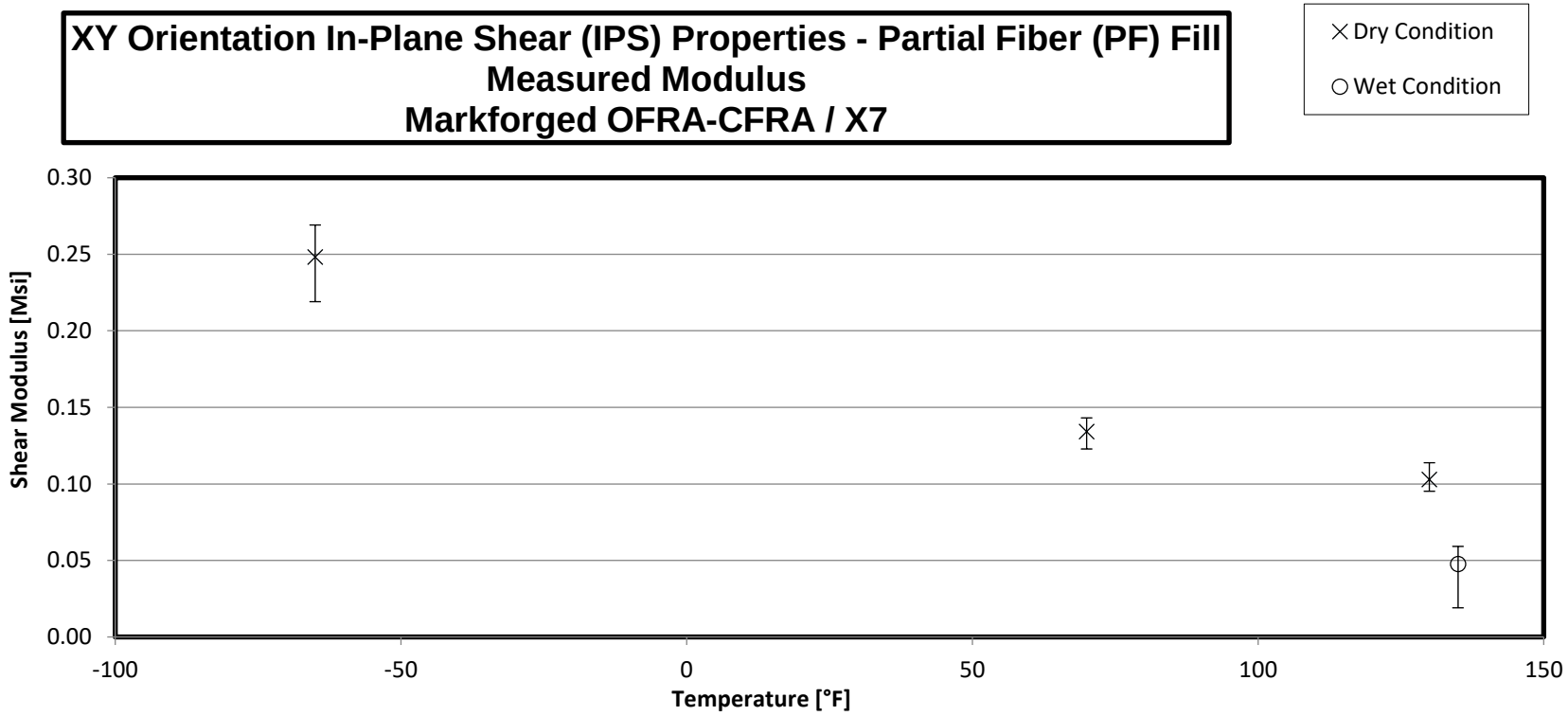

ZX Orientation No Fiber (NF) Flexural (F) Proc. A Modulus Measured
Markforged OFRA-CFRA / X7
Dry Condition
Wet Condition
Flexural Modulus [Msi]
0.70
0.60
0.50
0.40
0.30
0.20
0.10
0.00
-100
-50
0
50
100
150
Temperature [°F]

3.19 XY PF In-Plane Shear Properties

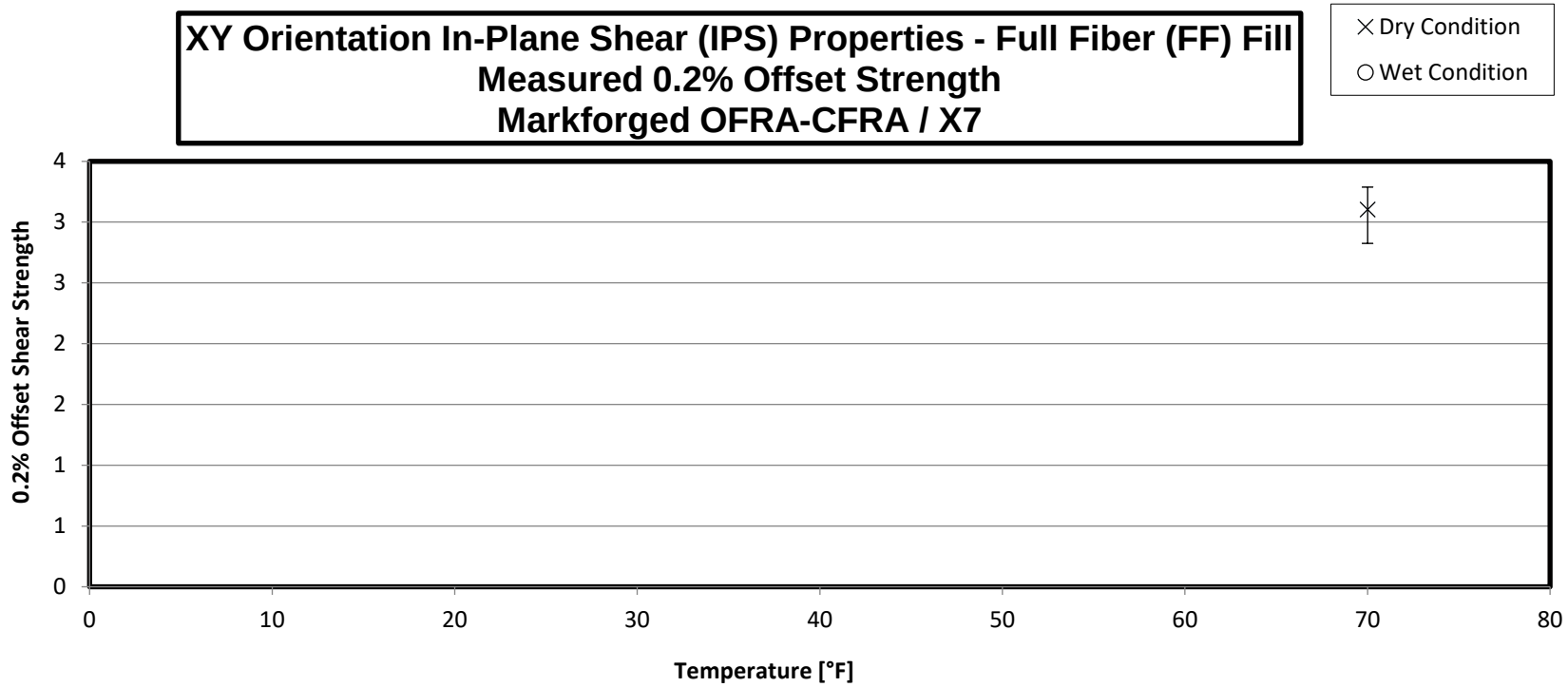


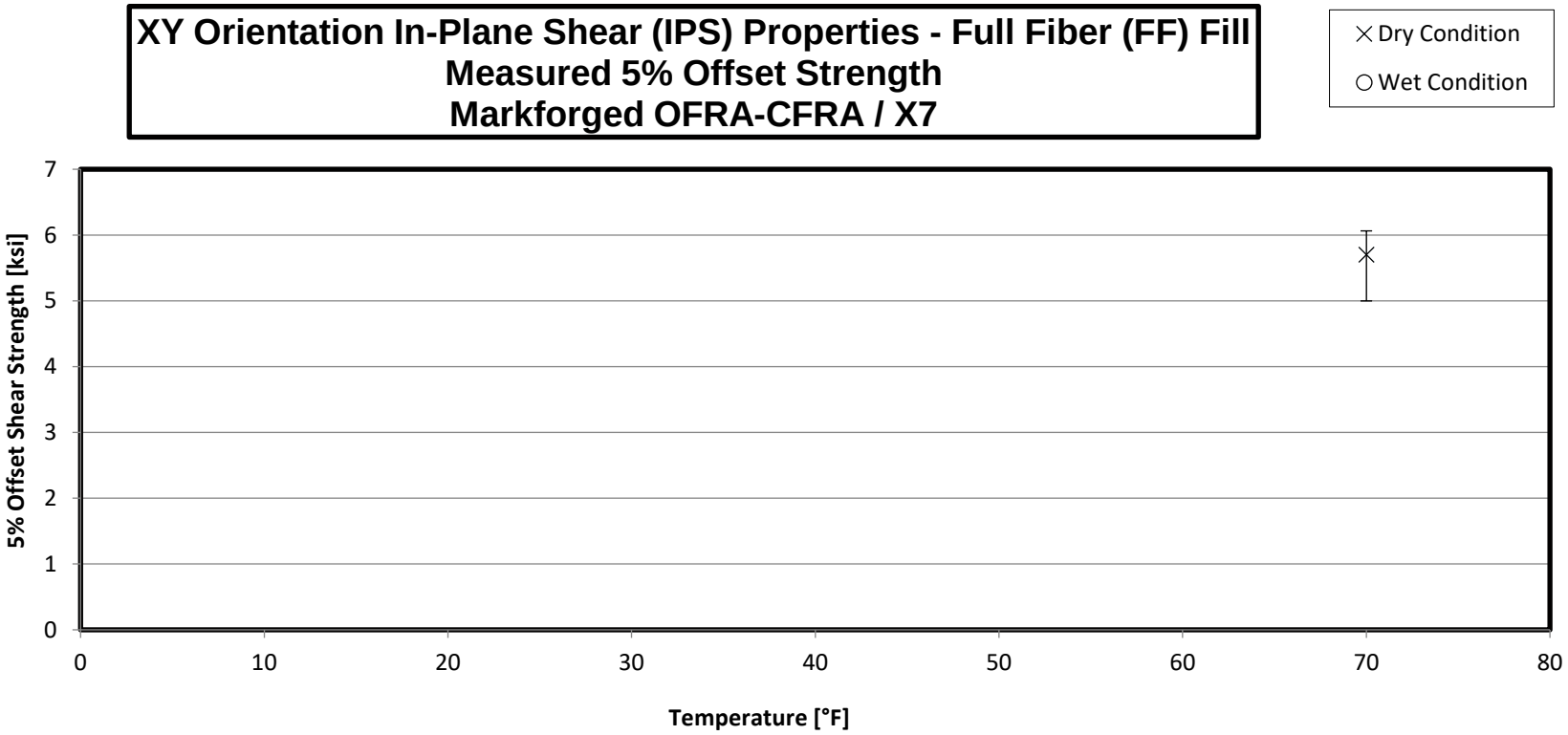

XY Orientation In-Plane Shear (IPS) Properties - Partial Fiber (PF) Fill
Measured 5% Offset Strength
Markforged OFRA-CFRA / X7
Dry Condition
Wet Condition
5% Offset Shear Strength [ksi]
4.00
3.50
3.00
2.50
2.00
1.50
1.00
0.50
0.00
-100
-50
0
50
100
150
Temperature [°F]

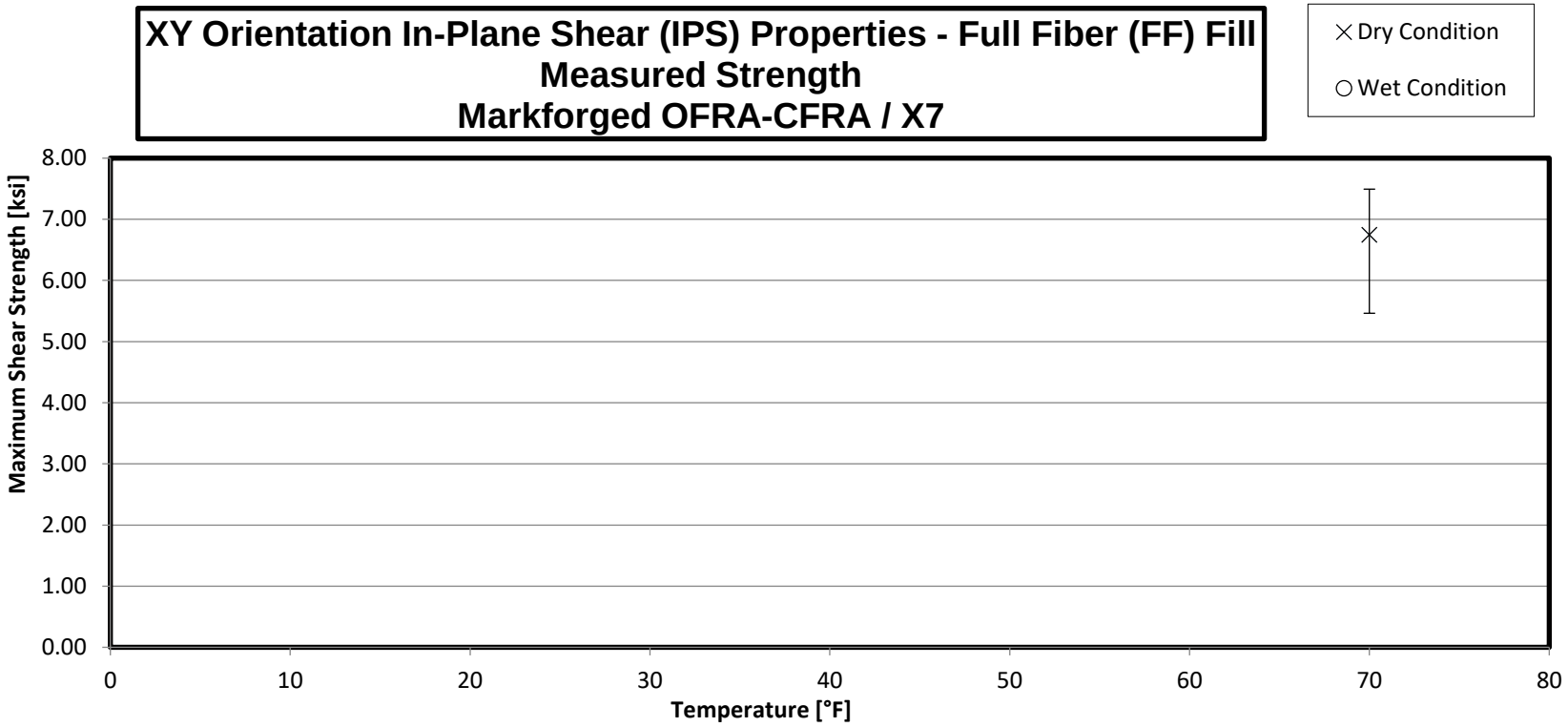

XY Orientation In-Plane Shear (IPS) Properties - Partial Fiber (PF) Fill
Measured Strength
Markforged OFRA-CFRA / X7
Dry Condition
Wet Condition
Maximum Shear Strength [ksi]
8.00
7.00
6.00
5.00
4.00
3.00
2.00
1.00
0.00
-100
-50
0
50
100
150
Temperature [°F]

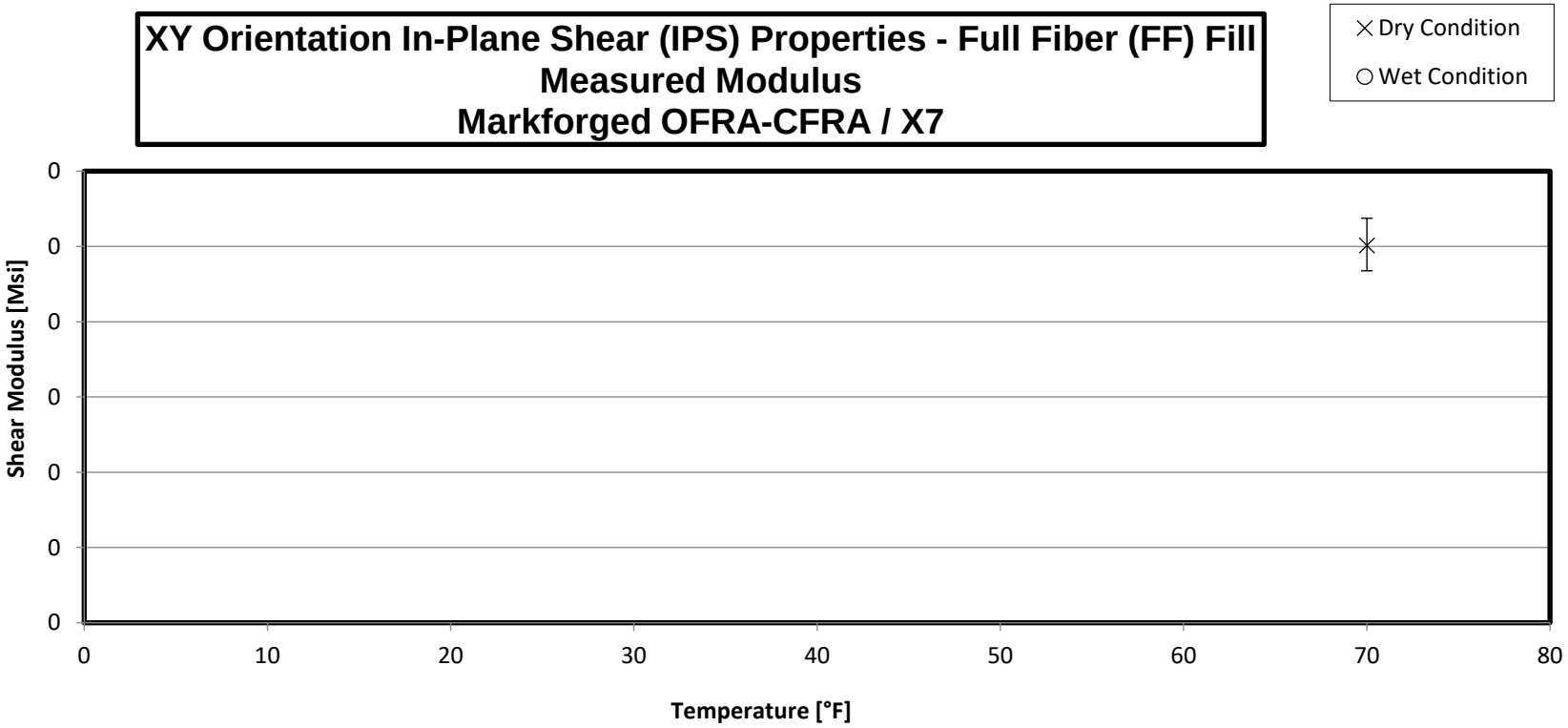

XY Orientation In-Plane Shear (IPS) Properties - Partial Fiber (PF) Fill
Measured Modulus
Markforged OFRA-CFRA / X7
Dry Condition
Wet Condition
Shear Modulus [Msi]
0.30
0.25
0.20
0.15
0.10
0.05
0.00
-100
-50
0
50
100
150
Temperature [°F]

3.20 XY FF In-Plane Shear Properties – Reference Only

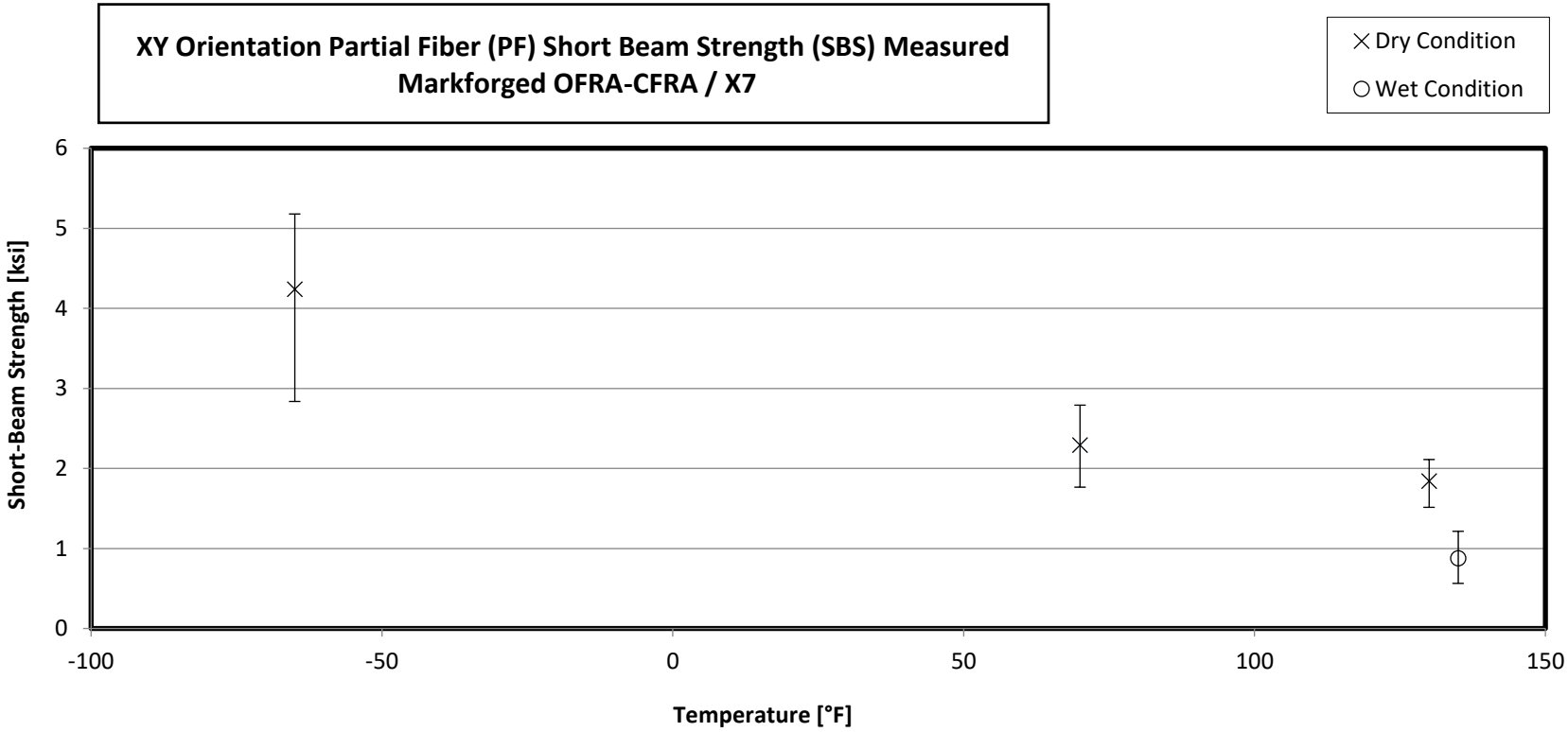



XY Orientation In-Plane Shear (IPS) Properties - Full Fiber (FF) Fill
Measured 5% Offset Strength
Markforged OFRA-CFRA / X7
Dry Condition
Wet Condition
5% Offset Shear Strength [ksi]
0
1
2
3
4
5
6
7
0
10
20
30
40
50
60
70
80
Temperature [°F]

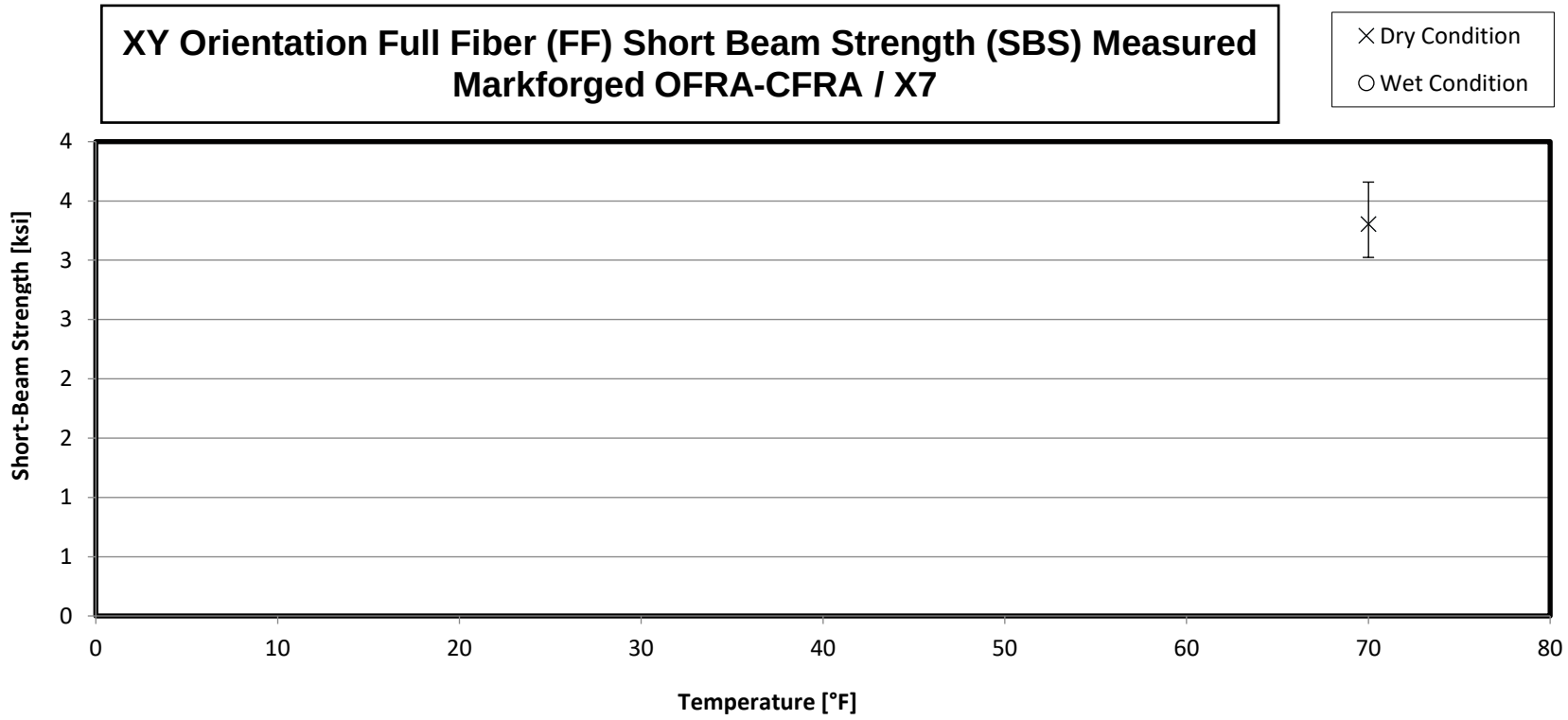

XY Orientation In-Plane Shear (IPS) Properties - Full Fiber (FF) Fill
Measured Strength
Markforged OFRA-CFRA / X7
Dry Condition
Wet Condition
Maximum Shear Strength [ksi]
8.00
7.00
6.00
5.00
4.00
3.00
2.00
1.00
0.00
0
10
20
30
40
50
60
70
80
Temperature [°F]


XY Orientation In-Plane Shear (IPS) Properties - Full Fiber (FF) Fill
Measured Modulus
Markforged OFRA-CFRA / X7
Dry Condition
Wet Condition
Shear Modulus [Msi]
0
0
0
0
0
0
0
10
20
30
40
50
60
70
80
Temperature [°F]

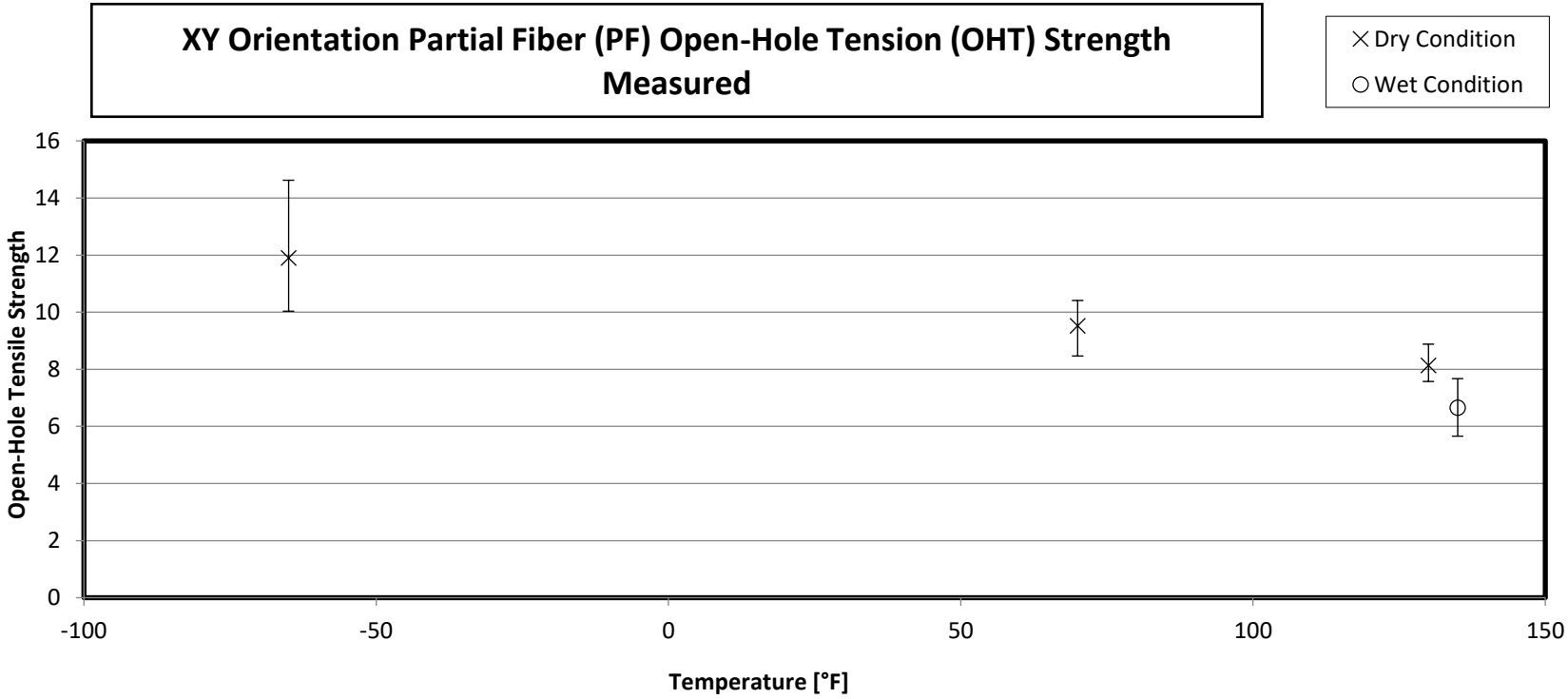
3.21 XY PF Short-Beam Strength Properties



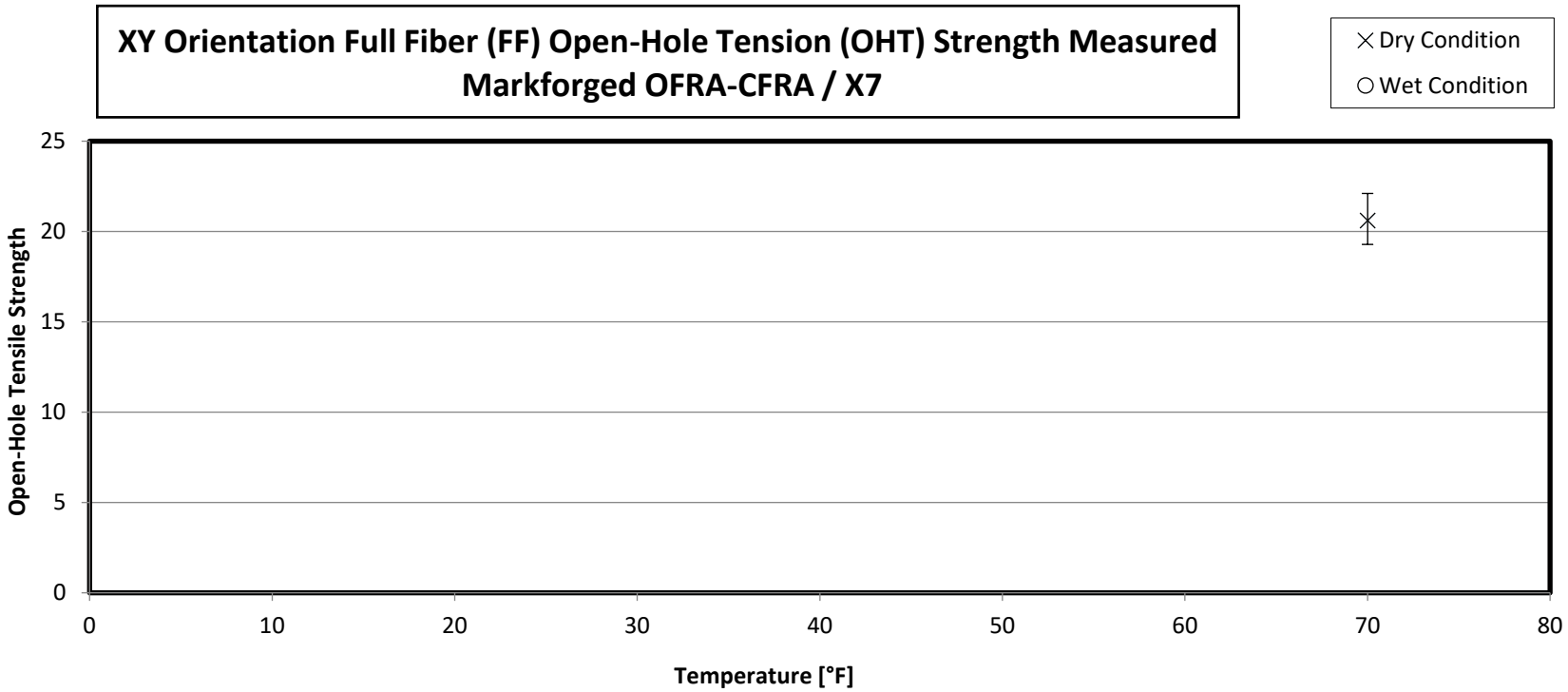
3.22 XY FF Short-Beam Strength Properties – Reference Only



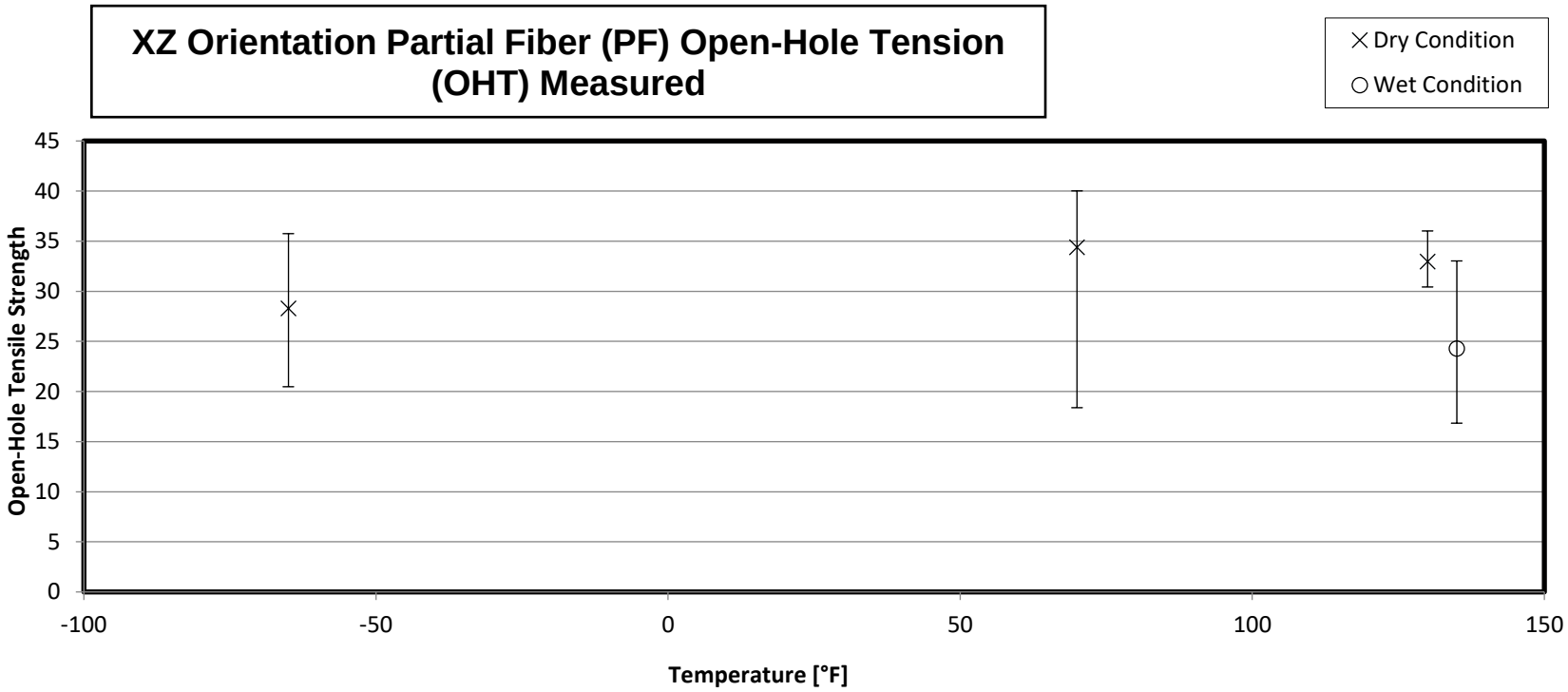
3.23 XY PF Open-Hole Tension Properties



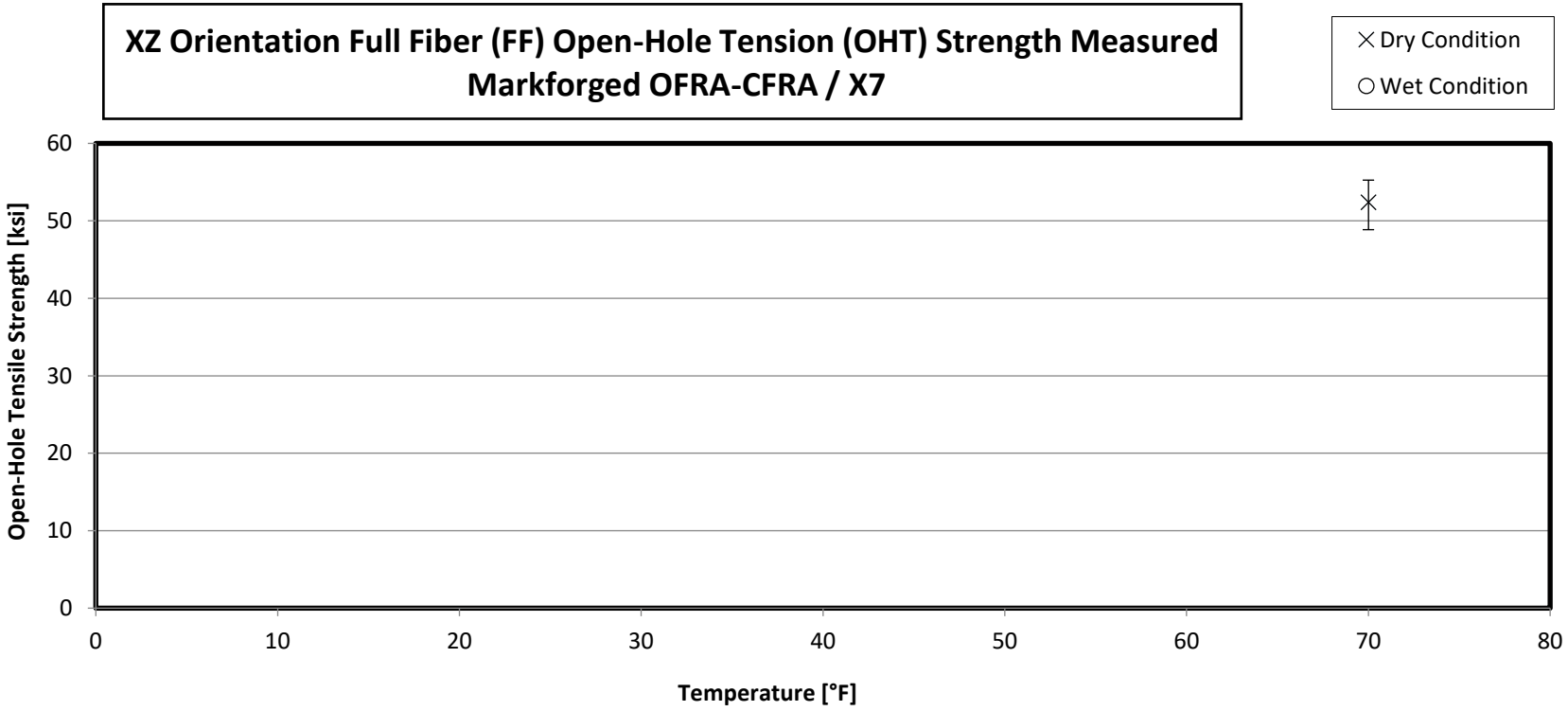
3.24 XY FF Open-Hole Tension Properties – Reference Only



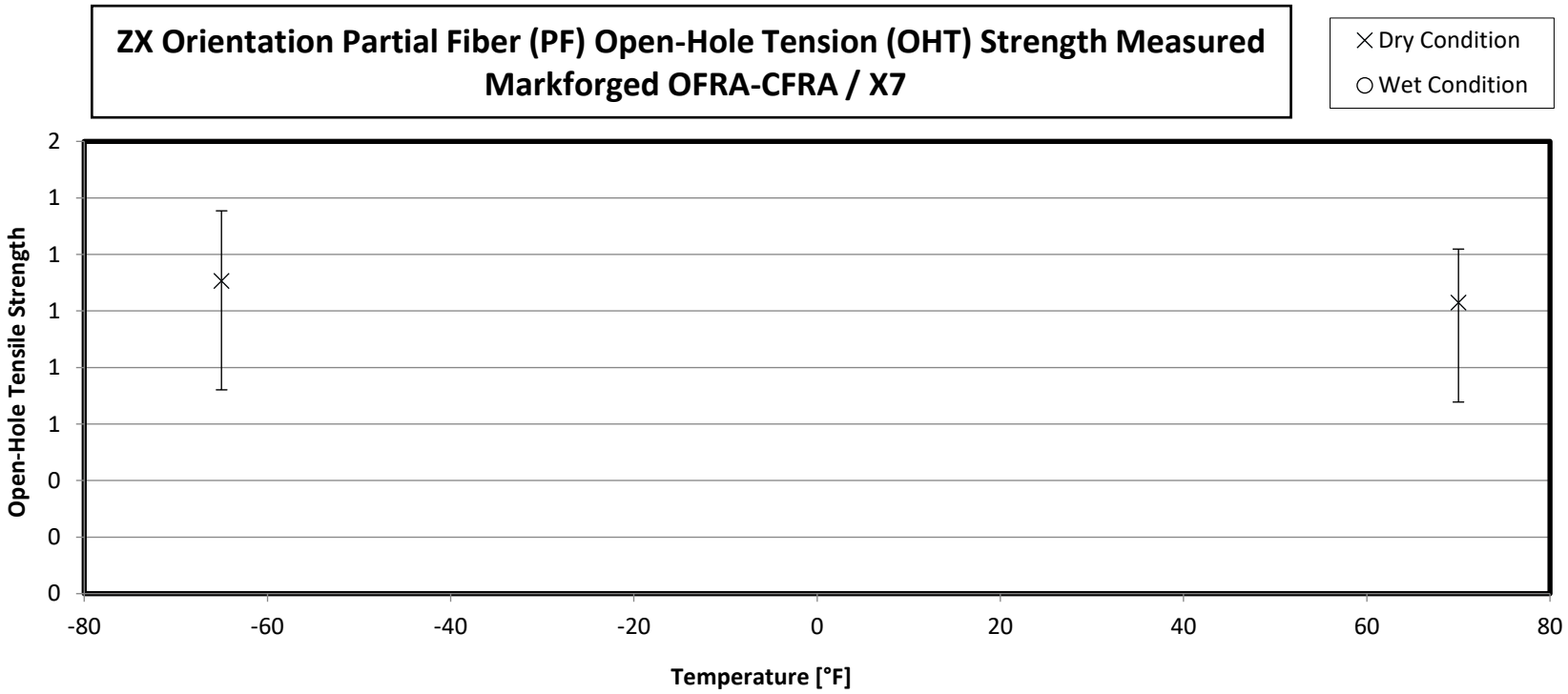
3.25 XZ PF Open-Hole Tension Properties



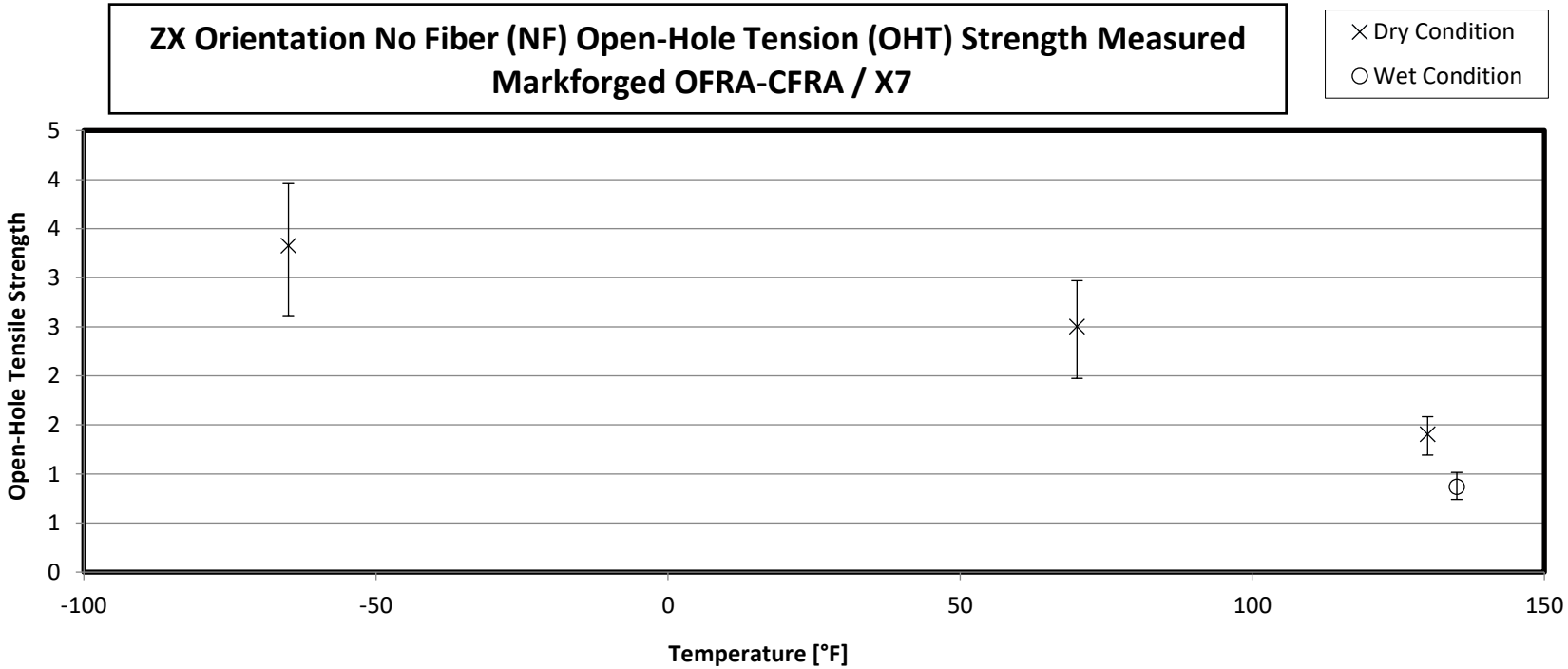
3.26 XZ FF Open-Hole Tension Properties – Reference Only



3.27 ZX PF Open-Hole Tension Properties – Reference Only

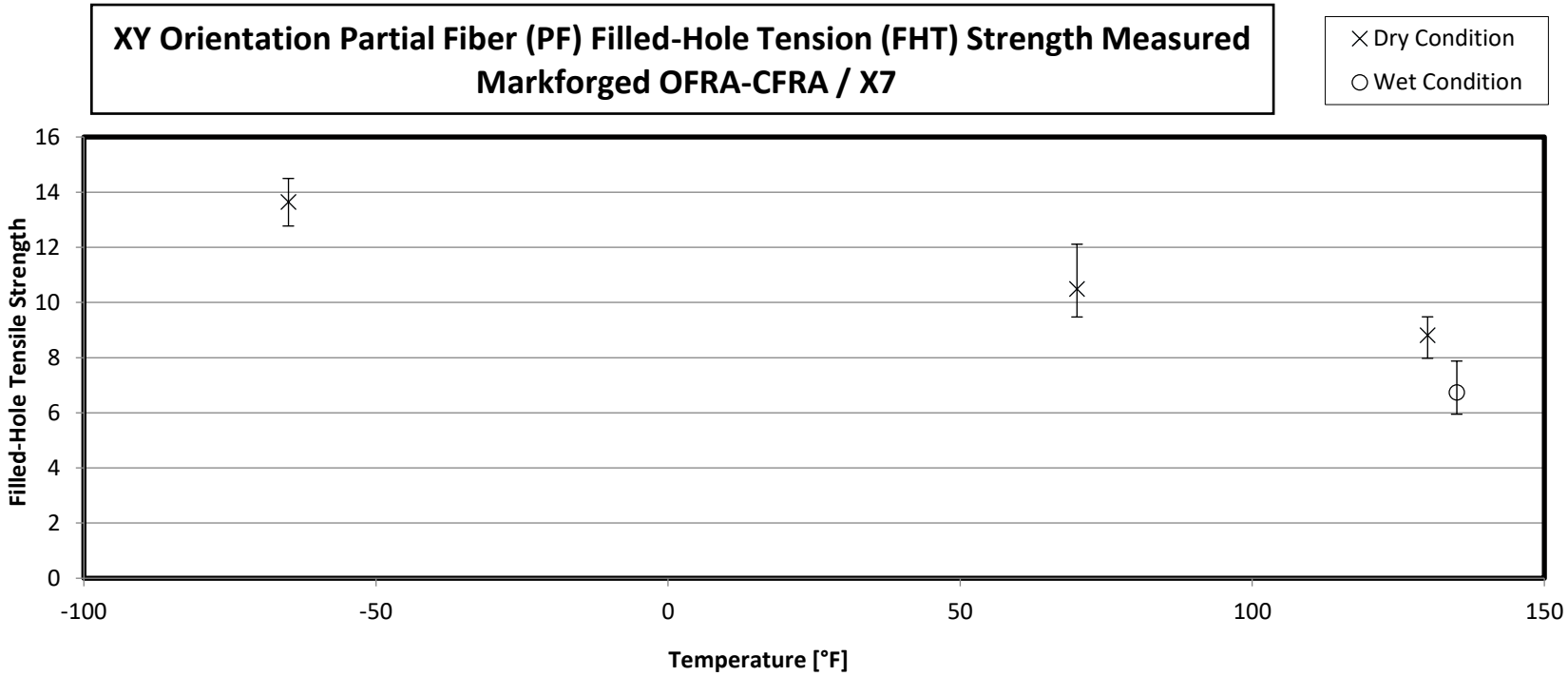


3.28 ZX NF Open-Hole Tension Properties

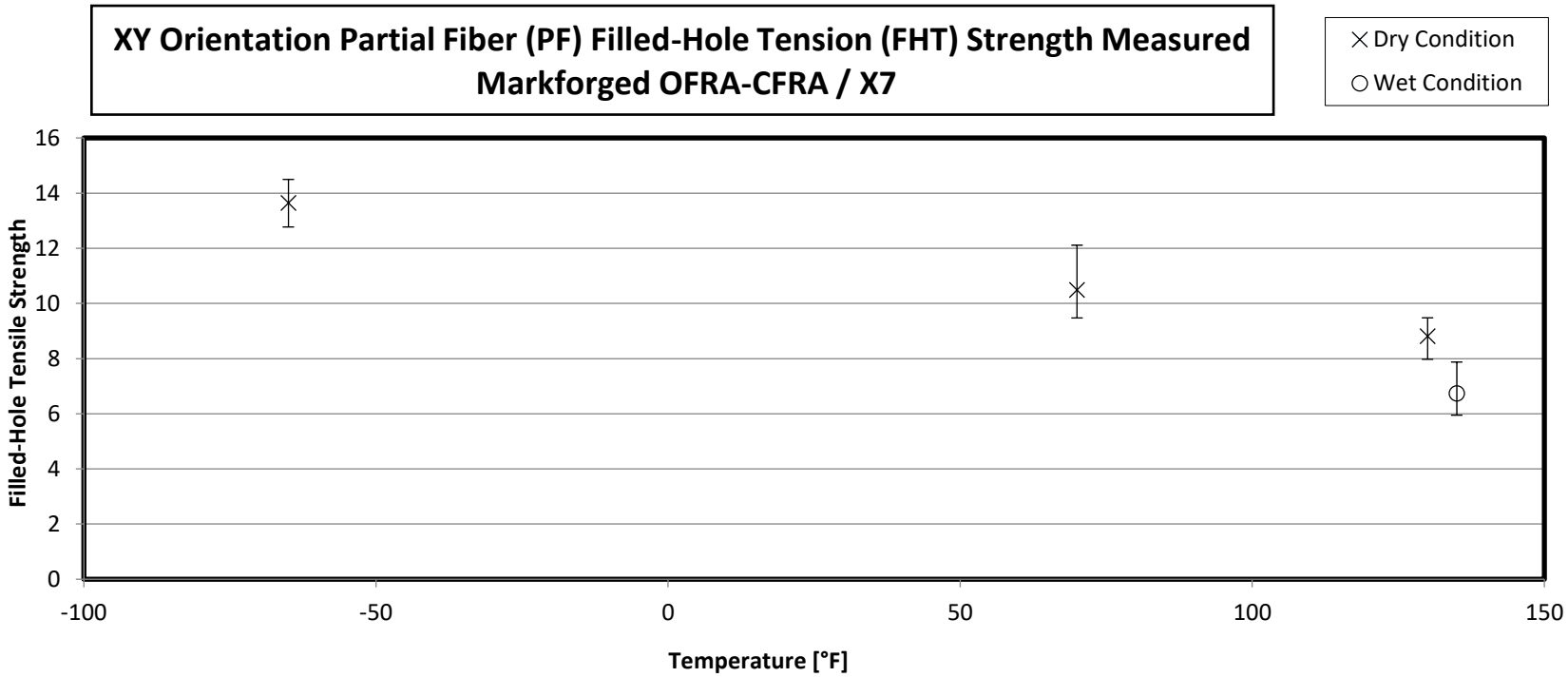


3.29 XY PF Filled-Hole Tension Properties

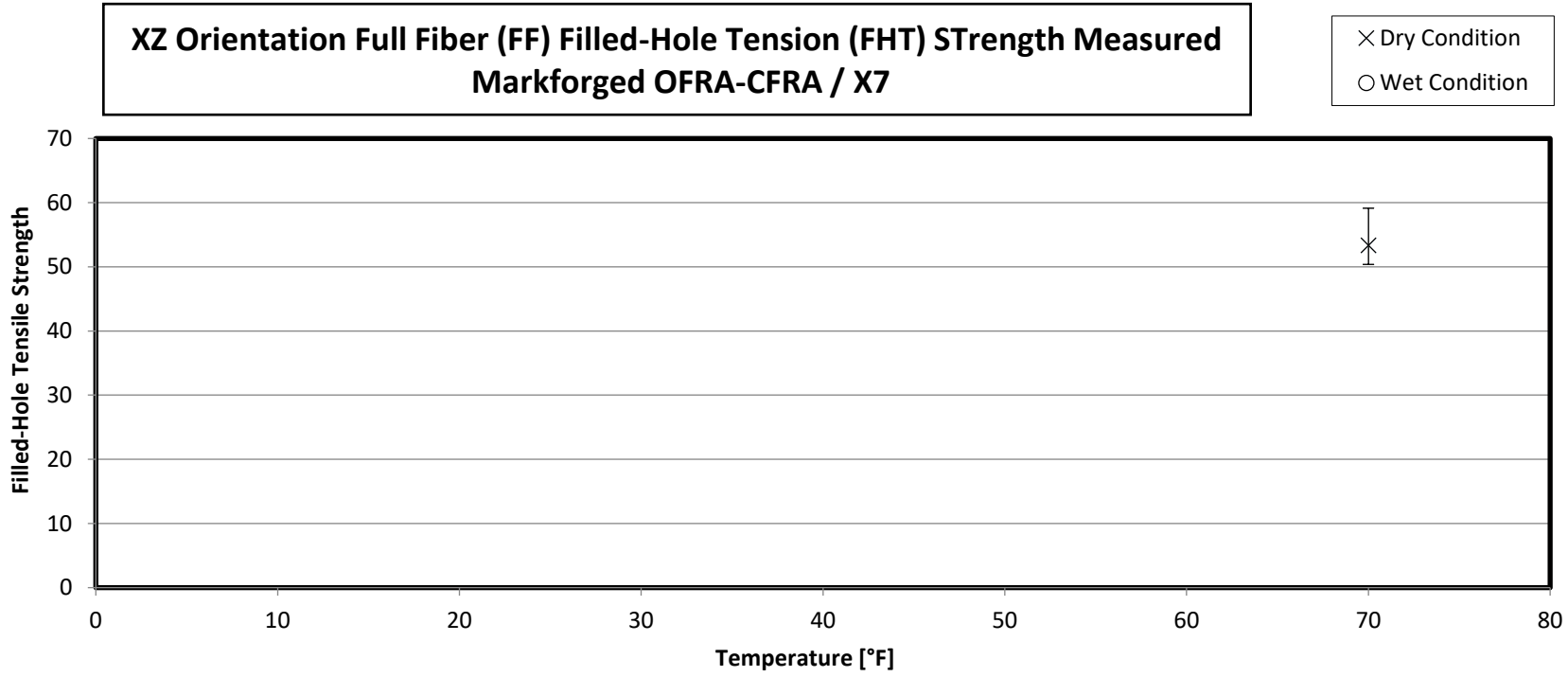
3.30 XY FF Filled-Hole Tension Properties – Reference Only



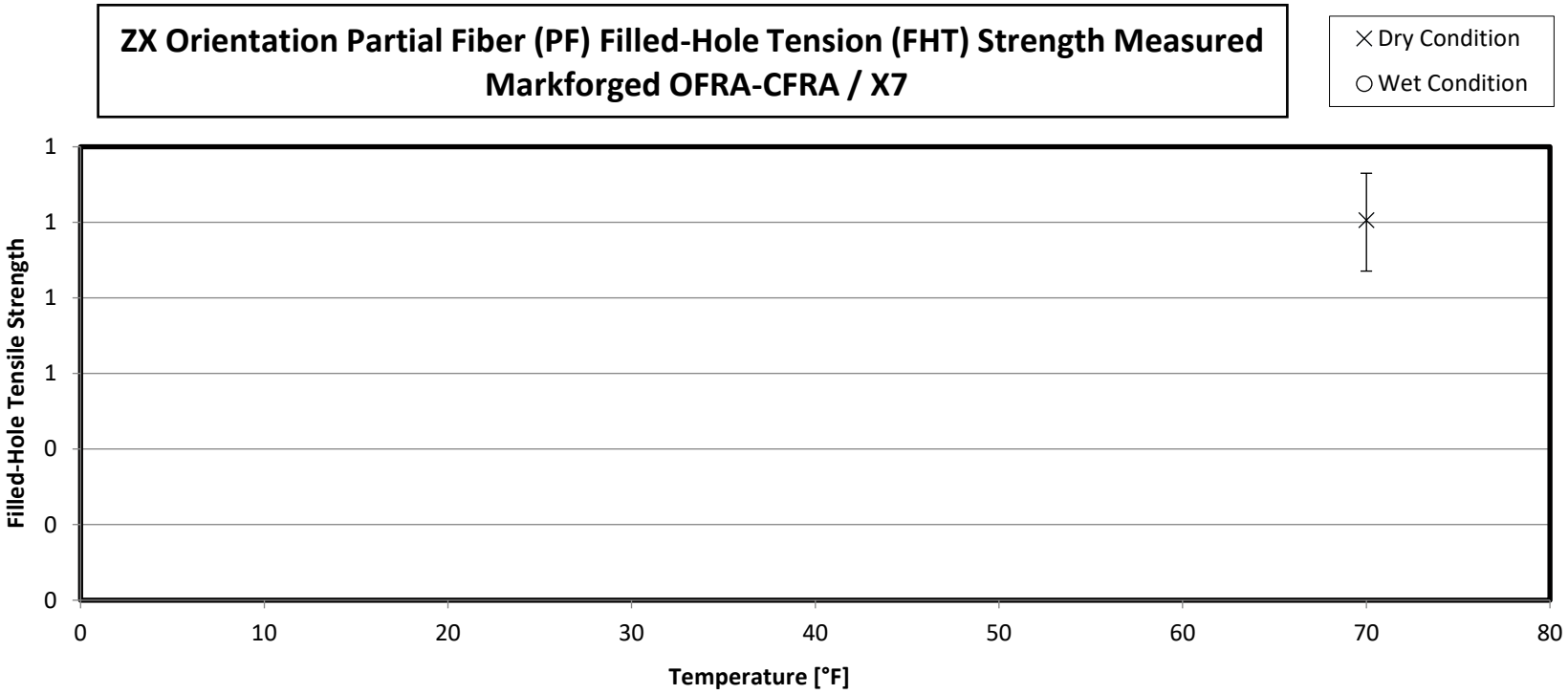
3.31 XZ PF Filled-Hole Tension Properties



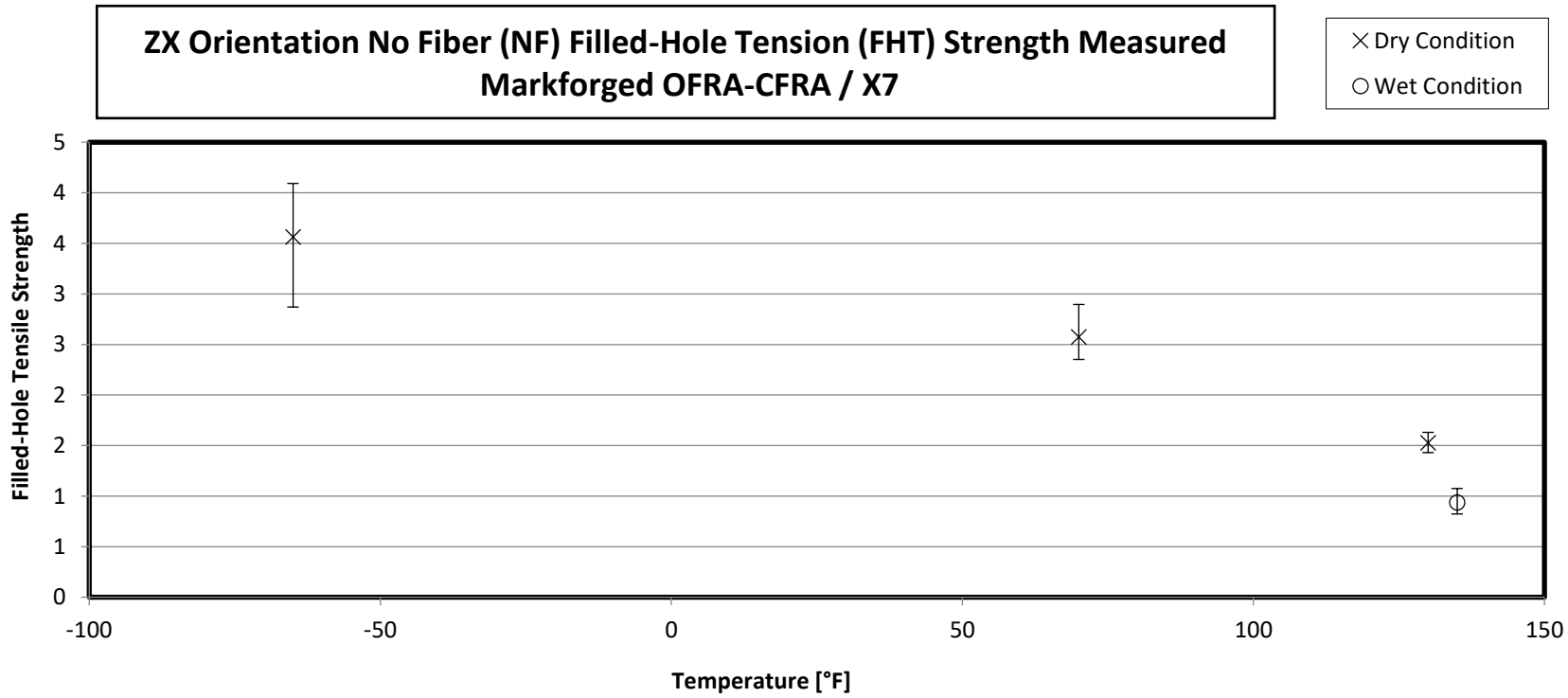
3.32 XZ FF Filled-Hole Tension Properties – Reference Only



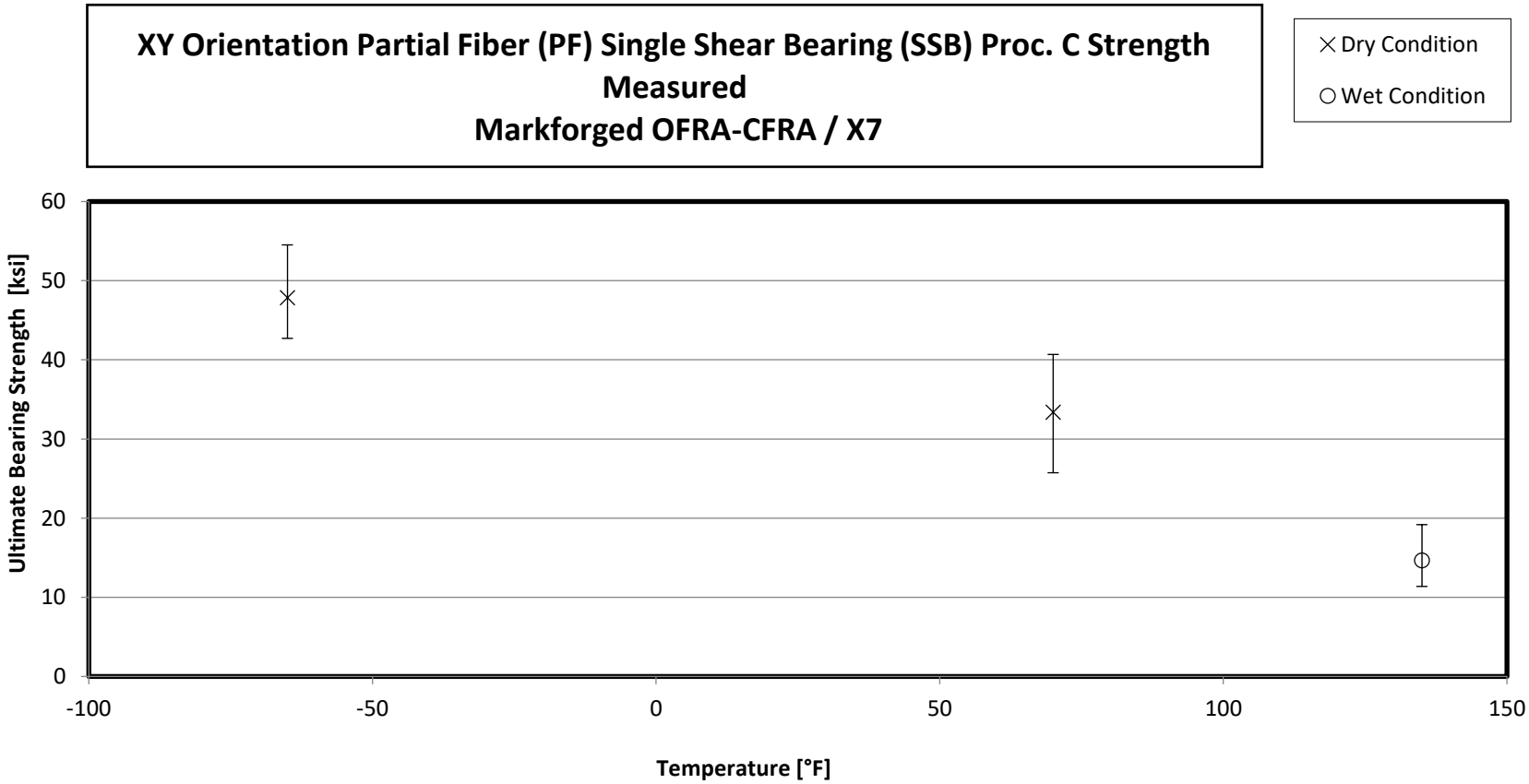
3.33 ZX PF Filled-Hole Tension Properties – Reference Only

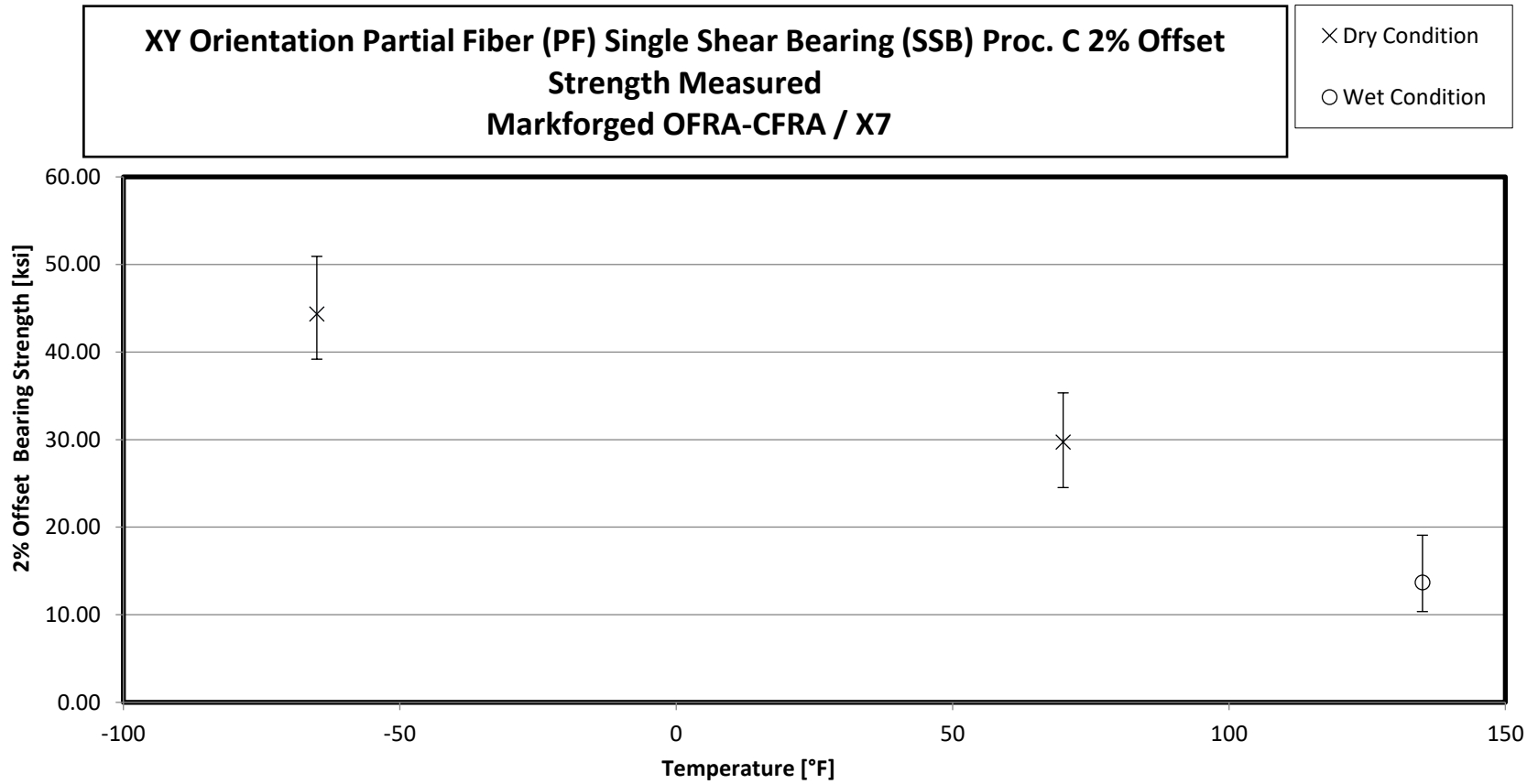


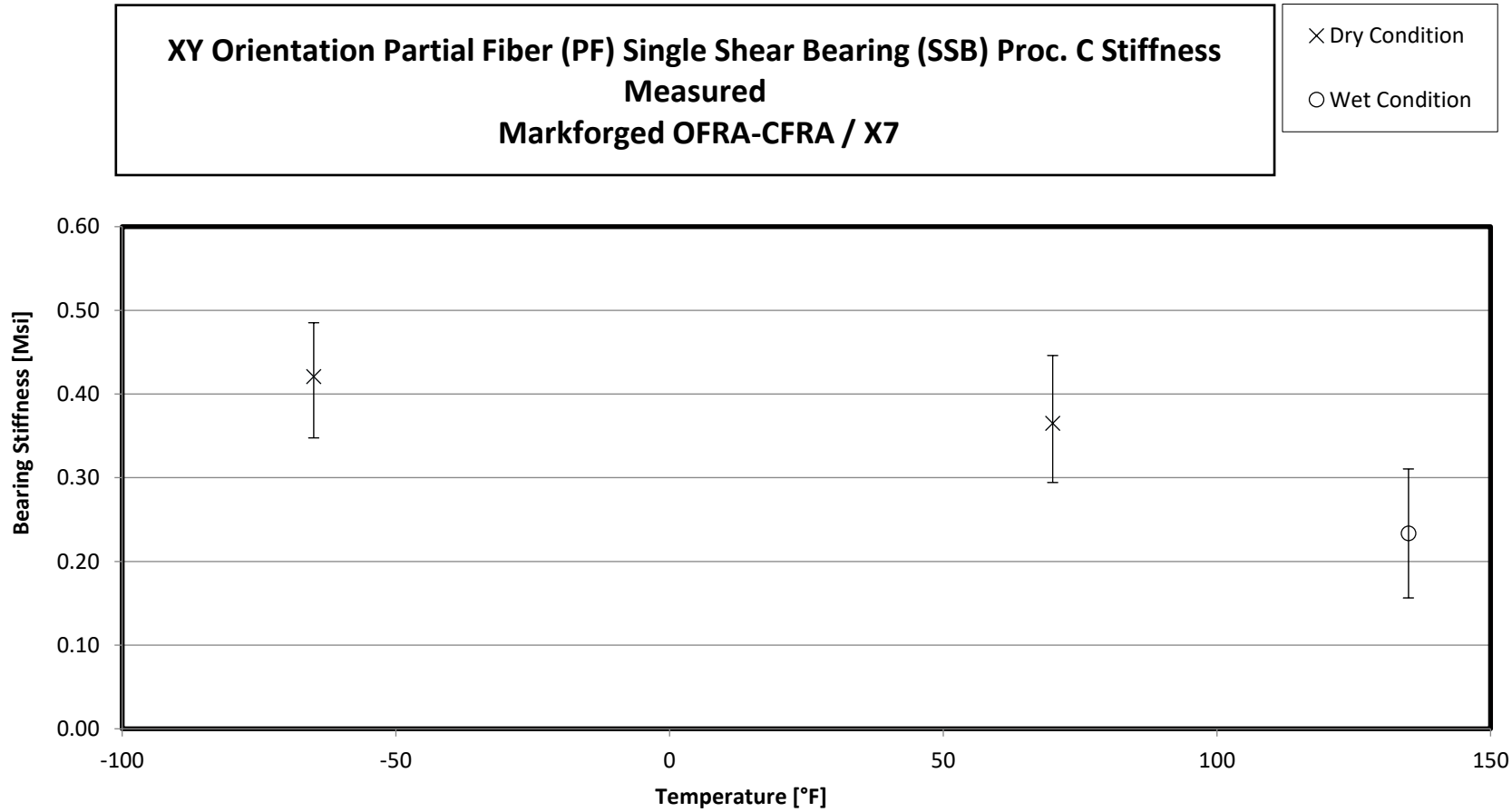
3.34 ZX NF Filled-Hole Tension Properties



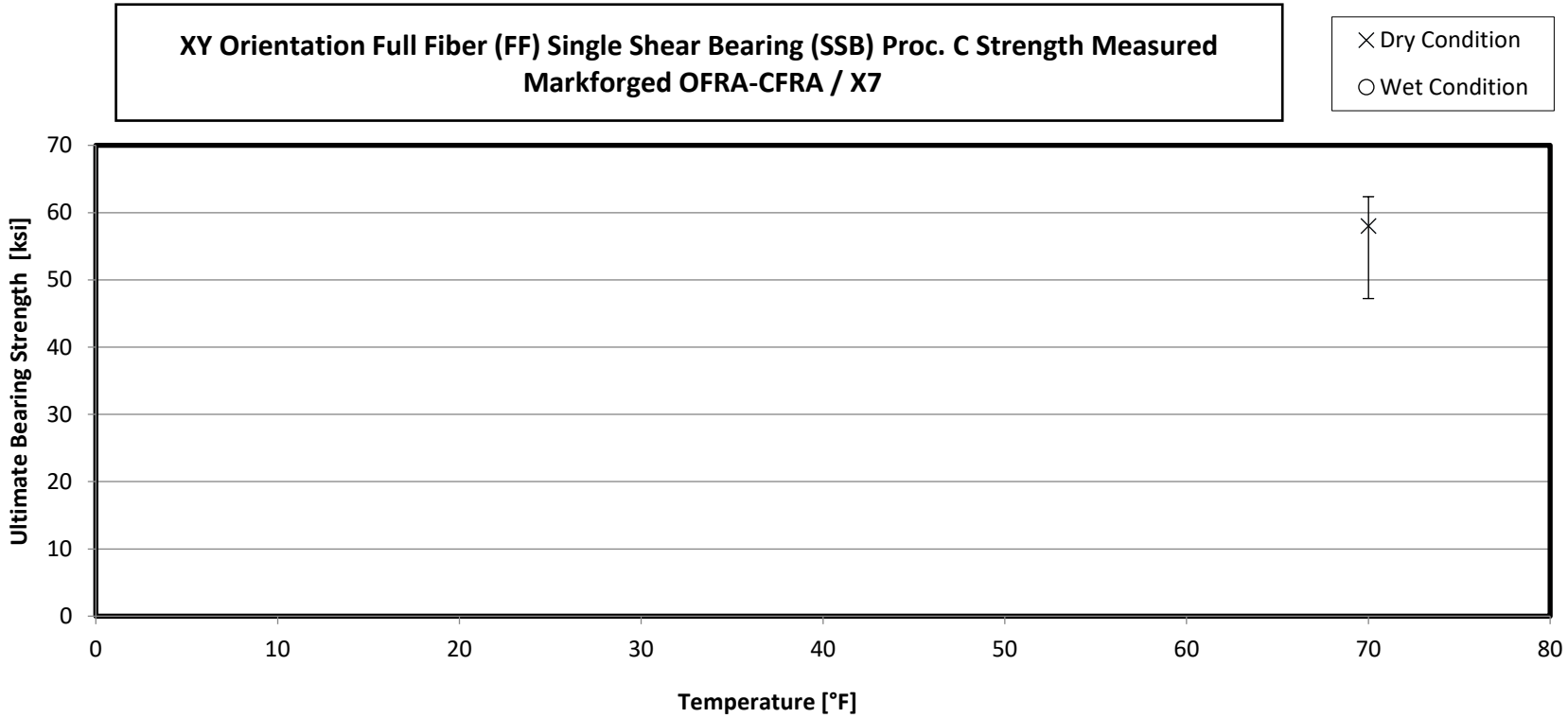
3.35 XY PF Single Shear Bearing Properties

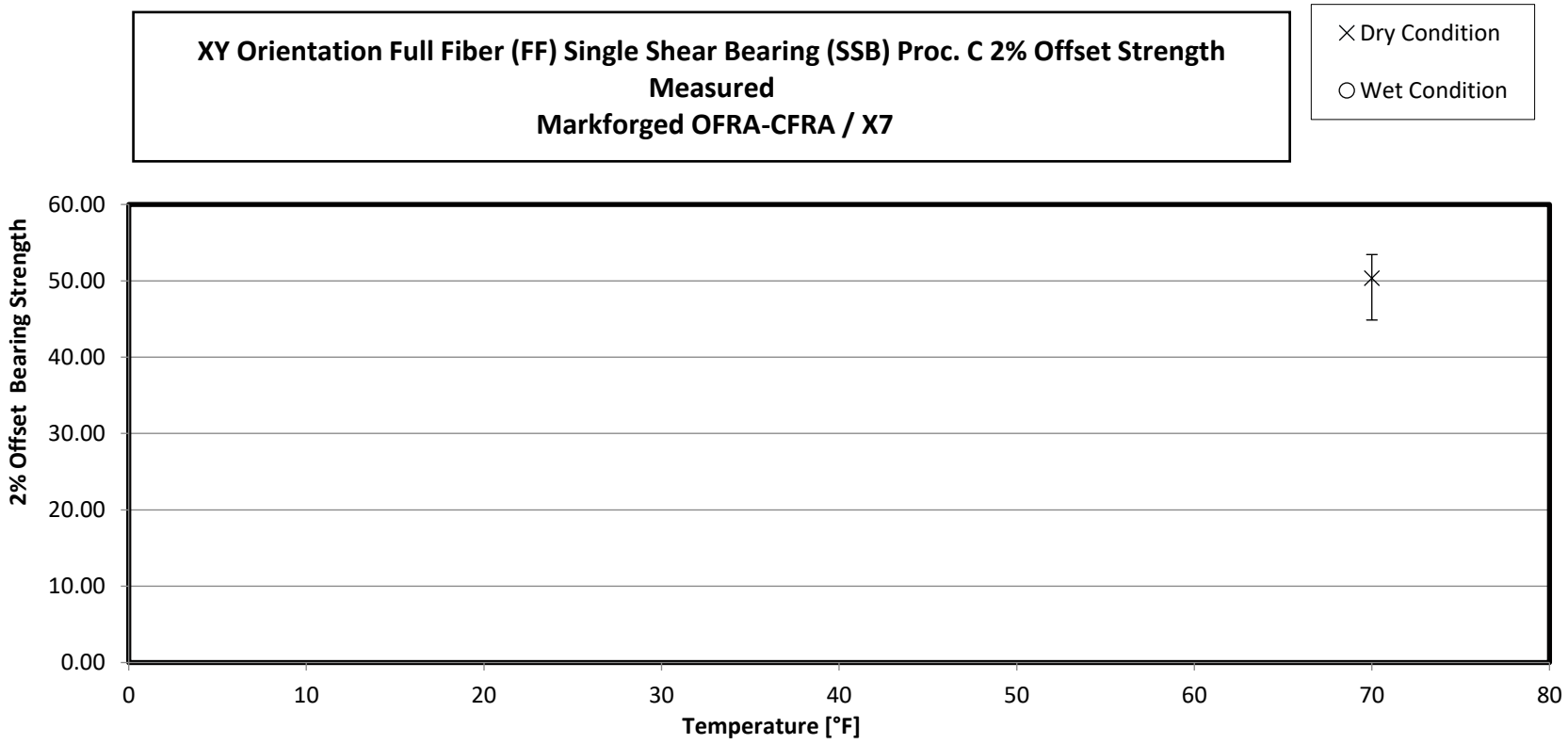


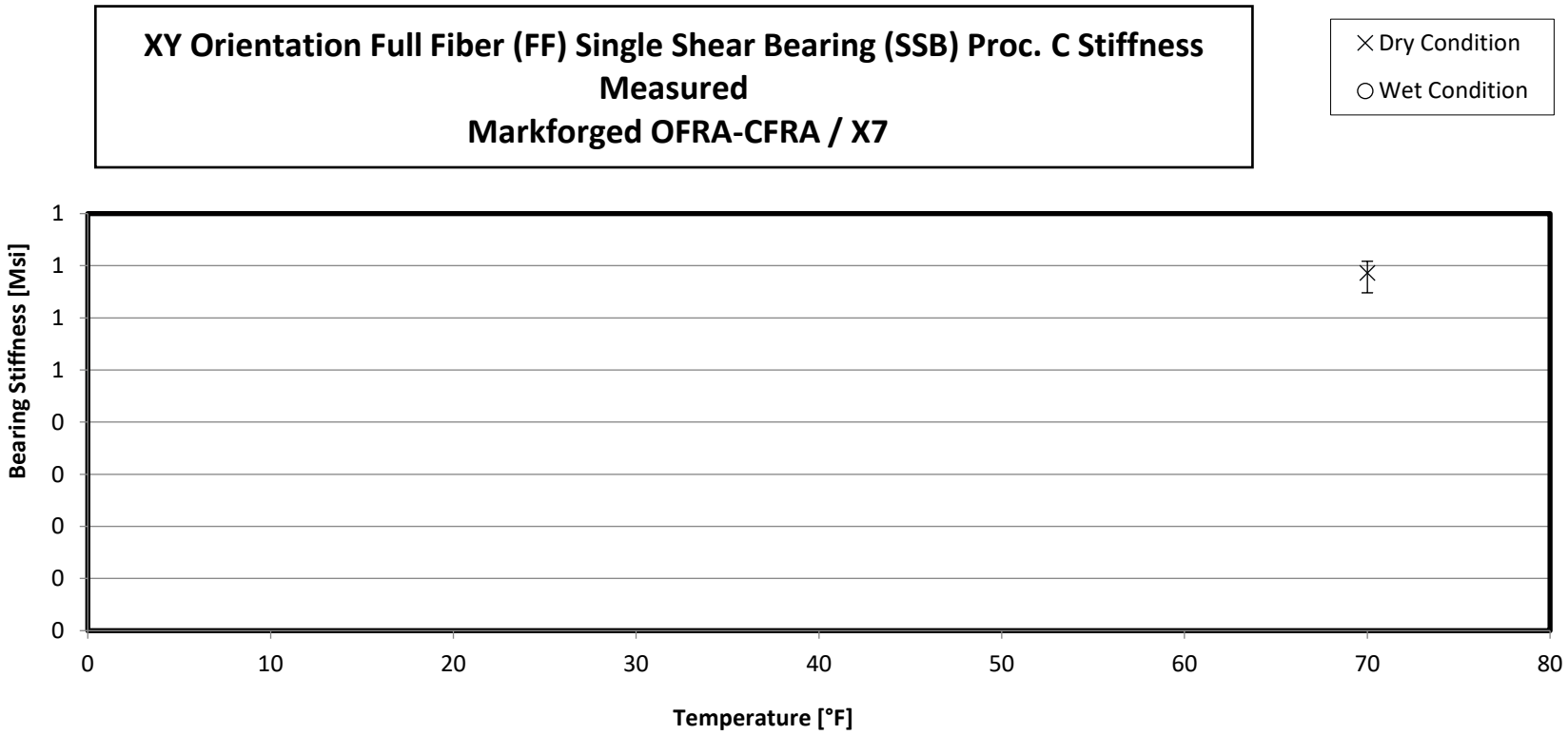

XY Orientation Partial Fiber (PF) Single Shear Bearing (SSB) Proc. C 2% Offset Strength Measured
Markforged OFRA-CFRA / X7
Dry Condition
Wet Condition
2% Offset Bearing Strength [ksi]
60.00
50.00
40.00
30.00
20.00
10.00
0.00
-100
-50
0
50
100
150
Temperature [°F]


XY Orientation Partial Fiber (PF) Single Shear Bearing (SSB) Proc. C Stiffness Measured
Markforged OFRA-CFRA / X7
Dry Condition
Wet Condition
Bearing Stiffness [Msi]
0.60
0.50
0.40
0.30
0.20
0.10
0.00
-100
-50
0
50
100
150
Temperature [°F]

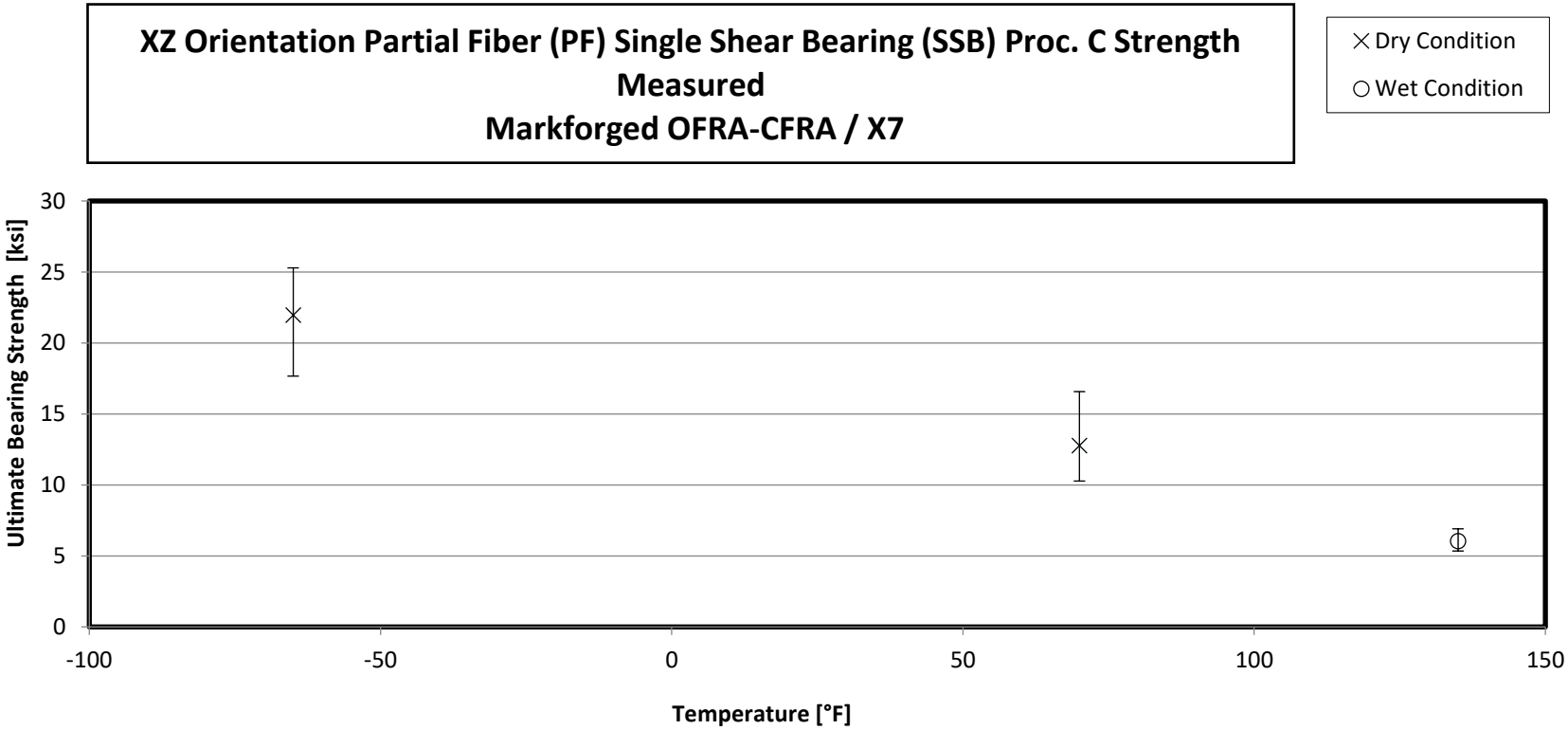
3.36 XY FF Single Shear Bearing Properties – Reference Only

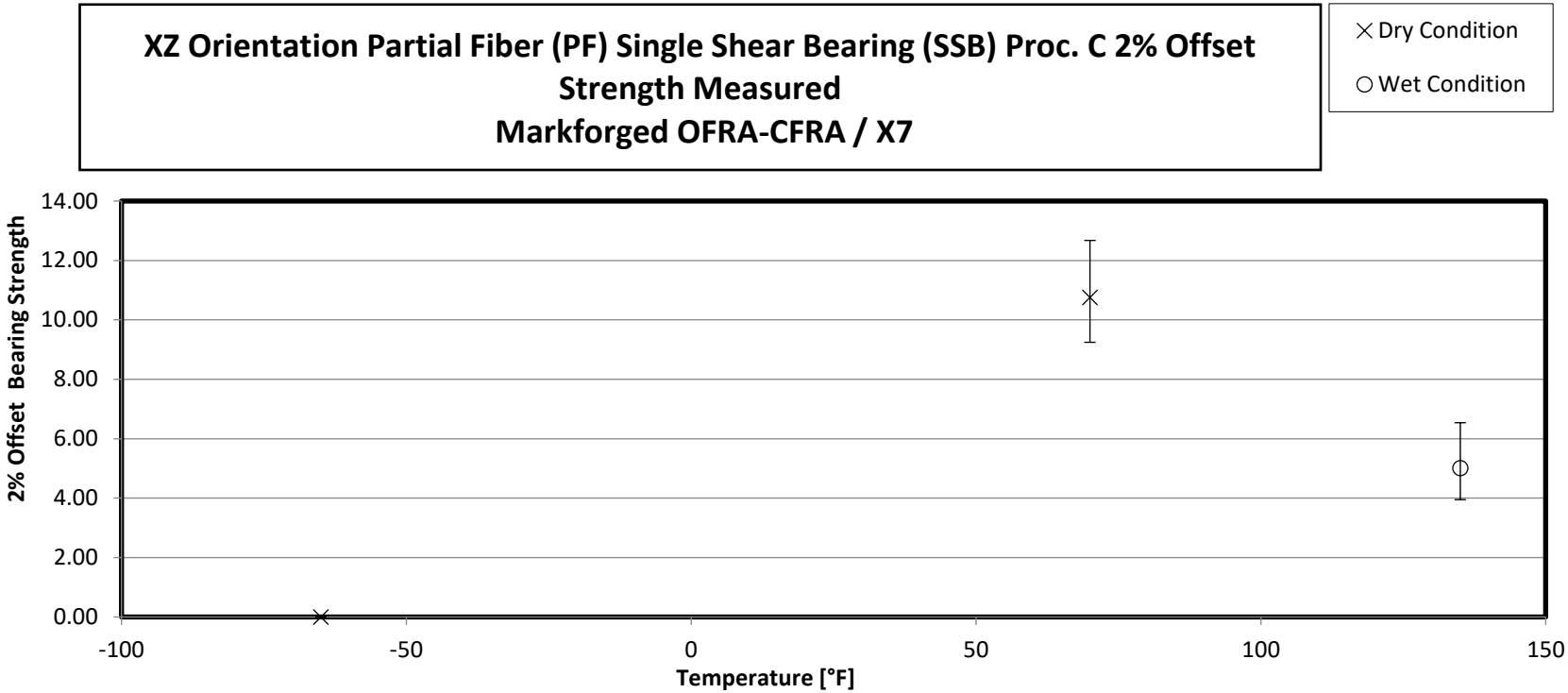


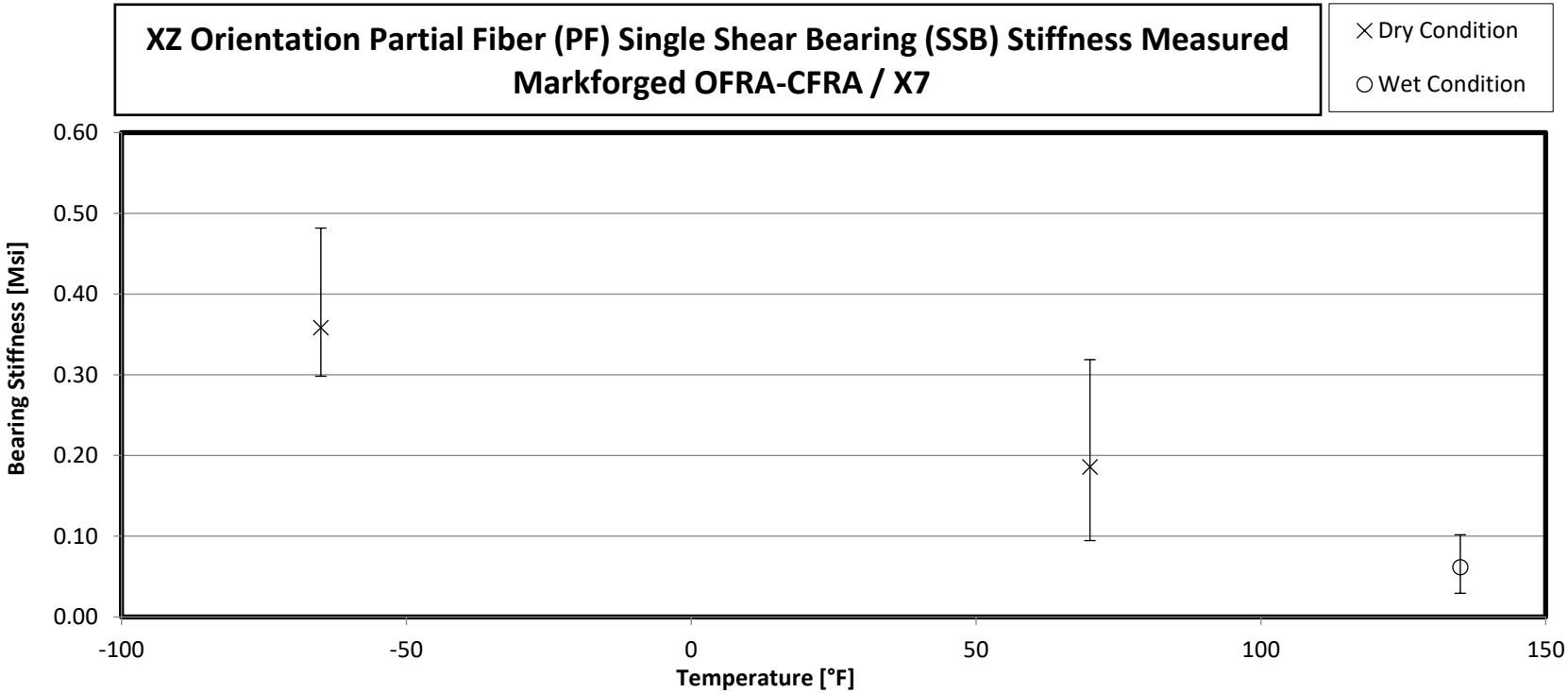

XY Orientation Full Fiber (FF) Single Shear Bearing (SSB) Proc. C 2% Offset Strength
Measured
Markforged OFRA-CFRA / X7
Dry Condition
Wet Condition
2% Offset Bearing Strength
60.00
50.00
40.00
30.00
20.00
10.00
0.00
0
10
20
30
40
50
60
70
80
Temperature [°F]


XY Orientation Full Fiber (FF) Single Shear Bearing (SSB) Proc. C Stiffness Measured
Markforged OFRA-CFRA / X7
Dry Condition
Wet Condition
Bearing Stiffness [Msi]
1
1
1
1
0
0
0
0
0
10
20
30
40
50
60
70
80
Temperature [°F]

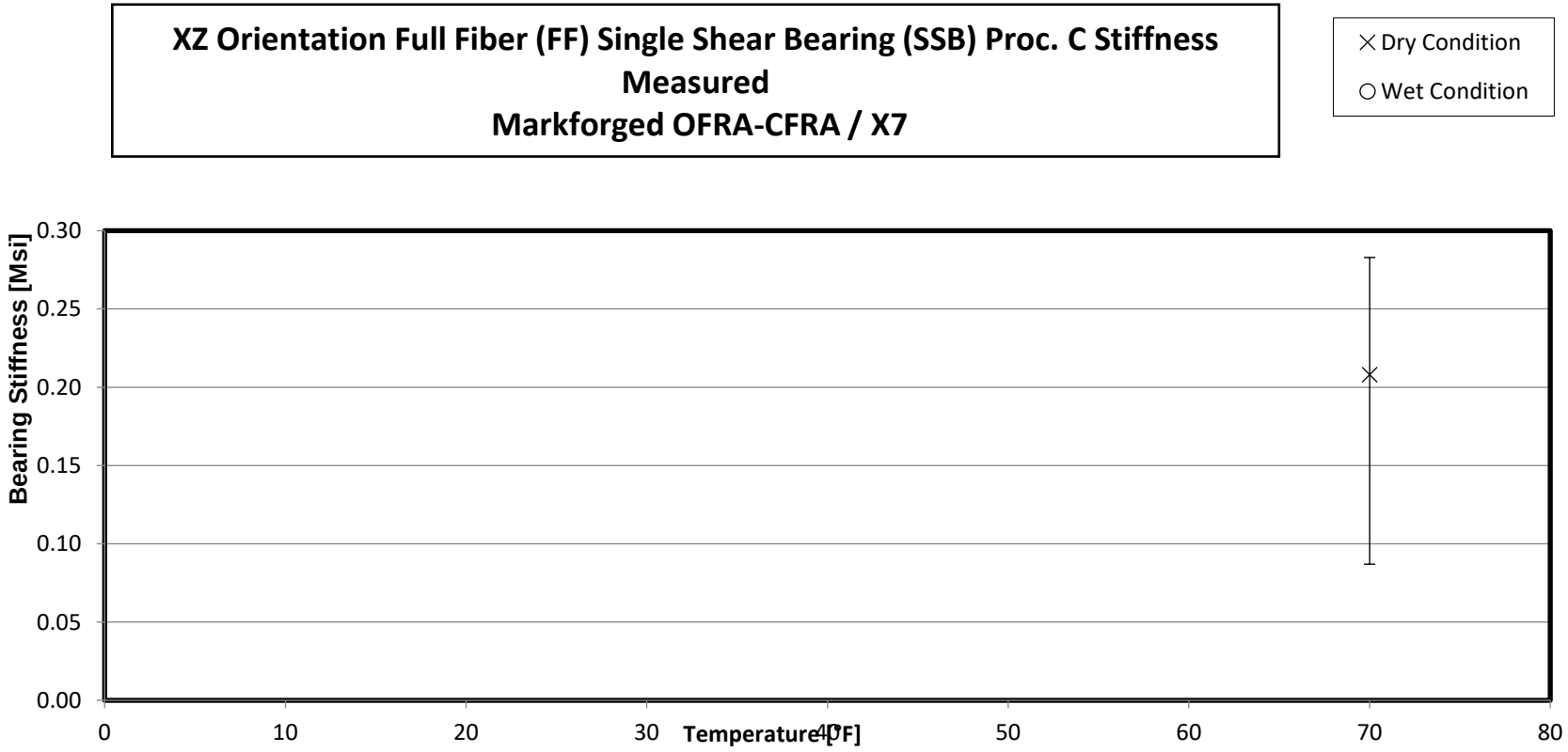
3.37 XZ PF Single Shear Bearing Properties

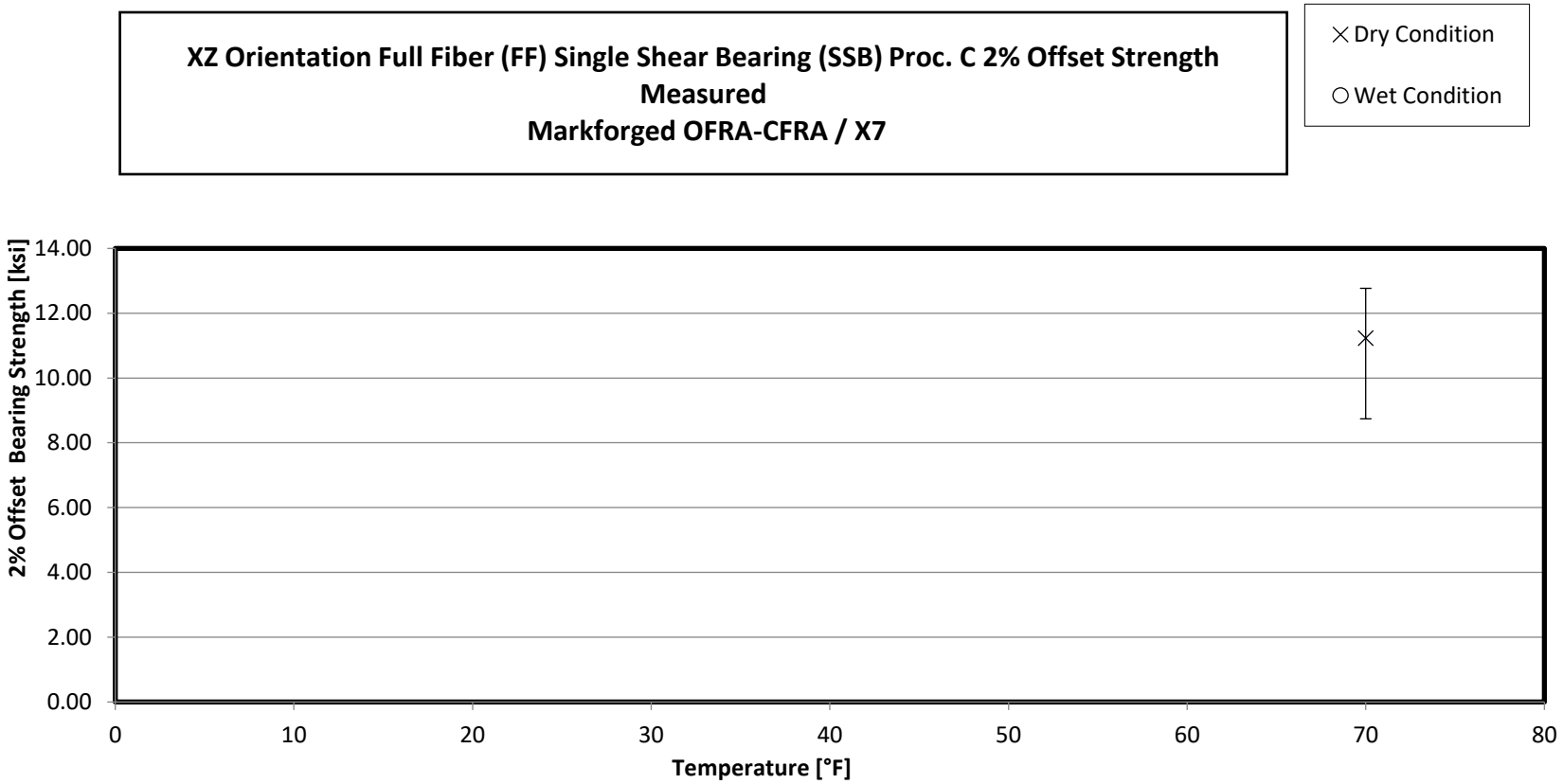


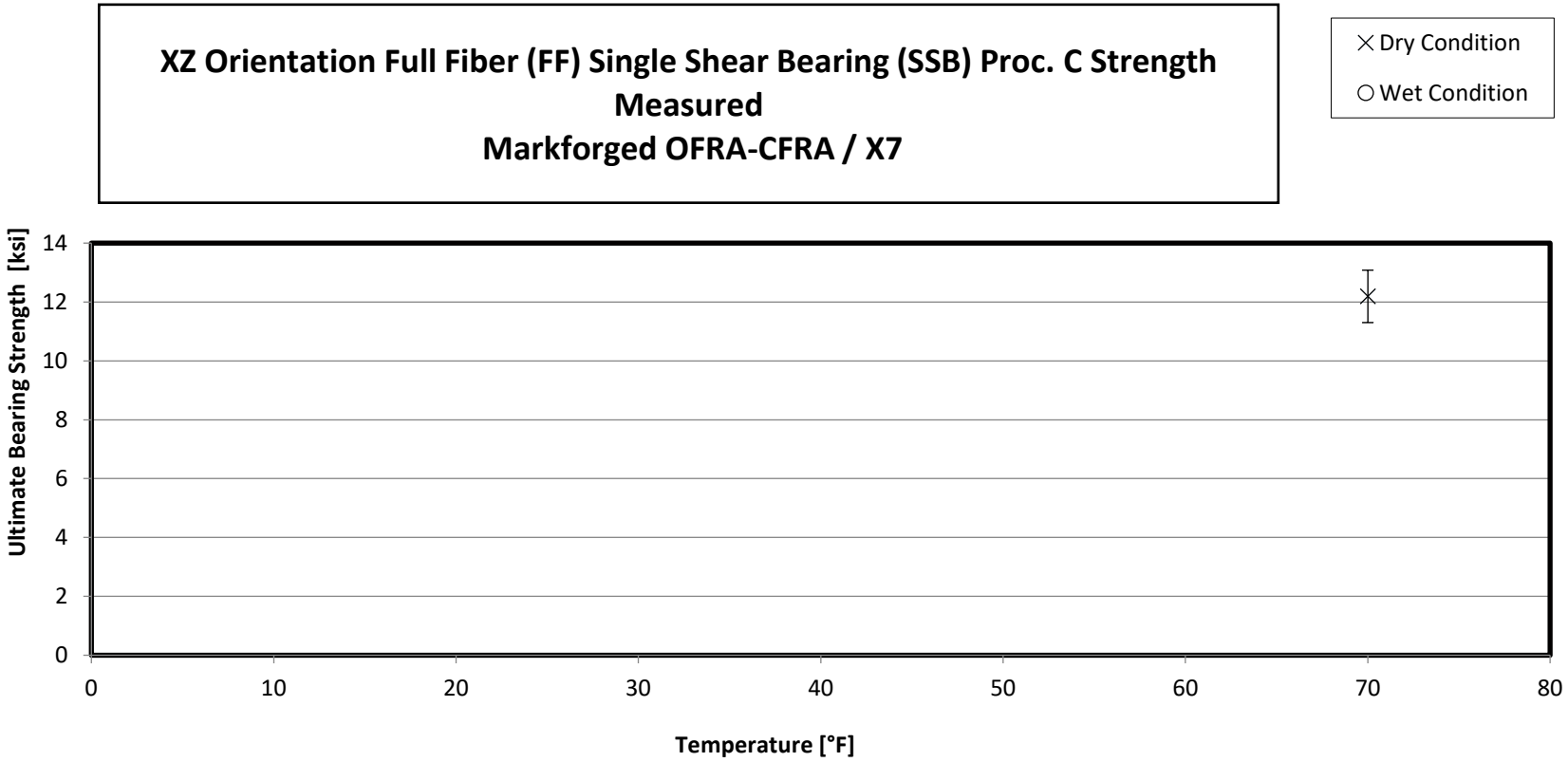

XZ Orientation Partial Fiber (PF) Single Shear Bearing (SSB) Proc. C 2% Offset Strength Measured
Markforged OFRA-CFRA / X7
Dry Condition
Wet Condition
2% Offset Bearing Strength
14.00
12.00
10.00
8.00
6.00
4.00
2.00
0.00
-100
-50
0
50
100
150
Temperature [°F]


XZ Orientation Partial Fiber (PF) Single Shear Bearing (SSB) Stiffness Measured
Markforged OFRA-CFRA / X7
Dry Condition
Wet Condition
Bearing Stiffness [Msi]
0.60
0.50
0.40
0.30
0.20
0.10
0.00
-100
-50
0
50
100
150
Temperature [°F]

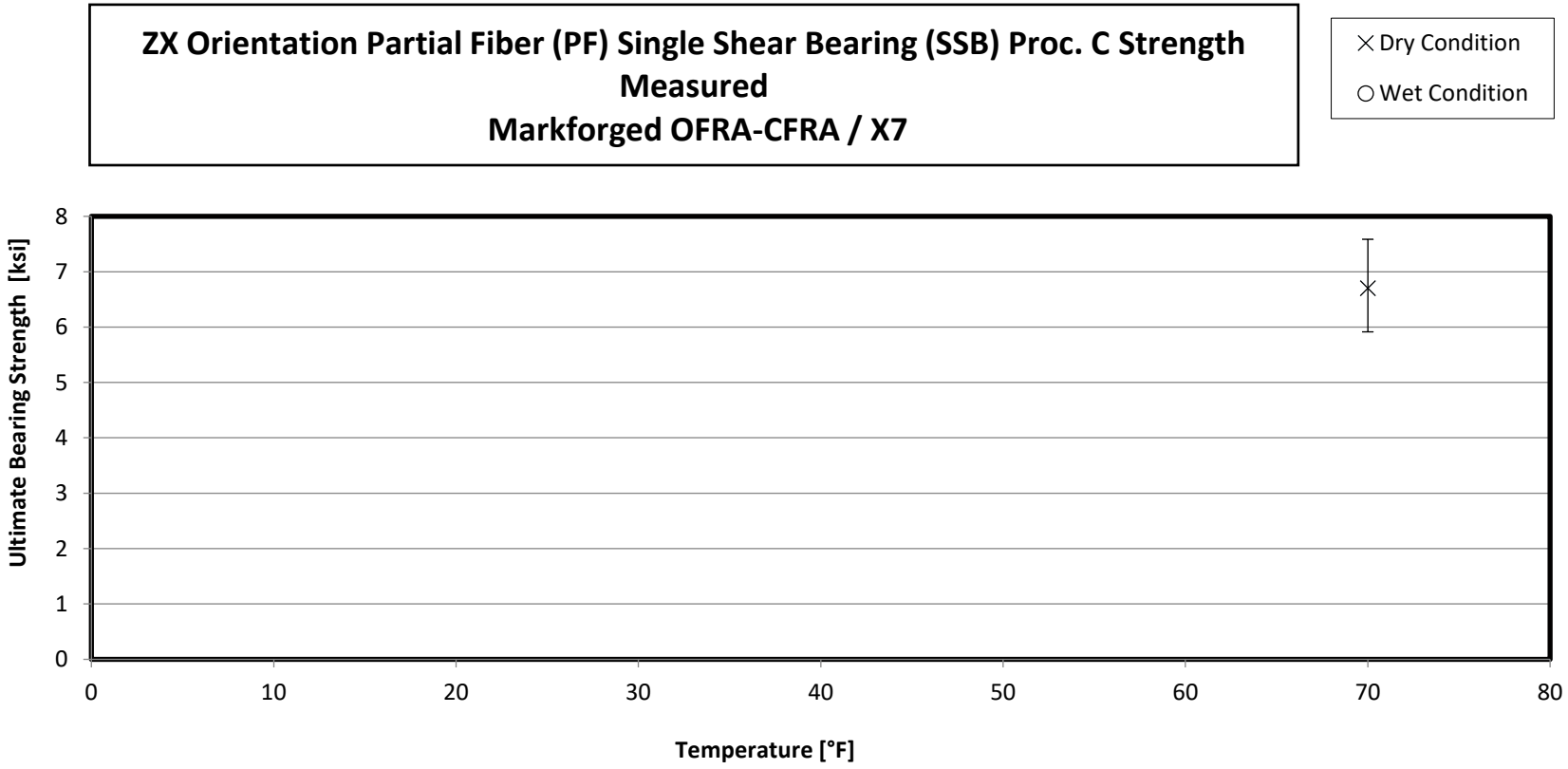
3.38 XZ FF Single Shear Bearing Properties – Reference Only

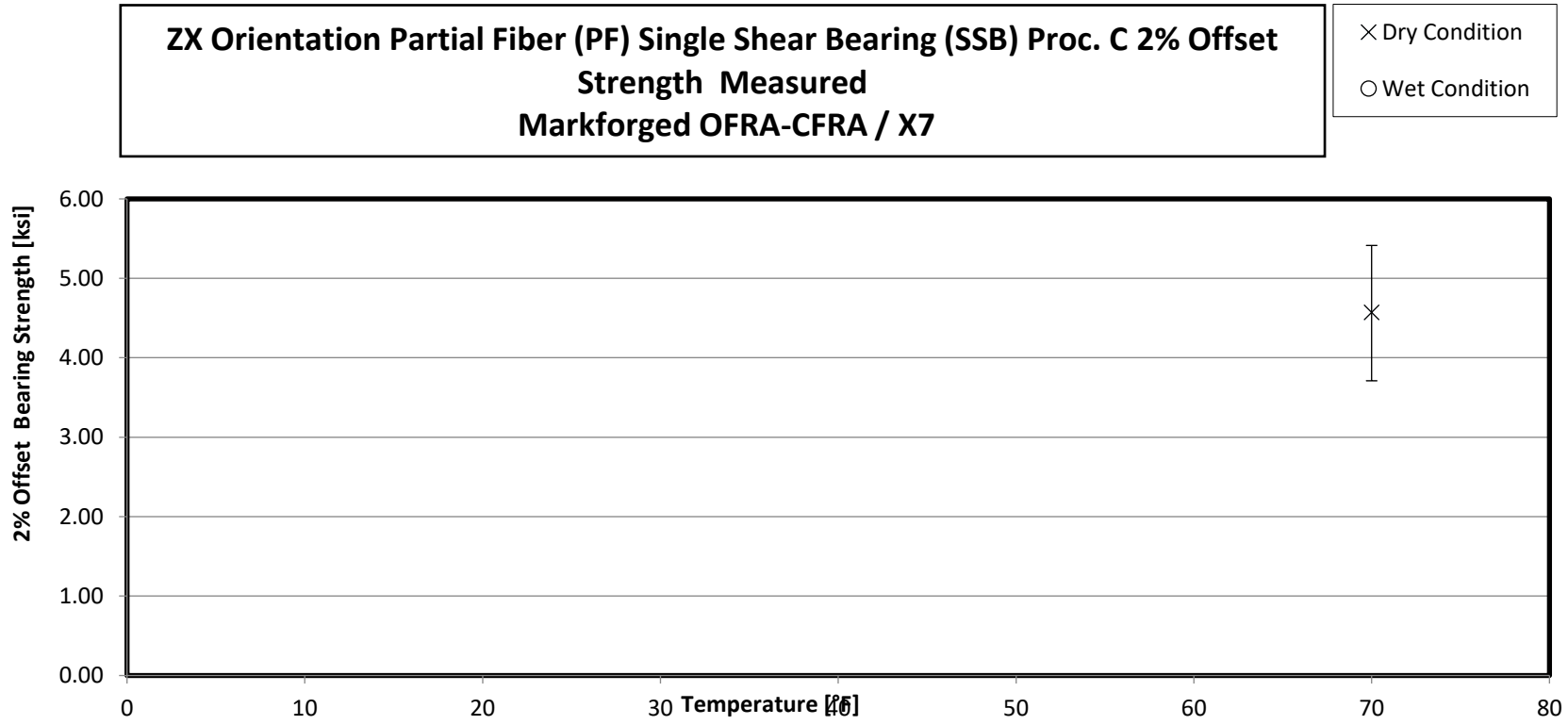


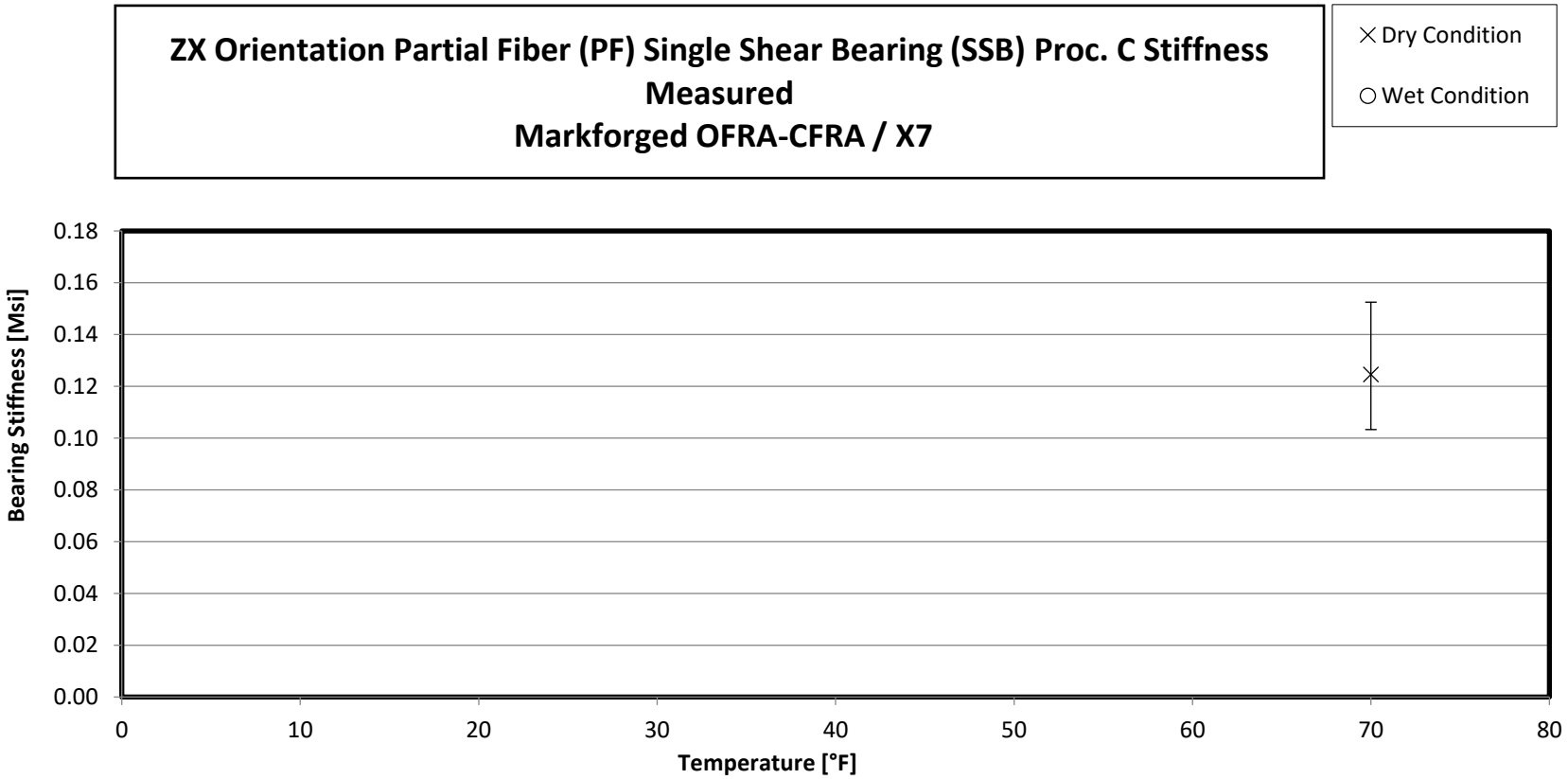

XZ Orientation Full Fiber (FF) Single Shear Bearing (SSB) Proc. C 2% Offset Strength Measured
Markforged OFRA-CFRA / X7
Dry Condition
Wet Condition
2% Offset Bearing Strength [ksi]
14.00
12.00
10.00
8.00
6.00
4.00
2.00
0.00
0
10
20
30
40
50
60
70
80
Temperature [°F]


XZ Orientation Full Fiber (FF) Single Shear Bearing (SSB) Proc. C Strength Measured
Markforged OFRA-CFRA / X7
Dry Condition
Wet Condition
Ultimate Bearing Strength [ksi]
0
2
4
6
8
10
12
14
0
10
20
30
40
50
60
70
80
Temperature [°F]

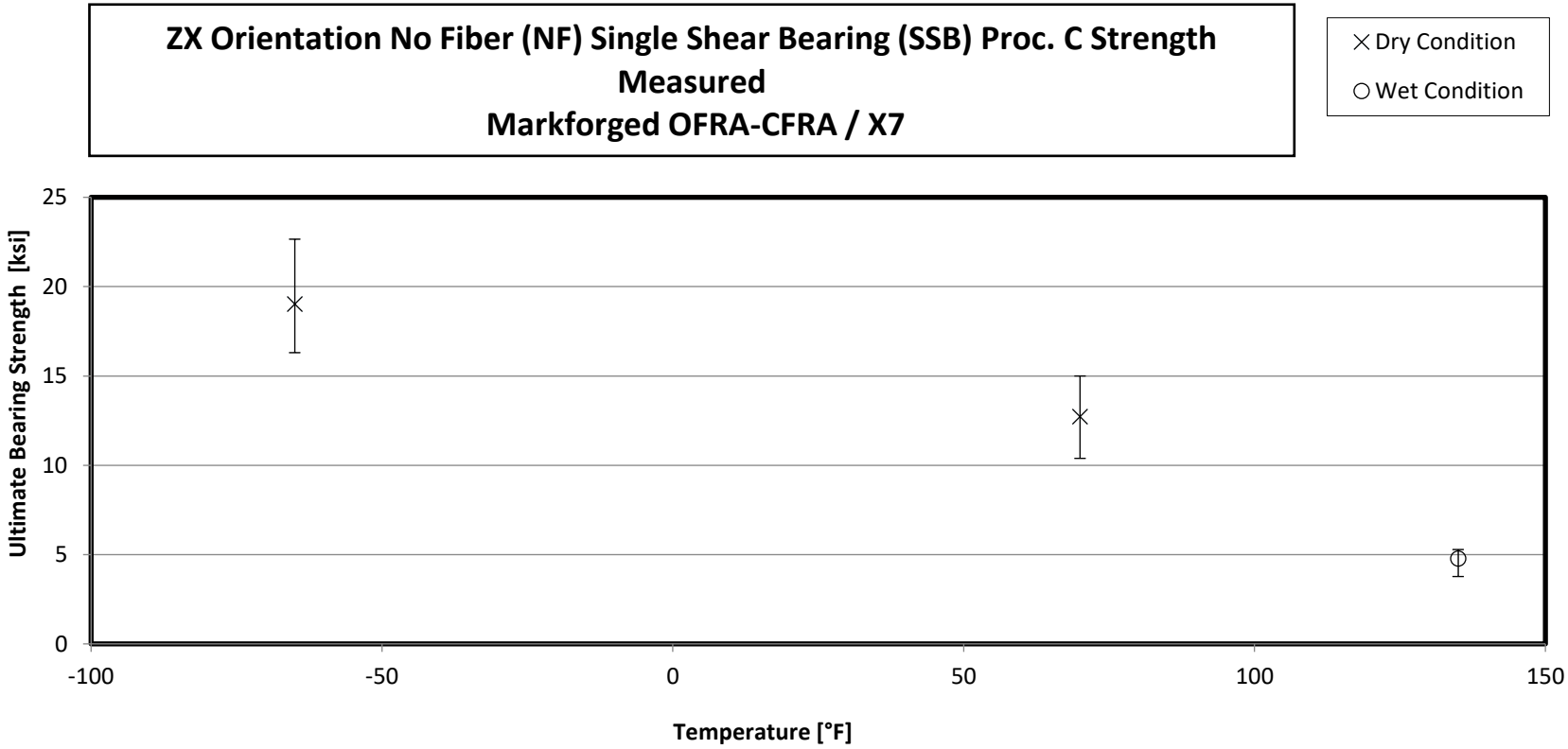
3.39 ZX PF Single Shear Bearing Properties – Reference Only

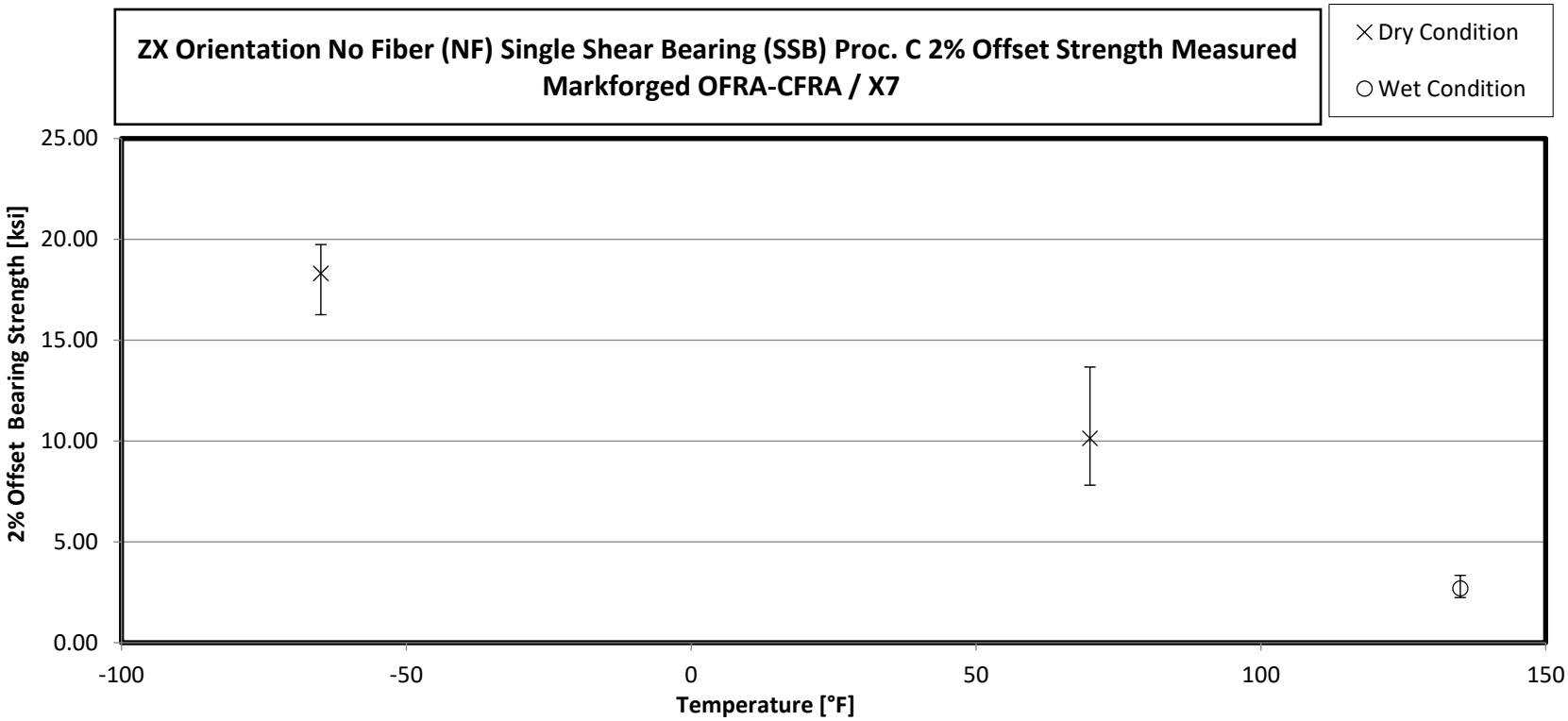


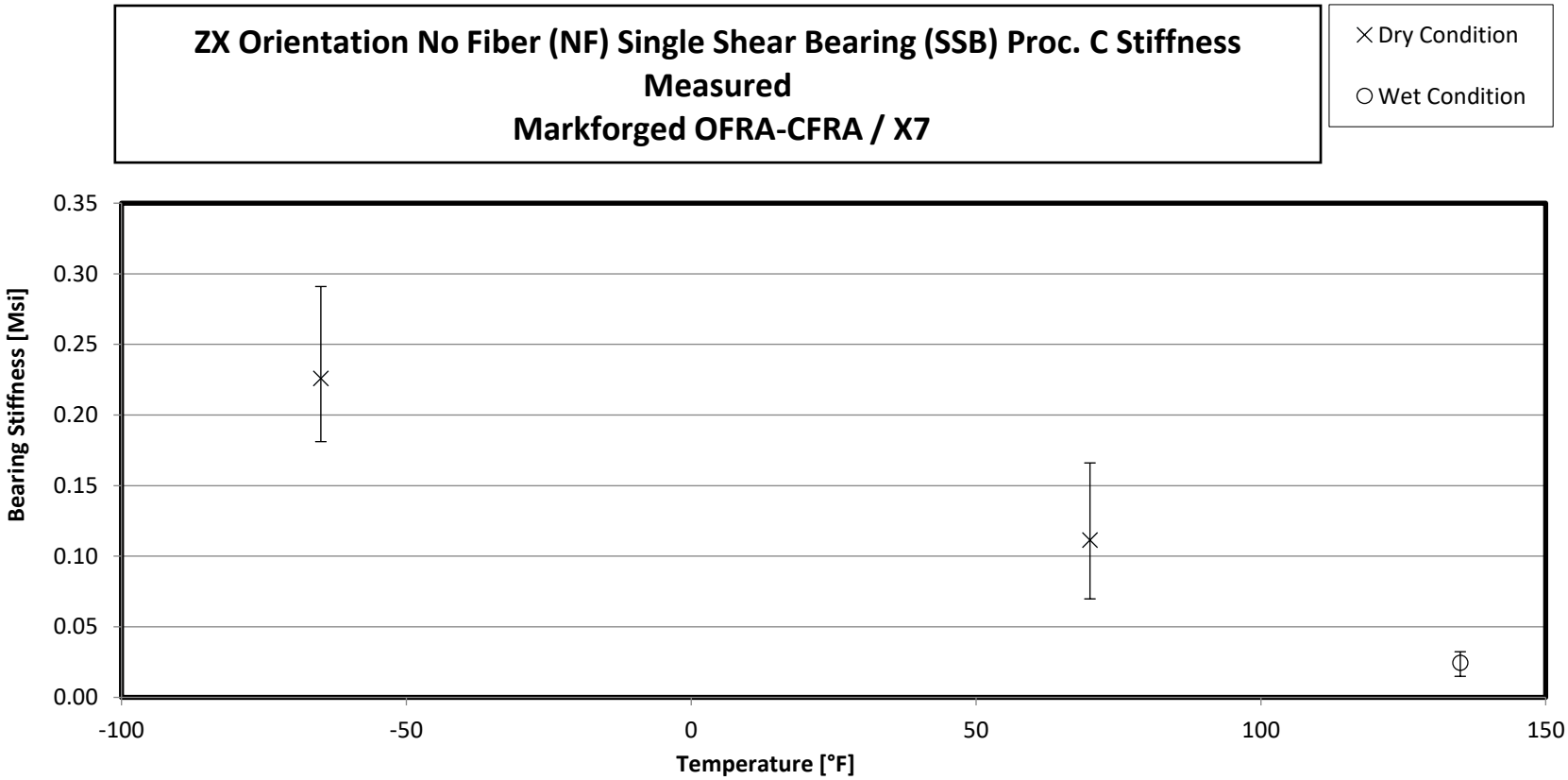

ZX Orientation Partial Fiber (PF) Single Shear Bearing (SSB) Proc. C 2% Offset Strength Measured
Markforged OFRA-CFRA / X7
Dry Condition
Wet Condition
2% Offset Bearing Strength [ksi]
6.00
5.00
4.00
3.00
2.00
1.00
0.00
0
10
20
30
40
50
60
70
80
Temperature [°F]


ZX Orientation Partial Fiber (PF) Single Shear Bearing (SSB) Proc. C Stiffness Measured
Markforged OFRA-CFRA / X7
× Dry Condition
○ Wet Condition
Bearing Stiffness [Msi]
0.18
0.16
0.14
0.12
0.10
0.08
0.06
0.04
0.02
0.00
0
10
20
30
40
50
60
70
80
Temperature [°F]

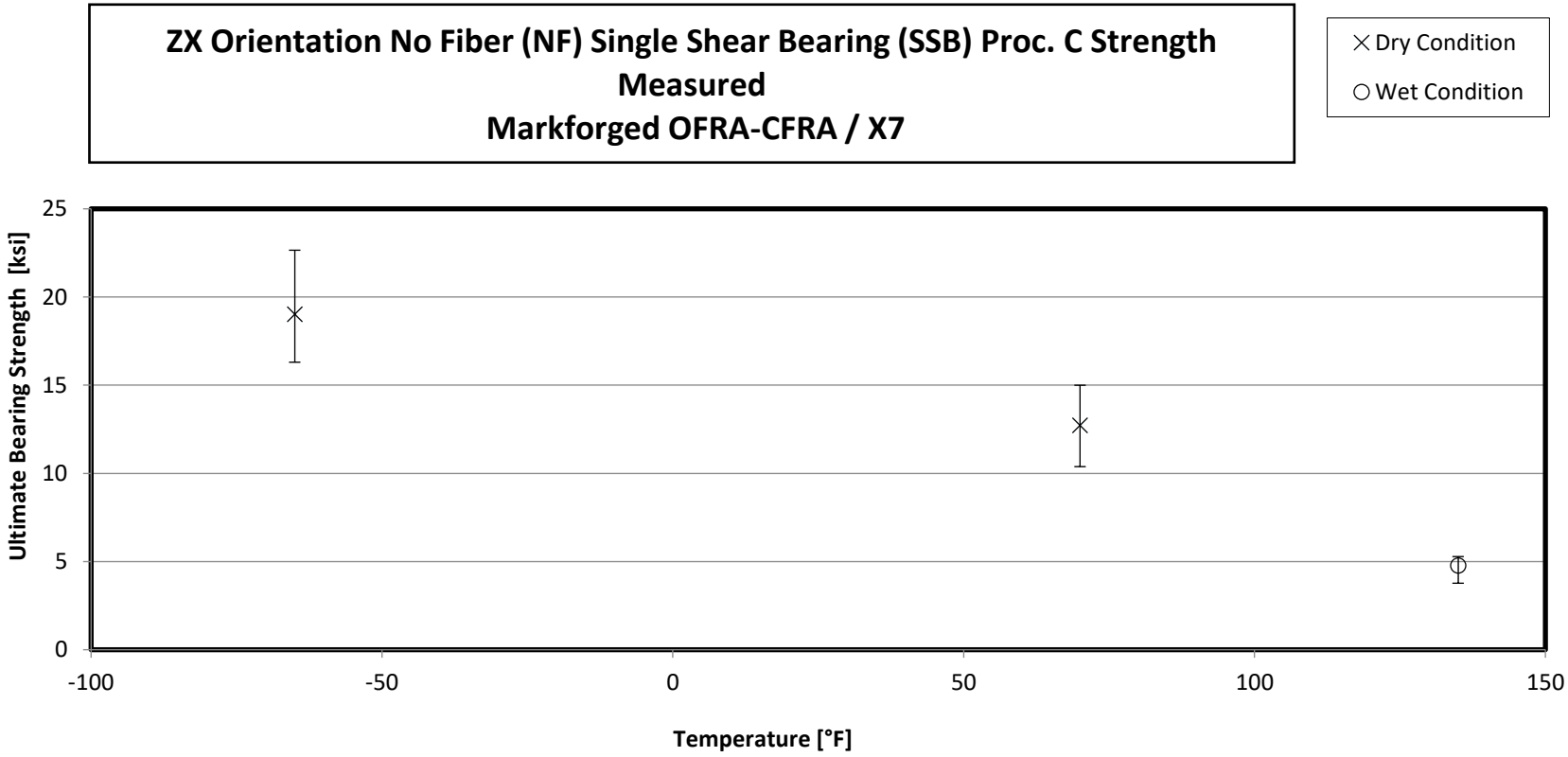
3.40 ZX NF Single Shear Bearing Properties

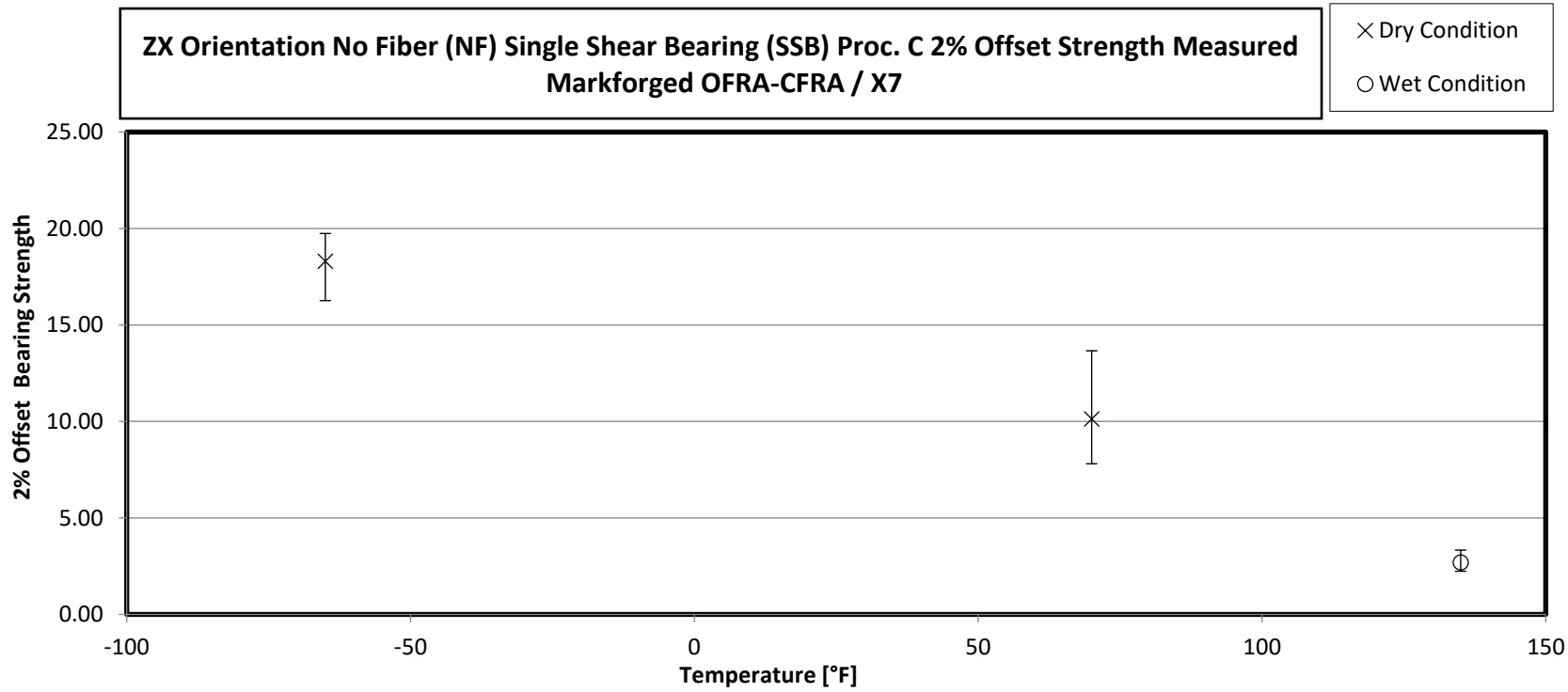


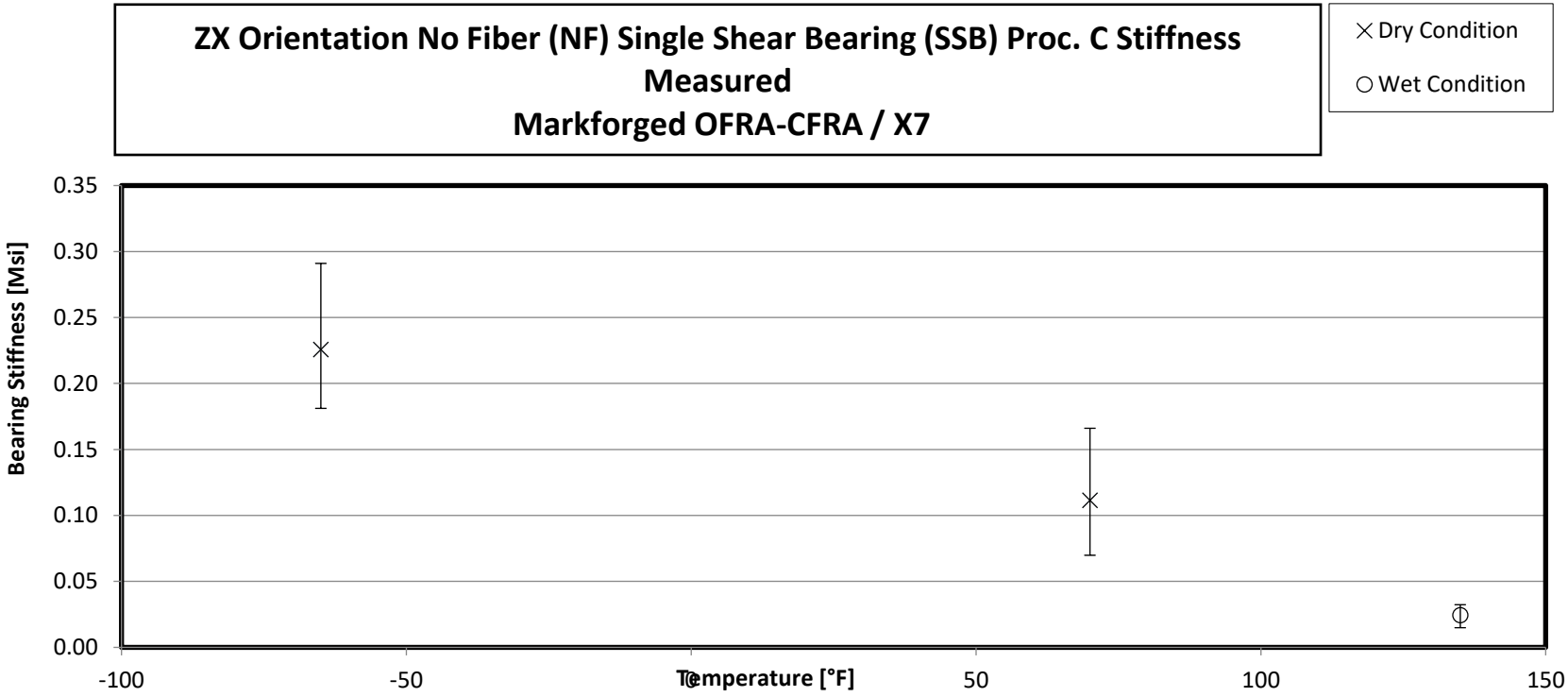

ZX Orientation No Fiber (NF) Single Shear Bearing (SSB) Proc. C 2% Offset Strength Measured
Markforged OFRA-CFRA / X7
Dry Condition
Wet Condition
2% Offset Bearing Strength [ksi]
25.00
20.00
15.00
10.00
5.00
0.00
-100
-50
0
50
100
150
Temperature [°F]


ZX Orientation No Fiber (NF) Single Shear Bearing (SSB) Proc. C Stiffness Measured
Markforged OFRA-CFRA / X7
Dry Condition
Wet Condition
Bearing Stiffness [Msi]
0.35
0.30
0.25
0.20
0.15
0.10
0.05
0.00
-100
-50
0
50
100
150
Temperature [°F]

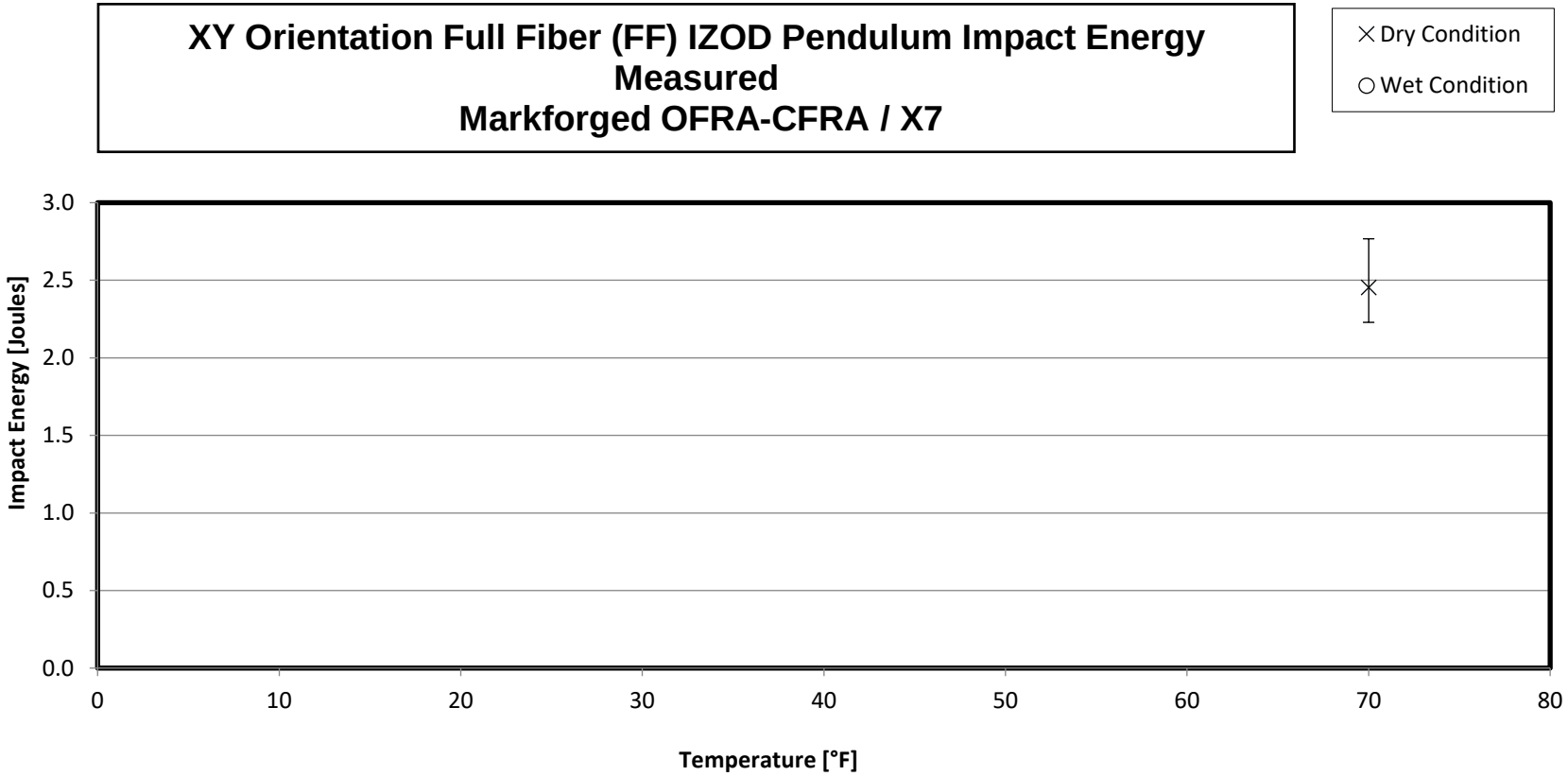
3.41 XY PF IZOD Pendulum Impact Properties – Reference Only

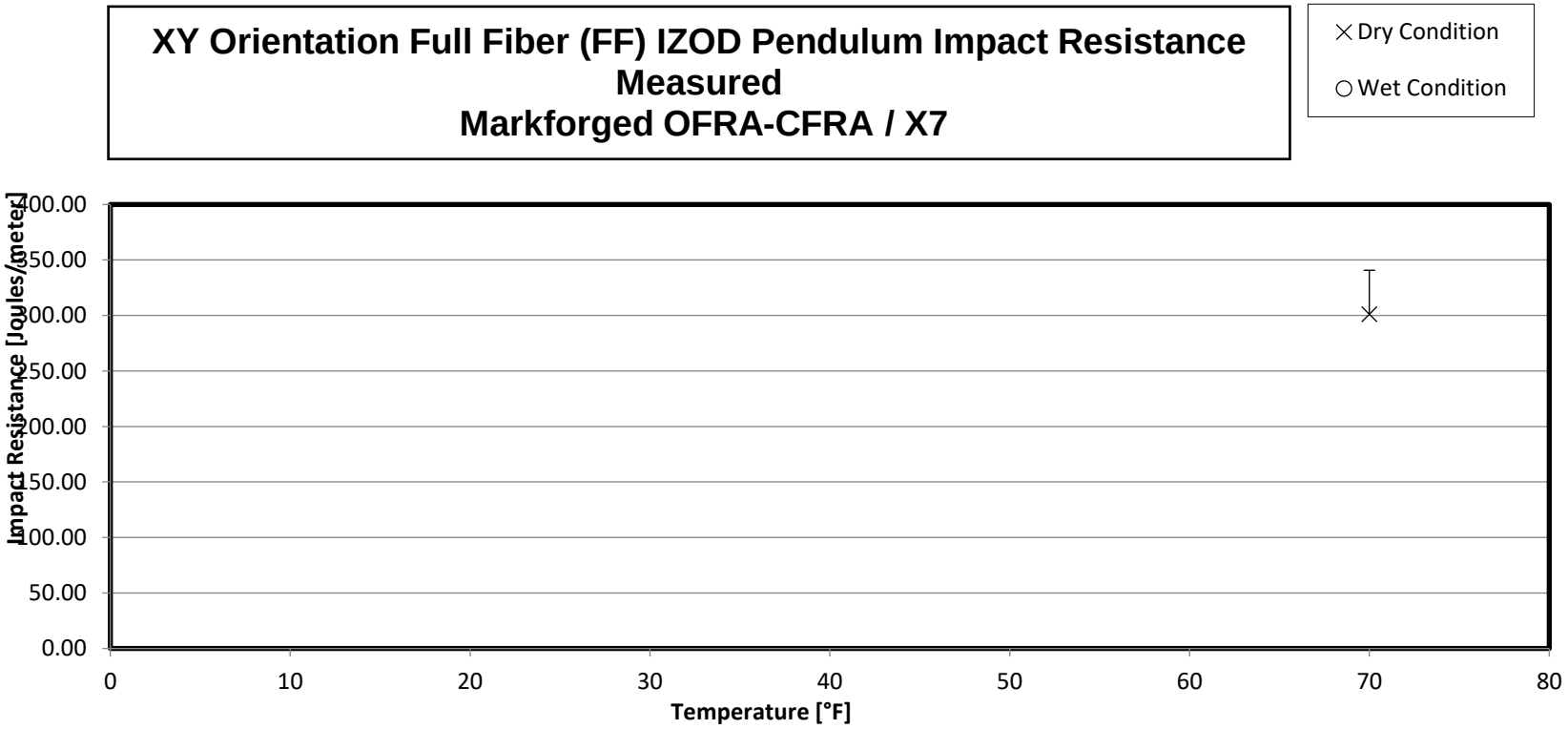



ZX Orientation No Fiber (NF) Single Shear Bearing (SSB) Proc. C 2% Offset Strength Measured
Markforged OFRA-CFRA / X7
Dry Condition
Wet Condition
2% Offset Bearing Strength
25.00
20.00
15.00
10.00
5.00
0.00
-100
-50
0
50
100
150
Temperature [°F]

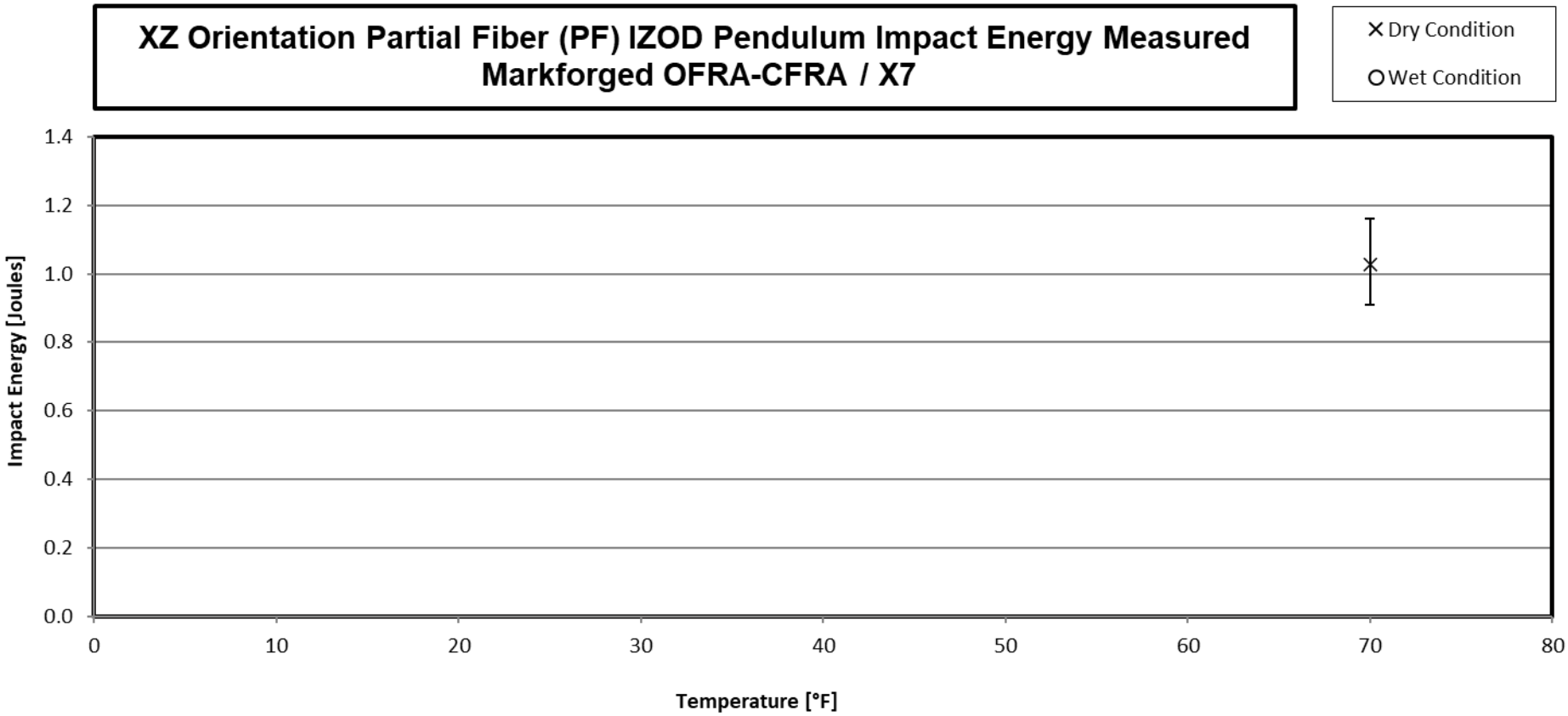

ZX Orientation No Fiber (NF) Single Shear Bearing (SSB) Proc. C Stiffness Measured
Markforged OFRA-CFRA / X7
Dry Condition
Wet Condition
Bearing Stiffness [Msi]
0.35
0.30
0.25
0.20
0.15
0.10
0.05
0.00
-100
-50
0
50
100
150
Temperature [°F]

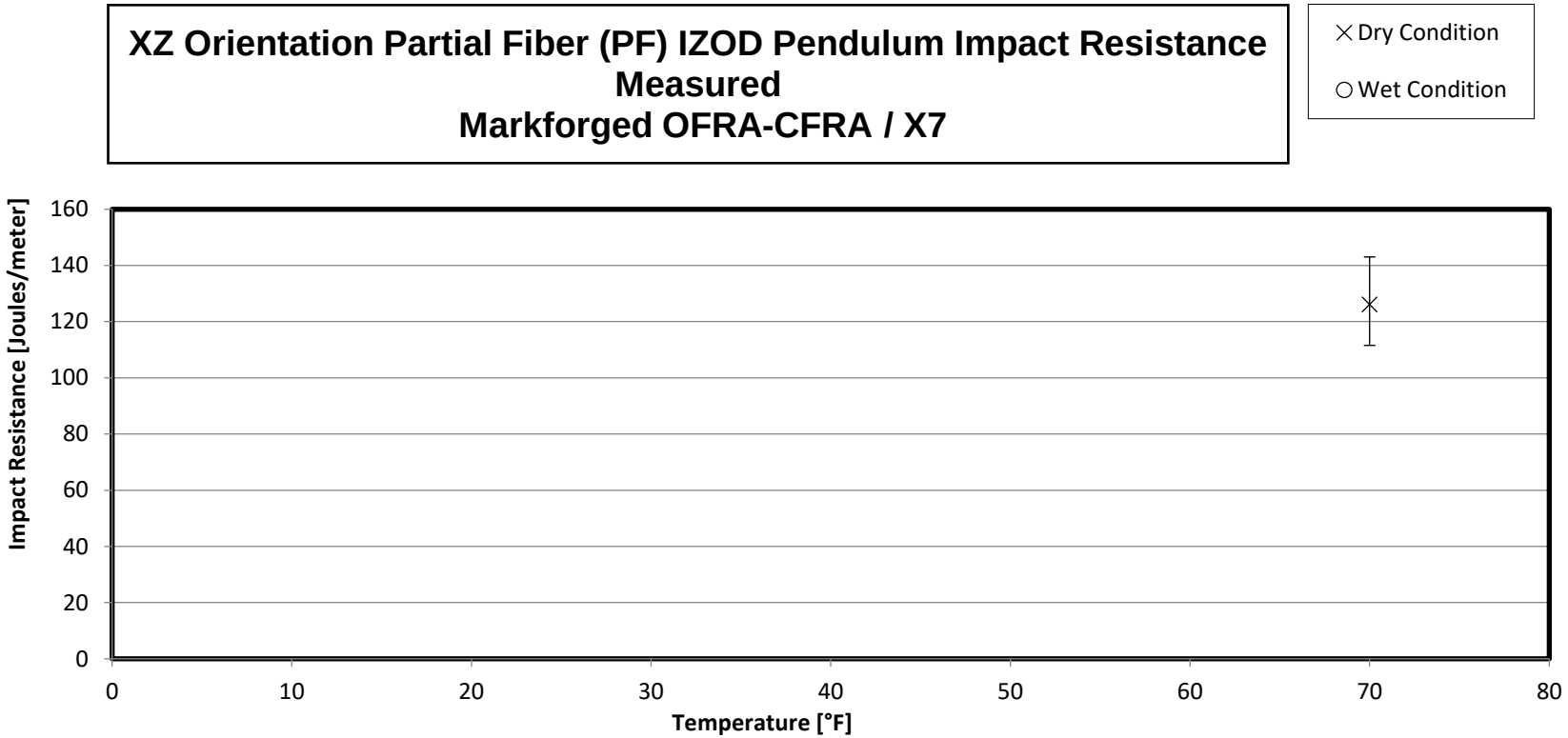
3.42 XY FF IZOD Pendulum Impact Properties – Reference Only



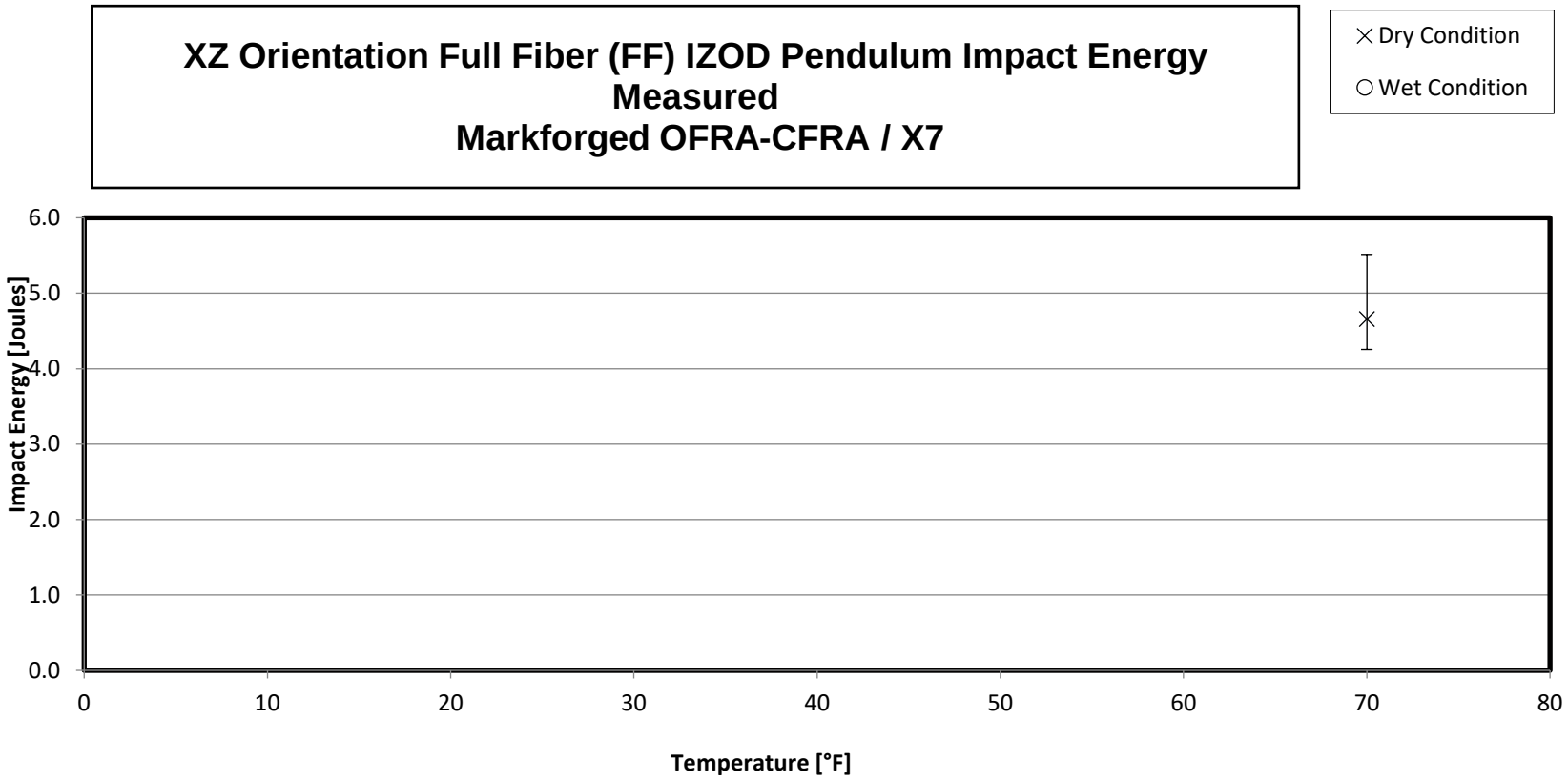

XY Orientation Full Fiber (FF) IZOD Pendulum Impact Resistance Measured
Markforged OFRA-CFRA / X7
Dry Condition
Wet Condition
Impact Resistance [Joules/meter]
400.00
350.00
300.00
250.00
200.00
150.00
100.00
50.00
0.00
0
10
20
30
40
50
60
70
80
Temperature [°F]

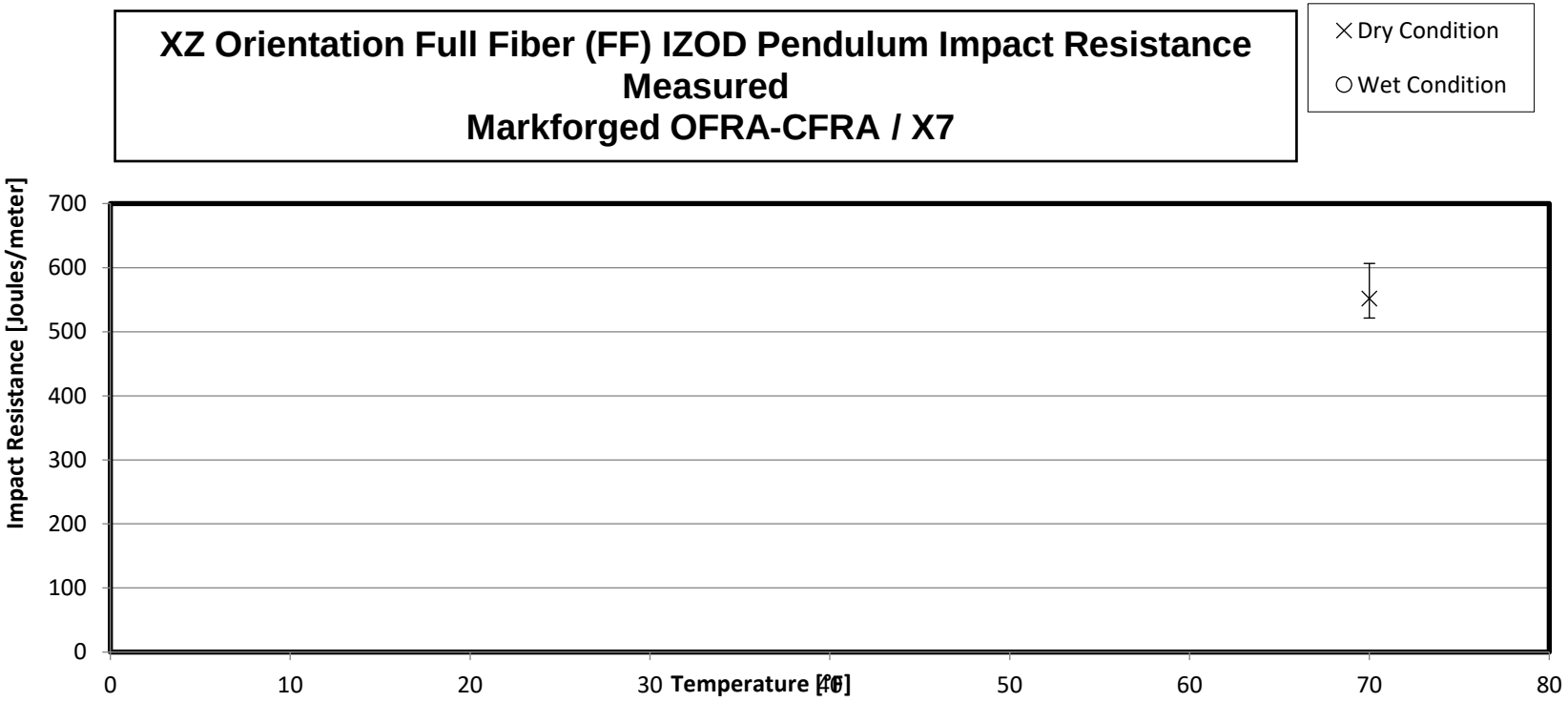
3.43 XZ PF IZOD Pendulum Impact Properties – Reference Only



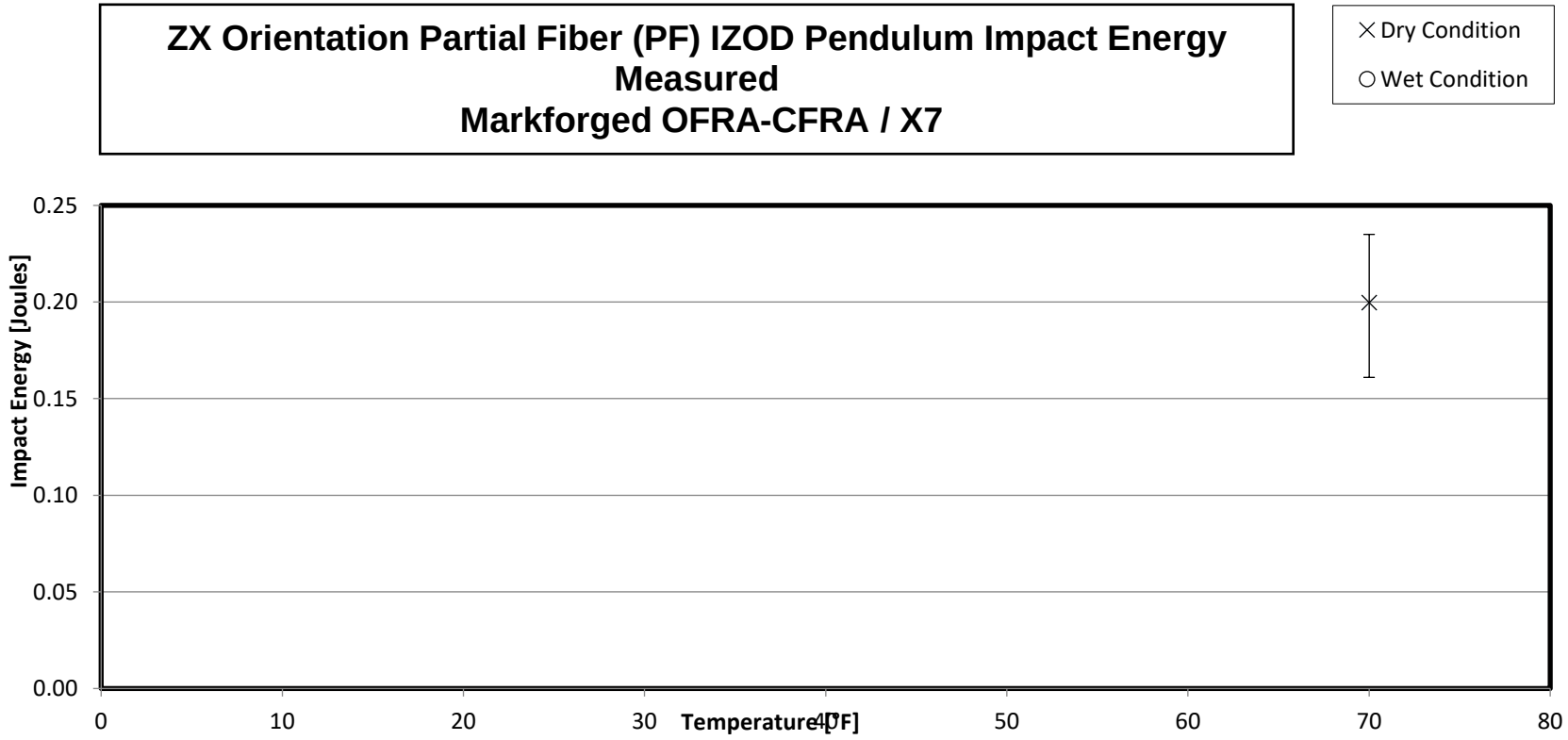

XZ Orientation Partial Fiber (PF) IZOD Pendulum Impact Resistance Measured
Markforged OFRA-CFRA / X7
Dry Condition
Wet Condition
Impact Resistance [Joules/meter]
160
140
120
100
80
60
40
20
0
0
10
20
30
40
50
60
70
80
Temperature [°F]

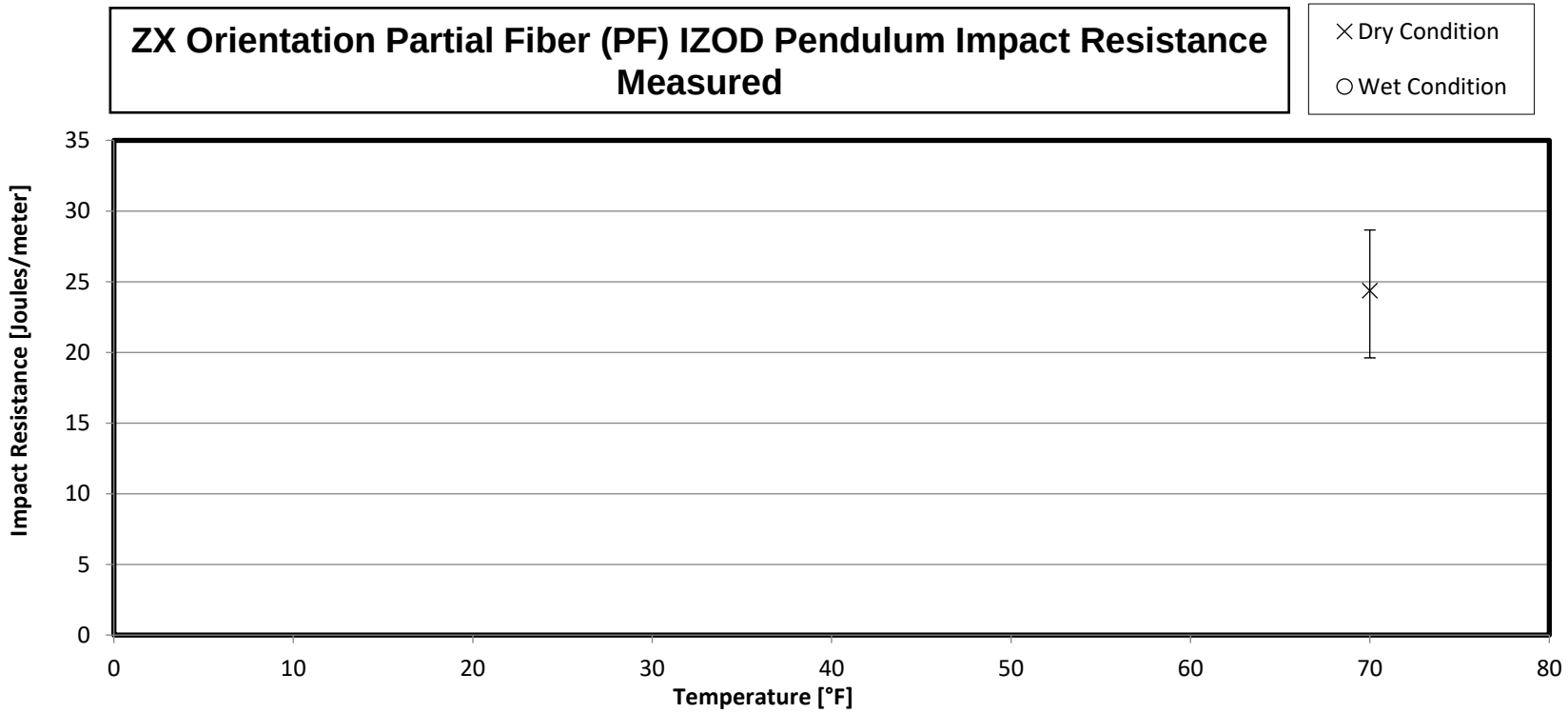
3.44 XZ FF IZOD Pendulum Impact Properties




XZ Orientation Full Fiber (FF) IZOD Pendulum Impact Resistance Measured
Markforged OFRA-CFRA / X7
Dry Condition
Wet Condition
Impact Resistance [Joules/meter]
700
600
500
400
300
200
100
0
0
10
20
30
40
50
60
70
80
Temperature [°F]

3.45 ZX PF IZOD Pendulum Impact Properties – Reference Only




ZX Orientation Partial Fiber (PF) IZOD Pendulum Impact Resistance Measured
Dry Condition
Wet Condition
Impact Resistance [Joules/meter]
35
30
25
20
15
10
5
0
0
10
20
30
40
50
60
70
80
Temperature [°F]

4. Raw Data

For Combined Loading Compression (CLC) specimens, Euler buckling which is an improper failure according to ASTM D6641 were present. This was observed on the XZ orientation PF specimens for both the RTD and ETD test conditions, and the majority of the ZX orientation NF specimens. For the ZX orientation NF specimens, no sharp load drop was witness during testing, therefore 0.2% offset strength was reported for consistency.

Excessive specimen bending was observed for ASTM D790 Flex and ASTM D2344 Short Beam Shear specimens. In regard to the Flex specimens, failures were occurring after 5% strain, which invalidates the test. This was observed on several XY and XZ orientation PF specimens in the ETW test condition, but was majorly present for ZX orientation NF specimens for the RTD, ETD, and ETW test conditions. As for the ASTM D2344 tests, XY orientation PF specimens that were tested in the ETW condition, exhibited inelastic deformation which is an improper failure mode.

The XZ orientation PF specimens across all test conditions exhibited long splitting failures for the Open Hole Tension and Filled-Hole Tension test methods, which are not acceptable according to both the ASTM D5766 and D6742 test standards. Furthermore, the ZX orientation NF Filled-Hole Tension specimens experienced failures away from the hole, which are not appropriate failures. In the XZ orientation PF ASTM 5961 Single Shear Bearing specimens, cleavage failures were observed for all test conditions, while lateral tension failures were observed for all test conditions in the ZX orientation NF specimens.

The improper failures modes discussed above appear to be closely associated to the print direction and fiber fill combination for the specimens and likely due to inherent material properties. Therefore, all improper failure modes will be noted and accepted as inherent material properties for B-basis allowable generation. It is the responsibility of the user, engineers, and relevant authorities to ensure that these failure types are taken into consideration where a part design is concerned.

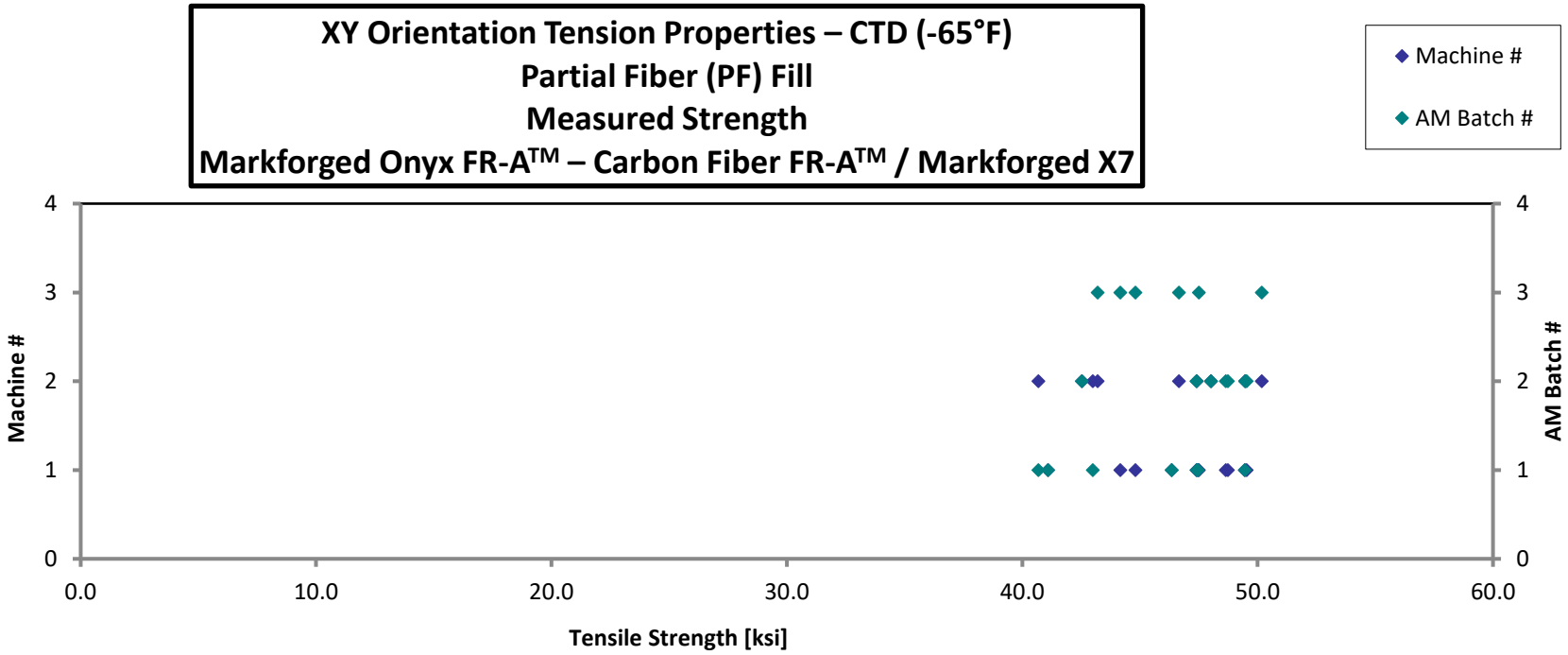
4.1 XY PF Tension Properties

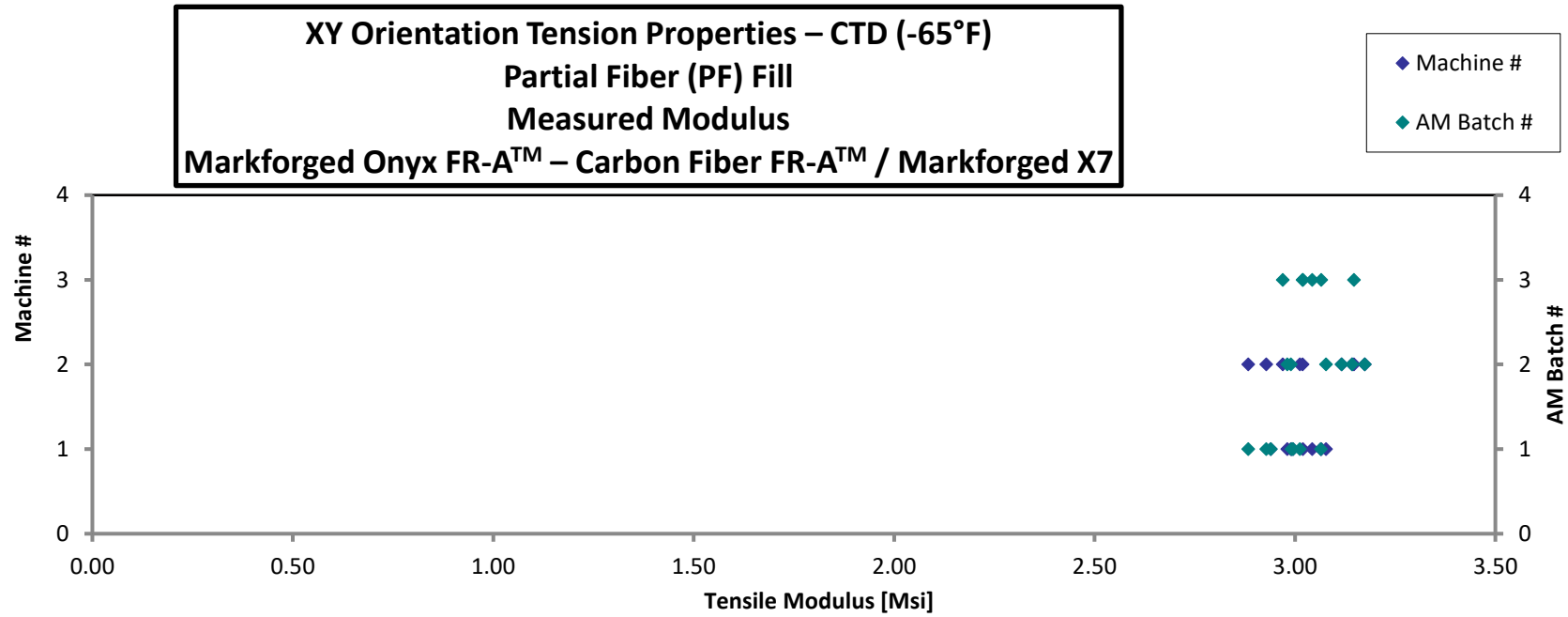
4.1.1 CTD Condition

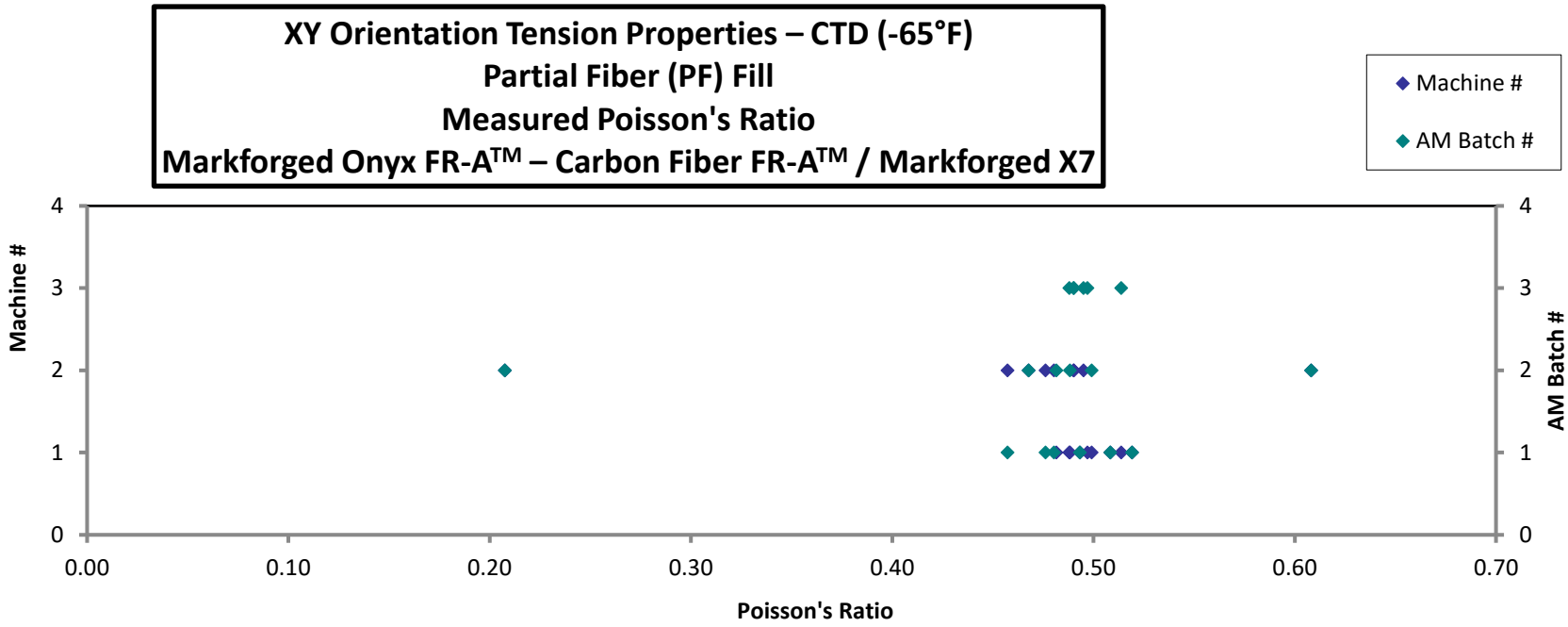
XY Orientation Tension Properties – CTD (-65°F)
Partial Fiber (PF) Fill
Strength & Modulus
Markforged Onyx FR-A™– Carbon Fiber FR-A™ / Markforged X7

Specimen Number	AM Batch #	Machine #	Avg. Specimen Thickness [in]	Tensile Strength [ksi]	Tensile Modulus [Msi]	Poisson's Ratio	Failure Mode
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M1-P30352-XY-T-11-CTD-PF-1*	1	1	0.140	49.46	3.065		M(A,L)GM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M1-P30602-XY-T-12-CTD-PF-2	1	1	0.143	46.35	2.991	0.508	SGM, M(A,L)AB
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M1-P30543-XY-T-13-CTD-PF-3	1	1	0.143	47.46	2.995	0.519	M(A,L)AB
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M1-P31153-XY-T-13-CTD-PF-SP	1	1	0.141	41.10	2.940	0.493	SGM, M(A,L)AB
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M2-P30351-XY-T-11-CTD-PF-1	1	2	0.141	40.68	2.884	0.476	M(S,D)GM, M(A,L)AT
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M2-P30601-XY-T-12-CTD-PF-2	1	2	0.143	43.00	2.928	0.457	M(S,D)GM, M(A,L)AT, M(A,L)WB
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M2-P30542-XY-T-13-CTD-PF-3	1	2	0.141	47.41	3.012	0.480	SGM, M(A,L)AT
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-B-M1-P32870-XY-T-11-CTD-PF-1	2	1	0.141	48.65	3.078	0.499	SGM, M(A,L)WB
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-B-M1-P32848-XY-T-12-CTD-PF-2**	2	1	0.144	47.40			SGM, M(A,L)AT
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-B-M1-P32236-XY-T-13-CTD-PF-3	2	1	0.141	48.73	2.981	0.488	SGM, M(A,L)AT
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-B-M1-P39037-XY-T-13-CTD-PF-SP	2	1	0.142	49.54	2.990	0.482	SGM, M(A,L)AT
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-B-M2-P32871-XY-T-11-CTD-PF-1	2	2	0.135	49.47	3.116	0.468	SGM, LAT
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-B-M2-P56064-XY-T-12-CTD-PF-2	2	2	0.136	42.54	3.143	0.608	AAB
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-B-M2-P32235-XY-T-13-CTD-PF-3	2	2	0.136	48.03	3.174	0.208	SGM, M(A,L)AB
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-C-M1-P35272-XY-T-11-CTD-PF-1	3	1	0.139	47.50	3.043	0.488	M(A,L)WT
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-C-M1-P35473-XY-T-12-CTD-PF-2	3	1	0.142	44.16	3.065	0.514	M(A,L)WT
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-C-M1-P35360-XY-T-13-CTD-PF-3	3	1	0.142	44.81	3.020	0.497	M(A,L)WT
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-C-M2-P35422-XY-T-12-CTD-PF-2	3	2	0.141	43.20	2.970	0.490	LAT
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-C-M2-P35359-XY-T-13-CTD-PF-3	3	2	0.140	46.66	3.147	0.495	M(A,L)AT
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-C-M2-P34942-XY-T-13-CTD-PF-6	3	2	0.140	50.17	3.019	0.490	AAT, SGM
	Average		**0.141**	**46.32**	**3.030**	**0.481**	
	Standard Dev.			**2.950**	**0.078**	**0.075**	
	Coeff. of Var. [%]			**6.369**	**2.587**	**15.63**	
	Min.		**0.135**	**40.68**	**2.884**	**0.208**	
	Max.		**0.144**	**50.17**	**3.174**	**0.608**	
	Number of Spec.		**20**	**20**	**19**	**18**	

* Poisson's ratio not reported due to transverse extensometer slippage
**Tensile Modulus and Poisson's ratio not reported due to unusaully high value


XY Orientation Tension Properties – CTD (-65°F)
Partial Fiber (PF) Fill
Measured Strength
Markforged Onyx FR-A™ – Carbon Fiber FR-A™ / Markforged X7
Machine #
AM Batch #
Machine #
AM Batch #
Tensile Strength [ksi]
0.0
10.0
20.0
30.0
40.0
50.0
60.0
0
1
2
3
4

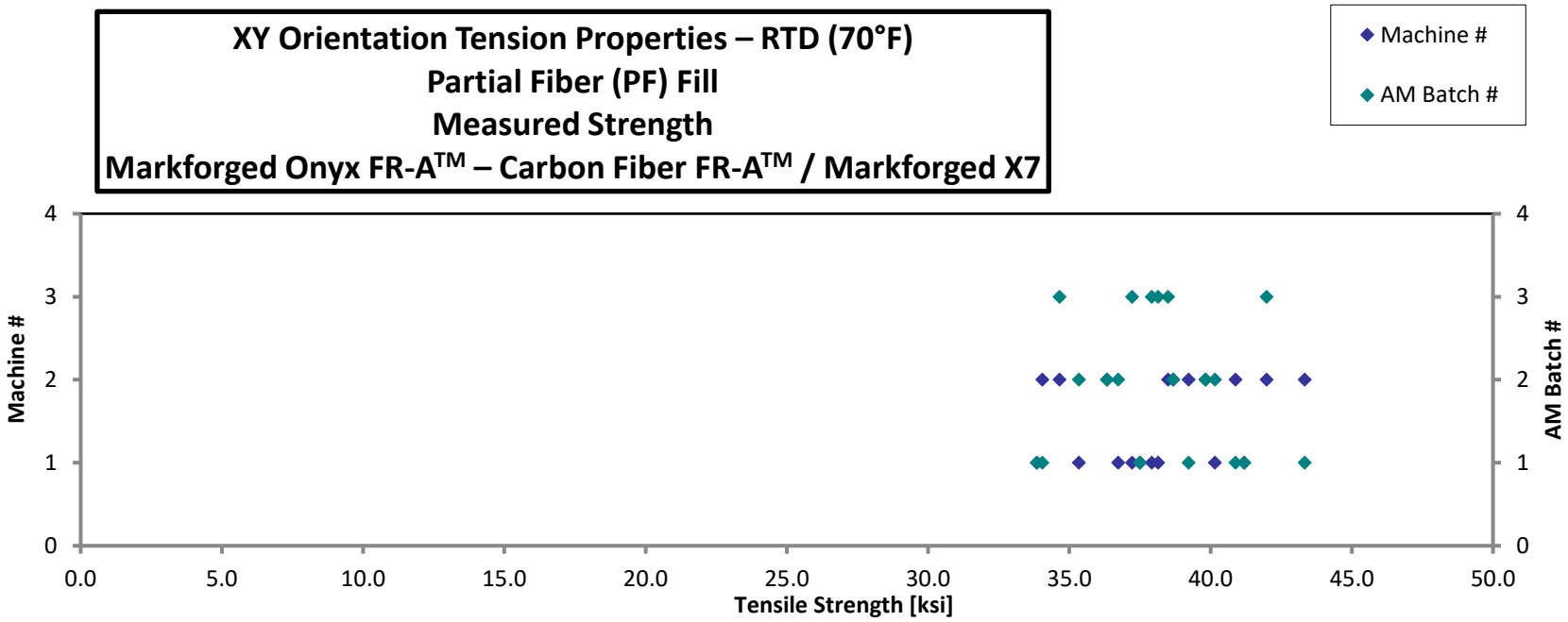

XY Orientation Tension Properties – CTD (-65°F)
Partial Fiber (PF) Fill
Measured Modulus
Markforged Onyx FR-A™ – Carbon Fiber FR-A™ / Markforged X7
Machine #
AM Batch #
Machine #
AM Batch #
Tensile Modulus [Msi]
0
1
2
3
4
0.00
0.50
1.00
1.50
2.00
2.50
3.00
3.50

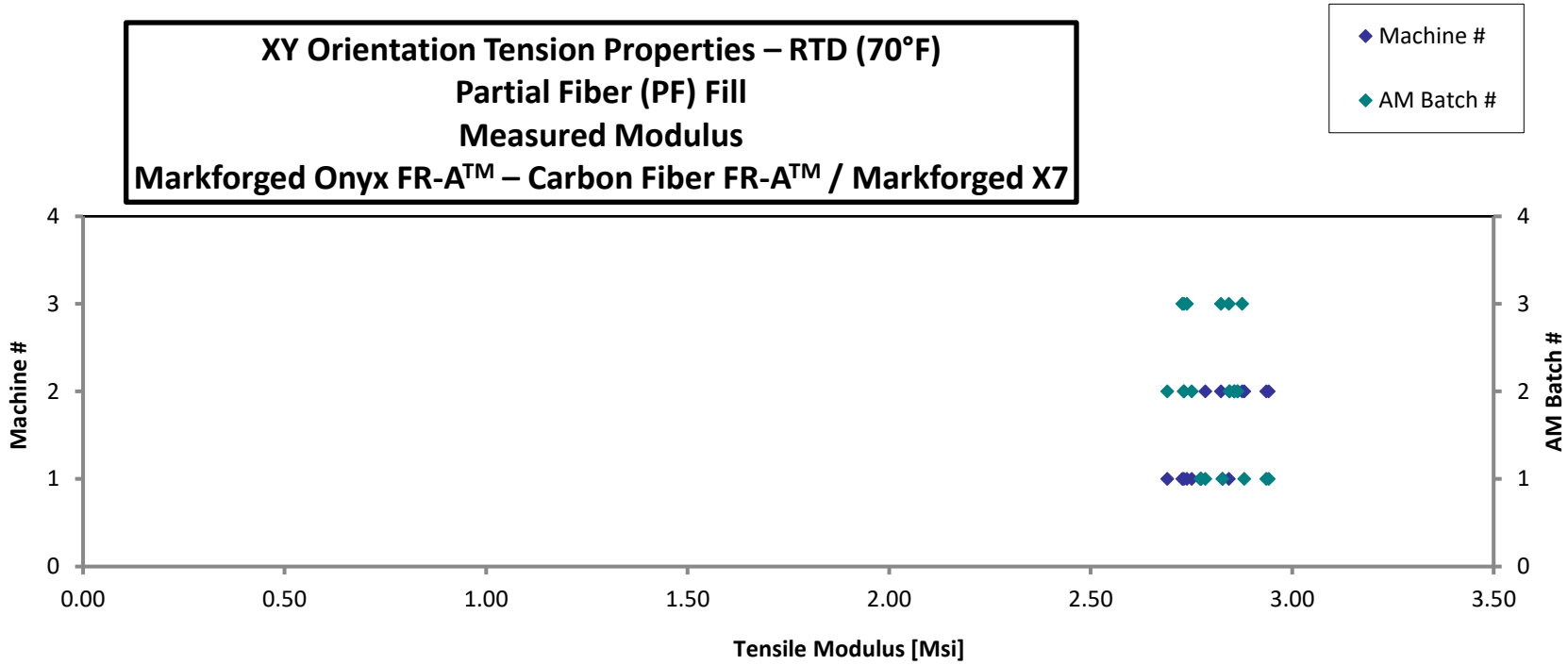

XY Orientation Tension Properties – CTD (-65°F)
Partial Fiber (PF) Fill
Measured Poisson's Ratio
Markforged Onyx FR-A™ – Carbon Fiber FR-A™ / Markforged X7
Machine #
AM Batch #
Machine #
AM Batch #
Poisson's Ratio
0.00
0.10
0.20
0.30
0.40
0.50
0.60
0.70
0
1
2
3
4

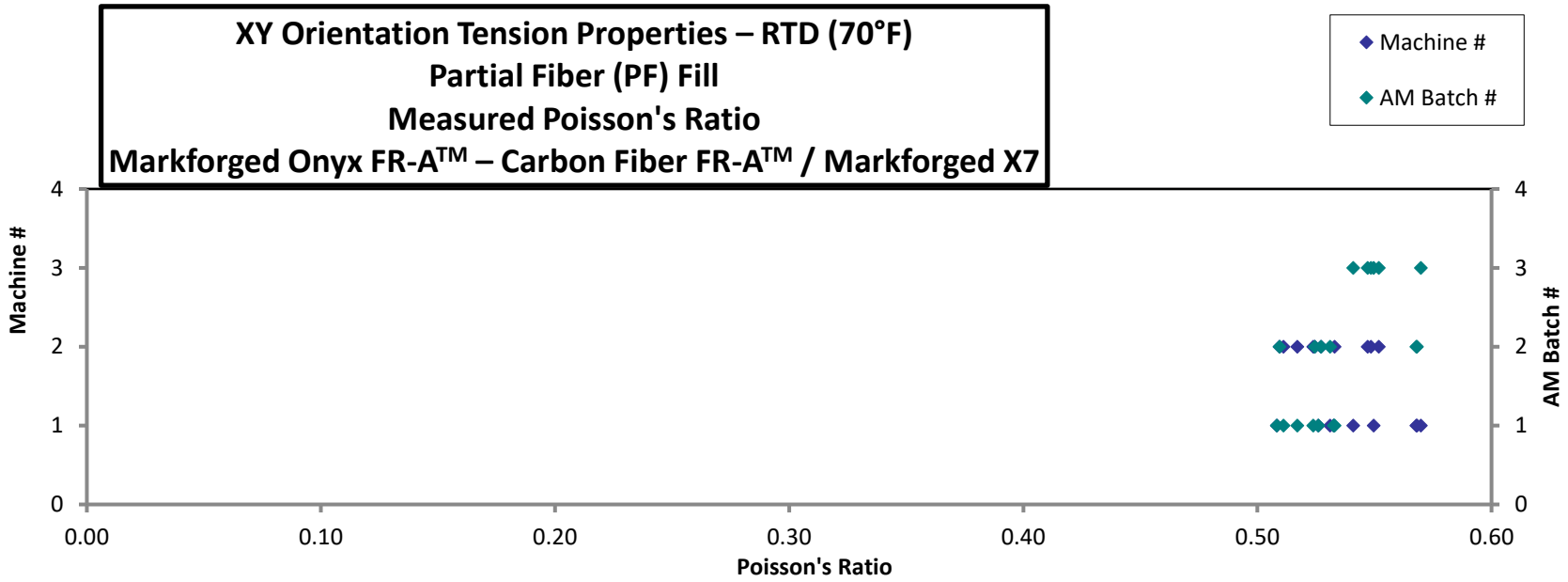
4.1.2 **RTD Condition**

XY Orientation Tension Properties – RTD (70°F)
Partial Fiber (PF) Fill
Strength & Modulus
Markforged Onyx FR-A™ – Carbon Fiber FR-A™ / Markforged X7

Specimen Number	AM Batch #	Machine #	Avg. Specimen Thickness [in]	Tensile Strength [ksi]	Tensile Modulus [Msi]	Poisson's Ratio	Failure Mode
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M1-P30543-XY-T-11-RTD-PF-1	1	1	0.141	33.85	2.827	0.508	M(A,L)WB
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M1-P30352-XY-T-12-RTD-PF-2	1	1	0.143	37.50	2.772	0.526	M(A,L)WT
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M1-P30602-XY-T-13-RTD-PF-3	1	1	0.142	41.20	2.774	0.533	M(A,L)WB, M(A,L)WT
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M2-P30542-XY-T-11-RTD-PF-1	1	2	0.139	40.88	2.942	0.511	M(A,L)AT
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M2-P30351-XY-T-12-RTD-PF-2	1	2	0.143	34.05	2.785	0.533	DGM, M(A,L)AB
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M2-P30601-XY-T-13-RTD-PF-3	1	2	0.139	43.33	2.936	0.517	M(A,L)WT, M(A,L)WB
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M2-P31152-XY-T-13-RTD-PF-SP	1	2	0.142	39.23	2.881	0.524	M(A,L)WB
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-B-M1-P32236-XY-T-11-RTD-PF-1	2	1	0.139	40.16	2.751	0.531	M(A,L)WB
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-B-M1-P32870-XY-T-12-RTD-PF-2	2	1	0.145	36.73	2.690	0.568	M(A,L)WB
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-B-M1-P32848-XY-T-13-RTD-PF-3	2	1	0.143	35.33	2.731	0.568	M(A,L)WT
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-B-M2-P32235-XY-T-11-RTD-PF-1	2	2	0.135	39.83	2.865	0.510	M(A,L)WB
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-B-M2-P32871-XY-T-12-RTD-PF-2	2	2	0.137	38.67	2.845	0.527	AWT
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-B-M2-P56064-XY-T-13-RTD-PF-3	2	2	0.135	36.33	2.857	0.524	AWT
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-C-M1-P35360-XY-T-11-RTD-PF-1	3	1	0.139	37.22	2.739	0.541	M(A,L)WT
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-C-M1-P35272-XY-T-12-RTD-PF-2	3	1	0.140	38.14	2.727	0.550	DGM, AWT
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-C-M1-P35473-XY-T-13-RTD-PF-3	3	1	0.137	37.92	2.843	0.570	M(A,L)WB
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-C-M2-P35359-XY-T-11-RTD-PF-1	3	2	0.140	38.50	2.876	0.547	M(A,L)AT
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-C-M2-P35422-XY-T-13-RTD-PF-3	3	2	0.140	34.66	2.731	0.552	M(A,L)AB
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-C-M2-P34942-XY-T-13-RTD-PF-6	3	2	0.137	41.98	2.823	0.549	M(A,L)WB
		Average	**0.140**	**38.18**	**2.810**	**0.536**	
		Standard Dev.		**2.675**	**0.073**	**0.020**	
		Coeff. of Var. [%]		**7.005**	**2.603**	**3.647**	
		Min.	**0.135**	**33.85**	**2.690**	**0.508**	
		Max.	**0.145**	**43.33**	**2.942**	**0.570**	
		Number of Spec.	**19**	**19**	**19**	**19**	


XY Orientation Tension Properties – RTD (70°F)
Partial Fiber (PF) Fill
Measured Strength
Markforged Onyx FR-A™ – Carbon Fiber FR-A™ / Markforged X7
Machine #
AM Batch #
Machine #
AM Batch #
Tensile Strength [ksi]
0.0
5.0
10.0
15.0
20.0
25.0
30.0
35.0
40.0
45.0
50.0
0
1
2
3
4

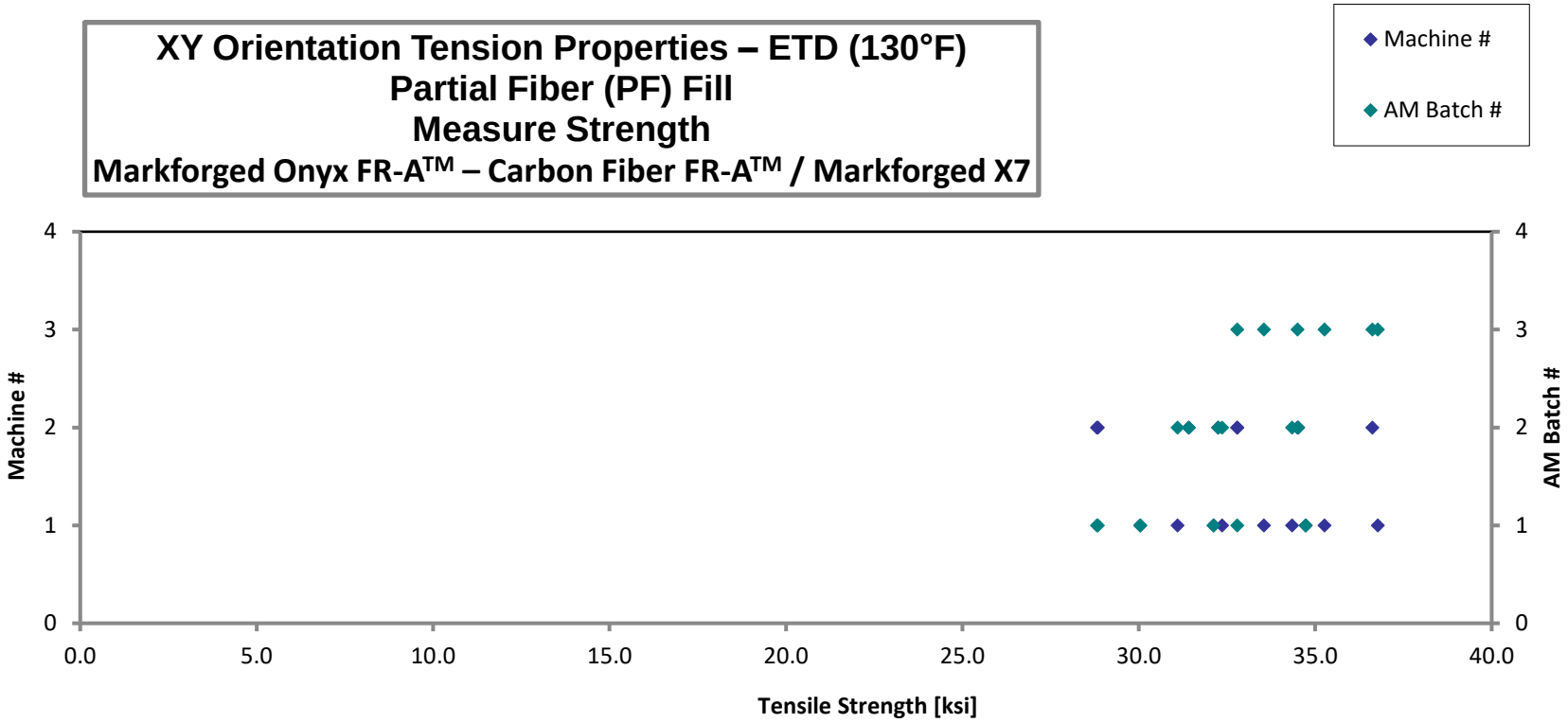

XY Orientation Tension Properties – RTD (70°F)
Partial Fiber (PF) Fill
Measured Modulus
Markforged Onyx FR-A™ – Carbon Fiber FR-A™ / Markforged X7
Machine #
AM Batch #
Machine #
AM Batch #
0
1
2
3
4
0.00
0.50
1.00
1.50
2.00
2.50
3.00
3.50
Tensile Modulus [Msi]

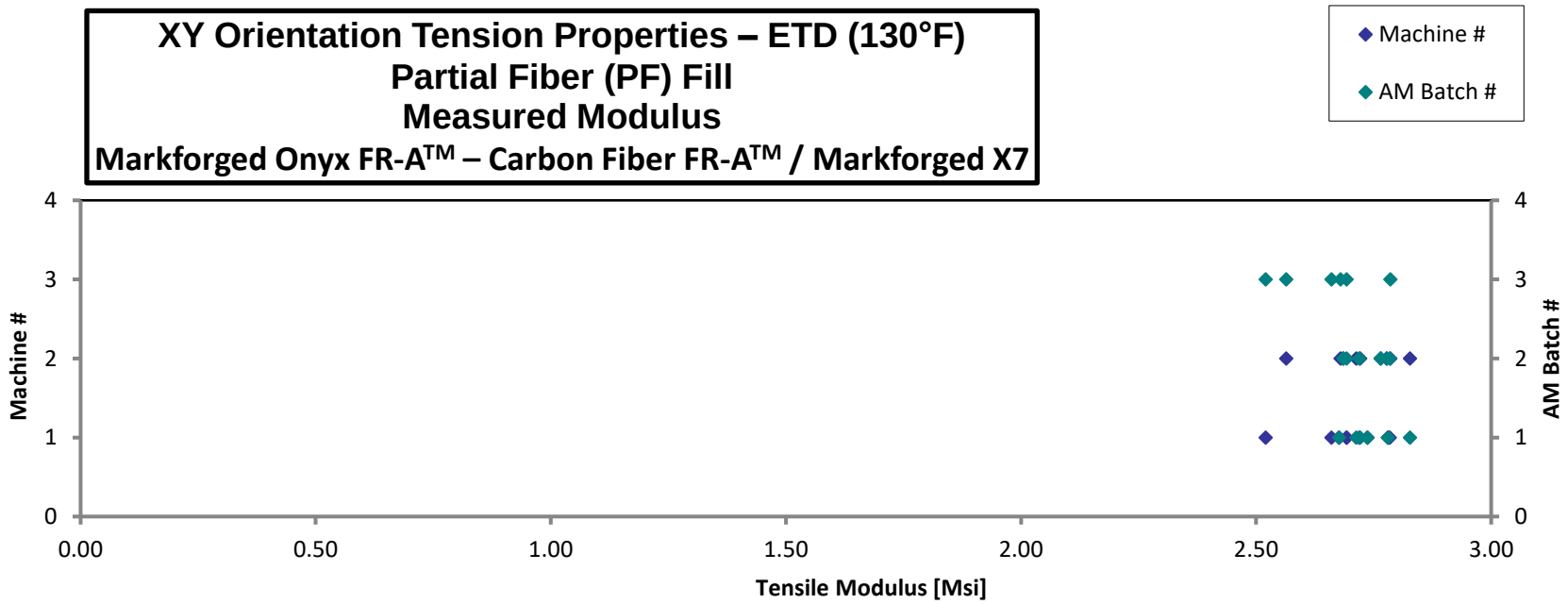

XY Orientation Tension Properties – RTD (70°F)
Partial Fiber (PF) Fill
Measured Poisson's Ratio
Markforged Onyx FR-A™ – Carbon Fiber FR-A™ / Markforged X7
Machine #
AM Batch #
Machine #
AM Batch #
Poisson's Ratio
0.00
0.10
0.20
0.30
0.40
0.50
0.60
0
1
2
3
4

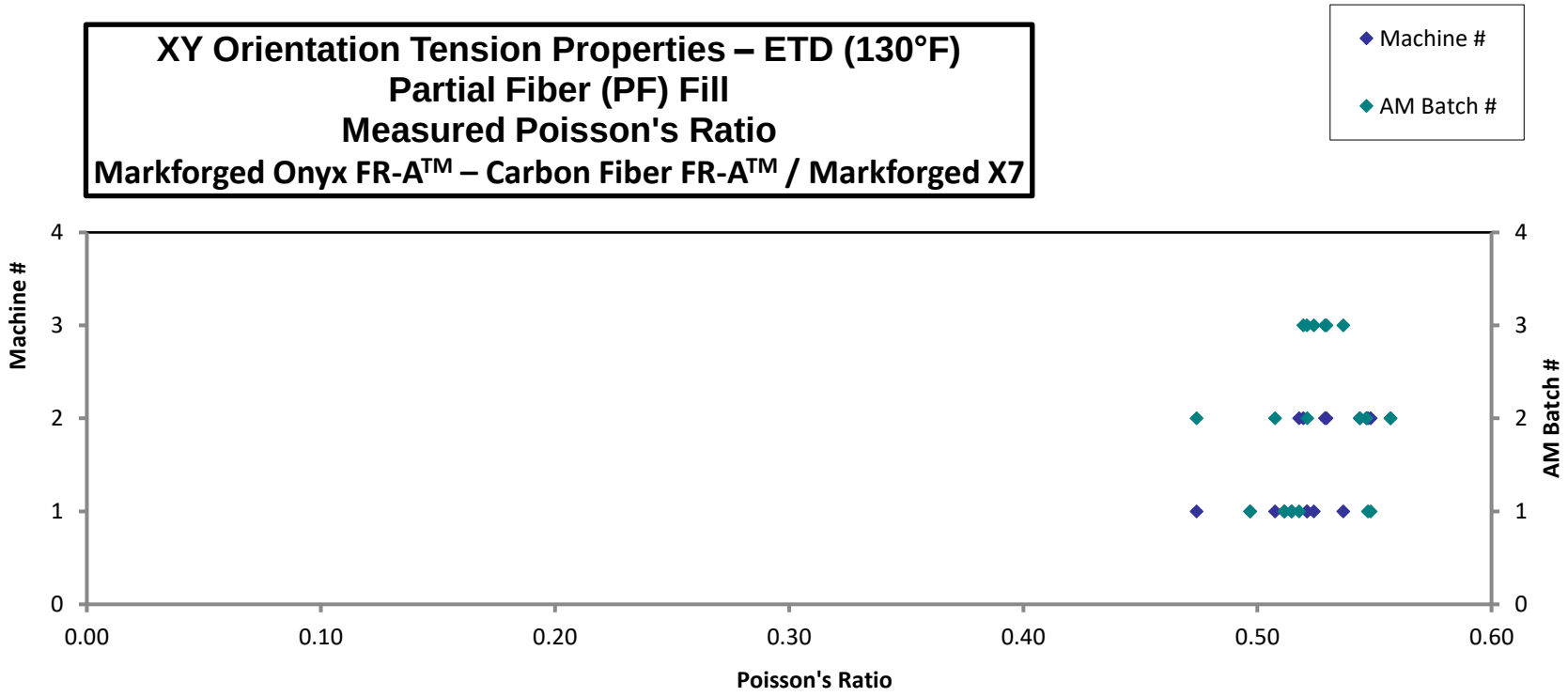
4.1.3 **ETD Condition**

XY Orientation Tension Properties – ETD (130°F)
Partial Fiber (PF) Fill
Strength & Modulus
Markforged Onyx FR-A™ – Carbon Fiber FR-A™ / Markforged X7

Specimen Number	AM Batch #	Machine #	Avg. Specimen Thickness [in]	Tensile Strength [ksi]	Tensile Modulus [Msi]	Poisson's Ratio	Failure Mode
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M1-P42981-XY-T-11-ETD-PF-1	1	1	0.140	34.73	2.780	0.497	M(A,L)WB
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M1-P44320-XY-T-12-ETD-PF-2	1	1	0.144	30.04	2.677	0.515	AWB
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M1-P44531-XY-T-13-ETD-PF-3	1	1	0.142	32.12	2.737	0.512	M(A,L)WB
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M2-P42495-XY-T-11-ETD-PF-1	1	2	0.136	28.82	2.827	0.548	M(A,L)AT
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M2-P46114-XY-T-12-ETD-PF-2	1	2	0.141	32.79	2.713	0.518	AAT
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M2-P42916-XY-T-13-ETD-PF-3	1	2	0.140	28.84	2.721	0.547	M(A,L)AT
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-B-M1-P41009-XY-T-11-ETD-PF-1	2	1	0.137	34.35	2.785	0.474	M(A,L)WB
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-B-M1-P39839-XY-T-12-ETD-PF-2	2	1	0.141	32.36	2.692	0.508	M(A,L)WT
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-B-M1-P40117-XY-T-13-ETD-PF-3	2	1	0.140	31.09	2.719	0.521	M(A,L)WB
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-B-M2-P46418-XY-T-11-ETD-PF-1	2	2	0.140	31.41	2.778	0.557	AWT
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-B-M2-P38143-XY-T-12-ETD-PF-2	2	2	0.140	34.52	2.765	0.544	M(A,L)WT
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-B-M2-P38680-XY-T-13-ETD-PF-3	2	2	0.143	32.25	2.686	0.547	M(A,L)WT
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-C-M1-P48076-XY-T-11-ETD-PF-1	3	1	0.140	36.77	2.692	0.521	AWT
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-C-M1-P49921-XY-T-12-ETD-PF-2	3	1	0.144	33.54	2.521	0.537	M(A,L)WB
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-C-M1-P47955-XY-T-13-ETD-PF-3	3	1	0.142	35.26	2.660	0.524	M(A,L)WT
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-C-M2-P47970-XY-T-11-ETD-PF-1	3	2	0.141	34.50	2.679	0.529	M(A,L)WT
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-C-M2-P49961-XY-T-12-ETD-PF-2	3	2	0.144	32.79	2.564	0.530	AWT
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-C-M2-P49458-XY-T-13-ETD-PF-3	3	2	0.142	36.62	2.785	0.520	M(A,L)WB
		Average	**0.141**	**32.93**	**2.710**	**0.525**	
		Standard Dev.		**2.346**	**0.077**	**0.020**	
		Coeff. of Var. [%]		**7.123**	**2.850**	**3.905**	
		Min.	**0.136**	**28.82**	**2.521**	**0.474**	
		Max.	**0.144**	**36.77**	**2.827**	**0.557**	
		Number of Spec.	**18**	**18**	**18**	**18**	


XY Orientation Tension Properties – ETD (130°F)
Partial Fiber (PF) Fill
Measure Strength
Markforged Onyx FR-A™ – Carbon Fiber FR-A™ / Markforged X7
Machine #
AM Batch #
Machine #
AM Batch #
Tensile Strength [ksi]
0
1
2
3
4
0.0
5.0
10.0
15.0
20.0
25.0
30.0
35.0
40.0

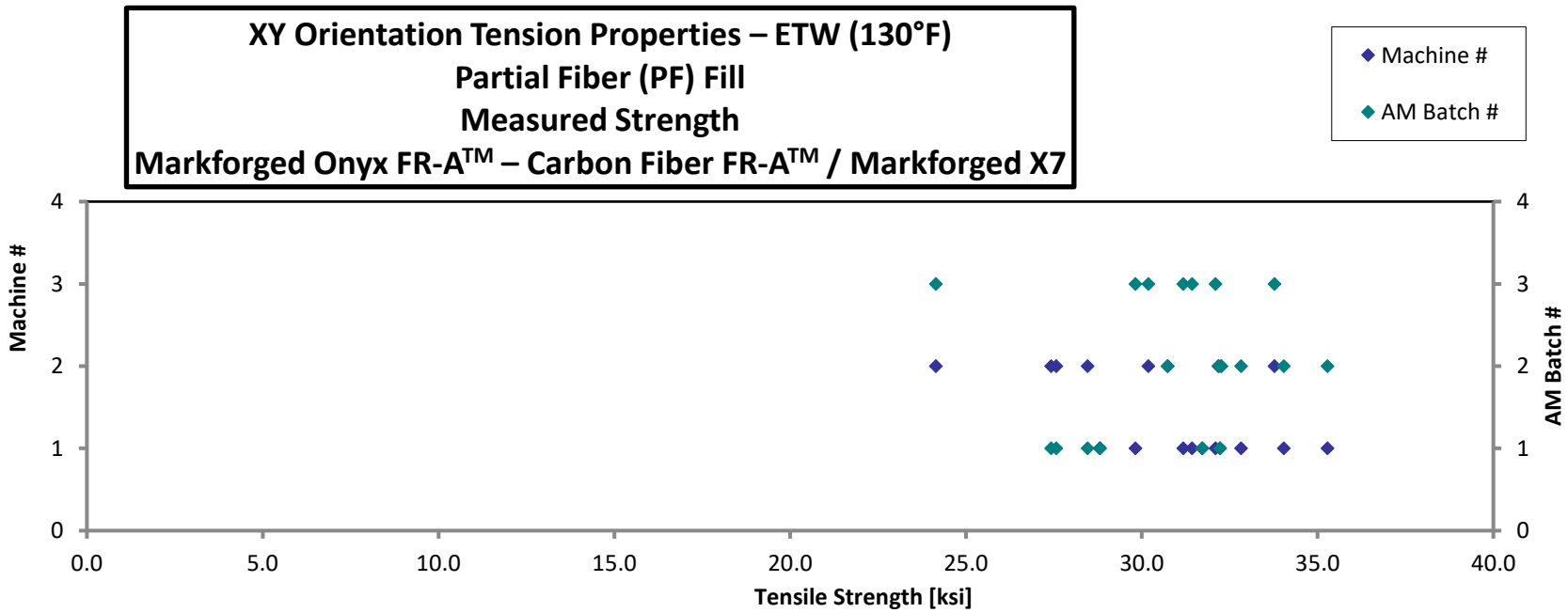

XY Orientation Tension Properties – ETD (130°F)
Partial Fiber (PF) Fill
Measured Modulus
Markforged Onyx FR-A™ – Carbon Fiber FR-A™ / Markforged X7
Machine #
AM Batch #
Machine #
AM Batch #
0
1
2
3
4
0.00
0.50
1.00
1.50
2.00
2.50
3.00
Tensile Modulus [Msi]

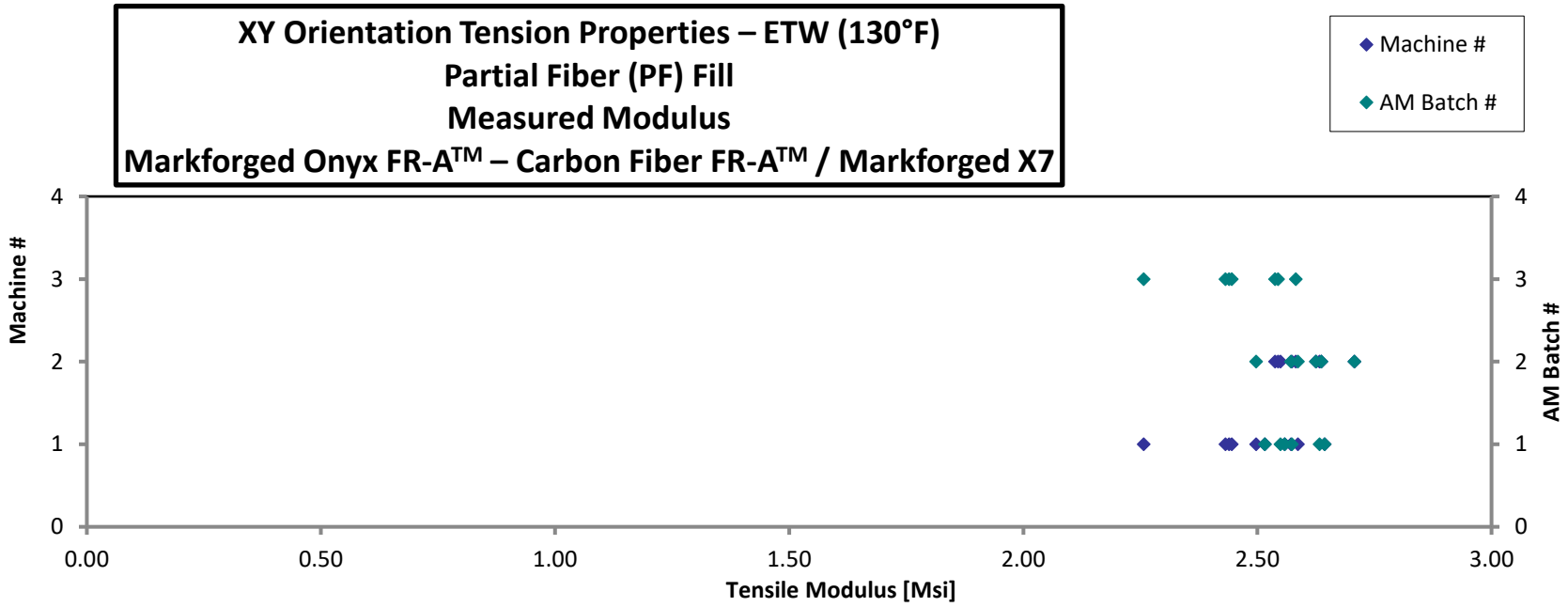

XY Orientation Tension Properties – ETD (130°F)
Partial Fiber (PF) Fill
Measured Poisson's Ratio
Markforged Onyx FR-A™ – Carbon Fiber FR-A™ / Markforged X7
Machine #
AM Batch #
Machine #
AM Batch #
Poisson's Ratio
0
1
2
3
4
0.00
0.10
0.20
0.30
0.40
0.50
0.60

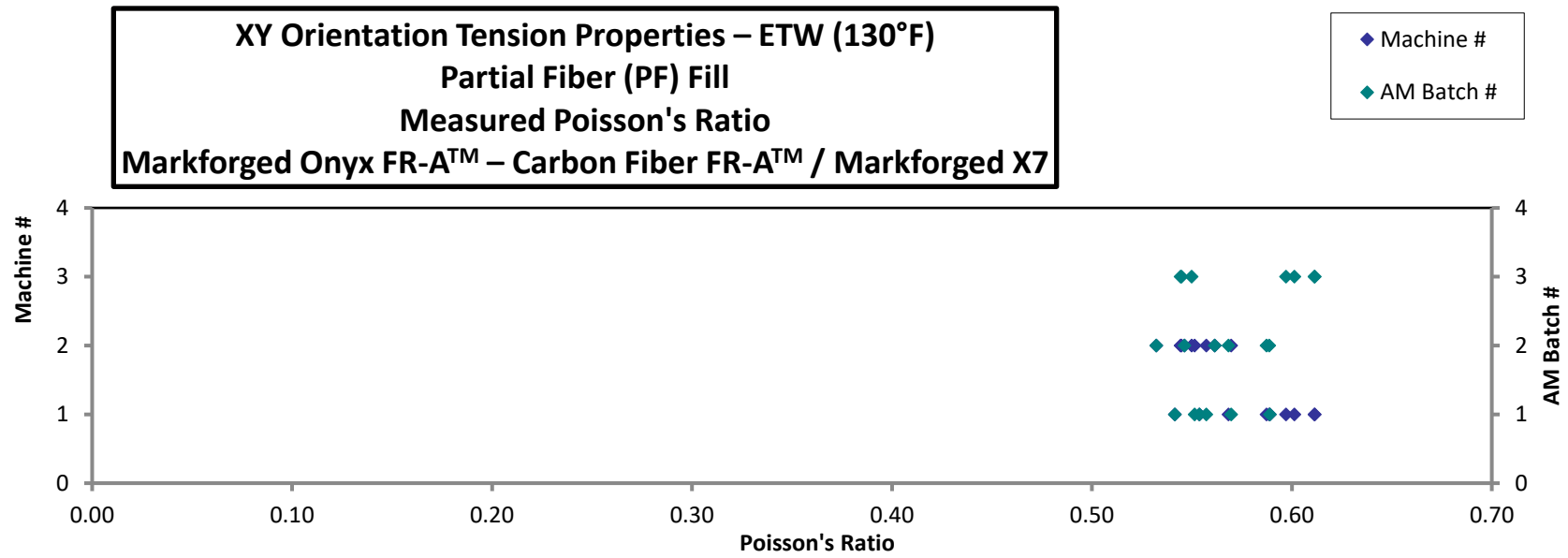
4.1.4 **ETW Condition**

XY Orientation Tension Properties – ETW (130°F)
Partial Fiber (PF) Fill
Strength & Modulus
Markforged Onyx FR-A™ – Carbon Fiber FR-A™ / Markforged X7

Specimen Number	AM Batch #	Machine #	Avg. Specimen Thickness [in]	Tensile Strength [ksi]	Tensile Modulus [Msi]	Poisson's Ratio	Failure Mode
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M1-P30602-XY-T-11-ETW-PF-1	1	1	0.141	32.22	2.558	0.589	M(A,L)AT
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M1-P30543-XY-T-12-ETW-PF-2	1	1	0.144	28.81	2.516	0.554	M(A,L)AB
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M1-P30352-XY-T-13-ETW-PF-3	1	1	0.142	31.72	2.644	0.542	M(A,L)AT
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M2-P69528-XY-T-11-ETW-PF-1	1	2	0.141	27.43	2.633	0.557	LAT
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M2-P69528-XY-T-12-ETW-PF-2	1	2	0.144	27.57	2.549	0.551	LAT
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M2-P69528-XY-T-13-ETW-PF-3	1	2	0.142	28.46	2.574	0.570	M(A,L)AT
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-B-M1-P32848-XY-T-11-ETW-PF-1	2	1	0.136	34.04	2.587	0.568	LAB
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-B-M1-P32236-XY-T-12-ETW-PF-2	2	1	0.135	35.28	2.572	0.587	M(A,D,L)GB
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-B-M1-P32870-XY-T-13-ETW-PF-3	2	1	0.136	32.82	2.497	0.589	M(A,L)GM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-B-M2-P56064-XY-T-11-ETW-PF-1	2	2	0.136	32.26	2.707	0.546	LAB
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-B-M2-P32235-XY-T-12-ETW-PF-2	2	2	0.136	30.73	2.625	0.561	M(A,L)WB
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-B-M2-P32871-XY-T-13-ETW-PF-3	2	2	0.136	32.19	2.636	0.532	LAB
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-C-M1-P35473-XY-T-11-ETW-PF-1	3	1	0.139	32.10	2.439	0.611	M(A,L)WT
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-C-M1-P35360-XY-T-12-ETW-PF-2	3	1	0.142	29.82	2.257	0.611	M(A,L)GM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-C-M1-P35272-XY-T-13-ETW-PF-3	3	1	0.138	31.43	2.446	0.597	M(A,L)WB
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-C-M1-P35650-XY-T-13-ETW-PF-SP	3	1	0.139	31.18	2.432	0.601	M(A,L)GM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-C-M2-P35422-XY-T-11-ETW-PF-1	3	2	0.143	24.14	2.538	0.550	LAT
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-C-M2-P35359-XY-T-12-ETW-PF-2	3	2	0.144	30.19	2.582	0.545	LAT
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-C-M2-P34965-XY-T-13-ETW-PF-SP	3	2	0.143	33.77	2.544	0.544	LAT
		Average	**0.140**	**30.85**	**2.544**	**0.569**	
		Standard Dev.		**2.682**	**0.101**	**0.025**	
		Coeff. of Var. [%]		**8.695**	**3.966**	**4.438**	
		Min.	**0.135**	**24.14**	**2.257**	**0.532**	
		Max.	**0.144**	**35.28**	**2.707**	**0.611**	
		Number of Spec.	**19**	**19**	**19**	**19**	


XY Orientation Tension Properties – ETW (130°F)
Partial Fiber (PF) Fill
Measured Strength
Markforged Onyx FR-A™ – Carbon Fiber FR-A™ / Markforged X7
Machine #
AM Batch #
Machine #
AM Batch #
Tensile Strength [ksi]
0.0
5.0
10.0
15.0
20.0
25.0
30.0
35.0
40.0
0
1
2
3
4


XY Orientation Tension Properties – ETW (130°F)
Partial Fiber (PF) Fill
Measured Modulus
Markforged Onyx FR-A™ – Carbon Fiber FR-A™ / Markforged X7
Machine #
AM Batch #
Machine #
AM Batch #
0
1
2
3
4
0.00
0.50
1.00
1.50
2.00
2.50
3.00
Tensile Modulus [Msi]

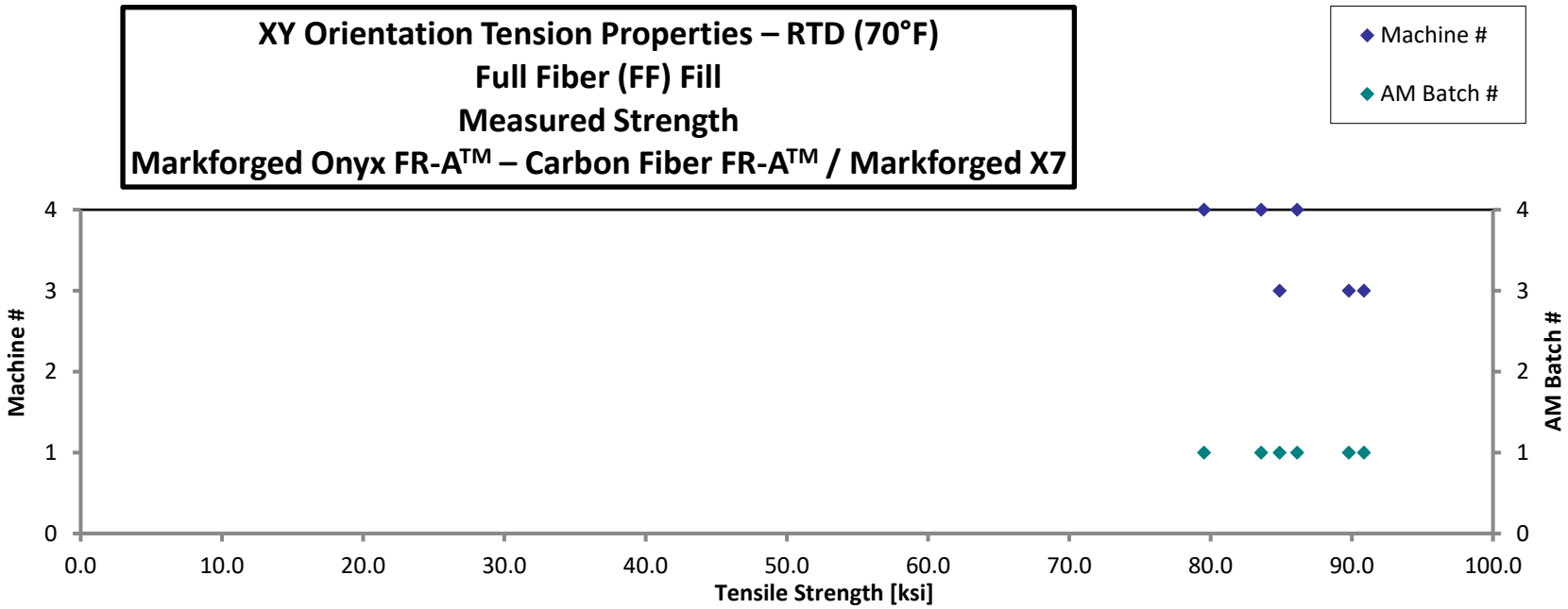

XY Orientation Tension Properties – ETW (130°F)
Partial Fiber (PF) Fill
Measured Poisson's Ratio
Markforged Onyx FR-A™ – Carbon Fiber FR-A™ / Markforged X7
Machine #
AM Batch #
Machine #
AM Batch #
0
1
2
3
4
0.00
0.10
0.20
0.30
0.40
0.50
0.60
0.70
Poisson's Ratio

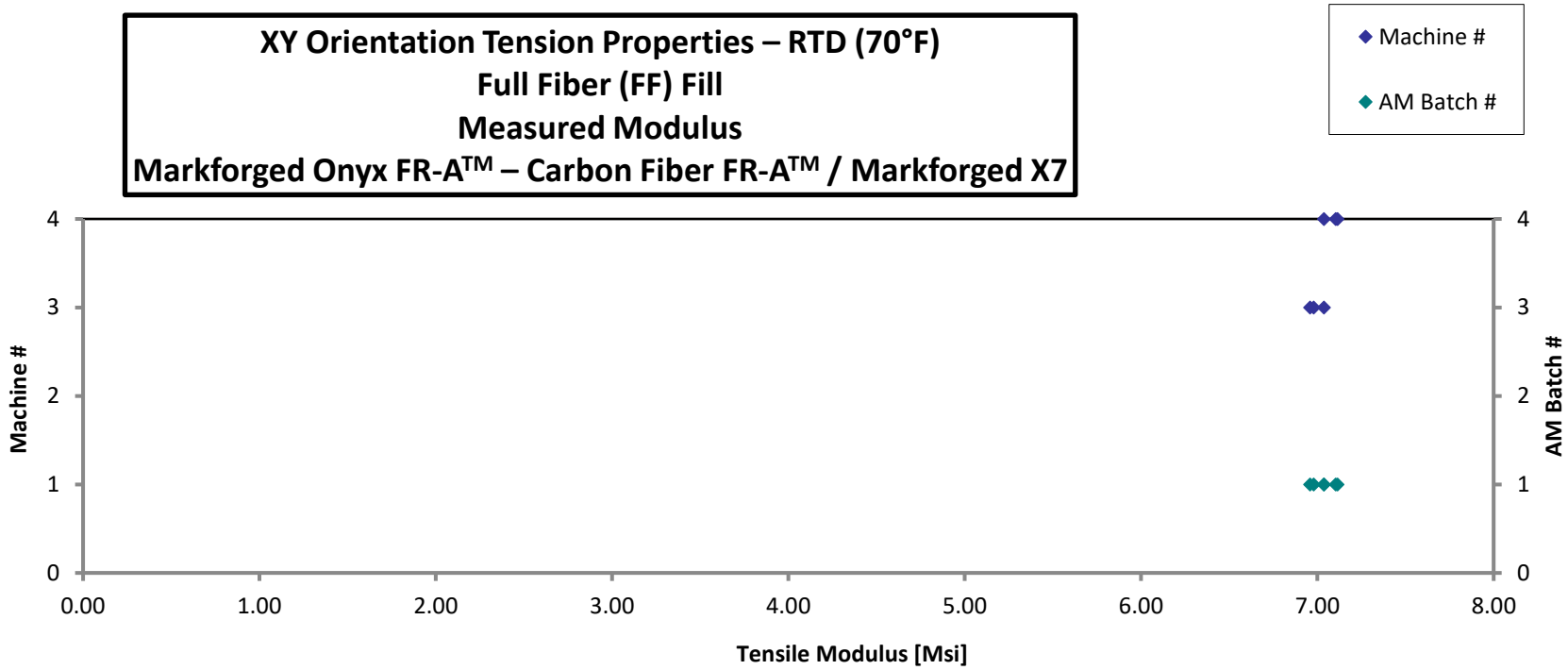
4.2 XY FF Tension Properties

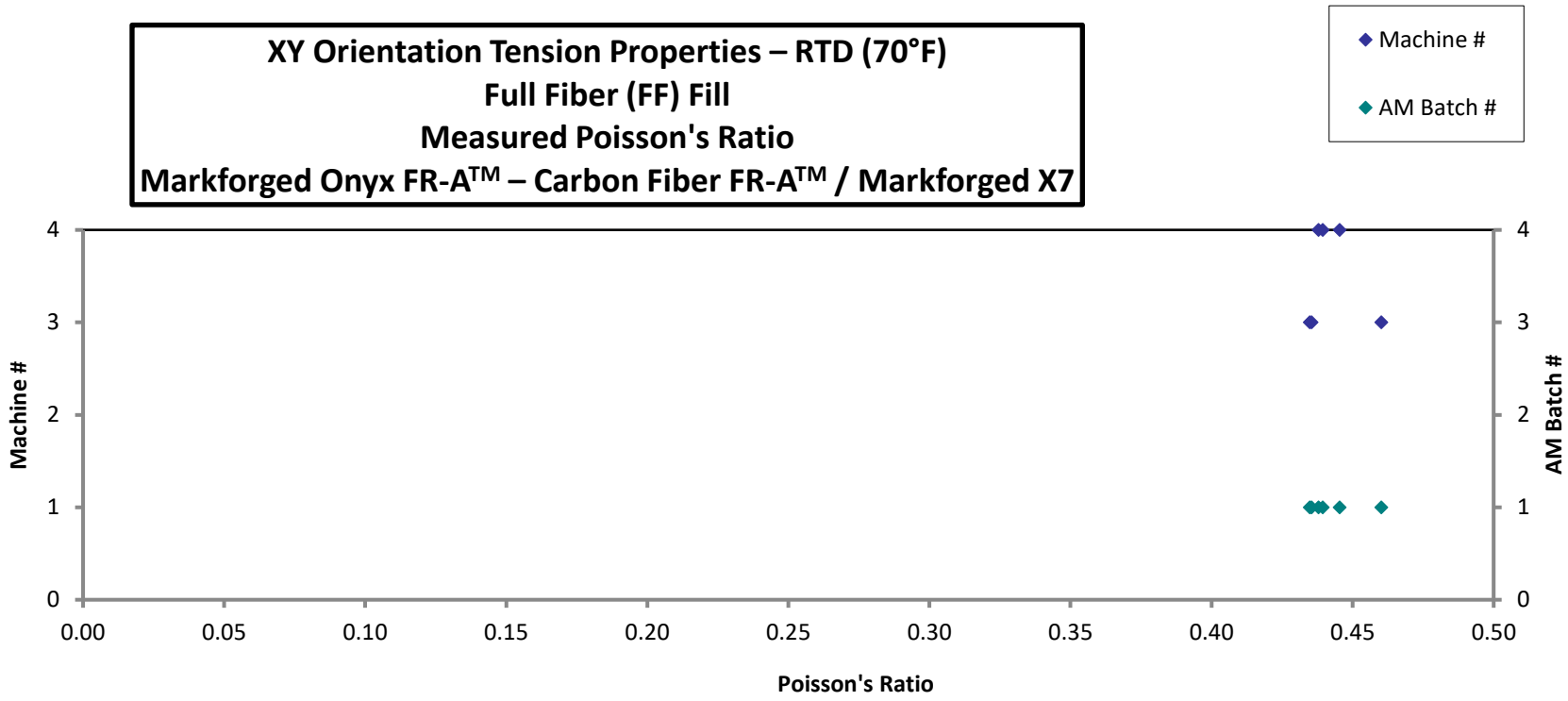
4.2.1 RTD Condition

XY Orientation Tension Properties – RTD (70°F)
Full Fiber (FF) Fill
Strength & Modulus
Markforged Onyx FR-A™ – Carbon Fiber FR-A™ / Markforged X7

Specimen Number	AM Batch #	Machine #	Tensile Strength [ksi]	Tensile Modulus [Msi]	Poisson's Ratio	Avg. Specimen Thickness [in]	Failure Mode
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M3-P34059-XY-T-11-RTD-FF-1[a]	1	3	89.79	6.979	0.460	0.141	AWB
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M3-P34369-XY-T-12-RTD-FF-2	1	3	90.86	7.038	0.435	0.141	AWT
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M3-P34051-XY-T-13-RTD-FF-3	1	3	84.89	6.958	0.435	0.141	M(A,L)WB, LAB
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M4-P42161-XY-T-11-RTD-FF-1	1	4	79.54	7.114	0.445	0.139	AGM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M4-P42319-XY-T-12-RTD-FF-2	1	4	83.58	7.037	0.438	0.140	SGM, M(A,L)WT
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M4-P41548-XY-T-13-RTD-FF-3	1	4	86.13	7.104	0.439	0.139	M(A,L)WB
		Average	**85.80**	**7.038**	**0.442**	**0.140**	
		Standard Dev.	**4.161**	**0.063**	**0.010**		
		Coeff. of Var. [%]	**4.850**	**0.899**	**2.169**		
		Min.	**79.54**	**6.958**	**0.435**	**0.139**	
		Max.	**90.86**	**7.114**	**0.460**	**0.141**	
		Number of Spec.	**6**	**6**	**6**	**6**	


XY Orientation Tension Properties – RTD (70°F)
Full Fiber (FF) Fill
Measured Strength
Markforged Onyx FR-A™ – Carbon Fiber FR-A™ / Markforged X7
Machine #
AM Batch #
Machine #
AM Batch #
Tensile Strength [ksi]
0
1
2
3
4
0.0
10.0
20.0
30.0
40.0
50.0
60.0
70.0
80.0
90.0
100.0


XY Orientation Tension Properties – RTD (70°F)
Full Fiber (FF) Fill
Measured Modulus
Markforged Onyx FR-A™ – Carbon Fiber FR-A™ / Markforged X7
Machine #
AM Batch #
Machine #
AM Batch #
Tensile Modulus [Msi]
0.00
1.00
2.00
3.00
4.00
5.00
6.00
7.00
8.00
0
1
2
3
4


XY Orientation Tension Properties – RTD (70°F)
Full Fiber (FF) Fill
Measured Poisson's Ratio
Markforged Onyx FR-A™ – Carbon Fiber FR-A™ / Markforged X7
Machine #
AM Batch #
Machine #
AM Batch #
Poisson's Ratio
0
1
2
3
4
0.00
0.05
0.10
0.15
0.20
0.25
0.30
0.35
0.40
0.45
0.50

4.3 XZ PF Tension Properties

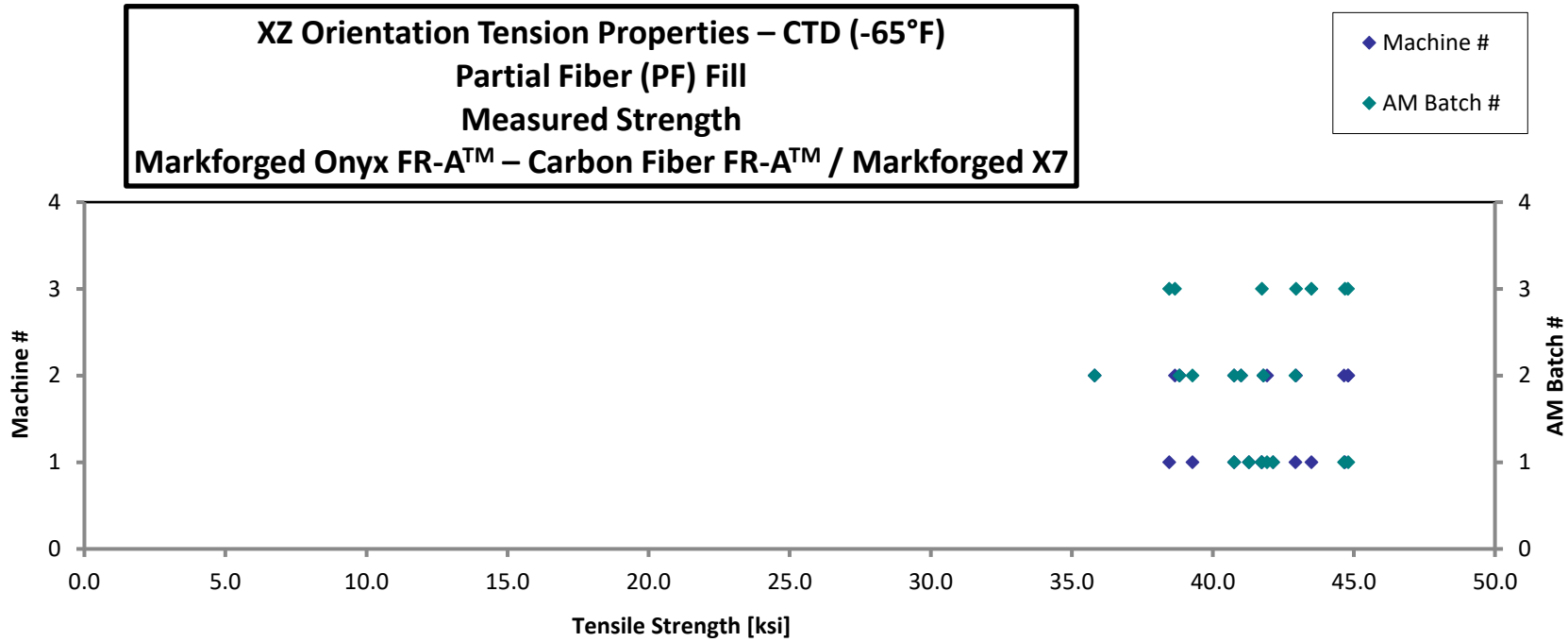
4.3.1 CTD Condition

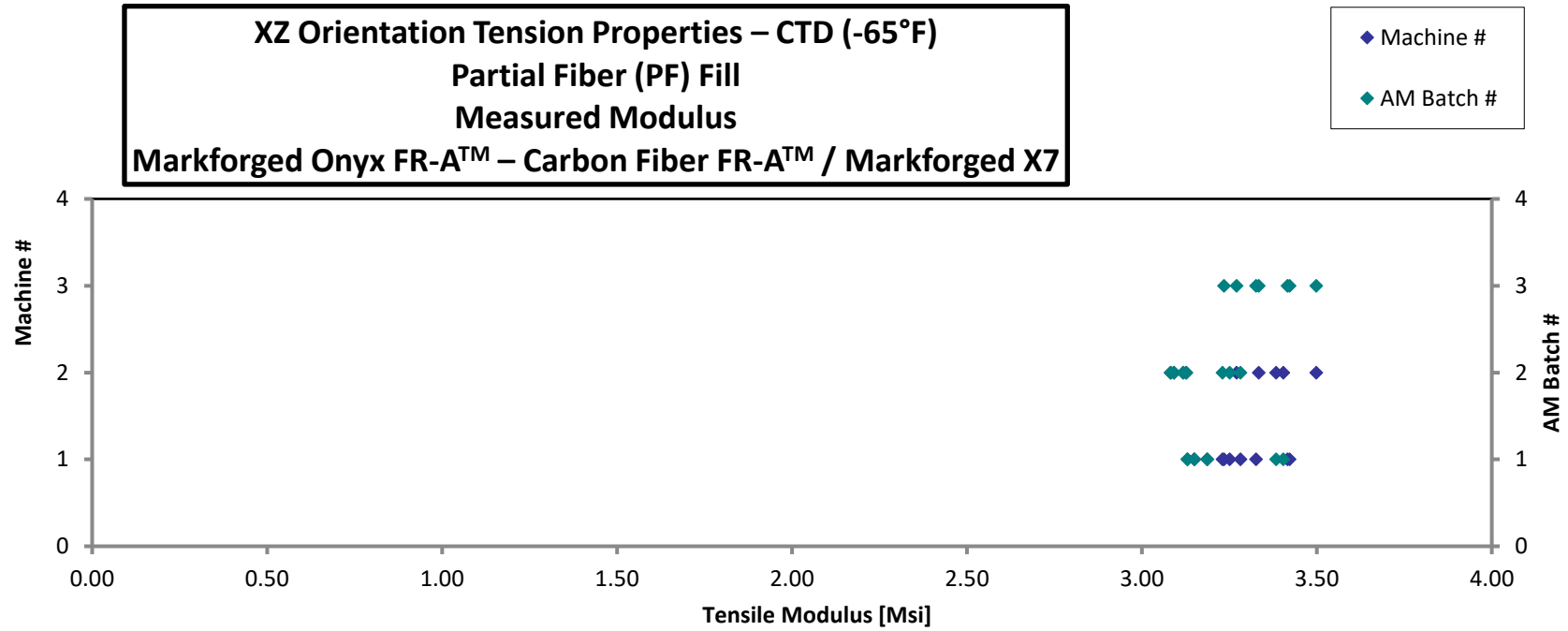
XZ Orientation Tension Properties – CTD (-65°F)
Partial Fiber (PF) Fill
Measured Strength
Markforged Onyx FR-A™ – Carbon Fiber FR-A™ / Markforged X7

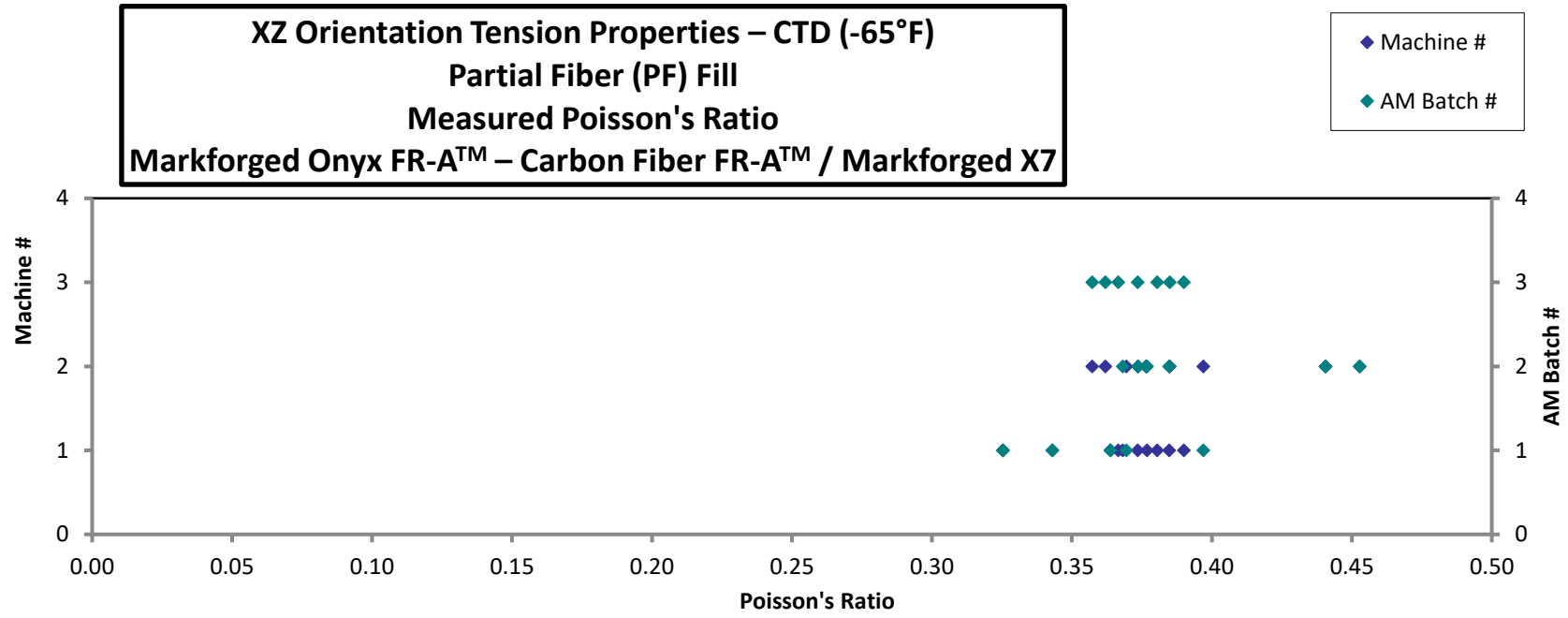
Specimen Number	AM Batch #	Machine #	Avg. Specimen Thickness [in]	Tensile Strength [ksi]	Tensile Modulus [Msi]	Poisson's Ratio	Failure Mode
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M1-P31153-XZ-T-11-CTD-PF-1	1	1	0.143	41.73	3.131	0.343	M(L,S)GM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M1-P29959-XZ-T-12-CTD-PF-2	1	1	0.142	41.28	3.150	0.364	SGM, LWT
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M1-P32097-XZ-T-13-CTD-PF-3	1	1	0.144	42.14	3.187	0.325	SGM, LWB, LAT
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M2-P31152-XZ-T-11-CTD-PF-1*	1	2	0.142	44.65			SGM, LAB
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M2-P29993-XZ-T-12-CTD-PF-2*	1	2	0.141	40.76			SGM, LAT
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M2-P30182-XZ-T-13-CTD-PF-3	1	2	0.141	41.92	3.404	0.369	SGM, LAB
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M2-P31697-XZ-T-13-CTD-PF-SP	1	2	0.141	44.81	3.384	0.397	M(L,S)GM. LWB
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-B-M1-P39037-XZ-T-11-CTD-PF-1	2	1	0.141	40.75	3.282	0.368	SGM, LAB
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-B-M1-P32267-XZ-T-12-CTD-PF-2	2	1	0.142	39.28	3.231	0.385	SGM, M(A,L)AB
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-B-M1-P41099-XZ-T-13-CTD-PF-3	2	1	0.139	42.93	3.251	0.377	SGM, LAT
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-B-M2-P55140-XZ-T-11-CTD-PF-1	2	2	0.142	41.00	3.091	0.374	SGM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-B-M2-P58165-XZ-T-12-CTD-PF-2	2	2	0.140	38.83	3.083	0.377	SGM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-B-M2-P32096-XZ-T-13-CTD-PF-3	2	2	0.142	35.81	3.127	0.453	SGM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-B-M2-P56216-XZ-T-13-CTD-PF-6	2	2	0.141	41.80	3.118	0.441	SGM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-C-M1-P35876-XZ-T-11-CTD-PF-1	3	1	0.142	44.69	3.422	0.380	SGM, LAB
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-C-M1-P49737-XZ-T-12-CTD-PF-2	3	1	0.142	43.49	3.235	0.373	SGM, LAB
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-C-M1-P36474-XZ-T-13-CTD-PF-3	3	1	0.143	38.46	3.416	0.367	SGM, LAT
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-C-M1-P35346-XZ-T-13-CTD-PF-6	3	1	0.142	41.75	3.326	0.390	SGM, LAB
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-C-M2-P34942-XZ-T-11-CTD-PF-1	3	2	0.139	44.79	3.334	0.362	SGM, LAB
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-C-M2-P36096-XZ-T-12-CTD-PF-2	3	2	0.137	38.66	3.271	0.357	SGM, LAT
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-C-M2-P36471-XZ-T-13-CTD-PF-3	3	2	0.137	42.95	3.499	0.385	SGM, LAB

*Tensile Modulus and Poisson's ratio not reported due to unusaully high value

Average	**0.141**	**41.55**	**3.260**	**0.378**
Standard Dev.		**2.386**	**0.126**	**0.029**
Coeff. of Var. [%]		**5.744**	**3.877**	**7.719**
Min.	**0.137**	**35.81**	**3.083**	**0.325**
Max.	**0.144**	**44.81**	**3.499**	**0.453**
Number of Spec.	**21**	**21**	**19**	**19**


XZ Orientation Tension Properties – CTD (-65°F)
Partial Fiber (PF) Fill
Measured Strength
Markforged Onyx FR-A™ – Carbon Fiber FR-A™ / Markforged X7
Machine #
AM Batch #
Machine #
AM Batch #
Tensile Strength [ksi]
0
1
2
3
4
0.0
5.0
10.0
15.0
20.0
25.0
30.0
35.0
40.0
45.0
50.0


XZ Orientation Tension Properties – CTD (-65°F)
Partial Fiber (PF) Fill
Measured Modulus
Markforged Onyx FR-A™ – Carbon Fiber FR-A™ / Markforged X7
Machine #
AM Batch #
Machine #
AM Batch #
Tensile Modulus [Msi]
0
1
2
3
4
0.00
0.50
1.00
1.50
2.00
2.50
3.00
3.50
4.00

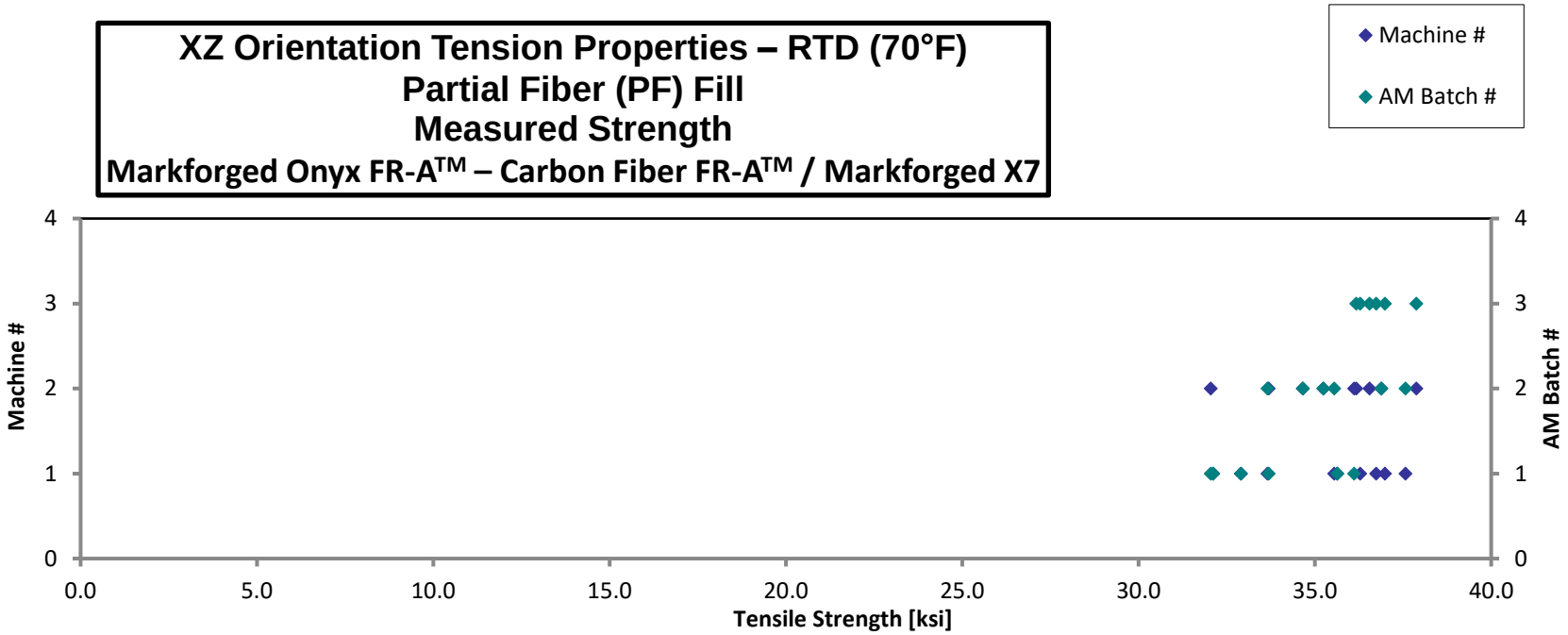

XZ Orientation Tension Properties – CTD (-65°F)
Partial Fiber (PF) Fill
Measured Poisson's Ratio
Markforged Onyx FR-A™ – Carbon Fiber FR-A™ / Markforged X7
Machine #
AM Batch #
Machine #
AM Batch #
Poisson's Ratio
0
1
2
3
4
0.00
0.05
0.10
0.15
0.20
0.25
0.30
0.35
0.40
0.45
0.50

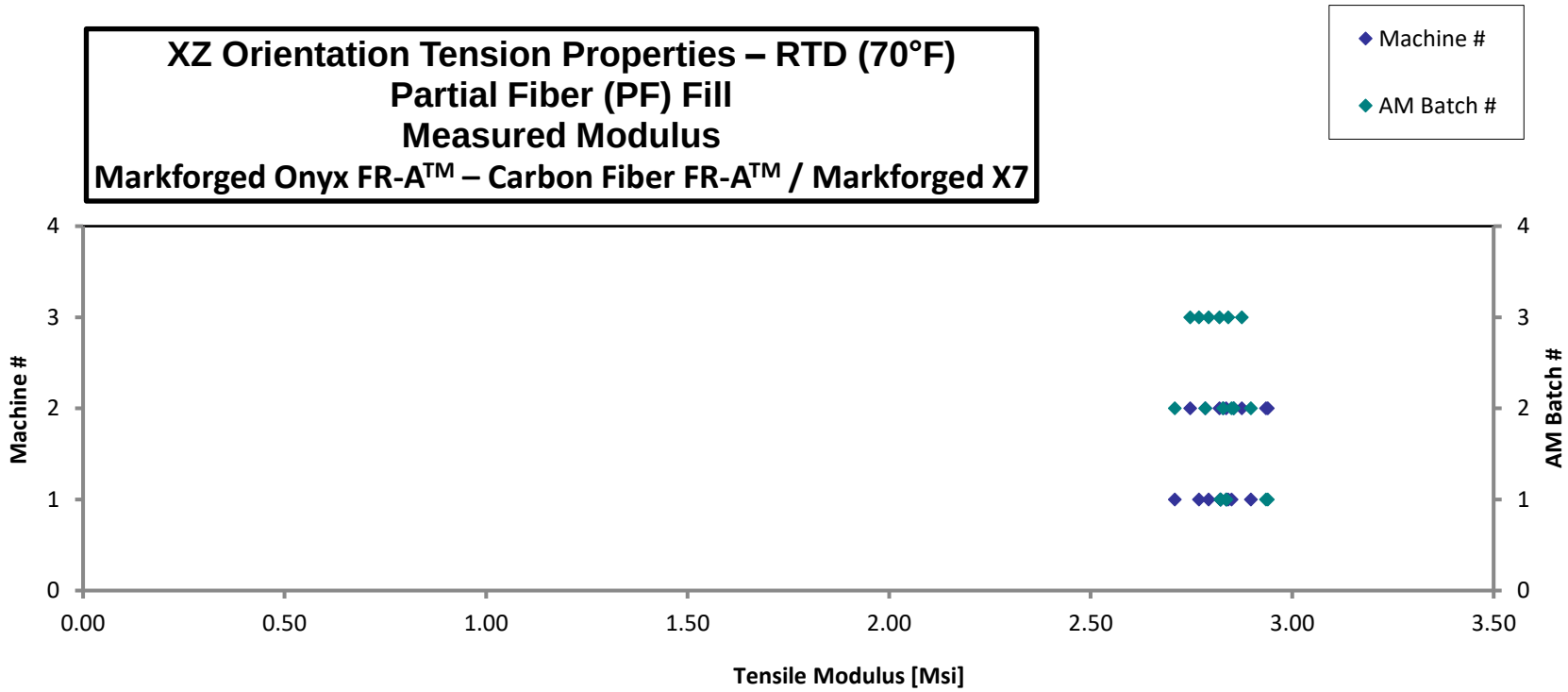
4.3.2 **RTD Condition**

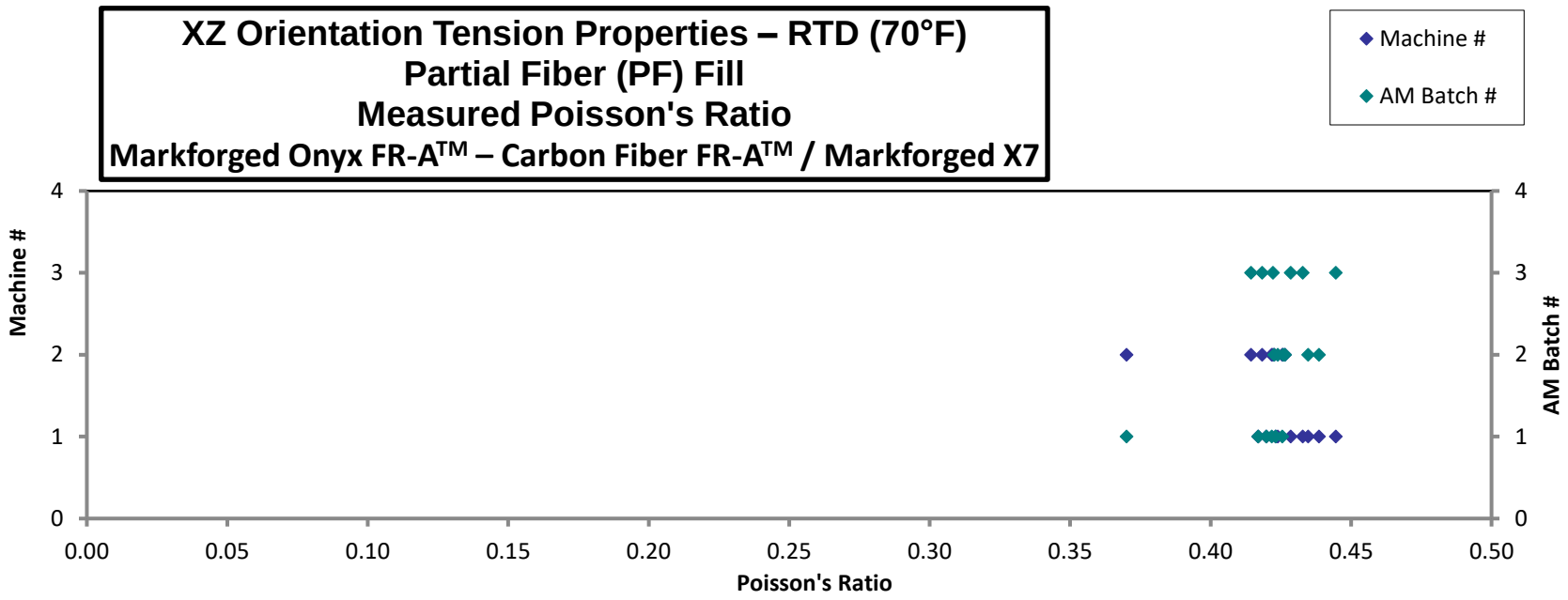
XZ Orientation Tension Properties – RTD (70°F)
Partial Fiber (PF) Fill
Strength & Modulus
Markforged Onyx FR-A™ – Carbon Fiber FR-A™ / Markforged X7

Specimen Number	AM Batch #	Machine #	Avg. Specimen Thickness [in]	Tensile Strength [ksi]	Tensile Modulus [Msi]	Poisson's Ratio	Failure Mode
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M1-P31455-XZ-T-11-RTD-PF-1	1	1	0.142	35.63	2.837	0.423	SGM, M(A,L)WB
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M1-P29994-XZ-T-12-RTD-PF-2	1	1	0.141	32.90	2.823	0.420	SGM, LWB
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M1-P30199-XZ-T-13-RTD-PF-3	1	1	0.141	32.11	2.822	0.417	M(L,S)GM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M2-P31456-XZ-T-11-RTD-PF-1	1	2	0.143	32.04	2.836	0.422	SGM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M2-P30074-XZ-T-12-RTD-PF-2	1	2	0.140	33.69	2.935	0.425	SGM, AWT
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M2-P30281-XZ-T-13-RTD-PF-3	1	2	0.141	36.11	2.939	0.370	SGM, M(A,L)WT
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-B-M1-P33244-XZ-T-11-RTD-PF-1	2	1	0.138	35.55	2.709	0.424	SGM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-B-M1-P32763-XZ-T-12-RTD-PF-2	2	1	0.139	33.65	2.850	0.439	SGM, LWB
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-B-M1-P33419-XZ-T-13-RTD-PF-3	2	1	0.138	37.57	2.898	0.435	SGM, LWB
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-B-M2-P33243-XZ-T-11-RTD-PF-1	2	2	0.140	36.88	2.829	0.426	SGM, LWB
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-B-M2-P32762-XZ-T-12-RTD-PF-2	2	2	0.140	34.65	2.855	0.423	SGM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-B-M2-P33417-XZ-T-13-RTD-PF-3	2	2	0.139	35.24	2.784	0.426	SGM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-C-M1-P49394-XZ-T-11-RTD-PF-1	3	1	0.143	36.74	2.841	0.433	SGM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-C-M1-P35121-XZ-T-12-RTD-PF-2	3	1	0.142	36.99	2.769	0.428	SGM, LAT
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-C-M1-P35079-XZ-T-13-RTD-PF-3	3	1	0.142	36.28	2.793	0.445	SGM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-C-M2-P35191-XZ-T-11-RTD-PF-1	3	2	0.141	37.87	2.747	0.414	SGM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-C-M2-P35124-XZ-T-12-RTD-PF-2	3	2	0.139	36.18	2.819	0.418	SGM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-C-M2-P35083-XZ-T-13-RTD-PF-3	3	2	0.139	36.55	2.875	0.422	SGM

Average	**0.140**	**35.37**	**2.831**	**0.423**
Standard Dev.		**1.806**	**0.059**	**0.015**
Coeff. of Var. [%]		**5.106**	**2.094**	**3.601**
Min.	**0.138**	**32.04**	**2.709**	**0.370**
Max.	**0.143**	**37.87**	**2.939**	**0.445**
Number of Spec.	**18**	**18**	**18**	**18**


XZ Orientation Tension Properties – RTD (70°F)
Partial Fiber (PF) Fill
Measured Strength
Markforged Onyx FR-A™ – Carbon Fiber FR-A™ / Markforged X7
Machine #
AM Batch #
Machine #
AM Batch #
Tensile Strength [ksi]
0
1
2
3
4
0.0
5.0
10.0
15.0
20.0
25.0
30.0
35.0
40.0

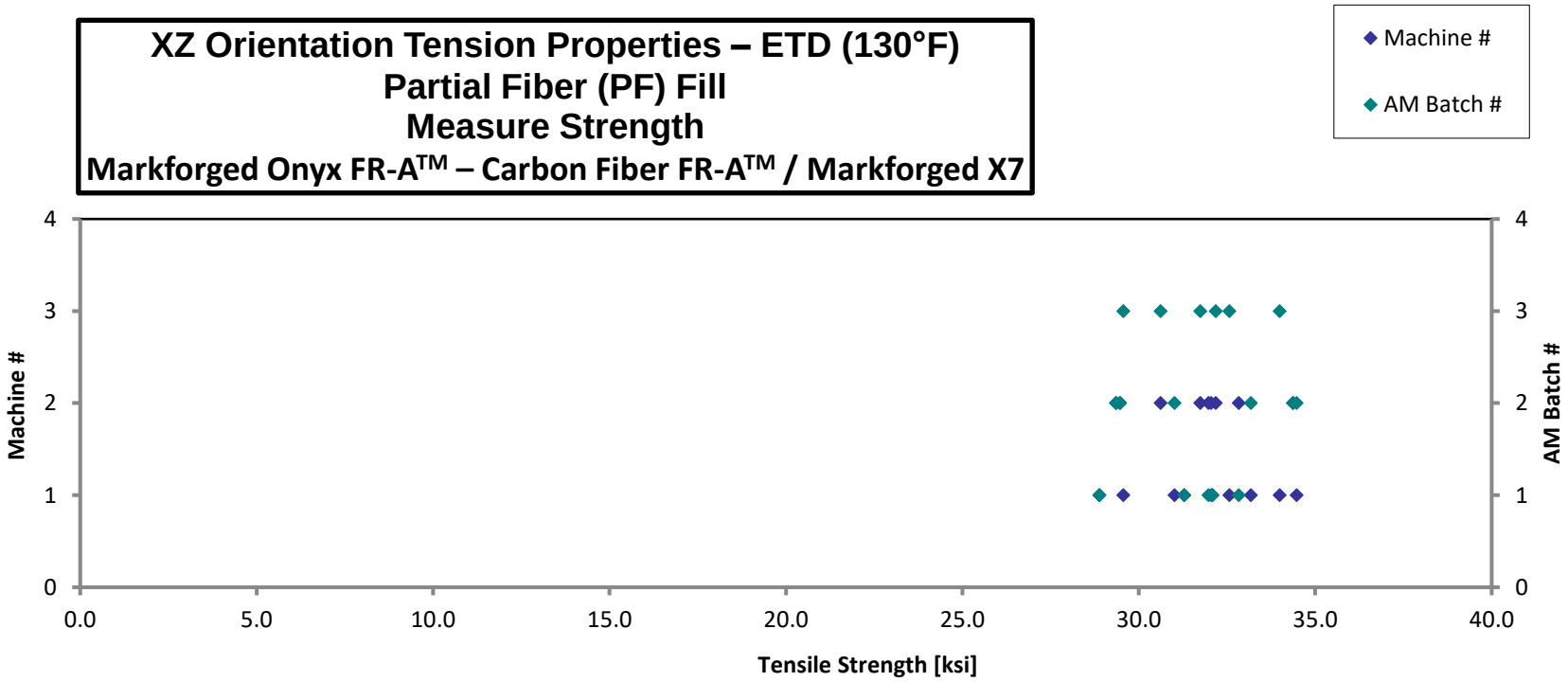

XZ Orientation Tension Properties – RTD (70°F)
Partial Fiber (PF) Fill
Measured Modulus
Markforged Onyx FR-A™ – Carbon Fiber FR-A™ / Markforged X7
Machine #
AM Batch #
Machine #
AM Batch #
Tensile Modulus [Msi]
0
1
2
3
4
0.00
0.50
1.00
1.50
2.00
2.50
3.00
3.50

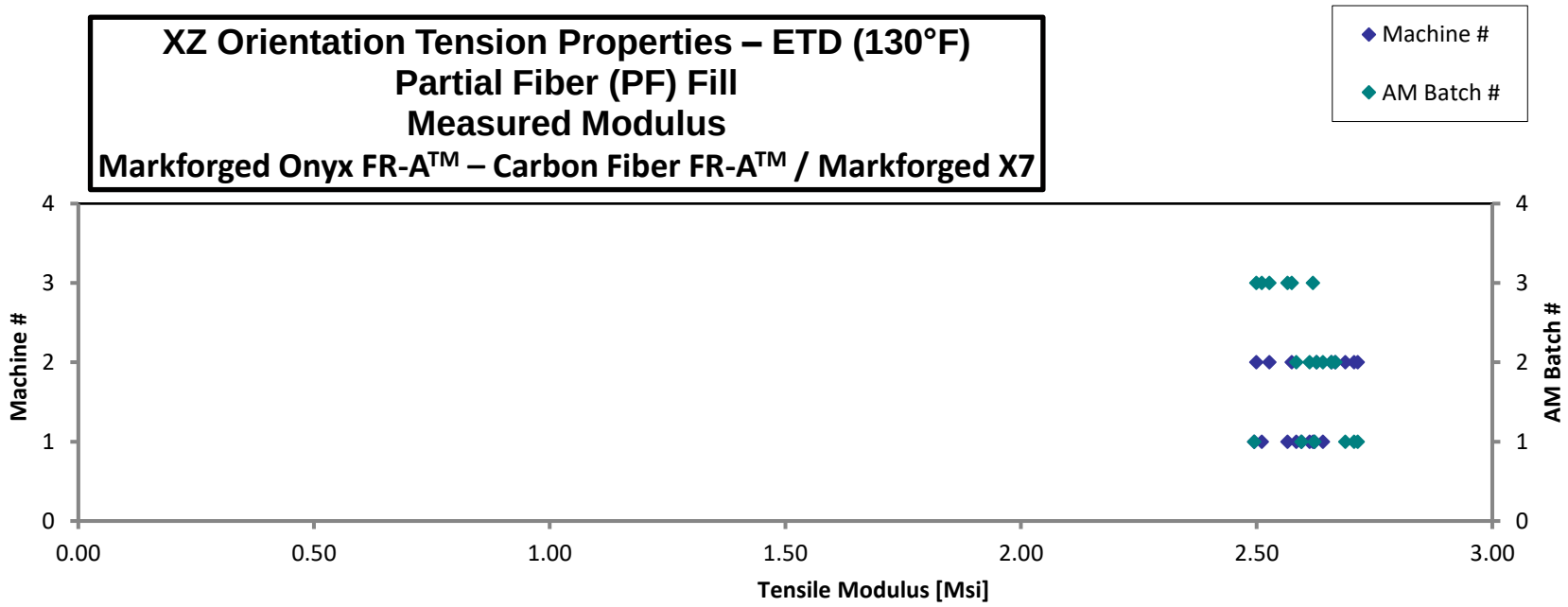

XZ Orientation Tension Properties – RTD (70°F)
Partial Fiber (PF) Fill
Measured Poisson's Ratio
Markforged Onyx FR-A™ – Carbon Fiber FR-A™ / Markforged X7
Machine #
AM Batch #
Machine #
AM Batch #
Poisson's Ratio
0
1
2
3
4
0.00
0.05
0.10
0.15
0.20
0.25
0.30
0.35
0.40
0.45
0.50

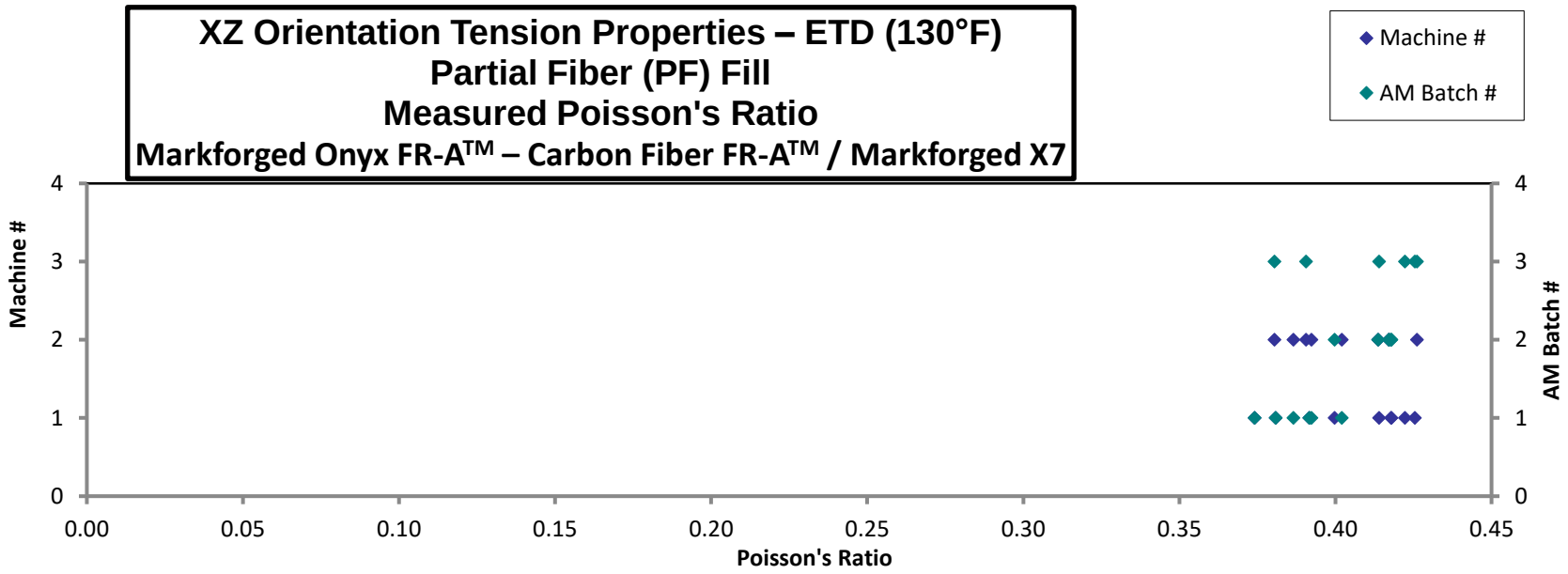
4.3.3 ETD Condition

XZ Orientation Tension Properties – ETD (130°F)
Partial Fiber (PF) Fill
Strength & Modulus
Markforged Onyx FR-A™ – Carbon Fiber FR-A™ / Markforged X7

Specimen Number	AM Batch #	Machine #	Avg. Specimen Thickness [in]	Tensile Strength [ksi]	Tensile Modulus [Msi]	Poisson's Ratio	Failure Mode
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M1-P45491-XZ-T-11-ETD-PF-1	1	1	0.143	28.89	2.623	0.381	SGM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M1-P54144-XZ-T-12-ETD-PF-2	1	1	0.143	32.08	2.595	0.374	SGM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M1-P54708-XZ-T-13-ETD-PF-3	1	1	0.142	31.29	2.495	0.392	SGM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M2-P43600-XZ-T-11-ETD-PF-1	1	2	0.139	32.83	2.715	0.387	SGM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M2-P53725-XZ-T-12-ETD-PF-2	1	2	0.140	31.98	2.707	0.392	SGM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M2-P53540-XZ-T-13-ETD-PF-3	1	2	0.139	32.05	2.688	0.402	SGM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-B-M1-P39520-XZ-T-11-ETD-PF-1	2	1	0.140	34.47	2.584	0.400	SGM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-B-M1-P58774-XZ-T-12-ETD-PF-2	2	1	0.141	31.02	2.613	0.418	SGM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-B-M1-P54969-XZ-T-13-ETD-PF-3	2	1	0.139	33.18	2.640	0.418	SGM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-B-M2-P41419-XZ-T-11-ETD-PF-1	2	2	0.137	34.37	2.667	0.414	SGM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-B-M2-P58165-XZ-T-12-ETD-PF-2	2	2	0.137	29.47	2.627	0.417	SGM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-B-M2-P58063-XZ-T-13-ETD-PF-3	2	2	0.137	29.35	2.659	0.417	SGM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-C-M1-P56820-XZ-T-11-ETD-PF-1	3	1	0.140	33.99	2.511	0.425	SGM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-C-M1-P51459-XZ-T-12-ETD-PF-2	3	1	0.141	32.57	2.565	0.414	SGM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-C-M1-P56904-XZ-T-13-ETD-PF-3	3	1	0.140	29.56	2.620	0.422	SGM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-C-M2-P47926-XZ-T-11-ETD-PF-1	3	2	0.141	30.62	2.527	0.380	SGM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-C-M2-P57301-XZ-T-12-ETD-PF-2	3	2	0.141	32.18	2.500	0.426	SGM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-C-M2-P51396-XZ-T-13-ETD-PF-3	3	2	0.140	31.74	2.575	0.391	SGM
		Average	**0.140**	**31.76**	**2.606**	**0.404**	
		Standard Dev.		**1.708**	**0.068**	**0.017**	
		Coeff. of Var. [%]		**5.379**	**2.624**	**4.242**	
		Min.	**0.137**	**28.89**	**2.495**	**0.374**	
		Max.	**0.143**	**34.47**	**2.715**	**0.426**	
		Number of Spec.	**18**	**18**	**18**	**18**	


XZ Orientation Tension Properties – ETD (130°F)
Partial Fiber (PF) Fill
Measure Strength
Markforged Onyx FR-A™ – Carbon Fiber FR-A™ / Markforged X7
Machine #
AM Batch #
Machine #
AM Batch #
Tensile Strength [ksi]
0
1
2
3
4
0.0
5.0
10.0
15.0
20.0
25.0
30.0
35.0
40.0


XZ Orientation Tension Properties – ETD (130°F)
Partial Fiber (PF) Fill
Measured Modulus
Markforged Onyx FR-A™ – Carbon Fiber FR-A™ / Markforged X7
Machine #
AM Batch #
Machine #
AM Batch #
Tensile Modulus [Msi]
0.00
0.50
1.00
1.50
2.00
2.50
3.00
0
1
2
3
4


XZ Orientation Tension Properties – ETD (130°F)
Partial Fiber (PF) Fill
Measured Poisson's Ratio
Markforged Onyx FR-A™ – Carbon Fiber FR-A™ / Markforged X7
Machine #
AM Batch #
Machine #
AM Batch #
Poisson's Ratio
0.00
0.05
0.10
0.15
0.20
0.25
0.30
0.35
0.40
0.45
0
1
2
3
4

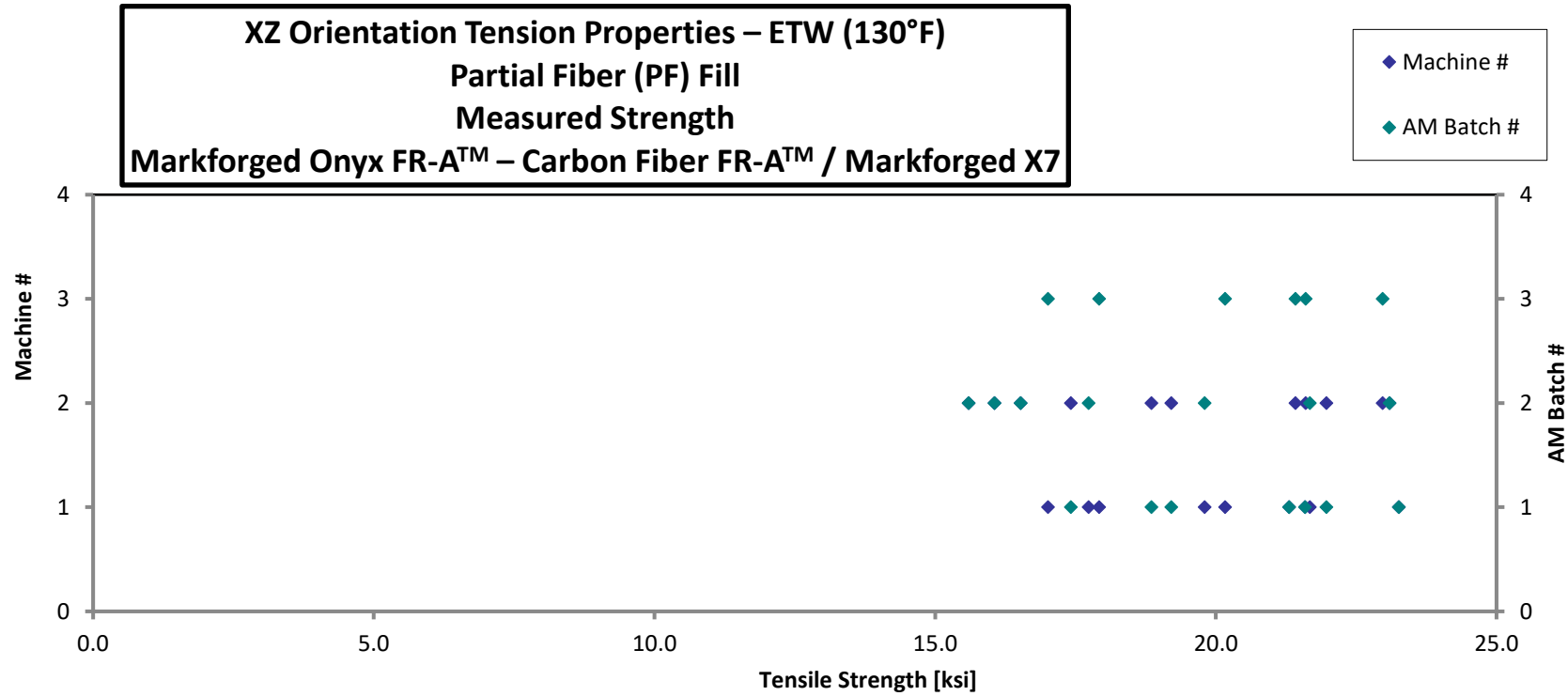
4.3.4 **ETW Condition**

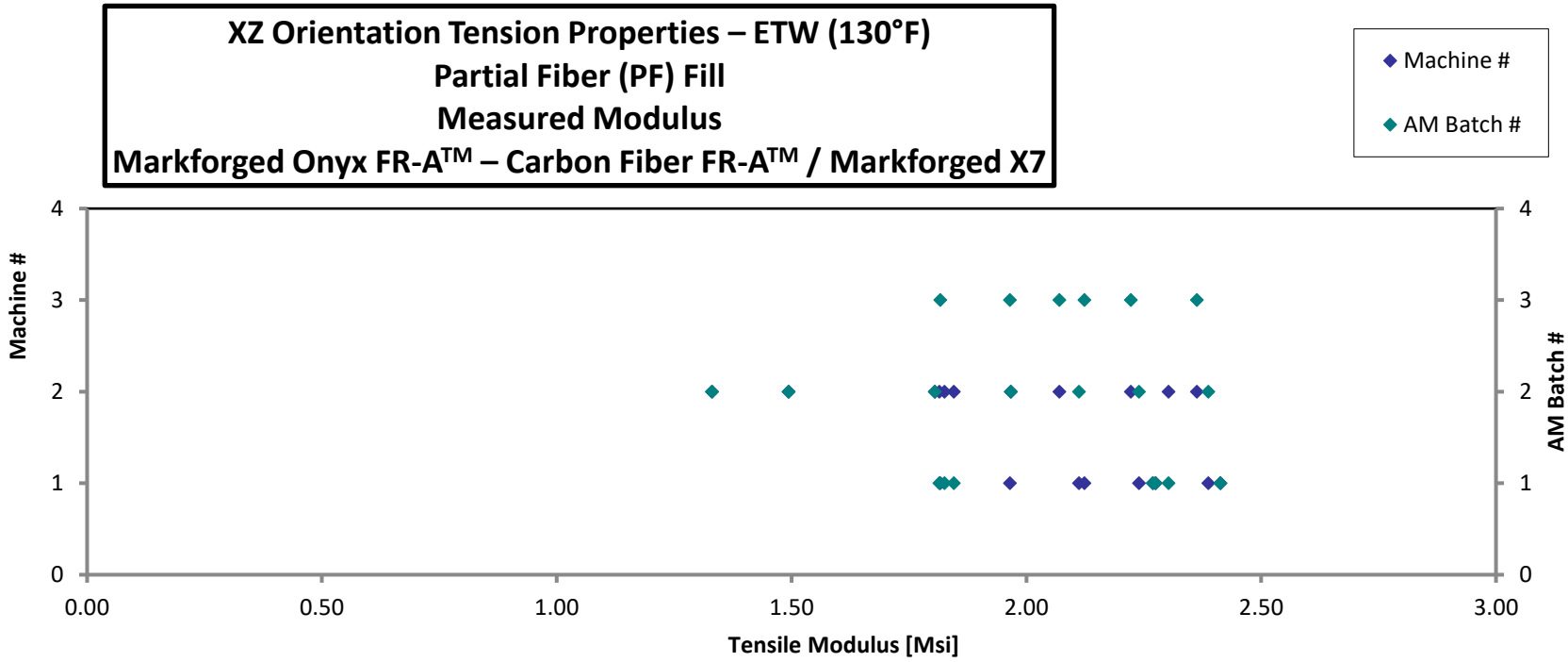
XZ Orientation Tension Properties – ETW (130°F)
Partial Fiber (PF) Fill
Strength & Modulus
Markforged Onyx FR-A™ – Carbon Fiber FR-A™ / Markforged X7

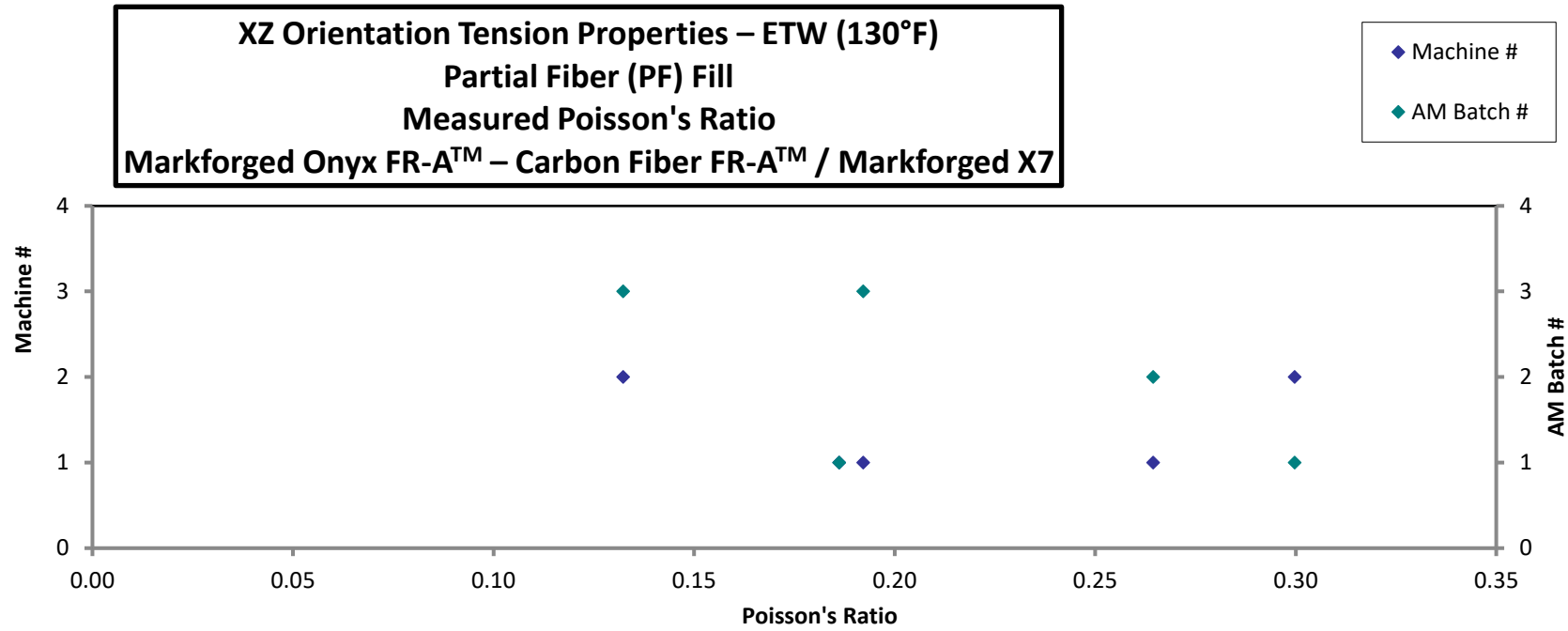
Specimen Number	AM Batch #	Machine #	Avg. Specimen Thickness [in]	Tensile Strength [ksi]	Tensile Modulus [Msi]	Poisson's Ratio	Failure Mode
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M1-P31429-XZ-T-11-ETW-PF-1*	1	1	0.144	23.26	2.269		SGM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M1-P31365-XZ-T-12-ETW-PF-2	1	1	0.143	21.59	2.413	0.186	SGM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M1-P54807-XZ-T-13-ETW-PF-3*	1	1	0.142	21.31	2.275		SGM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M2-P31428-XZ-T-11-ETW-PF-1*	1	2	0.142	21.97	1.815		SGM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M2-P31366-XZ-T-12-ETW-PF-2*	1	2	0.141	17.41	1.826		SGM, LAT
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M2-P31697-XZ-T-13-ETW-PF-3*	1	2	0.142	18.85	1.845		LAT
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M2-P31152-XZ-T-13-ETW-PF-SP	1	2	0.141	19.20	2.303	0.300	SGM, LWT
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-B-M1-P58774-XZ-T-11-ETW-PF-1*	2	1	0.144	19.80	2.112		SGM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-B-M1-P34954-XZ-T-12-ETW-PF-2	2	1	0.142	21.68	2.387	0.264	SGM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-B-M1-P33716-XZ-T-13-ETW-PF-3*	2	1	0.142	17.73	2.240		SGM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-B-M2-P41450-XZ-T-11-ETW-PF-1*	2	2	0.141	23.10	1.967		SGM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-B-M2-P34888-XZ-T-12-ETW-PF-2*	2	2	0.141	16.52	1.805		SGM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-B-M2-P56216-XZ-T-13-ETW-PF-3*	2	2	0.141	15.60	1.493		SGM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-B-M2-P55140-XZ-T-13-ETW-PF-6*	2	2	0.140	16.06	1.331		SGM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-C-M1-P36133-XZ-T-11-ETW-PF-1*	3	1	0.142	20.17	1.965		M(A,L)WT
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-C-M1-P48667-XZ-T-12-ETW-PF-2	3	1	0.141	17.01	2.123	0.192	LAT, SIT
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-C-M1-P35346-XZ-T-13-ETW-PF-3*	3	1	0.142	17.92	1.817		LAB
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-C-M2-P57301-XZ-T-11-ETW-PF-1	3	2	0.141	21.60	2.363	0.132	SGM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-C-M2-P35710-XZ-T-12-ETW-PF-2*	3	2	0.142	22.97	2.070		SGM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-C-M2-P35347-XZ-T-13-ETW-PF-3*	3	2	0.141	21.42	2.222		SGM

* Poisson's ratio not reported due to material behaviour
**Tensile Strength not reported due to improper failure mode

Average	**0.142**	**19.76**	**2.032**	**0.215**
Standard Dev.		**2.487**	**0.297**	**0.067**
Coeff. of Var. [%]		**12.58**	**14.63**	**31.04**
Min.	**0.140**	**15.60**	**1.331**	**0.132**
Max.	**0.144**	**23.26**	**2.413**	**0.300**
Number of Spec.	**20**	**20**	**20**	**5**


XZ Orientation Tension Properties – ETW (130°F)
Partial Fiber (PF) Fill
Measured Strength
Markforged Onyx FR-A™ – Carbon Fiber FR-A™ / Markforged X7
Machine #
AM Batch #
Machine #
AM Batch #
Tensile Strength [ksi]
0
1
2
3
4
0.0
5.0
10.0
15.0
20.0
25.0


XZ Orientation Tension Properties – ETW (130°F)
Partial Fiber (PF) Fill
Measured Modulus
Markforged Onyx FR-A™ – Carbon Fiber FR-A™ / Markforged X7
Machine #
AM Batch #
Machine #
AM Batch #
Tensile Modulus [Msi]
0.00
0.50
1.00
1.50
2.00
2.50
3.00
0
1
2
3
4

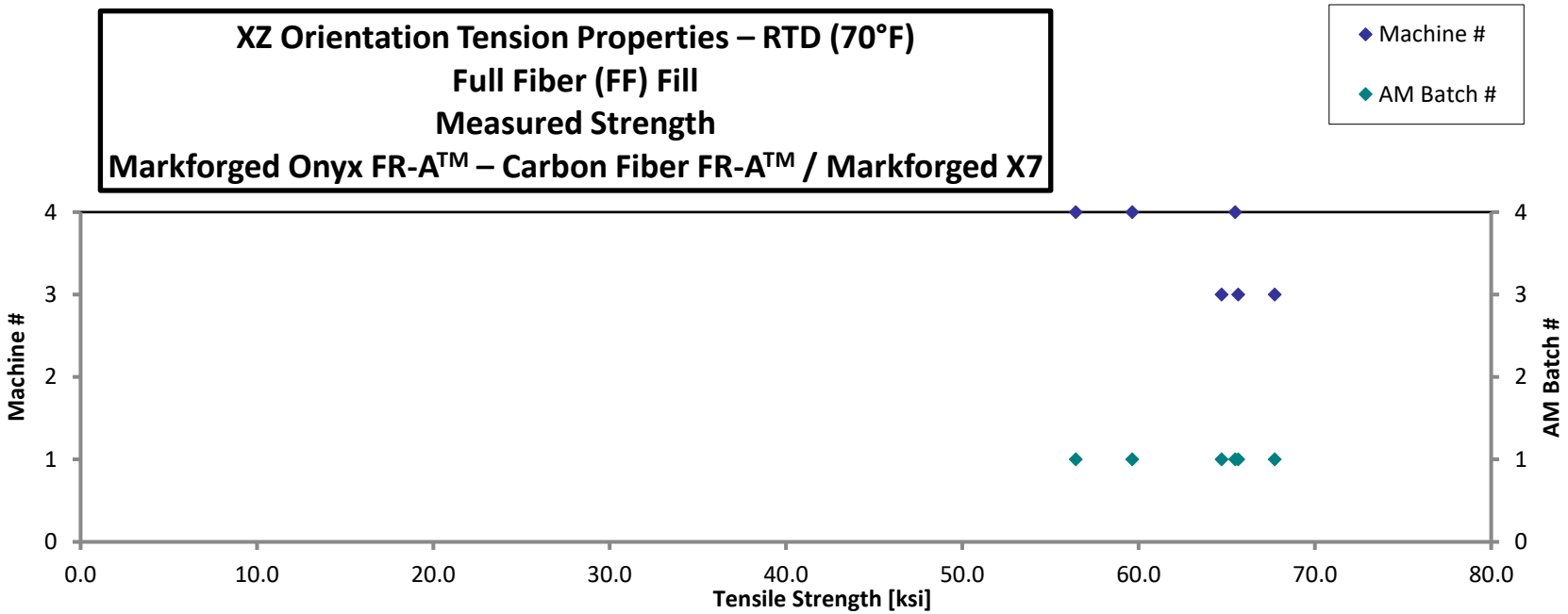

XZ Orientation Tension Properties – ETW (130°F)
Partial Fiber (PF) Fill
Measured Poisson's Ratio
Markforged Onyx FR-A™ – Carbon Fiber FR-A™ / Markforged X7
Machine #
AM Batch #
Machine #
AM Batch #
Poisson's Ratio
0
1
2
3
4
0.00
0.05
0.10
0.15
0.20
0.25
0.30
0.35

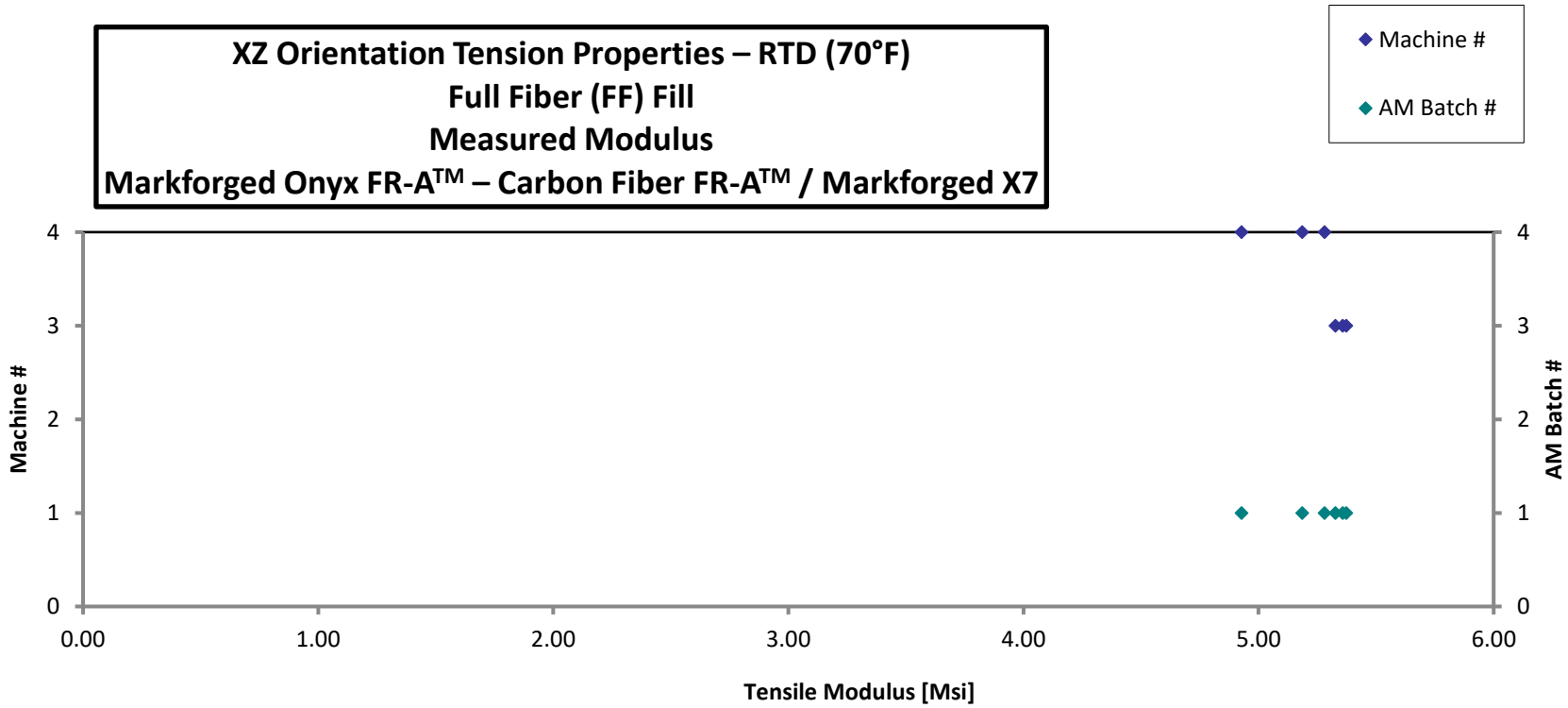
4.4 XZ FF Tension Properties

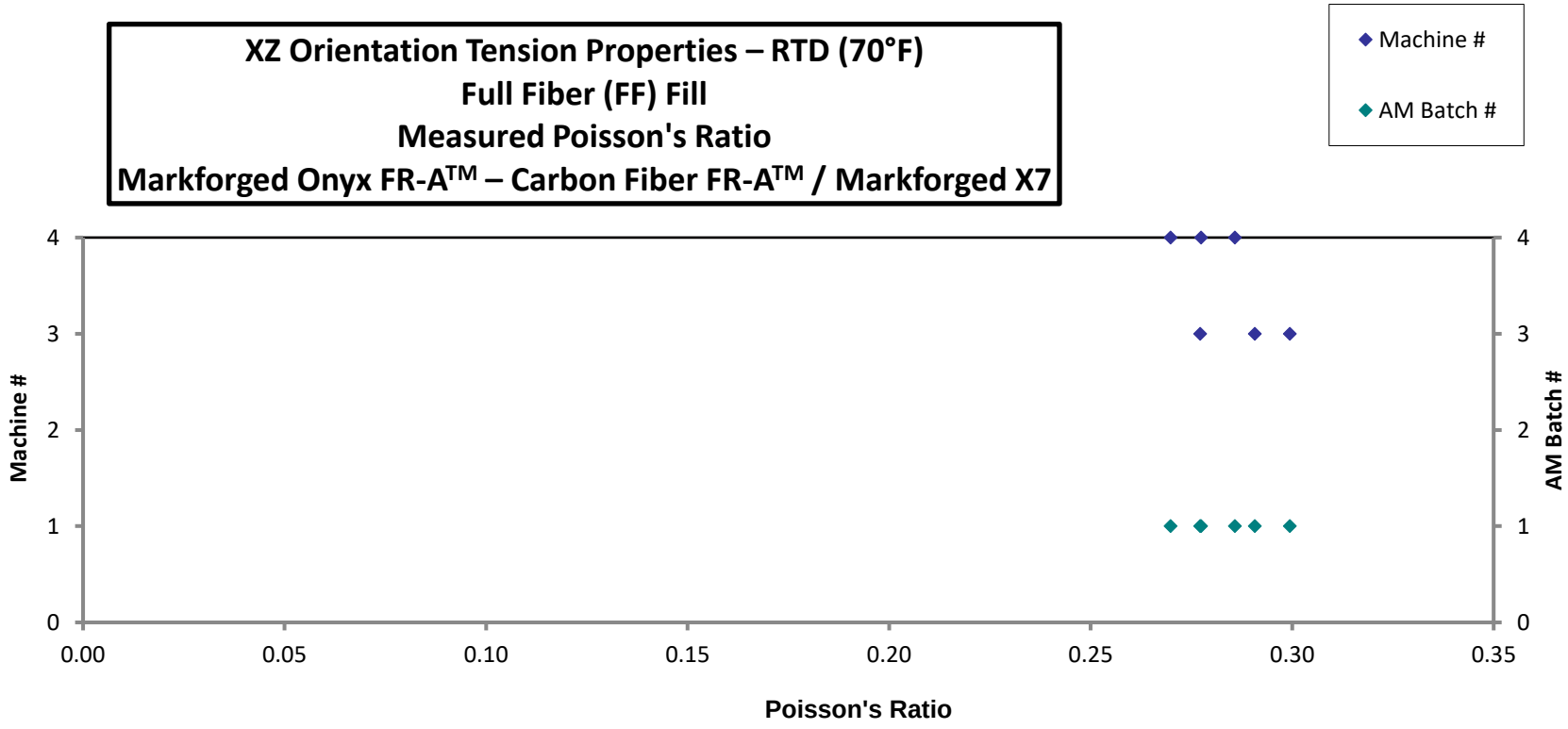
4.4.1 RTD Condition

XZ Orientation Tension Properties – RTD (70°F)
Full Fiber (FF) Fill
Strength & Modulus
Markforged Onyx FR-A™ – Carbon Fiber FR-A™ / Markforged X7

Specimen Number	AM Batch #	Machine #	Tensile Strength [ksi]	Tensile Modulus [Msi]	Poisson's Ratio	Avg. Specimen Thickness [in]	Failure Mode
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M3-P34059-XZ-T-11-RTD-FF-1	1	3	67.72	5.373	0.299	0.138	SGM, AWT, M(A,L)WB
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M3-P34369-XZ-T-12-RTD-FF-2	1	3	65.65	5.358	0.291	0.139	SGM, M(A,L)WT
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M3-P34051-XZ-T-13-RTD-FF-3	1	3	64.71	5.326	0.277	0.138	SGM, M(A,L)WT
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M4-P42161-XZ-T-11-RTD-FF-1	1	4	56.43	5.185	0.286	0.143	SGM, M(A,L)WT
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M4-P42319-XZ-T-12-RTD-FF-2	1	4	59.65	4.927	0.277	0.143	M(L,S)GM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M4-P41548-XZ-T-13-RTD-FF-3	1	4	65.49	5.281	0.270	0.142	M(A,L,S)GM
		Average	**63.27**	**5.242**	**0.283**	**0.140**	
		Standard Dev.	**4.297**	**0.168**	**0.011**		
		Coeff. of Var. [%]	**6.790**	**3.207**	**3.784**		
		Min.	**56.43**	**4.927**	**0.270**	**0.138**	
		Max.	**67.72**	**5.373**	**0.299**	**0.143**	
		Number of Spec.	**6**	**6**	**6**	**6**	


XZ Orientation Tension Properties – RTD (70°F)
Full Fiber (FF) Fill
Measured Strength
Markforged Onyx FR-A™ – Carbon Fiber FR-A™ / Markforged X7
Machine #
AM Batch #
Machine #
AM Batch #
Tensile Strength [ksi]
0.0
10.0
20.0
30.0
40.0
50.0
60.0
70.0
80.0
0
1
2
3
4


XZ Orientation Tension Properties – RTD (70°F)
Full Fiber (FF) Fill
Measured Modulus
Markforged Onyx FR-A™ – Carbon Fiber FR-A™ / Markforged X7
Machine #
AM Batch #
Machine #
AM Batch #
Tensile Modulus [Msi]
0.00
1.00
2.00
3.00
4.00
5.00
6.00
0
1
2
3
4


XZ Orientation Tension Properties – RTD (70°F)
Full Fiber (FF) Fill
Measured Poisson's Ratio
Markforged Onyx FR-A™ – Carbon Fiber FR-A™ / Markforged X7
Machine #
AM Batch #
Machine #
AM Batch #
Poisson's Ratio
0
1
2
3
4
0.00
0.05
0.10
0.15
0.20
0.25
0.30
0.35

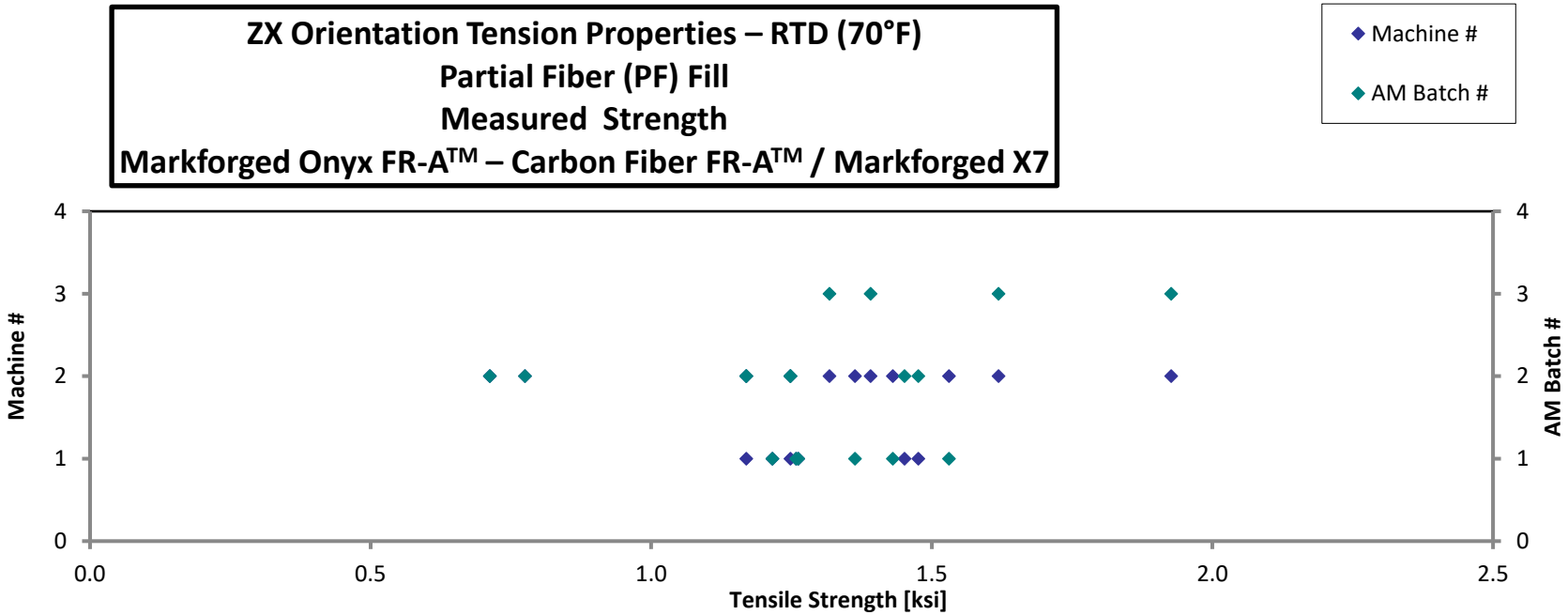
4.5 ZX PF Tension Properties – Reference Only

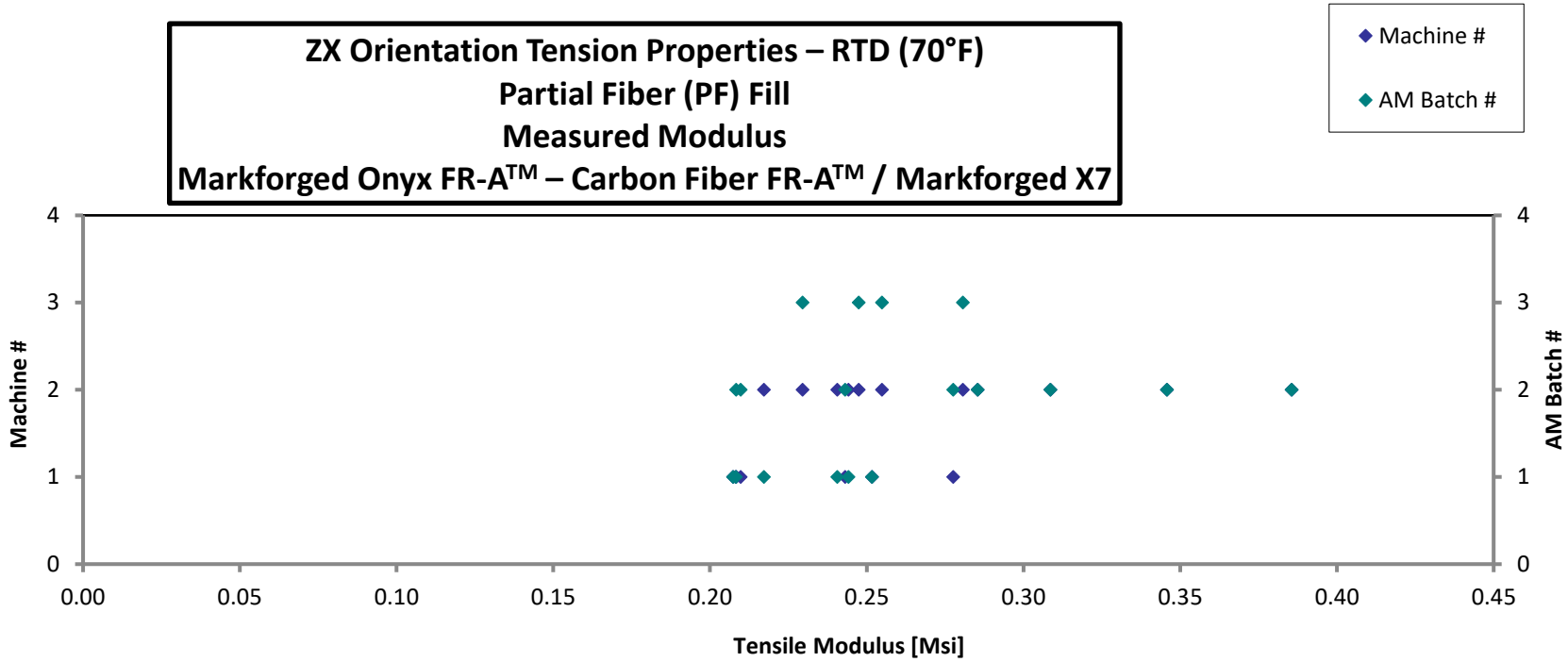
4.5.1 RTD Condition

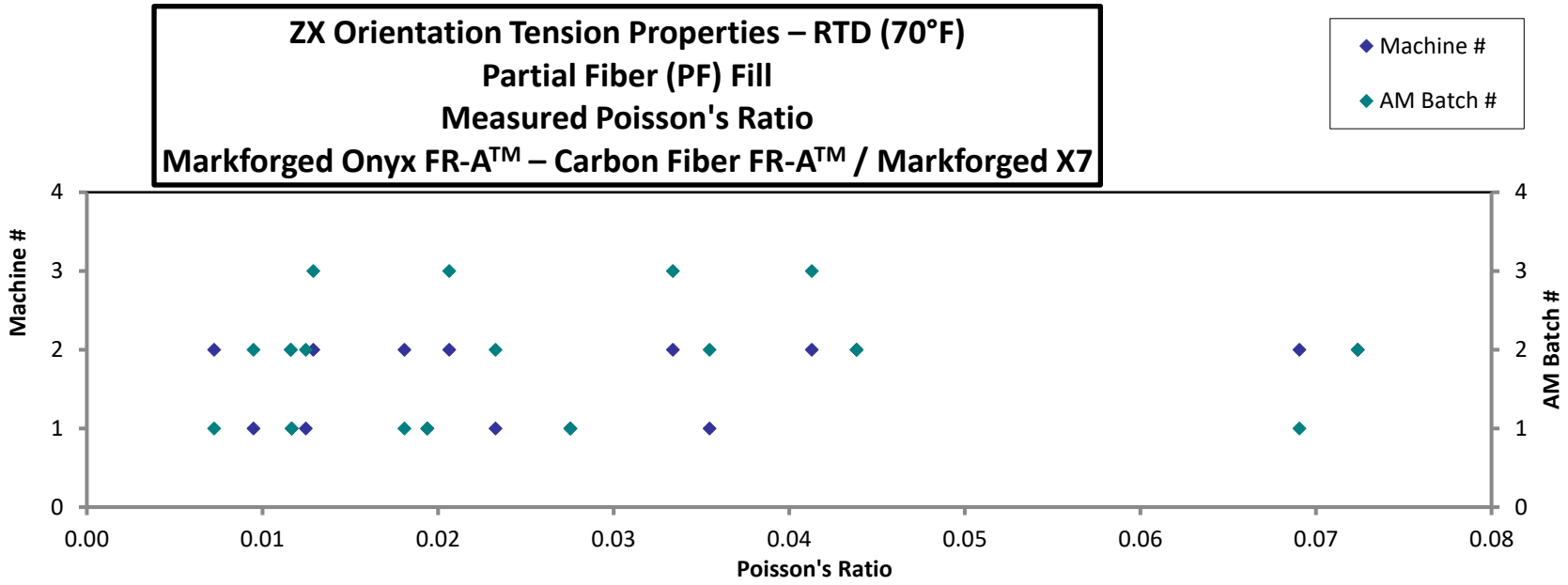
ZX Orientation Tension Properties – RTD (70°F)
Partial Fiber (PF) Fill
Strength & Modulus
Markforged Onyx FR-A™ – Carbon Fiber FR-A™ / Markforged X7

Specimen Number	AM Batch #	Machine #	Avg. Specimen Thickness [in]	Tensile Strength [ksi]	Tensile Modulus [Msi]	Poisson's Ratio	Failure Mode
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M1-P30894-ZX-T-11-RTD-PF-1	1	1	0.141	1.216	0.252	0.028	LGT
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M1-P30784-ZX-T-12-RTD-PF-2	1	1	0.140	1.262	0.207	0.012	LGT
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M1-P31311-ZX-T-13-RTD-PF-3	1	1	0.140	1.258	0.208	0.019	LGB
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M2-P30893-ZX-T-11-RTD-PF-1	1	2	0.138	1.430	0.244	0.069	LGB
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M2-P30783-ZX-T-12-RTD-PF-2	1	2	0.139	1.531	0.217	0.007	LGM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M2-P31300-ZX-T-13-RTD-PF-3	1	2	0.138	1.363	0.241	0.018	LGB
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-B-M1-P33879-ZX-T-11-RTD-PF-1	2	1	0.141	1.476	0.278	0.023	LGT
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-B-M1-P33130-ZX-T-12-RTD-PF-2	2	1	0.139	1.451	0.243	0.012	LGT
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-B-M1-P34367-ZX-T-13-RTD-PF-3	2	1	0.138	1.169	0.208	0.009	LGT
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-B-M1-P34106-ZX-T-13-RTD-PF-SP	2	1	0.137	1.248	0.210	0.035	LGB
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-B-M2-P33878-ZX-T-11-RTD-PF-1[1]	2	2	0.137	0.775	0.309	0.012	LGB
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-B-M2-P33132-ZX-T-12-RTD-PF-2[1]	2	2	0.139	1.248	0.285	0.044	LGT
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-B-M2-P34383-ZX-T-13-RTD-PF-3[2]	2	2	0.137	0.712	0.386		LGT
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-B-M2-P34107-ZX-T-13-RTD-PF-SP[3]	2	2	0.135	1.169	0.346	0.072	LGM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-C-M2-P35186-ZX-T-11-RTD-PF-1	3	2	0.140	1.619	0.247	0.013	LGT
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-C-M2-P35020-ZX-T-12-RTD-PF-2	3	2	0.139	1.927	0.281	0.041	LGB
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-C-M2-P35842-ZX-T-13-RTD-PF-3	3	2	0.137	1.318	0.230	0.021	LGB
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-C-M2-P36353-ZX-T-13-RTD-PF-SP	3	2	0.137	1.391	0.255	0.033	LGB
		Average	**0.138**	**1.309**	**0.258**	**0.028**	
		Standard Dev.		**0.277**	**0.049**	**0.020**	
		Coeff. of Var. [%]		**21.13**	**19.11**	**71.20**	
		Min.	**0.135**	**0.712**	**0.207**	**0.007**	
		Max.	**0.141**	**1.927**	**0.386**	**0.072**	
		Number of Spec.	**18**	**18**	**18**	**17**	

[1] Modulus Calculation used was 500-2000 microstrain
[2] Modulus Calculation used was 200-800 microstrain
[3] Modulus Calculation used was 500-1500 microstrain
All ZX Partial Fiber testing are reported for informational purposes only


ZX Orientation Tension Properties – RTD (70°F)
Partial Fiber (PF) Fill
Measured Strength
Markforged Onyx FR-A™ – Carbon Fiber FR-A™ / Markforged X7
Machine #
AM Batch #
Machine #
AM Batch #
Tensile Strength [ksi]
0
1
2
3
4
0.0
0.5
1.0
1.5
2.0
2.5


ZX Orientation Tension Properties – RTD (70°F)
Partial Fiber (PF) Fill
Measured Modulus
Markforged Onyx FR-A™ – Carbon Fiber FR-A™ / Markforged X7
Machine #
AM Batch #
Machine #
AM Batch #
Tensile Modulus [Msi]
0
1
2
3
4
0.00
0.05
0.10
0.15
0.20
0.25
0.30
0.35
0.40
0.45

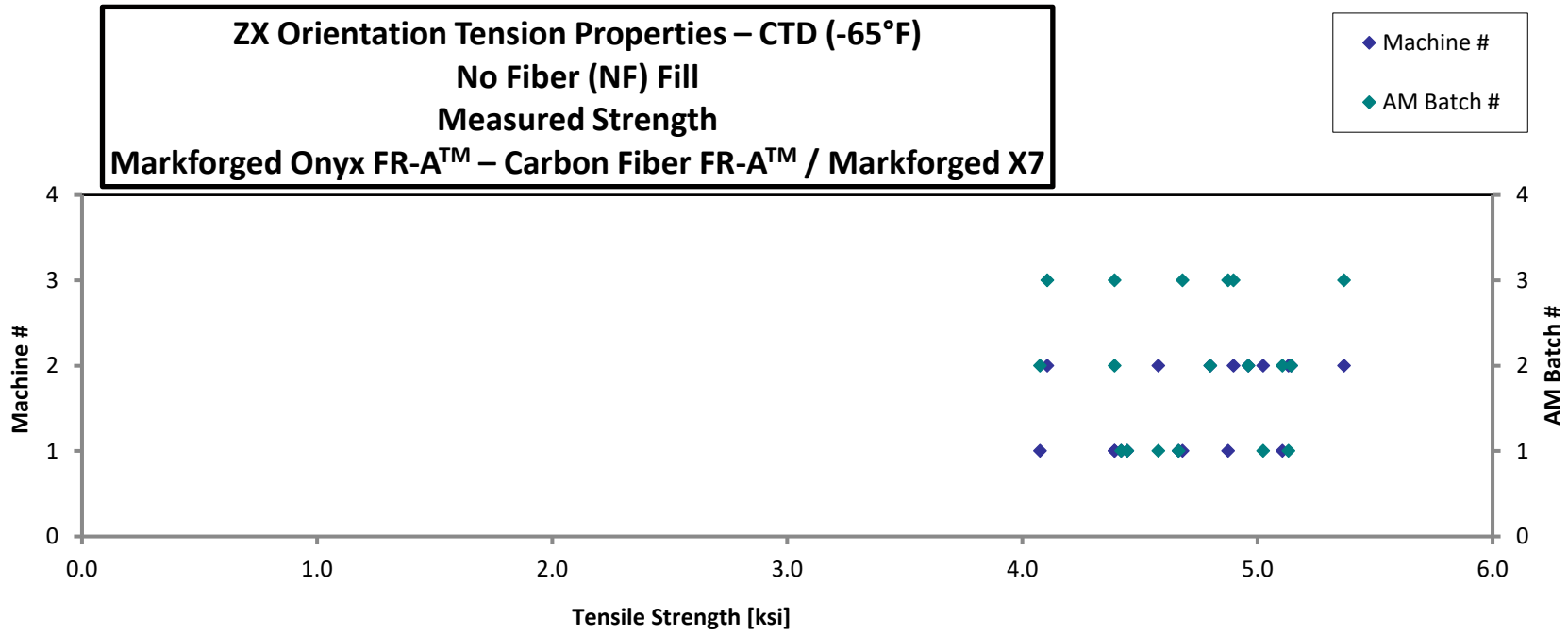

ZX Orientation Tension Properties – RTD (70°F)
Partial Fiber (PF) Fill
Measured Poisson's Ratio
Markforged Onyx FR-A™ – Carbon Fiber FR-A™ / Markforged X7
Machine #
AM Batch #
Machine #
AM Batch #
Poisson's Ratio
0.00
0.01
0.02
0.03
0.04
0.05
0.06
0.07
0.08
0
1
2
3
4

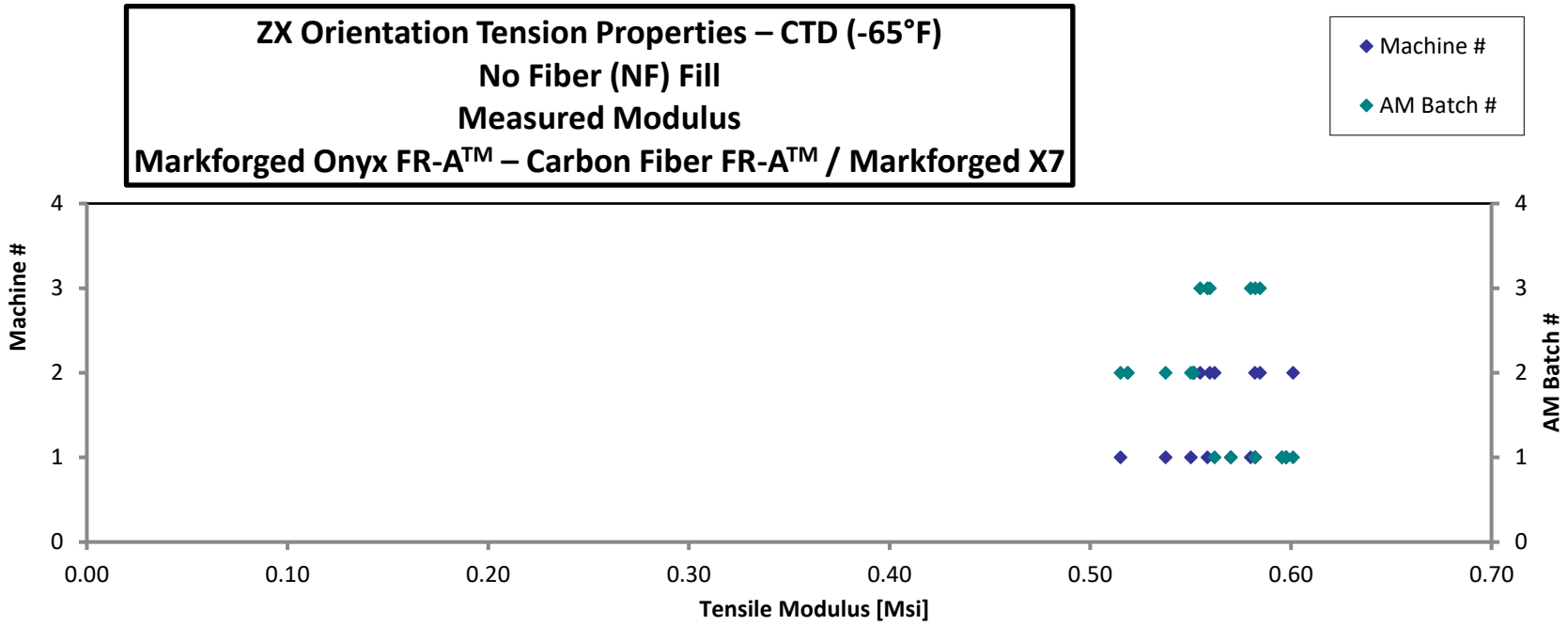
4.6 ZX NF Tension Properties

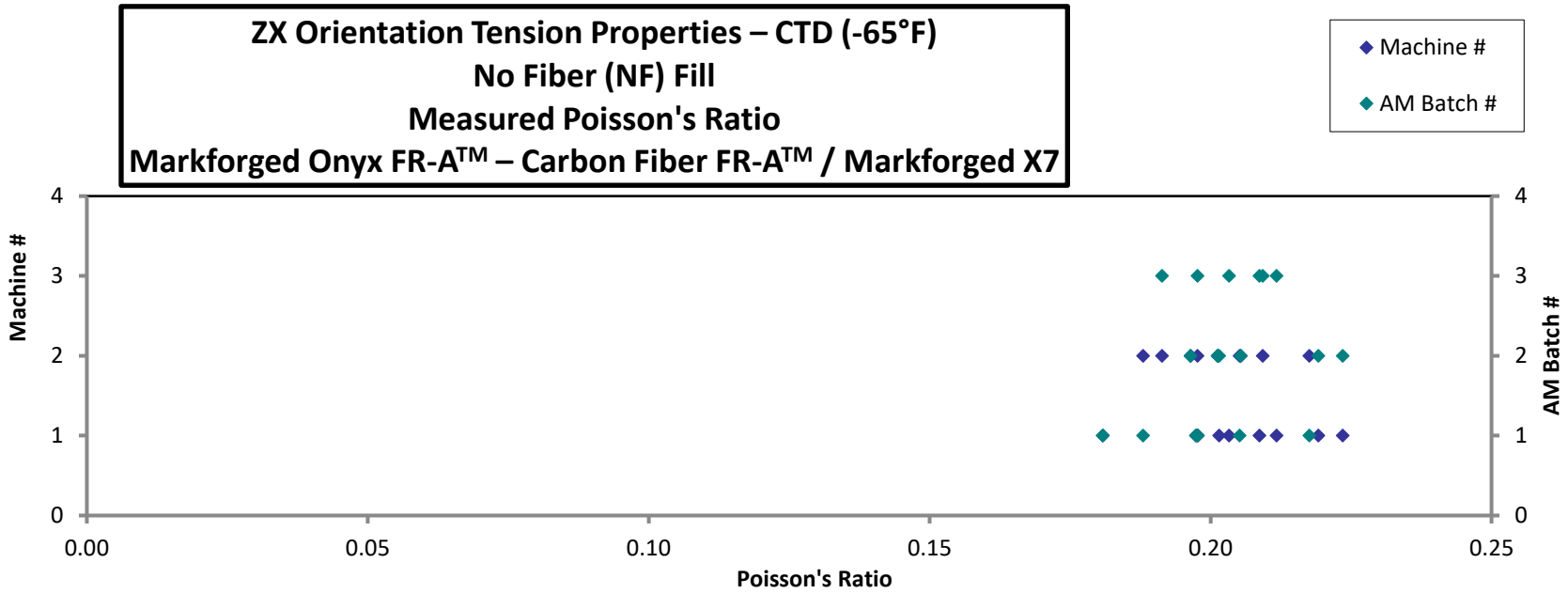
4.6.1 CTD Condition

ZX Orientation Tension Properties – CTD (-65°F)
No Fiber (NF) Fill
Strength & Modulus
Markforged Onyx FR-A™– Carbon Fiber FR-A™ / Markforged X7

Specimen Number	AM Batch #	Machine #	Avg. Specimen Thickness [in]	Tensile Strength [ksi]	Tensile Modulus [Msi]	Poisson's Ratio	Failure Mode
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M1-P61132-ZX-T-11-CTD-NF-1	1	1	0.149	4.665	0.598	0.198	LAT
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M1-P61751-ZX-T-12-CTD-NF-2	1	1	0.149	4.420	0.596	0.197	LWT
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M1-P61817-ZX-T-13-CTD-NF-3	1	1	0.146	4.447	0.570	0.181	LWT
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M2-P60434-ZX-T-11-CTD-NF-1	1	2	0.150	5.025	0.601	0.218	LAT
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M2-P61255-ZX-T-12-CTD-NF-2	1	2	0.147	4.579	0.582	0.205	LGM, LWB, LWT
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M2-P61818-ZX-T-13-CTD-NF-3	1	2	0.145	5.133	0.562	0.188	LGM, LWB, LWT
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-B-M1-P62411-ZX-T-11-CTD-NF-1	2	1	0.146	5.107	0.550	0.219	LAT
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-B-M1-P66639-ZX-T-12-CTD-NF-2	2	1	0.146	4.076	0.538	0.224	LAT
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-B-M1-P63018-ZX-T-13-CTD-NF-3	2	1	0.143	4.393	0.515	0.202	LWT
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-B-M2-P62412-ZX-T-11-CTD-NF-1	2	2	0.147	4.800	0.551	0.201	LAT
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-B-M2-P63352-ZX-T-12-CTD-NF-2	2	2	0.146	5.144	0.552	0.205	LWB, LAB
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-B-M2-P63506-ZX-T-13-CTD-NF-3	2	2	0.144	4.961	0.519	0.196	LWB, LAB
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-C-M1-P64600-ZX-T-11-CTD-NF-1	3	1	0.146	4.393	0.582	0.203	LWB
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-C-M1-P64991-ZX-T-12-CTD-NF-2	3	1	0.145	4.876	0.580	0.212	LGT, LWT
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-C-M1-P65365-ZX-T-13-CTD-NF-3	3	1	0.141	4.681	0.558	0.209	LWT
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-C-M2-P65281-ZX-T-11-CTD-NF-1	3	2	0.145	4.899	0.560	0.191	LAB
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-C-M2-P65426-ZX-T-12-CTD-NF-2	3	2	0.145	5.369	0.585	0.198	LGB, LWB
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-C-M2-P65831-ZX-T-13-CTD-NF-3	3	2	0.144	4.107	0.555	0.209	LAB
		Average	**0.146**	**4.726**	**0.564**	**0.203**	
		Standard Dev.		**0.370**	**0.025**	**0.011**	
		Coeff. of Var. [%]		**7.829**	**4.442**	**5.397**	
		Min.	**0.141**	**4.076**	**0.515**	**0.181**	
		Max.	**0.150**	**5.369**	**0.601**	**0.224**	
		Number of Spec.	**18**	**18**	**18**	**18**	


ZX Orientation Tension Properties – CTD (-65°F)
No Fiber (NF) Fill
Measured Strength
Markforged Onyx FR-A™ – Carbon Fiber FR-A™ / Markforged X7
Machine #
AM Batch #
Machine #
AM Batch #
Tensile Strength [ksi]
0
1
2
3
4
0.0
1.0
2.0
3.0
4.0
5.0
6.0


ZX Orientation Tension Properties – CTD (-65°F)
No Fiber (NF) Fill
Measured Modulus
Markforged Onyx FR-A™ – Carbon Fiber FR-A™ / Markforged X7
Machine #
AM Batch #
Machine #
AM Batch #
0
1
2
3
4
0.00
0.10
0.20
0.30
0.40
0.50
0.60
0.70
Tensile Modulus [Msi]

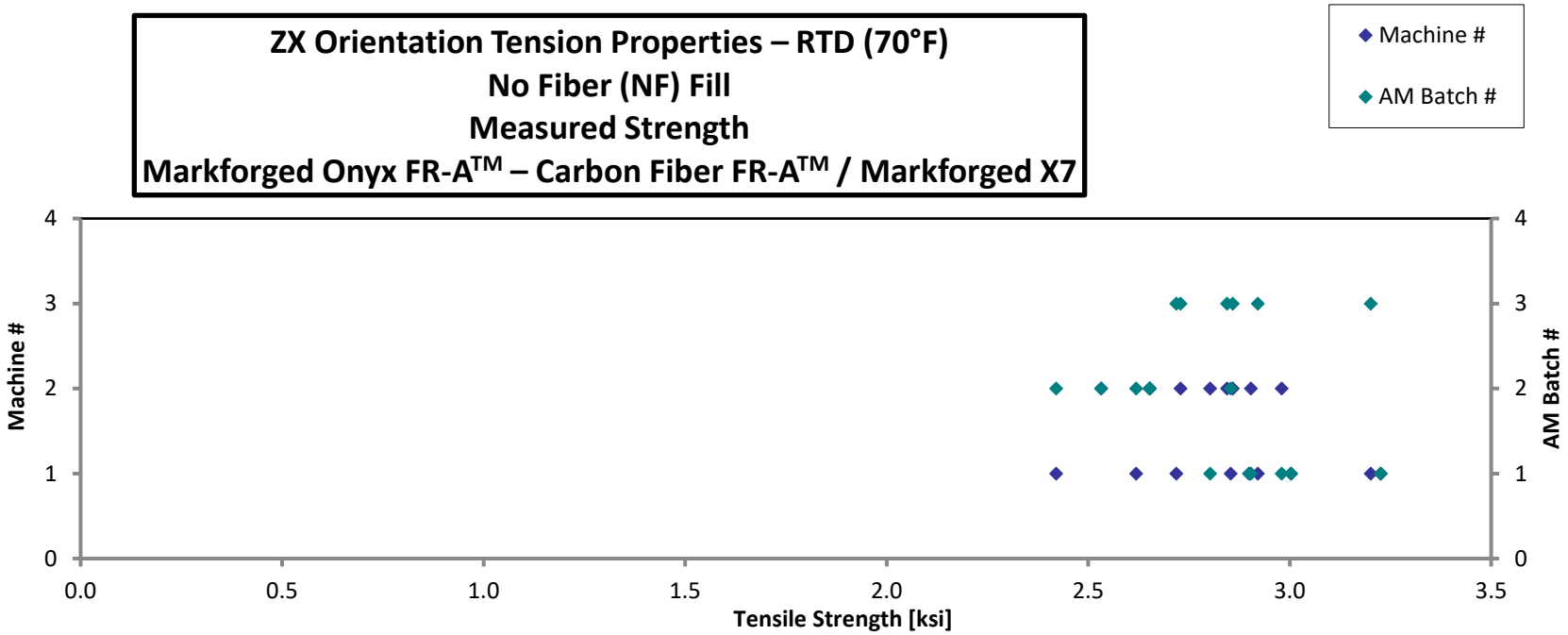

ZX Orientation Tension Properties – CTD (-65°F)
No Fiber (NF) Fill
Measured Poisson's Ratio
Markforged Onyx FR-A™ – Carbon Fiber FR-A™ / Markforged X7
Machine #
AM Batch #
Machine #
AM Batch #
Poisson's Ratio
0
1
2
3
4
0.00
0.05
0.10
0.15
0.20
0.25

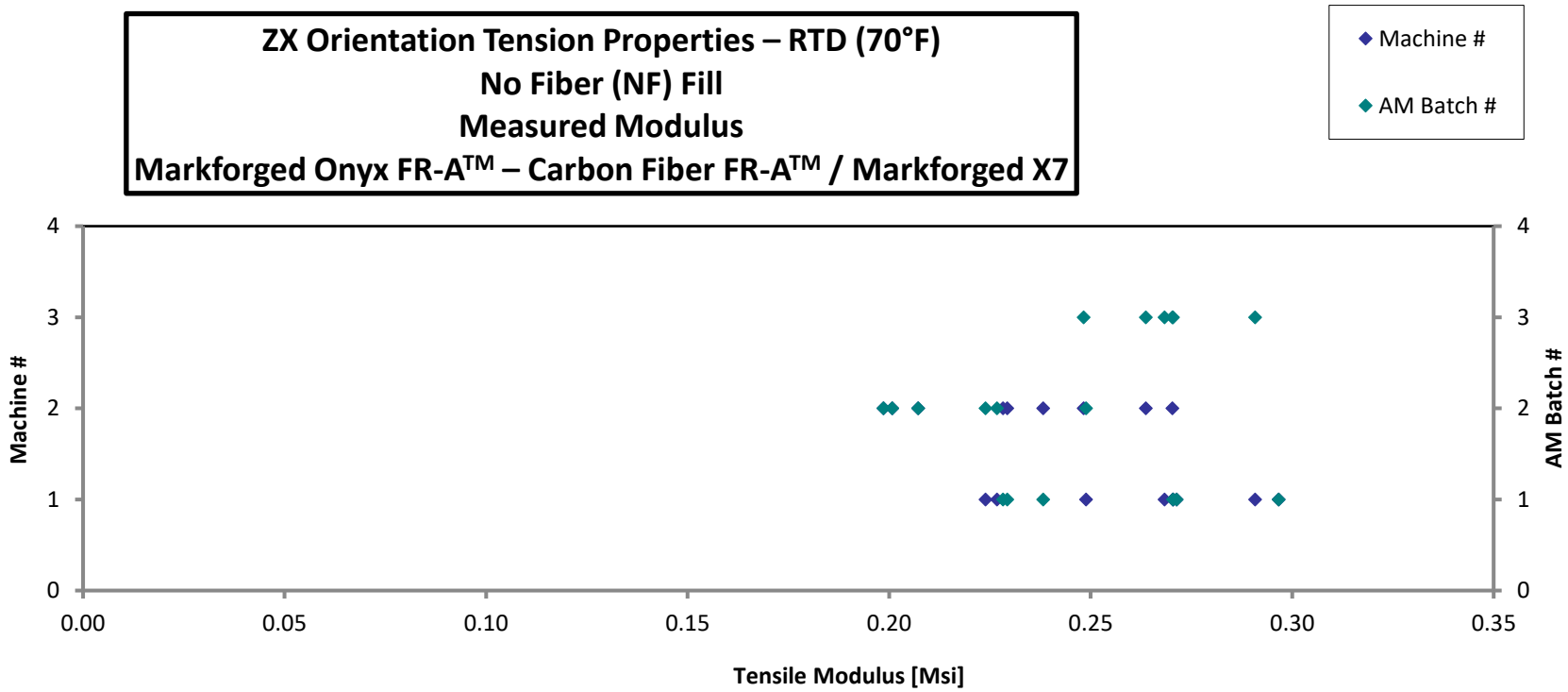
4.6.2 **RTD Condition**

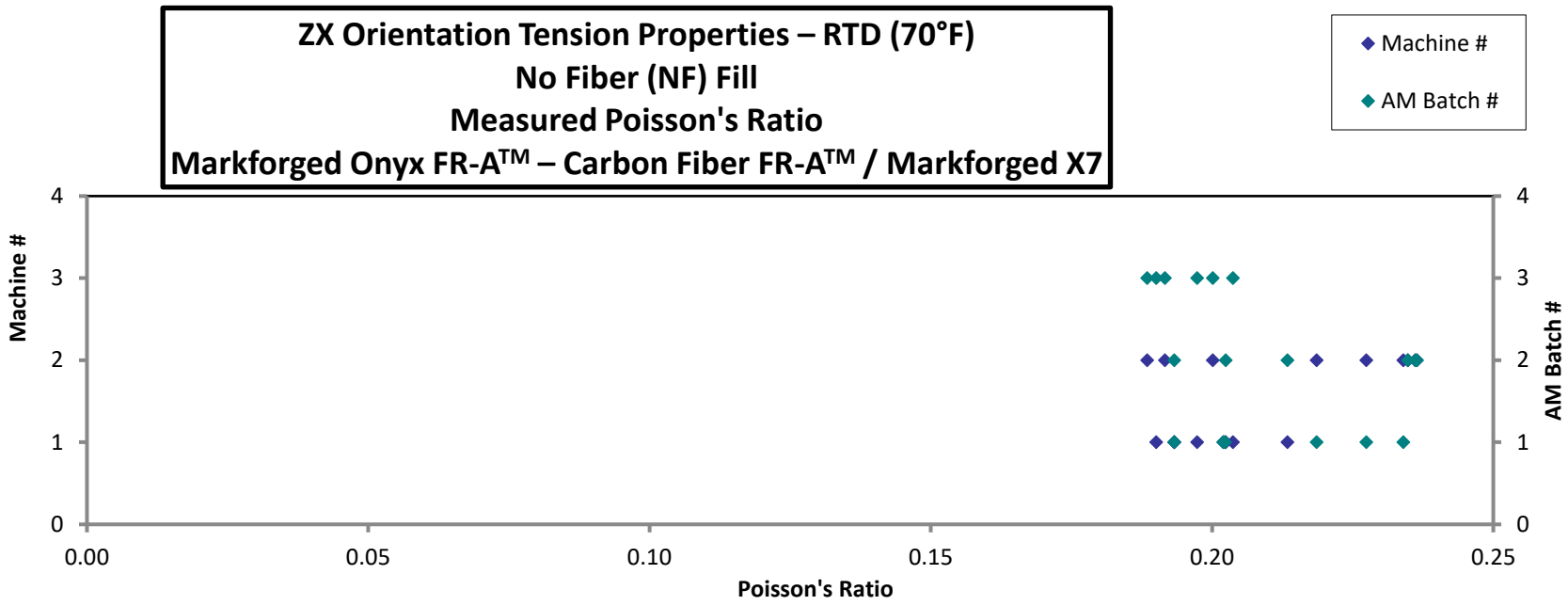
ZX Orientation Tension Properties – RTD (70°F)
No Fiber (NF) Fill
Strength & Modulus
Markforged Onyx FR-A™ – Carbon Fiber FR-A™ / Markforged X7

Specimen Number	AM Batch #	Machine #	Avg. Specimen Thickness [in]	Tensile Strength [ksi]	Tensile Modulus [Msi]	Poisson's Ratio	Failure Mode
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M1-P61132-ZX-T-11-RTD-NF-1	1	1	0.143	3.226	0.297	0.202	LWT
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M1-P61751-ZX-T-12-RTD-NF-2	1	1	0.144	3.004	0.270	0.202	LWB
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M1-P61817-ZX-T-13-RTD-NF-3	1	1	0.141	2.899	0.271	0.193	LWB
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M2-P60434-ZX-T-11-RTD-NF-1	1	2	0.145	2.980	0.228	0.227	LWB
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M2-P61255-ZX-T-12-RTD-NF-2	1	2	0.145	2.904	0.238	0.234	LGM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M2-P61818-ZX-T-13-RTD-NF-3	1	2	0.143	2.802	0.229	0.219	LWT
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-B-M1-P62411-ZX-T-11-RTD-NF-1	2	1	0.141	2.619	0.224	0.202	LWB
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-B-M1-P66639-ZX-T-12-RTD-NF-2	2	1	0.142	2.854	0.249	0.213	LWB
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-B-M1-P63018-ZX-T-13-RTD-NF-3	2	1	0.139	2.421	0.227	0.193	LWB
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-B-M2-P62412-ZX-T-11-RTD-NF-1	2	2	0.144	2.653	0.199	0.235	LAT
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-B-M2-P63352-ZX-T-12-RTD-NF-2	2	2	0.143	2.653	0.207	0.236	LWB
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-B-M2-P63506-ZX-T-13-RTD-NF-3	2	2	0.142	2.532	0.201	0.236	LWT
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-C-M1-P64600-ZX-T-11-RTD-NF-1	3	1	0.142	3.201	0.291	0.204	LGB
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-C-M1-P64991-ZX-T-12-RTD-NF-2	3	1	0.141	2.921	0.270	0.197	LGT
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-C-M1-P65365-ZX-T-13-RTD-NF-3	3	1	0.140	2.719	0.268	0.190	LGM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-C-M2-P65281-ZX-T-11-RTD-NF-1	3	2	0.141	2.729	0.248	0.188	LWT
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-C-M2-P65426-ZX-T-12-RTD-NF-2	3	2	0.141	2.845	0.264	0.192	LWT
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-C-M2-P65831-ZX-T-13-RTD-NF-3	3	2	0.141	2.859	0.270	0.200	LWT

Average	**0.142**	**2.823**	**0.247**	**0.209**
Standard Dev.		**0.210**	**0.030**	**0.017**
Coeff. of Var. [%]		**7.455**	**12.053**	**8.345**
Min.	**0.139**	**2.421**	**0.199**	**0.188**
Max.	**0.145**	**3.226**	**0.297**	**0.236**
Number of Spec.	**18**	**18**	**18**	**18**


ZX Orientation Tension Properties – RTD (70°F)
No Fiber (NF) Fill
Measured Strength
Markforged Onyx FR-A™ – Carbon Fiber FR-A™ / Markforged X7
Machine #
AM Batch #
Machine #
AM Batch #
Tensile Strength [ksi]
0
1
2
3
4
0.0
0.5
1.0
1.5
2.0
2.5
3.0
3.5

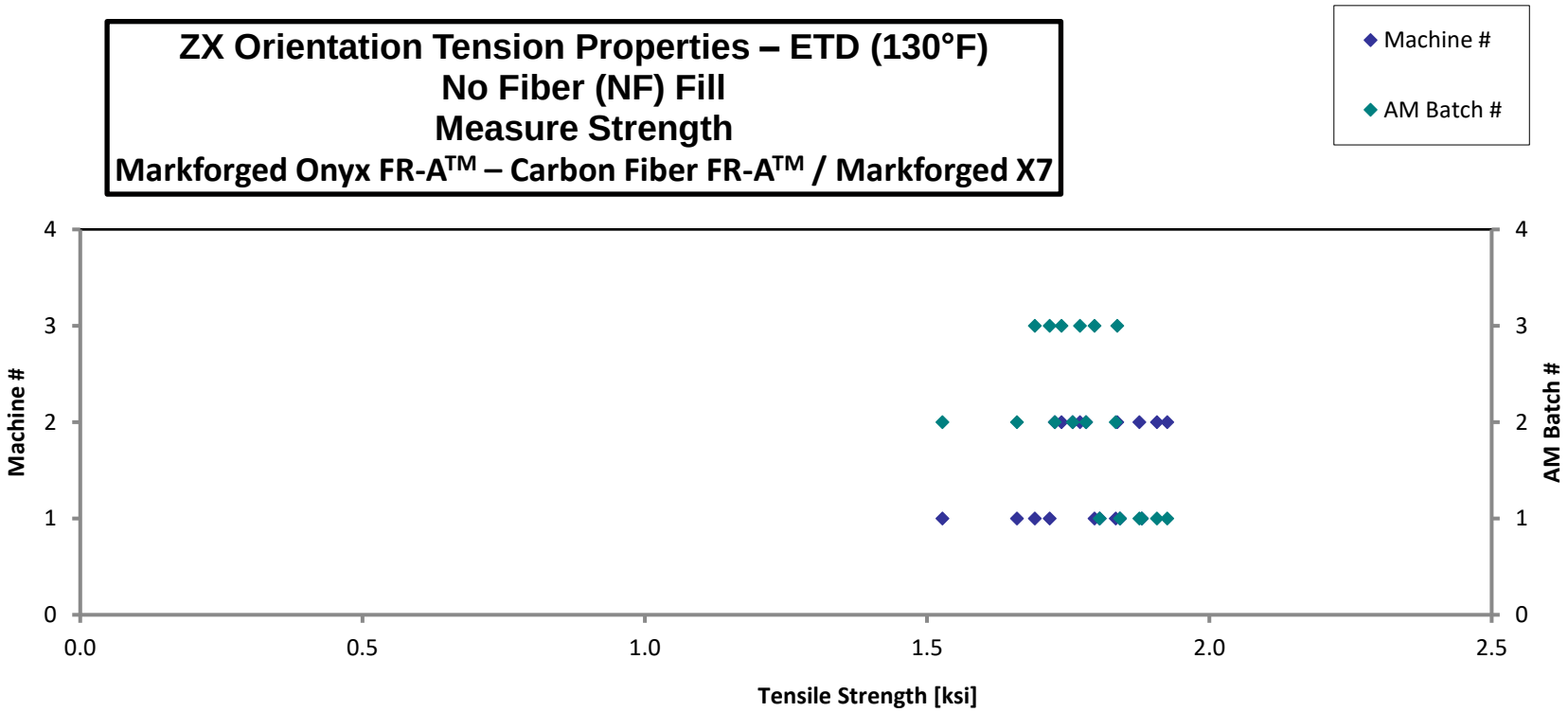

ZX Orientation Tension Properties – RTD (70°F)
No Fiber (NF) Fill
Measured Modulus
Markforged Onyx FR-A™ – Carbon Fiber FR-A™ / Markforged X7
Machine #
AM Batch #
Machine #
AM Batch #
Tensile Modulus [Msi]
0
1
2
3
4
0.00
0.05
0.10
0.15
0.20
0.25
0.30
0.35

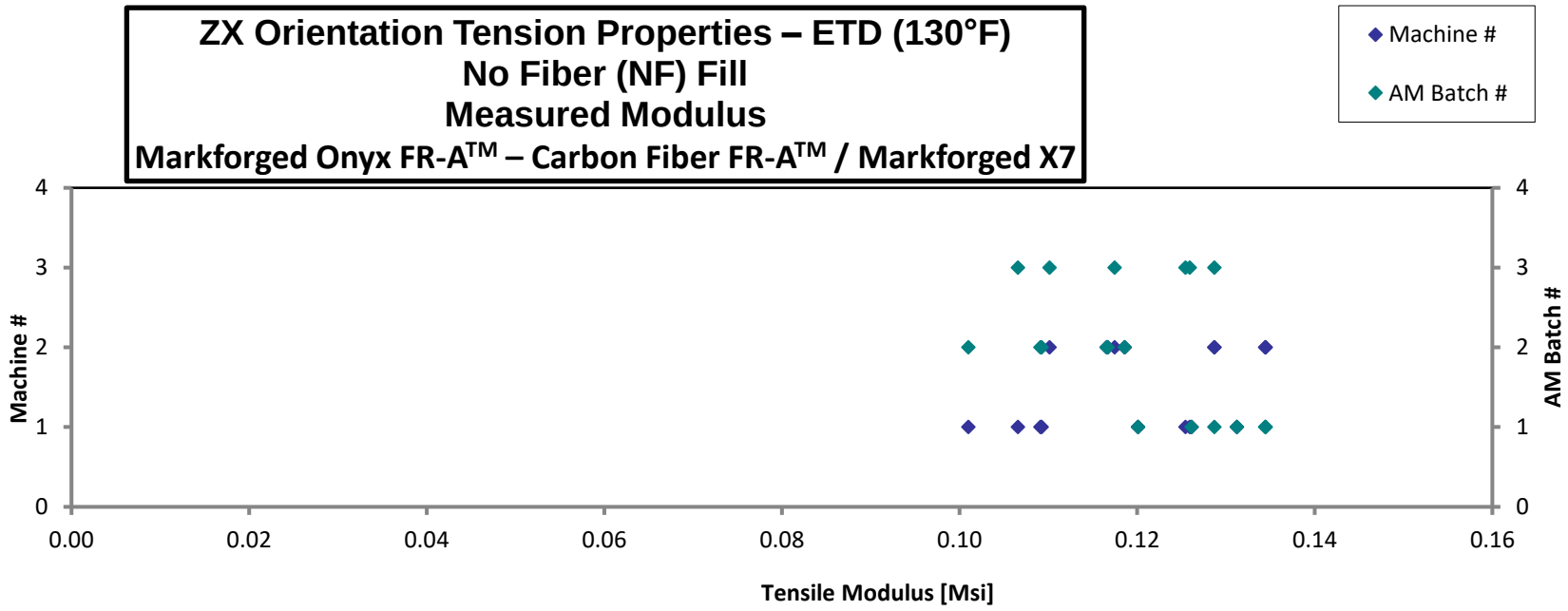

ZX Orientation Tension Properties – RTD (70°F)
No Fiber (NF) Fill
Measured Poisson's Ratio
Markforged Onyx FR-A™ – Carbon Fiber FR-A™ / Markforged X7
Machine #
AM Batch #
Machine #
AM Batch #
Poisson's Ratio
0.00
0.05
0.10
0.15
0.20
0.25
0
1
2
3
4

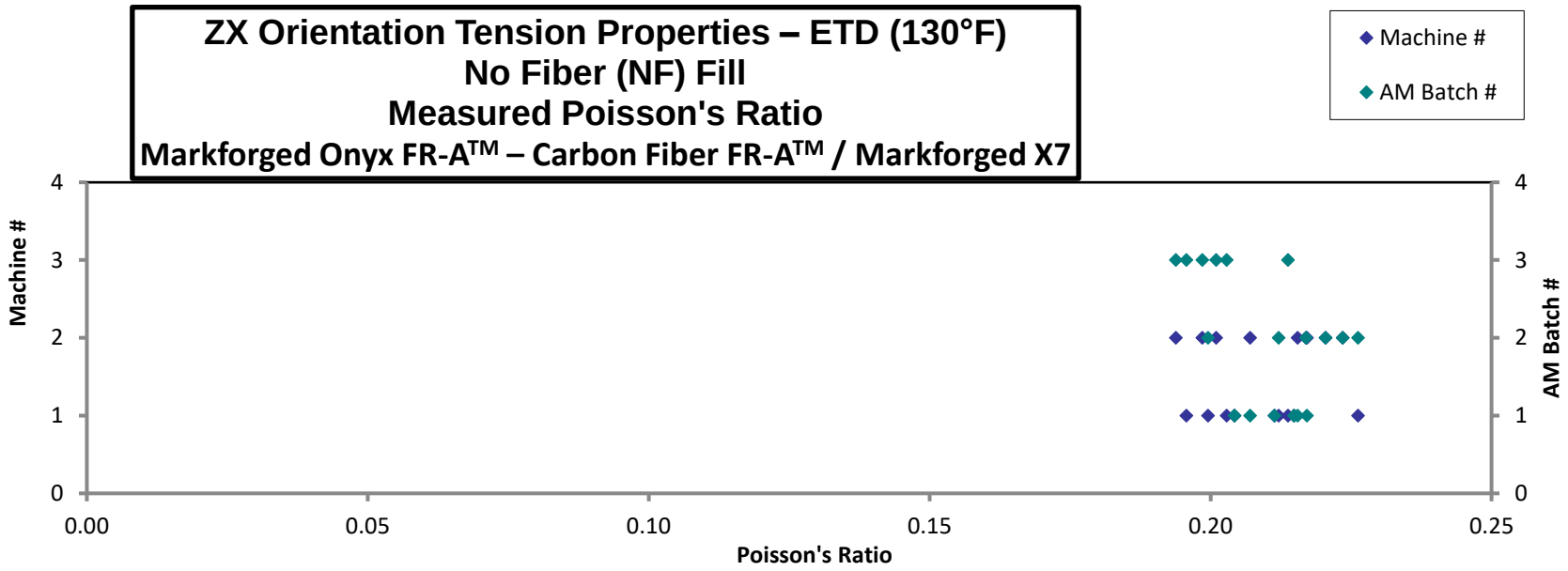
4.6.3 **ETD Condition**

ZX Orientation Tension Properties – ETD (130°F)
No Fiber (NF) Fill
Strength & Modulus
Markforged Onyx FR-A™ – Carbon Fiber FR-A™ / Markforged X7

Specimen Number	AM Batch #	Machine #	Avg. Specimen Thickness [in]	Tensile Strength [ksi]	Tensile Modulus [Msi]	Poisson's Ratio	Failure Mode
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M1-P61132-ZX-T-11-ETD-NF-1	1	1	0.141	1.842	0.131	0.215	LWB
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M1-P61751-ZX-T-12-ETD-NF-2	1	1	0.141	1.880	0.126	0.211	LWT
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M1-P61817-ZX-T-13-ETD-NF-3	1	1	0.140	1.806	0.120	0.204	LWB
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M2-P60434-ZX-T-11-ETD-NF-1	1	2	0.141	1.926	0.134	0.215	LWT
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M2-P61255-ZX-T-12-ETD-NF-2	1	2	0.140	1.907	0.134	0.217	LWB
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M2-P61818-ZX-T-13-ETD-NF-3	1	2	0.140	1.876	0.129	0.207	LGM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-B-M1-P62411-ZX-T-11-ETD-NF-1	2	1	0.140	1.659	0.109	0.212	LWB
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-B-M1-P66639-ZX-T-12-ETD-NF-2	2	1	0.141	1.834	0.109	0.226	LGM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-B-M1-P63018-ZX-T-13-ETD-NF-3	2	1	0.139	1.527	0.101	0.200	LWB
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-B-M2-P62412-ZX-T-11-ETD-NF-1	2	2	0.139	1.782	0.117	0.217	LWB
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-B-M2-P63352-ZX-T-12-ETD-NF-2	2	2	0.139	1.758	0.117	0.220	LWT
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-B-M2-P63506-ZX-T-13-ETD-NF-3	2	2	0.138	1.726	0.119	0.224	LWB
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-C-M1-P64600-ZX-T-11-ETD-NF-1	3	1	0.140	1.796	0.126	0.214	LGT
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-C-M1-P64991-ZX-T-12-ETD-NF-2	3	1	0.141	1.717	0.125	0.203	LWT
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-C-M1-P65365-ZX-T-13-ETD-NF-3	3	1	0.139	1.691	0.107	0.196	LGM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-C-M2-P65281-ZX-T-11-ETD-NF-1	3	2	0.138	1.771	0.117	0.199	LGB
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-C-M2-P65426-ZX-T-12-ETD-NF-2	3	2	0.139	1.837	0.129	0.201	LWB
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-C-M2-P65831-ZX-T-13-ETD-NF-3	3	2	0.141	1.738	0.110	0.194	LGB
		Average	**0.140**	**1.782**	**0.120**	**0.210**	
		Standard Dev.		**0.098**	**0.010**	**0.010**	
		Coeff. of Var. [%]		**5.495**	**8.337**	**4.643**	
		Min.	**0.138**	**1.527**	**0.101**	**0.194**	
		Max.	**0.141**	**1.926**	**0.134**	**0.226**	
		Number of Spec.	**18**	**18**	**18**	**18**	


ZX Orientation Tension Properties – ETD (130°F)
No Fiber (NF) Fill
Measure Strength
Markforged Onyx FR-A™ – Carbon Fiber FR-A™ / Markforged X7
Machine #
AM Batch #
Machine #
AM Batch #
Tensile Strength [ksi]
0
1
2
3
4
0.0
0.5
1.0
1.5
2.0
2.5

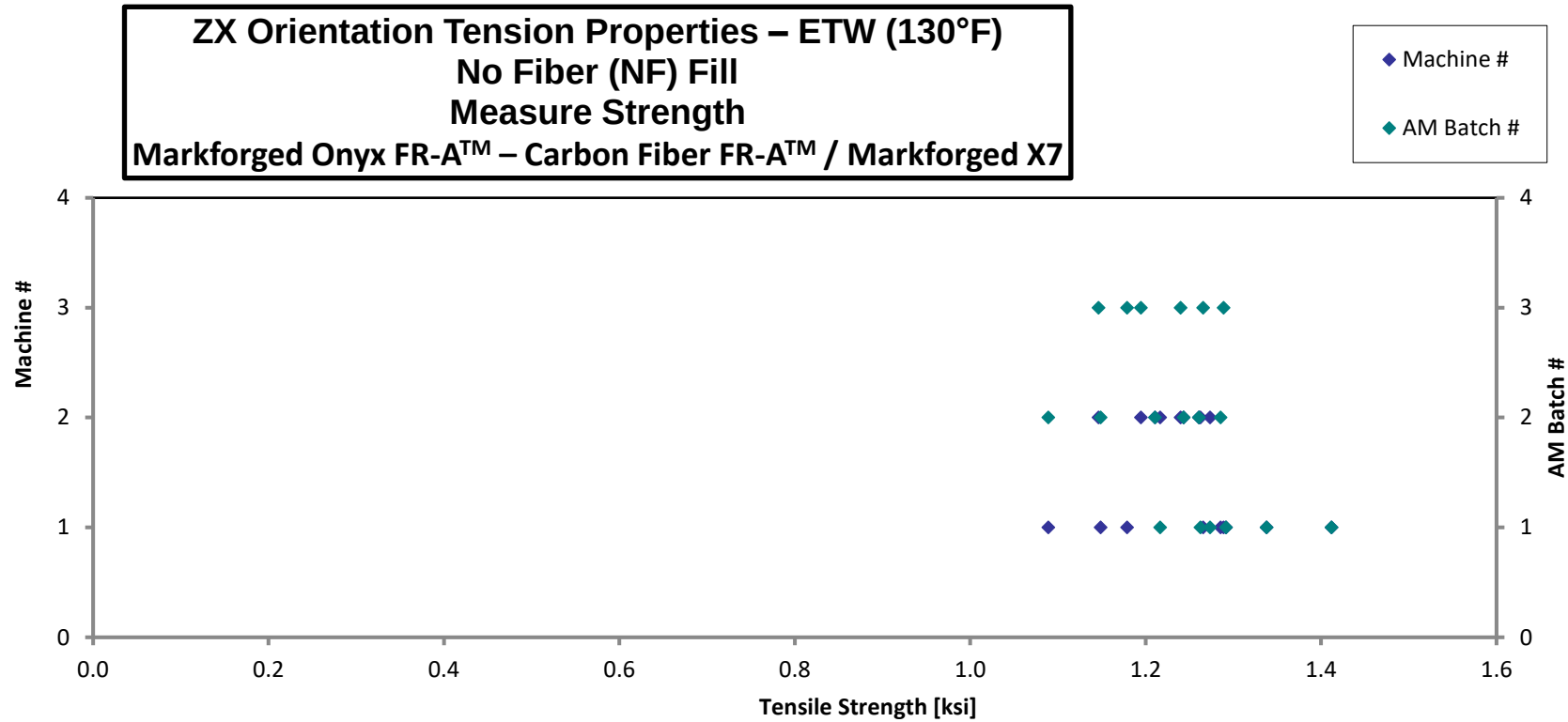

ZX Orientation Tension Properties – ETD (130°F)
No Fiber (NF) Fill
Measured Modulus
Markforged Onyx FR-A™ – Carbon Fiber FR-A™ / Markforged X7
Machine #
AM Batch #
Machine #
AM Batch #
Tensile Modulus [Msi]
0
1
2
3
4
0.00
0.02
0.04
0.06
0.08
0.10
0.12
0.14
0.16

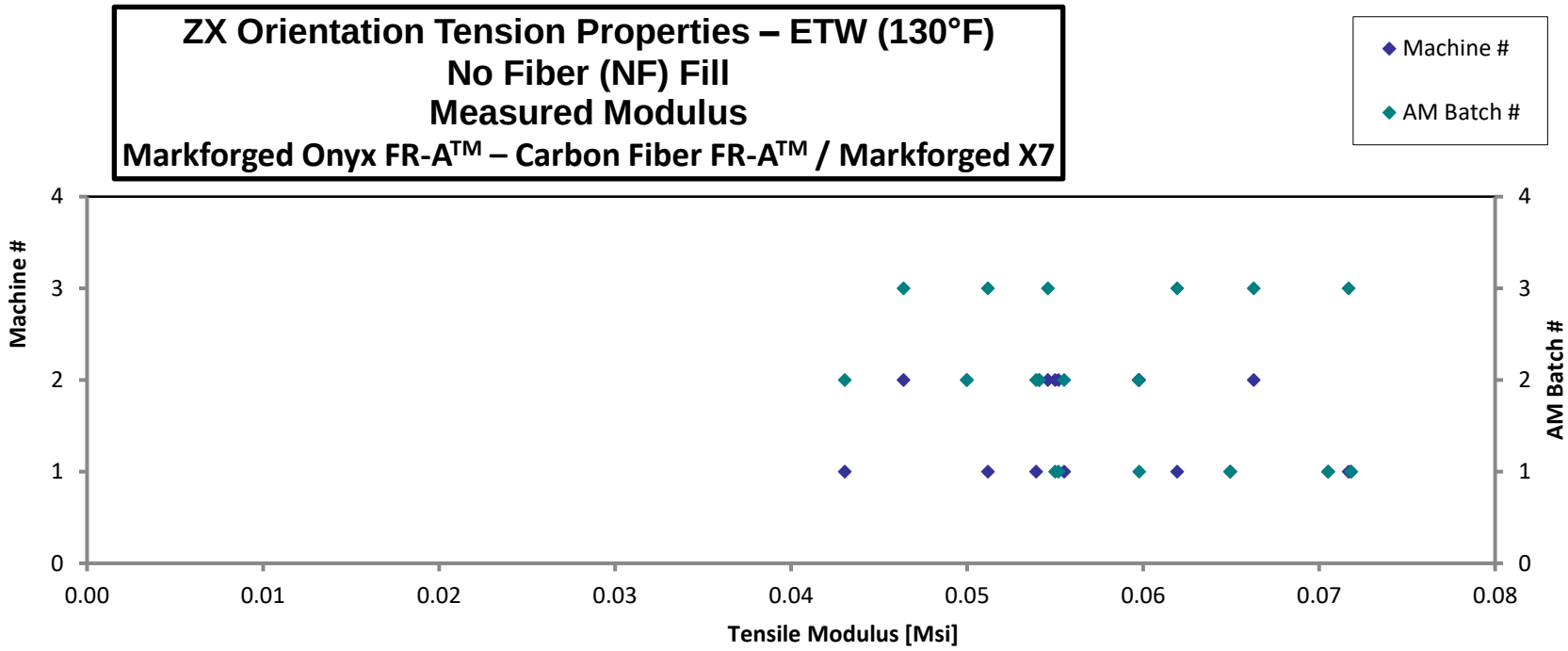

ZX Orientation Tension Properties – ETD (130°F)
No Fiber (NF) Fill
Measured Poisson's Ratio
Markforged Onyx FR-A™ – Carbon Fiber FR-A™ / Markforged X7
Machine #
AM Batch #
Machine #
AM Batch #
Poisson's Ratio
0.00
0.05
0.10
0.15
0.20
0.25
0
1
2
3
4

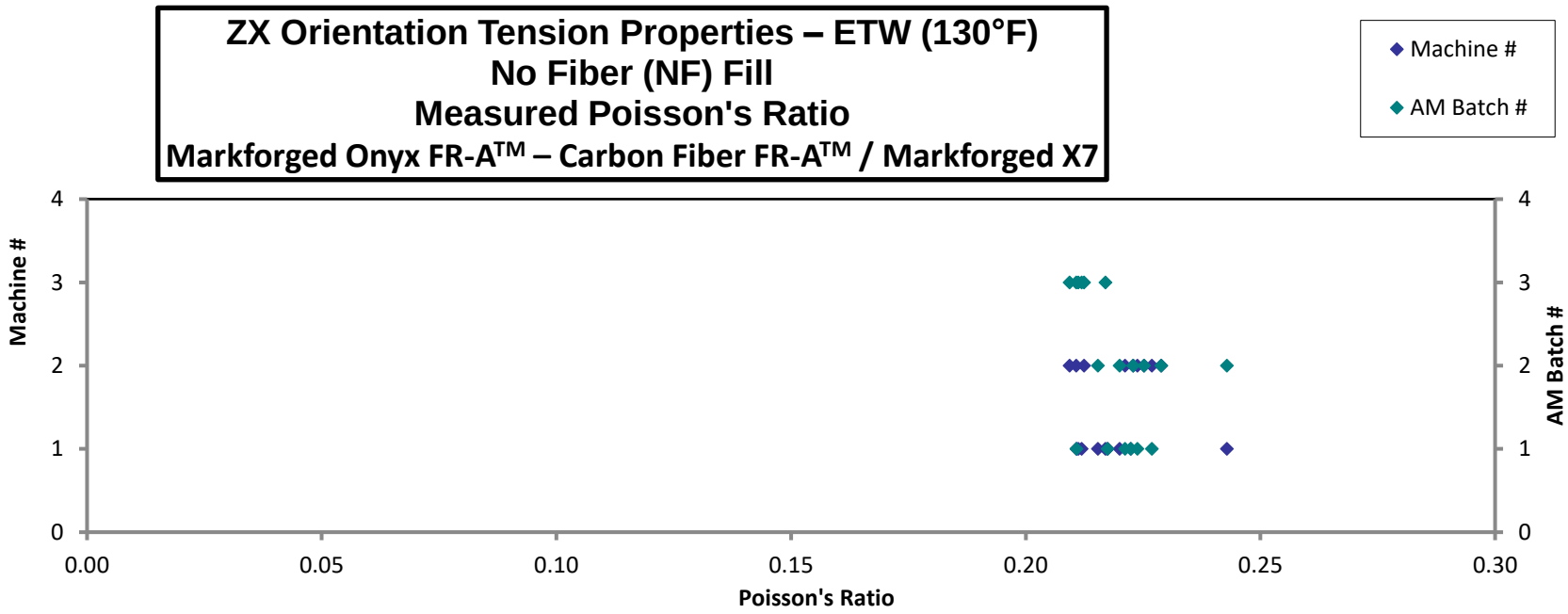
4.6.4 **ETW Condition**

ZX Orientation Tension Properties – ETW (130°F)
No Fiber (NF) Fill
Strength & Modulus
Markforged Onyx FR-A™ – Carbon Fiber FR-A™ / Markforged X7

Specimen Number	AM Batch #	Machine #	Avg. Specimen Thickness [in]	Tensile Strength [ksi]	Tensile Modulus [Msi]	Poisson's Ratio	Failure Mode
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M1-P61132-ZX-T-11-ETW-NF-1	1	1	0.140	1.412	0.072	0.222	LWB
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M1-P61751-ZX-T-12-ETW-NF-2	1	1	0.140	1.338	0.065	0.217	LWT
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M1-P61817-ZX-T-13-ETW-NF-3	1	1	0.139	1.292	0.071	0.211	LAB
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M2-P60434-ZX-T-11-ETW-NF-1	1	2	0.142	1.273	0.060	0.227	LWT
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M2-P61255-ZX-T-12-ETW-NF-2	1	2	0.142	1.216	0.055	0.224	LGM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M2-P61818-ZX-T-13-ETW-NF-3	1	2	0.141	1.263	0.055	0.221	LGT
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-B-M1-P62411-ZX-T-11-ETW-NF-1	2	1	0.139	1.149	0.054	0.220	LGM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-B-M1-P66639-ZX-T-12-ETW-NF-2	2	1	0.141	1.285	0.056	0.243	LGM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-B-M1-P63018-ZX-T-13-ETW-NF-3	2	1	0.140	1.089	0.043	0.215	LWB
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-B-M2-P62412-ZX-T-11-ETW-NF-1	2	2	0.139	1.211	0.054	0.223	LWT
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-B-M2-P63352-ZX-T-12-ETW-NF-2	2	2	0.138	1.243	0.050	0.229	LWB
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-B-M2-P63506-ZX-T-13-ETW-NF-3	2	2	0.138	1.261	0.060	0.225	LWB
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-C-M1-P64600-ZX-T-11-ETW-NF-1	3	1	0.140	1.289	0.072	0.217	LAT
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-C-M1-P64991-ZX-T-12-ETW-NF-2	3	1	0.140	1.265	0.062	0.212	LWB
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-C-M1-P65365-ZX-T-13-ETW-NF-3	3	1	0.140	1.179	0.051	0.211	LWB
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-C-M2-P65281-ZX-T-11-ETW-NF-1	3	2	0.139	1.146	0.046	0.212	LGB
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-C-M2-P65426-ZX-T-12-ETW-NF-2	3	2	0.139	1.195	0.066	0.211	LGM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-C-M2-P65831-ZX-T-13-ETW-NF-3	3	2	0.141	1.240	0.055	0.209	LWB
		Average	**0.140**	**1.241**	**0.058**	**0.219**	
		Standard Dev.		**0.075**	**0.008**	**0.008**	
		Coeff. of Var. [%]		**6.053**	**14.517**	**3.858**	
		Min.	**0.138**	**1.089**	**0.043**	**0.209**	
		Max.	**0.142**	**1.412**	**0.072**	**0.243**	
		Number of Spec.	**18**	**18**	**18**	**18**	


ZX Orientation Tension Properties – ETW (130°F)
No Fiber (NF) Fill
Measure Strength
Markforged Onyx FR-A™ – Carbon Fiber FR-A™ / Markforged X7
Machine #
AM Batch #
Machine #
AM Batch #
Tensile Strength [ksi]
0
1
2
3
4
0.0
0.2
0.4
0.6
0.8
1.0
1.2
1.4
1.6


ZX Orientation Tension Properties – ETW (130°F)
No Fiber (NF) Fill
Measured Modulus
Markforged Onyx FR-A™ – Carbon Fiber FR-A™ / Markforged X7
Machine #
AM Batch #
Machine #
AM Batch #
Tensile Modulus [Msi]
0
1
2
3
4
0.00
0.01
0.02
0.03
0.04
0.05
0.06
0.07
0.08


ZX Orientation Tension Properties – ETW (130°F)
No Fiber (NF) Fill
Measured Poisson's Ratio
Markforged Onyx FR-A™ – Carbon Fiber FR-A™ / Markforged X7
Machine #
AM Batch #
Machine #
AM Batch #
Poisson's Ratio
0
1
2
3
4
0.00
0.05
0.10
0.15
0.20
0.25
0.30

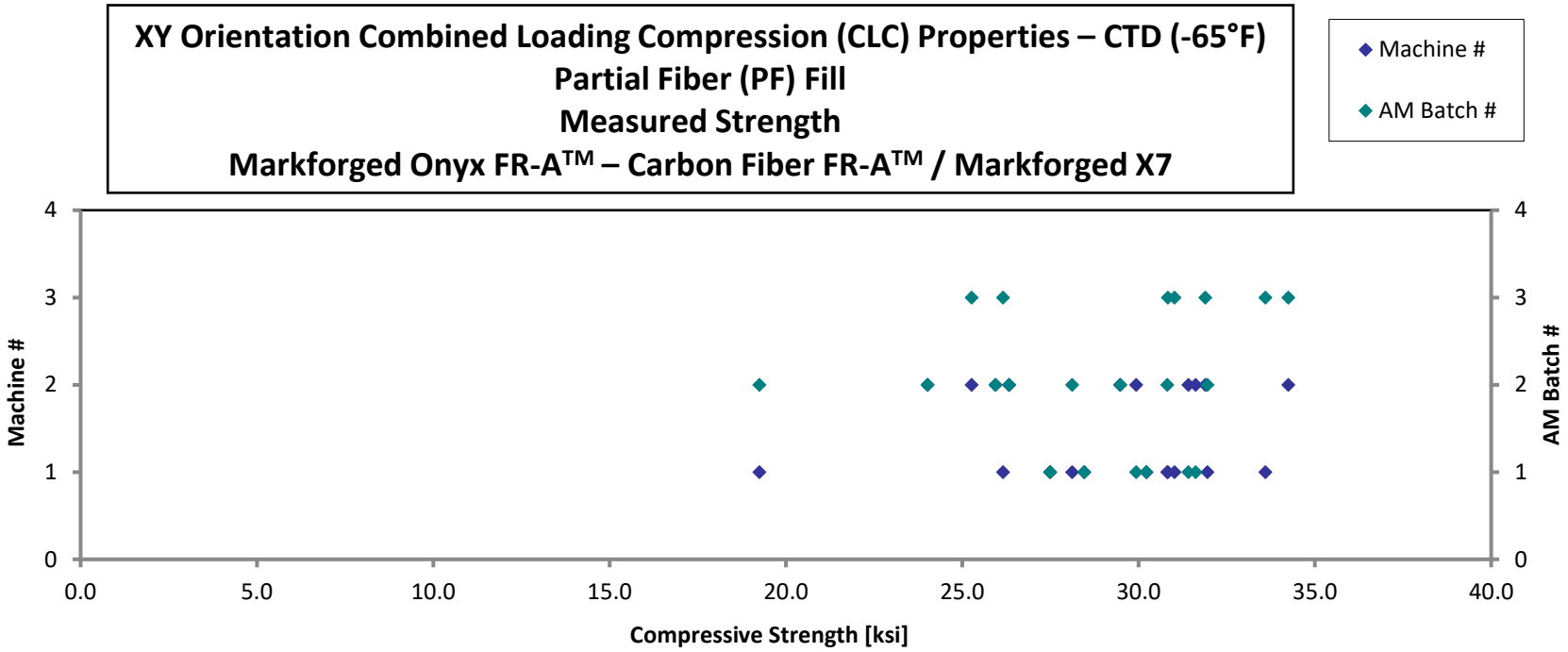
4.7 XY PF Compression Properties

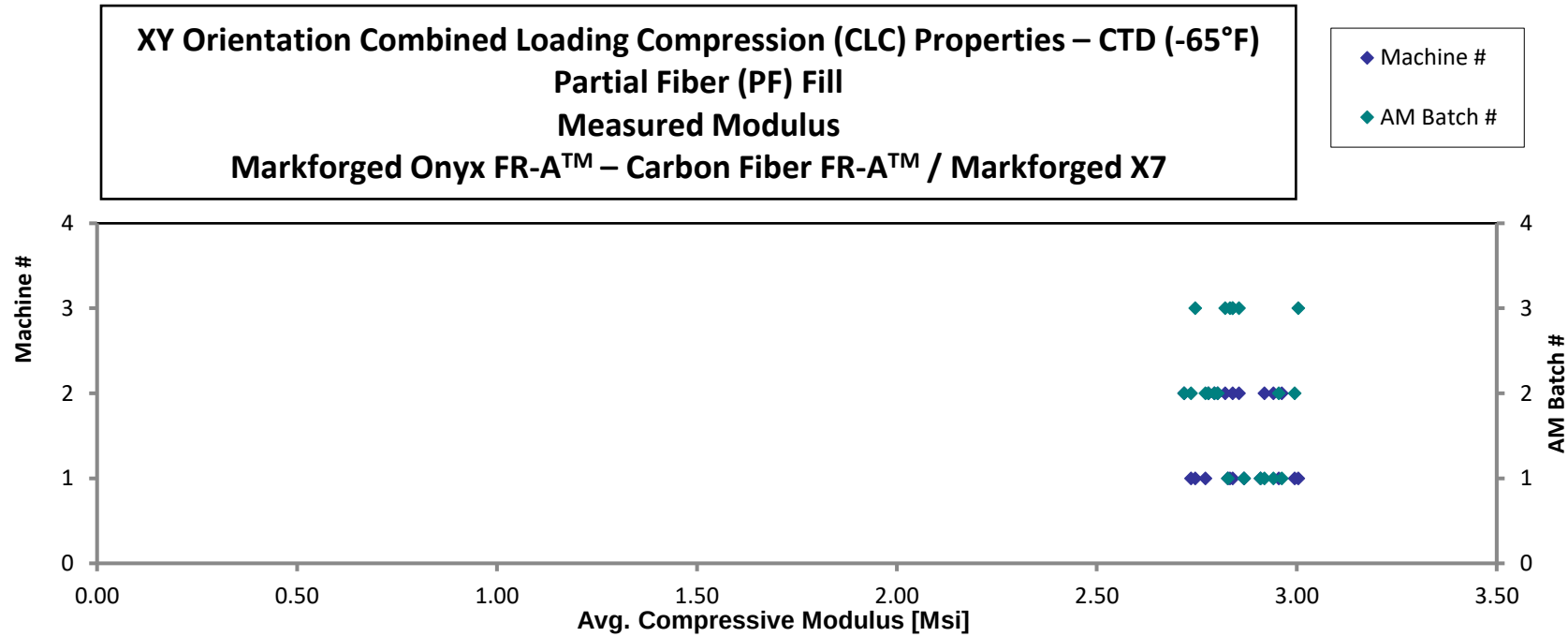
4.7.1 CTD Condition

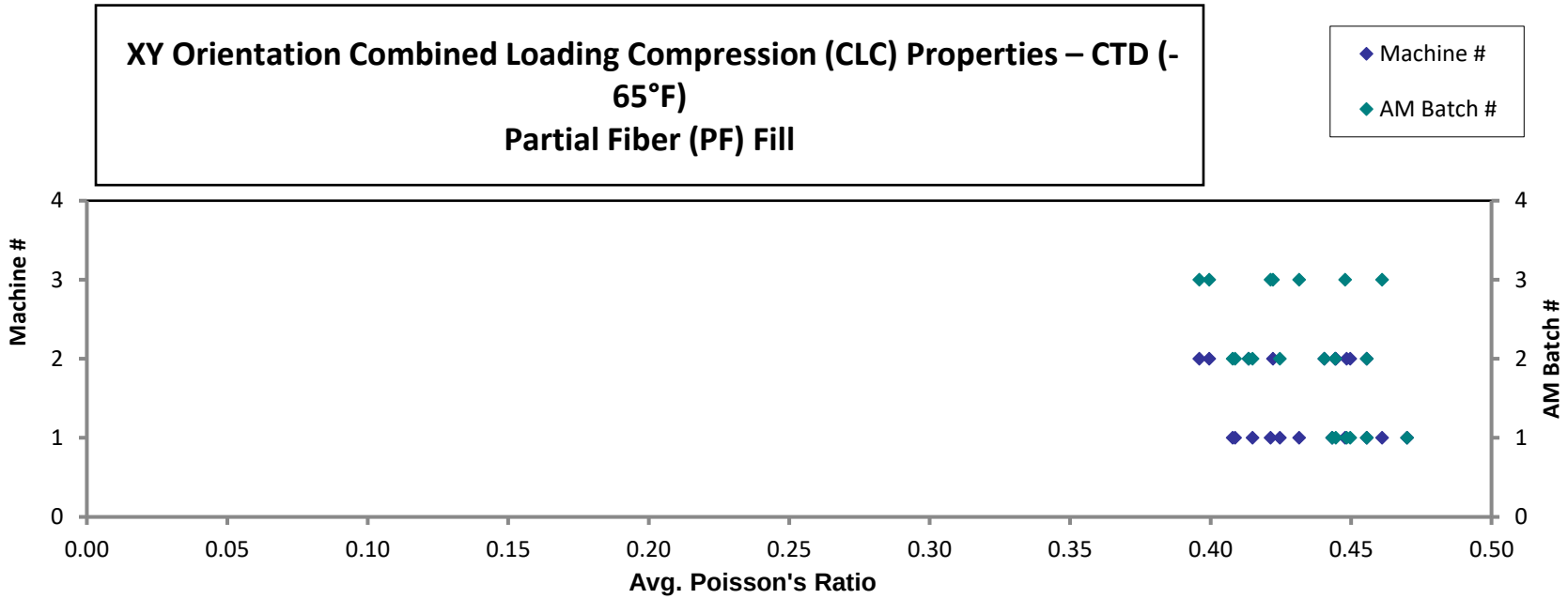
XY Orientation Combined Loading Compression (CLC) Properties – CTD (-65°F)
Partial Fiber (PF) Fill
Strength & Modulus
Markforged Onyx FR-A™ – Carbon Fiber FR-A™ / Markforged X7

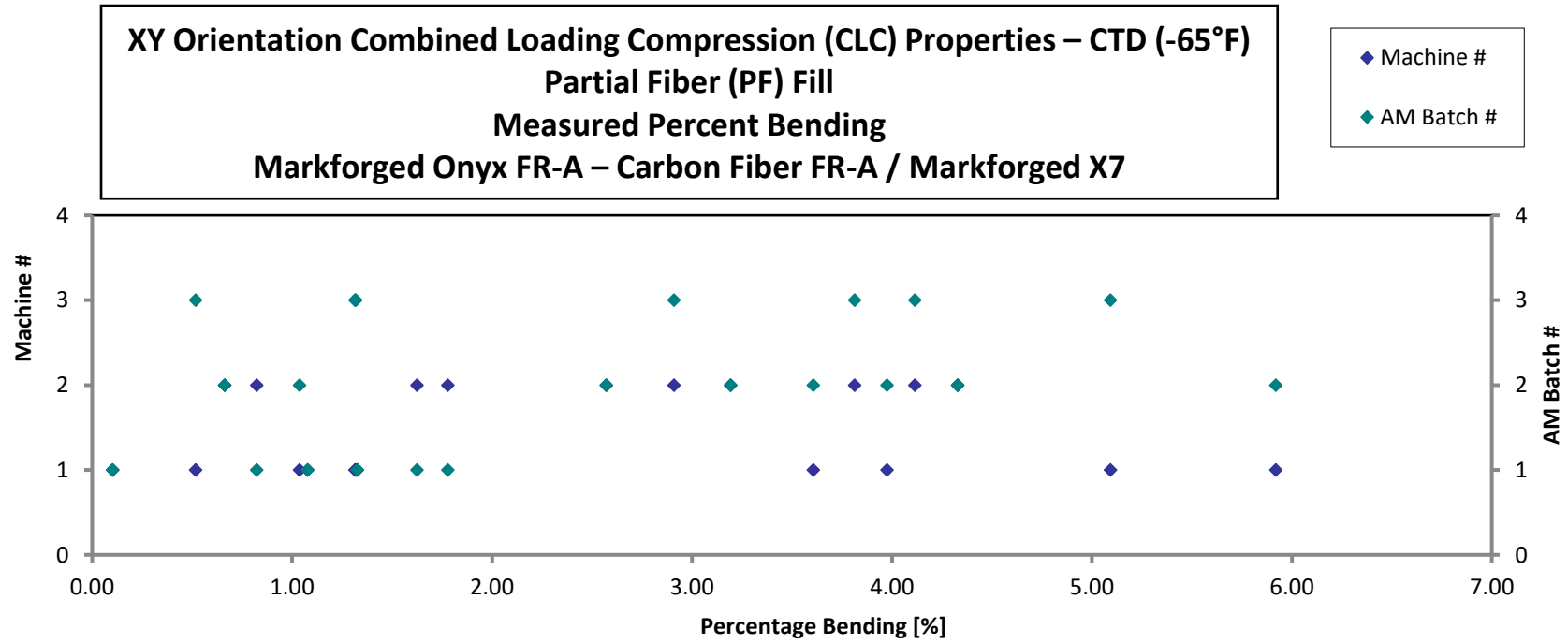
Specimen Number	AM Batch #	Machine #	Avg. Specimen Thickness [in]	Compressive Strength [ksi]	Avg. Compressive Modulus [Msi]	Avg. Poisson's Ratio	Percentage Bending [%]	Failure Mode
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M1-P31153-XY-CLC-11-CTD-PF-1	1	1	0.139	27.49	2.828	0.456	0.103	BGM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M1-P31494-XY-CLC-13-CTD-PF-3	1	1	0.140	30.22	2.909	0.470	1.078	BGM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M1-P31784-XY-CLC-13-CTD-PF-SP	1	1	0.141	28.46	2.868	0.443	1.327	BGM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M2-P31152-XY-CLC-11-CTD-PF-1	1	2	0.137	29.93	2.963	0.448	1.779	BGM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M2-P31428-XY-CLC-12-CTD-PF-2	1	2	0.139	31.61	2.919	0.450	1.624	BGM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M2-P31495-XY-CLC-13-CTD-PF-3	1	2	0.139	31.42	2.942	0.445	0.823	DGM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-B-M1-P39037-XY-CLC-11-CTD-PF-1	2	1	0.141	31.95	2.955	0.425	3.606	BGM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-B-M1-P58774-XY-CLC-12-CTD-PF-2	2	1	0.141	19.25	2.995	0.408	3.975	DGM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-B-M1-P55269-XY-CLC-13-CTD-PF-3	2	1	0.142	30.81	2.736	0.409	1.037	BGM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-B-M1-P33018-XY-CLC-13-CTD-PF-SP	2	1	0.143	28.12	2.772	0.415	5.920	DGM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-B-M2-P55140-XY-CLC-11-CTD-PF-1	2	2	0.141	26.32	2.794	0.456	0.663	BGM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-B-M2-P41450-XY-CLC-12-CTD-PF-2	2	2	0.143	25.94	2.779	0.441	2.572	BGM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-B-M2-P55764-XY-CLC-13-CTD-PF-3	2	2	0.142	24.02	2.718	0.444	3.193	BGM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-B-M2-P33019-XY-CLC-13-CTD-PF-SP	2	2	0.144	29.48	2.802	0.414	4.328	BGM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-C-M1-P35876-XY-CLC-11-CTD-PF-1	3	1	0.139	30.83	3.004	0.448	5.093	DGM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-C-M1-P36133-XY-CLC-12-CTD-PF-2	3	1	0.143	31.02	2.746	0.421	0.518	BGM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-C-M1-P47525-XY-CLC-13-CTD-PF-3	3	1	0.142	26.16	2.833	0.431	1.314	DGM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-C-M1-P35266-XY-CLC-13-CTD-PF-6	3	1	0.142	33.60	2.840	0.461	1.319	BGM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-C-M2-P34942-XY-CLC-11-CTD-PF-1	3	2	0.142	34.24	2.840	0.396	2.910	M(D,B)GM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-C-M2-P57299-XY-CLC-12-CTD-PF-2	3	2	0.144	25.27	2.855	0.400	3.814	M(D,B)GM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-C-M2-P35260-XY-CLC-13-CTD-PF-6	3	2	0.143	31.89	2.821	0.422	4.114	M(D,B)GM
		Average	**0.141**	**28.95**	**2.853**	**0.433**	**2.434**	
		Standard Dev.		**3.559**	**0.085**	**0.021**	**1.667**	
		Coeff. of Var. [%]		**12.29**	**2.983**	**4.913**	**68.48**	
		Min.	**0.137**	**19.25**	**2.718**	**0.396**	**0.103**	
		Max.	**0.144**	**34.24**	**3.004**	**0.470**	**5.920**	
		Number of Spec.	**21**	**21**	**21**	**21**	**21**	

Note: Modulus and Poisson's Ratio are average values of 2 strain gages


XY Orientation Combined Loading Compression (CLC) Properties – CTD (-65°F)
Partial Fiber (PF) Fill
Measured Strength
Markforged Onyx FR-A™ – Carbon Fiber FR-A™ / Markforged X7
Machine #
AM Batch #
Machine #
AM Batch #
Compressive Strength [ksi]
0.0
5.0
10.0
15.0
20.0
25.0
30.0
35.0
40.0
0
1
2
3
4


XY Orientation Combined Loading Compression (CLC) Properties – CTD (-65°F)
Partial Fiber (PF) Fill
Measured Modulus
Markforged Onyx FR-A™ – Carbon Fiber FR-A™ / Markforged X7
Machine #
AM Batch #
Machine #
AM Batch #
0
1
2
3
4
0.00
0.50
1.00
1.50
2.00
2.50
3.00
3.50
Avg. Compressive Modulus [Msi]


XY Orientation Combined Loading Compression (CLC) Properties – CTD (-65°F)
Partial Fiber (PF) Fill
Machine #
AM Batch #
Machine #
AM Batch #
0
1
2
3
4
0.00
0.05
0.10
0.15
0.20
0.25
0.30
0.35
0.40
0.45
0.50
Avg. Poisson's Ratio

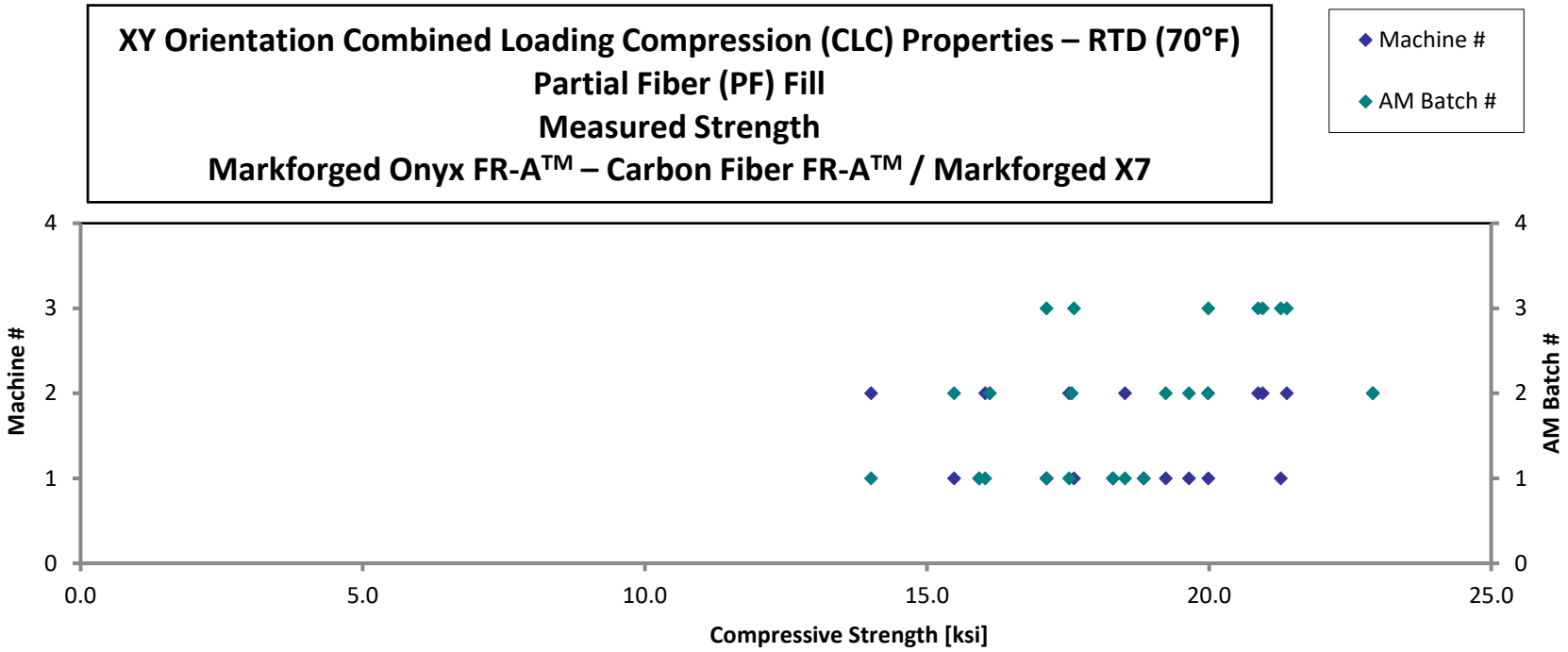

XY Orientation Combined Loading Compression (CLC) Properties – CTD (-65°F)
Partial Fiber (PF) Fill
Measured Percent Bending
Markforged Onyx FR-A – Carbon Fiber FR-A / Markforged X7
Machine #
AM Batch #
Machine #
AM Batch #
Percentage Bending [%]
0
1
2
3
4
0.00
1.00
2.00
3.00
4.00
5.00
6.00
7.00

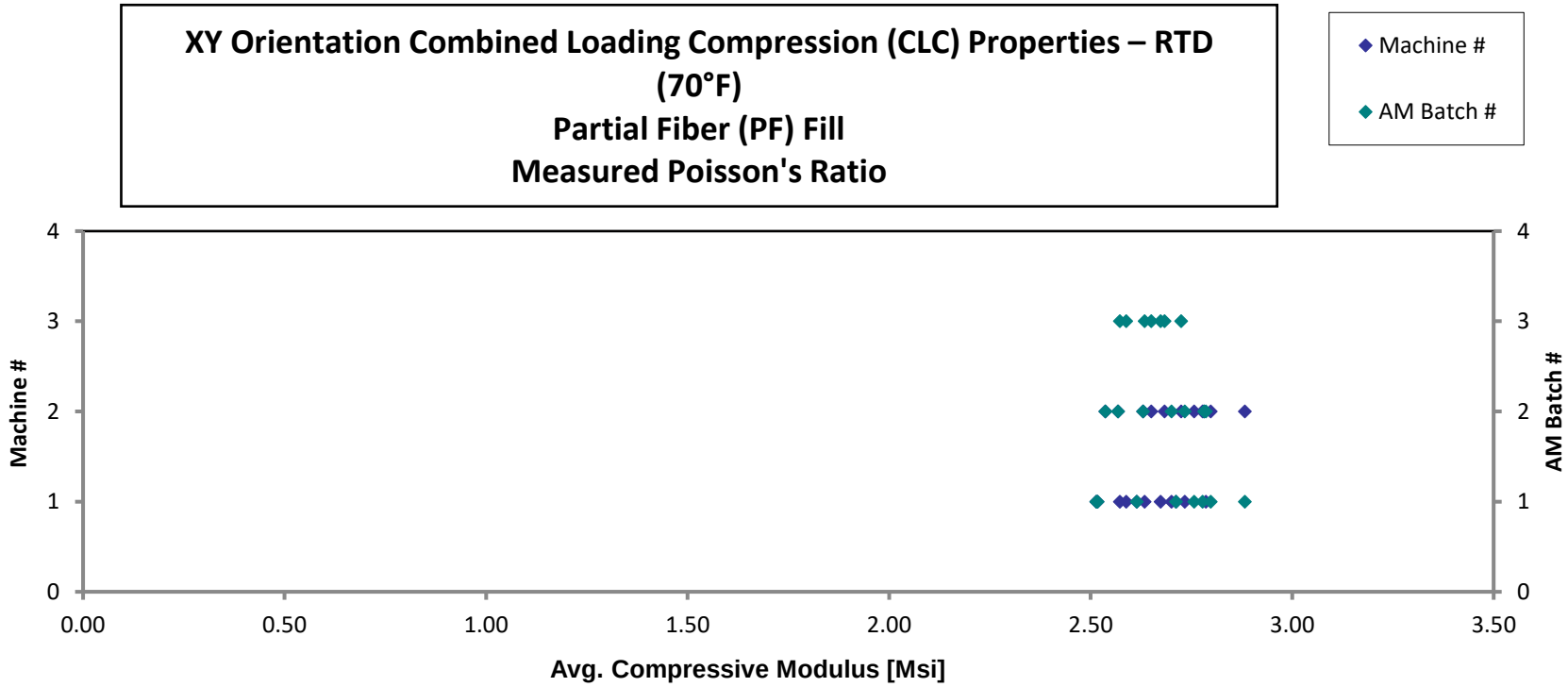
4.7.2 **RTD Condition**

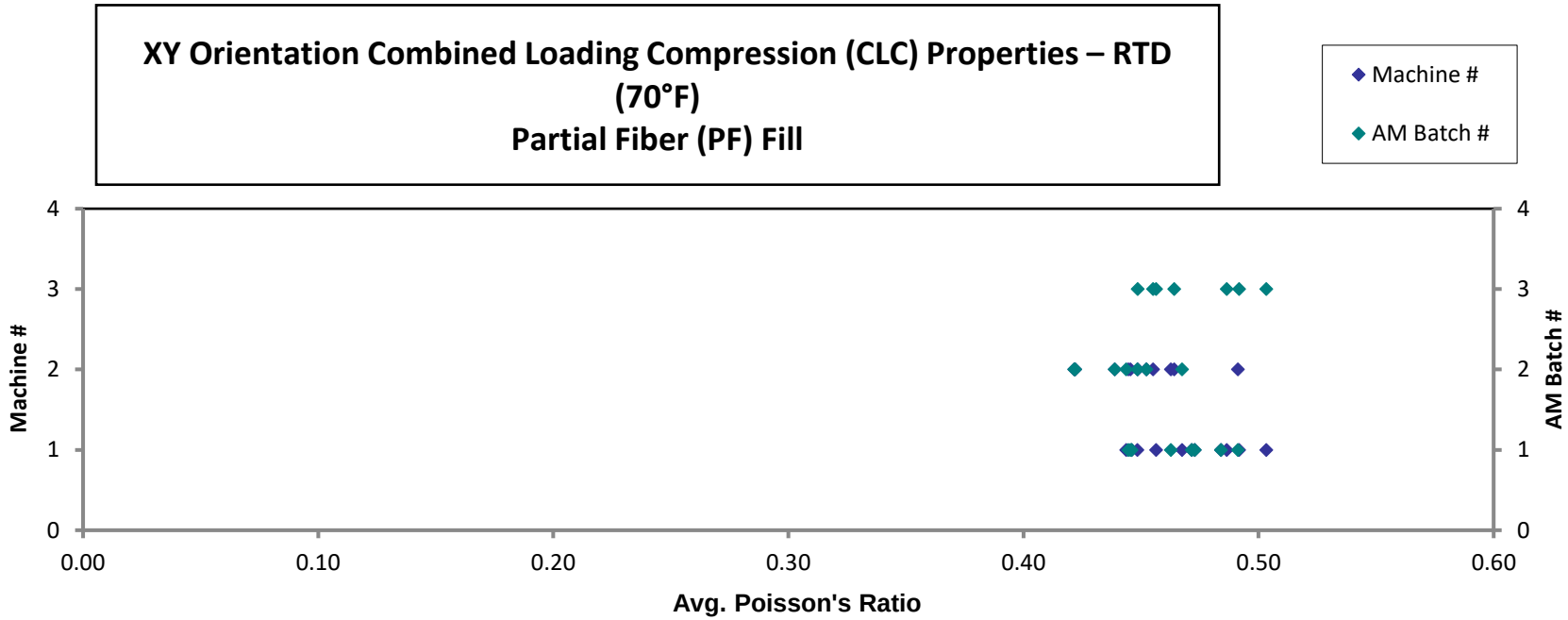
XY Orientation Combined Loading Compression (CLC) Properties – RTD (70°F)
Partial Fiber (PF) Fill
Strength & Modulus
Markforged Onyx FR-A™ – Carbon Fiber FR-A™ / Markforged X7

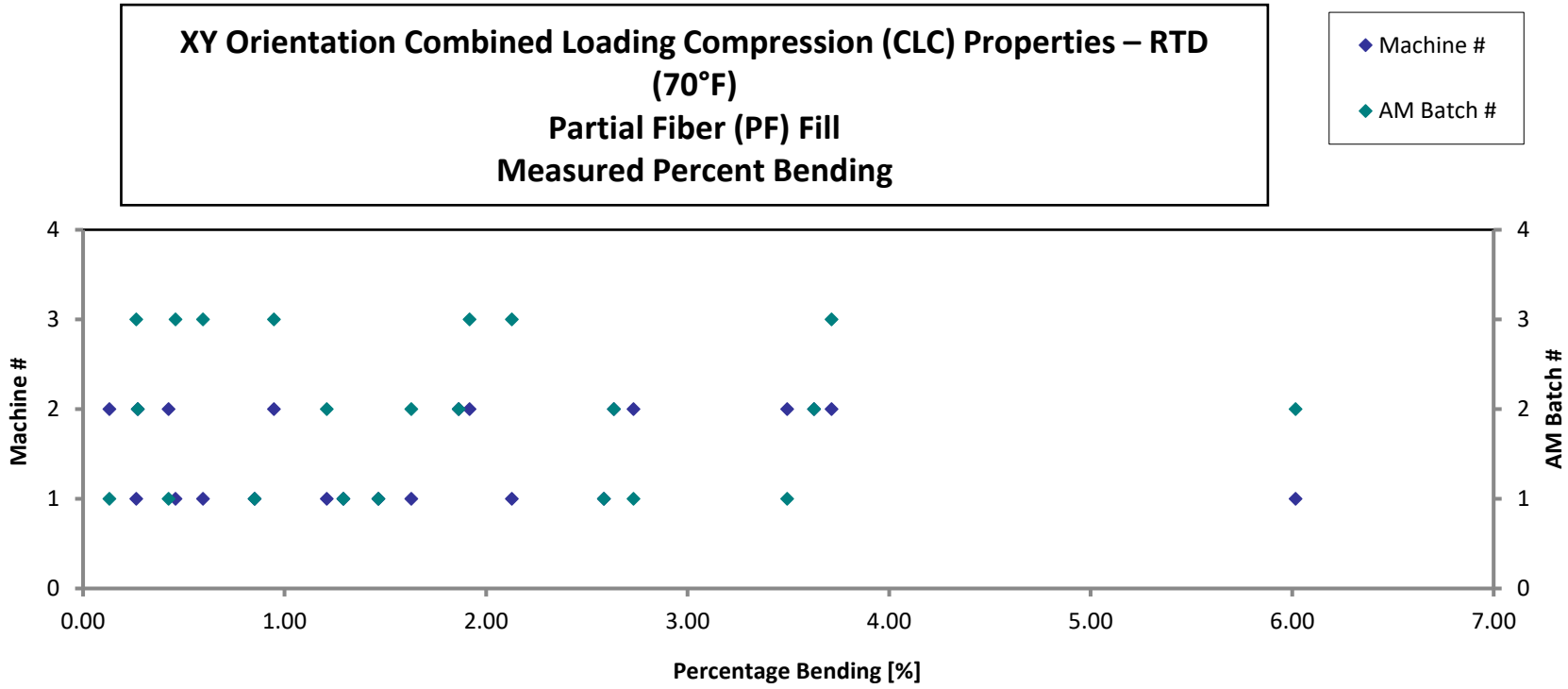
Specimen Number	AM Batch #	Machine #	Avg. Specimen Thickness [in]	Compressive Strength [ksi]	Avg. Compressive Modulus [Msi]	Avg. Poisson's Ratio	Percentage Bending [%]	Failure Mode
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M1-P54807-XY-CLC-11-RTD-PF-1	1	1	0.143	18.84	2.712	0.472	0.851	DGM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M1-P31153-XY-CLC-12-RTD-PF-2	1	1	0.144	17.12	2.514	0.446	2.585	DGM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M1-P31455-XY-CLC-13-RTD-PF-3	1	1	0.142	18.30	2.615	0.484	1.292	DGM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M1-P31610-XY-CLC-13-RTD-PF-SP	1	1	0.141	15.93	2.517	0.473	1.465	KGM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M2-P31697-XY-CLC-11-RTD-PF-1	1	2	0.137	18.51	2.778	0.463	2.731	KGM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M2-P31152-XY-CLC-12-RTD-PF-2	1	2	0.141	17.52	2.883	0.445	0.424	KGM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M2-P31456-XY-CLC-13-RTD-PF-3	1	2	0.139	14.01	2.757	0.446	0.130	KGM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M2-P31611-XY-CLC-13-RTD-PF-SP	1	2	0.140	16.03	2.798	0.491	3.494	KGM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-B-M1-P33716-XY-CLC-11-RTD-PF-1	2	1	0.137	19.64	2.786	0.444	6.017	HGM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-B-M1-P39037-XY-CLC-12-RTD-PF-2	2	1	0.141	19.23	2.734	0.448	1.628	HGM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-B-M1-P33244-XY-CLC-13-RTD-PF-3	2	1	0.138	15.48	2.700	0.467	1.209	HGM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-B-M2-P56216-XY-CLC-11-RTD-PF-1	2	2	0.142	19.98	2.537	0.422	2.634	DGM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-B-M2-P55140-XY-CLC-12-RTD-PF-2	2	2	0.143	16.11	2.568	0.422	3.628	DGM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-B-M2-P33243-XY-CLC-13-RTD-PF-3	2	2	0.138	17.56	2.781	0.452	0.271	DGM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-B-M2-P33154-XY-CLC-13-RTD-PF-SP	2	2	0.139	22.90	2.630	0.439	1.864	DGM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-C-M1-P35346-XY-CLC-11-RTD-PF-1	3	1	0.141	17.61	2.674	0.503	0.458	DGM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-C-M1-P35876-XY-CLC-12-RTD-PF-2	3	1	0.142	19.99	2.634	0.492	0.264	DGM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-C-M1-P49394-XY-CLC-13-RTD-PF-3	3	1	0.143	17.12	2.572	0.456	0.595	DGM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-C-M1-P35257-XY-CLC-13-RTD-PF-6	3	1	0.141	21.27	2.588	0.486	2.128	DGM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-C-M2-P35347-XY-CLC-11-RTD-PF-1	3	2	0.139	20.87	2.724	0.455	3.714	HGM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-C-M2-P34942-XY-CLC-12-RTD-PF-2	3	2	0.142	21.38	2.683	0.449	1.918	DGM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-C-M2-P35191-XY-CLC-13-RTD-PF-3	3	2	0.138	20.95	2.651	0.464	0.946	DGM
		Average	**0.141**	**18.47**	**2.674**	**0.460**	**1.829**	
		Standard Dev.		**2.262**	**0.101**	**0.022**	**1.463**	
		Coeff. of Var. [%]		**12.25**	**3.783**	**4.780**	**79.97**	
		Min.	**0.137**	**14.01**	**2.514**	**0.422**	**0.130**	
		Max.	**0.144**	**22.90**	**2.883**	**0.503**	**6.017**	
		Number of Spec.	**22**	**22**	**22**	**22**	**22**	

Note: Modulus and Poisson's Ratio are average values of 2 strain gages


XY Orientation Combined Loading Compression (CLC) Properties – RTD (70°F)
Partial Fiber (PF) Fill
Measured Strength
Markforged Onyx FR-A™ – Carbon Fiber FR-A™ / Markforged X7
Machine #
AM Batch #
Machine #
AM Batch #
Compressive Strength [ksi]
0.0
5.0
10.0
15.0
20.0
25.0
0
1
2
3
4


XY Orientation Combined Loading Compression (CLC) Properties – RTD (70°F)
Partial Fiber (PF) Fill
Measured Poisson's Ratio
Machine #
AM Batch #
Machine #
AM Batch #
0
1
2
3
4
0.00
0.50
1.00
1.50
2.00
2.50
3.00
3.50
Avg. Compressive Modulus [Msi]


XY Orientation Combined Loading Compression (CLC) Properties – RTD (70°F)
Partial Fiber (PF) Fill
Machine #
AM Batch #
Machine #
AM Batch #
0
1
2
3
4
0.00
0.10
0.20
0.30
0.40
0.50
0.60
Avg. Poisson's Ratio

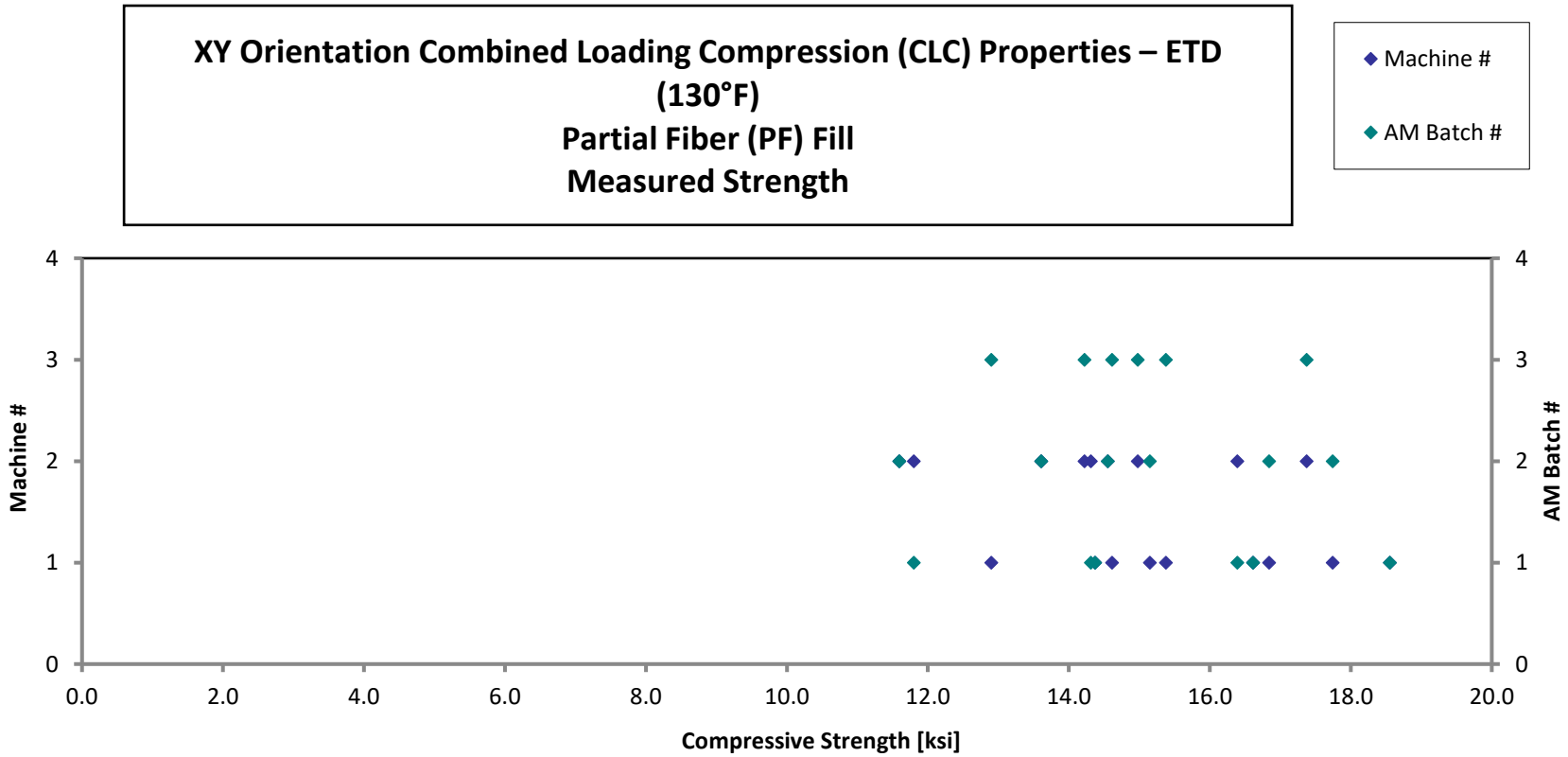

XY Orientation Combined Loading Compression (CLC) Properties – RTD (70°F)
Partial Fiber (PF) Fill
Measured Percent Bending
Machine #
AM Batch #
Machine #
AM Batch #
Percentage Bending [%]
0
1
2
3
4
0.00
1.00
2.00
3.00
4.00
5.00
6.00
7.00

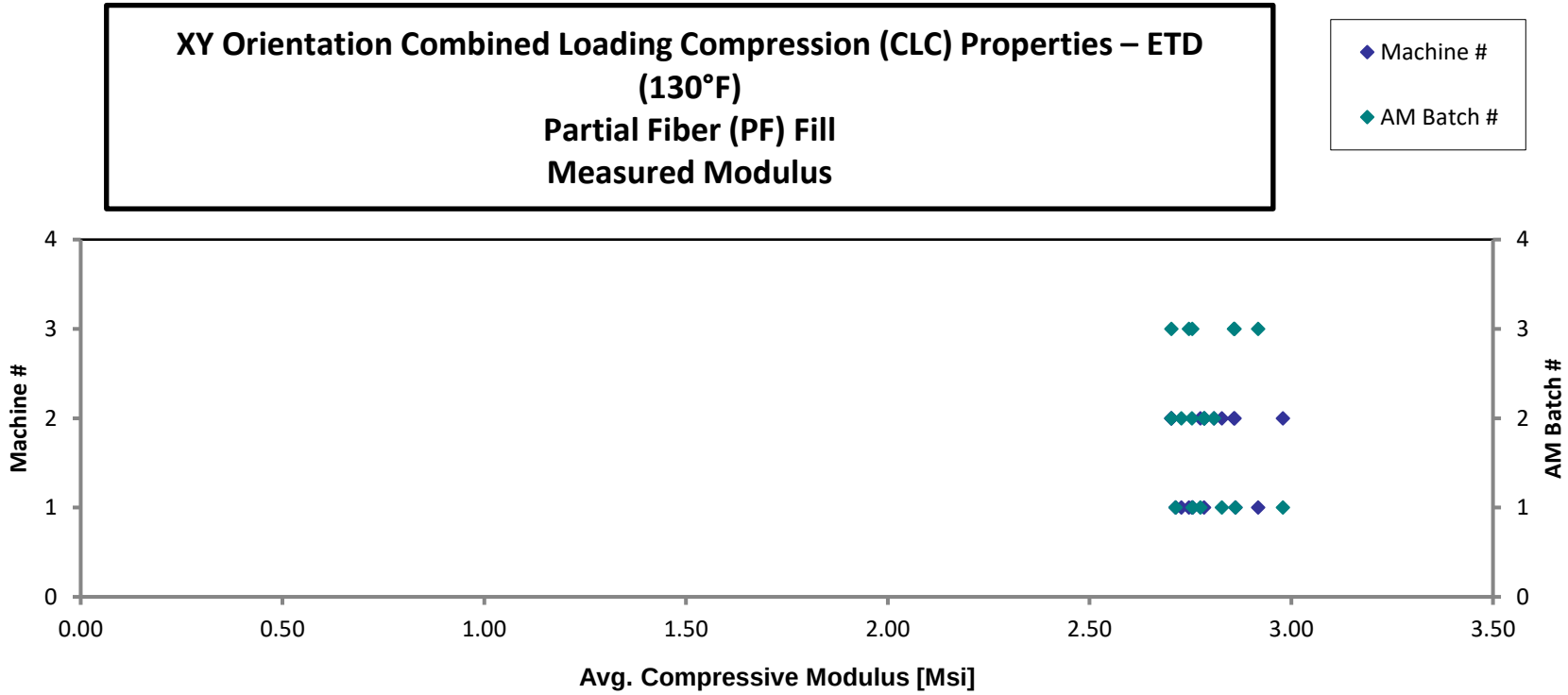
4.7.3 **ETD Condition**

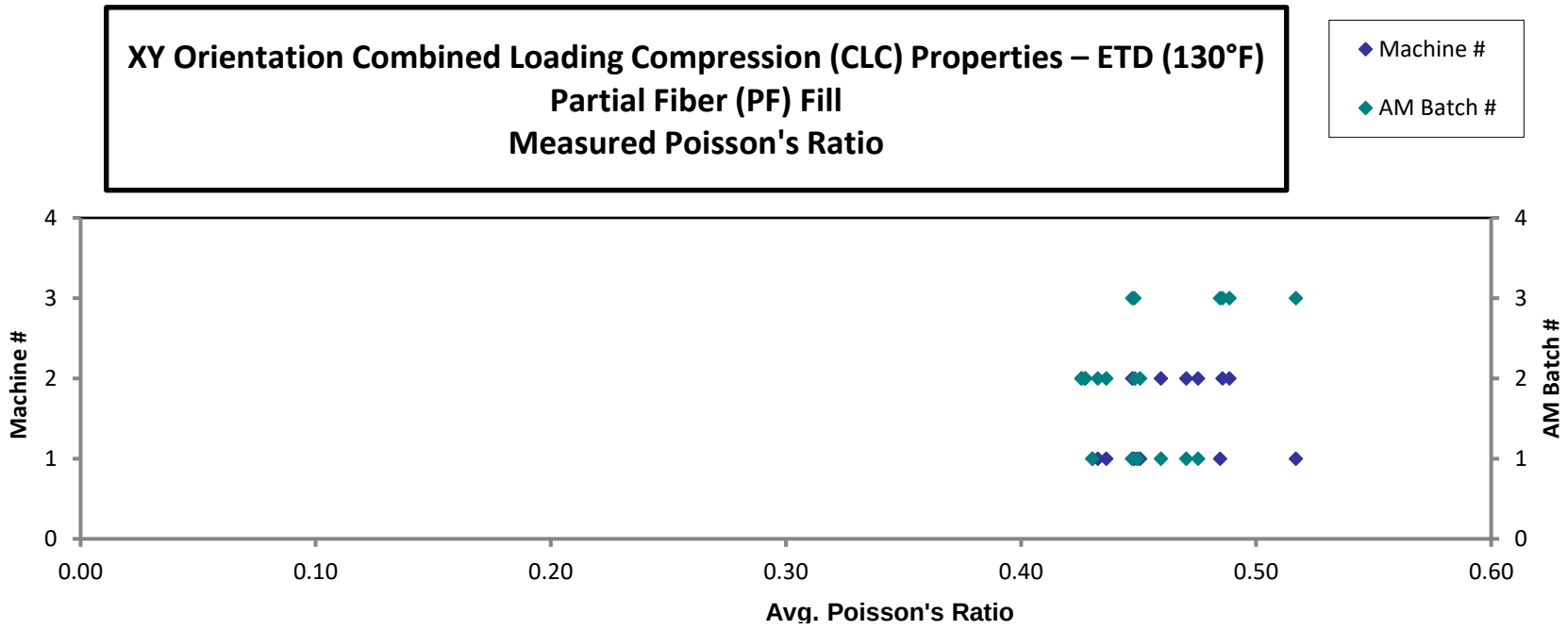
XY Orientation Combined Loading Compression (CLC) Properties – ETD (130°F)
Partial Fiber (PF) Fill
Strength & Modulus
Markforged Onyx FR-A™ – Carbon Fiber FR-A™ / Markforged X7

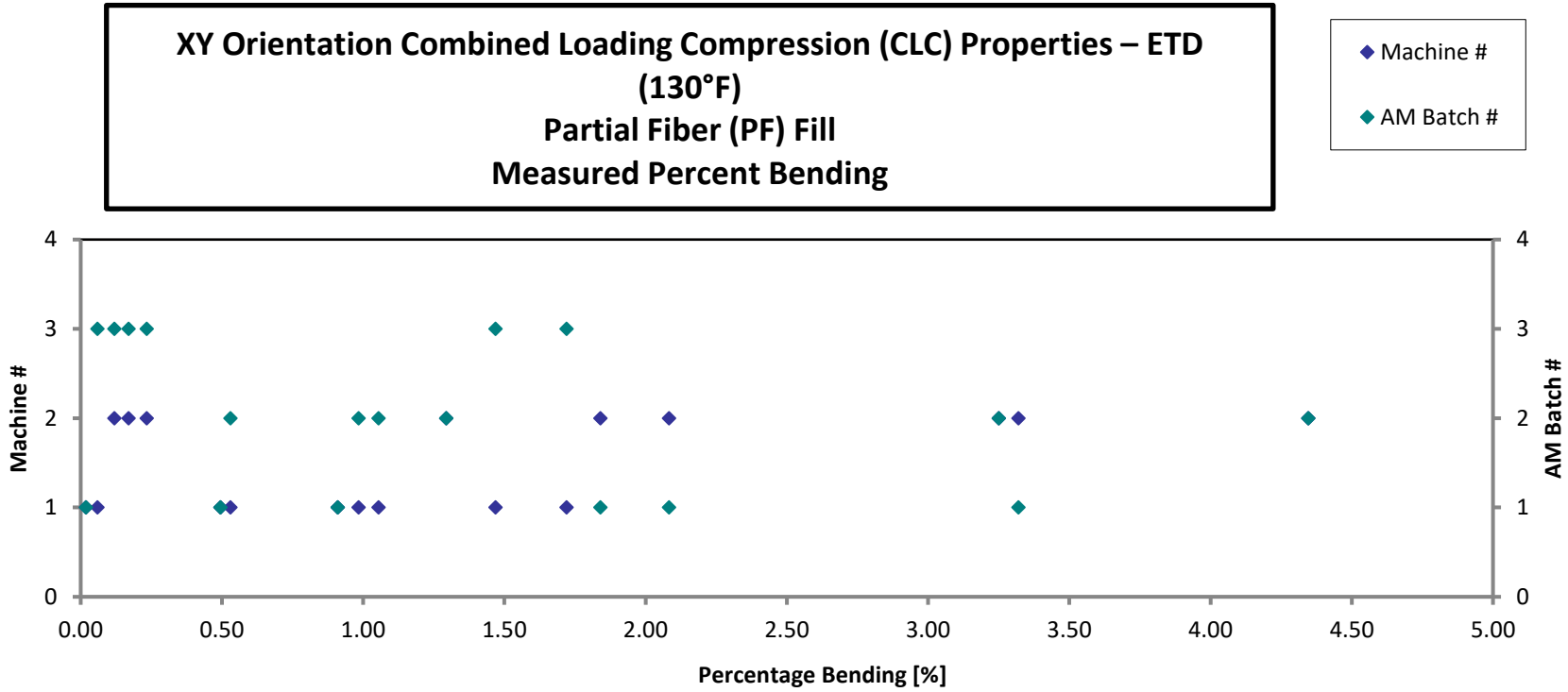
Specimen Number	AM Batch #	Machine #	Avg. Specimen Thickness [in]	Compressive Strength [ksi]	Avg. Compressive Modulus [Msi]	Avg. Poisson's Ratio	Percentage Bending [%]	Failure Mode
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M1-P44531-XY-CLC-11-ETD-PF-1	1	1	0.141	16.61	2.713	0.449	0.910	HGM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M1-P54259-XY-CLC-12-ETD-PF-2	1	1	0.142	18.56	2.862	0.430	0.018	HGM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M1-P42981-XY-CLC-13-ETD-PF-3	1	1	0.142	14.37	2.755	0.447	0.494	HGM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M2-P42916-XY-CLC-11-ETD-PF-1	1	2	0.142	14.31	2.775	0.470	2.083	HGM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M2-P54704-XY-CLC-12-ETD-PF-2	1	2	0.144	16.39	2.979	0.475	3.320	HGM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M2-P42495-XY-CLC-13-ETD-PF-3	1	2	0.143	11.80	2.828	0.460	1.840	HGM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-B-M1-P40117-XY-CLC-11-ETD-PF-1	2	1	0.141	17.74	2.754	0.436	0.984	HGM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-B-M1-P56493-XY-CLC-12-ETD-PF-2	2	1	0.143	16.84	2.784	0.433	0.530	HGM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-B-M1-P41009-XY-CLC-13-ETD-PF-3	2	1	0.143	15.15	2.727	0.451	1.055	HGM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-B-M2-P38680-XY-CLC-11-ETD-PF-1	2	2	0.141	13.61	2.703	0.427	1.294	HGM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-B-M2-P65963-XY-CLC-12-ETD-PF-2	2	2	0.141	14.55	2.785	0.426	3.250	HGM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-B-M2-P46418-XY-CLC-13-ETD-PF-3	2	2	0.143	11.60	2.808	0.448	4.346	HGM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-C-M1-P47955-XY-CLC-11-ETD-PF-1	3	1	0.143	15.38	2.754	0.485	1.720	HGM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-C-M1-P51329-XY-CLC-12-ETD-PF-2	3	1	0.145	14.61	2.918	0.517	0.059	HGM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-C-M1-P48076-XY-CLC-13-ETD-PF-3	3	1	0.145	12.90	2.746	0.448	1.469	HGM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-C-M2-P49458-XY-CLC-11-ETD-PF-1	3	2	0.141	17.37	2.858	0.447	0.169	HGM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-C-M2-P51557-XY-CLC-12-ETD-PF-2	3	2	0.145	14.98	2.859	0.486	0.234	HGM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-C-M2-P47970-XY-CLC-13-ETD-PF-3	3	2	0.145	14.22	2.703	0.489	0.119	HGM
		Average	**0.143**	**15.06**	**2.795**	**0.457**	**1.328**	
		Standard Dev.		**1.938**	**0.076**	**0.025**	**1.256**	
		Coeff. of Var. [%]		**12.87**	**2.733**	**5.500**	**94.59**	
		Min.	**0.141**	**11.60**	**2.703**	**0.426**	**0.018**	
		Max.	**0.145**	**18.56**	**2.979**	**0.517**	**4.346**	
		Number of Spec.	**18**	**18**	**18**	**18**	**18**	

Note: Modulus and Poisson's Ratio are average values of 2 strain gages


XY Orientation Combined Loading Compression (CLC) Properties – ETD (130°F)
Partial Fiber (PF) Fill
Measured Strength
Machine #
AM Batch #
Machine #
AM Batch #
Compressive Strength [ksi]
0
1
2
3
4
0.0
2.0
4.0
6.0
8.0
10.0
12.0
14.0
16.0
18.0
20.0


XY Orientation Combined Loading Compression (CLC) Properties – ETD (130°F)
Partial Fiber (PF) Fill
Measured Modulus
Machine #
AM Batch #
Machine #
AM Batch #
0
1
2
3
4
0.00
0.50
1.00
1.50
2.00
2.50
3.00
3.50
Avg. Compressive Modulus [Msi]


XY Orientation Combined Loading Compression (CLC) Properties – ETD (130°F)
Partial Fiber (PF) Fill
Measured Poisson's Ratio
Machine #
AM Batch #
Machine #
AM Batch #
0
1
2
3
4
0.00
0.10
0.20
0.30
0.40
0.50
0.60
Avg. Poisson's Ratio


XY Orientation Combined Loading Compression (CLC) Properties – ETD (130°F)
Partial Fiber (PF) Fill
Measured Percent Bending
Machine #
AM Batch #
Machine #
AM Batch #
Percentage Bending [%]
0
1
2
3
4
0.00
0.50
1.00
1.50
2.00
2.50
3.00
3.50
4.00
4.50
5.00

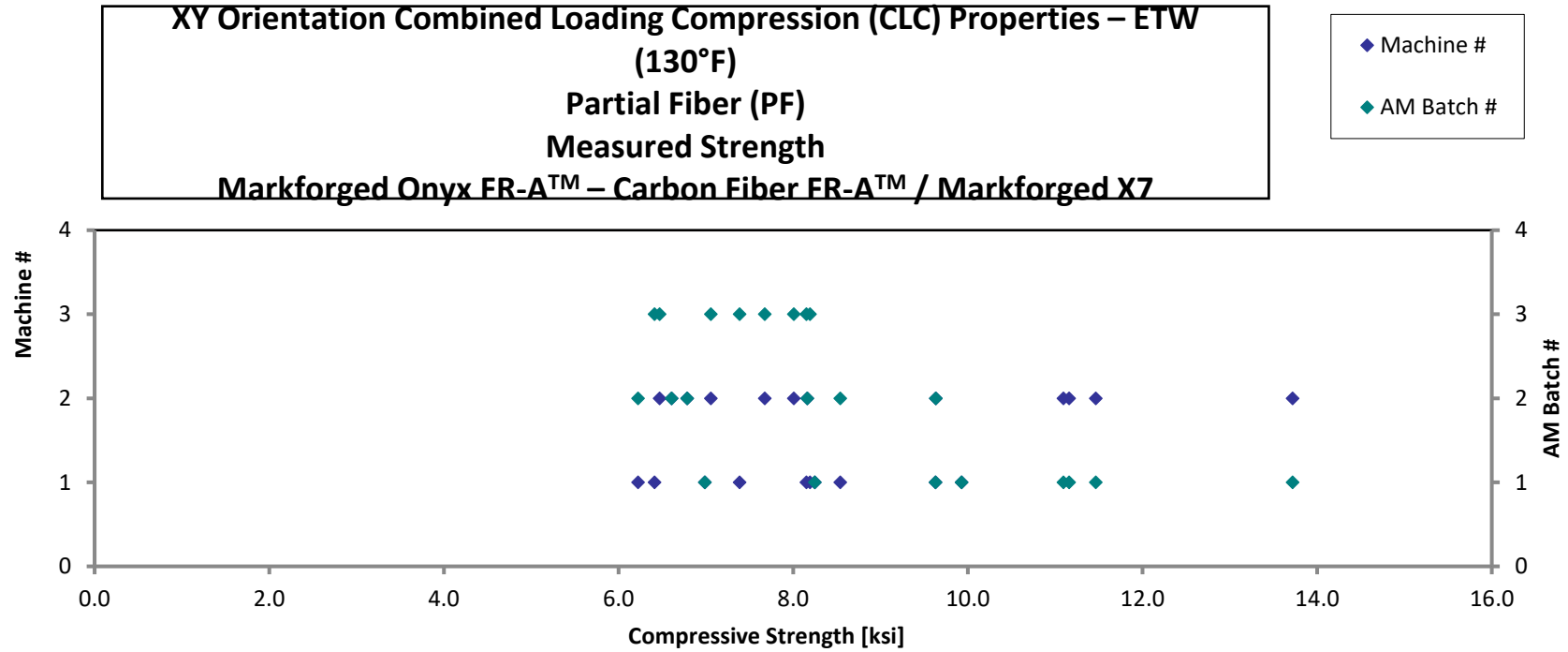
4.7.4 **ETW Condition**

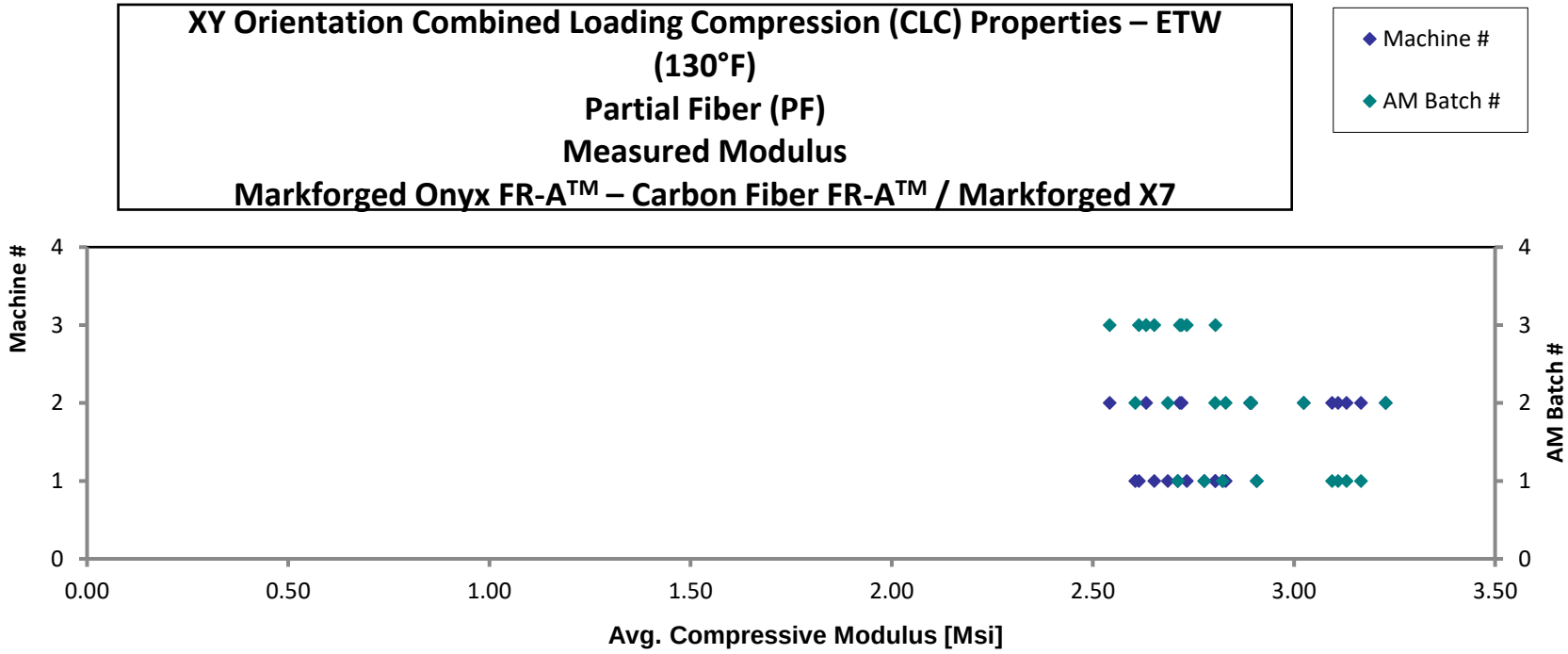
XY Orientation Combined Loading Compression (CLC) Properties – ETW (130°F)
Partial Fiber (PF)
FillStrength & Modulus
Markforged Onyx FR-A™ – Carbon Fiber FR-A™/ Markforged X7

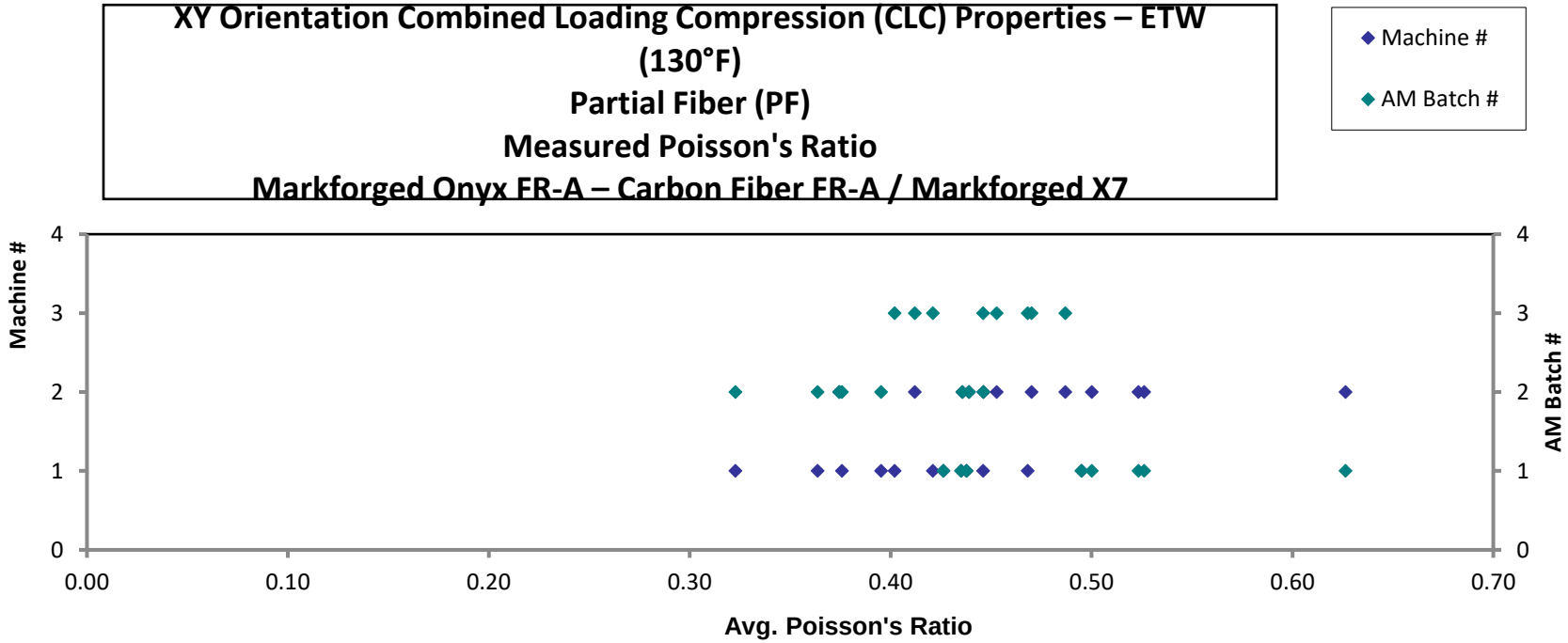
Specimen Number	AM Batch #	Machine #	Avg. Specimen Thickness [in]	Compressive Strength [ksi]	Avg. Compressive Modulus [Msi]	Avg. Poisson's Ratio	Percentage Bending [%]	Failure Mode
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M1-P54807-XY-CLC-11-ETW-PF-1	1	1	0.143	9.628	2.823	0.435	2.243	HGM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M1-P31490-XY-CLC-12-ETW-PF-2	1	1	0.145	9.928	2.908	0.438	1.906	HGM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M1-P31494-XY-CLC-13-ETW-PF-3	1	1	0.142	8.248	2.711	0.426	3.355	HGM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M1-P31784-XY-CLC-13-ETW-PF-SP****	1	1	0.142	6.987	2.777	0.495		HGM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M2-P31697-XY-CLC-11-ETW-PF-1	1	2	0.139	13.72	3.095	0.523	3.806	DGM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M2-P31491-XY-CLC-12-ETW-PF-2	1	2	0.141	11.09	3.131	0.526	0.170	DGM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M2-P31495-XY-CLC-13-ETW-PF-3	1	2	0.137	11.16	3.167	0.626	3.401	DGM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M2-P31785-XY-CLC-13-ETW-PF-SP	1	2	0.141	11.46	3.110	0.500	0.443	DGM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-B-M1-P33716-XY-CLC-11-ETW-PF-1*/**	2	1	0.140		2.804	0.376	16.46	HGM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-B-M1-P55801-XY-CLC-12-ETW-PF-2**	2	1	0.144	6.225	2.686	0.364	5.944	HGM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-B-M1-P55269-XY-CLC-13-ETW-PF-3**	2	1	0.142	8.538	2.830	0.395	0.488	HGM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-B-M1-P33018-XY-CLC-13-ETW-PF-SP*/**	2	1	0.144		2.605	0.323	16.54	HGM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-B-M2-P56216-XY-CLC-11-ETW-PF-1	2	2	0.140	9.633	3.024	0.446	1.164	HGM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-B-M2-P40904-XY-CLC-12-ETW-PF-2*	2	2	0.142	8.163	3.228	0.439	10.71	HGM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-B-M2-P55764-XY-CLC-13-ETW-PF-3	2	2	0.142	6.786	2.891	0.374	5.163	HGM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-B-M2-P33019-XY-CLC-13-ETW-PF-SP	2	2	0.143	6.607	2.894	0.436	3.928	HGM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-C-M1-P35346-XY-CLC-11-ETW-PF-1***	3	1	0.140	8.191	2.805	0.468	2.161	HGM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-C-M1-P35650-XY-CLC-12-ETW-PF-2***	3	1	0.145	8.152	2.615	0.421	4.843	HGM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-C-M1-P47525-XY-CLC-13-ETW-PF-3***	3	1	0.143	6.411	2.653	0.446	2.336	HGM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-C-M1-P35266-XY-CLC-13-ETW-PF-6***	3	1	0.144	7.387	2.734	0.402	2.415	HGM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-C-M2-P35347-XY-CLC-11-ETW-PF-1	3	2	0.139	7.674	2.721	0.453	7.343	HGM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-C-M2-P34965-XY-CLC-12-ETW-PF-2	3	2	0.144	8.006	2.633	0.470	0.615	HGM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-C-M2-P57239-XY-CLC-13-ETW-PF-3	3	2	0.143	6.471	2.542	0.487	8.991	HGM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-C-M2-P35260-XY-CLC-13-ETW-PF-6	3	2	0.142	7.058	2.716	0.412	0.275	HGM

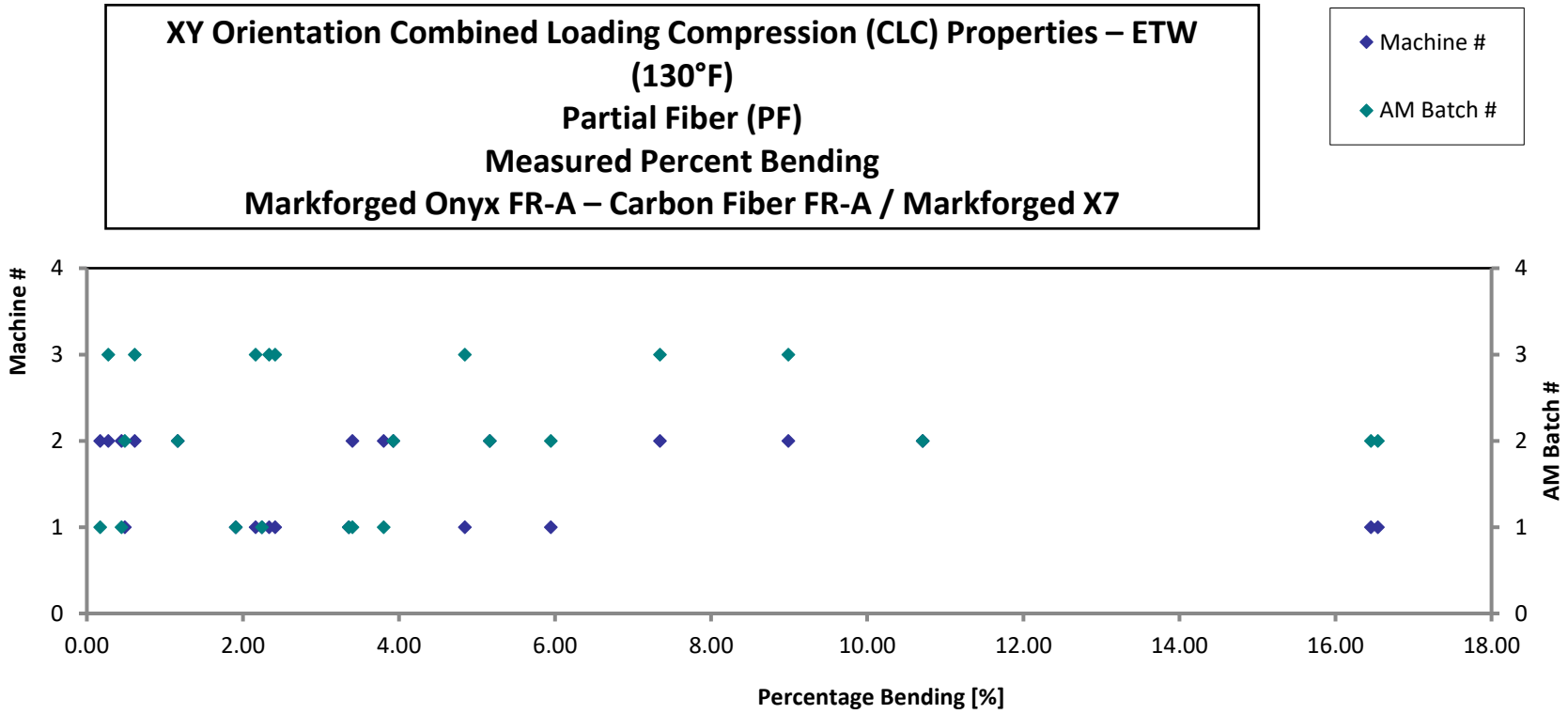
Average	**0.142**	**8.524**	**2.838**	**0.445**	**4.552**		
Standard Dev.		**1.970**	**0.196**	**0.063**	**4.683**		
Coeff. of Var. [%]		**23.11**	**6.911**	**14.22**	**102.9**		
Min.	**0.137**	**6.225**	**2.542**	**0.323**	**0.170**		
Max.	**0.145**	**13.72**	**3.228**	**0.626**	**16.54**		
Number of Spec.	**24**	**22**	**24**	**24**	**23**		

*Strength not reported due to percent bending being greater than 10% (invalid)
**Modulus calculation used 500-1500 microstrain
***Modulus calculation used 500-2000 microstrain
****Poisson's ratio and percent bending not reported due to strain gage failure
Note: Modulus and Poisson's Ratio are average values of 2 strain gages


XY Orientation Combined Loading Compression (CLC) Properties – ETW (130°F)
Partial Fiber (PF)
Measured Strength
Markforged Onyx FR-A™ – Carbon Fiber FR-A™ / Markforged X7
Machine #
AM Batch #
Machine #
AM Batch #
Compressive Strength [ksi]
0
1
2
3
4
0.0
2.0
4.0
6.0
8.0
10.0
12.0
14.0
16.0


XY Orientation Combined Loading Compression (CLC) Properties – ETW (130°F)
Partial Fiber (PF)
Measured Modulus
Markforged Onyx FR-A™ – Carbon Fiber FR-A™ / Markforged X7
Machine #
AM Batch #
Machine #
AM Batch #
0
1
2
3
4
0.00
0.50
1.00
1.50
2.00
2.50
3.00
3.50
Avg. Compressive Modulus [Msi]


XY Orientation Combined Loading Compression (CLC) Properties – ETW (130°F)
Partial Fiber (PF)
Measured Poisson's Ratio
Markforged Onyx FR-A – Carbon Fiber FR-A / Markforged X7
Machine #
AM Batch #
Machine #
AM Batch #
0
1
2
3
4
0.00
0.10
0.20
0.30
0.40
0.50
0.60
0.70
Avg. Poisson's Ratio


XY Orientation Combined Loading Compression (CLC) Properties – ETW (130°F)
Partial Fiber (PF)
Measured Percent Bending
Markforged Onyx FR-A – Carbon Fiber FR-A / Markforged X7
Machine #
AM Batch #
Machine #
AM Batch #
Percentage Bending [%]
0
1
2
3
4
0.00
2.00
4.00
6.00
8.00
10.00
12.00
14.00
16.00
18.00

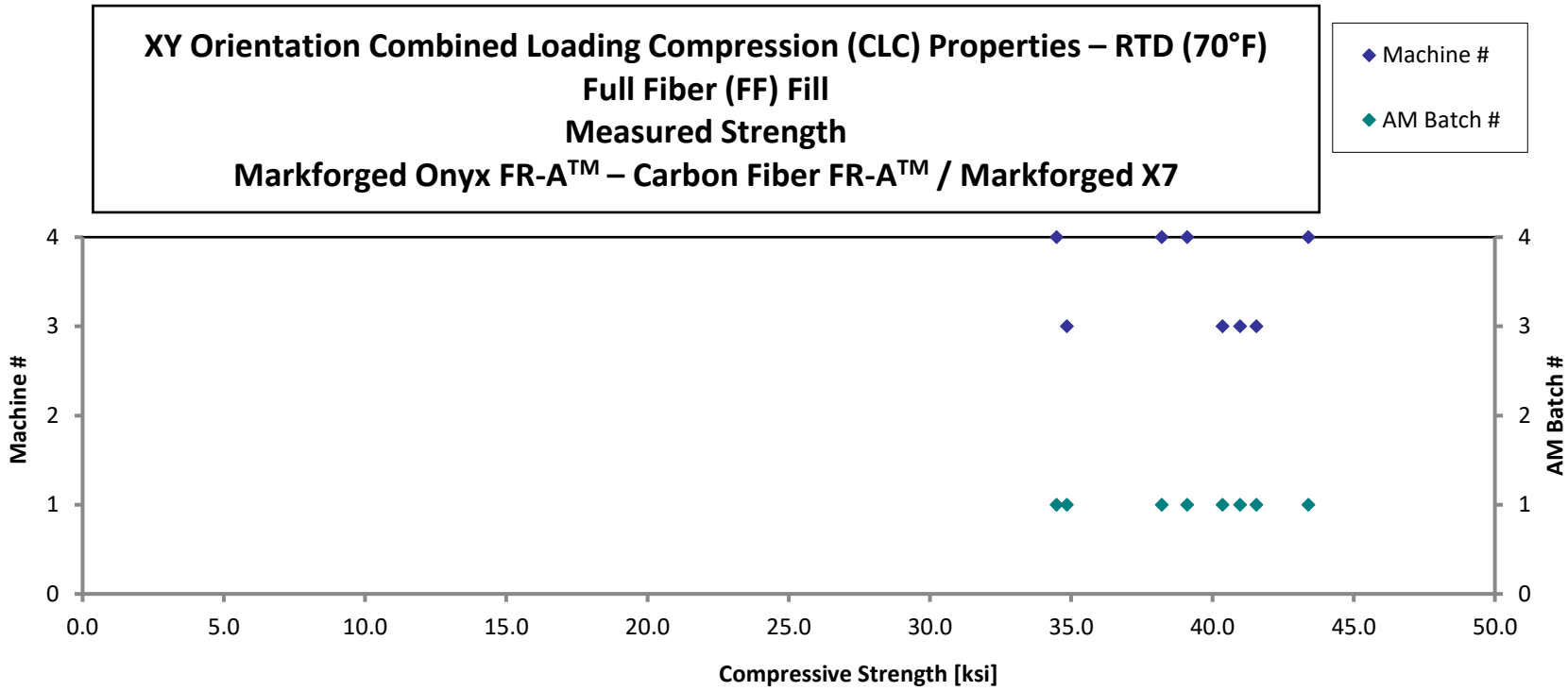
4.8 XY FF Compression Properties

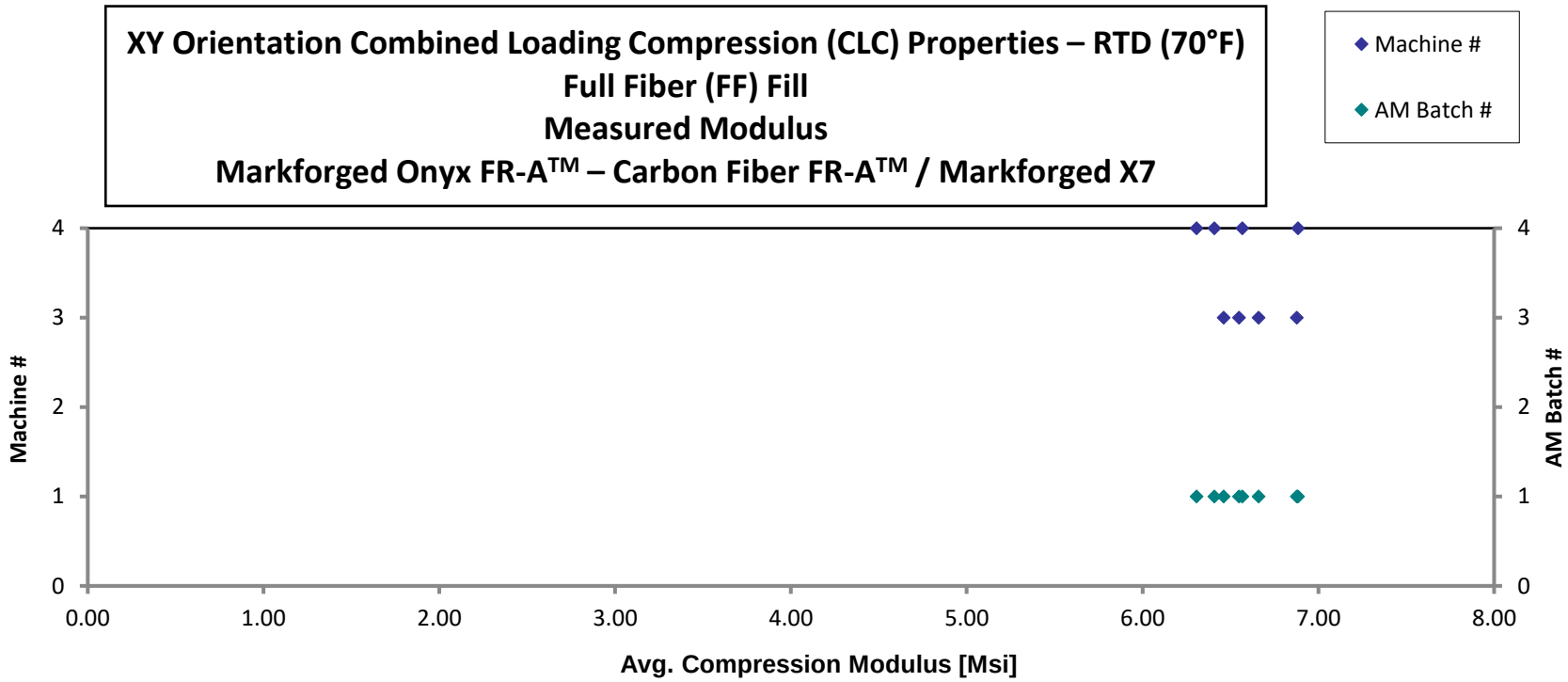
4.8.1 RTD Condition

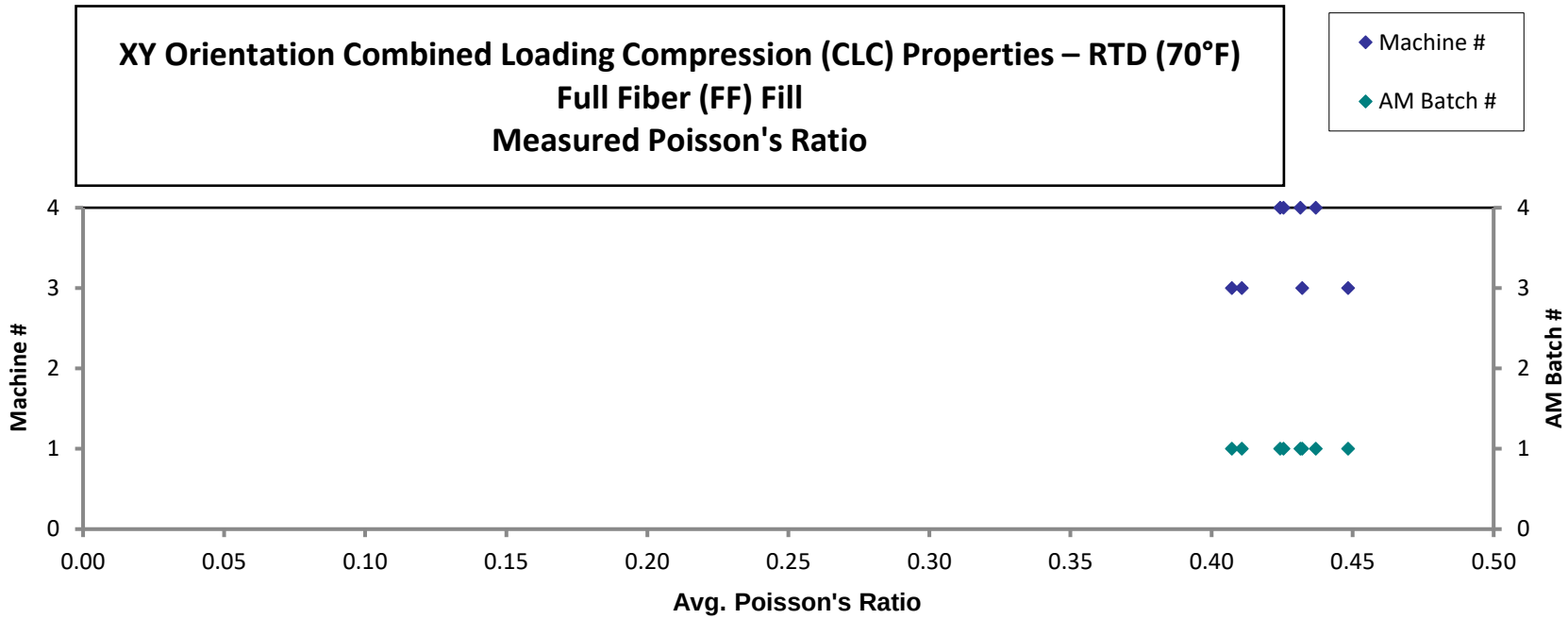
XY Orientation Combined Loading Compression (CLC) Properties – RTD (70°F)
Full Fiber (FF) Fill
Strength & Modulus
Markforged Onyx FR-A™ – Carbon Fiber FR-A™ / Markforged X7

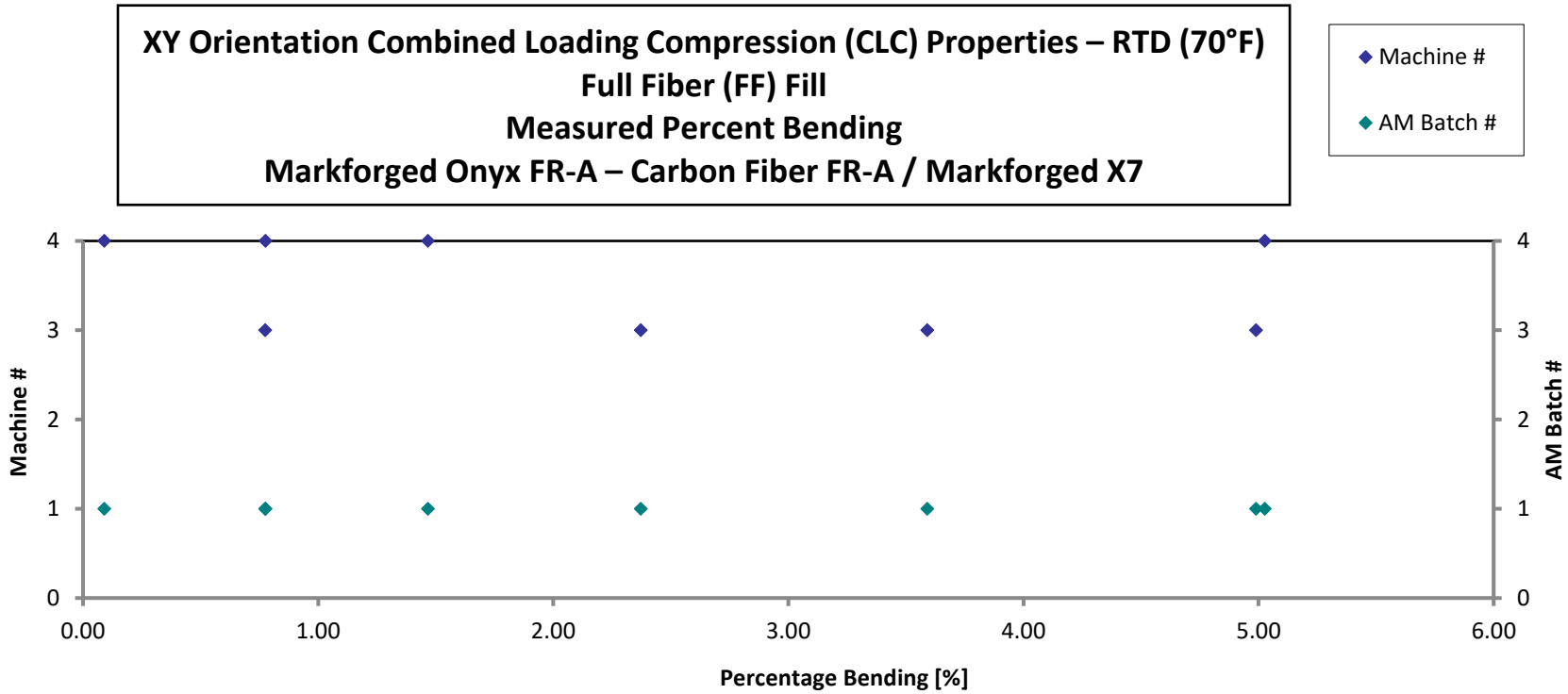
Specimen Number	AM Batch #	Machine #	Avg. Specimen Thickness [in]	Compressive Strength [ksi]	Avg. Compression Modulus [Msi]	Avg. Poisson's Ratio	Percentage Bending [%]	Failure Mode
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M3-P34369-XY-CLC-11-RTD-FF-1	1	3	0.141	41.56	6.660	0.432	0.774	EAB
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M3-P34051-XY-CLC-12-RTD-FF-2	1	3	0.142	40.98	6.461	0.411	2.372	EAB
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M3-P34059-XY-CLC-13-RTD-FF-3	1	3	0.141	34.85	6.549	0.407	4.989	EAT
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M3-P38445-XY-CLC-13-RTD-FF-SP	1	3	0.141	40.35	6.877	0.448	3.591	EAT
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M4-P42319-XY-CLC-11-RTD-FF-1	1	4	0.140	39.11	6.567	0.426	0.090	EAT
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M4-P41548-XY-CLC-12-RTD-FF-2	1	4	0.142	43.39	6.408	0.432	1.466	EAB
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M4-P42161-XY-CLC-13-RTD-FF-3	1	4	0.139	34.49	6.307	0.437	5.026	EAT
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M4-P41915-XY-CLC-13-RTD-FF-SP	1	4	0.139	38.21	6.884	0.424	0.776	EAB
		Average	**0.140**	**39.12**	**6.589**	**0.427**	**2.385**	
		Standard Dev.		**3.156**	**0.209**	**0.013**	**1.946**	
		Coeff. of Var. [%]		**8.067**	**3.171**	**3.149**	**81.58**	
		Min.	**0.139**	**34.49**	**6.307**	**0.407**	**0.090**	
		Max.	**0.142**	**43.39**	**6.884**	**0.448**	**5.026**	
		Number of Spec.	**8**	**8**	**8**	**8**	**8**	

Note: The main failure mode was Euler buckling which invalidates the test data.
Therefore results are provided for informational purposes.
Note: Modulus and Poisson's Ratio are average values of 2 strain gages


XY Orientation Combined Loading Compression (CLC) Properties – RTD (70°F)
Full Fiber (FF) Fill
Measured Strength
Markforged Onyx FR-A™ – Carbon Fiber FR-A™ / Markforged X7
Machine #
AM Batch #
Machine #
AM Batch #
Compressive Strength [ksi]
0.0
5.0
10.0
15.0
20.0
25.0
30.0
35.0
40.0
45.0
50.0
0
1
2
3
4


XY Orientation Combined Loading Compression (CLC) Properties – RTD (70°F)
Full Fiber (FF) Fill
Measured Modulus
Markforged Onyx FR-A™ – Carbon Fiber FR-A™ / Markforged X7
Machine #
AM Batch #
Machine #
AM Batch #
0
1
2
3
4
0.00
1.00
2.00
3.00
4.00
5.00
6.00
7.00
8.00
Avg. Compression Modulus [Msi]


XY Orientation Combined Loading Compression (CLC) Properties – RTD (70°F)
Full Fiber (FF) Fill
Measured Poisson's Ratio
Machine #
AM Batch #
Machine #
AM Batch #
Avg. Poisson's Ratio
0
1
2
3
4
0.00
0.05
0.10
0.15
0.20
0.25
0.30
0.35
0.40
0.45
0.50


XY Orientation Combined Loading Compression (CLC) Properties – RTD (70°F)
Full Fiber (FF) Fill
Measured Percent Bending
Markforged Onyx FR-A – Carbon Fiber FR-A / Markforged X7
Machine #
AM Batch #
Machine #
AM Batch #
Percentage Bending [%]
0
1
2
3
4
0.00
1.00
2.00
3.00
4.00
5.00
6.00

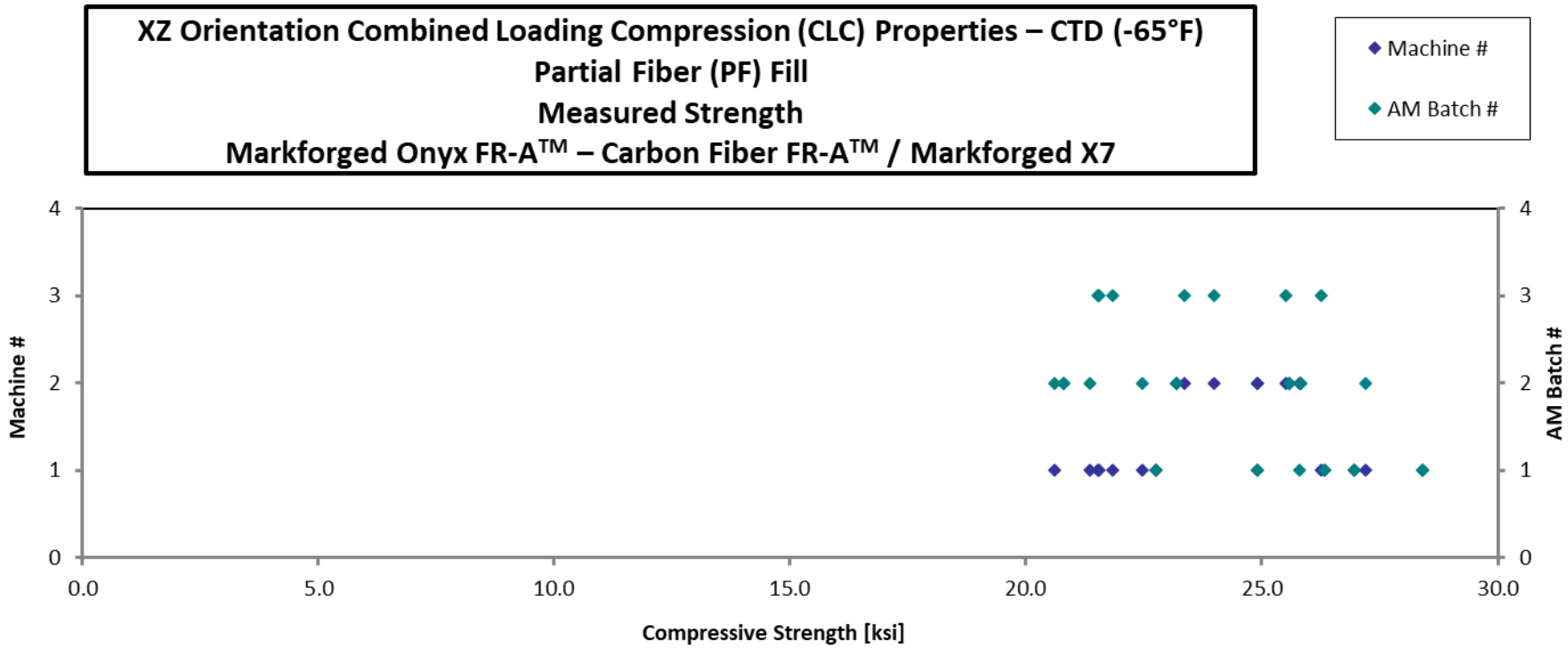
4.9 XZ PF Compression Properties

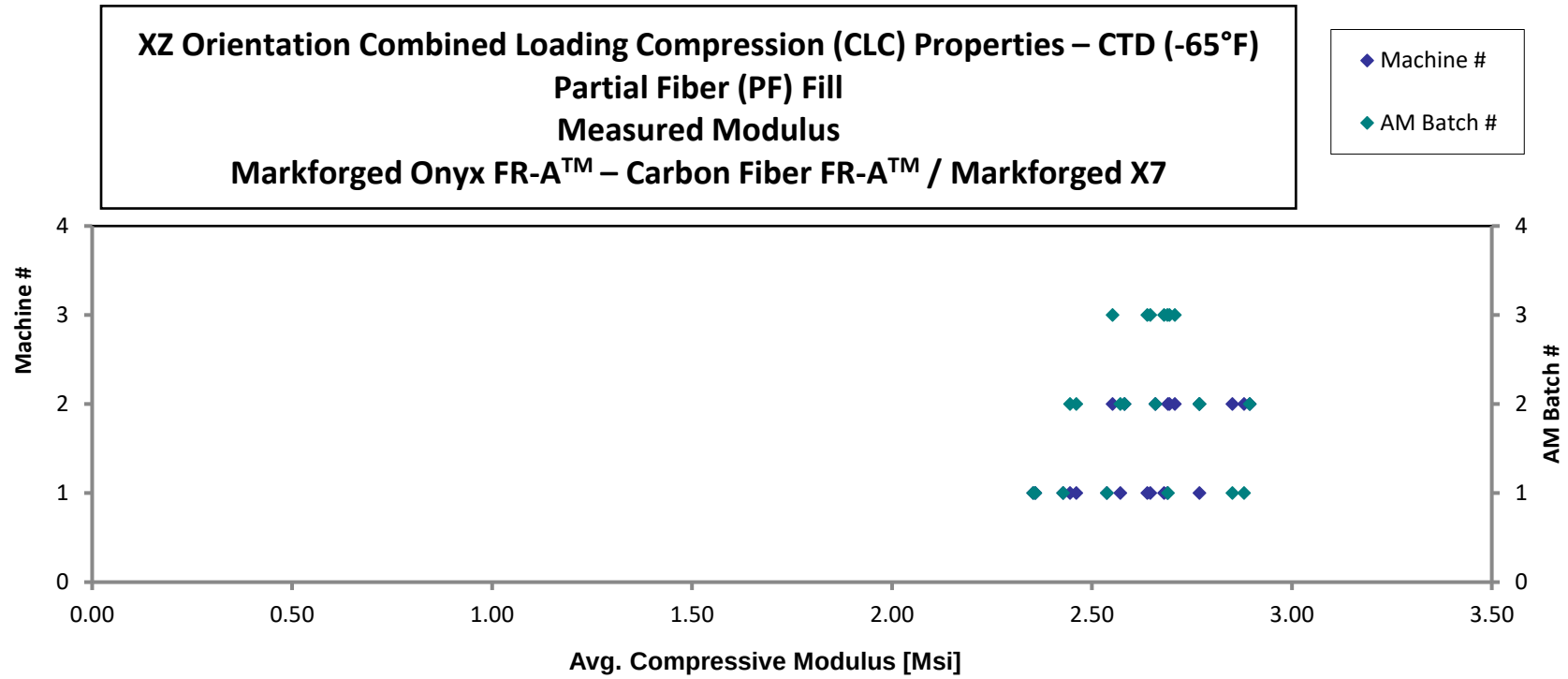
4.9.1 CTD Condition

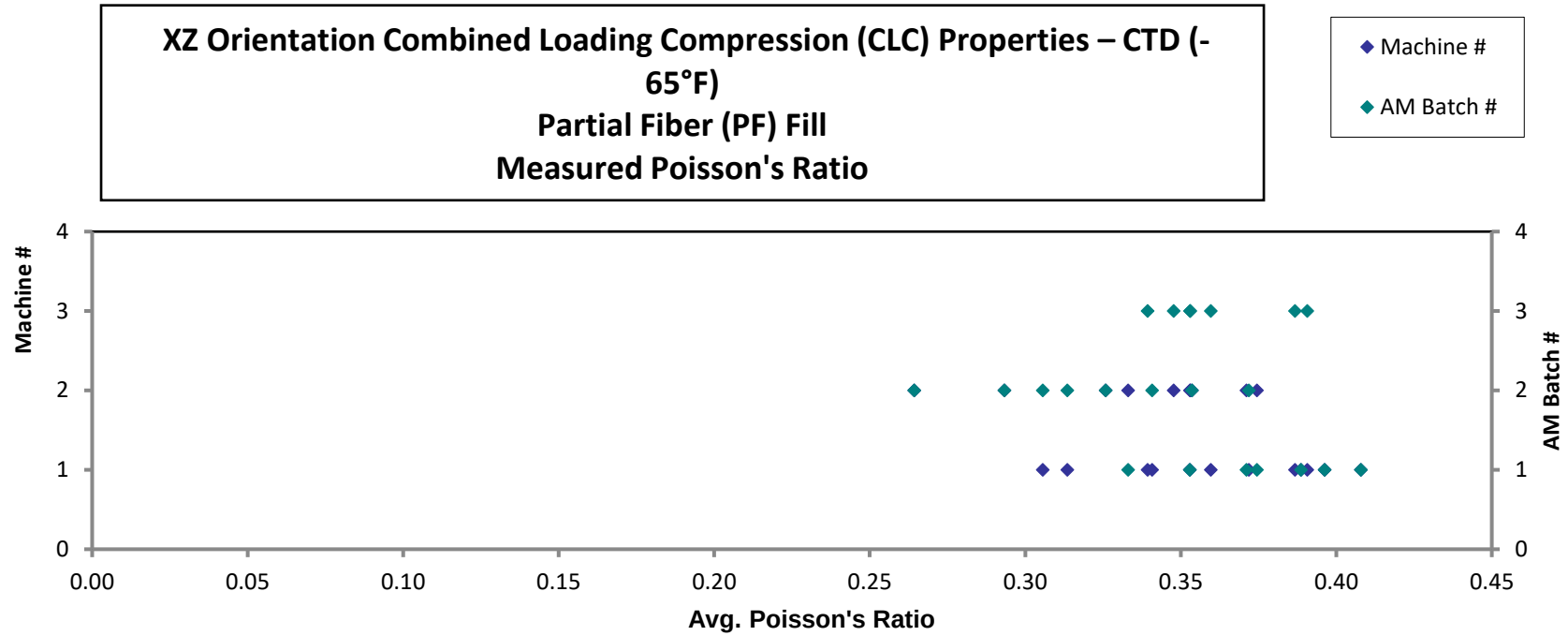
XZ Orientation Combined Loading Compression (CLC) Properties – CTD (-65°F)
Partial Fiber (PF) Fill
Strength & Modulus
Markforged Onyx FR-A™ – Carbon Fiber FR-A™ / Markforged X7

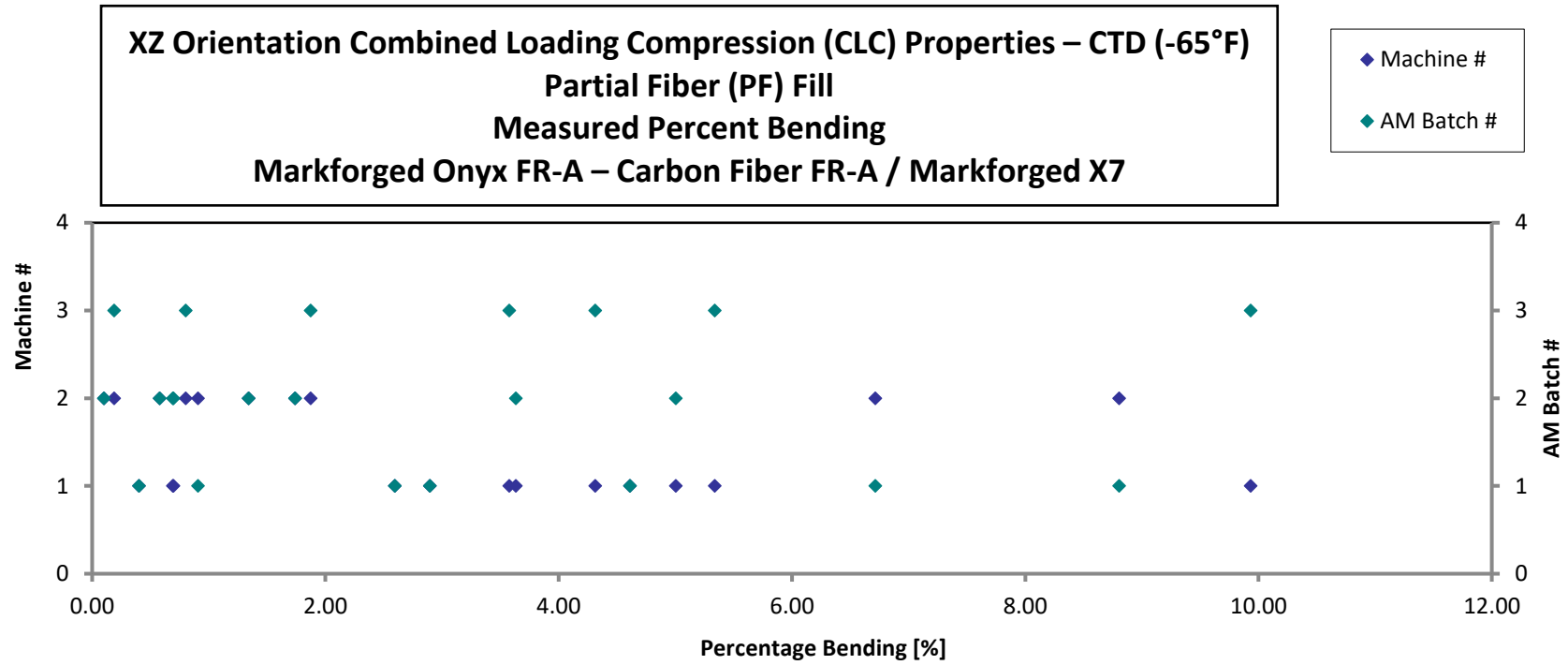
Specimen Number	AM Batch #	Machine #	Avg. Specimen Thickness [in]	Compressive Strength [ksi]	Avg. Compressive Modulus [Msi]	Avg. Poisson's Ratio	Percentage Bending [%]	Failure Mode
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M1-P54807-XZ-CLC-11-CTD-PF-1	1	1	0.142	26.34	2.359	0.396	4.611	M(D,H)GM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M1-P31429-XZ-CLC-12-CTD-PF-2	1	1	0.143	28.40	2.428	0.389	2.595	M(D,H)GM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M1-P45017-XZ-CLC-13-CTD-PF-3	1	1	0.141	22.76	2.353	0.408	2.895	M(D,H)GM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M1-P31494-XZ-CLC-13-CTD-PF-SP	1	1	0.142	26.95	2.538	0.353	0.402	M(D,H)GM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M2-P31697-XZ-CLC-11-CTD-PF-1	1	2	0.140	24.89	2.852	0.371	0.906	EGM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M2-P31428-XZ-CLC-12-CTD-PF-2	1	2	0.140	25.79	2.880	0.333	6.714	EGM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M2-P29960-XZ-CLC-13-CTD-PF-3	1	2	0.139	24.91	2.690	0.374	8.806	EGM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-B-M1-P33716-XZ-CLC-11-CTD-PF-1	2	1	0.142	22.46	2.445	0.306	5.005	DGM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-B-M1-P58774-XZ-CLC-12-CTD-PF-2	2	1	0.142	21.35	2.461	0.372	0.696	M(B,D)GM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-B-M1-P36645-XZ-CLC-13-CTD-PF-3	2	1	0.142	20.60	2.571	0.341	3.632	M(B,D)GM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-B-M1-P55269-XZ-CLC-13-CTD-PF-6	2	1	0.140	27.20	2.769	0.314	0.692	DGM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-B-M2-P56216-XZ-CLC-11-CTD-PF-1	2	2	0.141	25.83	2.582	0.326	0.578	DGM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-B-M2-P41450-XZ-CLC-12-CTD-PF-2	2	2	0.140	25.58	2.769	0.354	0.100	DGM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-B-M2-P58165-XZ-CLC-13-CTD-PF-3	2	2	0.140	20.81	2.659	0.293	1.341	M(B,D)GM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-B-M2-P55764-XZ-CLC-13-CTD-PF-6*	2	2	0.140	23.20	2.895	0.264	1.740	M(B,D)GM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-C-M1-P35346-XZ-CLC-11-CTD-PF-1	3	1	0.143	21.85	2.639	0.360	5.339	TGM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-C-M1-P36133-XZ-CLC-12-CTD-PF-2	3	1	0.142	26.27	2.689	0.391	4.313	TGM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-C-M1-P50410-XZ-CLC-13-CTD-PF-3	3	1	0.142	21.54	2.646	0.339	9.933	TGM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-C-M1-P47525-XZ-CLC-13-CTD-PF-6	3	1	0.142	21.52	2.681	0.387	3.576	M(B,T)GM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-C-M2-P35347-XZ-CLC-11-CTD-PF-1	3	2	0.142	23.99	2.552	0.353	0.801	HGM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-C-M2-P57299-XZ-CLC-13-CTD-PF-3	3	2	0.141	23.36	2.707	0.353	1.872	TGM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-C-M2-P57239-XZ-CLC-13-CTD-PF-6	3	2	0.141	25.51	2.694	0.348	0.187	DGM
		Average	**0.141**	**24.14**	**2.630**	**0.351**	**3.033**	
		Standard Dev.		**2.309**	**0.157**	**0.036**	**2.800**	
		Coeff. of Var. [%]		**9.564**	**5.959**	**10.13**	**92.31**	
		Min.	**0.139**	**20.60**	**2.353**	**0.264**	**0.100**	
		Max.	**0.143**	**28.40**	**2.895**	**0.408**	**9.933**	
		Number of Spec.	**22**	**22**	**22**	**22**	**22**	

*Poisson's ratio 2 not reported due to strain gage failure
Note: Modulus and Poisson's Ratio are average values of 2 strain gages


XZ Orientation Combined Loading Compression (CLC) Properties – CTD (-65°F)
Partial Fiber (PF) Fill
Measured Strength
Markforged Onyx FR-A™ – Carbon Fiber FR-A™ / Markforged X7
Machine #
AM Batch #
Machine #
AM Batch #
Compressive Strength [ksi]
0.0
5.0
10.0
15.0
20.0
25.0
30.0
0
1
2
3
4


XZ Orientation Combined Loading Compression (CLC) Properties – CTD (-65°F)
Partial Fiber (PF) Fill
Measured Modulus
Markforged Onyx FR-A™ – Carbon Fiber FR-A™ / Markforged X7
Machine #
AM Batch #
Machine #
AM Batch #
0
1
2
3
4
0.00
0.50
1.00
1.50
2.00
2.50
3.00
3.50
Avg. Compressive Modulus [Msi]


XZ Orientation Combined Loading Compression (CLC) Properties – CTD (-65°F)
Partial Fiber (PF) Fill
Measured Poisson's Ratio
Machine #
AM Batch #
Machine #
AM Batch #
Avg. Poisson's Ratio
0
1
2
3
4
0.00
0.05
0.10
0.15
0.20
0.25
0.30
0.35
0.40
0.45

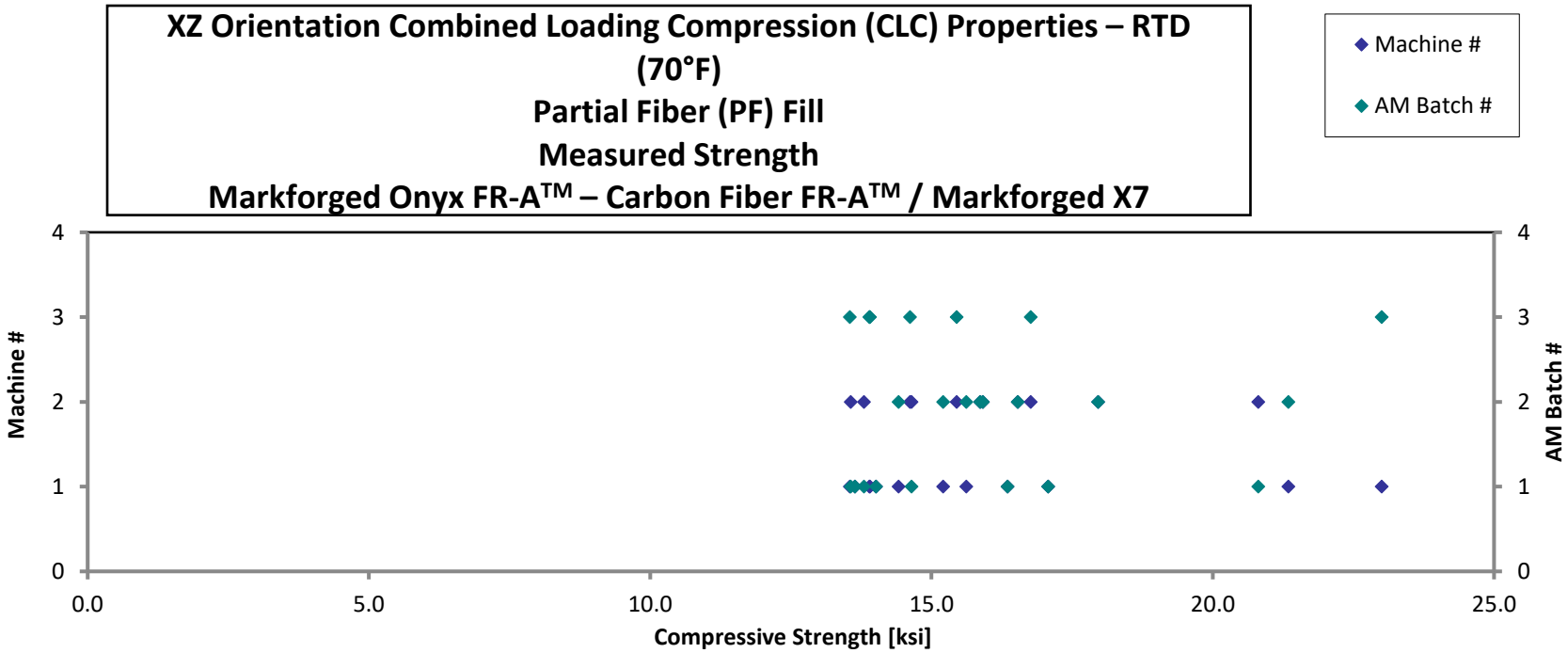

XZ Orientation Combined Loading Compression (CLC) Properties – CTD (-65°F)
Partial Fiber (PF) Fill
Measured Percent Bending
Markforged Onyx FR-A – Carbon Fiber FR-A / Markforged X7
Machine #
AM Batch #
Machine #
AM Batch #
Percentage Bending [%]
0.00
2.00
4.00
6.00
8.00
10.00
12.00
0
1
2
3
4

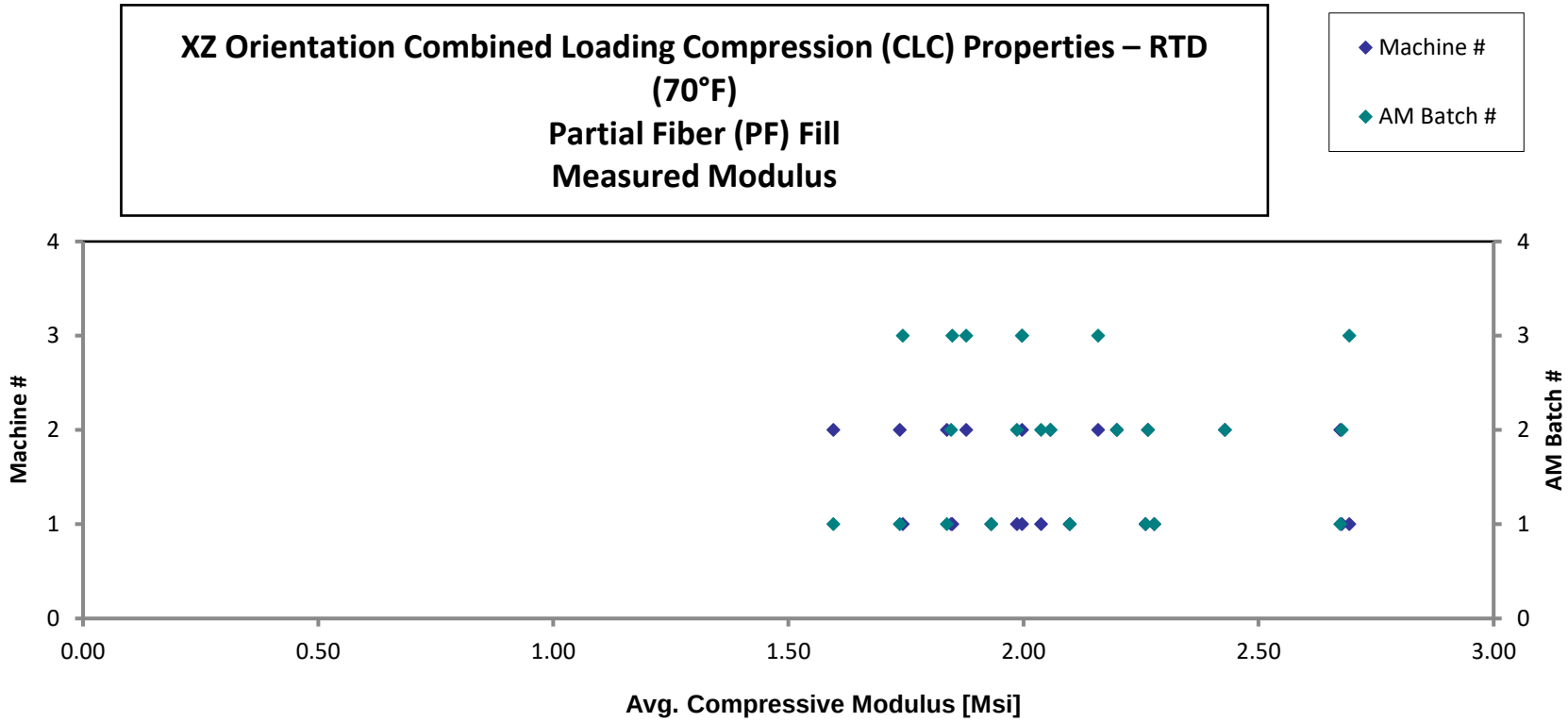
4.9.2 **RTD Condition**

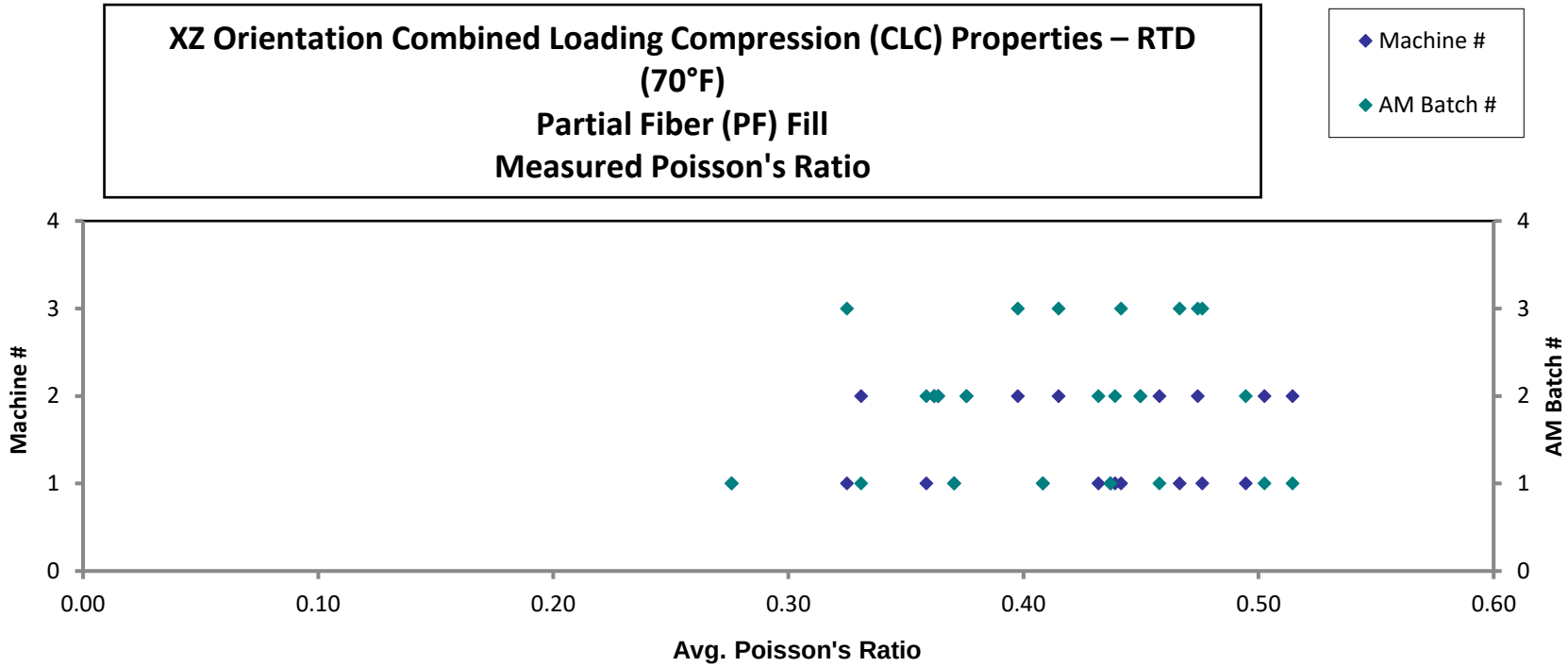
XZ Orientation Combined Loading Compression (CLC) Properties – RTD (70°F)
Partial Fiber (PF) Fill
Strength & Modulus
Markforged Onyx FR-A™ – Carbon Fiber FR-A™ / Markforged X7

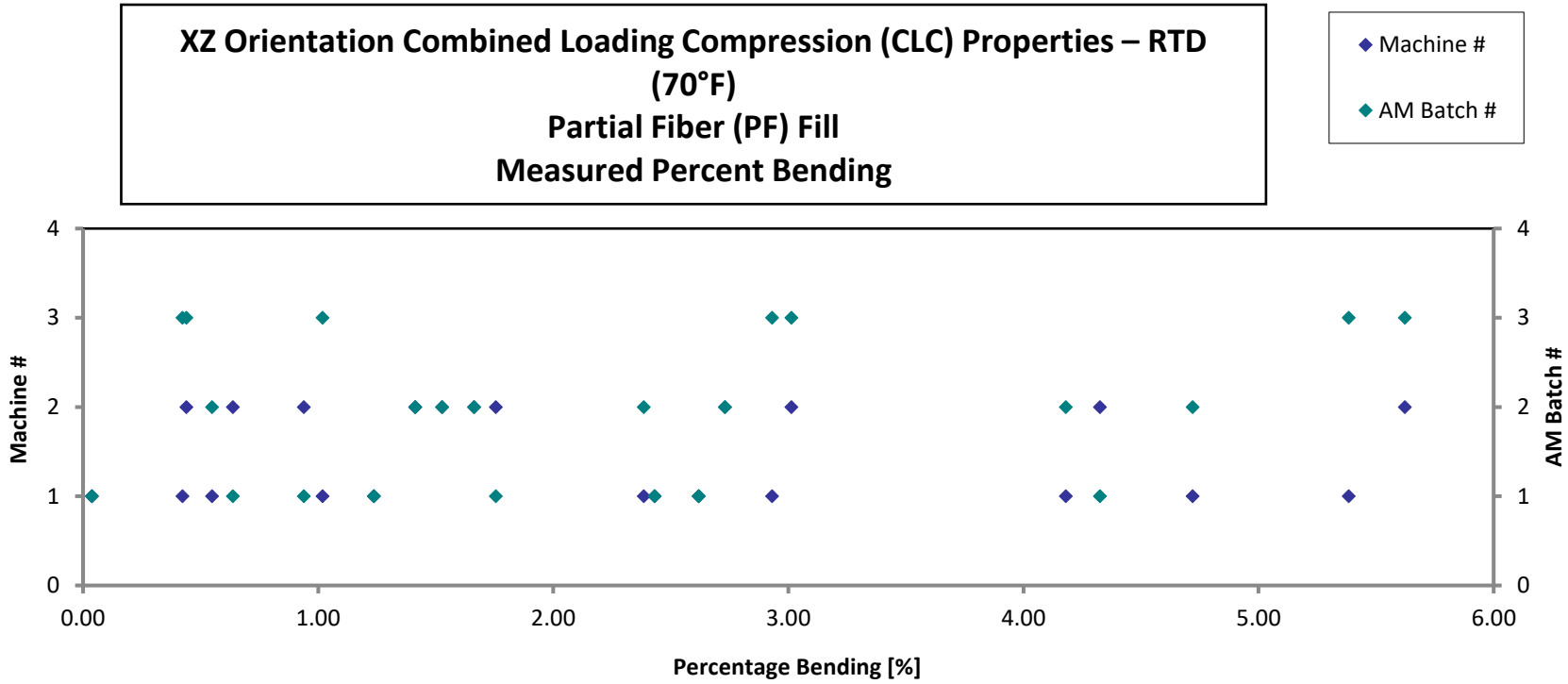
Specimen Number	AM Batch #	Machine #	Avg. Specimen Thickness [in]	Compressive Strength [ksi]	Avg. Compressive Modulus [Msi]	Avg. Poisson's Ratio	Percentage Bending [%]	Failure Mode
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M1-P31490-XZ-CLC-11-RTD-PF-1	1	1	0.144	17.08	2.259	0.276	2.431	M(D,T)GM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M1-P54807-XZ-CLC-12-RTD-PF-2	1	1	0.143	16.35	2.278	0.371	2.618	M(D,T)GM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M1-P31784-XZ-CLC-13-RTD-PF-3	1	1	0.145	14.01	1.931	0.437	0.038	M(D,T)GM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M1-P31610-XZ-CLC-13-RTD-PF-SP	1	1	0.143	13.64	2.099	0.408	1.237	M(D,T,B)GM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M2-P31491-XZ-CLC-11-RTD-PF-1*	1	2	0.142	14.65	1.837	0.458	0.637	EGM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M2-P31697-XZ-CLC-12-RTD-PF-2*	1	2	0.140	13.80	1.737	0.503	0.938	EGM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M2-P31785-XZ-CLC-13-RTD-PF-3*	1	2	0.139	13.57	1.595	0.514	4.326	EGM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M2-P31785-XZ-CLC-13-RTD-PF-SP	1	2	0.138	20.81	2.674	0.331	1.756	BGM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-B-M1-P33716-XZ-CLC-12-RTD-PF-2	2	1	0.142	14.41	2.038	0.439	4.720	HAB
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-B-M1-P33018-XZ-CLC-13-RTD-PF-3	2	1	0.143	15.62	1.846	0.495	4.180	HAT
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-B-M1-P33155-XZ-CLC-13-RTD-PF-SP	2	1	0.142	15.21	1.986	0.432	2.385	HGM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-B-M1-P33155-XZ-CLC-13-RTD-PF-1	2	1	0.142	21.34	2.677	0.359	0.548	M(T,S)GM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-B-M2-P40904-XZ-CLC-11-RTD-PF-1	2	2	0.142	15.91	2.265	0.376	1.663	M(D,T)GM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-B-M2-P56216-XZ-CLC-12-RTD-PF-2	2	2	0.139	16.53	2.199	0.364	1.527	M(D,T)GM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-B-M2-P33019-XZ-CLC-13-RTD-PF-3	2	2	0.141	15.87	2.057	0.450	1.412	M(D,T)GM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-B-M2-P33154-XZ-CLC-13-RTD-PF-SP	2	2	0.142	17.96	2.428	0.362	2.731	TGM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-C-M1-P35650-XZ-CLC-11-RTD-PF-1	3	1	0.139	13.90	1.997	0.441	5.383	BGM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-C-M1-P35346-XZ-CLC-12-RTD-PF-2	3	1	0.139	13.55	1.848	0.466	1.019	BGM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-C-M1-P35266-XZ-CLC-13-RTD-PF-3	3	1	0.142	13.91	1.743	0.476	2.931	BGM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-C-M1-P35266-XZ-CLC-13-RTD-PF-SP	3	1	0.141	23.00	2.693	0.325	0.423	BAT
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-C-M2-P34965-XZ-CLC-11-RTD-PF-1	3	2	0.140	16.76	2.159	0.398	0.439	BGM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-C-M2-P35347-XZ-CLC-12-RTD-PF-2	3	2	0.138	15.45	1.997	0.415	3.012	BGM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-C-M2-P35260-XZ-CLC-13-RTD-PF-3	3	2	0.139	14.62	1.878	0.474	5.622	BGM
		Average	**0.141**	**16.00**	**2.097**	**0.416**	**2.260**	
		Standard Dev.		**2.604**	**0.305**	**0.062**	**1.650**	
		Coeff. of Var. [%]		**16.28**	**14.55**	**15.02**	**73.00**	
		Min.	**0.138**	**13.55**	**1.595**	**0.276**	**0.038**	
		Max.	**0.145**	**23.00**	**2.693**	**0.514**	**5.622**	
		Number of Spec.	**23**	**23**	**23**	**23**	**23**	

*Specimens exhibited Euler buckling which is an improper failure mode per ASTM D6641. Spare specimens are being tested to confirm failure mode
Note: Modulus and Poisson's Ratio are average values of 2 strain gages


XZ Orientation Combined Loading Compression (CLC) Properties – RTD (70°F)
Partial Fiber (PF) Fill
Measured Strength
Markforged Onyx FR-A™ – Carbon Fiber FR-A™ / Markforged X7
Machine #
AM Batch #
Machine #
AM Batch #
Compressive Strength [ksi]
0.0
5.0
10.0
15.0
20.0
25.0
0
1
2
3
4


XZ Orientation Combined Loading Compression (CLC) Properties – RTD (70°F)
Partial Fiber (PF) Fill
Measured Modulus
Machine #
AM Batch #
Machine #
AM Batch #
0
1
2
3
4
0.00
0.50
1.00
1.50
2.00
2.50
3.00
Avg. Compressive Modulus [Msi]


XZ Orientation Combined Loading Compression (CLC) Properties – RTD (70°F)
Partial Fiber (PF) Fill
Measured Poisson's Ratio
Machine #
AM Batch #
Machine #
AM Batch #
Avg. Poisson's Ratio
0.00
0.10
0.20
0.30
0.40
0.50
0.60
0
1
2
3
4

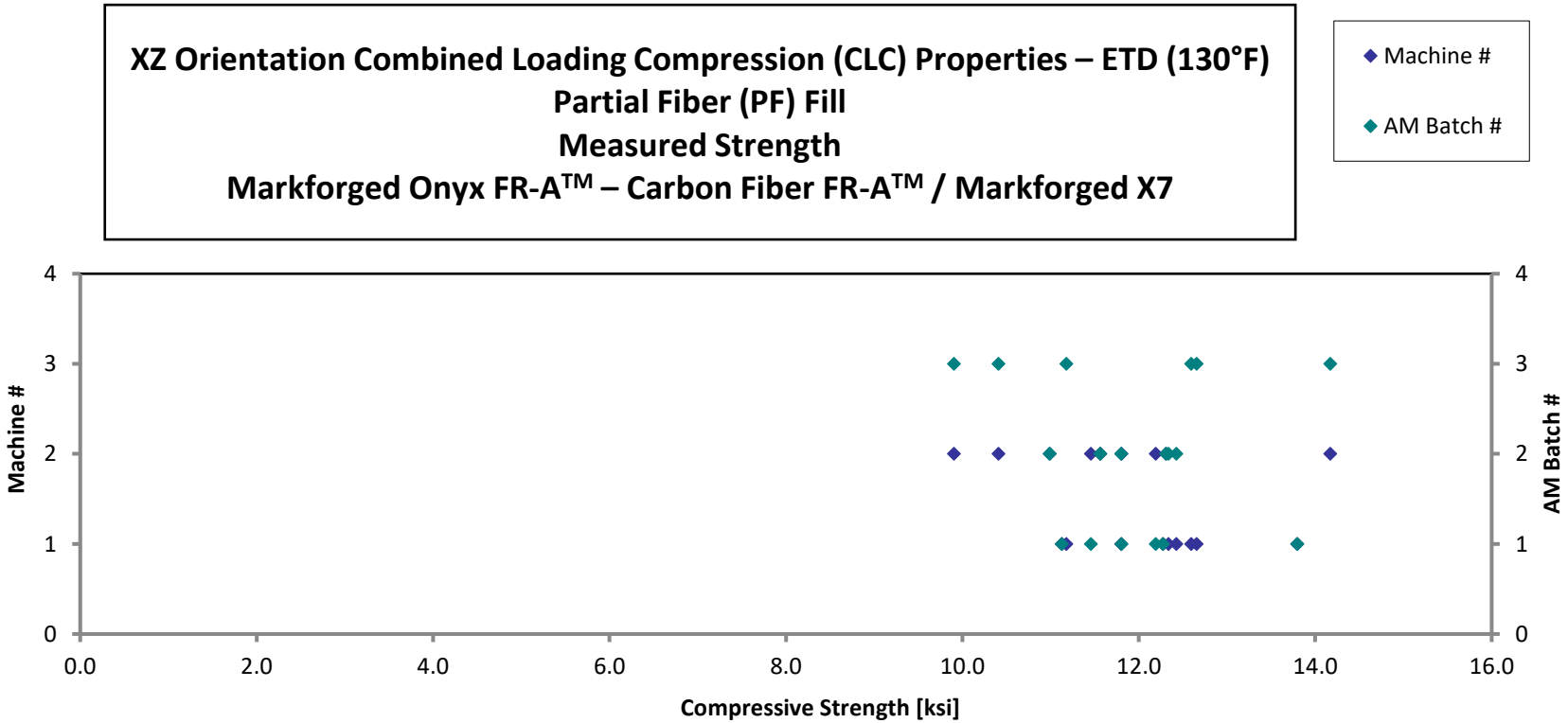

XZ Orientation Combined Loading Compression (CLC) Properties – RTD (70°F)
Partial Fiber (PF) Fill
Measured Percent Bending
Machine #
AM Batch #
Machine #
AM Batch #
Percentage Bending [%]
0
1
2
3
4
0.00
1.00
2.00
3.00
4.00
5.00
6.00

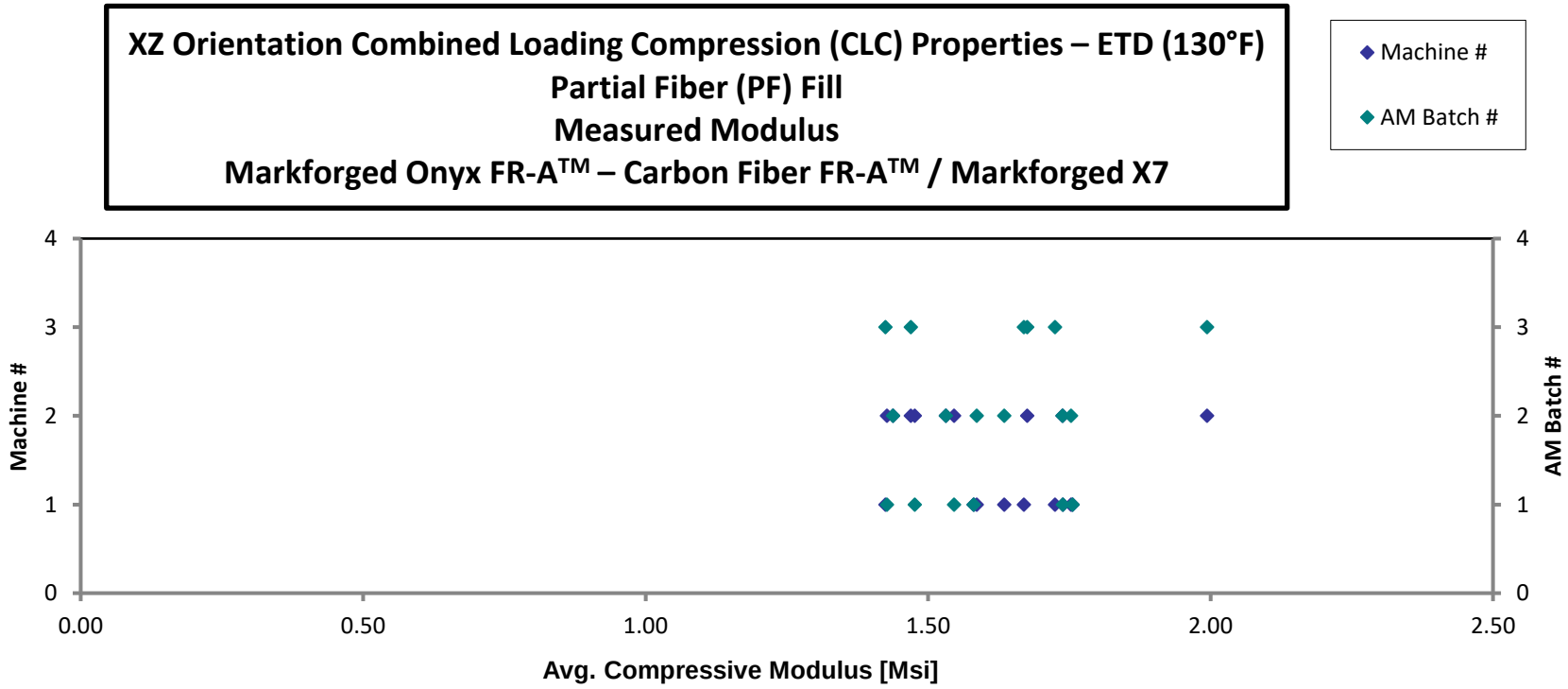
4.9.3 **ETD Condition**

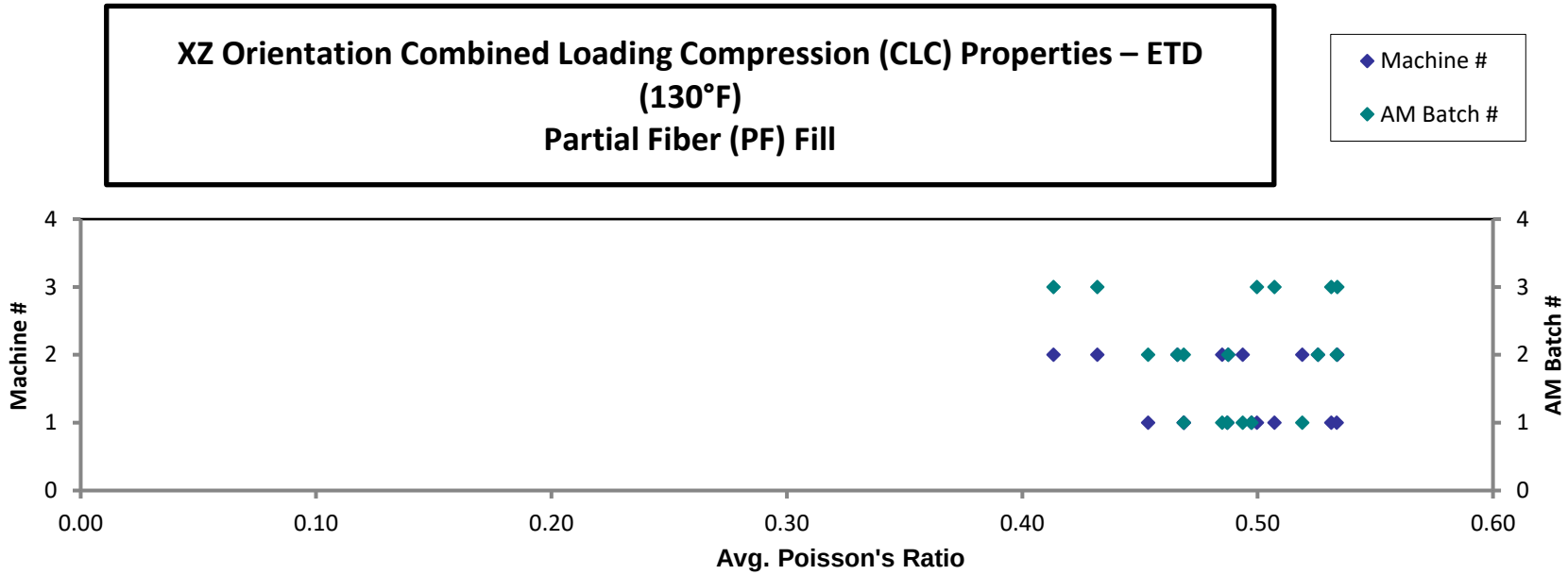
XZ Orientation Combined Loading Compression (CLC) Properties – ETD (130°F)
Partial Fiber (PF) Fill
Strength & Modulus
Markforged Onyx FR-A™ – Carbon Fiber FR-A™ / Markforged X7

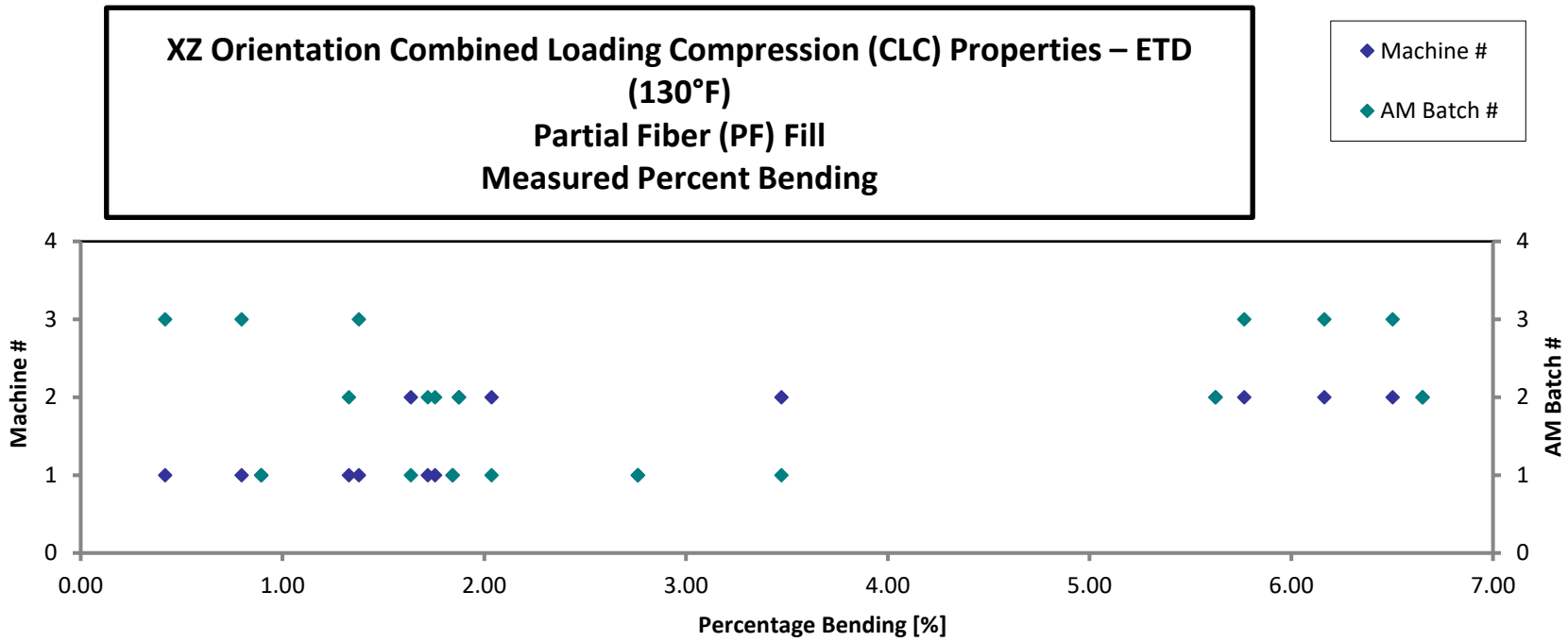
Specimen Number	AM Batch #	Machine #	Avg. Specimen Thickness [in]	Compressive Strength [ksi]	Avg. Compressive Modulus [Msi]	Avg. Poisson's Ratio	Percentage Bending [%]	Failure Mode
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M1-P54144-XZ-CLC-11-ETD-PF-1	1	1	0.141	13.79	1.581	0.497	2.761	M(D,T)GM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M1-P44531-XZ-CLC-12-ETD-PF-2	1	1	0.141	12.27	1.738	0.487	1.844	M(D,T)GM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M1-P42981-XZ-CLC-13-ETD-PF-3	1	1	0.140	11.13	1.756	0.469	0.895	M(D,T)GM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M2-P53725-XZ-CLC-11-ETD-PF-1*	1	2	0.142	12.19	1.427	0.519	2.037	EGM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M2-P42916-XZ-CLC-12-ETD-PF-2*	1	2	0.142	11.46	1.476	0.494	1.636	EGM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M2-P42495-XZ-CLC-13-ETD-PF-3*	1	2	0.141	11.80	1.546	0.485	3.474	EGM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-B-M1-P58774-XZ-CLC-11-ETD-PF-1	2	1	0.141	11.80	1.635	0.454	1.757	TGM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-B-M1-P40117-XZ-CLC-12-ETD-PF-2	2	1	0.141	12.34	1.753	0.469	1.329	TGM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-B-M1-P41009-XZ-CLC-13-ETD-PF-3	2	1	0.140	12.43	1.586	0.534	1.720	TGM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-B-M2-P58165-XZ-CLC-11-ETD-PF-1	2	2	0.141	11.56	1.438	0.487	5.625	TGM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-B-M2-P38680-XZ-CLC-12-ETD-PF-2	2	2	0.140	12.31	1.532	0.526	6.651	TGM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-B-M2-P46418-XZ-CLC-13-ETD-PF-3	2	2	0.137	10.99	1.738	0.466	1.875	TGM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-C-M1-P51459-XZ-CLC-11-ETD-PF-1	3	1	0.144	12.65	1.425	0.507	1.378	TGM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-C-M1-P47955-XZ-CLC-12-ETD-PF-2	3	1	0.144	12.59	1.725	0.531	0.418	TGM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-C-M1-P48076-XZ-CLC-13-ETD-PF-3	3	1	0.145	11.18	1.670	0.500	0.797	TGM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-C-M2-P57301-XZ-CLC-11-ETD-PF-1	3	2	0.141	14.17	1.470	0.534	6.163	TGM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-C-M2-P49458-XZ-CLC-12-ETD-PF-2	3	2	0.141	10.41	1.994	0.432	5.767	TGM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-C-M2-P47970-XZ-CLC-13-ETD-PF-3	3	2	0.139	9.905	1.676	0.413	6.503	TGM
		Average	**0.141**	**11.94**	**1.620**	**0.489**	**2.924**	
		Standard Dev.		**1.060**	**0.151**	**0.034**	**2.17**	
		Coeff. of Var. [%]		**8.876**	**9.326**	**7.045**	**74.32**	
		Min.	**0.137**	**9.905**	**1.425**	**0.413**	**0.418**	
		Max.	**0.145**	**14.17**	**1.994**	**0.534**	**6.651**	
		Number of Spec.	**18**	**18**	**18**	**18**	**18**	

Note: Due to inherent material properties, B-basis calculations will be calculated eventhough improper failure modes were present.
*Specimens exhibited Euler buckling which is an improper failure mode per ASTM D6641.
Note: Modulus and Poisson's Ratio are average values of 2 strain gages


XZ Orientation Combined Loading Compression (CLC) Properties – ETD (130°F)
Partial Fiber (PF) Fill
Measured Strength
Markforged Onyx FR-A™ – Carbon Fiber FR-A™ / Markforged X7
Machine #
AM Batch #
Machine #
AM Batch #
Compressive Strength [ksi]
0
1
2
3
4
0.0
2.0
4.0
6.0
8.0
10.0
12.0
14.0
16.0


XZ Orientation Combined Loading Compression (CLC) Properties – ETD (130°F)
Partial Fiber (PF) Fill
Measured Modulus
Markforged Onyx FR-A™ – Carbon Fiber FR-A™ / Markforged X7
Machine #
AM Batch #
Machine #
AM Batch #
0
1
2
3
4
0.00
0.50
1.00
1.50
2.00
2.50
Avg. Compressive Modulus [Msi]


XZ Orientation Combined Loading Compression (CLC) Properties – ETD (130°F)
Partial Fiber (PF) Fill
Machine #
AM Batch #
Machine #
AM Batch #
Avg. Poisson's Ratio
0
1
2
3
4
0.00
0.10
0.20
0.30
0.40
0.50
0.60


XZ Orientation Combined Loading Compression (CLC) Properties – ETD (130°F)
Partial Fiber (PF) Fill
Measured Percent Bending
Machine #
AM Batch #
Machine #
AM Batch #
Percentage Bending [%]
0.00
1.00
2.00
3.00
4.00
5.00
6.00
7.00
0
1
2
3
4

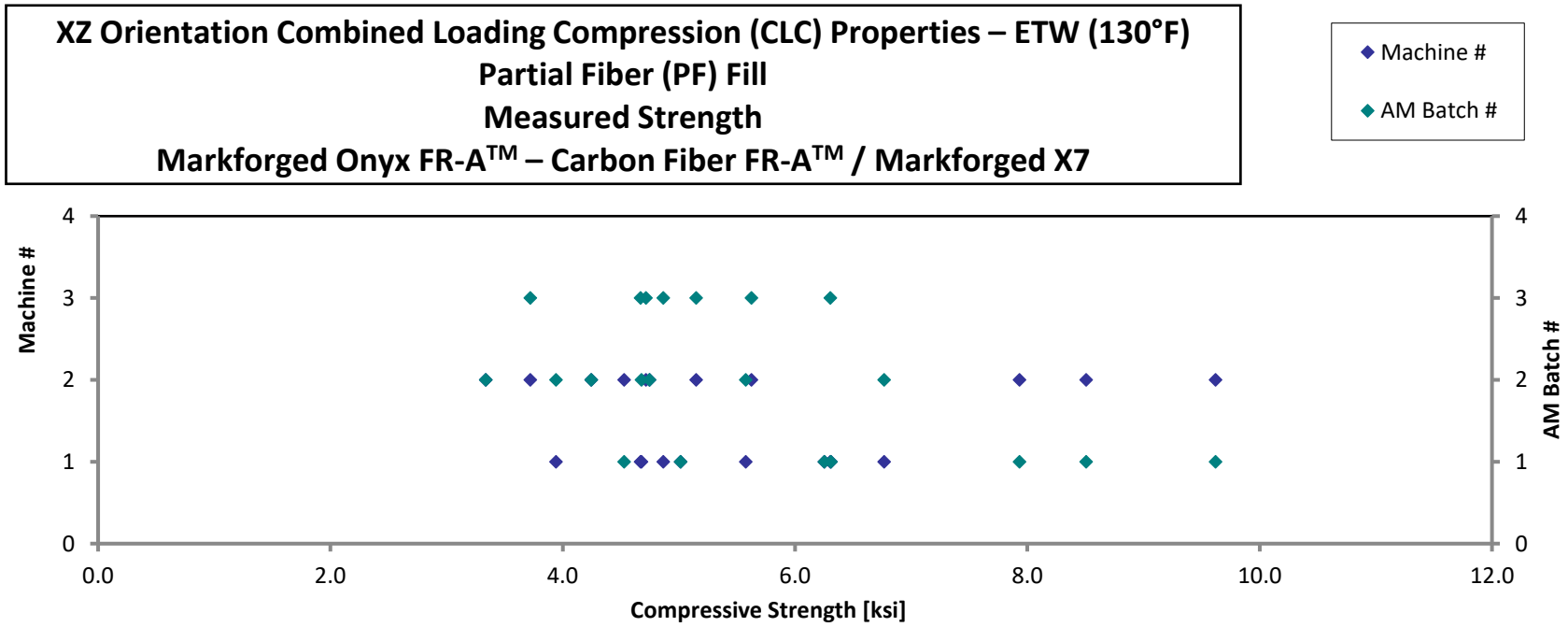
4.9.4 **ETW Condition**

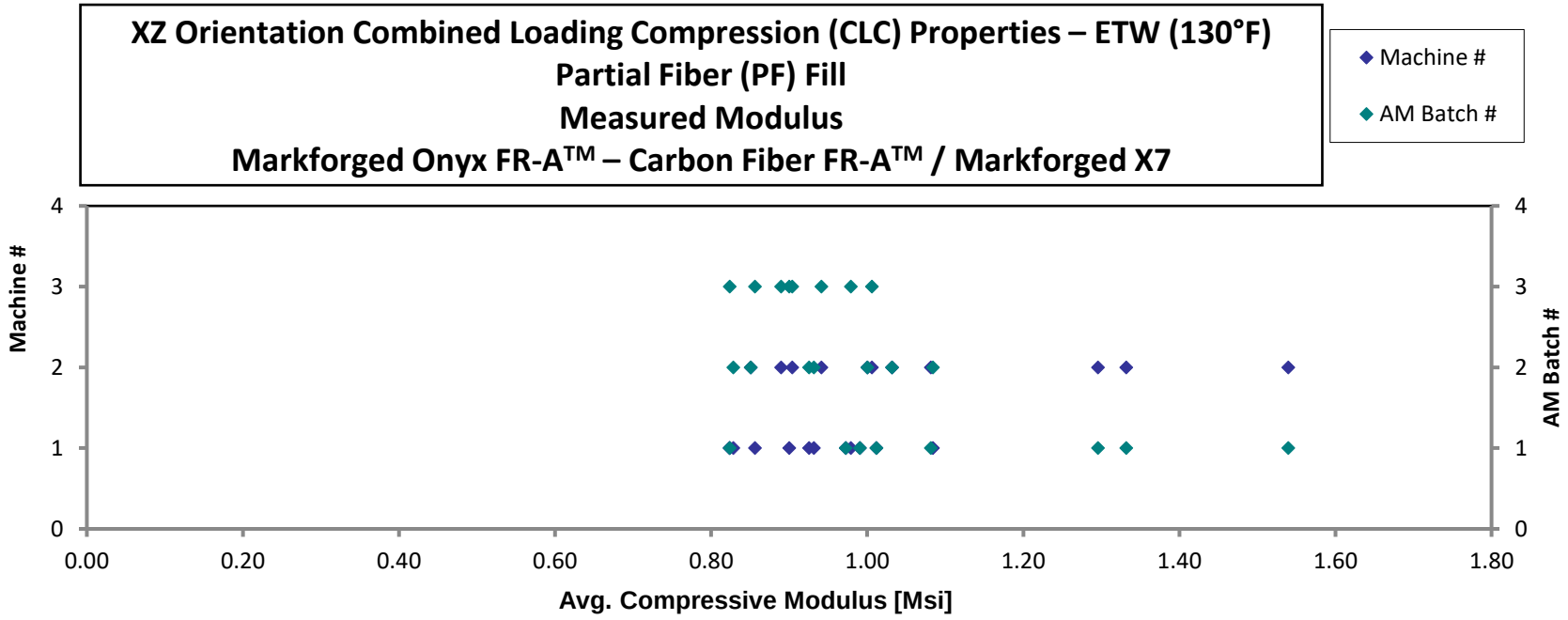
XZ Orientation Combined Loading Compression (CLC) Properties – ETW (130°F)
Partial Fiber (PF) Fill
Strength & Modulus
Markforged Onyx FR-A™ – Carbon Fiber FR-A™ / Markforged X7

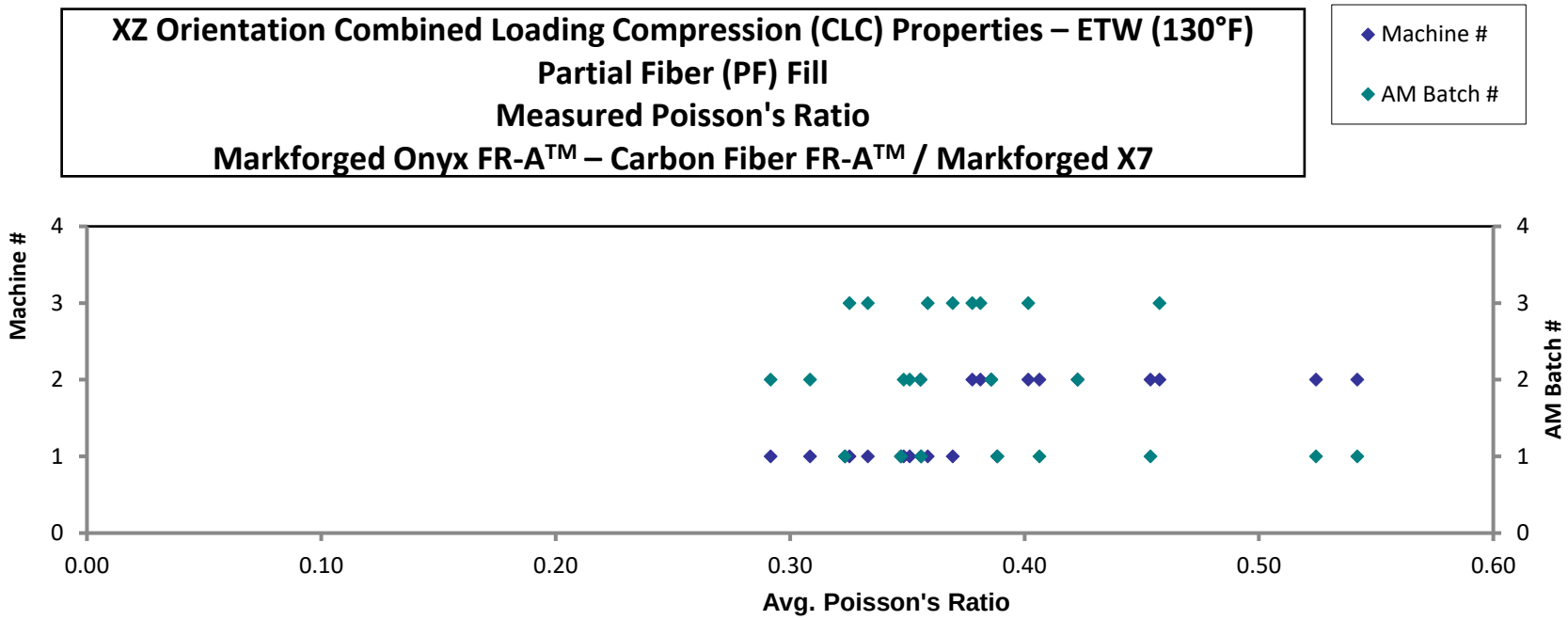
Specimen Number	AM Batch #	Machine #	Avg. Specimen Thickness [in]	Compressive Strength [ksi]	Avg. Compressive Modulus [Msi]	Avg. Poisson's Ratio	Percentage Bending [%]	Failure Mode
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M1-P31490-XZ-CLC-11-ETW-PF-1	1	1	0.145	6.308	0.973	0.347	4.936	HGM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M1-P54807-XZ-CLC-12-ETW-PF-2	1	1	0.143	5.016	0.991	0.388	1.754	TGM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M1-P31494-XZ-CLC-13-ETW-PF-3	1	1	0.145	6.252	1.012	0.356	5.947	TGM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M1-P31784-XZ-CLC-13-ETW-PF-SP*	1	1	0.144		0.824	0.323	11.07	TGM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M2-P31491-XZ-CLC-11-ETW-PF-1	1	2	0.139	9.621	1.296	0.524	1.497	HGM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M2-P31697-XZ-CLC-12-ETW-PF-2	1	2	0.139	4.530	1.081	0.454	4.283	EGM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M2-P31495-XZ-CLC-13-ETW-PF-3	1	2	0.140	8.507	1.539	0.542	4.432	HGM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M2-P31785-XZ-CLC-13-ETW-PF-SP***	1	2	0.138	7.933	1.332	0.406		HGM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-B-M1-P55801-XZ-CLC-11-ETW-PF-1	2	1	0.142	3.942	0.829	0.292	3.909	TGM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-B-M1-P33716-XZ-CLC-12-ETW-PF-2****	2	1	0.142	4.679	0.931	0.348	3.918	TGM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-B-M1-P55269-XZ-CLC-13-ETW-PF-3	2	1	0.140	6.766	1.084	0.351	8.849	TGM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-B-M1-P33018-XZ-CLC-13-ETW-PF-SP	2	1	0.142	5.574	0.925	0.308	2.608	TGM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-B-M2-P40904-XZ-CLC-11-ETW-PF-1	2	2	0.141	3.338	0.851	0.356	3.944	TGM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-B-M2-P56216-XZ-CLC-12-ETW-PF-2	2	2	0.140	4.747	1.032	0.423	1.809	HGM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-B-M2-P55764-XZ-CLC-13-ETW-PF-3	2	2	0.140	4.245	1.000	0.386	1.330	TGM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-C-M1-P35650-XZ-CLC-11-ETW-PF-1	3	1	0.143	6.304	0.979	0.359	2.045	TGM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-C-M1-P35346-XZ-CLC-12-ETW-PF-2	3	1	0.143	4.671	0.856	0.325	3.141	TGM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-C-M1-P47525-XZ-CLC-13-ETW-PF-3*/**	3	1	0.143		0.900	0.369	11.46	TGM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-C-M1-P35266-XZ-CLC-13-ETW-PF-6	3	1	0.143	4.866	0.824	0.333	8.043	TGM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-C-M2-P34965-XZ-CLC-11-ETW-PF-1*****	3	2	0.141	4.717	0.890	0.378	7.775	TGM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-C-M2-P35347-XZ-CLC-12-ETW-PF-2	3	2	0.142	5.148	0.904	0.381	9.484	HGM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-C-M2-P57239-XZ-CLC-13-ETW-PF-3	3	2	0.141	5.625	1.006	0.458	0.512	HGM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-C-M2-P35260-XZ-CLC-13-ETW-PF-6	3	2	0.142	3.720	0.941	0.402	0.136	TGM

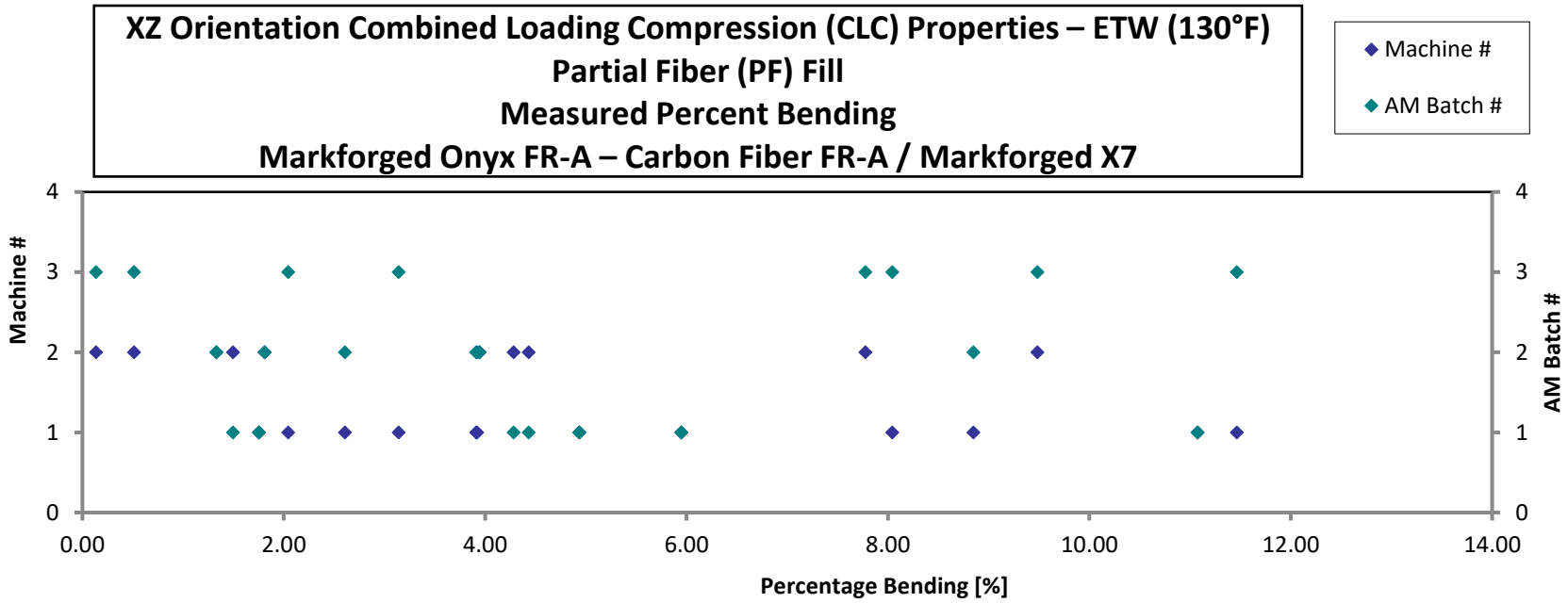
Average	**0.142**	**5.548**	**1.000**	**0.383**	**4.677**	
Standard Dev.		**1.604**	**0.176**	**0.063**	**3.392**	
Coeff. of Var. [%]		**28.91**	**17.64**	**16.46**	**72.53**	
Min.	**0.138**	**3.338**	**0.824**	**0.292**	**0.136**	
Max.	**0.145**	**9.621**	**1.539**	**0.542**	**11.46**	
Number of Spec.	**23**	**21**	**23**	**23**	**22**	

*Strength not reported due to percent bending being greater than 10% (invalid)
**Poisson's ratio 2 not reported due to strain gage failure
***Modulus 2 and percent bending not reported due to strain gage failure
****Modulus 2 and Poisson's ratio 2 not reported due to strain gage failure
*****Modulus calculation used 2000-4000 microstrain
Note: Modulus and Poisson's Ratio are average values of 2 strain gages


XZ Orientation Combined Loading Compression (CLC) Properties – ETW (130°F)
Partial Fiber (PF) Fill
Measured Strength
Markforged Onyx FR-A™ – Carbon Fiber FR-A™ / Markforged X7
Machine #
AM Batch #
Machine #
AM Batch #
Compressive Strength [ksi]
0
1
2
3
4
0.0
2.0
4.0
6.0
8.0
10.0
12.0


XZ Orientation Combined Loading Compression (CLC) Properties – ETW (130°F)
Partial Fiber (PF) Fill
Measured Modulus
Markforged Onyx FR-A™ – Carbon Fiber FR-A™ / Markforged X7
Machine #
AM Batch #
Machine #
AM Batch #
0
1
2
3
4
0.00
0.20
0.40
0.60
0.80
1.00
1.20
1.40
1.60
1.80
Avg. Compressive Modulus [Msi]


XZ Orientation Combined Loading Compression (CLC) Properties – ETW (130°F)
Partial Fiber (PF) Fill
Measured Poisson's Ratio
Markforged Onyx FR-A™ – Carbon Fiber FR-A™ / Markforged X7
Machine #
AM Batch #
Machine #
AM Batch #
0
1
2
3
4
0.00
0.10
0.20
0.30
0.40
0.50
0.60
Avg. Poisson's Ratio


XZ Orientation Combined Loading Compression (CLC) Properties – ETW (130°F)
Partial Fiber (PF) Fill
Measured Percent Bending
Markforged Onyx FR-A – Carbon Fiber FR-A / Markforged X7
Machine #
AM Batch #
Machine #
AM Batch #
Percentage Bending [%]
0
1
2
3
4
0.00
2.00
4.00
6.00
8.00
10.00
12.00
14.00

4.10 **XZ FF Compression Properties**

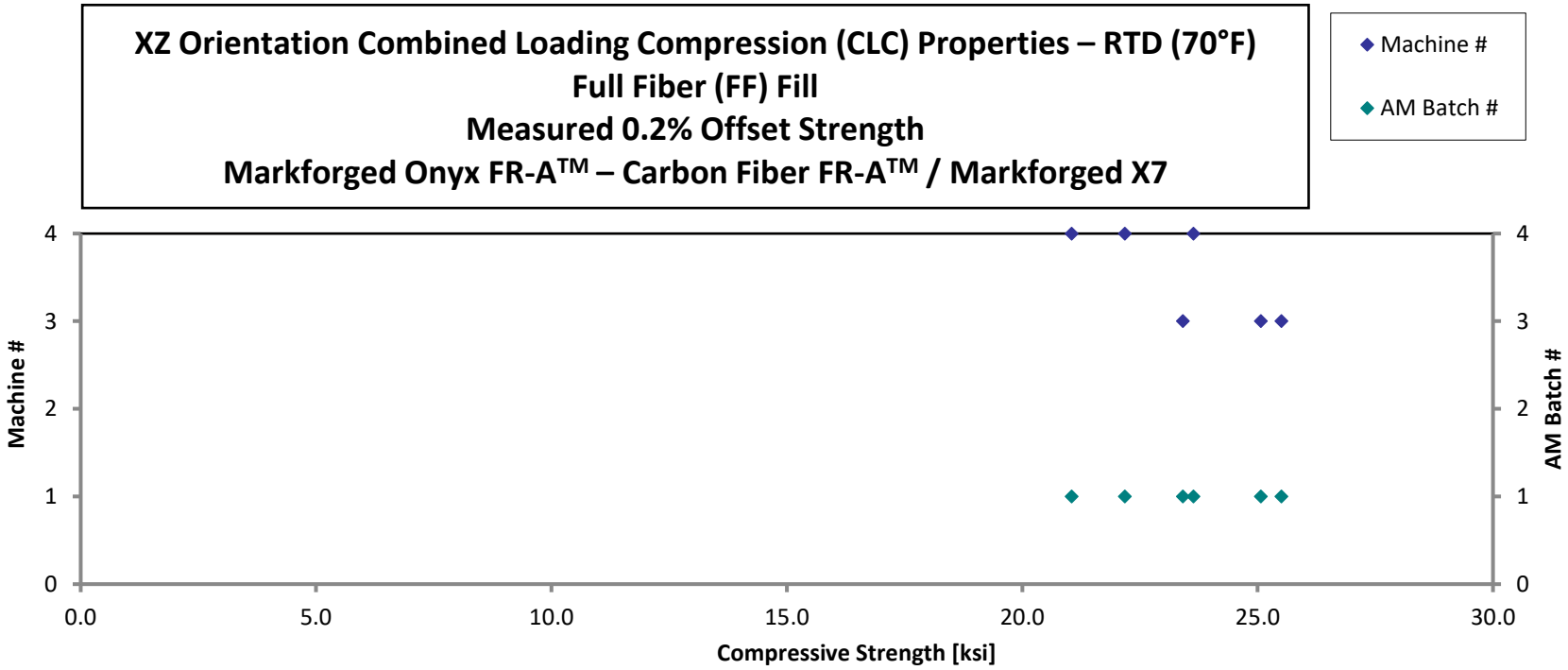
4.10.1 **RTD Condition**

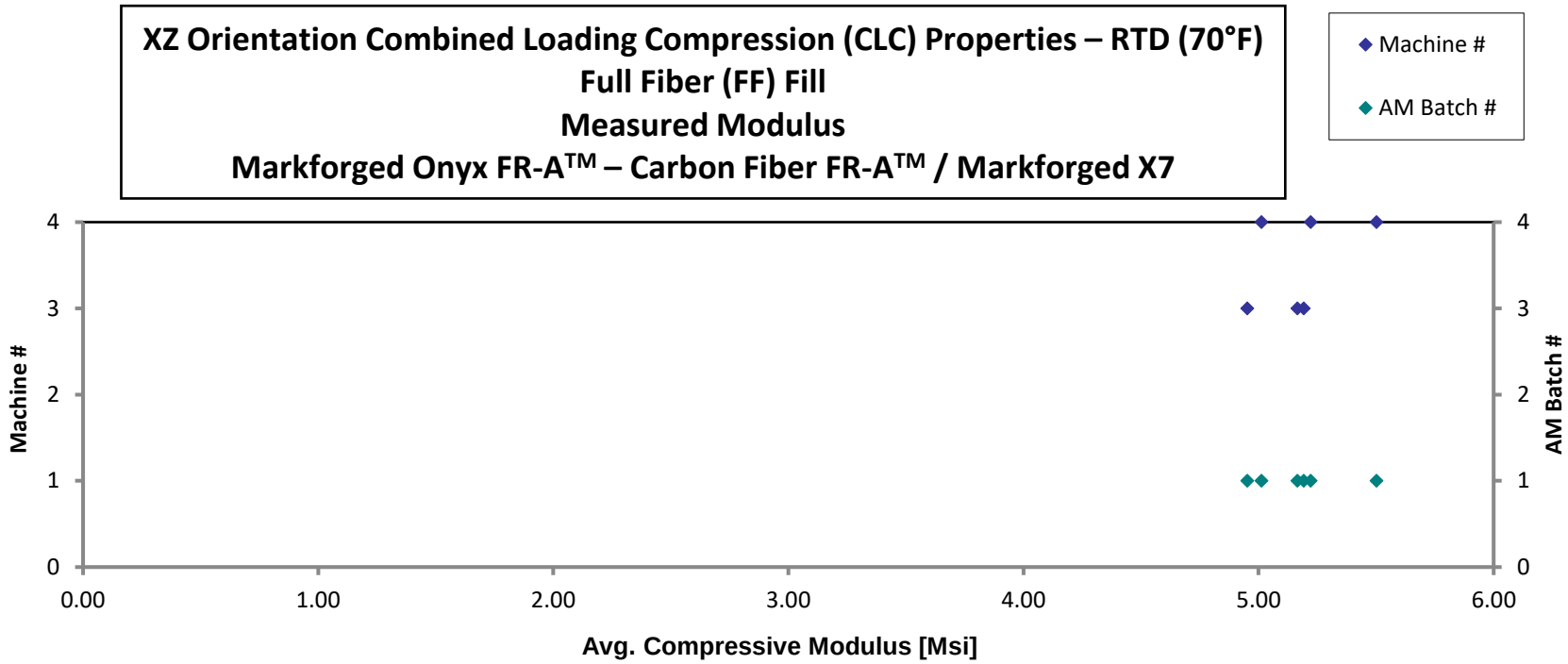
XZ Orientation Combined Loading Compression (CLC) Properties – RTD (70°F)
Full Fiber (FF) Fill
Strength & Modulus
Markforged Onyx FR-A™ – Carbon Fiber FR-A™ / Markforged X7

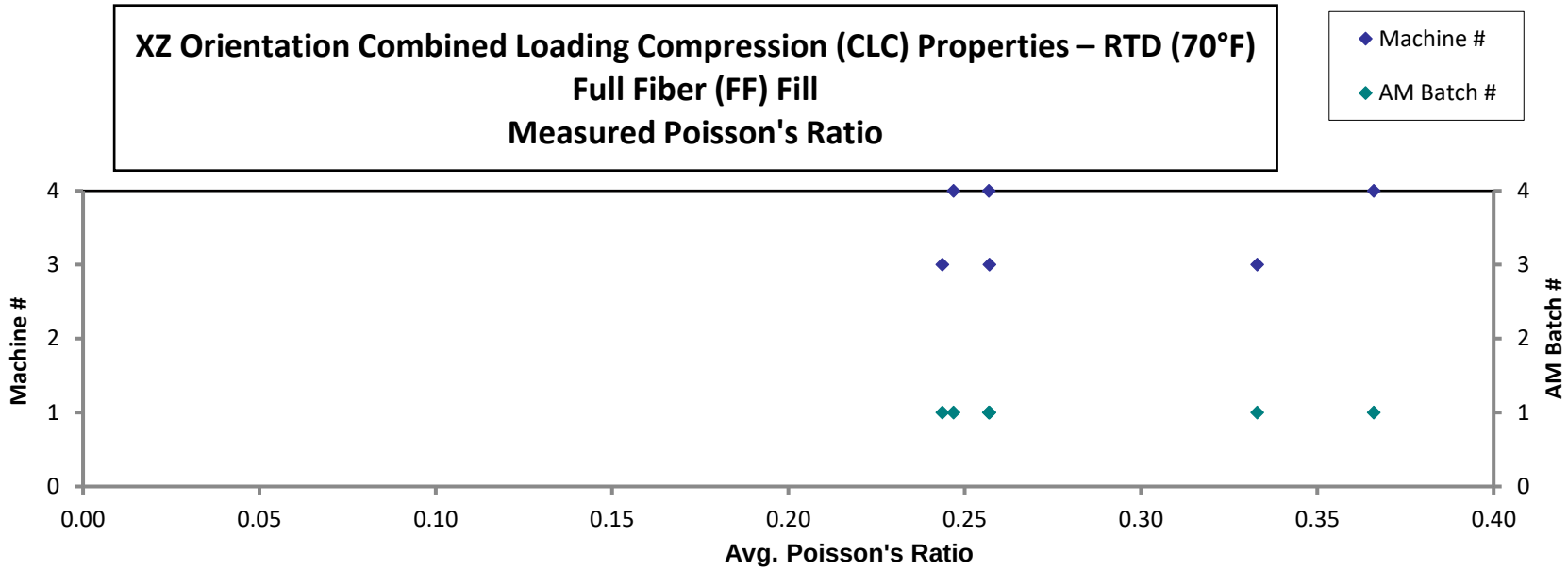
Specimen Number	AM Batch #	Machine #	Avg. Specimen Thickness [in]	Compressive Strength [ksi]	Avg. Compressive Modulus [Msi]	Avg. Poisson's Ratio	Percentage Bending [%]	Failure Mode
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M3-P34369-XZ-CLC-11-RTD-FF-1	1	3	0.140	23.41	5.165	0.244	2.007	EGM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M3-P34051-XZ-CLC-12-RTD-FF-2	1	3	0.143	25.07	5.191	0.257	4.127	EAT
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M3-P34059-XZ-CLC-13-RTD-FF-3	1	3	0.143	25.51	4.952	0.333	5.683	EAB
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M4-P42319-XZ-CLC-11-RTD-FF-1	1	4	0.139	21.05	5.501	0.257	4.077	EGM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M4-P41548-XZ-CLC-12-RTD-FF-2	1	4	0.139	22.18	5.221	0.247	1.600	EAB
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M4-P42161-XZ-CLC-13-RTD-FF-3	1	4	0.141	23.64	5.012	0.366	1.117	EGM

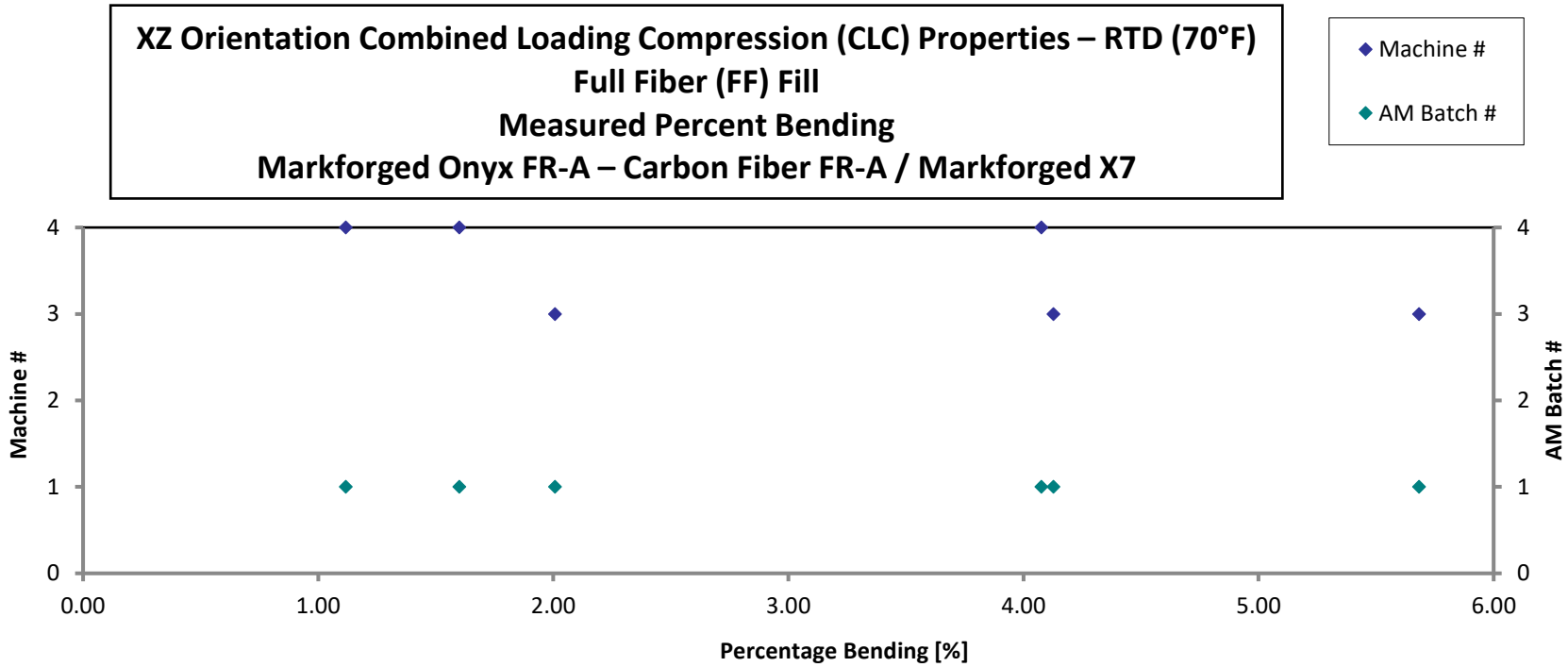
Note: The main failure mode was Euler buckling which invalidates the test data. Therefore results are provided for informational purposes.

Average	**0.141**	**23.48**	**5.174**	**0.284**	**3.102**	
Standard Dev.		**1.688**	**0.192**	**0.052**	**1.792**	
Coeff. of Var. [%]		**7.192**	**3.716**	**18.37**	**57.77**	
Min.	**0.139**	**21.05**	**4.952**	**0.244**	**1.117**	
Max.	**0.143**	**25.51**	**5.501**	**0.366**	**5.683**	
Number of Spec.	**6**	**6**	**6**	**6**	**6**	


XZ Orientation Combined Loading Compression (CLC) Properties – RTD (70°F)
Full Fiber (FF) Fill
Measured 0.2% Offset Strength
Markforged Onyx FR-A™ – Carbon Fiber FR-A™ / Markforged X7
Machine #
AM Batch #
Machine #
AM Batch #
Compressive Strength [ksi]
0.0
5.0
10.0
15.0
20.0
25.0
30.0
0
1
2
3
4


XZ Orientation Combined Loading Compression (CLC) Properties – RTD (70°F)
Full Fiber (FF) Fill
Measured Modulus
Markforged Onyx FR-A™ – Carbon Fiber FR-A™ / Markforged X7
Machine #
AM Batch #
Machine #
AM Batch #
0
1
2
3
4
0.00
1.00
2.00
3.00
4.00
5.00
6.00
Avg. Compressive Modulus [Msi]


XZ Orientation Combined Loading Compression (CLC) Properties – RTD (70°F)
Full Fiber (FF) Fill
Measured Poisson's Ratio
Machine #
AM Batch #
Machine #
AM Batch #
Avg. Poisson's Ratio
0
1
2
3
4
0.00
0.05
0.10
0.15
0.20
0.25
0.30
0.35
0.40


XZ Orientation Combined Loading Compression (CLC) Properties – RTD (70°F)
Full Fiber (FF) Fill
Measured Percent Bending
Markforged Onyx FR-A – Carbon Fiber FR-A / Markforged X7
Machine #
AM Batch #
Machine #
AM Batch #
Percentage Bending [%]
0
1
2
3
4
0.00
1.00
2.00
3.00
4.00
5.00
6.00

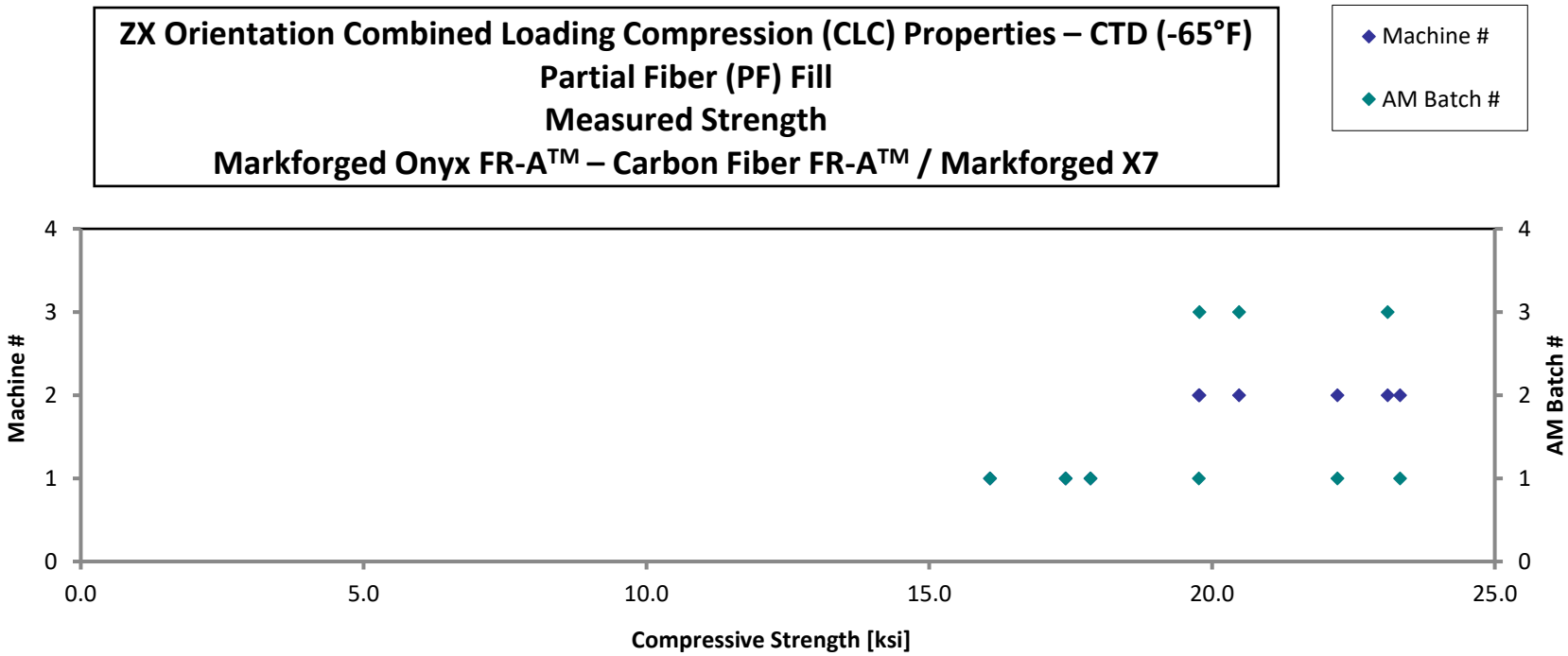
4.11 ZX PF Compression Properties – Reference Only

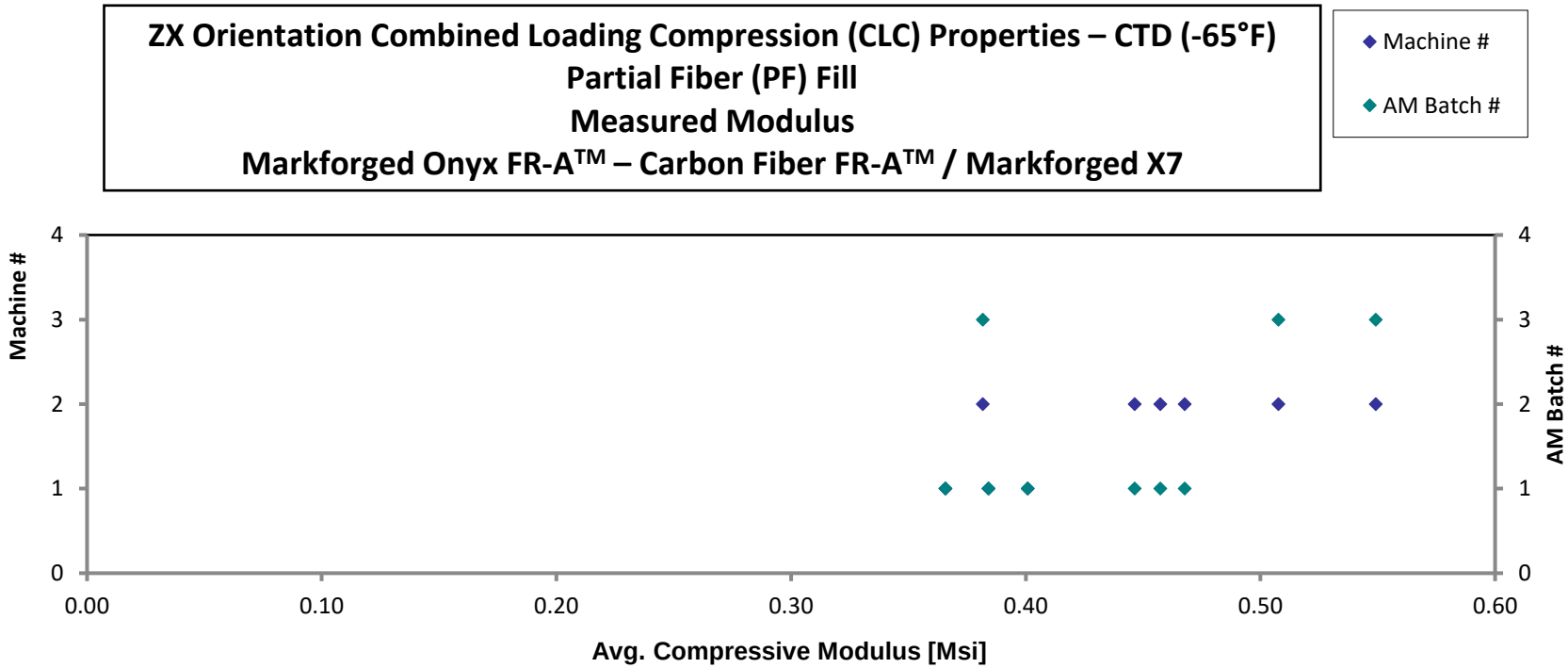
4.11.1 CTD Condition

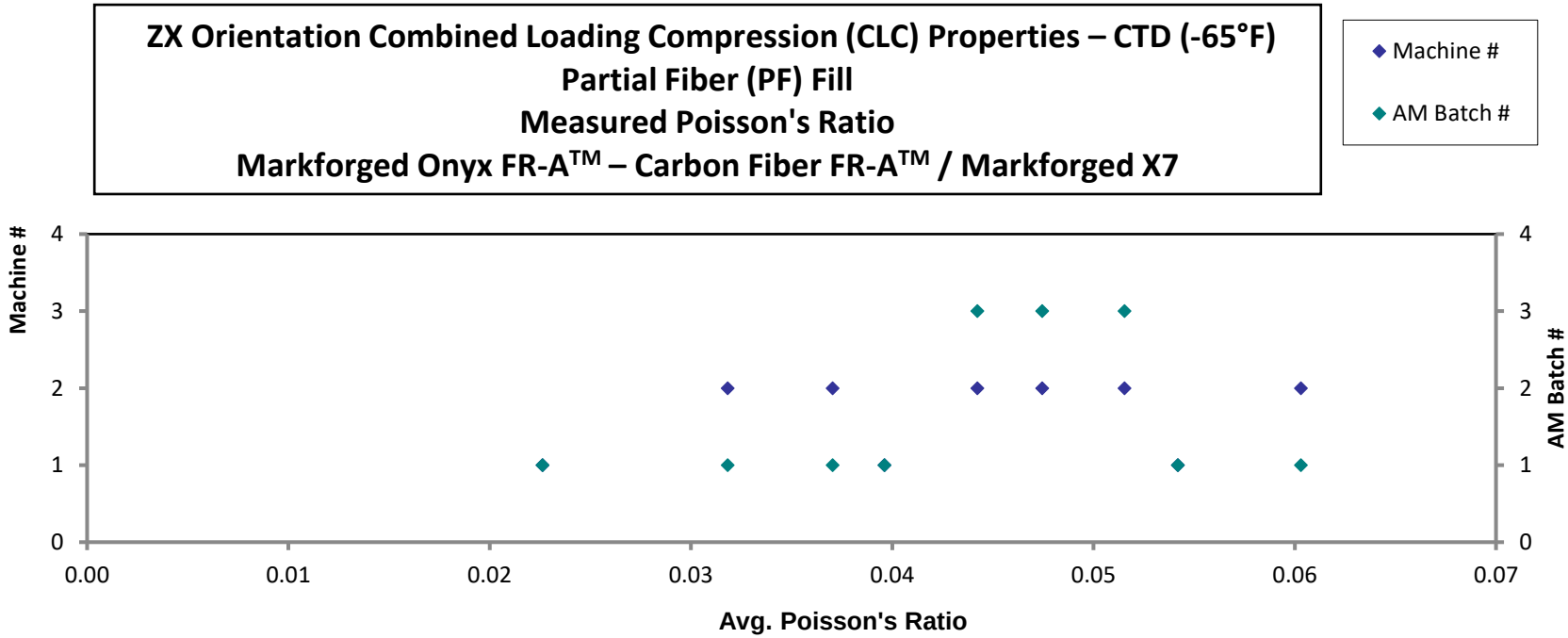
ZX Orientation Combined Loading Compression (CLC) Properties – CTD (-65°F)
Partial Fiber (PF) Fill
Strength & Modulus
Markforged Onyx FR-A™ – Carbon Fiber FR-A™ / Markforged X7

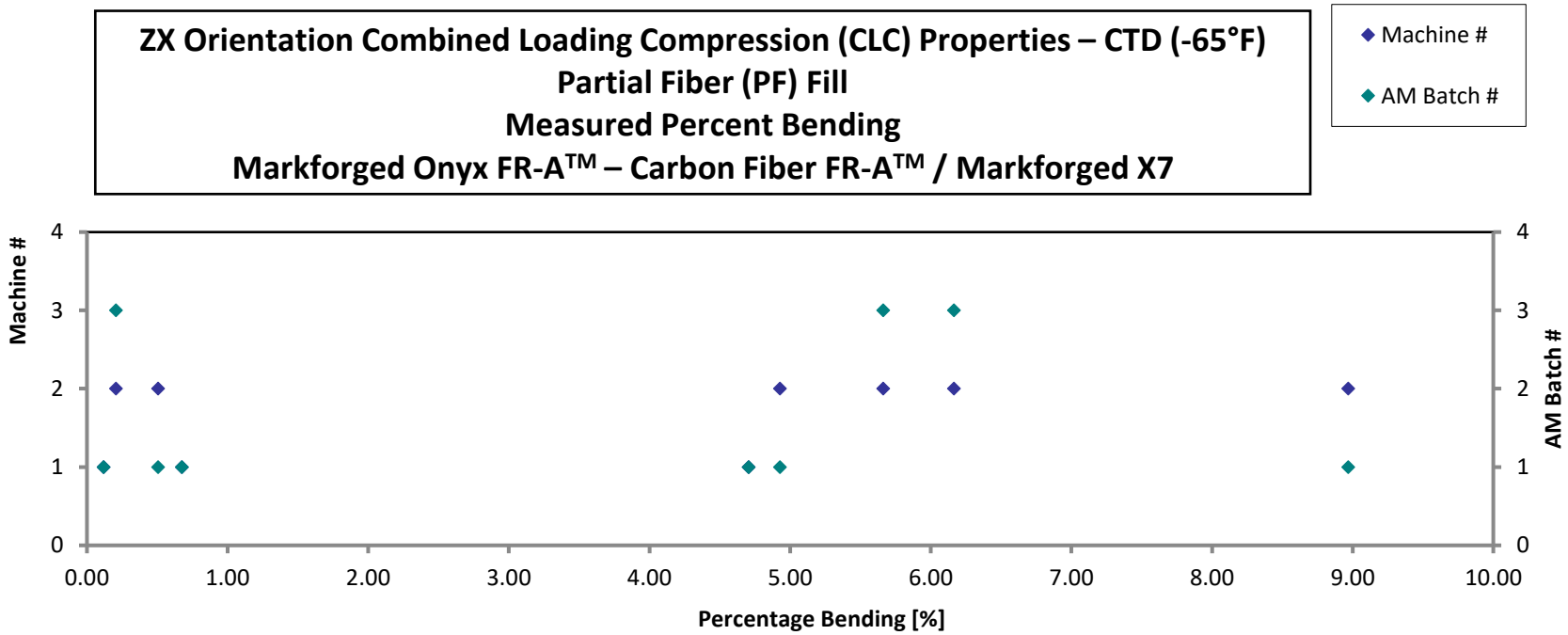
Specimen Number	AM Batch #	Machine #	Avg. Specimen Thickness [in]	Compressive Strength [ksi]	Avg. Compressive Modulus [Msi]	Avg. Poisson's Ratio	Percentage Bending [%]	Failure Mode
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M1-P29959-ZX-CLC-11-CTD-PF-1	1	1	0.141	16.07	0.366	0.054	0.675	BGM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M1-P30199-ZX-CLC-12-CTD-PF-2*	1	1	0.141	17.41	0.401	0.023	0.118	HGM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M1-P29994-ZX-CLC-13-CTD-PF-3	1	1	0.139	17.85	0.384	0.040	4.704	HGM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M2-P29993-ZX-CLC-11-CTD-PF-1	1	2	0.141	22.22	0.468	0.032	8.968	HGM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M2-P30281-ZX-CLC-12-CTD-PF-2	1	2	0.141	23.33	0.446	0.037	0.506	HGM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M2-P30074-ZX-CLC-13-CTD-PF-3	1	2	0.140	19.77	0.457	0.060	4.927	HGM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-C-M2-P36096-ZX-CLC-11-CTD-PF-1	3	2	0.140	19.78	0.382	0.047	0.205	BGM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-C-M2-P35083-ZX-CLC-12-CTD-PF-2	3	2	0.139	23.11	0.549	0.052	5.662	BGM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-C-M2-P35124-ZX-CLC-13-CTD-PF-3*	3	2	0.140	20.48	0.508	0.044	6.165	HGM
		Average	**0.140**	**20.00**	**0.440**	**0.043**	**3.548**	
		Standard Dev.		**2.567**	**0.062**	**0.012**	**3.248**	
		Coeff. of Var. [%]		**12.83**	**14.19**	**27.21**	**91.54**	
		Min.	**0.139**	**16.07**	**0.366**	**0.023**	**0.118**	
		Max.	**0.141**	**23.33**	**0.549**	**0.060**	**8.968**	
		Number of Spec.	**9**	**9**	**9**	**9**	**9**	

*Poisson's ratio 1 not reported due to strain gage failure
Note: Modulus and Poisson's Ratio are average values of 2 strain gages


ZX Orientation Combined Loading Compression (CLC) Properties – CTD (-65°F)
Partial Fiber (PF) Fill
Measured Strength
Markforged Onyx FR-A™ – Carbon Fiber FR-A™ / Markforged X7
Machine #
AM Batch #
Machine #
AM Batch #
Compressive Strength [ksi]
0.0
5.0
10.0
15.0
20.0
25.0
0
1
2
3
4


ZX Orientation Combined Loading Compression (CLC) Properties – CTD (-65°F)
Partial Fiber (PF) Fill
Measured Modulus
Markforged Onyx FR-A™ – Carbon Fiber FR-A™ / Markforged X7
Machine #
AM Batch #
Machine #
AM Batch #
0
1
2
3
4
0.00
0.10
0.20
0.30
0.40
0.50
0.60
Avg. Compressive Modulus [Msi]


ZX Orientation Combined Loading Compression (CLC) Properties – CTD (-65°F)
Partial Fiber (PF) Fill
Measured Poisson's Ratio
Markforged Onyx FR-A™ – Carbon Fiber FR-A™ / Markforged X7
Machine #
AM Batch #
Machine #
AM Batch #
0
1
2
3
4
0.00
0.01
0.02
0.03
0.04
0.05
0.06
0.07
Avg. Poisson's Ratio

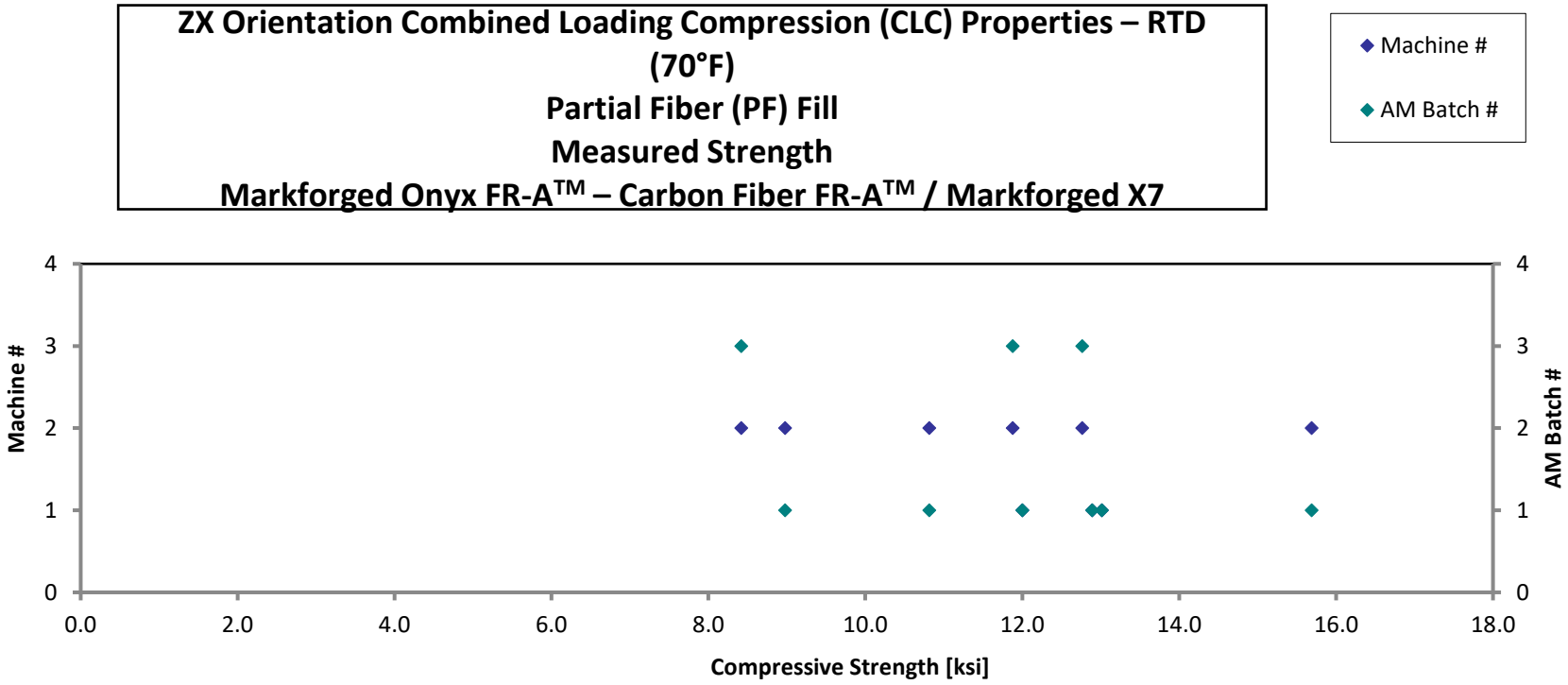

ZX Orientation Combined Loading Compression (CLC) Properties – CTD (-65°F)
Partial Fiber (PF) Fill
Measured Percent Bending
Markforged Onyx FR-A™ – Carbon Fiber FR-A™ / Markforged X7
Machine #
AM Batch #
Machine #
AM Batch #
0
1
2
3
4
0.00
1.00
2.00
3.00
4.00
5.00
6.00
7.00
8.00
9.00
10.00
Percentage Bending [%]

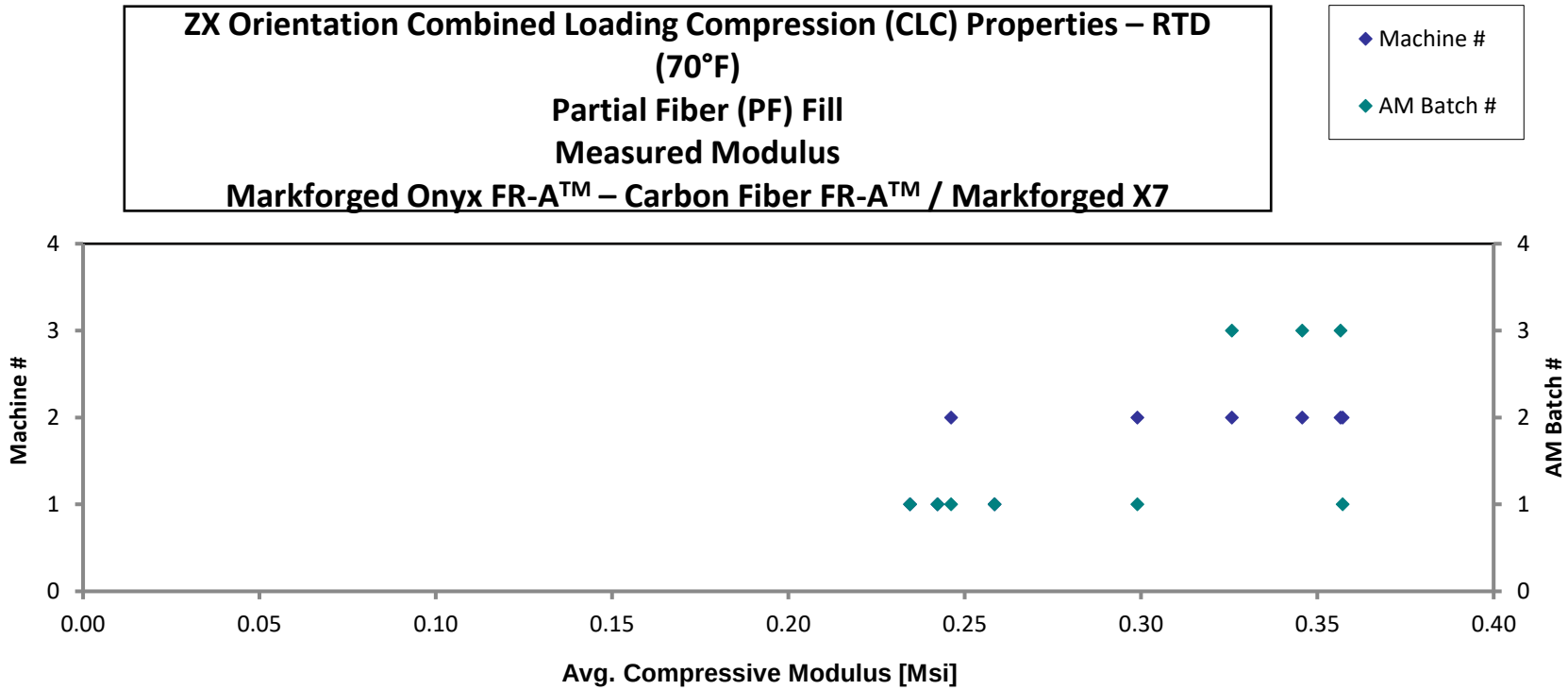
4.11.2 **RTD Condition**

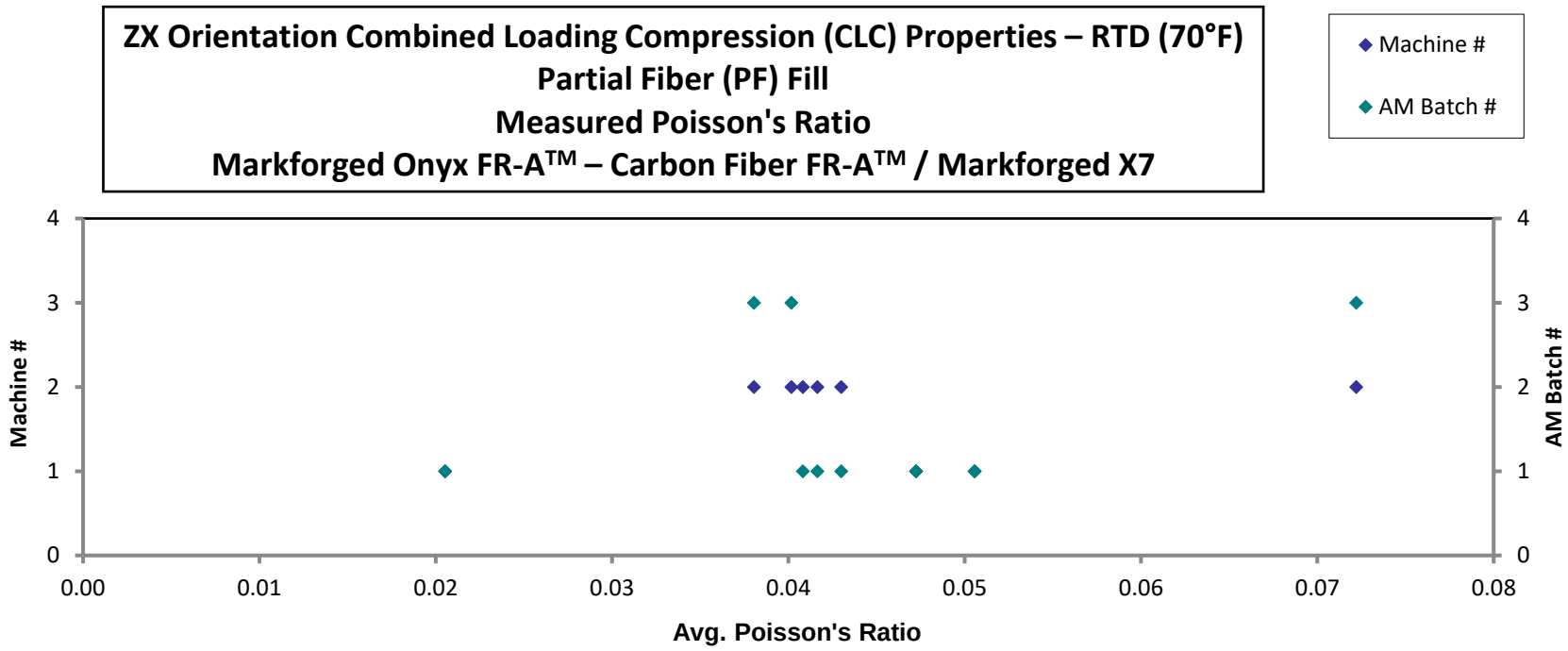
ZX Orientation Combined Loading Compression (CLC) Properties – RTD (70°F)
Partial Fiber (PF) Fill
Strength & Modulus
Markforged Onyx FR-A™ – Carbon Fiber FR-A™ / Markforged X7

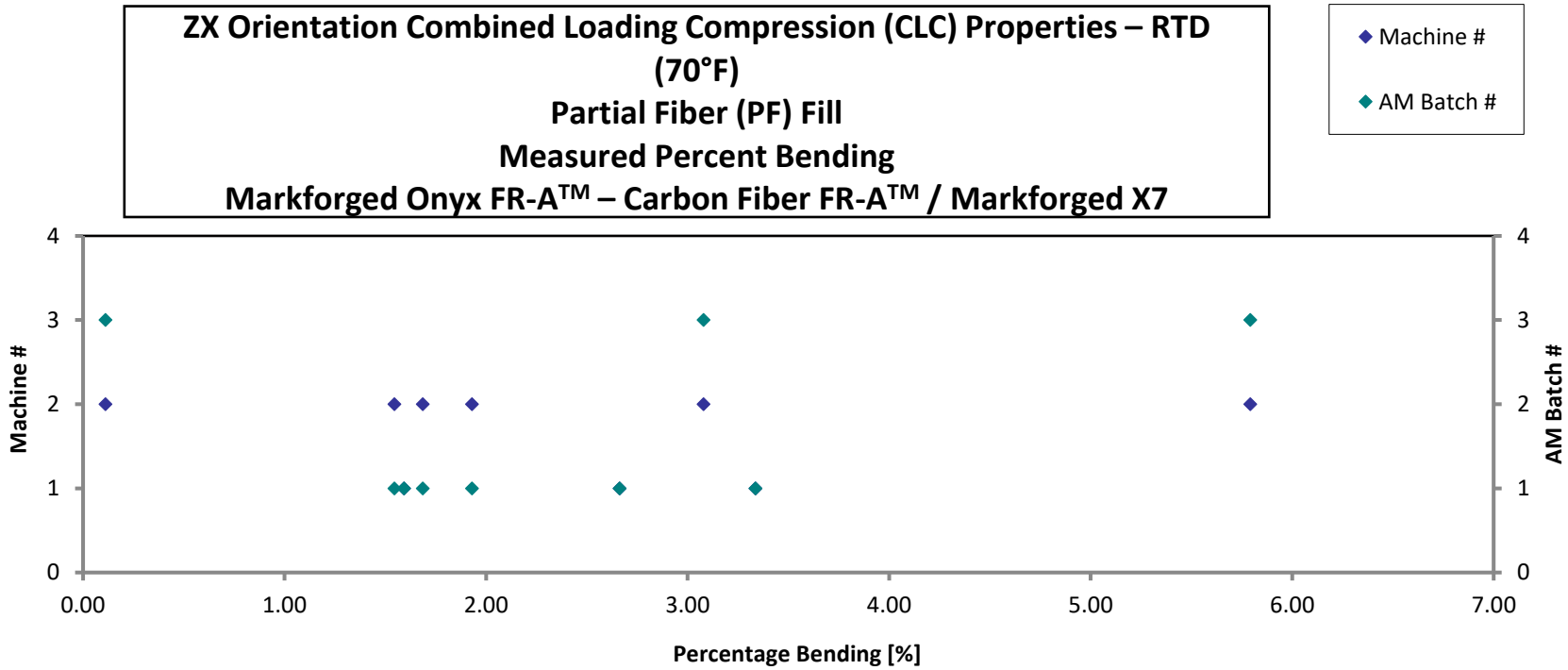
Specimen Number	AM Batch #	Machine #	Avg. Specimen Thickness [in]	Compressive Strength [ksi]	Avg. Compressive Modulus [Msi]	Avg. Poisson's Ratio	Percentage Bending [%]	Failure Mode
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M1-P29959-ZX-CLC-11-RTD-PF-1	1	1	0.142	12.89	0.258	0.051	2.662	M(D,H)GM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M1-P30199-ZX-CLC-12-RTD-PF-2*	1	1	0.141	12.00	0.242	0.021	1.593	M(E,H)GM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M1-P29994-ZX-CLC-13-RTD-PF-3	1	1	0.141	13.02	0.234	0.047	3.337	M(E,H)GM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M2-P29993-ZX-CLC-11-RTD-PF-1	1	2	0.142	10.82	0.246	0.042	1.930	M(D,H)GM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M2-P30281-ZX-CLC-12-RTD-PF-2	1	2	0.140	15.69	0.357	0.041	1.686	HGM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M2-P30074-ZX-CLC-13-RTD-PF-3*	1	2	0.141	8.978	0.299	0.043	1.545	M(D,E)GM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-C-M2-P36096-ZX-CLC-11-RTD-PF-1	3	2	0.141	8.420	0.326	0.072	3.079	M(D,H)GM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-C-M2-P35083-ZX-CLC-12-RTD-PF-2	3	2	0.140	12.76	0.357	0.040	0.111	EGM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-C-M2-P35124-ZX-CLC-13-RTD-PF-3	3	2	0.141	11.88	0.346	0.038	5.792	M(E,H)GM
		Average	**0.141**	**11.83**	**0.296**	**0.044**	**2.415**	
		Standard Dev.		**2.212**	**0.052**	**0.014**	**1.591**	
		Coeff. of Var. [%]		**18.70**	**17.44**	**30.90**	**65.90**	
		Min.	**0.140**	**8.420**	**0.234**	**0.021**	**0.111**	
		Max.	**0.142**	**15.69**	**0.357**	**0.072**	**5.792**	
		Number of Spec.	**9**	**9**	**9**	**9**	**9**	

*Poisson's ratio 1 not reported due to strain gage failure
Note: Modulus and Poisson's Ratio are average values of 2 strain gages


ZX Orientation Combined Loading Compression (CLC) Properties – RTD (70°F)
Partial Fiber (PF) Fill
Measured Strength
Markforged Onyx FR-A™ – Carbon Fiber FR-A™ / Markforged X7
Machine #
AM Batch #
Machine #
AM Batch #
Compressive Strength [ksi]
0.0
2.0
4.0
6.0
8.0
10.0
12.0
14.0
16.0
18.0
0
1
2
3
4


ZX Orientation Combined Loading Compression (CLC) Properties – RTD (70°F)
Partial Fiber (PF) Fill
Measured Modulus
Markforged Onyx FR-A™ – Carbon Fiber FR-A™ / Markforged X7
Machine #
AM Batch #
Machine #
AM Batch #
0
1
2
3
4
0.00
0.05
0.10
0.15
0.20
0.25
0.30
0.35
0.40
Avg. Compressive Modulus [Msi]


ZX Orientation Combined Loading Compression (CLC) Properties – RTD (70°F)
Partial Fiber (PF) Fill
Measured Poisson's Ratio
Markforged Onyx FR-A™ – Carbon Fiber FR-A™ / Markforged X7
Machine #
AM Batch #
Machine #
AM Batch #
Avg. Poisson's Ratio
0
1
2
3
4
0.00
0.01
0.02
0.03
0.04
0.05
0.06
0.07
0.08

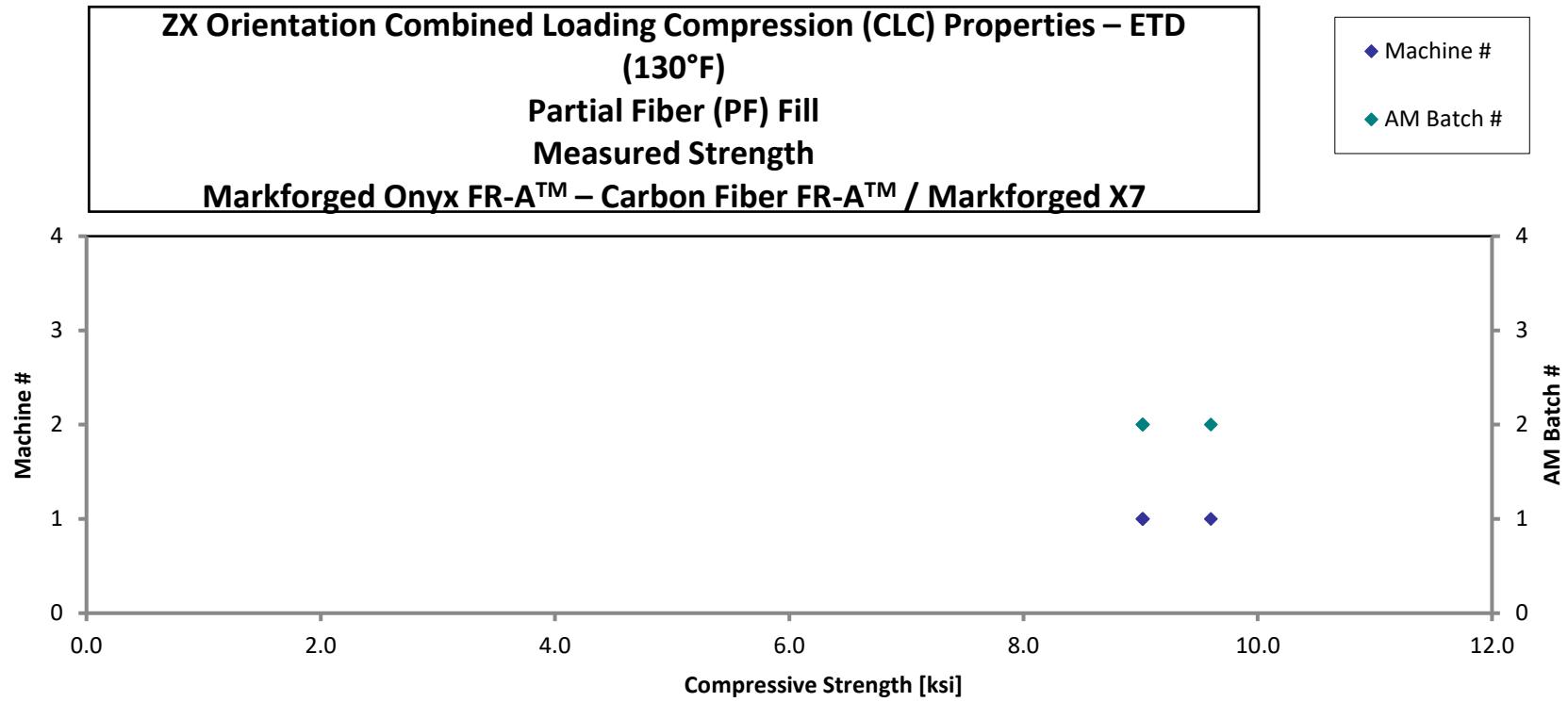

ZX Orientation Combined Loading Compression (CLC) Properties – RTD (70°F)
Partial Fiber (PF) Fill
Measured Percent Bending
Markforged Onyx FR-A™ – Carbon Fiber FR-A™ / Markforged X7
Machine #
AM Batch #
Machine #
AM Batch #
Percentage Bending [%]
0
1
2
3
4
0.00
1.00
2.00
3.00
4.00
5.00
6.00
7.00

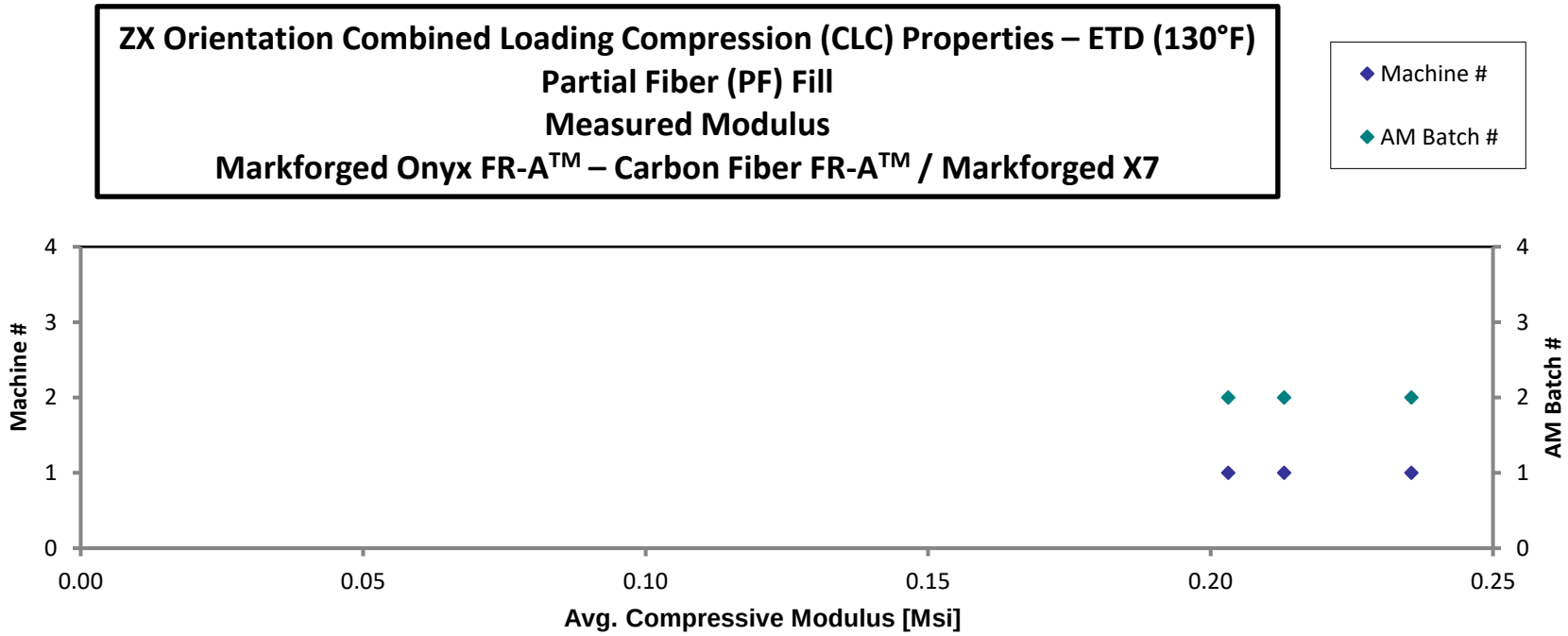
4.11.3 **ETD Condition**

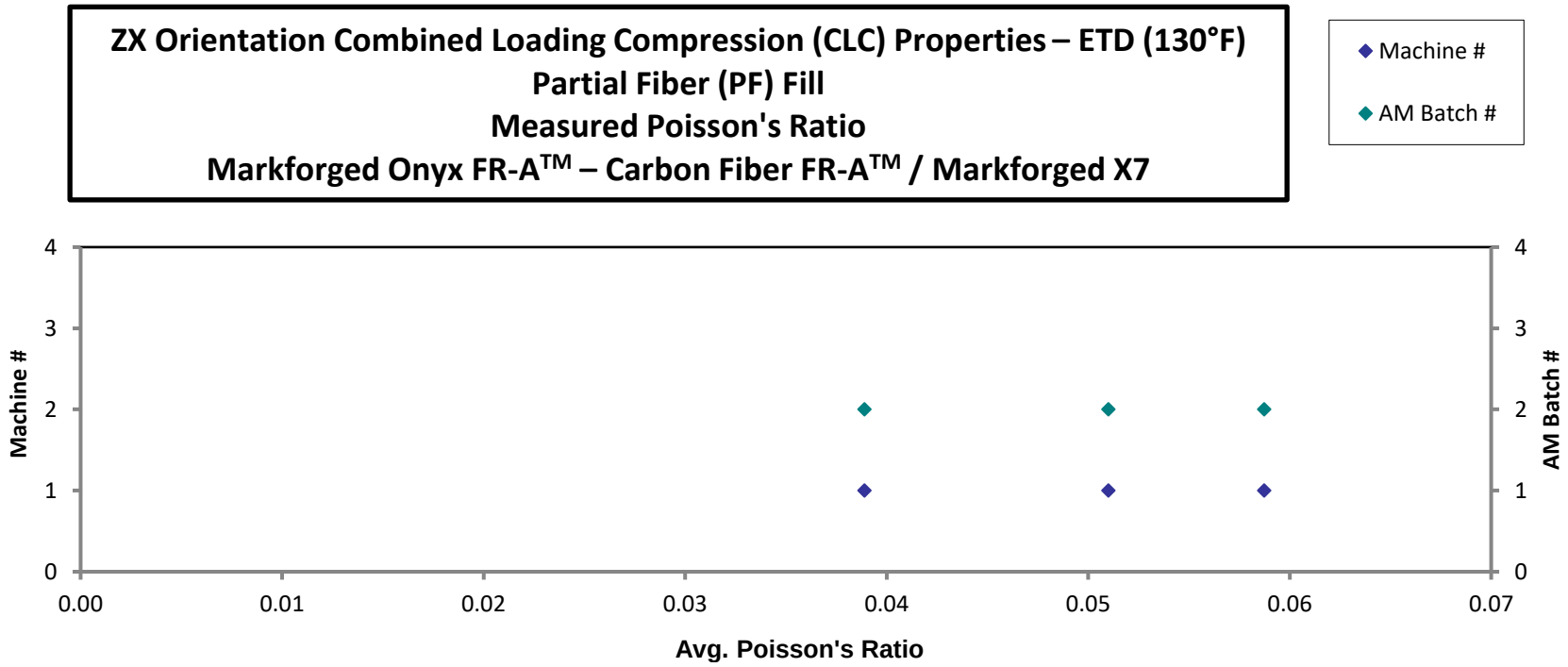
ZX Orientation Combined Loading Compression (CLC) Properties – ETD (130°F)
Partial Fiber (PF) Fill
Strength & Modulus
Markforged Onyx FR-A™ – Carbon Fiber FR-A™ / Markforged X7

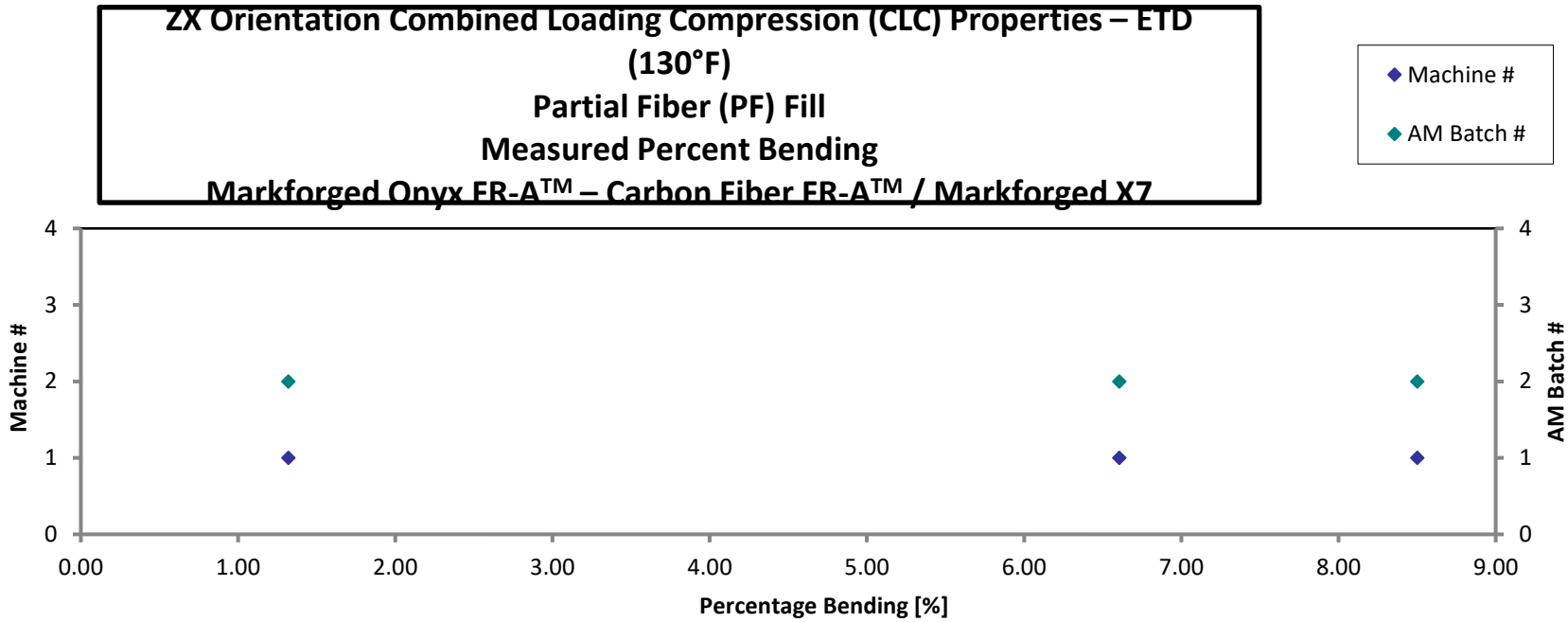
Specimen Number	AM Batch #	Machine #	Avg. Specimen Thickness [in]	Compressive Strength [ksi]	Avg. Compressive Modulus [Msi]	Avg. Poisson's Ratio	Percentage Bending [%]	Failure Mode
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-B-M1-P40767-ZX-CLC-11-ETD-PF-1**	2	1	0.135	9.020	0.213	0.059	8.502	EGM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-B-M1-P40434-ZX-CLC-12-ETD-PF-2	2	1	0.136	9.601	0.236	0.051	6.606	EGM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-B-M1-P40042-ZX-CLC-13-ETD-PF-3*	2	1	0.135	9.016	0.203	0.039	1.320	EGM
		Average	**0.135**	**9.212**	**0.217**	**0.050**	**5.476**	
		Standard Dev.		**0.337**	**0.017**	**0.010**	**3.722**	
		Coeff. of Var. [%]		**3.654**	**7.645**	**20.19**	**67.97**	
		Min.	**0.135**	**9.016**	**0.203**	**0.039**	**1.320**	
		Max.	**0.136**	**9.601**	**0.236**	**0.059**	**8.502**	
		Number of Spec.	**3**	**3**	**3**	**3**	**3**	

*Poisson's ratio 1 not reported due to strain gage failure
**Poisson's ratio 2 not reported due to strain gage failure
Note: Modulus and Poisson's Ratio are average values of 2 strain gages


ZX Orientation Combined Loading Compression (CLC) Properties – ETD (130°F)
Partial Fiber (PF) Fill
Measured Strength
Markforged Onyx FR-A™ – Carbon Fiber FR-A™ / Markforged X7
Machine #
AM Batch #
Machine #
AM Batch #
Compressive Strength [ksi]
0.0
2.0
4.0
6.0
8.0
10.0
12.0
0
1
2
3
4


ZX Orientation Combined Loading Compression (CLC) Properties – ETD (130°F)
Partial Fiber (PF) Fill
Measured Modulus
Markforged Onyx FR-A™ – Carbon Fiber FR-A™ / Markforged X7
Machine #
AM Batch #
Machine #
AM Batch #
0
1
2
3
4
0.00
0.05
0.10
0.15
0.20
0.25
Avg. Compressive Modulus [Msi]


ZX Orientation Combined Loading Compression (CLC) Properties – ETD (130°F)
Partial Fiber (PF) Fill
Measured Poisson's Ratio
Markforged Onyx FR-A™ – Carbon Fiber FR-A™ / Markforged X7
Machine #
AM Batch #
Machine #
AM Batch #
0
1
2
3
4
0.00
0.01
0.02
0.03
0.04
0.05
0.06
0.07
Avg. Poisson's Ratio


ZX Orientation Combined Loading Compression (CLC) Properties – ETD (130°F)
Partial Fiber (PF) Fill
Measured Percent Bending
Markforged Onyx FR-A™ – Carbon Fiber FR-A™ / Markforged X7
Machine #
AM Batch #
Machine #
AM Batch #
Percentage Bending [%]
0.00
1.00
2.00
3.00
4.00
5.00
6.00
7.00
8.00
9.00
0
1
2
3
4

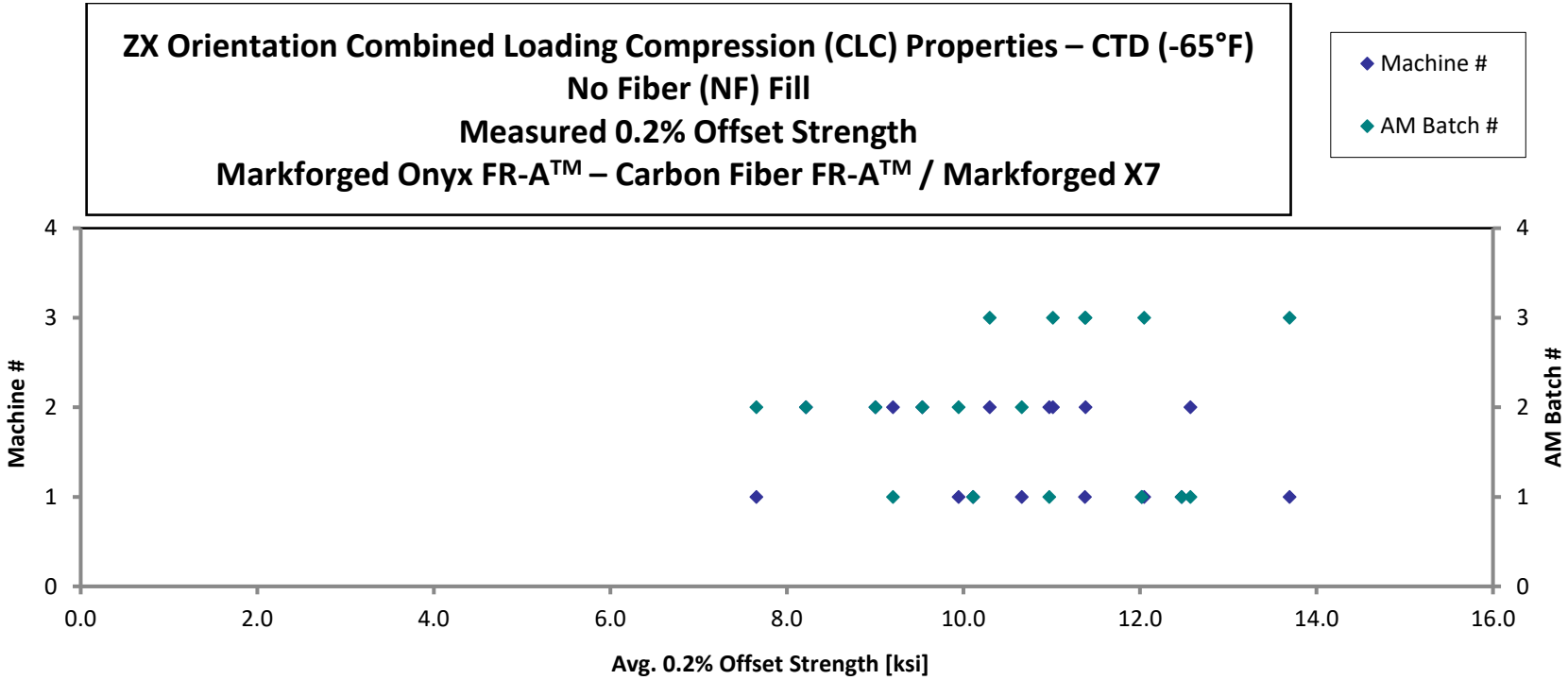
4.12 **ZX NF Compression Properties**

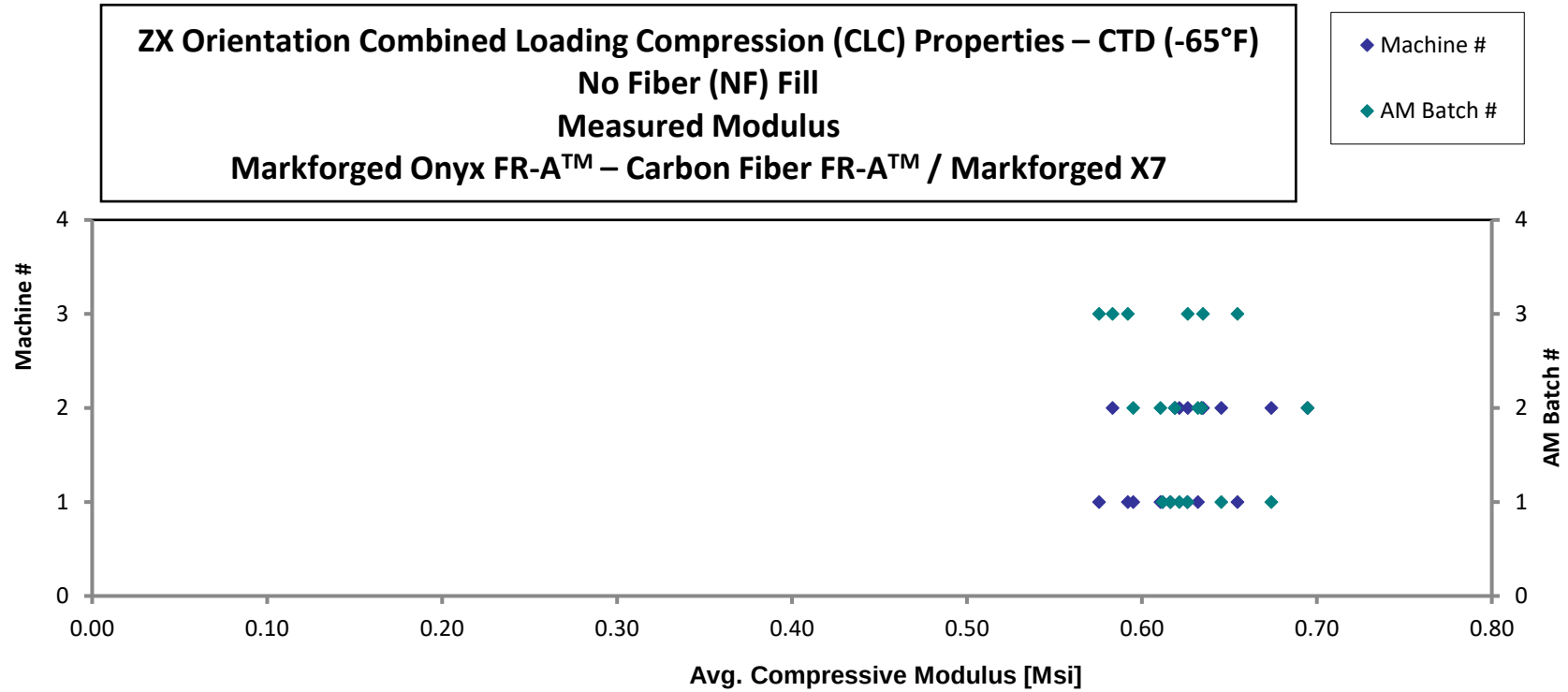
4.12.1 **CTD Condition**

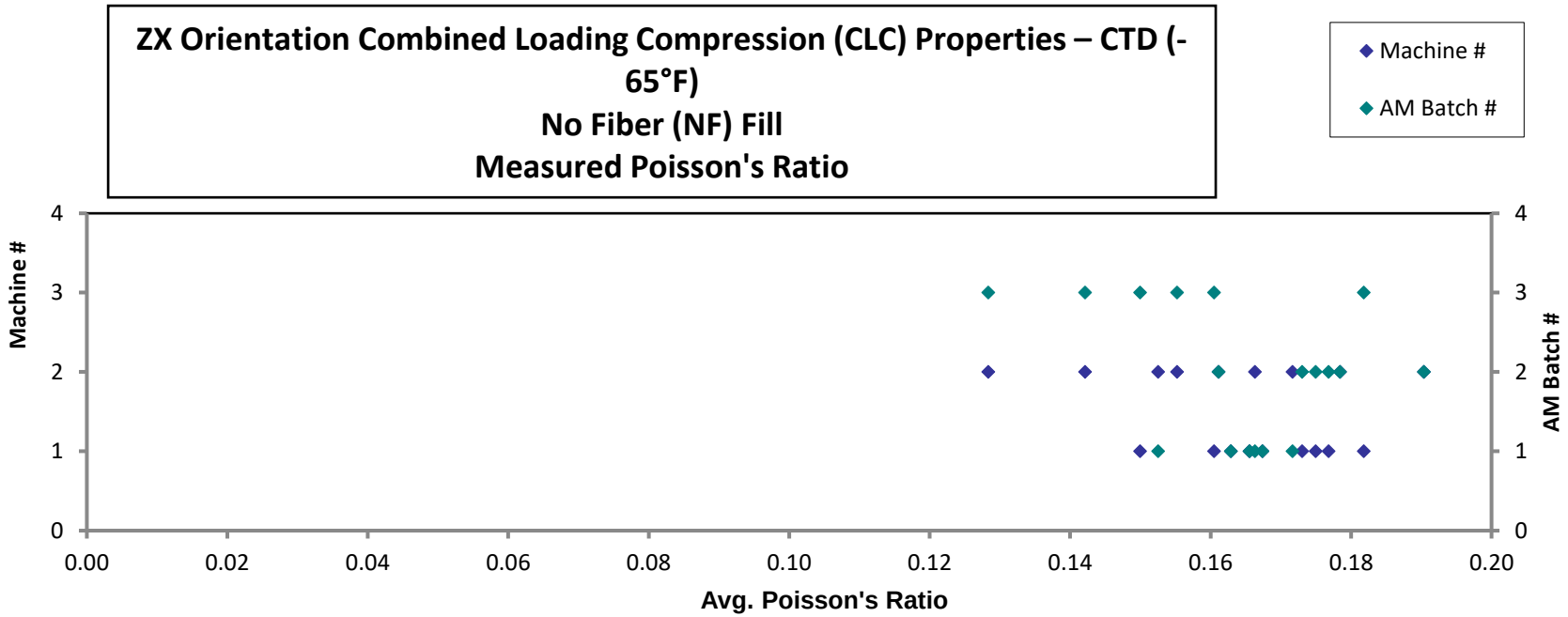
ZX Orientation Combined Loading Compression (CLC) Properties – CTD (-65°F)
No Fiber (NF) Fill
Strength & Modulus
Markforged Onyx FR-A™ – Carbon Fiber FR-A™ / Markforged X7

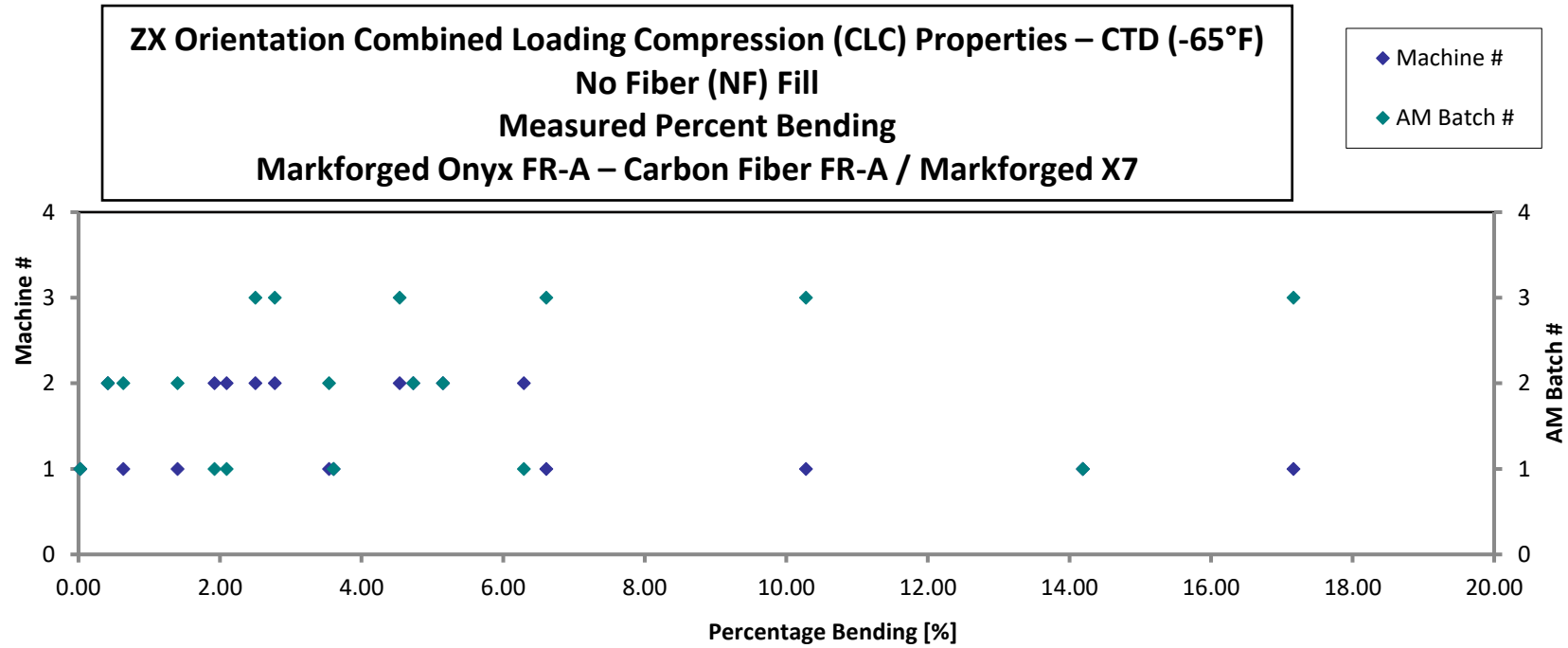
Specimen Number	AM Batch #	Machine #	Avg. Specimen Thickness [in]	Avg. 0.2% Offset Strength [ksi]	Avg. Compressive Modulus [Msi]	Avg. Poisson's Ratio	Percentage Bending [%]	Failure Mode
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M1-P60727-ZX-CLC-11-CTD-NF-1	1	1	0.146	12.020	0.612	0.167	0.027	EGM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M1-P67328-ZX-CLC-12-CTD-NF-2	1	1	0.146	10.110	0.616	0.163	3.602	EGM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M1-P67689-ZX-CLC-13-CTD-NF-3*	1	1	0.145	12.473	0.626	0.166	14.191	HGM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M2-P62038-ZX-CLC-11-CTD-NF-1	1	2	0.146	9.203	0.621	0.153	6.294	EGM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M2-P60130-ZX-CLC-12-CTD-NF-2	1	2	0.146	10.973	0.674	0.172	1.921	HGM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M2-P60979-ZX-CLC-13-CTD-NF-3	1	2	0.144	12.572	0.645	0.166	2.093	EGM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-B-M1-P62701-ZX-CLC-11-CTD-NF-1	2	1	0.144	7.656	0.595	0.173	1.399	EGM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-B-M1-P59506-ZX-CLC-12-CTD-NF-2	2	1	0.147	10.662	0.632	0.175	0.635	EGM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-B-M1-P62155-ZX-CLC-13-CTD-NF-3	2	1	0.142	9.947	0.611	0.177	3.539	EGM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-B-M2-P63004-ZX-CLC-11-CTD-NF-1	2	2	0.147	9.005	0.619	0.178	0.414	EGM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-B-M2-P59497-ZX-CLC-12-CTD-NF-2	2	2	0.147	9.535	0.695	0.190	5.149	EGM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-B-M2-P63802-ZX-CLC-13-CTD-NF-3	2	2	0.143	8.217	0.634	0.161	4.732	EGM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-C-M1-P64224-ZX-CLC-11-CTD-NF-1*	3	1	0.144	11.375	0.576	0.161	10.278	EGM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-C-M1-P63385-ZX-CLC-12-CTD-NF-2	3	1	0.146	12.048	0.655	0.182	6.611	EGM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-C-M1-P63784-ZX-CLC-13-CTD-NF-3*	3	1	0.144	13.695	0.592	0.150	17.164	EGM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-C-M2-P64990-ZX-CLC-11-CTD-NF-1	3	2	0.143	11.014	0.583	0.128	4.536	EGM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-C-M2-P64225-ZX-CLC-12-CTD-NF-2	3	2	0.144	10.299	0.635	0.142	2.774	EGM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-C-M2-P64680-ZX-CLC-13-CTD-NF-3	3	2	0.142	11.384	0.626	0.155	2.502	EGM
		Average	**0.145**	**10.677**	**0.625**	**0.164**	**4.881**	
		Standard Dev.		**1.595**	**0.030**	**0.015**	**4.701**	
		Coeff. of Var. [%]		**14.938**	**4.829**	**9.141**	**96.302**	
		Min.	**0.142**	**7.656**	**0.576**	**0.128**	**0.027**	
		Max.	**0.147**	**13.695**	**0.695**	**0.190**	**17.164**	
		Number of Spec.	**18**	**18**	**18**	**18**	**18**	

Note: Due to inherent material properties, B-basis calculations will be calculated eventhough improper failure modes were present.
Note: The main failure mode was Euler buckling which is an improper failure mode per ASTM D6641.
Note: No sharp load drop was witness during testing, therefore 0.2% offset strength was reported for consistency
*Percent bending was greater than 10% (Improper per ASTM D6641)
Note: Modulus and Poisson's Ratio are average values of 2 strain gages


ZX Orientation Combined Loading Compression (CLC) Properties – CTD (-65°F)
No Fiber (NF) Fill
Measured 0.2% Offset Strength
Markforged Onyx FR-A™ – Carbon Fiber FR-A™ / Markforged X7
Machine #
AM Batch #
Machine #
AM Batch #
Avg. 0.2% Offset Strength [ksi]
0
1
2
3
4
0.0
2.0
4.0
6.0
8.0
10.0
12.0
14.0
16.0


ZX Orientation Combined Loading Compression (CLC) Properties – CTD (-65°F)
No Fiber (NF) Fill
Measured Modulus
Markforged Onyx FR-A™ – Carbon Fiber FR-A™ / Markforged X7
Machine #
AM Batch #
Machine #
AM Batch #
0
1
2
3
4
0.00
0.10
0.20
0.30
0.40
0.50
0.60
0.70
0.80
Avg. Compressive Modulus [Msi]


ZX Orientation Combined Loading Compression (CLC) Properties – CTD (-65°F)
No Fiber (NF) Fill
Measured Poisson's Ratio
Machine #
AM Batch #
Machine #
AM Batch #
Avg. Poisson's Ratio
0
1
2
3
4
0.00
0.02
0.04
0.06
0.08
0.10
0.12
0.14
0.16
0.18
0.20


ZX Orientation Combined Loading Compression (CLC) Properties – CTD (-65°F)
No Fiber (NF) Fill
Measured Percent Bending
Markforged Onyx FR-A – Carbon Fiber FR-A / Markforged X7
Machine #
AM Batch #
Machine #
AM Batch #
Percentage Bending [%]
0
1
2
3
4
0.00
2.00
4.00
6.00
8.00
10.00
12.00
14.00
16.00
18.00
20.00

4.12.2 **RTD Condition**

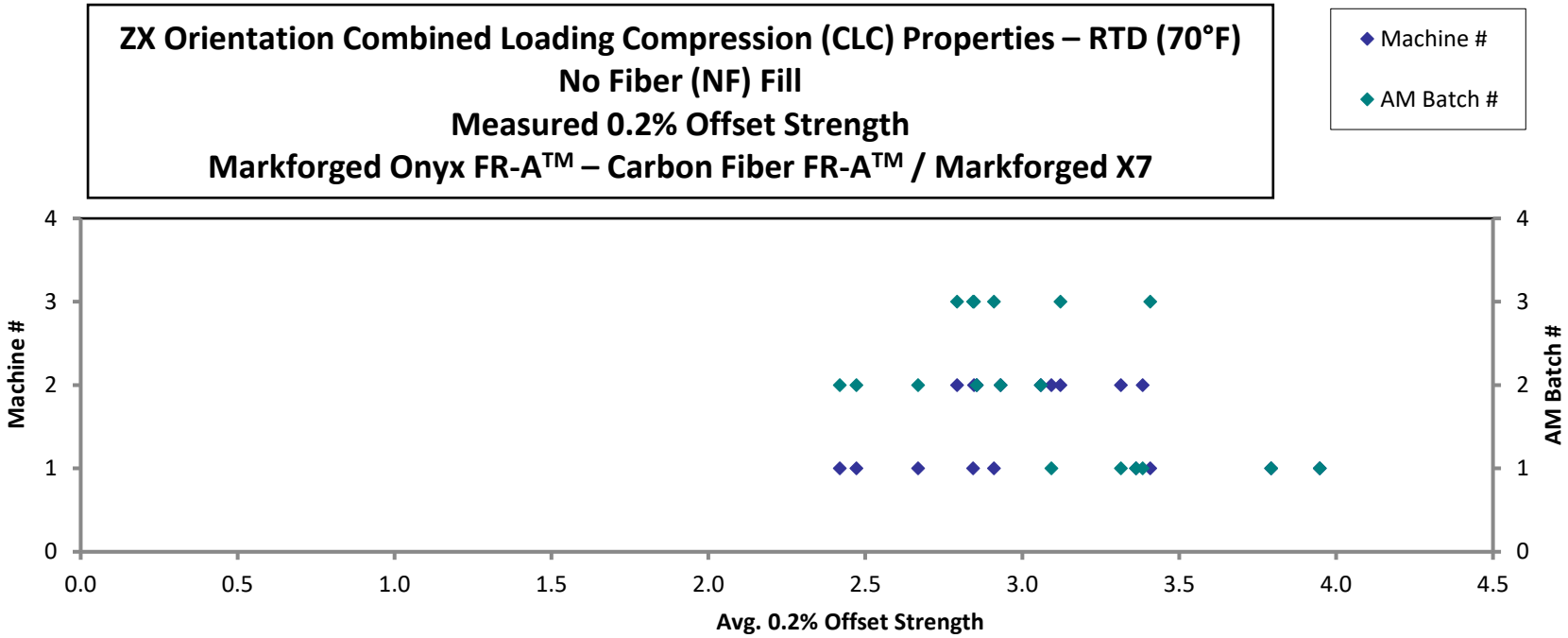
ZX Orientation Combined Loading Compression (CLC) Properties – RTD (70°F)
No Fiber (NF) Fill
Strength & Modulus
Markforged Onyx FR-A™ – Carbon Fiber FR-A™ / Markforged X7

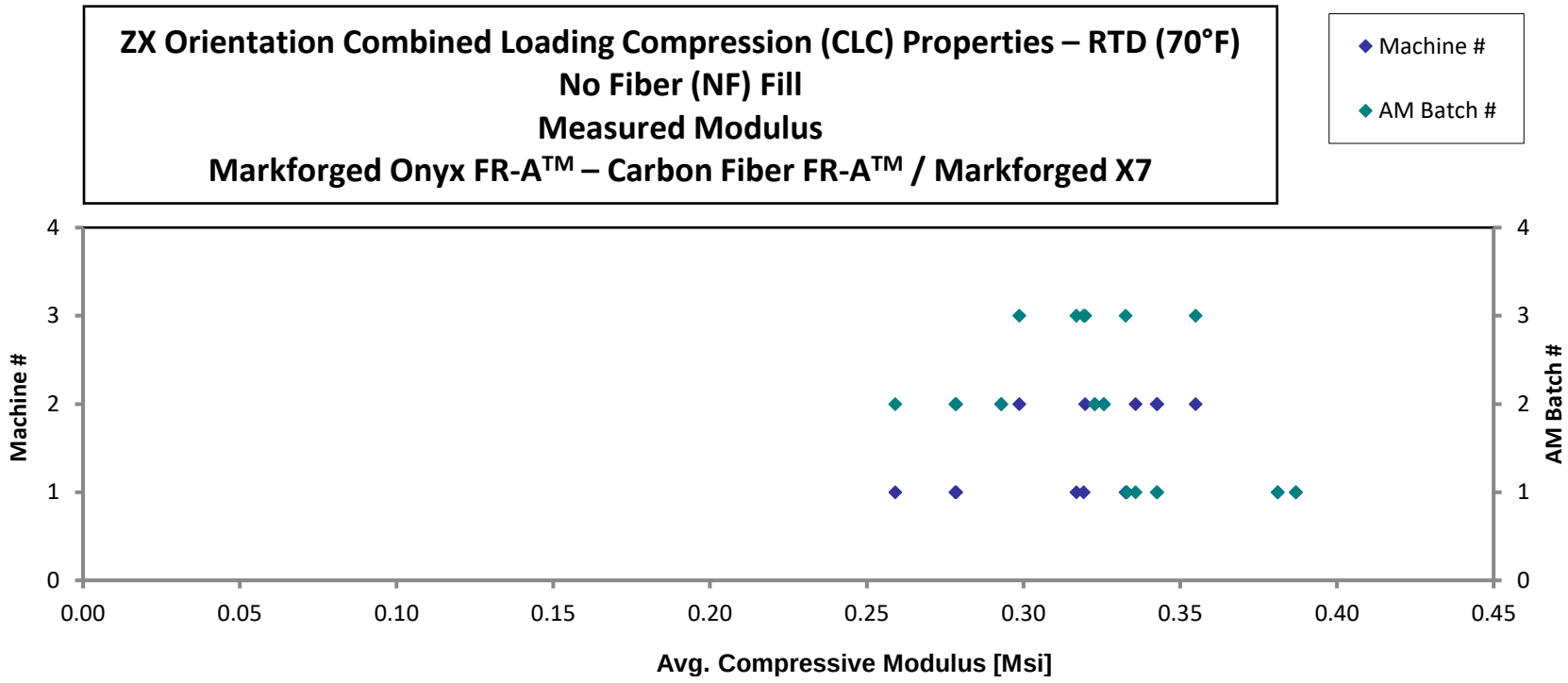
Specimen Number	AM Batch #	Machine #	Avg. Specimen Thickness [in]	Avg. 0.2% Offset Strength [ksi]	Avg. Compressive Modulus [Msi]	Avg. Poisson's Ratio	Percentage Bending [%]	Failure Mode
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M1-P60727-ZX-CLC-11-RTD-NF-1	1	1	0.143	3.362	0.333	0.183	3.392	M(E,H)GM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M1-P67328-ZX-CLC-12-RTD-NF-2	1	1	0.145	3.793	0.381	0.166	1.840	EGM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M1-P67689-ZX-CLC-13-RTD-NF-3	1	1	0.144	3.948	0.387	0.181	1.063	EGM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M2-P62038-ZX-CLC-11-RTD-NF-1	1	2	0.143	3.315	0.343	0.163	5.321	EGM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M2-P60130-ZX-CLC-12-RTD-NF-2	1	2	0.144	3.384	0.342	0.182	1.338	EGM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M2-P60979-ZX-CLC-13-RTD-NF-3	1	2	0.143	3.093	0.336	0.153	0.838	EGM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-B-M1-P62701-ZX-CLC-11-RTD-NF-1	2	1	0.143	2.419	0.259	0.170	6.654	EGM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-B-M1-P59506-ZX-CLC-12-RTD-NF-2	2	1	0.145	2.472	0.279	0.133	0.135	EGM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-B-M1-P62155-ZX-CLC-13-RTD-NF-3	2	1	0.142	2.668	0.278	0.185	0.075	EGM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-B-M2-P63004-ZX-CLC-11-RTD-NF-1	2	2	0.142	2.931	0.323	0.191	2.415	EGM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-B-M2-P59497-ZX-CLC-12-RTD-NF-2	2	2	0.143	2.855	0.293	0.193	4.691	EGM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-B-M2-P63802-ZX-CLC-13-RTD-NF-3	2	2	0.140	3.059	0.326	0.173	1.984	EGM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-C-M1-P64224-ZX-CLC-11-RTD-NF-1	3	1	0.141	3.408	0.333	0.162	0.712	EGM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-C-M1-P63385-ZX-CLC-12-RTD-NF-2	3	1	0.144	2.844	0.319	0.205	7.704	EGM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-C-M1-P63784-ZX-CLC-13-RTD-NF-3	3	1	0.143	2.910	0.317	0.179	2.811	EGM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-C-M2-P64990-ZX-CLC-11-RTD-NF-1	3	2	0.141	2.793	0.299	0.152	5.125	EGM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-C-M2-P64225-ZX-CLC-12-RTD-NF-2	3	2	0.143	2.847	0.320	0.161	0.773	EGM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-C-M2-P64680-ZX-CLC-13-RTD-NF-3	3	2	0.141	3.122	0.355	0.170	0.934	EGM
		Average	**0.143**	**3.068**	**0.323**	**0.172**	**2.656**	
		Standard Dev.		**0.411**	**0.034**	**0.017**	**2.319**	
		Coeff. of Var. [%]		**13.39**	**10.40**	**9.948**	**87.32**	
		Min.	**0.140**	**2.419**	**0.259**	**0.133**	**0.075**	
		Max.	**0.145**	**3.948**	**0.387**	**0.205**	**7.704**	
		Number of Spec.	**18**	**18**	**18**	**18**	**18**	

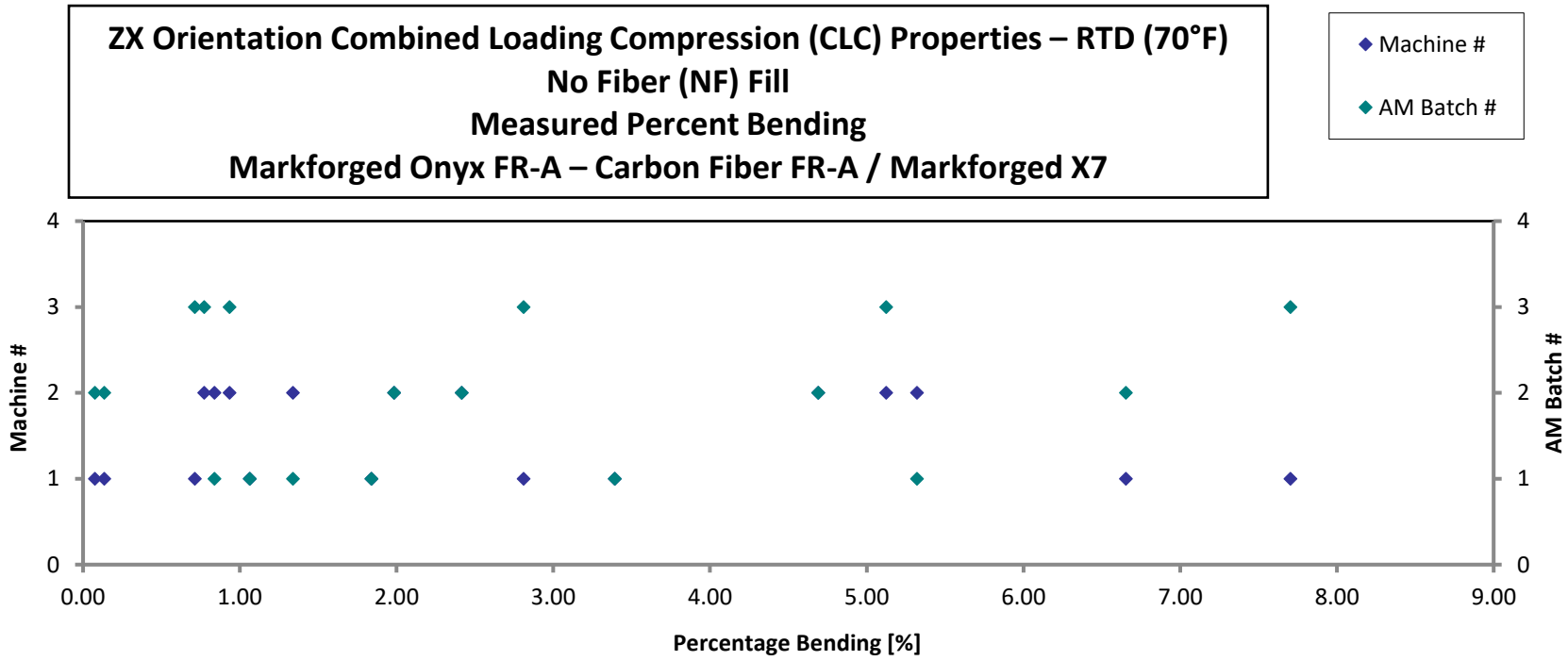
Note: Due to inherent material properties, B-basis calculations will be calculated eventhough improper failure modes were present.

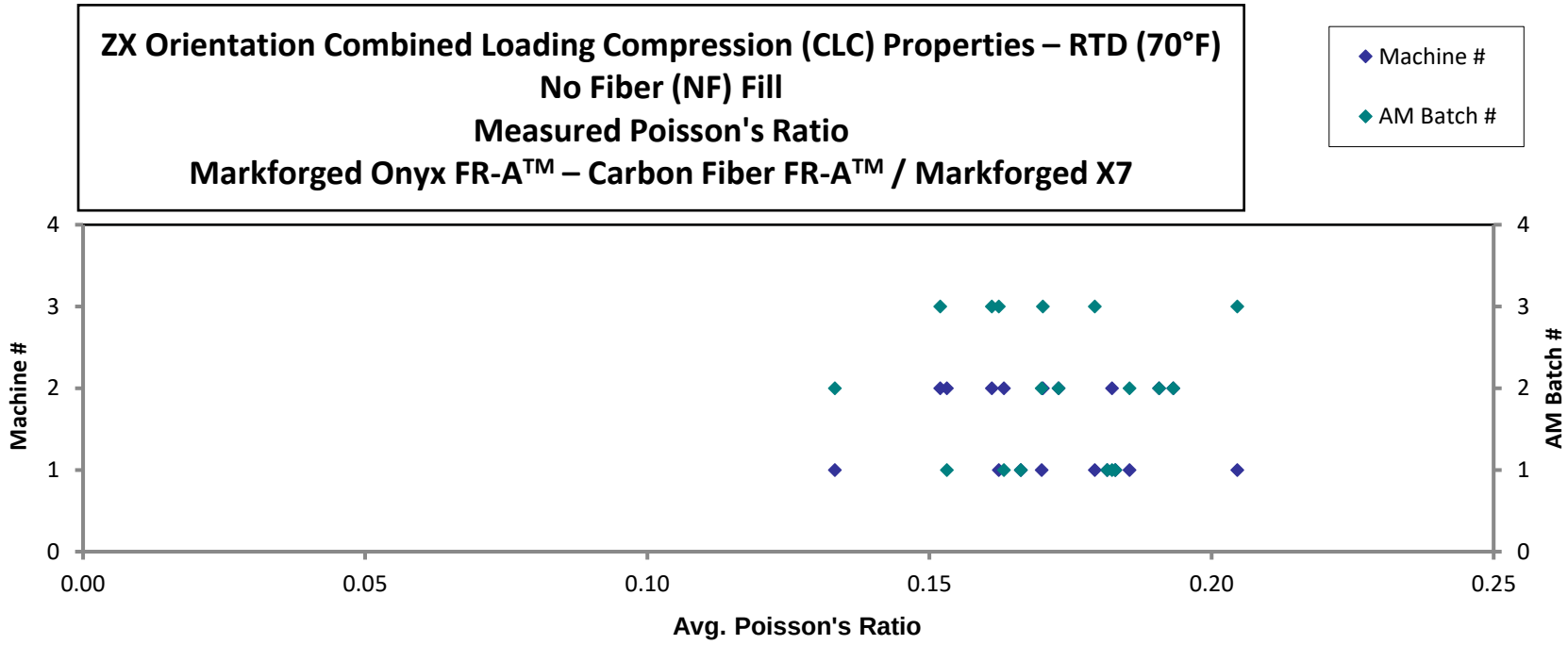
Note: The main failure mode was Euler buckling which invalidates the test data. Therefore results are provided for informational purposes.

Note: No sharp load drop was witness during testing, therefore 0.2% offset strength was reported for consistency


ZX Orientation Combined Loading Compression (CLC) Properties – RTD (70°F)
No Fiber (NF) Fill
Measured 0.2% Offset Strength
Markforged Onyx FR-A™ – Carbon Fiber FR-A™ / Markforged X7
Machine #
AM Batch #
Machine #
AM Batch #
Avg. 0.2% Offset Strength
0
1
2
3
4
0.0
0.5
1.0
1.5
2.0
2.5
3.0
3.5
4.0
4.5


ZX Orientation Combined Loading Compression (CLC) Properties – RTD (70°F)
No Fiber (NF) Fill
Measured Modulus
Markforged Onyx FR-A™ – Carbon Fiber FR-A™ / Markforged X7
Machine #
AM Batch #
Machine #
AM Batch #
0
1
2
3
4
0.00
0.05
0.10
0.15
0.20
0.25
0.30
0.35
0.40
0.45
Avg. Compressive Modulus [Msi]


ZX Orientation Combined Loading Compression (CLC) Properties – RTD (70°F)
No Fiber (NF) Fill
Measured Percent Bending
Markforged Onyx FR-A – Carbon Fiber FR-A / Markforged X7
Machine #
AM Batch #
Machine #
AM Batch #
Percentage Bending [%]
0.00
1.00
2.00
3.00
4.00
5.00
6.00
7.00
8.00
9.00
0
1
2
3
4


ZX Orientation Combined Loading Compression (CLC) Properties – RTD (70°F)
No Fiber (NF) Fill
Measured Poisson's Ratio
Markforged Onyx FR-A™ – Carbon Fiber FR-A™ / Markforged X7
Machine #
AM Batch #
Machine #
AM Batch #
Avg. Poisson's Ratio
0
1
2
3
4
0.00
0.05
0.10
0.15
0.20
0.25

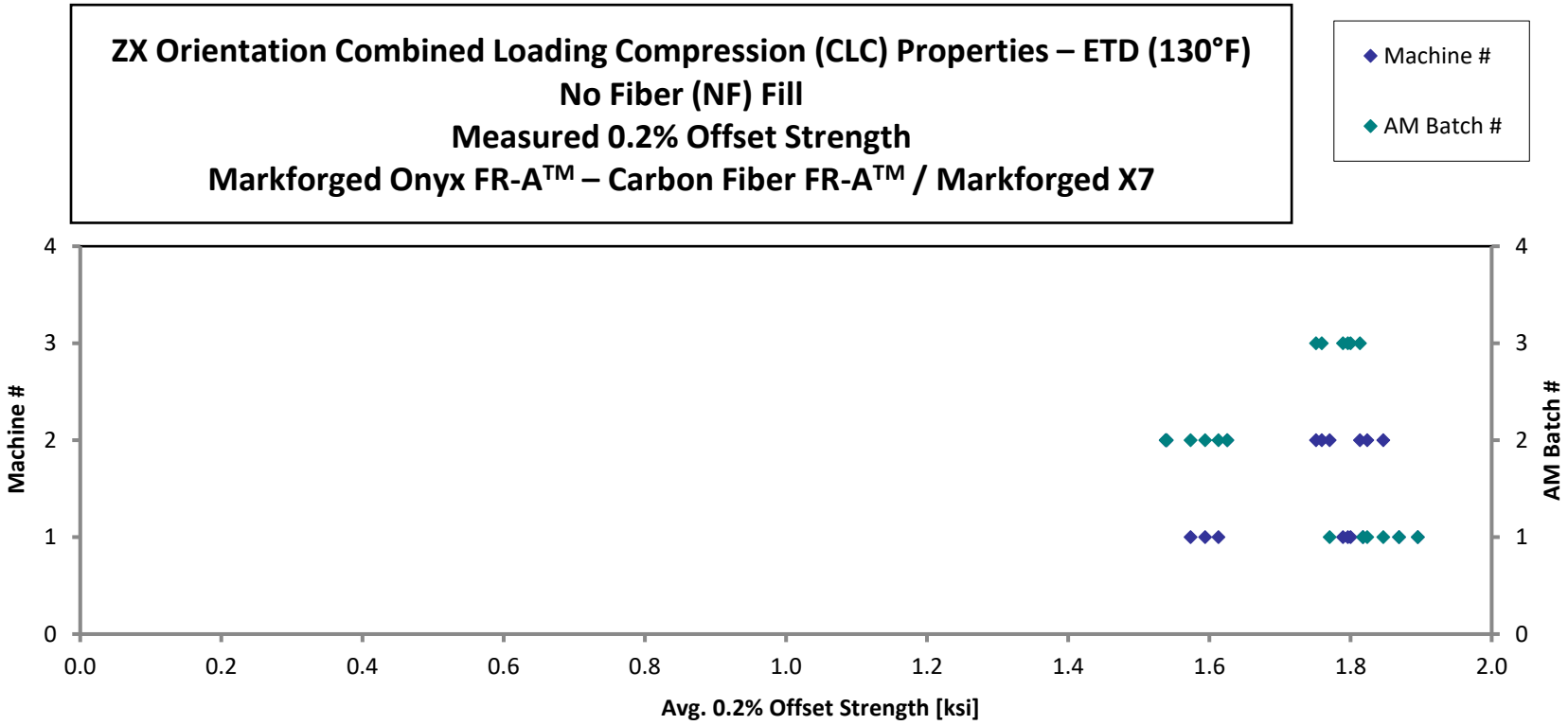
4.12.3 **ETD Condition**

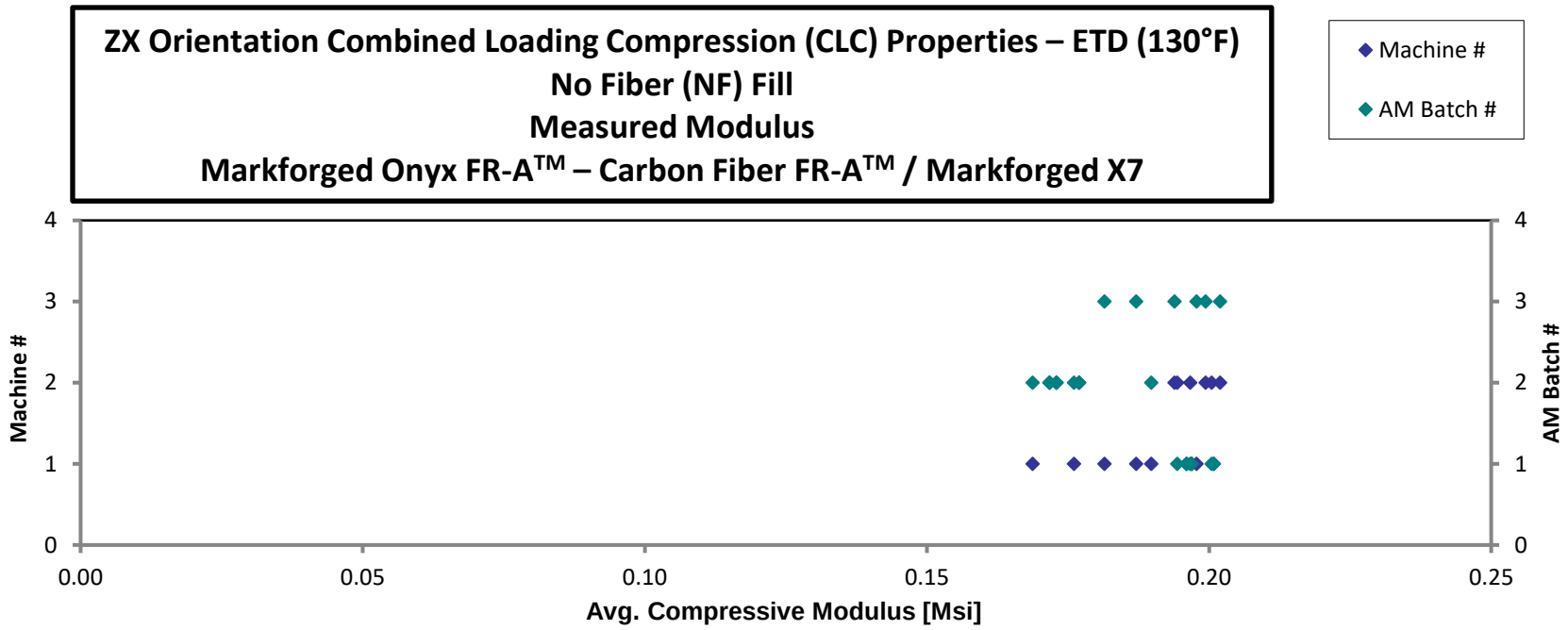
ZX Orientation Combined Loading Compression (CLC) Properties – ETD (130°F)
No Fiber (NF) Fill
Strength & Modulus
Markforged Onyx FR-A™ – Carbon Fiber FR-A™ / Markforged X7

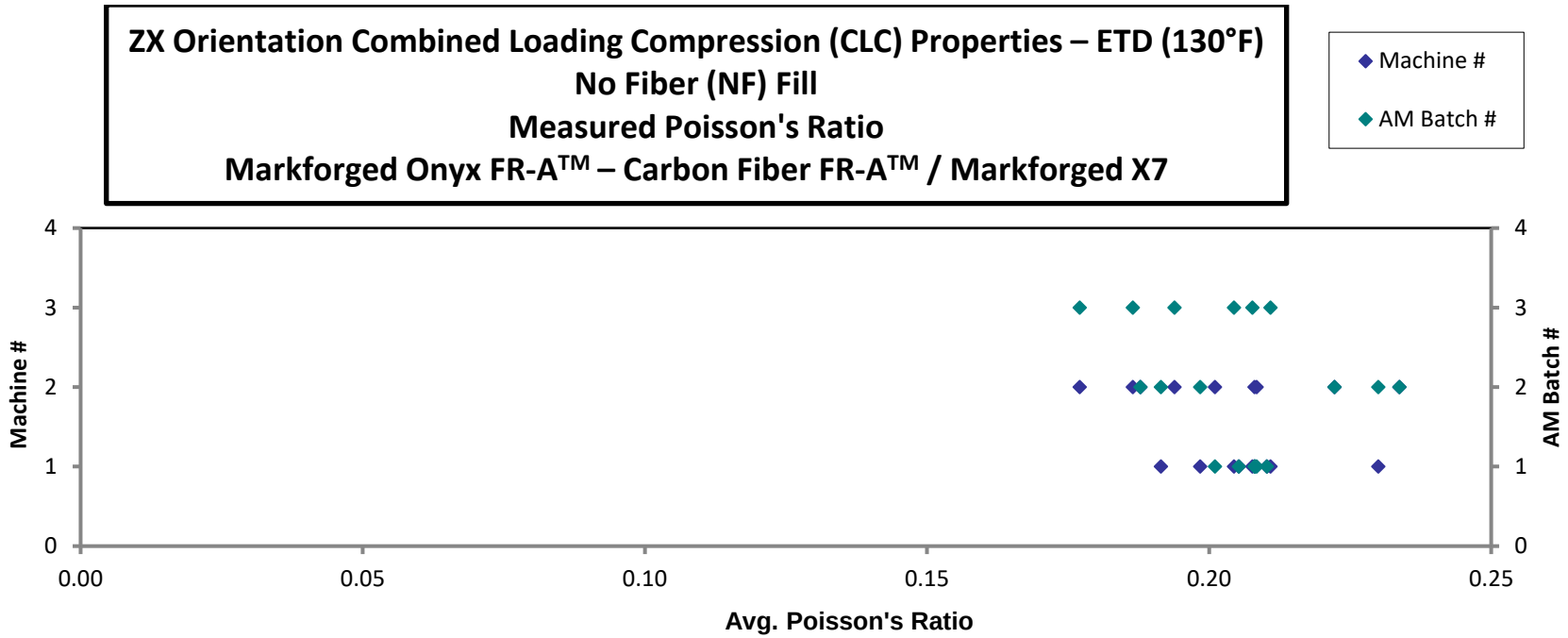
Specimen Number	AM Batch #	Machine #	Avg. Specimen Thickness [in]	Avg. 0.2% Offset Strength [ksi]	Avg. Compressive Modulus [Msi]	Avg. Poisson's Ratio	Percentage Bending [%]	Failure Mode
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M1-P60727-ZX-CLC-11-ETD-NF-1	1	1	0.140	1.818	0.197	0.205	0.609	EGM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M1-P67328-ZX-CLC-12-ETD-NF-2	1	1	0.142	1.869	0.201	0.210	2.125	EGM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M1-P67689-ZX-CLC-13-ETD-NF-3	1	1	0.141	1.895	0.196	0.208	1.026	EGM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M2-P62038-ZX-CLC-11-ETD-NF-1	1	2	0.140	1.846	0.197	0.201	0.717	EGM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M2-P60130-ZX-CLC-12-ETD-NF-2	1	2	0.140	1.824	0.200	0.208	2.327	EGM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M2-P60979-ZX-CLC-13-ETD-NF-3	1	2	0.141	1.770	0.194	0.208	6.257	EGM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-B-M1-P62701-ZX-CLC-11-ETD-NF-1	2	1	0.140	1.573	0.169	0.198	4.217	EGM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-B-M1-P59506-ZX-CLC-12-ETD-NF-2	2	1	0.142	1.613	0.190	0.230	4.714	EGM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-B-M1-P62155-ZX-CLC-13-ETD-NF-3	2	1	0.139	1.594	0.176	0.191	0.896	EGM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-B-M2-P63004-ZX-CLC-11-ETD-NF-1	2	2	0.142	1.539	0.173	0.222	2.479	EGM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-B-M2-P59497-ZX-CLC-12-ETD-NF-2	2	2	0.142	1.625	0.177	0.234	3.658	EGM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-B-M2-P63802-ZX-CLC-13-ETD-NF-3	2	2	0.140	1.538	0.172	0.188	0.305	EGM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-C-M1-P64224-ZX-CLC-11-ETD-NF-1	3	1	0.142	1.789	0.198	0.211	0.868	EGM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-C-M1-P63385-ZX-CLC-12-ETD-NF-2	3	1	0.142	1.800	0.181	0.204	1.337	EGM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-C-M1-P63784-ZX-CLC-13-ETD-NF-3	3	1	0.142	1.796	0.187	0.208	0.288	EGM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-C-M2-P64990-ZX-CLC-11-ETD-NF-1	3	2	0.140	1.751	0.199	0.187	3.824	EGM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-C-M2-P64225-ZX-CLC-12-ETD-NF-2	3	2	0.141	1.759	0.194	0.194	0.800	EGM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-C-M2-P64680-ZX-CLC-13-ETD-NF-3	3	2	0.140	1.813	0.202	0.177	3.866	EGM

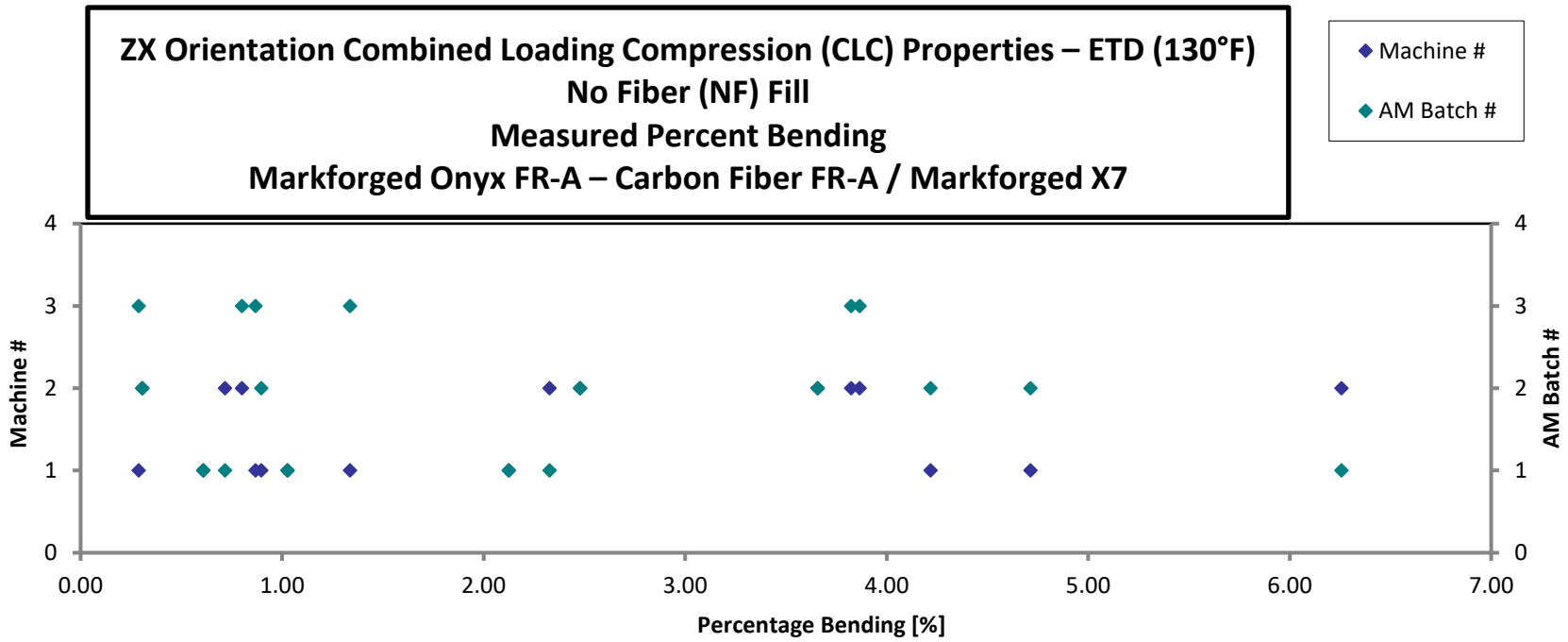
Average	**0.141**	**1.734**	**0.189**	**0.205**	**2.240**	
Standard Dev.		**0.119**	**0.011**	**0.015**	**1.782**	
Coeff. of Var. [%]		**6.848**	**6.001**	**7.138**	**79.58**	
Min.	**0.139**	**1.538**	**0.169**	**0.177**	**0.288**	
Max.	**0.142**	**1.895**	**0.202**	**0.234**	**6.257**	
Number of Spec.	**18**	**18**	**18**	**18**	**18**	

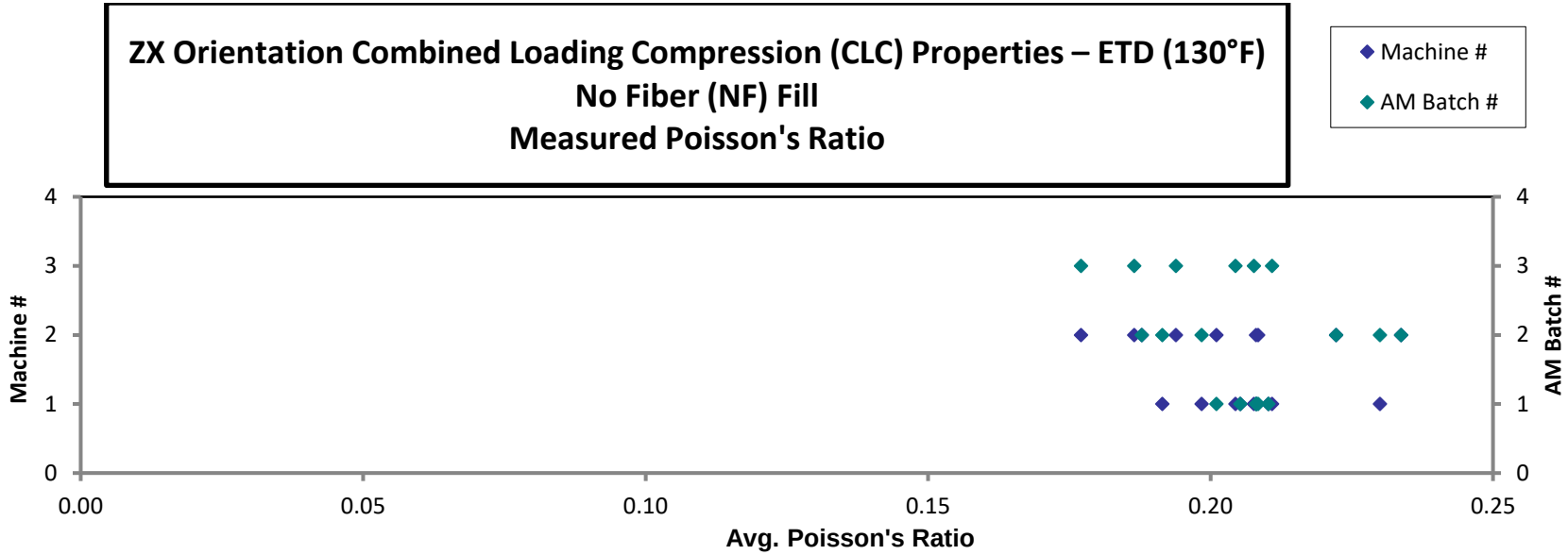
Note: Due to inherent material properties, B-basis calculations will be calculated eventhough improper failure modes were present.
Note: The main failure mode was Euler buckling which invalidates the test data. Therefore results are provided for informational purposes.
Note: No sharp load drop was witness during testing, therefore 0.2% offset strength was reported for consistency
Note: Modulus and Poisson's Ratio are average values of 2 strain gages


ZX Orientation Combined Loading Compression (CLC) Properties – ETD (130°F)
No Fiber (NF) Fill
Measured 0.2% Offset Strength
Markforged Onyx FR-A™ – Carbon Fiber FR-A™ / Markforged X7
Machine #
AM Batch #
Machine #
AM Batch #
0
1
2
3
4
0.0
0.2
0.4
0.6
0.8
1.0
1.2
1.4
1.6
1.8
2.0
Avg. 0.2% Offset Strength [ksi]


ZX Orientation Combined Loading Compression (CLC) Properties – ETD (130°F)
No Fiber (NF) Fill
Measured Modulus
Markforged Onyx FR-A™ – Carbon Fiber FR-A™ / Markforged X7
Machine #
AM Batch #
Machine #
AM Batch #
Avg. Compressive Modulus [Msi]
0
1
2
3
4
0.00
0.05
0.10
0.15
0.20
0.25


ZX Orientation Combined Loading Compression (CLC) Properties – ETD (130°F)
No Fiber (NF) Fill
Measured Poisson's Ratio
Markforged Onyx FR-A™ – Carbon Fiber FR-A™ / Markforged X7
Machine #
AM Batch #
Machine #
AM Batch #
Avg. Poisson's Ratio
0
1
2
3
4
0.00
0.05
0.10
0.15
0.20
0.25


ZX Orientation Combined Loading Compression (CLC) Properties – ETD (130°F)
No Fiber (NF) Fill
Measured Percent Bending
Markforged Onyx FR-A – Carbon Fiber FR-A / Markforged X7
Machine #
AM Batch #
Machine #
AM Batch #
Percentage Bending [%]
0.00
1.00
2.00
3.00
4.00
5.00
6.00
7.00
0
1
2
3
4


ZX Orientation Combined Loading Compression (CLC) Properties – ETD (130°F)
No Fiber (NF) Fill
Measured Poisson's Ratio
Machine #
AM Batch #
Machine #
AM Batch #
0
1
2
3
4
0.00
0.05
0.10
0.15
0.20
0.25
Avg. Poisson's Ratio

4.12.4 **ETW Condition**

ZX Orientation Combined Loading Compression (CLC) Properties – ETD (130°F)
No Fiber (NF) Fill
Strength & Modulus
Markforged Onyx FR-A™ – Carbon Fiber FR-A™/ Markforged X7

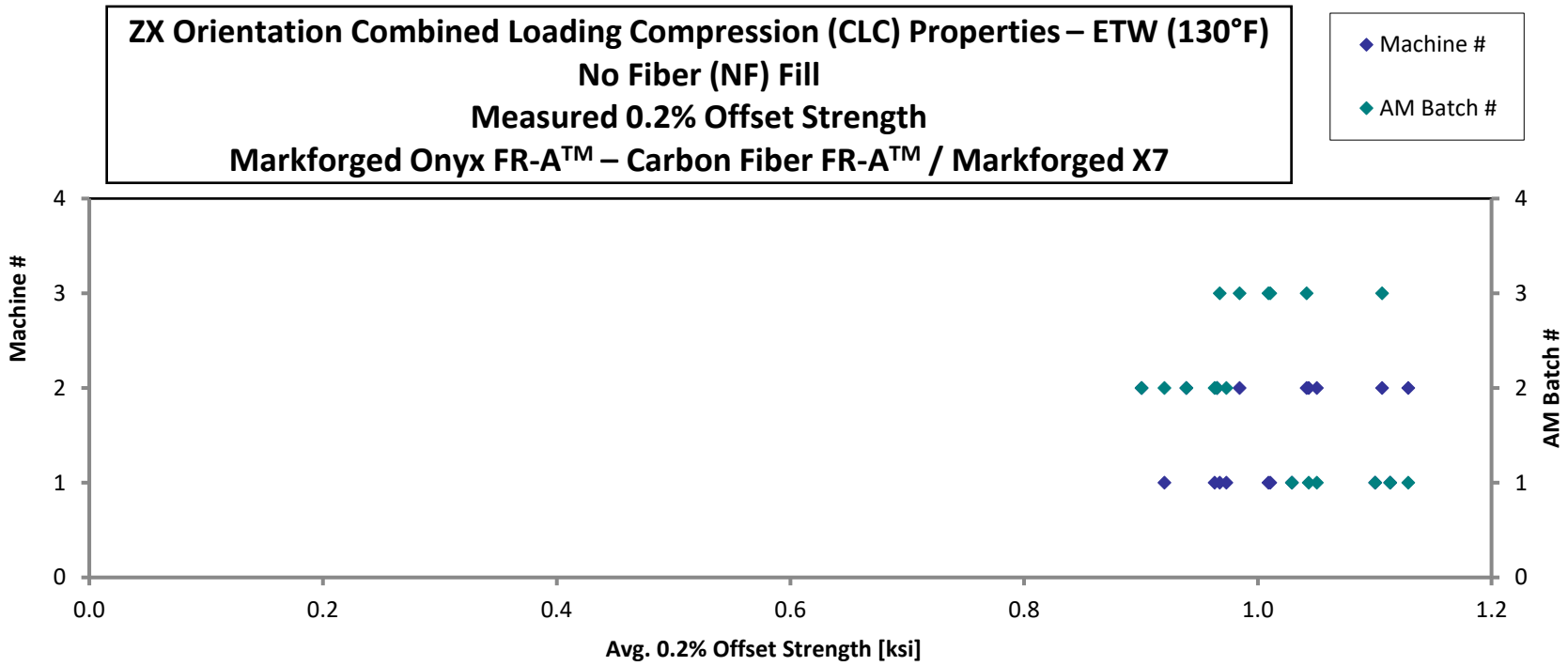
Specimen Number	AM Batch #	Machine #	Avg. Specimen Thickness [in]	Avg. 0.2% Offset Strength [ksi]	Avg. Compressive Modulus [Msi]	Avg. Poisson's Ratio	Percentage Bending [%]	Failure Mode
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M1-P60727-ZX-CLC-11-ETW-NF-1	1	1	0.141	1.029	0.128	0.243	1.512	M(E,H)GM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M1-P67328-ZX-CLC-12-ETW-NF-2	1	1	0.141	1.113	0.137	0.248	1.549	EGM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M1-P67689-ZX-CLC-13-ETW-NF-3	1	1	0.141	1.100	0.128	0.238	0.195	EGM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M2-P62038-ZX-CLC-11-ETW-NF-1	1	2	0.139	1.051	0.130	0.240	2.429	EGM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M2-P60130-ZX-CLC-12-ETW-NF-2	1	2	0.140	1.129	0.131	0.257	1.577	EGM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M2-P60979-ZX-CLC-13-ETW-NF-3	1	2	0.140	1.043	0.123	0.171	1.136	EGM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-B-M1-P62701-ZX-CLC-11-ETW-NF-1	2	1	0.140	0.920	0.115	0.235	4.029	EGM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-B-M1-P59506-ZX-CLC-12-ETW-NF-2	2	1	0.142	0.963	0.117	0.268	1.531	EGM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-B-M1-P62155-ZX-CLC-13-ETW-NF-3	2	1	0.139	0.973	0.114	0.233	2.997	EGM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-B-M2-P63004-ZX-CLC-11-ETW-NF-1	2	2	0.141	0.939	0.127	0.279	0.494	EGM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-B-M2-P59497-ZX-CLC-12-ETW-NF-2	2	2	0.141	0.965	0.122	0.256	2.260	EGM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-B-M2-P63802-ZX-CLC-13-ETW-NF-3	2	2	0.138	0.901	0.121	0.246	0.236	EGM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-C-M1-P64224-ZX-CLC-11-ETW-NF-1	3	1	0.140	0.967	0.128	0.257	0.011	EGM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-C-M1-P63385-ZX-CLC-12-ETW-NF-2	3	1	0.141	1.011	0.123	0.254	0.042	EGM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-C-M1-P63784-ZX-CLC-13-ETW-NF-3	3	1	0.140	1.009	0.130	0.251	1.062	EGM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-C-M2-P64990-ZX-CLC-11-ETW-NF-1	3	2	0.139	0.984	0.123	0.219	0.153	EGM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-C-M2-P64225-ZX-CLC-12-ETW-NF-2	3	2	0.140	1.106	0.123	0.227	0.661	EGM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-C-M2-P64680-ZX-CLC-13-ETW-NF-3	3	2	0.138	1.042	0.126	0.222	0.938	EGM
		Average	**0.140**	**1.014**	**0.125**	**0.241**	**1.267**	
		Standard Dev.		**0.068**	**0.006**	**0.023**	**1.110**	
		Coeff. of Var. [%]		**6.737**	**4.757**	**9.701**	**87.551**	
		Min.	**0.138**	**0.901**	**0.114**	**0.171**	**0.011**	
		Max.	**0.142**	**1.129**	**0.137**	**0.279**	**4.029**	
		Number of Spec.	**18**	**18**	**18**	**18**	**18**	

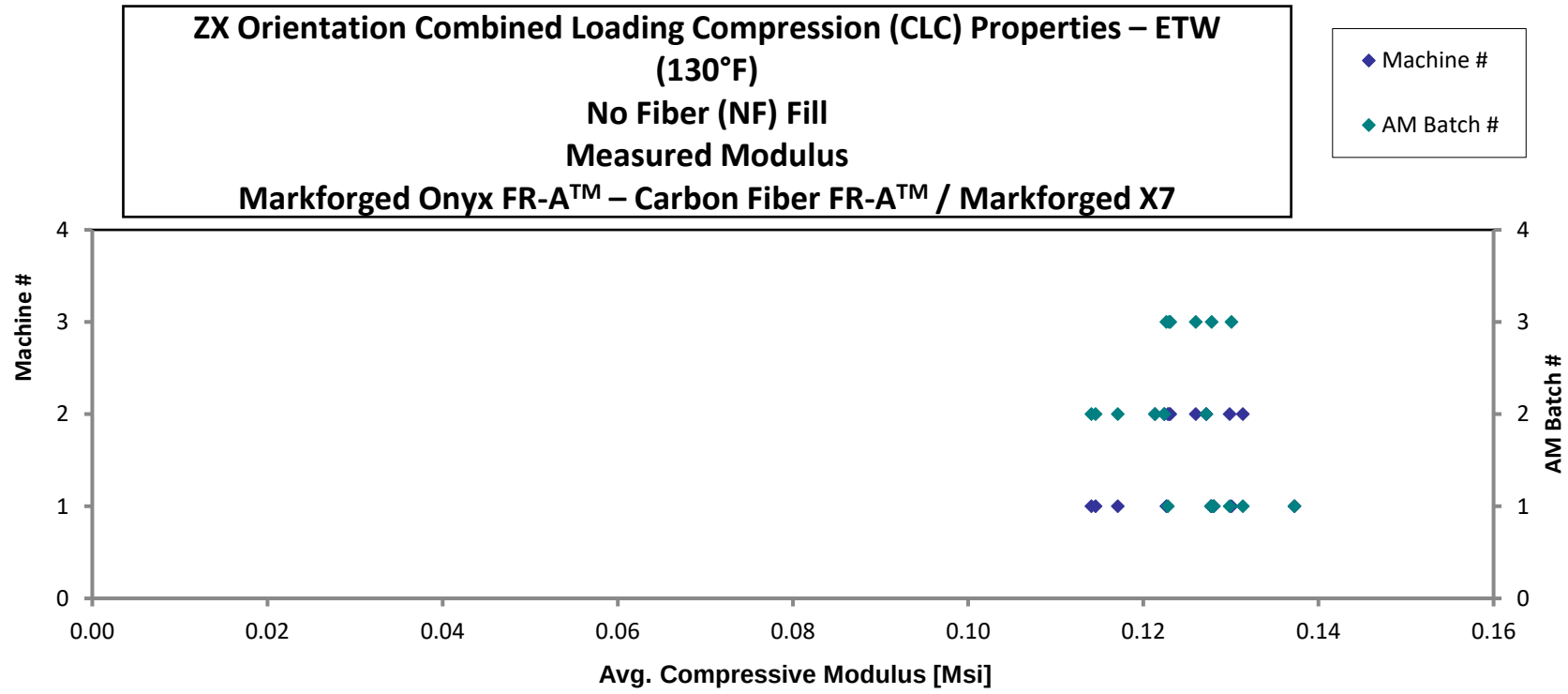
Note: Due to inherent material properties, B-basis calculations will be calculated eventhough improper failure modes were present.

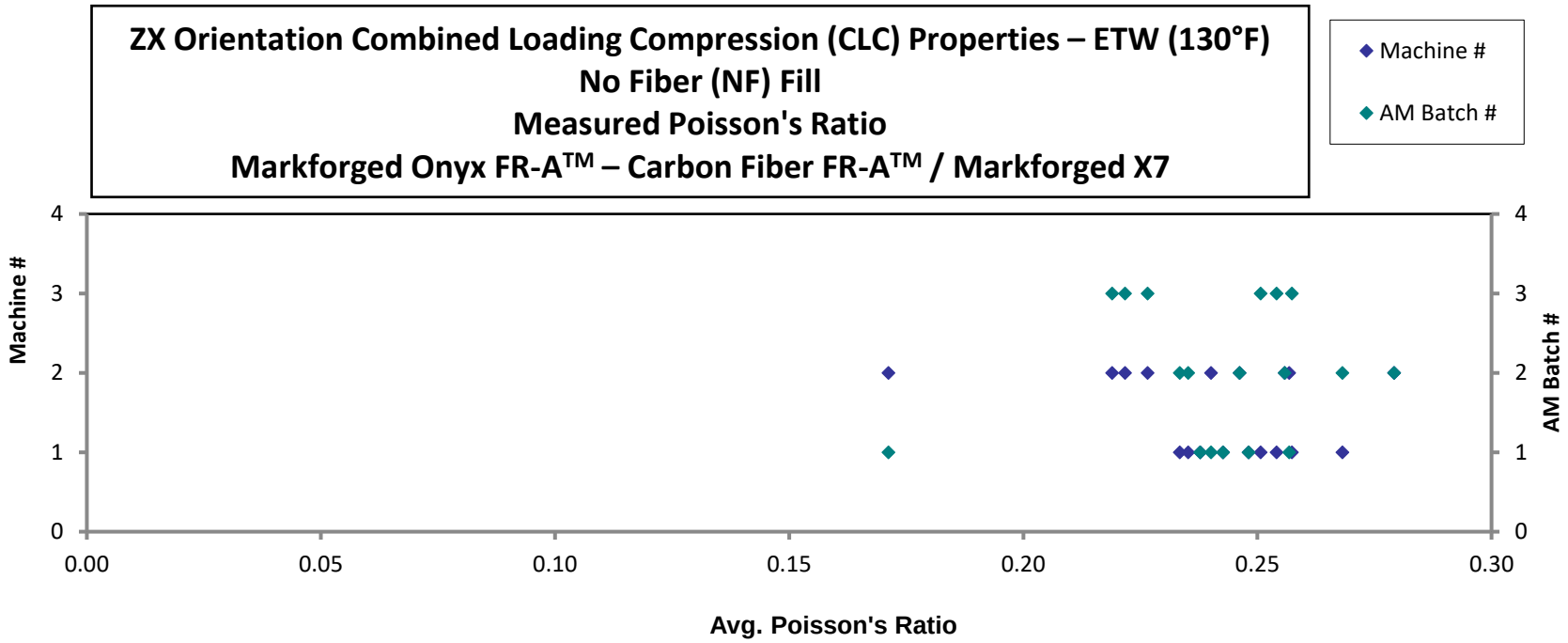
Note: The main failure mode was Euler buckling which invalidates the test data.

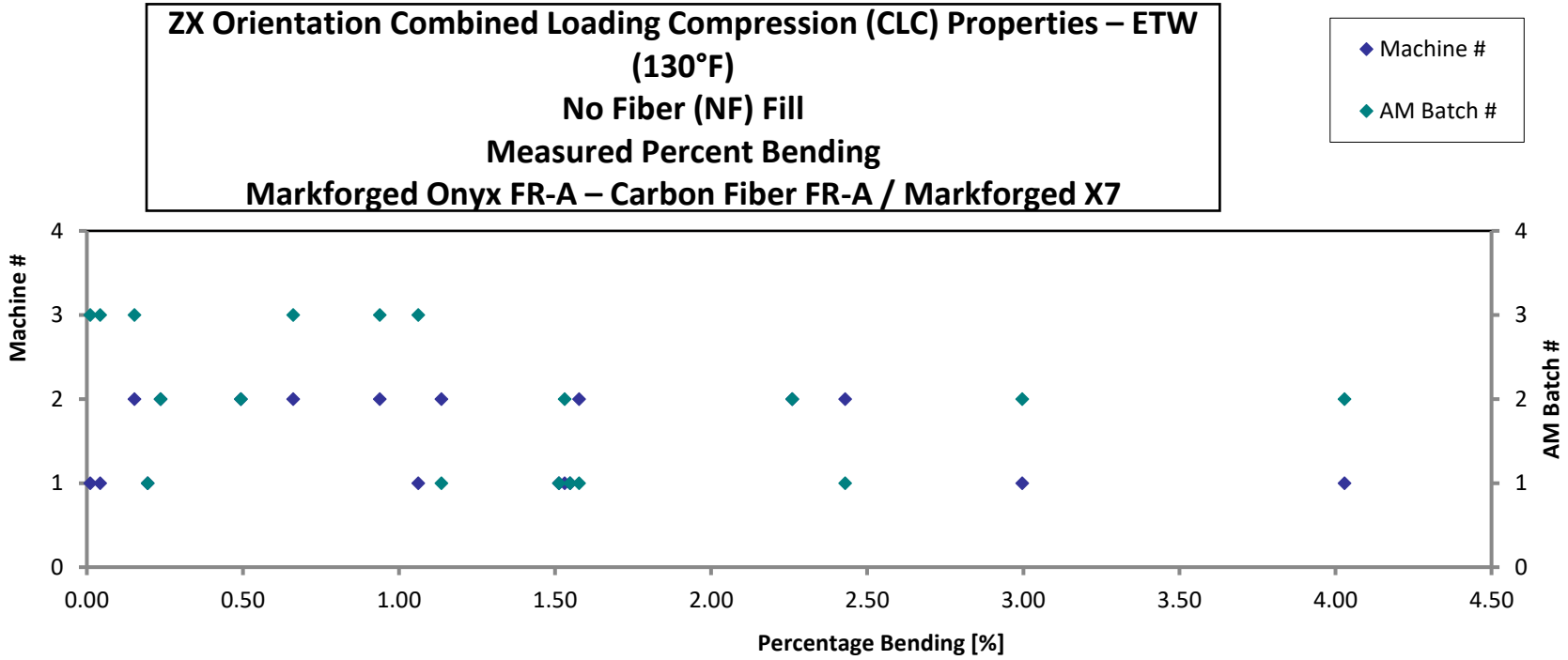
Note: No sharp load drop was witness during testing, therefore 0.2% offset strength was reported for consistency

Note: Modulus and Poisson's Ratio are average values of 2 strain gages


ZX Orientation Combined Loading Compression (CLC) Properties – ETW (130°F)
No Fiber (NF) Fill
Measured 0.2% Offset Strength
Markforged Onyx FR-A™ – Carbon Fiber FR-A™ / Markforged X7
Machine #
AM Batch #
Machine #
AM Batch #
0
1
2
3
4
0.0
0.2
0.4
0.6
0.8
1.0
1.2
Avg. 0.2% Offset Strength [ksi]


ZX Orientation Combined Loading Compression (CLC) Properties – ETW (130°F)
No Fiber (NF) Fill
Measured Modulus
Markforged Onyx FR-A™ – Carbon Fiber FR-A™ / Markforged X7
Machine #
AM Batch #
Machine #
AM Batch #
0
1
2
3
4
0.00
0.02
0.04
0.06
0.08
0.10
0.12
0.14
0.16
Avg. Compressive Modulus [Msi]


ZX Orientation Combined Loading Compression (CLC) Properties – ETW (130°F)
No Fiber (NF) Fill
Measured Poisson's Ratio
Markforged Onyx FR-A™ – Carbon Fiber FR-A™ / Markforged X7
Machine #
AM Batch #
Machine #
AM Batch #
0
1
2
3
4
0.00
0.05
0.10
0.15
0.20
0.25
0.30
Avg. Poisson's Ratio


ZX Orientation Combined Loading Compression (CLC) Properties – ETW (130°F)
No Fiber (NF) Fill
Measured Percent Bending
Markforged Onyx FR-A – Carbon Fiber FR-A / Markforged X7
Machine #
AM Batch #
Machine #
AM Batch #
0
1
2
3
4
0.00
0.50
1.00
1.50
2.00
2.50
3.00
3.50
4.00
4.50
Percentage Bending [%]

4.13 **XY PF Flex Properties**

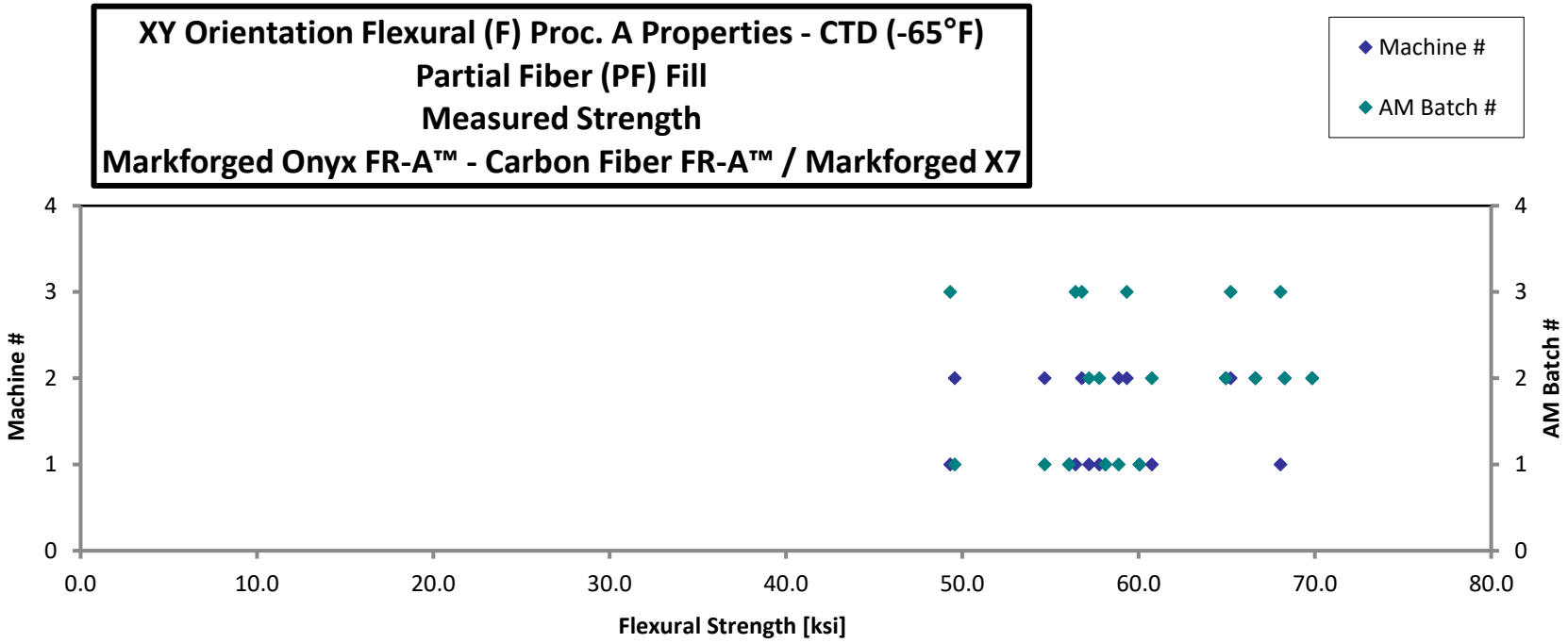
4.13.1 **CTD Condition**

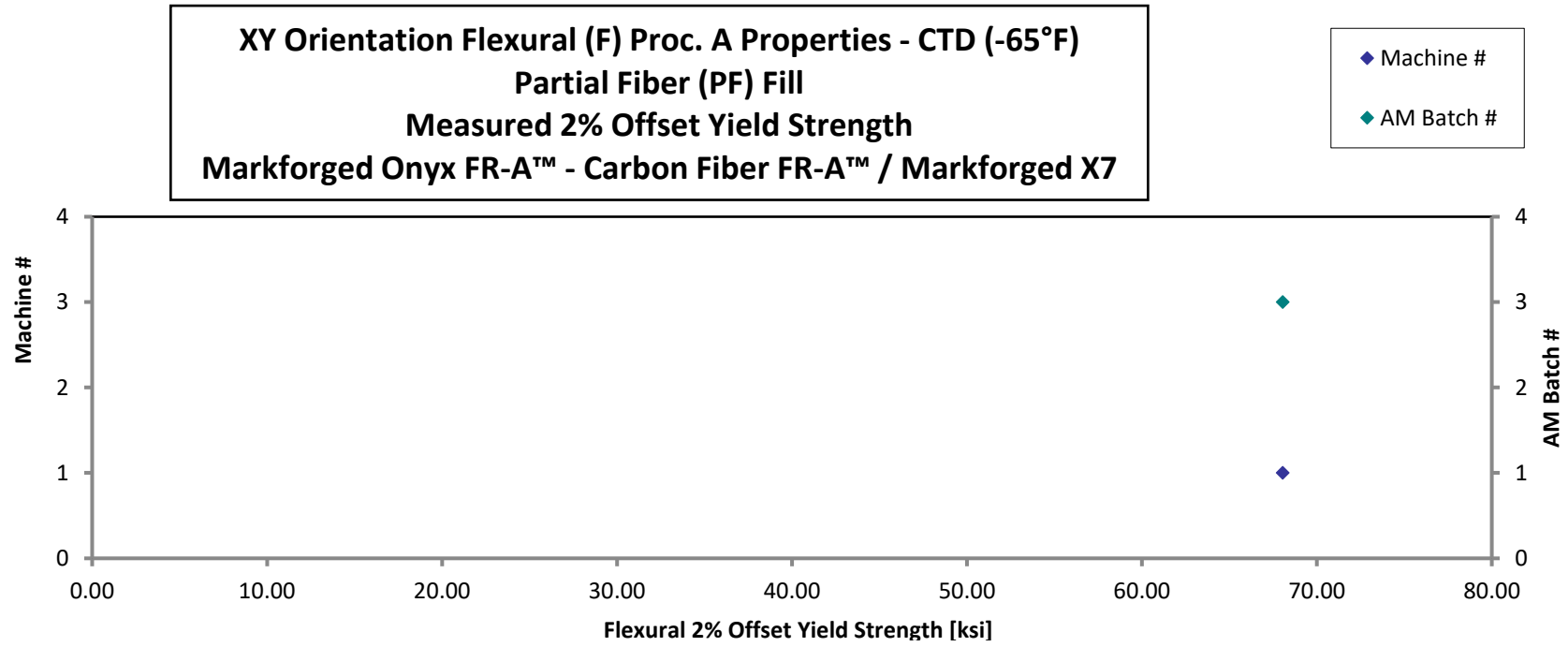
XY Orientation Flexural (F) Proc. A Properties - CTD (-65°F)
Partial Fiber (PF) Fill
Strength & Modulus
Markforged Onyx FR-A™ - Carbon Fiber FR-A™ / Markforged X7

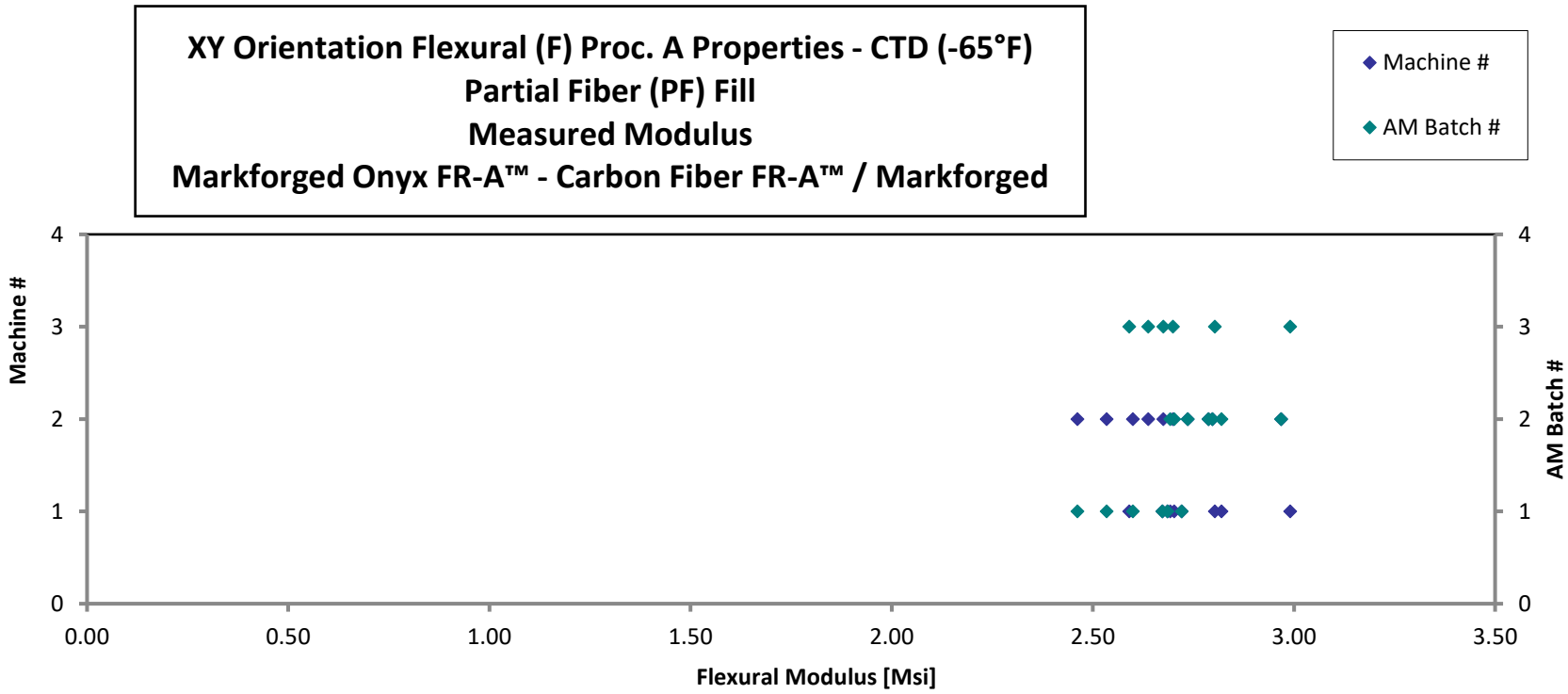
Specimen Number	AM Batch #	Machine #	Avg. Specimen Thickness [in]	Flexural Strength [ksi]	Flexural 2% Offset Yield Strength [ksi]	Flexural Modulus [Msi]	Failure Mode
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M1-P31490-XY-F-11-CTD-PF-1*	1	1	0.140	56.07		2.686	TAB, CAT
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M1-P54807-XY-F-12-CTD-PF-2*	1	1	0.144	60.06		2.721	CAT
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M1-P31610-XY-F-13-CTD-PF-3*	1	1	0.144	58.12		2.673	TAB, CAT
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M2-P31491-XY-F-11-CTD-PF-1*/**	1	2	0.139	58.88		2.600	CAT, TAB
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M2-P31697-XY-F-12-CTD-PF-2*/**	1	2	0.143	49.57		2.535	CAT
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M2-P31611-XY-F-13-CTD-PF-3*/**	1	2	0.143	54.68		2.462	CAT
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-B-M1-P55801-XY-F-11-CTD-PF-1*	2	1	0.141	57.20		2.820	CAT
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-B-M1-P33716-XY-F-12-CTD-PF-2*	2	1	0.145	60.76		2.692	CLT
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-B-M1-P33155-XY-F-13-CTD-PF-3*	2	1	0.145	57.77		2.702	CLT
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-B-M2-P40904-XY-F-11-CTD-PF-1*	2	2	0.138	66.62		2.968	CAT
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-B-M2-P56216-XY-F-12-CTD-PF-2*	2	2	0.143	64.95		2.798	CAT
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-B-M2-P33154-XY-F-13-CTD-PF-3*	2	2	0.144	69.85		2.787	CAT, TAB, ILS
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-B-M2-P33243-XY-F-13-CTD-PF-SP*	2	2	0.143	68.28		2.736	CLT
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-C-M1-P35346-XY-F-12-CTD-PF-2*	3	1	0.143	49.32		2.591	CAT
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-C-M1-P35257-XY-F-13-CTD-PF-3	3	1	0.140	68.05	68.05	2.991	CAT
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-C-M1-P49394-XY-F-13-CTD-PF-6*	3	1	0.143	56.42		2.804	CAT
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-C-M2-P34965-XY-F-11-CTD-PF-1*/**	3	2	0.139	65.23		2.699	CLT
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-C-M2-P35347-XY-F-12-CTD-PF-2*/**	3	2	0.143	59.33		2.638	CAT, TAB
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-C-M2-P35256-XY-F-13-CTD-PF-3*/**	3	2	0.141	56.78		2.676	CAT
	Average		**0.142**	**59.89**	**68.05**	**2.715**	
	Standard Dev.			**5.936**		**0.131**	
	Coeff. of Var. [%]			**9.911**		**4.818**	
	Min.		**0.138**	**49.32**	**68.05**	**2.462**	
	Max.		**0.145**	**69.85**	**68.05**	**2.991**	
	Number of Spec.		**19**	**19**	**1**	**19**	

*0.2% offset yield strength not reported due to specimen failure before 0.2% offset strain.

**Modulus calculation used 5000-20000 microstrain


XY Orientation Flexural (F) Proc. A Properties - CTD (-65°F)
Partial Fiber (PF) Fill
Measured Strength
Markforged Onyx FR-A™ - Carbon Fiber FR-A™ / Markforged X7
Machine #
AM Batch #
Machine #
AM Batch #
Flexural Strength [ksi]
0
1
2
3
4
0.0
10.0
20.0
30.0
40.0
50.0
60.0
70.0
80.0


XY Orientation Flexural (F) Proc. A Properties - CTD (-65°F)
Partial Fiber (PF) Fill
Measured 2% Offset Yield Strength
Markforged Onyx FR-A™ - Carbon Fiber FR-A™ / Markforged X7
Machine #
AM Batch #
Machine #
AM Batch #
0
1
2
3
4
0.00
10.00
20.00
30.00
40.00
50.00
60.00
70.00
80.00
Flexural 2% Offset Yield Strength [ksi]


XY Orientation Flexural (F) Proc. A Properties - CTD (-65°F)
Partial Fiber (PF) Fill
Measured Modulus
Markforged Onyx FR-A™ - Carbon Fiber FR-A™ / Markforged
Machine #
AM Batch #
Machine #
AM Batch #
Flexural Modulus [Msi]
0.00
0.50
1.00
1.50
2.00
2.50
3.00
3.50
0
1
2
3
4

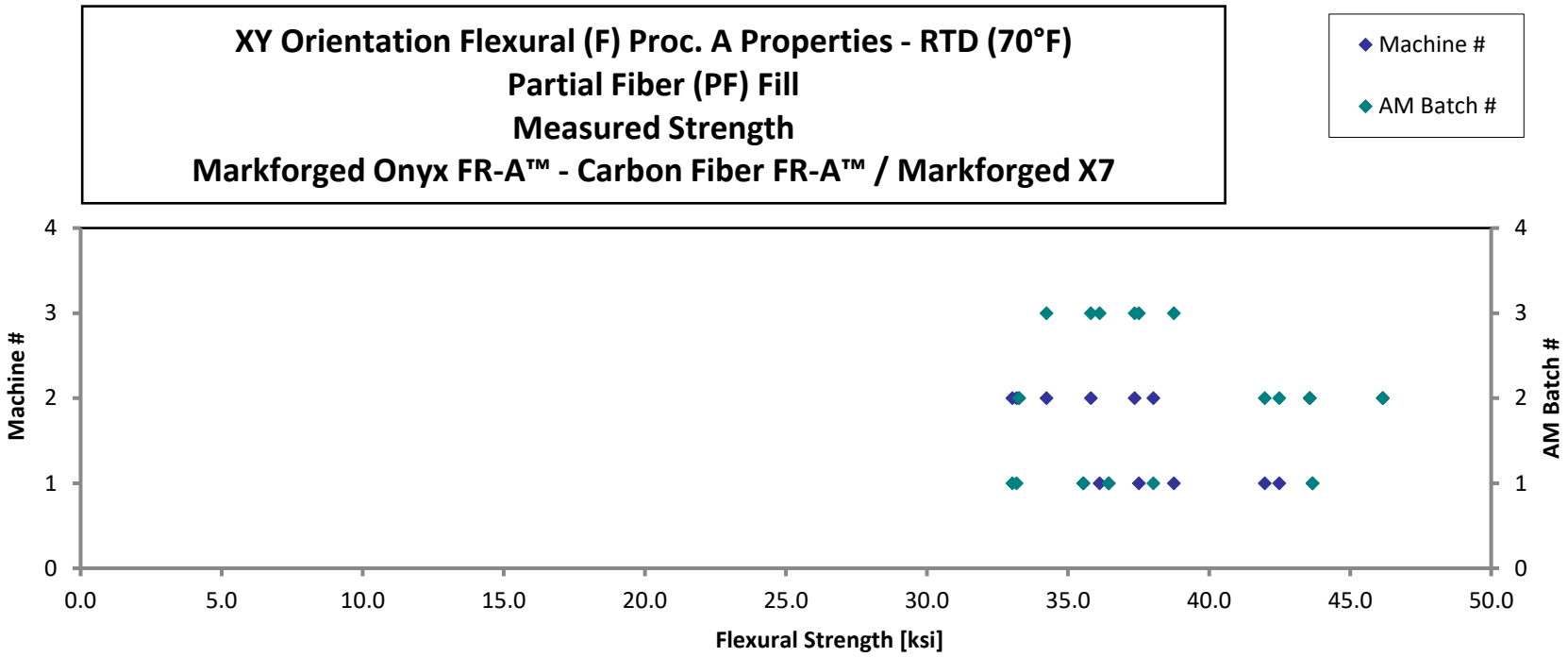
4.13.2 **RTD Condition**

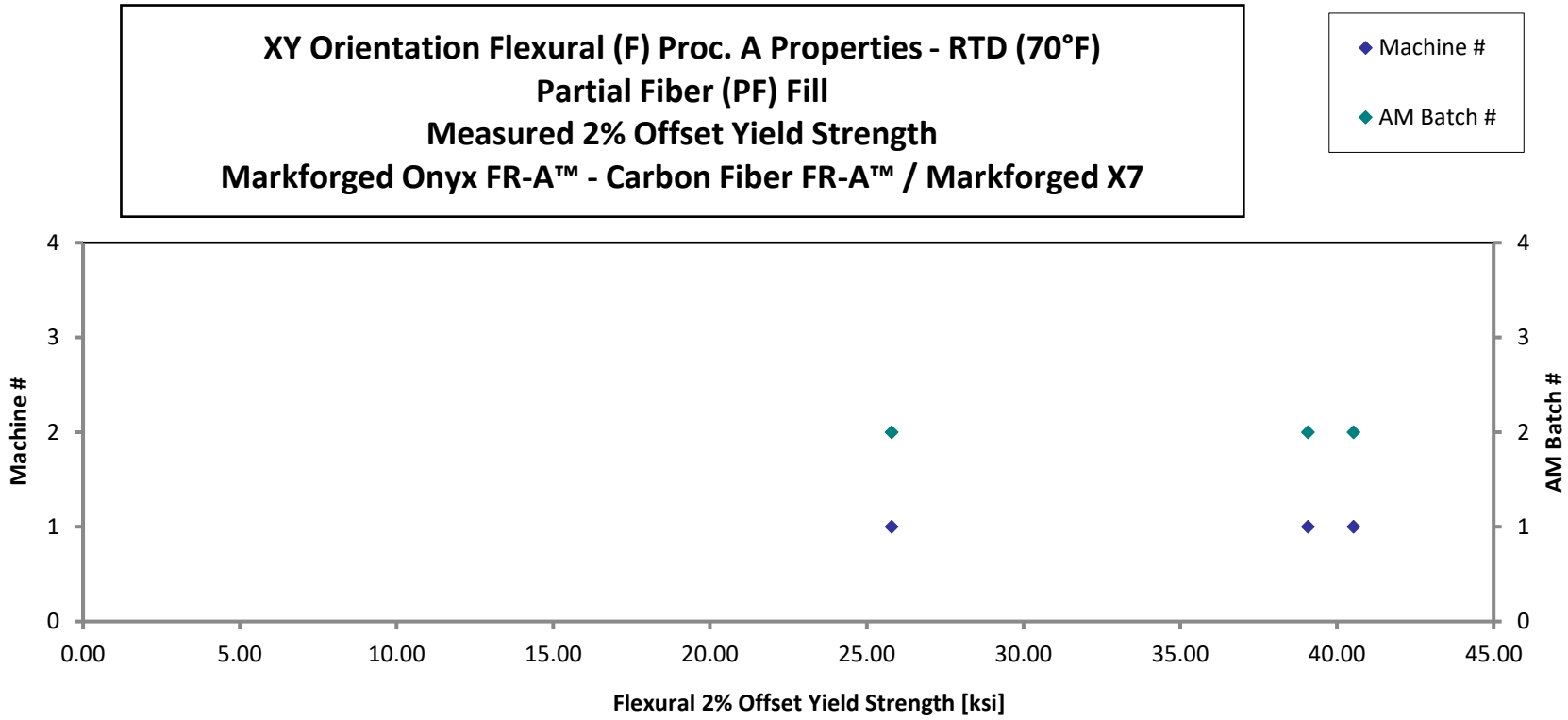
XY Orientation Flexural (F) Proc. A Properties - RTD (70°F)
Partial Fiber (PF) Fill
Strength & Modulus
Markforged Onyx FR-A™ - Carbon Fiber FR-A™ / Markforged X7

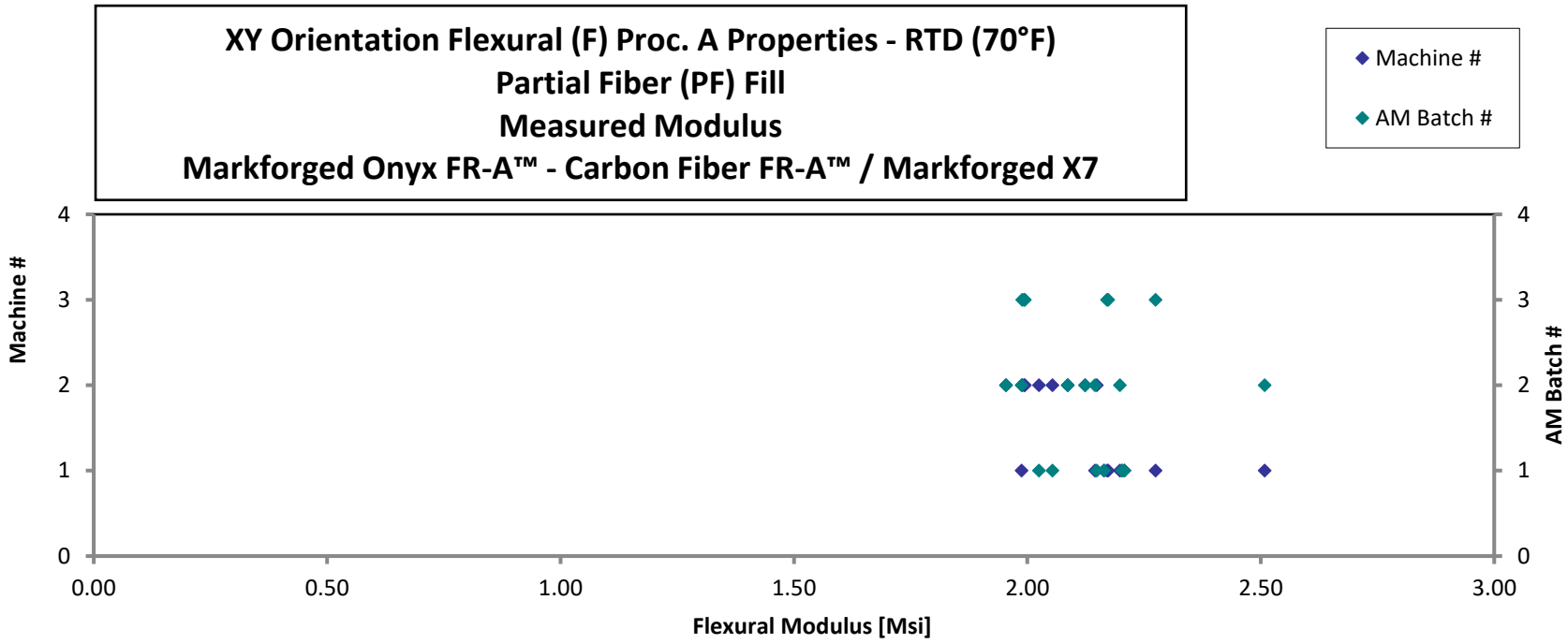
Specimen Number	AM Batch #	Machine #	Avg. Specimen Thickness [in]	Flexural Strength [ksi]	Flexural 2% Offset Yield Strength [ksi]	Flexural Modulus [Msi]	Failure Mode
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M1-P31153-XY-F-11-RTD-PF-1*	1	1	0.142	36.44		2.164	CAT
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M1-P54807-XY-F-12-RTD-PF-2*	1	1	0.144	43.66		2.203	CAT
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M1-P31610-XY-F-13-RTD-PF-3*	1	1	0.142	35.54		2.208	CAT
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M2-P31152-XY-F-11-RTD-PF-1*	1	2	0.137	38.02		2.149	CAT, TAB
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M2-P31697-XY-F-12-RTD-PF-2*	1	2	0.143	33.17		2.054	CAT, TAB
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M2-P31611-XY-F-13-RTD-PF-3*	1	2	0.142	33.02		2.025	CAT, TAB
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-B-M1-P39037-XY-F-11-RTD-PF-1	2	1	0.140	41.98	40.53	2.145	CAT
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-B-M1-P33716-XY-F-12-RTD-PF-2	2	1	0.142	42.48	39.08	2.198	CAT
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-B-M1-P33155-XY-F-13-RTD-PF-3**	2	1	0.143		25.79	1.987	SLR
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-B-M1-P33155-XY-F-13-RTD-PF-SP**	2	1	0.144			2.508	SLM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-B-M2-P55140-XY-F-11-RTD-PF-1*	2	2	0.140	33.26		2.124	CAT, TAB
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-B-M2-P56216-XY-F-12-RTD-PF-2*	2	2	0.142	43.57		2.087	TAB
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-B-M2-P33154-XY-F-13-RTD-PF-3*	2	2	0.143	46.16		1.954	TAB
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-C-M1-P35876-XY-F-11-RTD-PF-1*	3	1	0.143	38.76		2.275	CAT
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-C-M1-P35346-XY-F-12-RTD-PF-2*	3	1	0.144	36.12		2.173	CAT
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-C-M1-P35257-XY-F-13-RTD-PF-3*	3	1	0.142	37.51		2.170	TAB
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-C-M2-P34942-XY-F-11-RTD-PF-1*	3	2	0.140	37.36		1.993	TAB
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-C-M2-P35347-XY-F-12-RTD-PF-2*	3	2	0.144	35.81		1.995	TAB
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-C-M2-P35256-XY-F-13-RTD-PF-3*	3	2	0.141	34.23		1.989	CAT

*0.2% offset yield strength not reported due to specimen failure before 0.2% offset strain.
**Strength value not reported due to invalid failure mode.

Average	**0.142**	**38.07**	**35.13**	**2.126**
Standard Dev.		**4.095**	**8.124**	**0.132**
Coeff. of Var. [%]		**10.76**	**23.12**	**6.192**
Min.	**0.137**	**33.02**	**25.79**	**1.954**
Max.	**0.144**	**46.16**	**40.53**	**2.508**
Number of Spec.	**19**	**17**	**3**	**19**


XY Orientation Flexural (F) Proc. A Properties - RTD (70°F)
Partial Fiber (PF) Fill
Measured Strength
Markforged Onyx FR-A™ - Carbon Fiber FR-A™ / Markforged X7
Machine #
AM Batch #
Machine #
AM Batch #
Flexural Strength [ksi]
0
1
2
3
4
0.0
5.0
10.0
15.0
20.0
25.0
30.0
35.0
40.0
45.0
50.0


XY Orientation Flexural (F) Proc. A Properties - RTD (70°F)
Partial Fiber (PF) Fill
Measured 2% Offset Yield Strength
Markforged Onyx FR-A™ - Carbon Fiber FR-A™ / Markforged X7
Machine #
AM Batch #
Machine #
AM Batch #
0
1
2
3
4
0.00
5.00
10.00
15.00
20.00
25.00
30.00
35.00
40.00
45.00
Flexural 2% Offset Yield Strength [ksi]


XY Orientation Flexural (F) Proc. A Properties - RTD (70°F)
Partial Fiber (PF) Fill
Measured Modulus
Markforged Onyx FR-A™ - Carbon Fiber FR-A™ / Markforged X7
Machine #
AM Batch #
Machine #
AM Batch #
0
1
2
3
4
0.00
0.50
1.00
1.50
2.00
2.50
3.00
Flexural Modulus [Msi]

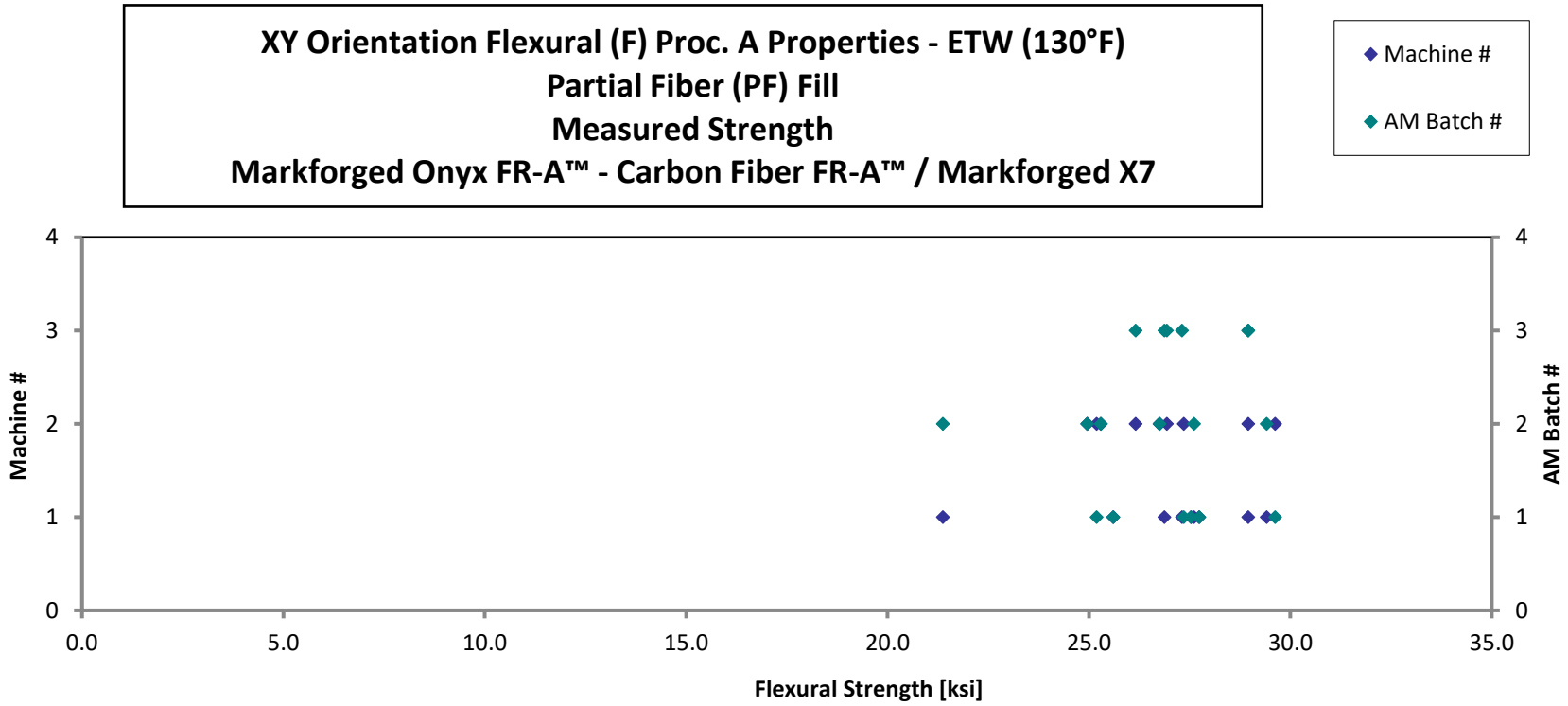
4.13.3 **ETD Condition**

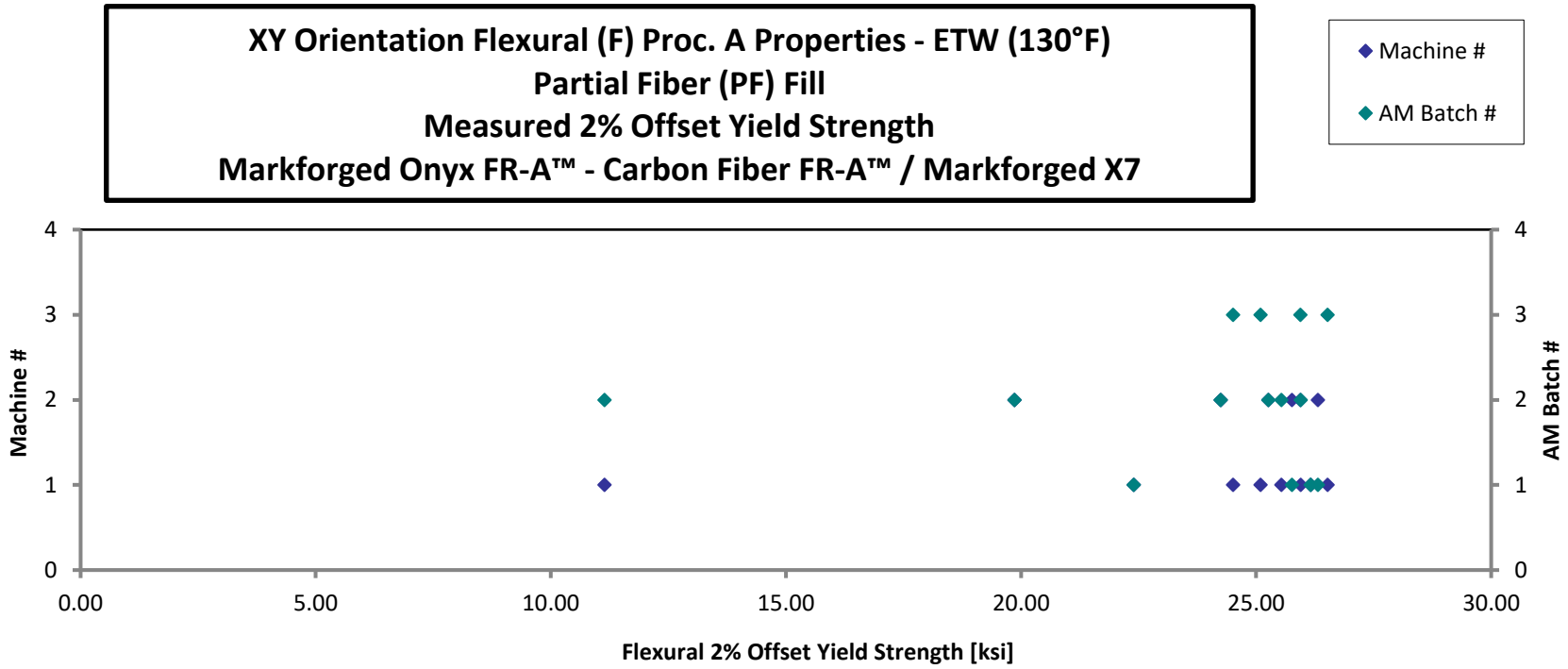
XY Orientation Flexural (F) Proc. A Properties - ETD (130°F)
Partial Fiber (PF) Fill
Strength & Modulus
Markforged Onyx FR-A™ - Carbon Fiber FR-A™ / Markforged X7

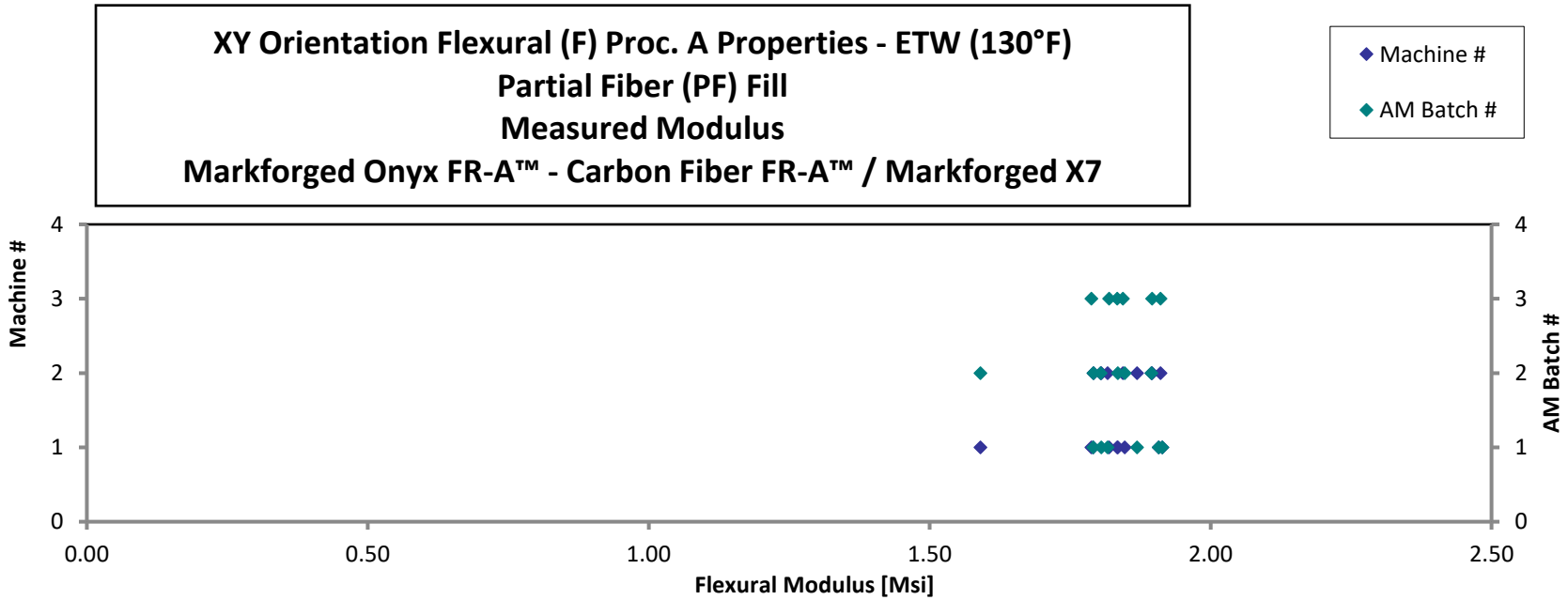
Specimen Number	AM Batch #	Machine #	Avg. Specimen Thickness [in]	Flexural Strength [ksi]	Flexural 2% Offset Yield Strength [ksi]	Flexural Modulus [Msi]	Failure Mode
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M1-P54144-XY-F-11-ETD-PF-1	1	1	0.138	27.74	22.40	1.791	CAT
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M1-P44320-XY-F-12-ETD-PF-2*	1	1	0.140	25.60		1.914	CAT, TAB
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M1-P44531-XY-F-13-ETD-PF-3	1	1	0.141	27.53	26.16	1.908	CAT, TAB
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M2-P53725-XY-F-11-ETD-PF-1	1	2	0.139	29.62	26.32	1.806	CAT, TAB
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M2-P46114-XY-F-12-ETD-PF-2	1	2	0.140	27.35	25.76	1.817	CAT, TAB
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M2-P42916-XY-F-13-ETD-PF-3*	1	2	0.141	25.19		1.869	CAT, TAB
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-B-M1-P58774-XY-F-11-ETD-PF-1**	2	1	0.140	21.37	11.14	1.590	TAB
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-B-M1-P39839-XY-F-12-ETD-PF-2	2	1	0.140	27.61	25.54	1.835	CAT, TAB
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-B-M1-P40117-XY-F-13-ETD-PF-3	2	1	0.140	29.41	25.95	1.847	CAT, TAB
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-B-M2-P58165-XY-F-11-ETD-PF-1	2	2	0.140	26.75	24.25	1.792	CAT
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-B-M2-P38143-XY-F-12-ETD-PF-2	2	2	0.136	24.95	19.86	1.895	CAT, TAB
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-B-M2-P38680-XY-F-13-ETD-PF-3	2	2	0.142	25.30	25.26	1.805	TAB
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-C-M1-P51459-XY-F-11-ETD-PF-1	3	1	0.140	28.95	25.09	1.834	TAB
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-C-M1-P49921-XY-F-12-ETD-PF-2	3	1	0.142	27.31	26.52	1.819	TAB
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-C-M1-P47955-XY-F-13-ETD-PF-3	3	1	0.144	26.87	24.51	1.788	TAB
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-C-M2-P57299-XY-F-11-ETD-PF-1*	3	2	0.140	26.16		1.911	CAT, TAB
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-C-M2-P49961-XY-F-12-ETD-PF-2*	3	2	0.140	26.93		1.844	CAT
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-C-M2-P49458-XY-F-13-ETD-PF-3	3	2	0.141	28.95	25.94	1.896	CAT

*0.2% offset yield strength not reported due to specimen failure before 0.2% offset strain.
**Specimen load curve was irregular but reached max stress and yielded before 5% strain.

Average	**0.140**	**26.87**	**23.91**	**1.831**
Standard Dev.		**1.973**	**4.090**	**0.074**
Coeff. of Var. [%]		**7.344**	**17.11**	**4.059**
Min.	**0.136**	**21.37**	**11.14**	**1.590**
Max.	**0.144**	**29.62**	**26.52**	**1.914**
Number of Spec.	**18**	**18**	**14**	**18**


XY Orientation Flexural (F) Proc. A Properties - ETW (130°F)
Partial Fiber (PF) Fill
Measured Strength
Markforged Onyx FR-A™ - Carbon Fiber FR-A™ / Markforged X7
Machine #
AM Batch #
Machine #
AM Batch #
Flexural Strength [ksi]
0
1
2
3
4
0.0
5.0
10.0
15.0
20.0
25.0
30.0
35.0


XY Orientation Flexural (F) Proc. A Properties - ETW (130°F)
Partial Fiber (PF) Fill
Measured 2% Offset Yield Strength
Markforged Onyx FR-A™ - Carbon Fiber FR-A™ / Markforged X7
Machine #
AM Batch #
Machine #
AM Batch #
0
1
2
3
4
0.00
5.00
10.00
15.00
20.00
25.00
30.00
Flexural 2% Offset Yield Strength [ksi]


XY Orientation Flexural (F) Proc. A Properties - ETW (130°F)
Partial Fiber (PF) Fill
Measured Modulus
Markforged Onyx FR-A™ - Carbon Fiber FR-A™ / Markforged X7
Machine #
AM Batch #
Machine #
AM Batch #
0
1
2
3
4
0.00
0.50
1.00
1.50
2.00
2.50
Flexural Modulus [Msi]

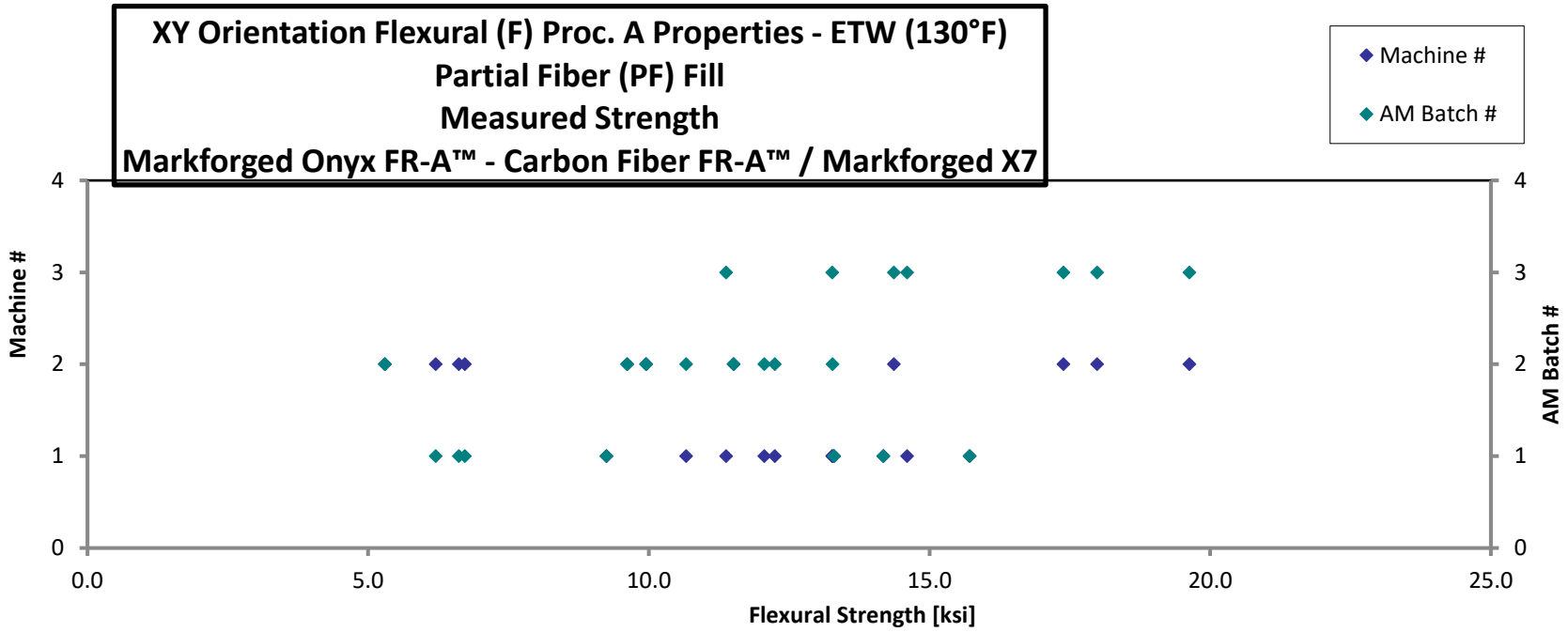
4.13.4 **ETW Condition**

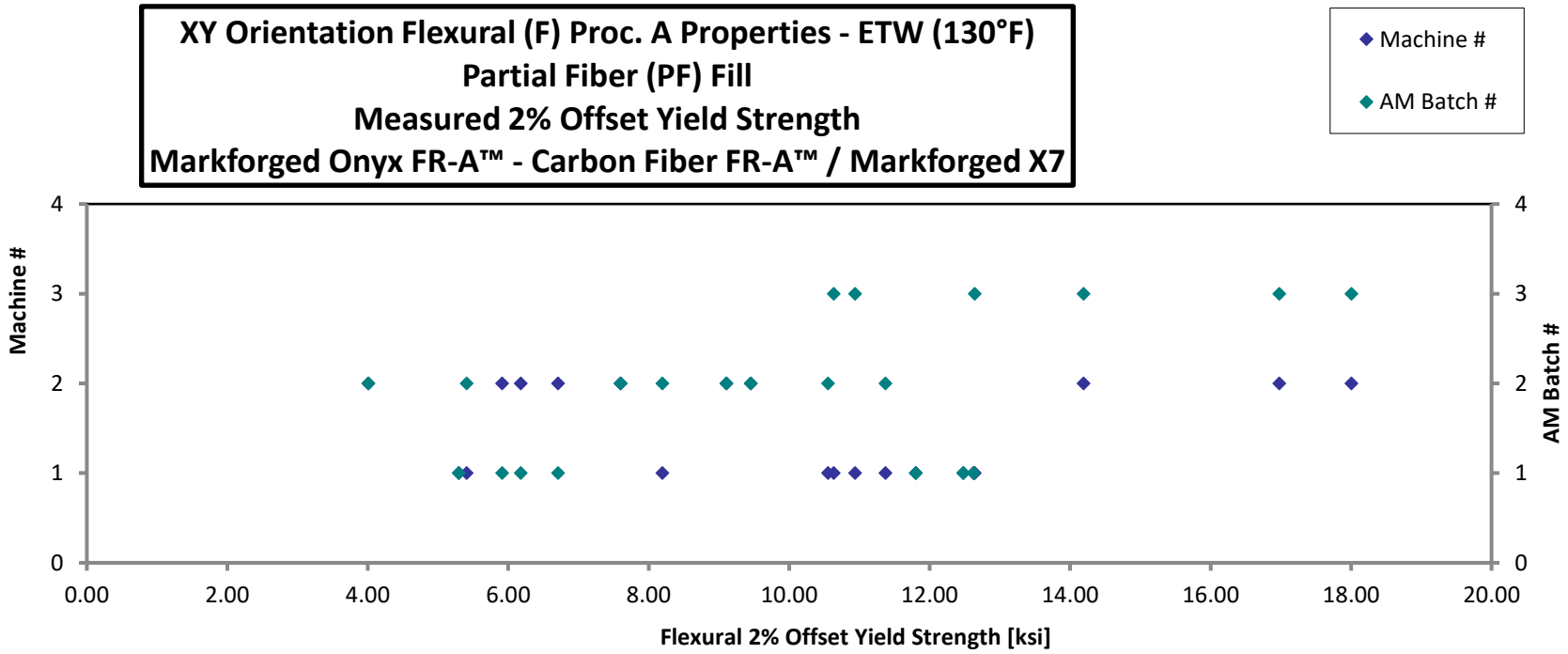
XY Orientation Flexural (F) Proc. A Properties - ETW (130°F)
Partial Fiber (PF) Fill
Strength & Modulus
Markforged Onyx FR-A™ - Carbon Fiber FR-A™ / Markforged X7

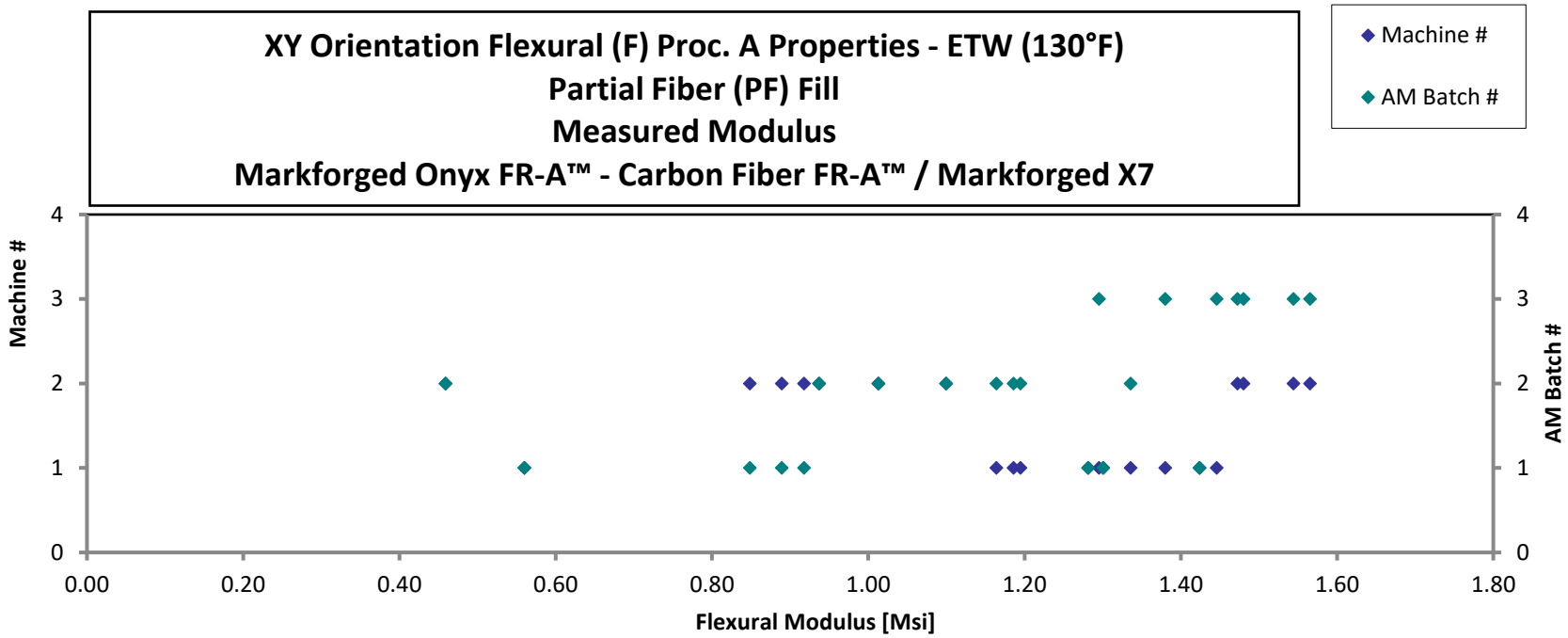
Specimen Number	AM Batch #	Machine #	Avg. Specimen Thickness [in]	Flexural Strength [ksi]	Flexural 2% Offset Yield Strength [ksi]	Flexural Modulus [Msi]	Failure Mode
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M1-P31490-XY-F-11-ETW-PF-1	1	1	0.142	15.71	12.62	1.424	BAT, TAB
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M1-P31153-XY-F-12-ETW-PF-2	1	1	0.144	9.245	5.296	0.560	BAT
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M1-P54807-XY-F-13-ETW-PF-3	1	1	0.143	14.18	12.48	1.301	BAT
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M1-P31455-XY-F-13-ETW-PF-SP	1	1	0.143	13.30	11.80	1.282	BAT
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M2-P31491-XY-F-11-ETW-PF-1*	1	2	0.142	6.618	6.180	0.889	BAT
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M2-P31152-XY-F-12-ETW-PF-2	1	2	0.143	6.725	6.707	0.918	BAT
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M2-P31697-XY-F-13-ETW-PF-3*	1	2	0.142	6.201	5.914	0.848	BAT
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-B-M1-P55801-XY-F-11-ETW-PF-1*	2	1	0.143	12.06	10.55	1.195	BAM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-B-M1-P39037-XY-F-12-ETW-PF-2*	2	1	0.145	12.24	8.196	1.164	BAM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-B-M1-P33716-XY-F-13-ETW-PF-3	2	1	0.143	13.27	11.37	1.336	BAM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-B-M1-P33244-XY-F-13-ETW-PF-SP**	2	1	0.143	10.66	5.409	1.186	BAM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-B-M2-P40904-XY-F-11-ETW-PF-1*	2	2	0.140	9.954	9.104	1.013	CAT
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-B-M2-P55140-XY-F-12-ETW-PF-2	2	2	0.143	5.299	4.008	0.459	CAT
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-B-M2-P56216-XY-F-13-ETW-PF-3	2	2	0.141	9.616	7.599	0.937	CAT
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-B-M2-P33243-XY-F-13-ETW-PF-SP	2	2	0.141	11.51	9.454	1.100	CAT
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-C-M1-P35650-XY-F-11-ETW-PF-1	3	1	0.141	14.60	12.64	1.380	CAT
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-C-M1-P35876-XY-F-12-ETW-PF-2	3	1	0.138	13.27	10.94	1.446	CAT
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-C-M1-P35346-XY-F-13-ETW-PF-3	3	1	0.141	11.38	10.63	1.295	CAT
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-C-M2-P34965-XY-F-11-ETW-PF-1	3	2	0.142	19.63	18.01	1.544	BAM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-C-M2-P34942-XY-F-12-ETW-PF-2	3	2	0.145	17.39	16.98	1.473	BAM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-C-M2-P35347-XY-F-13-ETW-PF-3	3	2	0.142	14.37	14.19	1.480	BAM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-C-M2-P35191-XY-F-13-ETW-PF-6***	3	2	0.140	17.98		1.565	BAM

Note: Due to inherent material properties, B-basis calculations will be calculated eventhough invalid tests were present.
Note: All specimens exhibited excessive bending during testing
Note:There appears to be significant difference in strength performance between specimens fabricated on machine 1 and machine 2.
*Maximum stress was obtained after 5% strain. (Invalid per ASTM D790)
**Modulus calculation used 200-1000 microstrain
***0.2% offset yield strength not reported due to specimen reaching maximum load first.

Average	**0.142**	**12.05**	**10.00**	**1.172**
Standard Dev.		**3.867**	**3.797**	**0.305**
Coeff. of Var. [%]		**32.08**	**37.96**	**25.99**
Min.	**0.138**	**5.299**	**4.008**	**0.459**
Max.	**0.145**	**19.63**	**18.01**	**1.565**
Number of Spec.	**22**	**22**	**21**	**22**


XY Orientation Flexural (F) Proc. A Properties - ETW (130°F)
Partial Fiber (PF) Fill
Measured Strength
Markforged Onyx FR-A™ - Carbon Fiber FR-A™ / Markforged X7
Machine #
AM Batch #
Machine #
AM Batch #
0
1
2
3
4
0.0
5.0
10.0
15.0
20.0
25.0
Flexural Strength [ksi]


XY Orientation Flexural (F) Proc. A Properties - ETW (130°F)
Partial Fiber (PF) Fill
Measured 2% Offset Yield Strength
Markforged Onyx FR-A™ - Carbon Fiber FR-A™ / Markforged X7
Machine #
AM Batch #
Machine #
AM Batch #
Flexural 2% Offset Yield Strength [ksi]
0
1
2
3
4
0.00
2.00
4.00
6.00
8.00
10.00
12.00
14.00
16.00
18.00
20.00


XY Orientation Flexural (F) Proc. A Properties - ETW (130°F)
Partial Fiber (PF) Fill
Measured Modulus
Markforged Onyx FR-A™ - Carbon Fiber FR-A™ / Markforged X7
Machine #
AM Batch #
Machine #
AM Batch #
Flexural Modulus [Msi]
0
1
2
3
4
0.00
0.20
0.40
0.60
0.80
1.00
1.20
1.40
1.60
1.80

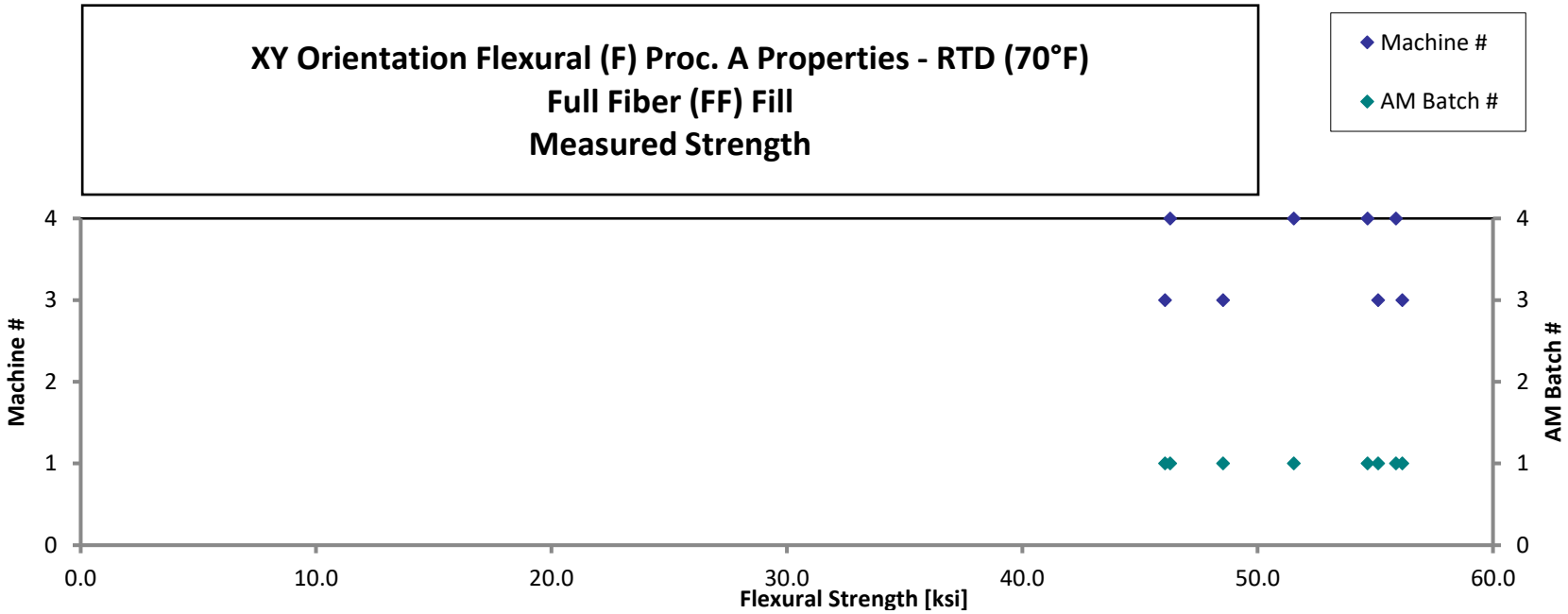
4.14 **XY FF Flex Properties**

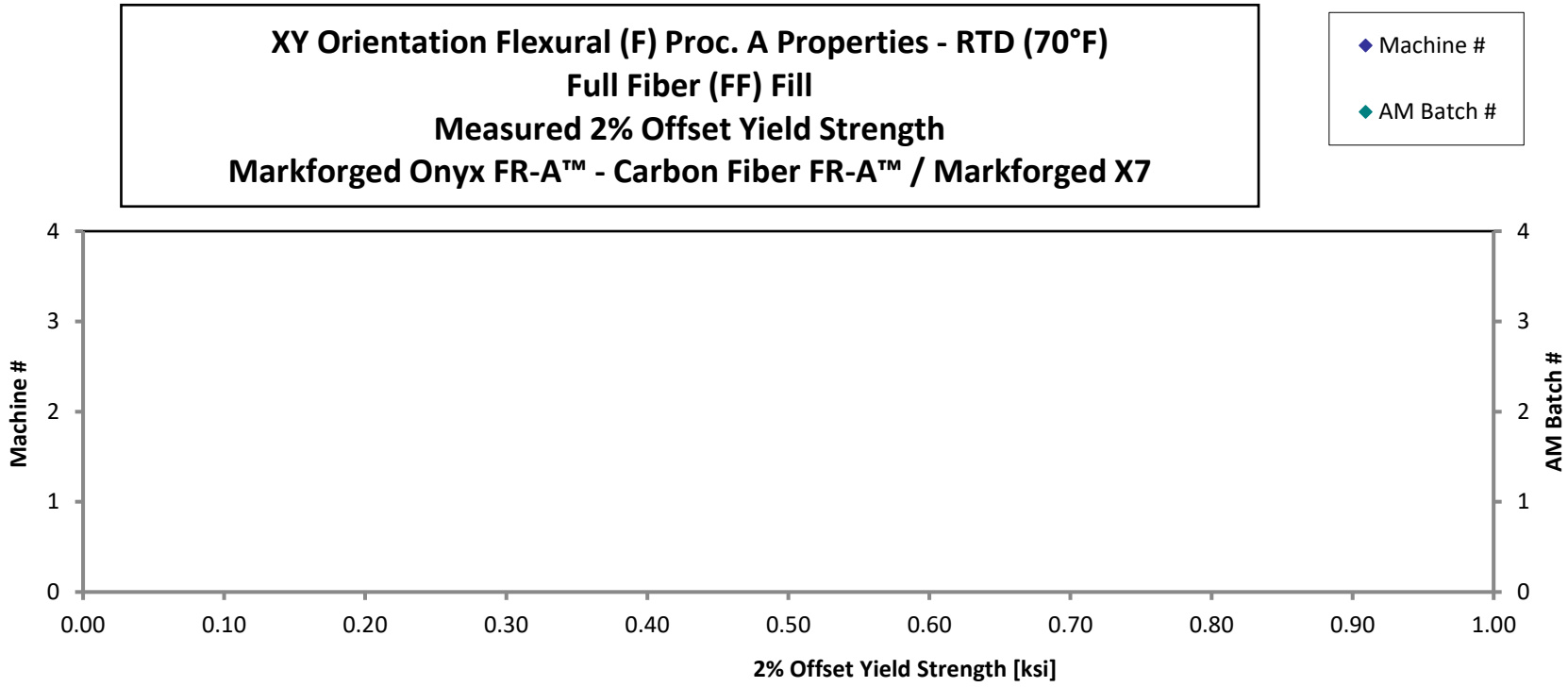
4.14.1 **RTD Condition**

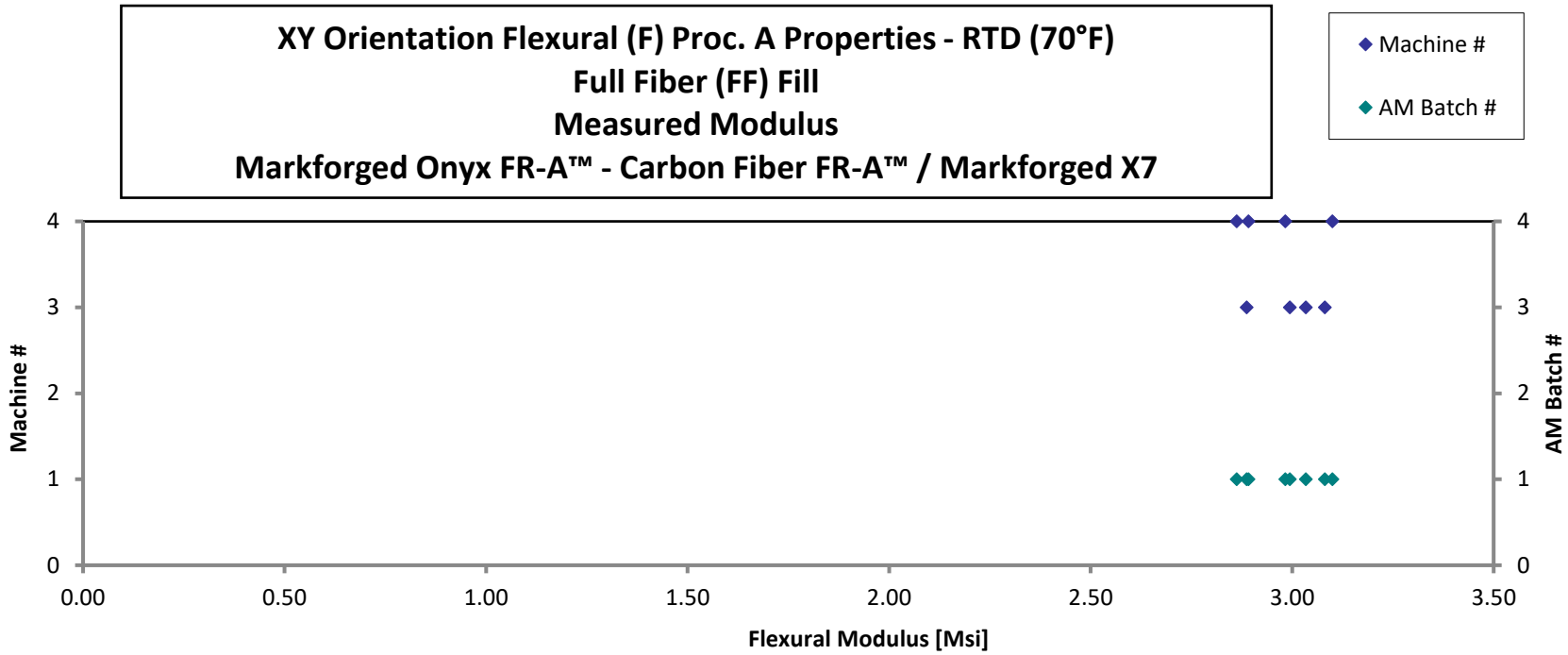
XY Orientation Flexural (F) Proc. A Properties - RTD (70°F)
Full Fiber (FF) Fill
Strength & Modulus
Markforged Onyx FR-A™ - Carbon Fiber FR-A™ / Markforged X7

Specimen Number	AM Batch #	Machine #	Flexural Strength [ksi]	2% Offset Yield Strength [ksi]	Flexural Modulus [Msi]	Avg. Specimen Thickness [in]	Failure Mode
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M3-P34051-XY-F-11-RTD-FF-1*	1	3	56.15		3.034	0.142	TAB
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M3-P34059-XY-F-12-RTD-FF-2*	1	3	46.07		3.081	0.143	TAB
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M3-P34369-XY-F-13-RTD-FF-3*	1	3	55.12		2.994	0.143	TAB
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M3-P38541-XY-F-13-RTD-FF-SP*	1	3	48.53		2.887	0.143	TAB
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M4-P41548-XY-F-11-RTD-FF-1*	1	4	54.67		2.863	0.143	TAB
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M4-P42161-XY-F-12-RTD-FF-2*	1	4	46.28		2.891	0.142	TAB
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M4-P42319-XY-F-13-RTD-FF-3*	1	4	55.87		2.983	0.140	TAB
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M4-P46438-XY-F-13-RTD-FF-SP*	1	4	51.54		3.100	0.140	TAB
		Average	**51.78**		**2.979**	**0.142**	
		Standard Dev.	**4.289**		**0.091**		
		Coeff. of Var. [%]	**8.283**		**3.051**		
		Min.	**46.07**		**2.863**	**0.140**	
		Max.	**56.15**		**3.100**	**0.143**	
		Number of Spec.	**8**		**8**	**8**	

*0.2% offset yield strength not reported due to specimen failure before 0.2% offset strain.


XY Orientation Flexural (F) Proc. A Properties - RTD (70°F)
Full Fiber (FF) Fill
Measured Strength
Machine #
AM Batch #
Machine #
AM Batch #
0
1
2
3
4
0.0
10.0
20.0
30.0
40.0
50.0
60.0
Flexural Strength [ksi]


XY Orientation Flexural (F) Proc. A Properties - RTD (70°F)
Full Fiber (FF) Fill
Measured 2% Offset Yield Strength
Markforged Onyx FR-A™ - Carbon Fiber FR-A™ / Markforged X7
Machine #
AM Batch #
Machine #
AM Batch #
0
1
2
3
4
0.00
0.10
0.20
0.30
0.40
0.50
0.60
0.70
0.80
0.90
1.00
2% Offset Yield Strength [ksi]


XY Orientation Flexural (F) Proc. A Properties - RTD (70°F)
Full Fiber (FF) Fill
Measured Modulus
Markforged Onyx FR-A™ - Carbon Fiber FR-A™ / Markforged X7
Machine #
AM Batch #
Machine #
AM Batch #
Flexural Modulus [Msi]
0
1
2
3
4
0.00
0.50
1.00
1.50
2.00
2.50
3.00
3.50

4.15 **XZ PF Flex Properties**

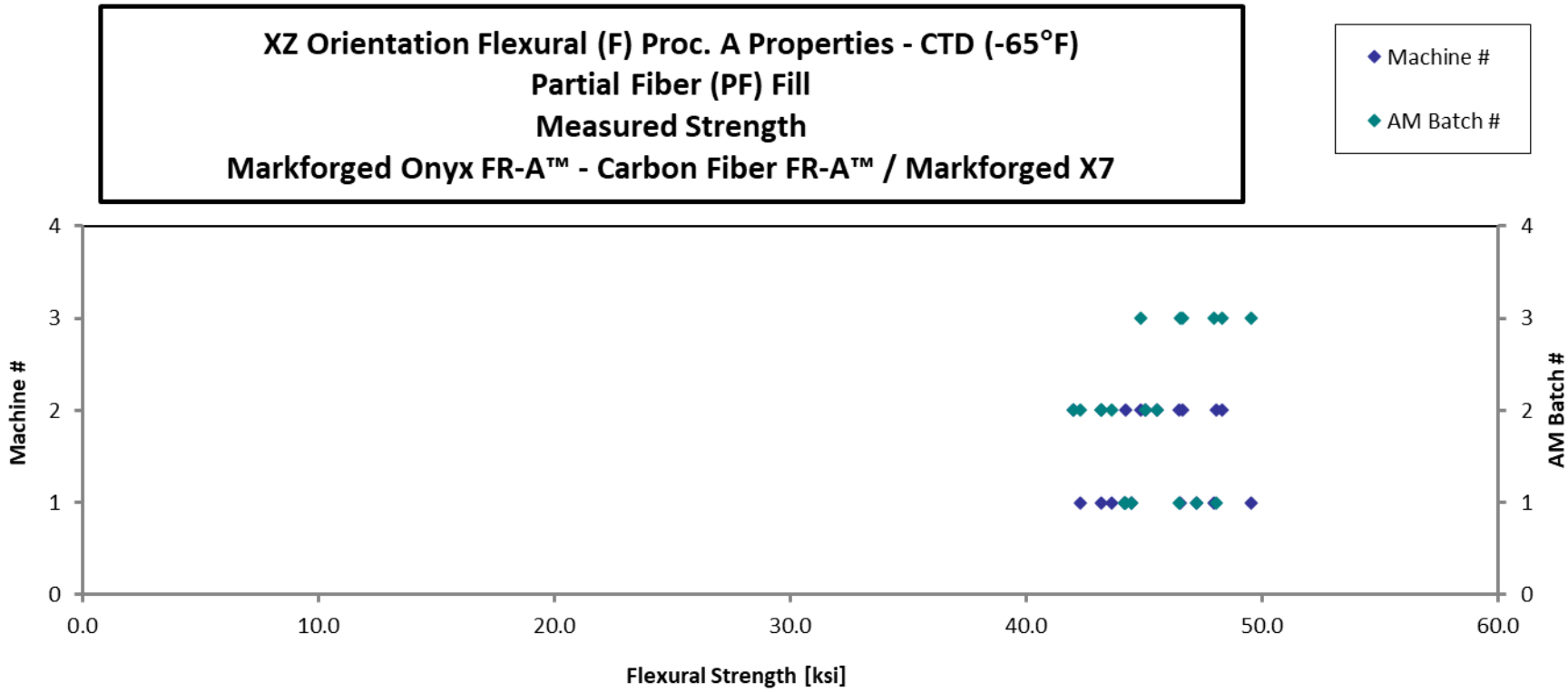
4.15.1 **CTD Condition**

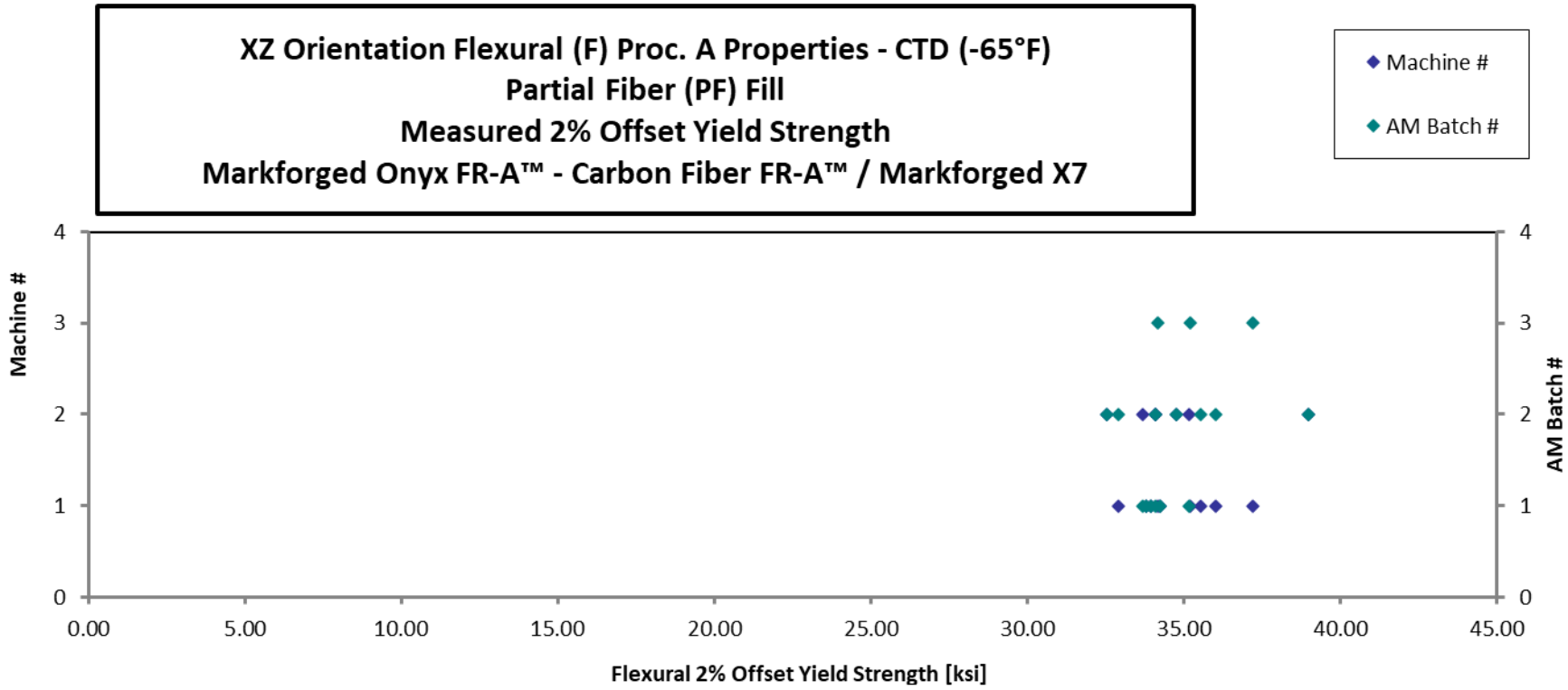
XZ Orientation Flexural (F) Proc. A Properties - CTD (-65°F)
Partial Fiber (PF) Fill
Strength & Modulus
Markforged Onyx FR-A™ - Carbon Fiber FR-A™ / Markforged X7

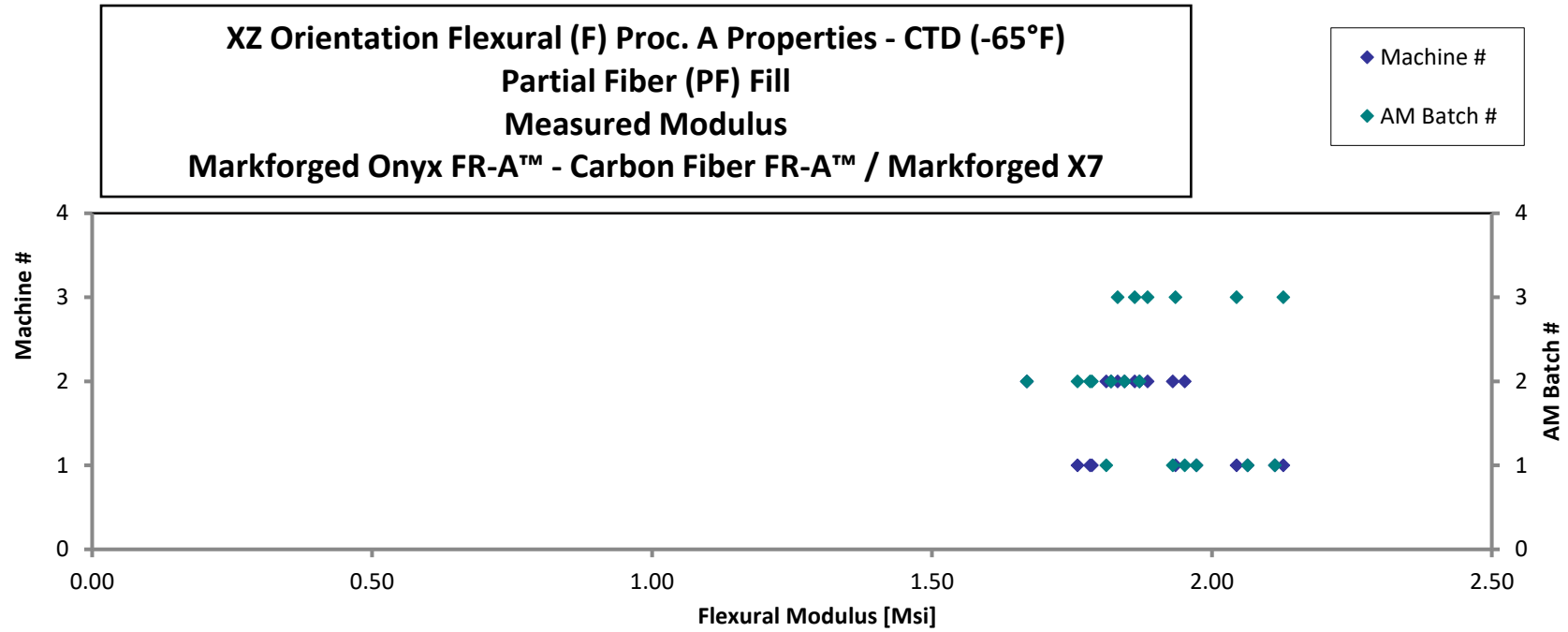
Specimen Number	AM Batch #	Machine #	Avg. Specimen Thickness [in]	Flexural Strength [ksi]	Flexural 2% Offset Yield Strength [ksi]	Flexural Modulus [Msi]	Failure Mode
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M1-P31490-XZ-F-11-CTD-PF-1	1	1	0.144	47.23	33.80	2.113	CAT, TAB
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M1-P45017-XZ-F-12-CTD-PF-2	1	1	0.142	44.46	34.24	1.973	CAT, TAB
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M1-P31455-XZ-F-13-CTD-PF-3	1	1	0.143	44.15	33.97	2.064	CAT, TAB
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M2-P31491-XZ-F-11-CTD-PF-1	1	2	0.143	48.02	34.11	1.930	CAT, TAB
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M2-P29960-XZ-F-12-CTD-PF-2	1	2	0.141	44.19	35.18	1.812	CAT, TAB
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M2-P31456-XZ-F-13-CTD-PF-3	1	2	0.141	46.49	33.67	1.952	CAT, TAB
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-B-M1-P55801-XZ-F-11-CTD-PF-1	2	1	0.142	43.60	36.01	1.760	CAT, TAB
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-B-M1-P36645-XZ-F-12-CTD-PF-2	2	1	0.141	43.18	35.53	1.786	CAT, TAB
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-B-M1-P33244-XZ-F-13-CTD-PF-3	2	1	0.141	42.28	32.91	1.782	CAT, TAB
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-B-M2-P40904-XZ-F-11-CTD-PF-1	2	2	0.139	45.55	34.08	1.844	CAT, TAB
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-B-M2-P58165-XZ-F-12-CTD-PF-2	2	2	0.138	41.98	38.98	1.670	CAT, TAB
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-B-M2-P33243-XZ-F-13-CTD-PF-3	2	2	0.142	45.06	32.56	1.820	CAT, TAB
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-B-M2-P36678-XZ-F-13-CTD-PF-6	2	2	0.138	43.17	34.78	1.871	CAT, TAB
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-C-M1-P35650-XZ-F-11-CTD-PF-1	3	1	0.141	49.52	34.17	2.128	CAT, TAB
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-C-M1-P50410-XZ-F-12-CTD-PF-2	3	1	0.139	46.51	37.20	1.935	CAT, TAB
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-C-M1-P49394-XZ-F-13-CTD-PF-3	3	1	0.140	47.93	35.20	2.044	CAT, TAB
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-C-M2-P34965-XZ-F-11-CTD-PF-1*	3	2	0.141	48.27		1.832	TAB, CAT
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-C-M2-P35396-XZ-F-13-CTD-PF-6*	3	2	0.140	44.85		1.885	TAB, CAT
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-C-M2-P57301-XZ-F-12-CTD-PF-2*	3	2	0.140	46.64		1.862	TAB, CAT

*0.2% offset yield strength not reported due to specimen failure before 0.2% offset strain.

Average	**0.141**	**45.42**	**34.77**	**1.898**
Standard Dev.		**2.169**	**1.607**	**0.125**
Coeff. of Var. [%]		**4.775**	**4.623**	**6.560**
Min.	**0.138**	**41.98**	**32.56**	**1.670**
Max.	**0.144**	**49.52**	**38.98**	**2.128**
Number of Spec.	**19**	**19**	**16**	**19**


XZ Orientation Flexural (F) Proc. A Properties - CTD (-65°F)
Partial Fiber (PF) Fill
Measured Strength
Markforged Onyx FR-A™ - Carbon Fiber FR-A™ / Markforged X7
Machine #
AM Batch #
Machine #
AM Batch #
0
1
2
3
4
0.0
10.0
20.0
30.0
40.0
50.0
60.0
Flexural Strength [ksi]

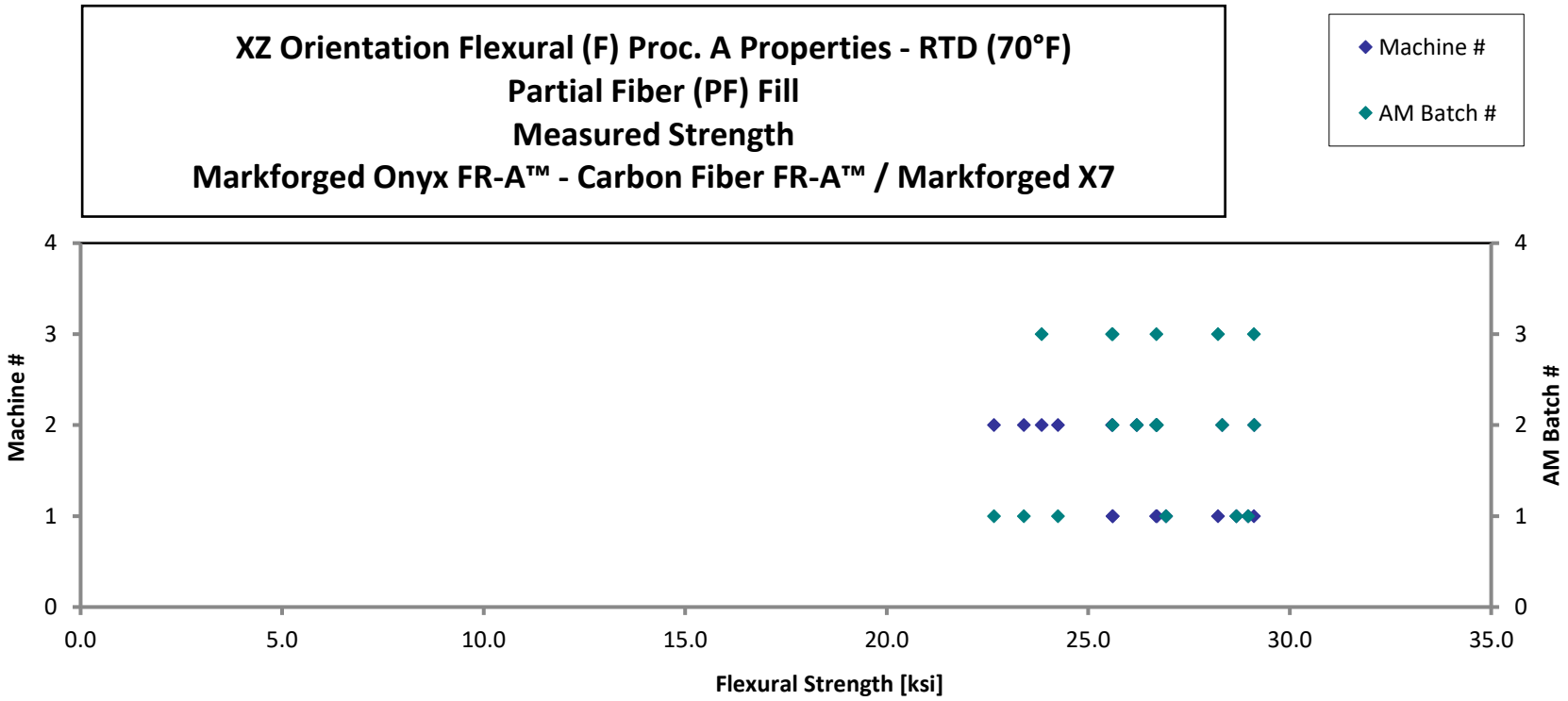

XZ Orientation Flexural (F) Proc. A Properties - CTD (-65°F)
Partial Fiber (PF) Fill
Measured 2% Offset Yield Strength
Markforged Onyx FR-A™ - Carbon Fiber FR-A™ / Markforged X7
Machine #
AM Batch #
Machine #
AM Batch #
0
1
2
3
4
0.00
5.00
10.00
15.00
20.00
25.00
30.00
35.00
40.00
45.00
Flexural 2% Offset Yield Strength [ksi]

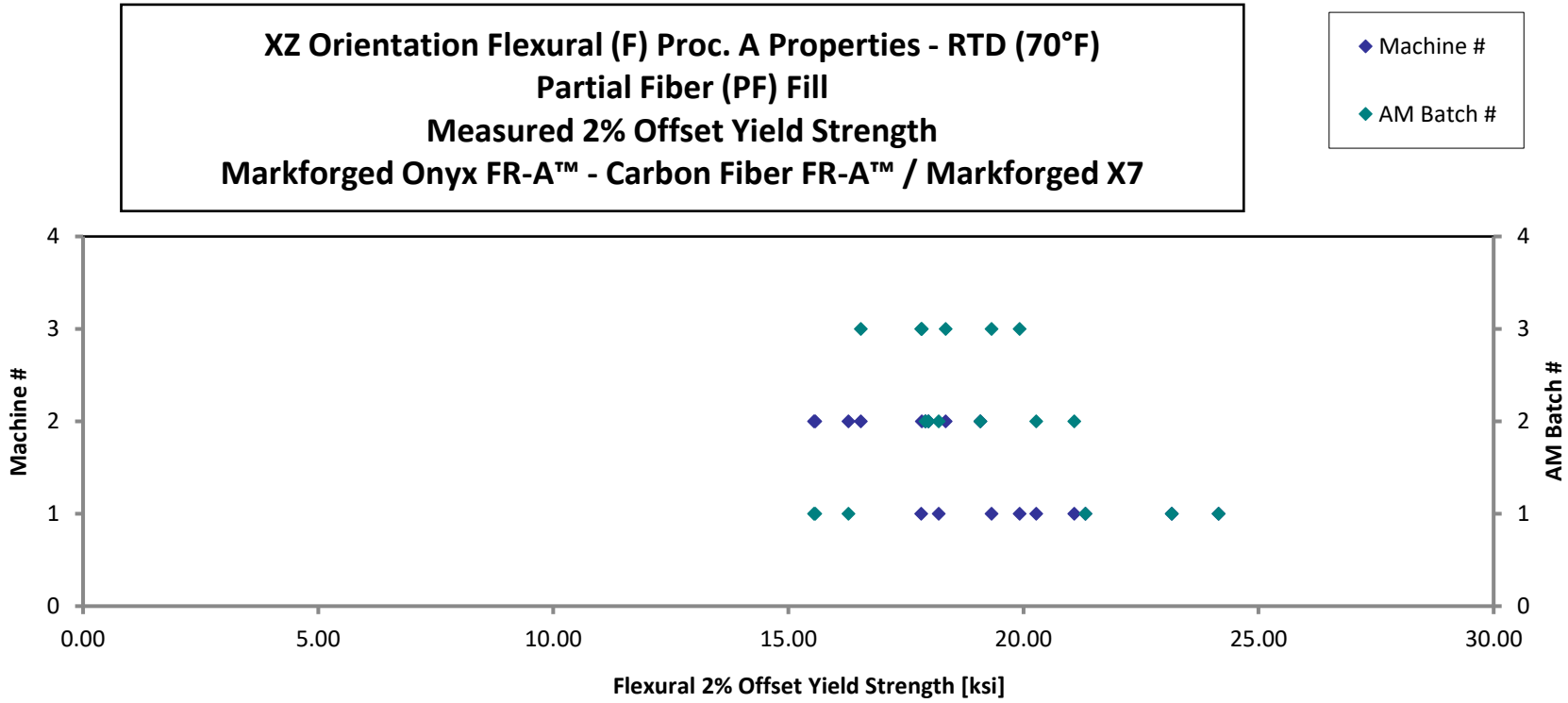

XZ Orientation Flexural (F) Proc. A Properties - CTD (-65°F)
Partial Fiber (PF) Fill
Measured Modulus
Markforged Onyx FR-A™ - Carbon Fiber FR-A™ / Markforged X7
Machine #
AM Batch #
Machine #
AM Batch #
Flexural Modulus [Msi]
0
1
2
3
4
0.00
0.50
1.00
1.50
2.00
2.50

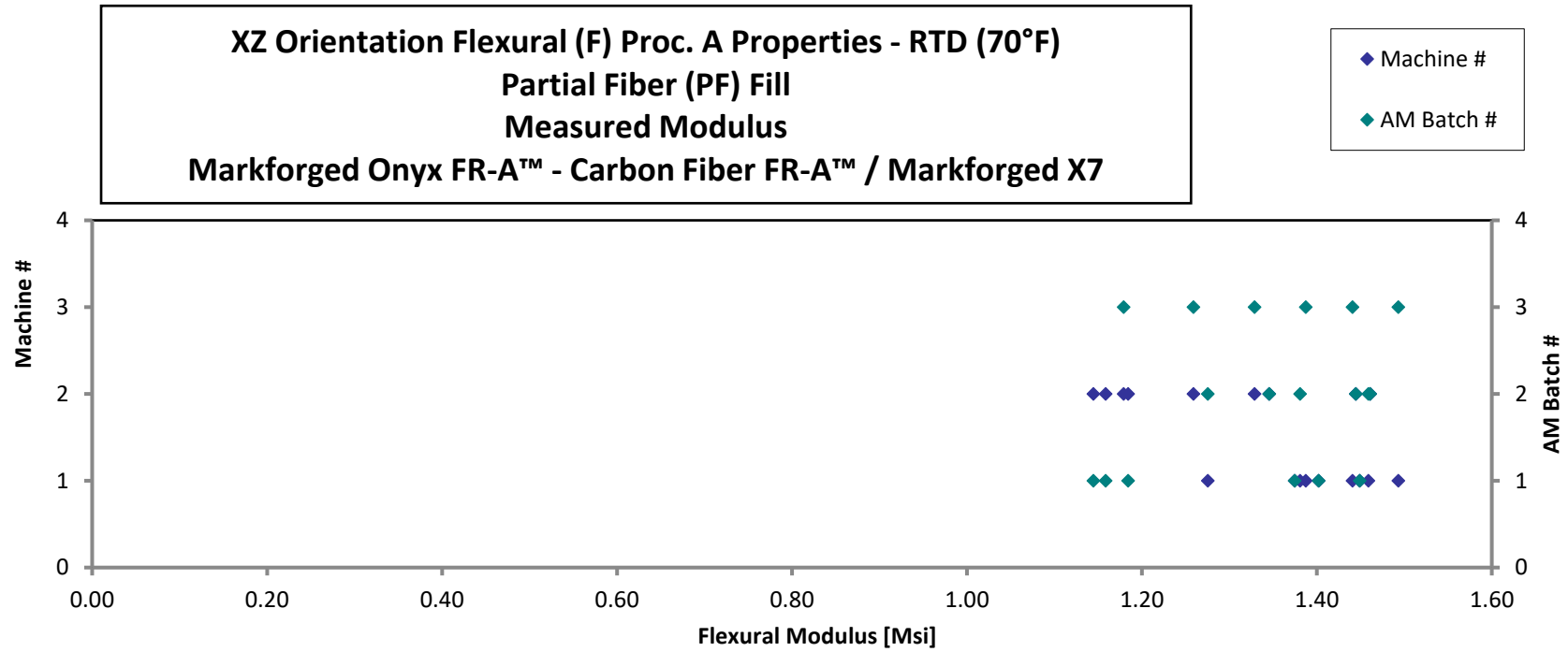
4.15.2 **RTD Condition**

XZ Orientation Flexural (F) Proc. A Properties - RTD (70°F)
Partial Fiber (PF) Fill
Strength & Modulus
Markforged Onyx FR-A™ - Carbon Fiber FR-A™ / Markforged X7

Specimen Number	AM Batch #	Machine #	Avg. Specimen Thickness [in]	Flexural Strength [ksi]	Flexural 2% Offset Yield Strength [ksi]	Flexural Modulus [Msi]	Failure Mode
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M1-P31490-XZ-F-11-RTD-PF-1	1	1	0.139	28.97	23.16	1.449	TAB
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M1-P54807-XZ-F-12-RTD-PF-2	1	1	0.140	28.68	24.15	1.402	TAB
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M1-P31610-XZ-F-13-RTD-PF-3	1	1	0.142	26.93	21.32	1.375	TAB
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M2-P31491-XZ-F-11-RTD-PF-1	1	2	0.139	23.40	16.28	1.159	TAB
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M2-P31697-XZ-F-12-RTD-PF-2	1	2	0.140	24.25	15.57	1.144	TAB
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M2-P31611-XZ-F-13-RTD-PF-3	1	2	0.141	22.66	15.54	1.184	TAB
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-B-M1-P55801-XZ-F-11-RTD-PF-1	2	1	0.137	26.71	20.27	1.459	TAB
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-B-M1-P33716-XZ-F-12-RTD-PF-2	2	1	0.139	25.60	21.08	1.276	TAB
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-B-M1-P33155-XZ-F-13-RTD-PF-3	2	1	0.141	26.69	18.19	1.381	TAB
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-B-M2-P40904-XZ-F-11-RTD-PF-1	2	2	0.137	29.12	17.92	1.445	TAB
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-B-M2-P56216-XZ-F-12-RTD-PF-2	2	2	0.139	26.21	17.98	1.346	TAB
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-B-M2-P33154-XZ-F-13-RTD-PF-3	2	2	0.139	28.33	19.09	1.461	TAB
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-C-M1-P35650-XZ-F-11-RTD-PF-1	3	1	0.137	28.22	19.92	1.441	TAB
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-C-M1-P35346-XZ-F-12-RTD-PF-2	3	1	0.140	25.61	17.82	1.387	TAB
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-C-M1-P35257-XZ-F-13-RTD-PF-3	3	1	0.141	29.11	19.32	1.493	TAB
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-C-M2-P34965-XZ-F-11-RTD-PF-1	3	2	0.139	25.59	17.84	1.329	TAB
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-C-M2-P35347-XZ-F-12-RTD-PF-2	3	2	0.140	23.85	18.34	1.179	TAB
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-C-M2-P35256-XZ-F-13-RTD-PF-3	3	2	0.141	26.69	16.54	1.259	TAB
		Average	**0.139**	**26.48**	**18.91**	**1.343**	
		Standard Dev.		**2.030**	**2.414**	**0.115**	
		Coeff. of Var. [%]		**7.667**	**12.77**	**8.594**	
		Min.	**0.137**	**22.66**	**15.54**	**1.144**	
		Max.	**0.142**	**29.12**	**24.15**	**1.493**	
		Number of Spec.	**18**	**18**	**18**	**18**	


XZ Orientation Flexural (F) Proc. A Properties - RTD (70°F)
Partial Fiber (PF) Fill
Measured Strength
Markforged Onyx FR-A™ - Carbon Fiber FR-A™ / Markforged X7
Machine #
AM Batch #
Machine #
AM Batch #
Flexural Strength [ksi]
0
1
2
3
4
0.0
5.0
10.0
15.0
20.0
25.0
30.0
35.0

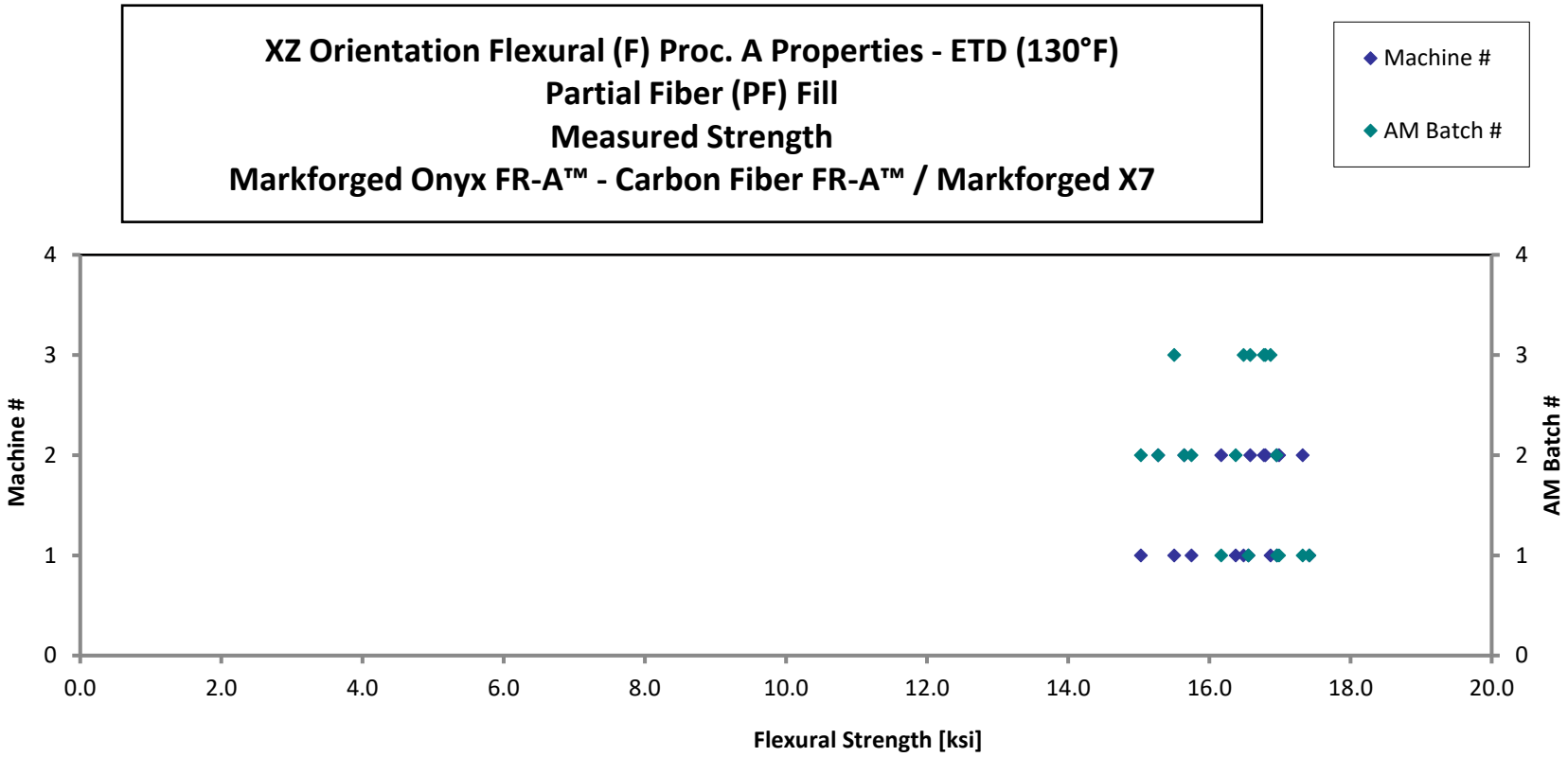

XZ Orientation Flexural (F) Proc. A Properties - RTD (70°F)
Partial Fiber (PF) Fill
Measured 2% Offset Yield Strength
Markforged Onyx FR-A™ - Carbon Fiber FR-A™ / Markforged X7
Machine #
AM Batch #
Machine #
AM Batch #
0
1
2
3
4
0.00
5.00
10.00
15.00
20.00
25.00
30.00
Flexural 2% Offset Yield Strength [ksi]

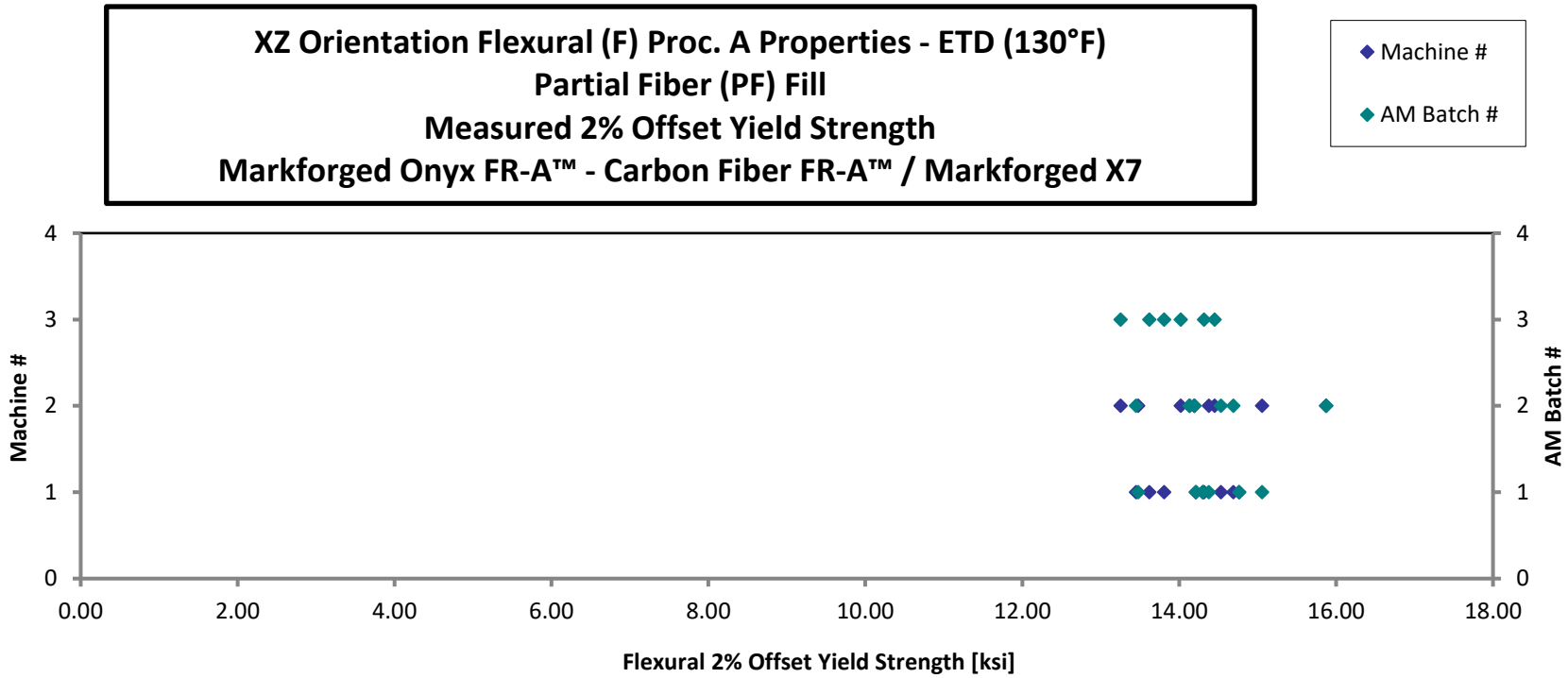

XZ Orientation Flexural (F) Proc. A Properties - RTD (70°F)
Partial Fiber (PF) Fill
Measured Modulus
Markforged Onyx FR-A™ - Carbon Fiber FR-A™ / Markforged X7
Machine #
AM Batch #
Machine #
AM Batch #
Flexural Modulus [Msi]
0
1
2
3
4
0.00
0.20
0.40
0.60
0.80
1.00
1.20
1.40
1.60

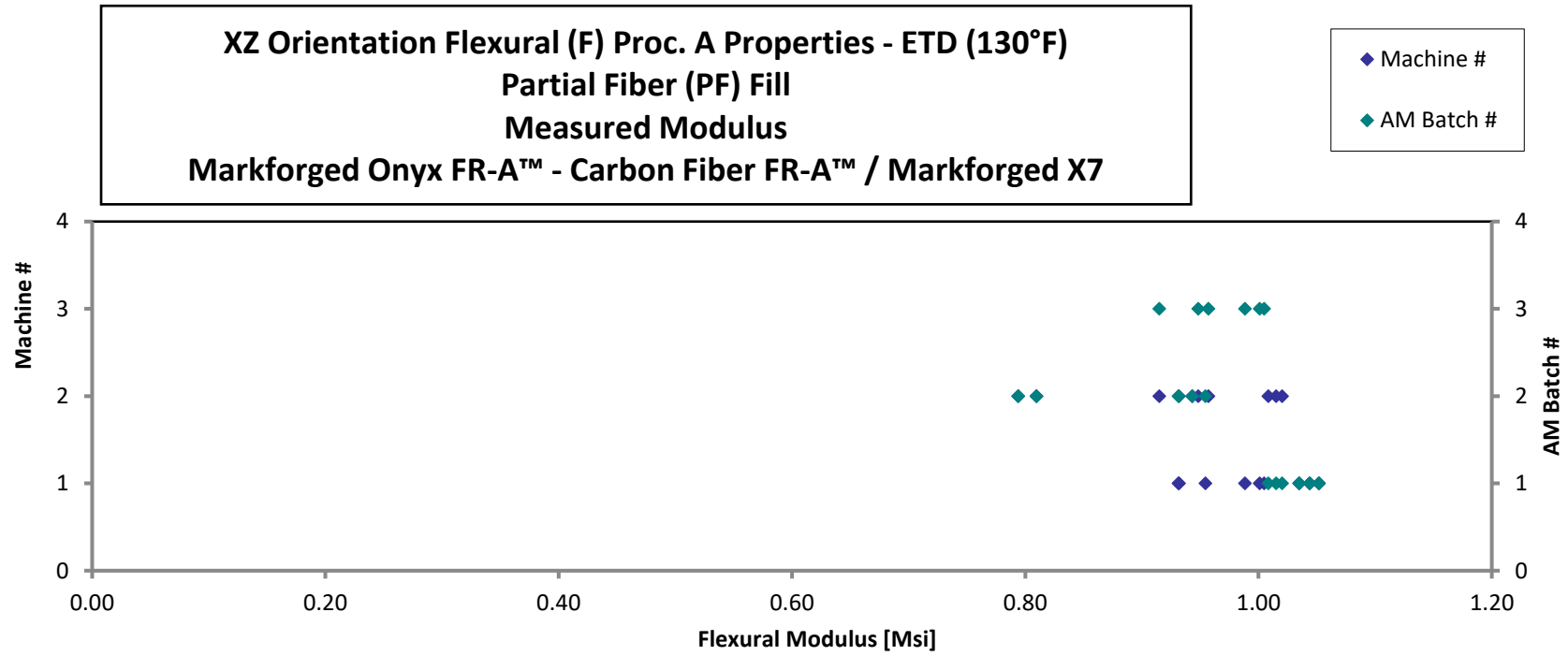
4.15.3 **ETD Condition**

XZ Orientation Flexural (F) Proc. A Properties - ETD (130°F)
Partial Fiber (PF) Fill
Strength & Modulus
Markforged Onyx FR-A™ - Carbon Fiber FR-A™ / Markforged X7

Specimen Number	AM Batch #	Machine #	Avg. Specimen Thickness [in]	Flexural Strength [ksi]	Flexural 2% Offset Yield Strength [ksi]	Flexural Modulus [Msi]	Failure Mode
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M1-P43092-XZ-F-11-ETD-PF-1	1	1	0.140	16.96	14.21	1.052	TAB
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M1-P44320-XZ-F-12-ETD-PF-2	1	1	0.139	16.55	14.76	1.035	TAB
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M1-P54144-XZ-F-13-ETD-PF-3	1	1	0.142	17.42	14.30	1.044	TAB
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M2-P43812-XZ-F-11-ETD-PF-1	1	2	0.140	16.17	13.48	1.008	CAT, TAB
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M2-P46114-XZ-F-12-ETD-PF-2	1	2	0.138	16.99	14.38	1.020	CAT, TAB
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M2-P53725-XZ-F-13-ETD-PF-3	1	2	0.140	17.32	15.06	1.015	CAT, TAB
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-B-M1-P41475-XZ-F-11-ETD-PF-1	2	1	0.140	16.37	14.69	0.932	TAB
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-B-M1-P39839-XZ-F-12-ETD-PF-2	2	1	0.137	15.75	14.53	0.931	TAB
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-B-M1-P58774-XZ-F-13-ETD-PF-3	2	1	0.139	15.03	13.45	0.955	TAB
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-B-M2-P46559-XZ-F-11-ETD-PF-1	2	2	0.141	15.64	14.19	0.810	TAB
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-B-M2-P38143-XZ-F-12-ETD-PF-2	2	2	0.137	15.27	14.13	0.794	TAB
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-B-M2-P58165-XZ-F-13-ETD-PF-3	2	2	0.136	16.95	15.87	0.943	TAB
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-C-M1-P47663-XZ-F-11-ETD-PF-1	3	1	0.142	15.50	13.62	1.005	TAB
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-C-M1-P49921-XZ-F-12-ETD-PF-2	3	1	0.140	16.49	14.32	1.001	TAB
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-C-M1-P51459-XZ-F-13-ETD-PF-3	3	1	0.142	16.87	13.81	0.988	TAB
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-C-M2-P46999-XZ-F-11-ETD-PF-1	3	2	0.141	16.79	13.26	0.957	TAB
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-C-M2-P49961-XZ-F-12-ETD-PF-2	3	2	0.139	16.58	14.02	0.948	TAB
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-C-M2-P57301-XZ-F-13-ETD-PF-3	3	2	0.140	16.77	14.45	0.915	TAB
		Average	**0.140**	**16.41**	**14.25**	**0.964**	
		Standard Dev.		**0.704**	**0.631**	**0.072**	
		Coeff. of Var. [%]		**4.287**	**4.430**	**7.484**	
		Min.	**0.136**	**15.03**	**13.26**	**0.794**	
		Max.	**0.142**	**17.42**	**15.87**	**1.052**	
		Number of Spec.	**18**	**18**	**18**	**18**	


XZ Orientation Flexural (F) Proc. A Properties - ETD (130°F)
Partial Fiber (PF) Fill
Measured Strength
Markforged Onyx FR-A™ - Carbon Fiber FR-A™ / Markforged X7
Machine #
AM Batch #
Machine #
AM Batch #
Flexural Strength [ksi]
0
1
2
3
4
0.0
2.0
4.0
6.0
8.0
10.0
12.0
14.0
16.0
18.0
20.0


XZ Orientation Flexural (F) Proc. A Properties - ETD (130°F)
Partial Fiber (PF) Fill
Measured 2% Offset Yield Strength
Markforged Onyx FR-A™ - Carbon Fiber FR-A™ / Markforged X7
Machine #
AM Batch #
Machine #
AM Batch #
0
1
2
3
4
0.00
2.00
4.00
6.00
8.00
10.00
12.00
14.00
16.00
18.00
Flexural 2% Offset Yield Strength [ksi]

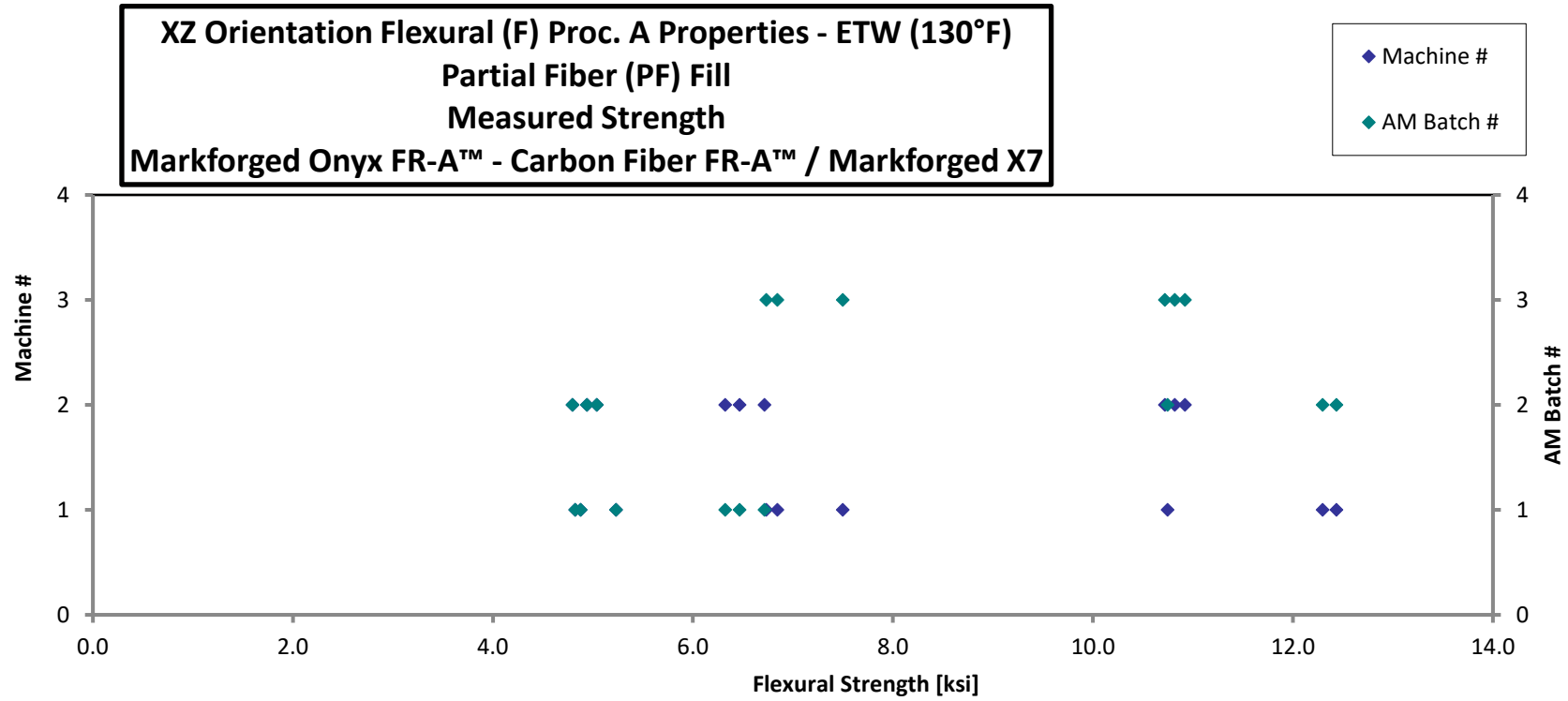

XZ Orientation Flexural (F) Proc. A Properties - ETD (130°F)
Partial Fiber (PF) Fill
Measured Modulus
Markforged Onyx FR-A™ - Carbon Fiber FR-A™ / Markforged X7
Machine #
AM Batch #
Machine #
AM Batch #
Flexural Modulus [Msi]
0
1
2
3
4
0.00
0.20
0.40
0.60
0.80
1.00
1.20

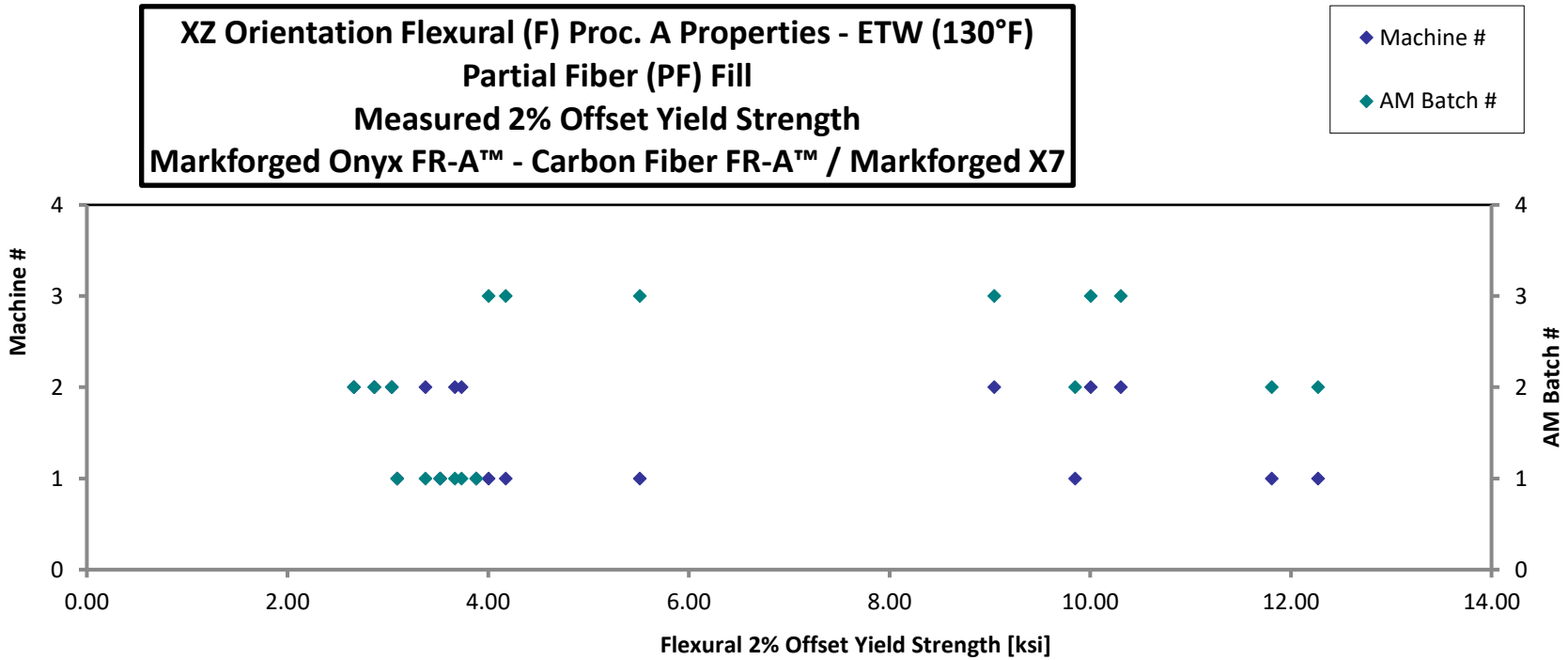
4.15.4 **ETW Condition**

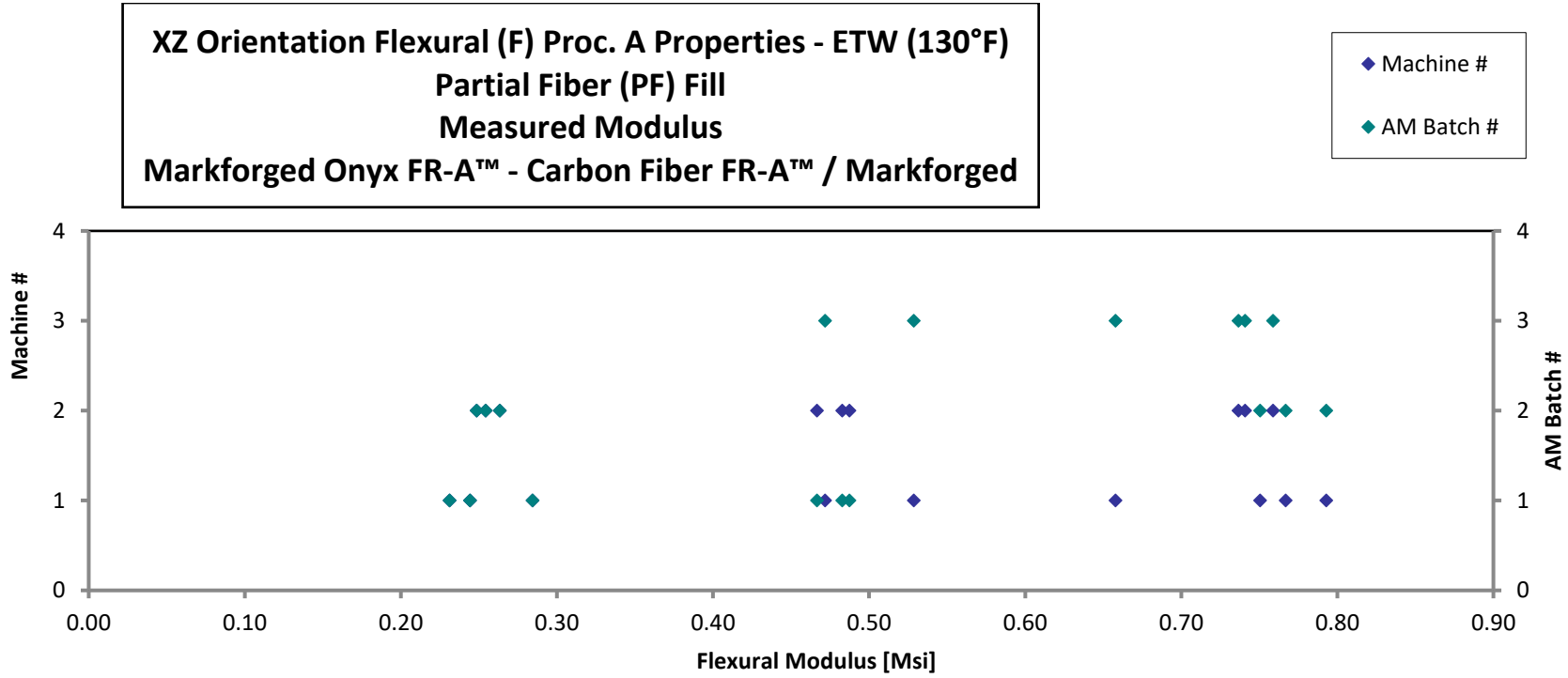
XZ Orientation Flexural (F) Proc. A Properties - ETW (130°F)
Partial Fiber (PF) Fill
Strength & Modulus
Markforged Onyx FR-A™ - Carbon Fiber FR-A™ / Markforged X7

Specimen Number	AM Batch #	Machine #	Avg. Specimen Thickness [in]	Flexural Strength [ksi]	Flexural 2% Offset Yield Strength [ksi]	Flexural Modulus [Msi]	Failure Mode
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M1-P31490-XZ-F-11-ETW-PF-1	1	1	0.142	5.230	3.522	0.231	TAB, BAT
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M1-P54807-XZ-F-12-ETW-PF-2	1	1	0.143	4.878	3.881	0.244	TAB, BAT
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M1-P31610-XZ-F-13-ETW-PF-3*	1	1	0.143	4.824	3.092	0.284	TAB, BAT
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M2-P31491-XZ-F-11-ETW-PF-1*	1	2	0.141	6.716	3.669	0.487	BAT
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M2-P31697-XZ-F-12-ETW-PF-2*	1	2	0.141	6.322	3.375	0.467	BAT
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M2-P31611-XZ-F-13-ETW-PF-3*	1	2	0.141	6.466	3.735	0.483	BAT
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-B-M1-P55801-XZ-F-11-ETW-PF-1	2	1	0.142	10.75	9.849	0.751	TAB
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-B-M1-P33716-XZ-F-12-ETW-PF-2	2	1	0.141	12.30	11.81	0.767	TAB
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-B-M1-P33155-XZ-F-13-ETW-PF-3	2	1	0.142	12.44	12.27	0.793	TAB
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-B-M2-P40904-XZ-F-11-ETW-PF-1*	2	2	0.139	5.040	3.039	0.254	CAT, TAB
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-B-M2-P56216-XZ-F-12-ETW-PF-2*	2	2	0.139	4.939	2.662	0.249	CAT, TAB
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-B-M2-P33154-XZ-F-13-ETW-PF-3*	2	2	0.141	4.796	2.866	0.263	CAT, TAB
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-C-M1-P35650-XZ-F-11-ETW-PF-1*	3	1	0.140	6.732	4.175	0.472	TAB
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-C-M1-P35346-XZ-F-12-ETW-PF-2*	3	1	0.140	6.843	4.003	0.529	TAB
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-C-M1-P35257-XZ-F-13-ETW-PF-3*	3	1	0.141	7.498	5.510	0.658	TAB
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-C-M2-P34965-XZ-F-11-ETW-PF-1	3	2	0.141	10.82	10.01	0.759	BAM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-C-M2-P35347-XZ-F-12-ETW-PF-2	3	2	0.141	10.72	10.30	0.737	BAM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-C-M2-P35256-XZ-F-13-ETW-PF-3	3	2	0.141	10.92	9.044	0.741	BAM
	Average		**0.141**	**7.679**	**5.934**	**0.509**	
	Standard Dev.			**2.803**	**3.477**	**0.216**	
	Coeff. of Var. [%]			**36.51**	**58.59**	**42.36**	
	Min.		**0.139**	**4.796**	**2.662**	**0.231**	
	Max.		**0.143**	**12.44**	**12.27**	**0.793**	
	Number of Spec.		**18**	**18**	**18**	**18**	

Note: Due to inherent material properties, B-basis calculations will be calculated eventhough invalid tests were present.
Note:There appears to be significant difference in strength performance between specimens fabricated on machine 1 and machine 2.
*Maximum stress was obtained after 5% strain. (Invalid per ASTM D790)


XZ Orientation Flexural (F) Proc. A Properties - ETW (130°F)
Partial Fiber (PF) Fill
Measured Strength
Markforged Onyx FR-A™ - Carbon Fiber FR-A™ / Markforged X7
Machine #
AM Batch #
Machine #
AM Batch #
Flexural Strength [ksi]
0
1
2
3
4
0.0
2.0
4.0
6.0
8.0
10.0
12.0
14.0


XZ Orientation Flexural (F) Proc. A Properties - ETW (130°F)
Partial Fiber (PF) Fill
Measured 2% Offset Yield Strength
Markforged Onyx FR-A™ - Carbon Fiber FR-A™ / Markforged X7
Machine #
AM Batch #
Machine #
AM Batch #
Flexural 2% Offset Yield Strength [ksi]
0.00
2.00
4.00
6.00
8.00
10.00
12.00
14.00
0
1
2
3
4


XZ Orientation Flexural (F) Proc. A Properties - ETW (130°F)
Partial Fiber (PF) Fill
Measured Modulus
Markforged Onyx FR-A™ - Carbon Fiber FR-A™ / Markforged
Machine #
AM Batch #
Machine #
AM Batch #
Flexural Modulus [Msi]
0
1
2
3
4
0.00
0.10
0.20
0.30
0.40
0.50
0.60
0.70
0.80
0.90

4.16 **XZ FF Flex Properties**

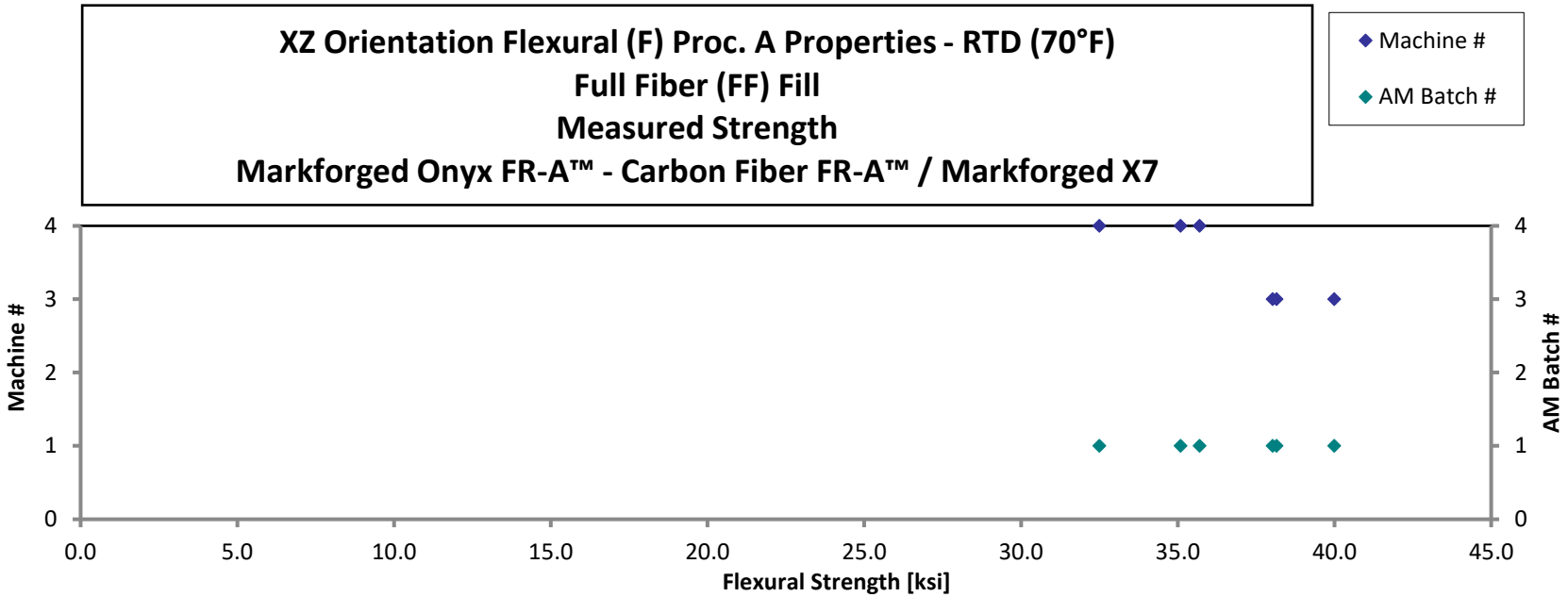
4.16.1 **RTD Condition**

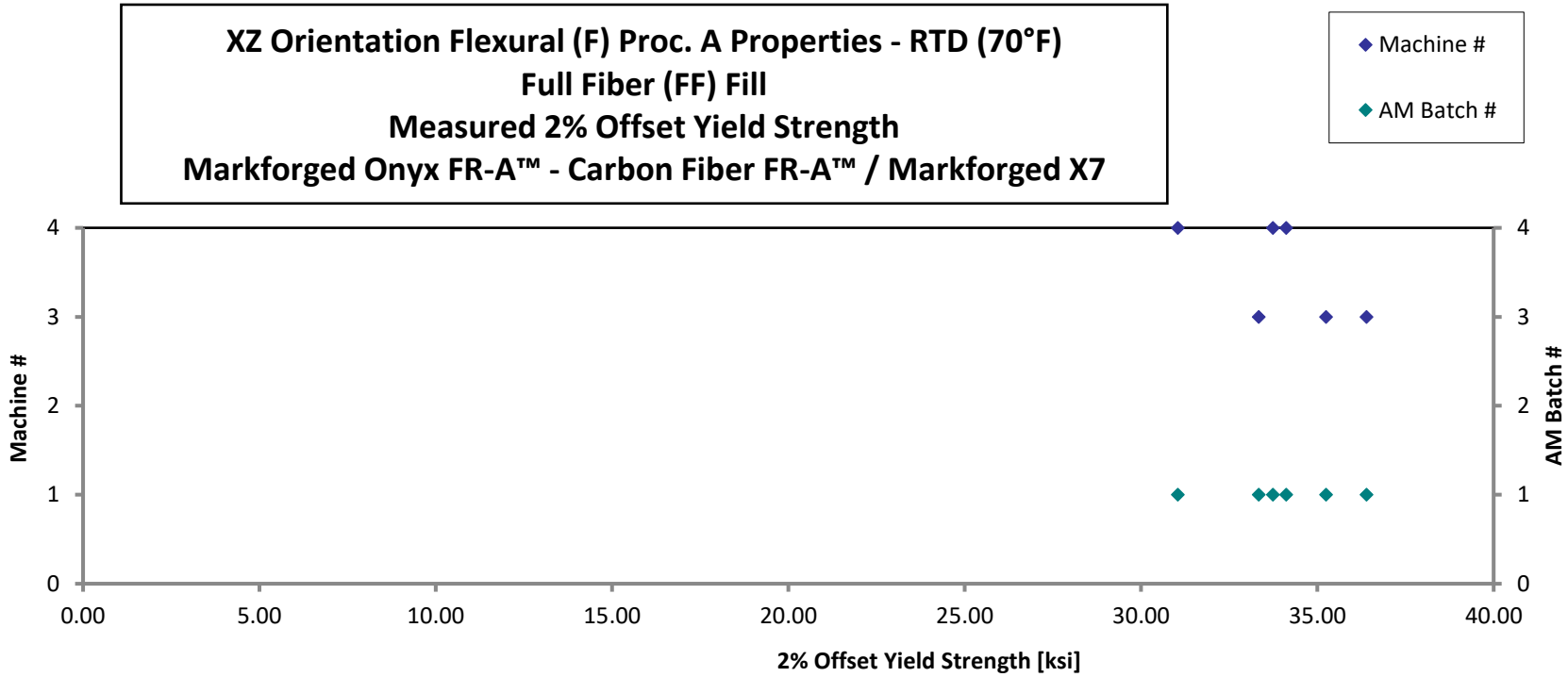
XZ Orientation Flexural (F) Proc. A Properties - RTD (70°F)
Full Fiber (FF) Fill
Strength & Modulus
Markforged Onyx FR-A™ - Carbon Fiber FR-A™ / Markforged X7

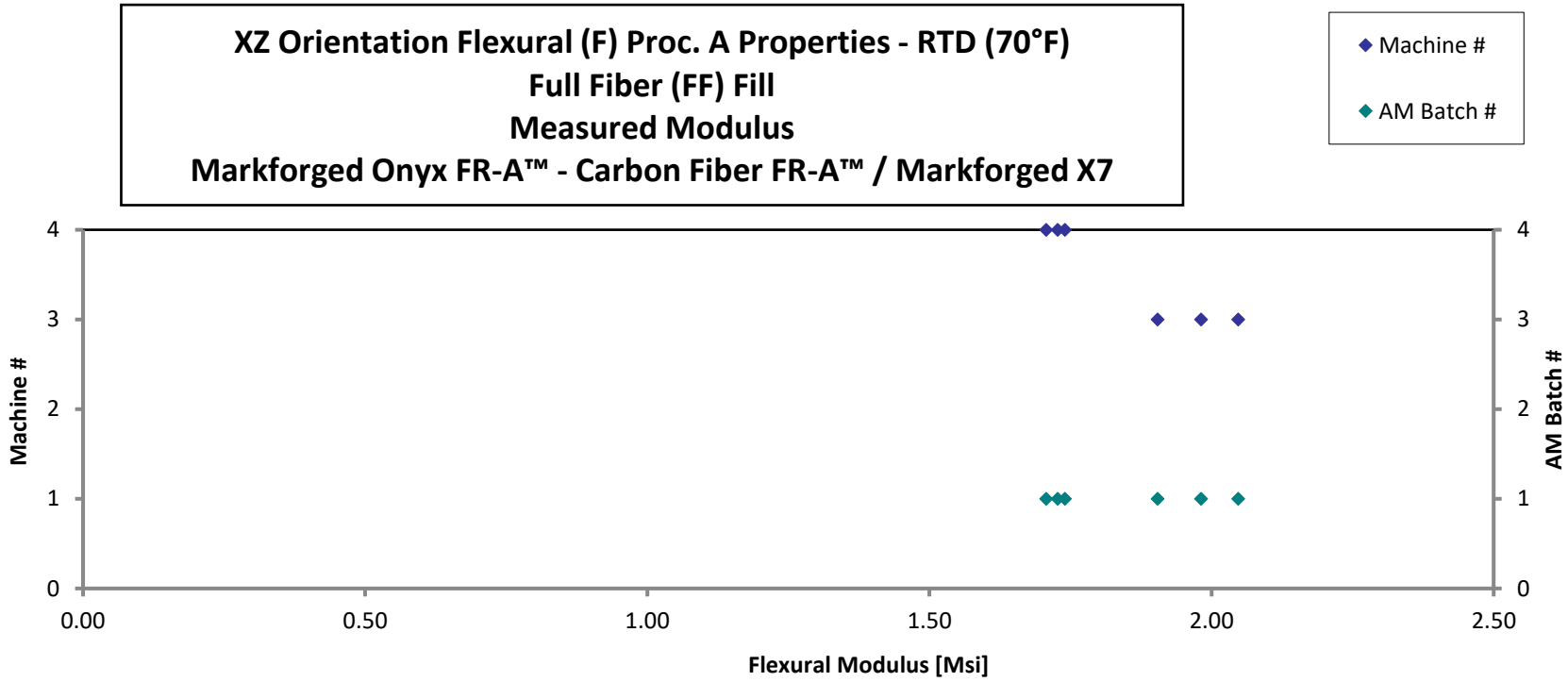
Specimen Number	AM Batch #	Machine #	Flexural Strength [ksi]	2% Offset Yield Strength [ksi]	Flexural Modulus [Msi]	Avg. Specimen Thickness [in]	Failure Mode
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M3-P34051-XZ-F-11-RTD-FF-1	1	3	38.15	36.40	1.904	0.146	TAB
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M3-P34059-XZ-F-12-RTD-FF-2	1	3	40.00	35.24	1.981	0.144	TAB
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M3-P34369-XZ-F-13-RTD-FF-3	1	3	38.03	33.34	2.047	0.142	TAB
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M4-P41548-XZ-F-11-RTD-FF-1*	1	4	35.69	33.74	1.740	0.142	TAB
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M4-P42161-XZ-F-12-RTD-FF-2*	1	4	32.50	31.05	1.707	0.143	TAB
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M4-P42319-XZ-F-13-RTD-FF-3*	1	4	35.09	34.12	1.727	0.142	TAB

*Modulus calculation used 8000-12000 microstrain

Average	**36.57**	**33.98**	**1.851**	**0.143**
Standard Dev.	**2.680**	**1.818**	**0.146**	
Coeff. of Var. [%]	**7.328**	**5.351**	**7.892**	
Min.	**32.50**	**31.05**	**1.707**	**0.142**
Max.	**40.00**	**36.40**	**2.047**	**0.146**
Number of Spec.	**6**	**6**	**6**	**6**


XZ Orientation Flexural (F) Proc. A Properties - RTD (70°F)
Full Fiber (FF) Fill
Measured Strength
Markforged Onyx FR-A™ - Carbon Fiber FR-A™ / Markforged X7
Machine #
AM Batch #
Machine #
AM Batch #
Flexural Strength [ksi]
0
1
2
3
4
0.0
5.0
10.0
15.0
20.0
25.0
30.0
35.0
40.0
45.0


XZ Orientation Flexural (F) Proc. A Properties - RTD (70°F)
Full Fiber (FF) Fill
Measured 2% Offset Yield Strength
Markforged Onyx FR-A™ - Carbon Fiber FR-A™ / Markforged X7
Machine #
AM Batch #
Machine #
AM Batch #
0
1
2
3
4
0.00
5.00
10.00
15.00
20.00
25.00
30.00
35.00
40.00
2% Offset Yield Strength [ksi]


XZ Orientation Flexural (F) Proc. A Properties - RTD (70°F)
Full Fiber (FF) Fill
Measured Modulus
Markforged Onyx FR-A™ - Carbon Fiber FR-A™ / Markforged X7
Machine #
AM Batch #
Machine #
AM Batch #
Flexural Modulus [Msi]
0
1
2
3
4
0.00
0.50
1.00
1.50
2.00
2.50

4.17 **ZX PF Flex Properties – Reference Only**

4.17.1 **CTD Condition**

ZX Orientation Flexural (F) Proc. A Properties - CTD (-65°F)
Partial Fiber (PF) Fill
Strength & Modulus
Markforged Onyx FR-A™ - Carbon Fiber FR-A™ / Markforged X7

Specimen Number	AM Batch #	Machine #	Avg. Specimen Thickness [in]	Flexural Strength [ksi]	Flexural 2% Offset Yield Strength [ksi]	Flexural Modulus [Msi]	Failure Mode
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M1-P30784-ZX-F-11-CTD-PF-1	1	1	0.140	6.758		0.477	CAT, TAB
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M1-P30894-ZX-F-12-CTD-PF-2*	1	1	0.140	4.812		0.413	TAB
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M1-P31226-ZX-F-13-CTD-PF-3	1	1	0.140	2.485		0.443	TAB
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M1-P31311-ZX-F-13-CTD-PF-SP	1	1	0.140	2.312		0.491	CAT, TAB
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M2-P30783-ZX-F-11-CTD-PF-1	1	2	0.142	3.929		0.435	CAT, TAB
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M2-P30893-ZX-F-12-CTD-PF-2***	1	2	0.140			0.475	CAT, TAB
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M2-P31255-ZX-F-13-CTD-PF-3	1	2	0.140	3.250		0.501	TAB
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M2-P31300-ZX-F-13-CTD-PF-SP	1	2	0.140	3.607		0.476	TAB
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-B-M1-P33130-ZX-F-11-CTD-PF-1	2	1	0.138	5.322		0.419	CAT, TAB
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-B-M1-P33879-ZX-F-12-CTD-PF-2	2	1	0.138	3.434		0.443	TAB
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-B-M1-P34106-ZX-F-13-CTD-PF-3	2	1	0.140	3.643		0.437	TAB
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-B-M1-P34367-ZX-F-13-CTD-PF-SP	2	1	0.139	5.823		0.440	CAT, TAB
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-B-M2-P33132-ZX-F-11-CTD-PF-1	2	2	0.139	5.786		0.468	CAT, TAB
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-B-M2-P33878-ZX-F-12-CTD-PF-2	2	2	0.140	5.953		0.459	CAT, TAB
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-B-M2-P34107-ZX-F-13-CTD-PF-3**	2	2	0.140			0.465	TAB
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-B-M2-P34383-ZX-F-13-CTD-PF-SP	2	2	0.141	5.672		0.454	CAT, TAB
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-C-M2-P35020-ZX-F-11-CTD-PF-1	3	2	0.141	5.564		0.446	CAT, TAB
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-C-M2-P35186-ZX-F-12-CTD-PF-2	3	2	0.140	3.214		0.474	TAB
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-C-M2-P36353-ZX-F-13-CTD-PF-3	3	2	0.142	4.984		0.466	TAB
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-C-M2-P35842-ZX-F-13-CTD-PF-SP	3	2	0.141	3.553		0.484	TAB

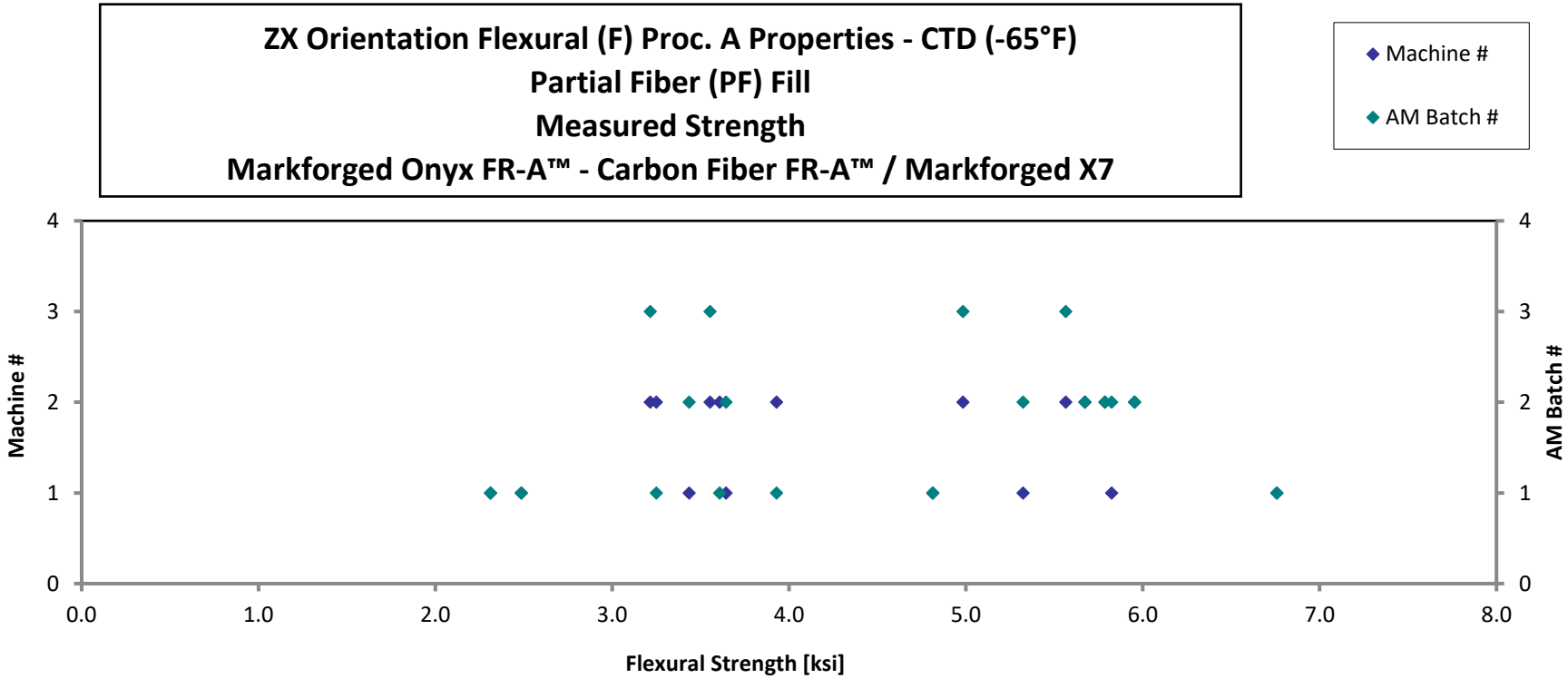
Note: 0.2% offset yield strength not reported for all specimens due to specimen failure before 0.2% offset strain.

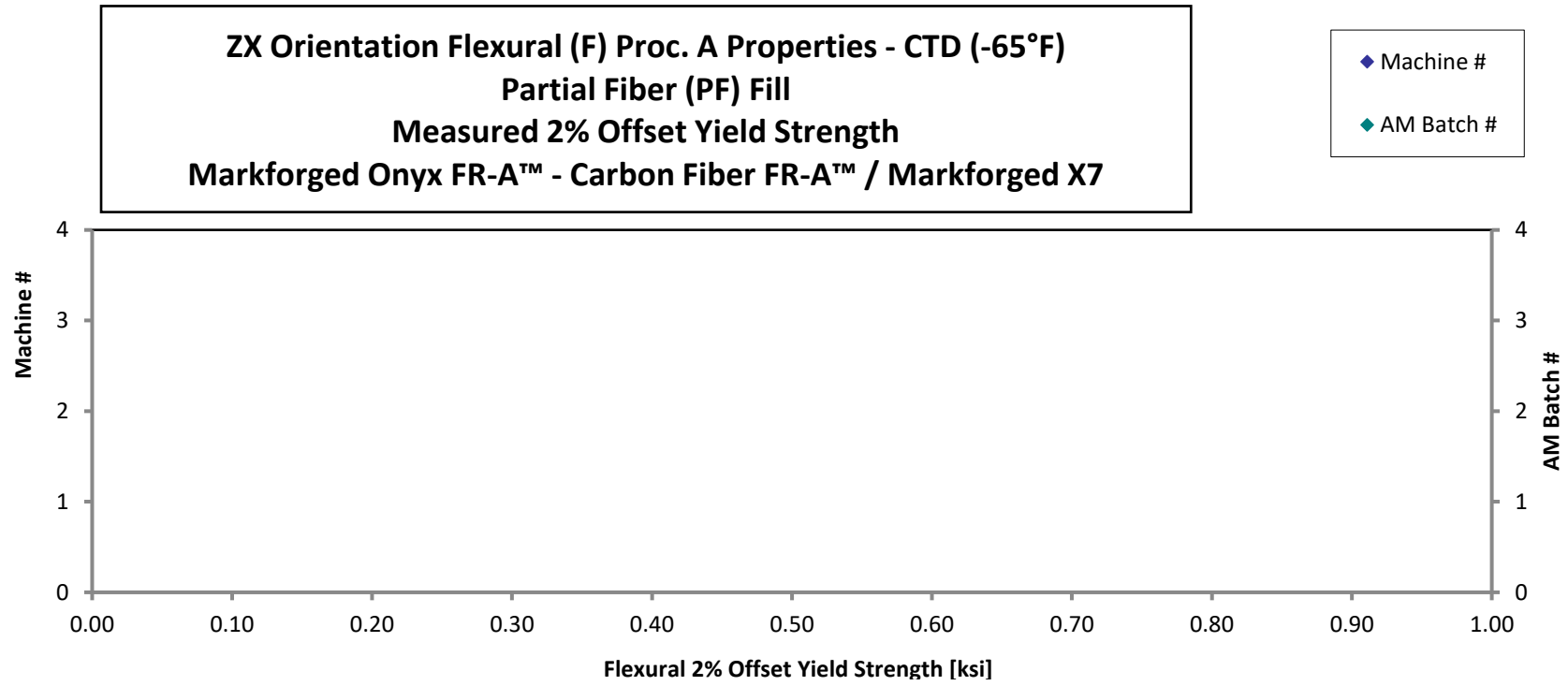
*Modulus calculation used 1000-2500 microstrain

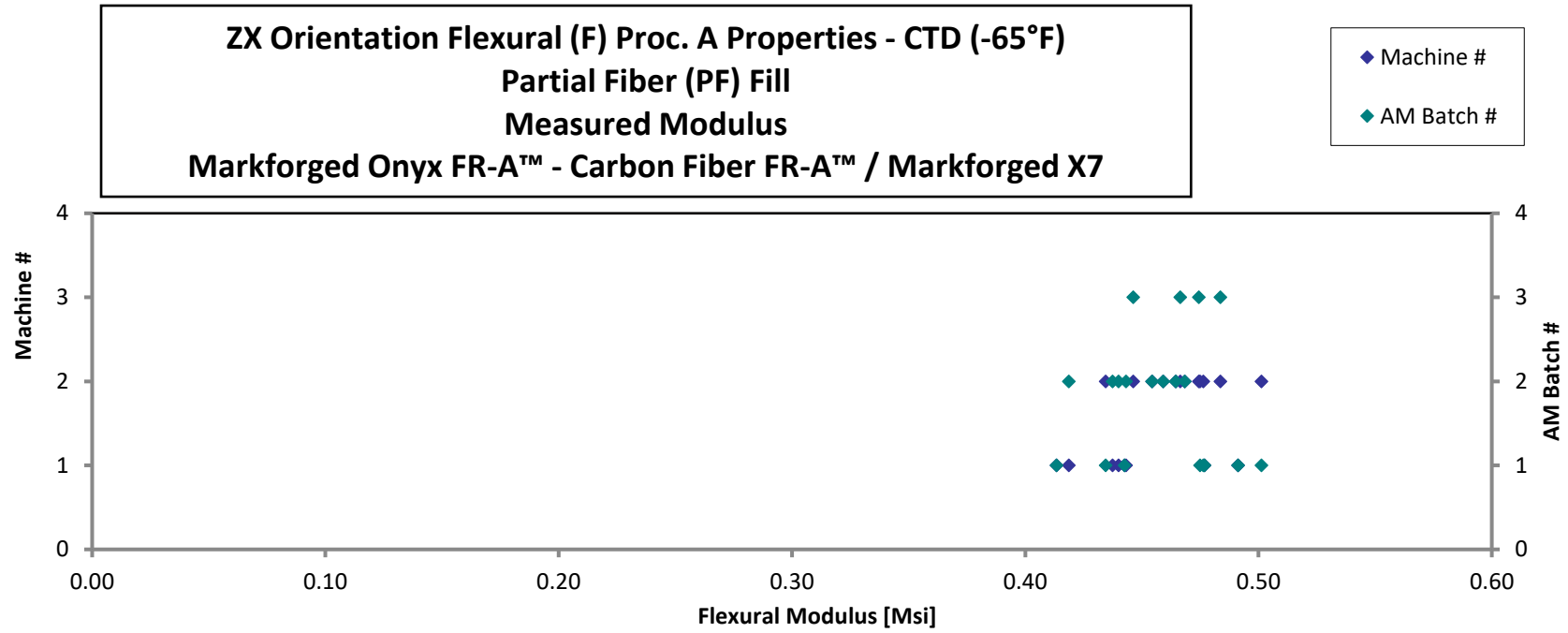
**Strength value not reported due to specimen failure at unusual low load.

***Strength value not reported due to specimen failure at unusual high load.

Average	**0.140**	**4.450**		**0.458**
Standard Dev.		**1.329**		**0.024**
Coeff. of Var. [%]		**29.87**		**5.138**
Min.	**0.138**	**2.312**		**0.413**
Max.	**0.142**	**6.758**		**0.501**
Number of Spec.	**20**	**18**		**20**


ZX Orientation Flexural (F) Proc. A Properties - CTD (-65°F)
Partial Fiber (PF) Fill
Measured Strength
Markforged Onyx FR-A™ - Carbon Fiber FR-A™ / Markforged X7
Machine #
AM Batch #
Machine #
AM Batch #
Flexural Strength [ksi]
0
1
2
3
4
0.0
1.0
2.0
3.0
4.0
5.0
6.0
7.0
8.0


ZX Orientation Flexural (F) Proc. A Properties - CTD (-65°F)
Partial Fiber (PF) Fill
Measured 2% Offset Yield Strength
Markforged Onyx FR-A™ - Carbon Fiber FR-A™ / Markforged X7
Machine #
AM Batch #
Machine #
AM Batch #
0
1
2
3
4
0.00
0.10
0.20
0.30
0.40
0.50
0.60
0.70
0.80
0.90
1.00
Flexural 2% Offset Yield Strength [ksi]


ZX Orientation Flexural (F) Proc. A Properties - CTD (-65°F)
Partial Fiber (PF) Fill
Measured Modulus
Markforged Onyx FR-A™ - Carbon Fiber FR-A™ / Markforged X7
Machine #
AM Batch #
Machine #
AM Batch #
Flexural Modulus [Msi]
0
1
2
3
4
0.00
0.10
0.20
0.30
0.40
0.50
0.60

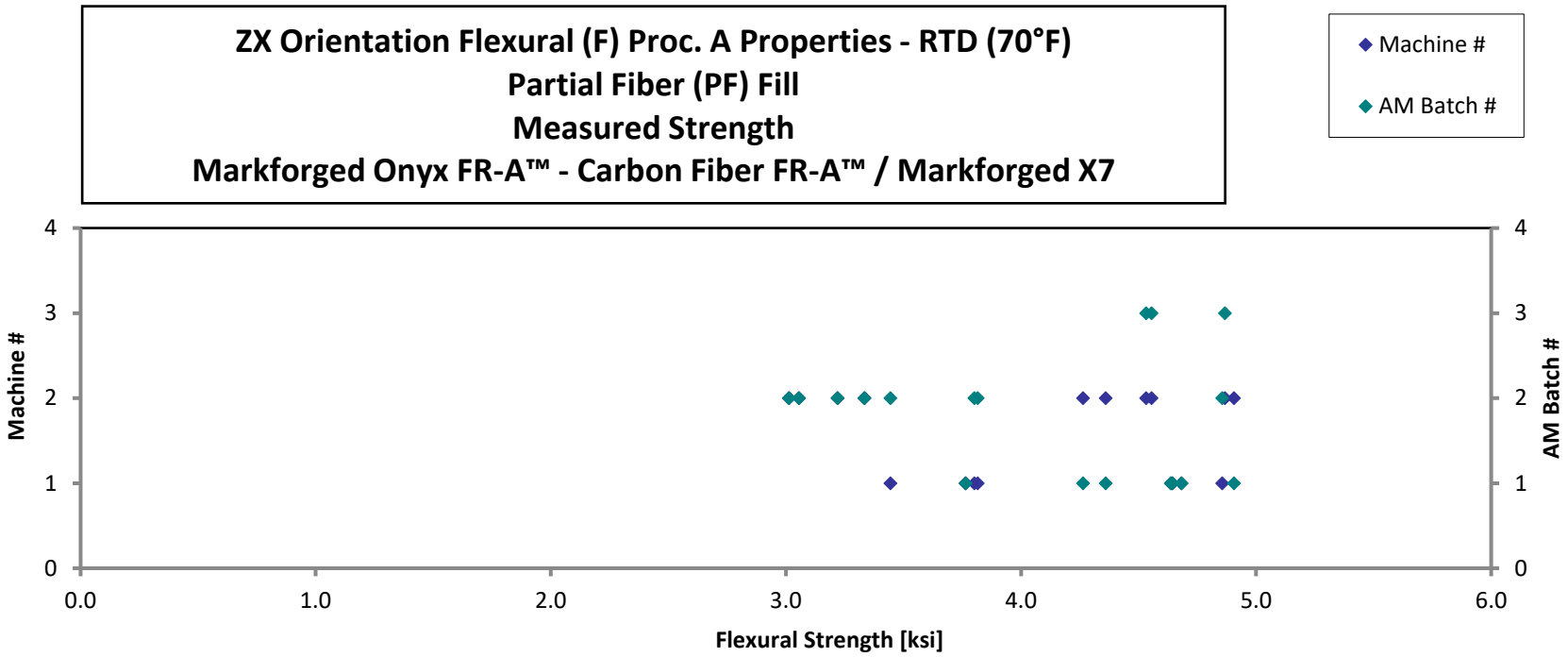
4.17.2 **RTD Condition**

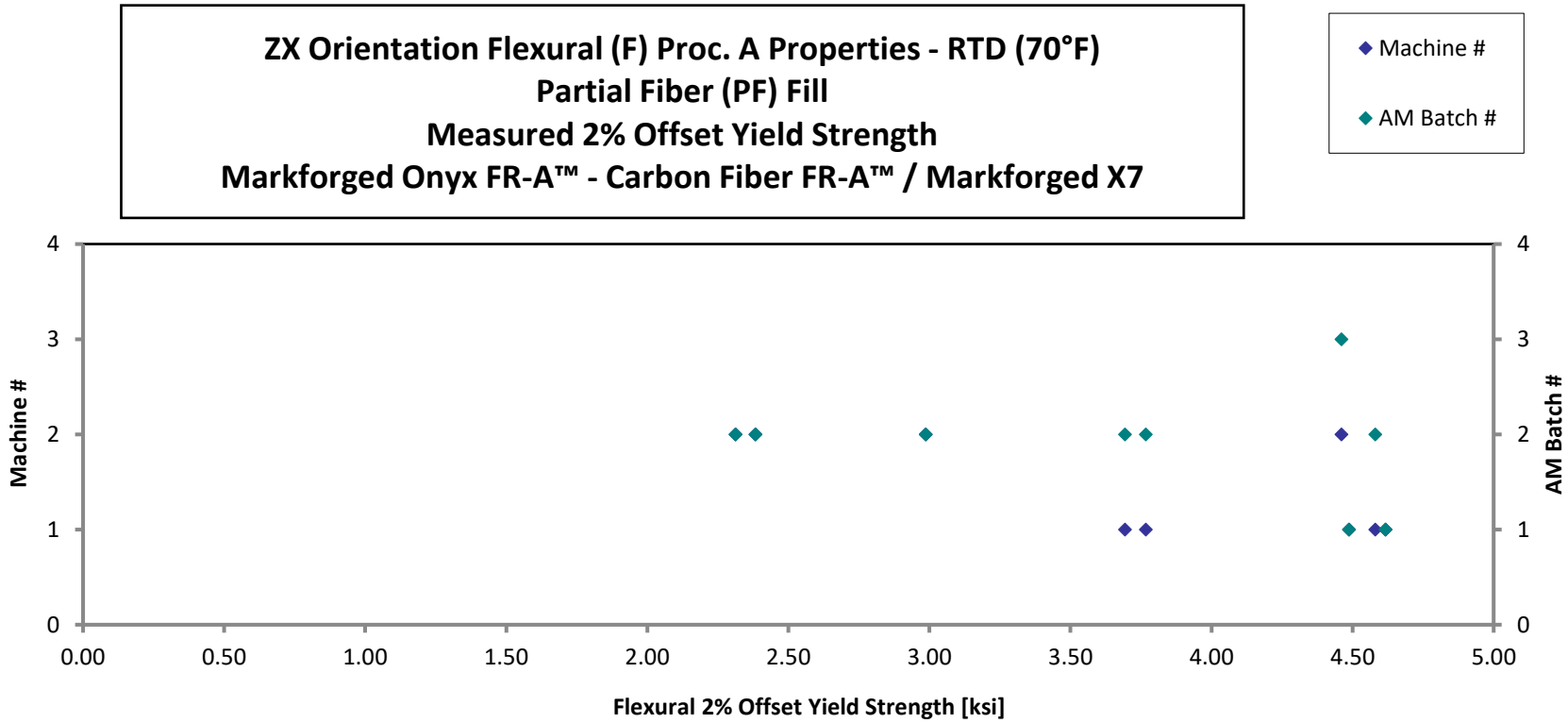
ZX Orientation Flexural (F) Proc. A Properties - RTD (70°F)
Partial Fiber (PF) Fill
Strength & Modulus
Markforged Onyx FR-A™ - Carbon Fiber FR-A™ / Markforged X7

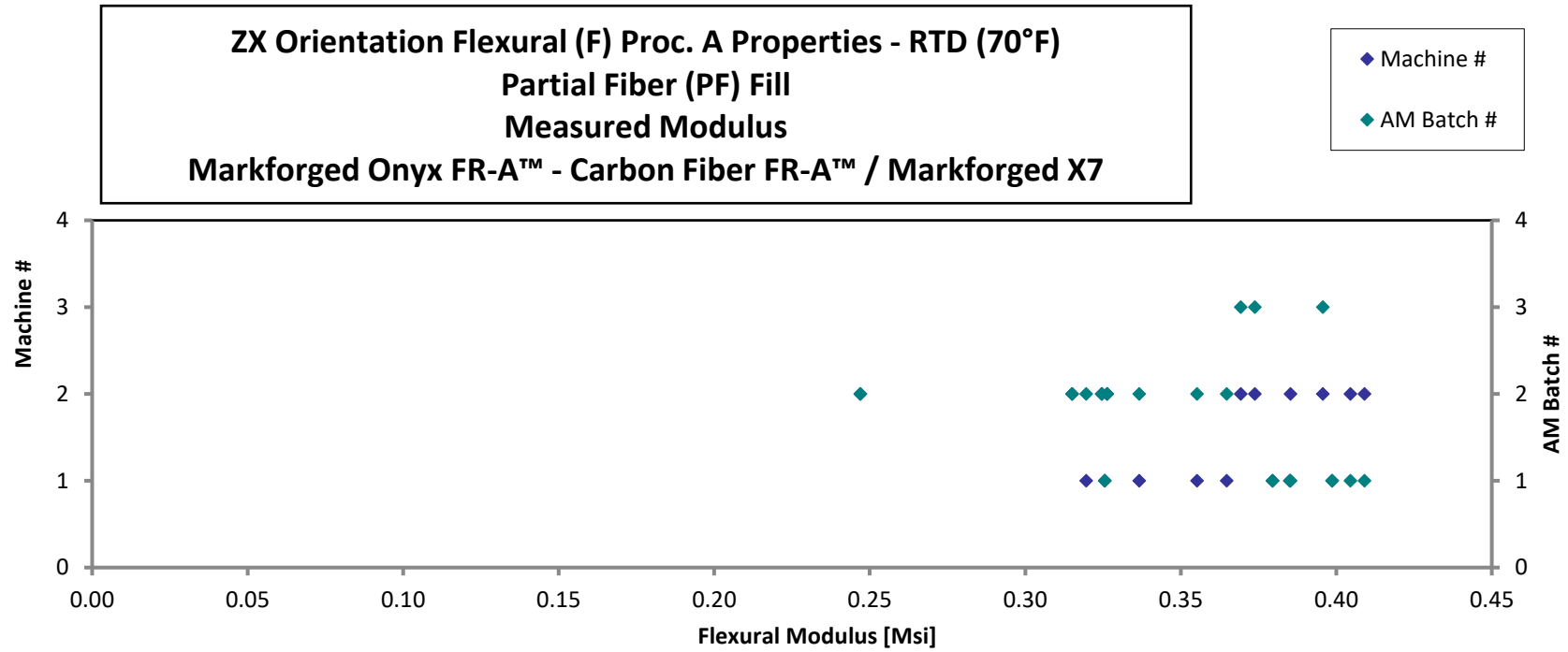
Specimen Number	AM Batch #	Machine #	Avg. Specimen Thickness [in]	Flexural Strength [ksi]	Flexural 2% Offset Yield Strength [ksi]	Flexural Modulus [Msi]	Failure Mode
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M1-P30784-ZX-F-11-RTD-PF-1	1	1	0.143	4.682	4.616	0.399	TAB
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M1-P30894-ZX-F-12-RTD-PF-2	1	1	0.143	4.644	4.487	0.385	TAB
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M1-P31226-ZX-F-13-RTD-PF-3*	1	1	0.143	3.764		0.326	TAB
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M1-P31311-ZX-F-13-RTD-PF-SP*	1	1	0.141	4.637		0.379	TAB
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M2-P30783-ZX-F-11-RTD-PF-1*	1	2	0.142	4.360		0.385	TAB
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M2-P30893-ZX-F-12-RTD-PF-2*	1	2	0.142	4.264		0.405	TAB
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M2-P31255-ZX-F-13-RTD-PF-3*	1	2	0.142	4.906		0.409	CAT, TAB
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-B-M1-P33130-ZX-F-11-RTD-PF-1	2	1	0.141	4.856	4.581	0.365	TAB
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-B-M1-P33879-ZX-F-12-RTD-PF-2	2	1	0.141	3.815	3.767	0.355	TAB
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-B-M1-P34106-ZX-F-13-RTD-PF-3*	2	1	0.141	3.445		0.320	TAB
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-B-M1-P34367-ZX-F-13-RTD-PF-SP	2	1	0.141	3.801	3.693	0.337	TAB
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-B-M2-P33132-ZX-F-11-RTD-PF-1	2	2	0.140	3.055	2.383	0.247	TAB, SAM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-B-M2-P33878-ZX-F-12-RTD-PF-2*	2	2	0.141	3.334		0.326	TAB, SAM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-B-M2-P34107-ZX-F-13-RTD-PF-3	2	2	0.140	3.220	2.313	0.315	TAB, SAM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-B-M2-P34383-ZX-F-13-RTD-PF-SP	2	2	0.141	3.013	2.987	0.325	TAB, SAM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-C-M2-P35020-ZX-F-11-RTD-PF-1*	3	2	0.143	4.867		0.396	TAB
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-C-M2-P35186-ZX-F-12-RTD-PF-2	3	2	0.142	4.532	4.461	0.369	TAB
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-C-M2-P36353-ZX-F-12-RTD-PF-3*	3	2	0.142	4.556		0.374	TAB

*0.2% offset yield strength not reported for all specimens due to specimen failure before 0.2% offset strain.

Average	**0.142**	**4.097**	**3.699**	**0.356**
Standard Dev.		**0.667**	**0.934**	**0.042**
Coeff. of Var. [%]		**16.29**	**25.26**	**11.67**
Min.	**0.140**	**3.013**	**2.313**	**0.247**
Max.	**0.143**	**4.906**	**4.616**	**0.409**
Number of Spec.	**18**	**18**	**9**	**18**


ZX Orientation Flexural (F) Proc. A Properties - RTD (70°F)
Partial Fiber (PF) Fill
Measured Strength
Markforged Onyx FR-A™ - Carbon Fiber FR-A™ / Markforged X7
Machine #
AM Batch #
Machine #
AM Batch #
Flexural Strength [ksi]
0
1
2
3
4
0.0
1.0
2.0
3.0
4.0
5.0
6.0


ZX Orientation Flexural (F) Proc. A Properties - RTD (70°F)
Partial Fiber (PF) Fill
Measured 2% Offset Yield Strength
Markforged Onyx FR-A™ - Carbon Fiber FR-A™ / Markforged X7
Machine #
AM Batch #
Machine #
AM Batch #
0
1
2
3
4
0.00
0.50
1.00
1.50
2.00
2.50
3.00
3.50
4.00
4.50
5.00
Flexural 2% Offset Yield Strength [ksi]


ZX Orientation Flexural (F) Proc. A Properties - RTD (70°F)
Partial Fiber (PF) Fill
Measured Modulus
Markforged Onyx FR-A™ - Carbon Fiber FR-A™ / Markforged X7
Machine #
AM Batch #
Machine #
AM Batch #
Flexural Modulus [Msi]
0
1
2
3
4
0.00
0.05
0.10
0.15
0.20
0.25
0.30
0.35
0.40
0.45

4.18 ZX NF Flex Properties

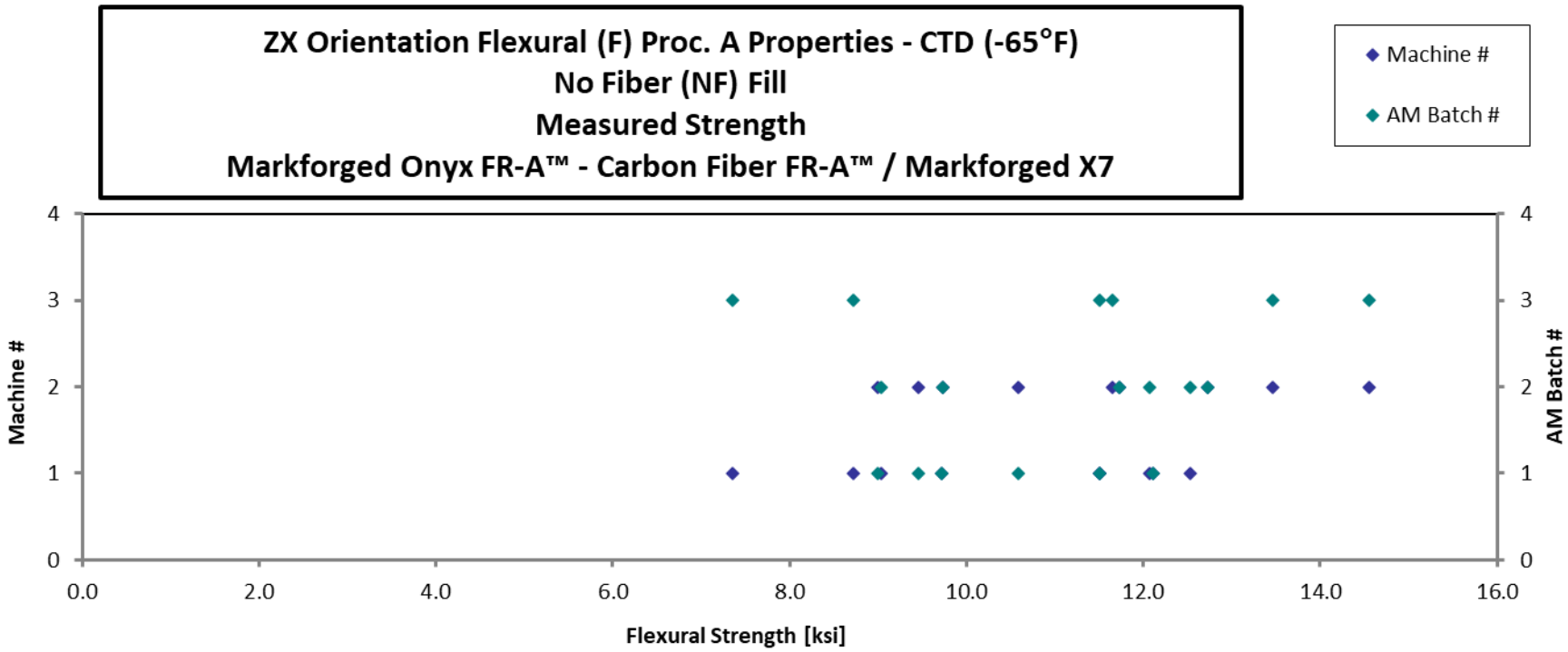
4.18.1 CTD Condition

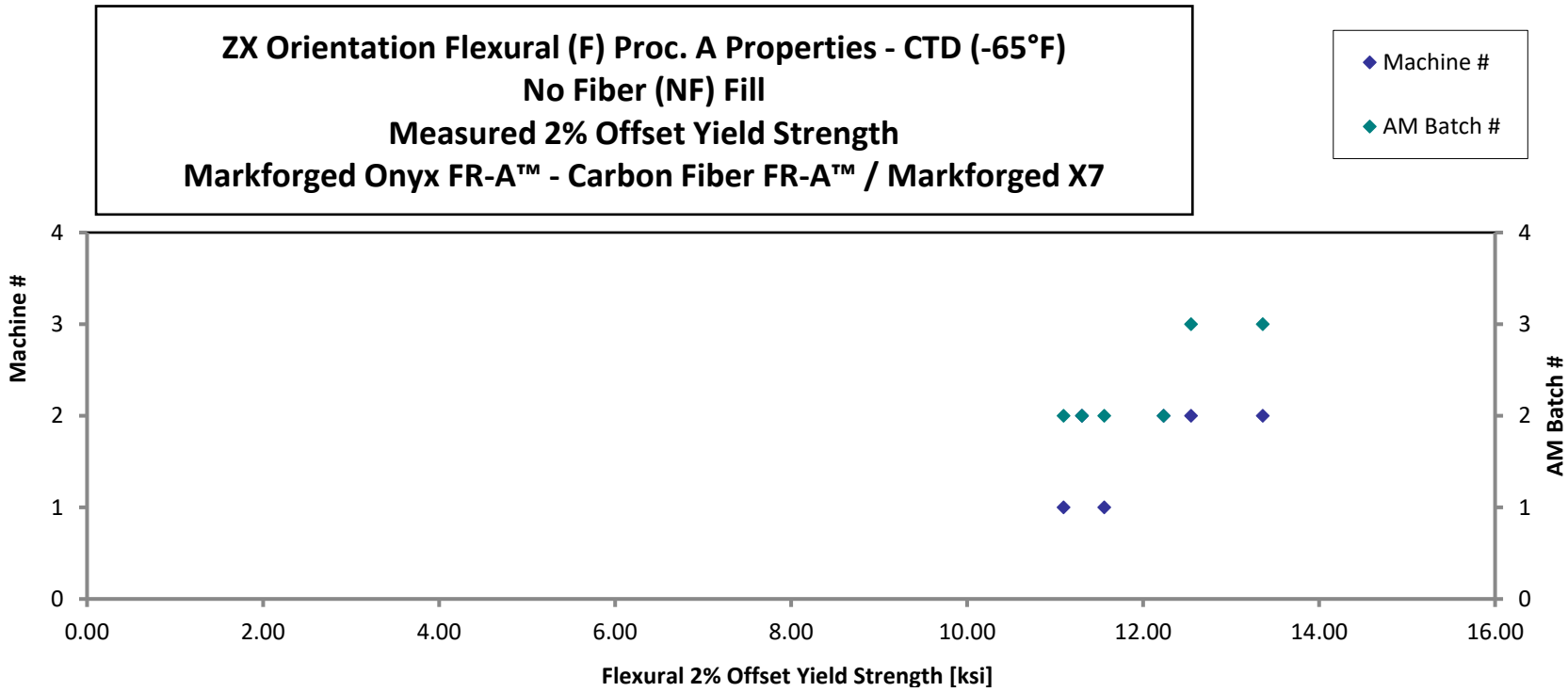
ZX Orientation Flexural (F) Proc. A Properties - CTD (-65°F)
No Fiber (NF) Fill
Strength & Modulus
Markforged Onyx FR-A™ - Carbon Fiber FR-A™ / Markforged X7

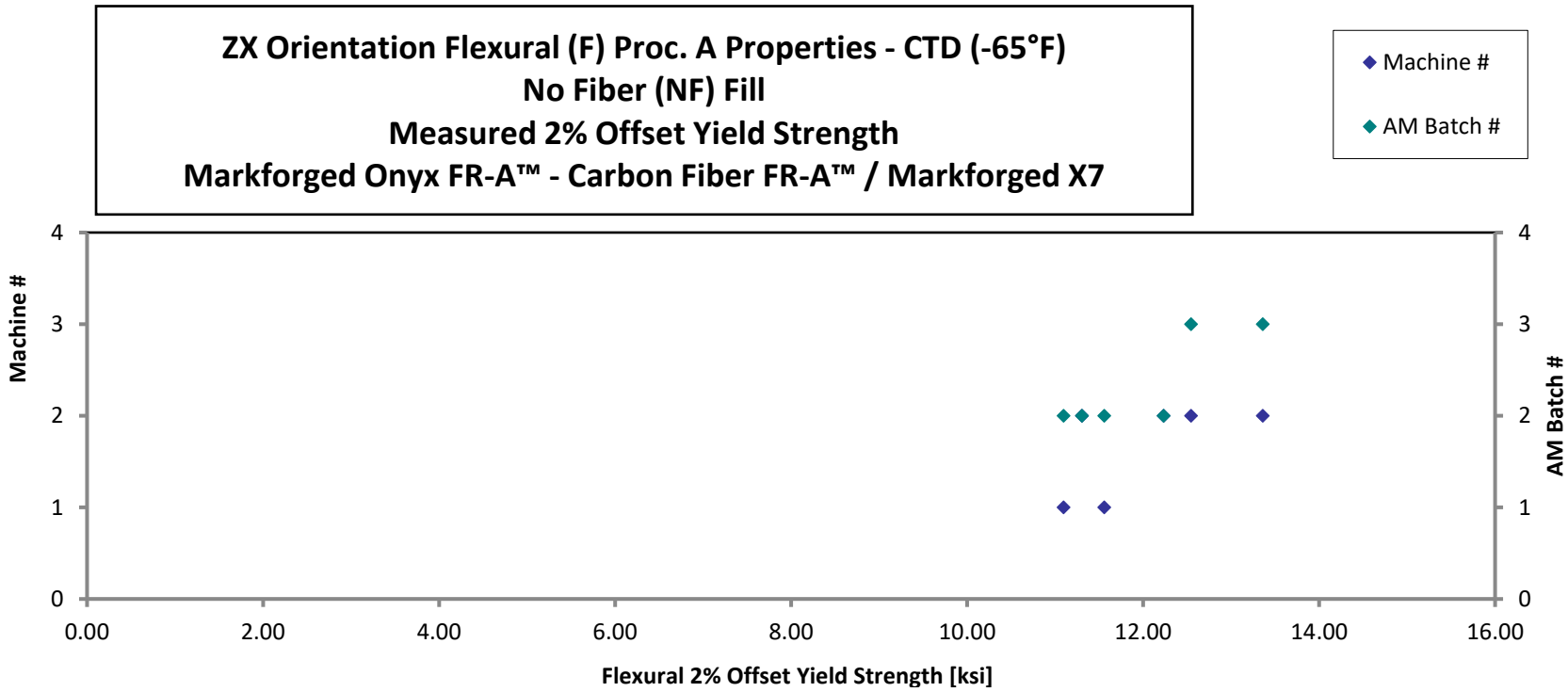
Specimen Number	AM Batch #	Machine #	Avg. Specimen Thickness [in]	Flexural Strength [ksi]	Flexural 2% Offset Yield Strength [ksi]	Flexural Modulus [Msi]	Failure Mode
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M1-P61751-ZX-F-11-CTD-NF-1*	1	1	0.147	9.721		0.636	CAT, TAB
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M1-P61817-ZX-F-12-CTD-NF-2*	1	1	0.142	11.50		0.586	CAT, TAB
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M1-P61132-ZX-F-13-CTD-NF-3*	1	1	0.142	12.11		0.524	CAT, TAB
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M2-P61255-ZX-F-11-CTD-NF-1*	1	2	0.147	10.58		0.552	CAT, TAB
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M2-P61818-ZX-F-12-CTD-NF-2*	1	2	0.143	8.995		0.586	CAT, TAB
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M2-P60434-ZX-F-13-CTD-NF-3*	1	2	0.142	9.462		0.631	CAT, TAB
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-B-M1-P66639-ZX-F-11-CTD-NF-1*	2	1	0.147	9.033		0.529	CAT, TAB
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-B-M1-P63018-ZX-F-12-CTD-NF-2	2	1	0.142	12.52	11.10	0.540	CAT, TAB
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-B-M1-P62411-ZX-F-13-CTD-NF-3	2	1	0.141	12.07	11.56	0.538	CAT, TAB
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-B-M2-P63352-ZX-F-11-CTD-NF-1*	2	2	0.147	9.736		0.550	CAT, TAB
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-B-M2-P63506-ZX-F-12-CTD-NF-2	2	2	0.140	12.72	12.23	0.519	CAT, TAB
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-B-M2-P62412-ZX-F-13-CTD-NF-3	2	2	0.141	11.72	11.31	0.553	CAT, TAB
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-C-M1-P64991-ZX-F-11-CTD-NF-1*	3	1	0.147	8.721		0.531	CAT, TAB
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-C-M1-P65365-ZX-F-12-CTD-NF-2*	3	1	0.141	11.50		0.563	CAT, TAB
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-C-M1-P64600-ZX-F-13-CTD-NF-3*	3	1	0.142	7.355		0.532	CAT, TAB
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-C-M2-P65426-ZX-F-11-CTD-NF-1	3	2	0.145	13.46	13.36	0.572	CAT, TAB
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-C-M2-P65831-ZX-F-12-CTD-NF-2	3	2	0.142	14.55	12.54	0.599	CAT, TAB
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-C-M2-P65281-ZX-F-13-CTD-NF-3*	3	2	0.139	11.65		0.561	CAT, TAB

*0.2% offset yield strength not reported due to specimen failure before 0.2% offset strain.

Average	**0.143**	**10.97**	**12.02**	**0.561**
Standard Dev.		**1.877**	**0.859**	**0.035**
Coeff. of Var. [%]		**17.12**	**7.147**	**6.202**
Min.	**0.139**	**7.355**	**11.10**	**0.519**
Max.	**0.147**	**14.55**	**13.36**	**0.636**
Number of Spec.	**18**	**18**	**6**	**18**


ZX Orientation Flexural (F) Proc. A Properties - CTD (-65°F)
No Fiber (NF) Fill
Measured Strength
Markforged Onyx FR-A™ - Carbon Fiber FR-A™ / Markforged X7
Machine #
AM Batch #
Machine #
AM Batch #
Flexural Strength [ksi]
0.0
2.0
4.0
6.0
8.0
10.0
12.0
14.0
16.0
0
1
2
3
4


ZX Orientation Flexural (F) Proc. A Properties - CTD (-65°F)
No Fiber (NF) Fill
Measured 2% Offset Yield Strength
Markforged Onyx FR-A™ - Carbon Fiber FR-A™ / Markforged X7
Machine #
AM Batch #
Machine #
AM Batch #
0
1
2
3
4
0.00
2.00
4.00
6.00
8.00
10.00
12.00
14.00
16.00
Flexural 2% Offset Yield Strength [ksi]


ZX Orientation Flexural (F) Proc. A Properties - CTD (-65°F)
No Fiber (NF) Fill
Measured 2% Offset Yield Strength
Markforged Onyx FR-A™ - Carbon Fiber FR-A™ / Markforged X7
Machine #
AM Batch #
Machine #
AM Batch #
0
1
2
3
4
0.00
2.00
4.00
6.00
8.00
10.00
12.00
14.00
16.00
Flexural 2% Offset Yield Strength [ksi]

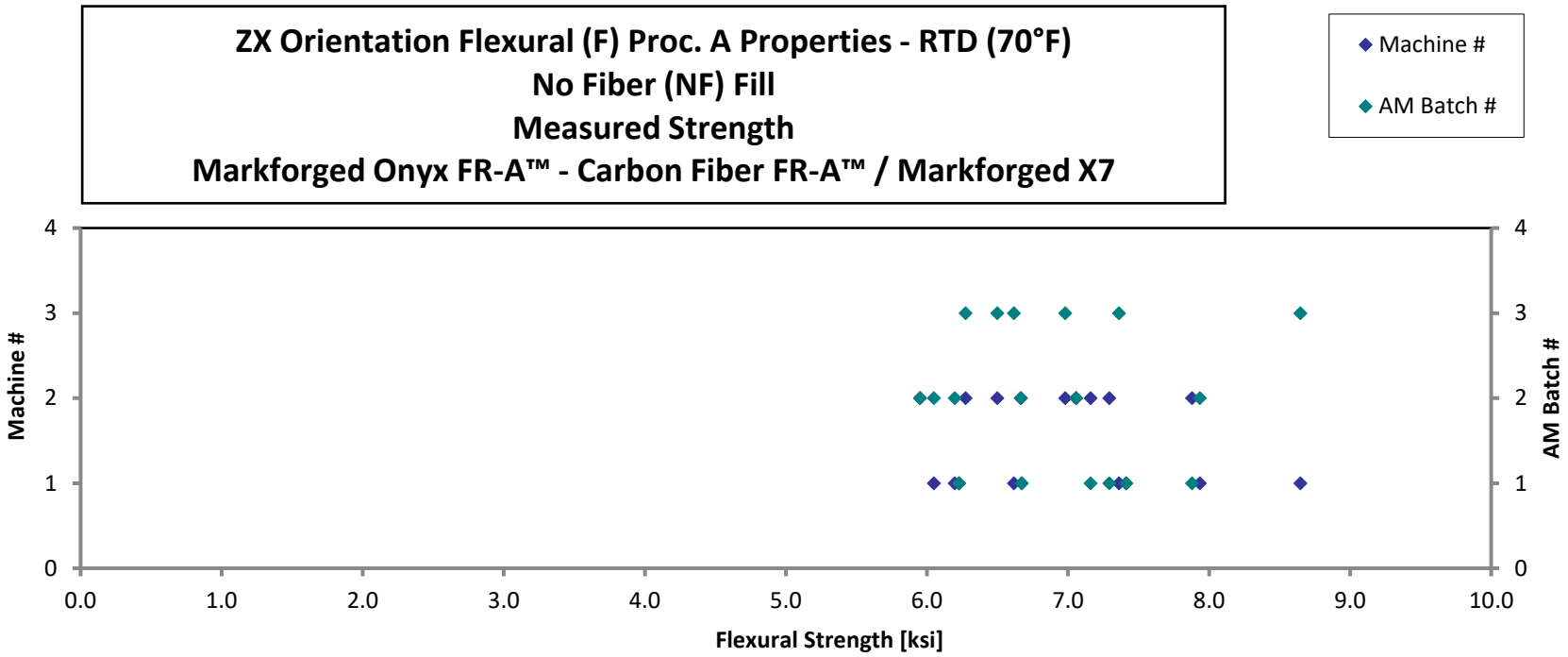
4.18.2 **RTD Condition**

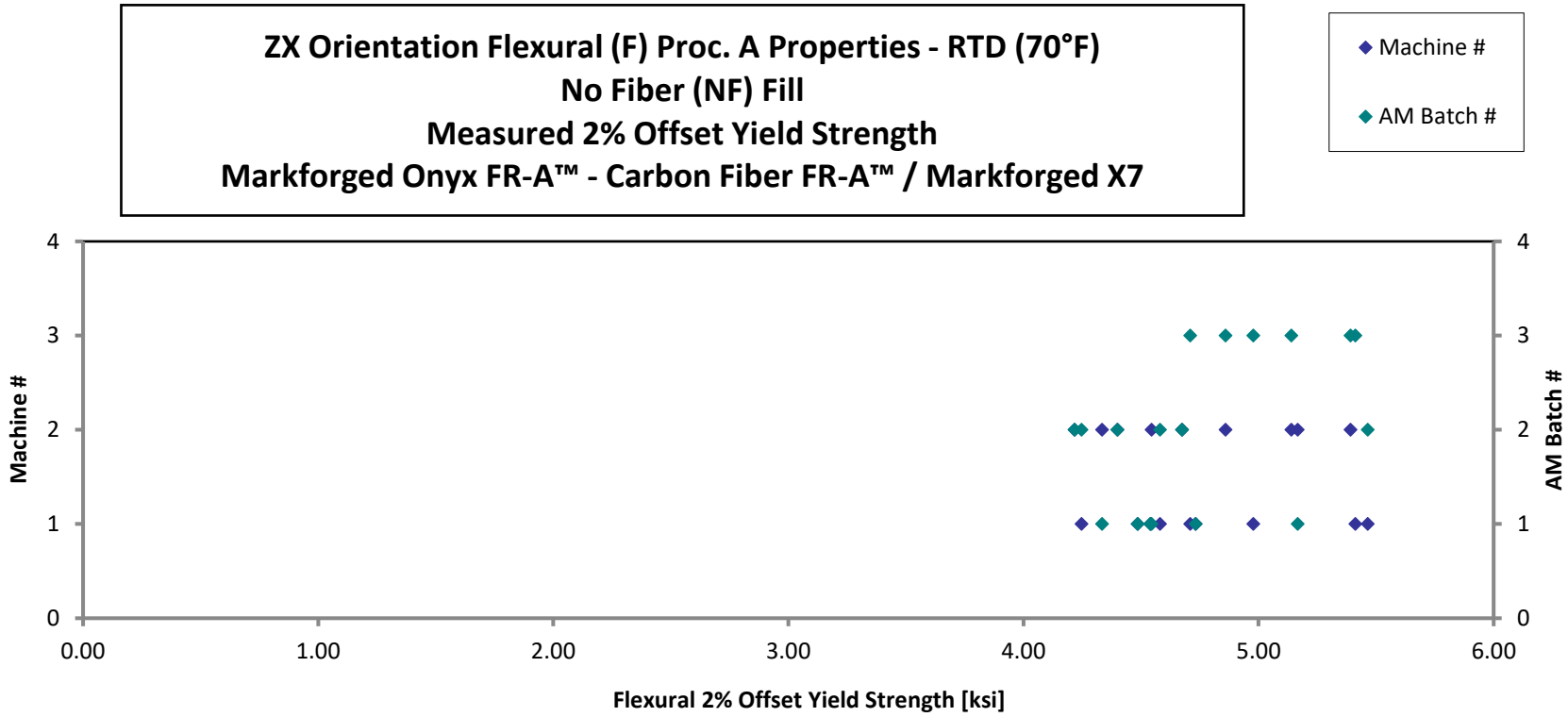
ZX Orientation Flexural (F) Proc. A Properties - RTD (70°F)
No Fiber (NF) Fill
Strength & Modulus
Markforged Onyx FR-A™ - Carbon Fiber FR-A™ / Markforged X7

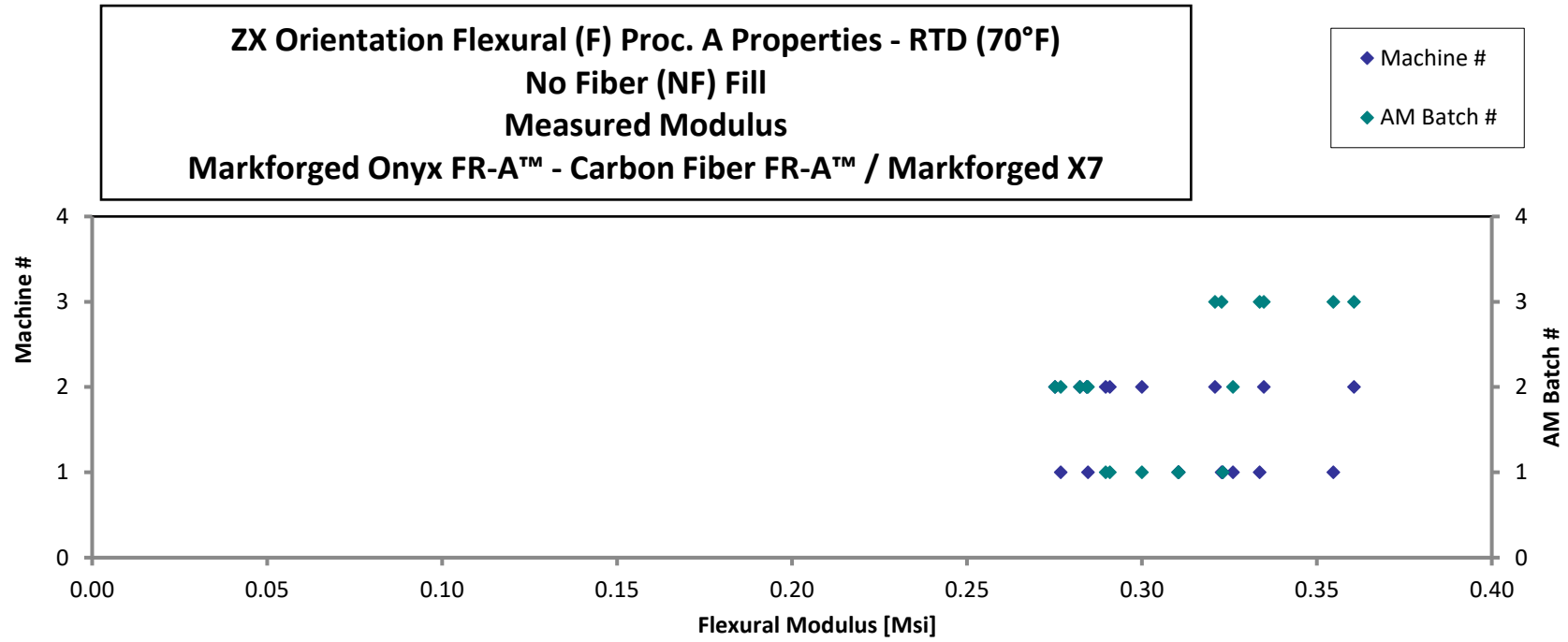
Specimen Number	AM Batch #	Machine #	Avg. Specimen Thickness [in]	Flexural Strength [ksi]	Flexural 2% Offset Yield Strength [ksi]	Flexural Modulus [Msi]	Failure Mode
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M1-P61751-ZX-F-11-RTD-NF-1	1	1	0.147	7.413	4.733	0.323	TAB
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M1-P61817-ZX-F-12-RTD-NF-2	1	1	0.143	6.227	4.486	0.311	TAB
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M1-P61132-ZX-F-13-RTD-NF-3	1	1	0.142	6.671	4.540	0.310	CAT, TAB
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M2-P61255-ZX-F-11-RTD-NF-1*	1	2	0.146	7.880	5.166	0.300	CAT, TAB
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M2-P61818-ZX-F-12-RTD-NF-2*	1	2	0.142	7.293	4.544	0.291	CAT, TAB
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M2-P60434-ZX-F-13-RTD-NF-3	1	2	0.142	7.161	4.335	0.290	CAT, TAB
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-B-M1-P66639-ZX-F-11-RTD-NF-1	2	1	0.146	7.934	5.465	0.326	CAT, TAB
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-B-M1-P63018-ZX-F-12-RTD-NF-2	2	1	0.141	6.198	4.580	0.285	TAB
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-B-M1-P62411-ZX-F-13-RTD-NF-3	2	1	0.140	6.048	4.246	0.277	TAB
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-B-M2-P63352-ZX-F-11-RTD-NF-1*	2	2	0.145	7.057	4.675	0.275	CAT, TAB
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-B-M2-P63506-ZX-F-12-RTD-NF-2	2	2	0.140	5.951	4.217	0.284	TAB
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-B-M2-P62412-ZX-F-13-RTD-NF-3	2	2	0.140	6.666	4.400	0.282	CAT, TAB
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-C-M1-P64991-ZX-F-11-RTD-NF-1*	3	1	0.144	8.647	5.412	0.355	CAT, TAB
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-C-M1-P65365-ZX-F-12-RTD-NF-2	3	1	0.141	6.616	4.978	0.323	TAB
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-C-M1-P64600-ZX-F-13-RTD-NF-3	3	1	0.141	7.361	4.709	0.334	CAT, TAB
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-C-M2-P65426-ZX-F-11-RTD-NF-1	3	2	0.144	6.979	5.391	0.361	TAB
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-C-M2-P65831-ZX-F-12-RTD-NF-2	3	2	0.142	6.498	5.140	0.321	TAB
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-C-M2-P65281-ZX-F-13-RTD-NF-3	3	2	0.139	6.274	4.860	0.335	CAT, TAB

Note: Due to inherent material properties, B-basis calculations will be calculated eventhough invalid tests were present.
*Maximum stress was obtained after 5% strain. (Invalid per ASTM D790)

Average	**0.143**	**6.937**	**4.771**	**0.310**
Standard Dev.		**0.732**	**0.403**	**0.026**
Coeff. of Var. [%]		**10.55**	**8.453**	**8.470**
Min.	**0.139**	**5.951**	**4.217**	**0.275**
Max.	**0.147**	**8.647**	**5.465**	**0.361**
Number of Spec.	**18**	**18**	**18**	**18**


ZX Orientation Flexural (F) Proc. A Properties - RTD (70°F)
No Fiber (NF) Fill
Measured Strength
Markforged Onyx FR-A™ - Carbon Fiber FR-A™ / Markforged X7
Machine #
AM Batch #
Machine #
AM Batch #
Flexural Strength [ksi]
0
1
2
3
4
0.0
1.0
2.0
3.0
4.0
5.0
6.0
7.0
8.0
9.0
10.0


ZX Orientation Flexural (F) Proc. A Properties - RTD (70°F)
No Fiber (NF) Fill
Measured 2% Offset Yield Strength
Markforged Onyx FR-A™ - Carbon Fiber FR-A™ / Markforged X7
Machine #
AM Batch #
Machine #
AM Batch #
0
1
2
3
4
0.00
1.00
2.00
3.00
4.00
5.00
6.00
Flexural 2% Offset Yield Strength [ksi]


ZX Orientation Flexural (F) Proc. A Properties - RTD (70°F)
No Fiber (NF) Fill
Measured Modulus
Markforged Onyx FR-A™ - Carbon Fiber FR-A™ / Markforged X7
Machine #
AM Batch #
Machine #
AM Batch #
Flexural Modulus [Msi]
0
1
2
3
4
0.00
0.05
0.10
0.15
0.20
0.25
0.30
0.35
0.40

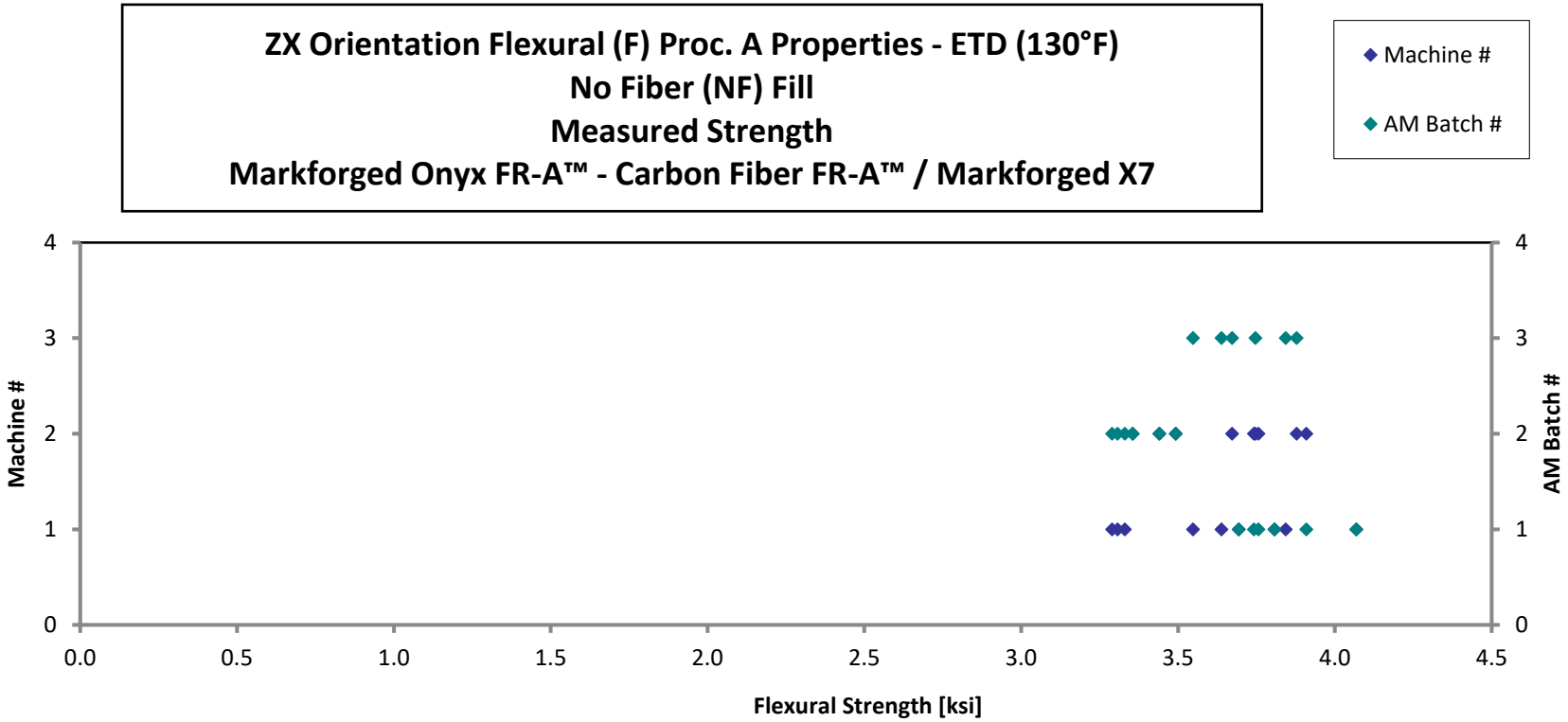
4.18.3 **ETD Condition**

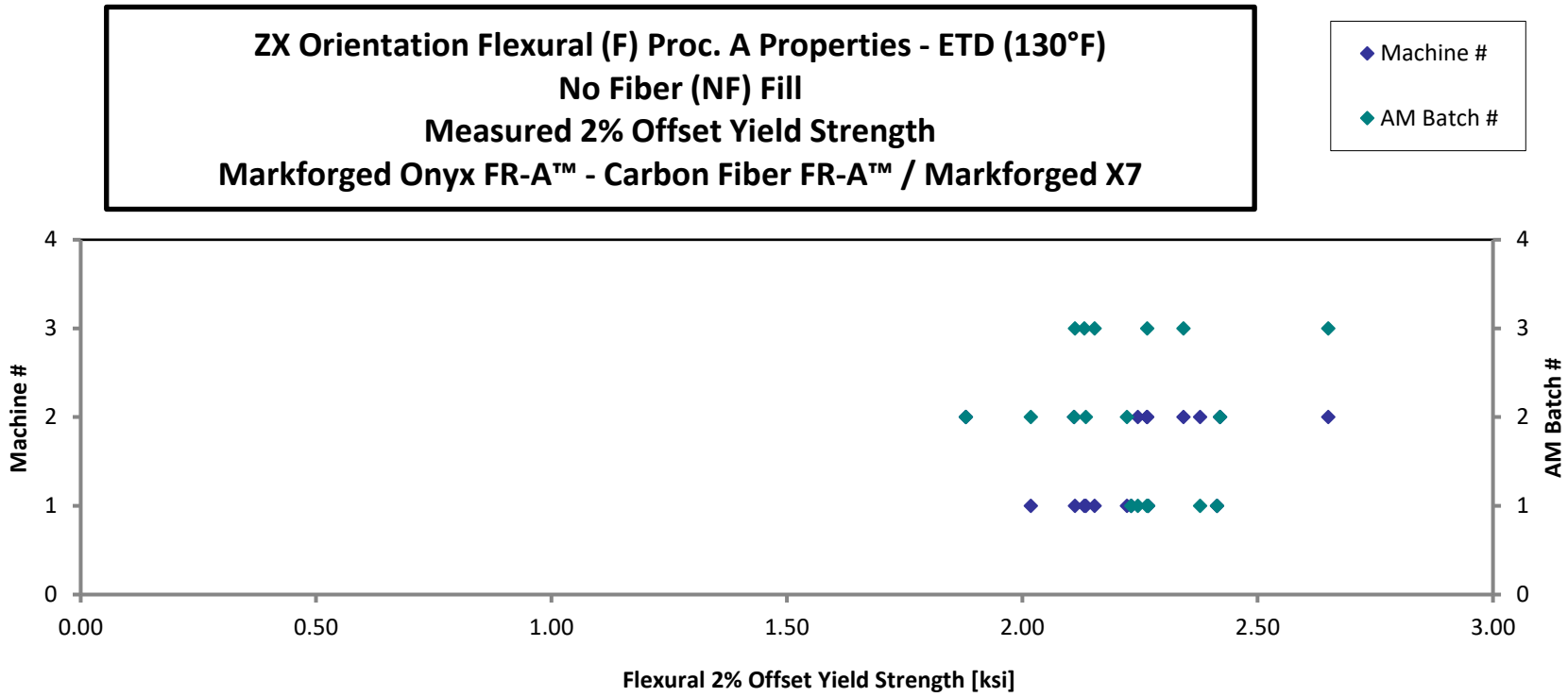
ZX Orientation Flexural (F) Proc. A Properties - ETD (130°F)
No Fiber (NF) Fill
Strength & Modulus
Markforged Onyx FR-A™ - Carbon Fiber FR-A™ / Markforged X7

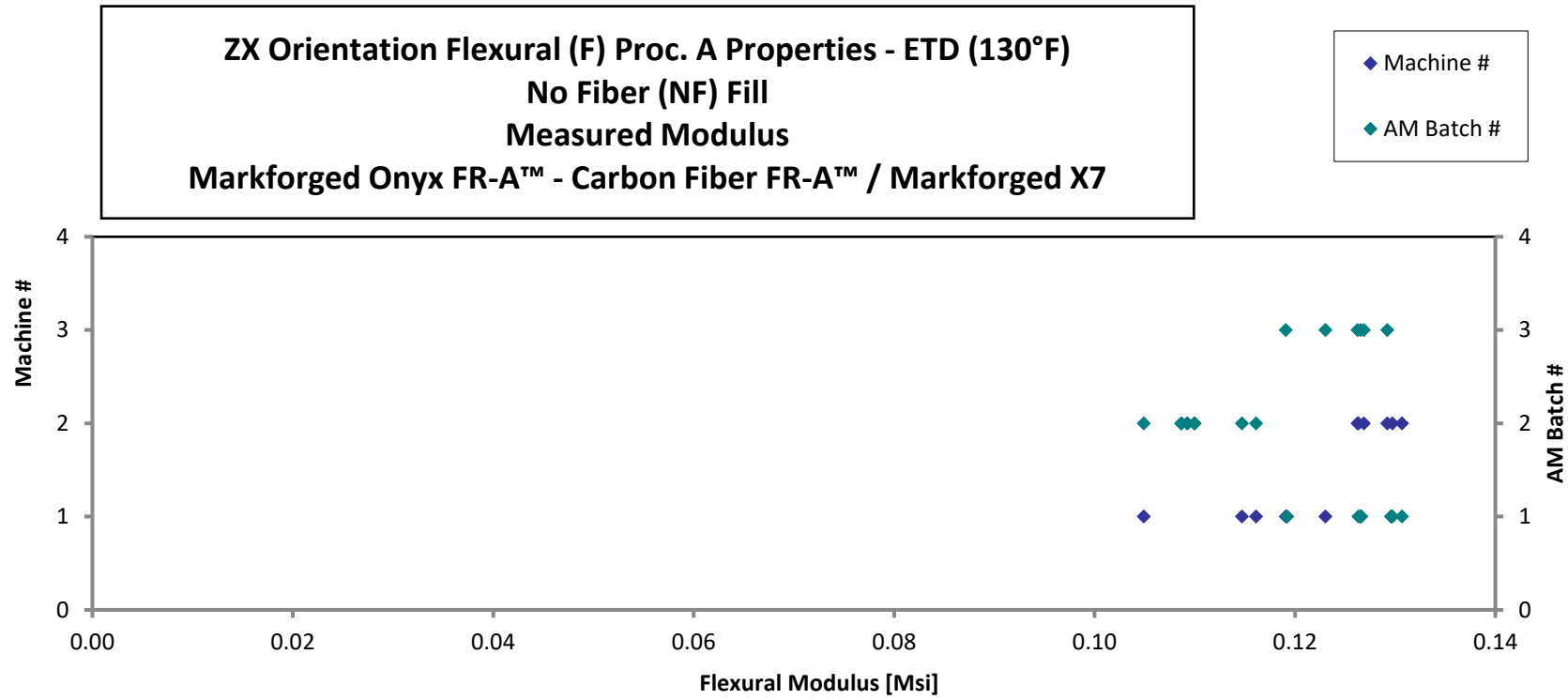
Specimen Number	AM Batch #	Machine #	Avg. Specimen Thickness [in]	Flexural Strength [ksi]	Flexural 2% Offset Yield Strength [ksi]	Flexural Modulus [Msi]	Failure Mode
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M1-P61751-ZX-F-11-ETD-NF-1*	1	1	0.144	4.069	2.414	0.130	TAB
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M1-P61817-ZX-F-12-ETD-NF-2*	1	1	0.141	3.808	2.231	0.127	TAB
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M1-P61132-ZX-F-13-ETD-NF-3*	1	1	0.142	3.694	2.267	0.119	TAB
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M2-P61255-ZX-F-11-ETD-NF-1*	1	2	0.145	3.909	2.378	0.130	TAB
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M2-P61818-ZX-F-12-ETD-NF-2*	1	2	0.142	3.756	2.265	0.126	TAB
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M2-P60434-ZX-F-13-ETD-NF-3*	1	2	0.142	3.742	2.246	0.131	TAB
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-B-M1-P66639-ZX-F-11-ETD-NF-1*	2	1	0.145	3.307	2.135	0.116	TAB
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-B-M1-P63018-ZX-F-12-ETD-NF-2*	2	1	0.141	3.331	2.222	0.105	TAB
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-B-M1-P62411-ZX-F-13-ETD-NF-3*	2	1	0.140	3.290	2.018	0.115	TAB
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-B-M2-P63352-ZX-F-11-ETD-NF-1*	2	2	0.143	3.493	2.420	0.109	TAB
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-B-M2-P63506-ZX-F-12-ETD-NF-2*	2	2	0.140	3.355	1.880	0.110	TAB
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-B-M2-P62412-ZX-F-13-ETD-NF-3*	2	2	0.140	3.441	2.110	0.109	TAB
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-C-M1-P64991-ZX-F-11-ETD-NF-1*	3	1	0.143	3.843	2.154	0.127	TAB
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-C-M1-P65365-ZX-F-12-ETD-NF-2*	3	1	0.142	3.639	2.132	0.119	TAB
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-C-M1-P64600-ZX-F-13-ETD-NF-3*	3	1	0.141	3.548	2.112	0.123	TAB
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-C-M2-P65426-ZX-F-11-ETD-NF-1*	3	2	0.142	3.878	2.266	0.129	TAB
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-C-M2-P65831-ZX-F-12-ETD-NF-2*	3	2	0.143	3.746	2.650	0.126	TAB
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-C-M2-P65281-ZX-F-13-ETD-NF-3*	3	2	0.138	3.673	2.342	0.127	TAB

Note: Due to inherent material properties, B-basis calculations will be calculated eventhough invalid tests were present.
*Maximum stress was obtained after 5% strain. (Invalid per ASTM D790)

Average	**0.142**	**3.640**	**2.236**	**0.121**
Standard Dev.		**0.230**	**0.172**	**0.008**
Coeff. of Var. [%]		**6.327**	**7.706**	**6.971**
Min.	**0.138**	**3.290**	**1.880**	**0.105**
Max.	**0.145**	**4.069**	**2.650**	**0.131**
Number of Spec.	**18**	**18**	**18**	**18**


ZX Orientation Flexural (F) Proc. A Properties - ETD (130°F)
No Fiber (NF) Fill
Measured Strength
Markforged Onyx FR-A™ - Carbon Fiber FR-A™ / Markforged X7
Machine #
AM Batch #
Machine #
AM Batch #
Flexural Strength [ksi]
0
1
2
3
4
0.0
0.5
1.0
1.5
2.0
2.5
3.0
3.5
4.0
4.5


ZX Orientation Flexural (F) Proc. A Properties - ETD (130°F)
No Fiber (NF) Fill
Measured 2% Offset Yield Strength
Markforged Onyx FR-A™ - Carbon Fiber FR-A™ / Markforged X7
Machine #
AM Batch #
Machine #
AM Batch #
0
1
2
3
4
0.00
0.50
1.00
1.50
2.00
2.50
3.00
Flexural 2% Offset Yield Strength [ksi]

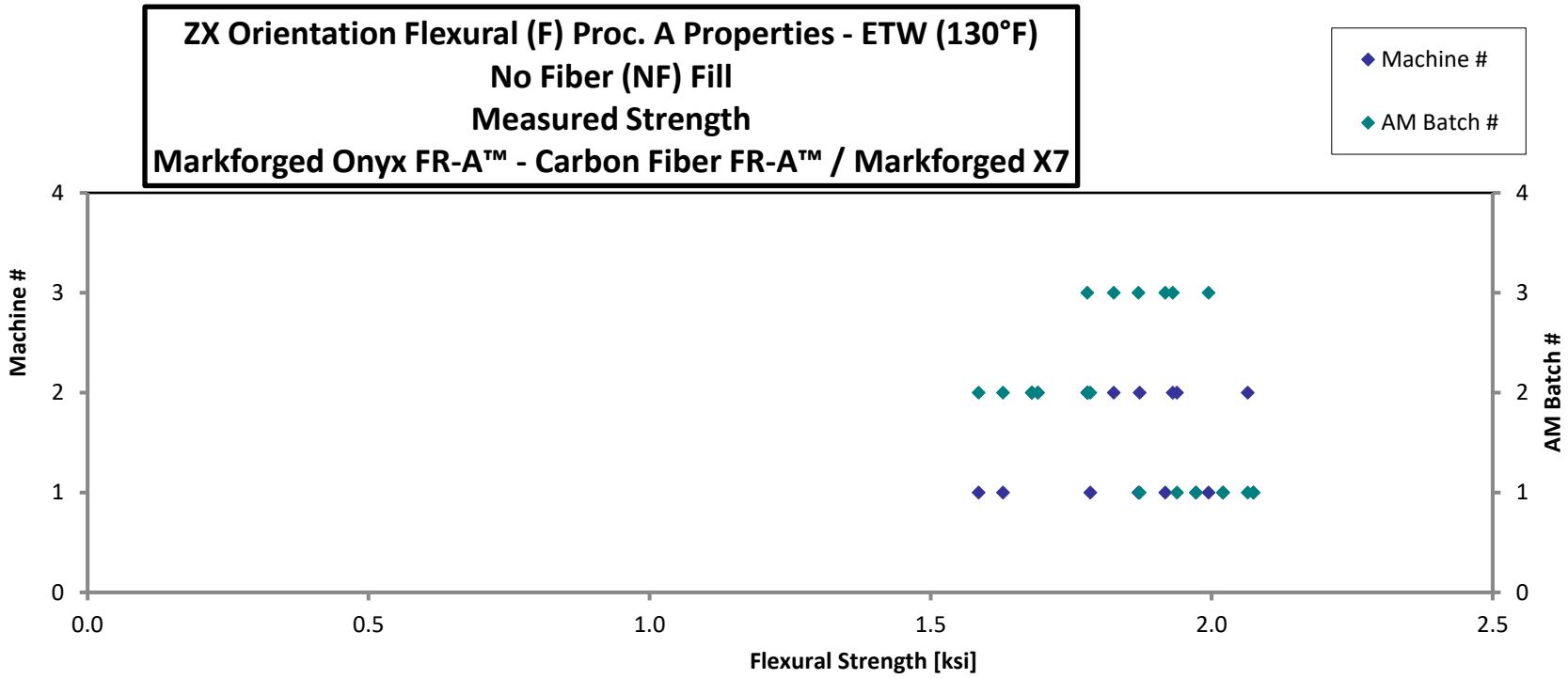

ZX Orientation Flexural (F) Proc. A Properties - ETD (130°F)
No Fiber (NF) Fill
Measured Modulus
Markforged Onyx FR-A™ - Carbon Fiber FR-A™ / Markforged X7
Machine #
AM Batch #
Machine #
AM Batch #
Flexural Modulus [Msi]
0
1
2
3
4
0.00
0.02
0.04
0.06
0.08
0.10
0.12
0.14

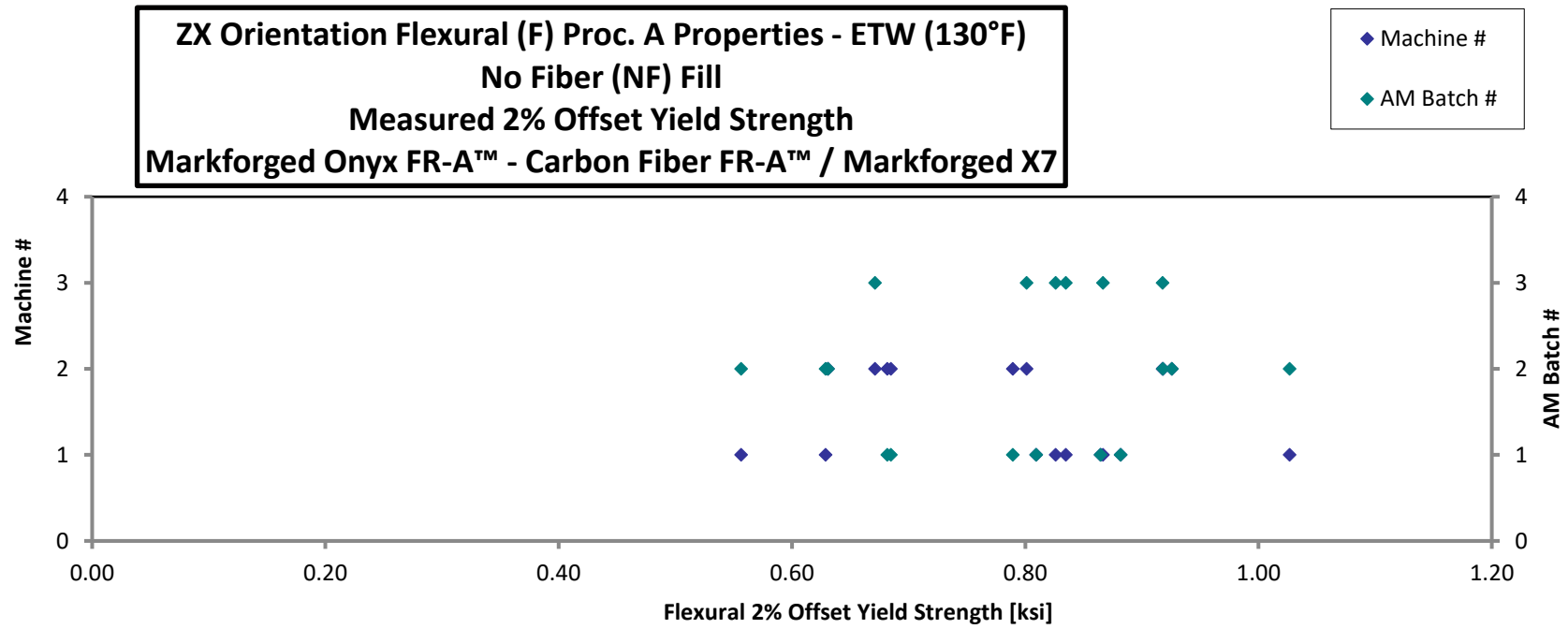
4.18.4 **ETW Condition**

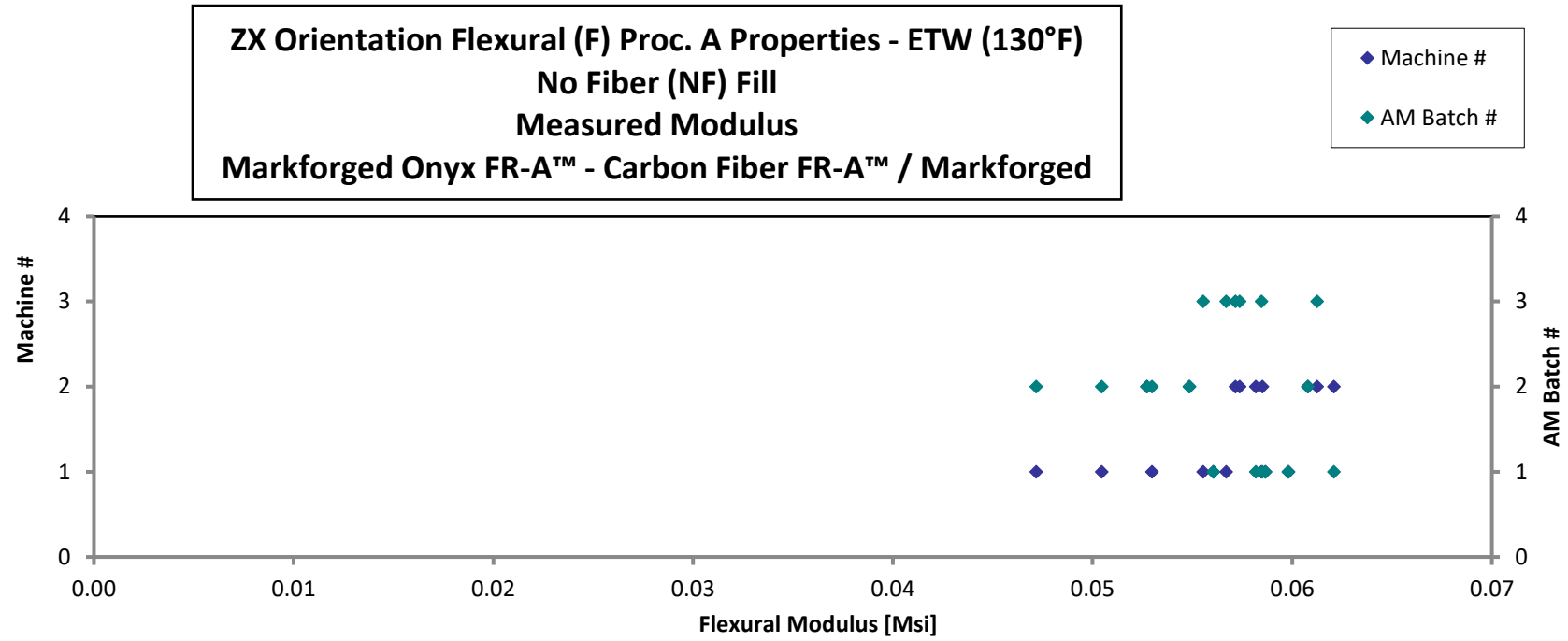
ZX Orientation Flexural (F) Proc. A Properties - ETW (130°F)
No Fiber (NF) Fill
Strength & Modulus
Markforged Onyx FR-A™ - Carbon Fiber FR-A™ / Markforged X7

Specimen Number	AM Batch #	Machine #	Avg. Specimen Thickness [in]	Flexural Strength [ksi]	Flexural 2% Offset Yield Strength [ksi]	Flexural Modulus [Msi]	Failure Mode
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M1-P61751-ZX-F-11-ETW-NF-1*	1	1	0.144	2.020	0.882	0.056	TAB
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M1-P61817-ZX-F-12-ETW-NF-2*	1	1	0.139	1.972	0.809	0.059	TAB
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M1-P61132-ZX-F-13-ETW-NF-3*	1	1	0.138	2.074	0.865	0.060	TAB
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M2-P61255-ZX-F-11-ETW-NF-1*	1	2	0.142	2.064	0.789	0.062	TAB
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M2-P61818-ZX-F-12-ETW-NF-2*	1	2	0.140	1.872	0.685	0.058	TAB
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M2-P60434-ZX-F-13-ETW-NF-3*	1	2	0.139	1.938	0.682	0.059	TAB
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-B-M1-P66639-ZX-F-11-ETW-NF-1*	2	1	0.142	1.784	1.027	0.053	TAB
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-B-M1-P63018-ZX-F-12-ETW-NF-2*	2	1	0.137	1.628	0.629	0.047	TAB
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-B-M1-P62411-ZX-F-13-ETW-NF-3*	2	1	0.137	1.585	0.556	0.050	TAB
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-B-M2-P63352-ZX-F-11-ETW-NF-1*	2	2	0.141	1.691	0.631	0.055	TAB
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-B-M2-P63506-ZX-F-12-ETW-NF-2*	2	2	0.137	1.680	0.926	0.053	TAB
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-B-M2-P62412-ZX-F-13-ETW-NF-3*	2	2	0.137	1.779	0.918	0.061	TAB
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-C-M1-P64991-ZX-F-11-ETW-NF-1*	3	1	0.142	1.995	0.867	0.057	TAB
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-C-M1-P65365-ZX-F-12-ETW-NF-2*	3	1	0.139	1.917	0.826	0.058	TAB
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-C-M1-P64600-ZX-F-13-ETW-NF-3*	3	1	0.138	1.870	0.835	0.056	TAB
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-C-M2-P65426-ZX-F-11-ETW-NF-1*	3	2	0.139	1.826	0.801	0.061	TAB
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-C-M2-P65831-ZX-F-12-ETW-NF-2*	3	2	0.141	1.931	0.918	0.057	TAB
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-C-M2-P65281-ZX-F-13-ETW-NF-3*	3	2	0.139	1.779	0.671	0.057	TAB
		Average	**0.140**	**1.856**	**0.795**	**0.057**	
		Standard Dev.		**0.147**	**0.127**	**0.004**	
		Coeff. of Var. [%]		**7.931**	**15.94**	**6.822**	
		Min.	**0.137**	**1.585**	**0.556**	**0.047**	
		Max.	**0.144**	**2.074**	**1.027**	**0.062**	
		Number of Spec.	**18**	**18**	**18**	**18**	

Note: Due to inherent material properties, B-basis calculations will be calculated eventhough invalid tests were present.
*Maximum stress was obtained after 5% strain. (Invalid per ASTM D790)


ZX Orientation Flexural (F) Proc. A Properties - ETW (130°F)
No Fiber (NF) Fill
Measured Strength
Markforged Onyx FR-A™ - Carbon Fiber FR-A™ / Markforged X7
Machine #
AM Batch #
Machine #
AM Batch #
Flexural Strength [ksi]
0
1
2
3
4
0.0
0.5
1.0
1.5
2.0
2.5


ZX Orientation Flexural (F) Proc. A Properties - ETW (130°F)
No Fiber (NF) Fill
Measured 2% Offset Yield Strength
Markforged Onyx FR-A™ - Carbon Fiber FR-A™ / Markforged X7
Machine #
AM Batch #
Machine #
AM Batch #
0
1
2
3
4
0.00
0.20
0.40
0.60
0.80
1.00
1.20
Flexural 2% Offset Yield Strength [ksi]


ZX Orientation Flexural (F) Proc. A Properties - ETW (130°F)
No Fiber (NF) Fill
Measured Modulus
Markforged Onyx FR-A™ - Carbon Fiber FR-A™ / Markforged
Machine #
AM Batch #
Machine #
AM Batch #
Flexural Modulus [Msi]
0
1
2
3
4
0.00
0.01
0.02
0.03
0.04
0.05
0.06
0.07

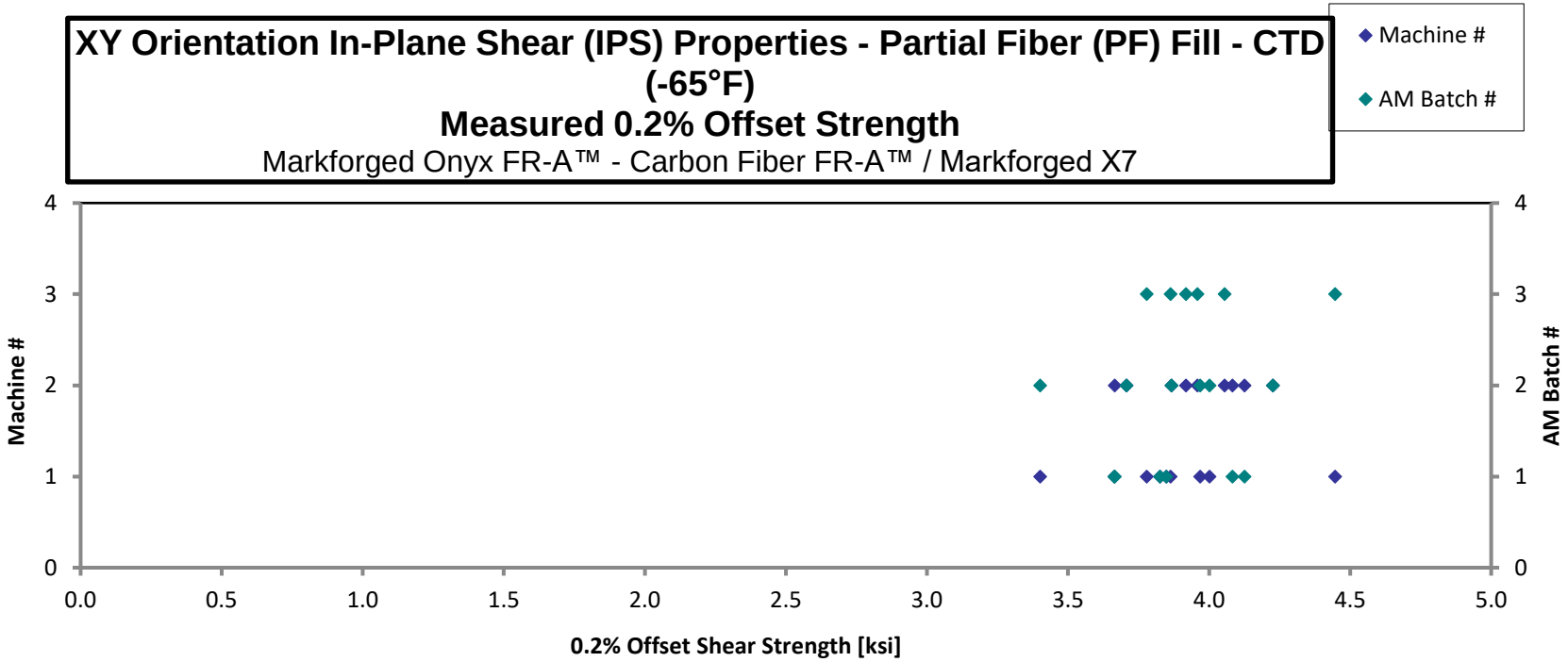
4.19 **XY PF In-Plane Shear Properties**

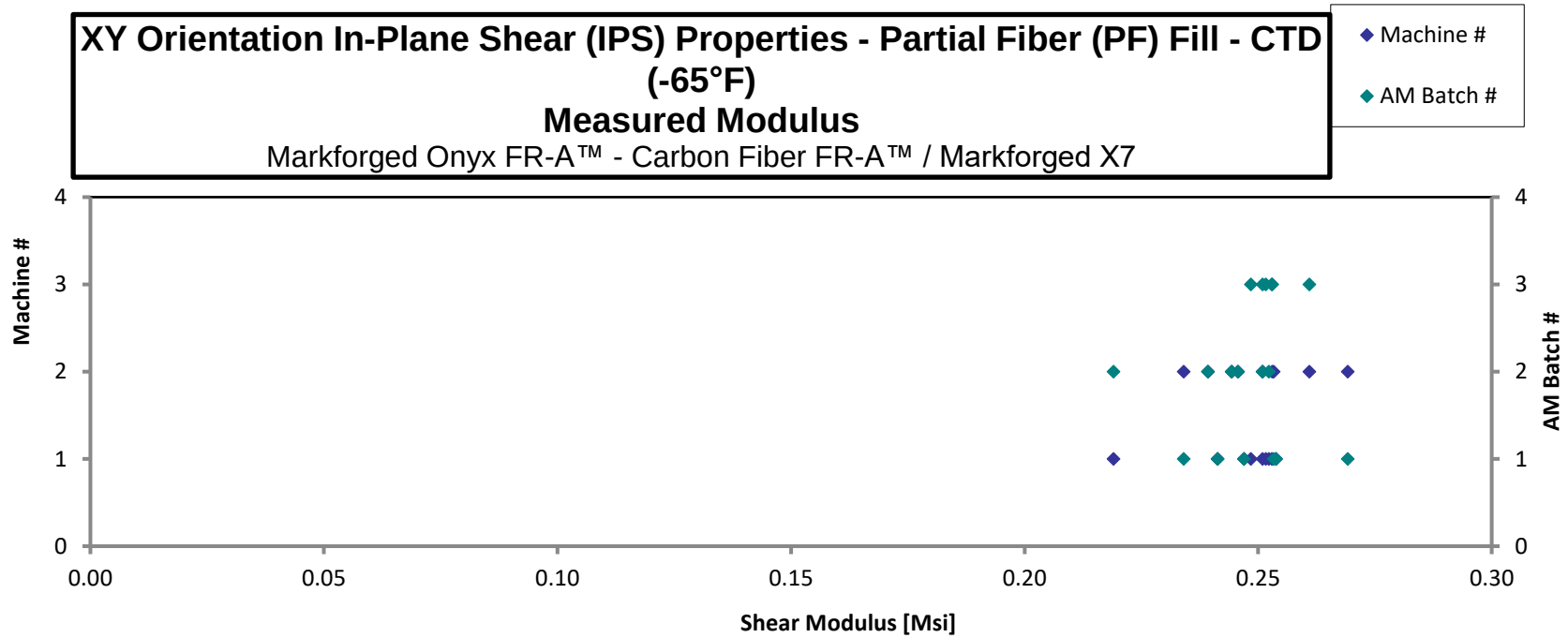
4.19.1 **CTD Condition**

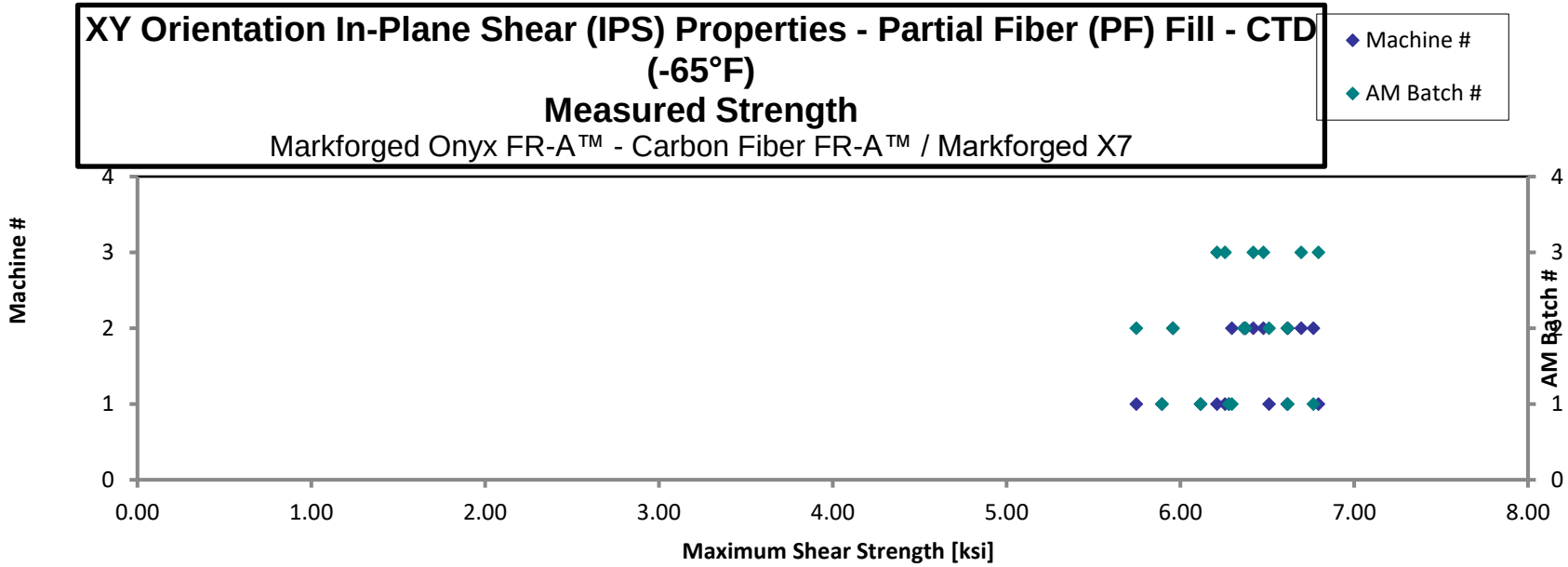
XY Orientation In-Plane Shear (IPS) Properties - CTD (-65°F)
Partial Fiber (PF) Fill
Strength and Modulus
Markforged Onyx FR-A™ - Carbon Fiber FR-A™ / Markforged X7

Specimen Number	AM Batch #	Machine #	Avg. Specimen Thickness [in]	0.2% Offset Shear Strength [ksi]	5% Offset Shear Strength [ksi]	Maximum Shear Strength [ksi]	Shear Modulus [Msi]	Failure Mode
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M1-P30602-XY-IPS-11-CTD-PF-1*	1	1	0.140	3.826		5.895	0.247	M(A,L)GT
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M1-P30543-XY-IPS-12-CTD-PF-2*	1	1	0.144	3.665		6.117	0.241	M(A,L)WB
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M1-P31784-XY-IPS-13-CTD-PF-SP*	1	1	0.140	3.849		6.280	0.254	M(A,L)WT
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M2-P30601-XY-IPS-11-CTD-PF-1*	1	2	0.142	4.083		6.766	0.269	M(A,L)WB
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M2-P30542-XY-IPS-12-CTD-PF-2*	1	2	0.143	4.126		6.618	0.253	M(A,L)WB
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M2-P30351-XY-IPS-13-CTD-PF-3*	1	2	0.138	3.665		6.296	0.234	M(A,L)WT
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-B-M1-P32848-XY-IPS-11-CTD-PF-1*	2	1	0.142	4.001		6.511	0.252	M(A,L)GM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-B-M1-P32236-XY-IPS-12-CTD-PF-2*	2	1	0.143	3.401		5.747	0.219	M(A,L)WT
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-B-M1-P32870-XY-IPS-13-CTD-PF-3*	2	1	0.141	3.968		6.615	0.251	M(A,L)GM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-B-M2-P56064-XY-IPS-11-CTD-PF-1*	2	2	0.144	3.867		6.366	0.244	M(A,L)GM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-B-M2-P32235-XY-IPS-12-CTD-PF-2*	2	2	0.143	3.708		5.958	0.239	M(A,L)GB
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-B-M2-P32871-XY-IPS-13-CTD-PF-3*	2	2	0.141	4.226		6.375	0.246	M(A,L)WB
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-C-M1-P35473-XY-IPS-11-CTD-PF-1*	3	1	0.142	3.779		6.211	0.253	M(A,L)WB
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-C-M1-P35360-XY-IPS-12-CTD-PF-2*	3	1	0.143	3.863		6.257	0.248	M(A,L)WT
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-C-M1-P35272-XY-IPS-13-CTD-PF-3*	3	1	0.138	4.447		6.794	0.252	M(A,L)WB
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-C-M2-P35422-XY-IPS-11-CTD-PF-1*	3	2	0.142	3.959		6.420	0.253	M(A,L)WB
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-C-M2-P35359-XY-IPS-12-CTD-PF-2*	3	2	0.143	3.919		6.478	0.251	M(A,L)GM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-C-M2-P35260-XY-IPS-13-CTD-PF-6*	3	2	0.139	4.055		6.695	0.261	M(A,L)GT
		Average	**0.142**	**3.911**		**6.355**	**0.248**	
		Standard Dev.		**0.237**		**0.296**	**0.011**	
		Coeff. of Var. [%]		**6.050**		**4.664**	**4.316**	
		Min.	**0.138**	**3.401**		**5.747**	**0.219**	
		Max.	**0.144**	**4.447**		**6.794**	**0.269**	
		Number of Spec.	**18**	**18**		**18**	**18**	

*Shear strength at 5% strain not reported due to failure occuring before 50,000 microstrain


XY Orientation In-Plane Shear (IPS) Properties - Partial Fiber (PF) Fill - CTD (-65°F)
Measured 0.2% Offset Strength
Markforged Onyx FR-A™ - Carbon Fiber FR-A™ / Markforged X7
Machine #
AM Batch #
Machine #
AM Batch #
0.2% Offset Shear Strength [ksi]
0.0
0.5
1.0
1.5
2.0
2.5
3.0
3.5
4.0
4.5
5.0
0
1
2
3
4

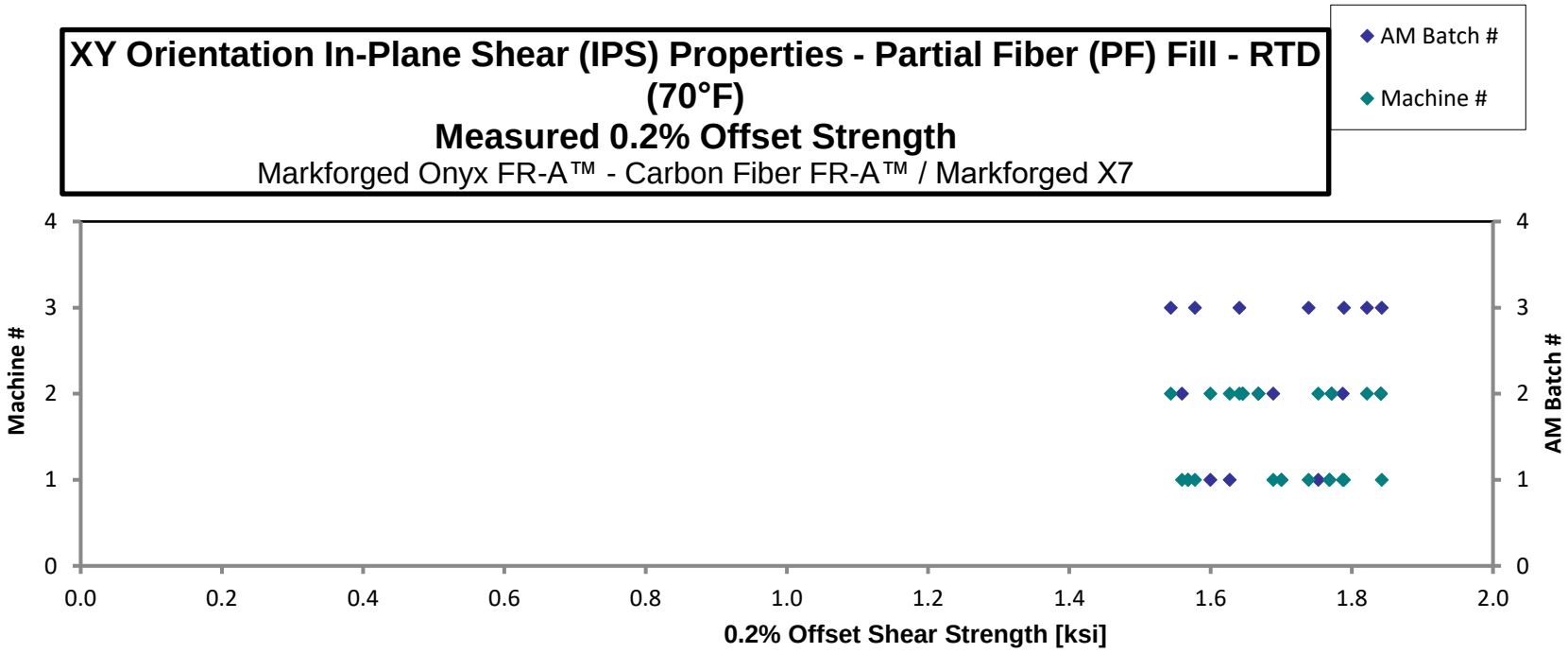

XY Orientation In-Plane Shear (IPS) Properties - Partial Fiber (PF) Fill - CTD (-65°F)
Measured Modulus
Markforged Onyx FR-A™ - Carbon Fiber FR-A™ / Markforged X7
Machine #
AM Batch #
Machine #
AM Batch #
0
1
2
3
4
0.00
0.05
0.10
0.15
0.20
0.25
0.30
Shear Modulus [Msi]

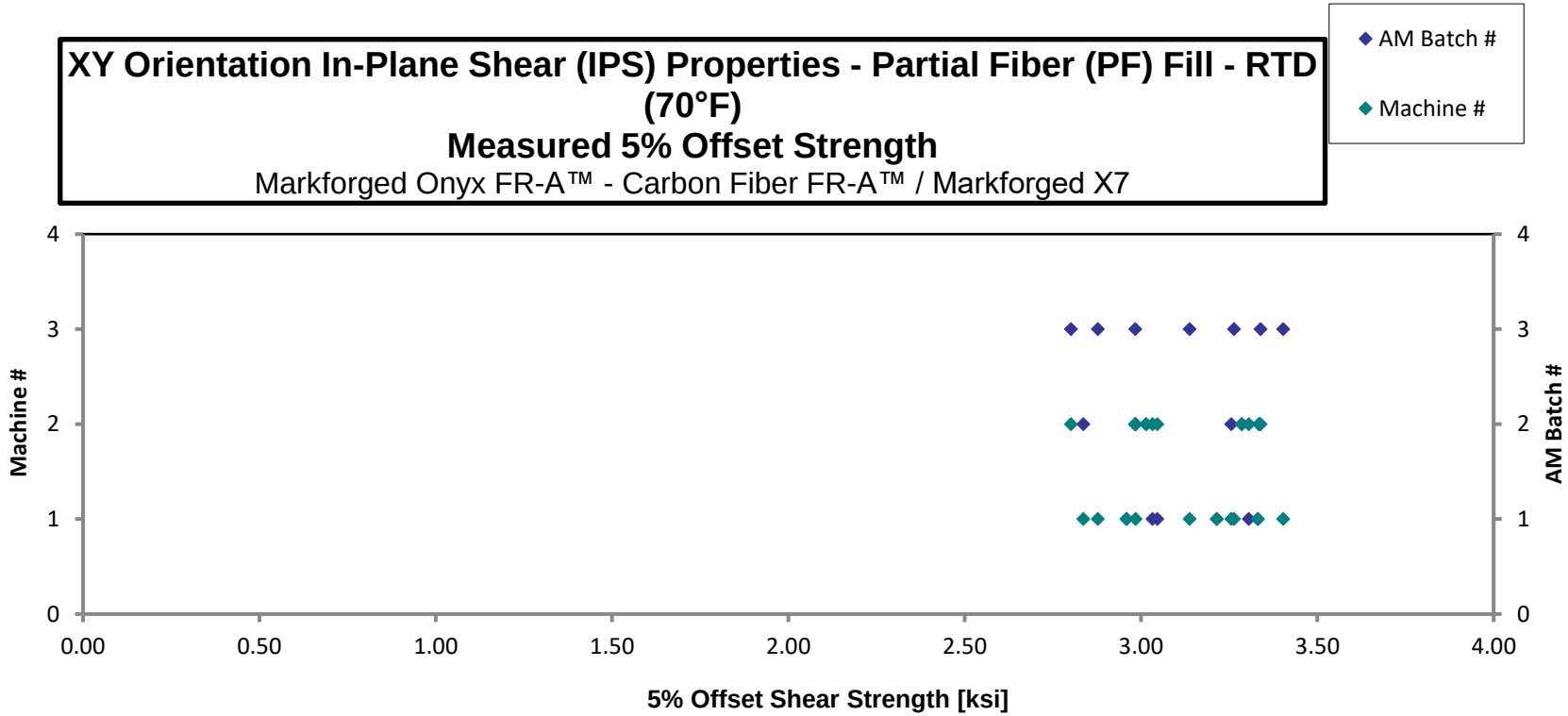

XY Orientation In-Plane Shear (IPS) Properties - Partial Fiber (PF) Fill - CTD (-65°F)
Measured Strength
Markforged Onyx FR-A™ - Carbon Fiber FR-A™ / Markforged X7
Machine #
AM Batch #
Machine #
AM Batch #
0
1
2
3
4
0.00
1.00
2.00
3.00
4.00
5.00
6.00
7.00
8.00
Maximum Shear Strength [ksi]

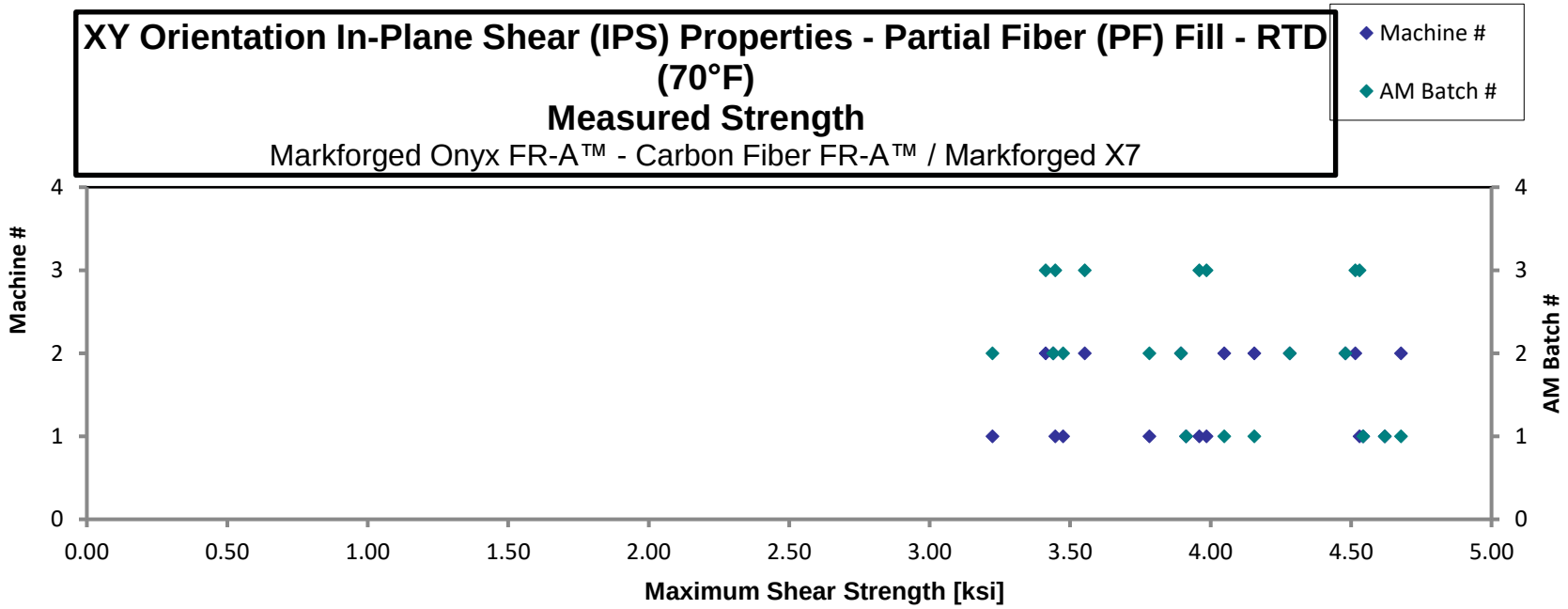
4.19.2 **RTD Condition**

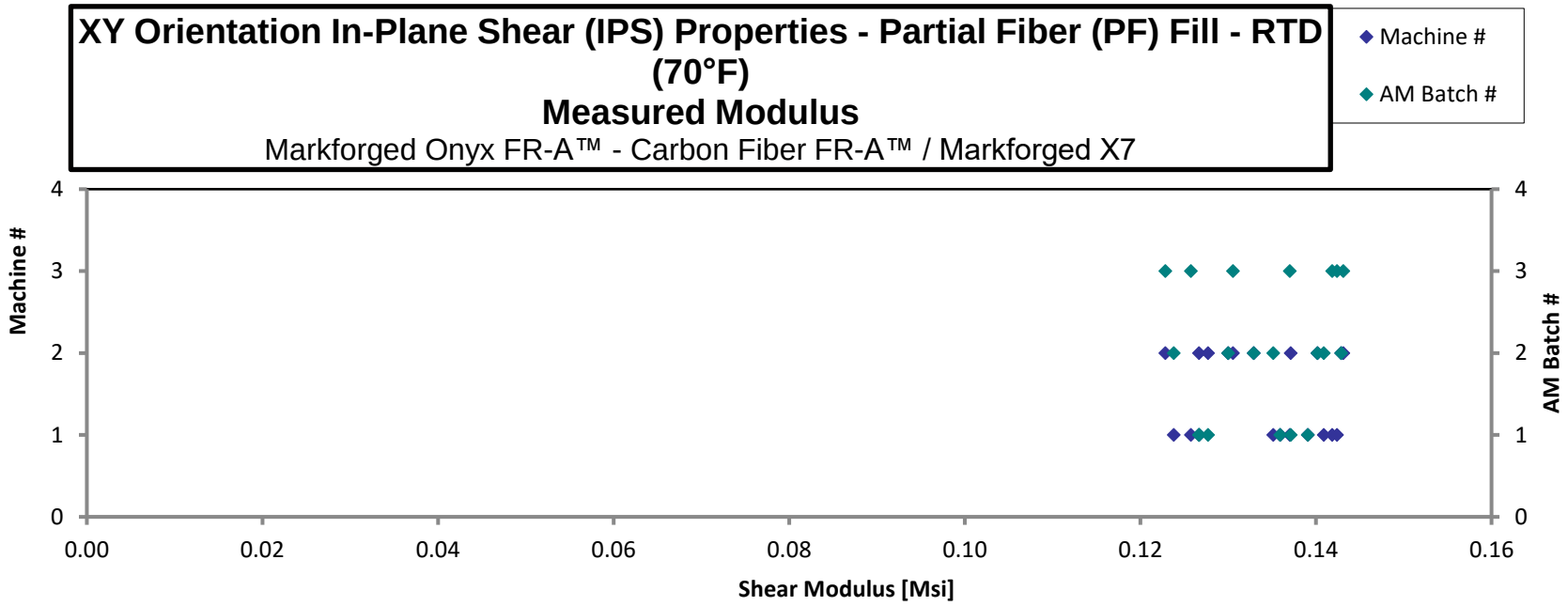
XY Orientation In-Plane Shear (IPS) Properties - RTD (70°F)
Partial Fiber (PF) Fill
Strength and Modulus
Markforged Onyx FR-A™ - Carbon Fiber FR-A™ / Markforged X7

Specimen Number	AM Batch #	Machine #	Avg. Specimen Thickness [in]	0.2% Offset Shear Strength [ksi]	5% Offset Shear Strength [ksi]	Maximum Shear Strength [ksi]	Shear Modulus [Msi]	Failure Mode
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M1-P30352-XY-IPS-11-RTD-PF-1	1	1	0.142	1.769	3.331	4.620	0.139	M(A,L)WB
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M1-P30602-XY-IPS-12-RTD-PF-2	1	1	0.143	1.568	2.959	3.913	0.127	M(A,L)GM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M1-P30543-XY-IPS-13-RTD-PF-3	1	1	0.139	1.700	3.215	4.544	0.136	M(A,L)GM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M2-P30351-XY-IPS-11-RTD-PF-1	1	2	0.141	1.600	3.046	4.156	0.128	M(A,L)WT
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M2-P30601-XY-IPS-12-RTD-PF-2	1	2	0.143	1.627	3.033	4.049	0.127	M(A,L)GM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M2-P30542-XY-IPS-13-RTD-PF-3	1	2	0.138	1.753	3.306	4.678	0.137	M(A,L)WB
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-B-M1-P32870-XY-IPS-11-RTD-PF-1	2	1	0.142	1.787	3.256	3.783	0.141	AGM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-B-M1-P32848-XY-IPS-12-RTD-PF-2	2	1	0.144	1.689	2.985	3.224	0.135	AGM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-B-M1-P33155-XY-IPS-13-RTD-PF-SP	2	1	0.141	1.559	2.836	3.476	0.124	AGM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-B-M2-P32871-XY-IPS-11-RTD-PF-1	2	2	0.141	1.772	3.286	4.282	0.140	M(A,L)GT
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-B-M2-P56064-XY-IPS-12-RTD-PF-2	2	2	0.144	1.646	2.984	3.894	0.130	M(A,L)GM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-B-M2-P32235-XY-IPS-13-RTD-PF-3	2	2	0.141	1.668	3.014	3.439	0.133	AGT
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-B-M2-P33154-XY-IPS-13-RTD-PF-SP	2	2	0.140	1.841	3.335	4.480	0.143	LGB
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-C-M1-P35272-XY-IPS-11-RTD-PF-1	3	1	0.140	1.842	3.403	4.530	0.142	M(A,L)GM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-C-M1-P35473-XY-IPS-12-RTD-PF-2	3	1	0.142	1.789	3.264	3.960	0.142	M(A,L)GM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-C-M1-P35360-XY-IPS-13-RTD-PF-3	3	1	0.141	1.578	2.878	3.447	0.126	AGB
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-C-M1-P35257-XY-IPS-13-RTD-PF-SP	3	1	0.140	1.739	3.137	3.985	0.137	M(A,L)GM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-C-M2-P35422-XY-IPS-12-RTD-PF-2	3	2	0.146	1.544	2.801	3.413	0.123	M(A,L)GB
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-C-M2-P35359-XY-IPS-13-RTD-PF-3	3	2	0.142	1.641	2.984	3.552	0.131	AGB
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-C-M2-P35256-XY-IPS-13-RTD-PF-SP	3	2	0.139	1.822	3.339	4.515	0.143	M(A,L)GT
		Average	**0.141**	**1.697**	**3.120**	**3.997**	**0.134**	
		Standard Dev.		**0.098**	**0.189**	**0.466**	**0.007**	
		Coeff. of Var. [%]		**5.800**	**6.047**	**11.67**	**5.133**	
		Min.	**0.138**	**1.544**	**2.801**	**3.224**	**0.123**	
		Max.	**0.146**	**1.842**	**3.403**	**4.678**	**0.143**	
		Number of Spec.	**20**	**20**	**20**	**20**	**20**	


XY Orientation In-Plane Shear (IPS) Properties - Partial Fiber (PF) Fill - RTD (70°F)
Measured 0.2% Offset Strength
Markforged Onyx FR-A™ - Carbon Fiber FR-A™ / Markforged X7
AM Batch #
Machine #
Machine #
AM Batch #
0.2% Offset Shear Strength [ksi]
0
1
2
3
4
0.0
0.2
0.4
0.6
0.8
1.0
1.2
1.4
1.6
1.8
2.0


XY Orientation In-Plane Shear (IPS) Properties - Partial Fiber (PF) Fill - RTD (70°F)
Measured 5% Offset Strength
Markforged Onyx FR-A™ - Carbon Fiber FR-A™ / Markforged X7
AM Batch #
Machine #
Machine #
AM Batch #
5% Offset Shear Strength [ksi]
0
1
2
3
4
0.00
0.50
1.00
1.50
2.00
2.50
3.00
3.50
4.00

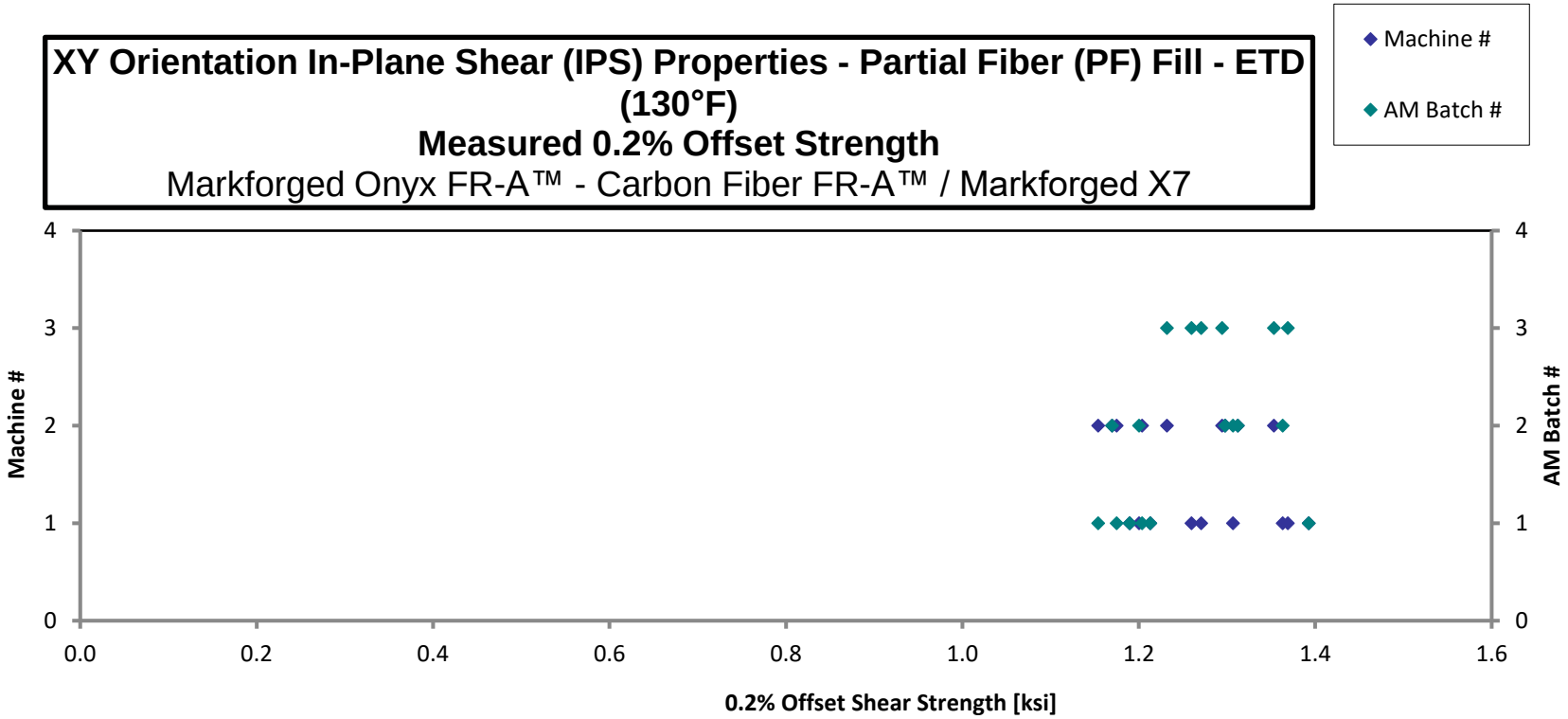

XY Orientation In-Plane Shear (IPS) Properties - Partial Fiber (PF) Fill - RTD (70°F)
Measured Strength
Markforged Onyx FR-A™ - Carbon Fiber FR-A™ / Markforged X7
Machine #
AM Batch #
Machine #
AM Batch #
Maximum Shear Strength [ksi]
0
1
2
3
4
0.00
0.50
1.00
1.50
2.00
2.50
3.00
3.50
4.00
4.50
5.00

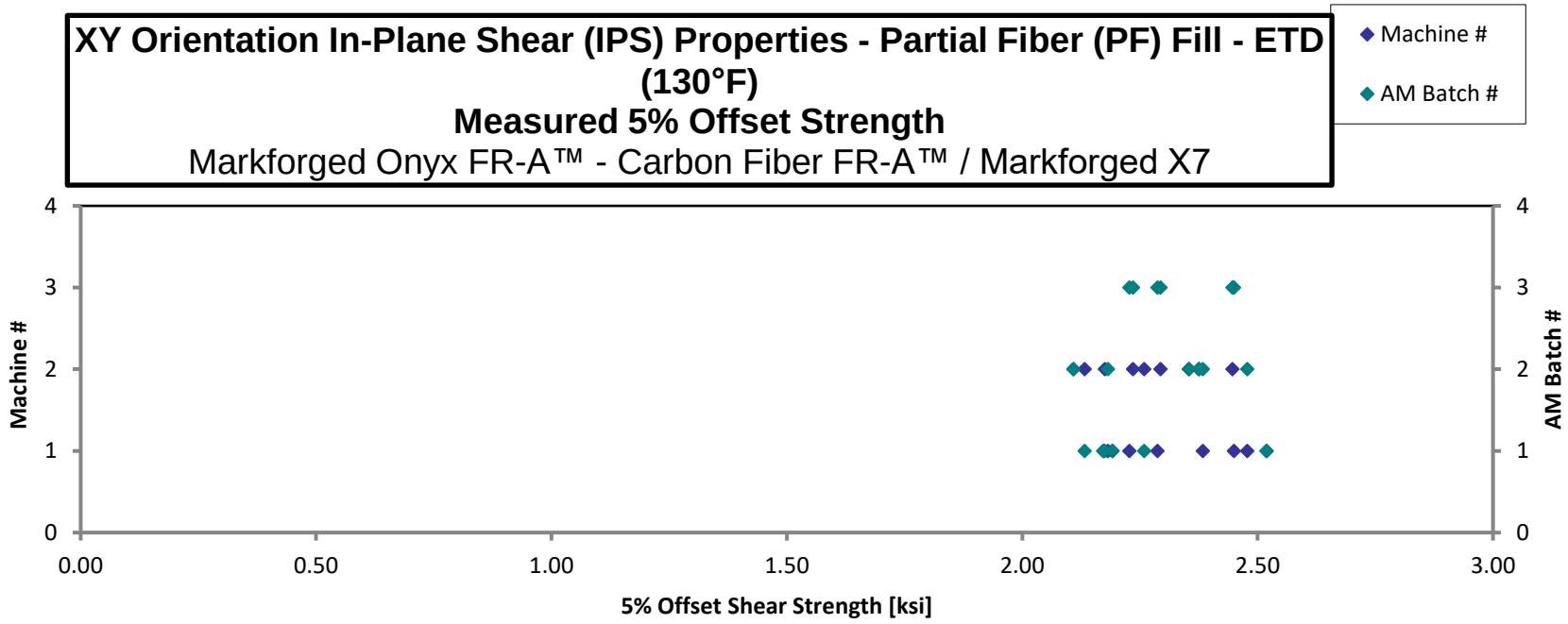

XY Orientation In-Plane Shear (IPS) Properties - Partial Fiber (PF) Fill - RTD (70°F)
Measured Modulus
Markforged Onyx FR-A™ - Carbon Fiber FR-A™ / Markforged X7
Machine #
AM Batch #
Machine #
AM Batch #
Shear Modulus [Msi]
0
1
2
3
4
0.00
0.02
0.04
0.06
0.08
0.10
0.12
0.14
0.16

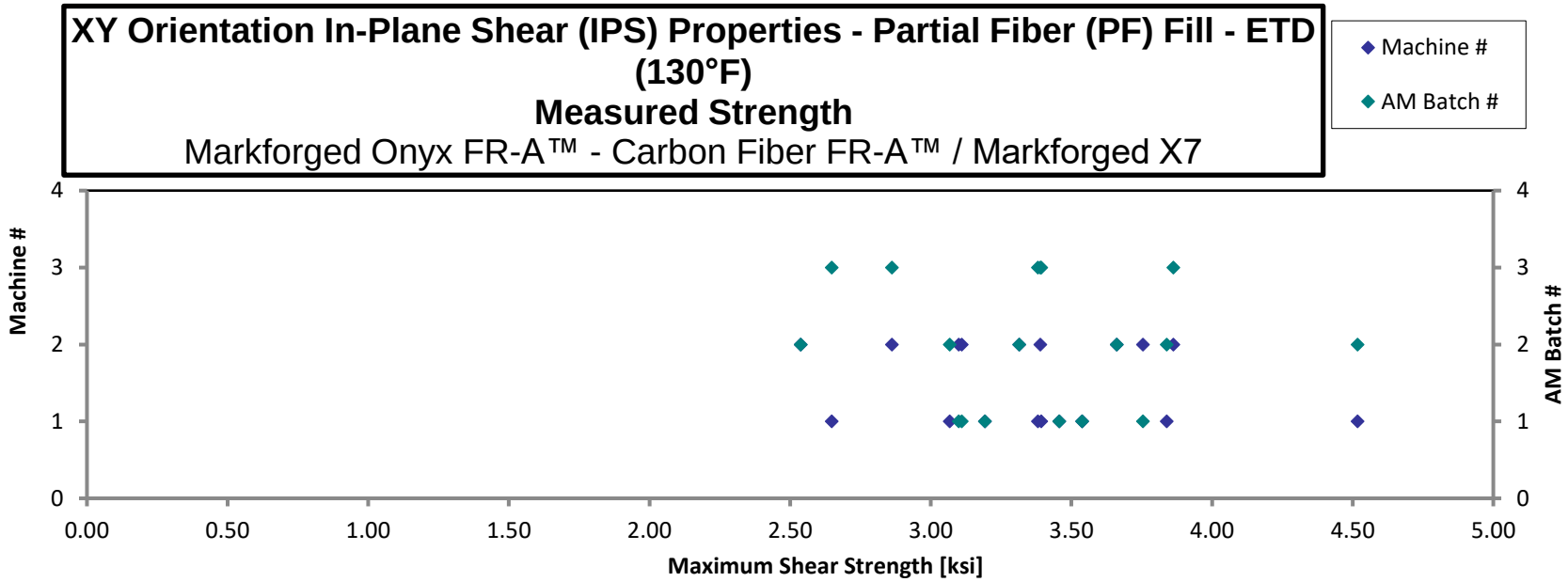
4.19.3 **ETD Condition**

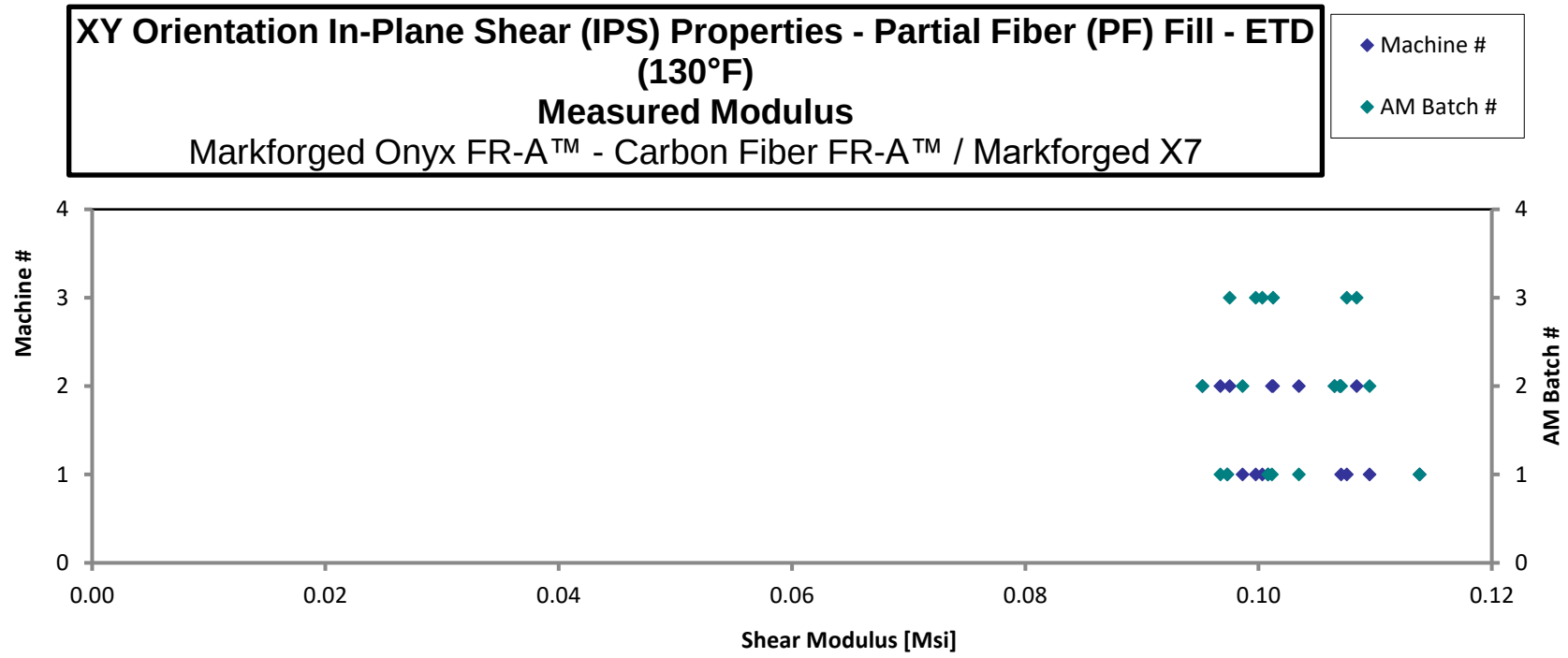
XY Orientation In-Plane Shear (IPS) Properties - ETD (130°F)
Partial Fiber (PF) Fill
Strength and Modulus
Markforged Onyx FR-A™ - Carbon Fiber FR-A™ / Markforged X7

Specimen Number	AM Batch #	Machine #	Avg. Specimen Thickness [in]	0.2% Offset Shear Strength [ksi]	5% Offset Shear Strength [ksi]	Maximum Shear Strength [ksi]	Shear Modulus [Msi]	Failure Mode
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M1-P44531-XY-IPS-11-ETD-PF-1	1	1	0.140	1.393	2.519	3.538	0.114	AGM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M1-P44320-XY-IPS-12-ETD-PF-2	1	1	0.143	1.189	2.172	3.457	0.097	AGT
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M1-P42981-XY-IPS-13-ETD-PF-3	1	1	0.142	1.213	2.192	3.193	0.101	AGM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M2-P42916-XY-IPS-11-ETD-PF-1	1	2	0.141	1.204	2.259	3.755	0.103	AGM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M2-P46114-XY-IPS-12-ETD-PF-2	1	2	0.144	1.175	2.175	3.099	0.101	AGM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M2-P42495-XY-IPS-13-ETD-PF-3	1	2	0.142	1.154	2.133	3.110	0.097	AGM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-B-M1-P40117-XY-IPS-11-ETD-PF-1	2	1	0.139	1.363	2.478	4.517	0.110	M(A,L)GM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-B-M1-P39839-XY-IPS-12-ETD-PF-2	2	1	0.143	1.200	2.182	3.067	0.099	AGM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-B-M1-P41009-XY-IPS-13-ETD-PF-3	2	1	0.142	1.307	2.384	3.839	0.107	M(A,L)GM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-B-M2-P38680-XY-IPS-11-ETD-PF-1	2	2	0.140	1.312	2.375	3.661	0.107	AGM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-B-M2-P38143-XY-IPS-12-ETD-PF-2	2	2	0.141	1.170	2.109	2.538	0.095	AGM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-B-M2-P46418-XY-IPS-13-ETD-PF-3	2	2	0.141	1.298	2.354	3.314	0.107	AGM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-C-M1-P47955-XY-IPS-11-ETD-PF-1	3	1	0.141	1.369	2.449	3.381	0.108	AGM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-C-M1-P49921-XY-IPS-12-ETD-PF-2	3	1	0.145	1.260	2.287	3.393	0.100	AGM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-C-M1-P48076-XY-IPS-13-ETD-PF-3	3	1	0.142	1.271	2.228	2.648	0.100	AGM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-C-M2-P49458-XY-IPS-11-ETD-PF-1	3	2	0.139	1.353	2.447	3.863	0.108	AGM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-C-M2-P49961-XY-IPS-12-ETD-PF-2	3	2	0.145	1.232	2.236	3.389	0.098	AGM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-C-M2-P47970-XY-IPS-13-ETD-PF-3	3	2	0.143	1.295	2.294	2.862	0.101	AGM
		Average	**0.142**	**1.264**	**2.293**	**3.368**	**0.103**	
		Standard Dev.		**0.076**	**0.126**	**0.472**	**0.005**	
		Coeff. of Var. [%]		**5.991**	**5.512**	**14.01**	**5.083**	
		Min.	**0.139**	**1.154**	**2.109**	**2.538**	**0.095**	
		Max.	**0.145**	**1.393**	**2.519**	**4.517**	**0.114**	
		Number of Spec.	**18**	**18**	**18**	**18**	**18**	


XY Orientation In-Plane Shear (IPS) Properties - Partial Fiber (PF) Fill - ETD (130°F)
Measured 0.2% Offset Strength
Markforged Onyx FR-A™ - Carbon Fiber FR-A™ / Markforged X7
Machine #
AM Batch #
Machine #
AM Batch #
0.2% Offset Shear Strength [ksi]
0
1
2
3
4
0.0
0.2
0.4
0.6
0.8
1.0
1.2
1.4
1.6


XY Orientation In-Plane Shear (IPS) Properties - Partial Fiber (PF) Fill - ETD (130°F)
Measured 5% Offset Strength
Markforged Onyx FR-A™ - Carbon Fiber FR-A™ / Markforged X7
Machine #
AM Batch #
Machine #
AM Batch #
5% Offset Shear Strength [ksi]
0
1
2
3
4
0.00
0.50
1.00
1.50
2.00
2.50
3.00

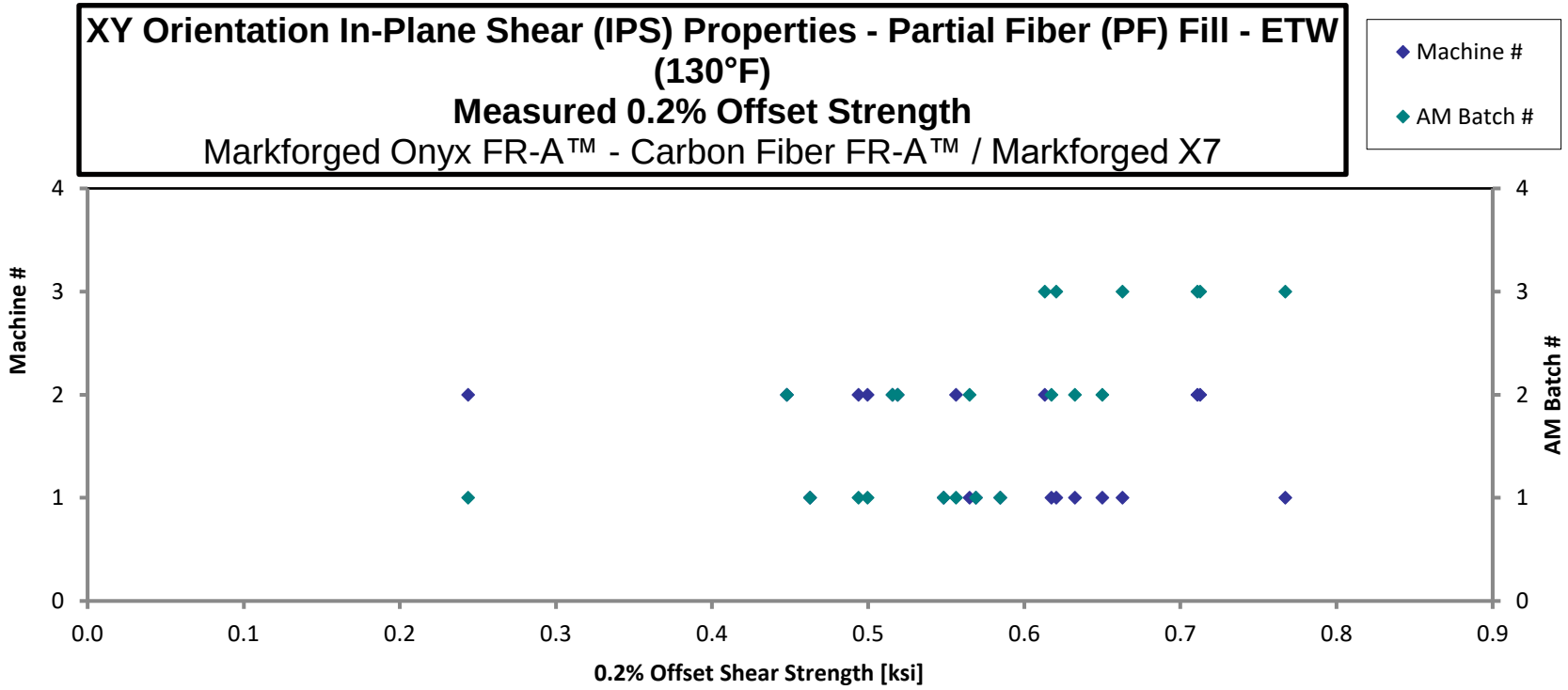

XY Orientation In-Plane Shear (IPS) Properties - Partial Fiber (PF) Fill - ETD (130°F)
Measured Strength
Markforged Onyx FR-A™ - Carbon Fiber FR-A™ / Markforged X7
Machine #
AM Batch #
Machine #
AM Batch #
Maximum Shear Strength [ksi]
0
1
2
3
4
0.00
0.50
1.00
1.50
2.00
2.50
3.00
3.50
4.00
4.50
5.00

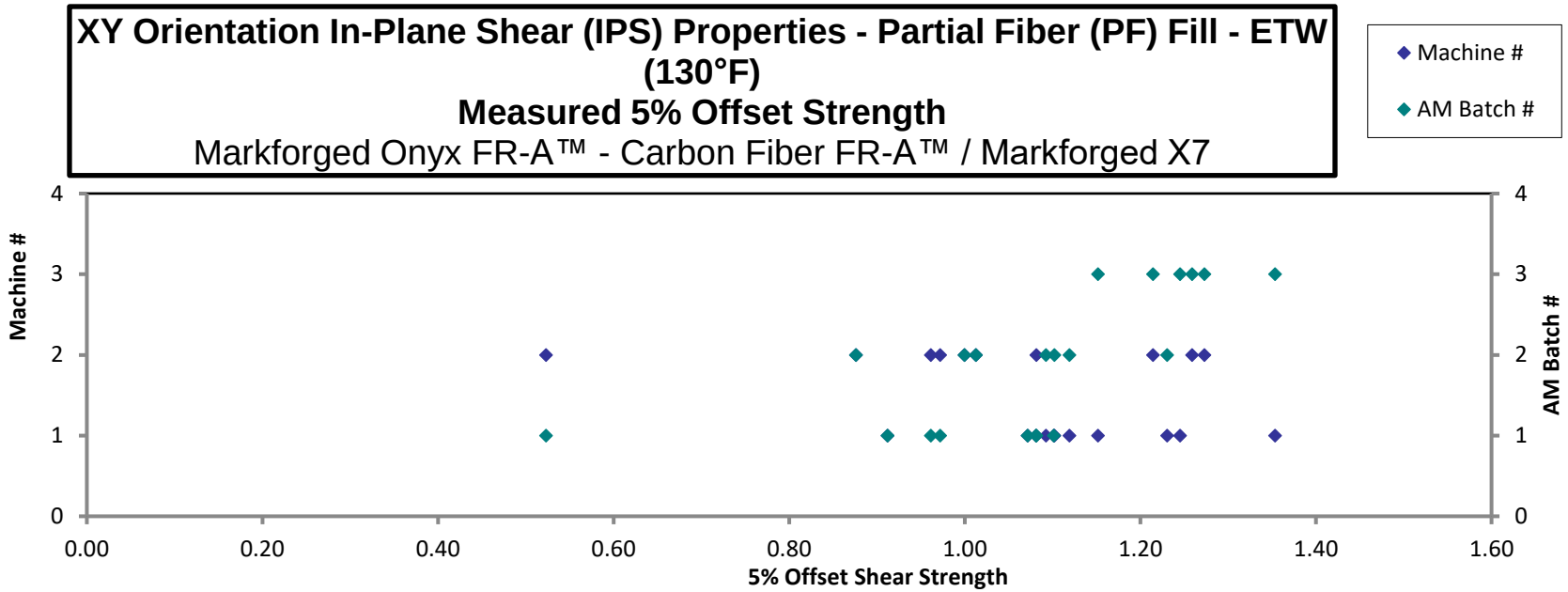

XY Orientation In-Plane Shear (IPS) Properties - Partial Fiber (PF) Fill - ETD (130°F)
Measured Modulus
Markforged Onyx FR-A™ - Carbon Fiber FR-A™ / Markforged X7
Machine #
AM Batch #
Machine #
AM Batch #
Shear Modulus [Msi]
0
1
2
3
4
0.00
0.02
0.04
0.06
0.08
0.10
0.12

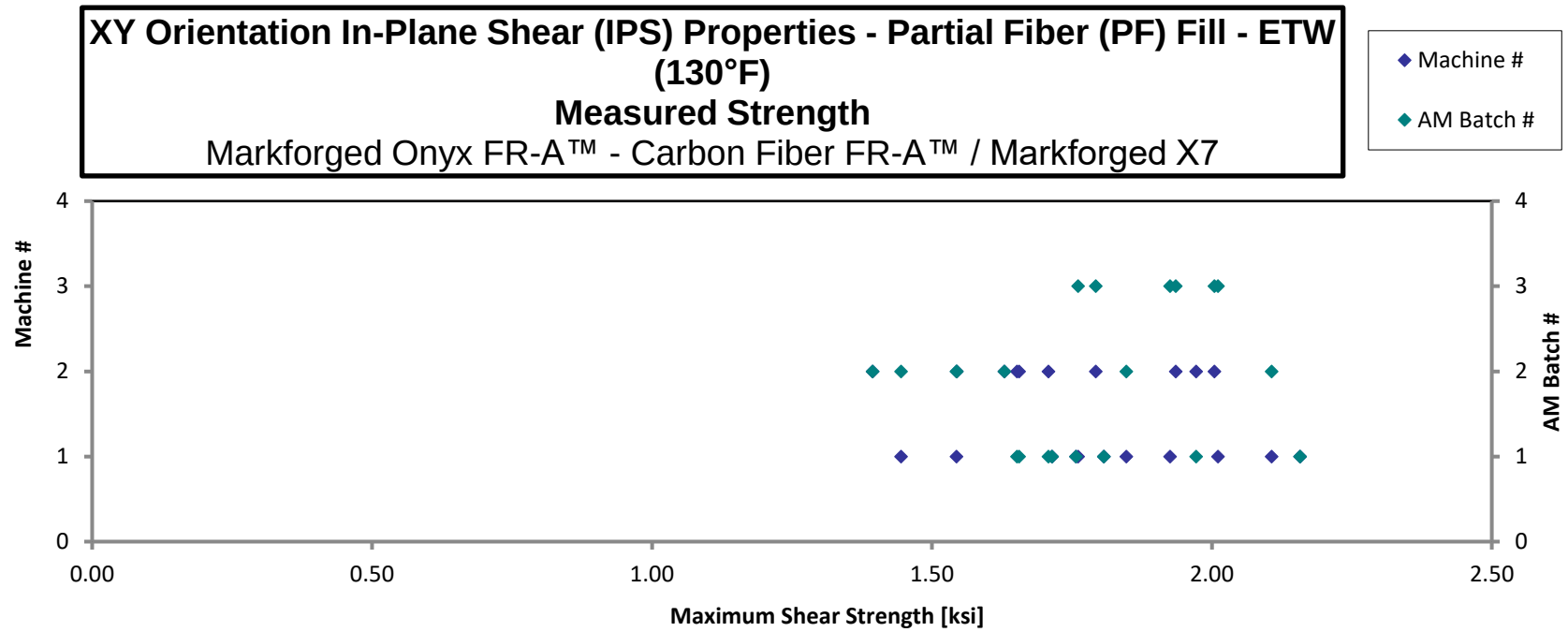
4.19.4 **ETW Condition**

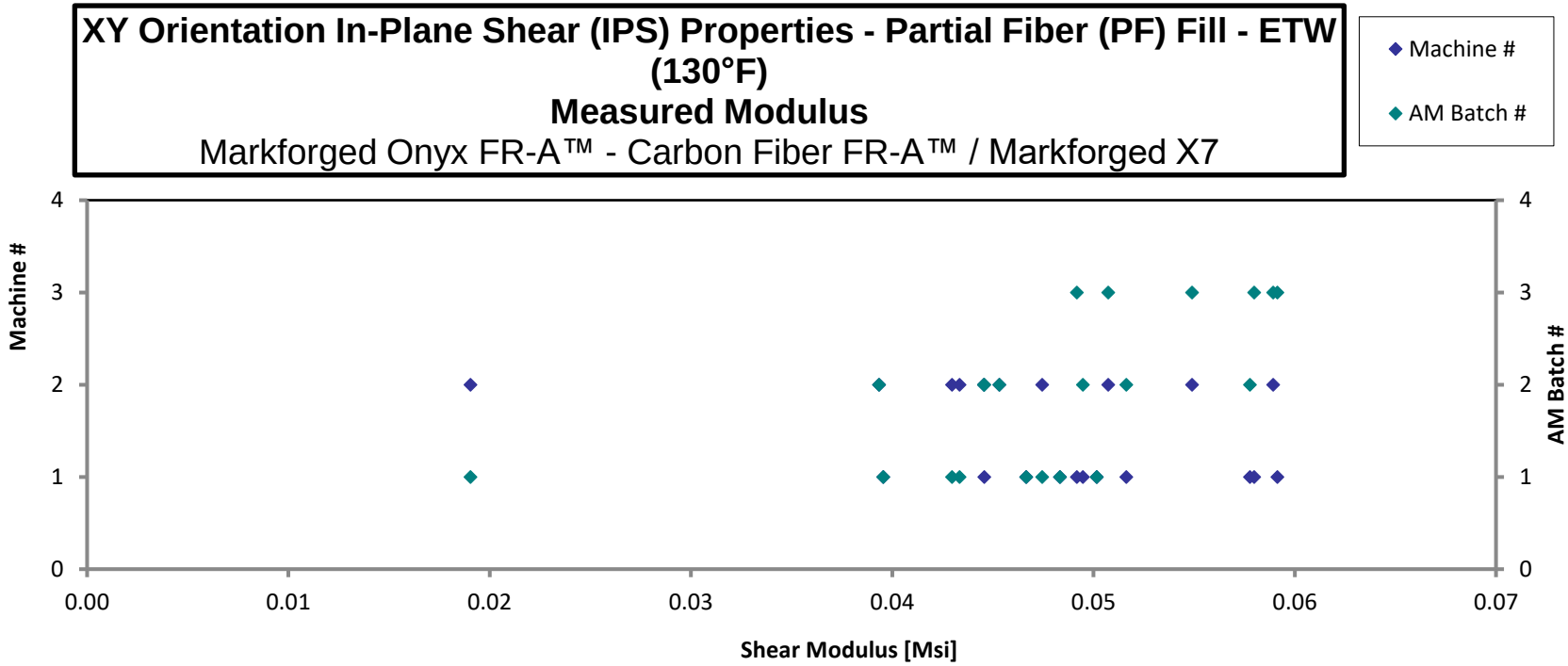
XY Orientation In-Plane Shear (IPS) Properties - ETW (130°F)
Partial Fiber (PF) Fill
Strength and Modulus
Markforged Onyx FR-A™ - Carbon Fiber FR-A™ / Markforged X7

Specimen Number	AM Batch #	Machine #	Avg. Specimen Thickness [in]	0.2% Offset Shear Strength [ksi]	5% Offset Shear Strength [ksi]	Maximum Shear Strength [ksi]	Shear Modulus [Msi]	Failure Mode
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M1-P30543-XY-IPS-11-ETW-PF-1	1	1	0.143	0.569	1.081	2.158	0.048	AGM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M1-P30352-XY-IPS-12-ETW-PF-2	1	1	0.143	0.548	1.072	1.807	0.047	AGM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M1-P30602-XY-IPS-13-ETW-PF-3	1	1	0.138	0.463	0.912	1.714	0.040	AGM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M1-P31494-XY-IPS-13-ETW-PF-SP	1	1	0.140	0.585	1.101	1.757	0.050	AGM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M2-P30542-XY-IPS-11-ETW-PF-1	1	2	0.143	0.556	1.082	1.972	0.047	AGM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M2-P30351-XY-IPS-12-ETW-PF-2	1	2	0.143	0.244	0.523	1.708	0.019	AGM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M2-P30601-XY-IPS-13-ETW-PF-3	1	2	0.138	0.500	0.972	1.652	0.043	AGM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M2-P31495-XY-IPS-13-ETW-PF-SP	1	2	0.139	0.494	0.961	1.656	0.043	AGM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-B-M1-P32236-XY-IPS-11-ETW-PF-1	2	1	0.141	0.650	1.231	1.847	0.058	AGM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-B-M1-P32870-XY-IPS-12-ETW-PF-2	2	1	0.145	0.632	1.119	1.445	0.052	AGM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-B-M1-P32848-XY-IPS-13-ETW-PF-3	2	1	0.142	0.565	1.102	1.544	0.049	AGM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-B-M1-P55269-XY-IPS-13-ETW-PF-6	2	1	0.139	0.617	1.092	2.107	0.045	AGM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-B-M2-P32235-XY-IPS-11-ETW-PF-1	2	2	0.140	0.516	1.013	1.544	0.045	AGM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-B-M2-P32871-XY-IPS-12-ETW-PF-2	2	2	0.143	0.448	0.876	1.394	0.039	AGM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-B-M2-P56064-XY-IPS-13-ETW-PF-3	2	2	0.142	0.519	1.000	1.630	0.045	AGM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-C-M1-P35360-XY-IPS-11-ETW-PF-1	3	1	0.141	0.767	1.353	2.011	0.059	AGM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-C-M1-P35272-XY-IPS-12-ETW-PF-2	3	1	0.142	0.620	1.245	1.925	0.058	AGM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-C-M1-P35473-XY-IPS-13-ETW-PF-3	3	1	0.140	0.663	1.152	1.761	0.049	AGM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-C-M2-P35359-XY-IPS-11-ETW-PF-1	3	2	0.142	0.613	1.259	2.004	0.059	AGM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-C-M2-P35422-XY-IPS-13-ETW-PF-3	3	2	0.142	0.711	1.273	1.793	0.055	AGM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-C-M2-P57239-XY-IPS-13-ETW-PF-6	3	2	0.141	0.713	1.214	1.935	0.051	AGM
		Average	**0.141**	**0.571**	**1.078**	**1.779**	**0.048**	
		Standard Dev.		**0.113**	**0.178**	**0.210**	**0.009**	
		Coeff. of Var. [%]		**19.76**	**16.55**	**11.78**	**18.63**	
		Min.	**0.138**	**0.244**	**0.523**	**1.394**	**0.019**	
		Max.	**0.145**	**0.767**	**1.353**	**2.158**	**0.059**	
		Number of Spec.	**21**	**21**	**21**	**21**	**21**	


XY Orientation In-Plane Shear (IPS) Properties - Partial Fiber (PF) Fill - ETW (130°F)
Measured 0.2% Offset Strength
Markforged Onyx FR-A™ - Carbon Fiber FR-A™ / Markforged X7
Machine #
AM Batch #
Machine #
AM Batch #
0.2% Offset Shear Strength [ksi]
0
1
2
3
4
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9


XY Orientation In-Plane Shear (IPS) Properties - Partial Fiber (PF) Fill - ETW (130°F)
Measured 5% Offset Strength
Markforged Onyx FR-A™ - Carbon Fiber FR-A™ / Markforged X7
Machine #
AM Batch #
Machine #
AM Batch #
5% Offset Shear Strength
0
1
2
3
4
0.00
0.20
0.40
0.60
0.80
1.00
1.20
1.40
1.60


XY Orientation In-Plane Shear (IPS) Properties - Partial Fiber (PF) Fill - ETW (130°F)
Measured Strength
Markforged Onyx FR-A™ - Carbon Fiber FR-A™ / Markforged X7
Machine #
AM Batch #
Machine #
AM Batch #
Maximum Shear Strength [ksi]
0
1
2
3
4
0.00
0.50
1.00
1.50
2.00
2.50

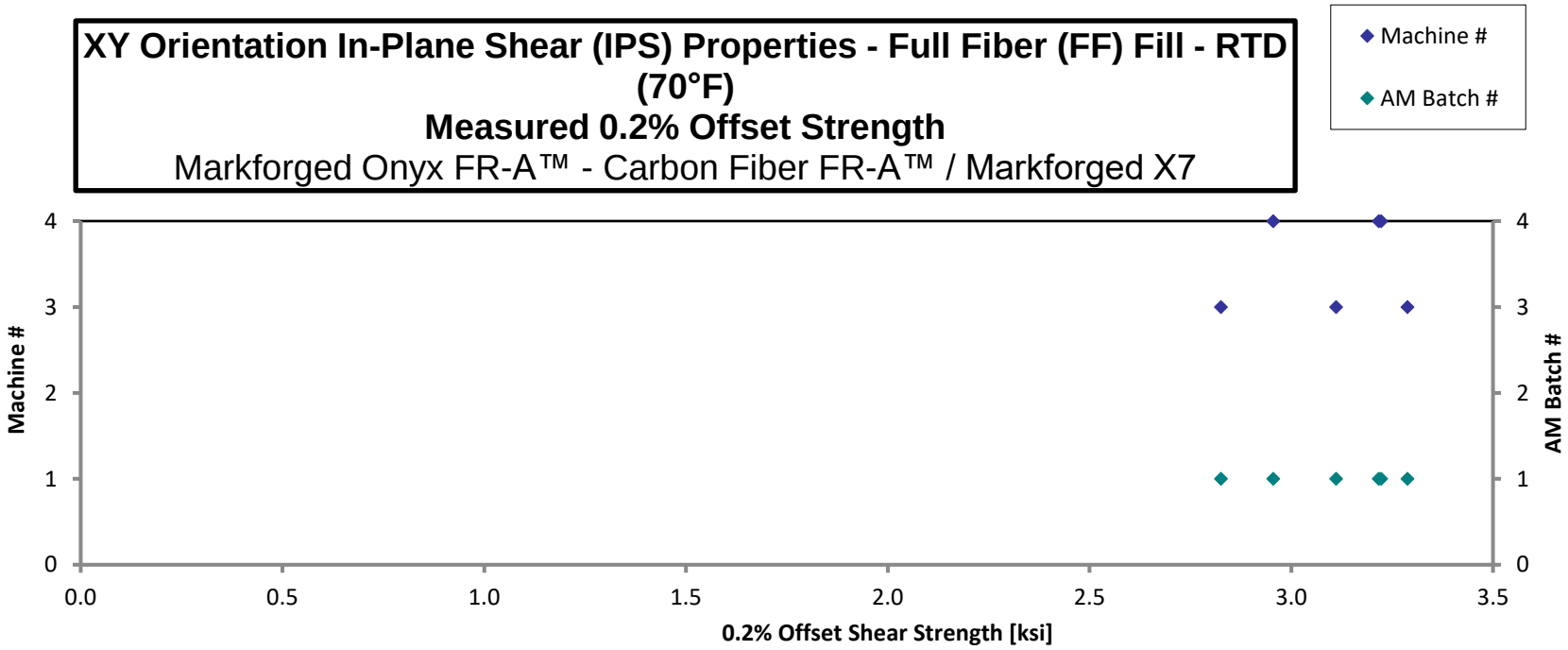

XY Orientation In-Plane Shear (IPS) Properties - Partial Fiber (PF) Fill - ETW (130°F)
Measured Modulus
Markforged Onyx FR-A™ - Carbon Fiber FR-A™ / Markforged X7
Machine #
AM Batch #
Machine #
AM Batch #
Shear Modulus [Msi]
0
1
2
3
4
0.00
0.01
0.02
0.03
0.04
0.05
0.06
0.07

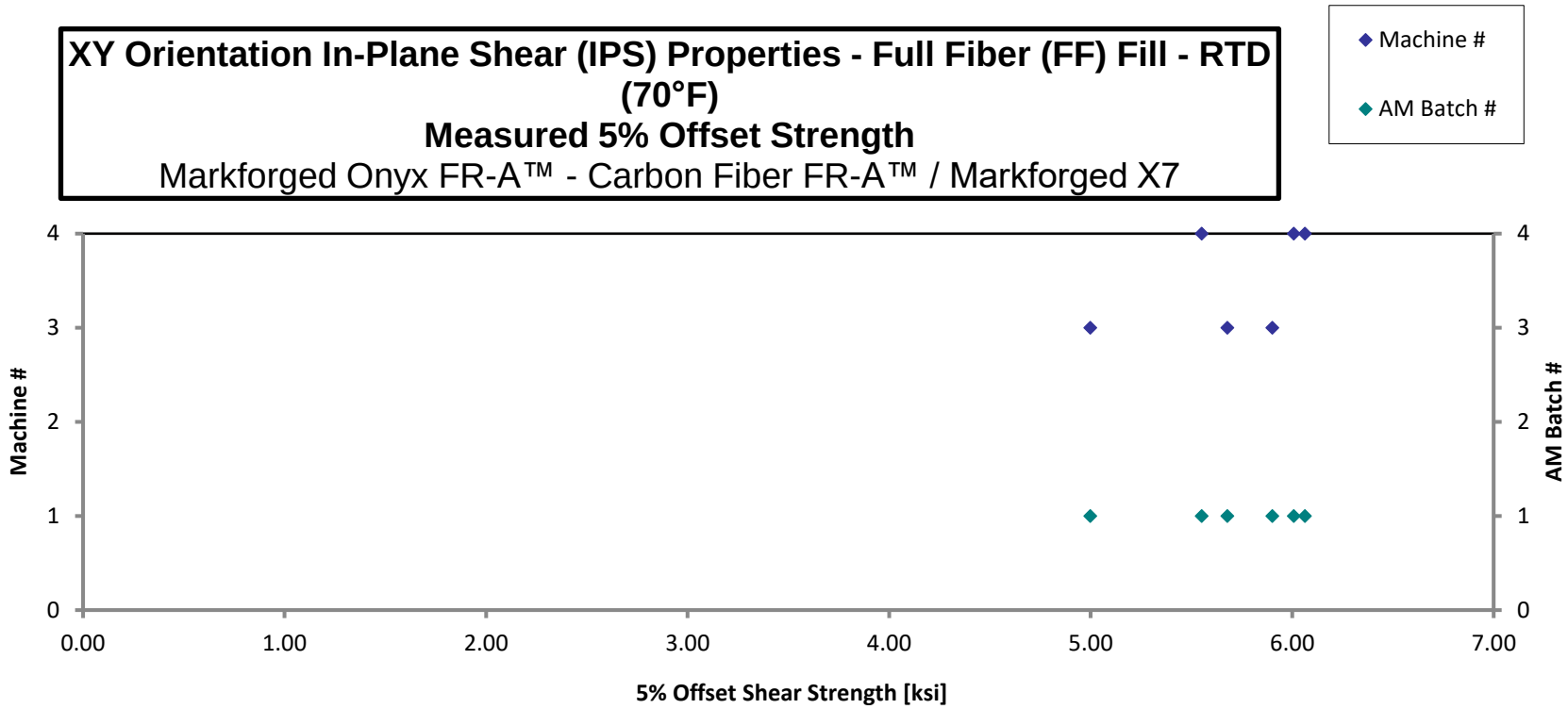
4.20 XY FF In-Plane Shear Properties – Reference Only

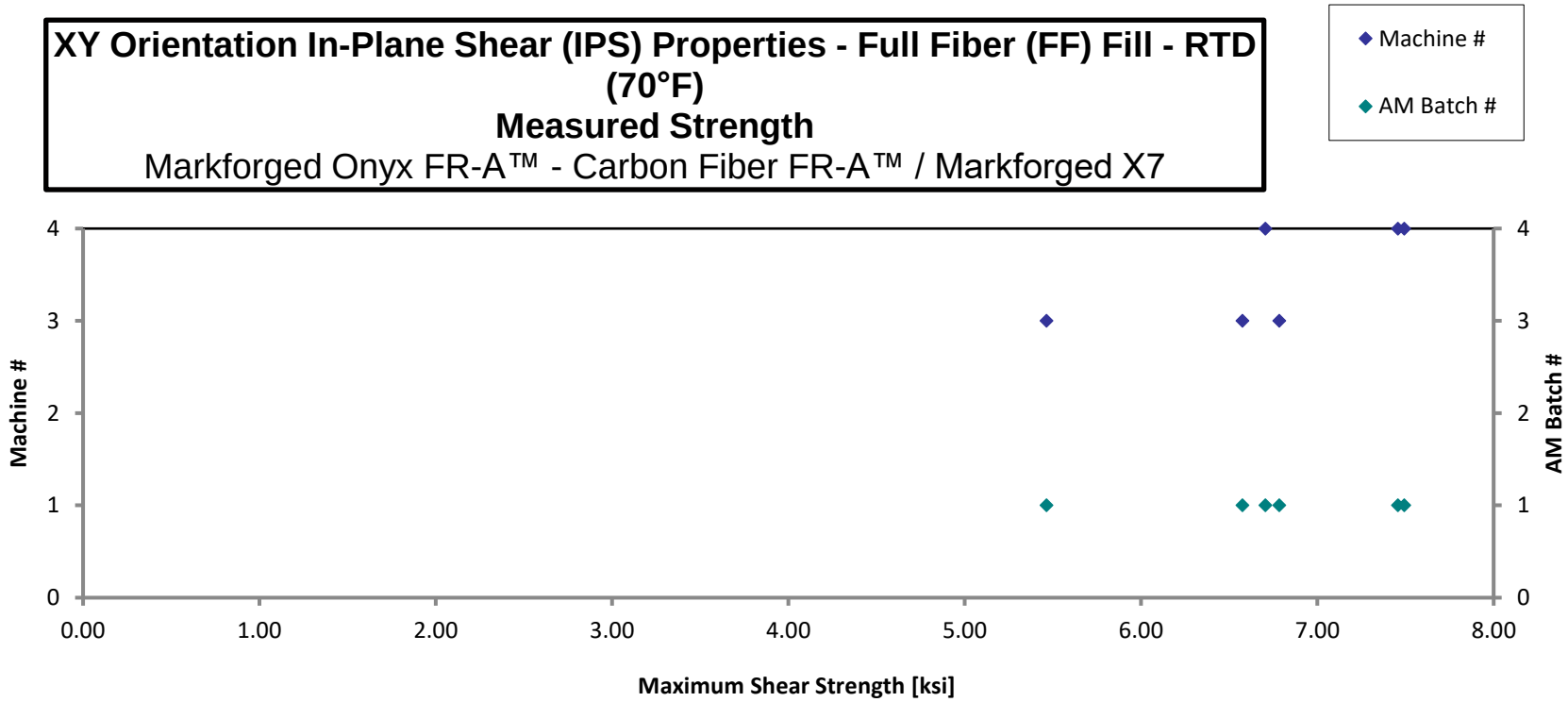
4.20.1 RTD Condition

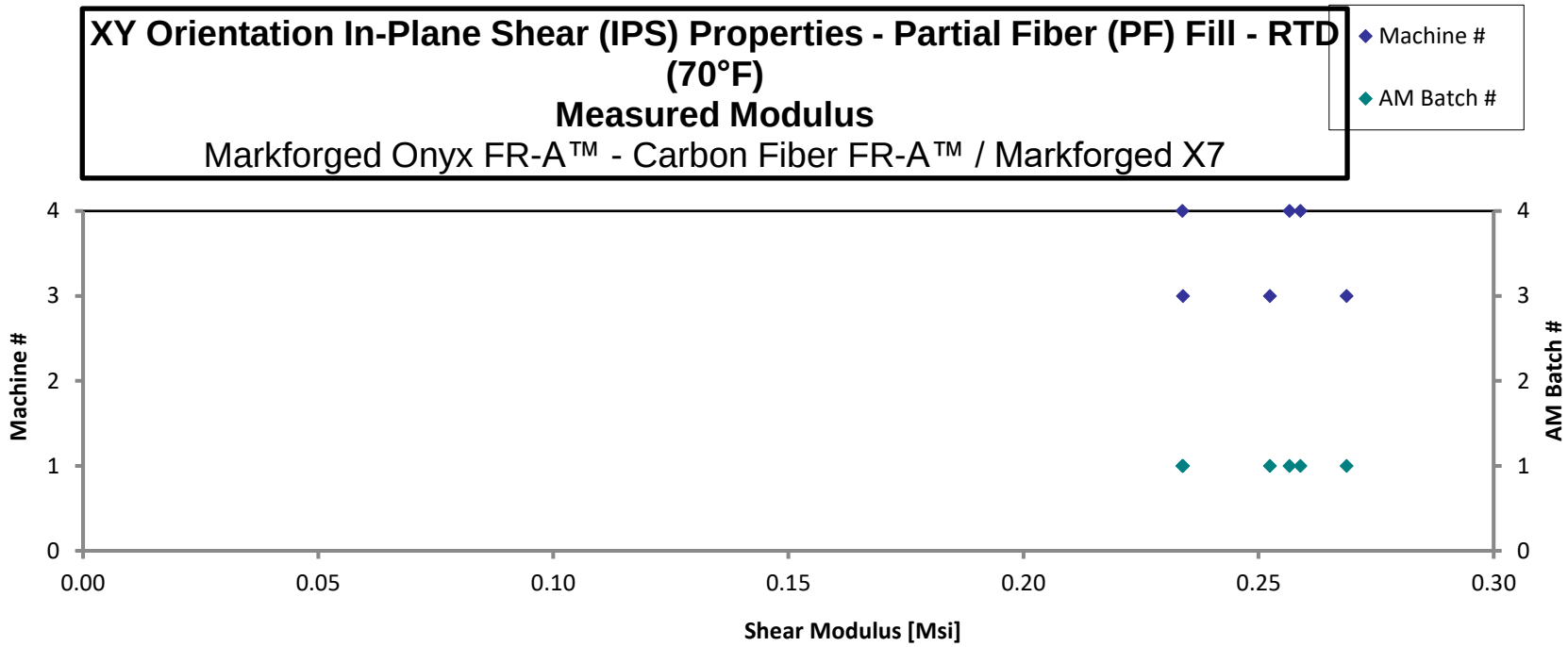
XY Orientation In-Plane Shear (IPS) Properties - RTD (70°F)
Full Fiber (FF) Fill
Strength and Modulus
Markforged Onyx FR-A™ - Carbon Fiber FR-A™ / Markforged X7

Specimen Number	AM Batch #	Machine #	Avg. Specimen Thickness [in]	0.2% Offset Shear Strength [ksi]	5% Offset Shear Strength [ksi]	Maximum Shear Strength [ksi]	Shear Modulus [Msi]	Failure Mode
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M3-P34369-XY-IPS-11-RTD-FF-1	1	3	0.143	3.288	5.902	6.783	0.269	M(A,L)WT
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M3-P34051-XY-IPS-12-RTD-FF-2	1	3	0.143	3.111	5.678	6.575	0.252	AGM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M3-P34059-XY-IPS-13-RTD-FF-3	1	3	0.143	2.826	4.999	5.464	0.234	M(A,L)GM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M4-P42319-XY-IPS-11-RTD-FF-1	1	4	0.141	3.223	6.008	7.457	0.259	M(A,L)WT
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M4-P41548-XY-IPS-12-RTD-FF-2	1	4	0.143	3.217	6.063	7.493	0.257	M(A,L)GM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M4-P42161-XY-IPS-13-RTD-FF-3	1	4	0.140	2.956	5.551	6.706	0.234	AWB
		Average	**0.142**	**3.103**	**5.700**	**6.746**	**0.251**	
		Standard Dev.		**0.179**	**0.396**	**0.740**	**0.014**	
		Coeff. of Var. [%]		**5.771**	**6.939**	**10.97**	**5.630**	
		Min.	**0.140**	**2.826**	**4.999**	**5.464**	**0.234**	
		Max.	**0.143**	**3.288**	**6.063**	**7.493**	**0.269**	
		Number of Spec.	**6**	**6**	**6**	**6**	**6**	


XY Orientation In-Plane Shear (IPS) Properties - Full Fiber (FF) Fill - RTD (70°F)
Measured 0.2% Offset Strength
Markforged Onyx FR-A™ - Carbon Fiber FR-A™ / Markforged X7
Machine #
AM Batch #
Machine #
AM Batch #
0.2% Offset Shear Strength [ksi]
0
1
2
3
4
0.0
0.5
1.0
1.5
2.0
2.5
3.0
3.5


XY Orientation In-Plane Shear (IPS) Properties - Full Fiber (FF) Fill - RTD (70°F)
Measured 5% Offset Strength
Markforged Onyx FR-A™ - Carbon Fiber FR-A™ / Markforged X7
Machine #
AM Batch #
Machine #
AM Batch #
0
1
2
3
4
0.00
1.00
2.00
3.00
4.00
5.00
6.00
7.00
5% Offset Shear Strength [ksi]


XY Orientation In-Plane Shear (IPS) Properties - Full Fiber (FF) Fill - RTD (70°F)
Measured Strength
Markforged Onyx FR-A™ - Carbon Fiber FR-A™ / Markforged X7
Machine #
AM Batch #
Machine #
AM Batch #
0
1
2
3
4
0.00
1.00
2.00
3.00
4.00
5.00
6.00
7.00
8.00
Maximum Shear Strength [ksi]


XY Orientation In-Plane Shear (IPS) Properties - Partial Fiber (PF) Fill - RTD (70°F)
Measured Modulus
Markforged Onyx FR-A™ - Carbon Fiber FR-A™ / Markforged X7
Machine #
AM Batch #
Machine #
AM Batch #
Shear Modulus [Msi]
0.00
0.05
0.10
0.15
0.20
0.25
0.30
0
1
2
3
4

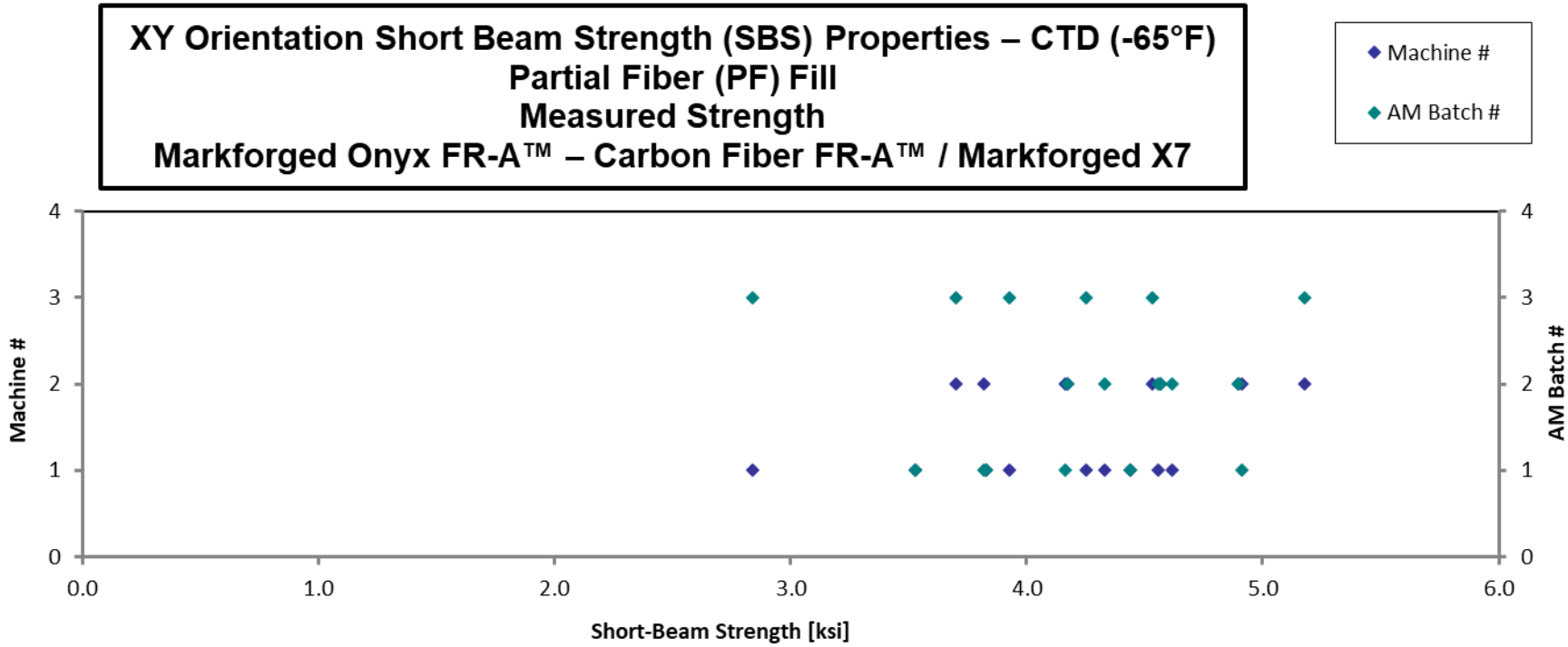
4.21 XY PF Short-Beam Strength Properties

4.21.1 CTD Condition

XY Orientation Short Beam Strength (SBS) Properties – CTD (-65°F)
Partial Fiber (PF) Fill
Strength
Markforged Onyx FR-A™ – Carbon Fiber FR-A™ / Markforged X7

Specimen Number	AM Batch #	Machine #	Avg. Specimen Thickness [in]	Short-Beam Strength [ksi]	Failure Mode
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M1-P42694-XY-SBS-11-CTD-PF-1	1	1	0.246	4.438	INTERLAMINAR SHEAR, COMPRESSION
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M1-P42485-XY-SBS-12-CTD-PF-2	1	1	0.247	3.830	INTERLAMINAR SHEAR
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M1-P56545-XY-SBS-13-CTD-PF-3	1	1	0.246	3.530	INTERLAMINAR SHEAR
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M2-P46125-XY-SBS-11-CTD-PF-1	1	2	0.247	4.913	INTERLAMINAR SHEAR, COMPRESSION
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M2-P42570-XY-SBS-12-CTD-PF-2	1	2	0.245	3.820	INTERLAMINAR SHEAR
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M2-P46278-XY-SBS-13-CTD-PF-3	1	2	0.247	4.164	INTERLAMINAR SHEAR
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-B-M1-P41167-XY-SBS-11-CTD-PF-1	2	1	0.246	4.616	INTERLAMINAR SHEAR, COMPRESSION
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-B-M1-P40689-XY-SBS-12-CTD-PF-2	2	1	0.246	4.331	INTERLAMINAR SHEAR, COMPRESSION
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-B-M1-P41281-XY-SBS-13-CTD-PF-3	2	1	0.247	4.558	INTERLAMINAR SHEAR, COMPRESSION
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-B-M2-P46401-XY-SBS-11-CTD-PF-1	2	2	0.247	4.173	INTERLAMINAR SHEAR, COMPRESSION
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-B-M2-P41201-XY-SBS-12-CTD-PF-2	2	2	0.244	4.566	INTERLAMINAR SHEAR
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-B-M2-P39984-XY-SBS-13-CTD-PF-3	2	2	0.246	4.898	INTERLAMINAR SHEAR, COMPRESSION
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-C-M1-P48475-XY-SBS-11-CTD-PF-1	3	1	0.245	4.252	INTERLAMINAR SHEAR
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-C-M1-P46997-XY-SBS-12-CTD-PF-2	3	1	0.247	3.929	INTERLAMINAR SHEAR
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-C-M1-P56877-XY-SBS-13-CTD-PF-3	3	1	0.246	2.837	INTERLAMINAR SHEAR
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-C-M2-P50292-XY-SBS-11-CTD-PF-1	3	2	0.247	5.179	INTERLAMINAR SHEAR, COMPRESSION
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-C-M2-P47150-XY-SBS-12-CTD-PF-2	3	2	0.246	4.533	INTERLAMINAR SHEAR, COMPRESSION
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-C-M2-P50104-XY-SBS-13-CTD-PF-3	3	2	0.247	3.700	INTERLAMINAR SHEAR, COMPRESSION

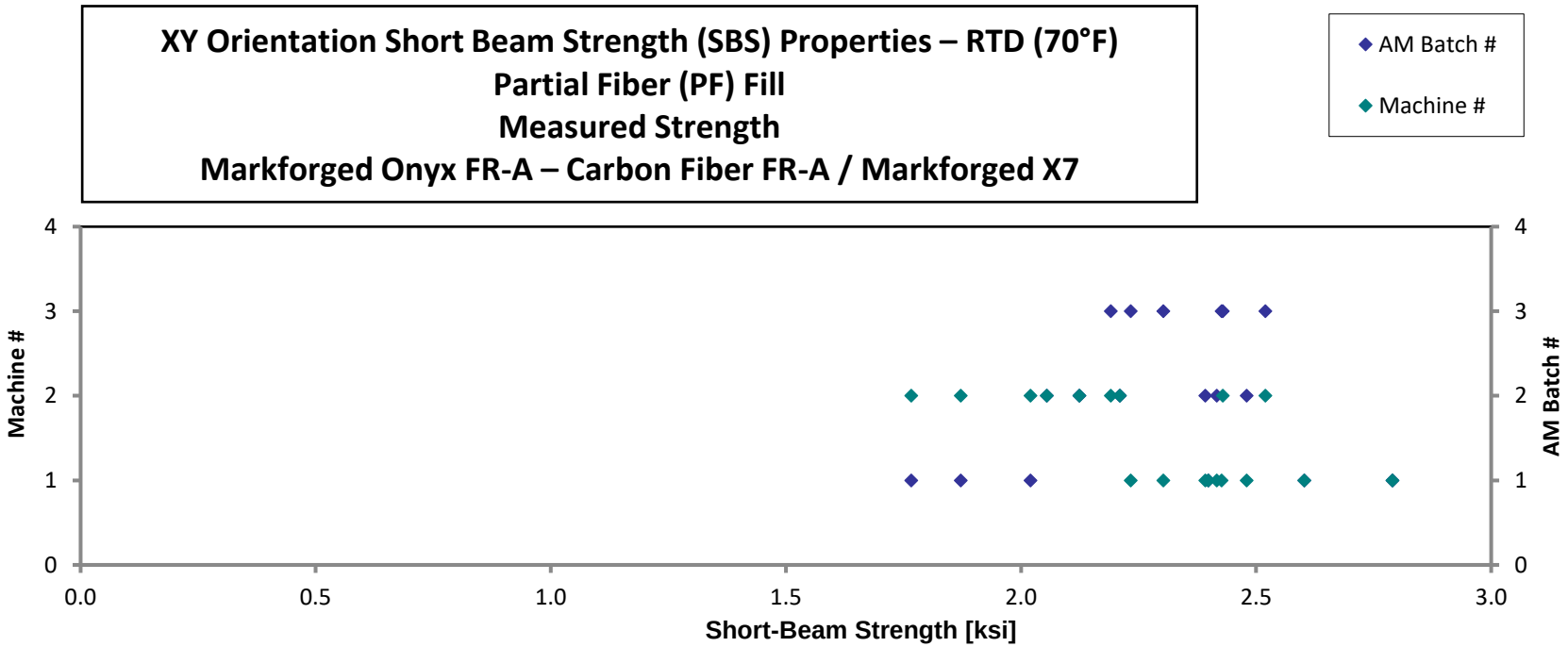
Average	**0.246**	**4.237**
Standard Dev.		**0.567**
Coeff. of Var. [%]		**13.38**
Min.	**0.244**	**2.837**
Max.	**0.247**	**5.179**
Number of Spec.	**18**	**18**


XY Orientation Short Beam Strength (SBS) Properties – CTD (-65°F)
Partial Fiber (PF) Fill
Measured Strength
Markforged Onyx FR-A™ – Carbon Fiber FR-A™ / Markforged X7
Machine #
AM Batch #
Machine #
AM Batch #
Short-Beam Strength [ksi]
0.0
1.0
2.0
3.0
4.0
5.0
6.0
0
1
2
3
4

4.21.2 **RTD Condition**

XY Orientation Short Beam Strength (SBS) Properties – RTD (70°F)
Partial Fiber (PF) Fill
Strength
Markforged Onyx FR-A™ – Carbon Fiber FR-A™ / Markforged X7

Specimen Number	AM Batch #	Machine #	Avg. Specimen Thickness [in]	Short-Beam Strength [ksi]	Failure Mode
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M1-P42485-XY-SBS-11-RTD-PF-1	1	1	0.247	2.790	INTERLAMINAR SHEAR
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M1-P56545-XY-SBS-12-RTD-PF-2	1	1	0.244	2.398	INTERLAMINAR SHEAR
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M1-P42694-XY-SBS-13-RTD-PF-3	1	1	0.245	2.603	INTERLAMINAR SHEAR
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M2-P42570-XY-SBS-11-RTD-PF-1	1	2	0.248	1.872	INTERLAMINAR SHEAR, INELASTIC DEFORMATION
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M2-P46278-XY-SBS-12-RTD-PF-2	1	2	0.244	1.766	INTERLAMINAR SHEAR, INELASTIC DEFORMATION
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M2-P46125-XY-SBS-13-RTD-PF-3	1	2	0.246	2.020	INTERLAMINAR SHEAR, INELASTIC DEFORMATION
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-B-M1-P40689-XY-SBS-11-RTD-PF-1	2	1	0.246	2.392	INTERLAMINAR SHEAR, INELASTIC DEFORMATION, TENSION
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-B-M1-P41281-XY-SBS-12-RTD-PF-2	2	1	0.246	2.417	INTERLAMINAR SHEAR, INELASTIC DEFORMATION
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-B-M1-P41167-XY-SBS-13-RTD-PF-3	2	1	0.245	2.480	INTERLAMINAR SHEAR, INELASTIC DEFORMATION, TENSION
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-B-M2-P41201-XY-SBS-11-RTD-PF-1	2	2	0.246	2.210	INTERLAMINAR SHEAR, INELASTIC DEFORMATION
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-B-M2-P39984-XY-SBS-12-RTD-PF-2	2	2	0.245	2.124	INTERLAMINAR SHEAR, INELASTIC DEFORMATION
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-B-M2-P46401-XY-SBS-13-RTD-PF-3	2	2	0.247	2.055	INTERLAMINAR SHEAR, INELASTIC DEFORMATION
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-C-M1-P46997-XY-SBS-11-RTD-PF-1	3	1	0.247	2.233	INTERLAMINAR SHEAR
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-C-M1-P56877-XY-SBS-12-RTD-PF-2	3	1	0.245	2.303	INTERLAMINAR SHEAR
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-C-M1-P48475-XY-SBS-13-RTD-PF-3	3	1	0.246	2.427	INTERLAMINAR SHEAR
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-C-M2-P47150-XY-SBS-11-RTD-PF-1	3	2	0.248	2.429	INTERLAMINAR SHEAR
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-C-M2-P50104-XY-SBS-12-RTD-PF-2	3	2	0.246	2.520	INTERLAMINAR SHEAR
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-C-M2-P50292-XY-SBS-13-RTD-PF-3	3	2	0.247	2.191	INTERLAMINAR SHEAR
		Average	**0.246**	**2.291**	
		Standard Dev.		**0.259**	
		Coeff. of Var. [%]		**11.29**	
		Min.	**0.244**	**1.766**	
		Max.	**0.248**	**2.790**	
		Number of Spec.	**18**	**18**	


XY Orientation Short Beam Strength (SBS) Properties – RTD (70°F)
Partial Fiber (PF) Fill
Measured Strength
Markforged Onyx FR-A – Carbon Fiber FR-A / Markforged X7
AM Batch #
Machine #
Machine #
AM Batch #
Short-Beam Strength [ksi]
0
1
2
3
4
0.0
0.5
1.0
1.5
2.0
2.5
3.0

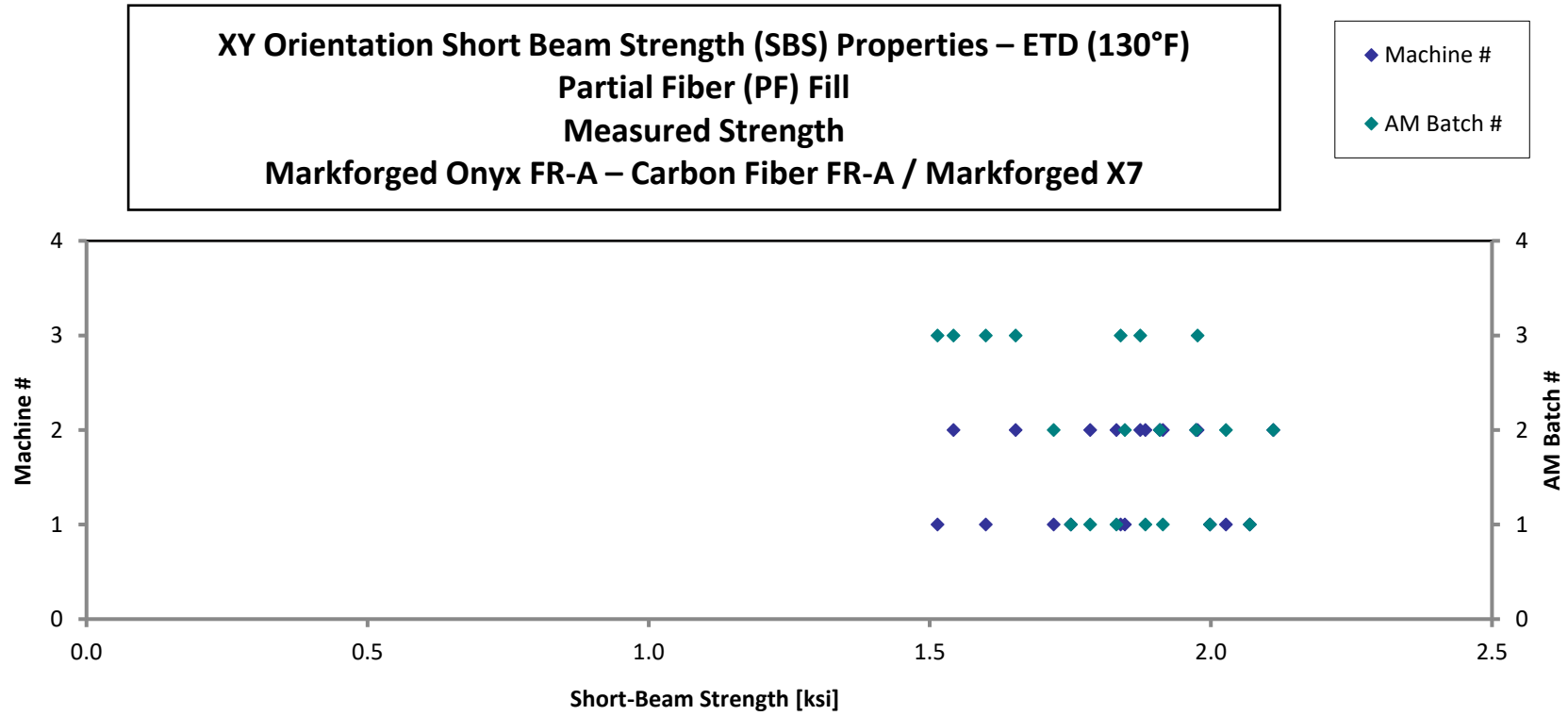
4.21.3 **ETD Condition**

XY Orientation Short Beam Strength (SBS) Properties – ETD (130°F)
Partial Fiber (PF) Fill
Strength
Markforged Onyx FR-A™ – Carbon Fiber FR-A™ / Markforged X7

Specimen Number	AM Batch #	Machine #	Avg. Specimen Thickness [in]	Short-Beam Strength [ksi]	Failure Mode
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M1-P43092-XY-SBS-11-ETD-PF-1	1	1	0.244	1.751	INTERLAMINAR SHEAR, INELASTIC DEFORMATION
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M1-P56664-XY-SBS-12-ETD-PF-2	1	1	0.247	1.998	INTERLAMINAR SHEAR, INELASTIC DEFORMATION, TENSION
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M1-P42981-XY-SBS-13-ETD-PF-3	1	1	0.242	2.069	INTERLAMINAR SHEAR, INELASTIC DEFORMATION, TENSION
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M2-P43812-XY-SBS-11-ETD-PF-1*	1	2	0.246	1.883	INTERLAMINAR SHEAR, INELASTIC DEFORMATION
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M2-P41580-XY-SBS-12-ETD-PF-2	1	2	0.248	1.785	INTERLAMINAR SHEAR, INELASTIC DEFORMATION
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M2-P42495-XY-SBS-13-ETD-PF-3	1	2	0.241	1.832	INTERLAMINAR SHEAR, INELASTIC DEFORMATION, TENSION
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M2-P43812-XY-SBS-13-ETD-PF-SP*	1	2	0.241	1.914	INTERLAMINAR SHEAR, INELASTIC DEFORMATION
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-B-M1-P41475-XY-SBS-11-ETD-PF-1*	2	1	0.244	2.027	INTERLAMINAR SHEAR, INELASTIC DEFORMATION
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-B-M1-P37827-XY-SBS-12-ETD-PF-2*	2	1	0.245	1.847	INTERLAMINAR SHEAR, INELASTIC DEFORMATION
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-B-M1-P41009-XY-SBS-13-ETD-PF-3	2	1	0.244	1.720	INTERLAMINAR SHEAR, TENSION, INELASTIC DEFORMATION
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-B-M2-P46559-XY-SBS-11-ETD-PF-1*	2	2	0.244	1.973	INTERLAMINAR SHEAR, INELASTIC DEFORMATION
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-B-M2-P38434-XY-SBS-12-ETD-PF-2*	2	2	0.245	2.111	INTERLAMINAR SHEAR, INELASTIC DEFORMATION, TENSION
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-B-M2-P46418-XY-SBS-13-ETD-PF-3	2	2	0.240	1.909	INTERLAMINAR SHEAR, INELASTIC DEFORMATION
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-C-M1-P47663-XY-SBS-11-ETD-PF-1	3	1	0.245	1.600	INTERLAMINAR SHEAR, INELASTIC DEFORMATION
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-C-M1-P48413-XY-SBS-12-ETD-PF-2	3	1	0.245	1.839	INTERLAMINAR SHEAR, INELASTIC DEFORMATION
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-C-M1-P47663-XY-SBS-13-ETD-PF-SP	3	1	0.246	1.514	INTERLAMINAR SHEAR, INELASTIC DEFORMATION
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-C-M2-P46999-XY-SBS-11-ETD-PF-1	3	2	0.247	1.653	INTERLAMINAR SHEAR, INELASTIC DEFORMATION, TENSION
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-C-M2-P49664-XY-SBS-12-ETD-PF-2	3	2	0.247	1.874	INTERLAMINAR SHEAR, INELASTIC DEFORMATION
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-C-M2-P47970-XY-SBS-13-ETD-PF-3	3	2	0.244	1.976	INTERLAMINAR SHEAR, INELASTIC DEFORMATION
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-C-M2-P46999-XY-SBS-13-ETD-PF-SP	3	2	0.242	1.542	INTERLAMINAR SHEAR, INELASTIC DEFORMATION

*Max load was obtained after the crosshead travel had exceeded specimen nominal thickness.

Average	**0.244**	**1.841**
Standard Dev.		**0.170**
Coeff. of Var. [%]		**9.231**
Min.	**0.240**	**1.514**
Max.	**0.248**	**2.111**
Number of Spec.	**20**	**20**


XY Orientation Short Beam Strength (SBS) Properties – ETD (130°F)
Partial Fiber (PF) Fill
Measured Strength
Markforged Onyx FR-A – Carbon Fiber FR-A / Markforged X7
Machine #
AM Batch #
Machine #
AM Batch #
Short-Beam Strength [ksi]
0
1
2
3
4
0.0
0.5
1.0
1.5
2.0
2.5

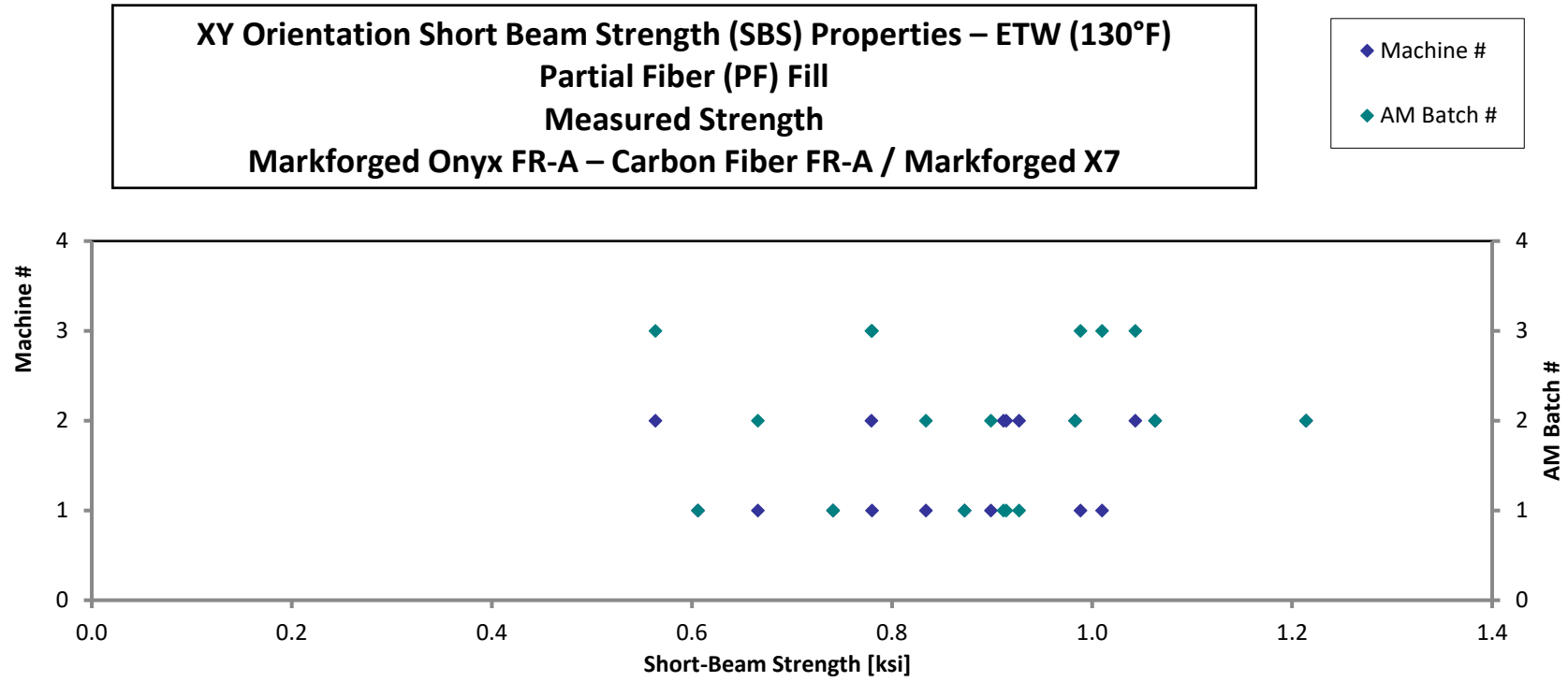
4.21.4 ETW Condition

XY Orientation Short Beam Strength (SBS) Properties – ETW (130°F)
Partial Fiber (PF) Fill
Strength
Markforged Onyx FR-A™ – Carbon Fiber FR-A™ / Markforged X7

Specimen Number	AM Batch #	Machine #	Avg. Specimen Thickness [in]	Short-Beam Strength [ksi]	Failure Mode
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M1-P56545-XY-SBS-11-ETW-PF-1	1	1	0.246	0.741	INELASTIC DEFORMATION
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M1-P42694-XY-SBS-12-ETW-PF-2	1	1	0.243	0.873	INTERLAMINAR SHEAR, INELASTIC DEFORMATION
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M1-P42485-XY-SBS-13-ETW-PF-3	1	1	0.246	0.606	INELASTIC DEFORMATION
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M2-P46278-XY-SBS-11-ETW-PF-1*	1	2	0.247	0.927	INELASTIC DEFORMATION
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M2-P46125-XY-SBS-12-ETW-PF-2*	1	2	0.244	0.914	INTERLAMINAR SHEAR, INELASTIC DEFORMATION
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M2-P42570-XY-SBS-13-ETW-PF-3*	1	2	0.248	0.912	INELASTIC DEFORMATION
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-B-M1-P41281-XY-SBS-11-ETW-PF-1	2	1	0.248	0.834	INTERLAMINAR SHEAR, INELASTIC DEFORMATION
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-B-M1-P41167-XY-SBS-12-ETW-PF-2*	2	1	0.244	0.899	INTERLAMINAR SHEAR, INELASTIC DEFORMATION
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-B-M1-P40689-XY-SBS-13-ETW-PF-3*	2	1	0.245	0.666	INELASTIC DEFORMATION
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-B-M2-P39984-XY-SBS-11-ETW-PF-1*	2	2	0.248	1.063	INELASTIC DEFORMATION
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-B-M2-P46401-XY-SBS-12-ETW-PF-2	2	2	0.245	0.983	INTERLAMINAR SHEAR, INELASTIC DEFORMATION
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-B-M2-P41201-XY-SBS-13-ETW-PF-3*	2	2	0.244	1.214	INTERLAMINAR SHEAR, INELASTIC DEFORMATION
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-C-M1-P56877-XY-SBS-11-ETW-PF-1	3	1	0.245	0.780	INELASTIC DEFORMATION
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-C-M1-P48475-XY-SBS-12-ETW-PF-2	3	1	0.243	1.010	INTERLAMINAR SHEAR, INELASTIC DEFORMATION
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-C-M1-P46997-XY-SBS-13-ETW-PF-3	3	1	0.246	0.988	INELASTIC DEFORMATION
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-C-M2-P50104-XY-SBS-11-ETW-PF-1	3	2	0.248	0.779	INELASTIC DEFORMATION
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-C-M2-P50292-XY-SBS-12-ETW-PF-2	3	2	0.245	1.043	INTERLAMINAR SHEAR, INELASTIC DEFORMATION
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-C-M2-P47150-XY-SBS-13-ETW-PF-3	3	2	0.245	0.563	INELASTIC DEFORMATION

*Max load was obtained after the crosshead travel had exceeded specimen nominal thickness.
Note: Inelastic deformation (invalid failure) was observed for all specimens due to the ductility of Onyx FR-A (Nylon) material. (Invalid per ASTM D2344)
Note: Due to inherent material properties, B-basis calculations will be calculated eventhough invalid tests were present.

Average	**0.246**	**0.878**
Standard Dev.		**0.168**
Coeff. of Var. [%]		**19.11**
Min.	**0.243**	**0.563**
Max.	**0.248**	**1.214**
Number of Spec.	**18**	**18**


XY Orientation Short Beam Strength (SBS) Properties – ETW (130°F)
Partial Fiber (PF) Fill
Measured Strength
Markforged Onyx FR-A – Carbon Fiber FR-A / Markforged X7
Machine #
AM Batch #
Machine #
AM Batch #
Short-Beam Strength [ksi]
0
1
2
3
4
0.0
0.2
0.4
0.6
0.8
1.0
1.2
1.4

4.22 **XY FF Short-Beam Strength Properties – Reference Only**

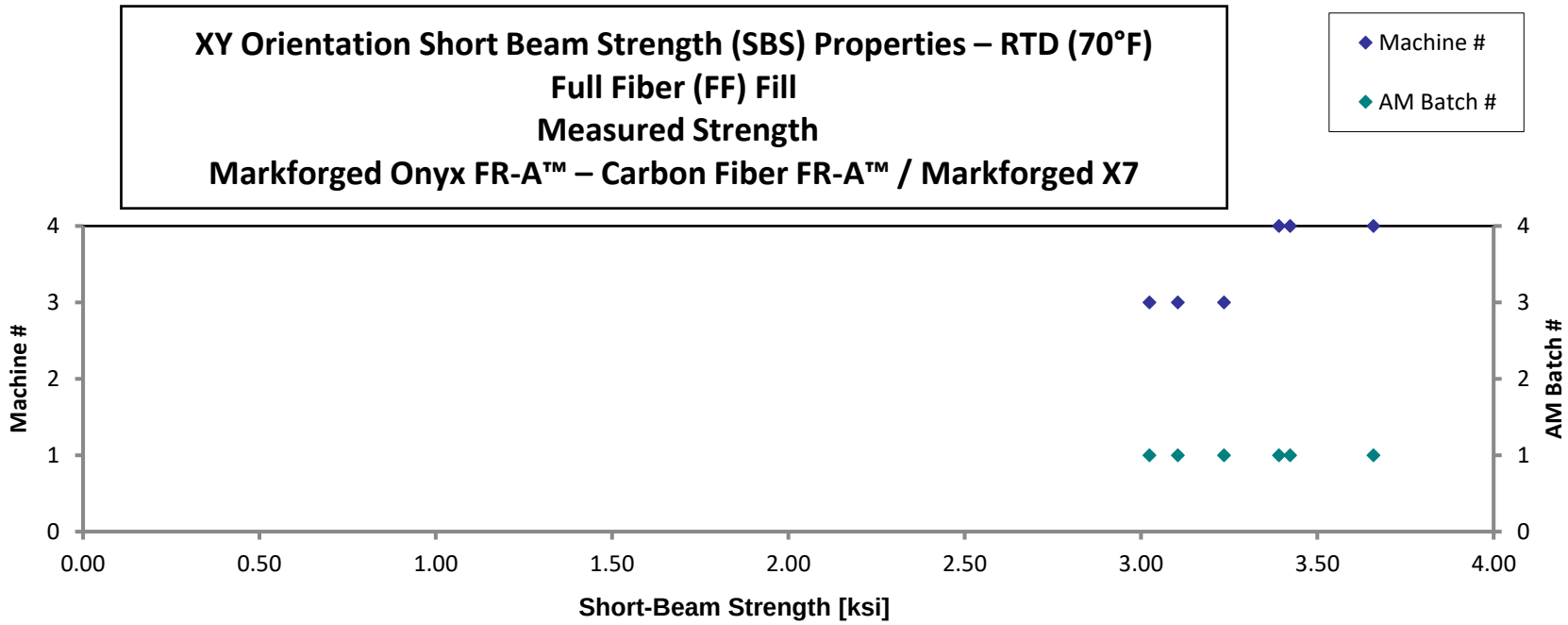
4.22.1 **RTD Condition**

XY Orientation Short Beam Strength (SBS) Properties – RTD (70°F)
Full Fiber (FF) Fill
Strength
Markforged Onyx FR-A™ – Carbon Fiber FR-A™ / Markforged X7

Specimen Number	AM Batch #	Machine #	Avg. Specimen Thickness [in]	Short-Beam Strength [ksi]	Failure Mode
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M3-P34051-XY-SBS-11-RTD-FF-1	1	3	0.246	3.105	INTERLAMINAR SHEAR, INELASTIC DEFORMATION
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M3-P34059-XY-SBS-12-RTD-FF-2	1	3	0.247	3.024	INTERLAMINAR SHEAR, INELASTIC DEFORMATION
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M3-P34369-XY-SBS-13-RTD-FF-3	1	3	0.247	3.235	INTERLAMINAR SHEAR, INELASTIC DEFORMATION
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M4-P41548-XY-SBS-11-RTD-FF-1	1	4	0.247	3.659	INTERLAMINAR SHEAR, INELASTIC DEFORMATION
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M4-P42161-XY-SBS-12-RTD-FF-2	1	4	0.246	3.391	INTERLAMINAR SHEAR, INELASTIC DEFORMATION
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M4-P42319-XY-SBS-13-RTD-FF-3	1	4	0.242	3.423	INTERLAMINAR SHEAR, INELASTIC DEFORMATION

Note: Inelastic deformation (invalid failure) was observed for all specimens due to the ductility of Onyx FR-A (Nylon) material, therefore, strength value reported for **reference only**.

Average	**0.246**	**3.306**
Standard Dev.		**0.233**
Coeff. of Var. [%]		**7.038**
Min.	**0.242**	**3.024**
Max.	**0.247**	**3.659**
Number of Spec.	**6**	**6**

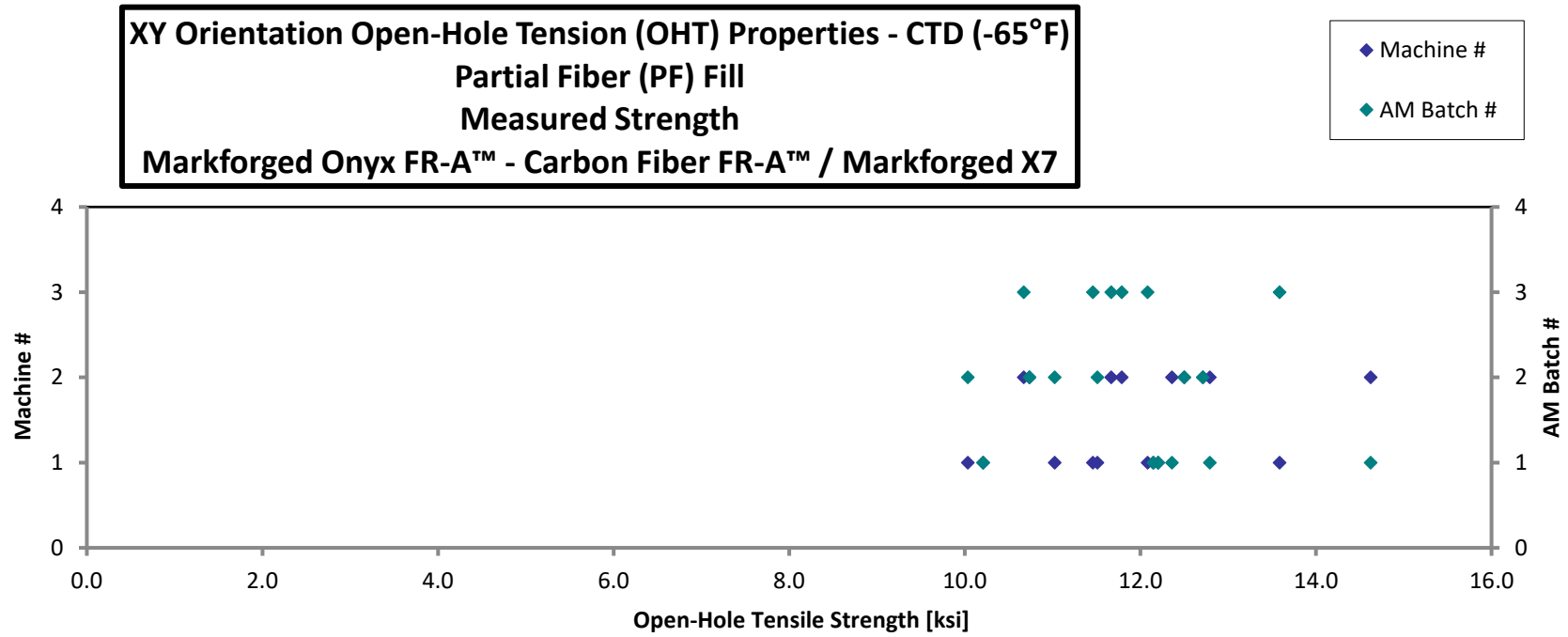

XY Orientation Short Beam Strength (SBS) Properties – RTD (70°F)
Full Fiber (FF) Fill
Measured Strength
Markforged Onyx FR-A™ – Carbon Fiber FR-A™ / Markforged X7
Machine #
AM Batch #
Machine #
AM Batch #
Short-Beam Strength [ksi]
0
1
2
3
4
0.00
0.50
1.00
1.50
2.00
2.50
3.00
3.50
4.00

4.23 XY PF Open-Hole Tension Properties

4.23.1 CTD Condition

XY Orientation Open-Hole Tension (OHT) Properties - CTD (-65°F)
Partial Fiber (PF) Fill
Strength
Markforged Onyx FR-A™ - Carbon Fiber FR-A™ / Markforged X7

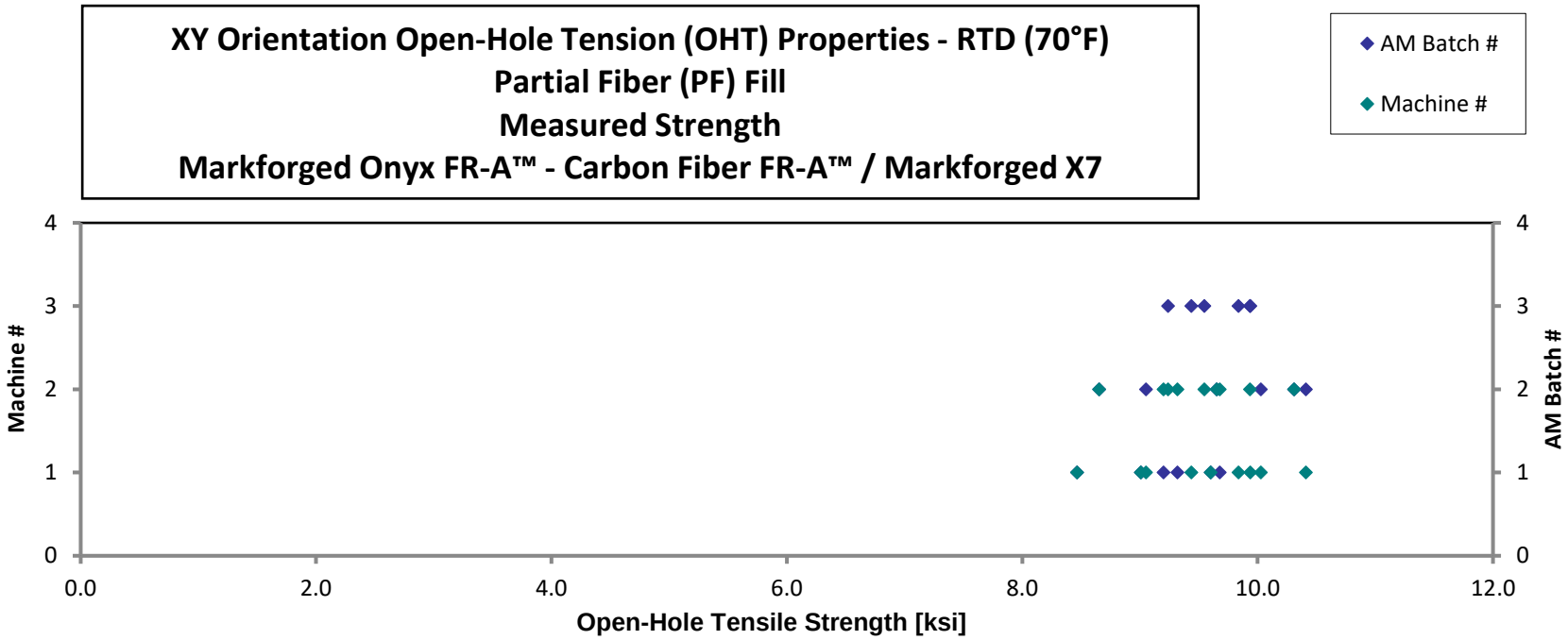
Specimen Number	AM Batch #	Machine #	Avg. Specimen Thickness [in]	Open-Hole Tensile Strength [ksi]	Failure Mode
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M1-P31365-XY-OHT-11-CTD-PF-1	1	1	0.146	12.15	M(A,L)GM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M1-P31575-XY-OHT-12-CTD-PF-2	1	1	0.152	12.20	M(A,L)GM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M1-P30189-XY-OHT-13-CTD-PF-3	1	1	0.151	10.21	M(A,L)GM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M2-P31366-XY-OHT-11-CTD-PF-1	1	2	0.143	12.79	M(A,L)GM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M2-P31576-XY-OHT-12-CTD-PF-2	1	2	0.146	14.62	M(A,L)GM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M2-P30202-XY-OHT-13-CTD-PF-3	1	2	0.148	12.36	M(A,L)GM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-B-M1-P34954-XY-OHT-11-CTD-PF-1	2	1	0.144	11.02	LGM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-B-M1-P33521-XY-OHT-12-CTD-PF-2	2	1	0.149	10.04	M(A,L)GM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-B-M1-P32607-XY-OHT-13-CTD-PF-3	2	1	0.149	11.51	M(A,L)GM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-B-M2-P34888-XY-OHT-11-CTD-PF-1	2	2	0.145	12.50	M(A,L)GM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-B-M2-P33520-XY-OHT-12-CTD-PF-2	2	2	0.149	12.71	M(A,L)GM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-B-M2-P36678-XY-OHT-13-CTD-PF-3	2	2	0.147	10.74	M(A,L)GM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-C-M1-P48667-XY-OHT-11-CTD-PF-1	3	1	0.143	11.46	M(A,L)GM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-C-M1-P49969-XY-OHT-12-CTD-PF-2	3	1	0.146	12.08	M(A,L)GM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-C-M1-P35834-XY-OHT-13-CTD-PF-3	3	1	0.145	13.59	M(A,L)GM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-C-M2-P35710-XY-OHT-11-CTD-PF-1	3	2	0.142	11.67	M(A,L)GM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-C-M2-P57301-XY-OHT-12-CTD-PF-2	3	2	0.146	10.67	M(A,L)GM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-C-M2-P35396-XY-OHT-13-CTD-PF-3	3	2	0.145	11.79	M(A,L)GM
		Average	**0.146**	**11.89**	
		Standard Dev.		**1.159**	
		Coeff. of Var. [%]		**9.747**	
		Min.	**0.142**	**10.04**	
		Max.	**0.152**	**14.62**	
		Number of Spec.	**18**	**18**	


XY Orientation Open-Hole Tension (OHT) Properties - CTD (-65°F)
Partial Fiber (PF) Fill
Measured Strength
Markforged Onyx FR-A™ - Carbon Fiber FR-A™ / Markforged X7
Machine #
AM Batch #
Machine #
AM Batch #
Open-Hole Tensile Strength [ksi]
0
1
2
3
4
0.0
2.0
4.0
6.0
8.0
10.0
12.0
14.0
16.0

4.23.2 **RTD Condition**

XY Orientation Open-Hole Tension (OHT) Properties - RTD (70°F)
Partial Fiber (PF) Fill
Strength
Markforged Onyx FR-A™ - Carbon Fiber FR-A™ / Markforged X7

Specimen Number	AM Batch #	Machine #	Avg. Specimen Thickness [in]	Open-Hole Tensile Strength [ksi]	Failure Mode
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M1-P31365-XY-OHT-11-RTD-PF-1	1	1	0.146	9.602	M(A,L)GM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M1-P30189-XY-OHT-12-RTD-PF-2	1	1	0.148	8.467	M(A,L)GM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M1-P45017-XY-OHT-13-RTD-PF-3	1	1	0.148	9.009	M(A,L)GM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M2-P31366-XY-OHT-11-RTD-PF-1	1	2	0.146	9.679	AGM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M2-P30202-XY-OHT-12-RTD-PF-2	1	2	0.147	9.199	AGM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M2-P29960-XY-OHT-13-RTD-PF-3	1	2	0.148	9.318	AGM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-B-M1-P34954-XY-OHT-11-RTD-PF-1	2	1	0.146	9.052	M(A,L)GM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-B-M1-P32607-XY-OHT-12-RTD-PF-2	2	1	0.149	10.41	M(A,L)GM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-B-M1-P36645-XY-OHT-13-RTD-PF-3	2	1	0.147	10.03	AGM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-B-M2-P56535-XY-OHT-11-RTD-PF-1	2	2	0.143	10.31	M(A,L)GM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-B-M2-P36678-XY-OHT-12-RTD-PF-2	2	2	0.142	9.652	M(A,L)GM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-B-M2-P56729-XY-OHT-13-RTD-PF-3	2	2	0.141	8.653	AGM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-C-M1-P48667-XY-OHT-11-RTD-PF-1	3	1	0.144	9.939	M(A,L)GM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-C-M1-P35834-XY-OHT-12-RTD-PF-2	3	1	0.144	9.836	M(A,L)GM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-C-M1-P50410-XY-OHT-13-RTD-PF-3	3	1	0.145	9.437	M(A,L)GM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-C-M2-P35710-XY-OHT-11-RTD-PF-1	3	2	0.144	9.934	M(A,L)GM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-C-M2-P35396-XY-OHT-12-RTD-PF-2	3	2	0.145	9.239	M(A,L)GM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-C-M2-P57299-XY-OHT-13-RTD-PF-3	3	2	0.145	9.548	M(A,L)GM
		Average	**0.145**	**9.517**	
		Standard Dev.		**0.528**	
		Coeff. of Var. [%]		**5.549**	
		Min.	**0.141**	**8.467**	
		Max.	**0.149**	**10.41**	
		Number of Spec.	**18**	**18**	

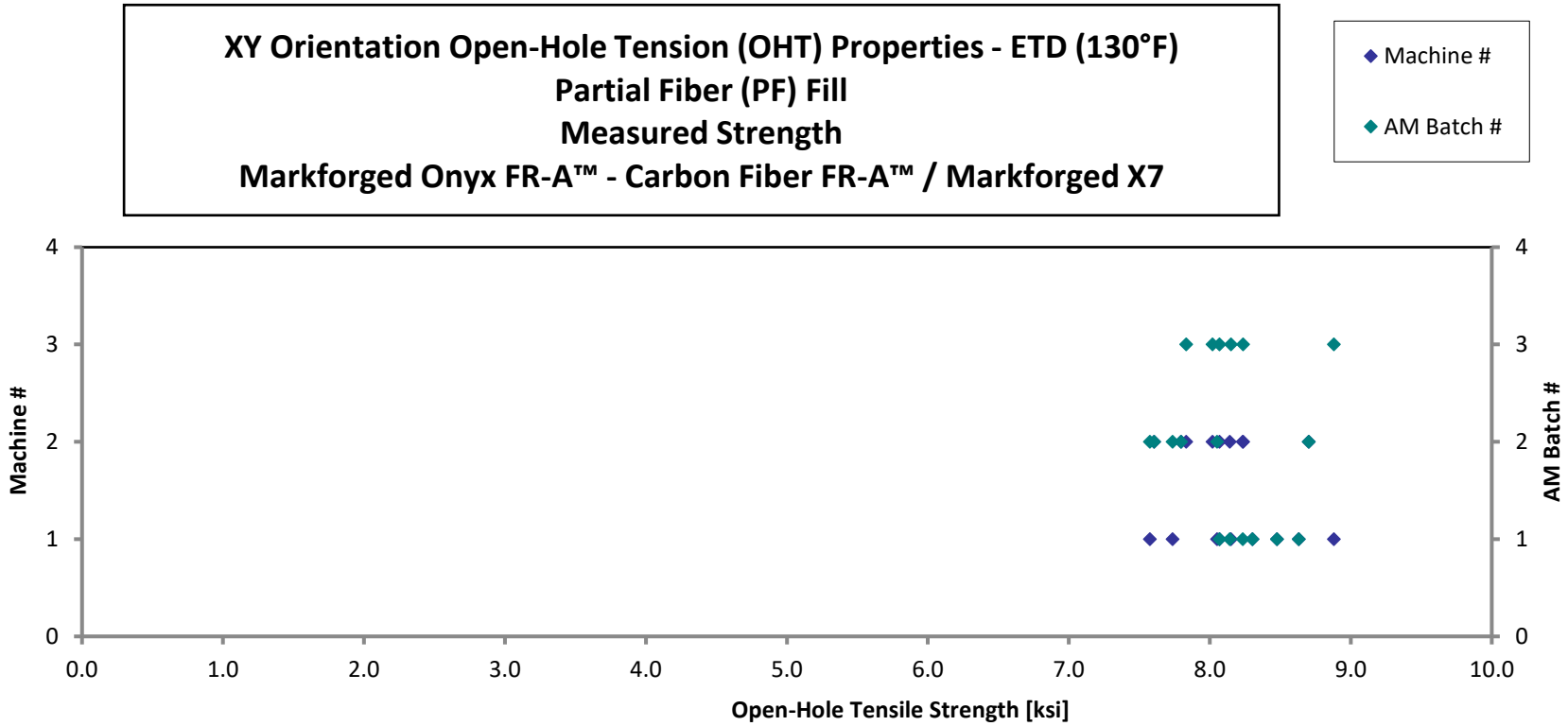

XY Orientation Open-Hole Tension (OHT) Properties - RTD (70°F)
Partial Fiber (PF) Fill
Measured Strength
Markforged Onyx FR-A™ - Carbon Fiber FR-A™ / Markforged X7
AM Batch #
Machine #
Machine #
AM Batch #
Open-Hole Tensile Strength [ksi]
0
1
2
3
4
0.0
2.0
4.0
6.0
8.0
10.0
12.0

4.23.3 ETD Condition

XY Orientation Open-Hole Tension (OHT) Properties - ETD (130°F)
Partial Fiber (PF) Fill
Strength
Markforged Onyx FR-A™ - Carbon Fiber FR-A™ / Markforged X7

Specimen Number	AM Batch #	Machine #	Avg. Specimen Thickness [in]	Open-Hole Tensile Strength [ksi]	Failure Mode
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M1-P53892-XY-OHT-11-ETD-PF-1	1	1	0.140	8.477	AGM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M1-P46009-XY-OHT-12-ETD-PF-2	1	1	0.143	8.303	M(A,L)GM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M1-P45710-XY-OHT-13-ETD-PF-3	1	1	0.140	8.630	M(A,L)GM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M2-P43340-XY-OHT-11-ETD-PF-1	1	2	0.145	8.141	M(A,L)GM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M2-P44383-XY-OHT-12-ETD-PF-2	1	2	0.147	8.068	AGM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M2-P44452-XY-OHT-13-ETD-PF-3	1	2	0.146	8.233	M(A,L)GM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-B-M1-P46400-XY-OHT-11-ETD-PF-1	2	1	0.141	7.735	AGM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-B-M1-P56226-XY-OHT-12-ETD-PF-2	2	1	0.145	7.575	AGM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-B-M1-P37474-XY-OHT-13-ETD-PF-3	2	1	0.142	8.052	AGM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-B-M2-P41336-XY-OHT-11-ETD-PF-1	2	2	0.140	8.702	AGM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-B-M2-P54843-XY-OHT-12-ETD-PF-2	2	2	0.144	7.605	AGM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-B-M2-P37467-XY-OHT-13-ETD-PF-3	2	2	0.142	7.796	AGM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-C-M1-P50045-XY-OHT-11-ETD-PF-1	3	1	0.141	8.149	M(A,L)GM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-C-M1-P50310-XY-OHT-12-ETD-PF-2	3	1	0.146	8.069	AGM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-C-M1-P49381-XY-OHT-13-ETD-PF-3	3	1	0.141	8.880	M(A,L)GM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-C-M2-P48418-XY-OHT-11-ETD-PF-1	3	2	0.146	7.833	AGM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-C-M2-P51235-XY-OHT-12-ETD-PF-2	3	2	0.148	8.236	AGM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-C-M2-P49354-XY-OHT-13-ETD-PF-3	3	2	0.146	8.018	AGM

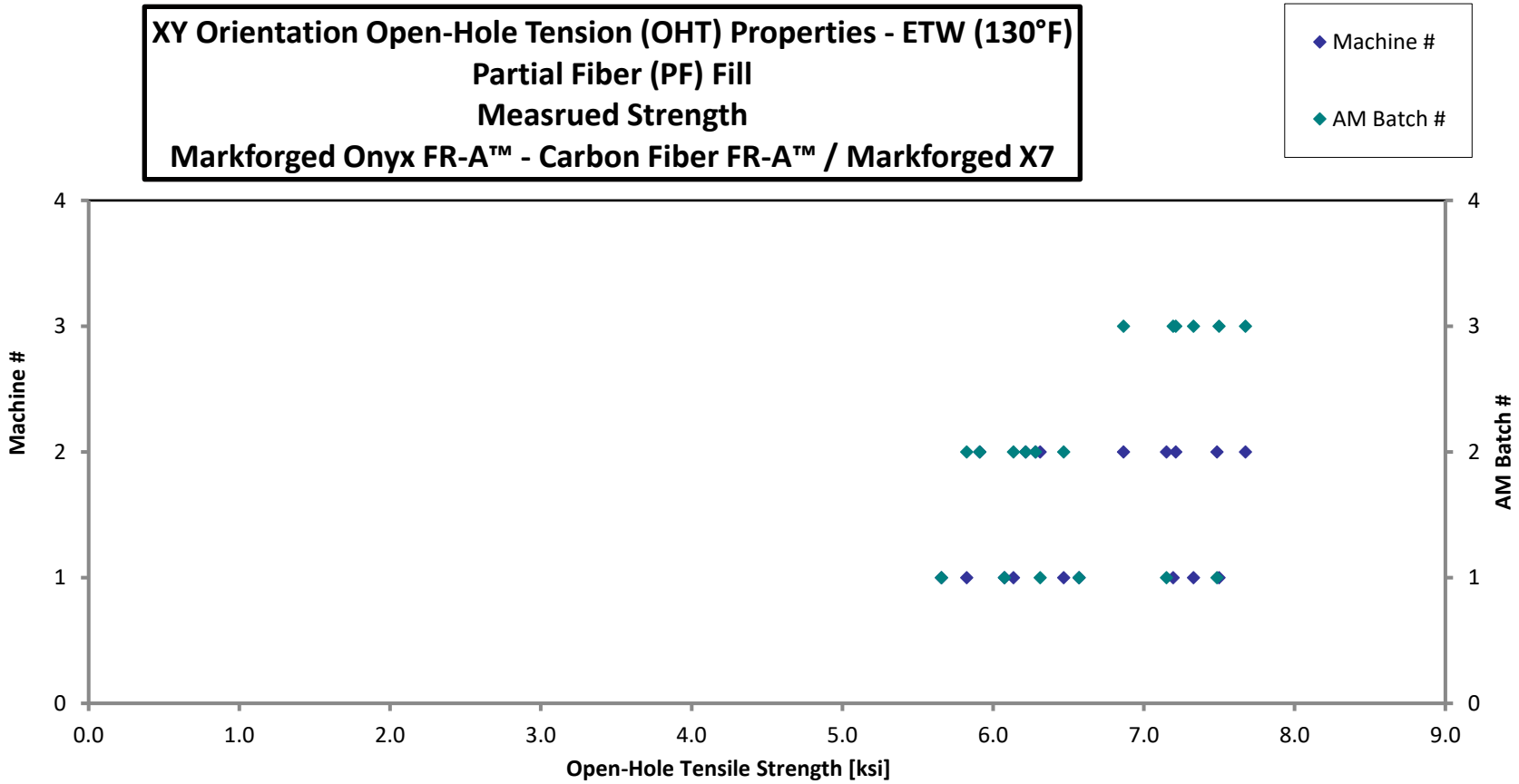
Average	**0.144**	**8.139**
Standard Dev.		**0.366**
Coeff. of Var. [%]		**4.496**
Min.	**0.140**	**7.575**
Max.	**0.148**	**8.880**
Number of Spec.	**18**	**18**


XY Orientation Open-Hole Tension (OHT) Properties - ETD (130°F)
Partial Fiber (PF) Fill
Measured Strength
Markforged Onyx FR-A™ - Carbon Fiber FR-A™ / Markforged X7
Machine #
AM Batch #
Machine #
AM Batch #
Open-Hole Tensile Strength [ksi]
0
1
2
3
4
0.0
1.0
2.0
3.0
4.0
5.0
6.0
7.0
8.0
9.0
10.0

4.23.4 ETW Condition

XY Orientation Open-Hole Tension (OHT) Properties - ETW (130°F)
Partial Fiber (PF) Fill
Strength
Markforged Onyx FR-A™ - Carbon Fiber FR-A™ / Markforged X7

Specimen Number	AM Batch #	Machine #	Avg. Specimen Thickness [in]	Open-Hole Tensile Strength [ksi]	Failure Mode
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M1-P45017-XY-OHT-11-ETW-PF-1	1	1	0.145	6.570	AGM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M1-P30189-XY-OHT-12-ETW-PF-2	1	1	0.147	5.658	AGM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M1-P31575-XY-OHT-13-ETW-PF-3	1	1	0.150	6.076	AGM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M2-P29960-XY-OHT-11-ETW-PF-1	1	2	0.143	7.149	AGM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M2-P30202-XY-OHT-12-ETW-PF-2	1	2	0.145	6.312	AGM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M2-P31576-XY-OHT-13-ETW-PF-3	1	2	0.146	7.485	AGM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-B-M1-P36645-XY-OHT-11-ETW-PF-1	2	1	0.144	6.135	AGM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-B-M1-P32607-XY-OHT-12-ETW-PF-2	2	1	0.149	6.468	AGM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-B-M1-P33521-XY-OHT-13-ETW-PF-3	2	1	0.151	5.826	AGM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-C-M1-P50410-XY-OHT-11-ETW-PF-1	3	1	0.144	7.194	AGM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-C-M1-P35834-XY-OHT-12-ETW-PF-2	3	1	0.143	7.329	AGM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-C-M1-P49969-XY-OHT-13-ETW-PF-3	3	1	0.147	7.499	AGM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-C-M2-P57299-XY-OHT-11-ETW-PF-1	3	2	0.142	7.675	M(A,L)GM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-C-M2-P35396-XY-OHT-12-ETW-PF-2	3	2	0.144	7.212	AGM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-C-M2-P57301-XY-OHT-13-ETW-PF-3	3	2	0.145	6.865	M(A,L)GM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-B-M2-P36678-XY-OHT-12-ETW-PF-2	2	2	0.142	6.215	AGM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-B-M2-P33520-XY-OHT-13-ETW-PF-3	2	2	0.144	5.912	M(A,L)GM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-B-M2-P33648-XY-OHT-13-ETW-PF-SP	2	2	0.144	6.282	M(A,L)GM
		Average	**0.145**	**6.659**	
		Standard Dev.		**0.647**	
		Coeff. of Var. [%]		**9.717**	
		Min.	**0.142**	**5.658**	
		Max.	**0.151**	**7.675**	
		Number of Spec.	**18**	**18**	

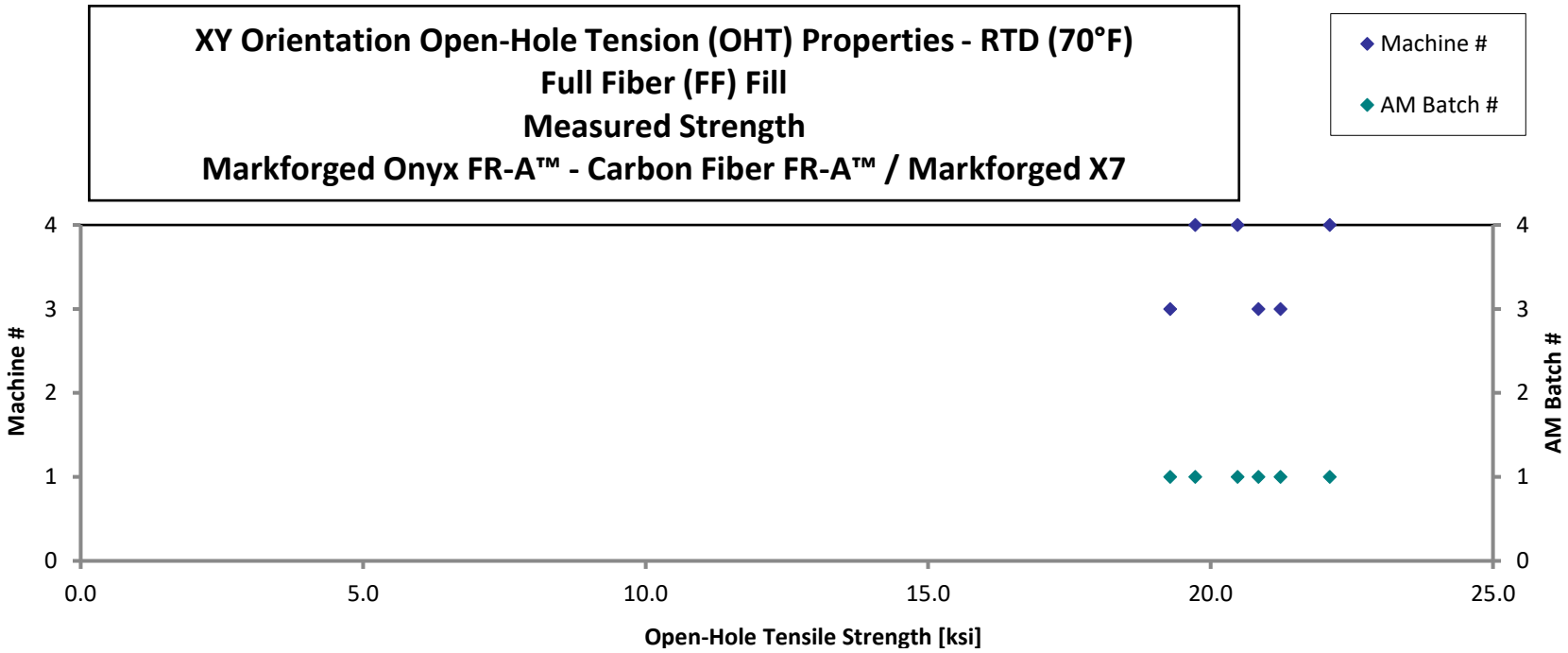


4.24 **XY FF Open-Hole Tension Properties**

4.24.1 **RTD Condition**

XY Orientation Open-Hole Tension (OHT) Properties - RTD (70°F)
Full Fiber (FF) Fill
Strength
Markforged Onyx FR-A™ - Carbon Fiber FR-A™ / Markforged X7

Specimen Number	AM Batch #	Machine #	Avg. Specimen Thickness [in]	Open-Hole Tensile Strength [ksi]	Failure Mode
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M3-P38723-XY-OHT-11-RTD-FF-1	1	3	0.145	20.85	AGM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M3-P35705-XY-OHT-12-RTD-FF-2	1	3	0.146	19.29	AGM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M3-P35616-XY-OHT-13-RTD-FF-3	1	3	0.148	21.24	M(A,L)GM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M3-P37825-XY-OHT-13-RTD-FF-SP	1	3	0.147		
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M4-P39960-XY-OHT-11-RTD-FF-1	1	4	0.144	19.73	M(A,L)GM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M4-P40549-XY-OHT-12-RTD-FF-2	1	4	0.146	20.48	M(A,L)GM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M4-P41629-XY-OHT-13-RTD-FF-3	1	4	0.145	22.11	M(A,L)GM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M4-P42076-XY-OHT-13-RTD-FF-SP	1	4	0.146		
		Average	**0.146**	**20.61**	
		Standard Dev.		**1.023**	
		Coeff. of Var. [%]		**4.964**	
		Min.	**0.144**	**19.29**	
		Max.	**22.11**	**22.11**	
		Number of Spec.	**8**	**6**	


XY Orientation Open-Hole Tension (OHT) Properties - RTD (70°F)
Full Fiber (FF) Fill
Measured Strength
Markforged Onyx FR-A™ - Carbon Fiber FR-A™ / Markforged X7
Machine #
AM Batch #
Machine #
AM Batch #
Open-Hole Tensile Strength [ksi]
0
1
2
3
4
0.0
5.0
10.0
15.0
20.0
25.0

4.25 XZ PF Open-Hole Tension Properties

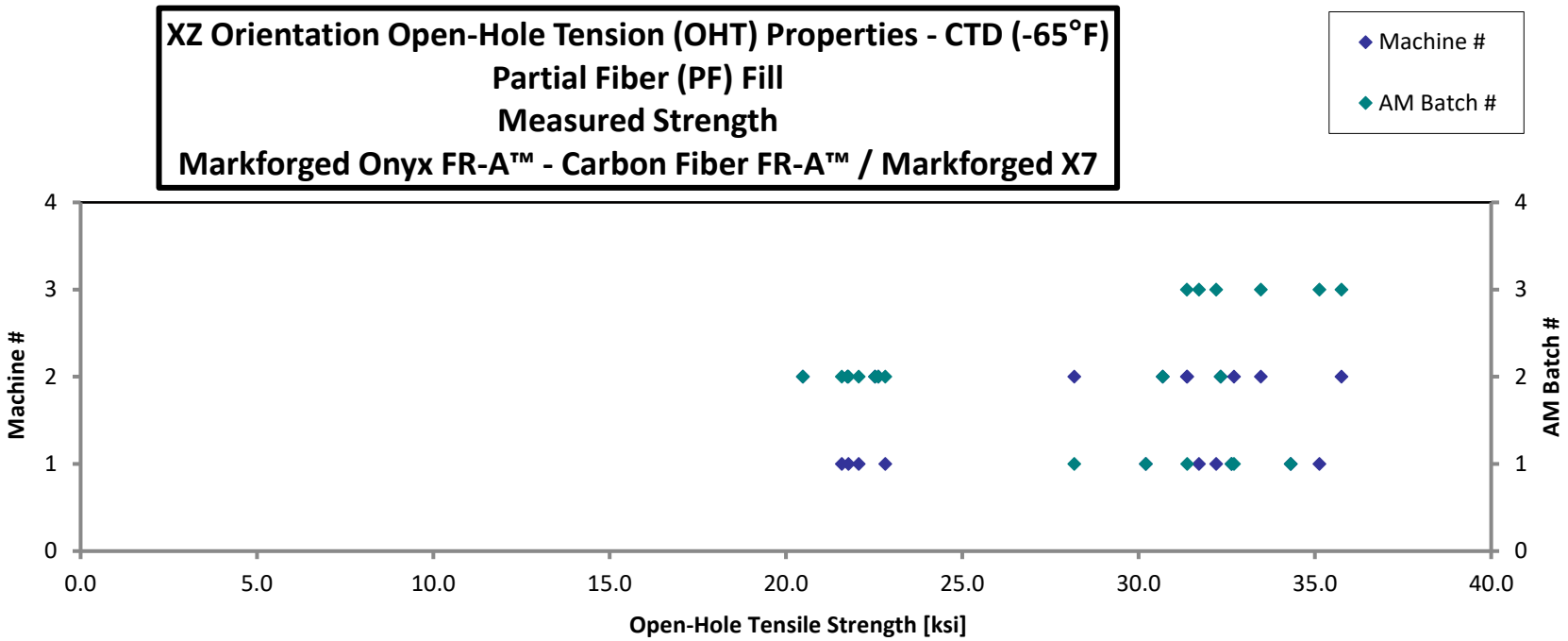
4.25.1 CTD Condition

XZ Orientation Open-Hole Tension (OHT) Properties - CTD (-65°F)
Partial Fiber (PF) Fill
Strength
Markforged Onyx FR-A™ - Carbon Fiber FR-A™ / Markforged X7

Specimen Number	AM Batch #	Machine #	Avg. Specimen Thickness [in]	Open-Hole Tensile Strength [ksi]	Failure Mode
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M1-P30480-XZ-OHT-11-CTD-PF-1	1	1	0.144	32.63	M(L,S)GM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M1-P30986-XZ-OHT-12-CTD-PF-2	1	1	0.143	34.31	M(L,S)GM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M1-P44627-XZ-OHT-13-CTD-PF-3	1	1	0.142	30.21	M(L,S)GM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M1-P31884-XZ-OHT-13-CTD-PF-SP	1	1	0.143		
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M2-P30481-XZ-OHT-11-CTD-PF-1	1	2	0.143	28.18	M(S,L)GM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M2-P30985-XZ-OHT-12-CTD-PF-2	1	2	0.142	32.71	M(A,S,L)GM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M2-P30648-XZ-OHT-13-CTD-PF-3	1	2	0.141	31.38	M(S,L)GM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M2-P31885-XZ-OHT-13-CTD-PF-SP	1	2	0.141		
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-B-M1-P34547-XZ-OHT-11-CTD-PF-1	2	1	0.141	22.82	M(S,L)GM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-B-M1-P34109-XZ-OHT-12-CTD-PF-2	2	1	0.142	22.06	M(S,L)GM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-B-M1-P34729-XZ-OHT-13-CTD-PF-3	2	1	0.141	21.78	M(S,L)GM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-B-M1-P32953-XZ-OHT-13-CTD-PF-SP	2	1	0.141	21.59	M(S,L)GM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-B-M2-P34546-XZ-OHT-11-CTD-PF-1	2	2	0.141	22.53	M(L,S)GM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-B-M2-P34108-XZ-OHT-12-CTD-PF-2	2	2	0.141	20.48	M(L,S)GM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-B-M2-P33809-XZ-OHT-13-CTD-PF-3	2	2	0.140	21.75	M(L,S)GM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-B-M2-P56729-XZ-OHT-11-CTD-PF-1	2	2	0.138	22.63	LGM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-B-M2-P58165-XZ-OHT-12-CTD-PF-2	2	2	0.138	32.33	LGM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-B-M2-P34108-XZ-OHT-13-CTD-PF-3	2	2	0.140	30.68	LGM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-C-M1-P48555-XZ-OHT-11-CTD-PF-1	3	1	0.144	32.20	M(A,L,S)GM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-C-M1-P50839-XZ-OHT-12-CTD-PF-2	3	1	0.143	35.13	M(A,L,S)GM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-C-M1-P35392-XZ-OHT-13-CTD-PF-3	3	1	0.142	31.72	M(A,L,S)GM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-C-M1-P35046-XZ-OHT-13-CTD-PF-6	3	1	0.142		
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-C-M2-P35981-XZ-OHT-11-CTD-PF-1	3	2	0.141	31.37	M(L,S)GM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-C-M2-P50838-XZ-OHT-12-CTD-PF-2	3	2	0.139	35.75	M(L,S)GM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-C-M2-P47353-XZ-OHT-13-CTD-PF-3	3	2	0.139	33.47	M(L,S)GM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-C-M2-P35052-XZ-OHT-13-CTD-PF-6	3	2	0.142		

The open hole tension and filled hole tension testing was conducted following ASTM standards. However, due to the manufacturing operations of the machine the fiber reinforcement is not fully integrated throughout the entire coupon, leaving the hole area un-reinforced. This causes the failure mode of the material to act erratically, causing both hole and long splitting failures. This test data is being provided as informational and should be used with caution keeping the design in mind and how fiber reinforcement will be used.

Average	**0.141**	**28.53**
Standard Dev.		**5.344**
Coeff. of Var. [%]		**18.73**
Min.	**0.138**	**20.48**
Max.	**0.144**	**35.75**
Number of Spec.	**24**	**22**


XZ Orientation Open-Hole Tension (OHT) Properties - CTD (-65°F)
Partial Fiber (PF) Fill
Measured Strength
Markforged Onyx FR-A™ - Carbon Fiber FR-A™ / Markforged X7
Machine #
AM Batch #
Machine #
AM Batch #
Open-Hole Tensile Strength [ksi]
0.0
5.0
10.0
15.0
20.0
25.0
30.0
35.0
40.0
0
1
2
3
4

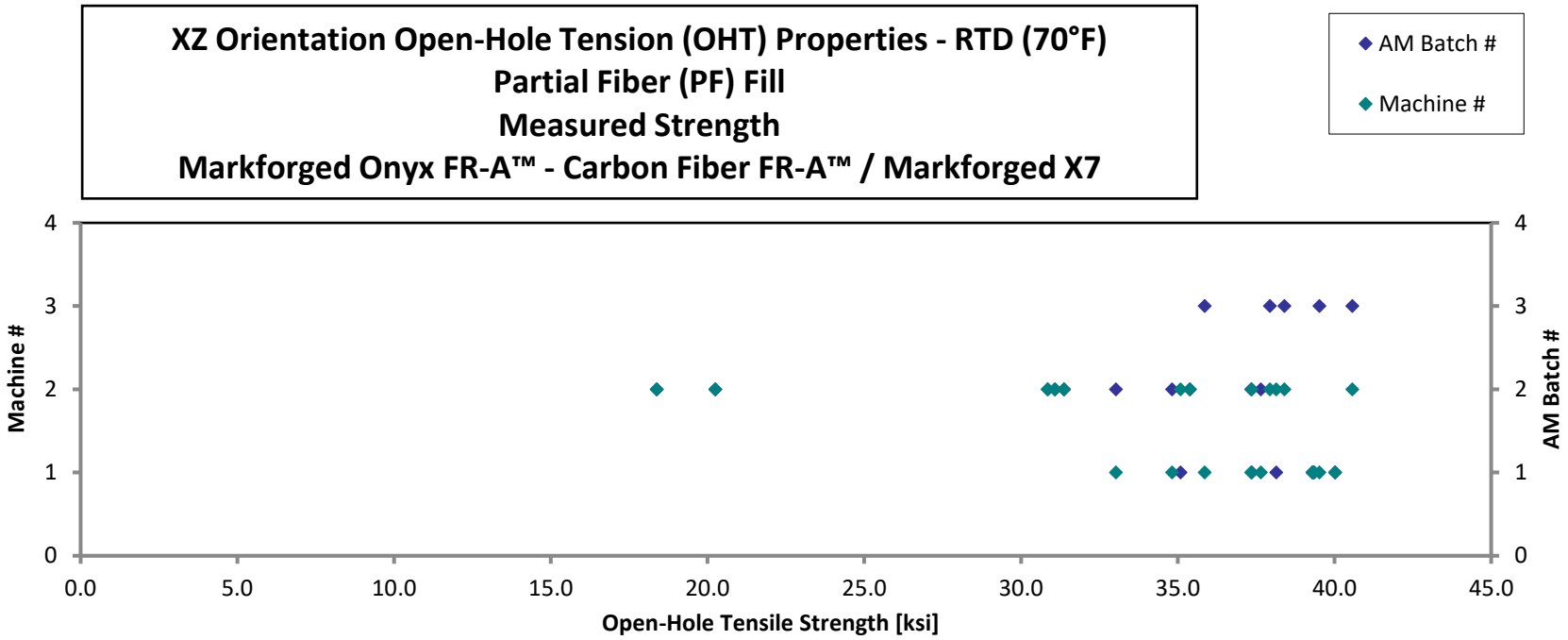
4.25.2 **RTD Condition**

XZ Orientation Open-Hole Tension (OHT) Properties - RTD (70°F)
Partial Fiber (PF) Fill
Strength
Markforged Onyx FR-A™ - Carbon Fiber FR-A™ / Markforged X7

Specimen Number	AM Batch #	Machine #	Avg. Specimen Thickness [in]	Open-Hole Tensile Strength [ksi]	Failure Mode
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M1-P44627-XZ-OHT-11-RTD-PF-1	1	1	0.142	39.30	M(A,S,L)GM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M1-P30480-XZ-OHT-12-RTD-PF-2	1	1	0.141	39.35	M(A,S,L)GM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M1-P30986-XZ-OHT-13-RTD-PF-3	1	1	0.142	40.02	M(L,S)GM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M1-P31365-XZ-OHT-13-RTD-PF-SP	1	1	0.142		
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M2-P30648-XZ-OHT-11-RTD-PF-1	1	2	0.142	38.14	M(A,L,S)GM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M2-P30481-XZ-OHT-12-RTD-PF-2	1	2	0.141	35.09	M(A,L,S)GM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M2-P30985-XZ-OHT-13-RTD-PF-3	1	2	0.142	37.37	M(A,L,S)GM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M2-P31366-XZ-OHT-13-RTD-PF-SP	1	2	0.142		
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-B-M1-P34729-XZ-OHT-11-RTD-PF-1	2	1	0.144	34.82	SGM, LAB
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-B-M1-P34547-XZ-OHT-12-RTD-PF-2	2	1	0.142	33.03	SGM, LAB
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-B-M1-P34109-XZ-OHT-13-RTD-PF-3	2	1	0.142	37.35	M(L,S)GM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-B-M1-P34954-XZ-OHT-13-RTD-PF-6	2	1	0.142	37.65	M(L,S)GM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-B-M2-P33809-XZ-OHT-11-RTD-PF-1	2	2	0.141	18.38	M(A,L)AB
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-B-M2-P34546-XZ-OHT-12-RTD-PF-2	2	2	0.140	20.24	M(A,L)AB
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-B-M2-P34108-XZ-OHT-13-RTD-PF-3	2	2	0.140	35.39	LIB, SGM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-B-M2-P41102-XZ-OHT-11-RTD-PF-1	2	2	0.139	30.85	M(A,L)GM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-B-M2-P56729-XZ-OHT-12-RTD-PF-2	2	2	0.139	31.38	LGM, SGM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-B-M2-P40904-XZ-OHT-13-RTD-PF-3	2	2	0.139	31.08	LGM, SGM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-B-M2-P56535-XZ-OHT-13-RTD-PF-6	2	2	0.139		
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-C-M1-P35392-XZ-OHT-11-RTD-PF-1	3	1	0.143	35.86	SGM, (M(A,L)AB
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-C-M1-P48555-XZ-OHT-12-RTD-PF-2	3	1	0.143		LAB, M(L,S)IB
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-C-M1-P50839-XZ-OHT-13-RTD-PF-3	3	1	0.144	39.52	M(L,S)GM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-C-M1-P48667-XZ-OHT-13-RTD-PF-6	3	1	0.143		LAB, M(L,S)IB
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-C-M2-P47353-XZ-OHT-11-RTD-PF-1	3	2	0.140	38.40	M(L,S)GM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-C-M2-P35981-XZ-OHT-12-RTD-PF-2	3	2	0.140	37.94	M(L,S)GM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-C-M2-P50838-XZ-OHT-13-RTD-PF-3	3	2	0.139	40.57	M(L,S)GM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-C-M2-P35710-XZ-OHT-13-RTD-PF-6	3	2	0.140		

The open hole tension and filled hole tension testing was conducted following ASTM standards. However, due to the manufacturing operations of the machine the fiber reinforcement is not fully integrated throughout the entire coupon, leaving the hole area un-reinforced. This causes the failure mode of the material to act erratically, causing both hole and long splitting failures. This test data is being provided as informational and should be used with caution keeping the design in mind and how fiber reinforcement will be used.

Average	**0.141**	**34.84**
Standard Dev.		**5.942**
Coeff. of Var. [%]		**17.05**
Min.	**0.139**	**18.38**
Max.	**0.144**	**40.57**
Number of Spec.	**24**	**19**


XZ Orientation Open-Hole Tension (OHT) Properties - RTD (70°F)
Partial Fiber (PF) Fill
Measured Strength
Markforged Onyx FR-A™ - Carbon Fiber FR-A™ / Markforged X7
AM Batch #
Machine #
Machine #
AM Batch #
Open-Hole Tensile Strength [ksi]
0
1
2
3
4
0.0
5.0
10.0
15.0
20.0
25.0
30.0
35.0
40.0
45.0

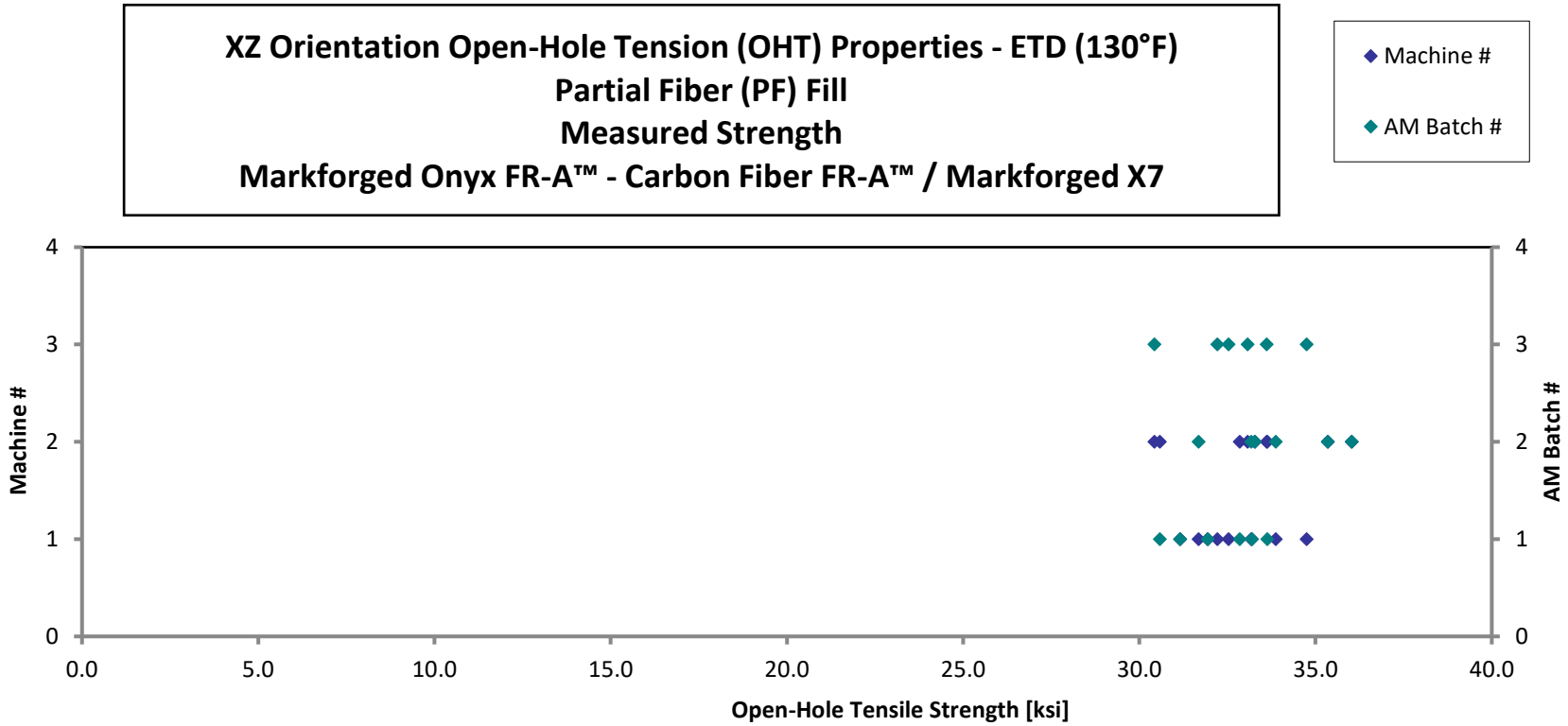
4.25.3 **ETD Condition**

XZ Orientation Open-Hole Tension (OHT) Properties - ETD (130°F)
Partial Fiber (PF) Fill
Strength
Markforged Onyx FR-A™ - Carbon Fiber FR-A™ / Markforged X7

Specimen Number	AM Batch #	Machine #	Avg. Specimen Thickness [in]	Open-Hole Tensile Strength [ksi]	Failure Mode
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M1-P53892-XZ-OHT-11-ETD-PF-1	1	1	0.143	33.20	SGM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M1-P46009-XZ-OHT-12-ETD-PF-2	1	1	0.142	31.16	SGM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M1-P45814-XZ-OHT-13-ETD-PF-3	1	1	0.142	31.94	SGM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M2-P43340-XZ-OHT-11-ETD-PF-1	1	2	0.142	30.58	M(A,S,L)GM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M2-P44383-XZ-OHT-12-ETD-PF-2	1	2	0.140	33.63	M(A,S,L)GM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M2-P44678-XZ-OHT-13-ETD-PF-3	1	2	0.141	32.85	M(A,S,L)GM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-B-M1-P46400-XZ-OHT-11-ETD-PF-1	2	1	0.142	31.68	SGM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-B-M1-P56226-XZ-OHT-12-ETD-PF-2	2	1	0.141	33.87	SGM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-B-M1-P41399-XZ-OHT-13-ETD-PF-3	2	1	0.141	33.18	SGM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-B-M2-P41336-XZ-OHT-11-ETD-PF-1	2	2	0.139	35.35	M(A,S,L)GM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-B-M2-P54843-XZ-OHT-12-ETD-PF-2	2	2	0.139	33.28	M(A,S,L)GM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-B-M2-P40747-XZ-OHT-13-ETD-PF-3	2	2	0.140	36.02	M(L,S)GM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-C-M1-P50045-XZ-OHT-11-ETD-PF-1	3	1	0.142	32.53	M(A,L)GM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-C-M1-P50310-XZ-OHT-12-ETD-PF-2	3	1	0.142	32.22	M(A,L)GM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-C-M1-P50520-XZ-OHT-13-ETD-PF-3	3	1	0.142	34.75	M(A,L)GM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-C-M2-P48418-XZ-OHT-11-ETD-PF-1	3	2	0.141	30.43	M(A,S)GM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-C-M2-P51235-XZ-OHT-12-ETD-PF-2	3	2	0.139	33.08	M(A,S)GM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-C-M2-P50450-XZ-OHT-13-ETD-PF-3	3	2	0.140	33.62	M(A,S)GM

The open hole tension and filled hole tension testing was conducted following ASTM standards. However, due to the manufacturing operations of the machine the fiber reinforcement is not fully integrated throughout the entire coupon, leaving the hole area un-reinforced. This causes the failure mode of the material to act erratically, causing both hole and long splitting failures. This test data is being provided as informational and should be used with caution keeping the design in mind and how fiber reinforcement will be used.

Average	**0.141**	**32.96**
Standard Dev.		**1.514**
Coeff. of Var. [%]		**4.592**
Min.	**0.139**	**30.43**
Max.	**0.143**	**36.02**
Number of Spec.	**18**	**18**

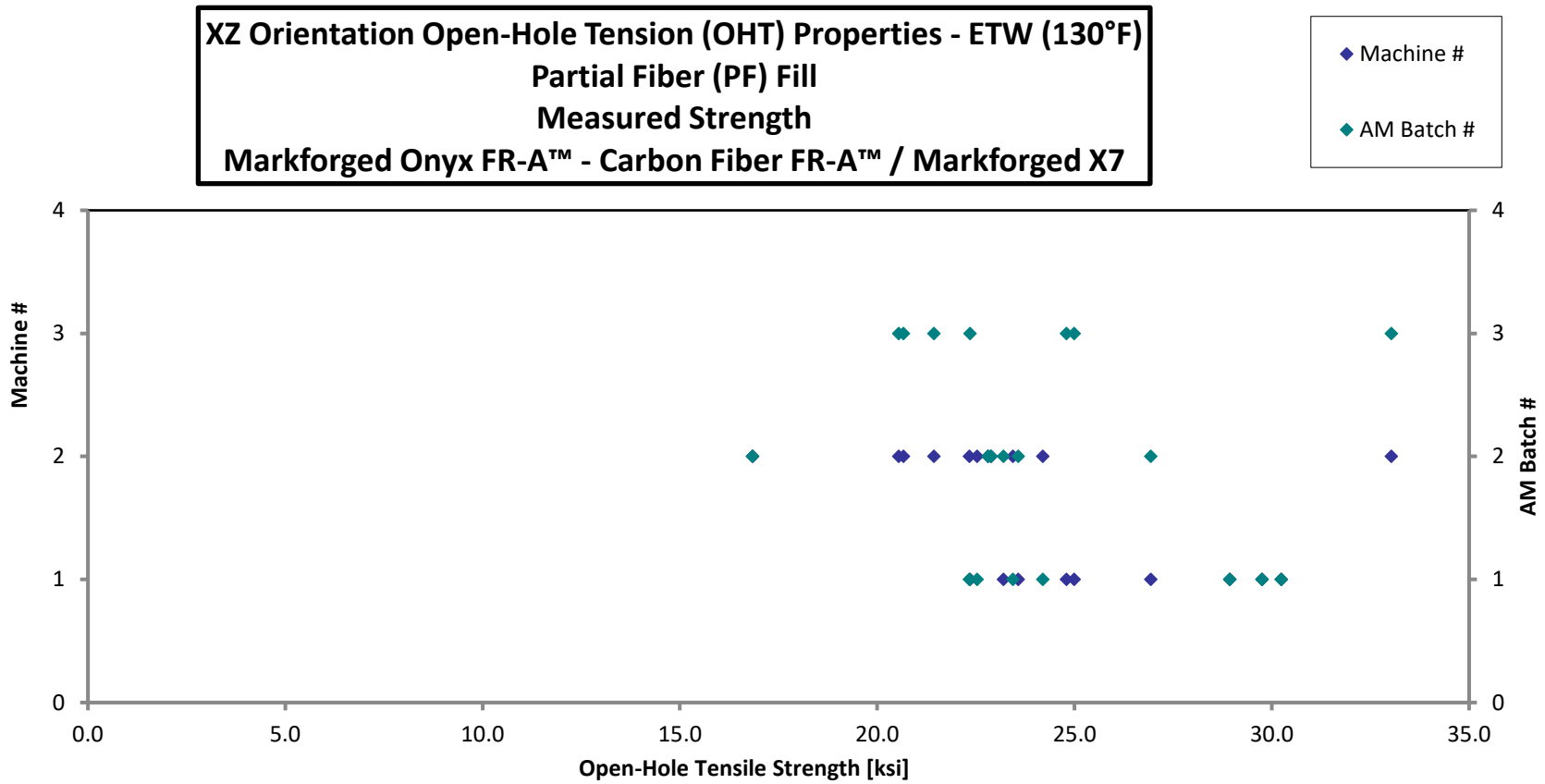

XZ Orientation Open-Hole Tension (OHT) Properties - ETD (130°F)
Partial Fiber (PF) Fill
Measured Strength
Markforged Onyx FR-A™ - Carbon Fiber FR-A™ / Markforged X7
Machine #
AM Batch #
Machine #
AM Batch #
Open-Hole Tensile Strength [ksi]
0
1
2
3
4
0.0
5.0
10.0
15.0
20.0
25.0
30.0
35.0
40.0

4.25.4 **ETW Condition**

XZ Orientation Open-Hole Tension (OHT) Properties - ETW (130°F)
Partial Fiber (PF) Fill
Strength
Markforged Onyx FR-A™ - Carbon Fiber FR-A™ / Markforged X7

Specimen Number	AM Batch #	Machine #	Avg. Specimen Thickness [in]	Open-Hole Tensile Strength [ksi]	Failure Mode
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M1-P30986-XZ-OHT-11-ETW-PF-1	1	1	0.144	29.75	LGM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M1-P44627-XZ-OHT-12-ETW-PF-2	1	1	0.143	30.24	M(A,L,S)GM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M1-P30480-XZ-OHT-13-ETW-PF-3	1	1	0.143	28.94	LGM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M1-P31365-XZ-OHT-13-ETW-PF-SP	1	1	0.142		
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M2-P30985-XZ-OHT-11-ETW-PF-1	1	2	0.143	22.34	M(L,S)GM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M2-P30648-XZ-OHT-12-ETW-PF-2	1	2	0.143	22.53	M(L,S)GM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M2-P30481-XZ-OHT-13-ETW-PF-3	1	2	0.140	23.44	M(L,S)GM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M2-P31366-XZ-OHT-13-ETW-PF-SP	1	2	0.142	24.20	M(L,S)GM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-B-M1-P34109-XZ-OHT-11-ETW-PF-1	2	1	0.143	26.94	M(A,S,L)GM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-B-M1-P34729-XZ-OHT-12-ETW-PF-2	2	1	0.143	23.58	M(A,L)GM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-B-M1-P34547-XZ-OHT-13-ETW-PF-3	2	1	0.141	23.20	M(S,L)GM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-B-M1-P34954-XZ-OHT-13-ETW-PF-6	2	1	0.141		
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-B-M2-P56535-XZ-OHT-11-ETW-PF-1	2	2	0.138	22.81	SGM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-B-M2-P33648-XZ-OHT-12-ETW-PF-2	2	2	0.139	22.88	SGM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-B-M2-P56729-XZ-OHT-13-ETW-PF-3	2	2	0.139	16.84	SGM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-B-M2-P56535-XZ-OHT-13-ETW-PF-6	2	2	0.138		
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-C-M1-P50839-XZ-OHT-11-ETW-PF-1	3	1	0.144	24.79	LGM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-C-M1-P35392-XZ-OHT-12-ETW-PF-2	3	1	0.143	24.99	LGM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-C-M1-P48555-XZ-OHT-13-ETW-PF-3	3	1	0.143	22.35	LGM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-C-M1-P48667-XZ-OHT-13-ETW-PF-6	3	1	0.143		
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-C-M2-P50838-XZ-OHT-11-ETW-PF-1	3	2	0.141	33.03	SGM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-C-M2-P47353-XZ-OHT-12-ETW-PF-2	3	2	0.140	21.44	M(L,S)GM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-C-M2-P35981-XZ-OHT-13-ETW-PF-3	3	2	0.140	20.67	M(L,S)GM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-C-M2-P35710-XZ-OHT-13-ETW-PF-6	3	2	0.141	20.55	M(L,S)GM
Average			**0.142**	**24.28**	
Standard Dev.				**3.832**	
Coeff. of Var. [%]				**15.78**	
Min.			**0.138**	**16.84**	
Max.			**0.144**	**33.03**	
Number of Spec.			**24**	**20**	

The open hole tension and filled hole tension testing was conducted following ASTM standards. However, due to the manufacturing operations of the machine the fiber reinforcement is not fully integrated throughout the entire coupon, leaving the hole area un-reinforced. This causes the failure mode of the material to act erratically, causing both hole and long splitting failures. This test data is being provided as informational and should be used with caution keeping the design in mind and how fiber reinforcement will be used.


XZ Orientation Open-Hole Tension (OHT) Properties - ETW (130°F)
Partial Fiber (PF) Fill
Measured Strength
Markforged Onyx FR-A™ - Carbon Fiber FR-A™ / Markforged X7
Machine #
AM Batch #
Machine #
AM Batch #
Open-Hole Tensile Strength [ksi]
0.0
5.0
10.0
15.0
20.0
25.0
30.0
35.0
0
1
2
3
4

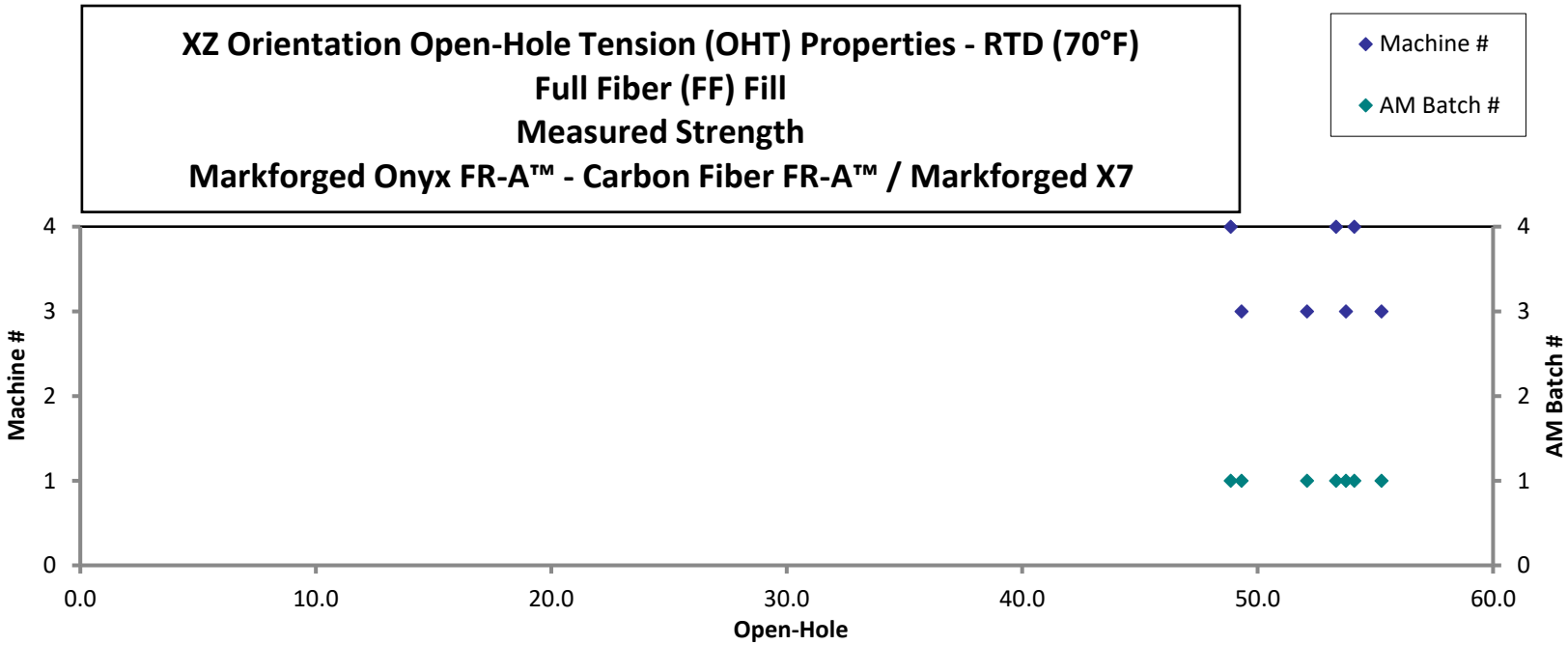
4.26 XZ FF Open-Hole Tension Properties

4.26.1 RTD Condition

XZ Orientation Open-Hole Tension (OHT) Properties - RTD (70°F)
Full Fiber (FF) Fill
Strength
Markforged Onyx FR-A™ - Carbon Fiber FR-A™ / Markforged X7

Specimen Number	AM Batch #	Machine #	Avg. Specimen Thickness [in]	Open-Hole Tensile Strength [ksi]	Failure Mode
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M3-P38723-XZ-OHT-11-RTD-FF-1	1	3	0.145	52.10	SGM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M3-P35705-XZ-OHT-12-RTD-FF-2	1	3	0.143	49.32	SGM, AWT
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M3-P35362-XZ-OHT-13-RTD-FF-3	1	3	0.143	53.75	SGM, M(A,L)WB
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M3-P38541-XZ-OHT-13-RTD-FF-SP	1	3	0.144	55.26	SGM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M4-P39960-XZ-OHT-11-RTD-FF-1	1	4	0.144	48.86	SGM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M4-P40549-XZ-OHT-12-RTD-FF-2	1	4	0.142	54.10	SGM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M4-P40077-XZ-OHT-13-RTD-FF-3	1	4	0.143	53.34	SGM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M4-P46438-XZ-OHT-13-RTD-FF-SP	1	4	0.143		
		Average	**0.143**	**52.39**	
		Standard Dev.		**2.447**	
		Coeff. of Var. [%]		**4.670**	
		Min.	**0.142**	**48.86**	
		Max.	**0.145**	**55.26**	
		Number of Spec.	**8**	**7**	

The open hole tension and filled hole tension testing was conducted following ASTM standards. However, due to the manufacturing operations of the machine the fiber reinforcement is not fully integrated throughout the entire coupon, leaving the hole area un-reinforced. This causes the failure mode of the material to act erratically, causing both hole and long splitting failures. This test data is being provided as informational and should be used with caution keeping the design in mind and how fiber reinforcement will be used.


XZ Orientation Open-Hole Tension (OHT) Properties - RTD (70°F)
Full Fiber (FF) Fill
Measured Strength
Markforged Onyx FR-A™ - Carbon Fiber FR-A™ / Markforged X7
Machine #
AM Batch #
Machine #
AM Batch #
Open-Hole
0
1
2
3
4
0.0
10.0
20.0
30.0
40.0
50.0
60.0

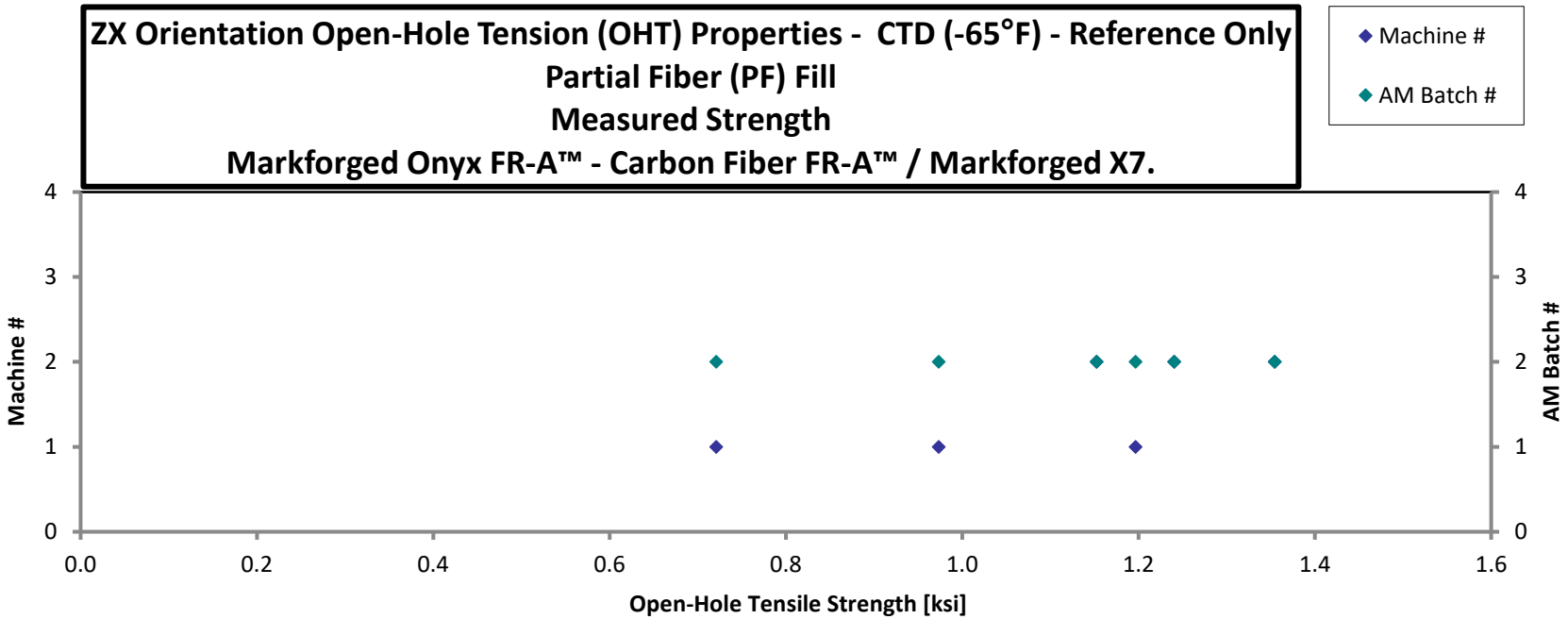
4.27 ZX PF Open-Hole Tension Properties – Reference Only

4.27.1 CTD Condition

ZX Orientation Open-Hole Tension (OHT) Properties - CTD (-65°F) - Reference Only
Partial Fiber (PF) Fill
CTD Condition
Markforged Onyx FR-A™ - Carbon Fiber FR-A™ / Markforged X7

Specimen Number	AM Batch #	Machine #	Avg. Specimen Thickness [in]	Open-Hole Tensile Strength [ksi]	Failure Mode
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-B-M1-P34547-ZX-OHT-11-CTD-PF-1	2	1	0.135	1.197	LGM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-B-M1-P34729-ZX-OHT-12-CTD-PF-2	2	1	0.135	0.973	LGM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-B-M1-P34109-ZX-OHT-13-CTD-PF-3	2	1	0.134		LWT
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-B-M1-P32953-ZX-OHT-13-CTD-PF-SP	2	1	0.134	0.721	LGM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-B-M2-P34546-ZX-OHT-11-CTD-PF-1	2	2	0.138	1.354	LGM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-B-M2-P33809-ZX-OHT-12-CTD-PF-2	2	2	0.139	1.240	LGM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-B-M2-P34108-ZX-OHT-13-CTD-PF-3	2	2	0.138	1.153	LGM

Average	**0.136**	**1.106**
Standard Dev.		**0.226**
Coeff. of Var. [%]		**20.45**
Min.	**0.134**	**0.721**
Max.	**0.139**	**1.354**
Number of Spec.	**7**	**6**

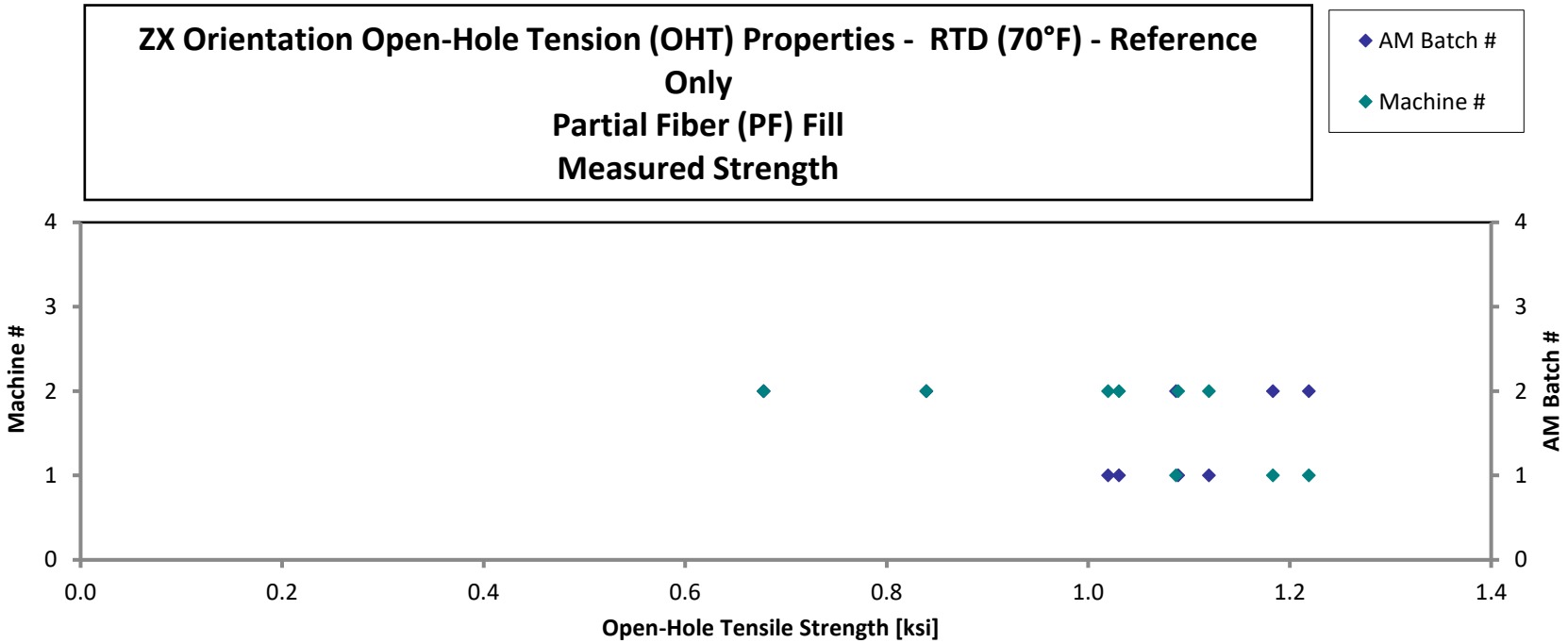

ZX Orientation Open-Hole Tension (OHT) Properties - CTD (-65°F) - Reference Only
Partial Fiber (PF) Fill
Measured Strength
Markforged Onyx FR-A™ - Carbon Fiber FR-A™ / Markforged X7.
Machine #
AM Batch #
Machine #
AM Batch #
Open-Hole Tensile Strength [ksi]
0
1
2
3
4
0.0
0.2
0.4
0.6
0.8
1.0
1.2
1.4
1.6

4.27.2 **RTD Condition**

ZX Orientation Open-Hole Tension (OHT) Properties - RTD (70°F) - Reference Only
Partial Fiber (PF) Fill
Strength
Markforged Onyx FR-A™ - Carbon Fiber FR-A™ / Markforged X7

Specimen Number	AM Batch #	Machine #	Avg. Specimen Thickness [in]	Open-Hole Tensile Strength [ksi]	Failure Mode
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M2-P30481-ZX-OHT-11-RTD-PF-1	1	2	0.141	1.089	LGM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M2-P30481-ZX-OHT-11-RTD-PF-2	1	2	0.140	1.031	LGM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M2-P30481-ZX-OHT-11-RTD-PF-3	1	2	0.140	1.020	LGM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M2-P30648-ZX-OHT-12-RTD-PF-1	1	2	0.139	1.120	LGM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-B-M1-P34547-ZX-OHT-11-RTD-PF-1	2	1	0.140	1.219	LGM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-B-M1-P34729-ZX-OHT-12-RTD-PF-2	2	1	0.137	1.183	LGM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-B-M1-P34109-ZX-OHT-13-RTD-PF-3	2	1	0.134	1.087	LGM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-B-M1-P32953-ZX-OHT-13-RTD-PF-SP	2	1	0.135		
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-B-M2-P34546-ZX-OHT-11-RTD-PF-1	2	2	0.140		
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-B-M2-P33809-ZX-OHT-12-RTD-PF-2	2	2	0.140	0.839	LGM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-B-M2-P34108-ZX-OHT-13-RTD-PF-3	2	2	0.138	0.678	LGM

Average	**0.139**	**1.030**
Standard Dev.		**0.171**
Coeff. of Var. [%]		**16.63**
Min.	**0.134**	**0.678**
Max.	**0.141**	**1.219**
Number of Spec.	**11**	**9**


ZX Orientation Open-Hole Tension (OHT) Properties - RTD (70°F) - Reference Only
Partial Fiber (PF) Fill
Measured Strength
AM Batch #
Machine #
Machine #
AM Batch #
Open-Hole Tensile Strength [ksi]
0
1
2
3
4
0.0
0.2
0.4
0.6
0.8
1.0
1.2
1.4

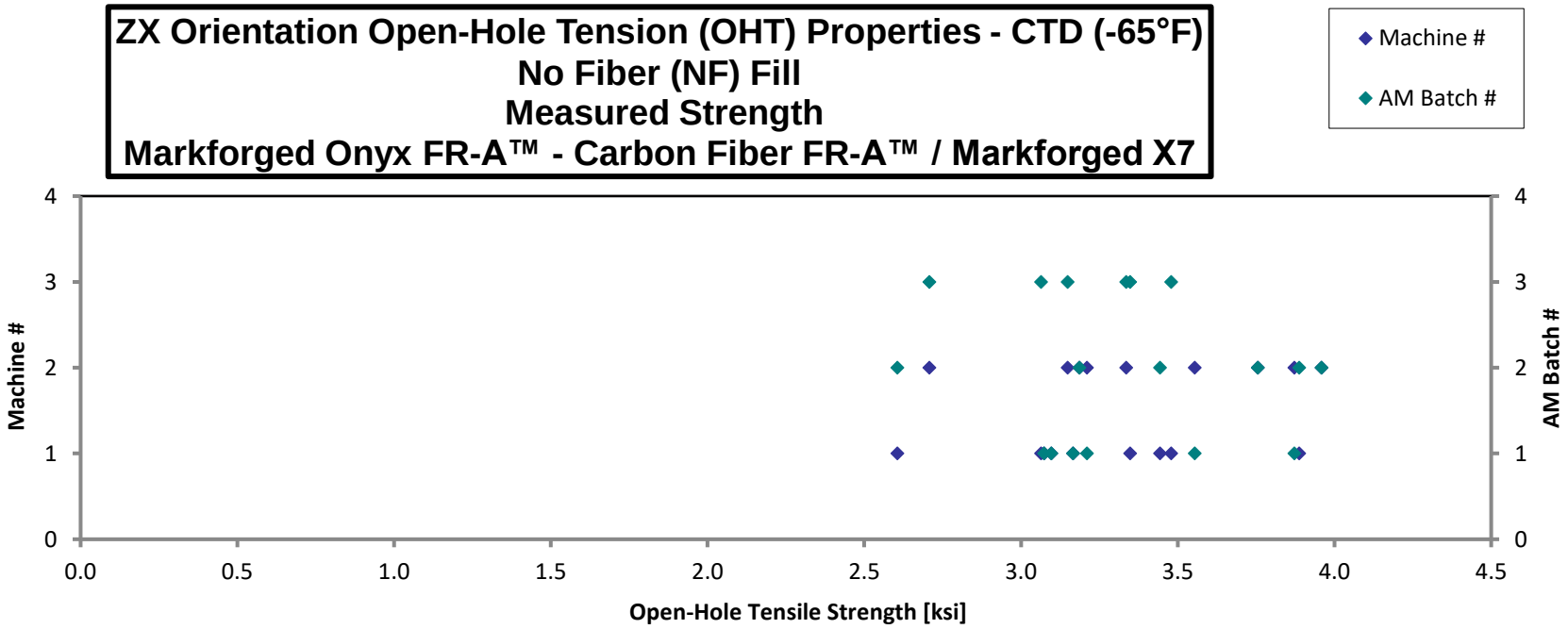
4.28 ZX NF Open-Hole Tension Properties

4.28.1 CTD Condition

ZX Orientation Open-Hole Tension (OHT) Properties - CTD (-65°F)
No Fiber (NF) Fill
Strength
Markforged Onyx FR-A™ - Carbon Fiber FR-A™ / Markforged X7

Specimen Number	AM Batch #	Machine #	Avg. Specimen Thickness [in]	Open-Hole Tensile Strength [ksi]	Failure Mode
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M1-P67328-ZX-OHT-11-CTD-NF-1	1	1	0.151	3.166	LGM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M1-P67689-ZX-OHT-12-CTD-NF-2	1	1	0.151	3.097	LGM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M1-P60727-ZX-OHT-13-CTD-NF-3	1	1	0.145	3.073	LGM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M2-P60130-ZX-OHT-11-CTD-NF-1	1	2	0.151	3.555	LGM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M2-P60979-ZX-OHT-12-CTD-NF-2	1	2	0.151	3.872	LGM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M2-P62038-ZX-OHT-13-CTD-NF-3	1	2	0.145	3.210	LGM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-B-M1-P59506-ZX-OHT-11-CTD-NF-1	2	1	0.151	3.887	LGM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-B-M1-P62155-ZX-OHT-12-CTD-NF-2	2	1	0.151	3.443	LGM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-B-M1-P62701-ZX-OHT-13-CTD-NF-3	2	1	0.145	2.605	LGM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-B-M2-P59497-ZX-OHT-11-CTD-NF-1	2	2	0.150	3.959	LGM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-B-M2-P63802-ZX-OHT-12-CTD-NF-2	2	2	0.149	3.756	LGM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-B-M2-P63004-ZX-OHT-13-CTD-NF-3	2	2	0.143	3.186	LGM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-C-M1-P63385-ZX-OHT-11-CTD-NF-1	3	1	0.151	3.479	LGM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-C-M1-P63784-ZX-OHT-12-CTD-NF-2	3	1	0.150	3.348	LGM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-C-M1-P64224-ZX-OHT-13-CTD-NF-3	3	1	0.143	3.064	LGM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-C-M2-P64225-ZX-OHT-11-CTD-NF-1	3	2	0.149	3.336	LGM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-C-M2-P64680-ZX-OHT-12-CTD-NF-2	3	2	0.149	3.148	LGM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-C-M2-P64990-ZX-OHT-13-CTD-NF-3	3	2	0.142	2.708	LGM

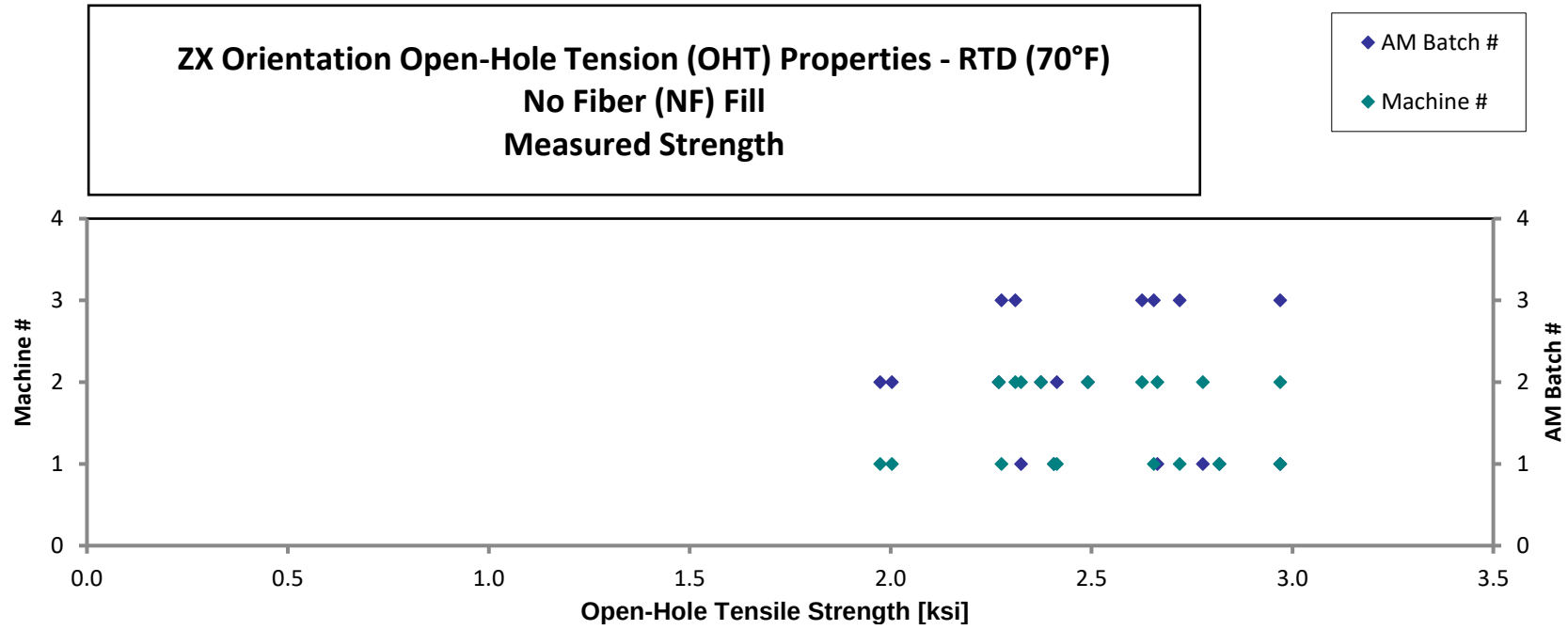
Average	**0.148**	**3.327**
Standard Dev.		**0.381**
Coeff. of Var. [%]		**11.44**
Min.	**0.142**	**2.605**
Max.	**0.151**	**3.959**
Number of Spec.	**18**	**18**


ZX Orientation Open-Hole Tension (OHT) Properties - CTD (-65°F)
No Fiber (NF) Fill
Measured Strength
Markforged Onyx FR-A™ - Carbon Fiber FR-A™ / Markforged X7
Machine #
AM Batch #
Machine #
AM Batch #
Open-Hole Tensile Strength [ksi]
0
1
2
3
4
0.0
0.5
1.0
1.5
2.0
2.5
3.0
3.5
4.0
4.5

4.28.2 **RTD Condition**

ZX Orientation Open-Hole Tension (OHT) Properties - RTD (70°F)
No Fiber (NF) Fill
Strength
Markforged Onyx FR-A™ - Carbon Fiber FR-A™ / Markforged X7

Specimen Number	AM Batch #	Machine #	Avg. Specimen Thickness [in]	Open-Hole Tensile Strength [ksi]	Failure Mode
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M1-P67328-ZX-OHT-11-RTD-NF-1	1	1	0.148	2.970	LGM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M1-P67689-ZX-OHT-12-RTD-NF-2	1	1	0.147	2.818	LGM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M1-P60727-ZX-OHT-13-RTD-NF-3	1	1	0.142	2.406	LGM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M2-P60130-ZX-OHT-11-RTD-NF-1	1	2	0.147	2.777	LGM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M2-P60979-ZX-OHT-12-RTD-NF-2	1	2	0.145	2.664	LGM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M2-P62038-ZX-OHT-13-RTD-NF-3	1	2	0.143	2.325	LGM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-B-M1-P59506-ZX-OHT-11-RTD-NF-1	2	1	0.145	2.414	LGM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-B-M1-P62155-ZX-OHT-12-RTD-NF-2	2	1	0.144	2.003	LGM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-B-M1-P62701-ZX-OHT-13-RTD-NF-3	2	1	0.141	1.974	LGM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-B-M2-P59497-ZX-OHT-11-RTD-NF-1	2	2	0.146	2.491	LGM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-B-M2-P63802-ZX-OHT-12-RTD-NF-2	2	2	0.143	2.374	LGM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-B-M2-P63004-ZX-OHT-13-RTD-NF-3	2	2	0.141	2.269	LGM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-C-M1-P63385-ZX-OHT-11-RTD-NF-1	3	1	0.142	2.720	LGM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-C-M1-P63784-ZX-OHT-12-RTD-NF-2	3	1	0.143	2.655	LGM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-C-M1-P64224-ZX-OHT-13-RTD-NF-3	3	1	0.139	2.276	LGM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-C-M2-P64225-ZX-OHT-11-RTD-NF-1	3	2	0.144	2.626	LGM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-C-M2-P64680-ZX-OHT-12-RTD-NF-2	3	2	0.141	2.311	LGM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-C-M2-P64990-ZX-OHT-13-RTD-NF-3	3	2	0.148	2.970	LGM
		Average	**0.144**	**2.502**	
		Standard Dev.		**0.293**	
		Coeff. of Var. [%]		**11.71**	
		Min.	**0.139**	**1.974**	
		Max.	**0.148**	**2.970**	
		Number of Spec.	**18**	**18**	

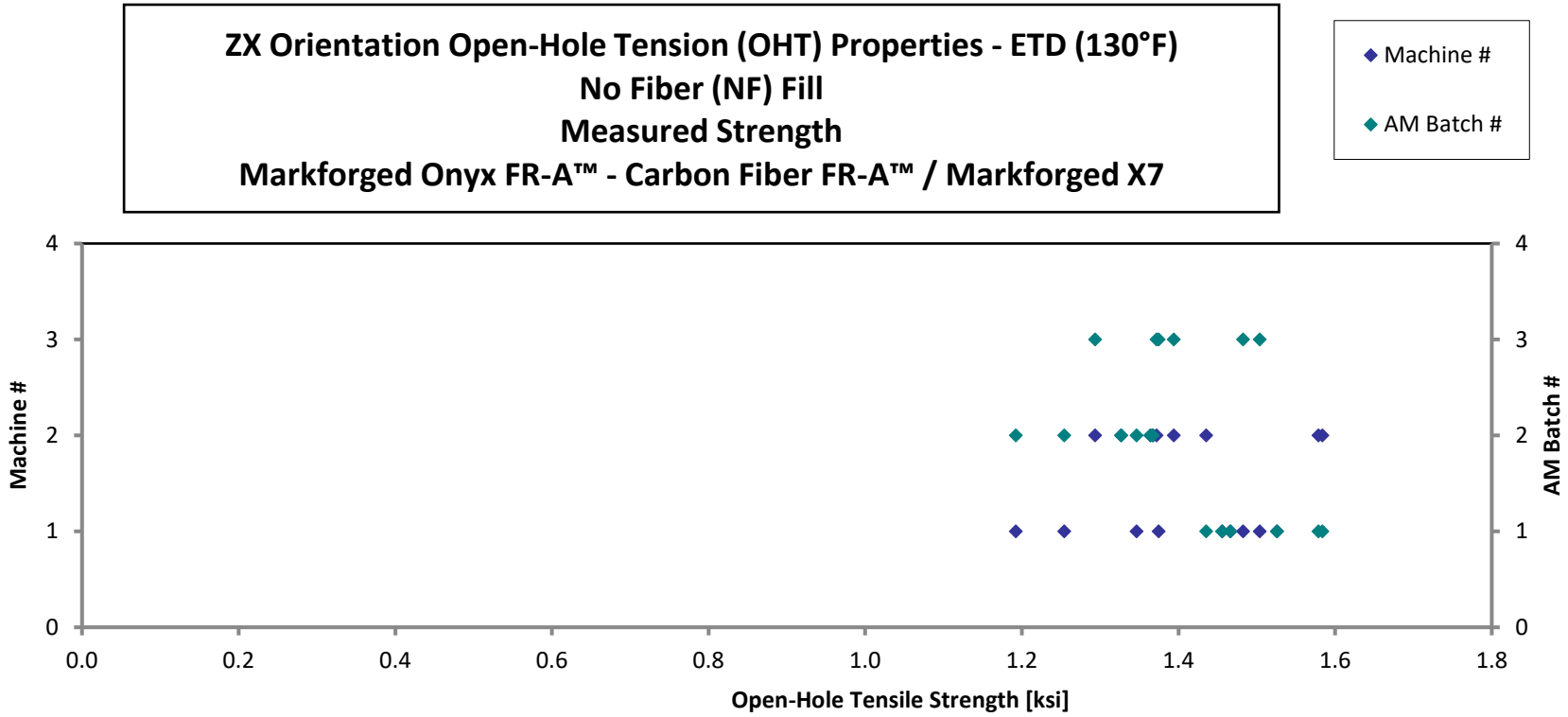

ZX Orientation Open-Hole Tension (OHT) Properties - RTD (70°F)
No Fiber (NF) Fill
Measured Strength
AM Batch #
Machine #
Machine #
AM Batch #
Open-Hole Tensile Strength [ksi]
0
1
2
3
4
0.0
0.5
1.0
1.5
2.0
2.5
3.0
3.5

4.28.3 **ETD Condition**

ZX Orientation Open-Hole Tension (OHT) Properties - ETD (130°F)
No Fiber (NF) Fill
Strength
Markforged Onyx FR-A™ - Carbon Fiber FR-A™ / Markforged X7

Specimen Number	AM Batch #	AM Batch #	Machine #	Avg. Specimen Thickness [in]	Open-Hole Tensile Strength [ksi]	Failure Mode
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M1-P67328-ZX-OHT-11-ETD-NF-1	A	1	1	0.145	1.526	LGM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M1-P67689-ZX-OHT-12-ETD-NF-2	A	1	1	0.145	1.466	LGM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M1-P60727-ZX-OHT-13-ETD-NF-3	A	1	1	0.142	1.456	LGM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M2-P60130-ZX-OHT-11-ETD-NF-1	A	1	2	0.143	1.584	LGM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M2-P60979-ZX-OHT-12-ETD-NF-2	A	1	2	0.143	1.579	LGM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M2-P62038-ZX-OHT-13-ETD-NF-3	A	1	2	0.141	1.435	LGM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-B-M1-P59506-ZX-OHT-11-ETD-NF-1	A	2	1	0.145	1.347	LGM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-B-M1-P62155-ZX-OHT-12-ETD-NF-2	A	2	1	0.144	1.254	LGM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-B-M1-P62701-ZX-OHT-13-ETD-NF-3	A	2	1	0.141	1.192	LGM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-B-M2-P59497-ZX-OHT-11-ETD-NF-1	A	2	2	0.144	1.367	LGM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-B-M2-P63802-ZX-OHT-12-ETD-NF-2	A	2	2	0.142	1.327	LGM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-B-M2-P63004-ZX-OHT-13-ETD-NF-3	A	2	2	0.141	1.364	LGM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-C-M1-P63385-ZX-OHT-11-ETD-NF-1	A	3	1	0.142	1.482	M(A,L)GM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-C-M1-P63784-ZX-OHT-12-ETD-NF-2	A	3	1	0.142	1.504	LGM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-C-M1-P64224-ZX-OHT-13-ETD-NF-3	A	3	1	0.141	1.375	LGM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-C-M2-P64225-ZX-OHT-11-ETD-NF-1	A	3	2	0.143	1.394	LGM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-C-M2-P64680-ZX-OHT-12-ETD-NF-2	A	3	2	0.141	1.372	LGM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-C-M2-P64990-ZX-OHT-13-ETD-NF-3	A	3	2	0.141	1.294	LGM

Average	**0.143**	**1.407**
Standard Dev.		**0.107**
Coeff. of Var. [%]		**7.613**
Min.	**0.141**	**1.192**
Max.	**0.145**	**1.584**
Number of Spec.	**18**	**18**

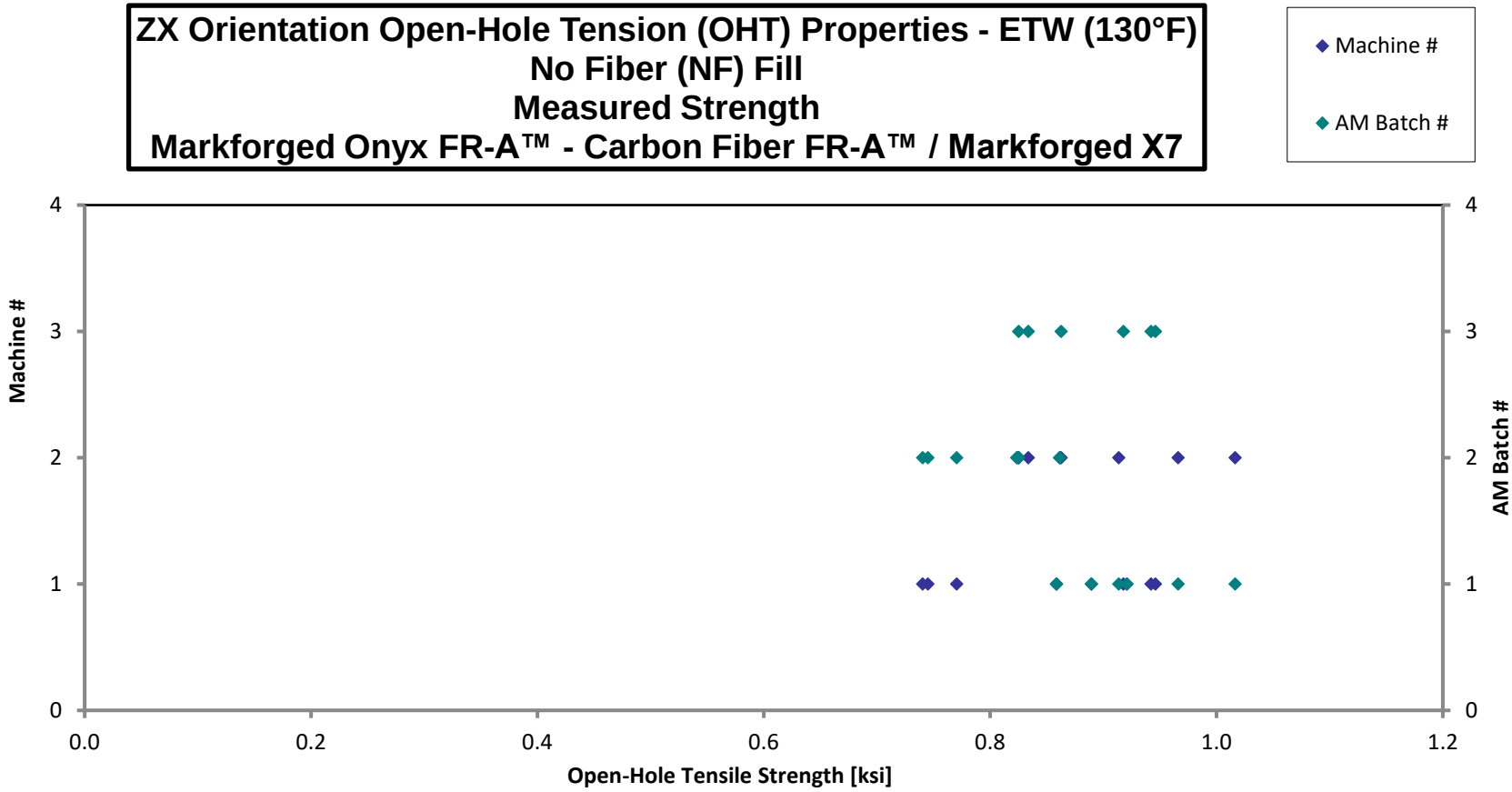

ZX Orientation Open-Hole Tension (OHT) Properties - ETD (130°F)
No Fiber (NF) Fill
Measured Strength
Markforged Onyx FR-A™ - Carbon Fiber FR-A™ / Markforged X7
Machine #
AM Batch #
Machine #
AM Batch #
Open-Hole Tensile Strength [ksi]
0
1
2
3
4
0.0
0.2
0.4
0.6
0.8
1.0
1.2
1.4
1.6
1.8

4.28.4 **ETW Condition**

ZX Orientation Open-Hole Tension (OHT) Properties - ETW (130°F)
No Fiber (NF) Fill
Strength
Markforged Onyx FR-A™ - Carbon Fiber FR-A™ / Markforged X7

Specimen Number	AM Batch #	Machine #	Avg. Specimen Thickness [in]	Open-Hole Tensile Strength [ksi]	Failure Mode
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M1-P67328-ZX-OHT-11-ETW-NF-1	1	1	0.145	0.921	LGM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M1-P67689-ZX-OHT-12-ETW-NF-2	1	1	0.143	0.890	LGM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M1-P60727-ZX-OHT-13-ETW-NF-3	1	1	0.143	0.859	LGM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M2-P60130-ZX-OHT-11-ETW-NF-1	1	2	0.142	0.966	M(A,L)GM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M2-P60979-ZX-OHT-12-ETW-NF-2	1	2	0.143	1.016	LGM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M2-P62038-ZX-OHT-13-ETW-NF-3	1	2	0.141	0.914	LGM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-B-M1-P59506-ZX-OHT-11-ETW-NF-1	2	1	0.143	0.770	LGM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-B-M1-P62155-ZX-OHT-12-ETW-NF-2	2	1	0.144	0.741	LGM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-B-M1-P62701-ZX-OHT-13-ETW-NF-3	2	1	0.142	0.745	LGM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-B-M2-P59497-ZX-OHT-11-ETW-NF-1	2	2	0.142	0.824	LGM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-B-M2-P63802-ZX-OHT-12-ETW-NF-2	2	2	0.141	0.825	LGM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-B-M2-P63004-ZX-OHT-13-ETW-NF-3	2	2	0.143	0.861	LGM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-C-M1-P63385-ZX-OHT-11-ETW-NF-1	3	1	0.142	0.946	LGM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-C-M1-P63784-ZX-OHT-12-ETW-NF-2	3	1	0.142	0.942	LGM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-C-M1-P64224-ZX-OHT-13-ETW-NF-3	3	1	0.141	0.918	LGM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-C-M2-P64225-ZX-OHT-11-ETW-NF-1	3	2	0.142	0.863	LGM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-C-M2-P64680-ZX-OHT-12-ETW-NF-2	3	2	0.141	0.834	LGM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-C-M2-P64990-ZX-OHT-13-ETW-NF-3	3	2	0.141	0.825	LGM

Average	**0.142**	**0.870**
Standard Dev.		**0.076**
Coeff. of Var. [%]		**8.766**
Min.	**0.141**	**0.741**
Max.	**0.145**	**1.016**
Number of Spec.	**18**	**18**


ZX Orientation Open-Hole Tension (OHT) Properties - ETW (130°F)
No Fiber (NF) Fill
Measured Strength
Markforged Onyx FR-A™ - Carbon Fiber FR-A™ / Markforged X7
Machine #
AM Batch #
Machine #
AM Batch #
Open-Hole Tensile Strength [ksi]
0
1
2
3
4
0.0
0.2
0.4
0.6
0.8
1.0
1.2

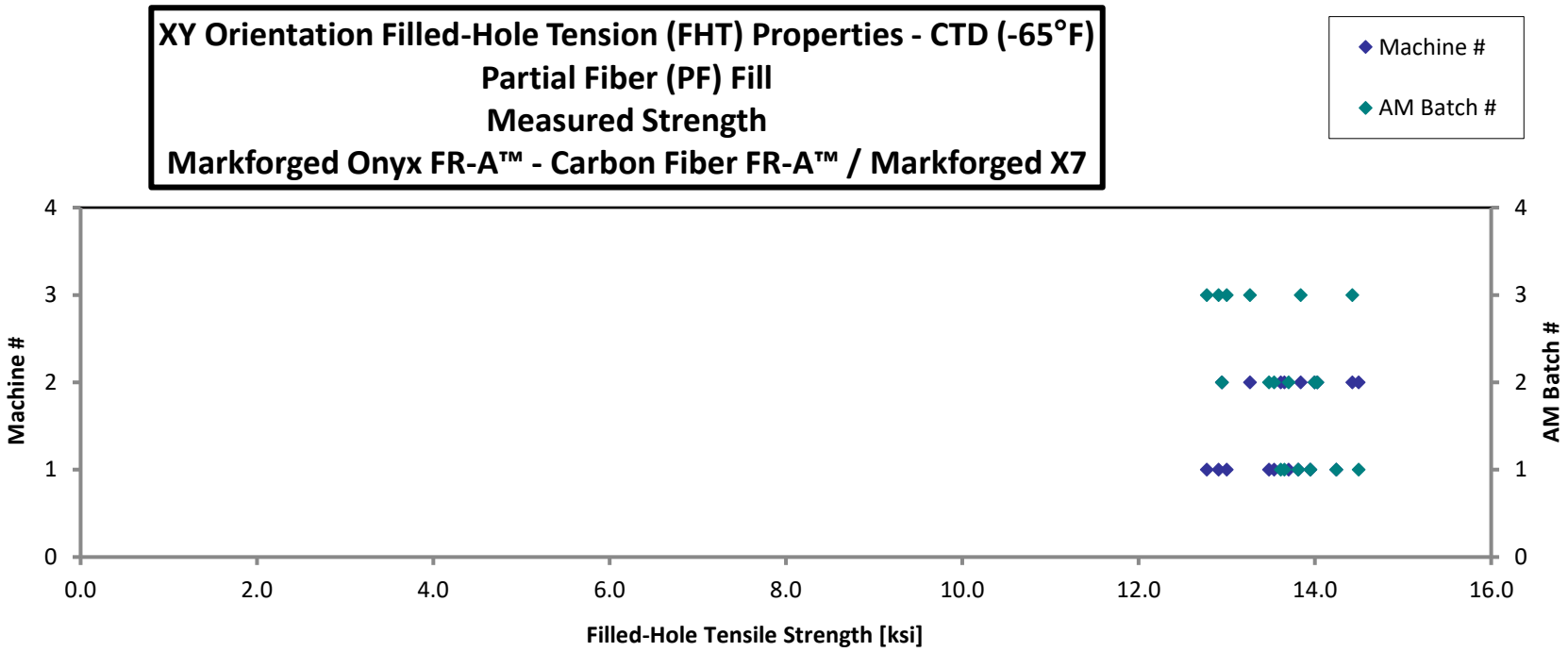
4.29 **XY PF Filled-Hole Tension Properties**

4.29.1 **CTD Condition**

XY Orientation Filled-Hole Tension (FHT) Properties - CTD (-65°F)
Partial Fiber (PF) Fill
Strength
Markforged Onyx FR-A™ - Carbon Fiber FR-A™ / Markforged X7

Specimen Number	AM Batch #	Machine #	Avg. Specimen Thickness [in]	Filled-Hole Tensile Strength [ksi]	Failure Mode
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M1-P46302-XY-FHT-11-CTD-PF-1	1	1	0.144	14.24	M(A,L)GM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M1-P45814-XY-FHT-12-CTD-PF-2	1	1	0.146	13.95	M(A,L)GM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M1-P43092-XY-FHT-13-CTD-PF-3	1	1	0.150	13.81	M(A,L)GM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M2-P54641-XY-FHT-11-CTD-PF-1	1	2	0.139	13.61	M(A,L)GM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M2-P44678-XY-FHT-12-CTD-PF-2	1	2	0.140	14.50	M(A,L)GM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M2-P43812-XY-FHT-13-CTD-PF-3	1	2	0.143	13.65	M(A,L)GM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-B-M1-P55481-XY-FHT-11-CTD-PF-1	2	1	0.139	13.54	M(A,L)GM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-B-M1-P41399-XY-FHT-12-CTD-PF-2	2	1	0.140	13.70	M(A,L)GM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-B-M1-P41475-XY-FHT-13-CTD-PF-3	2	1	0.142	13.48	M(A,L)GM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-B-M2-P55461-XY-FHT-11-CTD-PF-1	2	2	0.140	14.03	AGM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-B-M2-P40747-XY-FHT-12-CTD-PF-2	2	2	0.143	14.00	AGM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-B-M2-P46559-XY-FHT-13-CTD-PF-3	2	2	0.145	12.94	AGM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-C-M1-P52530-XY-FHT-11-CTD-PF-1	3	1	0.141	12.91	LGM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-C-M1-P50520-XY-FHT-12-CTD-PF-2	3	1	0.144	13.00	M(A,L)GM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-C-M1-P47663-XY-FHT-13-CTD-PF-3	3	1	0.149	12.77	M(A,L)GM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-C-M2-P57147-XY-FHT-11-CTD-PF-1	3	2	0.140	14.42	M(A,L)GM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-C-M2-P50450-XY-FHT-12-CTD-PF-2	3	2	0.145	13.27	LGM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-C-M2-P46999-XY-FHT-13-CTD-PF-3	3	2	0.146	13.84	LGM

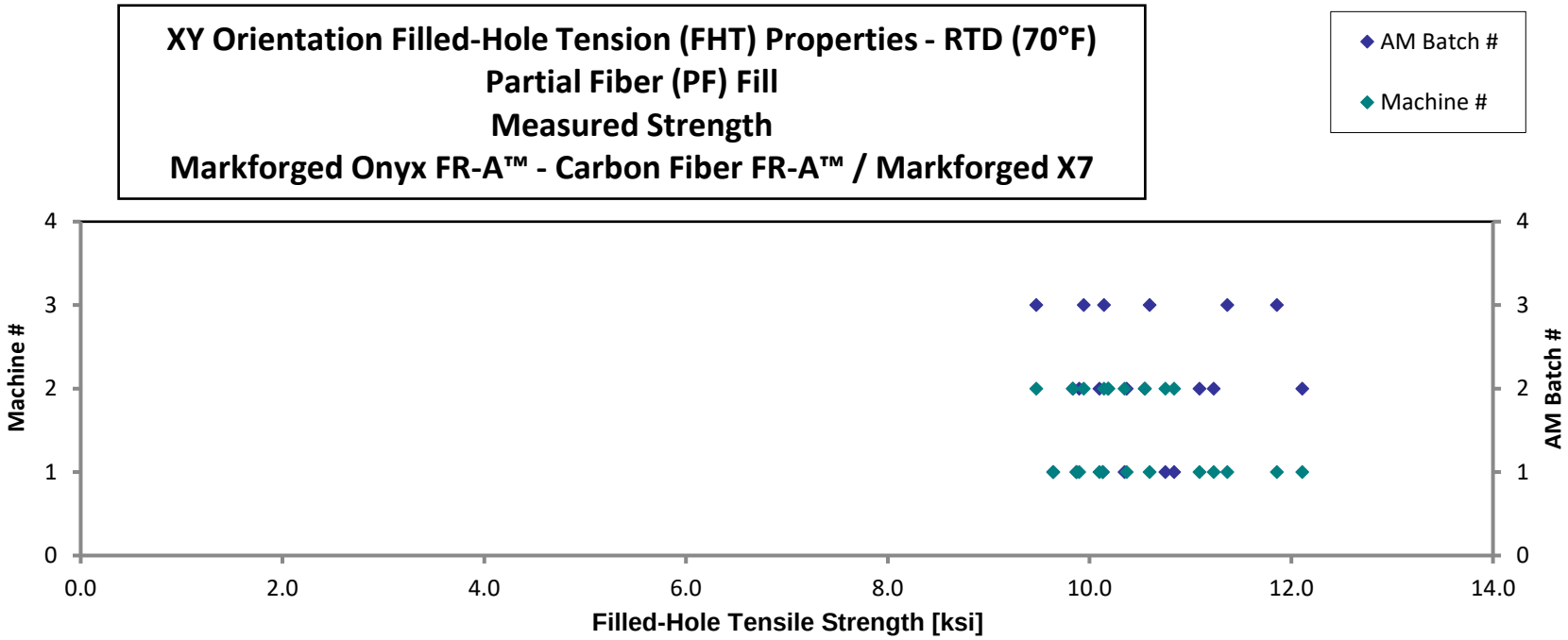
Average	**0.143**	**13.65**
Standard Dev.		**0.516**
Coeff. of Var. [%]		**3.778**
Min.	**0.139**	**12.77**
Max.	**0.150**	**14.50**
Number of Spec.	**18**	**18**


XY Orientation Filled-Hole Tension (FHT) Properties - CTD (-65°F)
Partial Fiber (PF) Fill
Measured Strength
Markforged Onyx FR-A™ - Carbon Fiber FR-A™ / Markforged X7
Machine #
AM Batch #
Machine #
AM Batch #
Filled-Hole Tensile Strength [ksi]
0
1
2
3
4
0.0
2.0
4.0
6.0
8.0
10.0
12.0
14.0
16.0

4.29.2 **RTD Condition**

XY Orientation Filled-Hole Tension (FHT) Properties - RTD (70°F)
Partial Fiber (PF) Fill
Strength
Markforged Onyx FR-A™ - Carbon Fiber FR-A™ / Markforged X7

Specimen Number	AM Batch #	Machine #	Avg. Specimen Thickness [in]	Filled-Hole Tensile Strength [ksi]	Failure Mode
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M1-P44088-XY-FHT-11-RTD-PF-1	1	1	0.145	10.13	AGM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M1-P46209-XY-FHT-12-RTD-PF-2	1	1	0.147	9.872	AGM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M1-P46302-XY-FHT-13-RTD-PF-3	1	1	0.147	9.641	AGM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M2-P42470-XY-FHT-11-RTD-PF-1	1	2	0.143	10.75	M(A,L)GM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M2-P45327-XY-FHT-12-RTD-PF-2	1	2	0.143	10.35	M(A,L)GM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M2-P54641-XY-FHT-13-RTD-PF-3	1	2	0.143	10.84	M(A,L)GM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-B-M1-P38052-XY-FHT-11-RTD-PF-1	2	1	0.138	12.11	M(A,L)GM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-B-M1-P40814-XY-FHT-12-RTD-PF-2	2	1	0.143	11.09	M(A,L)GM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-B-M1-P55481-XY-FHT-13-RTD-PF-3	2	1	0.139	11.23	M(A,L)GM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-B-M1-P33521-XY-FHT-11-RTD-PF-1	2	1	0.145	9.899	AGM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-B-M1-P36645-XY-FHT-12-RTD-PF-2	2	1	0.145	10.37	AGM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-B-M1-P33716-XY-FHT-13-RTD-PF-3	2	1	0.144	10.10	AGM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-B-M2-P46477-XY-FHT-11-RTD-PF-1	2	2	0.141	10.18	M(A,L)GM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-B-M2-P40813-XY-FHT-12-RTD-PF-2	2	2	0.143	10.55	M(A,L)GM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-B-M2-P55461-XY-FHT-13-RTD-PF-3	2	2	0.144	9.836	AGM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-C-M1-P47772-XY-FHT-11-RTD-PF-1	3	1	0.142	10.60	M(A,L)GM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-C-M1-P50945-XY-FHT-12-RTD-PF-2	3	1	0.144	11.37	AGM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-C-M1-P52174-XY-FHT-13-RTD-PF-3	3	1	0.144	11.86	AGM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-C-M2-P51055-XY-FHT-11-RTD-PF-1	3	2	0.140	10.14	AGM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-C-M2-P53036-XY-FHT-12-RTD-PF-2	3	2	0.142	9.474	AGM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-C-M2-P57147-XY-FHT-13-RTD-PF-3	3	2	0.141	9.944	AGM
		Average	**0.143**	**10.49**	
		Standard Dev.		**0.711**	
		Coeff. of Var. [%]		**6.780**	
		Min.	**0.138**	**9.474**	
		Max.	**0.147**	**12.11**	
		Number of Spec.	**21**	**21**	

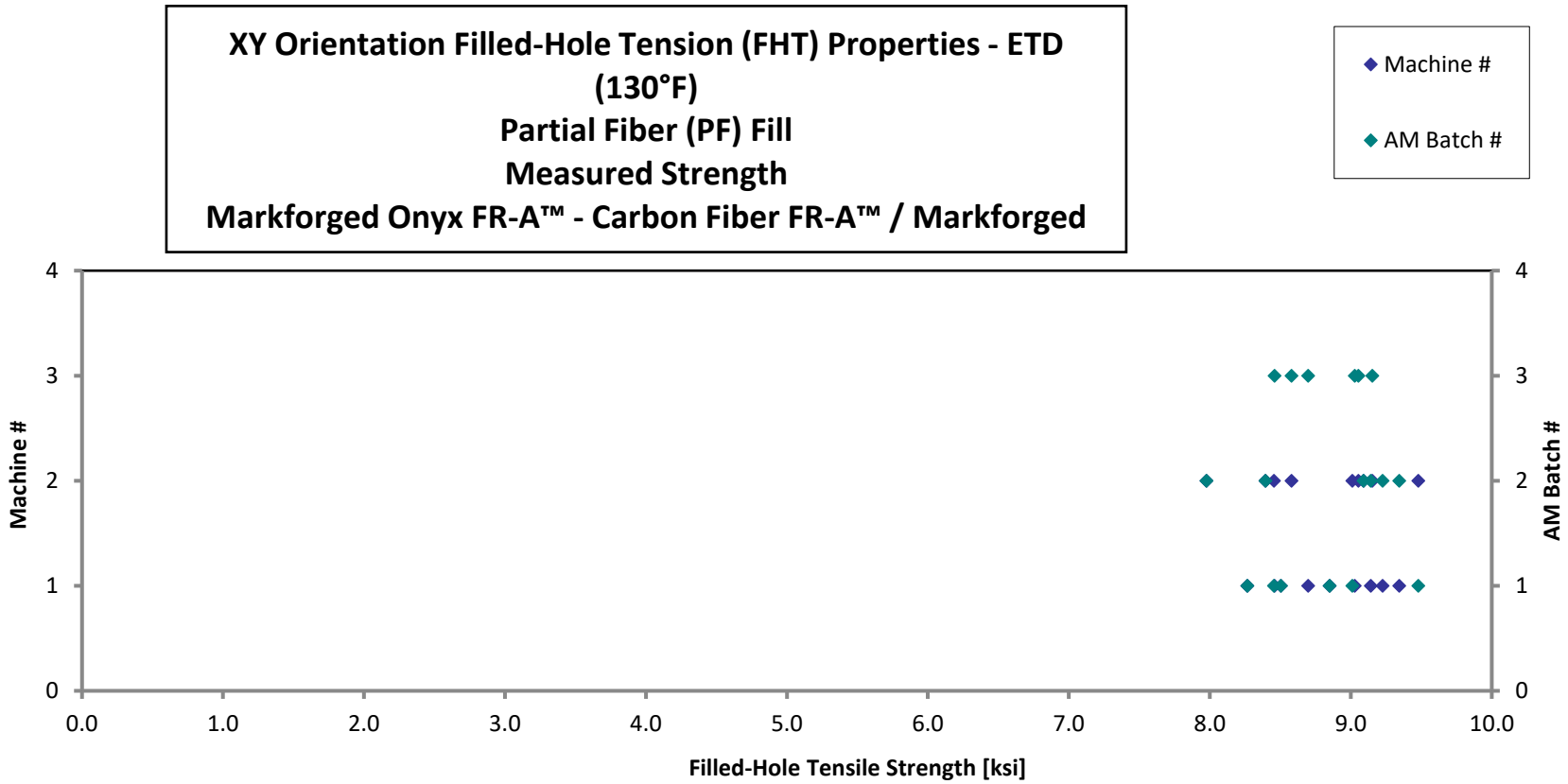

XY Orientation Filled-Hole Tension (FHT) Properties - RTD (70°F)
Partial Fiber (PF) Fill
Measured Strength
Markforged Onyx FR-A™ - Carbon Fiber FR-A™ / Markforged X7
AM Batch #
Machine #
Machine #
AM Batch #
Filled-Hole Tensile Strength [ksi]
0
1
2
3
4
0.0
2.0
4.0
6.0
8.0
10.0
12.0
14.0

4.29.3 **ETD Condition**

XY Orientation Filled-Hole Tension (FHT) Properties - ETD (130°F)
Partial Fiber (PF) Fill
Strength
Markforged Onyx FR-A™ - Carbon Fiber FR-A™ / Markforged X7

Specimen Number	AM Batch #	Machine #	Avg. Specimen Thickness [in]	Filled-Hole Tensile Strength [ksi]	Failure Mode
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M1-P44320-XY-FHT-11-ETD-PF-1	1	1	0.144	8.850	AGM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M1-P46302-XY-FHT-12-ETD-PF-2	1	1	0.148	8.266	AGM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M1-P44088-XY-FHT-13-ETD-PF-3	1	1	0.146	8.505	AGM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M2-P46114-XY-FHT-11-ETD-PF-1	1	2	0.141	9.480	M(A,L)GM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M2-P54641-XY-FHT-12-ETD-PF-2	1	2	0.144	9.011	M(A,L)GM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M2-P42470-XY-FHT-13-ETD-PF-3	1	2	0.143	8.455	AGM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-B-M1-P39839-XY-FHT-11-ETD-PF-1	2	1	0.139	9.344	AGM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-B-M1-P55481-XY-FHT-12-ETD-PF-2	2	1	0.140	9.141	M(A,L)GM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-B-M1-P38052-XY-FHT-13-ETD-PF-3	2	1	0.140	9.225	M(A,L)GM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-B-M2-P38143-XY-FHT-11-ETD-PF-1	2	2	0.138	9.089	AGM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-B-M2-P55461-XY-FHT-12-ETD-PF-2	2	2	0.142	8.395	AGM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-B-M2-P46477-XY-FHT-13-ETD-PF-3	2	2	0.138	7.976	AGM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-C-M1-P49921-XY-FHT-11-ETD-PF-1	3	1	0.143	9.028	M(A,L)GM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-C-M1-P51660-XY-FHT-12-ETD-PF-2	3	1	0.144	8.697	M(A,L)GM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-C-M1-P47772-XY-FHT-13-ETD-PF-3	3	1	0.147	8.459	M(A,L)GM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-C-M2-P49961-XY-FHT-11-ETD-PF-1	3	2	0.142	9.053	M(A,L)GM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-C-M2-P57147-XY-FHT-12-ETD-PF-2	3	2	0.143	8.580	AGM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-C-M2-P51055-XY-FHT-13-ETD-PF-3	3	2	0.142	9.152	M(A,L)GM

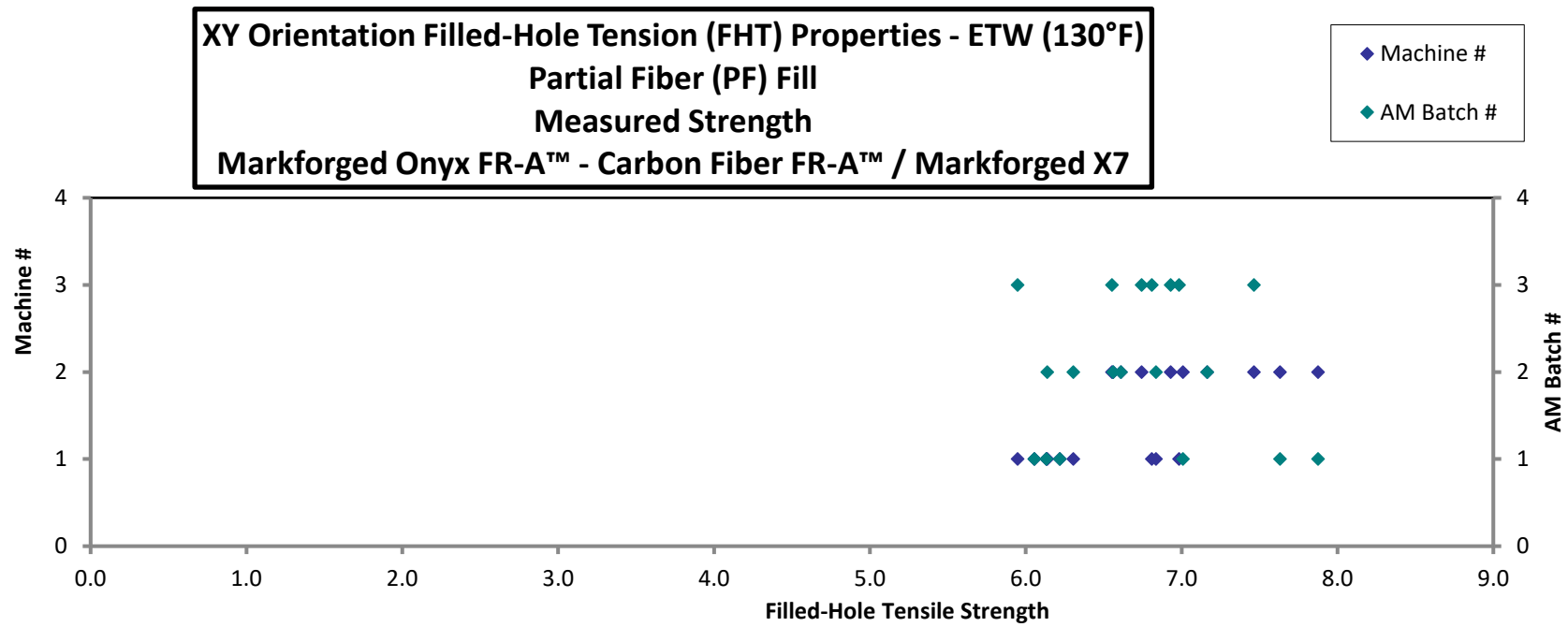
Average	**0.142**	**8.817**
Standard Dev.		**0.415**
Coeff. of Var. [%]		**4.708**
Min.	**0.138**	**7.976**
Max.	**0.148**	**9.480**
Number of Spec.	**18**	**18**


XY Orientation Filled-Hole Tension (FHT) Properties - ETD (130°F)
Partial Fiber (PF) Fill
Measured Strength
Markforged Onyx FR-A™ - Carbon Fiber FR-A™ / Markforged
Machine #
AM Batch #
Machine #
AM Batch #
Filled-Hole Tensile Strength [ksi]
0.0
1.0
2.0
3.0
4.0
5.0
6.0
7.0
8.0
9.0
10.0
0
1
2
3
4

4.29.4 **ETW Condition**

XY Orientation Filled-Hole Tension (FHT) Properties - ETW (130°F)
Partial Fiber (PF) Fill
Strength
Markforged Onyx FR-A™ - Carbon Fiber FR-A™ / Markforged X7

Specimen Number	AM Batch #	Machine #	Avg. Specimen Thickness [in]	Filled-Hole Tensile Strength [ksi]	Failure Mode
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M1-P41934-XY-FHT-11-ETW-PF-1	1	1	0.144	6.132	AGM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M1-P43092-XY-FHT-12-ETW-PF-2	1	1	0.149	6.056	M(A,L)GM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M1-P44320-XY-FHT-13-ETW-PF-3	1	1	0.148	6.219	AGM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M2-P45748-XY-FHT-11-ETW-PF-1	1	2	0.140	7.630	AGM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M2-P43812-XY-FHT-12-ETW-PF-2	1	2	0.146	7.009	AGM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M2-P46114-XY-FHT-13-ETW-PF-3	1	2	0.141	7.876	AGM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-B-M1-P37885-XY-FHT-11-ETW-PF-1	2	1	0.143	6.836	AGM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-B-M1-P41475-XY-FHT-12-ETW-PF-2	2	1	0.147	6.305	AGM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-B-M1-P39839-XY-FHT-13-ETW-PF-3	2	1	0.146	6.139	AGM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-B-M2-P38519-XY-FHT-11-ETW-PF-1	2	2	0.143	7.164	AGM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-B-M2-P46559-XY-FHT-12-ETW-PF-2	2	2	0.149	6.610	AGM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-B-M2-P38143-XY-FHT-13-ETW-PF-3	2	2	0.145	6.561	AGM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-C-M1-P47343-XY-FHT-11-ETW-PF-1	3	1	0.144	6.984	AGM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-C-M1-P47404-XY-FHT-12-ETW-PF-2	3	1	0.152	5.948	AGM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-C-M1-P49921-XY-FHT-13-ETW-PF-3	3	1	0.148	6.809	AGM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-C-M2-P51135-XY-FHT-11-ETW-PF-1	3	2	0.142	7.464	AGM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-C-M2-P46999-XY-FHT-12-ETW-PF-2	3	2	0.145	6.929	AGM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-C-M2-P49961-XY-FHT-13-ETW-PF-3	3	2	0.144	6.744	AGM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-C-M2-P46999-XY-FHT-13-ETW-PF-SP	3	2	0.145	6.553	AGM
		Average	**0.145**	**6.735**	
		Standard Dev.		**0.545**	
		Coeff. of Var. [%]		**8.085**	
		Min.	**0.140**	**5.948**	
		Max.	**0.152**	**7.876**	
		Number of Spec.	**19**	**19**	

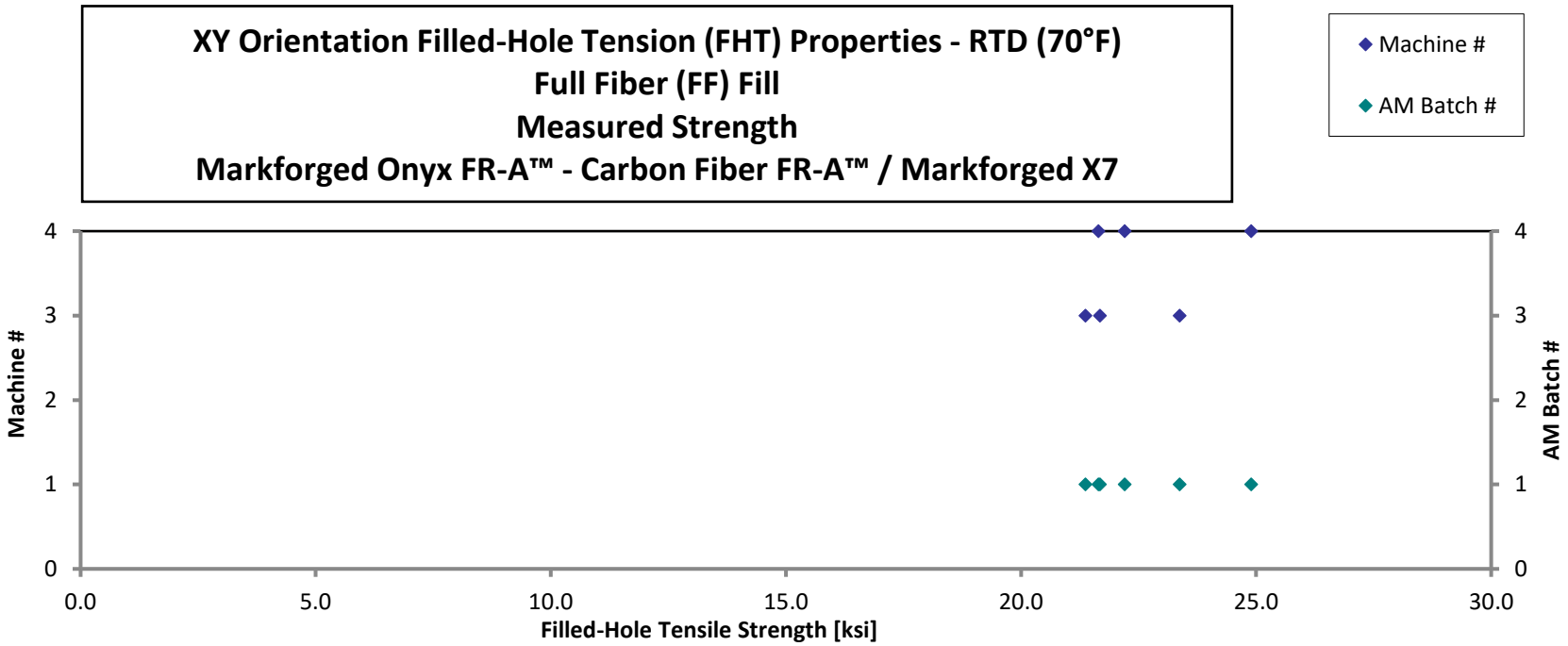

XY Orientation Filled-Hole Tension (FHT) Properties - ETW (130°F)
Partial Fiber (PF) Fill
Measured Strength
Markforged Onyx FR-A™ - Carbon Fiber FR-A™ / Markforged X7
Machine #
AM Batch #
Machine #
AM Batch #
Filled-Hole Tensile Strength
0
1
2
3
4
0.0
1.0
2.0
3.0
4.0
5.0
6.0
7.0
8.0
9.0

4.30 XY FF Filled-Hole Tension Properties

4.30.1 RTD Condition

XY Orientation Filled-Hole Tension (FHT) Properties - RTD (70°F)
Full Fiber (FF) Fill
Strength
Markforged Onyx FR-A™ - Carbon Fiber FR-A™ / Markforged X7

Specimen Number	AM Batch #	Machine #	Avg. Specimen Thickness [in]	Filled-Hole Tensile Strength [ksi]	Failure Mode
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M3-P35616-XY-FHT-11-RTD-FF-1	1	3	0.145	23.37	M(A,L)GM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M3-P35809-XY-FHT-12-RTD-FF-2	1	3	0.146	21.68	M(A,L)GM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M3-P35362-XY-FHT-13-RTD-FF-3	1	3	0.150	21.37	M(A,L)GM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M4-P41629-XY-FHT-11-RTD-FF-1	1	4	0.143	24.90	M(A,L)GM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M4-P40676-XY-FHT-12-RTD-FF-2	1	4	0.145	22.20	M(A,L)GM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M4-P40077-XY-FHT-13-RTD-FF-3	1	4	0.146	21.64	M(A,L)GM
		Average	**0.146**	**22.53**	
		Standard Dev.		**1.361**	
		Coeff. of Var. [%]		**6.043**	
		Min.	**0.143**	**21.37**	
		Max.	**0.150**	**24.90**	
		Number of Spec.	**6**	**6**	


XY Orientation Filled-Hole Tension (FHT) Properties - RTD (70°F)
Full Fiber (FF) Fill
Measured Strength
Markforged Onyx FR-A™ - Carbon Fiber FR-A™ / Markforged X7
Machine #
AM Batch #
Machine #
AM Batch #
0
1
2
3
4
0.0
5.0
10.0
15.0
20.0
25.0
30.0
Filled-Hole Tensile Strength [ksi]

4.31 XZ PF Filled-Hole Tension Properties

4.31.1 CTD Condition

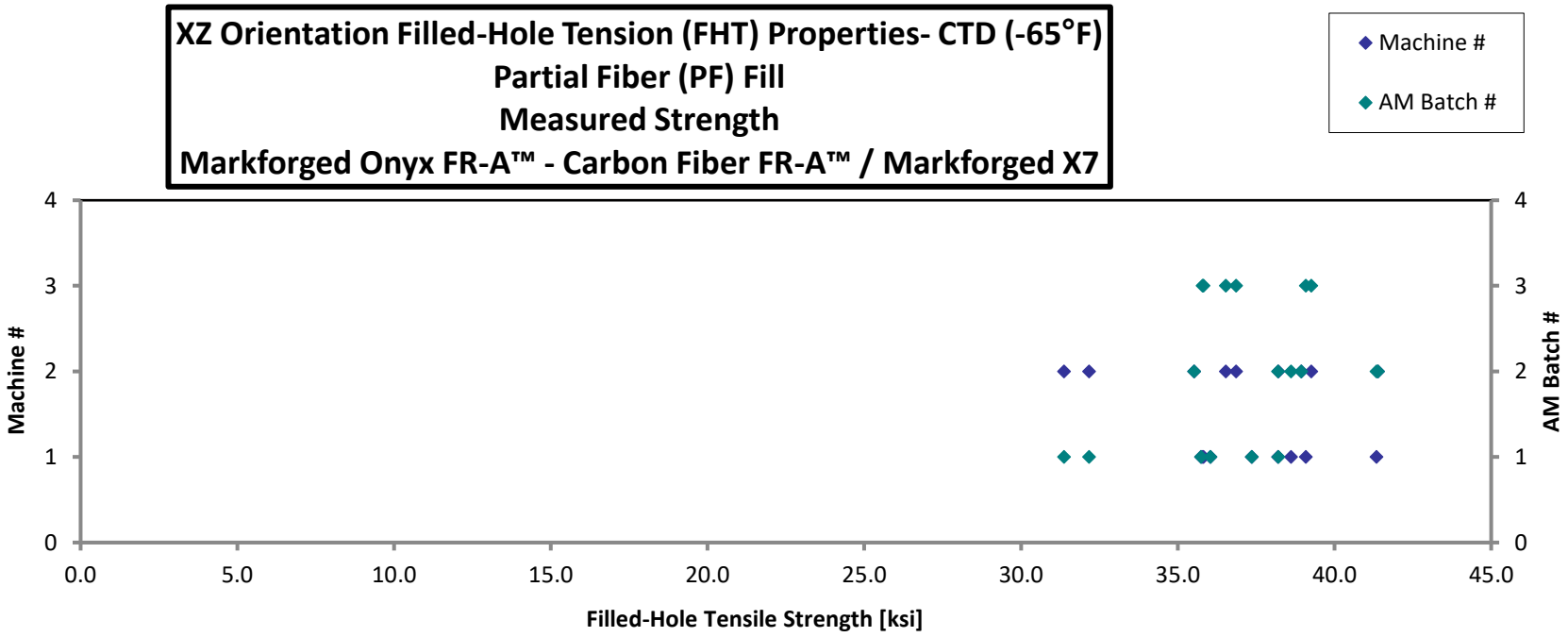
XZ Orientation Filled-Hole Tension (FHT) Properties - CTD (-65°F)
Partial Fiber (PF) Fill
Strength
Markforged Onyx FR-A™ - Carbon Fiber FR-A™ / Markforged X7

Specimen Number	AM Batch #	Machine #	Avg. Specimen Thickness [in]	Filled-Hole Tensile Strength [ksi]	Failure Mode
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M1-P46302-XZ-FHT-11-CTD-PF-1	1	1	0.141	37.36	M(L,S)GM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M1-P42485-XZ-FHT-12-CTD-PF-2	1	1	0.142	35.75	M(L,S)GM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M1-P46009-XZ-FHT-13-CTD-PF-3	1	1	0.141	36.04	M(L,S)GM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M2-P54641-XZ-FHT-11-CTD-PF-1	1	2	0.141	38.21	SGM, M(LS)IT
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M2-P42570-XZ-FHT-12-CTD-PF-2	1	2	0.140	32.17	M(L,S)GM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M2-P44383-XZ-FHT-13-CTD-PF-3	1	2	0.140	31.37	M(L,S)GM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-B-M1-P55481-XZ-FHT-11-CTD-PF-1	2	1	0.141	38.61	M(L,S)GM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-B-M1-P40689-XZ-FHT-12-CTD-PF-2	2	1	0.142	38.20	M(L,S)GM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-B-M1-P56226-XZ-FHT-13-CTD-PF-3	2	1	0.141	41.34	M(L,S)GM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-B-M2-P55461-XZ-FHT-11-CTD-PF-1	2	2	0.139	41.39	SGM, LAB
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-B-M2-P41201-XZ-FHT-12-CTD-PF-2	2	2	0.139	38.95	M(S,L)GM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-B-M2-P54843-XZ-FHT-13-CTD-PF-3	2	2	0.138	35.53	M(S,L)GM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-C-M1-P52000-XZ-FHT-11-CTD-PF-1	3	1	0.142	39.08	M(L,S)GM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-C-M1-P46997-XZ-FHT-12-CTD-PF-2	3	1	0.142	35.79	M(L,S)GM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-C-M1-P50310-XZ-FHT-13-CTD-PF-3	3	1	0.142	35.83	M(L,S)GM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-C-M2-P57147-XZ-FHT-11-CTD-PF-1	3	2	0.141	36.87	M(L,S)GM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-C-M2-P47150-XZ-FHT-12-CTD-PF-2	3	2	0.140	39.26	SGM, LAT
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-C-M2-P51235-XZ-FHT-13-CTD-PF-3	3	2	0.139	36.54	M(L,S)GM

Note: Due to inherent material properties and print orientation, B-basis calculations will be calculated eventhough failure modes deviated from ASTM D6742.

Note: The open hole tension and filled hole tension testing was conducted following ASTM standards. However, due to the manufacturing operations of the machine, the fiber reinforcement is not fully integrated throughout the entire coupon, leaving the hole area un-reinforced. This causes the failure mode of the material to act erratically, causing both hole and long splitting failures. This test data is being provided as informational and should be used with caution keeping the design in mind and how fiber reinforcement will be used.

Average	**0.141**	**37.13**
Standard Dev.		**2.650**
Coeff. of Var. [%]		**7.137**
Min.	**0.138**	**31.37**
Max.	**0.142**	**41.39**
Number of Spec.	**18**	**18**


XZ Orientation Filled-Hole Tension (FHT) Properties- CTD (-65°F)
Partial Fiber (PF) Fill
Measured Strength
Markforged Onyx FR-A™ - Carbon Fiber FR-A™ / Markforged X7
Machine #
AM Batch #
Machine #
AM Batch #
Filled-Hole Tensile Strength [ksi]
0
1
2
3
4
0.0
5.0
10.0
15.0
20.0
25.0
30.0
35.0
40.0
45.0

4.31.2 **RTD Condition**

XZ Orientation Filled-Hole Tension (FHT) Properties - RTD (70°F)
Partial Fiber (PF) Fill
Strength
Markforged Onyx FR-A™ - Carbon Fiber FR-A™ / Markforged X7

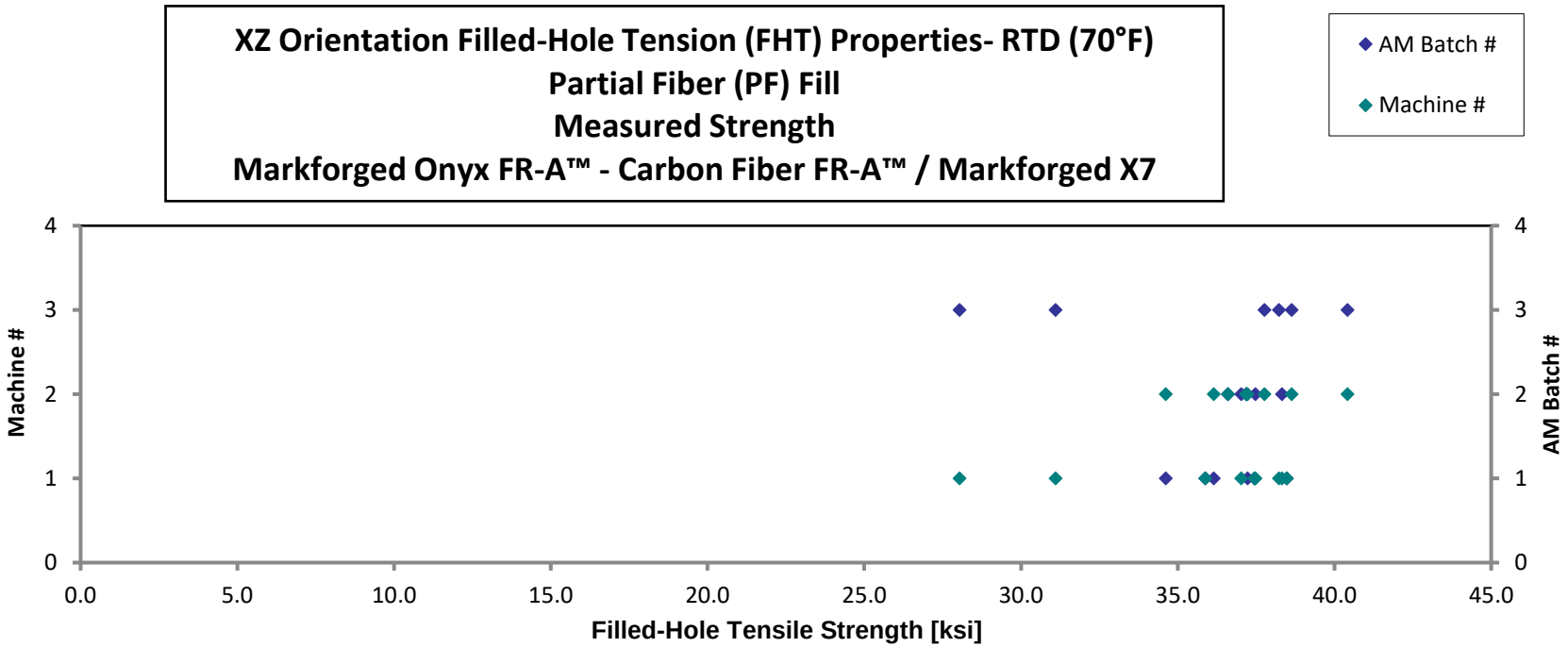
Specimen Number	AM Batch #	Machine #	Avg. Specimen Thickness [in]	Filled-Hole Tensile Strength [ksi]	Failure Mode
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M1-P56545-XZ-FHT-11-RTD-PF-1	1	1	0.141	37.45	SGM, LGF
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M1-P46302-XZ-FHT-12-RTD-PF-2	1	1	0.142	35.88	M(A,S,L)GM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M1-P46009-XZ-FHT-13-RTD-PF-3	1	1	0.141	38.48	SGM, LGT
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M2-P46278-XZ-FHT-11-RTD-PF-1	1	2	0.140	36.15	SGM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M2-P54641-XZ-FHT-12-RTD-PF-2	1	2	0.140	34.62	SGM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M2-P44383-XZ-FHT-13-RTD-PF-3	1	2	0.140	37.23	SGM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-B-M1-P41281-XZ-FHT-11-RTD-PF-1	2	1	0.141	37.48	M(A,L)GM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-B-M1-P55481-XZ-FHT-12-RTD-PF-2	2	1	0.140	37.03	SGM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-B-M1-P56226-XZ-FHT-13-RTD-PF-3	2	1	0.140	38.32	SGM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-B-M2-P39984-XZ-FHT-11-RTD-PF-1	2	2	0.141	36.60	M(S,A,L)GM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-B-M2-P55461-XZ-FHT-12-RTD-PF-2	2	2	0.139	37.19	M(S,A,L)GM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-B-M2-P54843-XZ-FHT-13-RTD-PF-3	2	2	0.139	37.19	M(S,A,L)GM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-C-M1-P35744-XZ-FHT-11-RTD-PF-1*	3	1	0.143		SGM, LAB
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-C-M1-P35046-XZ-FHT-12-RTD-PF-2*	3	1	0.141		SGM, LAB
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-C-M1-P48667-XZ-FHT-13-RTD-PF-3	3	1	0.142	31.10	M(A,S)GM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-C-M1-P35392-XZ-FHT-13-RTD-PF-SP	3	1	0.141	28.04	SGM, M(A,L)WT
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-C-M1-P56877-XZ-FHT-11-RTD-PF-1*	3	1	0.143		LAB
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-C-M1-P52000-XZ-FHT-12-RTD-PF-2	3	1	0.143	38.23	M(A,L)GM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-C-M1-P50310-XZ-FHT-13-RTD-PF-3*	3	1	0.142		LAT, SGM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-C-M2-P50104-XZ-FHT-11-RTD-PF-1	3	2	0.142	37.77	SGM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-C-M2-P57147-XZ-FHT-12-RTD-PF-2	3	2	0.139	40.42	M(A,S,L)GM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-C-M2-P51235-XZ-FHT-13-RTD-PF-3	3	2	0.139	38.63	M(A,S,L)GM

Note: Due to inherent material properties and print orientation, B-basis calculations will be calculated eventhough failure modes deviated from ASTM D6742.

*Failure away from hole

Note: The open hole tension and filled hole tension testing was conducted following ASTM standards. However, due to the manufacturing operations of the machine, the fiber reinforcement is not fully integrated throughout the entire coupon, leaving the hole area un-reinforced. This causes the failure mode of the material to act erratically, causing both hole and long splitting failures. This test data is being provided as informational and should be used with caution keeping the design in mind and how fiber reinforcement will be used.

Average	**0.141**	**36.54**
Standard Dev.		**2.870**
Coeff. of Var. [%]		**7.853**
Min.	**0.139**	**28.04**
Max.	**0.143**	**40.42**
Number of Spec.	**22**	**18**


XZ Orientation Filled-Hole Tension (FHT) Properties- RTD (70°F)
Partial Fiber (PF) Fill
Measured Strength
Markforged Onyx FR-A™ - Carbon Fiber FR-A™ / Markforged X7
AM Batch #
Machine #
Machine #
AM Batch #
Filled-Hole Tensile Strength [ksi]
0
1
2
3
4
0.0
5.0
10.0
15.0
20.0
25.0
30.0
35.0
40.0
45.0

4.31.3 **ETD Condition**

XZ Orientation Filled-Hole Tension (FHT) Properties - ETD (130°F)
Partial Fiber (PF) Fill
Strength
Markforged Onyx FR-A™ - Carbon Fiber FR-A™ / Markforged X7

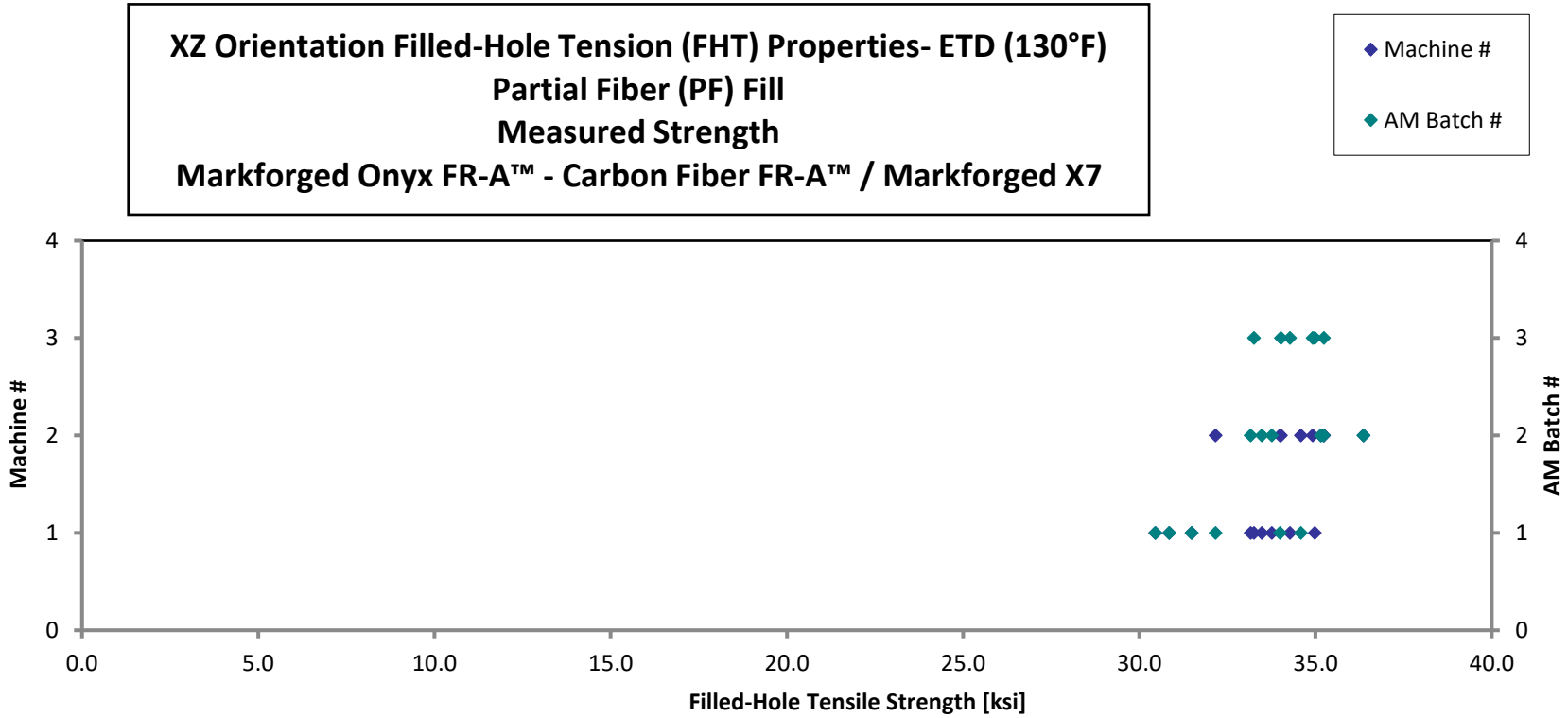
Specimen Number	AM Batch #	Machine #	Avg. Specimen Thickness [in]	Filled-Hole Tensile Strength [ksi]	Failure Mode
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M1-P42485-XZ-FHT-11-ETD-PF-1*	1	1	0.143	31.49	LAB
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M1-P42694-XZ-FHT-12-ETD-PF-2	1	1	0.142	30.45	SGM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M1-P46209-XZ-FHT-13-ETD-PF-3	1	1	0.142	30.85	M(A,S)GM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M2-P42570-XZ-FHT-11-ETD-PF-1	1	2	0.141	32.16	M(A,S,L)GM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M2-P46125-XZ-FHT-12-ETD-PF-2	1	2	0.139	33.99	M(A,S,L)GM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M2-P45327-XZ-FHT-13-ETD-PF-3	1	2	0.140	34.59	M(A,S,L)GM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-B-M1-P40689-XZ-FHT-11-ETD-PF-1	2	1	0.142	33.47	M(L,S)GM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-B-M1-P41167-XZ-FHT-12-ETD-PF-2	2	1	0.142	33.16	M(A,S,L)GM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-B-M1-P40814-XZ-FHT-13-ETD-PF-3	2	1	0.139	33.76	M(A,S,L)GM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-B-M2-P41201-XZ-FHT-11-ETD-PF-1	2	2	0.139	35.23	SGM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-B-M2-P46401-XZ-FHT-12-ETD-PF-2	2	2	0.137	35.15	SGM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-B-M2-P40813-XZ-FHT-13-ETD-PF-3	2	2	0.138	36.36	SGM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-C-M1-P46997-XZ-FHT-11-ETD-PF-1	3	1	0.143	34.98	SGM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-C-M1-P48475-XZ-FHT-12-ETD-PF-2	3	1	0.142	33.26	SGM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-C-M1-P50945-XZ-FHT-13-ETD-PF-3	3	1	0.143	34.27	SGM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-C-M2-P47150-XZ-FHT-11-ETD-PF-1	3	2	0.138	34.01	M(A,S,L)GM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-C-M2-P50292-XZ-FHT-12-ETD-PF-2	3	2	0.137	34.92	M(A,S,L)GM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-C-M2-P53036-XZ-FHT-13-ETD-PF-3	3	2	0.138	35.23	M(A,S,L)GM

Note: Due to inherent material properties and print orientation, B-basis calculations will be calculated eventhough failure modes deviated from ASTM D6742.

*Failure away from hole

Note: The open hole tension and filled hole tension testing was conducted following ASTM standards. However, due to the manufacturing operations of the machine, the fiber reinforcement is not fully integrated throughout the entire coupon, leaving the hole area un-reinforced. This causes the failure mode of the material to act erratically, causing both hole and long splitting failures. This test data is being provided as informational and should be used with caution keeping the design in mind and how fiber reinforcement will be used.

Average	**0.140**	**33.74**
Standard Dev.		**1.622**
Coeff. of Var. [%]		**4.806**
Min.	**0.137**	**30.45**
Max.	**0.143**	**36.36**
Number of Spec.	**18**	**18**


XZ Orientation Filled-Hole Tension (FHT) Properties- ETD (130°F)
Partial Fiber (PF) Fill
Measured Strength
Markforged Onyx FR-A™ - Carbon Fiber FR-A™ / Markforged X7
Machine #
AM Batch #
Machine #
AM Batch #
Filled-Hole Tensile Strength [ksi]
0
1
2
3
4
0.0
5.0
10.0
15.0
20.0
25.0
30.0
35.0
40.0

4.31.4 **ETW Condition**

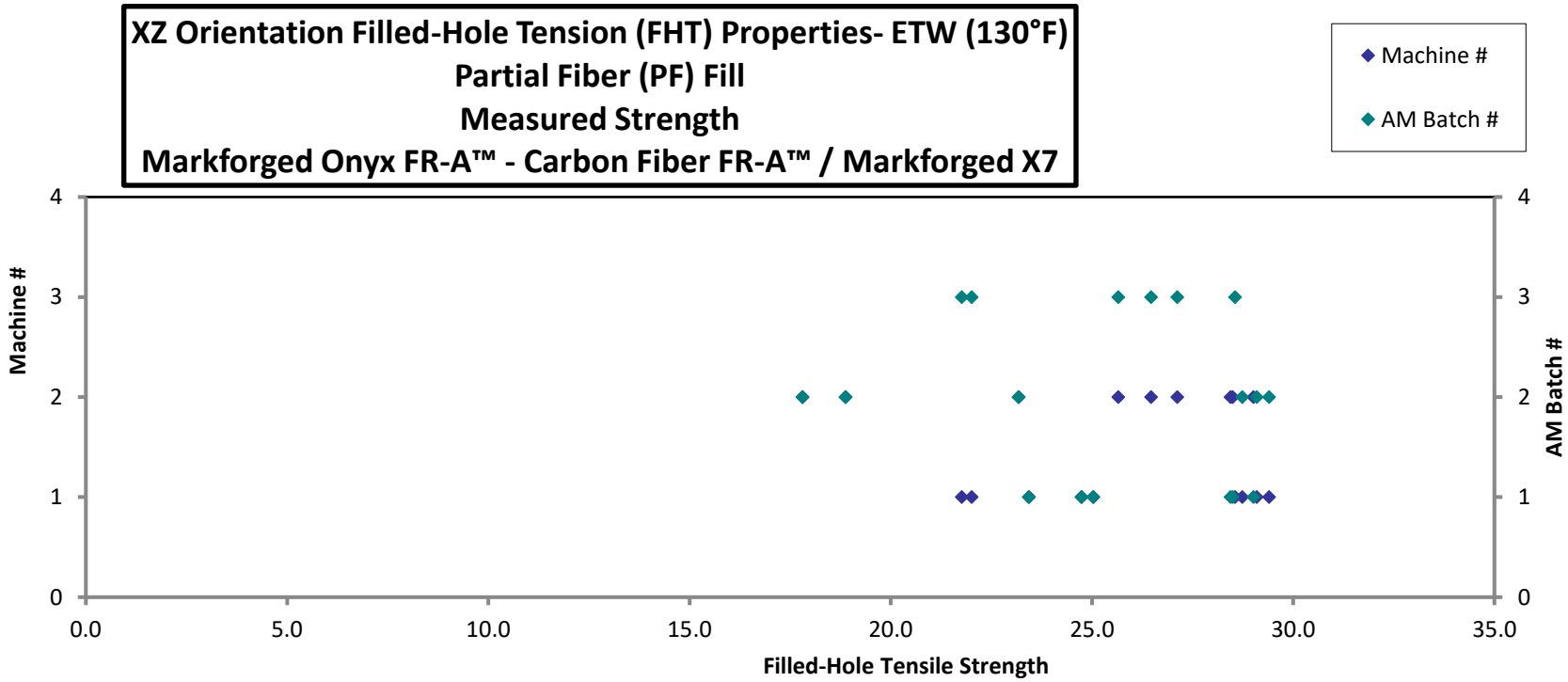
XZ Orientation Filled-Hole Tension (FHT) Properties - ETW (130°F)
Partial Fiber (PF) Fill
Strength
Markforged Onyx FR-A™ - Carbon Fiber FR-A™ / Markforged X7

Specimen Number	AM Batch #	Machine #	Avg. Specimen Thickness [in]	Filled-Hole Tensile Strength [ksi]	Failure Mode
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M1-P42694-XZ-FHT-11-ETW-PF-1	1	1	0.143	25.03	SGM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M1-P56545-XZ-FHT-12-ETW-PF-2	1	1	0.142	23.43	SGM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M1-P46302-XZ-FHT-13-ETW-PF-3	1	1	0.143	24.74	SGM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M2-P46125-XZ-FHT-11-ETW-PF-1	1	2	0.140	29.01	M(A,S,L)GM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M2-P46278-XZ-FHT-12-ETW-PF-2	1	2	0.139	28.50	M(A,S,L)GM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M2-P54641-XZ-FHT-13-ETW-PF-3	1	2	0.139	28.44	M(A,S,L)GM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-B-M1-P41167-XZ-FHT-11-ETW-PF-1	2	1	0.140	29.40	M(L,S)GM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-B-M1-P41281-XZ-FHT-12-ETW-PF-2	2	1	0.139	28.73	M(A,S,L)GM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-B-M1-P55481-XZ-FHT-13-ETW-PF-3	2	1	0.140	29.09	M(L,S)GM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-B-M2-P46401-XZ-FHT-11-ETW-PF-1	2	2	0.139	23.18	SGM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-B-M2-P39984-XZ-FHT-12-ETW-PF-2	2	2	0.139	18.87	SGB
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-B-M2-P55461-XZ-FHT-13-ETW-PF-3	2	2	0.139	17.81	SGB
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-C-M1-P48475-XZ-FHT-11-ETW-PF-1	3	1	0.144	22.01	SGM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-C-M1-P56877-XZ-FHT-12-ETW-PF-2	3	1	0.142	28.56	SGM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-C-M1-P52483-XZ-FHT-13-ETW-PF-3	3	1	0.142	21.76	SGM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-C-M2-P50292-XZ-FHT-11-ETW-PF-1	3	2	0.140	26.47	SGM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-C-M2-P50104-XZ-FHT-12-ETW-PF-2	3	2	0.139	27.12	SGM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-C-M2-P57147-XZ-FHT-13-ETW-PF-3	3	2	0.140	25.66	SGM

Note: Due to inherent material properties and print orientation, B-basis calculations will be calculated eventhough failure modes deviated from ASTM D6742.

Note: The open hole tension and filled hole tension testing was conducted following ASTM standards. However, due to the manufacturing operations of the machine, the fiber reinforcement is not fully integrated throughout the entire coupon, leaving the hole area un-reinforced. This causes the failure mode of the material to act erratically, causing both hole and long splitting failures. This test data is being provided as informational and should be used with caution keeping the design in mind and how fiber reinforcement will be used.

Average	**0.140**	**25.43**
Standard Dev.		**3.606**
Coeff. of Var. [%]		**14.18**
Min.	**0.139**	**17.81**
Max.	**0.144**	**29.40**
Number of Spec.	**18**	**18**


XZ Orientation Filled-Hole Tension (FHT) Properties- ETW (130°F)
Partial Fiber (PF) Fill
Measured Strength
Markforged Onyx FR-A™ - Carbon Fiber FR-A™ / Markforged X7
Machine #
AM Batch #
Machine #
AM Batch #
Filled-Hole Tensile Strength
0
1
2
3
4
0.0
5.0
10.0
15.0
20.0
25.0
30.0
35.0

4.32 XZ FF Filled-Hole Tension Properties

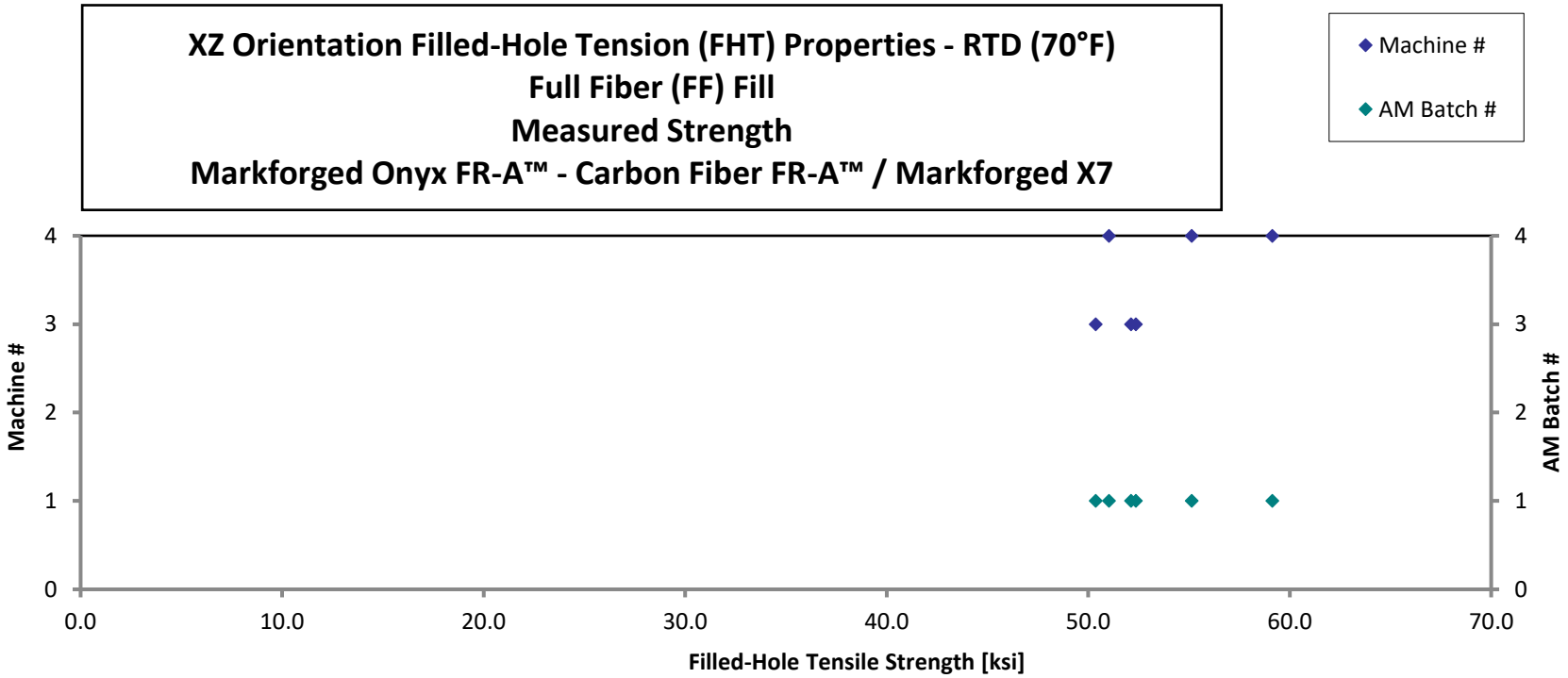
4.32.1 RTD Condition

XZ Orientation Filled-Hole Tension (FHT) Properties - RTD (70°F)
Full Fiber (FF) Fill
Strength
Markforged Onyx FR-A™ - Carbon Fiber FR-A™ / Markforged X7

Specimen Number	AM Batch #	Machine #	Avg. Specimen Thickness [in]	Filled-Hole Tensile Strength [ksi]	Failure Mode
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M3-P35746-XZ-FHT-11-RTD-FF-1	1	3	0.144	50.38	SGM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M3-P35809-XZ-FHT-12-RTD-FF-2	1	3	0.143	52.36	SGM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M3-P35616-XZ-FHT-13-RTD-FF-3	1	3	0.143	52.12	SGM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M4-P40603-XZ-FHT-11-RTD-FF-1	1	4	0.142	51.04	SGM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M4-P40676-XZ-FHT-12-RTD-FF-2	1	4	0.142	55.13	SGM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M4-P41629-XZ-FHT-13-RTD-FF-3	1	4	0.143	59.13	SGM

Note: Due to the fiber fill lay up and specimen orientation, the main failure mode are long splitting failures adjacent to the holes.

Average	**0.143**	**53.36**
Standard Dev.		**3.264**
Coeff. of Var. [%]		**6.117**
Min.	**0.142**	**50.38**
Max.	**0.144**	**59.13**
Number of Spec.	**6**	**6**


XZ Orientation Filled-Hole Tension (FHT) Properties - RTD (70°F)
Full Fiber (FF) Fill
Measured Strength
Markforged Onyx FR-A™ - Carbon Fiber FR-A™ / Markforged X7
Machine #
AM Batch #
Machine #
AM Batch #
Filled-Hole Tensile Strength [ksi]
0
1
2
3
4
0.0
10.0
20.0
30.0
40.0
50.0
60.0
70.0

4.33 ZX PF Filled-Hole Tension Properties – Reference Only

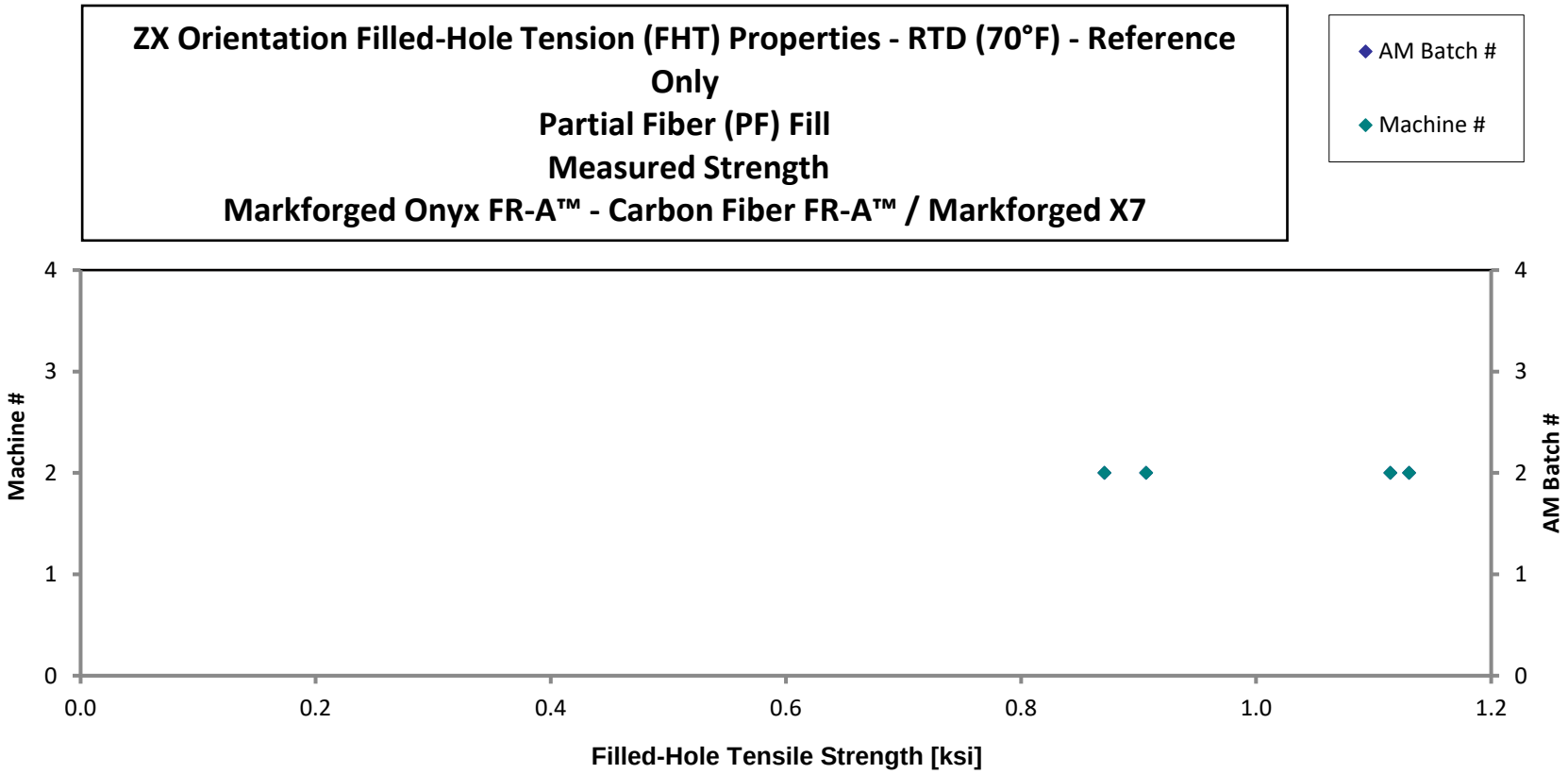
4.33.1 RTD Condition

ZX Orientation Filled-Hole Tension (FHT) Properties - RTD (70°F) - Reference Only
Partial Fiber (PF) Fill
Strength
Markforged Onyx FR-A™ - Carbon Fiber FR-A™ / Markforged X7

Specimen Number	AM Batch #	Machine #	Avg. Specimen Thickness [in]	Filled-Hole Tensile Strength [ksi]	Failure Mode
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-B-M2-P37655-ZX-FHT-11-RTD-PF-1	2	2	0.139	0.906	LGM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-B-M2-P37655-ZX-FHT-11-RTD-PF-2	2	2	0.141	1.130	LGM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-B-M2-P37655-ZX-FHT-11-RTD-PF-3	2	2	0.141	1.114	LGM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-B-M2-P51150-ZX-FHT-12-RTD-PF-1	2	2	0.144	0.871	LGB

Note: Only four of nine specimens reported due to improper failure modes

Average	**0.141**	**1.005**
Standard Dev.		**0.136**
Coeff. of Var. [%]		**13.50**
Min.	**0.139**	**0.871**
Max.	**0.144**	**1.130**
Number of Spec.	**4**	**4**


ZX Orientation Filled-Hole Tension (FHT) Properties - RTD (70°F) - Reference Only
Partial Fiber (PF) Fill
Measured Strength
Markforged Onyx FR-A™ - Carbon Fiber FR-A™ / Markforged X7
AM Batch #
Machine #
Machine #
AM Batch #
0
1
2
3
4
0.0
0.2
0.4
0.6
0.8
1.0
1.2
Filled-Hole Tensile Strength [ksi]

4.34 ZX NF Filled-Hole Tension Properties

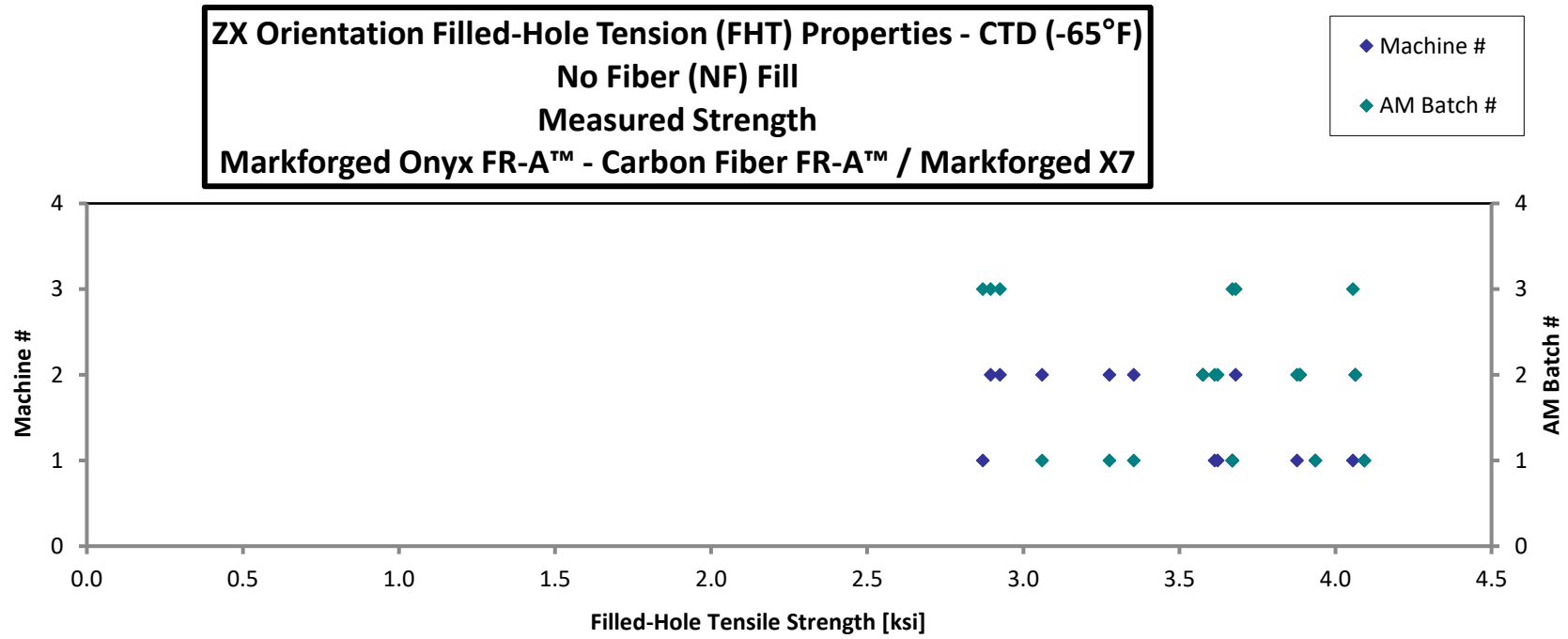
4.34.1 CTD Condition

ZX Orientation Filled-Hole Tension (FHT) Properties - CTD (-65°F)
No Fiber (NF) Fill
Strength
Markforged Onyx FR-A™ - Carbon Fiber FR-A™ / Markforged X7

Specimen Number	AM Batch #	Machine #	Avg. Specimen Thickness [in]	Filled-Hole Tensile Strength [ksi]	Failure Mode
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M1-P67328-ZX-FHT-11-CTD-NF-1	1	1	0.144	3.670	LGM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M1-P67689-ZX-FHT-12-CTD-NF-2	1	1	0.144	4.093	LGM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M1-P60727-ZX-FHT-13-CTD-NF-3	1	1	0.143	3.935	LGM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M2-P60130-ZX-FHT-11-CTD-NF-1	1	2	0.142	3.276	LGM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M2-P60979-ZX-FHT-12-CTD-NF-2	1	2	0.142	3.060	LGM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M2-P62038-ZX-FHT-13-CTD-NF-3	1	2	0.142	3.354	LGM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-B-M1-P59506-ZX-FHT-11-CTD-NF-1*	2	1	0.143	3.613	LGO
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-B-M1-P62155-ZX-FHT-12-CTD-NF-2	2	1	0.142	3.877	LGM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-B-M1-P62701-ZX-FHT-13-CTD-NF-3	2	1	0.142	3.622	LGM, LGB
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-B-M2-P59497-ZX-FHT-11-CTD-NF-1	2	2	0.143	3.576	LGM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-B-M2-P63802-ZX-FHT-12-CTD-NF-2	2	2	0.140	4.064	LGM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-B-M2-P63004-ZX-FHT-13-CTD-NF-3	2	2	0.143	3.887	LGM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-C-M1-P63385-ZX-FHT-11-CTD-NF-1*	3	1	0.142	2.870	LAB
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-C-M1-P63784-ZX-FHT-12-CTD-NF-2*	3	1	0.142	3.669	LGB
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-C-M1-P64224-ZX-FHT-13-CTD-NF-3	3	1	0.141	4.056	LGM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-C-M2-P64225-ZX-FHT-11-CTD-NF-1	3	2	0.141	3.681	LGM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-C-M2-P64680-ZX-FHT-12-CTD-NF-2	3	2	0.141	2.925	LGM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-C-M2-P64990-ZX-FHT-13-CTD-NF-3	3	2	0.140	2.896	LGM

Note: Due to inherent material properties, B-basis calculations will be calculated eventhough improper failure modes were present.
*Specimen exhibited improper failure mode per ASTM D6742

Average	**0.142**	**3.562**
Standard Dev.		**0.411**
Coeff. of Var. [%]		**11.54**
Min.	**0.140**	**2.870**
Max.	**0.144**	**4.093**
Number of Spec.	**18**	**18**


ZX Orientation Filled-Hole Tension (FHT) Properties - CTD (-65°F)
No Fiber (NF) Fill
Measured Strength
Markforged Onyx FR-A™ - Carbon Fiber FR-A™ / Markforged X7
Machine #
AM Batch #
Machine #
AM Batch #
Filled-Hole Tensile Strength [ksi]
0
1
2
3
4
0.0
0.5
1.0
1.5
2.0
2.5
3.0
3.5
4.0
4.5

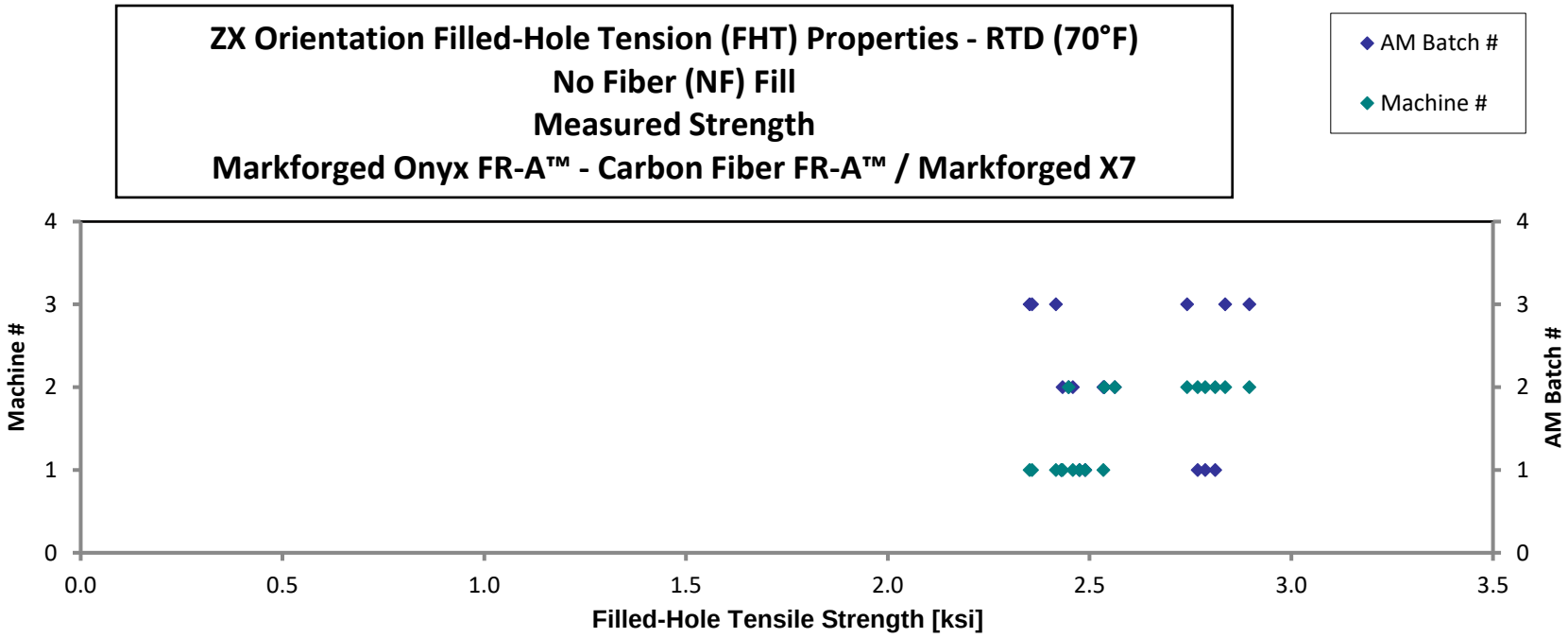
4.34.2 **RTD Condition**

ZX Orientation Filled-Hole Tension (FHT) Properties - RTD (70°F)
No Fiber (NF) Fill
Strength
Markforged Onyx FR-A™ - Carbon Fiber FR-A™ / Markforged X7

Specimen Number	AM Batch #	Machine #	Avg. Specimen Thickness [in]	Filled-Hole Tensile Strength [ksi]	Failure Mode
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M1-P67328-ZX-FHT-11-RTD-NF-1	1	1	0.144	2.490	LGM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M1-P67689-ZX-FHT-12-RTD-NF-2	1	1	0.143	2.430	LGF
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M1-P60727-ZX-FHT-13-RTD-NF-3	1	1	0.142	2.475	LGM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M2-P60130-ZX-FHT-11-RTD-NF-1	1	2	0.141	2.768	LGF
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M2-P60979-ZX-FHT-12-RTD-NF-2*	1	2	0.143	2.787	LAT
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M2-P62038-ZX-FHT-13-RTD-NF-3*	1	2	0.141	2.812	LAB
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-B-M1-P59506-ZX-FHT-11-RTD-NF-1	2	1	0.142	2.433	LGM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-B-M1-P62155-ZX-FHT-12-RTD-NF-2	2	1	0.141	2.459	LGM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-B-M1-P62701-ZX-FHT-13-RTD-NF-3	2	1	0.142	2.534	LGM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-B-M2-P59497-ZX-FHT-11-RTD-NF-1	2	2	0.141	2.449	LGM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-B-M2-P63802-ZX-FHT-12-RTD-NF-2	2	2	0.142	2.536	LGM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-B-M2-P63004-ZX-FHT-13-RTD-NF-3*	2	2	0.141	2.563	LGT
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-C-M1-P63385-ZX-FHT-11-RTD-NF-1	3	1	0.142	2.357	LGF
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-C-M1-P63784-ZX-FHT-12-RTD-NF-2	3	1	0.143	2.417	LGM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-C-M1-P64224-ZX-FHT-13-RTD-NF-3	3	1	0.142	2.352	LGM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-C-M2-P64225-ZX-FHT-11-RTD-NF-1	3	2	0.142	2.896	LGM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-C-M2-P64680-ZX-FHT-12-RTD-NF-2	3	2	0.142	2.837	LGM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-C-M2-P64990-ZX-FHT-13-RTD-NF-3	3	2	0.140	2.742	LGM

Note: Due to inherent material properties, B-basis calculations will be calculated eventhough improper failure modes were present.
*Specimen exhibited improper failure mode per ASTM D6742

Average	**0.142**	**2.574**
Standard Dev.		**0.180**
Coeff. of Var. [%]		**6.992**
Min.	**0.140**	**2.352**
Max.	**0.144**	**2.896**
Number of Spec.	**18**	**18**


ZX Orientation Filled-Hole Tension (FHT) Properties - RTD (70°F)
No Fiber (NF) Fill
Measured Strength
Markforged Onyx FR-A™ - Carbon Fiber FR-A™ / Markforged X7
AM Batch #
Machine #
Machine #
AM Batch #
Filled-Hole Tensile Strength [ksi]
0
1
2
3
4
0.0
0.5
1.0
1.5
2.0
2.5
3.0
3.5

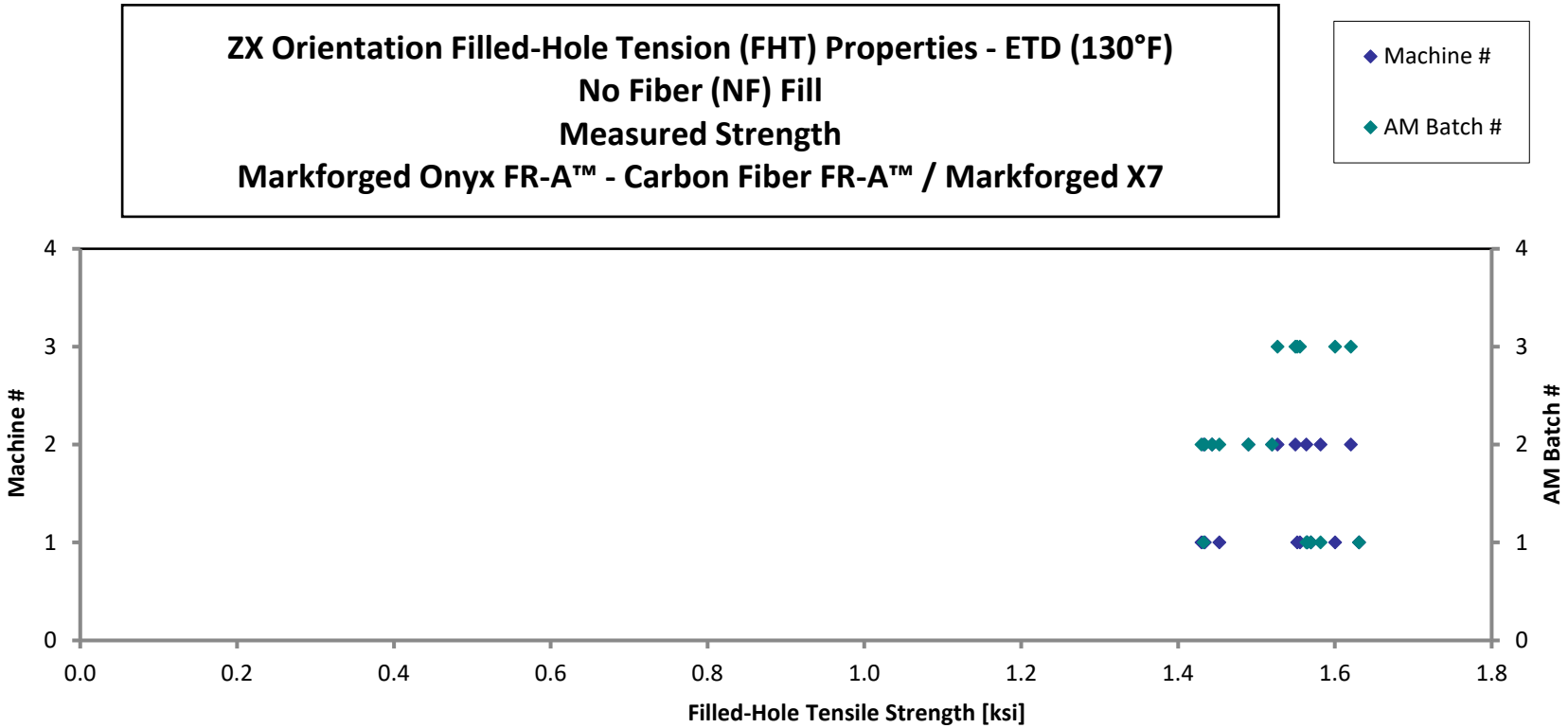
4.34.3 **ETD Condition**

ZX Orientation Filled-Hole Tension (FHT) Properties - ETD (130°F)
No Fiber (NF) Fill
Strength
Markforged Onyx FR-A™ - Carbon Fiber FR-A™ / Markforged X7

Specimen Number	AM Batch #	Machine #	Avg. Specimen Thickness [in]	Filled-Hole Tensile Strength [ksi]	Failure Mode
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M1-P67328-ZX-FHT-11-ETD-NF-1	1	1	0.143	1.631	LGM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M1-P67689-ZX-FHT-12-ETD-NF-2	1	1	0.144	1.565	LGM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M1-P60727-ZX-FHT-13-ETD-NF-3	1	1	0.142	1.569	LGM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M2-P60130-ZX-FHT-11-ETD-NF-1	1	2	0.142	1.433	LGM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M2-P60979-ZX-FHT-12-ETD-NF-2	1	2	0.142	1.582	LGF
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M2-P62038-ZX-FHT-13-ETD-NF-3	1	2	0.142	1.564	LGM, LGF
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-B-M1-P59506-ZX-FHT-11-ETD-NF-1	2	1	0.143	1.430	LGM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-B-M1-P62155-ZX-FHT-12-ETD-NF-2	2	1	0.142	1.434	LGM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-B-M1-P62701-ZX-FHT-13-ETD-NF-3	2	1	0.142	1.453	LGM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-B-M2-P59497-ZX-FHT-11-ETD-NF-1	2	2	0.142	1.490	LGM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-B-M2-P63802-ZX-FHT-12-ETD-NF-2	2	2	0.141	1.443	LGM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-B-M2-P63004-ZX-FHT-13-ETD-NF-3	2	2	0.141	1.520	LGM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-C-M1-P63385-ZX-FHT-11-ETD-NF-1	3	1	0.141	1.555	LGM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-C-M1-P63784-ZX-FHT-12-ETD-NF-2	3	1	0.141	1.600	LGM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-C-M1-P64224-ZX-FHT-13-ETD-NF-3	3	1	0.140	1.552	LGF
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-C-M2-P64225-ZX-FHT-11-ETD-NF-1	3	2	0.142	1.620	LGM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-C-M2-P64680-ZX-FHT-12-ETD-NF-2	3	2	0.141	1.550	LGM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-C-M2-P64990-ZX-FHT-13-ETD-NF-3	3	2	0.140	1.527	LGM

Note: Due to inherent material properties, B-basis calculations will be calculated eventhough improper failure modes were present.

Average	**0.142**	**1.529**
Standard Dev.		**0.067**
Coeff. of Var. [%]		**4.352**
Min.	**0.140**	**1.430**
Max.	**0.144**	**1.631**
Number of Spec.	**18**	**18**


ZX Orientation Filled-Hole Tension (FHT) Properties - ETD (130°F)
No Fiber (NF) Fill
Measured Strength
Markforged Onyx FR-A™ - Carbon Fiber FR-A™ / Markforged X7
Machine #
AM Batch #
Machine #
AM Batch #
Filled-Hole Tensile Strength [ksi]
0
1
2
3
4
0.0
0.2
0.4
0.6
0.8
1.0
1.2
1.4
1.6
1.8

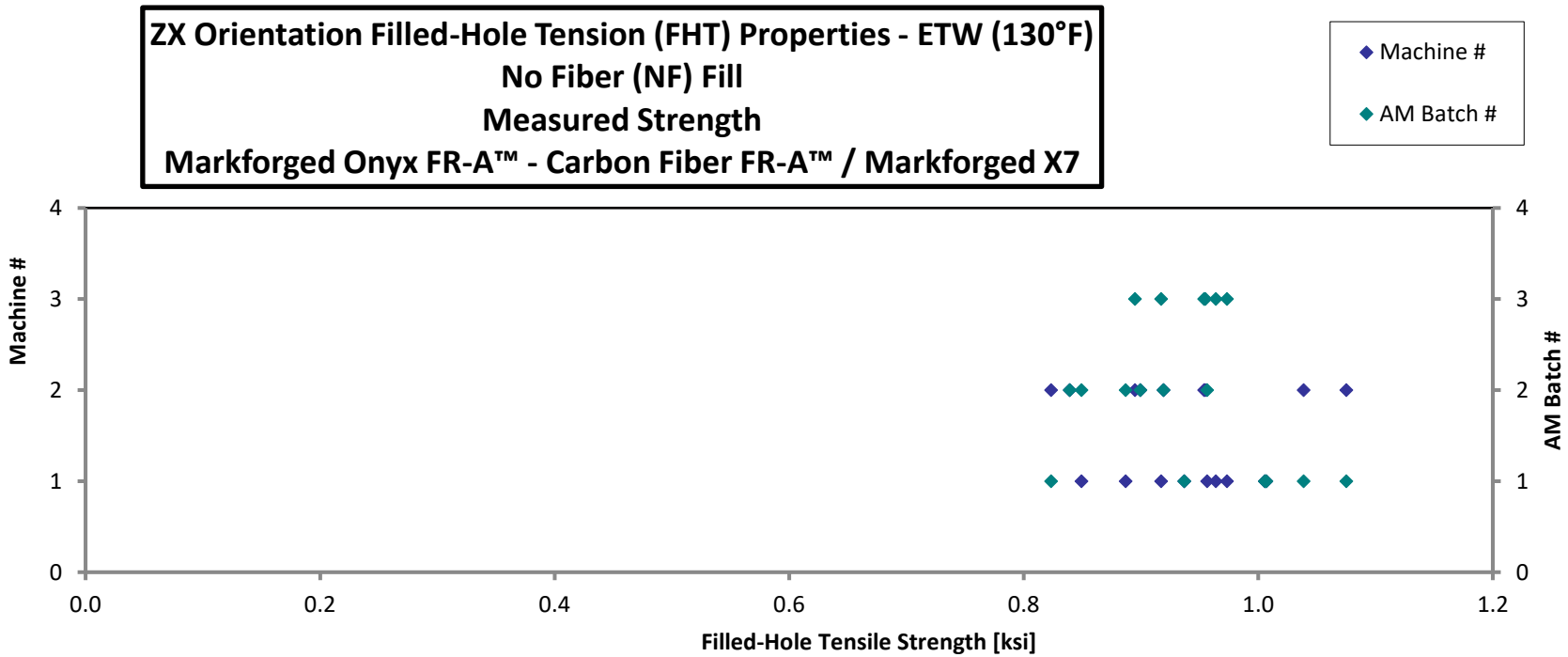
4.34.4 ETW Condition

ZX Orientation Filled-Hole Tension (FHT) Properties - ETW (130°F)
No Fiber (NF) Fill
Strength
Markforged Onyx FR-A™ - Carbon Fiber FR-A™ / Markforged X7

Specimen Number	AM Batch #	Machine #	Avg. Specimen Thickness [in]	Filled-Hole Tensile Strength [ksi]	Failure Mode
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M1-P67328-ZX-FHT-11-ETW-NF-1	1	1	0.143	1.007	LGM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M1-P67689-ZX-FHT-12-ETW-NF-2	1	1	0.143	1.006	LGM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M1-P60727-ZX-FHT-13-ETW-NF-3	1	1	0.141	0.937	LGM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M2-P60130-ZX-FHT-11-ETW-NF-1	1	2	0.141	0.823	LGM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M2-P60979-ZX-FHT-12-ETW-NF-2	1	2	0.142	1.075	LGM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M2-P62038-ZX-FHT-13-ETW-NF-3	1	2	0.142	1.039	LGM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-B-M1-P59506-ZX-FHT-X-ETW-NF-1	2	1	0.143	0.887	LGM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-B-M1-P62155-ZX-FHT-12-ETW-NF-2	2	1	0.141	0.849	LGM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-B-M1-P62701-ZX-FHT-13-ETW-NF-3	2	1	0.141	0.956	LGM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-B-M2-P59497-ZX-FHT-11-ETW-NF-1	2	2	0.141	0.839	LGM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-B-M2-P63802-ZX-FHT-12-ETW-NF-2	2	2	0.140	0.899	LGM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-B-M2-P63004-ZX-FHT-13-ETW-NF-3*	2	2	0.141	0.919	LGT
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-C-M1-P63385-ZX-FHT-11-ETW-NF-1	3	1	0.142	0.973	LGM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-C-M1-P63784-ZX-FHT-12-ETW-NF-2	3	1	0.141	0.964	LGM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-C-M1-P64224-ZX-FHT-13-ETW-NF-3	3	1	0.141	0.917	LGM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-C-M2-P64225-ZX-FHT-11-ETW-NF-1	3	2	0.141	0.955	LGM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-C-M2-P64680-ZX-FHT-12-ETW-NF-2	3	2	0.141	0.954	LGM
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-C-M2-P64990-ZX-FHT-13-ETW-NF-3	3	2	0.141	0.895	LGM

Note: Due to inherent material properties, B-basis calculations will be calculated eventhough improper failure modes were present.
*Specimen exhibited improper failure mode per ASTM D6742

Average	**0.141**	**0.939**
Standard Dev.		**0.068**
Coeff. of Var. [%]		**7.240**
Min.	**0.140**	**0.823**
Max.	**0.143**	**1.075**
Number of Spec.	**18**	**18**

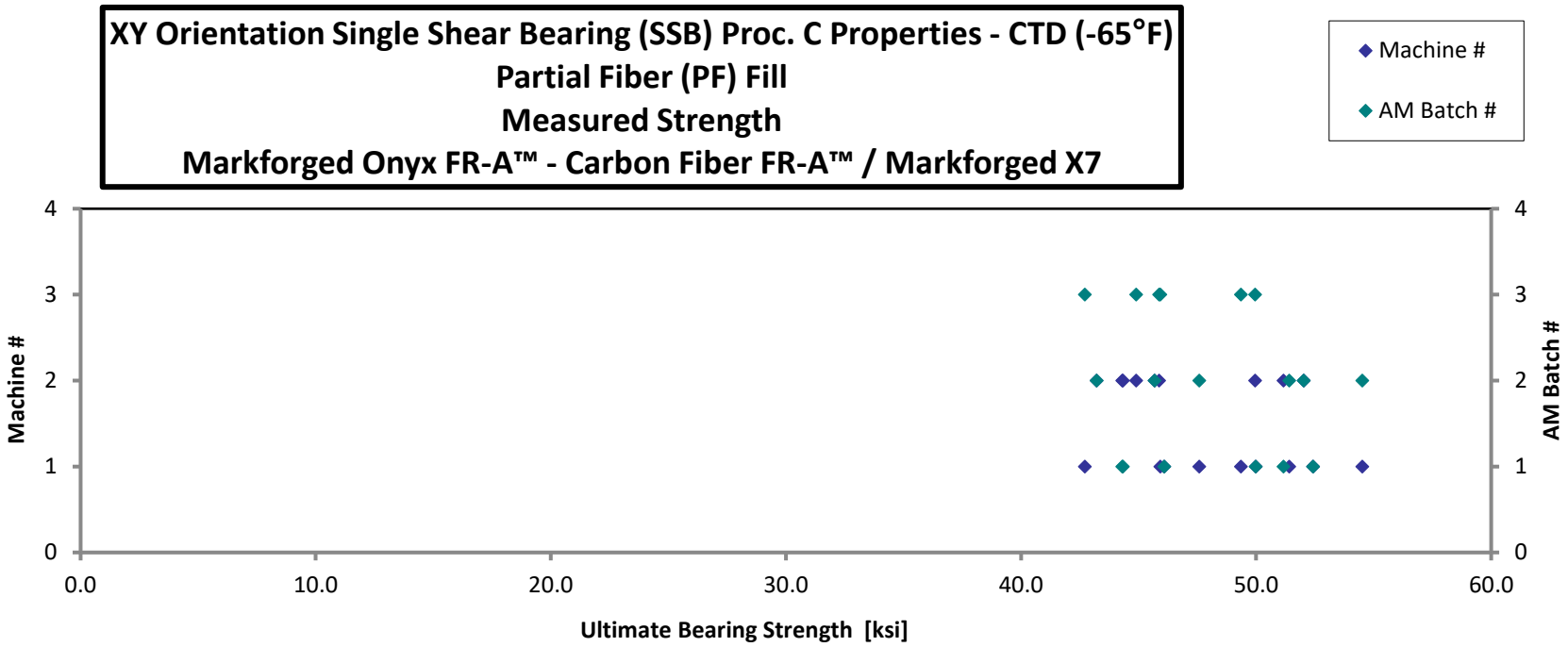

ZX Orientation Filled-Hole Tension (FHT) Properties - ETW (130°F)
No Fiber (NF) Fill
Measured Strength
Markforged Onyx FR-A™ - Carbon Fiber FR-A™ / Markforged X7
Machine #
AM Batch #
Machine #
AM Batch #
0
1
2
3
4
0.0
0.2
0.4
0.6
0.8
1.0
1.2
Filled-Hole Tensile Strength [ksi]

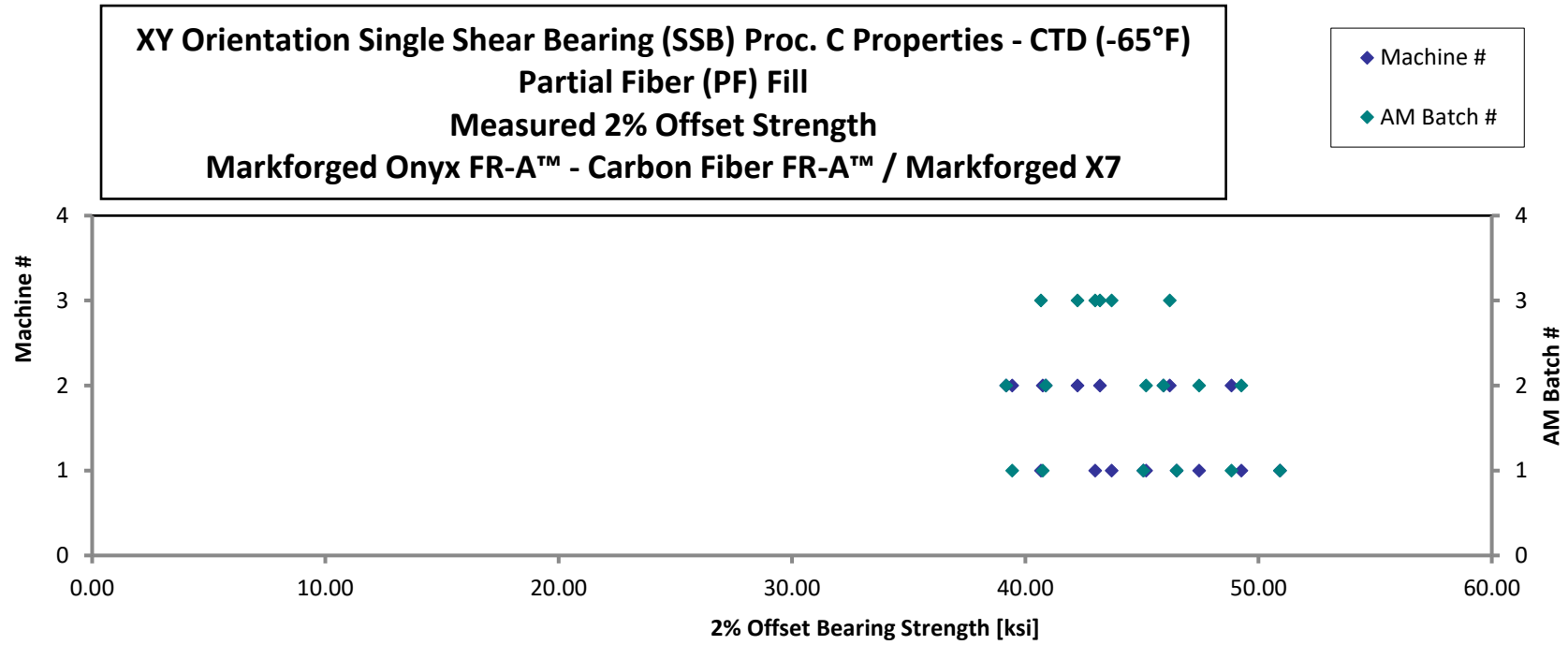
4.35 XY PF Single Shear Bearing Properties

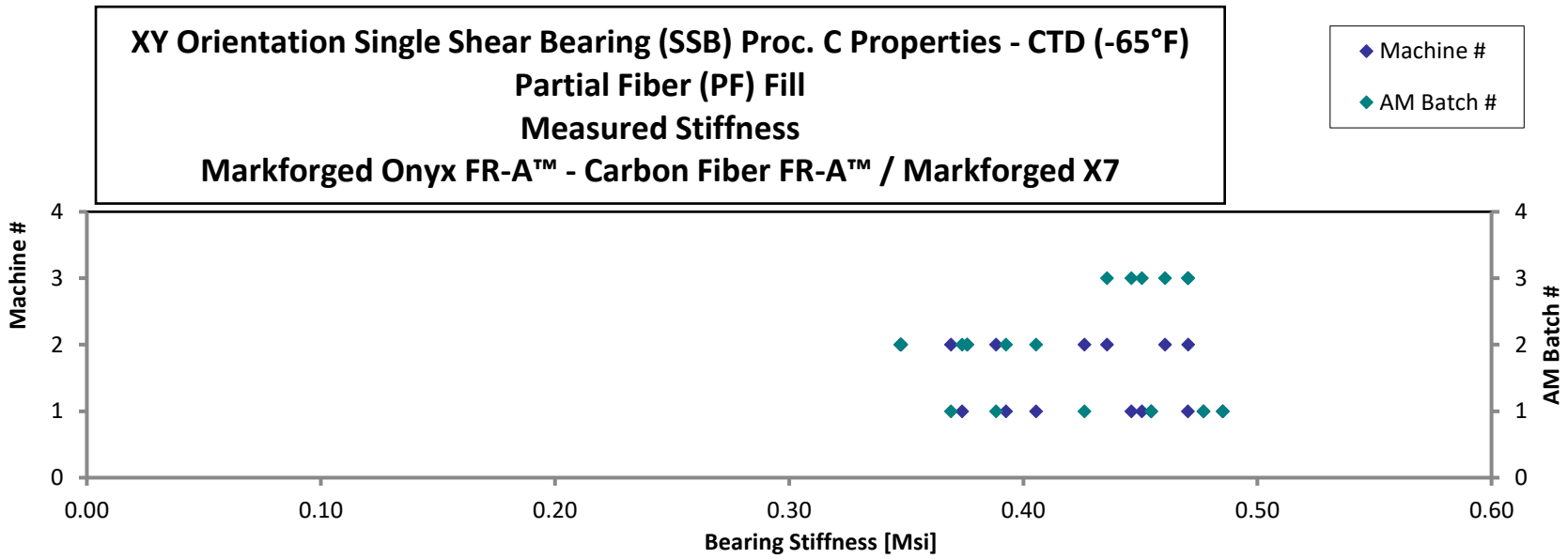
4.35.1 CTD Condition

XY Orientation Single Shear Bearing (SSB) Proc. C Properties - CTD (-65°F)
Partial Fiber (PF) Fill
Strength and Stiffness
Markforged Onyx FR-A™ - Carbon Fiber FR-A™ / Markforged X7

Specimen Number	AM Batch #	Machine #	Avg. Specimen Thickness [in]	Ultimate Bearing Strength [ksi]	2% Offset Bearing Strength [ksi]	Bearing Stiffness [Msi]	Failure Mode
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M1-P42694-XY-SSB-11-CTD-PF-1	1	1	0.138	49.98	46.49	0.477	M(B,L)1I
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M1-P42485-XY-SSB-12-CTD-PF-2	1	1	0.144	46.09	45.07	0.455	B1I
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M1-P56545-XY-SSB-13-CTD-PF-3	1	1	0.140	52.42	50.92	0.485	B1I
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M2-P46125-XY-SSB-11-CTD-PF-1	1	2	0.140	51.16	48.85	0.426	B1B, B1I
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M2-P42570-XY-SSB-12-CTD-PF-2	1	2	0.146	44.31	40.76	0.388	B1B, B1I
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M2-P46278-XY-SSB-13-CTD-PF-3	1	2	0.143	44.34	39.44	0.369	B1B, B1I
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-B-M1-P41167-XY-SSB-11-CTD-PF-1	2	1	0.141	51.41	47.45	0.393	B1I
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-B-M1-P40689-XY-SSB-12-CTD-PF-2	2	1	0.145	47.58	45.19	0.374	B1I
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-B-M1-P41281-XY-SSB-13-CTD-PF-3	2	1	0.145	54.52	49.27	0.405	B1I, L1I
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-B-M2-P46401-XY-SSB-11-CTD-PF-1	2	2	0.147	43.21	40.88	0.348	B1B, B1I
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-B-M2-P41201-XY-SSB-12-CTD-PF-2	2	2	0.145	45.69	39.19	0.376	B1I, C1I
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-B-M2-P39984-XY-SSB-13-CTD-PF-3	2	2	0.140	52.02	45.92	0.348	B1B, B1I
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-C-M1-P48475-XY-SSB-11-CTD-PF-1	3	1	0.137	45.93	43.71	0.470	M(B,L)1I
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-C-M1-P46997-XY-SSB-12-CTD-PF-2	3	1	0.143	49.36	43.00	0.446	B1I
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-C-M1-P56877-XY-SSB-13-CTD-PF-3	3	1	0.141	42.71	40.68	0.451	B1I
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-C-M2-P50292-XY-SSB-11-CTD-PF-1	3	2	0.135	49.96	46.20	0.470	B1I
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-C-M2-P47150-XY-SSB-12-CTD-PF-2	3	2	0.144	45.88	42.24	0.436	B1I
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-C-M2-P50104-XY-SSB-13-CTD-PF-3	3	2	0.138	44.90	43.20	0.461	B1I
		Average	**0.142**	**47.86**	**44.36**	**0.421**	
		Standard Dev.		**3.554**	**3.482**	**0.046**	
		Coeff. of Var. [%]		**7.426**	**7.849**	**10.99**	
		Min.	**0.135**	**42.71**	**39.19**	**0.348**	
		Max.	**0.147**	**54.52**	**50.92**	**0.485**	
		Number of Spec.	**18**	**18**	**18**	**18**	


XY Orientation Single Shear Bearing (SSB) Proc. C Properties - CTD (-65°F)
Partial Fiber (PF) Fill
Measured Strength
Markforged Onyx FR-A™ - Carbon Fiber FR-A™ / Markforged X7
Machine #
AM Batch #
Machine #
AM Batch #
Ultimate Bearing Strength [ksi]
0
1
2
3
4
0.0
10.0
20.0
30.0
40.0
50.0
60.0

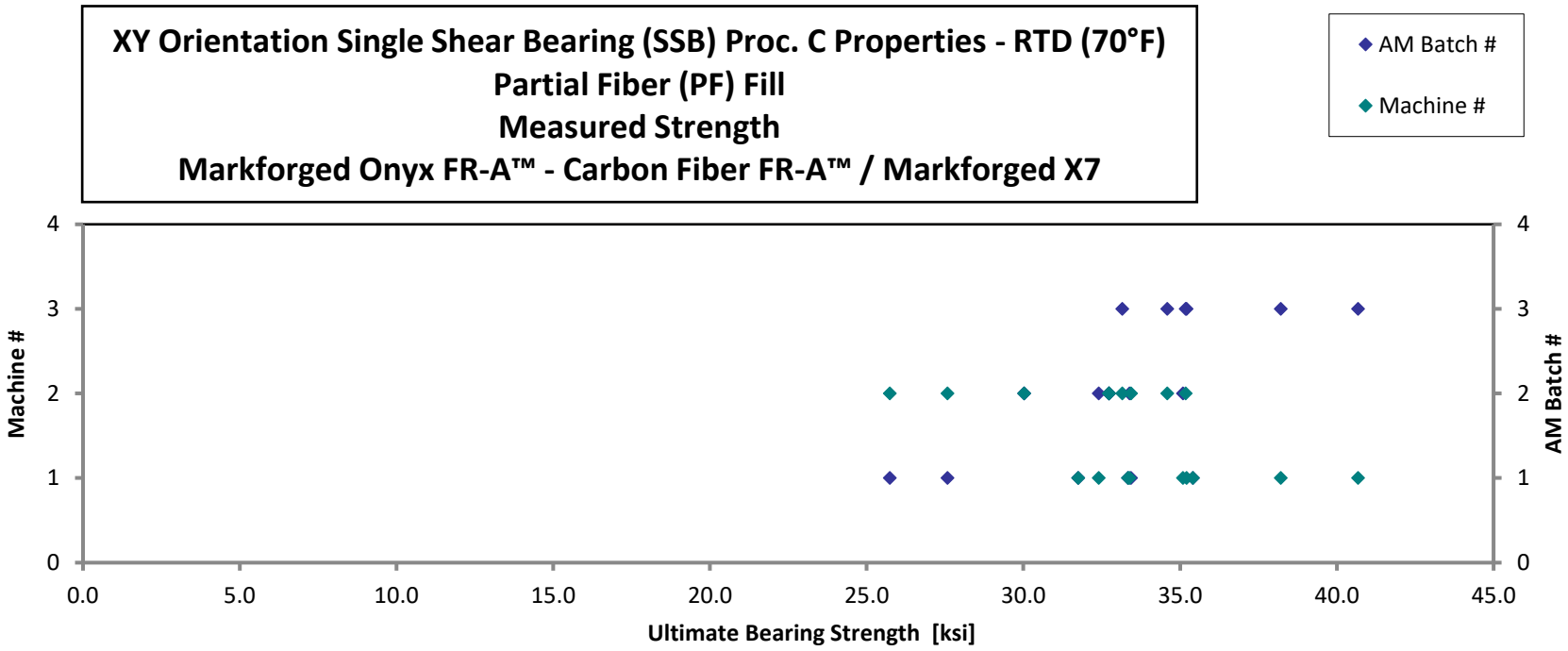

XY Orientation Single Shear Bearing (SSB) Proc. C Properties - CTD (-65°F)
Partial Fiber (PF) Fill
Measured 2% Offset Strength
Markforged Onyx FR-A™ - Carbon Fiber FR-A™ / Markforged X7
Machine #
AM Batch #
Machine #
AM Batch #
0
1
2
3
4
0.00
10.00
20.00
30.00
40.00
50.00
60.00
2% Offset Bearing Strength [ksi]

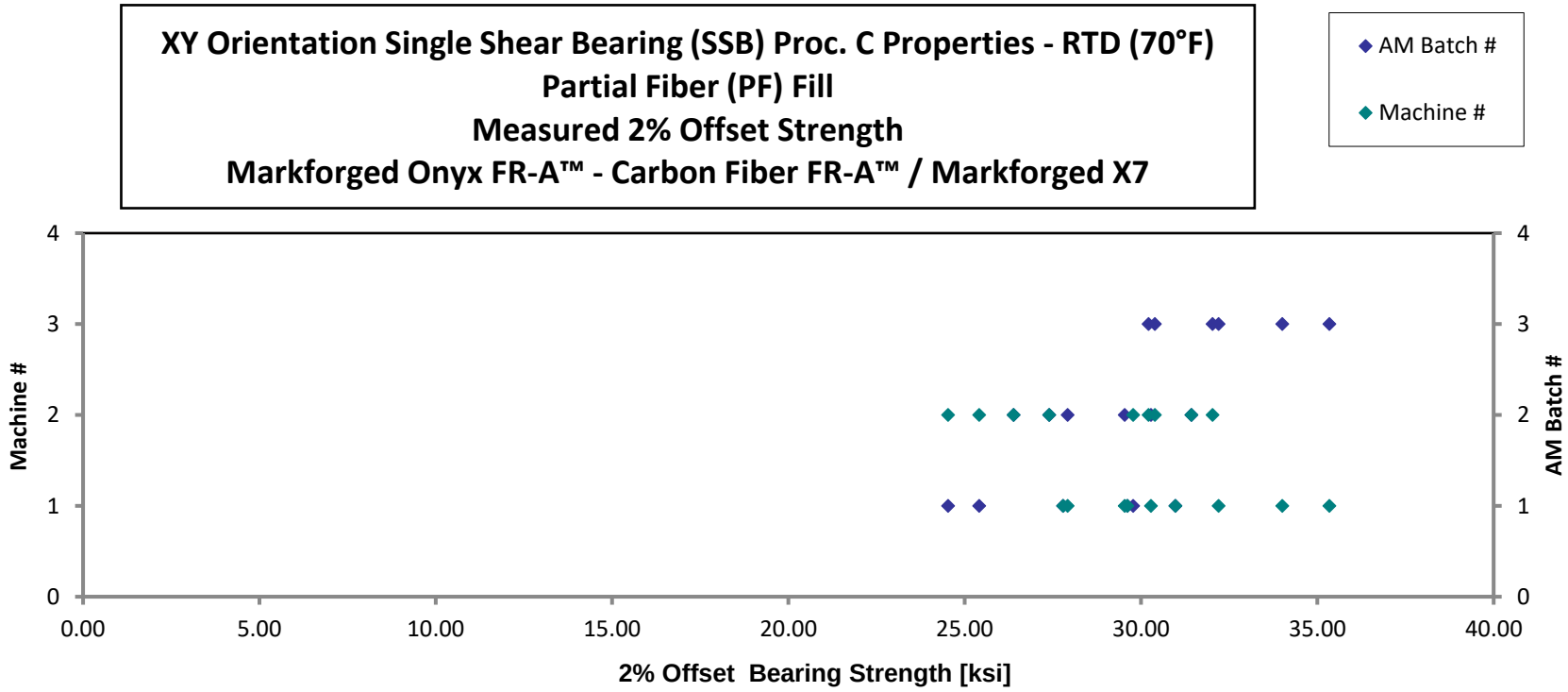

XY Orientation Single Shear Bearing (SSB) Proc. C Properties - CTD (-65°F)
Partial Fiber (PF) Fill
Measured Stiffness
Markforged Onyx FR-A™ - Carbon Fiber FR-A™ / Markforged X7
Machine #
AM Batch #
Machine #
AM Batch #
0
1
2
3
4
0.00
0.10
0.20
0.30
0.40
0.50
0.60
Bearing Stiffness [Msi]

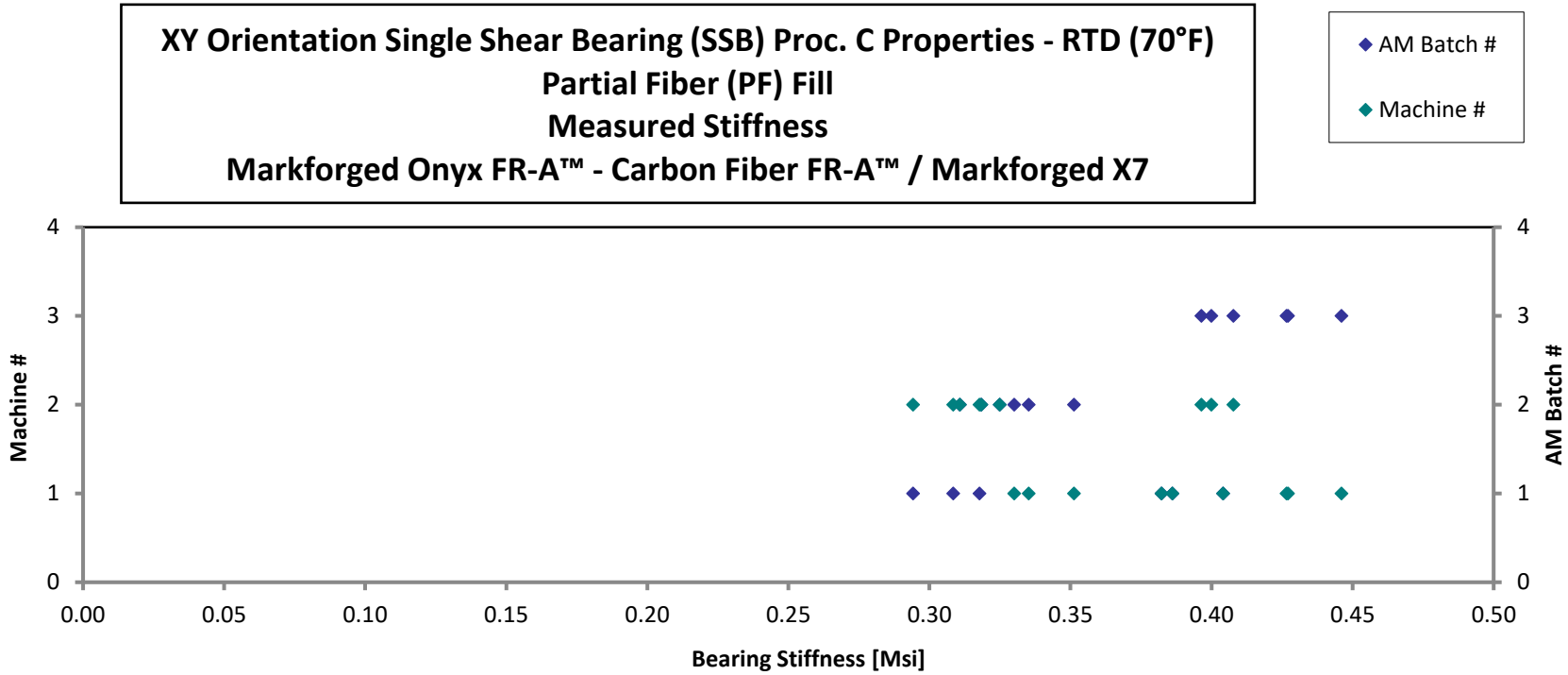
4.35.2 **RTD Condition**

XY Orientation Single Shear Bearing (SSB) Proc. C Properties - RTD (70°F)
Partial Fiber (PF) Fill
Strength & Stiffness
Markforged Onyx FR-A™ - Carbon Fiber FR-A™ / Markforged X7

Specimen Number	AM Batch #	Machine #	Avg. Specimen Thickness [in]	Ultimate Bearing Strength [ksi]	2% Offset Bearing Strength [ksi]	Bearing Stiffness [Msi]	Failure Mode
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M1-P42485-XY-SSB-11-RTD-PF-1	1	1	0.143	35.41	30.97	0.404	B1I
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M1-P56545-XY-SSB-12-RTD-PF-2	1	1	0.143	31.75	27.79	0.386	B1I
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M1-P42694-XY-SSB-13-RTD-PF-3	1	1	0.144	33.34	29.61	0.382	B1I
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M2-P42570-XY-SSB-11-RTD-PF-1	1	2	0.148	25.73	24.53	0.294	B1I
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M2-P46278-XY-SSB-12-RTD-PF-2	1	2	0.144	27.58	25.41	0.308	B1I
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M2-P46125-XY-SSB-13-RTD-PF-3	1	2	0.142	33.43	29.78	0.318	B1I, C1I
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-B-M1-P40689-XY-SSB-11-RTD-PF-1	2	1	0.139	35.09	30.28	0.351	B1B, B1I
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-B-M1-P41281-XY-SSB-12-RTD-PF-2	2	1	0.145	32.40	29.54	0.330	B1B, B1I
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-B-M1-P41167-XY-SSB-13-RTD-PF-3	2	1	0.141	33.38	27.92	0.335	B1B, B1I
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-B-M2-P41201-XY-SSB-11-RTD-PF-1	2	2	0.148	30.03	27.40	0.311	B1B, B1I, L1I
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-B-M2-P39984-XY-SSB-12-RTD-PF-2	2	2	0.146	32.73	31.42	0.318	B1B, B1I
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-B-M2-P46401-XY-SSB-13-RTD-PF-3	2	2	0.145	32.73	26.39	0.325	B1B, B1I, C1I
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-C-M1-P46997-XY-SSB-11-RTD-PF-1	3	1	0.141	40.68	35.34	0.427	M(B,C)1I
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-C-M1-P56877-XY-SSB-12-RTD-PF-2	3	1	0.145	35.21	32.20	0.427	B1I
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-C-M1-P48475-XY-SSB-13-RTD-PF-3	3	1	0.141	38.21	34.01	0.446	B1I
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-C-M2-P47150-XY-SSB-11-RTD-PF-1	3	2	0.143	35.18	32.03	0.408	B1I
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-C-M2-P50104-XY-SSB-12-RTD-PF-2	3	2	0.143	33.15	30.21	0.400	B1I
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-C-M2-P50292-XY-SSB-13-RTD-PF-3	3	2	0.146	34.59	30.40	0.396	B1I
		Average	**0.144**	**33.37**	**29.73**	**0.365**	
		Standard Dev.		**3.426**	**2.829**	**0.048**	
		Coeff. of Var. [%]		**10.27**	**9.515**	**13.29**	
		Min.	**0.139**	**25.73**	**24.53**	**0.294**	
		Max.	**0.148**	**40.68**	**35.34**	**0.446**	
		Number of Spec.	**18**	**18**	**18**	**18**	


XY Orientation Single Shear Bearing (SSB) Proc. C Properties - RTD (70°F)
Partial Fiber (PF) Fill
Measured Strength
Markforged Onyx FR-A™ - Carbon Fiber FR-A™ / Markforged X7
AM Batch #
Machine #
Machine #
AM Batch #
Ultimate Bearing Strength [ksi]
0
1
2
3
4
0.0
5.0
10.0
15.0
20.0
25.0
30.0
35.0
40.0
45.0


XY Orientation Single Shear Bearing (SSB) Proc. C Properties - RTD (70°F)
Partial Fiber (PF) Fill
Measured 2% Offset Strength
Markforged Onyx FR-A™ - Carbon Fiber FR-A™ / Markforged X7
AM Batch #
Machine #
Machine #
AM Batch #
0
1
2
3
4
0.00
5.00
10.00
15.00
20.00
25.00
30.00
35.00
40.00
2% Offset Bearing Strength [ksi]


XY Orientation Single Shear Bearing (SSB) Proc. C Properties - RTD (70°F)
Partial Fiber (PF) Fill
Measured Stiffness
Markforged Onyx FR-A™ - Carbon Fiber FR-A™ / Markforged X7
AM Batch #
Machine #
Machine #
AM Batch #
Bearing Stiffness [Msi]
0
1
2
3
4
0.00
0.05
0.10
0.15
0.20
0.25
0.30
0.35
0.40
0.45
0.50

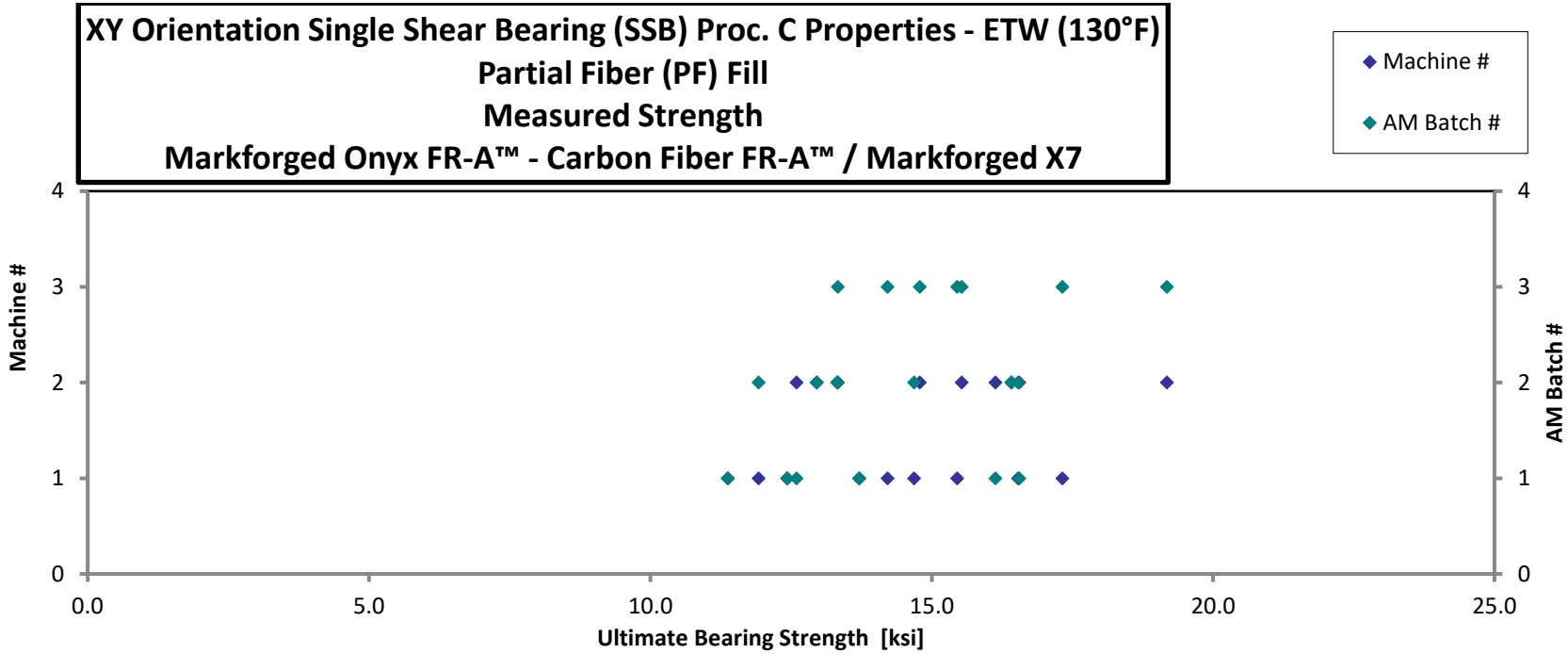
4.35.3 **ETW Condition**

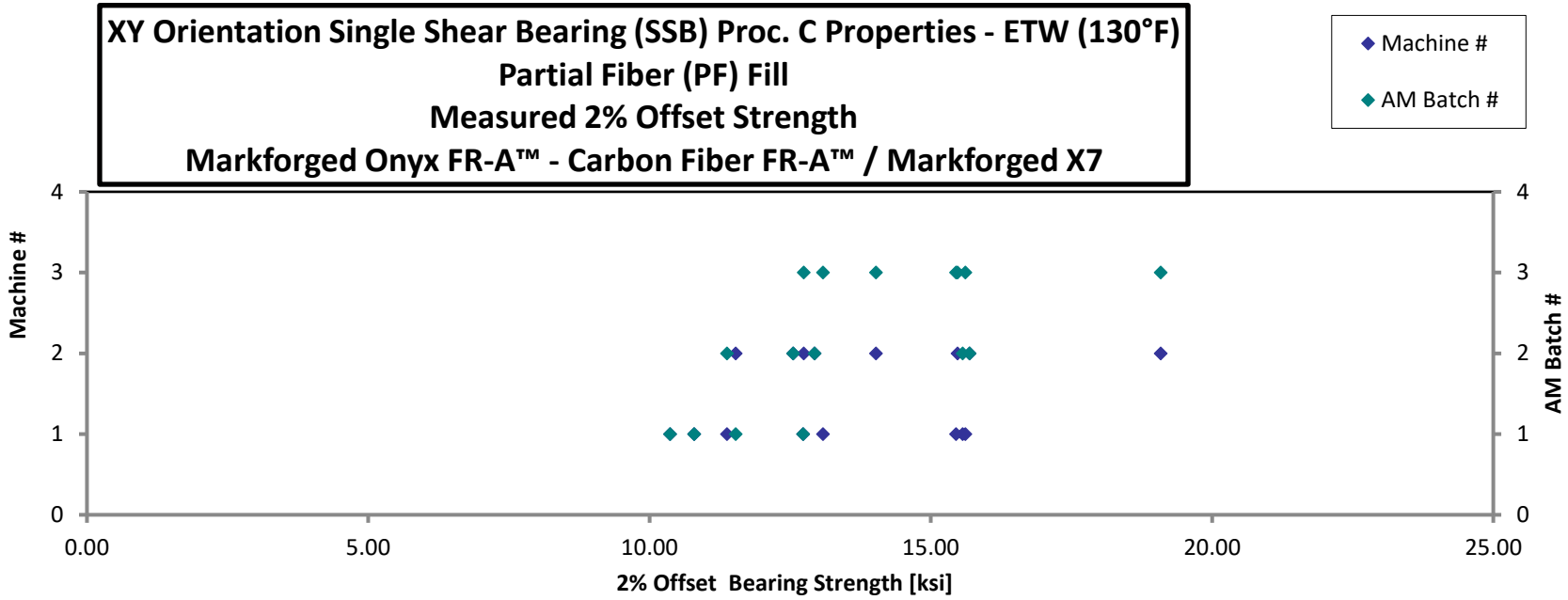
XY Orientation Single Shear Bearing (SSB) Proc. C Properties - ETW (130°F)
Partial Fiber (PF) Fill
Strength & Stiffness
Markforged Onyx FR-A™ - Carbon Fiber FR-A™ / Markforged X7

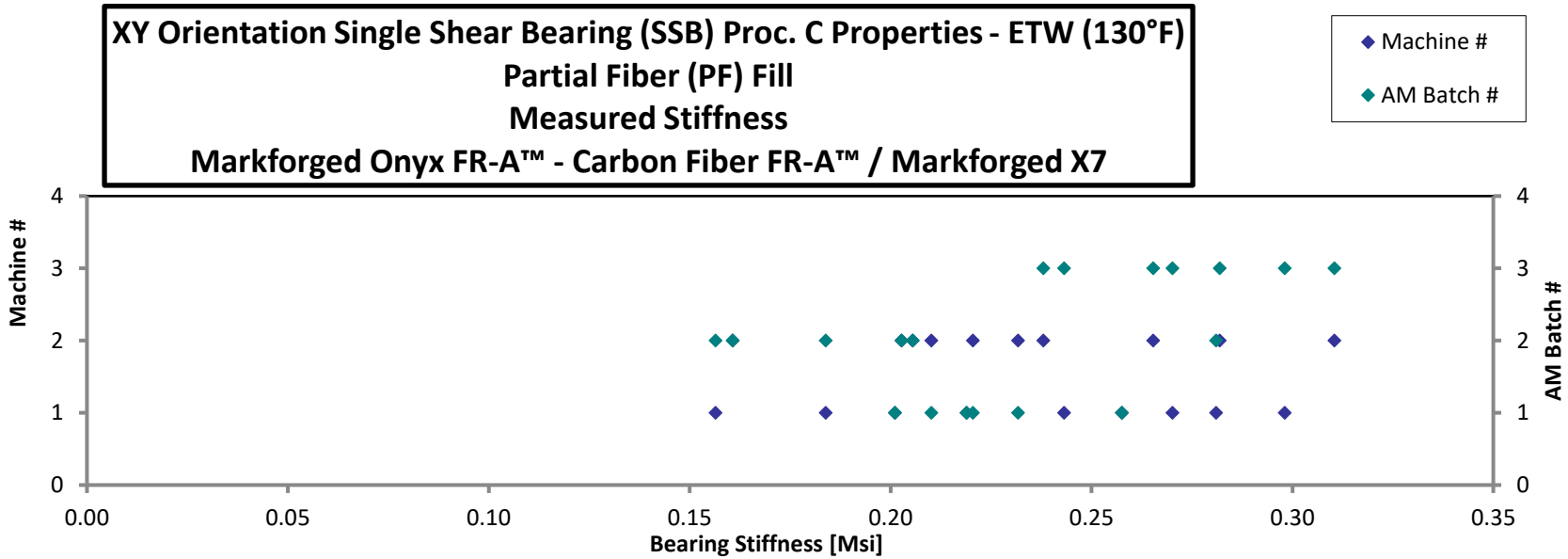
Specimen Number	AM Batch #	Machine #	Avg. Specimen Thickness [in]	Ultimate Bearing Strength [ksi]	2% Offset Bearing Strength [ksi]	Bearing Stiffness [Msi]	Failure Mode
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M1-P56545-XY-SSB-11-ETW-PF-1	1	1	0.139	13.71	12.73	0.258	B1I
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M1-P42694-XY-SSB-12-ETW-PF-2	1	1	0.142	12.43	10.37	0.219	B1I
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M1-P42485-XY-SSB-13-ETW-PF-3	1	1	0.146	11.37	10.79	0.201	B1I
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M2-P46278-XY-SSB-11-ETW-PF-1*	1	2	0.142	16.55		0.232	B1I
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M2-P46125-XY-SSB-12-ETW-PF-2*	1	2	0.145	16.13		0.220	B1I
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M2-P42570-XY-SSB-13-ETW-PF-3	1	2	0.144	12.60	11.53	0.210	B1I
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-B-M1-P41281-XY-SSB-11-ETW-PF-1	2	1	0.146	16.53	15.57	0.281	B1I
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-B-M1-P41167-XY-SSB-12-ETW-PF-2*	2	1	0.147	14.69		0.184	B1I
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-B-M1-P40689-XY-SSB-13-ETW-PF-3	2	1	0.148	11.92	11.38	0.156	B1I
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-B-M2-P39984-XY-SSB-11-ETW-PF-1	2	2	0.142	16.41	15.69	0.161	B1I
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-B-M2-P46401-XY-SSB-12-ETW-PF-2	2	2	0.146	13.32	12.93	0.205	B1I
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-B-M2-P41201-XY-SSB-13-ETW-PF-3	2	2	0.141	12.96	12.55	0.203	B1I
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-C-M1-P56877-XY-SSB-11-ETW-PF-1	3	1	0.140	14.21	13.09	0.243	B1I
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-C-M1-P48475-XY-SSB-12-ETW-PF-2	3	1	0.144	15.45	15.62	0.298	B1I
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-C-M1-P46997-XY-SSB-13-ETW-PF-3	3	1	0.144	17.32	15.45	0.270	B1I
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-C-M2-P50104-XY-SSB-11-ETW-PF-1	3	2	0.139	15.53	15.48	0.282	B1I
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-C-M2-P50292-XY-SSB-12-ETW-PF-2	3	2	0.145	13.33	12.74	0.238	M(B,D)1I
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-C-M2-P47150-XY-SSB-13-ETW-PF-3	3	2	0.138	19.18	19.09	0.310	B1I
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-C-M2-P49664-XY-SSB-13-ETW-PF-SP	3	2	0.137	14.79	14.03	0.265	B1I

*2% Offset strength not reported due to the specimen reaching max load first

Average	**0.143**	**14.66**	**13.69**	**0.234**
Standard Dev.		**2.059**	**2.313**	**0.044**
Coeff. of Var. [%]		**14.05**	**16.90**	**18.92**
Min.	**0.137**	**11.37**	**10.37**	**0.156**
Max.	**0.148**	**19.18**	**19.09**	**0.310**
Number of Spec.	**19**	**19**	**16**	**19**


XY Orientation Single Shear Bearing (SSB) Proc. C Properties - ETW (130°F)
Partial Fiber (PF) Fill
Measured Strength
Markforged Onyx FR-A™ - Carbon Fiber FR-A™ / Markforged X7
Machine #
AM Batch #
Machine #
AM Batch #
0
1
2
3
4
0.0
5.0
10.0
15.0
20.0
25.0
Ultimate Bearing Strength [ksi]


XY Orientation Single Shear Bearing (SSB) Proc. C Properties - ETW (130°F)
Partial Fiber (PF) Fill
Measured 2% Offset Strength
Markforged Onyx FR-A™ - Carbon Fiber FR-A™ / Markforged X7
Machine #
AM Batch #
Machine #
AM Batch #
0
1
2
3
4
0.00
5.00
10.00
15.00
20.00
25.00
2% Offset Bearing Strength [ksi]

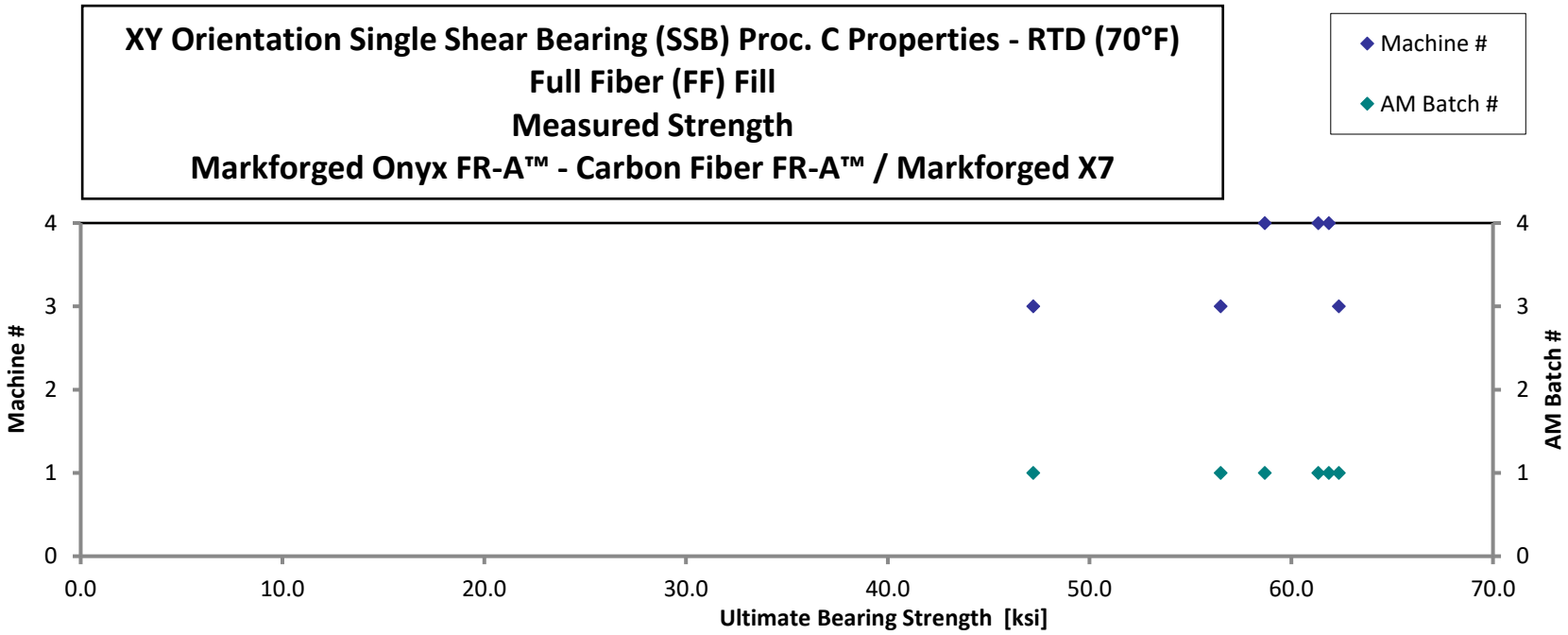

XY Orientation Single Shear Bearing (SSB) Proc. C Properties - ETW (130°F)
Partial Fiber (PF) Fill
Measured Stiffness
Markforged Onyx FR-A™ - Carbon Fiber FR-A™ / Markforged X7
Machine #
AM Batch #
Machine #
AM Batch #
0
1
2
3
4
0.00
0.05
0.10
0.15
0.20
0.25
0.30
0.35
Bearing Stiffness [Msi]

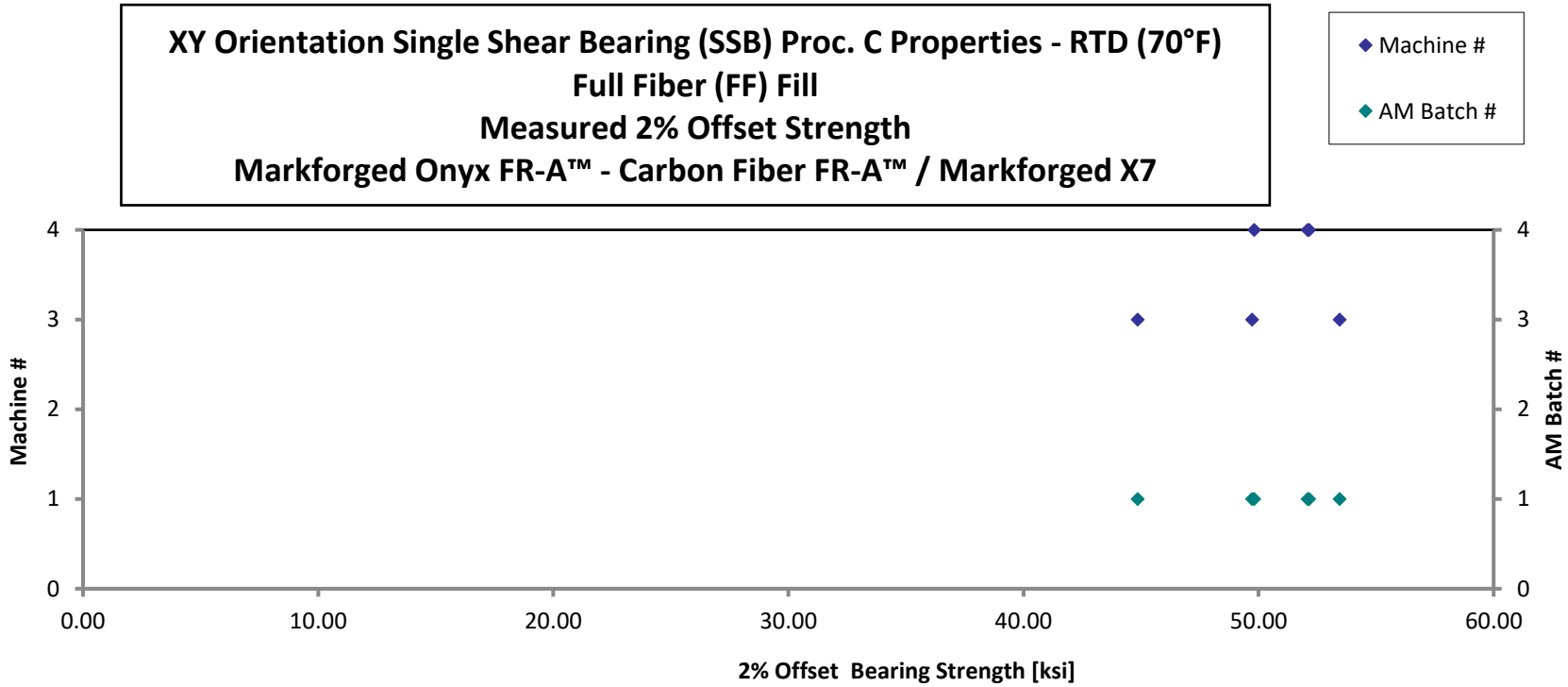
4.36 XY FF Single Shear Bearing Properties

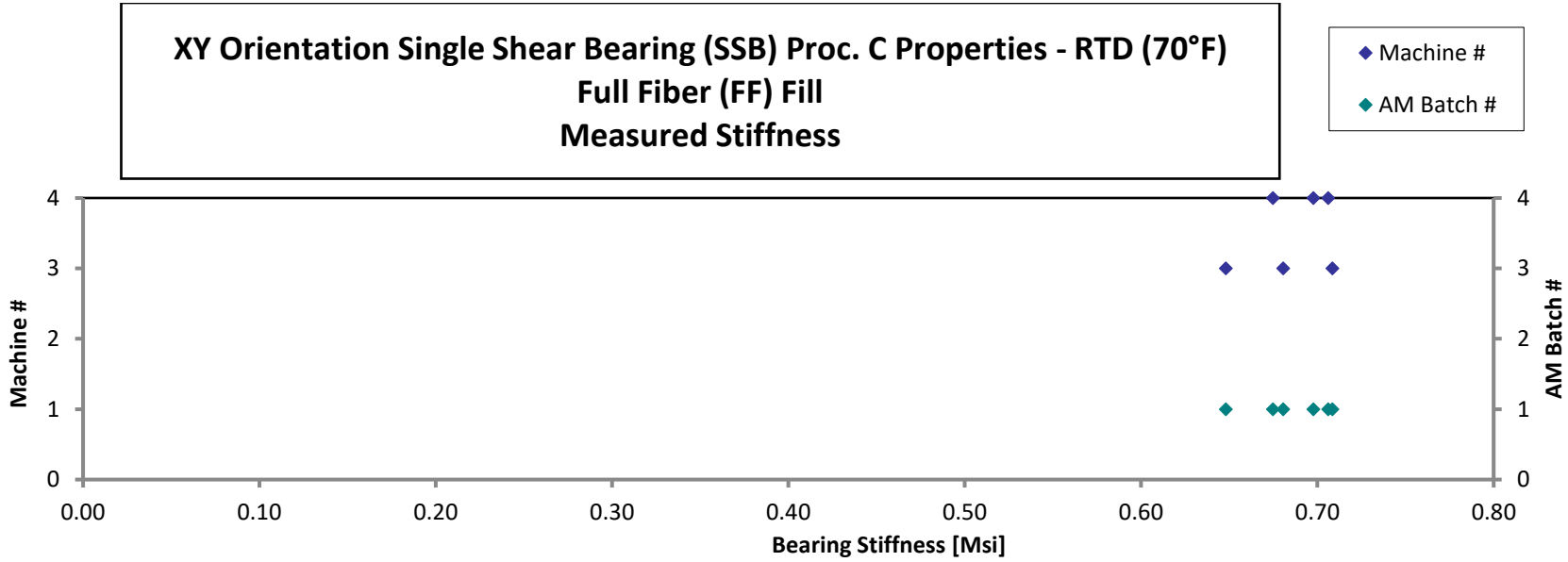
4.36.1 RTD Condition

XY Orientation Single Shear Bearing (SSB) Proc. C Properties - RTD (70°F)
Full Fiber (FF) Fill
Strength & Stiffness
Markforged Onyx FR-A™ - Carbon Fiber FR-A™ / Markforged X7

Specimen Number	AM Batch #	Machine #	Ultimate Bearing Strength [ksi]	2% Offset Bearing Strength [ksi]	Bearing Stiffness [Msi]	Avg. Specimen Thickness [in]	Failure Mode
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M3-P35945-XY-SSB-11-RTD-FF-1	1	3	47.22	44.86	0.648	0.146	B1B, B1I
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M3-P36089-XY-SSB-12-RTD-FF-2	1	3	62.35	53.44	0.709	0.144	B1B, B1I
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M3-P38445-XY-SSB-13-RTD-FF-3	1	3	56.50	49.72	0.681	0.144	B1B, B1I
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M4-P48396-XY-SSB-11-RTD-FF-1	1	4	61.35	52.15	0.698	0.143	B1B, B1I
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M4-P40905-XY-SSB-12-RTD-FF-2	1	4	61.87	52.08	0.706	0.144	B1B, B1I
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M4-P41915-XY-SSB-13-RTD-FF-3	1	4	58.69	49.81	0.675	0.143	B1B, B1I
		Average	**58.00**	**50.35**	**0.686**	**0.144**	
		Standard Dev.	**5.729**	**3.053**	**0.023**		
		Coeff. of Var. [%]	**9.877**	**6.064**	**3.357**		
		Min.	**47.22**	**44.86**	**0.648**	**0.143**	
		Max.	**62.35**	**53.44**	**0.709**	**0.146**	
		Number of Spec.	**6**	**6**	**6**	**6**	


XY Orientation Single Shear Bearing (SSB) Proc. C Properties - RTD (70°F)
Full Fiber (FF) Fill
Measured Strength
Markforged Onyx FR-A™ - Carbon Fiber FR-A™ / Markforged X7
Machine #
AM Batch #
Machine #
AM Batch #
0
1
2
3
4
0.0
10.0
20.0
30.0
40.0
50.0
60.0
70.0
Ultimate Bearing Strength [ksi]


XY Orientation Single Shear Bearing (SSB) Proc. C Properties - RTD (70°F)
Full Fiber (FF) Fill
Measured 2% Offset Strength
Markforged Onyx FR-A™ - Carbon Fiber FR-A™ / Markforged X7
Machine #
AM Batch #
Machine #
AM Batch #
0
1
2
3
4
0.00
10.00
20.00
30.00
40.00
50.00
60.00
2% Offset Bearing Strength [ksi]


XY Orientation Single Shear Bearing (SSB) Proc. C Properties - RTD (70°F)
Full Fiber (FF) Fill
Measured Stiffness
Machine #
AM Batch #
Machine #
AM Batch #
Bearing Stiffness [Msi]
0
1
2
3
4
0.00
0.10
0.20
0.30
0.40
0.50
0.60
0.70
0.80

4.37 XZ PF Single Shear Bearing Properties

4.37.1 CTD Condition

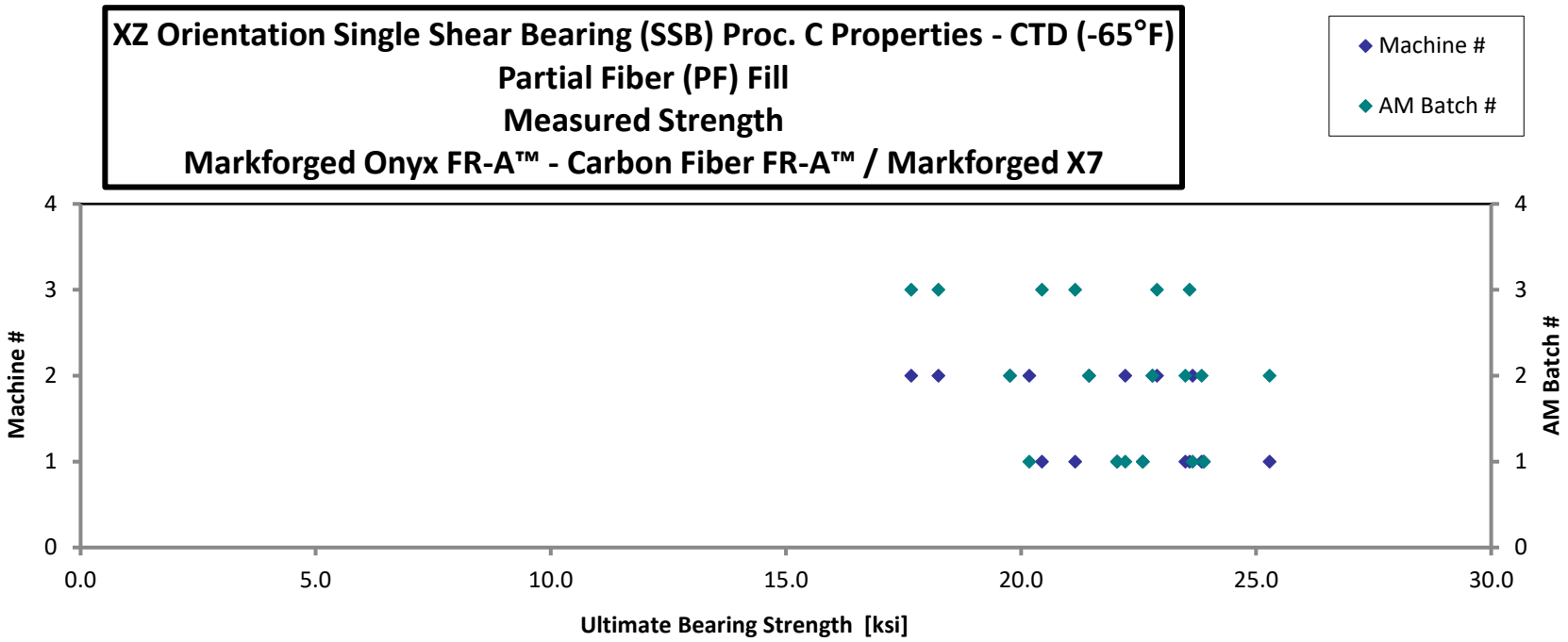
XZ Orientation Single Shear Bearing (SSB) Proc. C Properties - CTD (-65°F)
Partial Fiber (PF) Fill
Strength and Stiffness
Markforged Onyx FR-A™ - Carbon Fiber FR-A™ / Markforged X7

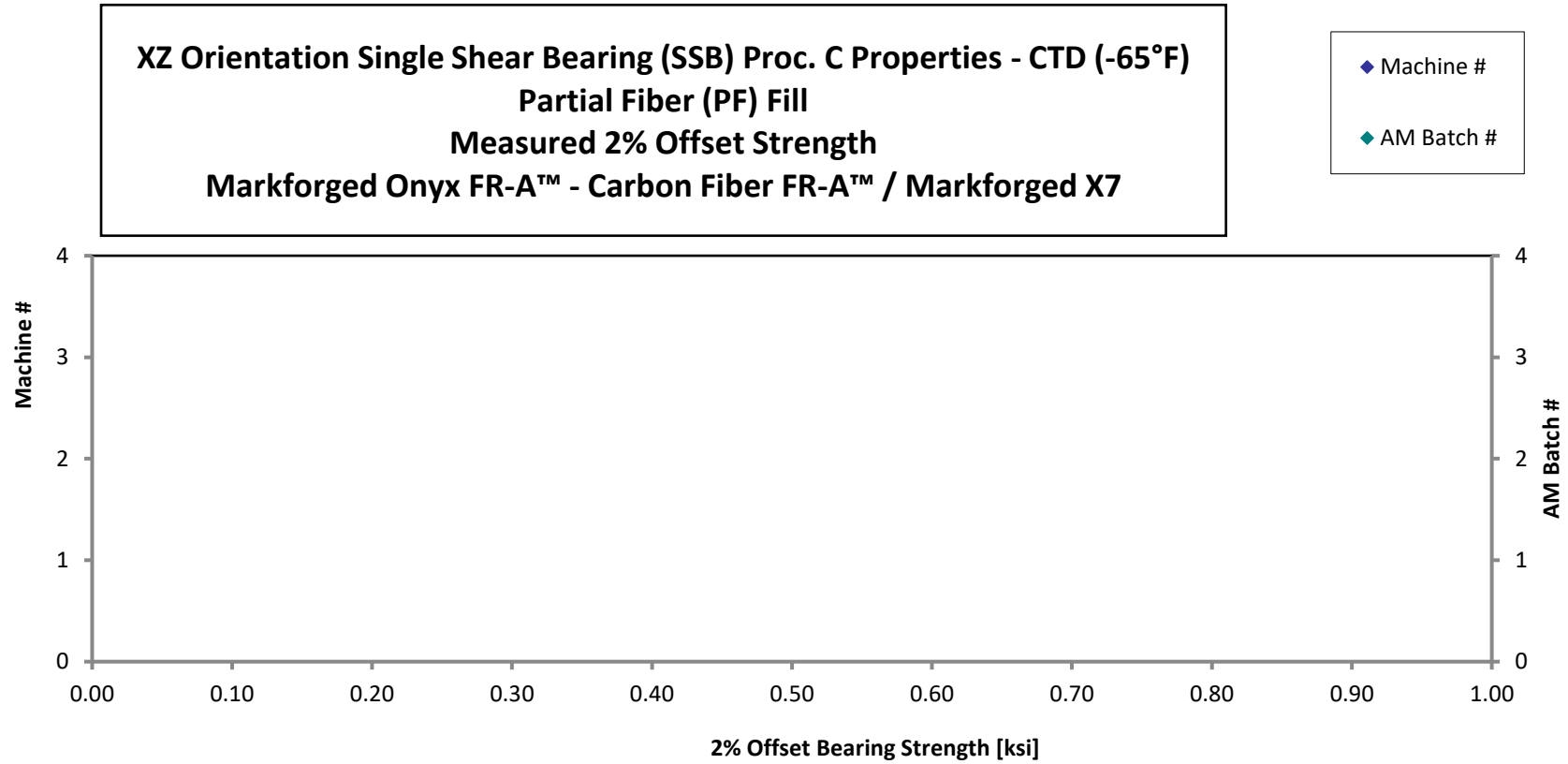
Specimen Number	AM Batch #	Machine #	Avg. Specimen Thickness [in]	Ultimate Bearing Strength [ksi]	2% Offset Bearing Strength [ksi]	Bearing Stiffness [Msi]	Failure Mode
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M1-P42694-XZ-SSB-11-CTD-PF-1	1	1	0.143	23.887		0.375	C1I
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M1-P42485-XZ-SSB-12-CTD-PF-2	1	1	0.143	22.591		0.373	C1I
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M1-P56545-XZ-SSB-13-CTD-PF-3	1	1	0.145	22.045		0.345	C1I
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M2-P46125-XZ-SSB-11-CTD-PF-1	1	2	0.141	22.221		0.322	C1I
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M2-P42570-XZ-SSB-12-CTD-PF-2	1	2	0.140	20.178		0.380	C1I
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M2-P46278-XZ-SSB-13-CTD-PF-3	1	2	0.140	23.649		0.346	C1I
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-B-M1-P41167-XZ-SSB-11-CTD-PF-1	2	1	0.142	25.287		0.433	C1I
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-B-M1-P40689-XZ-SSB-12-CTD-PF-2	2	1	0.141	23.840		0.299	C1I
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-B-M1-P41281-XZ-SSB-13-CTD-PF-3	2	1	0.140	23.499		0.298	C1I
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-B-M2-P46401-XZ-SSB-11-CTD-PF-1	2	2	0.141	19.762		0.323	C1I
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-B-M2-P41201-XZ-SSB-12-CTD-PF-2	2	2	0.140	22.794		0.331	C1I
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-B-M2-P39984-XZ-SSB-13-CTD-PF-3	2	2	0.141	21.449		0.482	C1I
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-C-M1-P48475-XZ-SSB-11-CTD-PF-1	3	1	0.144	20.444		0.356	C1I
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-C-M1-P46997-XZ-SSB-12-CTD-PF-2	3	1	0.142	23.585		0.356	C1I
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-C-M1-P56877-XZ-SSB-13-CTD-PF-3	3	1	0.142	21.153		0.340	C1I
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-C-M2-P50292-XZ-SSB-11-CTD-PF-1	3	2	0.141	22.892		0.387	C1I
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-C-M2-P47150-XZ-SSB-12-CTD-PF-2	3	2	0.141	18.245		0.343	C1I
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-C-M2-P50104-XZ-SSB-13-CTD-PF-3	3	2	0.140	17.664		0.364	C1I

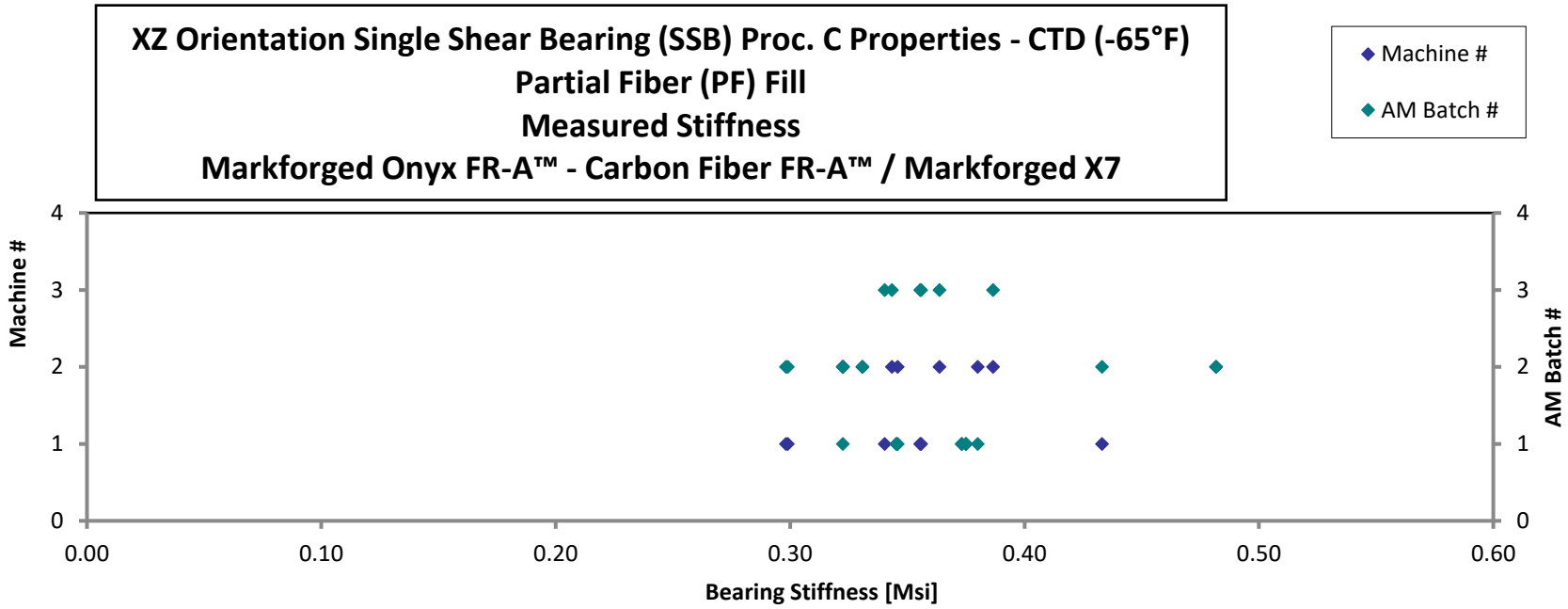
Note: Due to inherent material properties and print orientation, B-basis calculations will be calculated eventhough improper failure modes were present.

All specimens exhibited cleavage failure mode, which is due to XZ specimen print orientation. (Improper failure per ASTM D5961 Procedure C)
2% Offset strength not reported for all specimens due to the specimens reaching max load first.

Average	**0.141**	**21.955**	**0.358**
Standard Dev.		**2.054**	**0.045**
Coeff. of Var. [%]		**9.354**	**12.467**
Min.	**0.140**	**17.664**	**0.298**
Max.	**0.145**	**25.287**	**0.482**
Number of Spec.	**18**	**18**	**18**


XZ Orientation Single Shear Bearing (SSB) Proc. C Properties - CTD (-65°F)
Partial Fiber (PF) Fill
Measured Strength
Markforged Onyx FR-A™ - Carbon Fiber FR-A™ / Markforged X7
Machine #
AM Batch #
Machine #
AM Batch #
Ultimate Bearing Strength [ksi]
0
1
2
3
4
0.0
5.0
10.0
15.0
20.0
25.0
30.0


XZ Orientation Single Shear Bearing (SSB) Proc. C Properties - CTD (-65°F)
Partial Fiber (PF) Fill
Measured 2% Offset Strength
Markforged Onyx FR-A™ - Carbon Fiber FR-A™ / Markforged X7
Machine #
AM Batch #
Machine #
AM Batch #
0
1
2
3
4
0.00
0.10
0.20
0.30
0.40
0.50
0.60
0.70
0.80
0.90
1.00
2% Offset Bearing Strength [ksi]


XZ Orientation Single Shear Bearing (SSB) Proc. C Properties - CTD (-65°F)
Partial Fiber (PF) Fill
Measured Stiffness
Markforged Onyx FR-A™ - Carbon Fiber FR-A™ / Markforged X7
Machine #
AM Batch #
Machine #
AM Batch #
Bearing Stiffness [Msi]
0
1
2
3
4
0.00
0.10
0.20
0.30
0.40
0.50
0.60

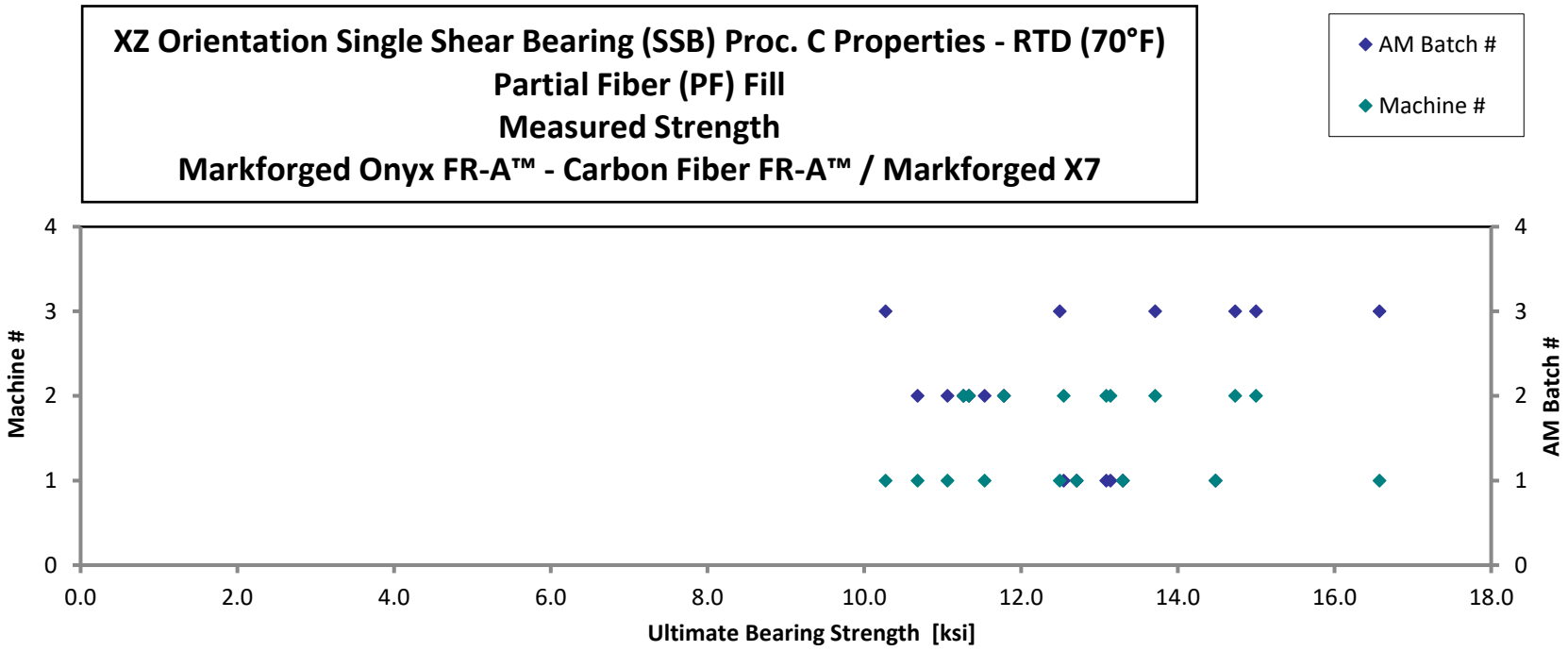
4.37.2 **RTD Condition**

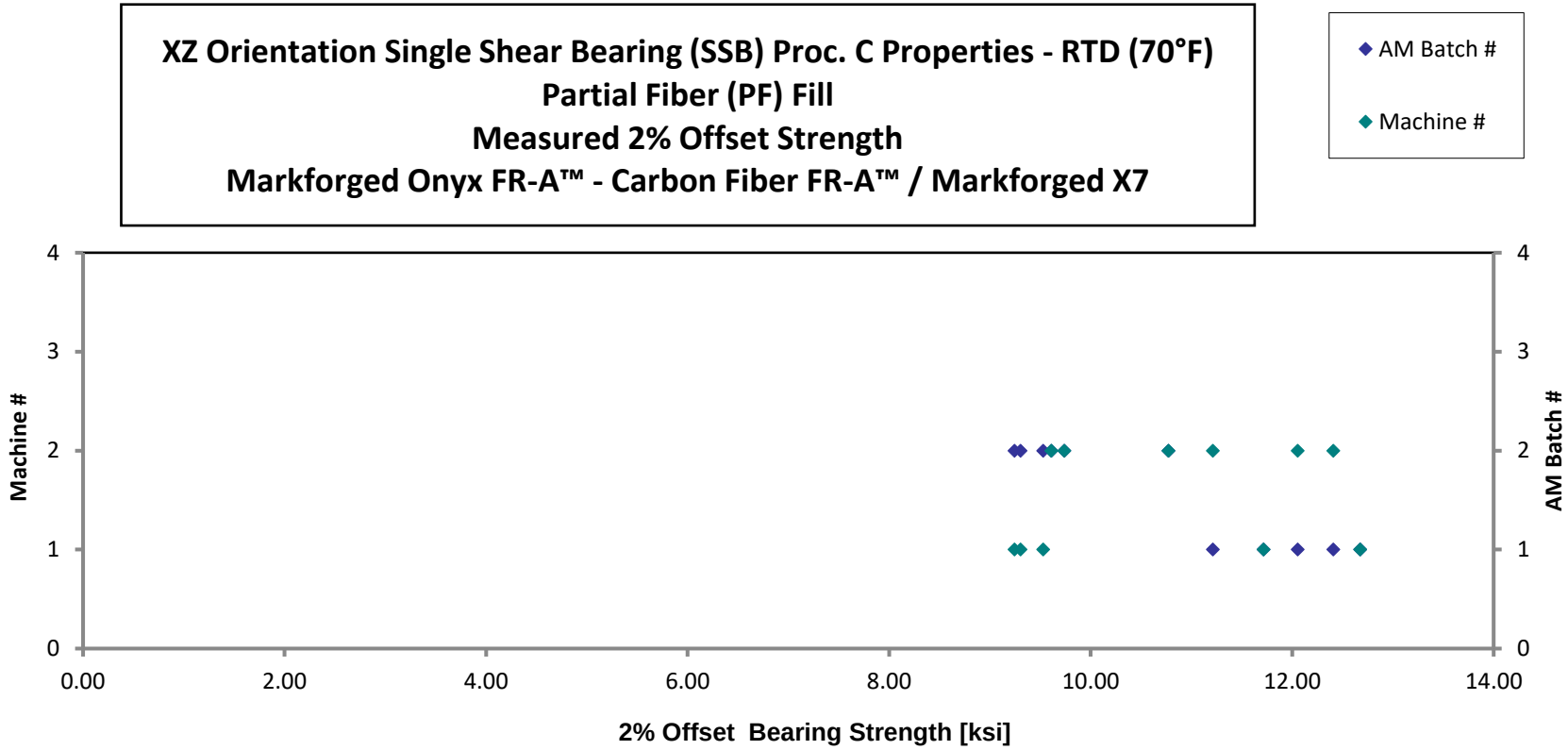
XZ Orientation Single Shear Bearing (SSB) Proc. C Properties - RTD (70°F)
Partial Fiber (PF) Fill
Strength & Stiffness
Markforged Onyx FR-A™ - Carbon Fiber FR-A™ / Markforged X7

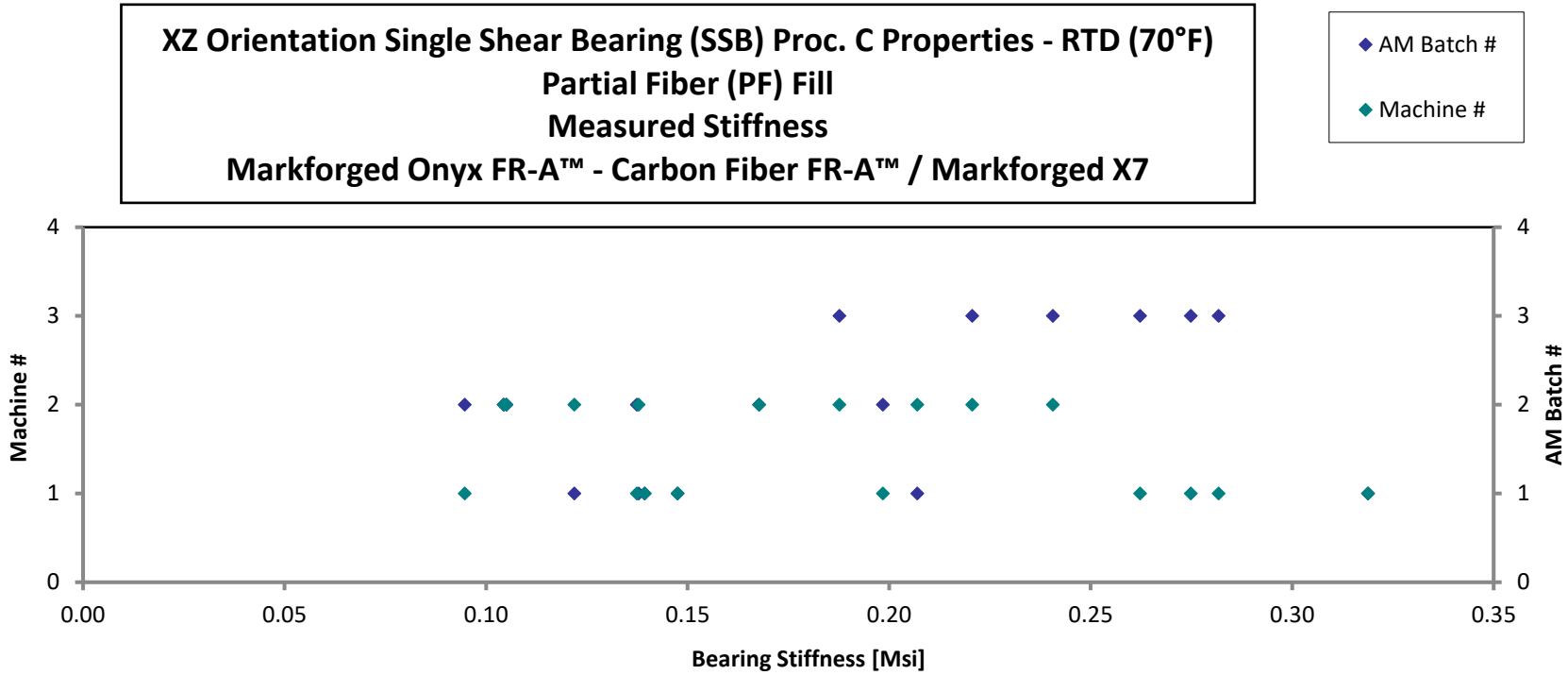
Specimen Number	AM Batch #	Machine #	Avg. Specimen Thickness [in]	Ultimate Bearing Strength [ksi]	2% Offset Bearing Strength [ksi]	Bearing Stiffness [Msi]	Failure Mode
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M1-P42485-XZ-SSB-11-RTD-PF-1*	1	1	0.142	14.48	11.72	0.319	C1I
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M1-P56545-XZ-SSB-12-RTD-PF-2*	1	1	0.141	12.71	12.67	0.147	C1I
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M1-P42694-XZ-SSB-13-RTD-PF-3*/**	1	1	0.140	13.30		0.139	C1I
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M2-P42570-XZ-SSB-11-RTD-PF-1*	1	2	0.143	12.54	12.41	0.122	C1I
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M2-P46278-XZ-SSB-12-RTD-PF-2*	1	2	0.139	13.09	11.21	0.207	C1I
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M2-P46125-XZ-SSB-13-RTD-PF-3*	1	2	0.140	13.14	12.05	0.138	C1I
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-B-M1-P40689-XZ-SSB-11-RTD-PF-1*	2	1	0.141	11.54	9.528	0.137	C1I
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-B-M1-P41281-XZ-SSB-12-RTD-PF-2*	2	1	0.140	10.68	9.246	0.095	C1I
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-B-M1-P41167-XZ-SSB-13-RTD-PF-3*	2	1	0.141	11.06	9.304	0.198	C1I
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-B-M2-P41201-XZ-SSB-11-RTD-PF-1*	2	2	0.141	11.78	10.77	0.104	C1I
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-B-M2-P39984-XZ-SSB-12-RTD-PF-2	2	2	0.140	11.27	9.739	0.168	S1I
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-B-M2-P46401-XZ-SSB-13-RTD-PF-3*	2	2	0.140	11.33	9.609	0.105	C1I
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-C-M1-P46997-XZ-SSB-11-RTD-PF-1*/**	3	1	0.143	10.27		0.275	C1I
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-C-M1-P56877-XZ-SSB-12-RTD-PF-2*/**	3	1	0.143	16.57		0.282	C1I
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-C-M1-P48475-XZ-SSB-13-RTD-PF-3*/**	3	1	0.143	12.49		0.262	C1I
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-C-M2-P47150-XZ-SSB-11-RTD-PF-1*/**	3	2	0.140	13.71		0.188	C1I
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-C-M2-P50104-XZ-SSB-12-RTD-PF-2*/**	3	2	0.139	14.73		0.241	C1I
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-C-M2-P50292-XZ-SSB-13-RTD-PF-3*/**	3	2	0.139	15.00		0.221	C1I

Note: Due to inherent material properties and print orientation, B-basis calculations will be calculated eventhough improper failure modes were present.
*Specimen exhibited cleavage failure mode, which is due to XZ specimen print orientation. (Improper failure per ASTM D5961 Procedure C)
**2% Offset strength not reported due to the specimen reaching max load first.

Average	**0.141**	**12.76**	**10.75**	**0.186**
Standard Dev.		**1.682**	**1.322**	**0.068**
Coeff. of Var. [%]		**13.18**	**12.29**	**36.80**
Min.	**0.139**	**10.27**	**9.246**	**0.095**
Max.	**0.143**	**16.57**	**12.67**	**0.319**
Number of Spec.	**18**	**18**	**11**	**18**


XZ Orientation Single Shear Bearing (SSB) Proc. C Properties - RTD (70°F)
Partial Fiber (PF) Fill
Measured Strength
Markforged Onyx FR-A™ - Carbon Fiber FR-A™ / Markforged X7
AM Batch #
Machine #
Machine #
AM Batch #
Ultimate Bearing Strength [ksi]
0
1
2
3
4
0.0
2.0
4.0
6.0
8.0
10.0
12.0
14.0
16.0
18.0


XZ Orientation Single Shear Bearing (SSB) Proc. C Properties - RTD (70°F)
Partial Fiber (PF) Fill
Measured 2% Offset Strength
Markforged Onyx FR-A™ - Carbon Fiber FR-A™ / Markforged X7
AM Batch #
Machine #
Machine #
AM Batch #
0
1
2
3
4
0.00
2.00
4.00
6.00
8.00
10.00
12.00
14.00
2% Offset Bearing Strength [ksi]


XZ Orientation Single Shear Bearing (SSB) Proc. C Properties - RTD (70°F)
Partial Fiber (PF) Fill
Measured Stiffness
Markforged Onyx FR-A™ - Carbon Fiber FR-A™ / Markforged X7
AM Batch #
Machine #
Machine #
AM Batch #
Bearing Stiffness [Msi]
0
1
2
3
4
0.00
0.05
0.10
0.15
0.20
0.25
0.30
0.35

4.37.3 **ETW Condition**

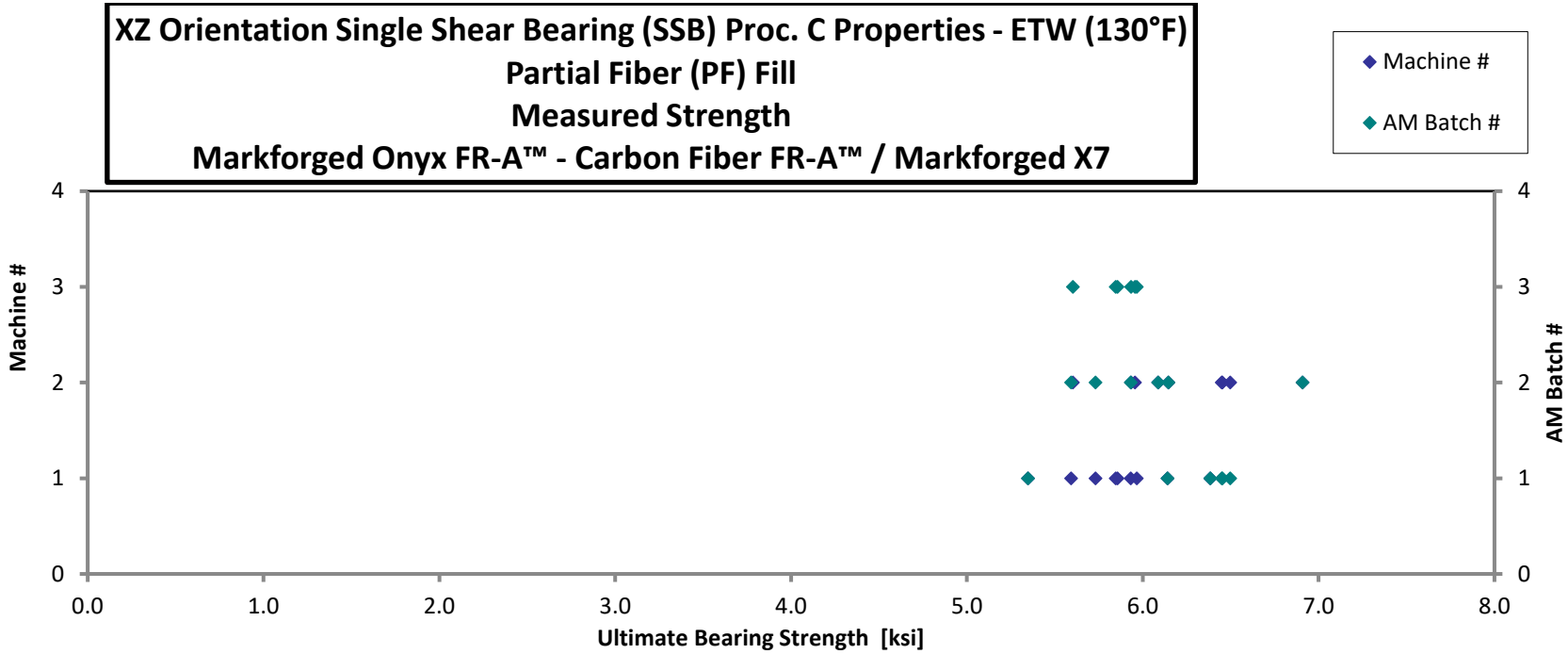
XZ Orientation Single Shear Bearing (SSB) Proc. C K6Properties - ETW (130°F)
Partial Fiber (PF) Fill
Strength & Stiffness
Markforged Onyx FR-A™ - Carbon Fiber FR-A™ / Markforged X7

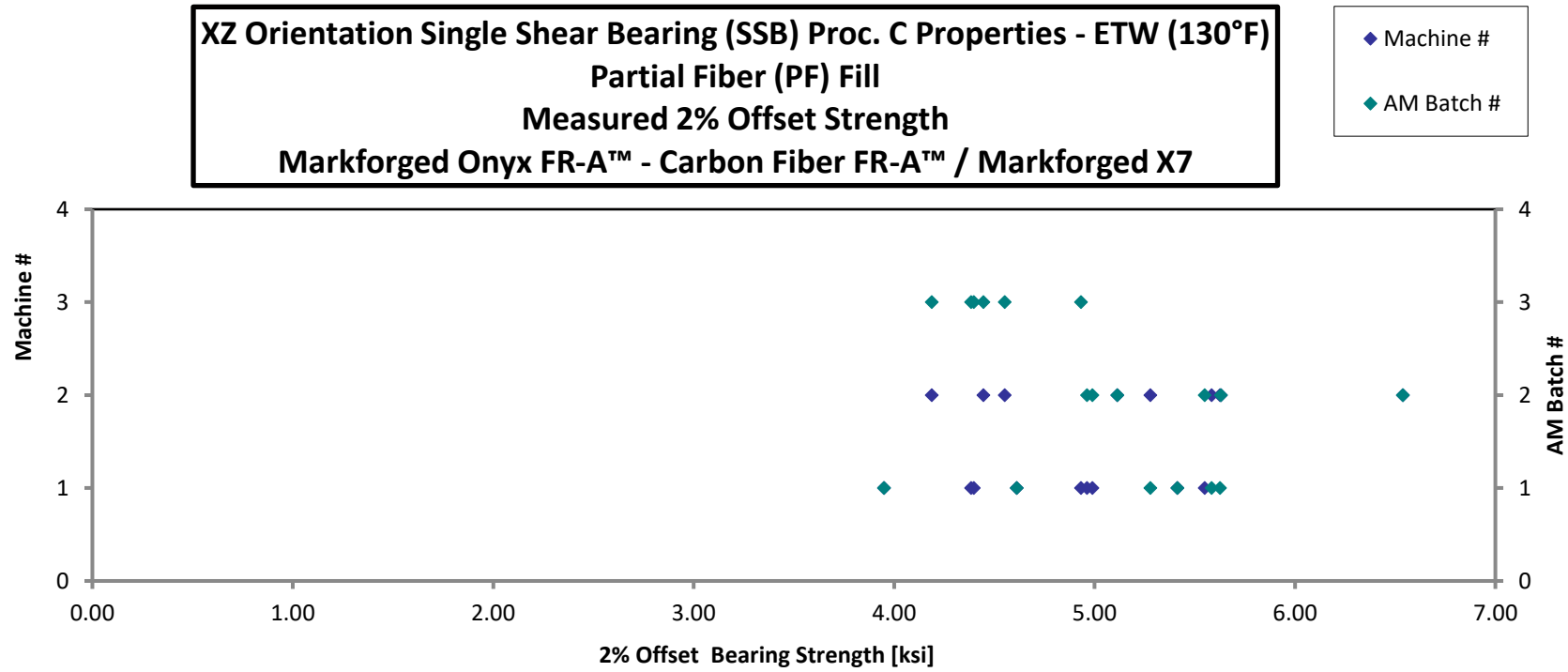
Specimen Number	AM Batch #	Machine #	Avg. Specimen Thickness [in]	Ultimate Bearing Strength [ksi]	2% Offset Bearing Strength [ksi]	Bearing Stiffness [Msi]	Failure Mode
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M1-P56545-XZ-SSB-X-ETW-PF-1	1	1	0.142	6.384	5.414	0.070	C1I
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M1-P42694-XZ-SSB-X-ETW-PF-2	1	1	0.141	6.142	4.612	0.065	C1I
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M1-P42485-XZ-SSB-X-ETW-PF-3	1	1	0.142	5.347	3.950	0.102	C1I
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M2-P46278-XZ-SSB-11-ETW-PF-1	1	2	0.140	6.497	5.626	0.051	M(B,C)1I
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M2-P46125-XZ-SSB-12-ETW-PF-2	1	2	0.139	6.449	5.279	0.051	M(B,C)1I
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M2-P42570-XZ-SSB-13-ETW-PF-3	1	2	0.140	6.452	5.584	0.034	M(B,C)1I
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-B-M1-P41281-XZ-SSB-11-ETW-PF-1	2	1	0.141	5.931	5.550	0.032	M(B,C)1I
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-B-M1-P41167-XZ-SSB-12-ETW-PF-2	2	1	0.140	5.731	4.989	0.035	M(B,C)1I
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-B-M1-P40689-XZ-SSB-13-ETW-PF-3	2	1	0.142	5.592	4.963	0.029	M(B,C)1I
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-B-M2-P39984-XZ-SSB-11-ETW-PF-1	2	2	0.141	6.908	6.538	0.039	M(B,C)1I
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-B-M2-P46401-XZ-SSB-12-ETW-PF-2	2	2	0.141	6.146	5.630	0.030	M(B,C)1I
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-B-M2-P41201-XZ-SSB-13-ETW-PF-3	2	2	0.140	6.088	5.114	0.066	M(B,C)1I
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-C-M1-P56877-XZ-SSB-11-ETW-PF-1	3	1	0.142	5.967	4.384	0.084	M(B,C)1I
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-C-M1-P48475-XZ-SSB-12-ETW-PF-2	3	1	0.142	5.846	4.932	0.096	M(B,C)1I
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-C-M1-P46997-XZ-SSB-13-ETW-PF-3	3	1	0.143	5.857	4.397	0.097	M(B,C)1I
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-C-M2-P50104-XZ-SSB-11-ETW-PF-1	3	2	0.141	5.956	4.188	0.085	M(B,C)1I
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-C-M2-P50292-XZ-SSB-12-ETW-PF-2	3	2	0.140	5.933	4.552	0.080	M(B,C)1I
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-C-M2-P47150-XZ-SSB-13-ETW-PF-3	3	2	0.140	5.602	4.446	0.064	M(B,C)1I

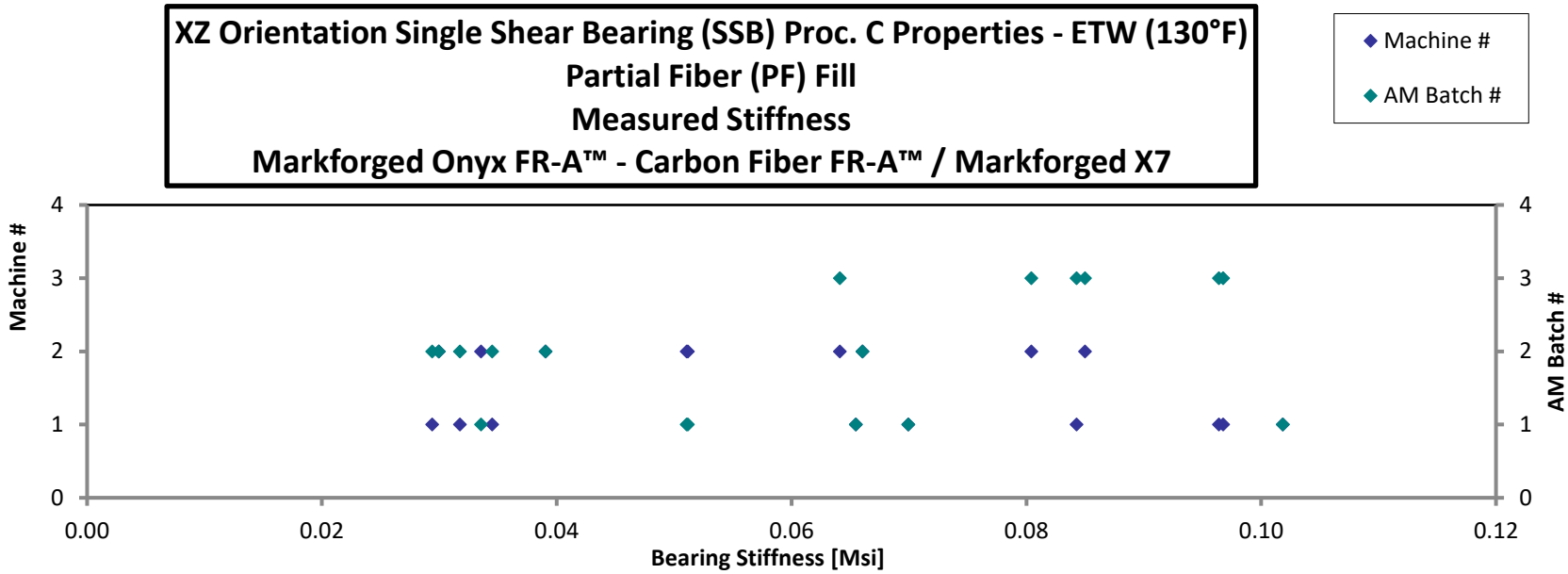
Note: Due to inherent material properties and print orientation, B-basis calculations will be calculated eventhough improper failure modes were present.

All specimens exhibited cleavage failure mode, which is due to XZ specimen print orientation. (Improper failure per ASTM D5961 Procedure C)

Average	**0.141**	**6.046**	**5.008**	**0.062**
Standard Dev.		**0.385**	**0.652**	**0.025**
Coeff. of Var. [%]		**6.362**	**13.02**	**40.79**
Min.	**0.139**	**5.347**	**3.950**	**0.029**
Max.	**0.143**	**6.908**	**6.538**	**0.102**
Number of Spec.	**18**	**18**	**18**	**18**


XZ Orientation Single Shear Bearing (SSB) Proc. C Properties - ETW (130°F)
Partial Fiber (PF) Fill
Measured Strength
Markforged Onyx FR-A™ - Carbon Fiber FR-A™ / Markforged X7
Machine #
AM Batch #
Machine #
AM Batch #
0
1
2
3
4
0.0
1.0
2.0
3.0
4.0
5.0
6.0
7.0
8.0
Ultimate Bearing Strength [ksi]


XZ Orientation Single Shear Bearing (SSB) Proc. C Properties - ETW (130°F)
Partial Fiber (PF) Fill
Measured 2% Offset Strength
Markforged Onyx FR-A™ - Carbon Fiber FR-A™ / Markforged X7
Machine #
AM Batch #
Machine #
AM Batch #
0
1
2
3
4
0.00
1.00
2.00
3.00
4.00
5.00
6.00
7.00
2% Offset Bearing Strength [ksi]


XZ Orientation Single Shear Bearing (SSB) Proc. C Properties - ETW (130°F)
Partial Fiber (PF) Fill
Measured Stiffness
Markforged Onyx FR-A™ - Carbon Fiber FR-A™ / Markforged X7
Machine #
AM Batch #
Machine #
AM Batch #
0
1
2
3
4
0.00
0.02
0.04
0.06
0.08
0.10
0.12
Bearing Stiffness [Msi]

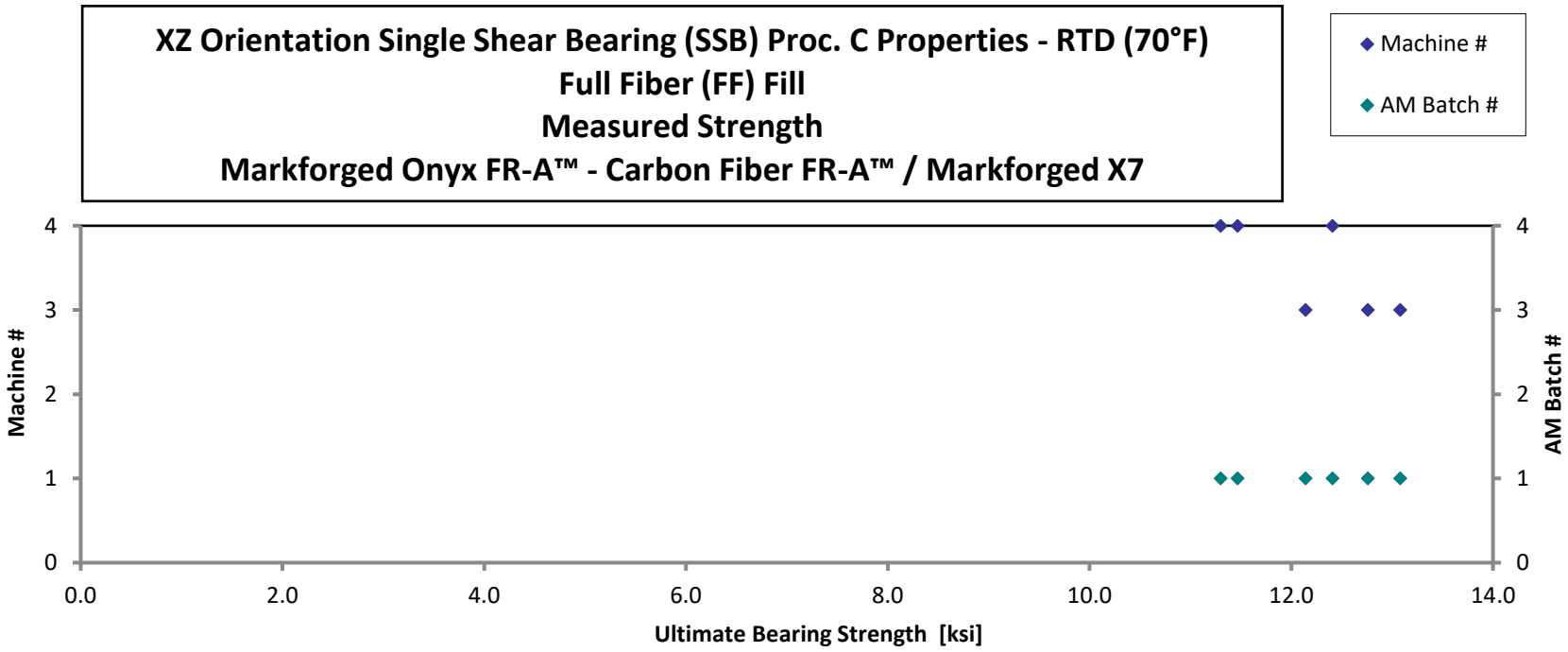
4.38 XZ FF Single Shear Bearing Properties

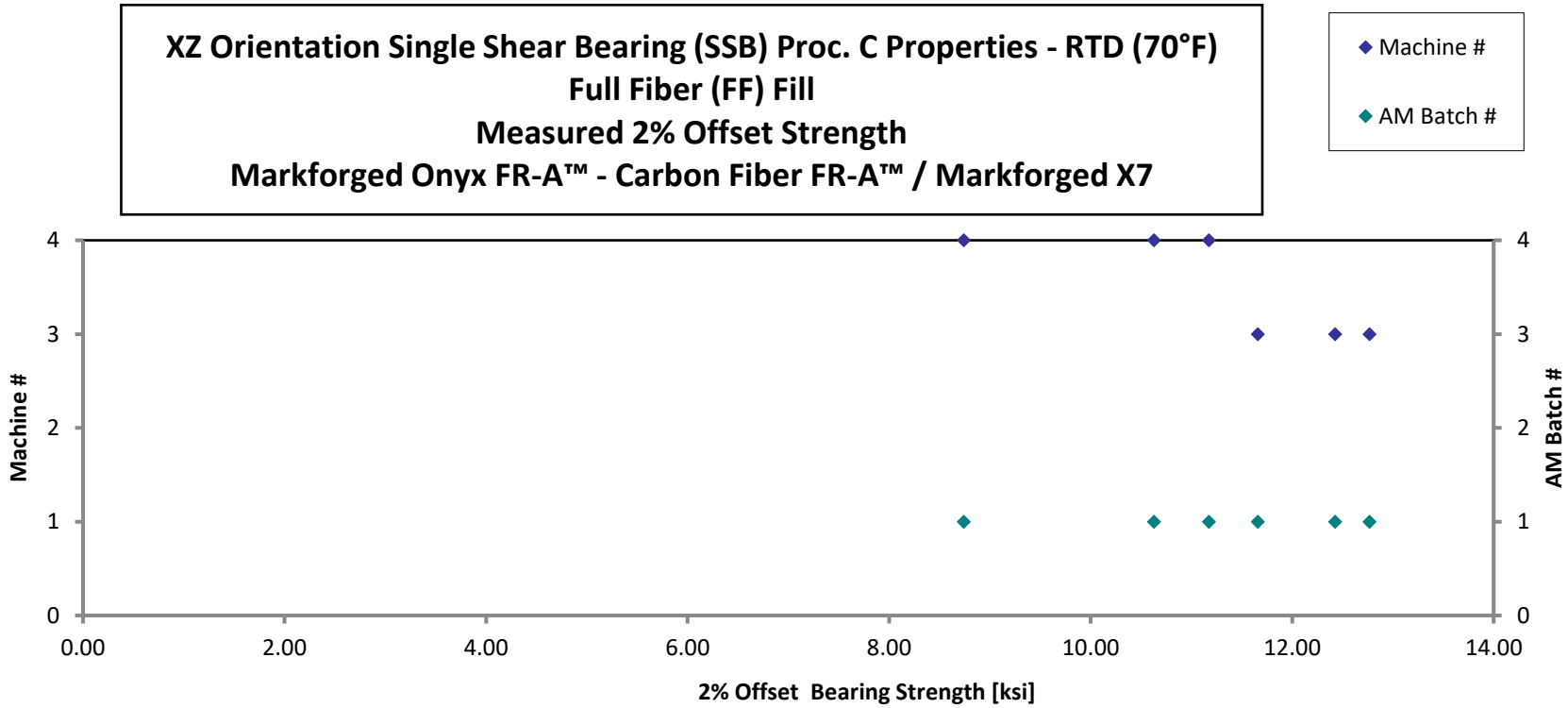
4.38.1 RTD Condition

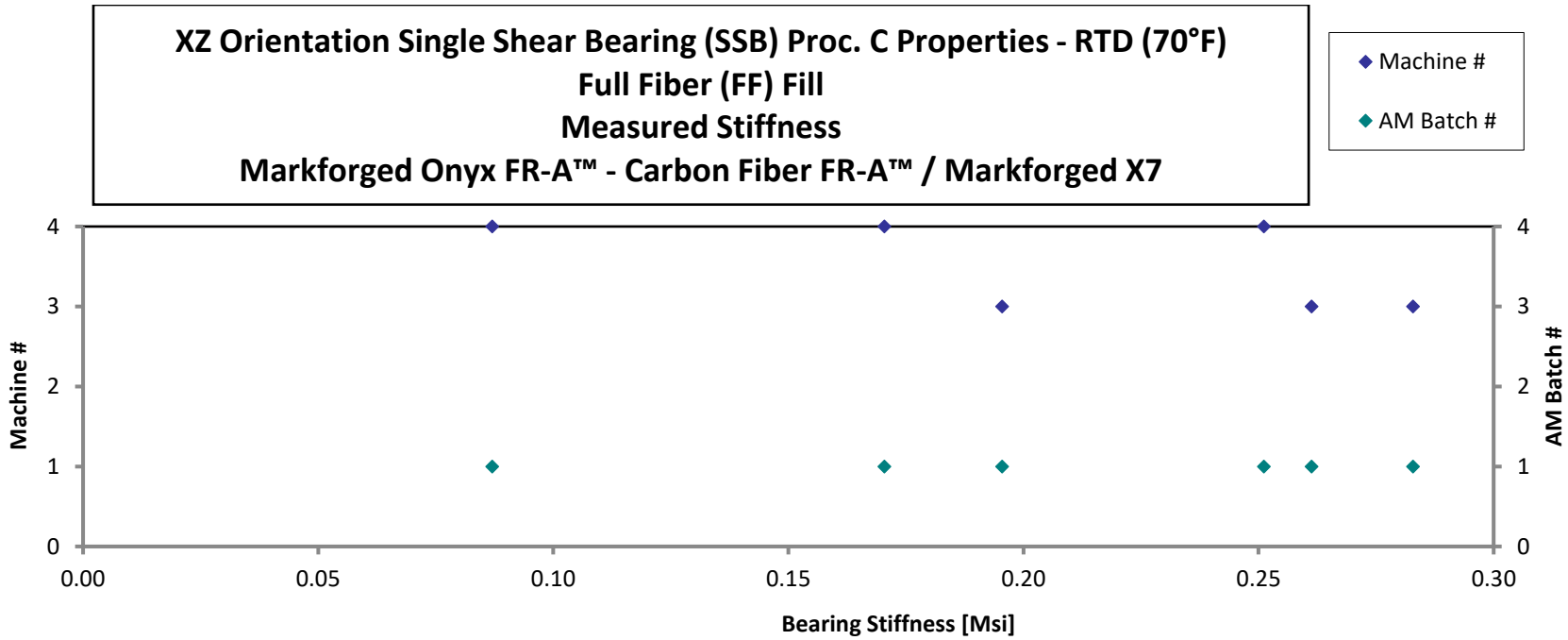
XZ Orientation Single Shear Bearing (SSB) Proc. C Properties - RTD (70°F)
Full Fiber (FF) Fill
Strength & Stiffness
Markforged Onyx FR-A™ - Carbon Fiber FR-A™ / Markforged X7

Specimen Number	AM Batch #	Machine #	Ultimate Bearing Strength [ksi]	2% Offset Bearing Strength [ksi]	Bearing Stiffness [Msi]	Avg. Specimen Thickness [in]	Failure Mode
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M3-P35945-XZ-SSB-11-RTD-FF-1*	1	3	12.14	11.66	0.195	0.143	C1I
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M3-P36089-XZ-SSB-12-RTD-FF-2**	1	3	13.08	12.77	0.261	0.142	S1I
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M3-P39193-XZ-SSB-13-RTD-FF-3*	1	3	12.76	12.43	0.283	0.141	C1I
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M4-P48396-XZ-SSB-11-RTD-FF-1**	1	4	11.47	8.740	0.087	0.142	S1I
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M4-P40905-XZ-SSB-12-RTD-FF-2**	1	4	12.41	10.63	0.170	0.141	S1I
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M4-P41915-XZ-SSB-13-RTD-FF-SP**	1	4	11.30	11.17	0.251	0.141	S1I
		Average	**12.19**	**11.23**	**0.208**	**0.142**	
		Standard Dev.	**0.705**	**1.452**	**0.073**		
		Coeff. of Var. [%]	**5.779**	**12.93**	**35.00**		
		Min.	**11.30**	**8.740**	**0.087**	**0.141**	
		Max.	**13.08**	**12.77**	**0.283**	**0.143**	
		Number of Spec.	**6**	**6**	**6**	**6**	

*Specimen exhibited cleavage failure mode, which is due to ZX specimen print orientation. Strength reported for reference only.
**Specimen exhibited shear out failure mode, which is due to ZX specimen print orientation. Strength reported for reference only.


XZ Orientation Single Shear Bearing (SSB) Proc. C Properties - RTD (70°F)
Full Fiber (FF) Fill
Measured Strength
Markforged Onyx FR-A™ - Carbon Fiber FR-A™ / Markforged X7
Machine #
AM Batch #
Machine #
AM Batch #
Ultimate Bearing Strength [ksi]
0
1
2
3
4
0.0
2.0
4.0
6.0
8.0
10.0
12.0
14.0


XZ Orientation Single Shear Bearing (SSB) Proc. C Properties - RTD (70°F)
Full Fiber (FF) Fill
Measured 2% Offset Strength
Markforged Onyx FR-A™ - Carbon Fiber FR-A™ / Markforged X7
Machine #
AM Batch #
Machine #
AM Batch #
0
1
2
3
4
0.00
2.00
4.00
6.00
8.00
10.00
12.00
14.00
2% Offset Bearing Strength [ksi]


XZ Orientation Single Shear Bearing (SSB) Proc. C Properties - RTD (70°F)
Full Fiber (FF) Fill
Measured Stiffness
Markforged Onyx FR-A™ - Carbon Fiber FR-A™ / Markforged X7
Machine #
AM Batch #
Machine #
AM Batch #
Bearing Stiffness [Msi]
0
1
2
3
4
0.00
0.05
0.10
0.15
0.20
0.25
0.30

4.39 ZX PF Single Shear Bearing Properties – Reference Only

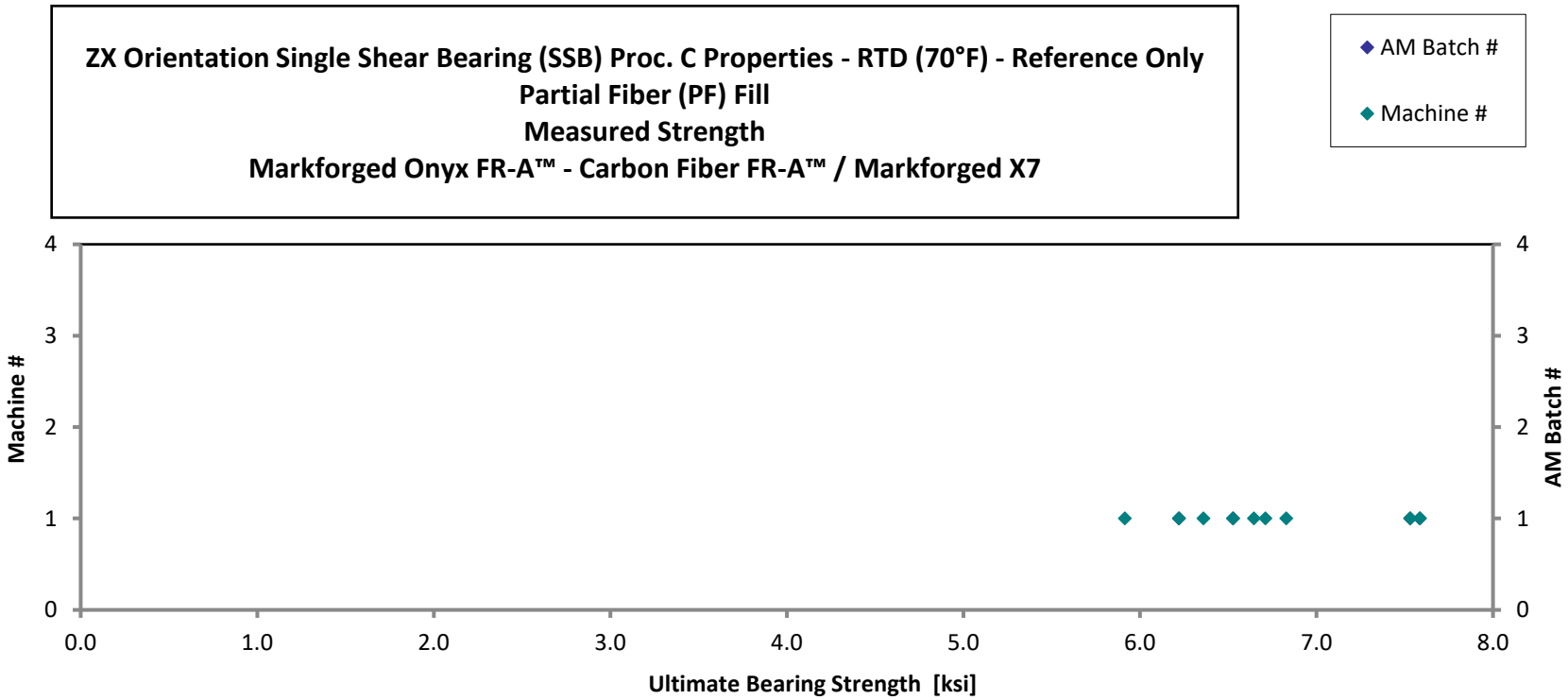
4.39.1 RTD Condition

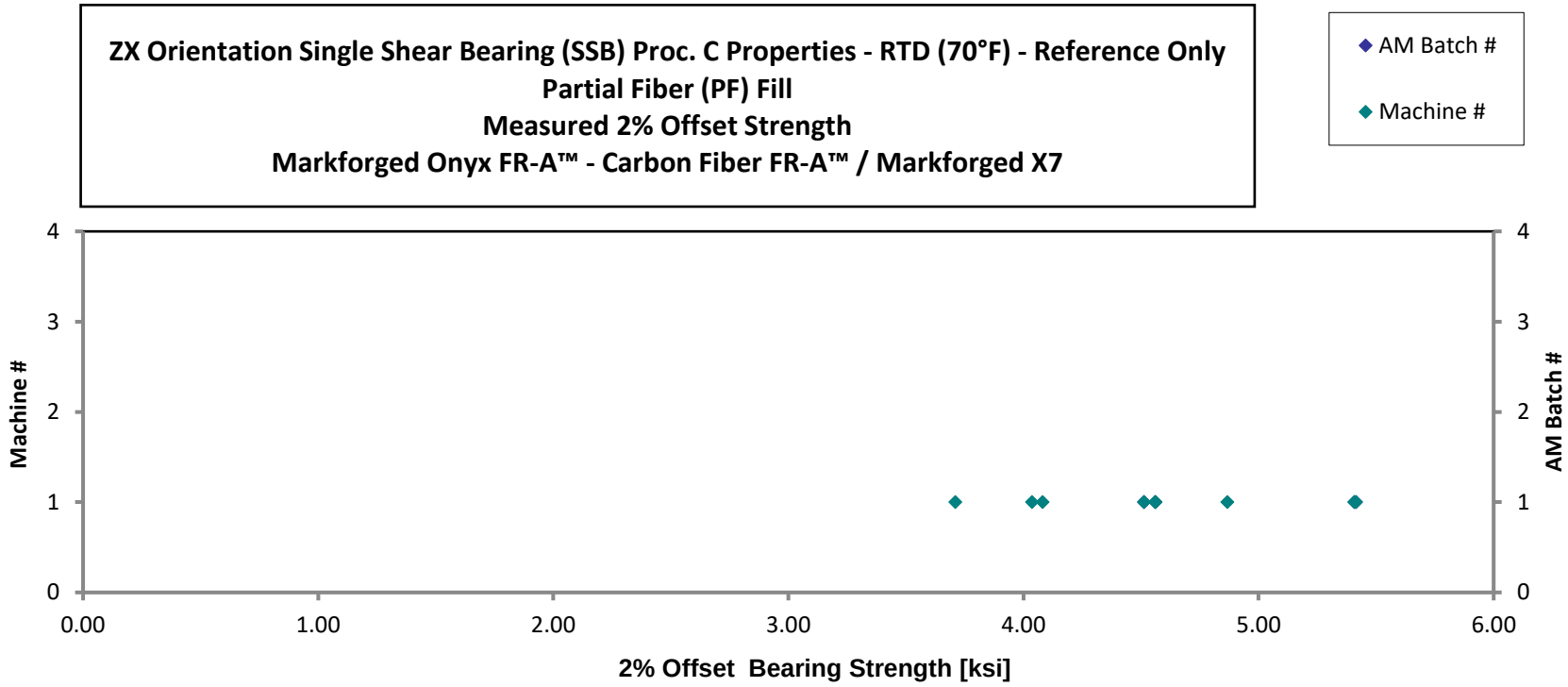
ZX Orientation Single Shear Bearing (SSB) Proc. C Properties - RTD (70°F) - Reference Only
Partial Fiber (PF) Fill
Strength & Stiffness
Markforged Onyx FR-A™ - Carbon Fiber FR-A™ / Markforged X7

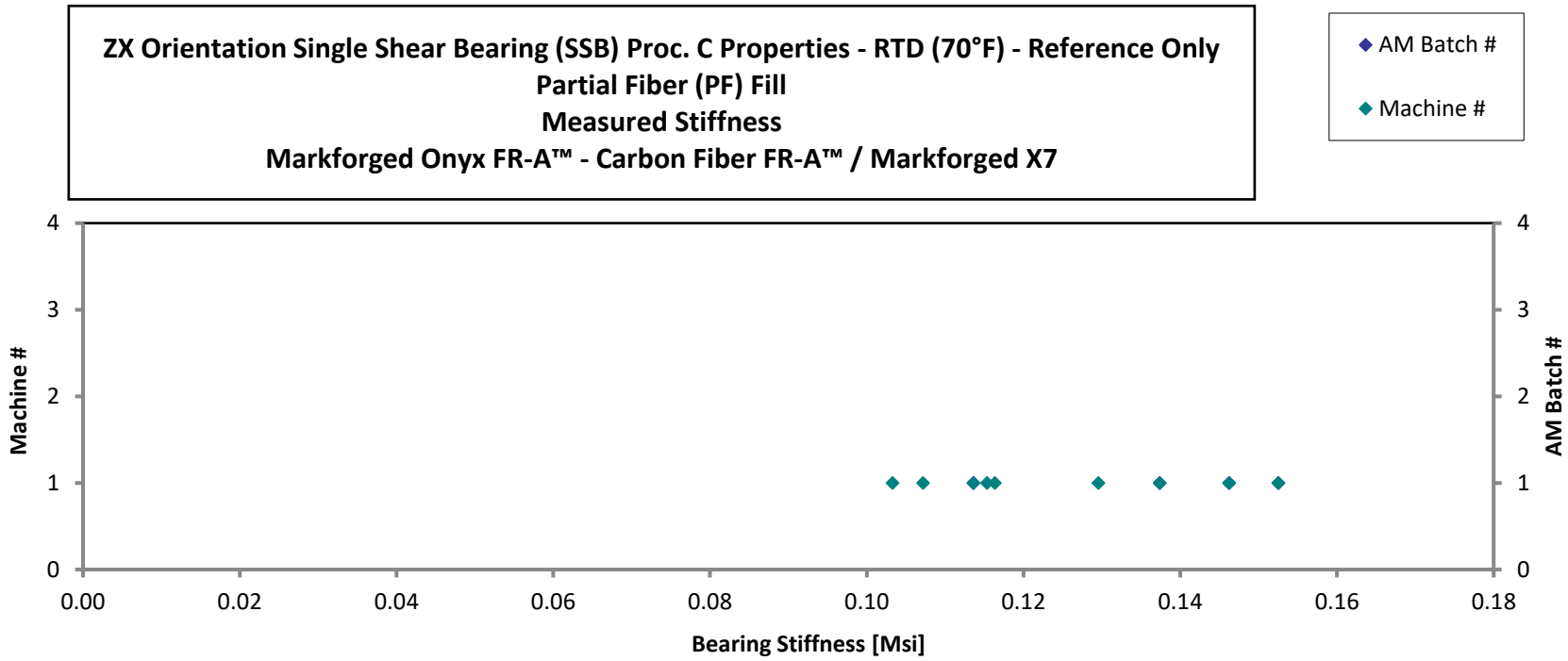
Specimen Number	AM Batch #	Machine #	Avg. Specimen Thickness [in]	Ultimate Bearing Strength [ksi]	2% Offset Bearing Strength [ksi]	Bearing Stiffness [Msi]	Failure Mode
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M1-P43092-ZX-SSB-11-RTD-PF-1	1	1	0.141	7.587	4.562	0.153	L1I
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M1-P43092-ZX-SSB-11-RTD-PF-2	1	1	0.137	7.531	4.512	0.146	L1I
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M1-P43092-ZX-SSB-11-RTD-PF-3	1	1	0.138	6.527	5.408	0.114	LAMINATE NET TENSILE FAILURE
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M1-P42342-ZX-SSB-12-RTD-PF-1	1	1	0.138	6.221	5.414	0.137	LAMINATE NET TENSILE FAILURE
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M1-P42342-ZX-SSB-12-RTD-PF-2	1	1	0.141	6.646	4.867	0.115	LAMINATE NET TENSILE FAILURE
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M1-P42342-ZX-SSB-12-RTD-PF-3	1	1	0.141	6.829	4.560	0.130	LAMINATE NET TENSILE FAILURE
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M1-P44320-ZX-SSB-13-RTD-PF-1	1	1	0.140	6.360	4.081	0.107	LAMINATE NET TENSILE FAILURE
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M1-P44320-ZX-SSB-13-RTD-PF-2	1	1	0.137	5.914	4.036	0.116	LAMINATE NET TENSILE FAILURE
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M1-P44320-ZX-SSB-13-RTD-PF-3	1	1	0.137	6.712	3.710	0.103	LAMINATE NET TENSILE FAILURE

All specimens exhibited laminate (lateral) net tensile failure mode, which is due to ZX specimen print orientation. Strength reported for reference only.

Average	**0.139**	**6.703**	**4.572**	**0.125**
Standard Dev.		**0.558**	**0.588**	**0.018**
Coeff. of Var. [%]		**8.320**	**12.87**	**14.09**
Min.	**0.137**	**5.914**	**3.710**	**0.103**
Max.	**0.141**	**7.587**	**5.414**	**0.153**
Number of Spec.	**9**	**9**	**9**	**9**


ZX Orientation Single Shear Bearing (SSB) Proc. C Properties - RTD (70°F) - Reference Only
Partial Fiber (PF) Fill
Measured Strength
Markforged Onyx FR-A™ - Carbon Fiber FR-A™ / Markforged X7
AM Batch #
Machine #
Machine #
AM Batch #
Ultimate Bearing Strength [ksi]
0
1
2
3
4
0.0
1.0
2.0
3.0
4.0
5.0
6.0
7.0
8.0


ZX Orientation Single Shear Bearing (SSB) Proc. C Properties - RTD (70°F) - Reference Only
Partial Fiber (PF) Fill
Measured 2% Offset Strength
Markforged Onyx FR-A™ - Carbon Fiber FR-A™ / Markforged X7
AM Batch #
Machine #
Machine #
AM Batch #
0
1
2
3
4
0.00
1.00
2.00
3.00
4.00
5.00
6.00
2% Offset Bearing Strength [ksi]


ZX Orientation Single Shear Bearing (SSB) Proc. C Properties - RTD (70°F) - Reference Only
Partial Fiber (PF) Fill
Measured Stiffness
Markforged Onyx FR-A™ - Carbon Fiber FR-A™ / Markforged X7
AM Batch #
Machine #
Machine #
AM Batch #
Bearing Stiffness [Msi]
0
1
2
3
4
0.00
0.02
0.04
0.06
0.08
0.10
0.12
0.14
0.16
0.18

4.40 ZX NF Single Shear Bearing Properties

4.40.1 CTD Condition

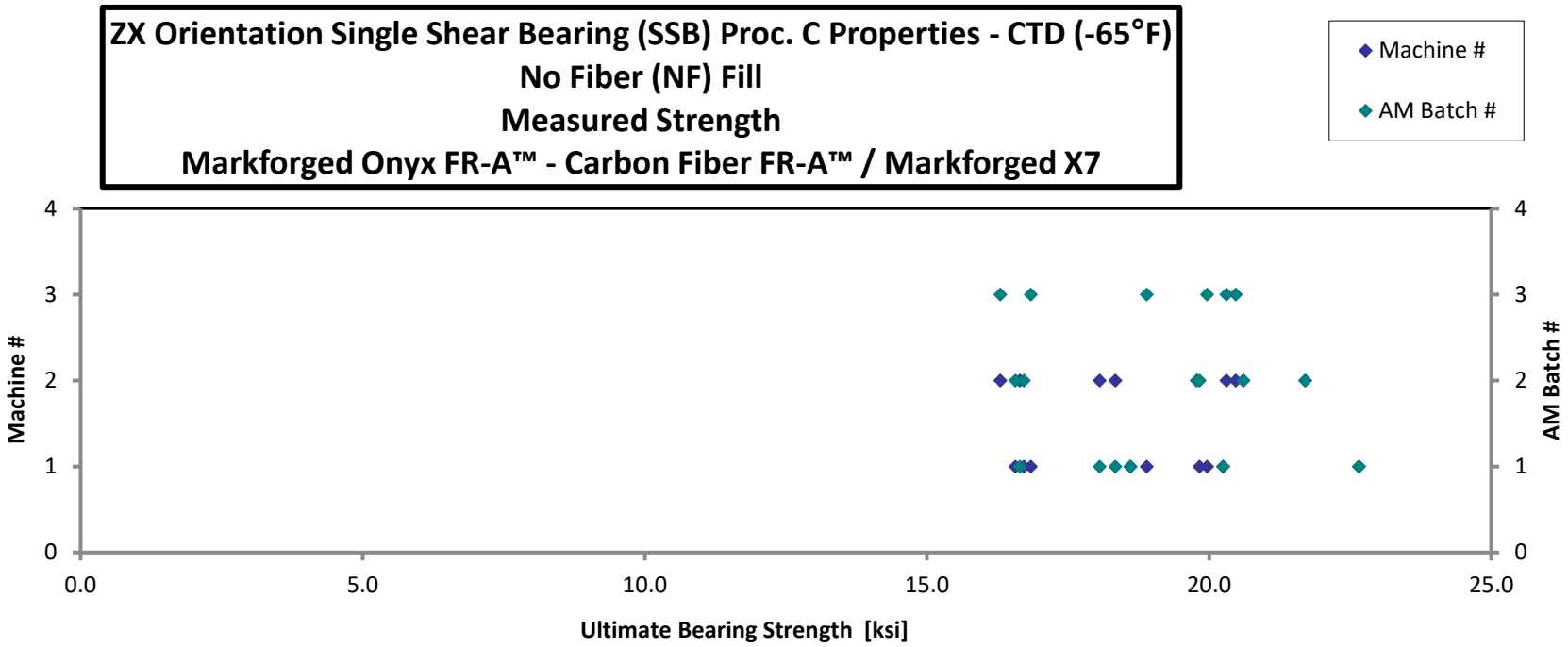
ZX Orientation Single Shear Bearing (SSB) Proc. C Properties - CTD (-65°F)
No Fiber (NF) Fill
Strength & Stiffness
Markforged Onyx FR-A™ - Carbon Fiber FR-A™ / Markforged X7

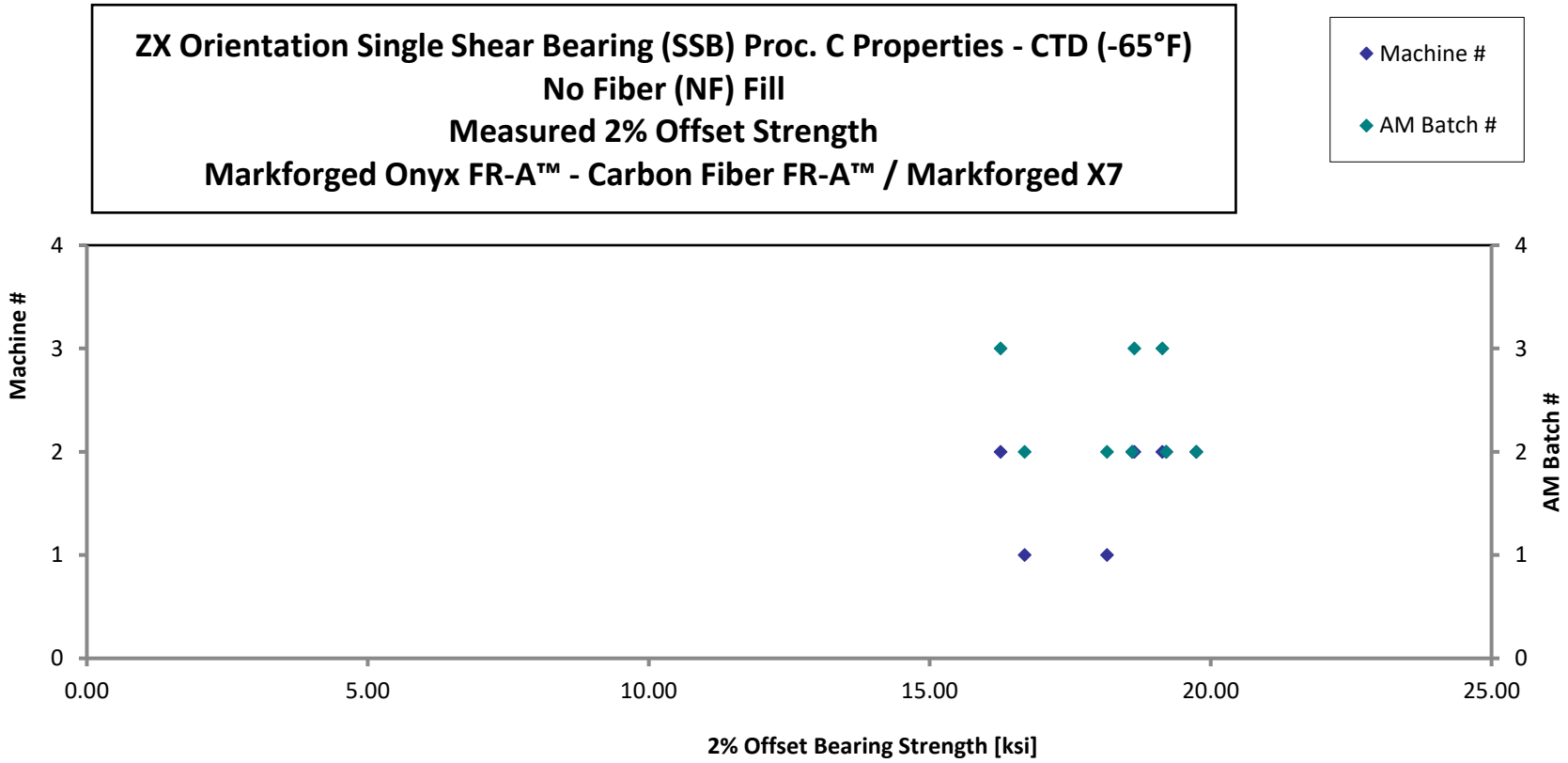
Specimen Number	AM Batch #	Machine #	Avg. Specimen Thickness [in]	Ultimate Bearing Strength [ksi]	2% Offset Bearing Strength [ksi]	Bearing Stiffness [Msi]	Failure Mode
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M1-P61817-ZX-SSB-11-CTD-NF-1*	1	1	0.148	20.25		0.187	L1I
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M1-P61132-ZX-SSB-12-CTD-NF-2*	1	1	0.148	18.61		0.198	L1I
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M1-P61751-ZX-SSB-13-CTD-NF-3*	1	1	0.146	22.65		0.214	L1I
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M2-P61818-ZX-SSB-11-CTD-NF-1*	1	2	0.148	18.34		0.196	L1I
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M2-P60434-ZX-SSB-12-CTD-NF-2*	1	2	0.145	16.65		0.198	L1I
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M2-P61255-ZX-SSB-13-CTD-NF-3*	1	2	0.144	18.06		0.192	L1I
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-B-M1-P63018-ZX-SSB-11-CTD-NF-1*	2	1	0.147	16.57		0.216	L1I
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-B-M1-P62411-ZX-SSB-12-CTD-NF-2	2	1	0.144	19.83	18.15	0.245	L1I
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-B-M1-P66639-ZX-SSB-13-CTD-NF-3	2	1	0.146	16.72	16.69	0.255	L1I
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-B-M2-P63506-ZX-SSB-11-CTD-NF-1	2	2	0.148	20.61	19.21	0.275	L1I
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-B-M2-P62412-ZX-SSB-12-CTD-NF-2	2	2	0.144	21.71	19.74	0.258	L1I
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-B-M2-P63352-ZX-SSB-13-CTD-NF-3	2	2	0.143	19.78	18.61	0.251	L1I
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-C-M1-P65365-ZX-SSB-11-CTD-NF-1*	3	1	0.146	18.90		0.188	L1I
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-C-M1-P64600-ZX-SSB-12-CTD-NF-2*	3	1	0.146	19.96		0.194	L1I
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-C-M1-P64991-ZX-SSB-13-CTD-NF-3*	3	1	0.144	16.84		0.181	L1I
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-C-M2-P65831-ZX-SSB-11-CTD-NF-1	3	2	0.148	20.31	18.64	0.291	L1I
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-C-M2-P65281-ZX-SSB-12-CTD-NF-2	3	2	0.144	20.48	19.14	0.247	L1I
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-C-M2-P65426-ZX-SSB-13-CTD-NF-3	3	2	0.144	16.30	16.26	0.279	L1I
		Average	**0.146**	**19.03**	**18.31**	**0.226**	
		Standard Dev.		**1.895**	**1.230**	**0.036**	
		Coeff. of Var. [%]		**9.955**	**6.721**	**16.13**	
		Min.	**0.143**	**16.30**	**16.26**	**0.181**	
		Max.	**0.148**	**22.65**	**19.74**	**0.291**	
		Number of Spec.	**18**	**18**	**8**	**18**	

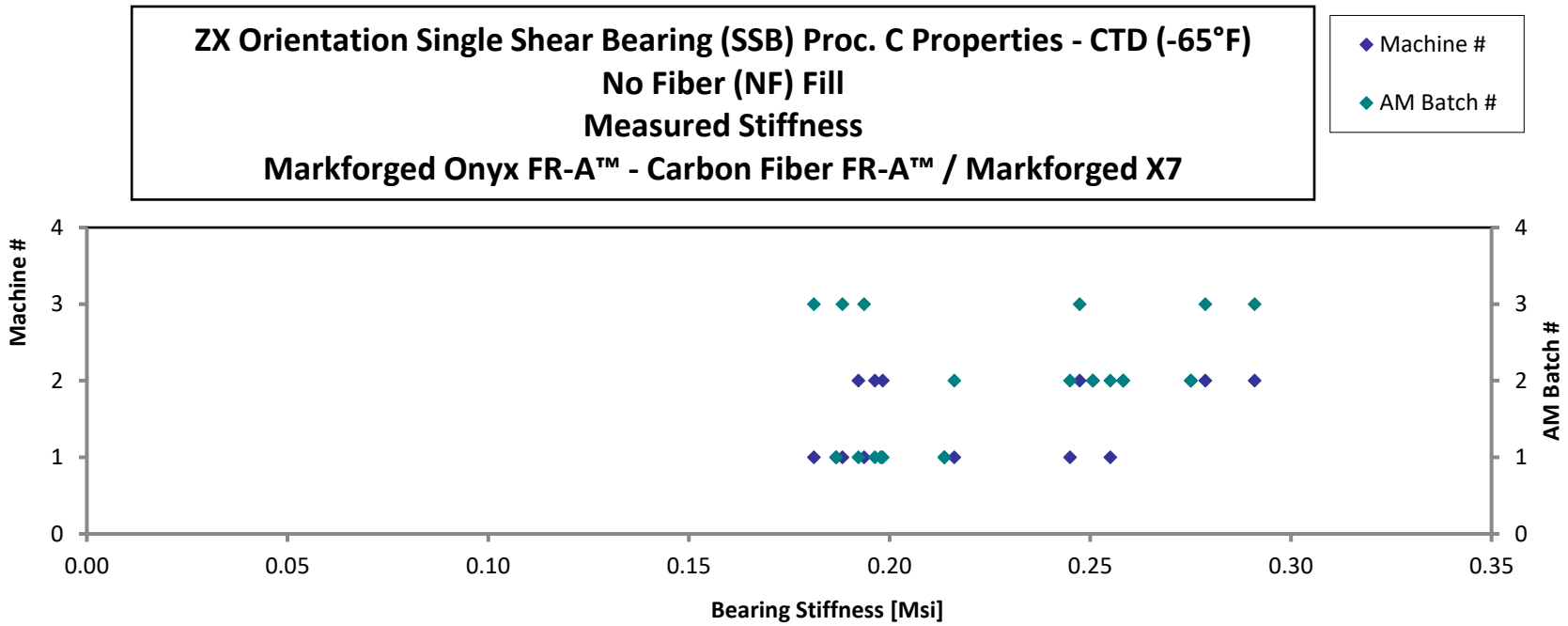
Note: Due to inherent material properties and print orientation, B-basis calculations will be calculated eventhough improper failure modes were present.

All specimens exhibited laminate (lateral) net tension failure mode, which is due to ZX specimen print orientation. (Improper failure per ASTM D5961 Procedure C)

* 2% Offset strength not reported due to the specimens reaching max load first.


ZX Orientation Single Shear Bearing (SSB) Proc. C Properties - CTD (-65°F)
No Fiber (NF) Fill
Measured Strength
Markforged Onyx FR-A™ - Carbon Fiber FR-A™ / Markforged X7
Machine #
AM Batch #
Machine #
AM Batch #
Ultimate Bearing Strength [ksi]
0
1
2
3
4
0.0
5.0
10.0
15.0
20.0
25.0


ZX Orientation Single Shear Bearing (SSB) Proc. C Properties - CTD (-65°F)
No Fiber (NF) Fill
Measured 2% Offset Strength
Markforged Onyx FR-A™ - Carbon Fiber FR-A™ / Markforged X7
Machine #
AM Batch #
Machine #
AM Batch #
0
1
2
3
4
0.00
5.00
10.00
15.00
20.00
25.00
2% Offset Bearing Strength [ksi]


ZX Orientation Single Shear Bearing (SSB) Proc. C Properties - CTD (-65°F)
No Fiber (NF) Fill
Measured Stiffness
Markforged Onyx FR-A™ - Carbon Fiber FR-A™ / Markforged X7
Machine #
AM Batch #
Machine #
AM Batch #
Bearing Stiffness [Msi]
0
1
2
3
4
0.00
0.05
0.10
0.15
0.20
0.25
0.30
0.35

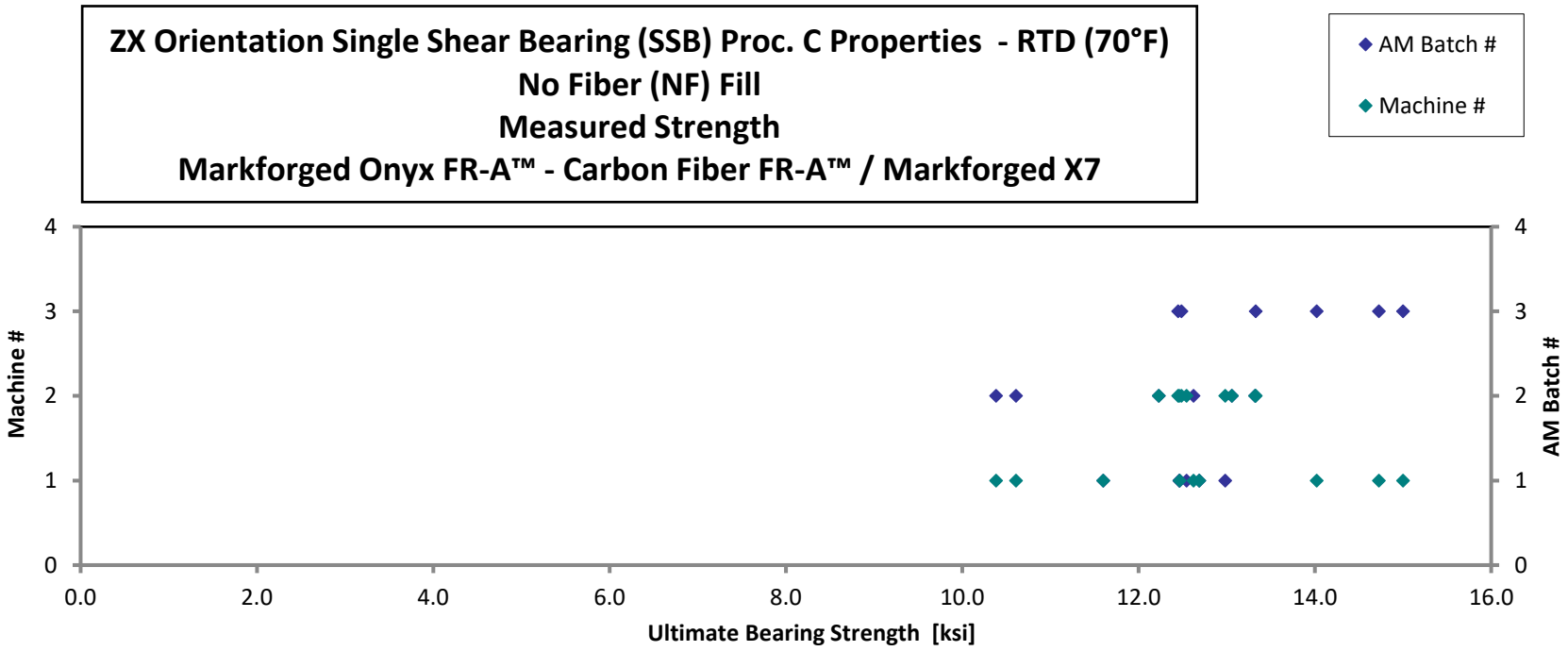
4.40.2 **RTD Condition**

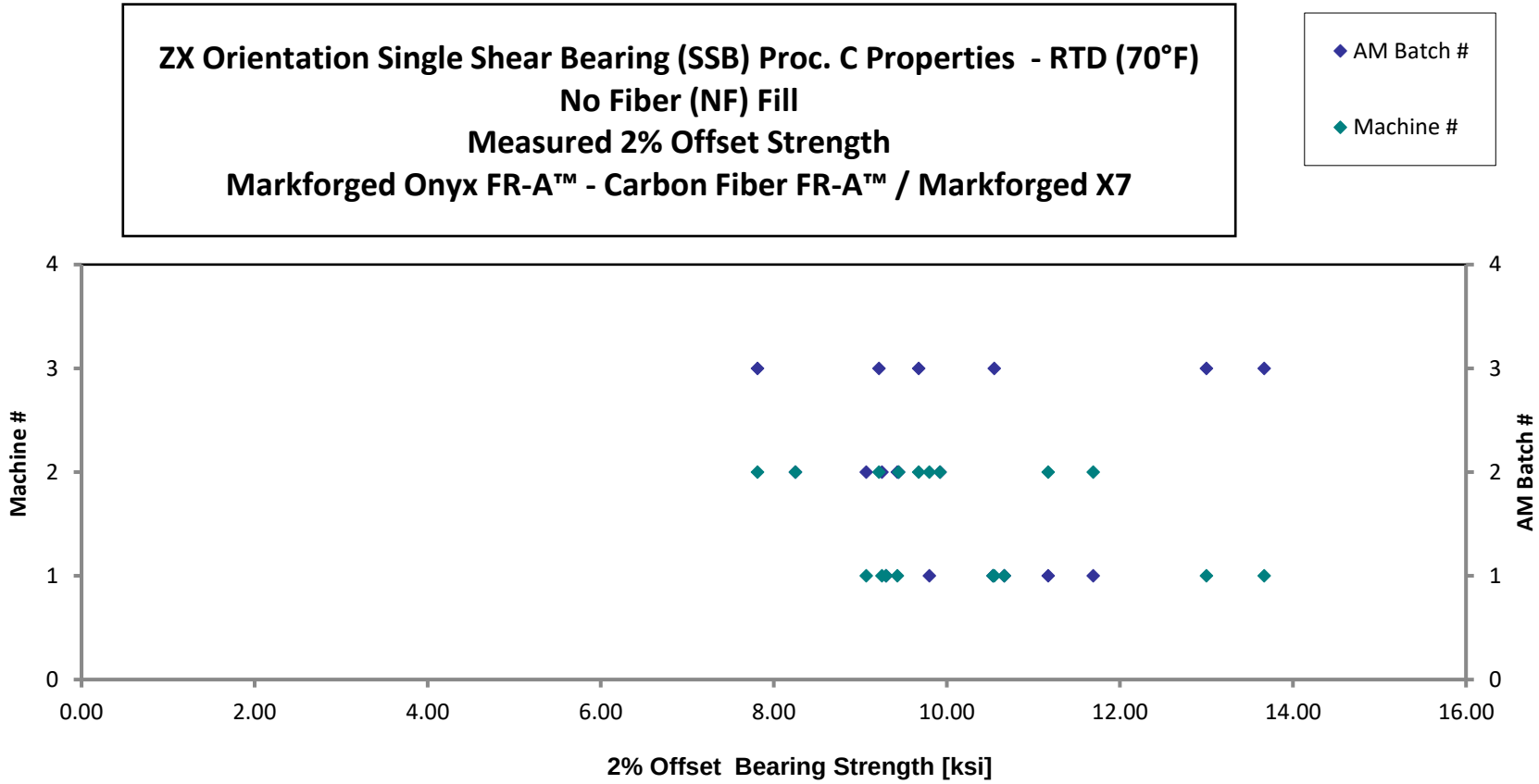
ZX Orientation Single Shear Bearing (SSB) Proc. C Properties - RTD (70°F)
No Fiber (NF) Fill
Strength & Stiffness
Markforged Onyx FR-A™ - Carbon Fiber FR-A™ / Markforged X7

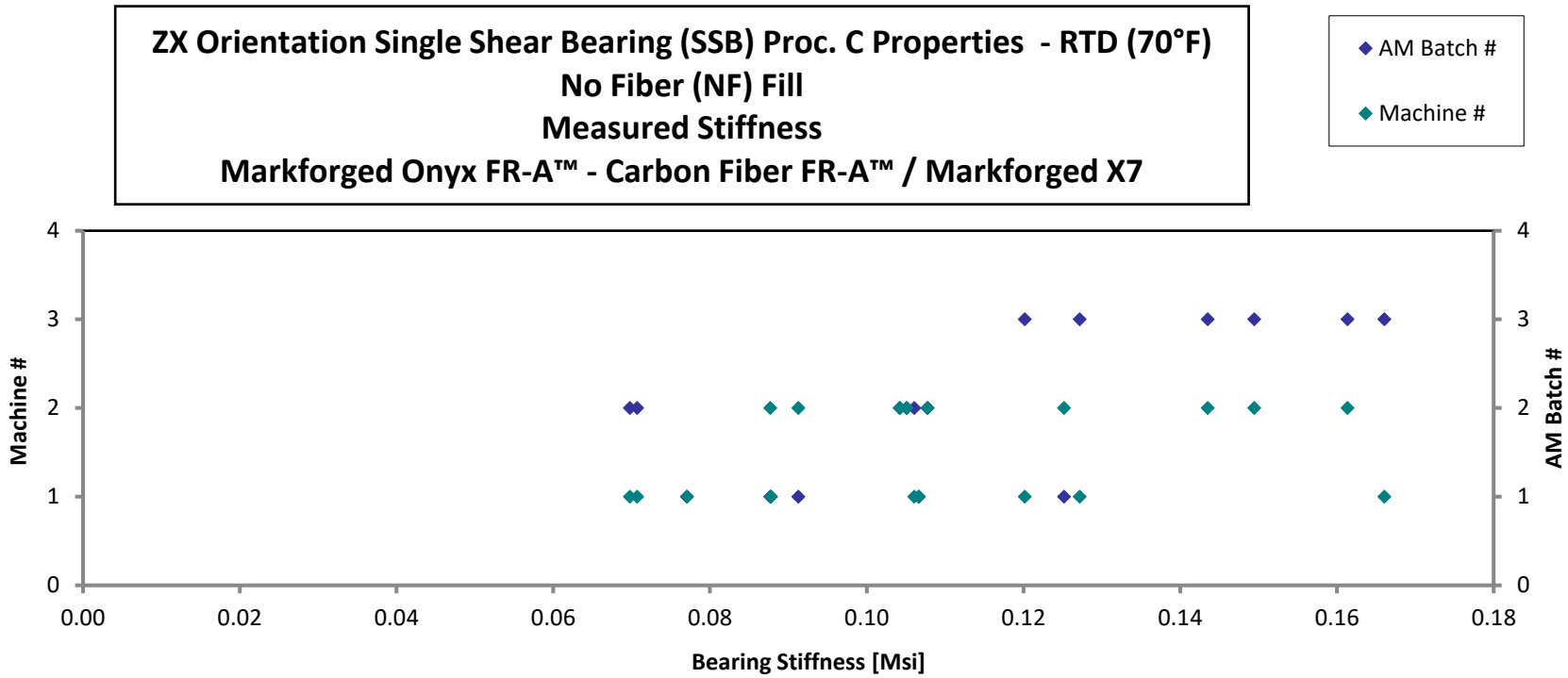
Specimen Number	AM Batch #	Machine #	Avg. Specimen Thickness [in]	Ultimate Bearing Strength [ksi]	2% Offset Bearing Strength [ksi]	Bearing Stiffness [Msi]	Failure Mode
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M1-P61817-ZX-SSB-11-RTD-NF-1	1	1	0.143	12.47	10.66	0.088	L1I
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M1-P61132-ZX-SSB-12-RTD-NF-2	1	1	0.144	12.69	9.297	0.107	L1I
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M1-P61751-ZX-SSB-13-RTD-NF-3	1	1	0.146	11.60	10.53	0.077	L1I
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M2-P61818-ZX-SSB-11-RTD-NF-1	1	2	0.145	12.46	9.797	0.125	L1I
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M2-P60434-ZX-SSB-12-RTD-NF-2	1	2	0.144	12.98	11.69	0.088	L1I
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M2-P61255-ZX-SSB-13-RTD-NF-3	1	2	0.145	12.55	11.17	0.091	L1I
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-B-M1-P63018-ZX-SSB-11-RTD-NF-1	2	1	0.143	10.61	9.068	0.070	L1I
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-B-M1-P62411-ZX-SSB-12-RTD-NF-2	2	1	0.143	10.39	9.428	0.071	L1I
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-B-M1-P66639-ZX-SSB-13-RTD-NF-3	2	1	0.144	12.62	9.249	0.106	L1I
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-B-M2-P63506-ZX-SSB-11-RTD-NF-1	2	2	0.142	13.32	9.920	0.104	L1I
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-B-M2-P62412-ZX-SSB-12-RTD-NF-2	2	2	0.141	13.06	9.443	0.108	L1I
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-B-M2-P63352-ZX-SSB-13-RTD-NF-3	2	2	0.141	12.23	8.250	0.105	L1I
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-C-M1-P65365-ZX-SSB-11-RTD-NF-1	3	1	0.140	14.02	10.55	0.166	L1I
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-C-M1-P64600-ZX-SSB-12-RTD-NF-2	3	1	0.140	14.73	13.00	0.127	L1I
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-C-M1-P64991-ZX-SSB-13-RTD-NF-3	3	1	0.140	15.00	13.67	0.120	L1I
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-C-M2-P65831-ZX-SSB-11-RTD-NF-1	3	2	0.144	13.33	9.675	0.143	L1I
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-C-M2-P65281-ZX-SSB-12-RTD-NF-2	3	2	0.143	12.45	9.215	0.149	L1I
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-C-M2-P65426-ZX-SSB-13-RTD-NF-3	3	2	0.141	12.49	7.812	0.161	L1I
		Average	**0.143**	**12.72**	**10.13**	**0.111**	
		Standard Dev.		**1.176**	**1.506**	**0.029**	
		Coeff. of Var. [%]		**9.247**	**14.86**	**26.40**	
		Min.	**0.140**	**10.39**	**7.812**	**0.070**	
		Max.	**0.146**	**15.00**	**13.67**	**0.166**	
		Number of Spec.	**18**	**18**	**18**	**18**	

Note: Due to inherent material properties and print orientation, B-basis calculations will be calculated eventhough improper failure modes were present.

All specimens exhibited laminate (lateral) net tension failure mode, which is due to ZX specimen print orientation. (Improper failure per ASTM D5961 Procedure C)


ZX Orientation Single Shear Bearing (SSB) Proc. C Properties - RTD (70°F)
No Fiber (NF) Fill
Measured Strength
Markforged Onyx FR-A™ - Carbon Fiber FR-A™ / Markforged X7
AM Batch #
Machine #
Machine #
AM Batch #
Ultimate Bearing Strength [ksi]
0
1
2
3
4
0.0
2.0
4.0
6.0
8.0
10.0
12.0
14.0
16.0


ZX Orientation Single Shear Bearing (SSB) Proc. C Properties - RTD (70°F)
No Fiber (NF) Fill
Measured 2% Offset Strength
Markforged Onyx FR-A™ - Carbon Fiber FR-A™ / Markforged X7
AM Batch #
Machine #
Machine #
AM Batch #
0
1
2
3
4
0.00
2.00
4.00
6.00
8.00
10.00
12.00
14.00
16.00
2% Offset Bearing Strength [ksi]


ZX Orientation Single Shear Bearing (SSB) Proc. C Properties - RTD (70°F)
No Fiber (NF) Fill
Measured Stiffness
Markforged Onyx FR-A™ - Carbon Fiber FR-A™ / Markforged X7
AM Batch #
Machine #
Machine #
AM Batch #
Bearing Stiffness [Msi]
0
1
2
3
4
0.00
0.02
0.04
0.06
0.08
0.10
0.12
0.14
0.16
0.18

4.40.3 **ETW Condition**

ZX Orientation Single Shear Bearing (SSB) Proc. C Properties - ETW (130°F)
No Fiber (NF) Fill
Strength & Stiffness
Markforged Onyx FR-A™ - Carbon Fiber FR-A™ / Markforged X7

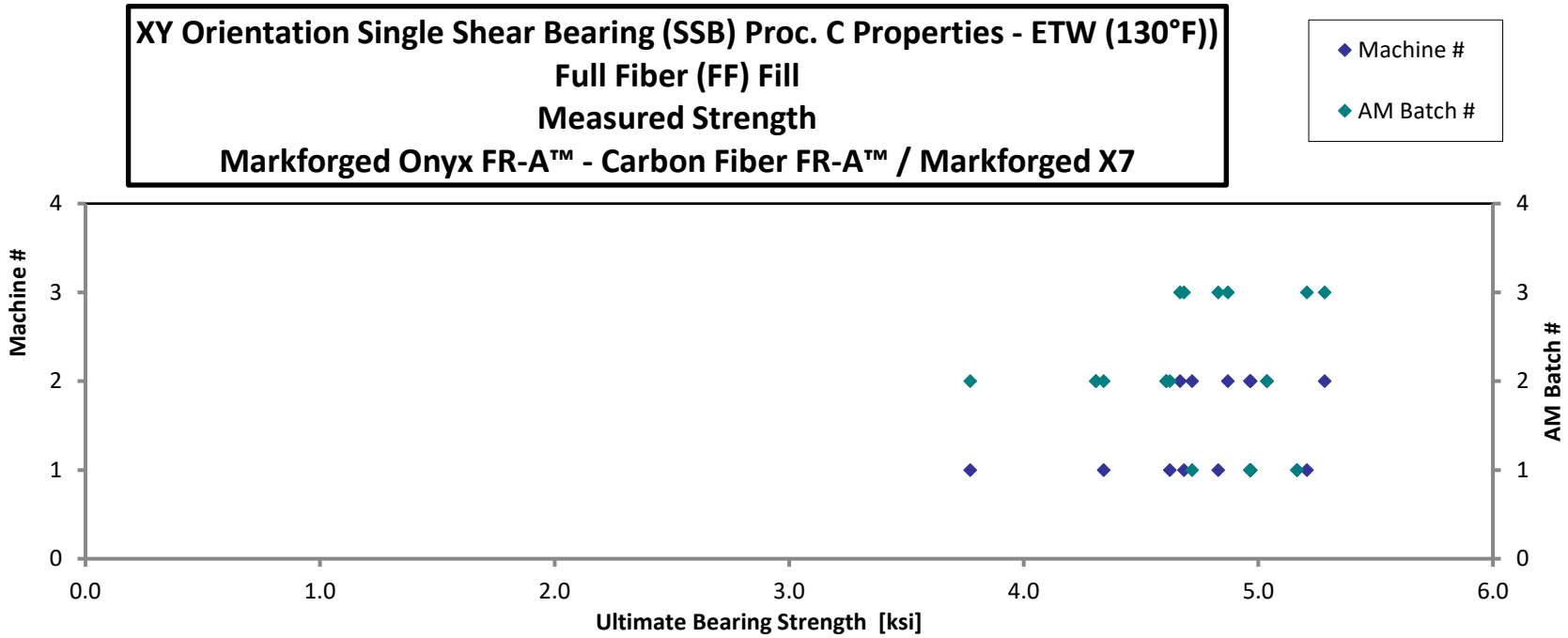
Specimen Number	AM Batch #	Machine #	Avg. Specimen Thickness [in]	Ultimate Bearing Strength [ksi]	2% Offset Bearing Strength [ksi]	Bearing Stiffness [Msi]	Failure Mode
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M1-P61817-ZX-SSB-11-ETW-NF-1*	1	1	0.142	5.166	3.149	0.022	B1I
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M1-P61132-ZX-SSB-12-ETW-NF-2*	1	1	0.143	4.967	3.007	0.024	B1I
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M1-P61751-ZX-SSB-13-ETW-NF-3*	1	1	0.141	4.967	3.184	0.024	B1I
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M2-P61818-ZX-SSB-11-ETW-NF-1*/**	1	2	0.142	4.718	2.559	0.028	L1I
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M2-P60434-ZX-SSB-12-ETW-NF-2*/**	1	2	0.142	4.964	2.522	0.032	L1I
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M2-P61255-ZX-SSB-13-ETW-NF-3*	1	2	0.142	4.968	2.393	0.024	B1I
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-B-M1-P63018-ZX-SSB-11-ETW-NF-1*	2	1	0.141	4.341	2.361	0.015	B1I
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-B-M1-P62411-ZX-SSB-12-ETW-NF-2**	2	1	0.142	3.772	2.294	0.023	M(B,L)1I
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-B-M1-P66639-ZX-SSB-13-ETW-NF-3*	2	1	0.142	4.623	2.569	0.024	B1I
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-B-M2-P63506-ZX-SSB-11-ETW-NF-1	2	2	0.139	4.607	3.029	0.025	B1I
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-B-M2-P62412-ZX-SSB-12-ETW-NF-2*	2	2	0.139	5.037	3.040	0.026	B1I
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-B-M2-P63352-ZX-SSB-13-ETW-NF-3*	2	2	0.138	4.308	2.818	0.017	B1I
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-C-M1-P65365-ZX-SSB-11-ETW-NF-1*	3	1	0.141	5.207	2.658	0.025	B1I
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-C-M1-P64600-ZX-SSB-12-ETW-NF-2*	3	1	0.141	4.683	2.432	0.031	B1I
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-C-M1-P64991-ZX-SSB-13-ETW-NF-3*	3	1	0.141	4.829	2.238	0.031	B1I
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-C-M2-P65831-ZX-SSB-11-ETW-NF-1*	3	2	0.142	5.283	3.336	0.021	B1I
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-C-M2-P65281-ZX-SSB-12-ETW-NF-2*	3	2	0.141	4.871	2.417	0.024	B1I
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-C-M2-P65426-ZX-SSB-13-ETW-NF-3*	3	2	0.140	4.666	2.417	0.023	B1I

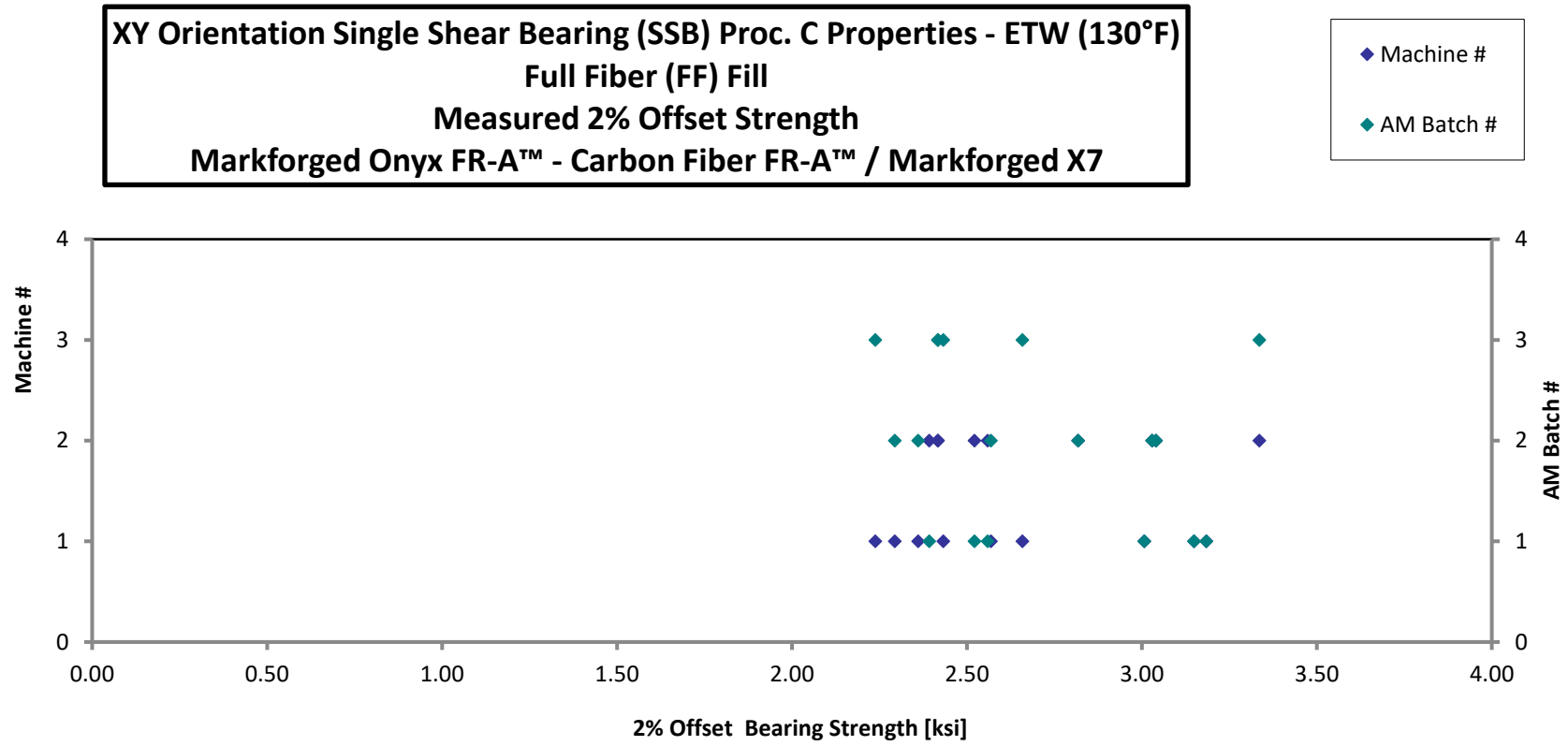
Note: Due to inherent material properties and print orientation, B-basis calculations will be calculated eventhough improper failure modes were present.

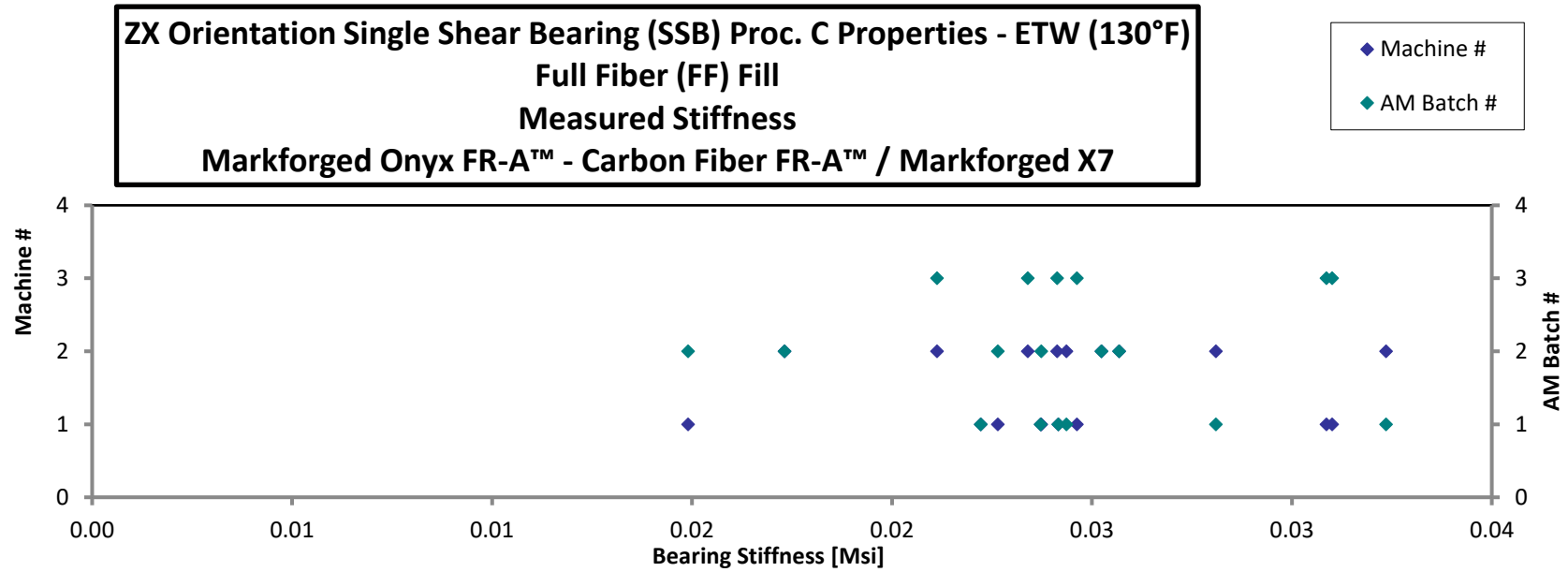
*Ultimate bearing strength obtained from max load at 50% hole deformation.

**Specimen exhibited laminate (lateral) net tension failure mode, which is due to ZX specimen print orientation. (Improper failure per ASTM D5961 Procedure C)

Average	**0.141**	**4.776**	**2.690**	**0.024**
Standard Dev.		**0.369**	**0.348**	**0.004**
Coeff. of Var. [%]		**7.721**	**12.943**	**17.923**
Min.	**0.138**	**3.772**	**2.238**	**0.015**
Max.	**0.143**	**5.283**	**3.336**	**0.032**
Number of Spec.	**18**	**18**	**18**	**18**


XY Orientation Single Shear Bearing (SSB) Proc. C Properties - ETW (130°F))
Full Fiber (FF) Fill
Measured Strength
Markforged Onyx FR-A™ - Carbon Fiber FR-A™ / Markforged X7
Machine #
AM Batch #
Machine #
AM Batch #
0
1
2
3
4
0.0
1.0
2.0
3.0
4.0
5.0
6.0
Ultimate Bearing Strength [ksi]


XY Orientation Single Shear Bearing (SSB) Proc. C Properties - ETW (130°F)
Full Fiber (FF) Fill
Measured 2% Offset Strength
Markforged Onyx FR-A™ - Carbon Fiber FR-A™ / Markforged X7
Machine #
AM Batch #
Machine #
AM Batch #
0
1
2
3
4
0.00
0.50
1.00
1.50
2.00
2.50
3.00
3.50
4.00
2% Offset Bearing Strength [ksi]

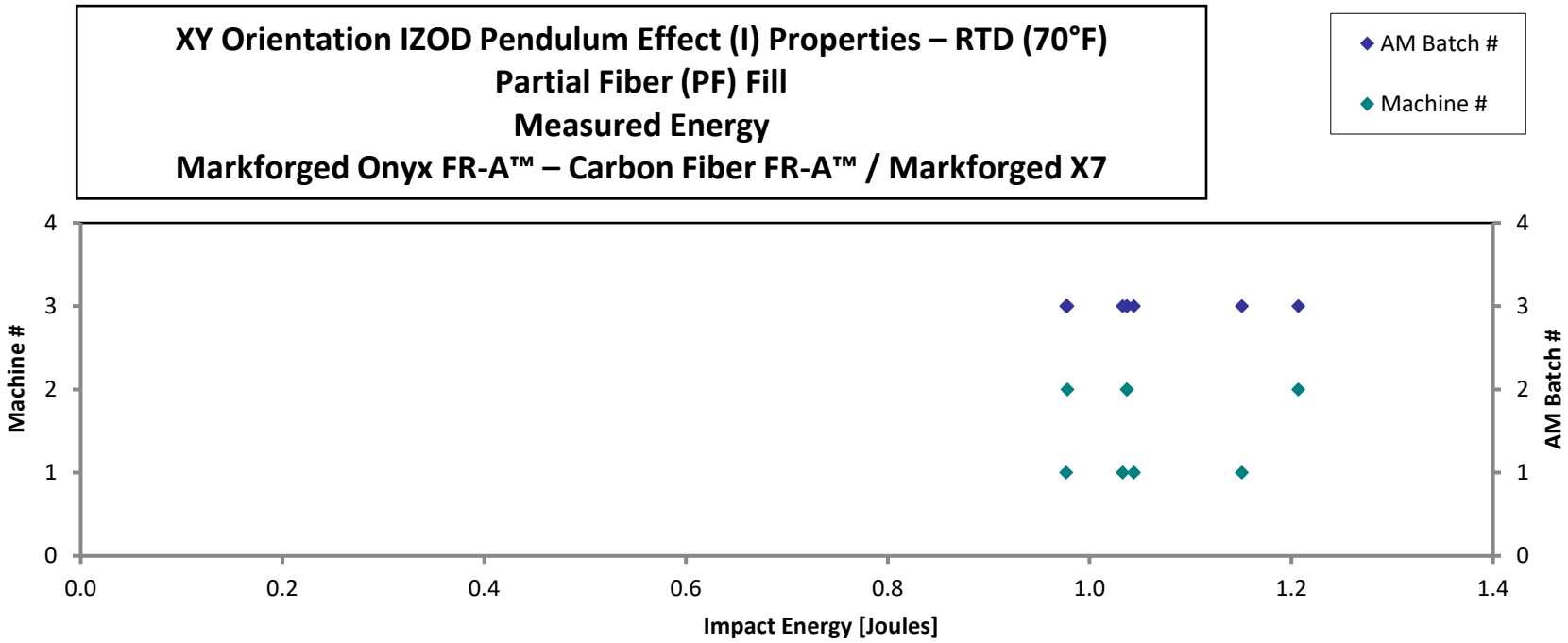

ZX Orientation Single Shear Bearing (SSB) Proc. C Properties - ETW (130°F)
Full Fiber (FF) Fill
Measured Stiffness
Markforged Onyx FR-A™ - Carbon Fiber FR-A™ / Markforged X7
Machine #
AM Batch #
Machine #
AM Batch #
0
1
2
3
4
0.00
0.01
0.01
0.02
0.02
0.03
0.03
0.04
Bearing Stiffness [Msi]

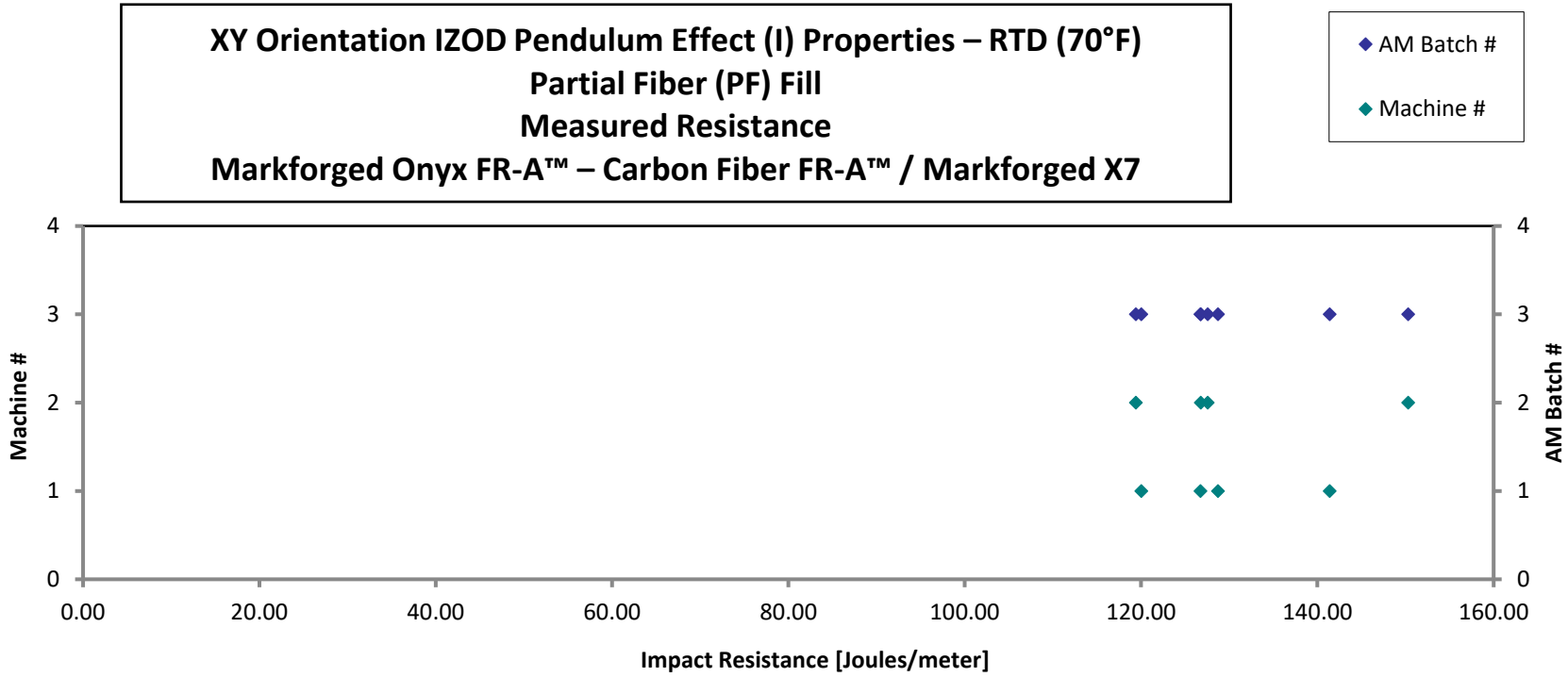
4.41 XY PF IZOD Pendulum Impact Properties

4.41.1 RTD Condition

XY Orientation IZOD Pendulum Effect (I) Properties – RTD (70°F)
Partial Fiber (PF) Fill
Energy & Resistance
Markforged Onyx FR-A™ – Carbon Fiber FR-A™ / Markforged X7

Specimen Number	AM Batch #	Machine #	Avg. Specimen Thickness [in]	Impact Energy [Joules]	Impact Resistance [Joules/meter]	Failure Mode
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-C-M1-P51916-XY-I-11-RTD-PF-1	3	1	0.319	1.044	128.7	P
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-C-M1-P51660-XY-I-12-RTD-PF-2	3	1	0.321	1.033	126.7	P
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-C-M1-P52174-XY-I-13-RTD-PF-3	3	1	0.321	0.977	120.0	P
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-C-M1-P52530-XY-I-13-RTD-PF-SP	3	1	0.320	1.151	141.4	P
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-C-M2-P52203-XY-I-11-RTD-PF-1	3	2	0.320	1.037	127.6	P
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-C-M2-P51644-XY-I-12-RTD-PF-2	3	2	0.322	0.978	119.4	P
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-C-M2-P51823-XY-I-13-RTD-PF-3	3	2	0.322	1.037	126.8	P
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-C-M2-P57299-XY-I-13-RTD-PF-SP	3	2	0.316	1.207	150.3	P
		Average	**0.320**	**1.058**	**130.1**	
		Standard Dev.		**0.081**	**10.57**	
		Coeff. of Var. [%]		**7.621**	**8.126**	
		Min.	**0.316**	**0.977**	**119.4**	
		Max.	**0.322**	**1.207**	**150.3**	
		Number of Spec.	**8**	**8**	**8**	


XY Orientation IZOD Pendulum Effect (I) Properties – RTD (70°F)
Partial Fiber (PF) Fill
Measured Energy
Markforged Onyx FR-A™ – Carbon Fiber FR-A™ / Markforged X7
AM Batch #
Machine #
Machine #
AM Batch #
Impact Energy [Joules]
0
1
2
3
4
0.0
0.2
0.4
0.6
0.8
1.0
1.2
1.4

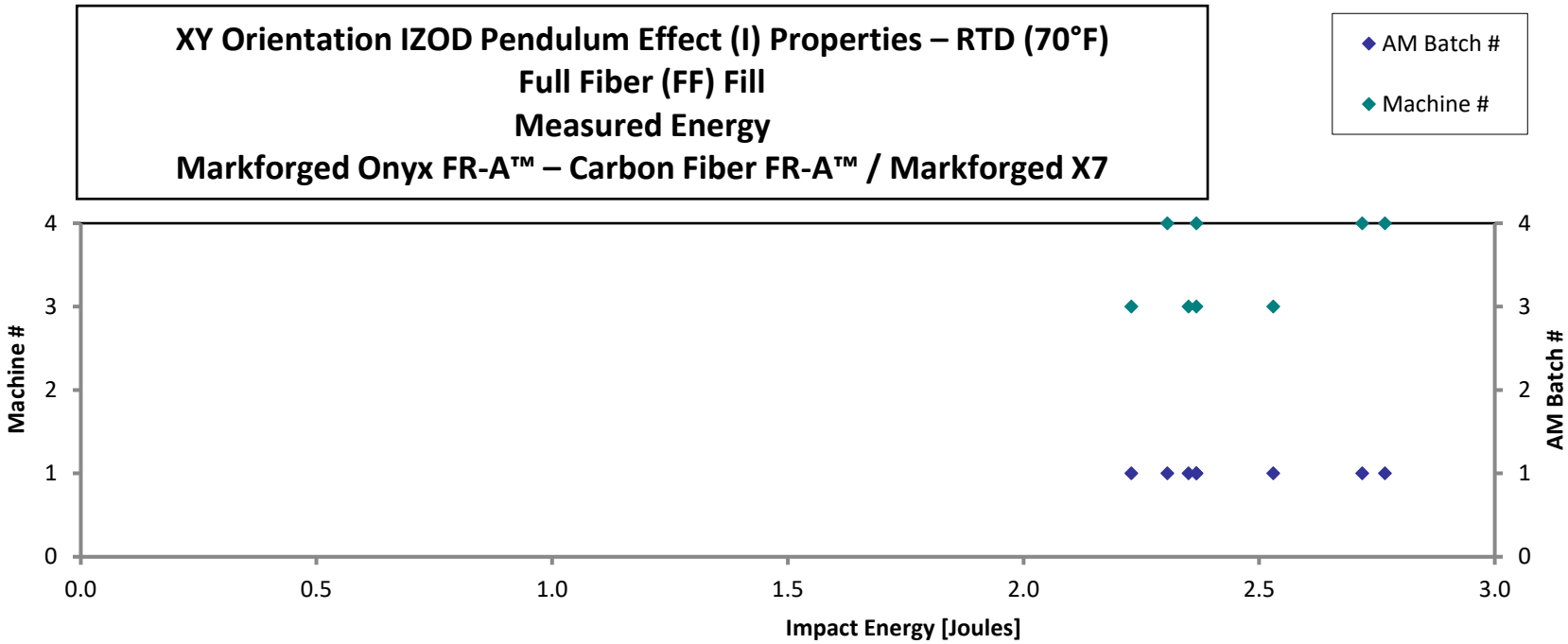

XY Orientation IZOD Pendulum Effect (I) Properties – RTD (70°F)
Partial Fiber (PF) Fill
Measured Resistance
Markforged Onyx FR-A™ – Carbon Fiber FR-A™ / Markforged X7
AM Batch #
Machine #
Machine #
AM Batch #
Impact Resistance [Joules/meter]
0
1
2
3
4
0.00
20.00
40.00
60.00
80.00
100.00
120.00
140.00
160.00

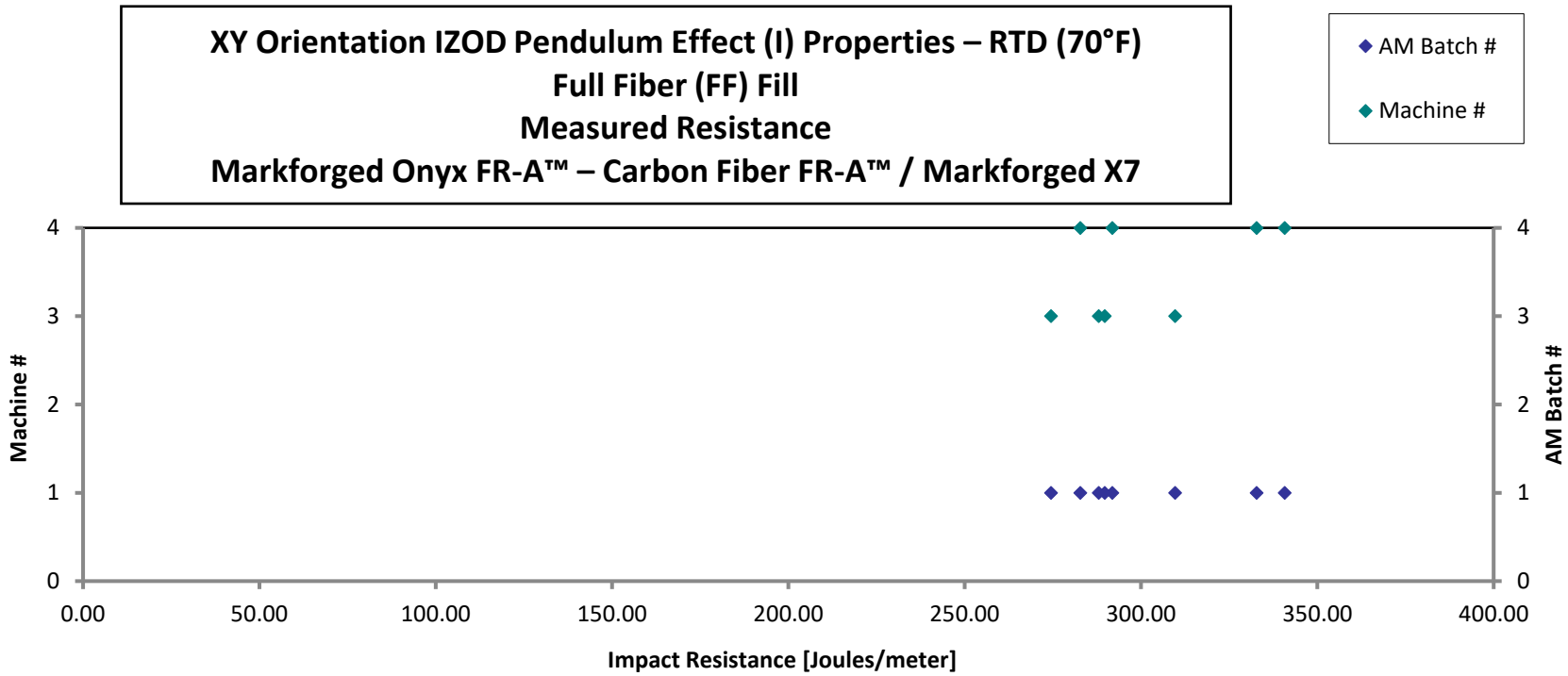
4.42 **XY FF IZOD Pendulum Impact Properties**

4.42.1 **RTD Condition**

XY Orientation IZOD Pendulum Effect (I) Properties – RTD (70°F)
Full Fiber (FF) Fill
Energy & Resistance
Markforged Onyx FR-A™ – Carbon Fiber FR-A™ / Markforged X7

Specimen Number	AM Batch #	Machine #	Avg. Specimen Thickness [in]	Impact Energy [Joules]	Impact Resistance [Joules/meter]	Failure Mode
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M3-P36089-XY-I-11-RTD-FF-1	1	3	0.319	2.229	274.5	P
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M3-P39193-XY-I-12-RTD-FF-2	1	3	0.321	2.530	309.7	P
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M3-P38541-XY-I-13-RTD-FF-3	1	3	0.322	2.367	289.7	P
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M3-P36089-XY-I-13-RTD-FF-SP	1	3	0.321	2.350	288.0	P
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M4-P40905-XY-I-11-RTD-FF-1	1	4	0.319	2.367	291.9	P
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M4-P41830-XY-I-12-RTD-FF-2	1	4	0.321	2.305	282.8	P
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M4-P46438-XY-I-13-RTD-FF-3	1	4	0.321	2.719	332.8	P
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M4-P40905-XY-I-13-RTD-FF-SP	1	4	0.320	2.767	340.8	P
		Average	**0.321**	**2.454**	**301.3**	
		Standard Dev.		**0.197**	**24.14**	
		Coeff. of Var. [%]		**8.043**	**8.013**	
		Min.	**0.319**	**2.229**	**274.5**	
		Max.	**0.322**	**2.767**	**340.8**	
		Number of Spec.	**8**	**8**	**8**	


XY Orientation IZOD Pendulum Effect (I) Properties – RTD (70°F)
Full Fiber (FF) Fill
Measured Energy
Markforged Onyx FR-A™ – Carbon Fiber FR-A™ / Markforged X7
AM Batch #
Machine #
Machine #
AM Batch #
Impact Energy [Joules]
0
1
2
3
4
0.0
0.5
1.0
1.5
2.0
2.5
3.0

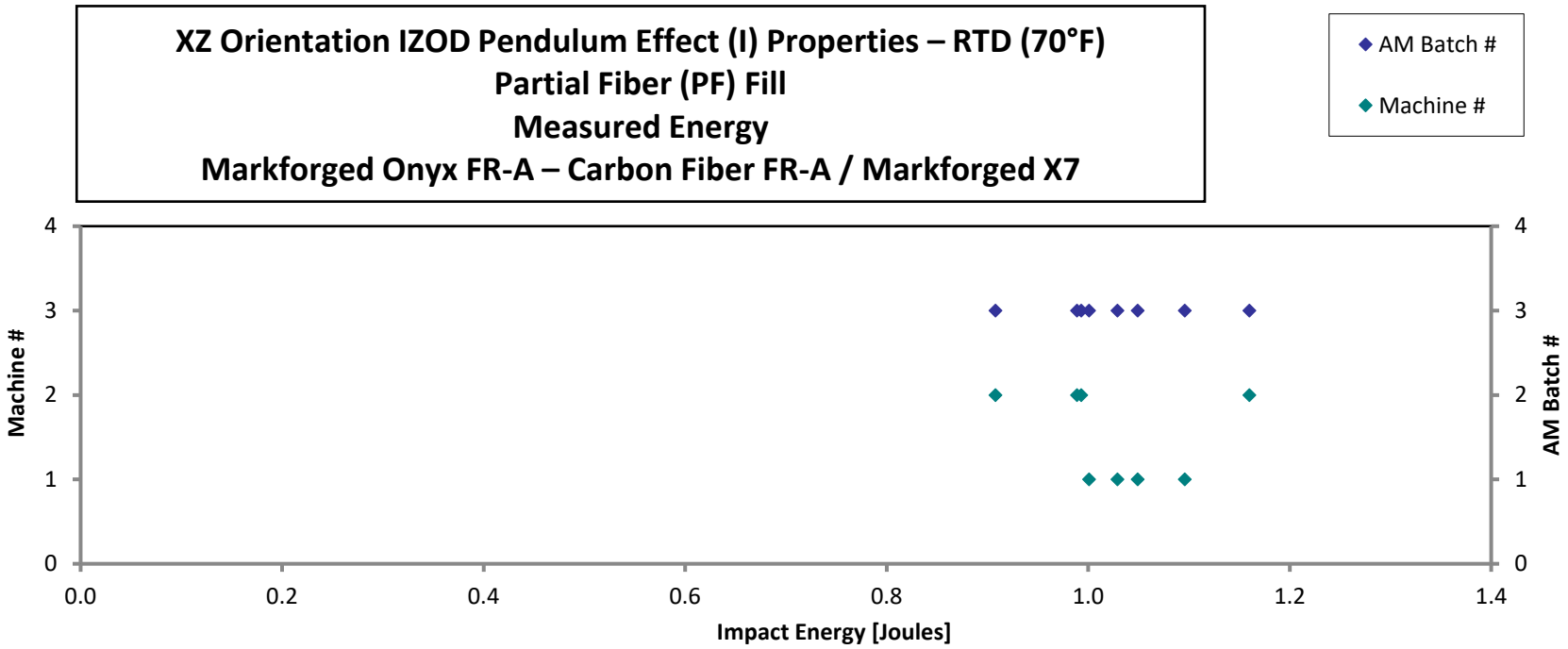

XY Orientation IZOD Pendulum Effect (I) Properties – RTD (70°F)
Full Fiber (FF) Fill
Measured Resistance
Markforged Onyx FR-A™ – Carbon Fiber FR-A™ / Markforged X7
AM Batch #
Machine #
Machine #
AM Batch #
0
1
2
3
4
0.00
50.00
100.00
150.00
200.00
250.00
300.00
350.00
400.00
Impact Resistance [Joules/meter]

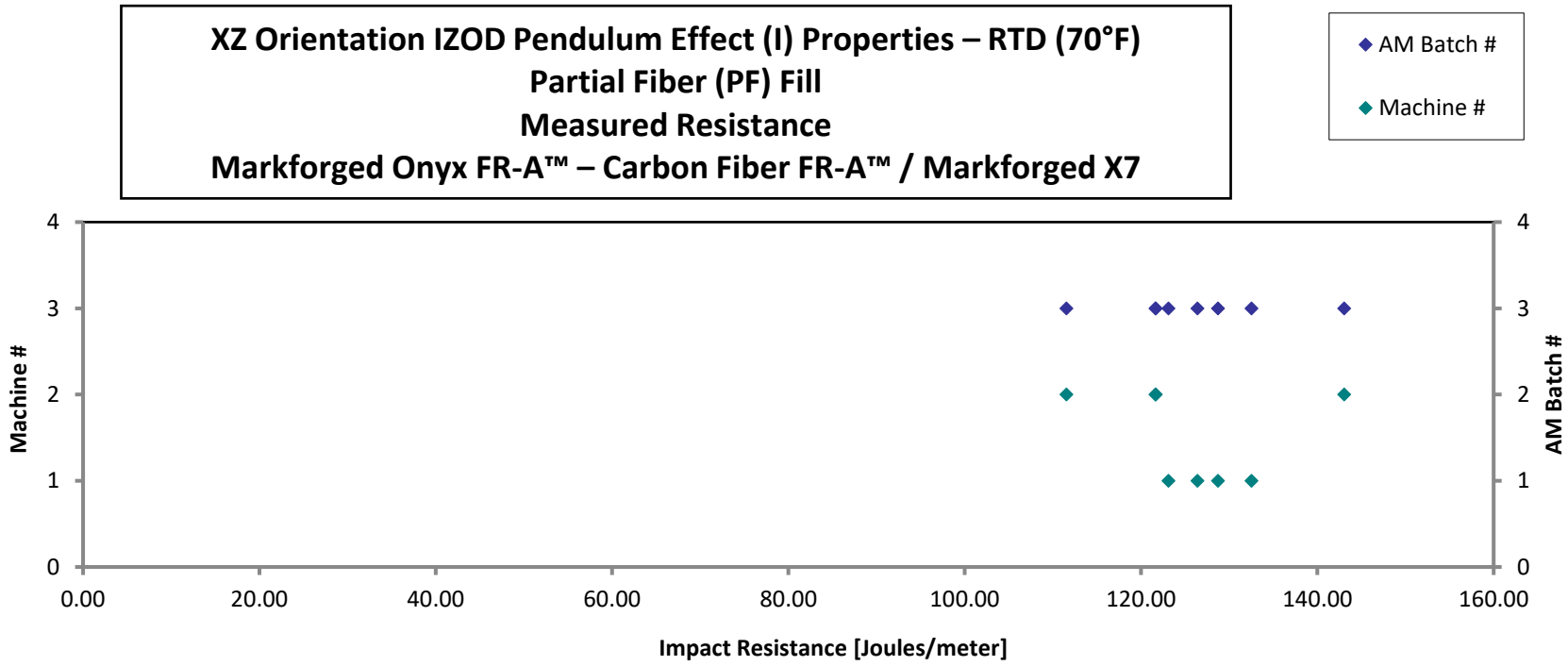
4.43 XZ PF IZOD Pendulum Impact Properties

4.43.1 RTD Condition

XZ Orientation IZOD Pendulum Effect (I) Properties – RTD (70°F)
Partial Fiber (PF) Fill
Energy & Resistance
Markforged Onyx FR-A™ – Carbon Fiber FR-A™ / Markforged X7

Specimen Number	AM Batch #	Machine #	Avg. Specimen Thickness [in]	Impact Energy [Joules]	Impact Resistance [Joules/meter]	Failure Mode
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-C-M1-P52174-XZ-I-11-RTD-PF-1	3	1	0.320	1.029	126.4	P
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-C-M1-P51916-XZ-I-12-RTD-PF-2	3	1	0.321	1.049	128.7	P
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-C-M1-P51660-XZ-I-13-RTD-PF-3	3	1	0.320	1.001	123.1	P
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-C-M1-P52530-XZ-I-13-RTD-PF-SP	3	1	0.325	1.096	132.5	P
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-C-M2-P51823-XZ-I-11-RTD-PF-1	3	2	0.320	0.989	121.6	P
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-C-M2-P52203-XZ-I-12-RTD-PF-2	3	2	0.319	1.160	143.0	P
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-C-M2-P51644-XZ-I-13-RTD-PF-3	3	2	0.321	0.908	111.5	P
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-C-M2-P57299-XZ-I-13-RTD-PF-SP	3	2	0.321	0.993	121.7	P
		Average	**0.321**	**1.028**	**126.1**	
		Standard Dev.		**0.076**	**9.218**	
		Coeff. of Var. [%]		**7.386**	**7.311**	
		Min.	**0.319**	**0.908**	**111.5**	
		Max.	**0.325**	**1.160**	**143.0**	
		Number of Spec.	**8**	**8**	**8**	


XZ Orientation IZOD Pendulum Effect (I) Properties – RTD (70°F)
Partial Fiber (PF) Fill
Measured Energy
Markforged Onyx FR-A – Carbon Fiber FR-A / Markforged X7
AM Batch #
Machine #
Machine #
AM Batch #
Impact Energy [Joules]
0
1
2
3
4
0.0
0.2
0.4
0.6
0.8
1.0
1.2
1.4


XZ Orientation IZOD Pendulum Effect (I) Properties – RTD (70°F)
Partial Fiber (PF) Fill
Measured Resistance
Markforged Onyx FR-A™ – Carbon Fiber FR-A™ / Markforged X7
AM Batch #
Machine #
Machine #
AM Batch #
Impact Resistance [Joules/meter]
0
1
2
3
4
0.00
20.00
40.00
60.00
80.00
100.00
120.00
140.00
160.00

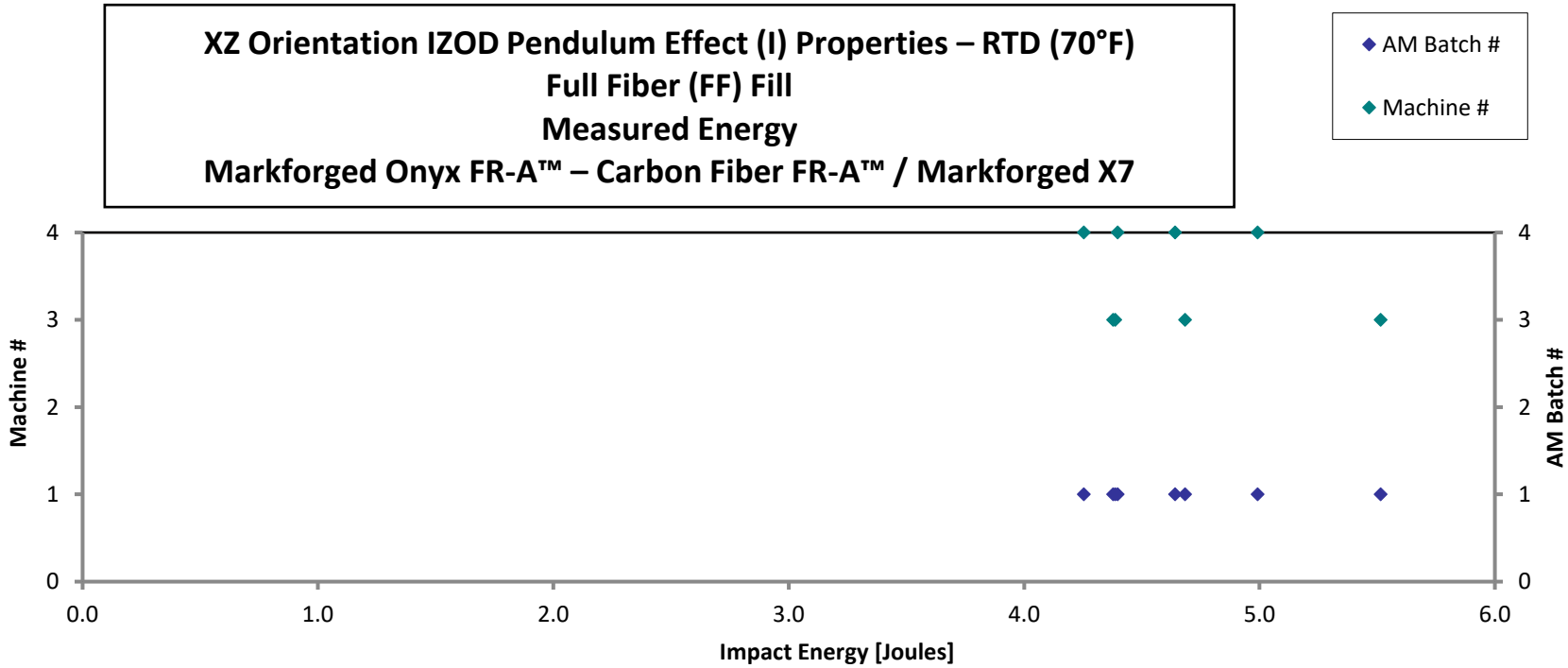
4.44 XZ FF IZOD Pendulum Impact Properties

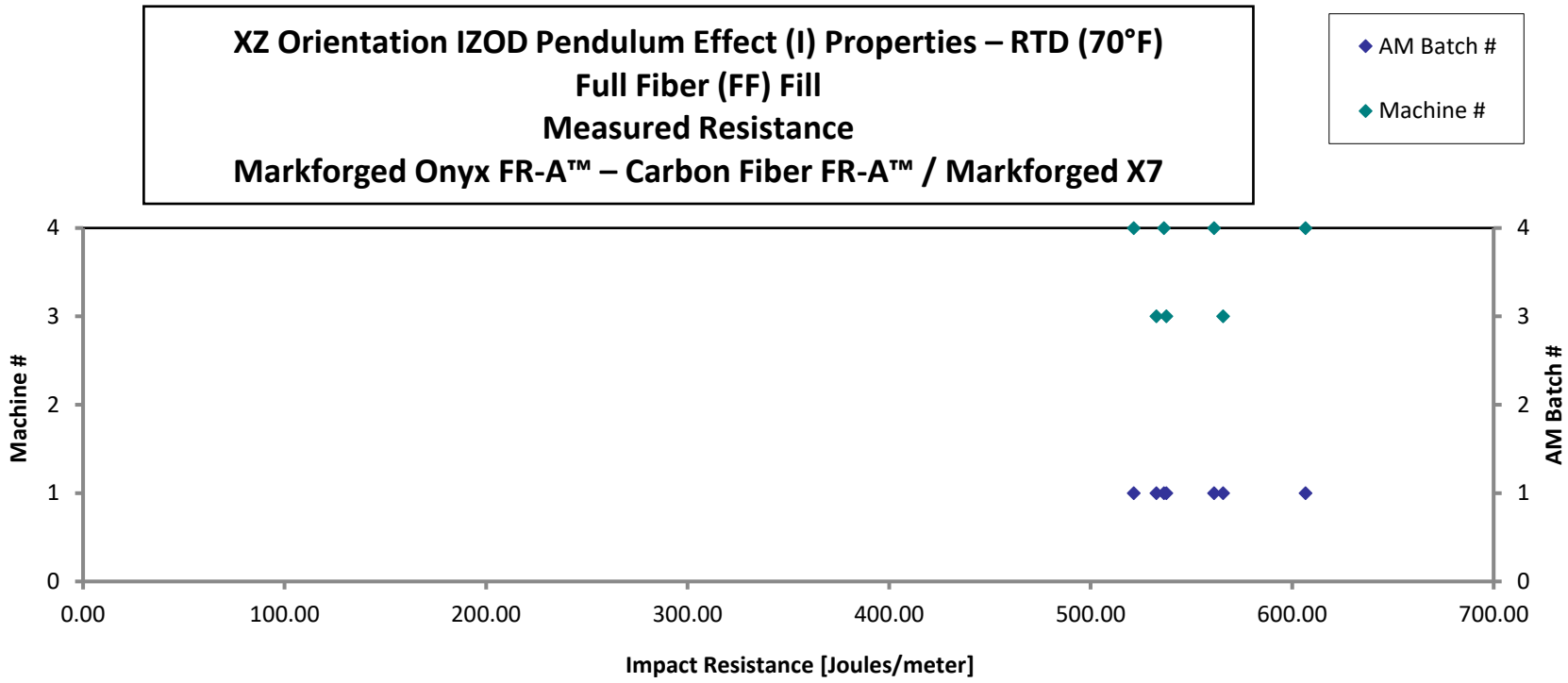
4.44.1 RTD Condition

XZ Orientation IZOD Pendulum Effect (I) Properties – RTD (70°F)
Full Fiber (FF) Fill
Energy & Resistance
Markforged Onyx FR-A™ – Carbon Fiber FR-A™ / Markforged X7

Specimen Number	AM Batch #	Machine #	Avg. Specimen Thickness [in]	Impact Energy [Joules]	Impact Resistance [Joules/meter]	Failure Mode
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M3-P36089-XZ-I-11-RTD-FF-1	1	3	0.321	4.387	537.6	P
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M3-P38541-XZ-I-12-RTD-FF-2	1	3	0.324	4.378	532.6	P
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M3-P38445-XZ-I-13-RTD-FF-3*	1	3	0.324	5.514		NB
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M3-P38541-XZ-I-13-RTD-FF-SP	1	3	0.326	4.684	565.7	P
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M4-P40905-XZ-I-11-RTD-FF-1	1	4	0.323	4.398	536.3	P
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M4-P46438-XZ-I-12-RTD-FF-2	1	4	0.326	4.641	561.2	P
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M4-P41915-XZ-I-13-RTD-FF-3	1	4	0.321	4.254	521.3	P
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M4-P46438-XZ-I-13-RTD-FF-SP	1	4	0.324	4.992	606.6	P
		Average	**0.324**	**4.656**	**551.6**	
		Standard Dev.		**0.419**	**28.92**	
		Coeff. of Var. [%]		**8.995**	**5.242**	
		Min.	**0.321**	**4.254**	**521.3**	
		Max.	**0.326**	**5.514**	**606.6**	
		Number of Spec.	**8**	**8**	**7**	

Note: Per ASTM D256, results obtained from "nonbreak (NB)" specimens shall be considered a departure from standard and shall not be reported.
*Impact resistance not reported due to improper failure mode.


XZ Orientation IZOD Pendulum Effect (I) Properties – RTD (70°F)
Full Fiber (FF) Fill
Measured Energy
Markforged Onyx FR-A™ – Carbon Fiber FR-A™ / Markforged X7
AM Batch #
Machine #
Machine #
AM Batch #
Impact Energy [Joules]
0
1
2
3
4
0.0
1.0
2.0
3.0
4.0
5.0
6.0


XZ Orientation IZOD Pendulum Effect (I) Properties – RTD (70°F)
Full Fiber (FF) Fill
Measured Resistance
Markforged Onyx FR-A™ – Carbon Fiber FR-A™ / Markforged X7
AM Batch #
Machine #
Machine #
AM Batch #
0
1
2
3
4
0.00
100.00
200.00
300.00
400.00
500.00
600.00
700.00
Impact Resistance [Joules/meter]

4.45 ZX PF IZOD Pendulum Impact Properties – Reference Only

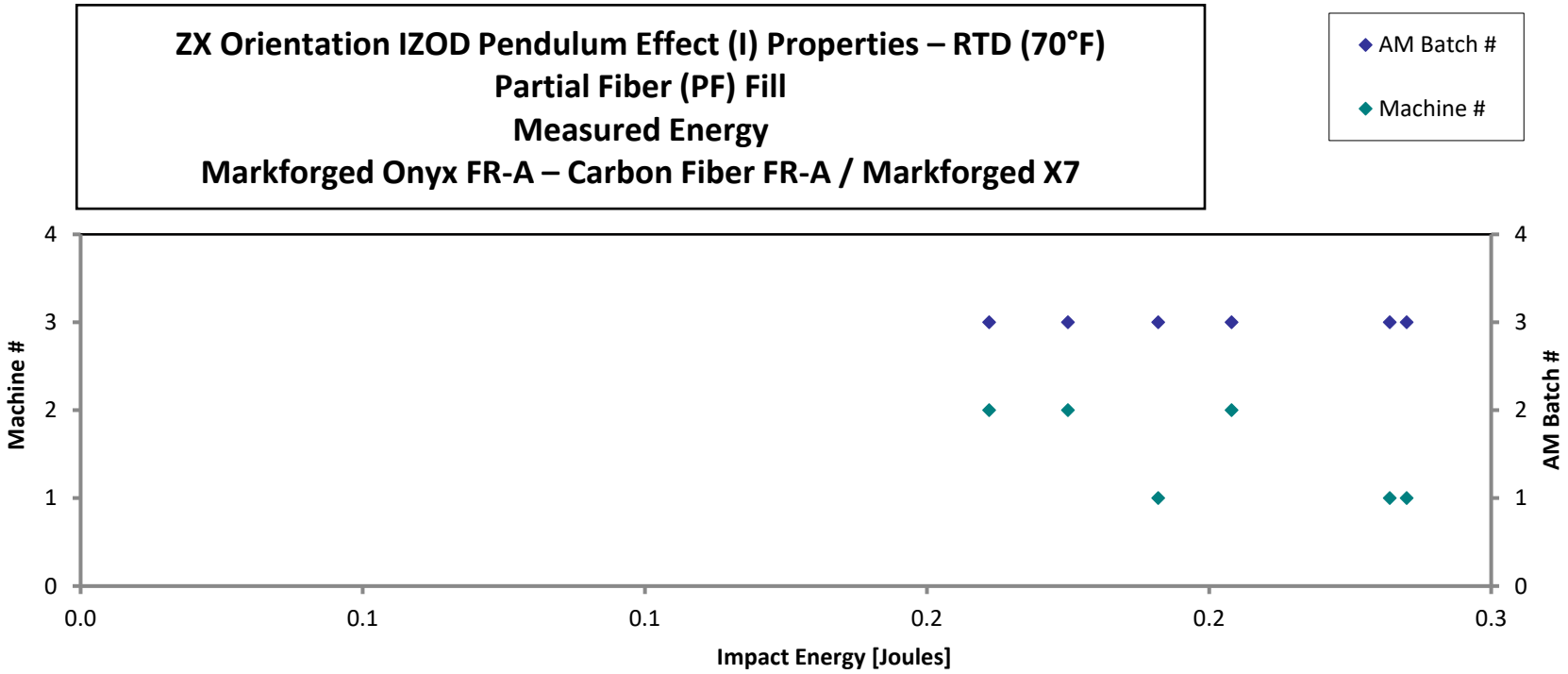
4.45.1 RTD Condition

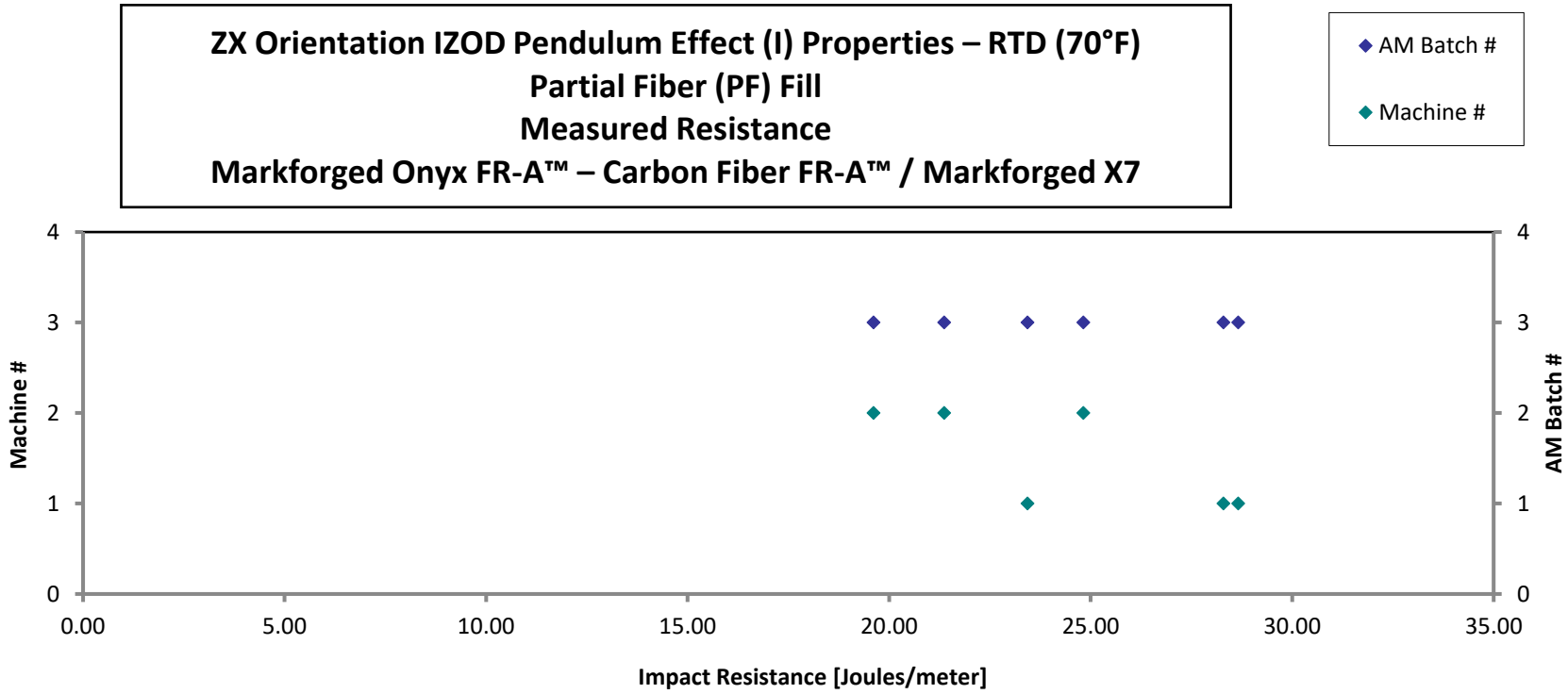
ZX Orientation IZOD Pendulum Effect (I) Properties – RTD (70°F)
Partial Fiber (PF) Fill
Energy & Resistance
Markforged Onyx FR-A™ – Carbon Fiber FR-A™ / Markforged X7

Specimen Number	AM Batch #	Machine #	Avg. Specimen Thickness [in]	Impact Energy [Joules]	Impact Resistance [Joules/meter]	Failure Mode
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-C-M1-P68949-ZX-I-11-RTD-PF-1*	3	1	0.321	0.191	23.44	P
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-C-M1-P68989-ZX-I-12-RTD-PF-2	3	1	0.323	0.232	28.29	C
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-C-M1-P68833-ZX-I-13-RTD-PF-3	3	1	0.323	0.235	28.66	C
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-C-M2-P68815-ZX-I-11-RTD-PF-1	3	2	0.323	0.161	19.61	C
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-C-M2-P68946-ZX-I-12-RTD-PF-2	3	2	0.322	0.175	21.37	C
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-C-M2-P68990-ZX-I-13-RTD-PF-3	3	2	0.324	0.204	24.82	C

Note: Per ASTM D256, averages reported must be derived from specimens contained within a single failure category.
*Specimen failure mode was different from rest of samples.

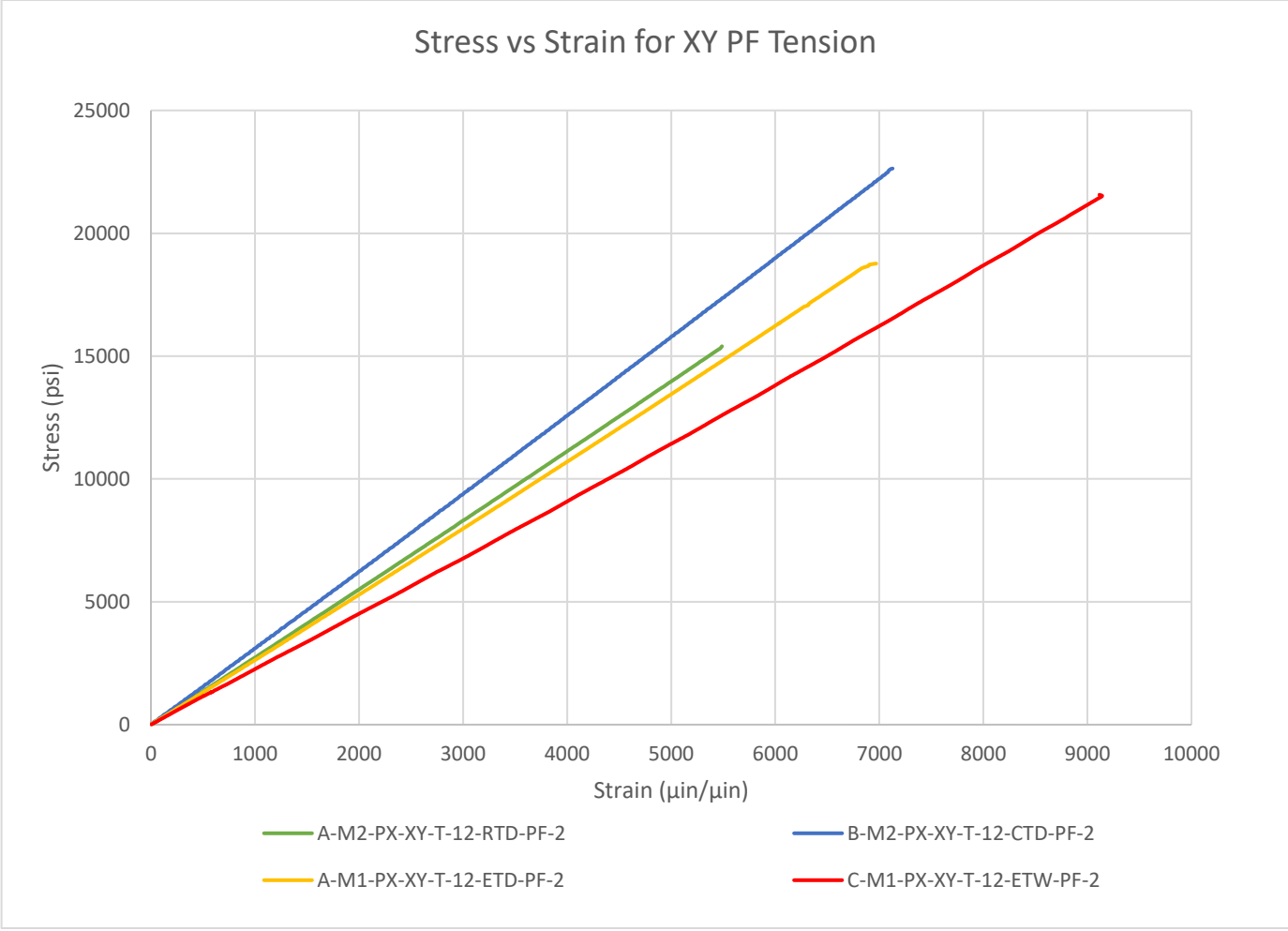
Average	**0.323**	**0.200**	**24.36**
Standard Dev.		**0.030**	**3.648**
Coeff. of Var. [%]		**15.01**	**14.97**
Min.	**0.321**	**0.161**	**19.61**
Max.	**0.324**	**0.235**	**28.66**
Number of Spec.	**6**	**6**	**6**


ZX Orientation IZOD Pendulum Effect (I) Properties – RTD (70°F)
Partial Fiber (PF) Fill
Measured Energy
Markforged Onyx FR-A – Carbon Fiber FR-A / Markforged X7
AM Batch #
Machine #
Machine #
AM Batch #
Impact Energy [Joules]
0
1
2
3
4
0.0
0.1
0.1
0.2
0.2
0.3

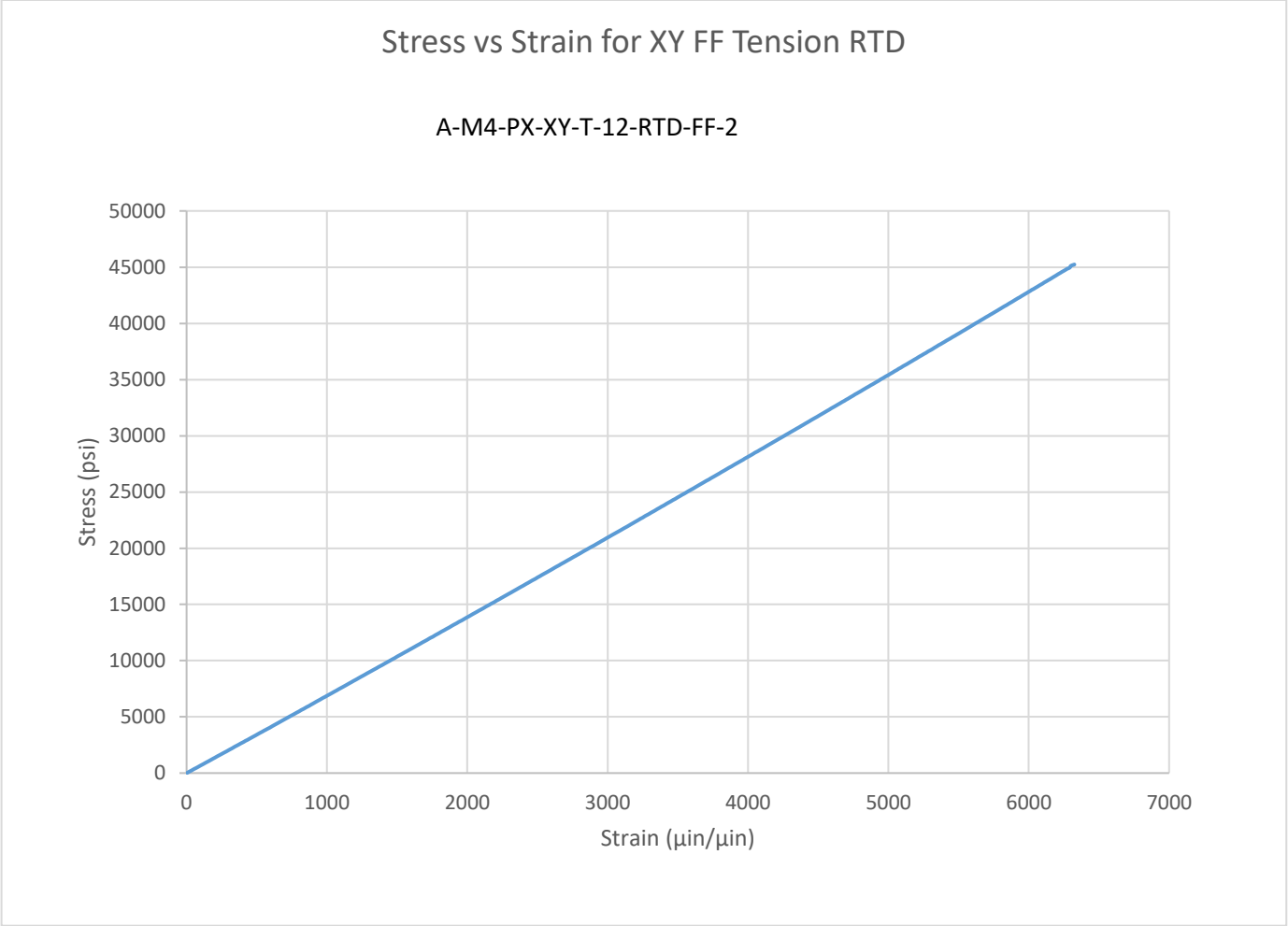

ZX Orientation IZOD Pendulum Effect (I) Properties – RTD (70°F)
Partial Fiber (PF) Fill
Measured Resistance
Markforged Onyx FR-A™ – Carbon Fiber FR-A™ / Markforged X7
AM Batch #
Machine #
Machine #
AM Batch #
Impact Resistance [Joules/meter]
0
1
2
3
4
0.00
5.00
10.00
15.00
20.00
25.00
30.00
35.00

5. Stress vs. Strain Curve

5.1 XY PF Tension Properties

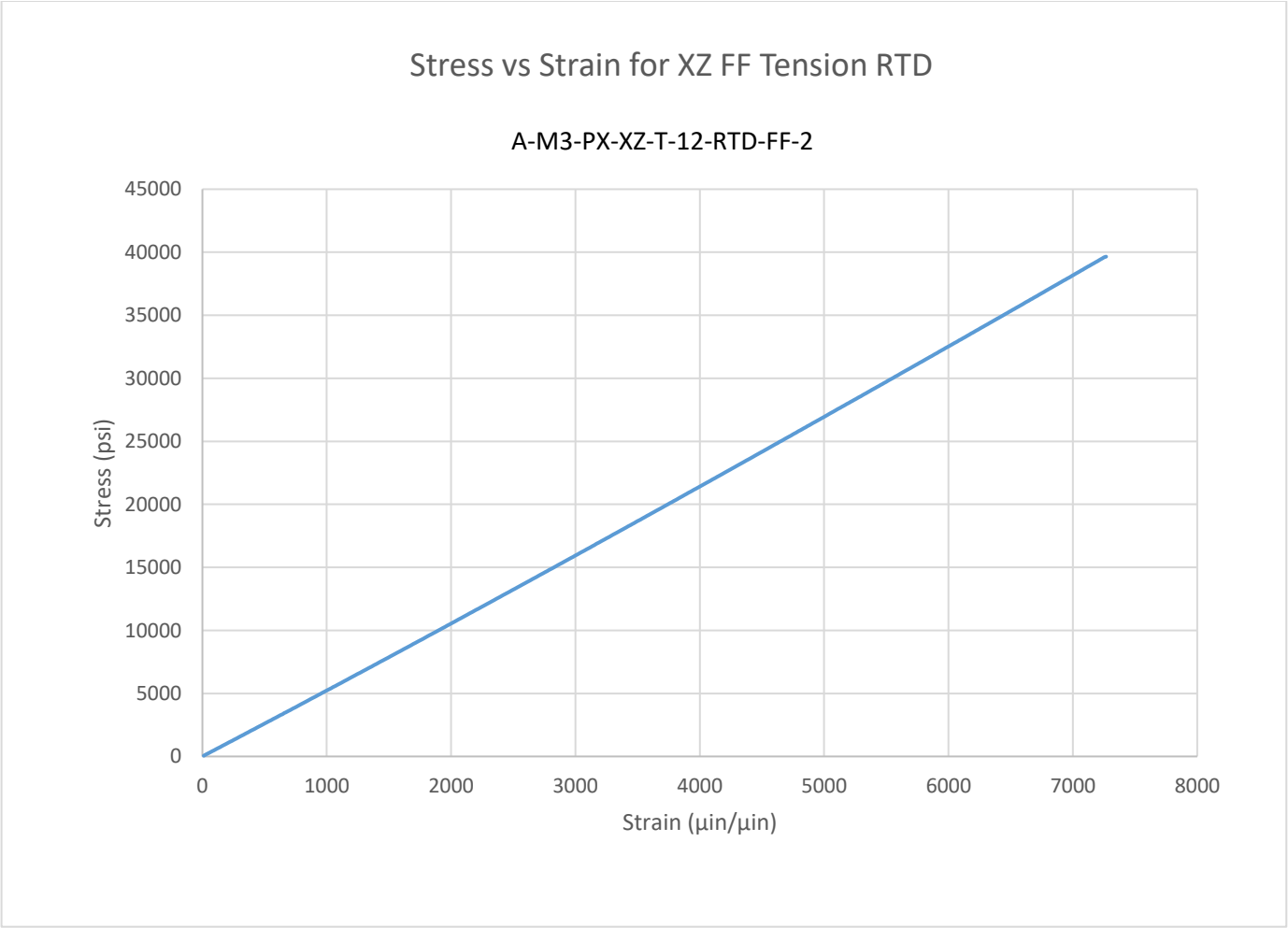


5.2 XY FF Tension Properties

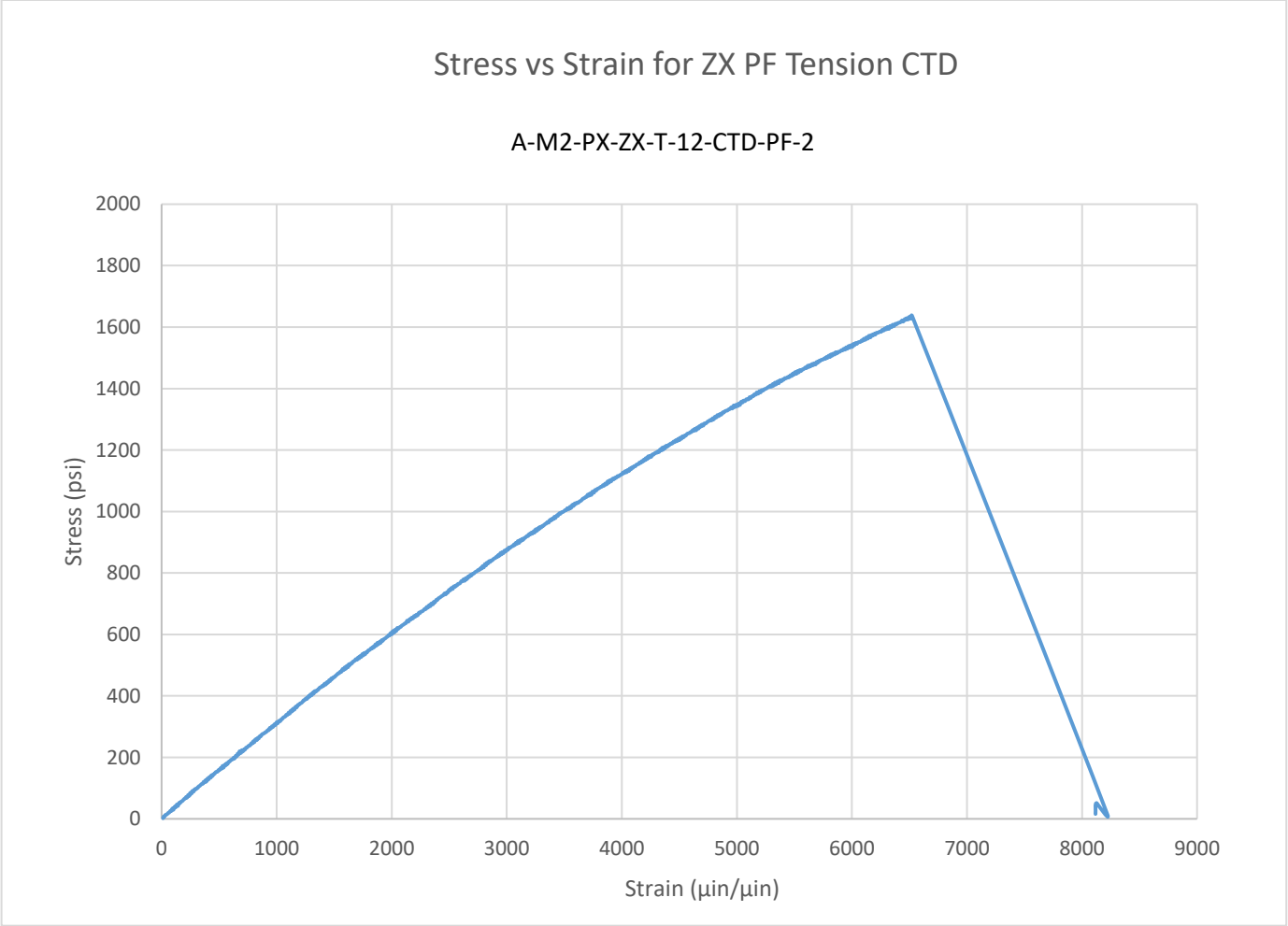


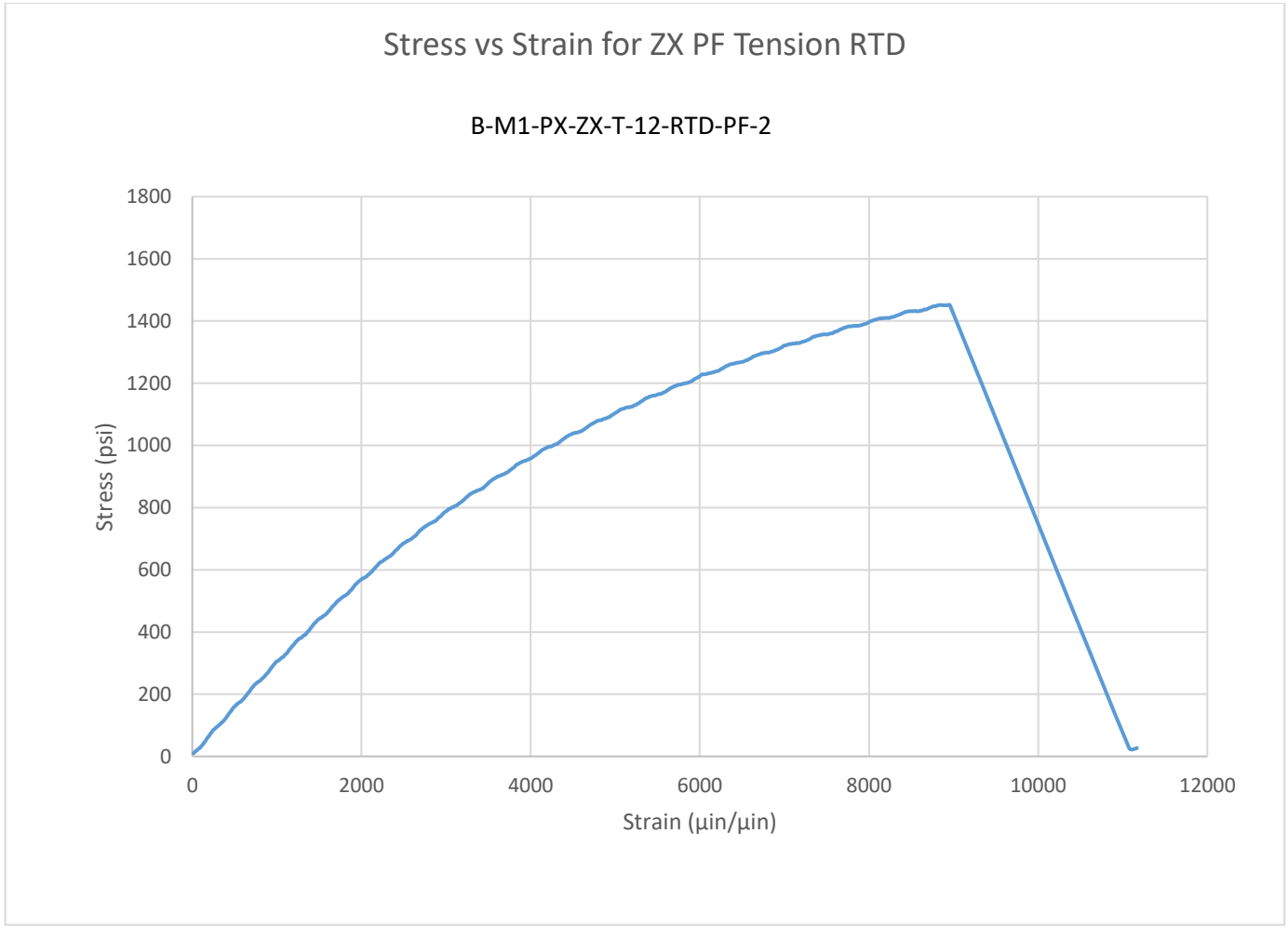
5.3 XZ PF Tension Properties

5.4 XZ FF Tension Properties

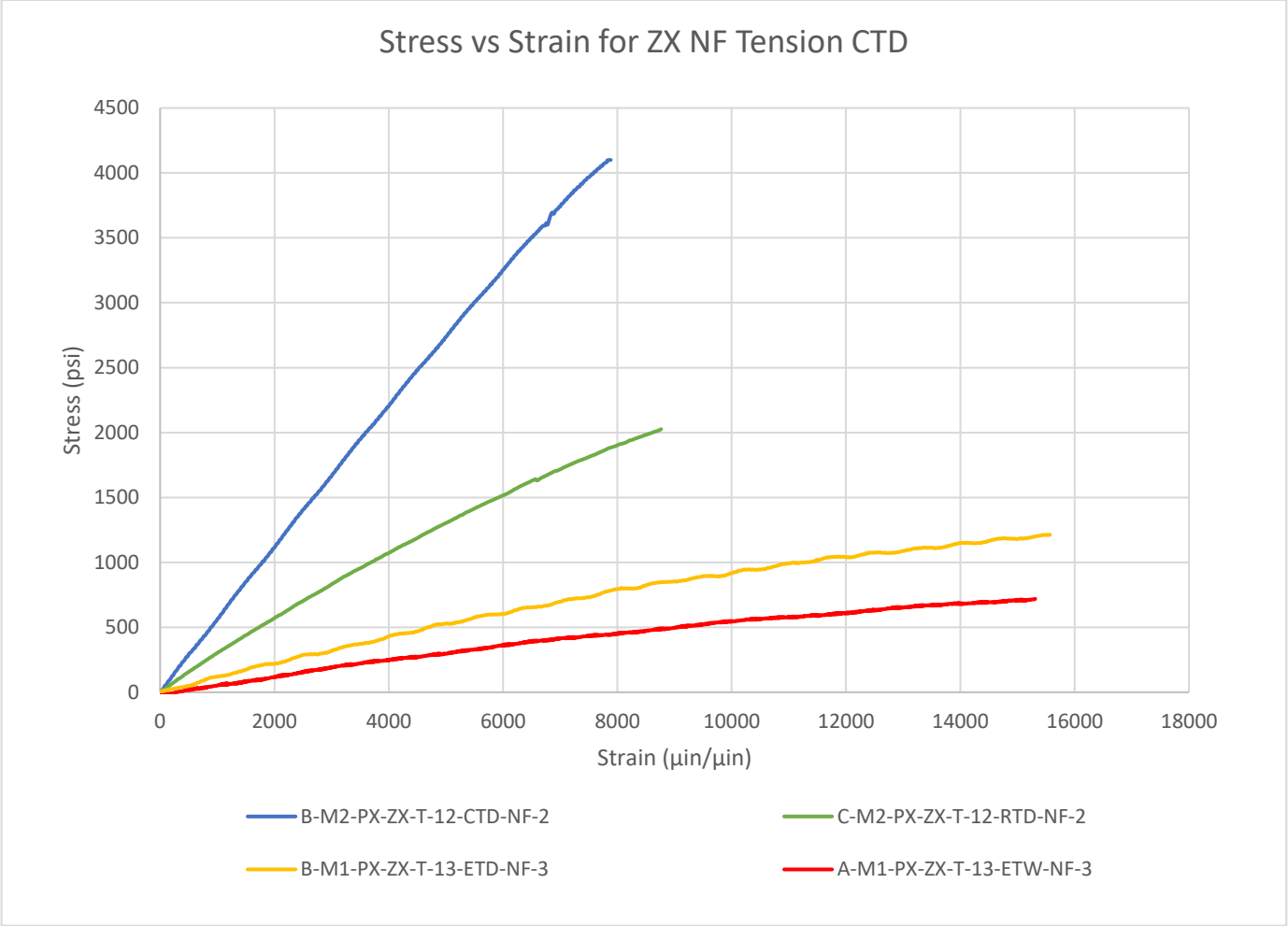


5.5 ZX PF Tension Properties – Reference Only

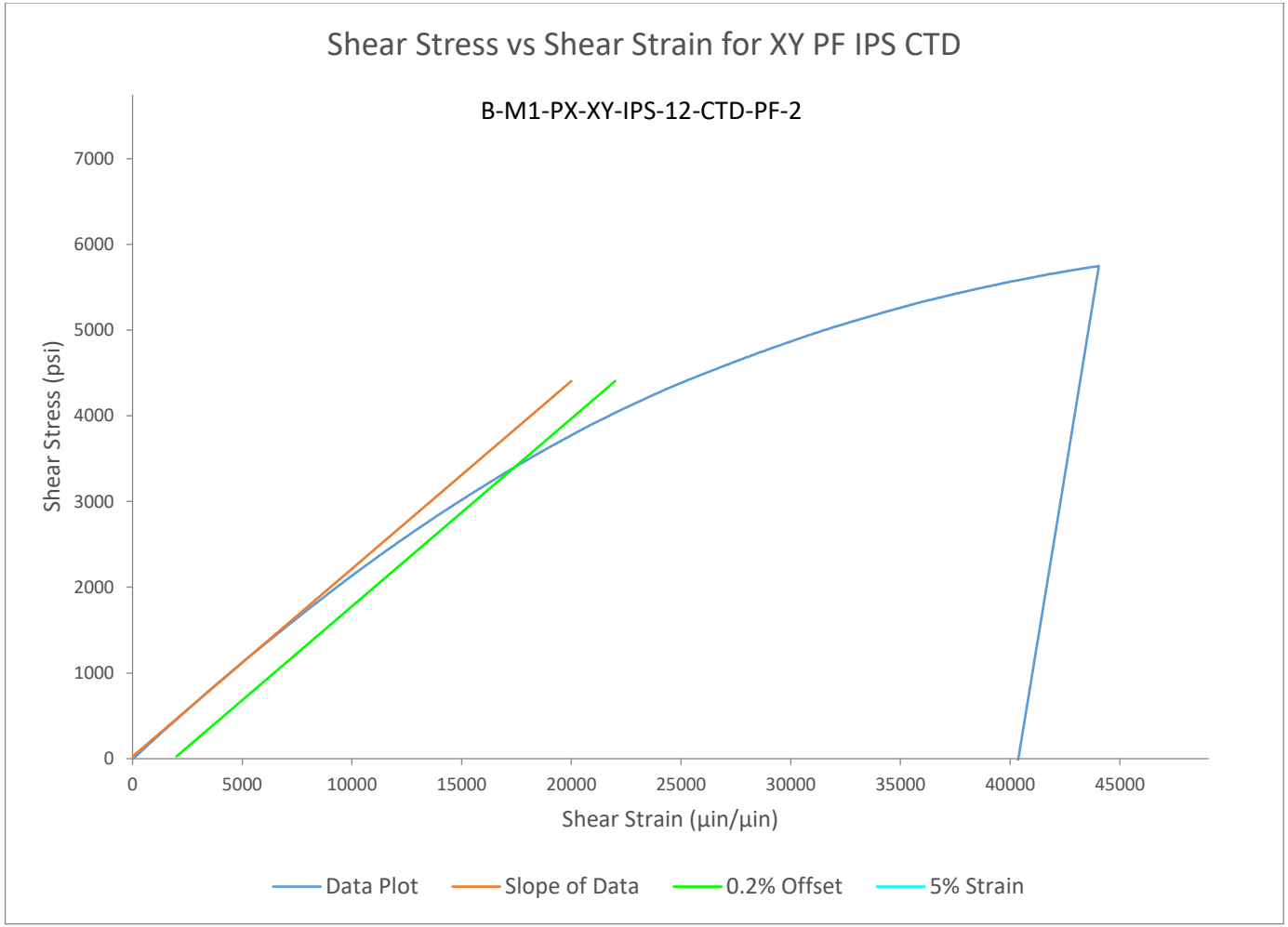


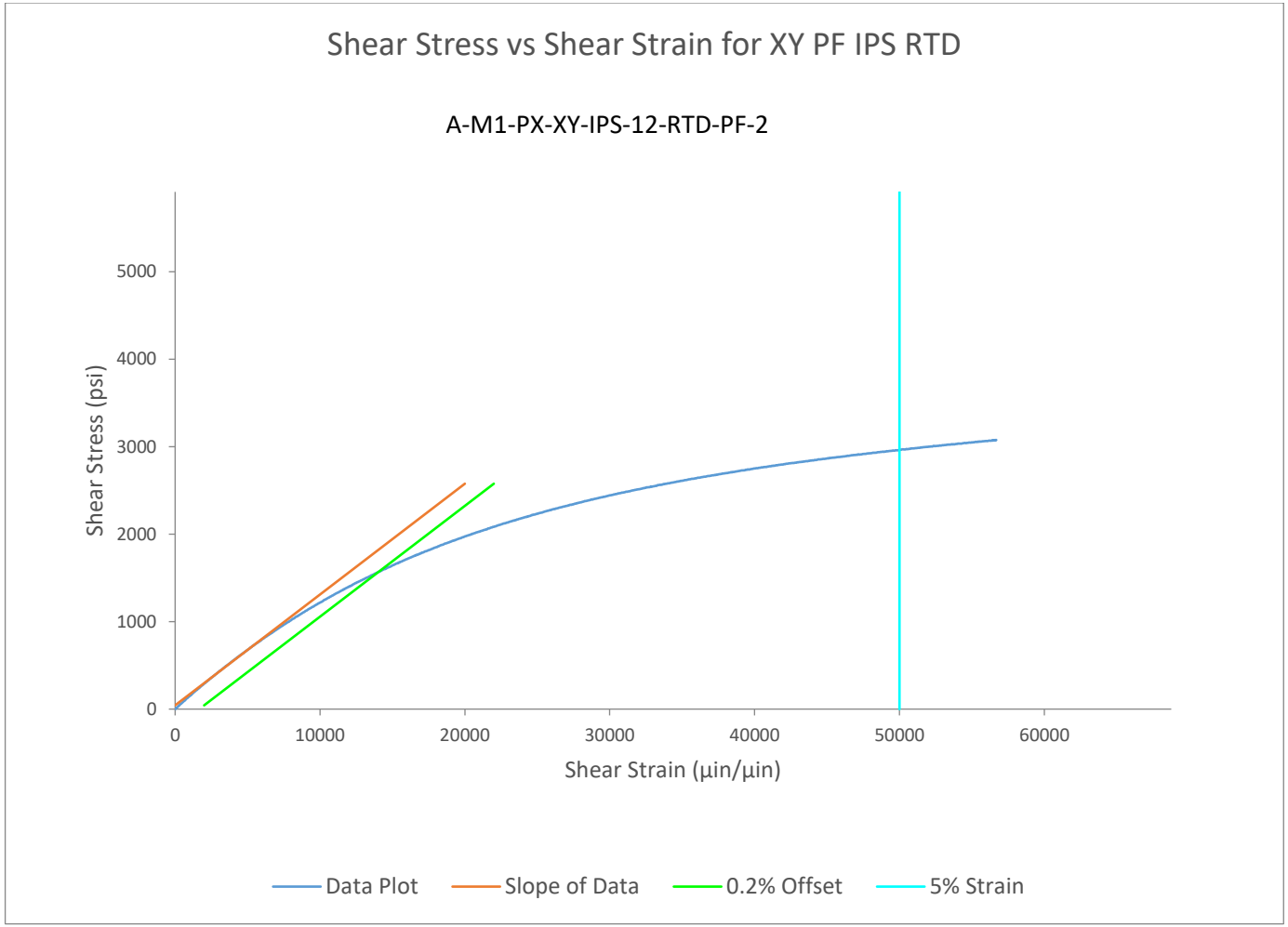

Stress vs Strain for ZX PF Tension RTD
B-M1-PX-ZX-T-12-RTD-PF-2
Stress (psi)
1800
1600
1400
1200
1000
800
600
400
200
0
0
2000
4000
6000
8000
10000
12000
Strain (µin/µin)

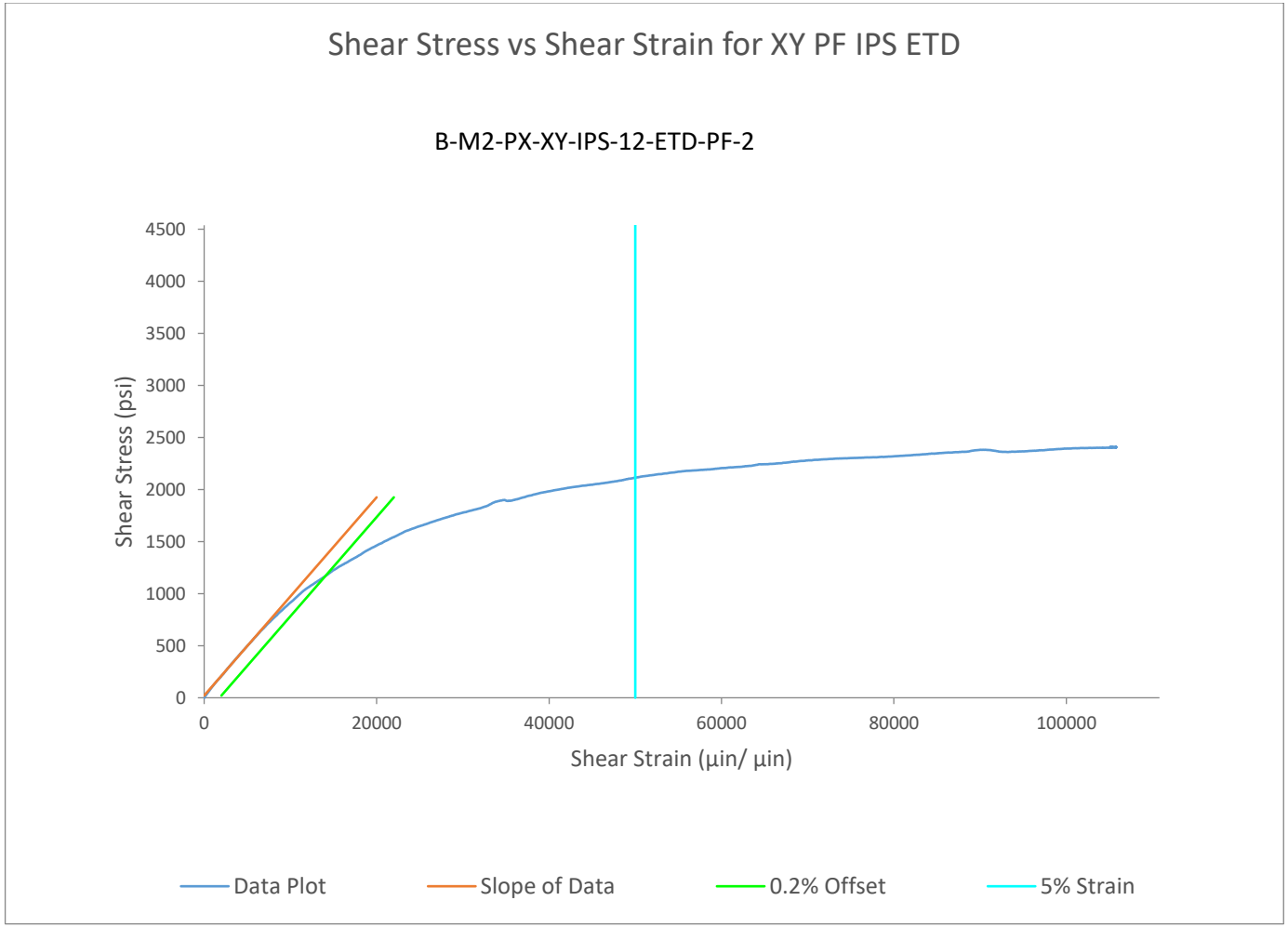
5.6 ZX NF Tension Properties

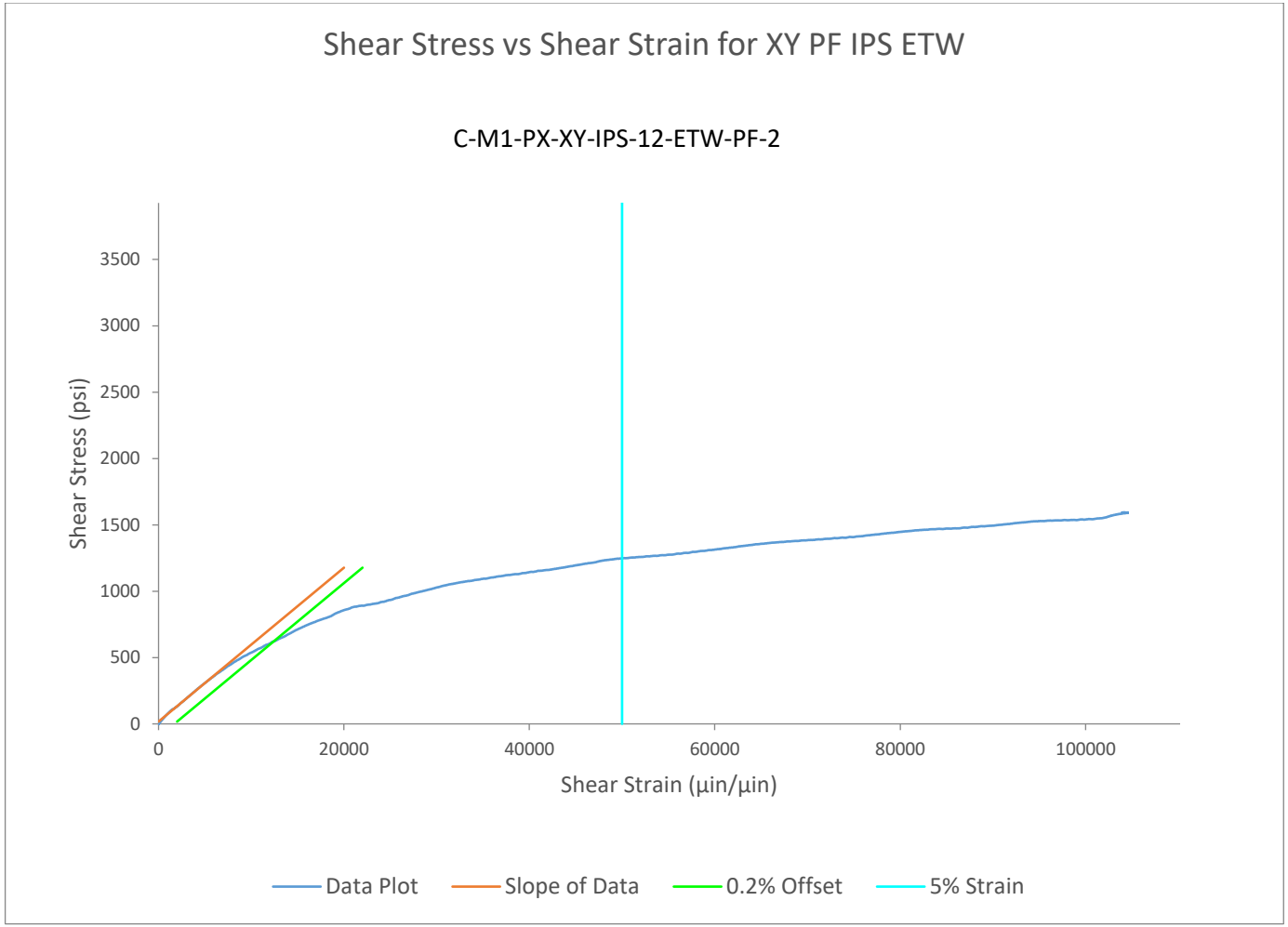


5.7 XY PF In-Plane Shear Properties

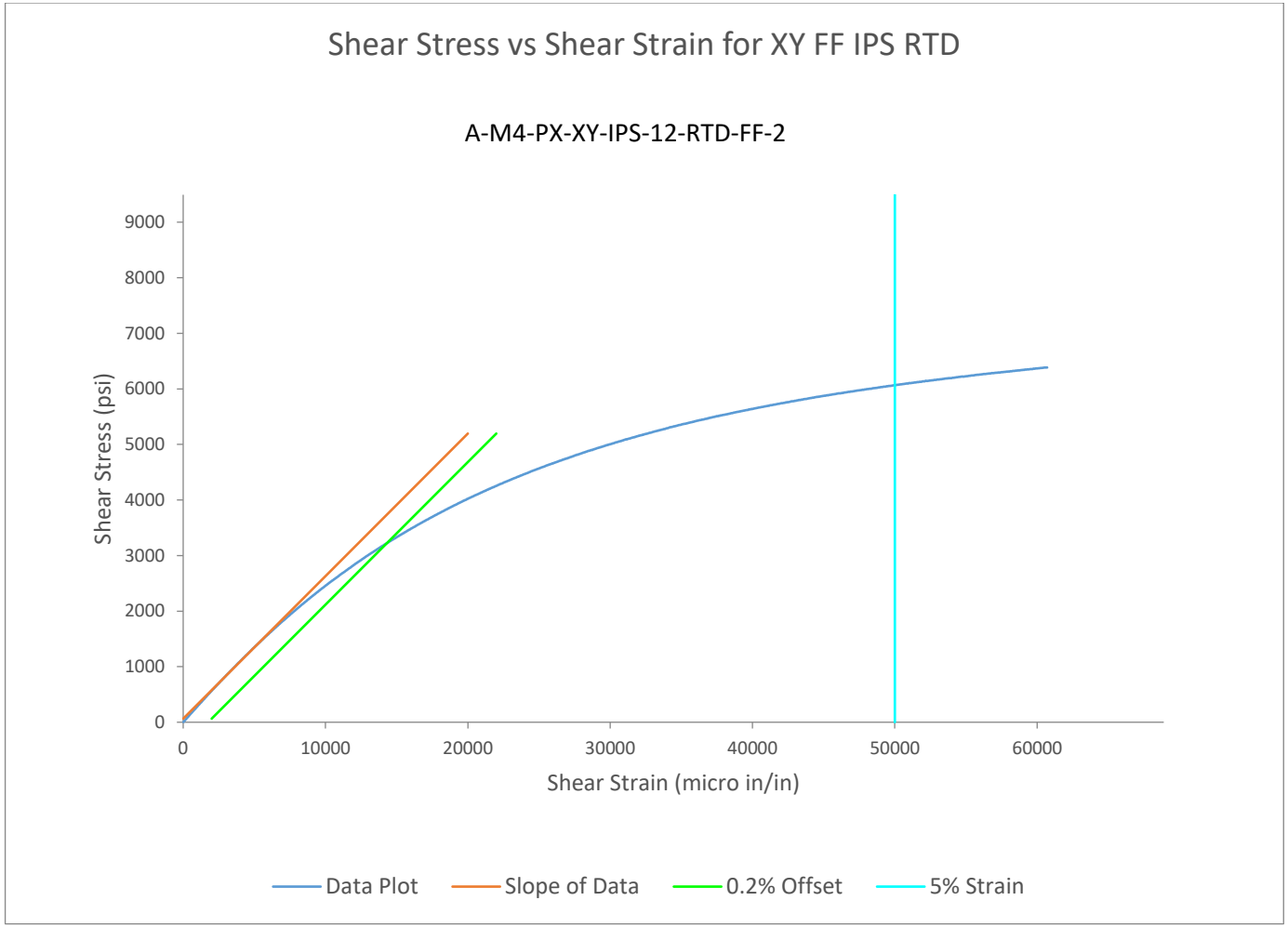



Shear Stress vs Shear Strain for XY PF IPS RTD
A-M1-PX-XY-IPS-12-RTD-PF-2
Shear Stress (psi)
5000
4000
3000
2000
1000
0
0
10000
20000
30000
40000
50000
60000
Shear Strain (µin/µin)
Data Plot
Slope of Data
0.2% Offset
5% Strain


Shear Stress vs Shear Strain for XY PF IPS ETD
B-M2-PX-XY-IPS-12-ETD-PF-2
Shear Stress (psi)
4500
4000
3500
3000
2500
2000
1500
1000
500
0
0
20000
40000
60000
80000
100000
Shear Strain (µin/ µin)
Data Plot
Slope of Data
0.2% Offset
5% Strain


Shear Stress vs Shear Strain for XY PF IPS ETW
C-M1-PX-XY-IPS-12-ETW-PF-2
Shear Stress (psi)
3500
3000
2500
2000
1500
1000
500
0
0
20000
40000
60000
80000
100000
Shear Strain (µin/µin)
Data Plot
Slope of Data
0.2% Offset
5% Strain

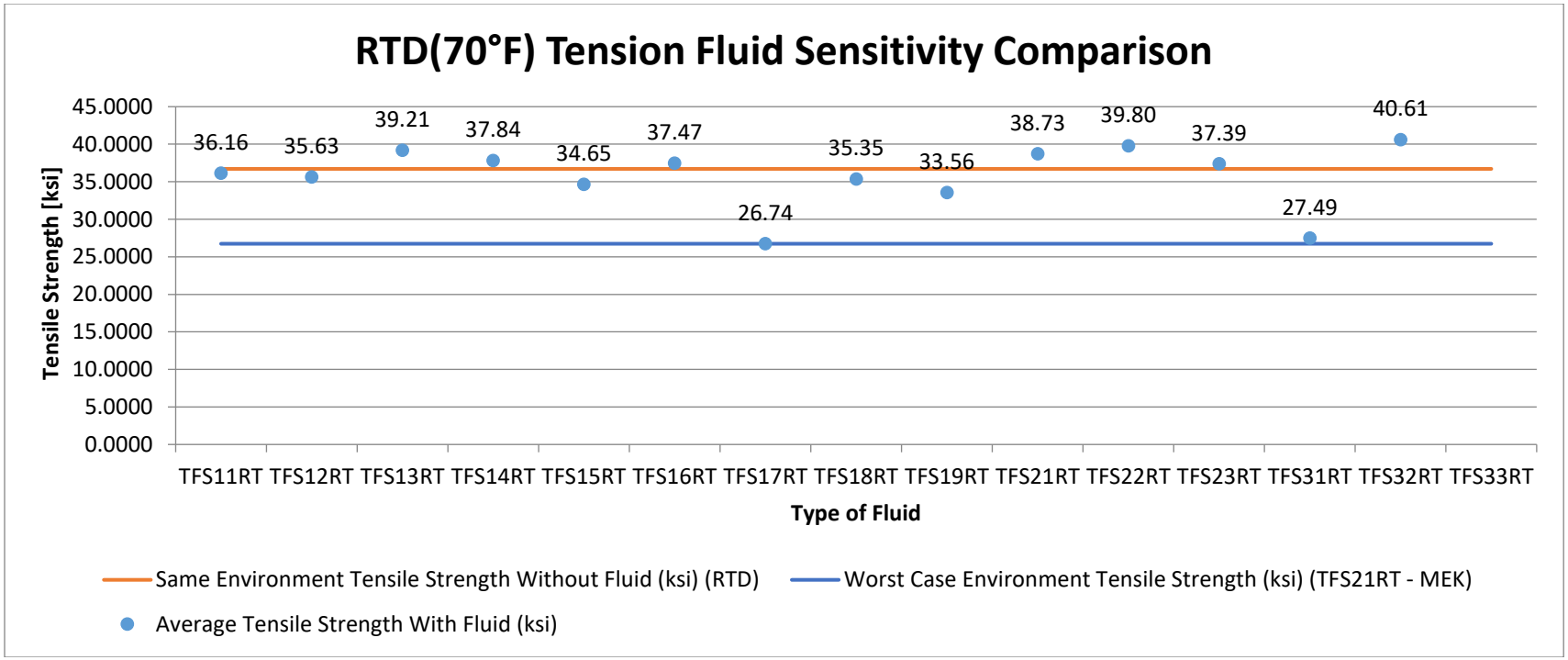
5.8 XY FF In-Plane Shear Properties

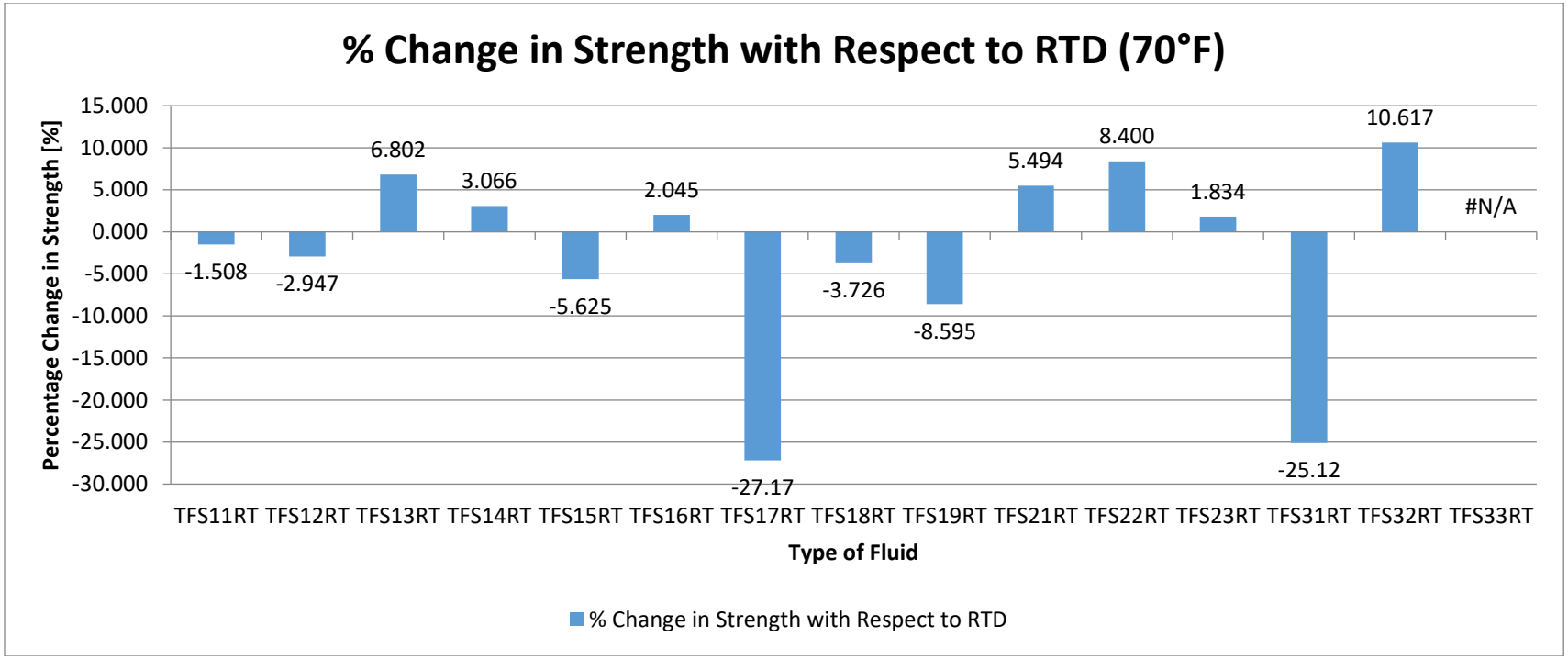


6. Fluid Sensitivity Comparison

Extended Contact:	Exposure	Test Condition	Code (1)
100 Low Lead Aviation Fuel (ASTM D910)	90 days min. @ 70°F±10°F	70°F	TFS11RT
	90 days min. @ 70°F±10°F	160°F	TFS11ET
ASTM D1655 Jet A Fuel (other jet fuel may be used but its type must be reported)	90 days min. @ 70°F±10°F	70°F	TFS12RT
	90 days min. @ 70°F±10°F	160°F	TFS12ET
MIL-PRF-5606 Hydraulic Oil	90 days min. @ 70°F±10°F	70°F	TFS13RT
	90 days min. @ 70°F±10°F	160°F	TFS13ET
MIL-PRF-83282 Hydraulic Oil	90 days min. @ 70°F±10°F	70°F	TFS14RT
	90 days min. @ 70°F±10°F	160°F	TFS14ET
MIL-PRF-7808 Engine Oil	90 days min. @ 70°F±10°F	70°F	TFS15RT
	90 days min. @ 70°F±10°F	160°F	TFS15ET
MIL-PRF-23699, Class STD Engine Oil	90 days min. @ 70°F±10°F	70°F	TFS16RT
	90 days min. @ 70°F±10°F	160°F	TFS16ET
Sea Water (ASTM D1141 or equiv.)	90 days min. @ 70°F±10°F	70°F	TFS17RT
	90 days min. @ 70°F±10°F	160°F	TFS17ET
Skydrol LD-4 (SAE AS1241, Type IV, Class 1)	90 days min. @ 70°F±10°F	70°F	TFS18RT
	90 days min. @ 70°F±10°F	160°F	TFS18ET
50% Water with 50% Skydrol LD-4 (SAE AS1241, Type IV, Class 1)	90 days min. @ 70°F±10°F	70°F	TFS19RT
	90 days min. @ 70°F±10°F	160°F	TFS19ET
Short Duration Contact:			
MEK washing fluid. ASTM D740	90 minutes min. @ 70°F±10°F	70°F	TFS21RT
	90 minutes min. @ 70°F±10°F	160°F	TFS21ET
Polypropylene Glycol Deicer (Type I) SAE AMS 1424	90 minutes min. @ 70°F±10°F	70°F	TFS22RT
	90 minutes min. @ 70°F±10°F	160°F	TFS22ET
Isopropyl Alcohol Deicing Agent (TT-I-735)	48±4 hours @70°F±10°F	70°F	TFS23RT
	48±4 hours @70°F±10°F	160°F	TFS23ET
Control Tests:			
Distilled Water	90 days min. at 70°F±10°F	70°F	TFS31RT
	90 days min. at 70°F±10°F	160°F	TFS31ET
Dry	Dry per section 5.2	70°F	TFS32RT
	Dry per section 5.2	160°F	TFS32ET

6.1 Room Temperature Test Data




% Change in Strength with Respect to RTD (70°F)
Percentage Change in Strength [%]
15.000
10.000
5.000
0.000
-5.000
-10.000
-15.000
-20.000
-25.000
-30.000
-1.508
-2.947
6.802
3.066
-5.625
2.045
-27.17
-3.726
-8.595
5.494
8.400
1.834
-25.12
10.617
#N/A
TFS11RT TFS12RT TFS13RT TFS14RT TFS15RT TFS16RT TFS17RT TFS18RT TFS19RT TFS21RT TFS22RT TFS23RT TFS31RT TFS32RT TFS33RT
Type of Fluid
% Change in Strength with Respect to RTD

Tension Fluid Sensitivity (TFS) Screening Properties RTD Strength
Markforged Onyx FR-A™ - Carbon Fiber FR-A™ / Markforged X7

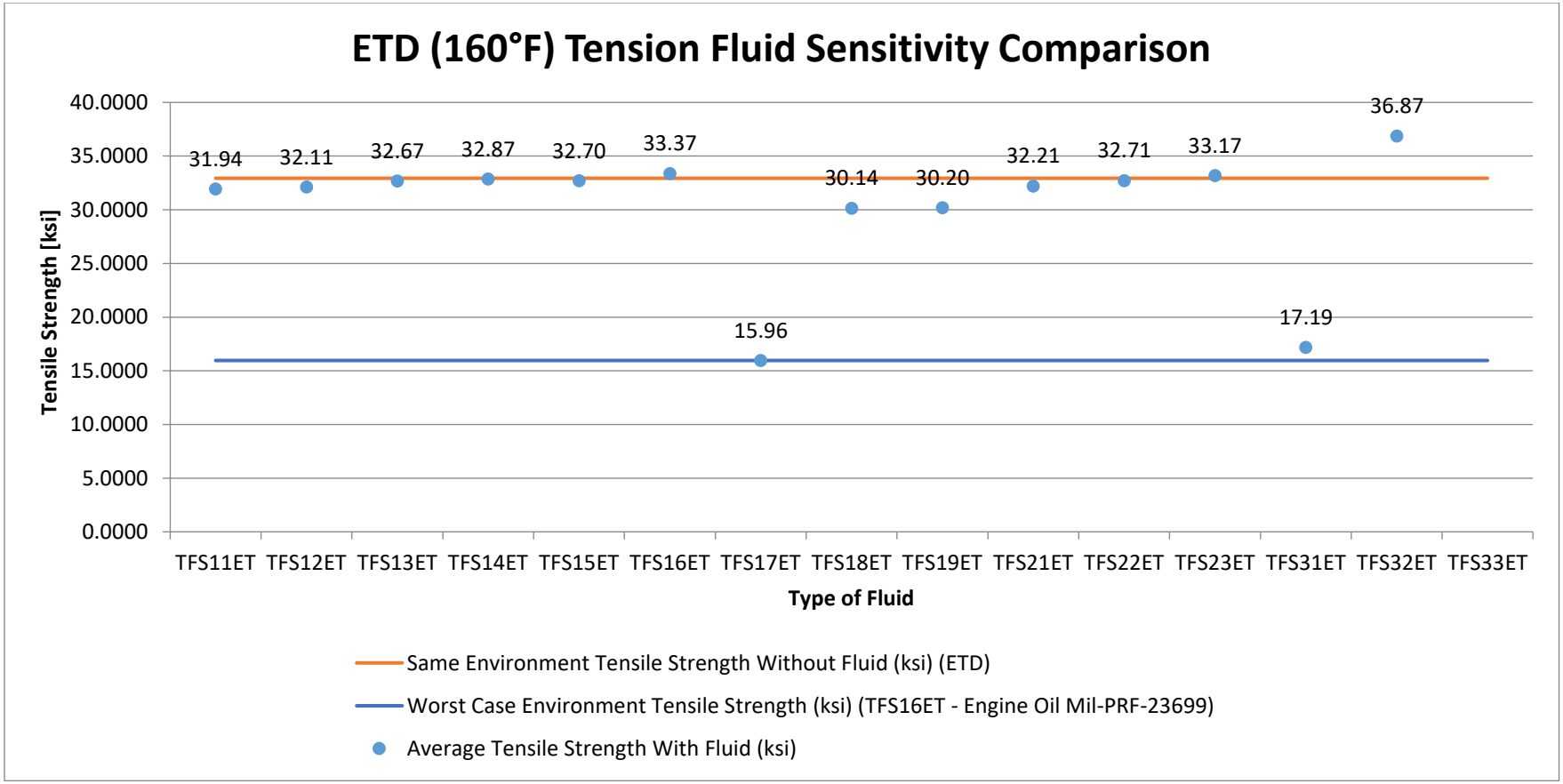
Fluid Code	Specimen Number	AM Batch #	Machine #	Tensile Strength [ksi]	Avg. Specimen Thickness [in]	Failure Mode	Average
TFS11RT	NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M3-P31996-XY-TFS11RT-11-RTA-PF-1	1	3	36.487	0.143	M(A,L,D)WT	36.161
	NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M3-P32761-XY-TFS11RT-12-RTA-PF-2	1	3	35.874	0.143	M(A,L,D)WB	
	NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M3-P32500-XY-TFS11RT-13-RTA-PF-3	1	3	35.778	0.143	M(A,D,L)GM	
	NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M3-P32266-XY-TFS11RT-11-RTA-PF-4	1	3	35.798	0.143	DGM, AWB	
	NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M3-P32699-XY-TFS11RT-13-RTA-PF-5	1	3	36.869	0.144	M(A,D,L)GB	
TFS12RT	NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M3-P32500-XY-TFS12RT-11-RTA-PF-1	1	3	33.820	0.143	M(A,L)AT, DGM	35.633
	NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M3-P31996-XY-TFS12RT-12-RTA-PF-2	1	3	41.404	0.143	DGM, AWT, AWB	
	NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M3-P32761-XY-TFS12RT-13-RTA-PF-3	1	3	37.875	0.142	M(A,L)WT	
	NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M3-P32699-XY-TFS12RT-11-RTA-PF-4	1	3	32.718	0.144	DGM, AWT	
	NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M3-P38306-XY-TFS12RT-13-RTA-PF-5	1	3	32.348	0.142	M(A,D)GM, M(A,L)WT	
TFS13RT	NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M3-P32761-XY-TFS13RT-11-RTA-PF-1	1	3	39.420	0.141	DGT, M(A,L)WT	39.212
	NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M3-P32500-XY-TFS13RT-12-RTA-PF-2	1	3	40.141	0.143	DGB, M(A,L)WB	
	NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M3-P31996-XY-TFS13RT-13-RTA-PF-3	1	3	41.317	0.142	DGB, M(A,L)WB	
	NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M3-P38306-XY-TFS13RT-11-RTA-PF-4	1	3	36.773	0.140	M(A,L,D)GT	
	NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M3-P32266-XY-TFS13RT-13-RTA-PF-5	1	3	38.409	0.143	M(A,L,D)GT	
TFS14RT	NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M3-P32095-XY-TFS14RT-11-RTA-PF-1	1	3	38.911	0.144	M(A,L)AT	37.840
	NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M3-P33017-XY-TFS14RT-12-RTA-PF-2	1	3	38.348	0.145	M(A,L)GB, DGM	
	NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M3-P32872-XY-TFS14RT-13-RTA-PF-3	1	3	34.442	0.144	M(A,L)WT, DGM	
	NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M3-P32343-XY-TFS14RT-11-RTA-PF-4	1	3	37.438	0.144	M(A,L,D)WB	
	NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M3-P32951-XY-TFS14RT-13-RTA-PF-5	1	3	40.062	0.143	M(A,L,D)WB	
TFS15RT	NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M3-P32872-XY-TFS15RT-11-RTA-PF-1	1	3	34.404	0.142	M(A,L)WB	34.650
	NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M3-P32095-XY-TFS15RT-12-RTA-PF-2	1	3	36.852	0.142	M(A,L)WB, DGM	
	NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M3-P33017-XY-TFS15RT-13-RTA-PF-3	1	3	32.780	0.143	M(A,L,D)GT	
	NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M3-P32951-XY-TFS15RT-11-RTA-PF-4	1	3	33.561	0.143	DGM, M(A,L)WB	
	NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M3-P33094-XY-TFS15RT-13-RTA-PF-5	1	3	35.651	0.143	M(A,L,D)WB	
TFS16RT	NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M3-P33017-XY-TFS16RT-11-RTA-PF-1	1	3	37.617	0.143	M(A,L)WB, DGM	37.465
	NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M3-P32872-XY-TFS16RT-12-RTA-PF-2	1	3	37.778	0.142	DGM, AWT	
	NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M3-P32095-XY-TFS16RT-13-RTA-PF-3	1	3	36.941	0.141	DGM, M(A,L)WT, M(A,L)WB	
	NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M3-P33094-XY-TFS16RT-11-RTA-PF-4	1	3	38.136	0.143	M(A,D,L)GM	
	NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M3-P32343-XY-TFS16RT-13-RTA-PF-5	1	3	36.856	0.142	M(A,L)WB, DGM	
TFS17RT	NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M3-P32185-XY-TFS17RT-11-RTA-PF-1	1	3	27.065	0.142	M(A,L)WB, GRIP SECTION CRUSH	26.740
	NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M3-P33420-XY-TFS17RT-12-RTA-PF-2	1	3	27.020	0.141	M(A,L)WB, GRIP SECTION CRUSH	
	NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M3-P37011-XY-TFS17RT-13-RTA-PF-3	1	3	27.116	0.141	M(A,L)WB, GRIP SECTION CRUSH	
	NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M3-P32401-XY-TFS17RT-11-RTA-PF-4	1	3	26.633	0.142	M(A,L)WB, GRIP SECTION CRUSH	
	NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M3-P33292-XY-TFS17RT-13-RTA-PF-5	1	3	25.865	0.142	M(A,L)WB, GRIP SECTION CRUSH	

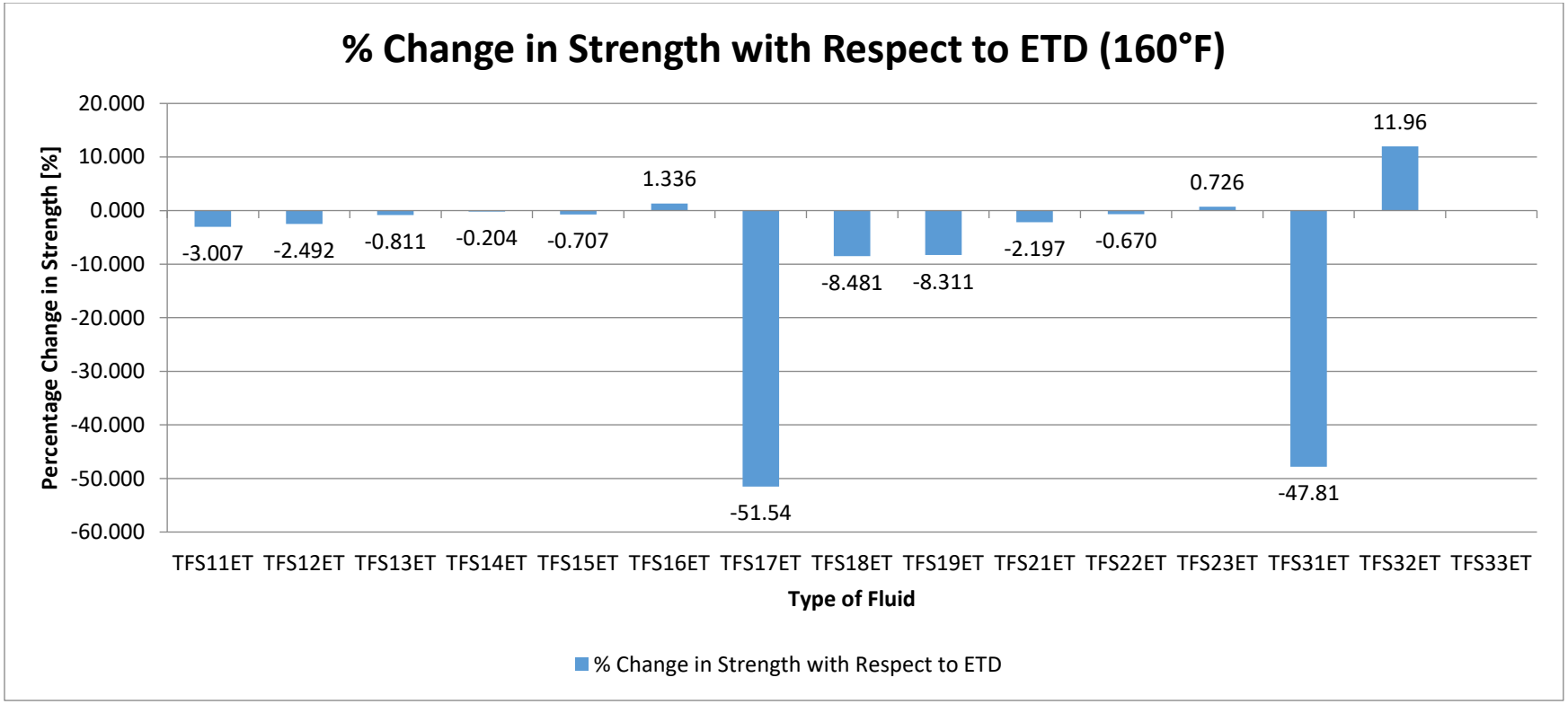
	NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M3-P37011-XY-TFS18RT-11-RTA-PF-1	1	3	37.582	0.142	M(A,L)WB	
	NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M3-P32185-XY-TFS18RT-12-RTA-PF-2	1	3	35.797	0.142	DGM, M(A,L)GT	
TFS18RT	NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M3-P33420-XY-TFS18RT-13-RTA-PF-3	1	3	35.505	0.142	M(A,L)WT	35.347
	NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M3-P33292-XY-TFS18RT-11-RTA-PF-4	1	3	34.517	0.143	DGM, M(A,L)WT, M(A,L)WB	
	NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M3-P33441-XY-TFS18RT-13-RTA-PF-5	1	3	33.333	0.142	M(A,L)WT	
	NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M3-P33420-XY-TFS19RT-11-RTA-PF-1	1	3	27.797	0.142	M(A,L)GT	
	NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M3-P37011-XY-TFS19RT-12-RTA-PF-2	1	3	34.810	0.142	M(A,L)GB	
TFS19RT	NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M3-P32185-XY-TFS19RT-13-RTA-PF-3	1	3	36.942	0.141	M(A,L)WB	33.559
	NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M3-P33441-XY-TFS19RT-11-RTA-PF-4	1	3	34.231	0.143	AWB	
	NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M3-P32401-XY-TFS19RT-13-RTA-PF-5	1	3	34.015	0.142	AWB	
	NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M3-P37720-XY-TFS21RT-11-RTA-PF-1	1	3	39.279	0.141	M(A,L)WT	
	NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M3-P33649-XY-TFS21RT-12-RTA-PF-2	1	3	39.411	0.142	M(A,L)GB	
TFS21RT	NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M3-P33518-XY-TFS21RT-13-RTA-PF-3	1	3	38.095	0.142	AGB	38.732
	NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M3-P32419-XY-TFS21RT-11-RTA-PF-4	1	3	37.672	0.143	LAT	
	NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M3-P33599-XY-TFS21RT-13-RTA-PF-5	1	3	39.201	0.142	M(A,L)GT	
	NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M3-P33518-XY-TFS22RT-11-RTA-PF-1	1	3	39.412	0.143	DGM, M(A,L)WT	
	NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M3-P37720-XY-TFS22RT-12-RTA-PF-2	1	3	38.017	0.142	M(A,L)WT	
TFS22RT	NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M3-P33649-XY-TFS22RT-13-RTA-PF-3	1	3	39.722	0.143	AWT	39.799
	NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M3-P33599-XY-TFS22RT-11-RTA-PF-4	1	3	40.939	0.143	DGM, AGT	
	NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M3-P33690-XY-TFS22RT-13-RTA-PF-5	1	3	40.905	0.142	M(A,L)GM	
	NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M3-P33649-XY-TFS23RT-11-RTA-PF-1	1	3	36.967	0.143	M(A,L)WT	
	NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M3-P33518-XY-TFS23RT-12-RTA-PF-2	1	3	34.618	0.144	M(A,L)WT	
TFS23RT	NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M3-P37720-XY-TFS23RT-13-RTA-PF-3	1	3	36.807	0.141	M(A,L)WT	37.388
	NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M3-P33690-XY-TFS23RT-11-RTA-PF-4	1	3	39.218	0.141	M(A,L)WT	
	NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M3-P32419-XY-TFS23RT-13-RTA-PF-5	1	3	39.329	0.142	DGM	
	NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M3-P32249-XY-TFS31RT-11-RTA-PF-1*	1	3	30.180	0.142	M(A,L)AB, GRIP SECTION CRUSH	
	NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M3-P33844-XY-TFS31RT-12-RTA-PF-2*	1	3	30.456	0.142	M(A,L)AB, GRIP SECTION CRUSH	
TFS31RT	NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M3-P33739-XY-TFS31RT-13-RTA-PF-3*	1	3	27.404	0.141	M(A,L)AB, GRIP SECTION CRUSH	27.493
	NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M3-P32455-XY-TFS31RT-11-RTA-PF-4*	1	3	25.436	0.142	M(A,L)AT, GRIP SECTION CRUSH	
	NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M3-P33797-XY-TFS31RT-13-RTA-PF-5*	1	3	23.990	0.143	M(A,L)AB, GRIP SECTION CRUSH	
	NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M3-P33739-XY-TFS32RT-11-RTA-PF-1	1	3	37.194	0.142	AGM	
	NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M3-P32249-XY-TFS32RT-12-RTA-PF-2	1	3	44.040	0.142	M(A,L)GM	
TFS32RT	NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M3-P33844-XY-TFS32RT-13-RTA-PF-3	1	3	40.660	0.141	M(A,L)WB	40.613
	NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M3-P33797-XY-TFS32RT-11-RTA-PF-4	1	3	39.391	0.142	M(A,L)WT	
	NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M3-P33871-XY-TFS32RT-13-RTA-PF-5	1	3	41.778	0.143	DGM, M(A,L)WT, M(A,L)WB	

* Improper failure mode (Data reported for reference only)

Average	**35.759**	**0.142**
Standard Dev.	**4.468**	
Coeff. of Var. [%]	**12.493**	
Min.	**23.990**	**0.140**
Max.	**44.040**	**0.145**
Number of Spec.	**70**	**70**

6.2 Elevated Temperature Test Data




% Change in Strength with Respect to ETD (160°F)
Percentage Change in Strength [%]
20.000
10.000
0.000
-10.000
-20.000
-30.000
-40.000
-50.000
-60.000
-3.007
-2.492
-0.811
-0.204
-0.707
1.336
-51.54
-8.481
-8.311
-2.197
-0.670
0.726
-47.81
11.96
TFS11ET TFS12ET TFS13ET TFS14ET TFS15ET TFS16ET TFS17ET TFS18ET TFS19ET TFS21ET TFS22ET TFS23ET TFS31ET TFS32ET TFS33ET
Type of Fluid
% Change in Strength with Respect to ETD

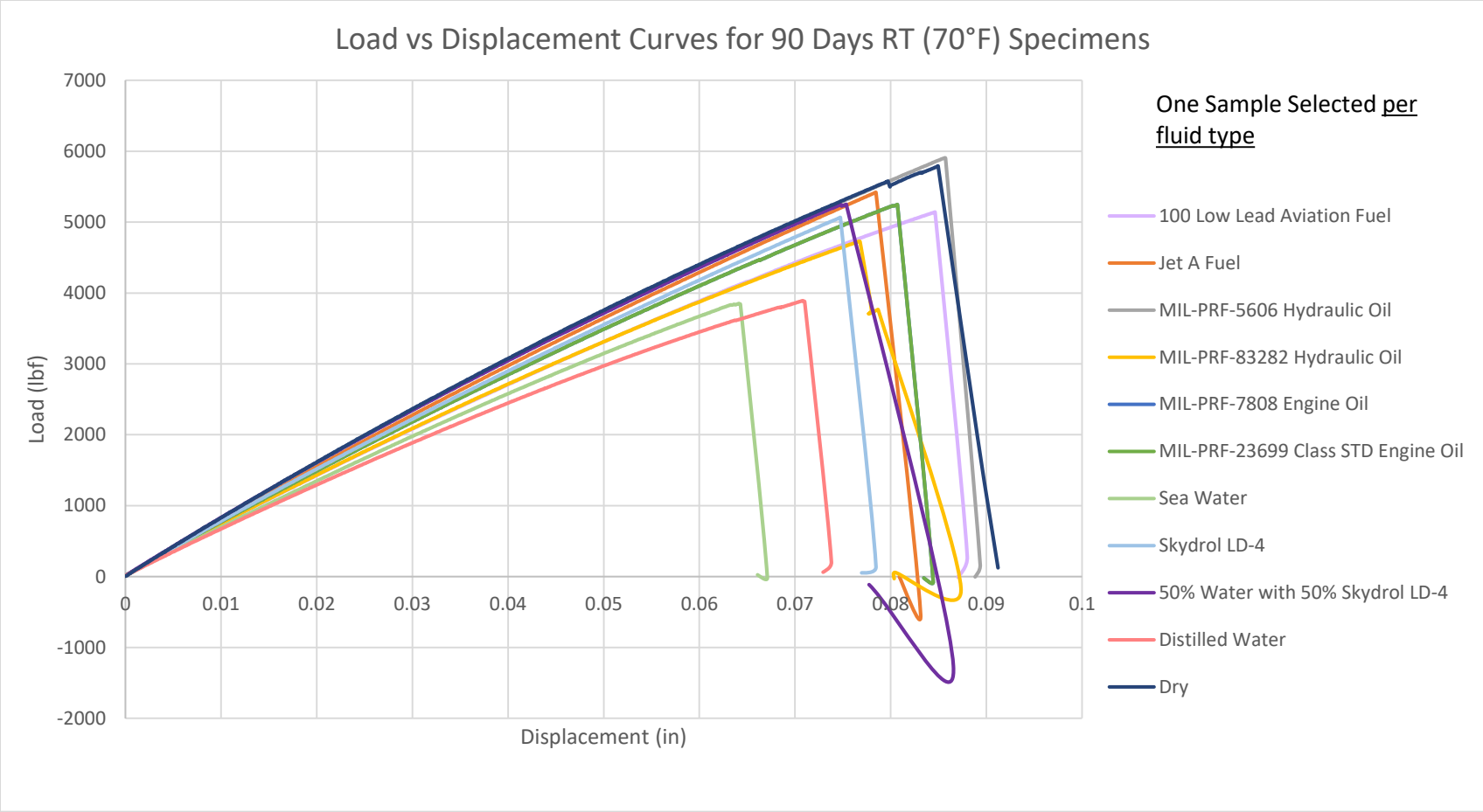
Tension Fluid Sensitivity (TFS) Screening Properties ETD Strength
Markforged OFRA-CFRA Qualification

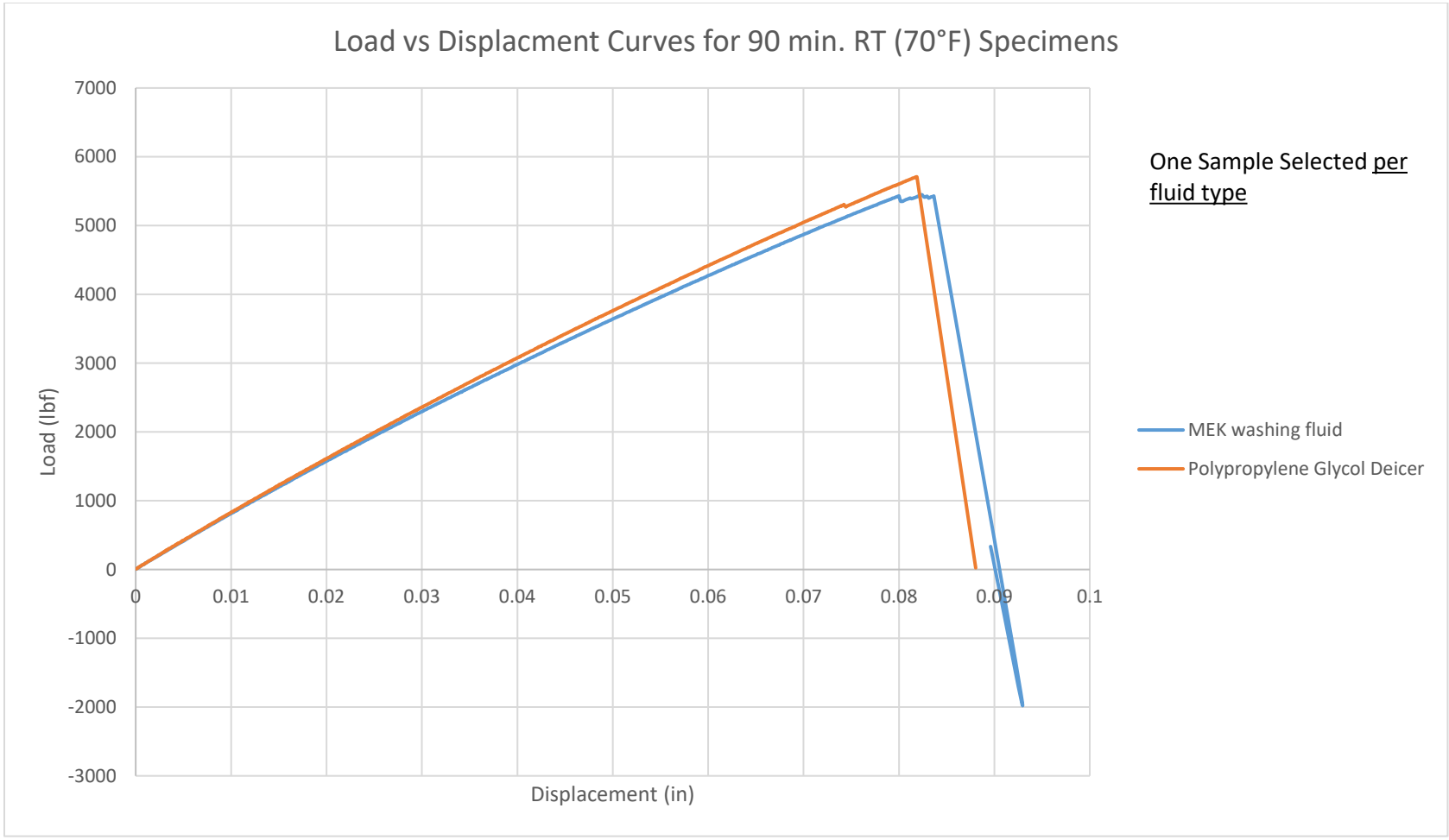
Fluid Code	Specimen Number	AM Batch #	Machine #	Tensile Strength [ksi]	Avg. Specimen Thickness [in]	Failure Mode	Average
TFS11ET	NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M3-P31996-XY-TFS11ET-11-ETA-PF-1	1	3	32.742	0.142	M(A,L)AB	31.943
	NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M3-P38306-XY-TFS11ET-12-ETA-PF-2	1	3	29.831	0.142	M(A,L)WT	
	NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M3-P32500-XY-TFS11ET-13-ETA-PF-3	1	3	33.064	0.142	M(A,L)WT	
	NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M3-P32266-XY-TFS11ET-11-ETA-PF-4	1	3	31.427	0.142	M(A,L)WB	
	NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M3-P32699-XY-TFS11ET-13-ETA-PF-5	1	3	32.651	0.143	M(A,L)WT	
TFS12ET	NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M3-P32500-XY-TFS12ET-11-ETA-PF-1	1	3	31.356	0.142	M(A,L)AB	32.113
	NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M3-P32266-XY-TFS12ET-12-ETA-PF-2	1	3	33.346	0.143	M(A,L)WT	
	NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M3-P32761-XY-TFS12ET-13-ETA-PF-3	1	3	34.562	0.142	M(A,L)WB	
	NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M3-P32699-XY-TFS12ET-11-ETA-PF-4	1	3	30.115	0.143	M(A,L)WT	
	NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M3-P38306-XY-TFS12ET-13-ETA-PF-5	1	3	31.186	0.142	M(A,L)WB	
TFS13ET	NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M3-P32761-XY-TFS13ET-11-ETA-PF-1	1	3	33.789	0.142	M(A,L)WT	32.666
	NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M3-P32699-XY-TFS13ET-12-ETA-PF-2	1	3	32.633	0.143	M(A,L)WT	
	NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M3-P31996-XY-TFS13ET-13-ETA-PF-3	1	3	34.205	0.143	M(A,L)WB	
	NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M3-P38306-XY-TFS13ET-11-ETA-PF-4	1	3	32.311	0.140	M(A,L)WB	
	NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M3-P32266-XY-TFS13ET-13-ETA-PF-5	1	3	30.394	0.143	M(A,L)WB	
TFS14ET	NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M3-P32095-XY-TFS14ET-11-ETA-PF-1	1	3	32.840	0.142	M(A,L)AB	32.866
	NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M3-P33094-XY-TFS14ET-12-ETA-PF-2	1	3	32.815	0.143	M(A,L)WB	
	NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M3-P32872-XY-TFS14ET-13-ETA-PF-3	1	3	31.592	0.142	M(A,L)WB	
	NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M3-P32343-XY-TFS14ET-11-ETA-PF-4	1	3	34.233	0.141	M(A,L)WB	
	NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M3-P32951-XY-TFS14ET-13-ETA-PF-5	1	3	32.851	0.142	M(A,L)AB	
TFS15ET	NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M3-P32872-XY-TFS15ET-11-ETA-PF-1	1	3	31.790	0.143	M(A,L)WB	32.700
	NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M3-P32343-XY-TFS15ET-12-ETA-PF-2	1	3	32.632	0.142	M(A,L)WT	
	NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M3-P33017-XY-TFS15ET-13-ETA-PF-3	1	3	31.865	0.145	M(A,D,L)GM	
	NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M3-P32951-XY-TFS15ET-11-ETA-PF-4	1	3	34.374	0.143	M(A,L)WT, M(A,L)WB	
	NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M3-P33094-XY-TFS15ET-13-ETA-PF-5	1	3	32.841	0.144	DGM, AWB	
TFS16ET	NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M3-P33017-XY-TFS16ET-11-ETA-PF-1	1	3	34.322	0.143	M(A,L)WT	33.373
	NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M3-P32951-XY-TFS16ET-12-ETA-PF-2	1	3	33.771	0.142	M(A,L)WT	
	NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M3-P32095-XY-TFS16ET-13-ETA-PF-3	1	3	33.646	0.142	M(A,L)AT	
	NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M3-P33094-XY-TFS16ET-11-ETA-PF-4	1	3	33.170	0.143	M(A,L)WB	
	NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M3-P32343-XY-TFS16ET-13-ETA-PF-5	1	3	31.958	0.143	M(A,L)WB	
TFS17ET	NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M3-P32185-XY-TFS17ET-11-ETA-PF-1	1	3		0.143	DIT, DIB, GRIP SECTION CRUSH	15.959
	NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M3-P33441-XY-TFS17ET-12-ETA-PF-2	1	3	15.602	0.144	AGM, DIT, DIB, GRIP SECTION CRUSH	
	NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M3-P37011-XY-TFS17ET-13-ETA-PF-3	1	3		0.142	DIT, DIB, GRIP SECTION CRUSH	
	NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M3-P32401-XY-TFS17ET-11-ETA-PF-4	1	3	17.434	0.143	AGM, DIT, DIB, GRIP SECTION CRUSH	
	NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M3-P33292-XY-TFS17ET-13-ETA-PF-5	1	3	14.841	0.144	AWB, DIT, DIB, GRIP SECTION CRUSH	

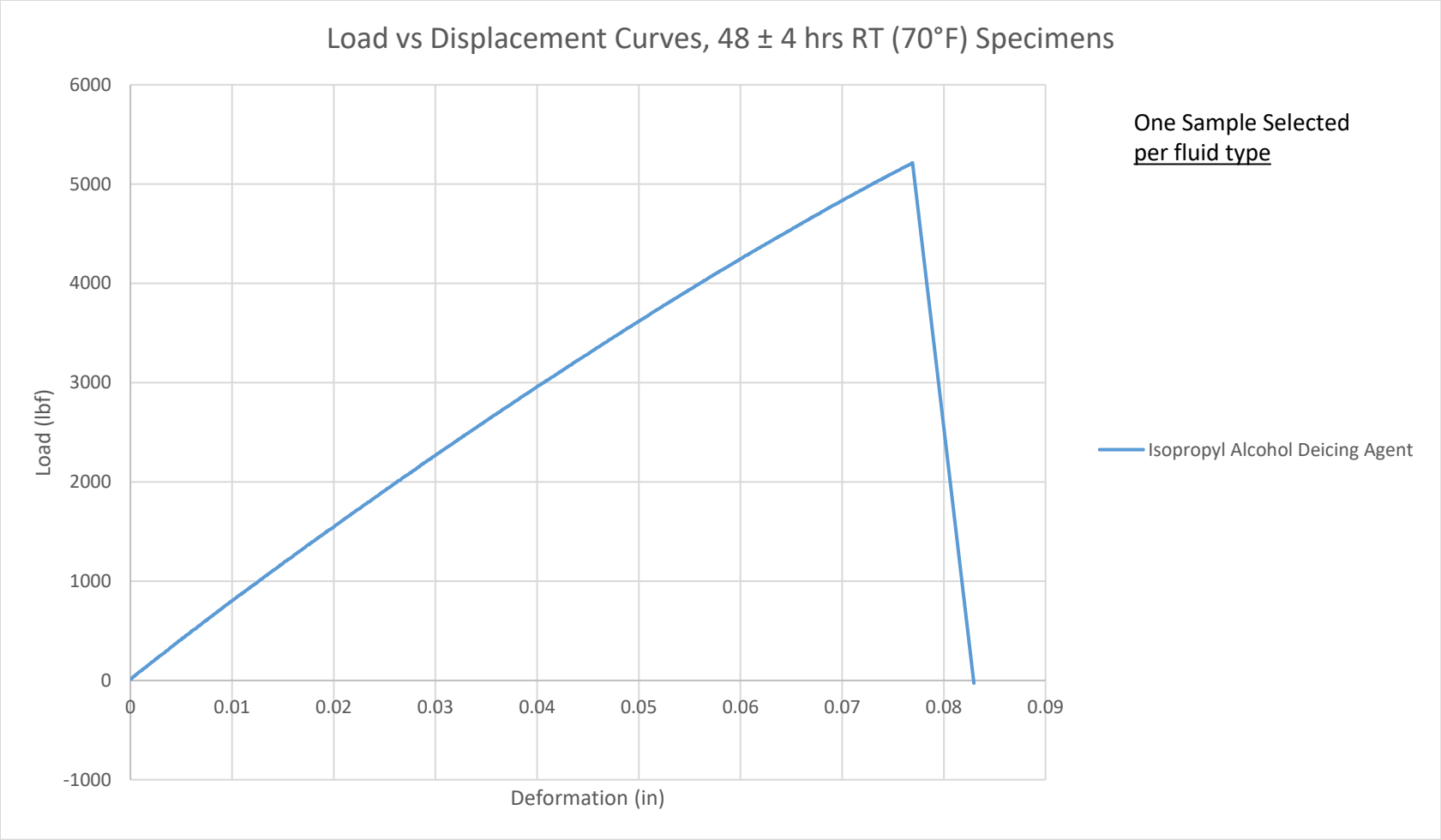
	NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M3-P37011-XY-TFS18ET-11-ETA-PF-1	1	3	29.772	0.142	AWT	
	NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M3-P32401-XY-TFS18ET-12-ETA-PF-2	1	3	30.685	0.143	AWB	
TFS18ET	NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M3-P33420-XY-TFS18ET-13-ETA-PF-3	1	3	29.943	0.144	M(A,L)WT	30.140
	NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M3-P33292-XY-TFS18ET-11-ETA-PF-4	1	3	30.841	0.144	DGM, M(A,L)WT	
	NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M3-P33441-XY-TFS18ET-13-ETA-PF-5	1	3	29.460	0.144	M(A,L)WB	
	NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M3-P33420-XY-TFS19ET-11-ETA-PF-1	1	3	30.285	0.143	LAT	
	NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M3-P33292-XY-TFS19ET-12-ETA-PF-2	1	3	29.274	0.144	M(A,L)WT	
TFS19ET	NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M3-P32185-XY-TFS19ET-13-ETA-PF-3	1	3	30.002	0.142	M(A,L)GM	30.196
	NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M3-P33441-XY-TFS19ET-11-ETA-PF-4	1	3	31.447	0.143	M(A,L)WT	
	NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M3-P32401-XY-TFS19ET-13-ETA-PF-5	1	3	29.973	0.143	M(A,L)WB	
	NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M3-P37720-XY-TFS21ET-11-ETA-PF-1	1	3	31.070	0.142	AWT	
	NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M3-P33690-XY-TFS21ET-12-ETA-PF-2	1	3	34.074	0.142	M(A,L)WB	
TFS21ET	NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M3-P33518-XY-TFS21ET-13-ETA-PF-3	1	3	30.245	0.143	M(A,L)WT	32.210
	NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M3-P32419-XY-TFS21ET-11-ETA-PF-4	1	3	32.126	0.143	M(A,L)WB	
	NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M3-P33599-XY-TFS21ET-13-ETA-PF-5	1	3	33.534	0.143	M(A,L)WB	
	NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M3-P33518-XY-TFS22ET-11-ETA-PF-1	1	3	33.971	0.142	M(A,L)WT	
	NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M3-P32419-XY-TFS22ET-12-ETA-PF-2	1	3	34.013	0.142	M(A,L)WT	
TFS22ET	NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M3-P33649-XY-TFS22ET-13-ETA-PF-3	1	3	34.902	0.143	M(A,L)WT	32.713
	NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M3-P33599-XY-TFS22ET-11-ETA-PF-4	1	3	29.077	0.143	M(A,L)WB	
	NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M3-P33690-XY-TFS22ET-13-ETA-PF-5	1	3	31.600	0.142	M(A,L)WB	
	NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M3-P33649-XY-TFS23ET-11-ETA-PF-1	1	3	35.422	0.143	M(A,L)WT	
	NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M3-P33599-XY-TFS23ET-12-ETA-PF-2	1	3	32.780	0.143	AWT	
TFS23ET	NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M3-P37720-XY-TFS23ET-13-ETA-PF-3	1	3	29.617	0.142	M(A,L)WT	33.173
	NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M3-P33690-XY-TFS23ET-11-ETA-PF-4	1	3	34.384	0.143	M(A,L)WB	
	NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M3-P32419-XY-TFS23ET-13-ETA-PF-5	1	3	33.660	0.144	M(A,L)WT	
	NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M3-P32249-XY-TFS31ET-11-ETA-PF-1	1	3	19.504	0.143	M(A,L)GM, DIT, DIB, GRIP SECTION CRUSH	
	NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M3-P33871-XY-TFS31ET-12-ETA-PF-2	1	3	17.201	0.143	AGM, DIT, DIB, GRIP SECTION CRUSH	
TFS31ET	NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M3-P33739-XY-TFS31ET-13-ETA-PF-3	1	3	15.870	0.143	M(A,L)WB, DIT, DIB, GRIP SECTION CRUSH	17.186
	NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M3-P32455-XY-TFS31ET-11-ETA-PF-4	1	3	16.856	0.142	AWT, DIT, DIB, GRIP SECTION CRUSH	
	NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M3-P33797-XY-TFS31ET-13-ETA-PF-5	1	3	16.500	0.143	M(A,L)WB, DIT, DIB, GRIP SECTION CRUSH	
	NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M3-P33739-XY-TFS32ET-11-ETA-PF-1	1	3	38.206	0.141	DGM, AWT	
	NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M3-P32455-XY-TFS32ET-12-ETA-PF-2	1	3	38.566	0.142	AWT	
TFS32ET	NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M3-P33844-XY-TFS32ET-13-ETA-PF-3	1	3	35.343	0.143	M(A,L)WB	36.874
	NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M3-P33797-XY-TFS32ET-11-ETA-PF-4	1	3	37.114	0.142	M(A,L)WT	
	NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M3-P33871-XY-TFS32ET-13-ETA-PF-5	1	3	35.139	0.143	DGM	

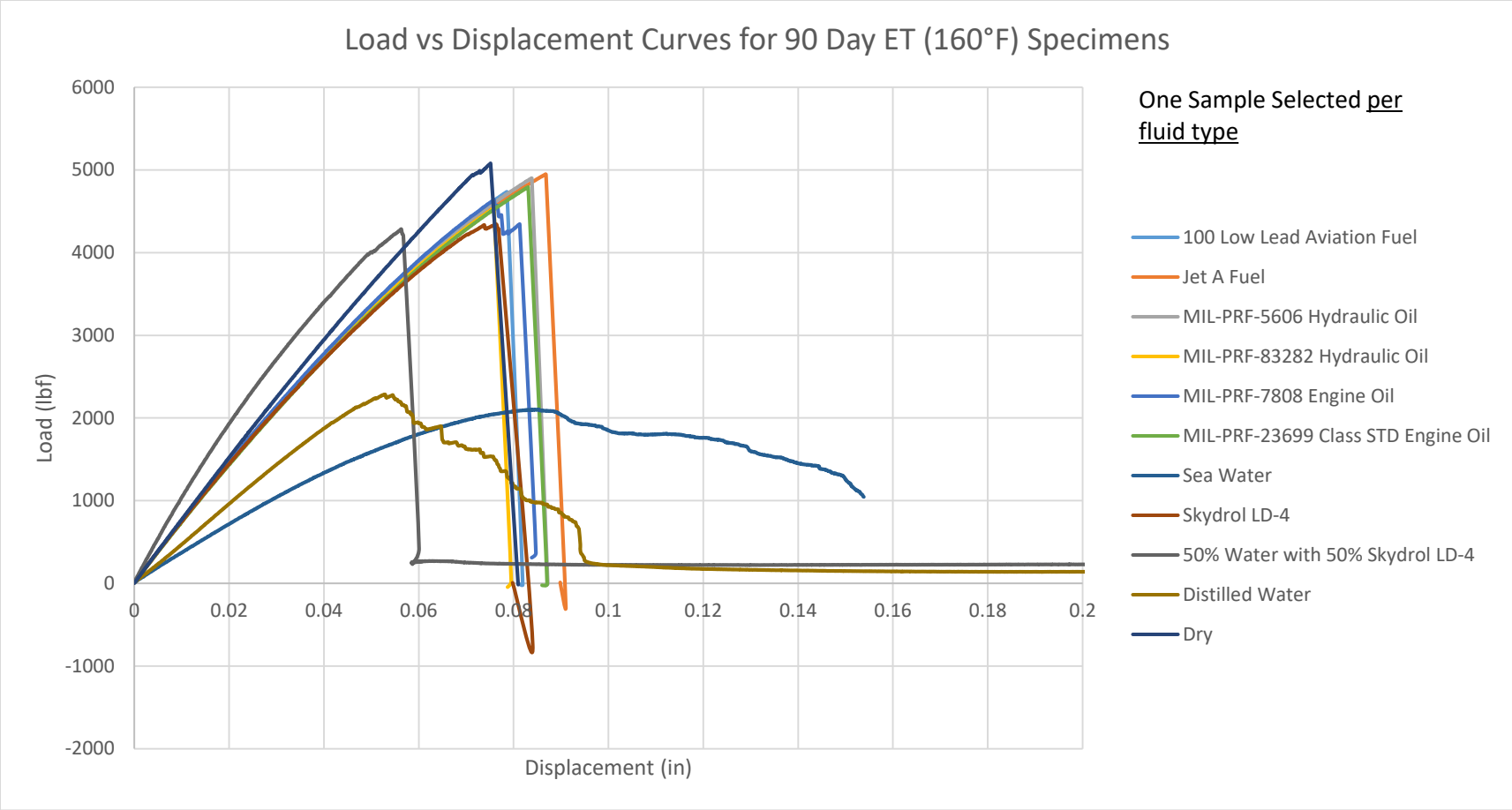
Average	**30.715**	**0.143**
Standard Dev.	**5.538**	
Coeff. of Var. [%]	**18.029**	
Min.	**14.841**	**0.140**
Max.	**38.566**	**0.145**
Number of Spec.	**68**	**70**

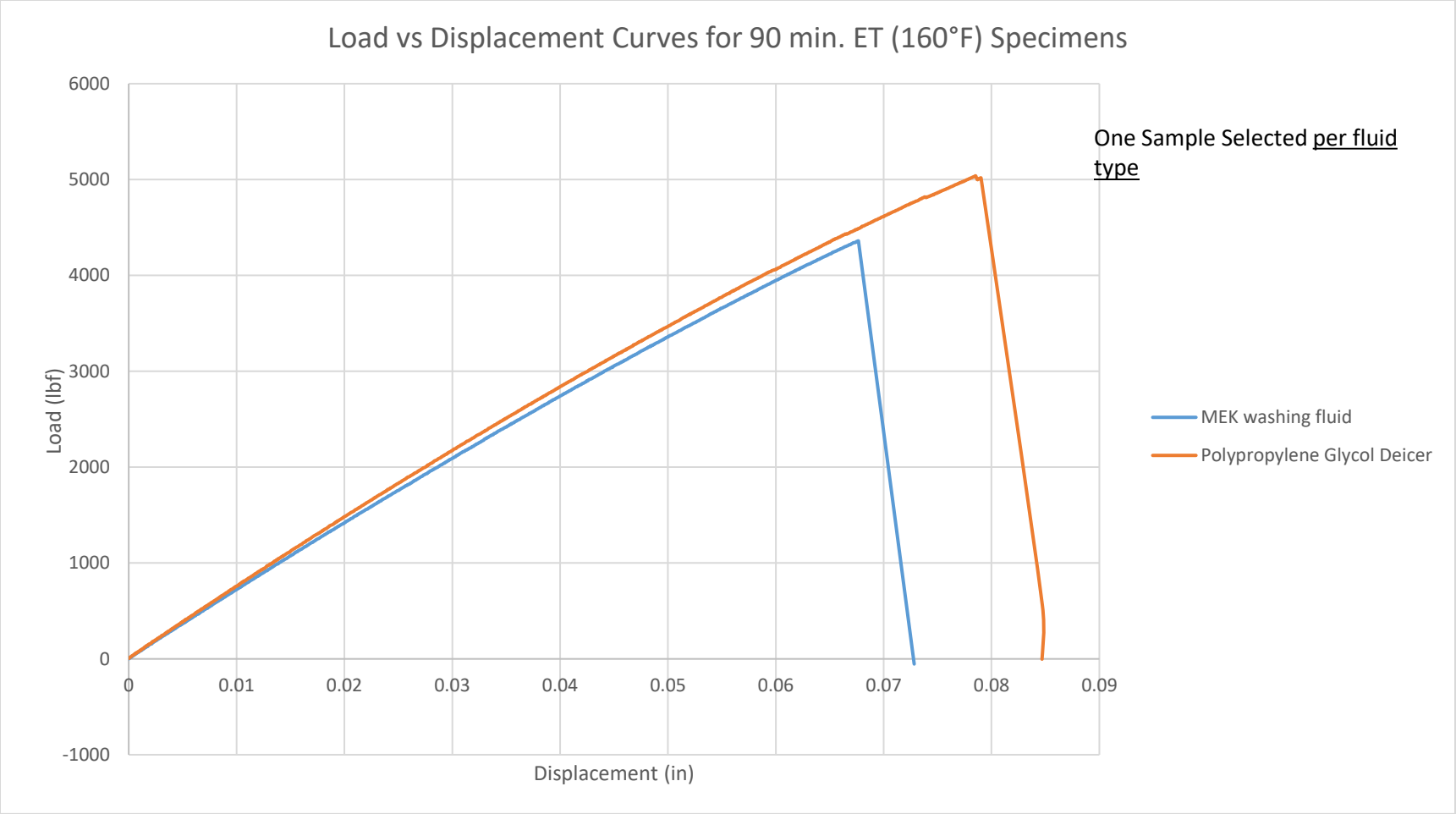
6.3 Load Displacement Curves

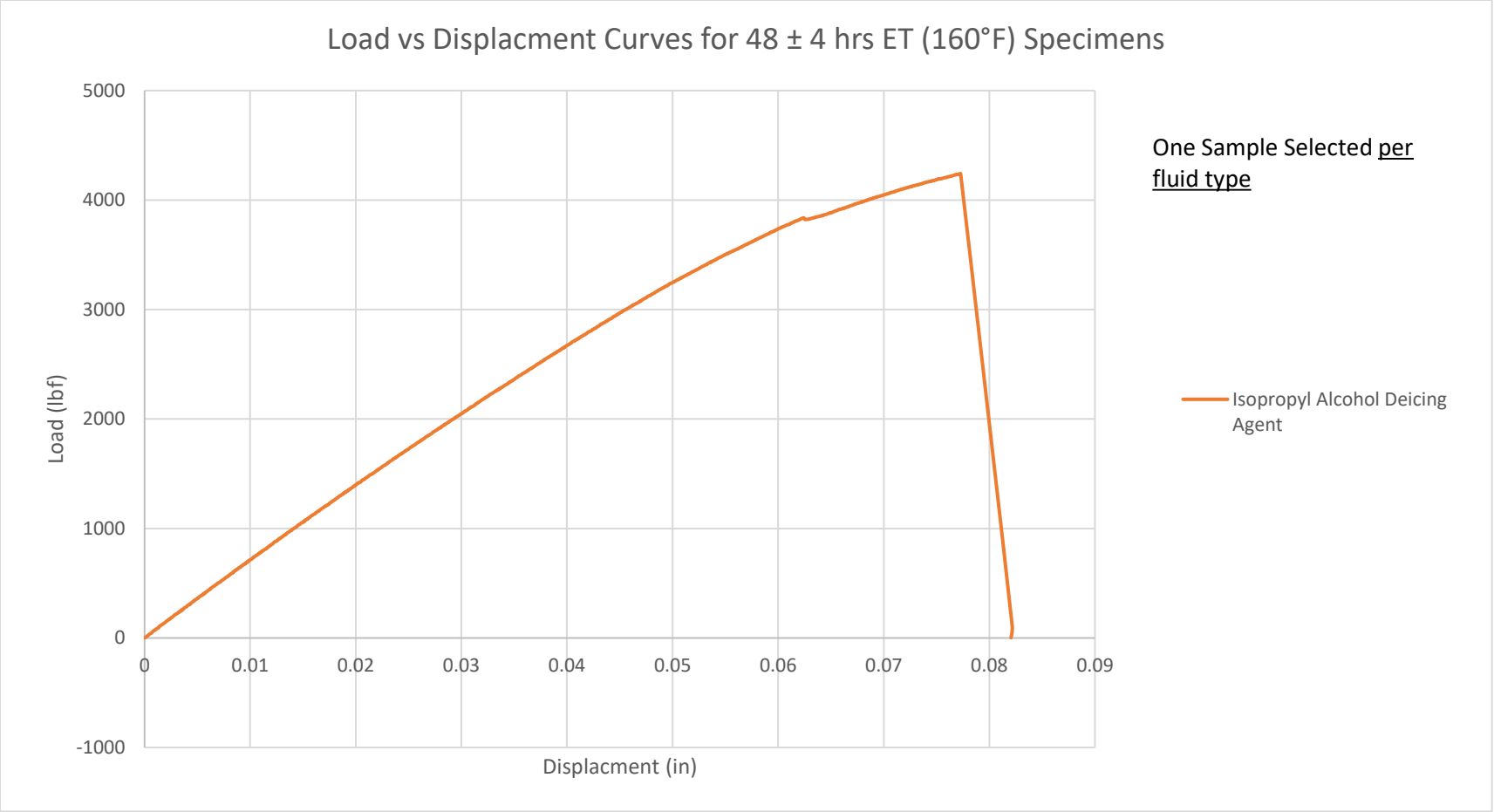



Load vs Displacment Curves for 90 min. RT (70°F) Specimens
Load (lbf)
7000
6000
5000
4000
3000
2000
1000
0
-1000
-2000
-3000
0
0.01
0.02
0.03
0.04
0.05
0.06
0.07
0.08
0.09
0.1
Displacement (in)
One Sample Selected per fluid type
MEK washing fluid
Polypropylene Glycol Deicer


Load vs Displacement Curves, 48 ± 4 hrs RT (70°F) Specimens
6000
5000
4000
3000
2000
1000
0
-1000
Load (lbf)
0
0.01
0.02
0.03
0.04
0.05
0.06
0.07
0.08
0.09
Deformation (in)
One Sample Selected
per fluid type
Isopropyl Alcohol Deicing Agent

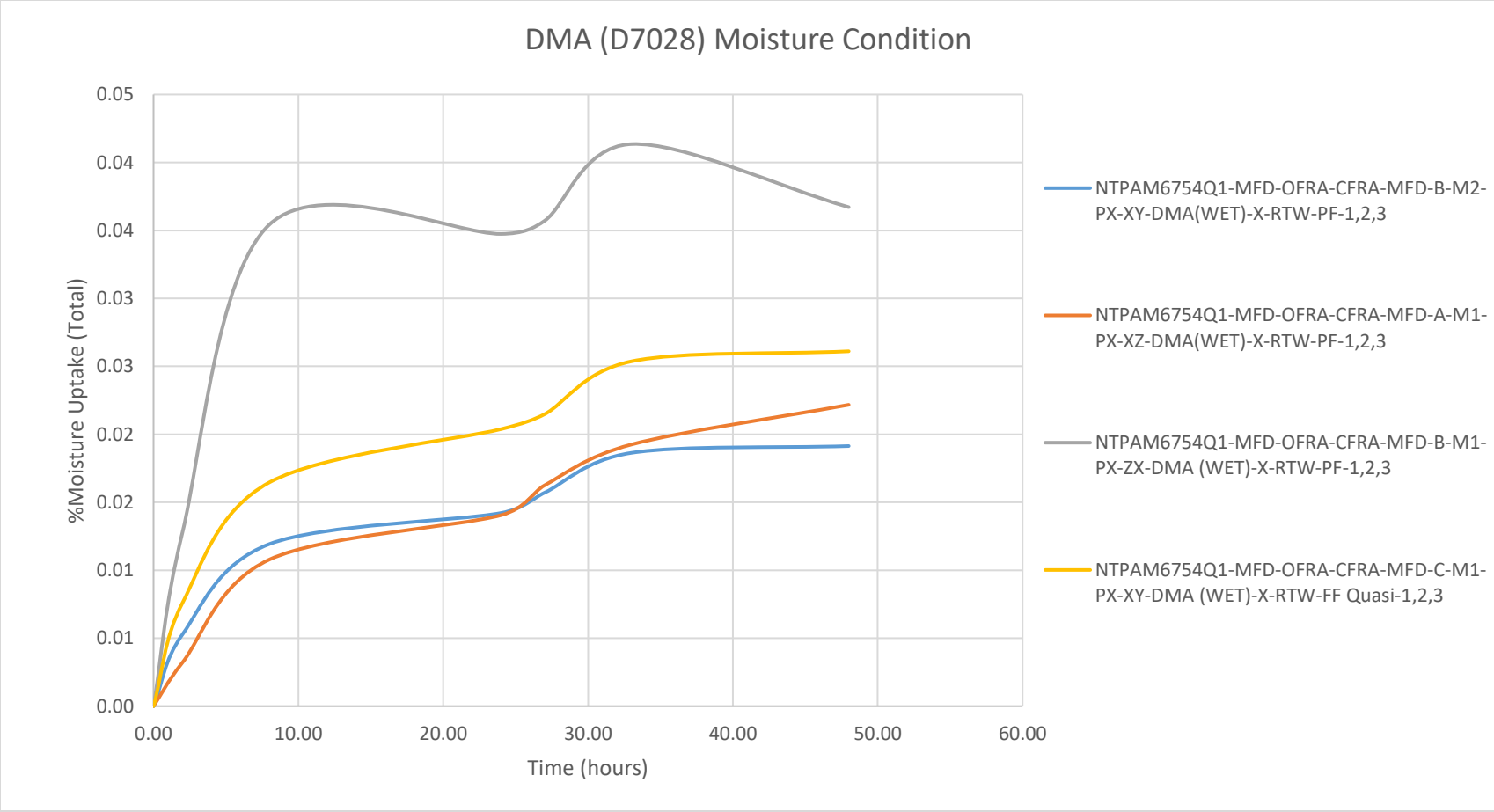

Load vs Displacement Curves for 90 Day ET (160°F) Specimens
Load (lbf)
6000
5000
4000
3000
2000
1000
0
-1000
-2000
0
0.02
0.04
0.06
0.08
0.1
0.12
0.14
0.16
0.18
0.2
Displacement (in)
One Sample Selected per fluid type
100 Low Lead Aviation Fuel
Jet A Fuel
MIL-PRF-5606 Hydraulic Oil
MIL-PRF-83282 Hydraulic Oil
MIL-PRF-7808 Engine Oil
MIL-PRF-23699 Class STD Engine Oil
Sea Water
Skydrol LD-4
50% Water with 50% Skydrol LD-4
Distilled Water
Dry


Load vs Displacement Curves for 90 min. ET (160°F) Specimens
6000
5000
4000
3000
2000
1000
0
-1000
Load (lbf)
0
0.01
0.02
0.03
0.04
0.05
0.06
0.07
0.08
0.09
Displacement (in)
One Sample Selected per fluid type
MEK washing fluid
Polypropylene Glycol Deicer

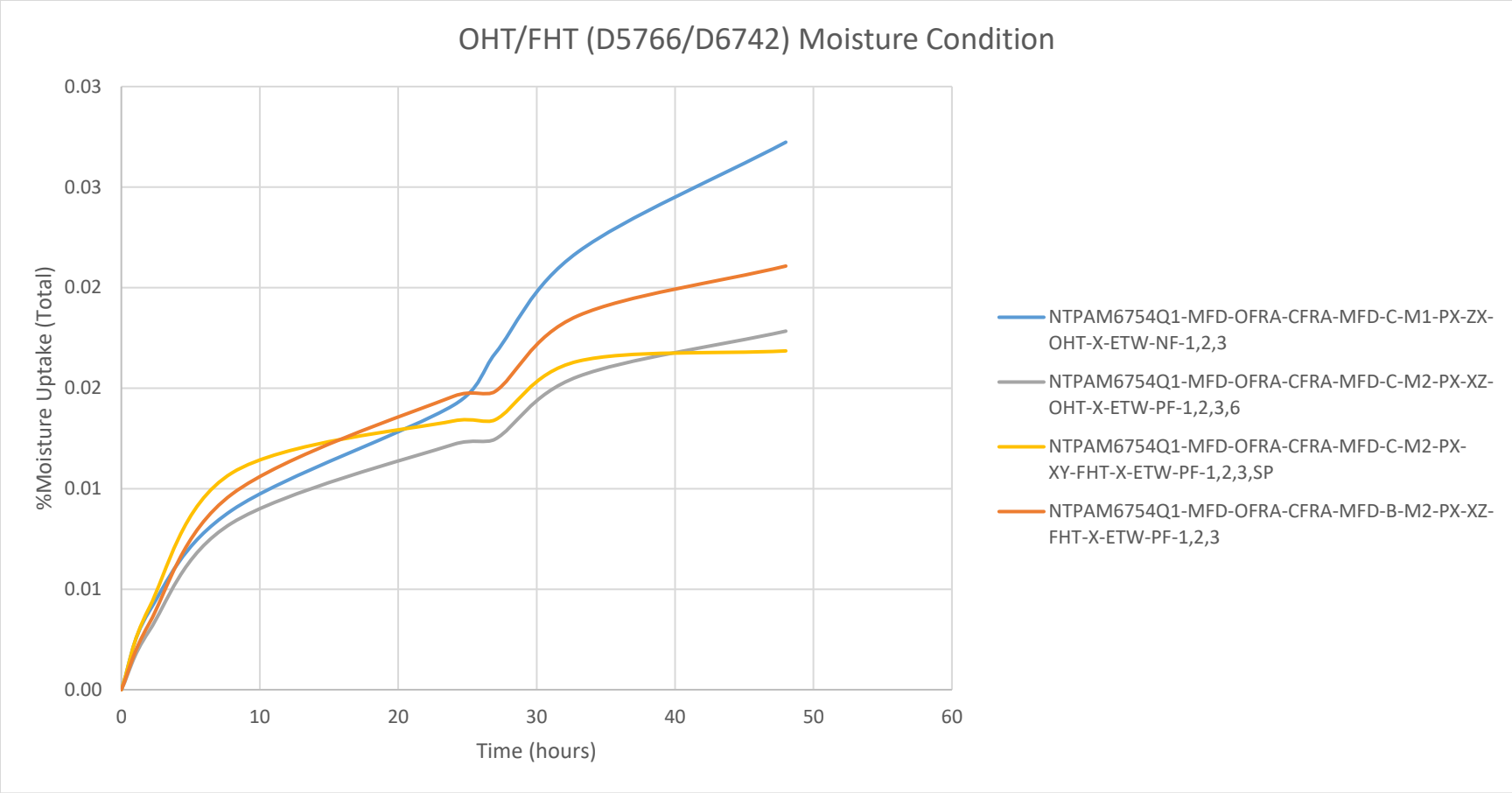

Load vs Displacment Curves for 48 ± 4 hrs ET (160°F) Specimens
5000
4000
3000
2000
1000
0
-1000
Load (lbf)
0
0.01
0.02
0.03
0.04
0.05
0.06
0.07
0.08
0.09
Displacment (in)
One Sample Selected per fluid type
Isopropyl Alcohol Deicing Agent

7. Moisture Conditioning Charts

7.1 Smallest Sample – Dynamic Mechanical Analysis (0.5” x 2.3”)



7.2 Largest Sample – Open-Hole Tension/Filled-Hole Tension (1.5” x 7.5”)



8. Moisture Loss Data

Moisture loss data was not completed during qualification effort.

9. Physical Testing

9.1 DMA Results

DMA Results Summary
XY DMA Dry

Specimen ID	Onset Storage Modulus		Peak of Tangent Delta	
	T_g [°C]	T_g [°F]	T_g [°C]	T_g [°F]
A-M1-PX-XY-DMA-11-RTD-PF-1	107.92	226.26	119.553	247.20
A-M1-PX-XY-DMA-12-RTD-PF-2	109.11	228.40	121.29	250.32
A-M1-PX-XY-DMA-13-RTD-PF-3	106.97	224.55	121.85	251.33
A-M2-PX-XY-DMA-11-RTD-PF-1	106.67	224.01	119.8	247.64
A-M2-PX-XY-DMA-12-RTD-PF-2	107.99	226.38	120.82	249.48
A-M2-PX-XY-DMA-13-RTD-PF-3	106.94	224.49	120.82	249.48
B-M1-PX-XY-DMA-11-RTD-PF-1	109.53	229.15	116.04	240.87
B-M1-PX-XY-DMA-12-RTD-PF-2	117.09	242.76	124.35	255.83
B-M1-PX-XY-DMA-13-RTD-PF-3	112.38	234.28	119.64	247.35
B-M2-PX-XY-DMA-11-RTD-PF-1	112.12	233.82	119.43	246.97
B-M2-PX-XY-DMA-12-RTD-PF-2	118.9	246.02	125.89	258.60
B-M2-PX-XY-DMA-13-RTD-PF-3	113.51	236.32	120.87	249.57
C-M1-PX-XY-DMA-11-RTD-PF-1	99.37	210.87	108.62	227.52
C-M1-PX-XY-DMA-12-RTD-PF-2	102.71	216.88	111.73	233.11
C-M1-PX-XY-DMA-13-RTD-PF-3	99.77	211.59	108.56	227.41
C-M2-PX-XY-DMA-11-RTD-PF-1	114.7	238.46	122.16	251.89
C-M2-PX-XY-DMA-12-RTD-PF-2	118.22	244.80	125.59	258.06
C-M2-PX-XY-DMA-13-RTD-PF-3	113.73	236.71	120.45	248.81
A-M1-PX-XY-DMA-13-RTD-FF-1	108.17	226.71	117.24	243.03
A-M2-PX-XY-DMA-13-RTD-FF-1	108.5	227.30	116.5	241.70
B-M1-PX-XY-DMA-13-RTD-FF-1	99.51	211.12	109.05	228.29
B-M2-PX-XY-DMA-13-RTD-FF-1	102.91	217.24	111.87	233.37
C-M1-PX-XY-DMA-13-RTD-FF-1	98.92	210.06	107.95	226.31
C-M2-PX-XY-DMA-13-RTD-FF-1	99.88	211.78	109.01	228.22
A-M1-PX-XY-DMA-13-RTD-NF-1	90.35	194.63	117.67	243.81
A-M2-PX-XY-DMA-13-RTD-NF-1	92.09	197.76	119.53	247.15
B-M1-PX-XY-DMA-13-RTD-NF-1	88.32	190.98	116.18	241.12
B-M2-PX-XY-DMA-13-RTD-NF-1	81.32	178.38	100.32	212.58
C-M1-PX-XY-DMA-13-RTD-NF-1	83.28	181.90	104.37	219.87
C-M2-PX-XY-DMA-13-RTD-NF-1	90.7	195.26	117.36	243.25
C-M1-PX-XY-DMA-11-RTD-PF Quasi-1	126.41	259.54	133.78	272.80
C-M1-PX-XY-DMA-12-RTD-PF Quasi-2	126.5	259.70	132.92	271.26
C-M1-PX-XY-DMA-13-RTD-PF Quasi-3	126.17	259.11	132.5	270.50
C-M2-PX-XY-DMA-11-RTD-PF Quasi-1	118.77	245.79	125.15	257.27
C-M2-PX-XY-DMA-12-RTD-PF Quasi-2	122.73	252.91	129.56	265.21
C-M2-PX-XY-DMA-13-RTD-PF Quasi-3	118.23	244.81	124.35	255.83
C-M1-PX-XY-DMA-11-RTD-FF Quasi-1	110.6	231.08	118.27	244.89
C-M1-PX-XY-DMA-12-RTD-FF Quasi-2	110.88	231.58	118.74	245.73
C-M1-PX-XY-DMA-13-RTD-FF Quasi-3	110.03	230.05	117.80	244.04
C-M2-PX-XY-DMA-11-RTD-FF Quasi-1	108.87	227.97	116.98	242.56
C-M2-PX-XY-DMA-12-RTD-FF Quasi-2	110.7	231.26	119	246.20
C-M2-PX-XY-DMA-13-RTD-FF Quasi-3	112.43	234.37	120.83	249.49
Average	107.71	225.88	118.68	245.62
Standard Deviation	10.85	19.52	7.19	12.94

DMA Results Summary
XZ DMA Dry

Specimen ID	Onset Storage Modulus		Peak of Tangent Delta	
	T_g [°C]	T_g [°F]	T_g [°C]	T_g [°F]
A-M1-PX-XZ-DMA-11-RTD-PF-1	114.63	238.33	124.7	256.46
A-M1-PX-XZ-DMA-12-RTD-PF-2	113.01	235.42	123.44	254.19
A-M1-PX-XZ-DMA-13-RTD-PF-3	117.63	243.73	127.08	260.74
A-M2-PX-XZ-DMA-11-RTD-PF-1	104.99	220.98	118.01	244.42
A-M2-PX-XZ-DMA-12-RTD-PF-2	104.35	219.83	119.74	247.53
A-M2-PX-XZ-DMA-13-RTD-PF-3	104.93	220.87	120.19	248.34
B-M1-PX-XZ-DMA-11-RTD-PF-1	119.14	246.45	129.32	264.78
B-M1-PX-XZ-DMA-12-RTD-PF-2	116.86	242.35	126.24	259.23
B-M1-PX-XZ-DMA-13-RTD-PF-3	121.21	250.18	130.43	266.77
B-M2-PX-XZ-DMA-11-RTD-PF-1	119.25	246.65	129.22	264.60
B-M2-PX-XZ-DMA-12-RTD-PF-2	116.99	242.58	127.13	260.83
B-M2-PX-XZ-DMA-13-RTD-PF-3	119.84	247.71	129.23	264.61
C-M1-PX-XZ-DMA-11-RTD-PF-1	119.5	247.10	128.66	263.59
C-M1-PX-XZ-DMA-12-RTD-PF-2	118.36	245.05	127.85	262.13
C-M1-PX-XZ-DMA-13-RTD-PF-3	115.53	239.95	125.67	258.21
C-M2-PX-XZ-DMA-11-RTD-PF-1	105.74	222.33	115.72	240.30
C-M2-PX-XZ-DMA-12-RTD-PF-2	108.86	227.95	118.83	245.89
C-M2-PX-XZ-DMA-13-RTD-PF-3	115.9	240.62	125.33	257.59
Average	114.26	237.67	124.82	256.68
Standard Deviation	5.66	10.19	4.36	7.85

Note: XY orientation DMA specimens labeled with PF Quasi contains fiber orientation in the Quasi-isotropic stack [45/0/-45/90____90/-45/0/45] pattern/angle.

DMA Results Summary
ZX DMA Dry

Specimen ID	Onset Storage Modulus		Peak of Tangent Delta	
	T_g [°C]	T_g [°F]	T_g [°C]	T_g [°F]
A-M1-PX-ZX-DMA-11-RTD-PF-1	126.85	260.33	134.63	274.33
A-M1-PX-ZX-DMA-12-RTD-PF-2	126.61	259.90	134.41	273.94
A-M1-PX-ZX-DMA-13-RTD-PF-3	126.59	259.86	133.76	272.77
A-M2-PX-ZX-DMA-11-RTD-PF-1	112.1	233.78	125.69	258.24
A-M2-PX-ZX-DMA-12-RTD-PF-2	109.13	228.43	123.28	253.90
A-M2-PX-ZX-DMA-13-RTD-PF-3	111.04	231.87	122.61	252.70
B-M1-PX-ZX-DMA-11-RTD-PF-1	126.37	259.47	133.46	272.23
B-M1-PX-ZX-DMA-12-RTD-PF-2	127.63	261.73	134.88	274.78
B-M1-PX-ZX-DMA-13-RTD-PF-3	125.09	257.16	132.08	269.74
B-M2-PX-ZX-DMA-11-RTD-PF-1	109	228.20	120.41	248.74
B-M2-PX-ZX-DMA-12-RTD-PF-2	108.29	226.92	119.53	247.15
B-M2-PX-ZX-DMA-13-RTD-PF-3	113.54	236.37	124.12	255.42
B-M2-PX-ZX-DMA-13-RTD-PF-3	114.24	237.63	126.22	259.20
C-M1-PX-ZX-DMA-11-RTD-PF-1	116.12	241.02	129.14	264.45
C-M1-PX-ZX-DMA-12-RTD-PF-2	112.82	235.08	125.01	257.02
C-M1-PX-ZX-DMA-13-RTD-PF-3	112.16	233.89	125.55	257.99
C-M2-PX-ZX-DMA-11-RTD-PF-1	110.79	231.42	125.49	257.88
C-M2-PX-ZX-DMA-12-RTD-PF-2	111.52	232.74	125.96	258.73
C-M2-PX-ZX-DMA-13-RTD-PF-3	114.91	238.84	126.41	259.54
Average	116.57	241.82	127.51	261.51
Standard Deviation	7.03	12.66	4.82	8.67

DMA Results Summary
XY DMA Wet

Specimen ID	Onset Storage Modulus		Peak of Tangent Delta	
	T_g [°C]	T_g [°F]	T_g [°C]	T_g [°F]
A-M1-PX-XY-DMA-11-RTW-PF-1	69.73	157.51	91.23	196.21
A-M1-PX-XY-DMA-12-RTW-PF-2	71.42	160.56	92.38	198.28
A-M1-PX-XY-DMA-13-RTW-PF-3	68.69	155.64	87.96	190.33
A-M2-PX-XY-DMA-11-RTW-PF-1	70.87	159.57	91.31	196.36
A-M2-PX-XY-DMA-12-RTW-PF-2	70.79	159.42	89.88	193.78
A-M2-PX-XY-DMA-13-RTW-PF-3	70.97	159.75	90.55	194.99
B-M1-PX-XY-DMA-11-RTW-PF-1	52.83	127.09	85.36	185.65
B-M1-PX-XY-DMA-12-RTW-PF-2	54.51	130.12	78.65	173.57
B-M1-PX-XY-DMA-13-RTW-PF-3	52.2	125.96	80.6	177.08
B-M2-PX-XY-DMA-11-RTW-PF-1	45.2	113.36	53.87	128.97
B-M2-PX-XY-DMA-12-RTW-PF-2	45.36	113.65	52.9	127.22
B-M2-PX-XY-DMA-13-RTW-PF-3	45.05	113.09	57.46	135.43
C-M1-PX-XY-DMA-11-RTW-PF-1	46.71	116.08	56.28	133.30
C-M1-PX-XY-DMA-12-RTW-PF-2	47.2	116.96	57.84	136.11
C-M1-PX-XY-DMA-13-RTW-PF-3	48.35	119.03	59.92	139.86
C-M2-PX-XY-DMA-11-RTW-PF-1	56.55	133.79	86.52	187.74
C-M2-PX-XY-DMA-12-RTW-PF-2	54.77	130.59	88.72	191.70
C-M2-PX-XY-DMA-13-RTW-PF-3	51.92	125.46	86.64	187.95
A-M1-PX-XY-DMA-13-RTW-FF-1	72.76	162.97	86.43	187.57
A-M2-PX-XY-DMA-13-RTW-FF-1	74.53	166.15	88.77	191.79
B-M1-PX-XY-DMA-13-RTW-FF-1	42.99	109.38	91.15	196.07
B-M2-PX-XY-DMA-13-RTW-FF-1	52.13	125.83	92.72	198.90
C-M1-PX-XY-DMA-13-RTW-FF-1	82.47	180.45	95.01	203.02
C-M2-PX-XY-DMA-13-RTW-FF-1	80.96	177.73	93.54	200.37
A-M1-PX-XY-DMA-13-RTW-NF-1	41.7	107.06	85.39	185.70
A-M2-PX-XY-DMA-13-RTW-NF-1	50.13	122.23	87.76	189.97
B-M1-PX-XY-DMA-13-RTW-NF-1	50.18	122.32	83.4	182.12
B-M2-PX-XY-DMA-13-RTW-NF-1	48.99	120.18	81.68	179.02
C-M1-PX-XY-DMA-13-RTW-NF-1	47.83	118.09	80.43	176.77
C-M2-PX-XY-DMA-13-RTW-NF-1	54.99	130.98	87.18	188.92
C-M1-PX-XY-DMA-11-RTW-PF Quasi-1	76.84	170.31	84.47	184.05
C-M1-PX-XY-DMA-12-RTW-PF Quasi-2	57.9	136.22	77.86	172.15
C-M1-PX-XY-DMA-13-RTW-PF Quasi-3	57.9	136.22	74.19	165.54
C-M2-PX-XY-DMA-11-RTW-PF Quasi-1	59.05	138.29	72.48	162.46
C-M2-PX-XY-DMA-12-RTW-PF Quasi-2	58.28	136.90	69.64	157.35
C-M2-PX-XY-DMA-13-RTW-PF Quasi-3	59.93	139.87	74.49	166.08
C-M1-PX-XY-DMA-11-RTW-FF Quasi-1	55.47	131.85	81.55	178.79
C-M1-PX-XY-DMA-12-RTW-FF Quasi-2	63.83	146.89	54.96	130.93
C-M1-PX-XY-DMA-13-RTW-FF Quasi-3	61.06	141.91	80.06	176.11
C-M2-PX-XY-DMA-11-RTW-FF Quasi-1	56.21	133.18	67.81	154.06
C-M2-PX-XY-DMA-12-RTW-FF Quasi-2	53.58	128.44	64.22	147.60
C-M2-PX-XY-DMA-13-RTW-FF Quasi-3	51.12	124.02	60.98	141.76
Average	57.95	136.31	78.67	173.61
Standard Deviation	10.71	19.28	12.72	22.89

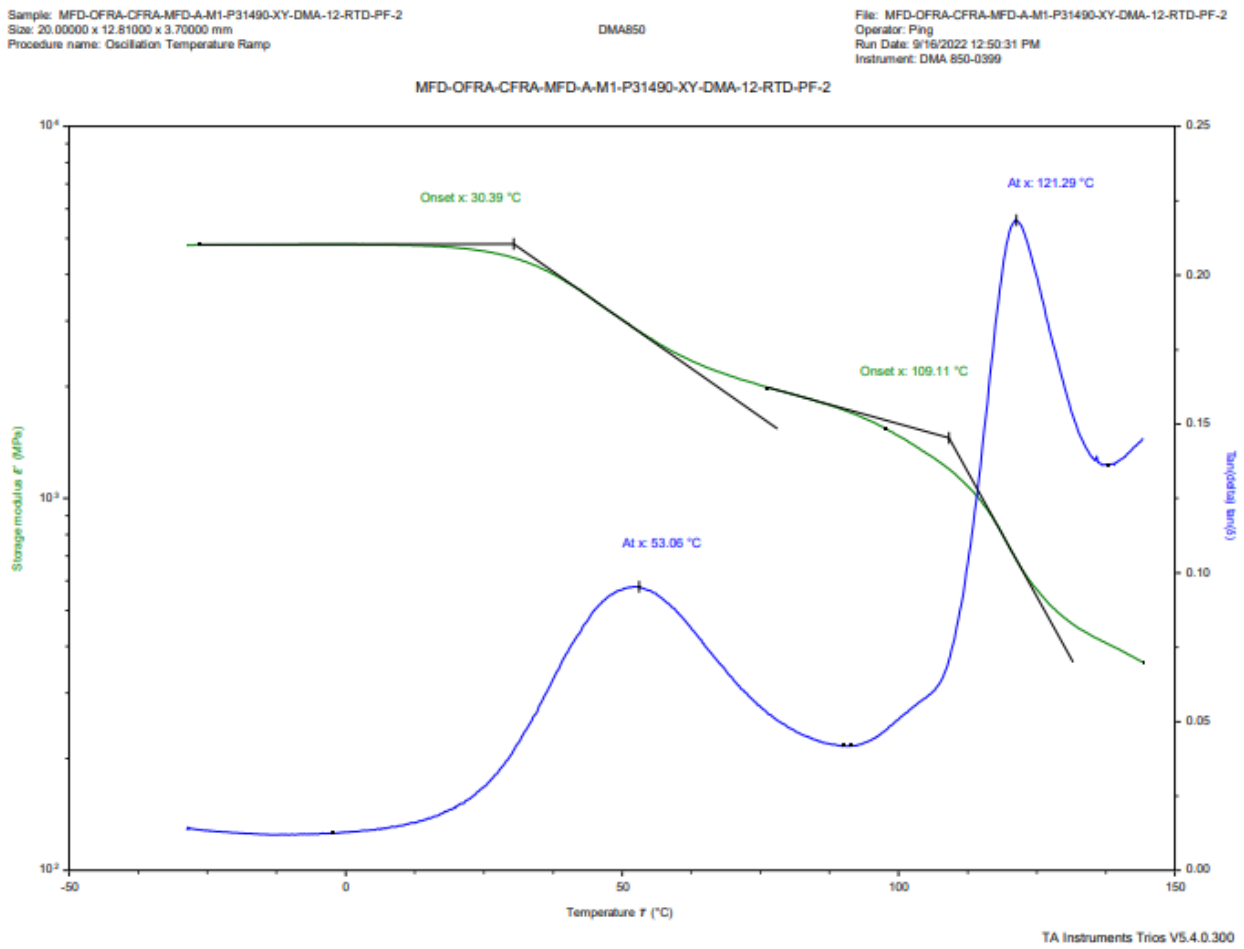
DMA Results Summary
XZ DMA Wet

Specimen ID	Onset Storage Modulus		Peak of Tangent Delta	
	T_g [°C]	T_g [°F]	T_g [°C]	T_g [°F]
A-M1-PX-XZ-DMA-11-RTW-PF-1	43.14	109.65	52.22	126.00
A-M1-PX-XZ-DMA-12-RTW-PF-2	45.36	113.65	53.93	129.07
A-M1-PX-XZ-DMA-13-RTW-PF-3	46.66	115.99	54.59	130.26
A-M2-PX-XZ-DMA-11-RTW-PF-1	64.77	148.59	77.15	170.87
A-M2-PX-XZ-DMA-12-RTW-PF-2	63.52	146.34	75.53	167.95
A-M2-PX-XZ-DMA-13-RTW-PF-3	60.64	141.15	73.3	163.94
B-M1-PX-XZ-DMA-11-RTW-PF-1	47.73	117.91	62.28	144.10
B-M1-PX-XZ-DMA-12-RTW-PF-2	50.04	122.07	62.2	143.96
B-M1-PX-XZ-DMA-13-RTW-PF-3	49.96	121.93	60.69	141.24
B-M2-PX-XZ-DMA-11-RTW-PF-1	45.35	113.63	53.68	128.62
B-M2-PX-XZ-DMA-12-RTW-PF-2	41.95	107.51	52.53	126.55
B-M2-PX-XZ-DMA-13-RTW-PF-3	45.44	113.79	53.7	128.66
C-M1-PX-XZ-DMA-11-RTW-PF-1	45.05	113.09	53.28	127.90
C-M1-PX-XZ-DMA-12-RTW-PF-2	46.09	114.96	54.11	129.40
C-M1-PX-XZ-DMA-13-RTW-PF-3	43.55	110.39	52.24	126.03
C-M2-PX-XZ-DMA-11-RTW-PF-1	45.33	113.59	53.15	127.67
C-M2-PX-XZ-DMA-12-RTW-PF-2	43.17	109.71	53.32	127.98
C-M2-PX-XZ-DMA-13-RTW-PF-3	45.97	114.75	53.66	128.59
Average	48.54	119.37	58.42	137.16
Standard Deviation	6.81	12.25	8.20	14.77

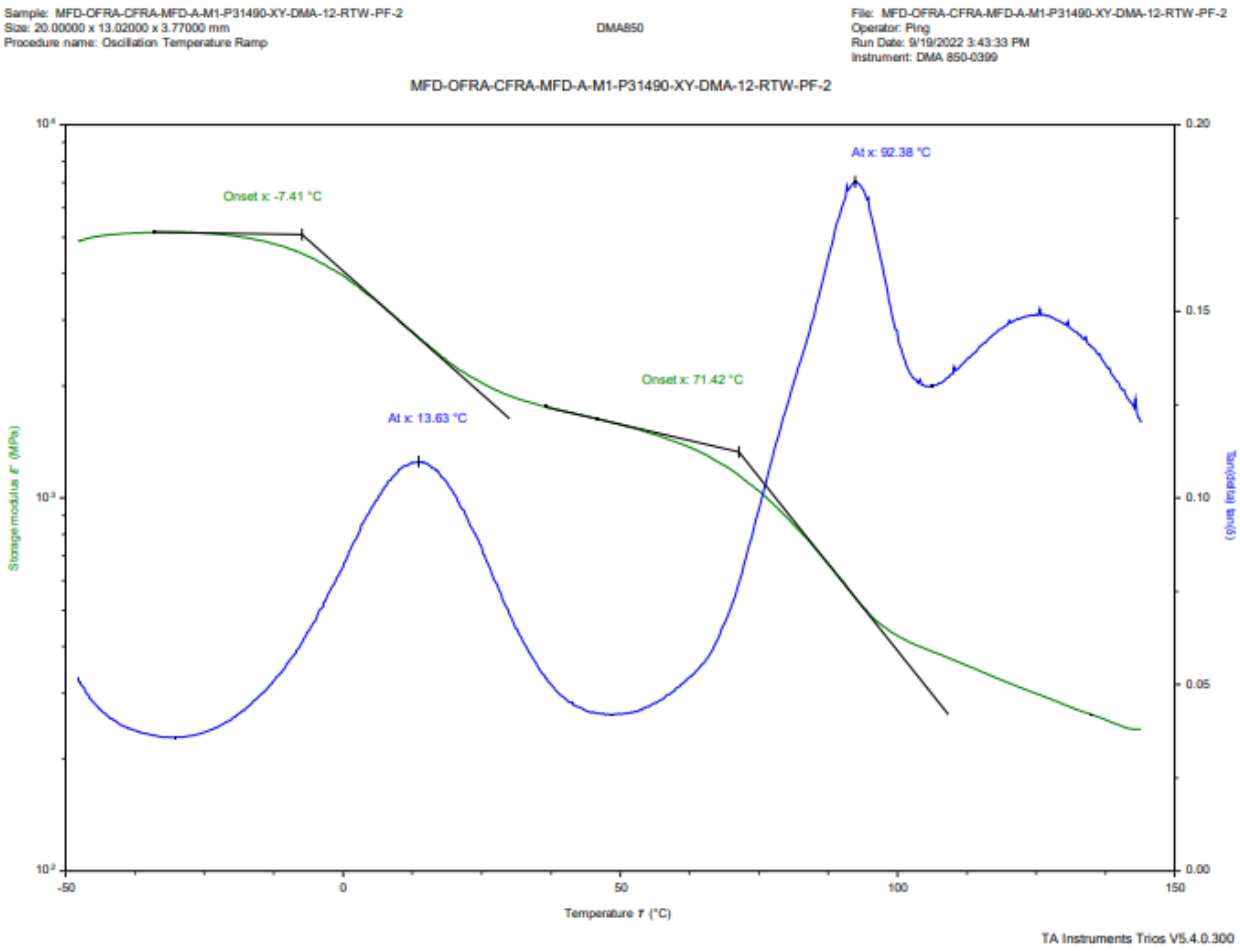
DMA Results Summary
ZX DMA Wet

Specimen ID	Onset Storage Modulus		Peak of Tangent Delta	
	T_g [°C]	T_g [°F]	T_g [°C]	T_g [°F]
A-M1-PX-ZX-DMA-11-RTW-PF-1	45.1	113.18	57.46	135.43
A-M1-PX-ZX-DMA-12-RTW-PF-2	49.72	121.50	60.83	141.49
A-M1-PX-ZX-DMA-13-RTW-PF-3	47.05	116.69	58.15	136.67
A-M2-PX-ZX-DMA-11-RTW-PF-1	57.25	135.05	69.66	157.39
A-M2-PX-ZX-DMA-12-RTW-PF-2	54.71	130.48	69.32	156.78
A-M2-PX-ZX-DMA-13-RTW-PF-3	50.16	122.29	60.8	141.44
A-M2-PX-ZX-DMA-13-RTW-PF-3	49.04	120.27	62.07	143.73
B-M1-PX-ZX-DMA-11-RTW-PF-1	45.17	113.31	54.58	130.24
B-M1-PX-ZX-DMA-12-RTW-PF-2	46.46	115.63	56.15	133.07
B-M1-PX-ZX-DMA-13-RTW-PF-3	47.79	118.02	58.32	136.98
B-M2-PX-ZX-DMA-11-RTW-PF-1	54.86	130.75	67.51	153.52
B-M2-PX-ZX-DMA-12-RTW-PF-2	56.65	133.97	69.63	157.33
B-M2-PX-ZX-DMA-13-RTW-PF-3	48.7	119.66	62.14	143.85
C-M1-PX-ZX-DMA-11-RTW-PF-1	54.39	129.90	68.04	154.47
C-M1-PX-ZX-DMA-12-RTW-PF-2	55.05	131.09	67.42	153.36
C-M1-PX-ZX-DMA-13-RTW-PF-3	45.84	114.51	58.17	136.71
C-M1-PX-ZX-DMA-13-RTW-PF-3	47.71	117.88	59.35	138.83
C-M2-PX-ZX-DMA-11-RTW-PF-1	45.74	114.33	53.16	127.69
C-M2-PX-ZX-DMA-12-RTW-PF-2	46.87	116.37	54.49	130.08
C-M2-PX-ZX-DMA-13-RTW-PF-3	48.14	118.65	55.84	132.51
Average	49.82	121.68	61.15	142.08
Standard Deviation	3.98	7.16	5.42	9.76

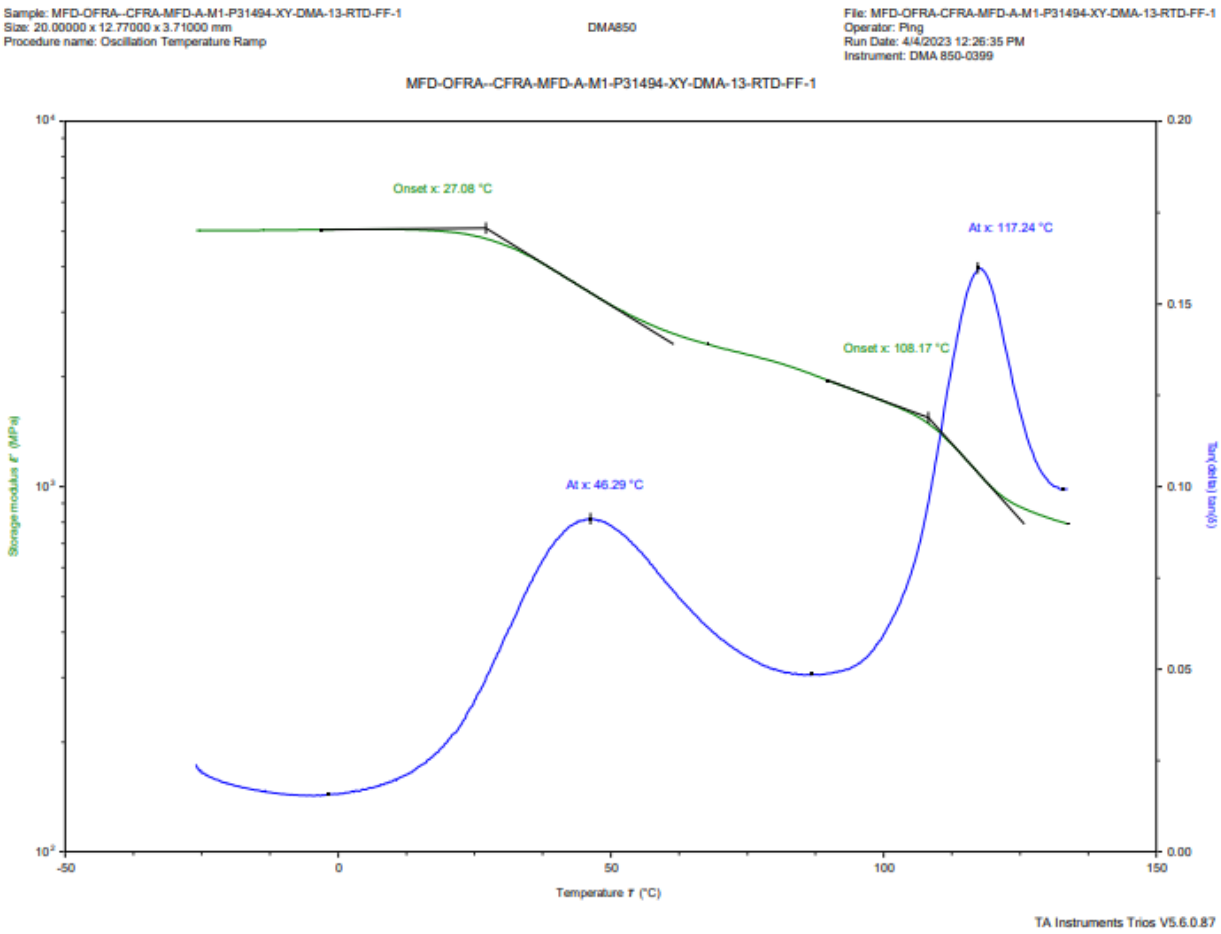
9.1.1 **XY PF DMA Dry Batch A**



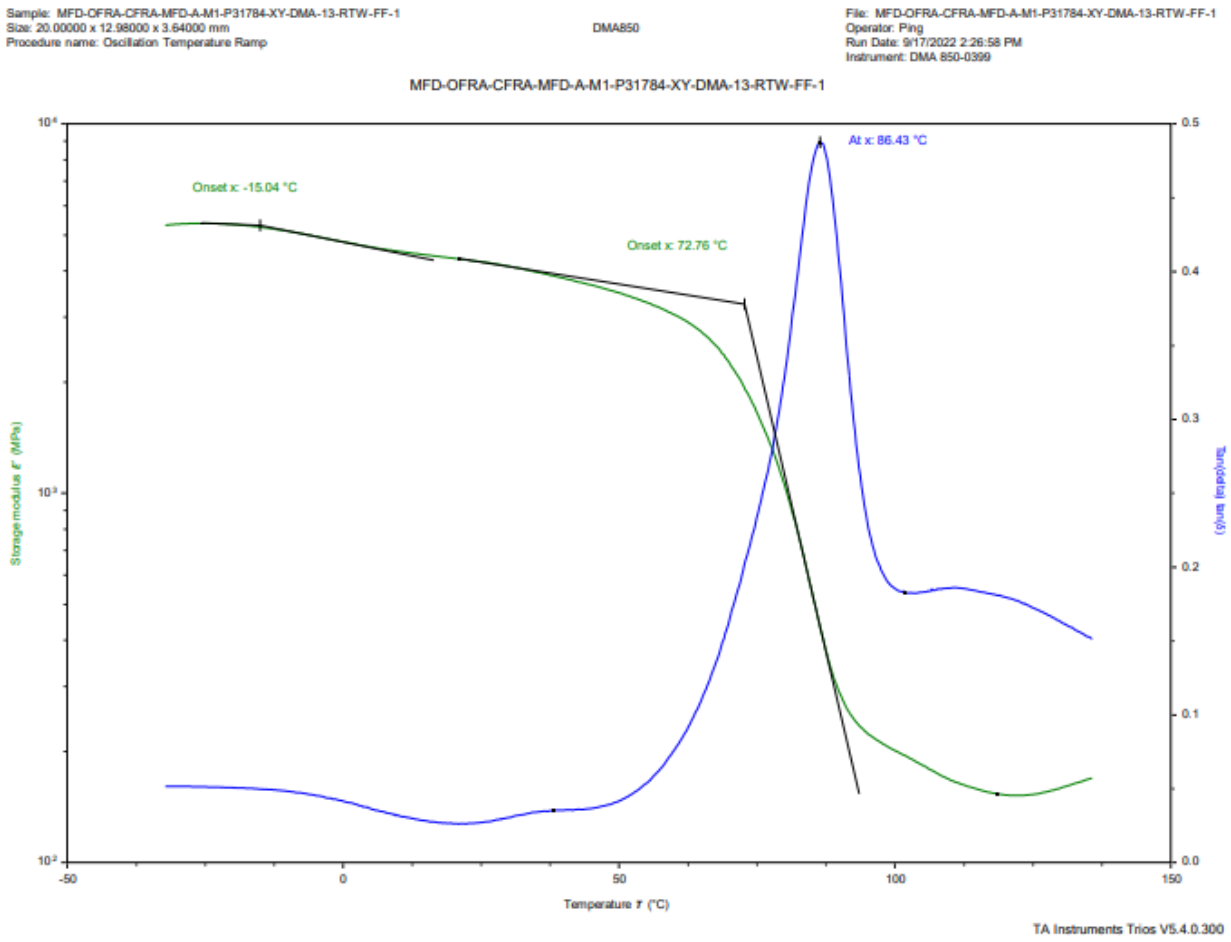
9.1.2 **XY PF DMA Wet Batch A**



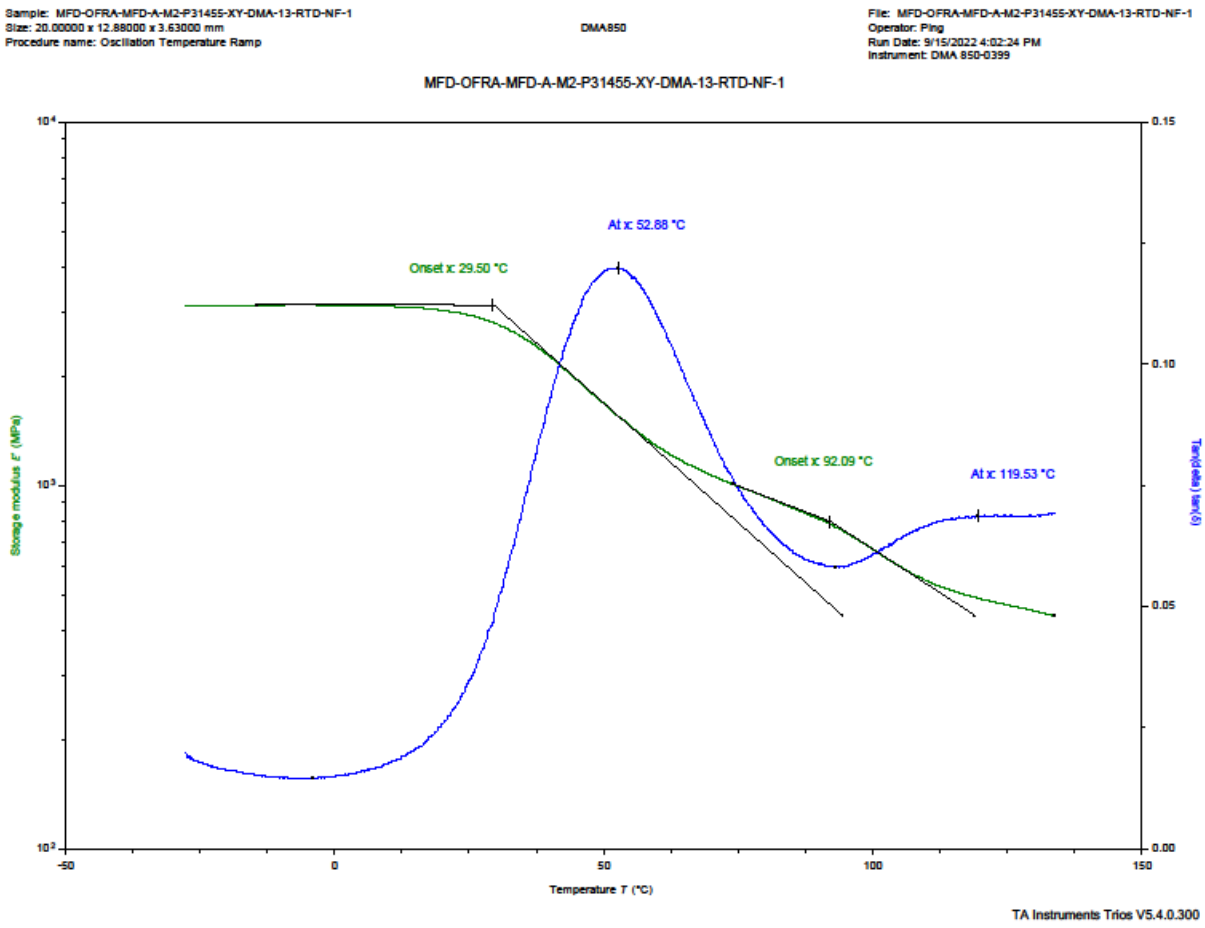
9.1.3 **XY FF DMA Dry Batch A**



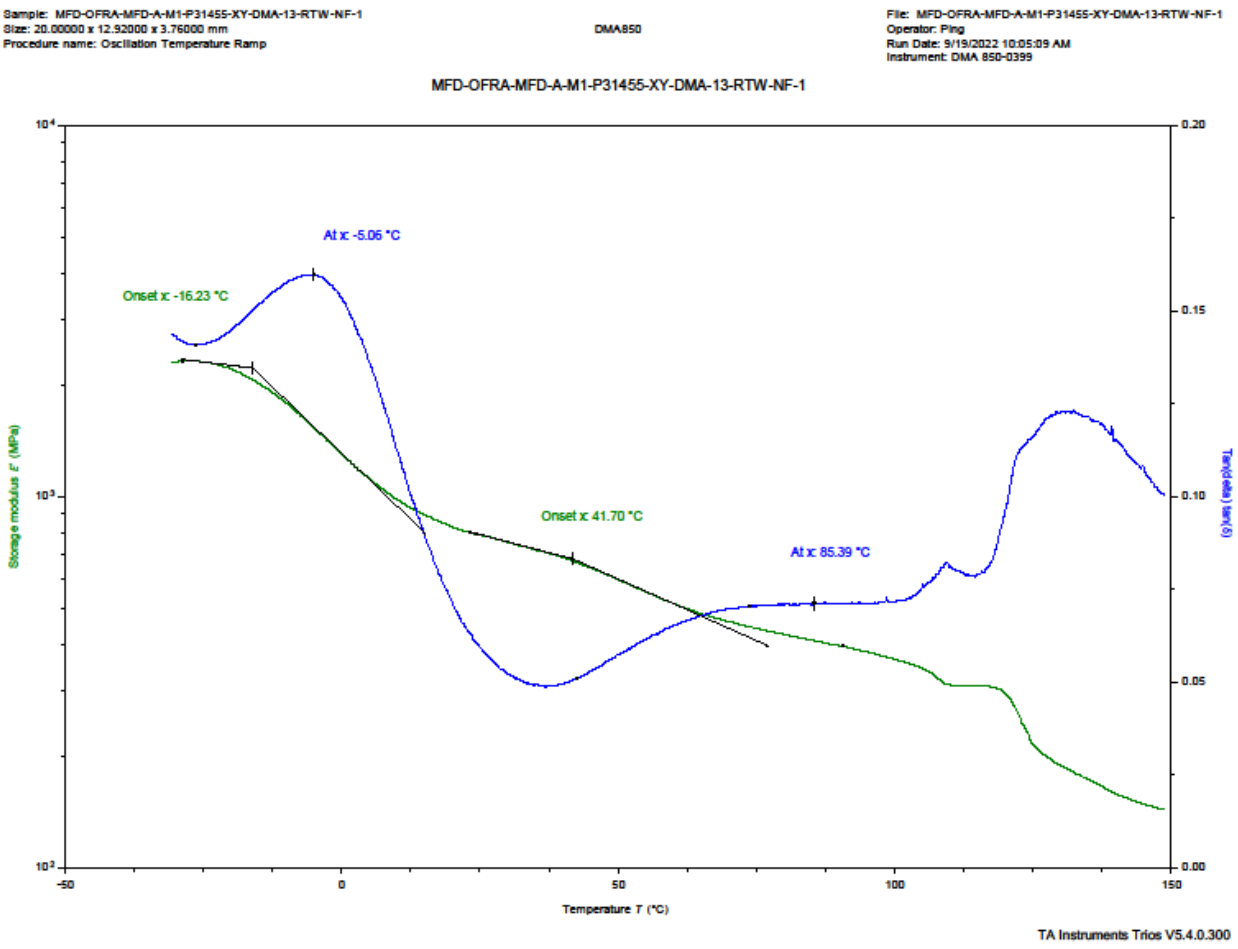
9.1.4 **XY FF DMA Wet Batch A**



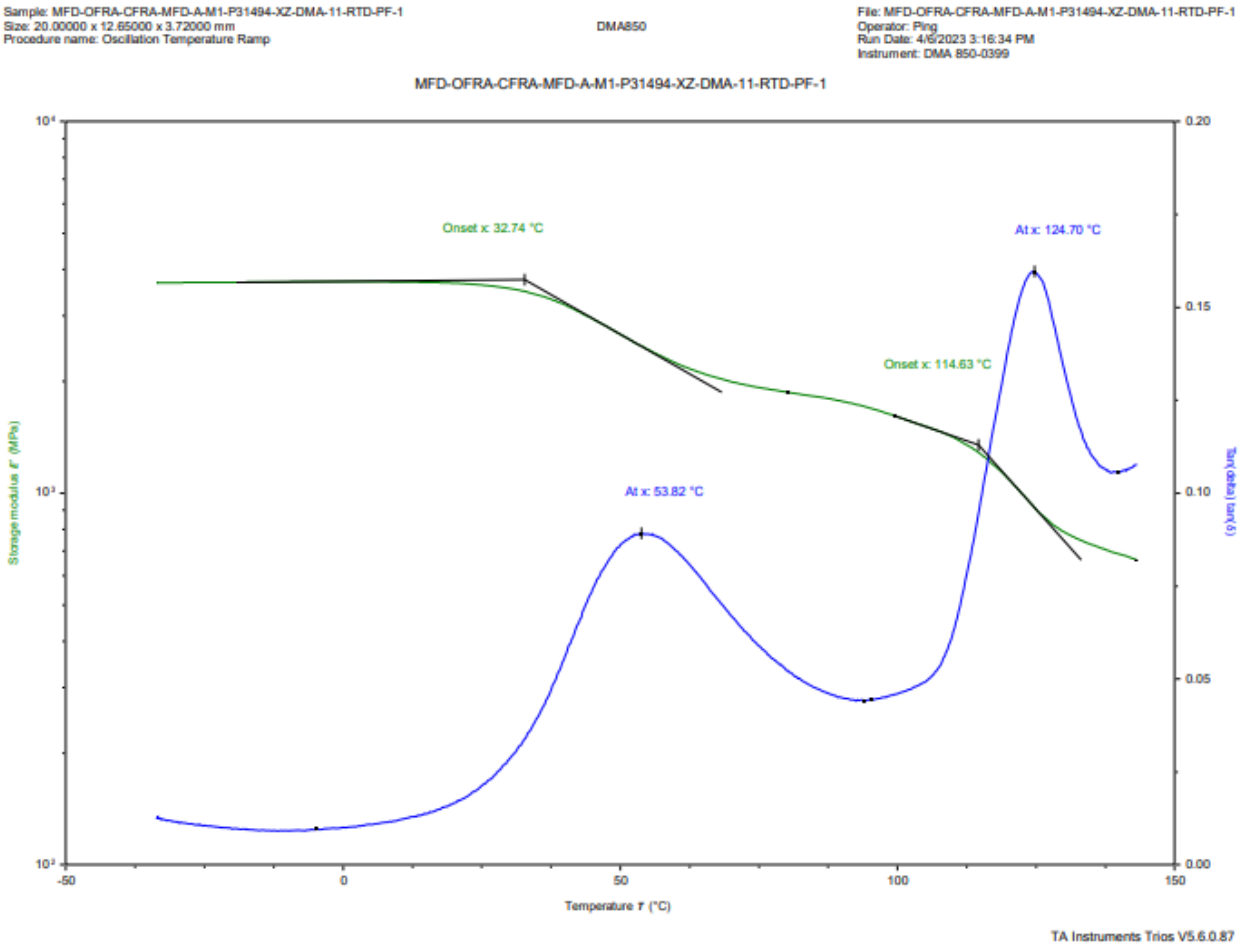
9.1.5 **XY NF DMA Dry Batch A**



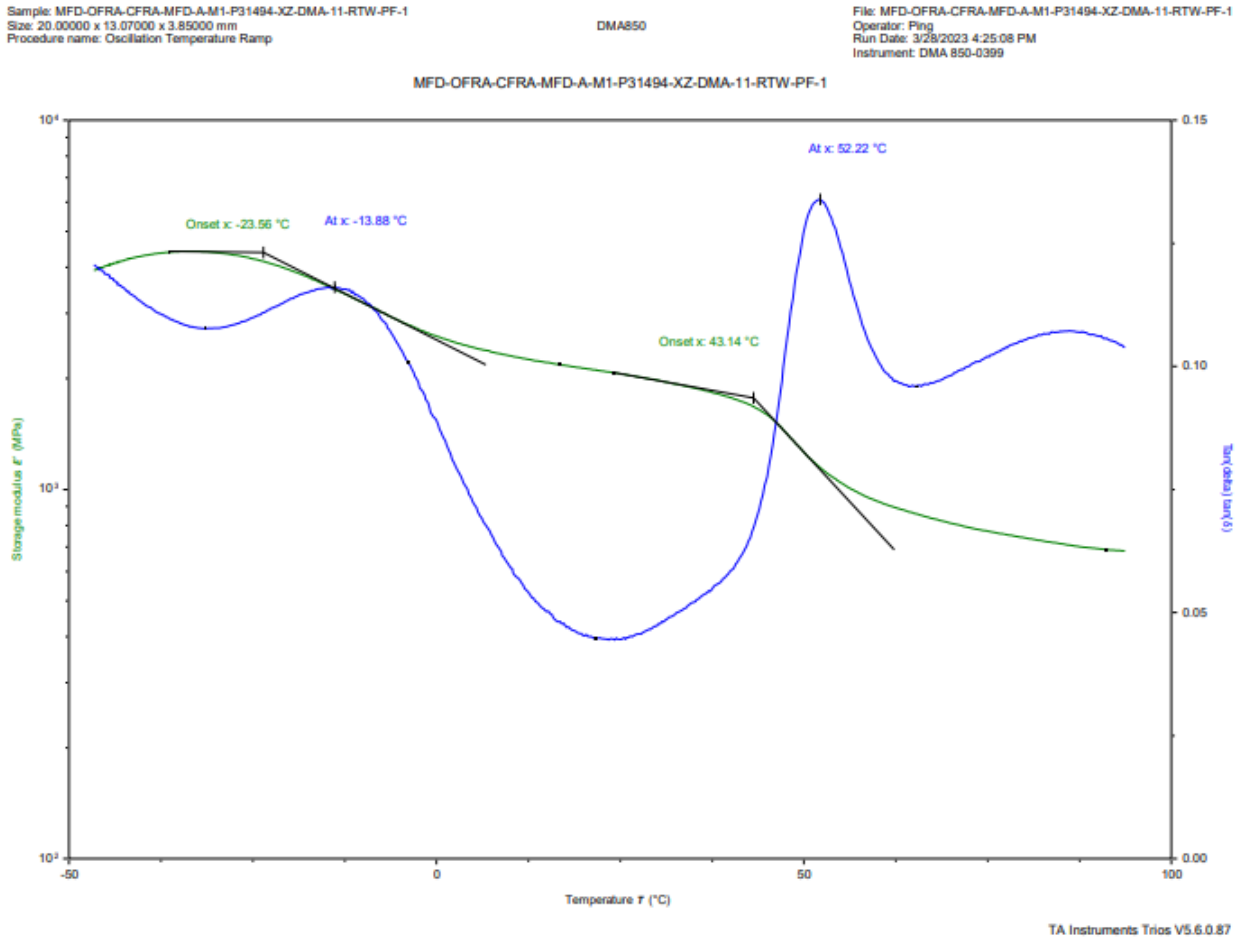
9.1.6 **XY NF DMA Wet Batch A**



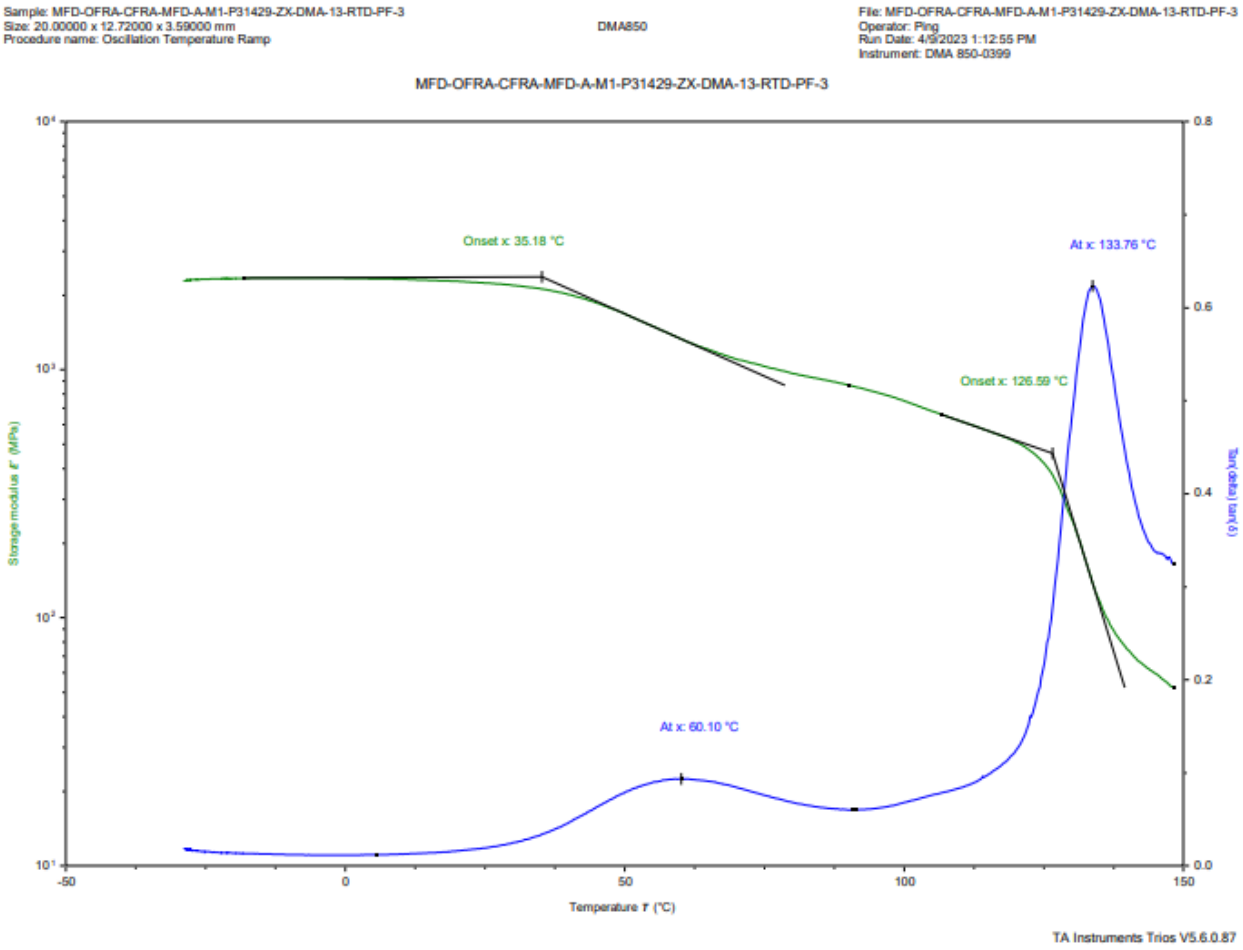
9.1.7 **XZ PF DMA Dry Batch A**



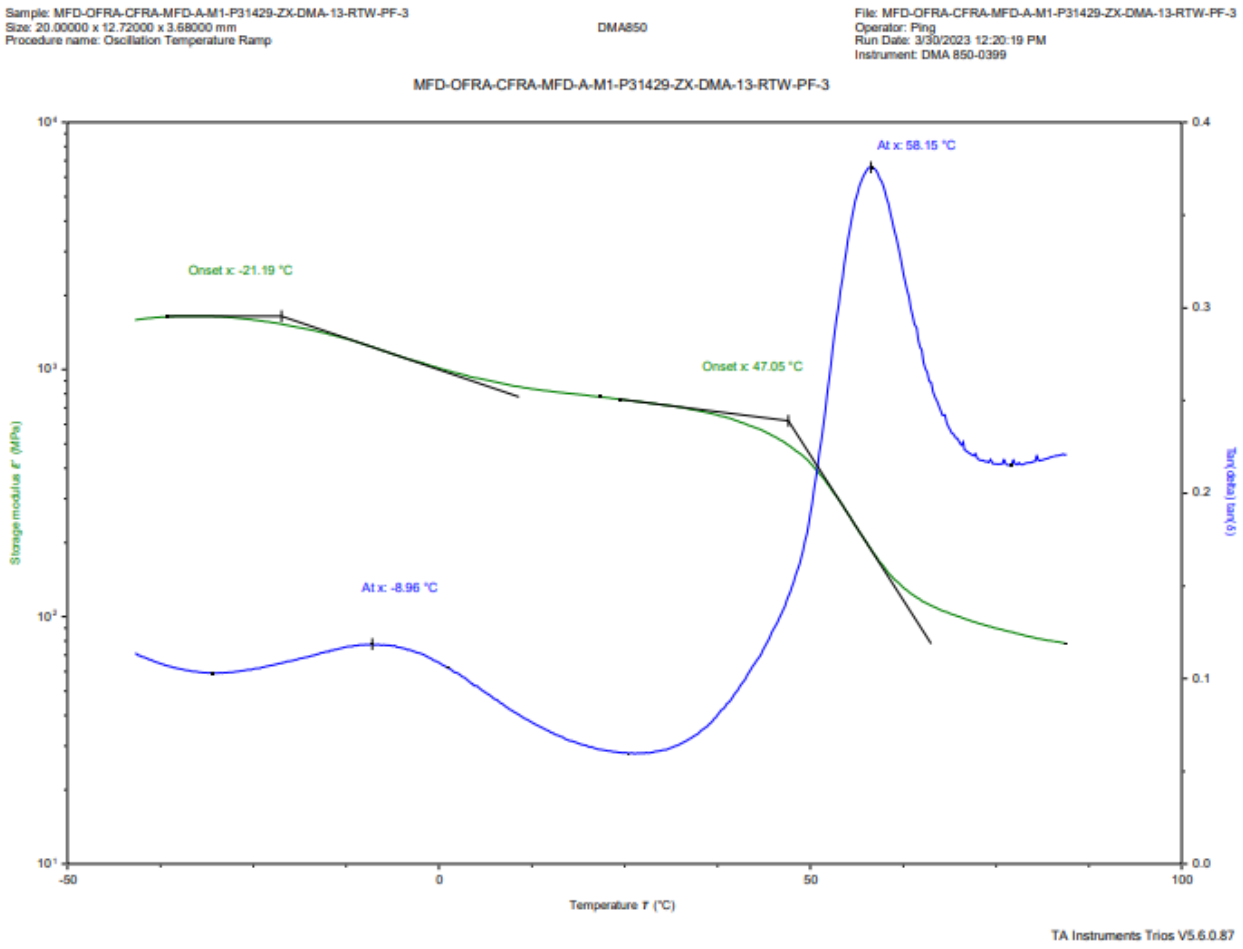
9.1.8 **XZ PF DMA Wet Batch A**



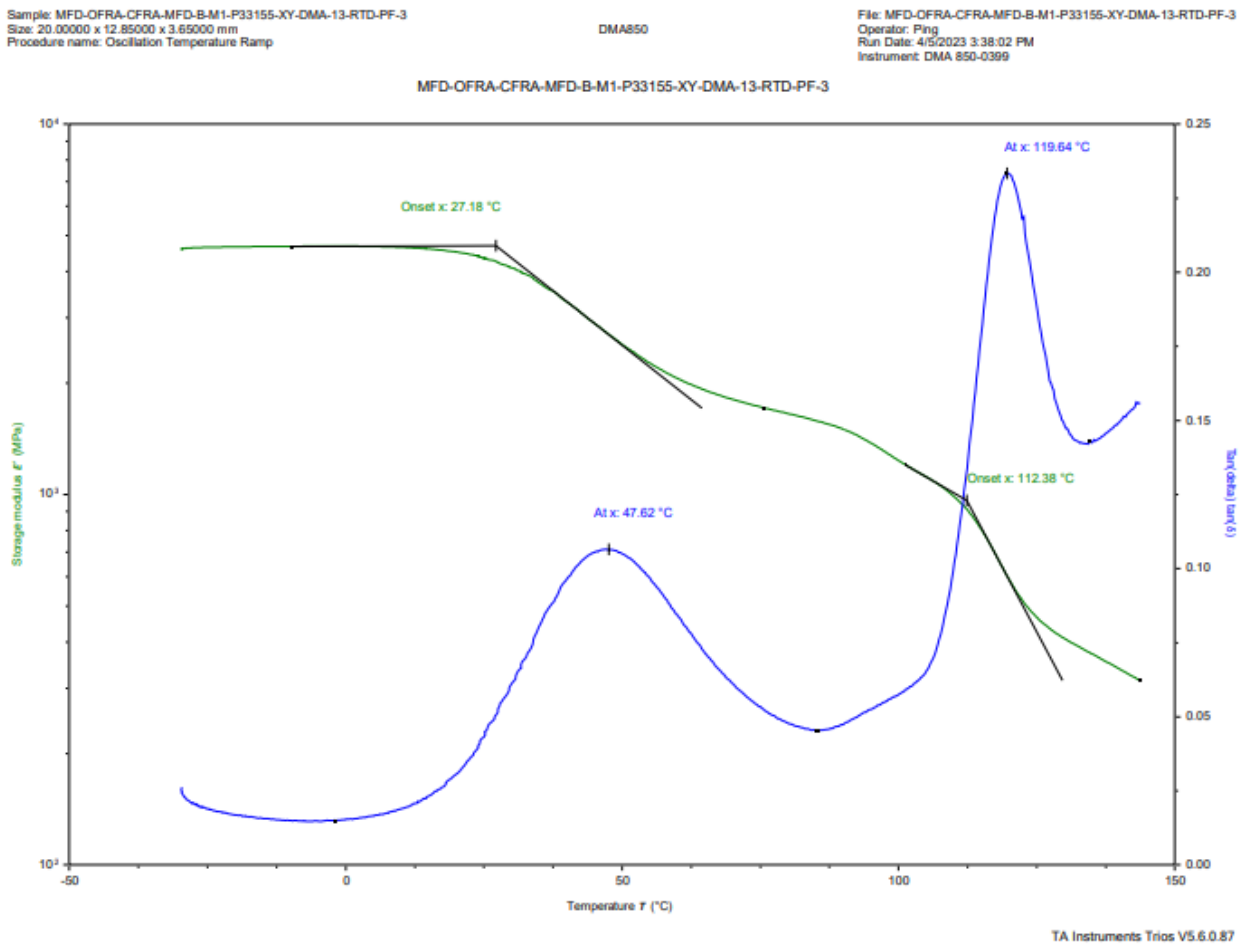
9.1.9 **ZX PF DMA Dry Batch A**



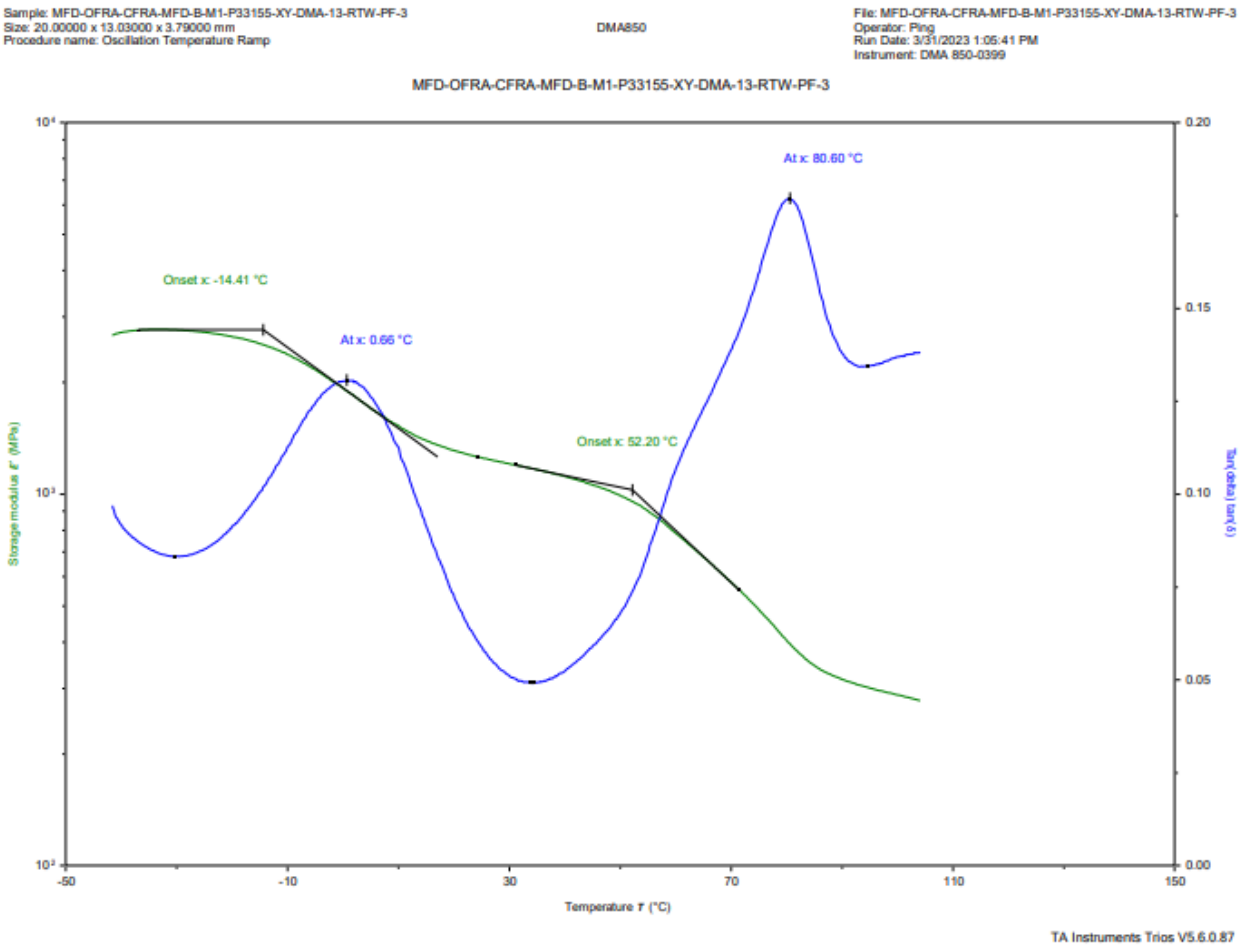
9.1.10 **ZX PF DMA Wet Batch A**



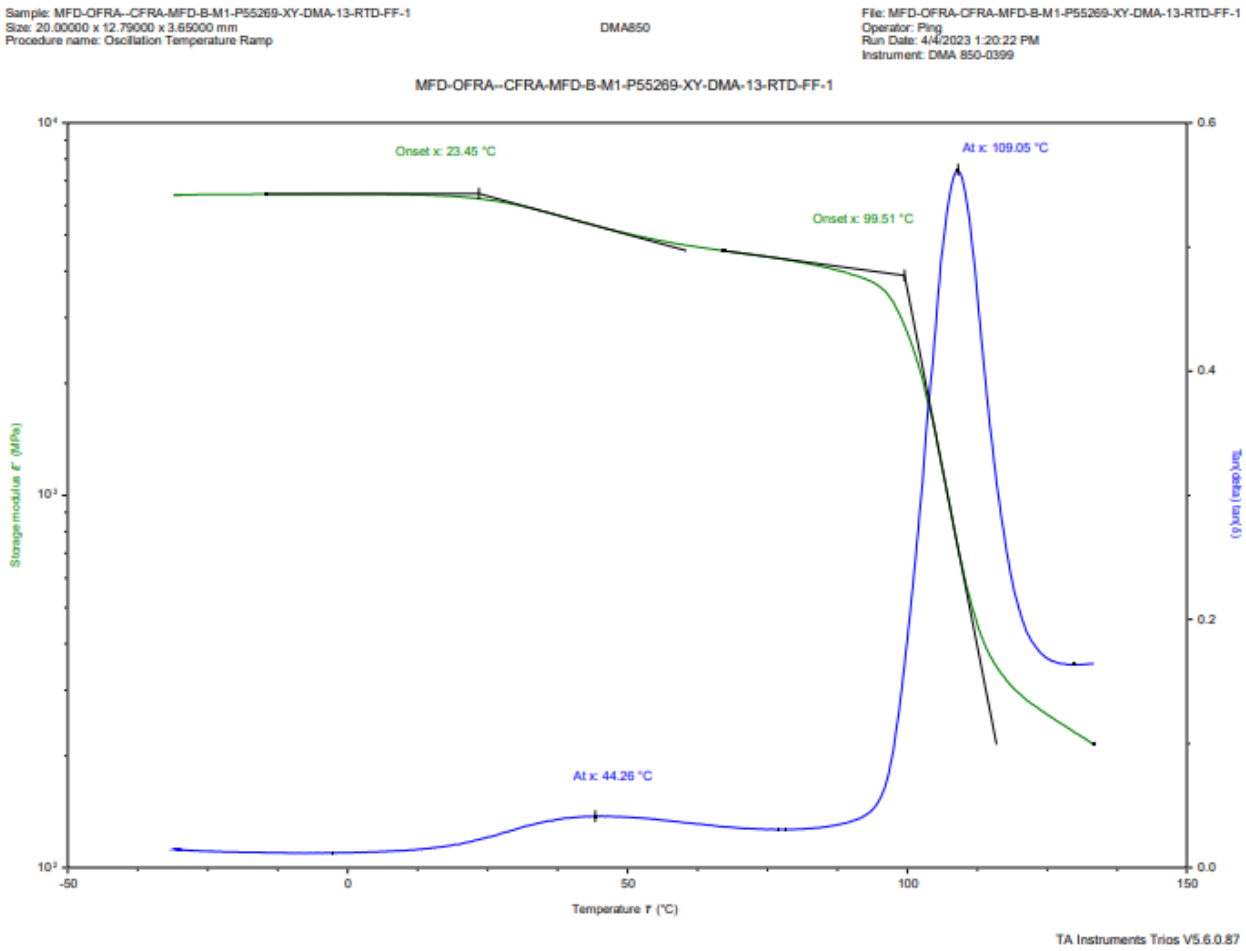
9.1.11 **XY PF DMA Dry Batch B**



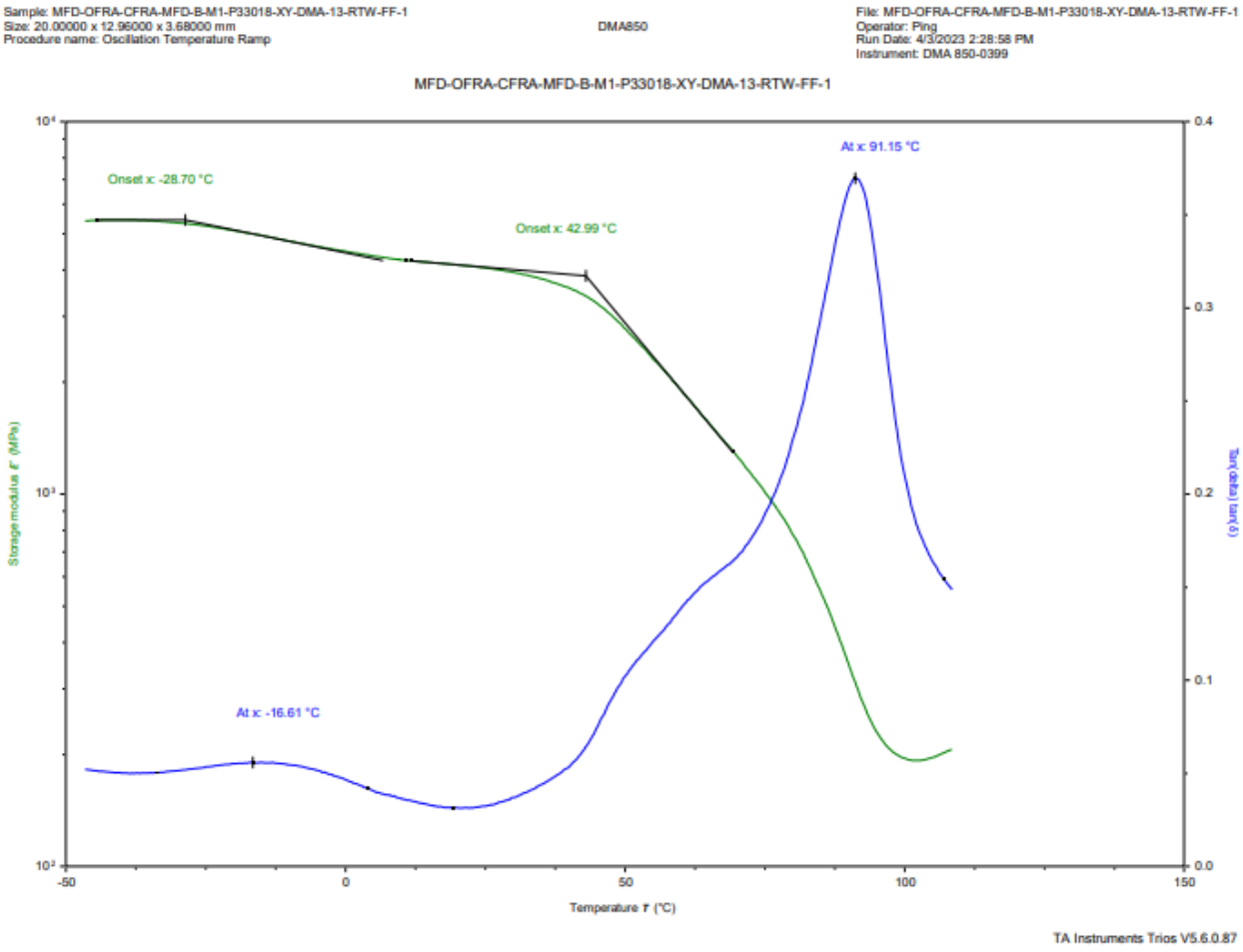
9.1.12 **XY PF DMA Wet Batch B**



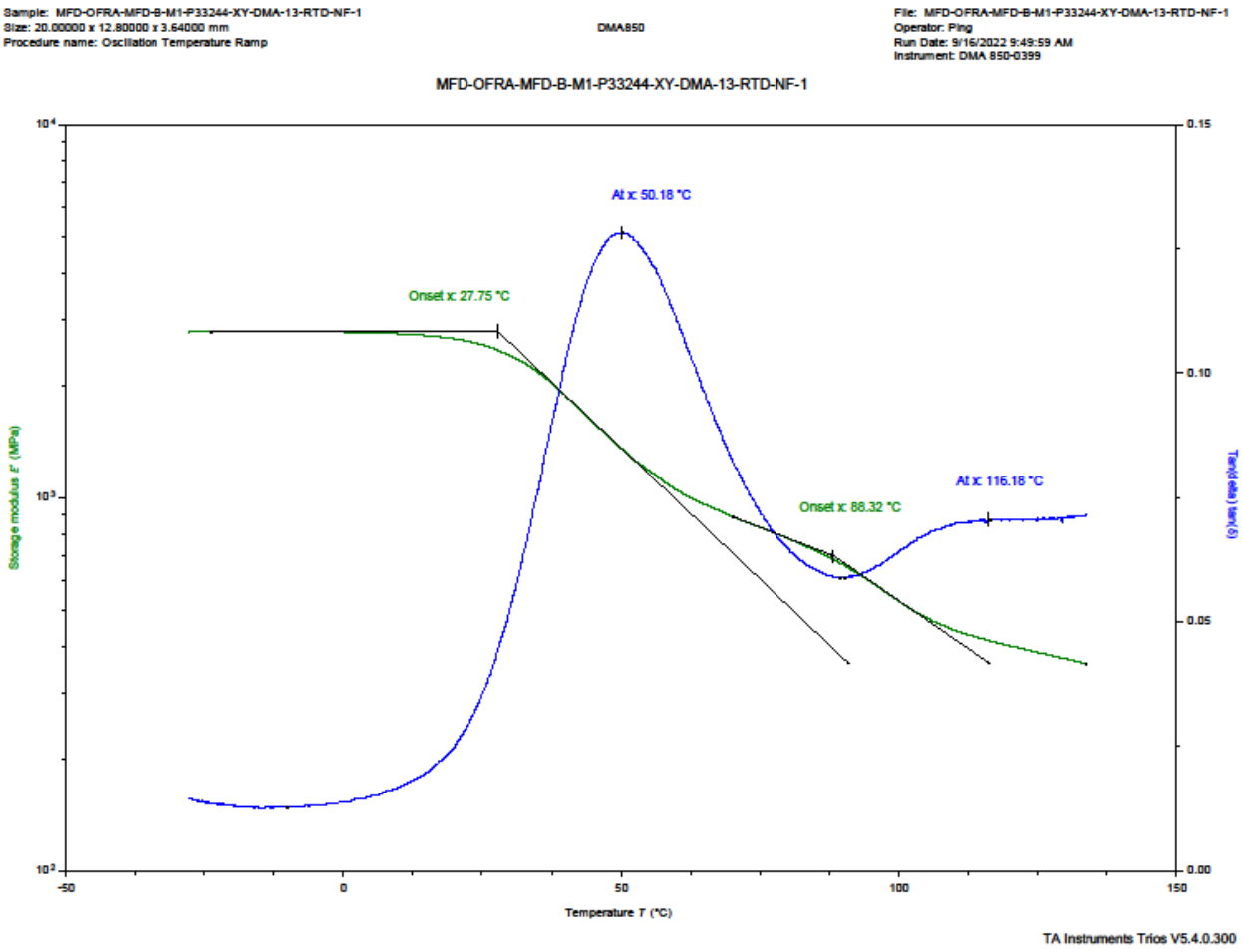
9.1.13 **XY FF DMA Dry Batch B**



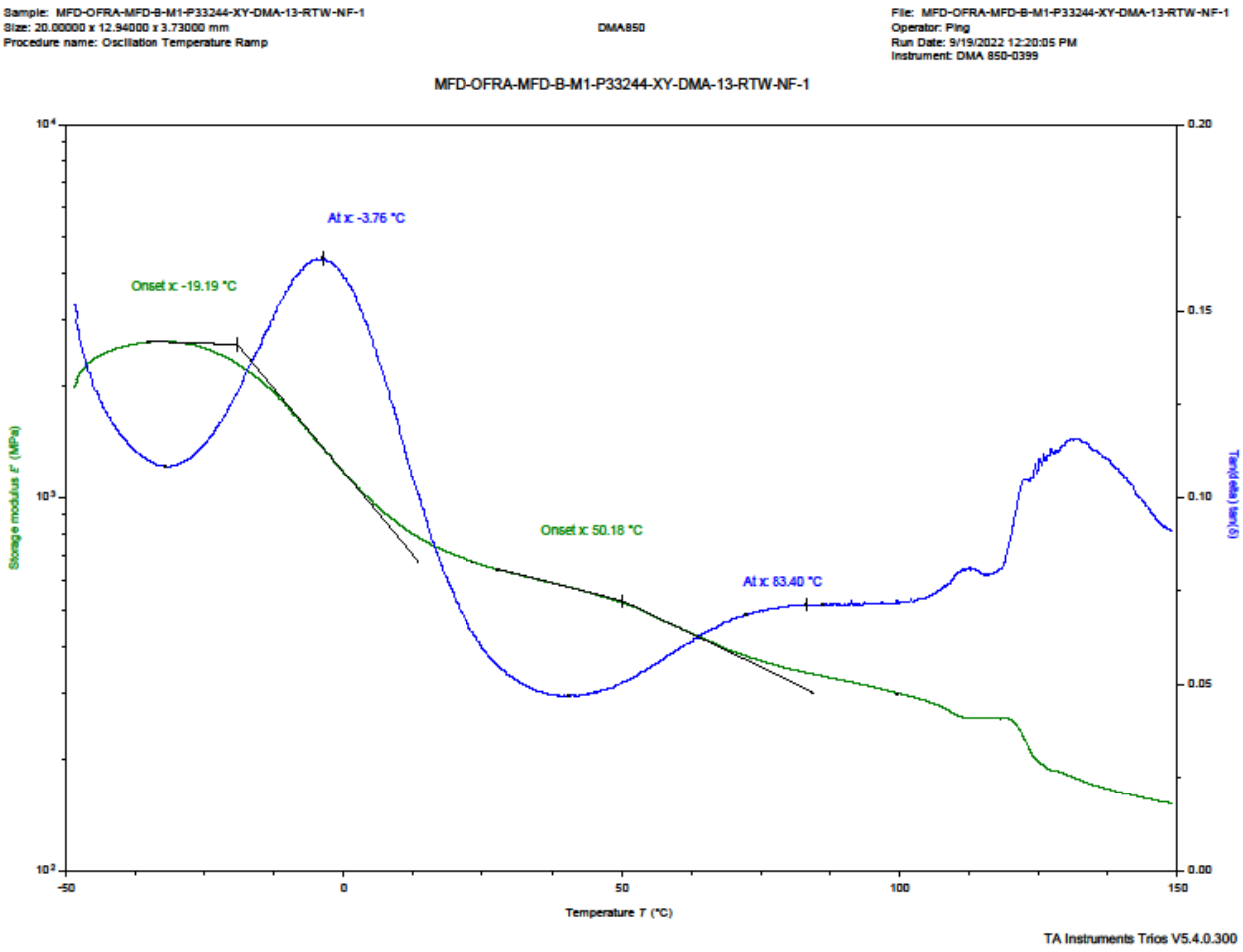
9.1.14 **XY FF DMA Wet Batch B**



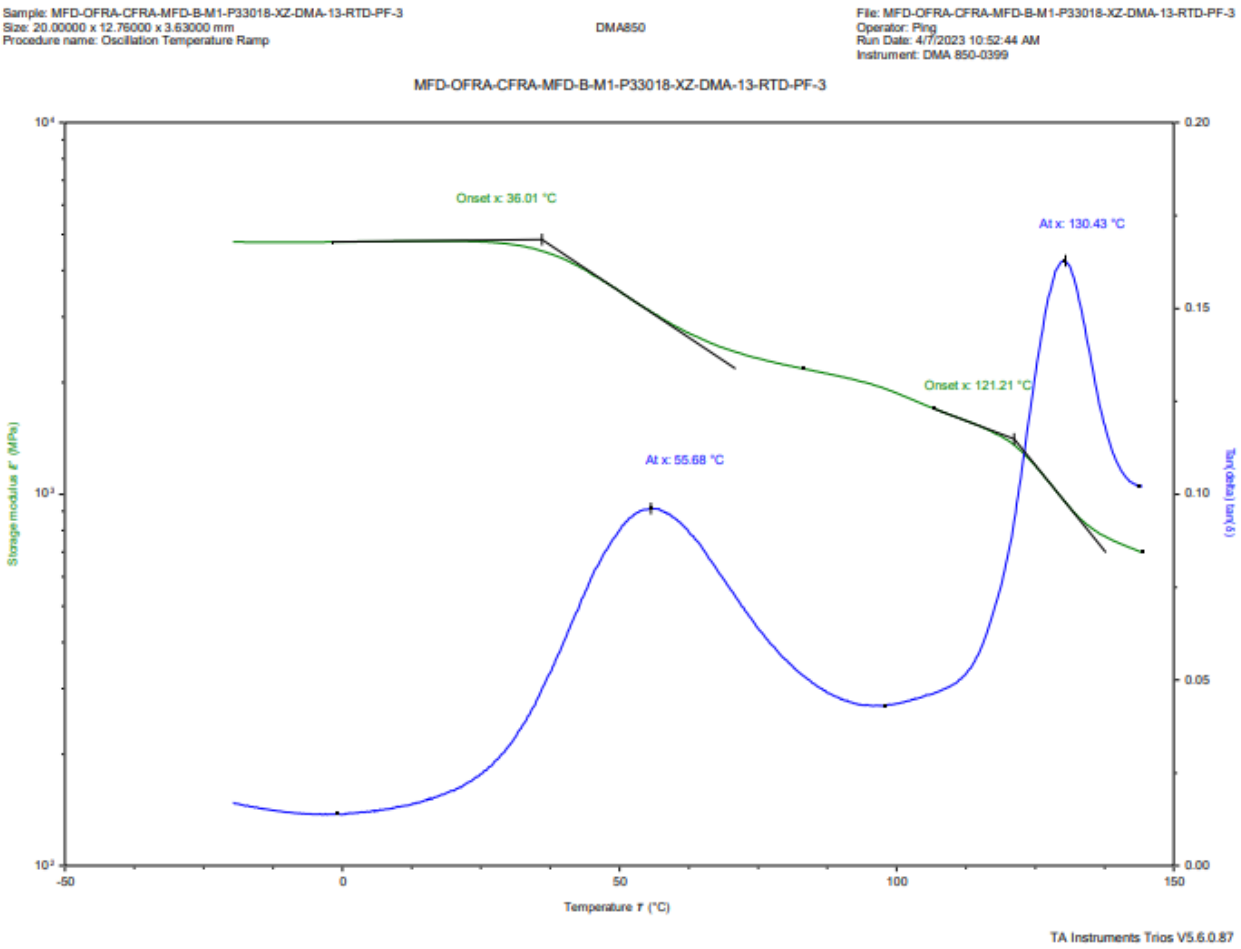
9.1.15 **XY NF DMA Dry Batch B**



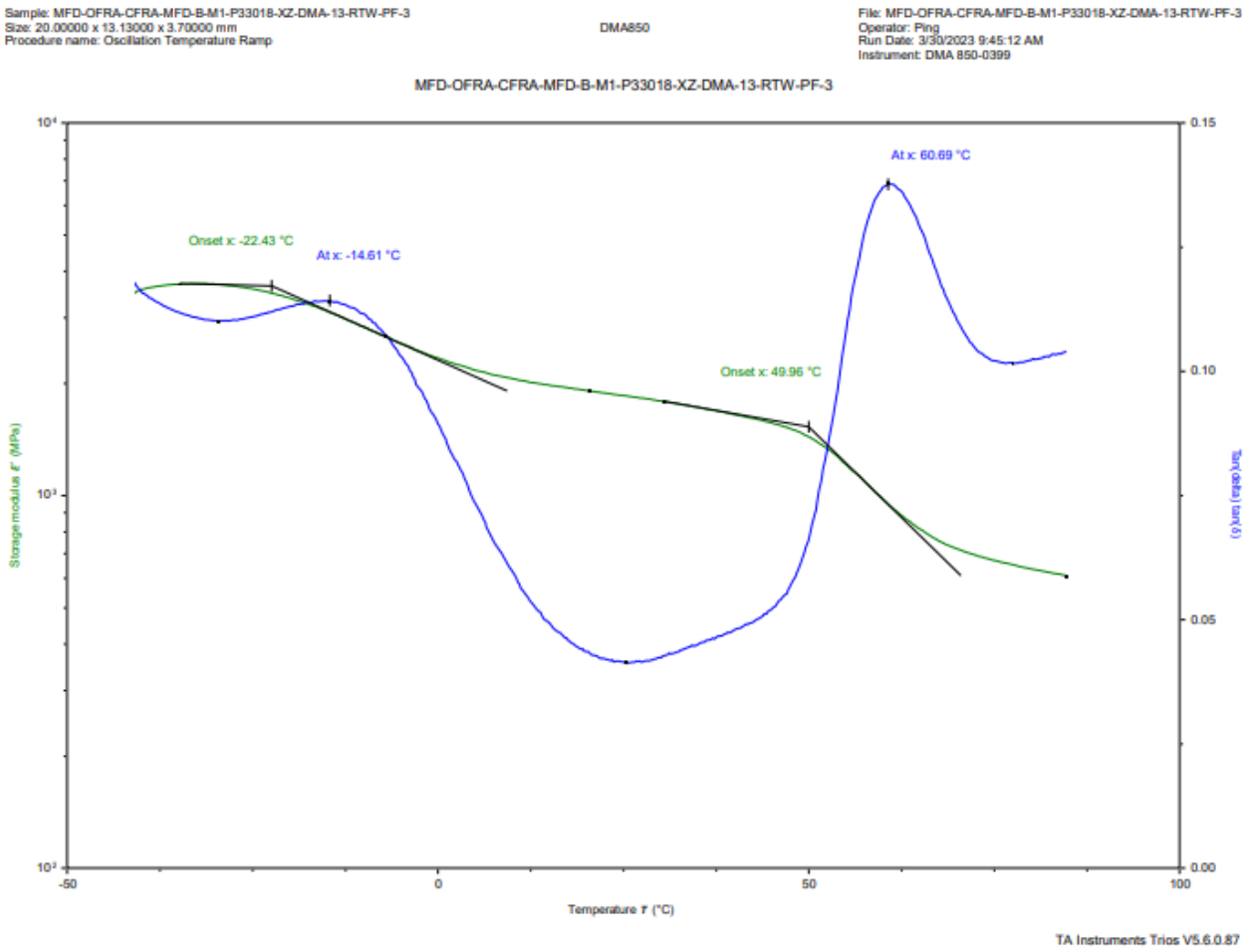
9.1.16 **XY NF DMA Wet Batch B**



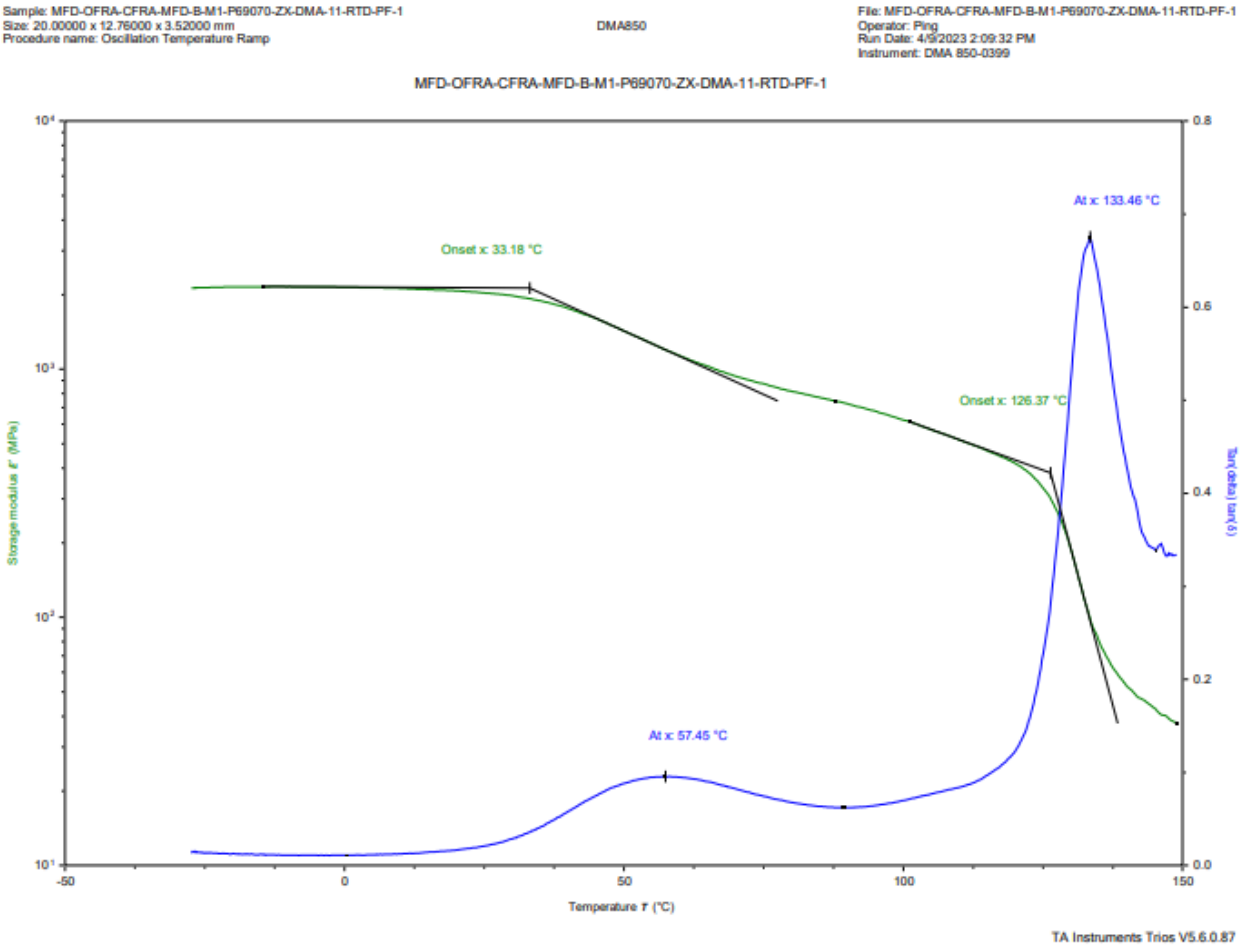
9.1.17 **XZ PF DMA Dry Batch B**



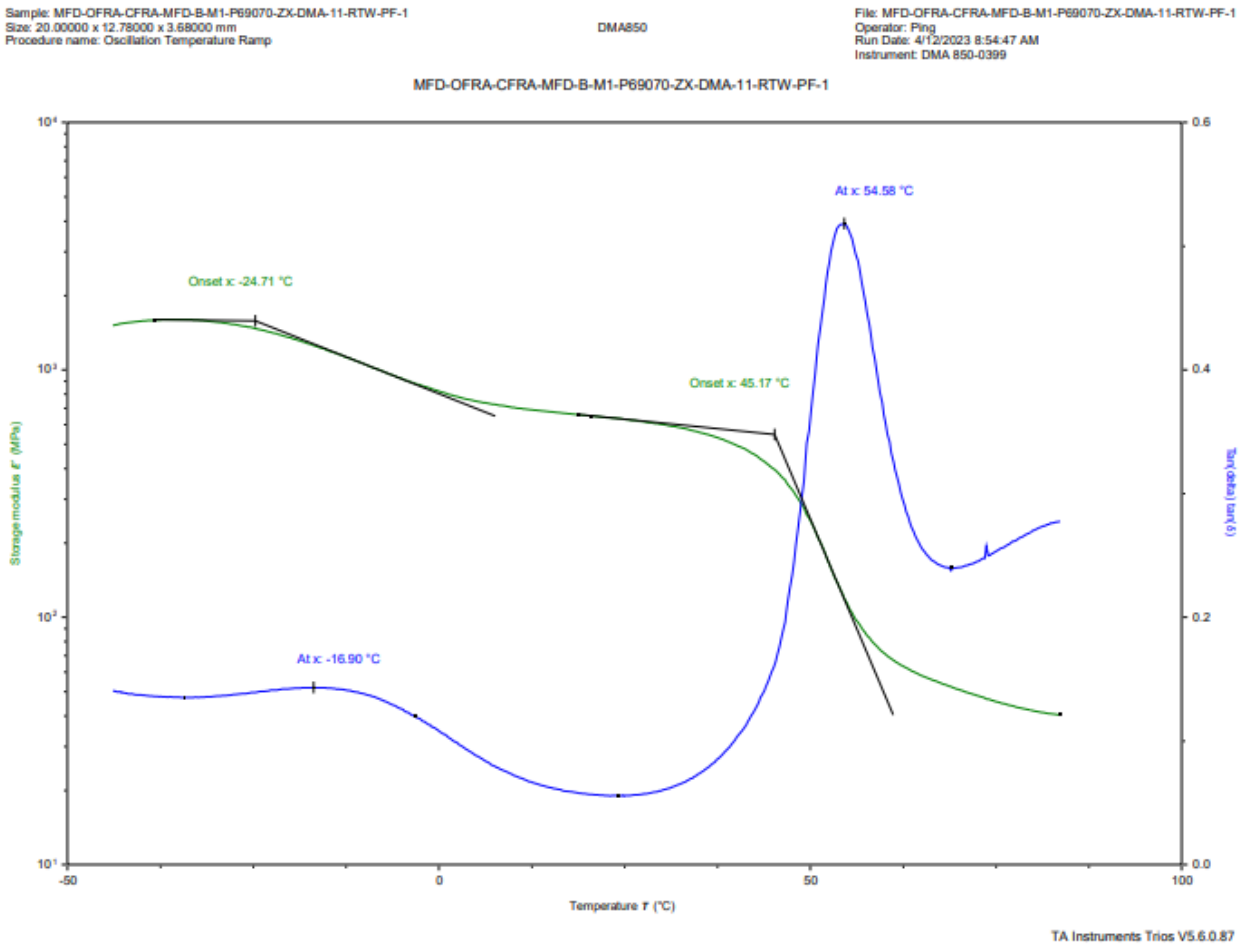
9.1.18 **XZ PF DMA Wet Batch B**



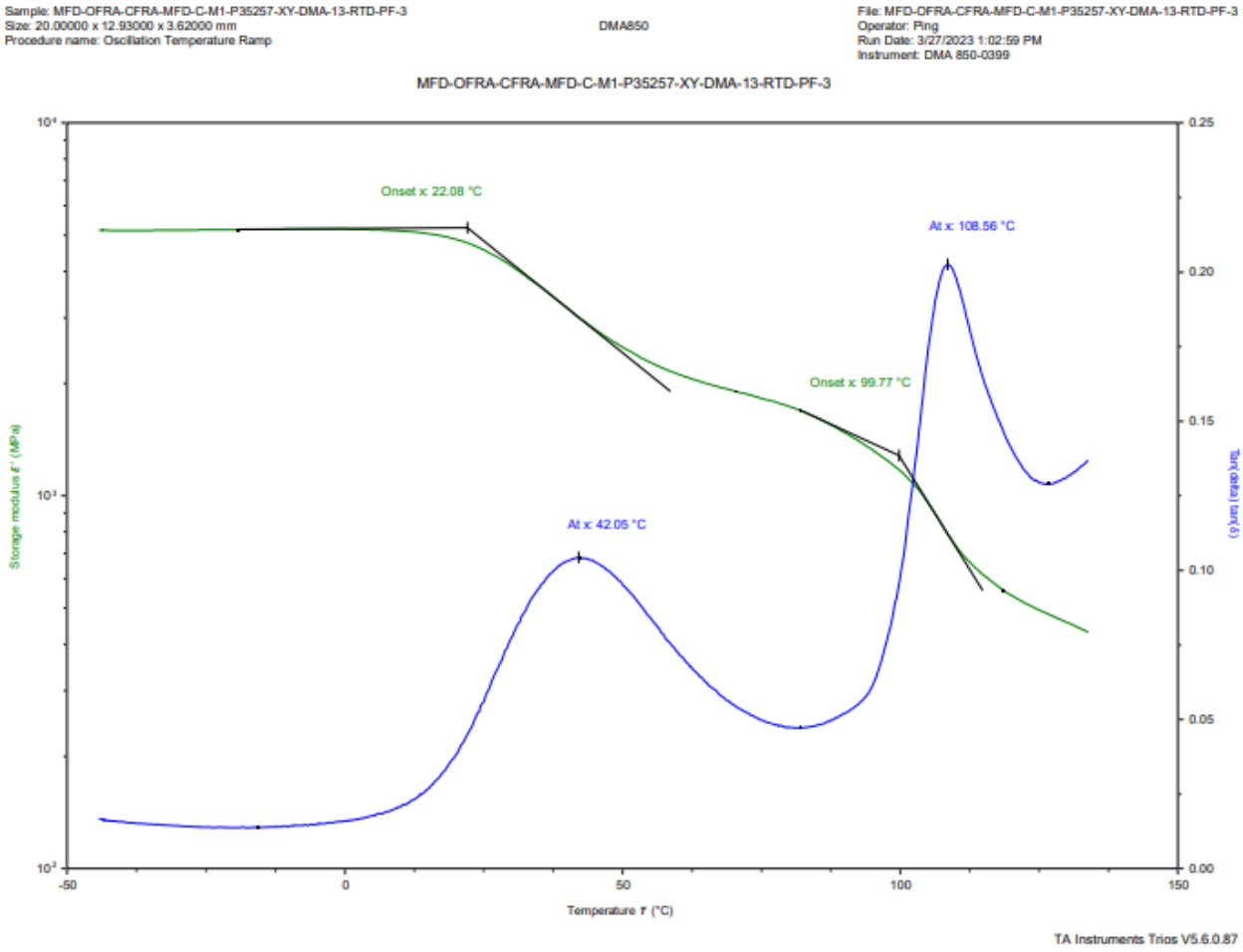
9.1.19 **ZX PF DMA Dry Batch B**



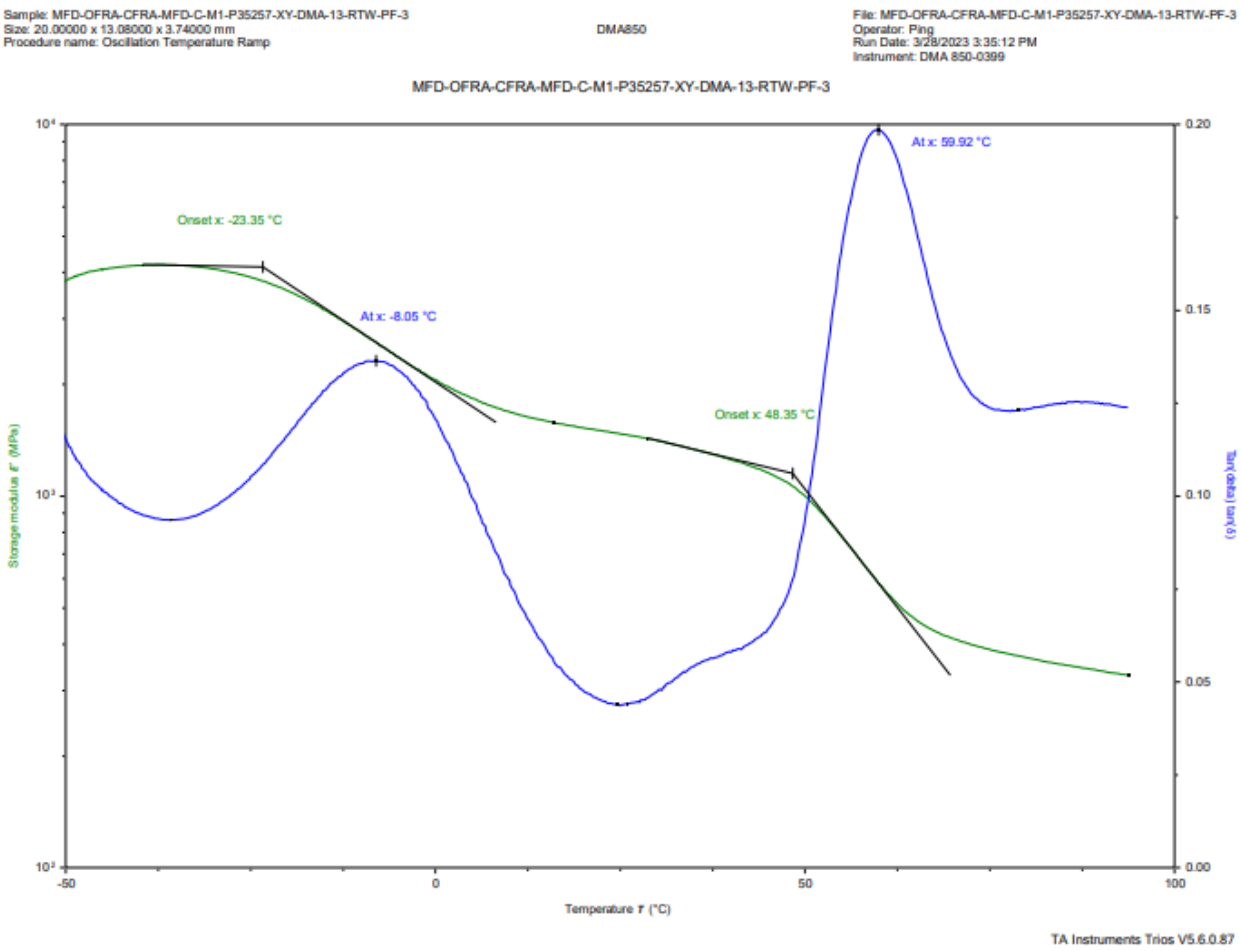
9.1.20 **ZX PF DMA Wet Batch B**



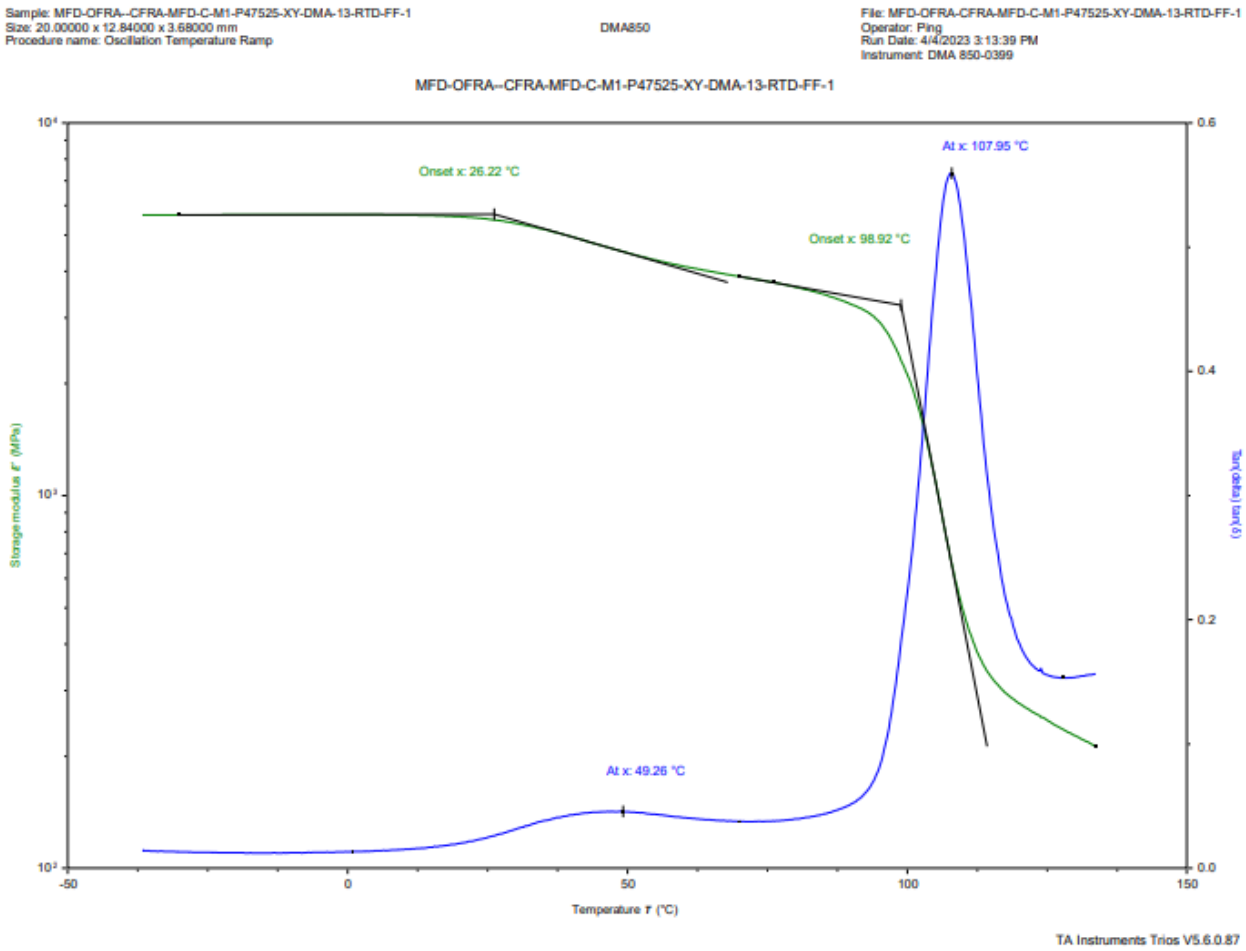
9.1.21 **XY PF DMA Dry Batch C**



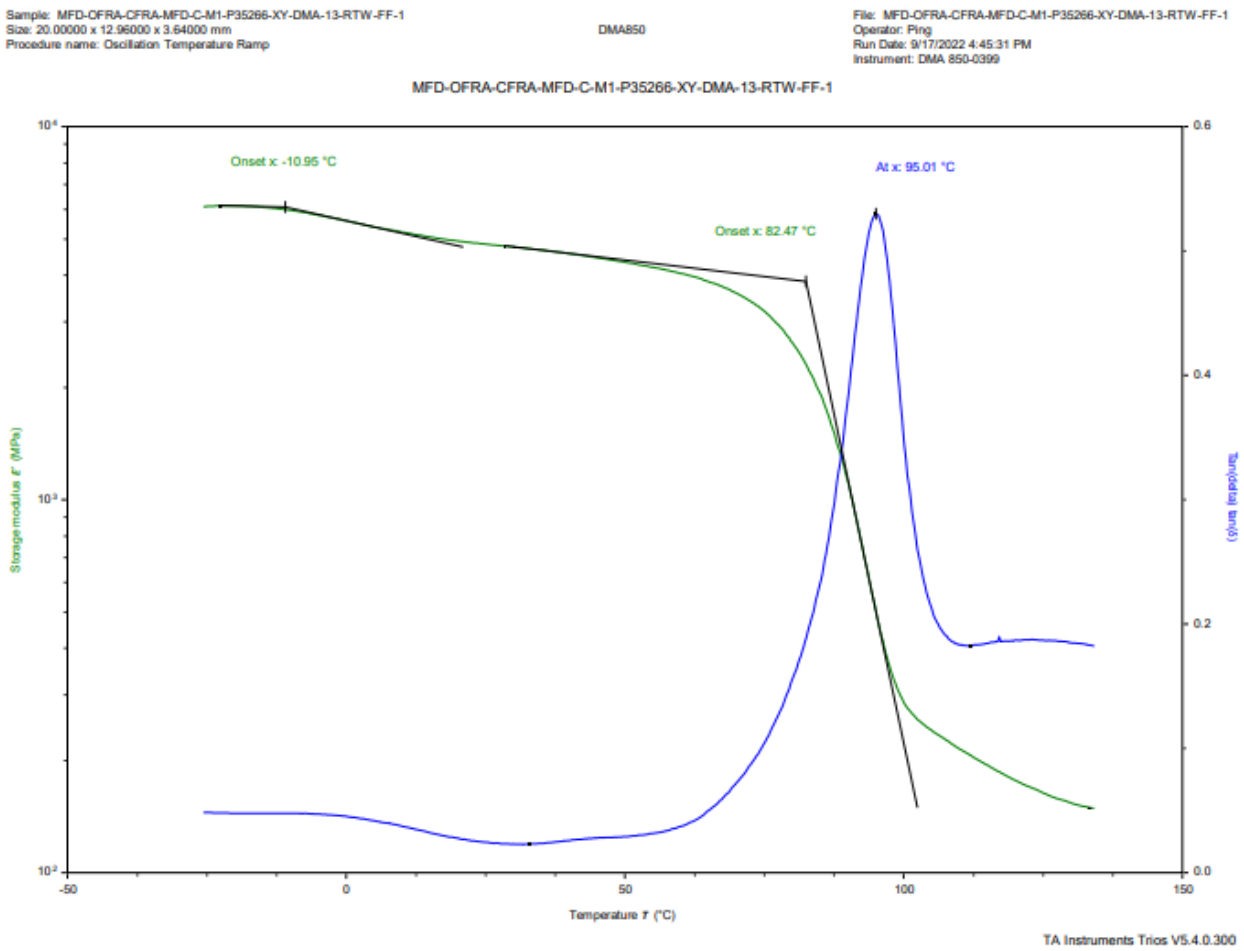
9.1.22 **XY PF DMA Wet Batch C**



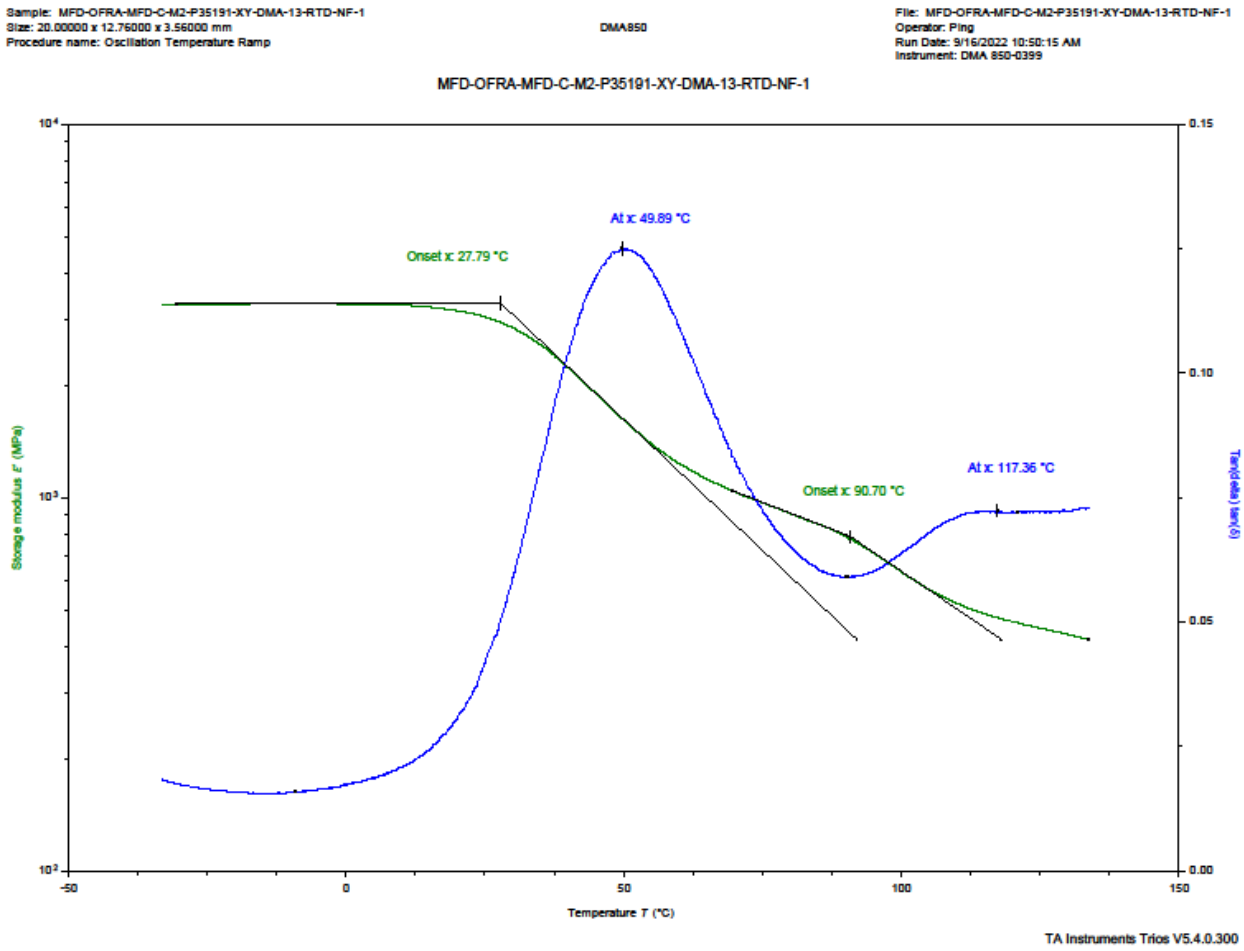
9.1.23 **XY FF DMA Dry Batch C**



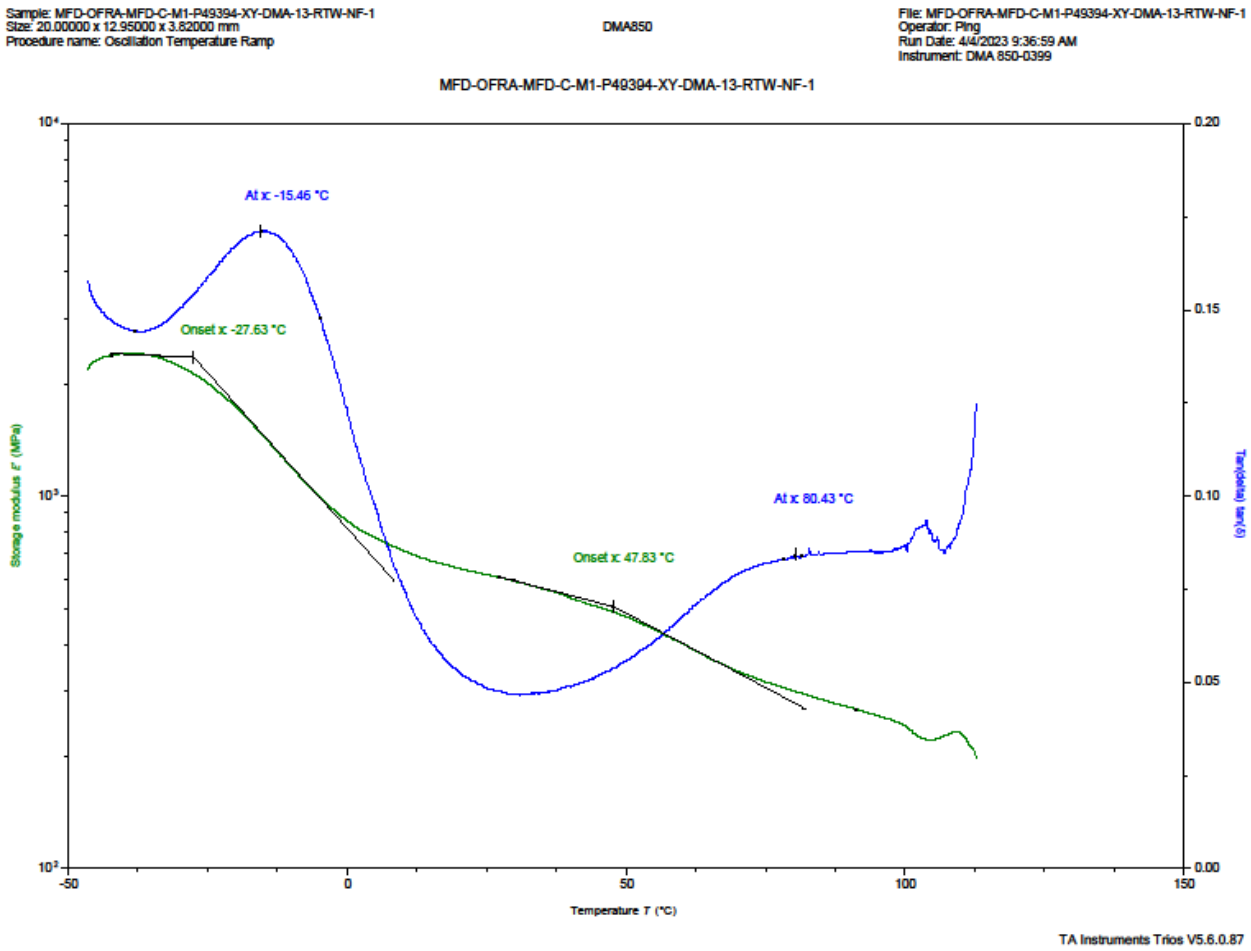
9.1.24 **XY FF DMA Wet Batch C**



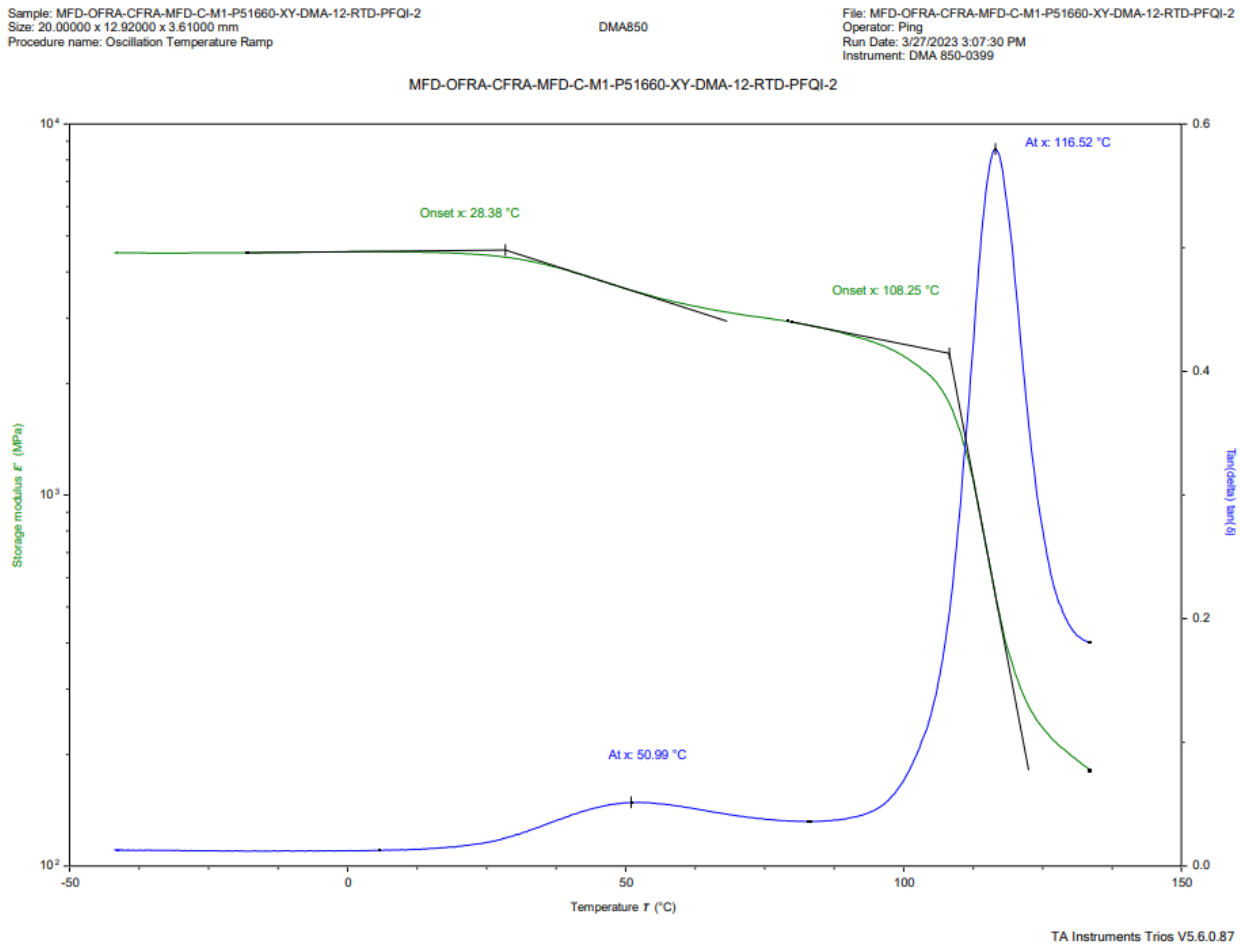
9.1.25 **XY NF DMA Dry Batch C**



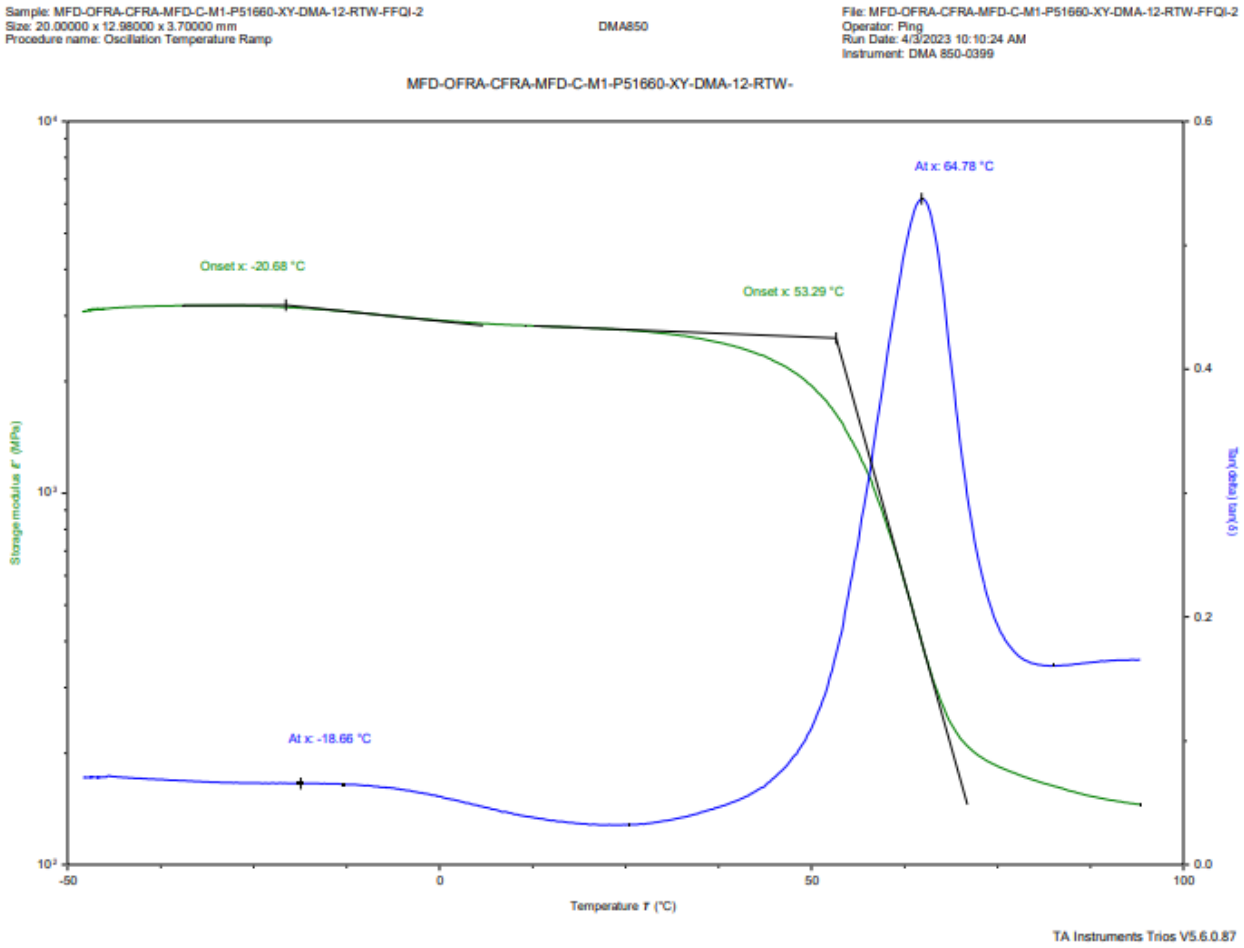
9.1.26 **XY NF DMA Wet Batch C**



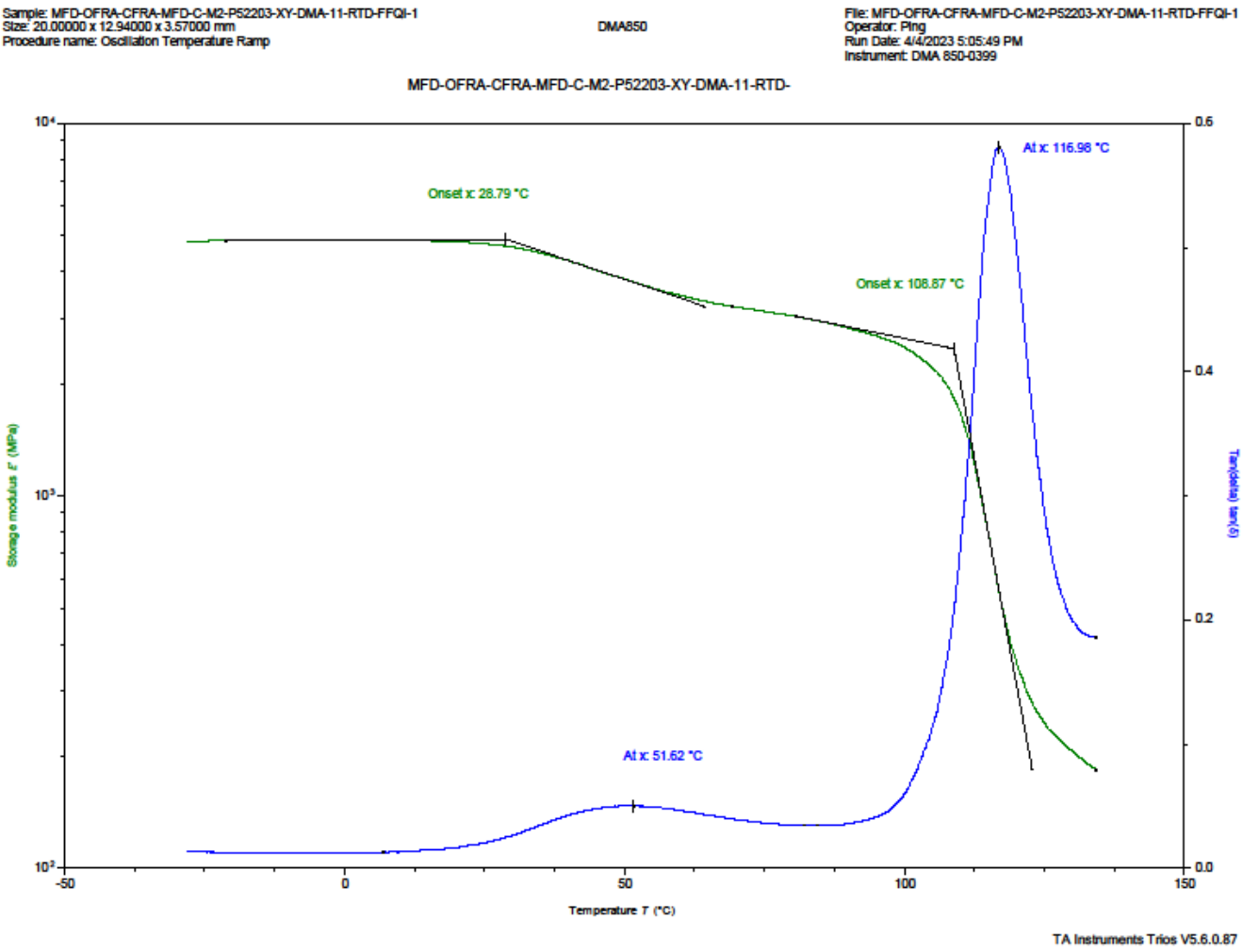
9.1.27 **XY PF Quasi DMA Dry Batch C**



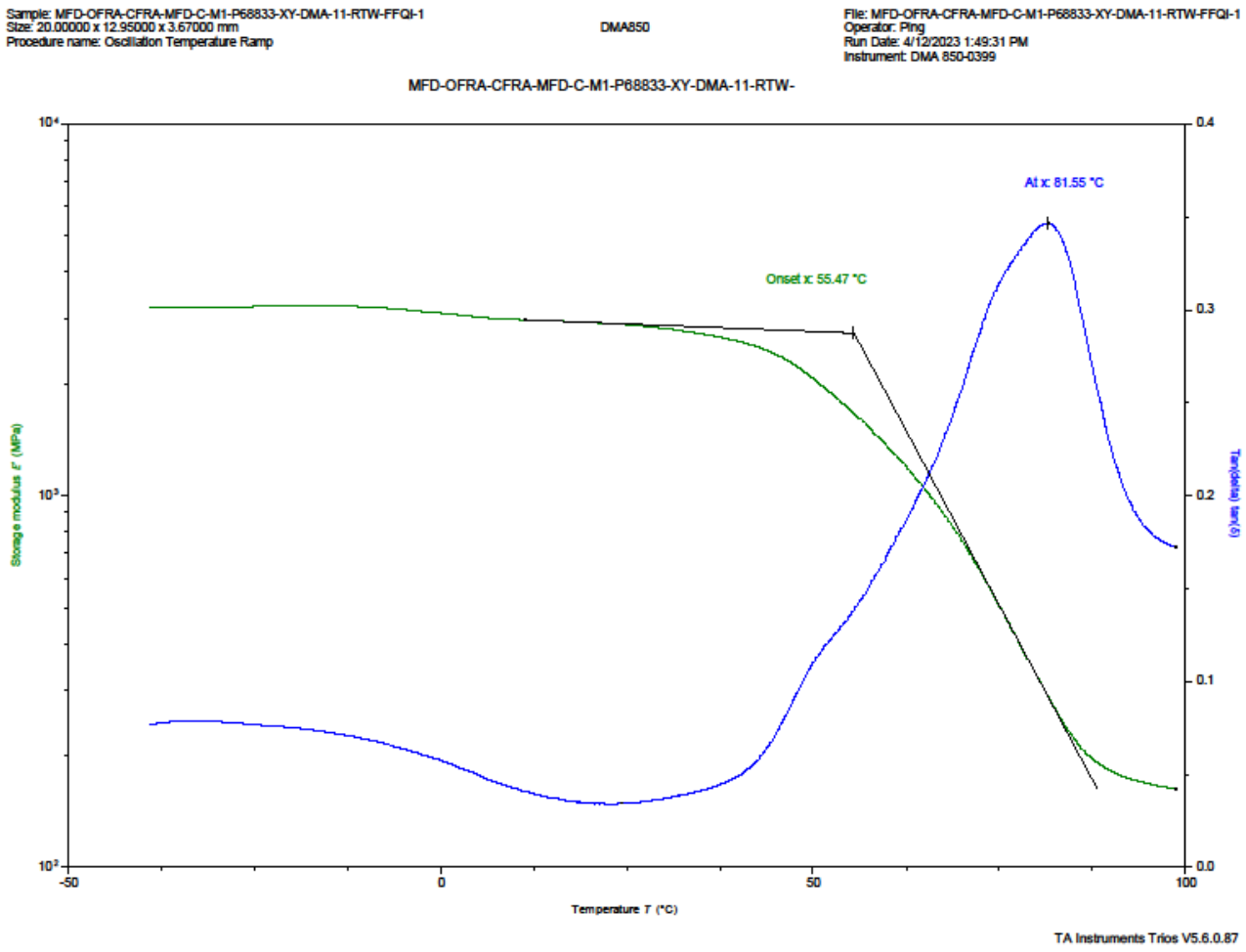
9.1.28 **XY PF Quasi DMA Wet Batch C**



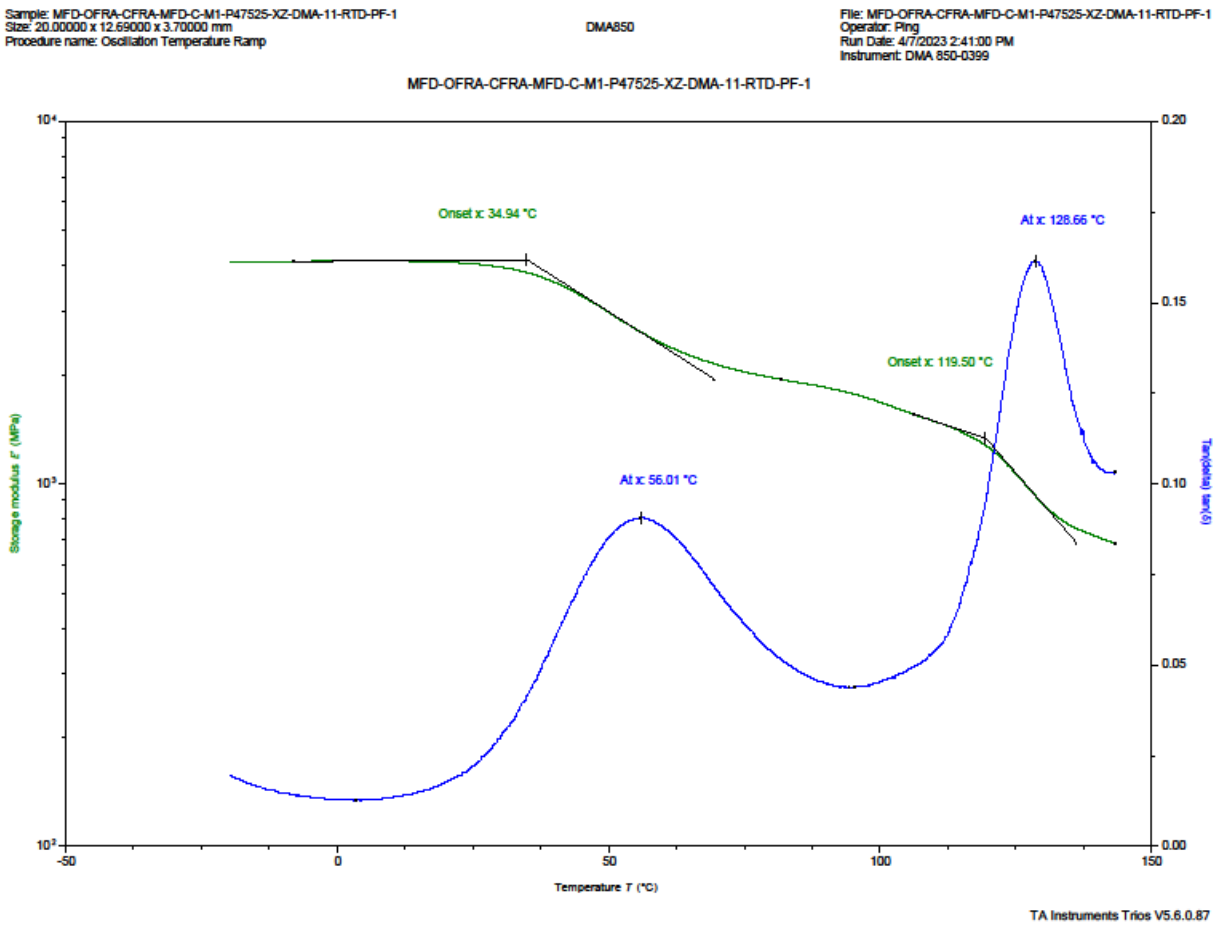
9.1.29 **XY FF Quasi DMA Dry Batch C**



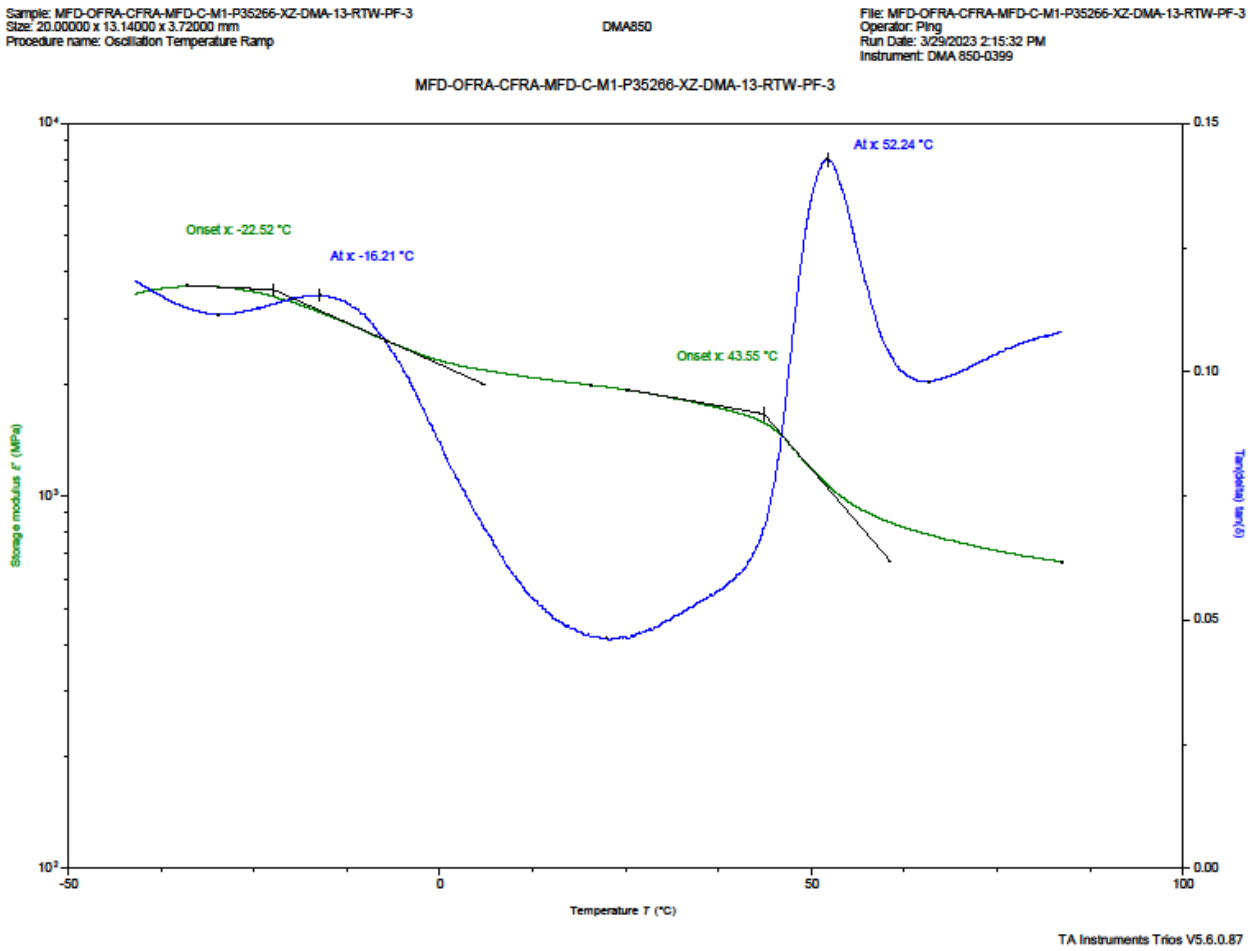
9.1.30 **XY FF Quasi DMA Wet Batch C**



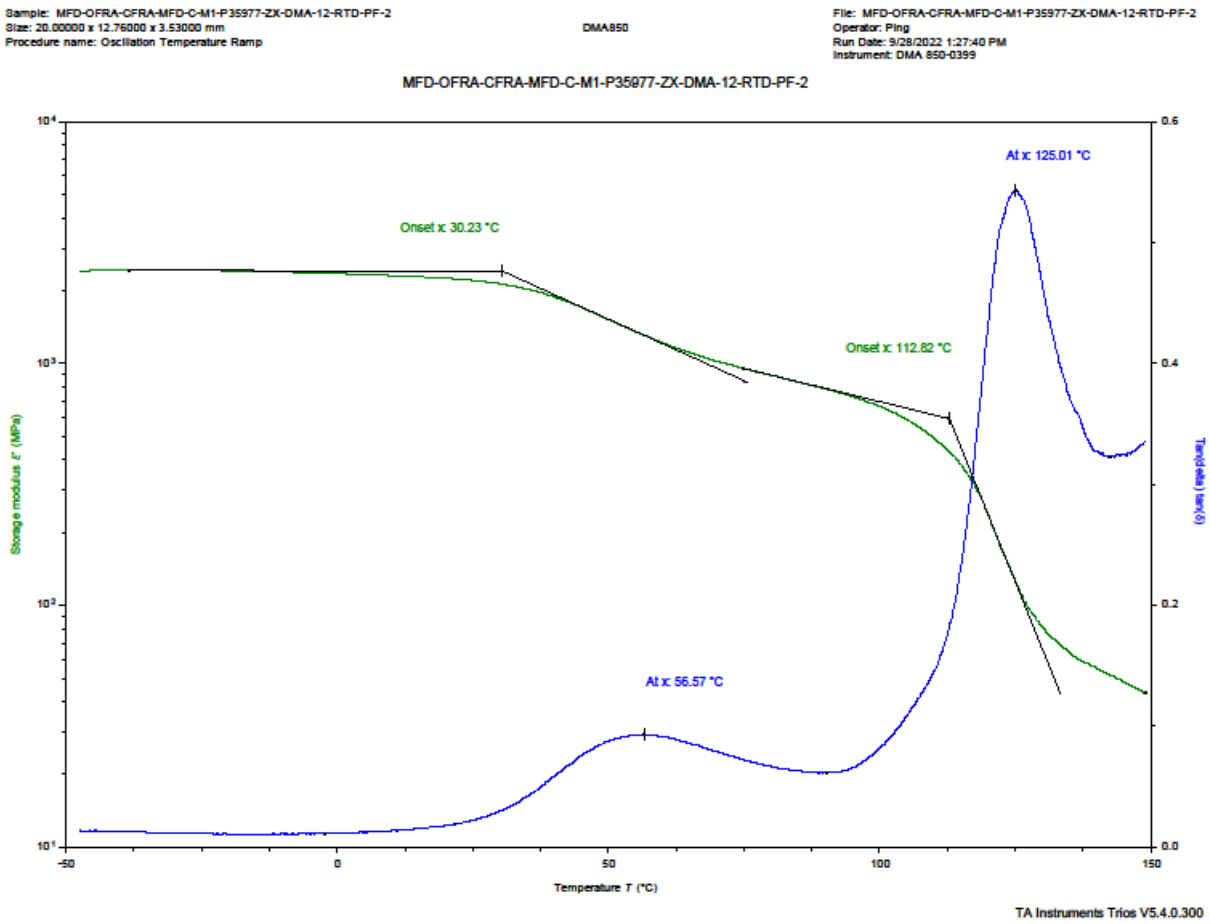
9.1.31 **XZ PF DMA Dry Batch C**



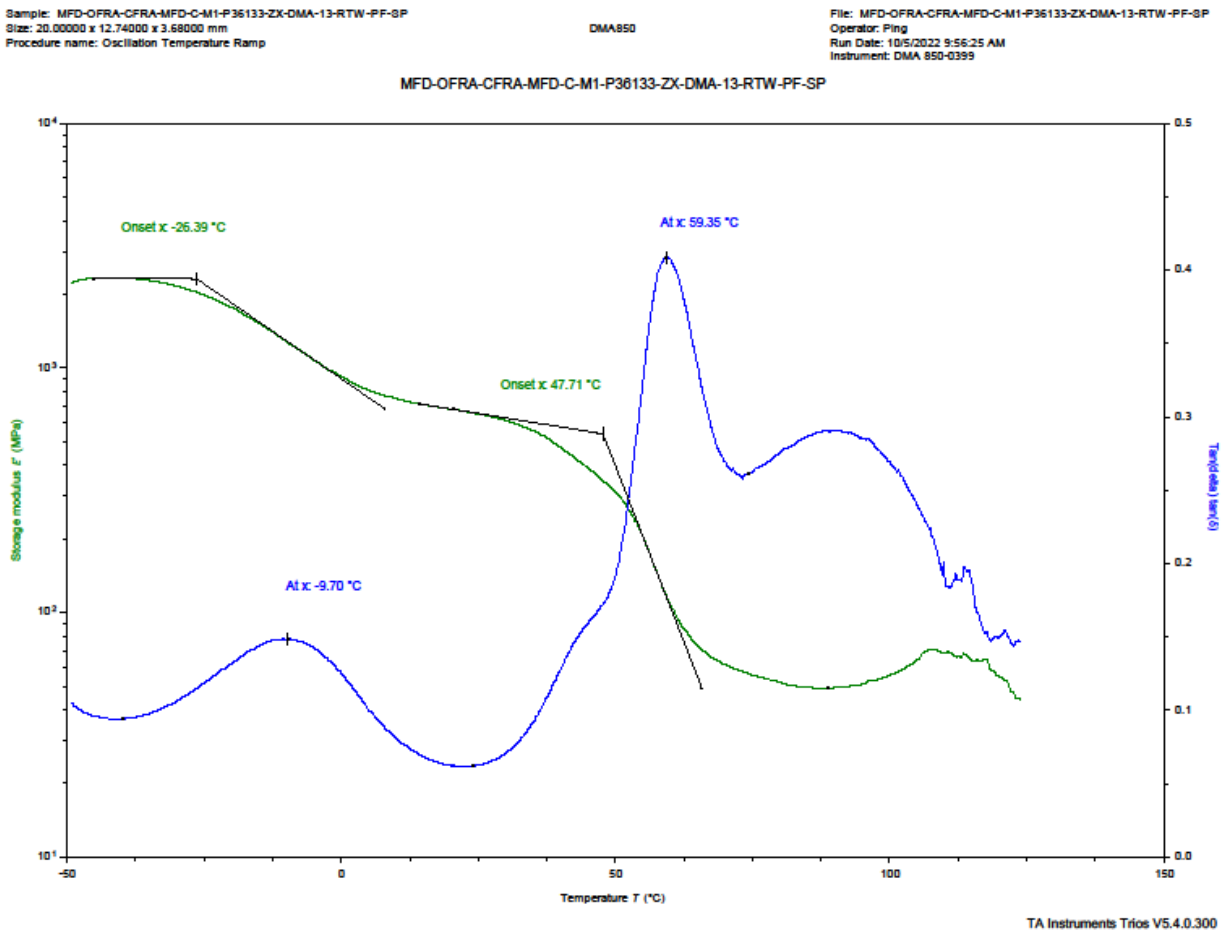
9.1.32 **XZ PF DMA Wet Batch C**



9.1.33 **ZX PF DMA Dry Batch C**



9.1.34 **ZX PF DMA Wet Batch C**



9.2 **TMA Results**

TMA Results		
XY TMA Dry		
Specimen ID	Coefficient of Thermal Expansion [µm/m°C]	
	Value 1	Value 2
MFD-OFRA-CFRA-MFD-A-M1-PX-XY-TMA-13-RTD-FF-+45-1	29.69	47.40
MFD-OFRA-CFRA-MFD-A-M1-PX-XY-TMA-13-RTD-FF-1	4.29	9.193
MFD-OFRA-CFRA-MFD-A-M1-PX-XY-TMA-13-RTD-FF-Quasi-1	15.13	14.02
MFD-OFRA-CFRA-MFD-A-M1-PX-XY-TMA-13-RTD-PF-+45-1	34.34	50.28
MFD-OFRA-CFRA-MFD-A-M1-PX-XY-TMA-13-RTD-PF-1	20.05	32.18
MFD-OFRA-CFRA-MFD-A-M1-PX-XY-TMA-13-RTD-PF-Quasi-1	32.36	38.21
MFD-OFRA-CFRA-MFD-A-M2-PX-XY-TMA-13-RTD-FF+-45-1	28.10	39.61
MFD-OFRA-CFRA-MFD-A-M2-PX-XY-TMA-13-RTD-FF-1	2.88	5.639
MFD-OFRA-CFRA-MFD-A-M2-PX-XY-TMA-13-RTD-FFQI-1	13.79	21.69
MFD-OFRA-CFRA-MFD-A-M2-PX-XY-TMA-13-RTD-PF+-45-1	32.21	43.32
MFD-OFRA-CFRA-MFD-A-M2-PX-XY-TMA-13-RTD-PF-1	17.71	40.35
MFD-OFRA-CFRA-MFD-A-M2-PX-XY-TMA-13-RTD-PF-Quasi-1	28.80	27.52
MFD-OFRA-CFRA-MFD-B-M1-PX-XY-TMA-13-RTD-FF+-45-1	24.40	33.05
MFD-OFRA-CFRA-MFD-B-M1-PX-XY-TMA-13-RTD-FF-1	9.51	15.09
MFD-OFRA-CFRA-MFD-B-M1-PX-XY-TMA-13-RTD-FFQI-1	19.42	20.00
MFD-OFRA-CFRA-MFD-B-M1-PX-XY-TMA-13-RTD-PF+-45-1	36.58	52.68
MFD-OFRA-CFRA-MFD-B-M1-PX-XY-TMA-13-RTD-PF-1	16.02	25.46
MFD-OFRA-CFRA-MFD-B-M1-PX-XY-TMA-13-RTD-PFQI-1	27.32	32.56
MFD-OFRA-CFRA-MFD-B-M2-PX-XY-TMA-13-RTD-FF+-45-1	29.83	42.66
MFD-OFRA-CFRA-MFD-B-M2-PX-XY-TMA-13-RTD-FF-1	2.18	27.24
MFD-OFRA-CFRA-MFD-B-M2-PX-XY-TMA-13-RTD-FFQI-1	12.40	17.74
MFD-OFRA-CFRA-MFD-B-M2-PX-XY-TMA-13-RTD-PF+-45-1	35.17	55.32
MFD-OFRA-CFRA-MFD-B-M2-PX-XY-TMA-13-RTD-PF-1	17.72	38.80
MFD-OFRA-CFRA-MFD-B-M2-PX-XY-TMA-13-RTD-PF-Quasi-1	33.81	41.12
MFD-OFRA-CFRA-MFD-C-M1-PX-XY-TMA-13-RTD-FF+-45-1	33.49	51.23
MFD-OFRA-CFRA-MFD-C-M1-PX-XY-TMA-13-RTD-FF-1	3.64	20.00
MFD-OFRA-CFRA-MFD-C-M1-PX-XY-TMA-13-RTD-FF-Quasi-1	12.90	9.084
MFD-OFRA-CFRA-MFD-C-M1-PX-XY-TMA-13-RTD-PF+-45-1	33.63	50.10
MFD-OFRA-CFRA-MFD-C-M1-PX-XY-TMA-13-RTD-PF-1	20.57	23.20
MFD-OFRA-CFRA-MFD-C-M1-PX-XY-TMA-13-RTD-PFQI-1	31.42	41.63
MFD-OFRA-CFRA-MFD-C-M2-PX-XY-TMA-13-RTD-FF+-45-1	29.28	38.33
MFD-OFRA-CFRA-MFD-C-M2-PX-XY-TMA-13-RTD-FF-1	4.10	9.26
MFD-OFRA-CFRA-MFD-C-M2-PX-XY-TMA-13-RTD-FFQI-1	11.93	15.42
MFD-OFRA-CFRA-MFD-C-M2-PX-XY-TMA-13-RTD-PF+-45-1	31.65	44.11
MFD-OFRA-CFRA-MFD-C-M2-PX-XY-TMA-13-RTD-PF-1	18.80	40.20
MFD-OFRA-CFRA-MFD-C-M2-PX-XY-TMA-13-RTD-PFQI-1	27.96	34.45
MFD-OFRA-CFRA-MFD-A-M1-PX-XY-TMA-13-RTD-NF-1	37.32	53.02
MFD-OFRA-CFRA-MFD-A-M2-PX-XY-TMA-13-RTD-NF-1	39.03	57.37
MFD-OFRA-MFD-B-M1-PX-XY-TMA-13-RTD-NF-1	38.99	55.73
MFD-OFRA-MFD-B-M2-PX-XY-TMA-13-RTD-NF-1	37.58	55.14
MFD-OFRA-MFD-C-M1-PX-XY-TMA-13-RTD-NF-1	37.99	59.93
MFD-OFRA-MFD-C-M2-PX-XY-TMA-13-RTD-NF-1	35.66	51.18
Average	24.04	35.25
St. Dev.	11.43	15.56

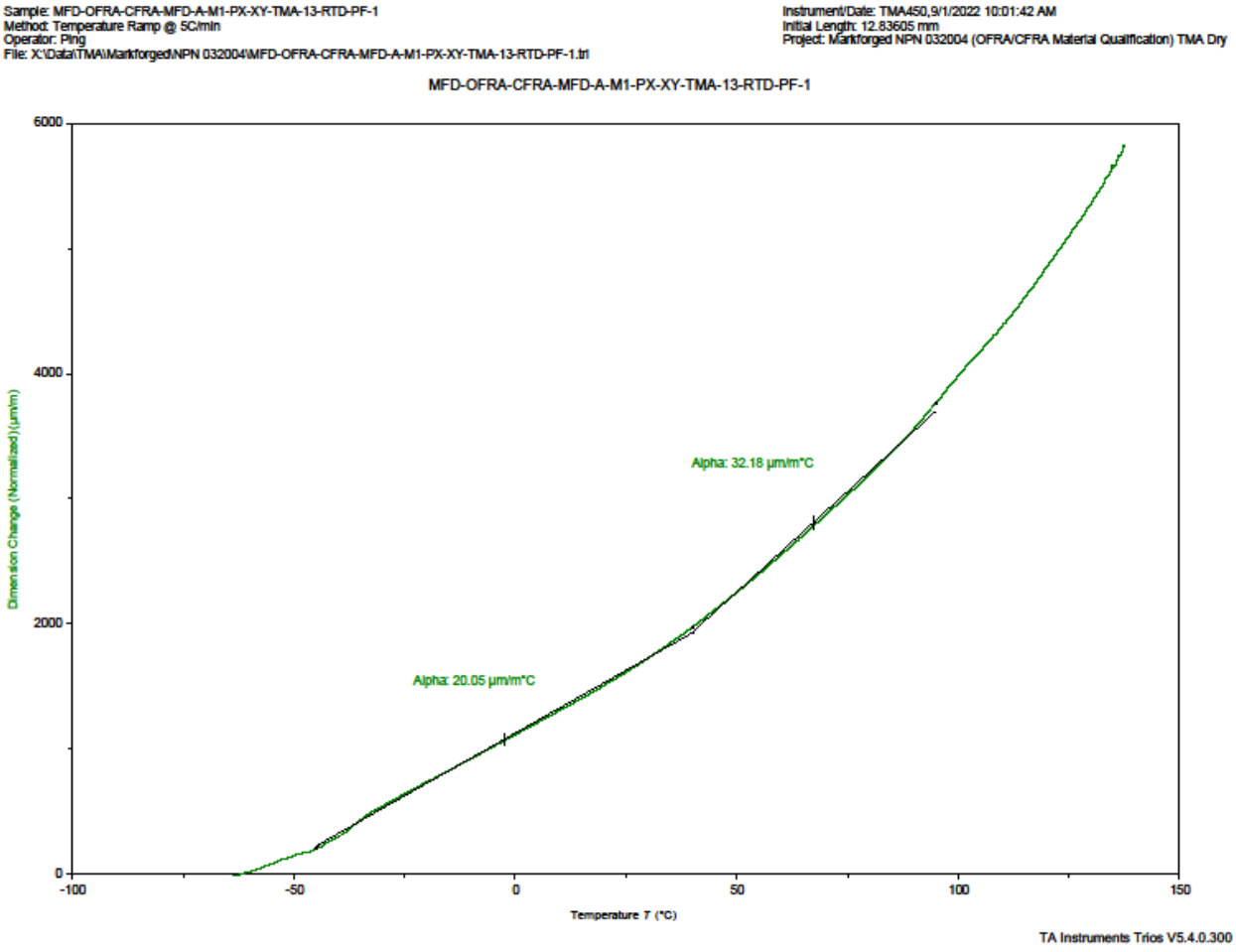
TMA Results		
XZ TMA Dry		
Specimen ID	**Coefficient of Thermal Expansion [µm/m°C]**	
	Value 1	**Value 2**
MFD-OFRA-CFRA-MFD-A-M1-PX-XZ-TMA-13-RTD-FF-1	33.6	52.19
MFD-OFRA-CFRA-MFD-A-M1-PX-XZ-TMA-13-RTD-PF-1	38.23	54.82
MFD-OFRA-CFRA-MFD-A-M2-PX-XZ-TMA-13-RTD-FF-1	36.41	53.27
MFD-OFRA-CFRA-MFD-A-M2-PX-XZ-TMA-13-RTD-PF-1	40.69	58.36
MFD-OFRA-CFRA-MFD-B-M1-PX-XZ-TMA-13-RTD-FF-1	35.54	54.47
MFD-OFRA-CFRA-MFD-B-M1-PX-XZ-TMA-13-RTD-PF-1	39.59	56.16
MFD-OFRA-CFRA-MFD-B-M2-PX-XZ-TMA-13-RTD-FF-1	36.6	54.67
MFD-OFRA-CFRA-MFD-B-M2-PX-XZ-TMA-13-RTD-PF-1	38.95	57.67
MFD-OFRA-CFRA-MFD-C-M1-PX-XZ-TMA-13-RTD-FF-1	33.91	47.85
MFD-OFRA-CFRA-MFD-C-M1-PX-XZ-TMA-13-RTD-PF-1	38.93	54.36
MFD-OFRA-CFRA-MFD-C-M2-PX-XZ-TMA-13-RTD-FF-1	33.97	50.26
MFD-OFRA-CFRA-MFD-C-M2-PX-XZ-TMA-13-RTD-PF-1	42.33	63.89
MFD-OFRA-CFRA-MFD-A-M1-PX-XZ-TMA-13-RTD-NF-1	40.85	59.3
MFD-OFRA-CFRA-MFD-A-M2-PX-XZ-TMA-13-RTD-NF-1	38.48	56.1
MFD-OFRA-CFRA-MFD-B-M1-PX-XZ-TMA-13-RTD-NF-1	37.59	58.71
MFD-OFRA-CFRA-MFD-B-M2-PX-XZ-TMA-13-RTD-NF-1	38.25	57.98
MFD-OFRA-CFRA-MFD-C-M1-PX-XZ-TMA-13-RTD-NF-1	36.67	58.57
MFD-OFRA-CFRA-MFD-C-M1-PX-XZ-TMA-13-RTD-NF-2	35.14	53.59
MFD-OFRA-CFRA-MFD-C-M1-PX-XZ-TMA-13-RTD-NF-3	36.25	56.73
MFD-OFRA-CFRA-MFD-C-M2-PX-XZ-TMA-13-RTD-NF-1	39.69	63.28
Average	37.58	56.11
St. Dev.	2.45	3.89

TMA Results

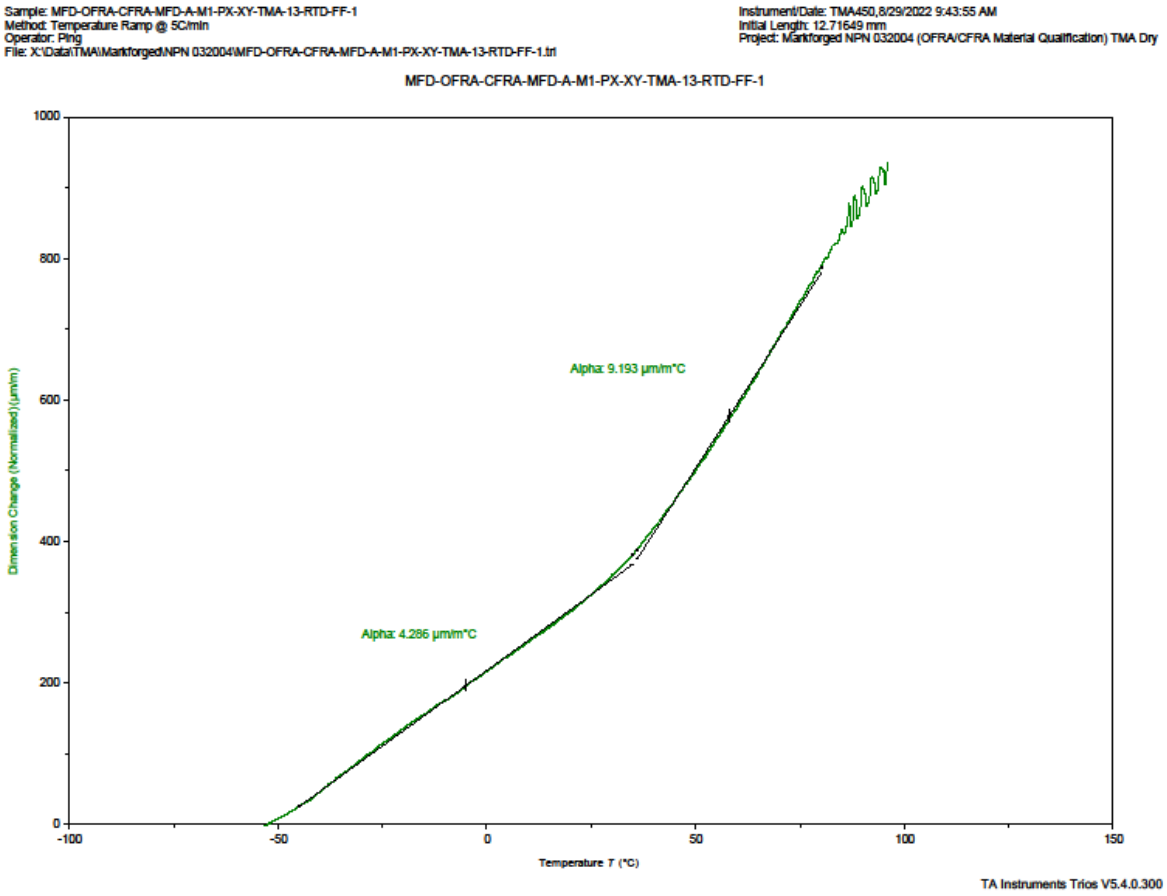
ZX TMA Dry

Specimen ID	Coefficient of Thermal Expansion [µm/m°C]	
	Value 1	Value 2
MFD-OFRA-CFRA-MFD-A-M1-PX-ZX-TMA-13-RTD-FF-1	74.77	118.4
MFD-OFRA-CFRA-MFD-A-M1-PX-ZX-TMA-13-RTD-PF-1	26.4	37.37
MFD-OFRA-CFRA-MFD-A-M2-PX-ZX-TMA-13-RTD-FF-1	82.74	86.72
MFD-OFRA-CFRA-MFD-A-M2-PX-ZX-TMA-13-RTD-PF-1	25.17	44.98
MFD-OFRA-CFRA-MFD-B-M1-PX-ZX-TMA-13-RTD-FF-1	1.909	18.51
MFD-OFRA-CFRA-MFD-B-M1-PX-ZX-TMA-13-RTD-PF-1	98.3	204.4
MFD-OFRA-CFRA-MFD-B-M2-PX-ZX-TMA-13-RTD-FF-1	71.35	138.5
MFD-OFRA-CFRA-MFD-B-M2-PX-ZX-TMA-13-RTD-PF-1	98.46	217.4
MFD-OFRA-CFRA-MFD-C-M1-PX-ZX-TMA-13-RTD-FF-1	78.86	128.9
MFD-OFRA-CFRA-MFD-C-M1-PX-ZX-TMA-13-RTD-PF-1	97.99	215.7
MFD-OFRA-CFRA-MFD-C-M2-PX-ZX-TMA-13-RTD-FF-1	72.8	143.5
MFD-OFRA-CFRA-MFD-C-M2-PX-ZX-TMA-13-RTD-PF-1	91.99	158.7
MFD-OFRA-MFD-A-M1-PX-ZX-TMA-13-RTD-NF-1	113	197
MFD-OFRA-MFD-A-M2-PX-ZX-TMA-13-RTD-NF-1	111.4	197.4
MFD-OFRA-MFD-B-M1-PX-ZX-TMA-13-RTD-NF-1	39.05	61.04
MFD-OFRA-MFD-B-M2-PX-ZX-TMA-13-RTD-NF-1	97.85	201.3
MFD-OFRA-MFD-C-M1-PX-ZX-TMA-13-RTD-NF-1	102.7	223.6
MFD-OFRA-MFD-C-M2-PX-ZX-TMA-13-RTD-NF-1	101.1	214.9
Average	76.99	144.91
St. Dev.	32.68	69.74

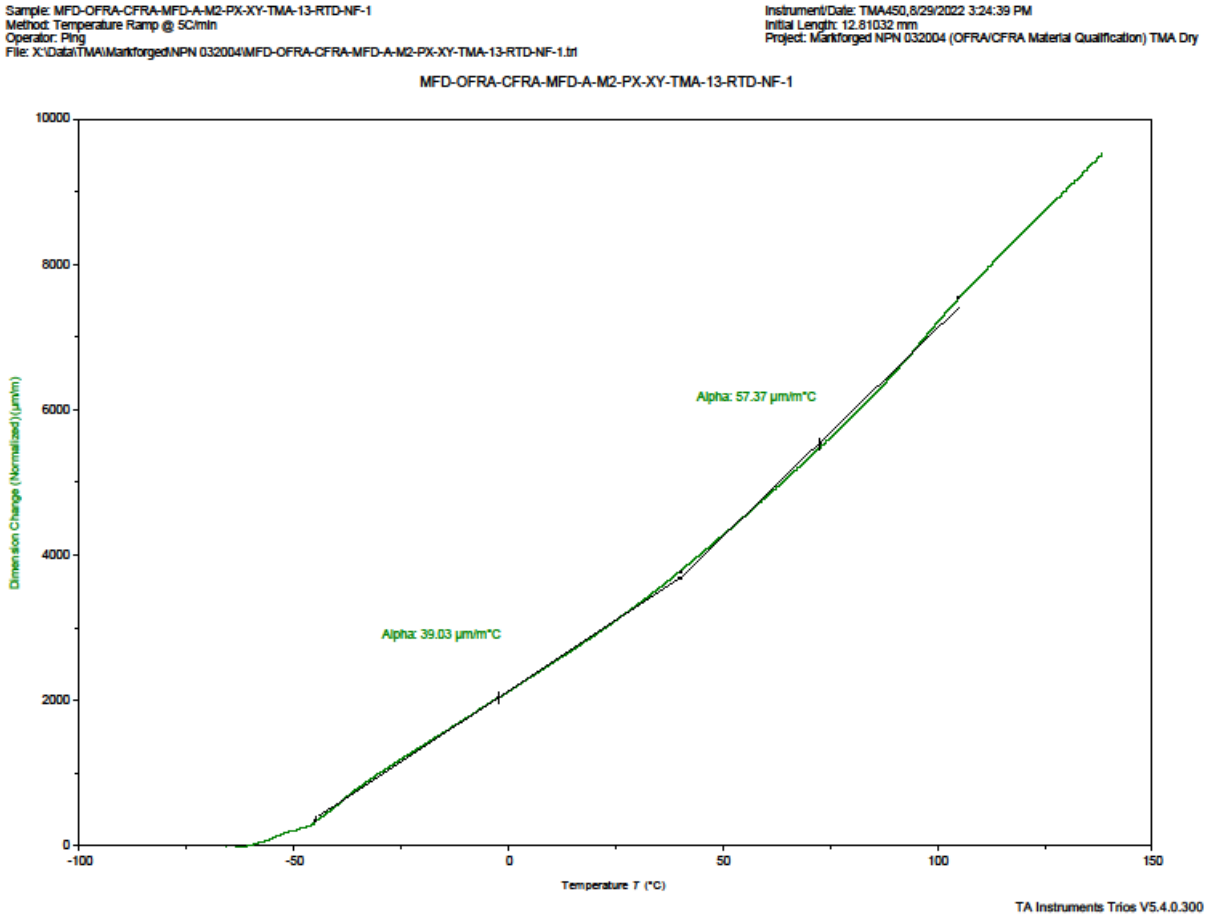
9.2.1 **XY PF TMA Batch A**



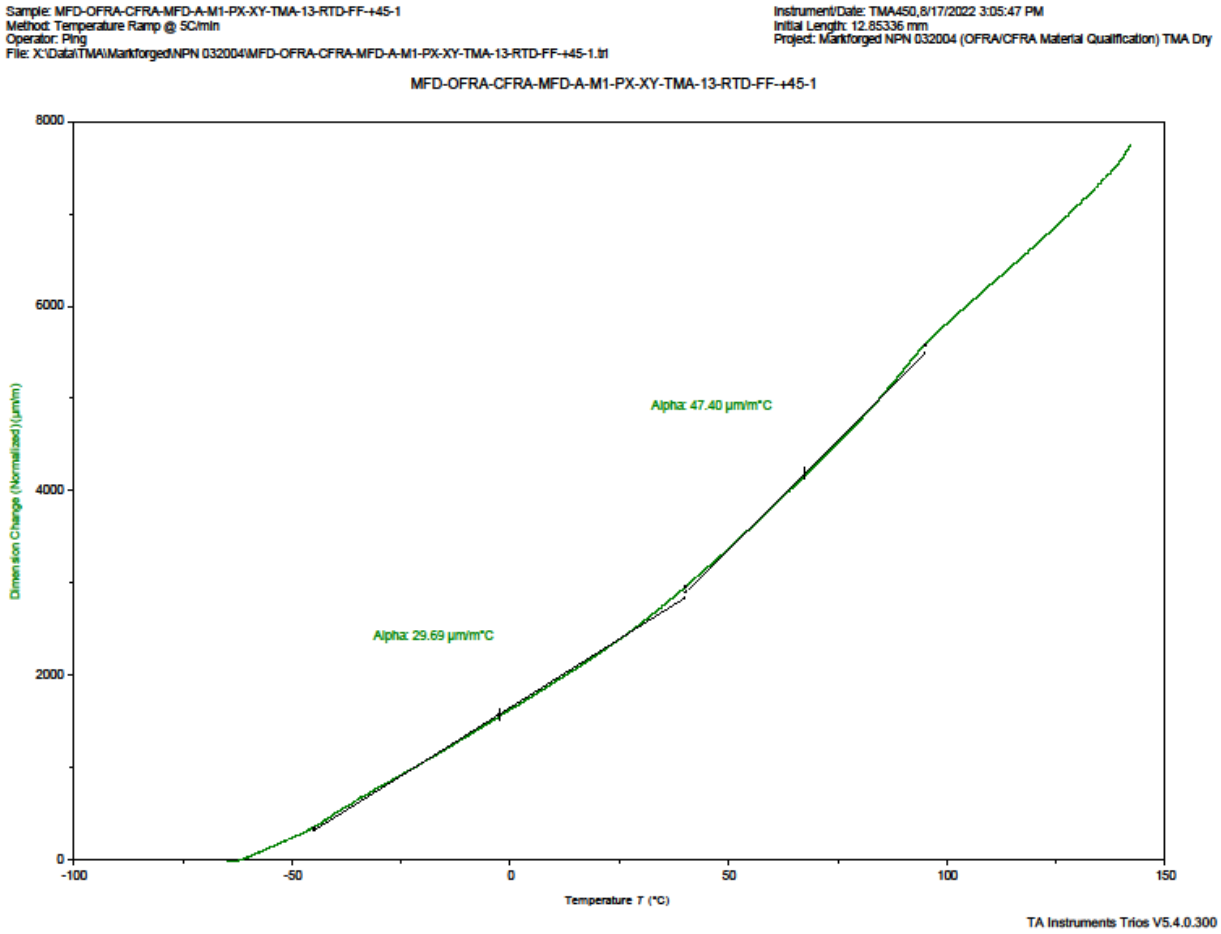
9.2.2 **XY FF TMA Batch A**



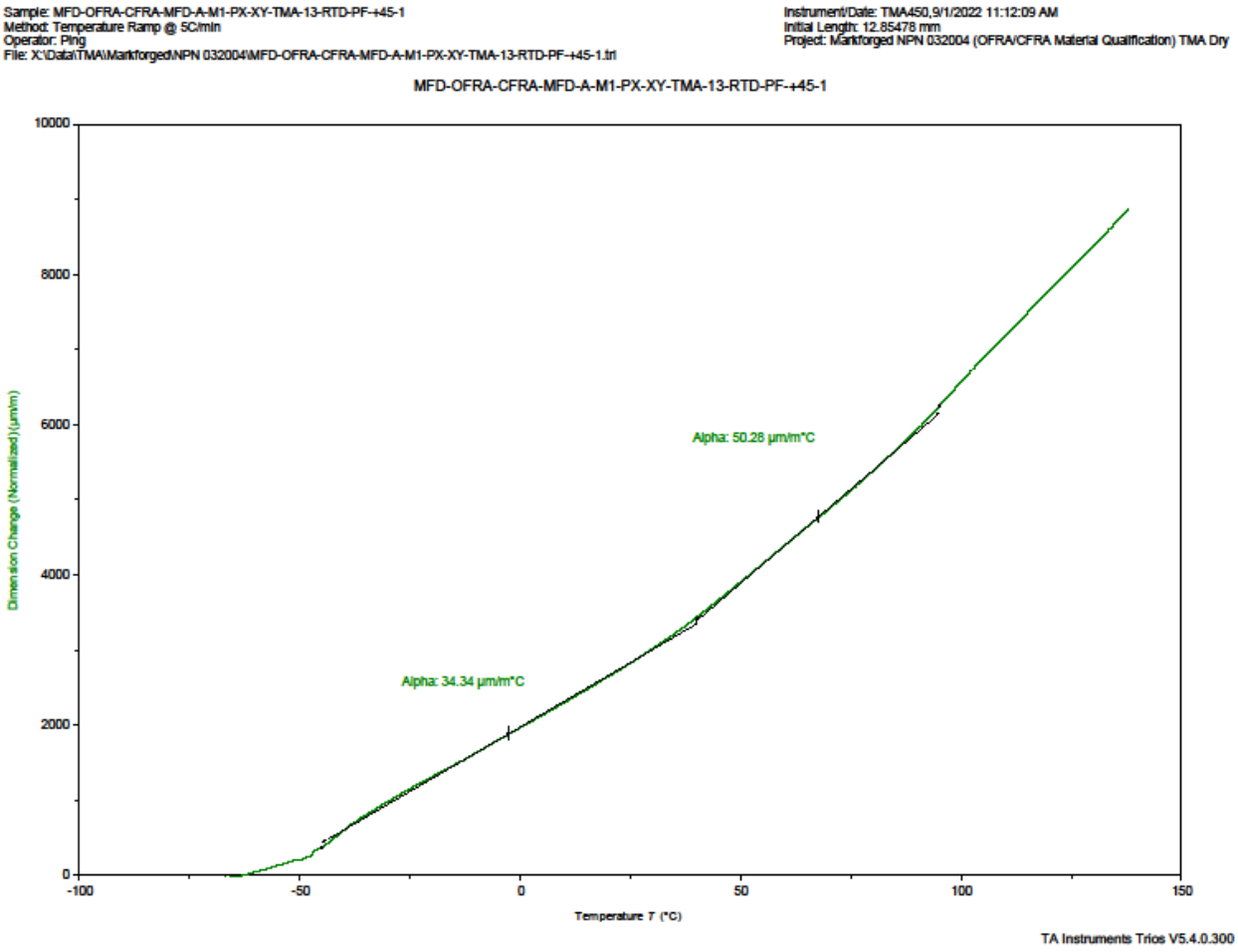
9.2.3 **XY NF TMA Batch A**



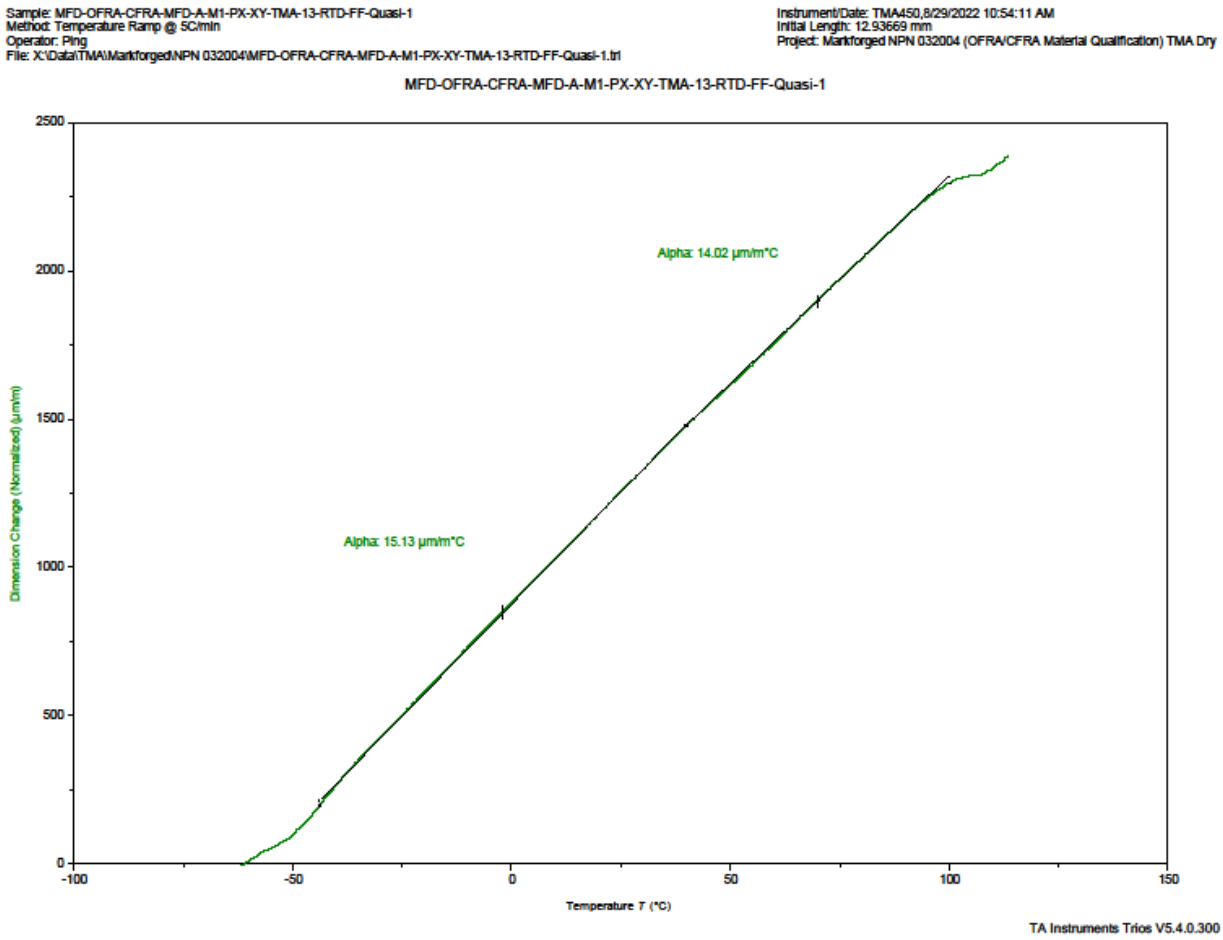
9.2.4 **XY FF±45 TMA Batch A**



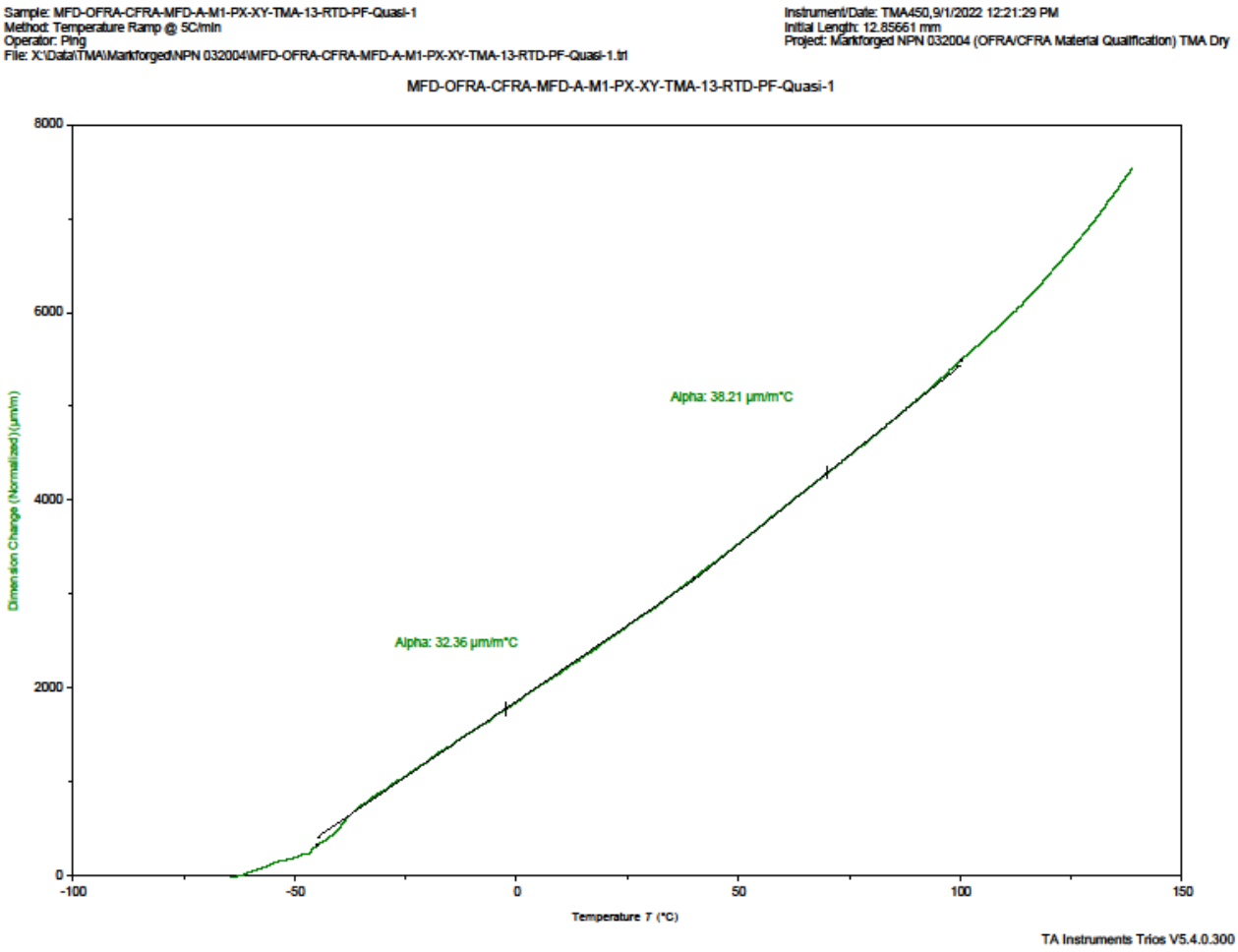
9.2.5 **XY PF±45 TMA Batch A**



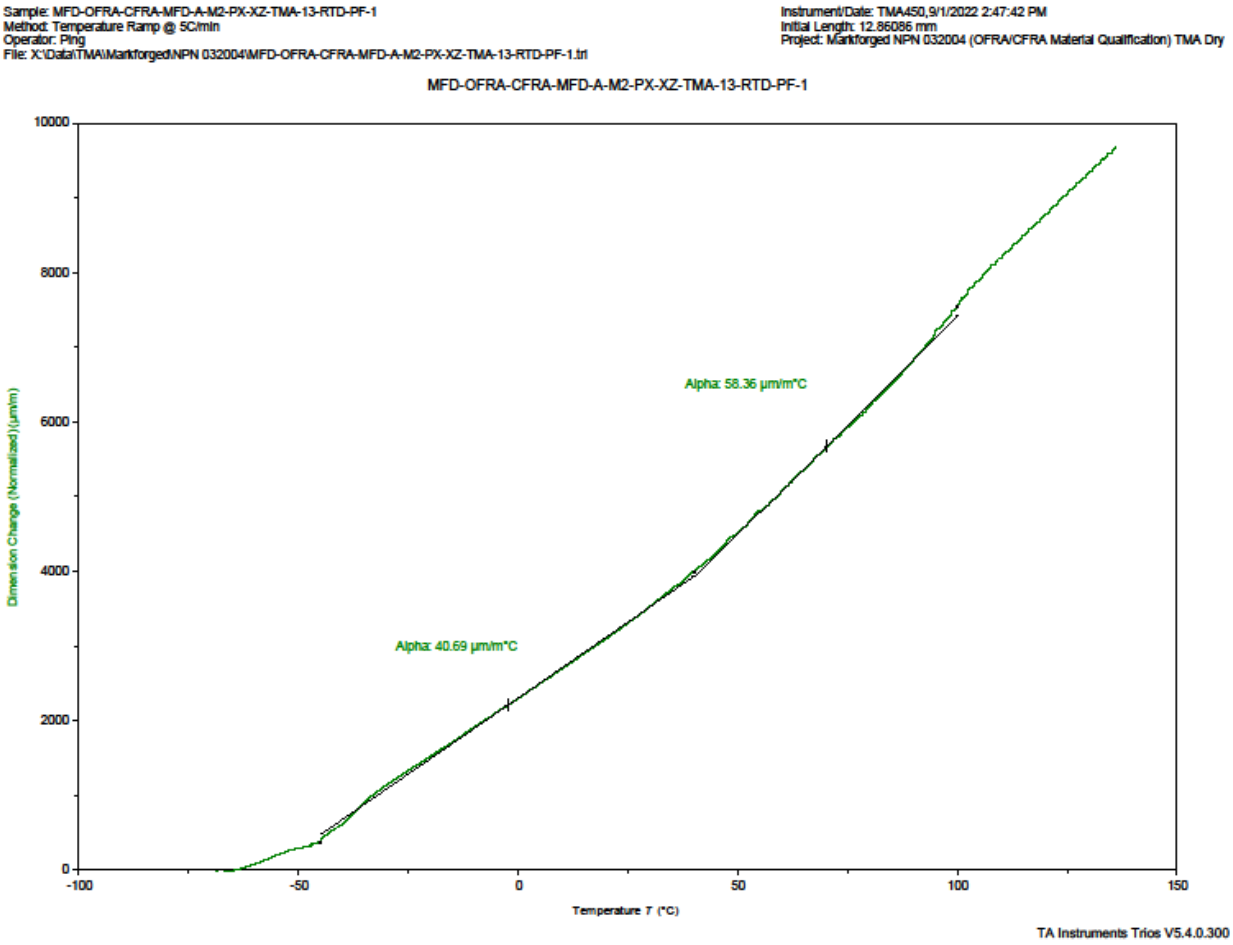
9.2.6 **XY FF Quasi TMA Batch A**



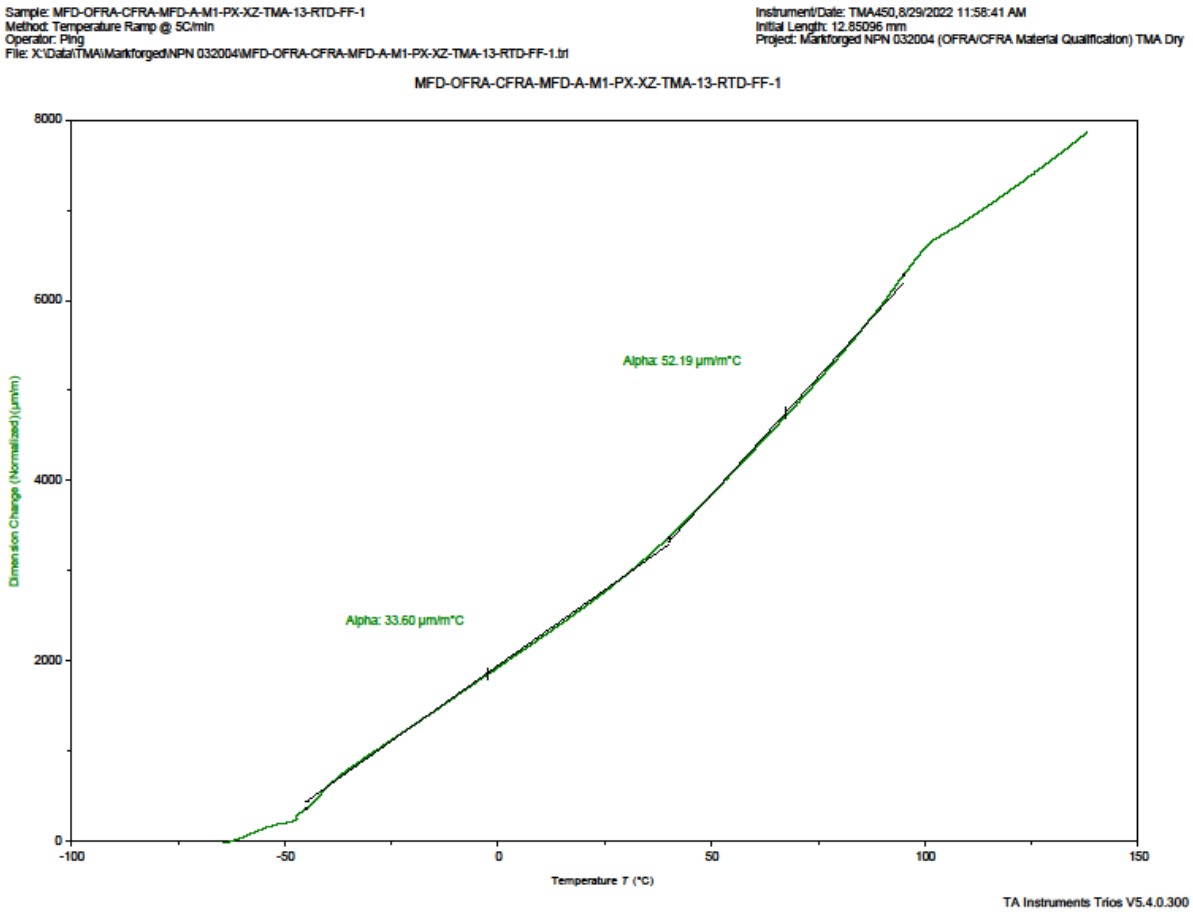
9.2.7 **XY PF Quasi TMA Batch A**



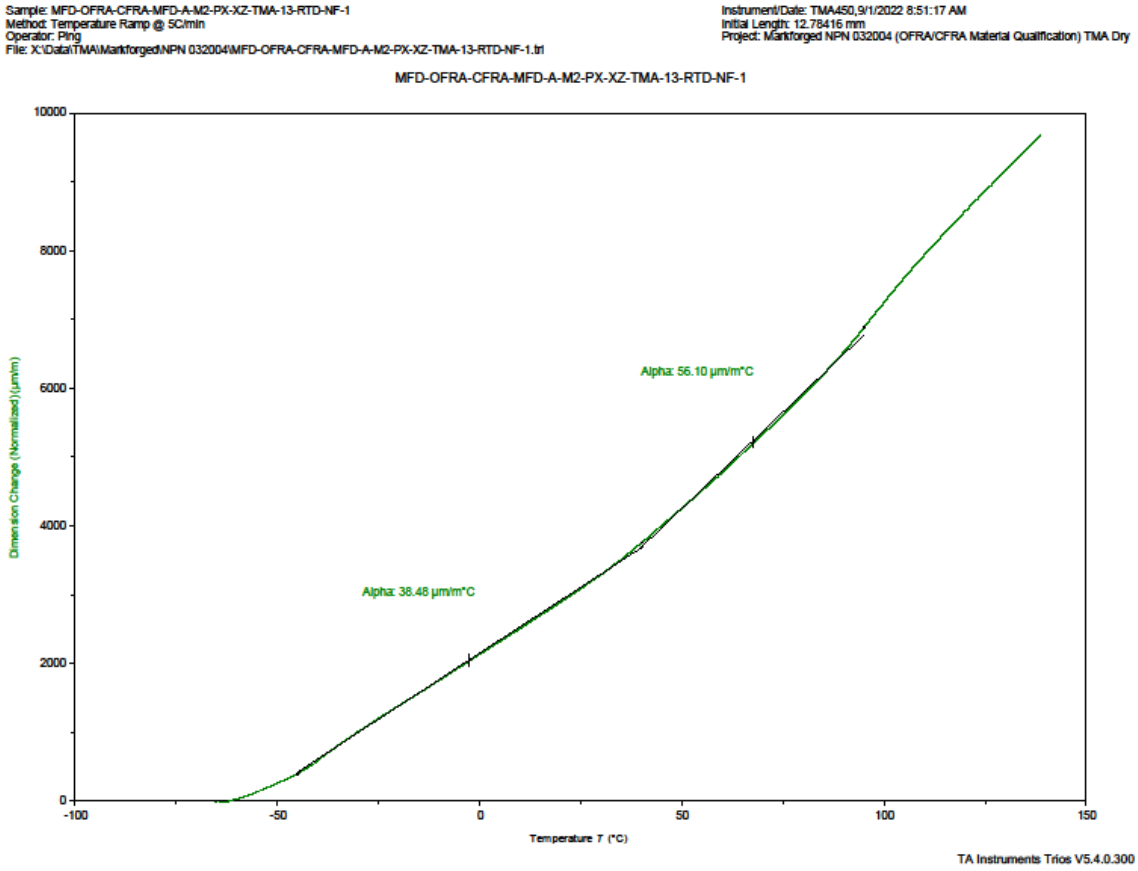
9.2.8 **XZ PF TMA Batch A**



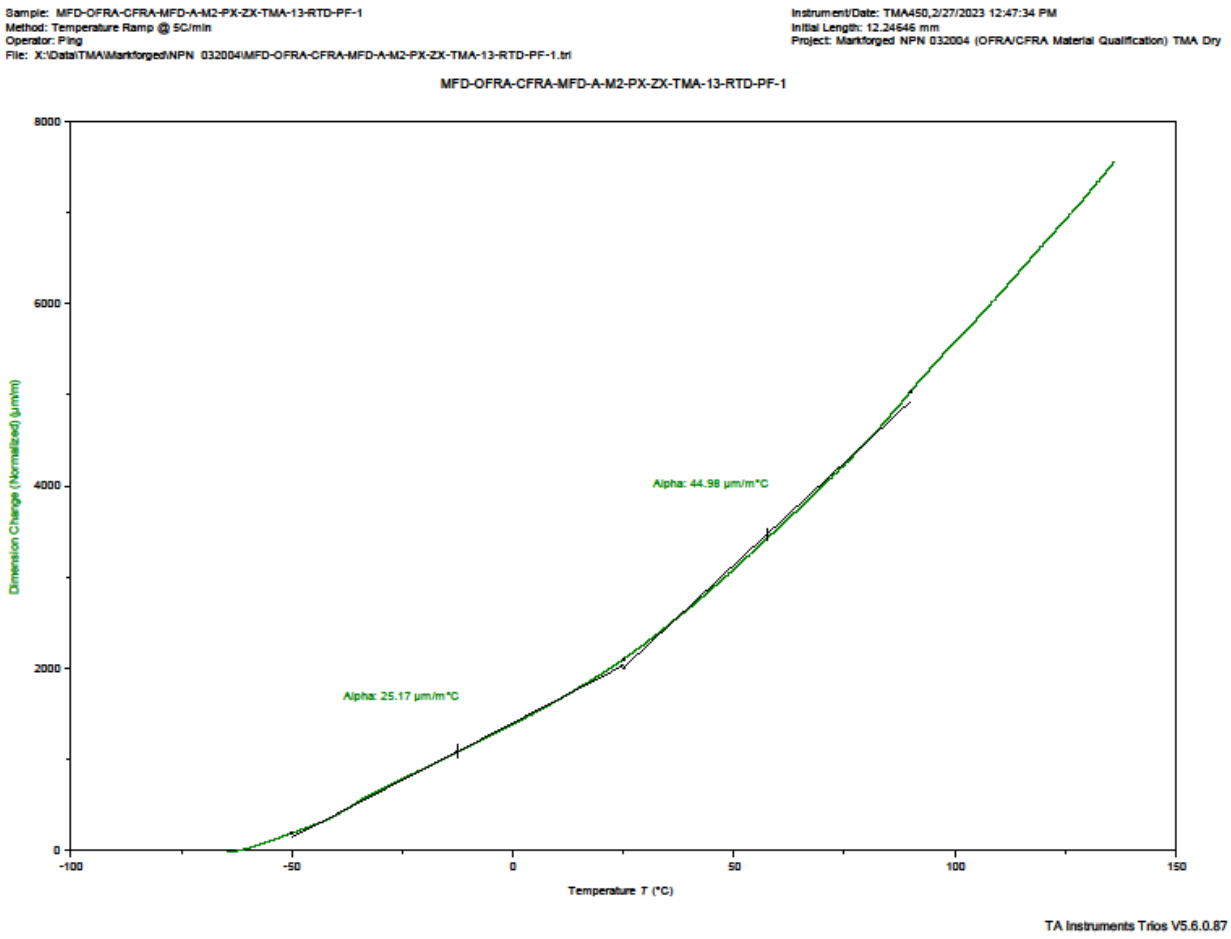
9.2.9 **XZ FF TMA Batch A**



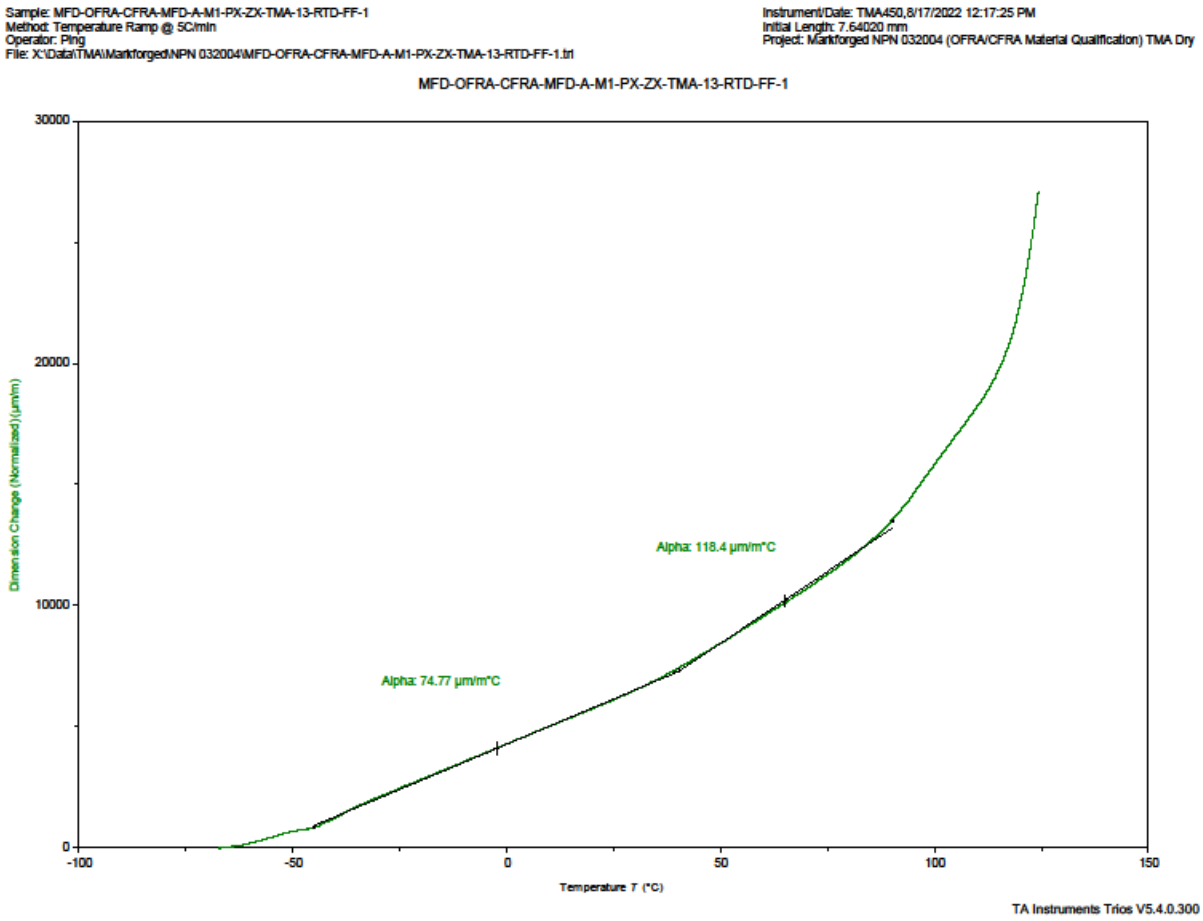
9.2.10 **XZ NF TMA Batch A**



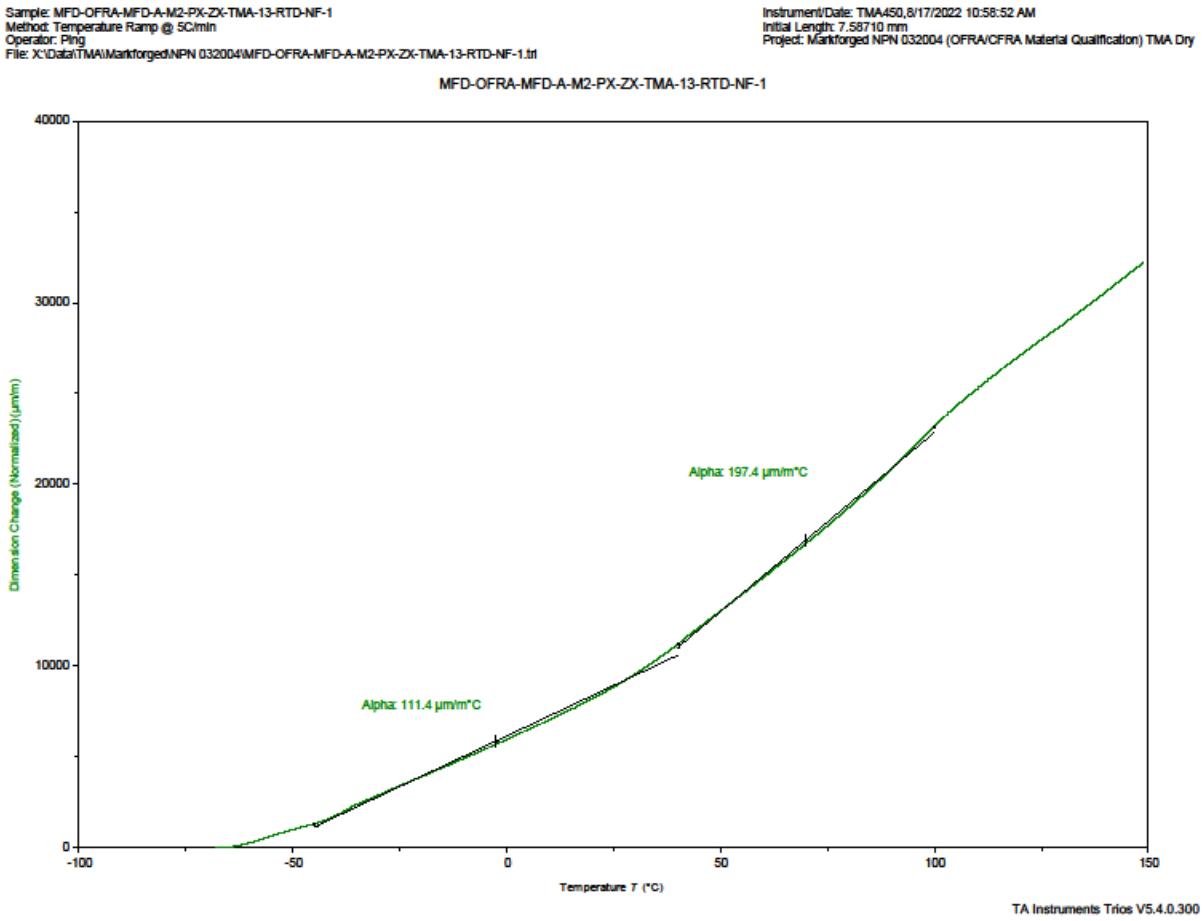
9.2.11 **ZX PF TMA Batch A**



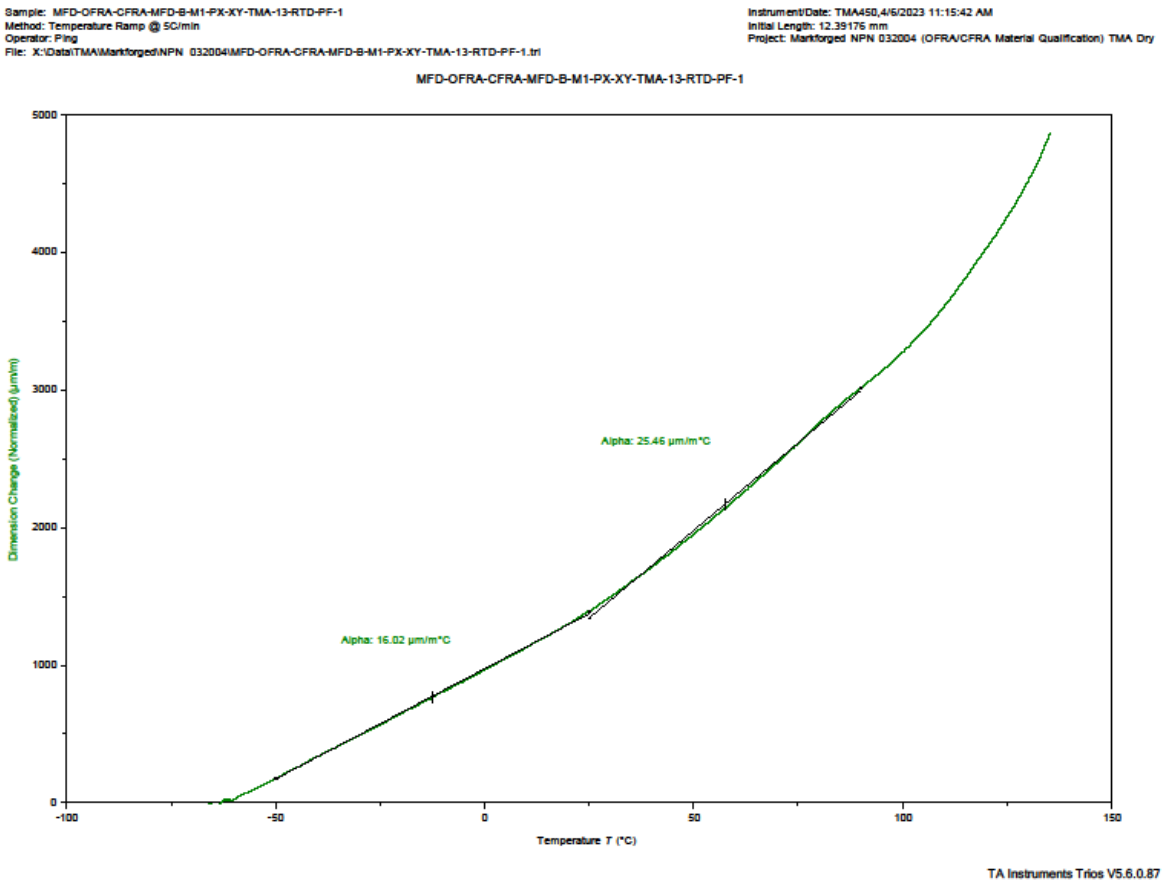
9.2.12 **ZX FF TMA Batch A**



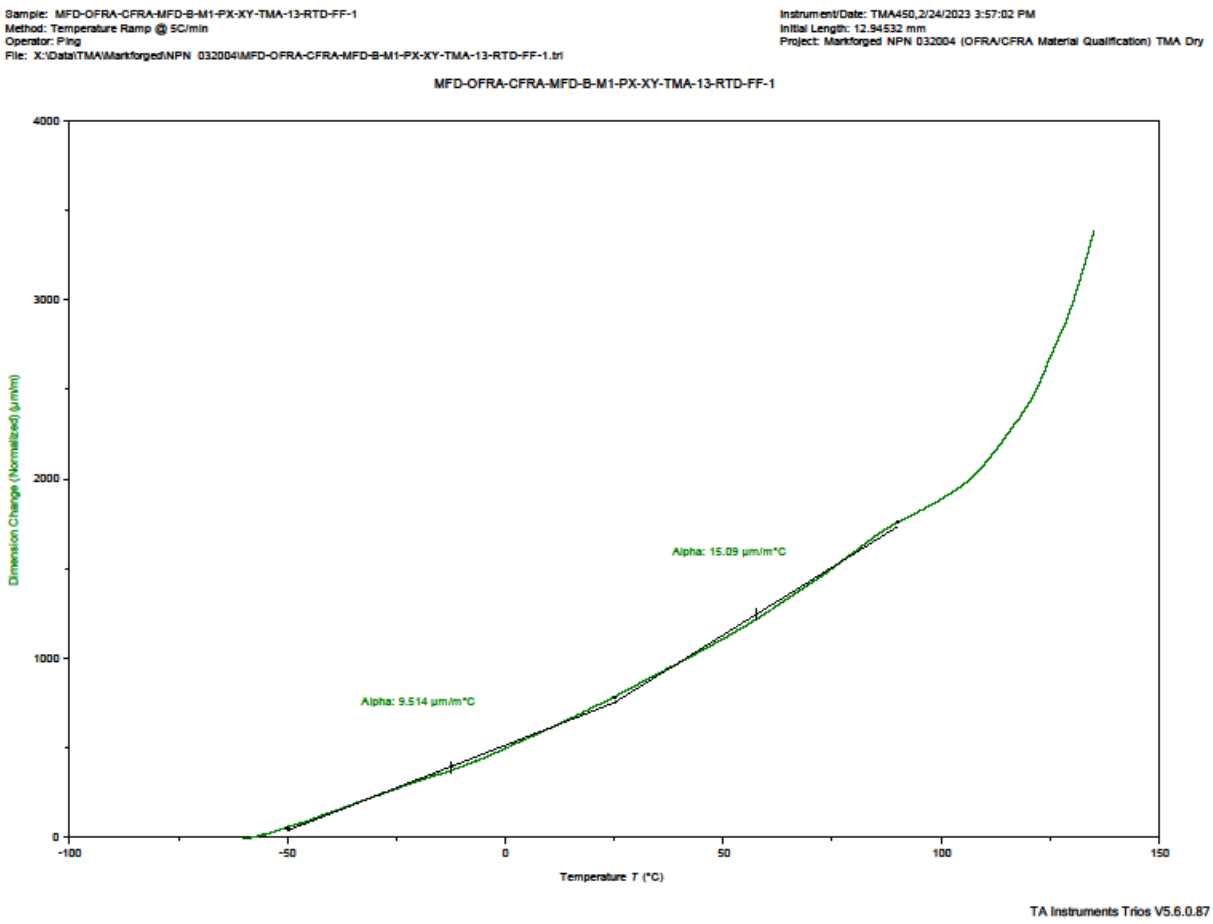
9.2.13 **ZX NF TMA Batch A**



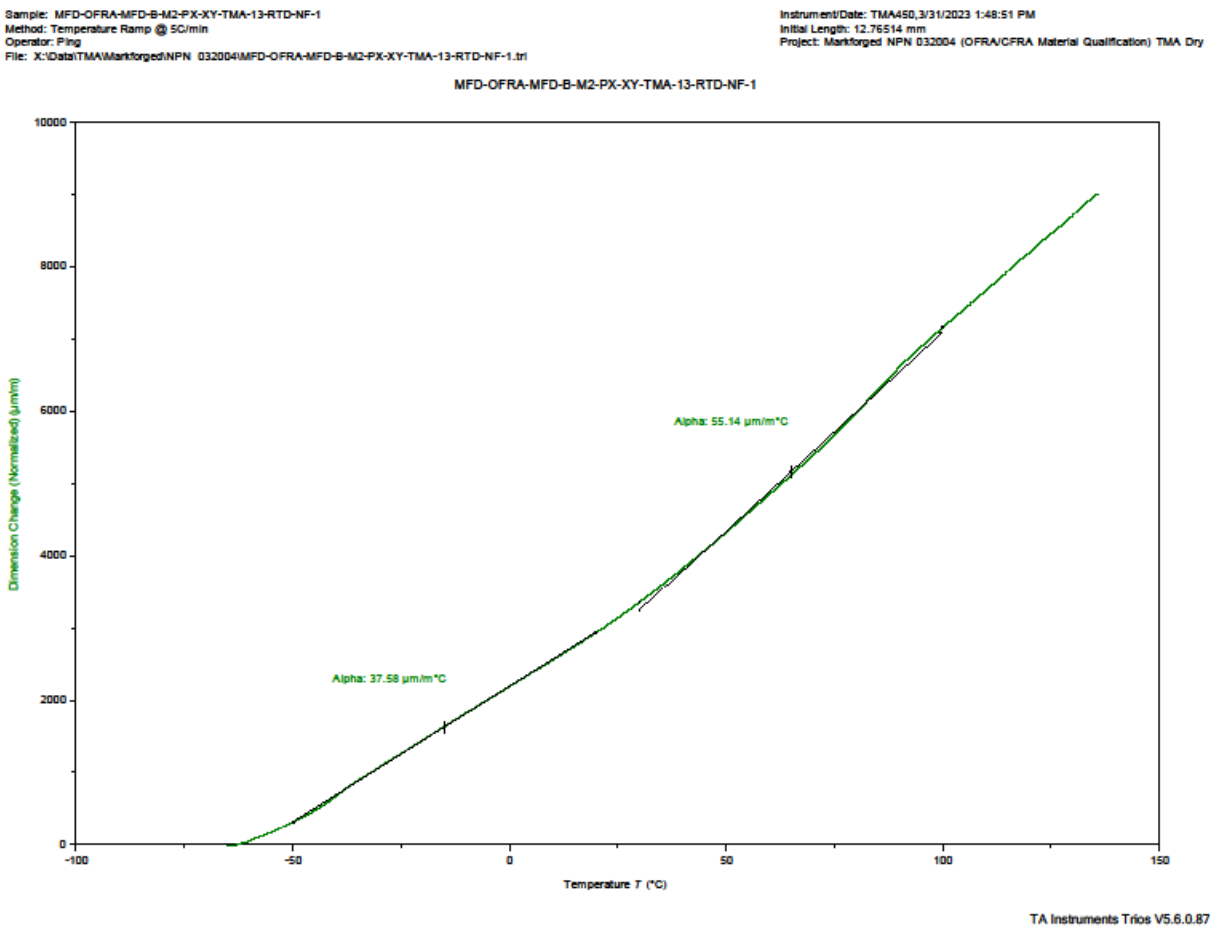
9.2.14 **XY PF TMA Batch B**



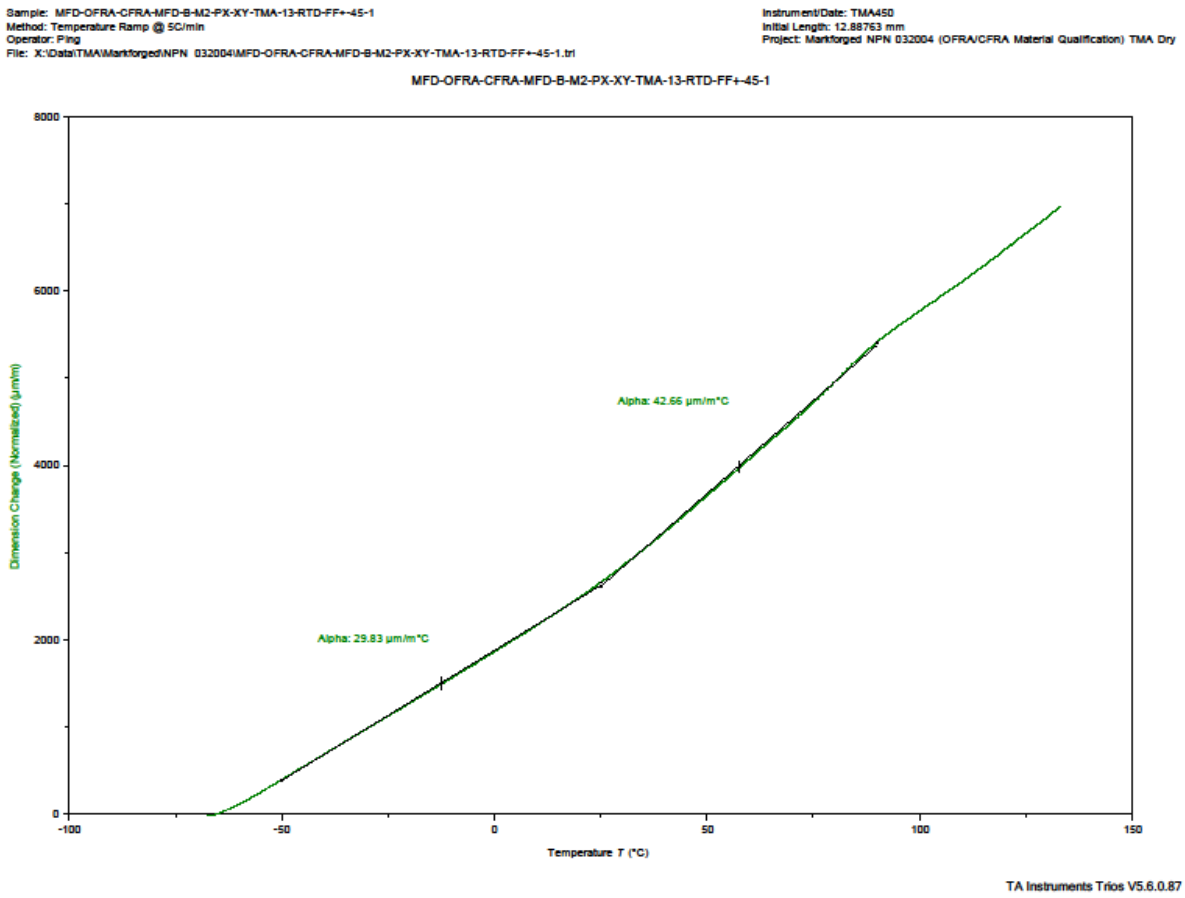
9.2.15 **XY FF TMA Batch B**



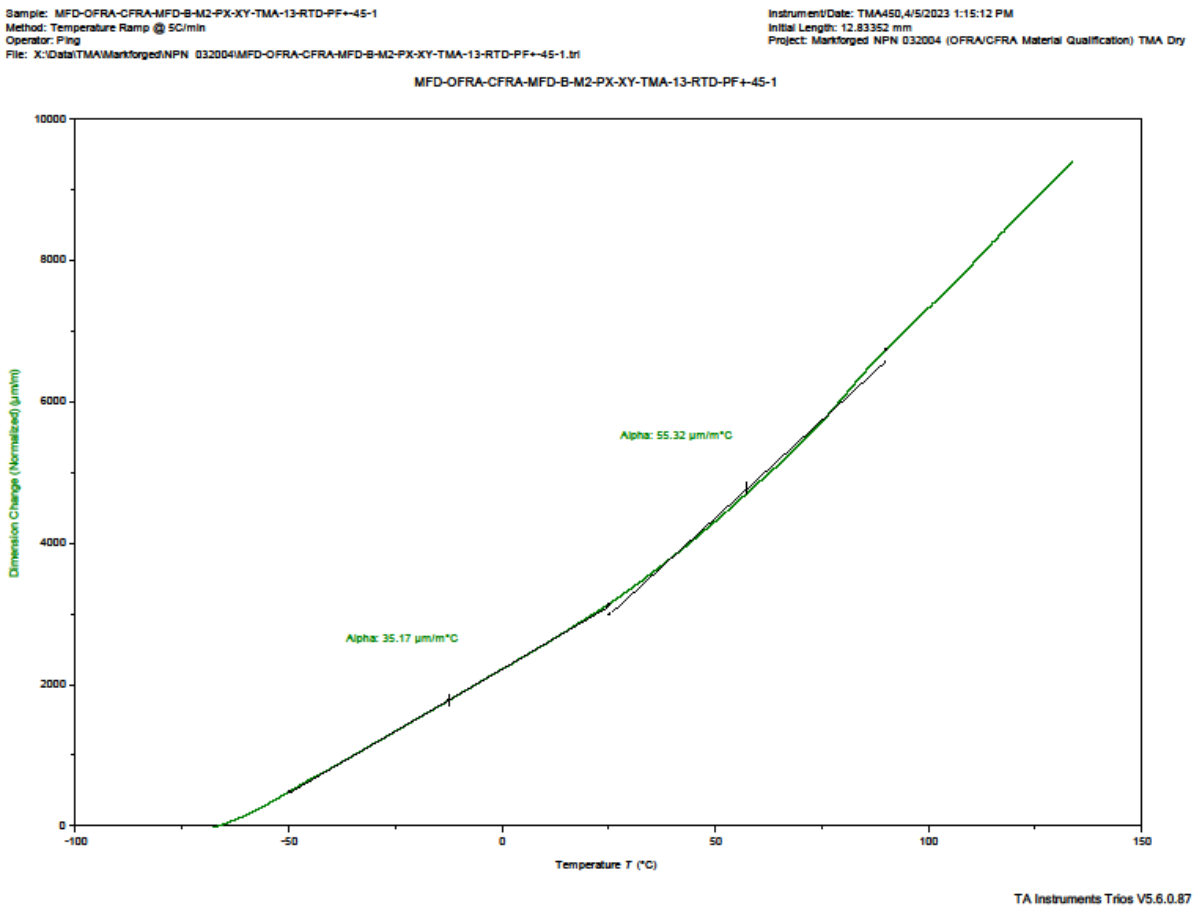
9.2.16 **XY NF TMA Batch B**



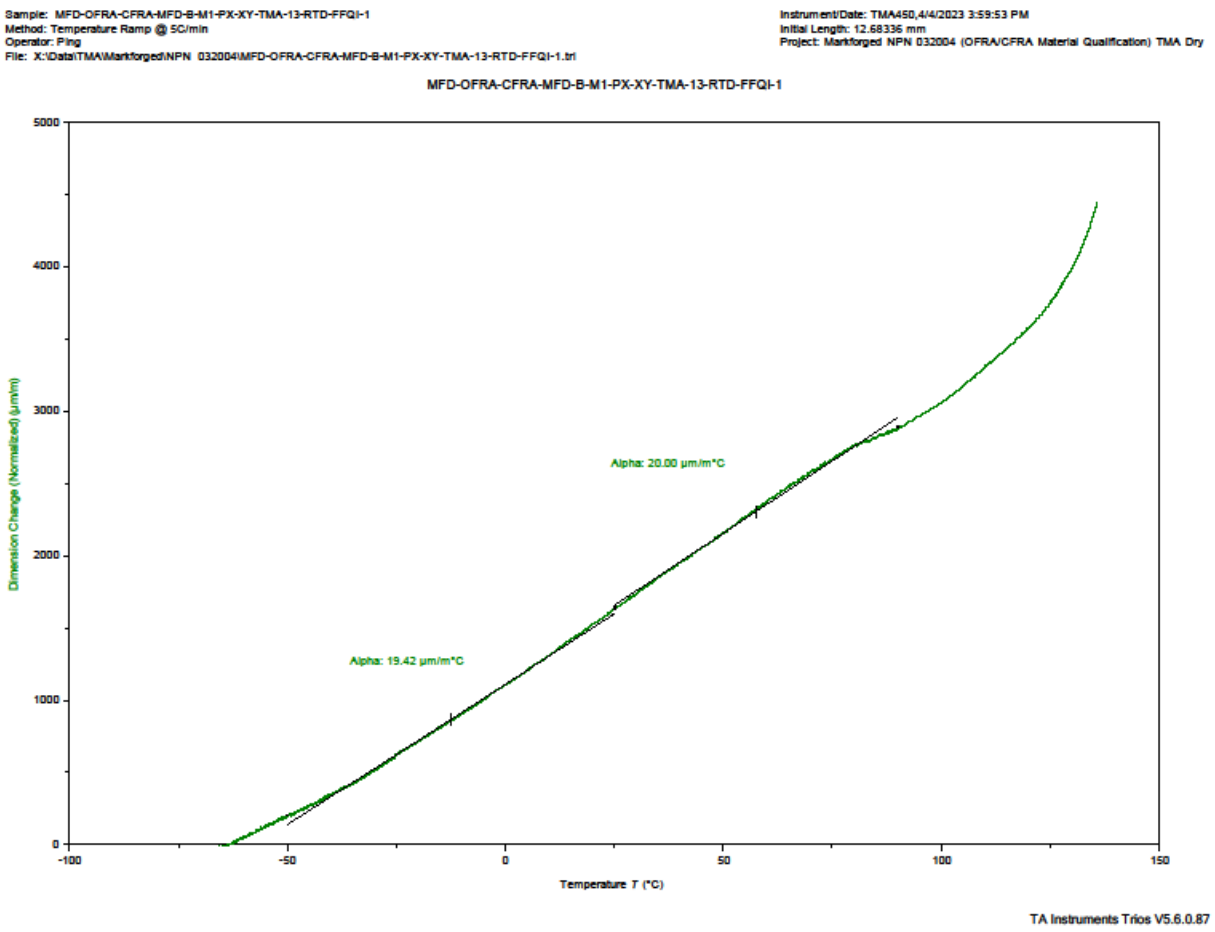
9.2.17 **XY FF±45 TMA Batch B**



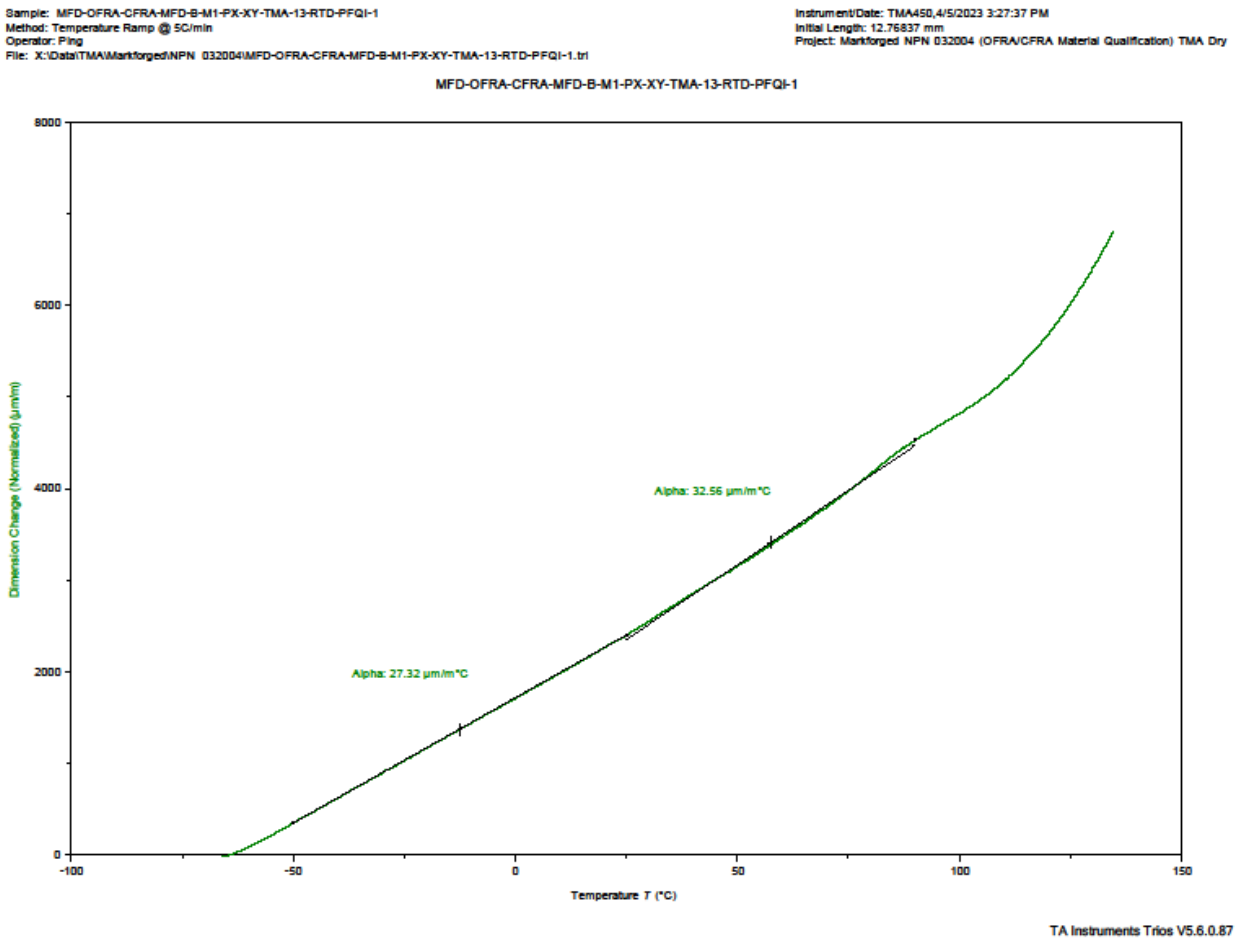
9.2.18 **XY PF±45 TMA Batch B**



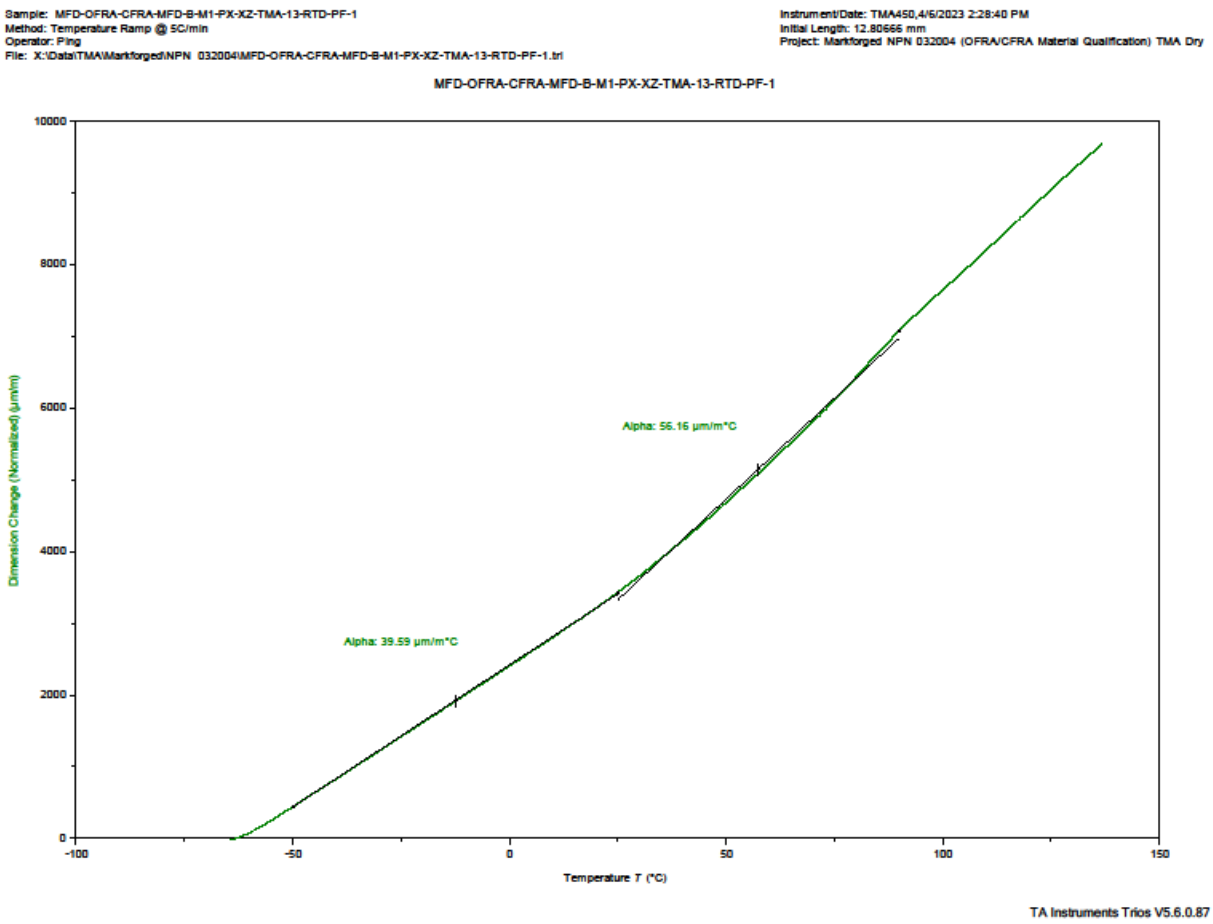
9.2.19 **XY FF Quasi TMA Batch B**



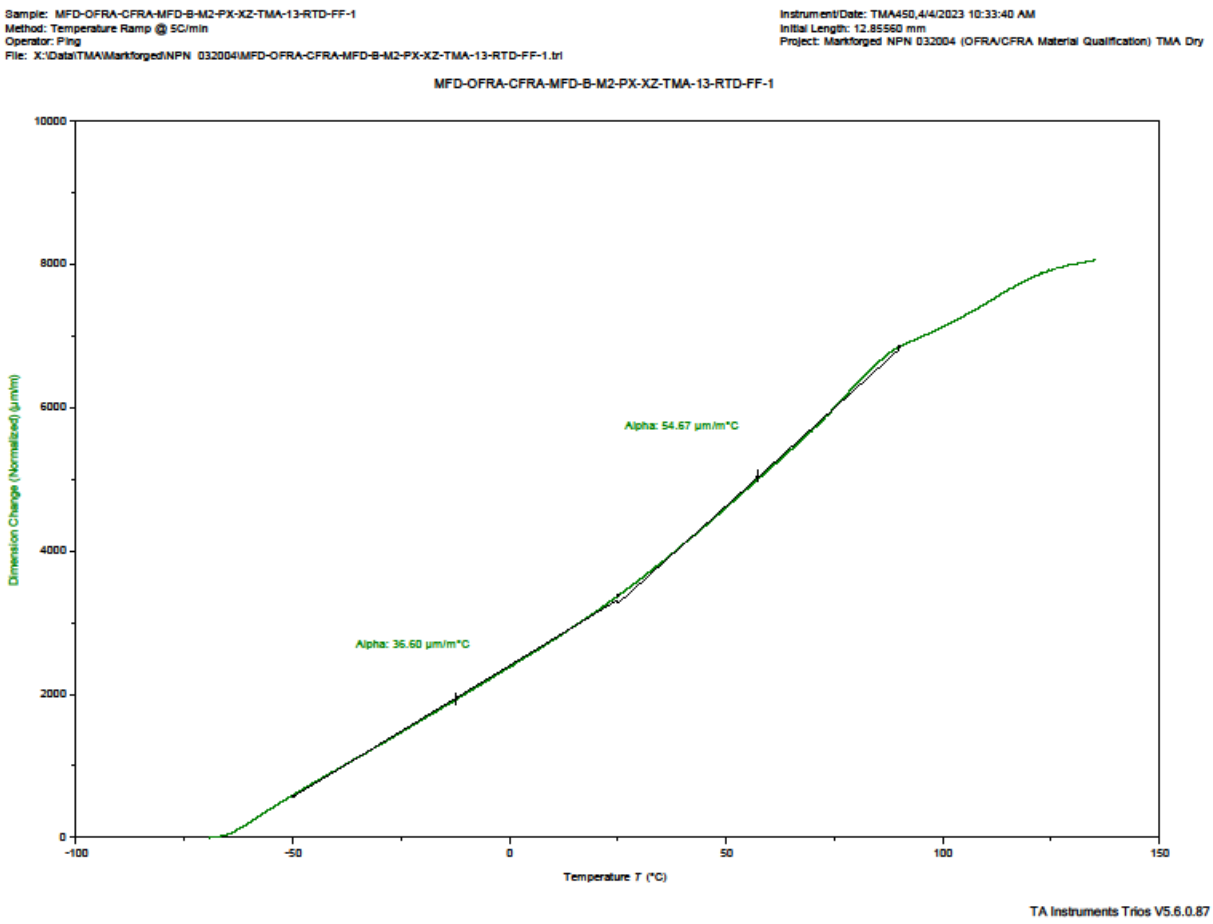
9.2.20 **XY PF Quasi TMA Batch B**



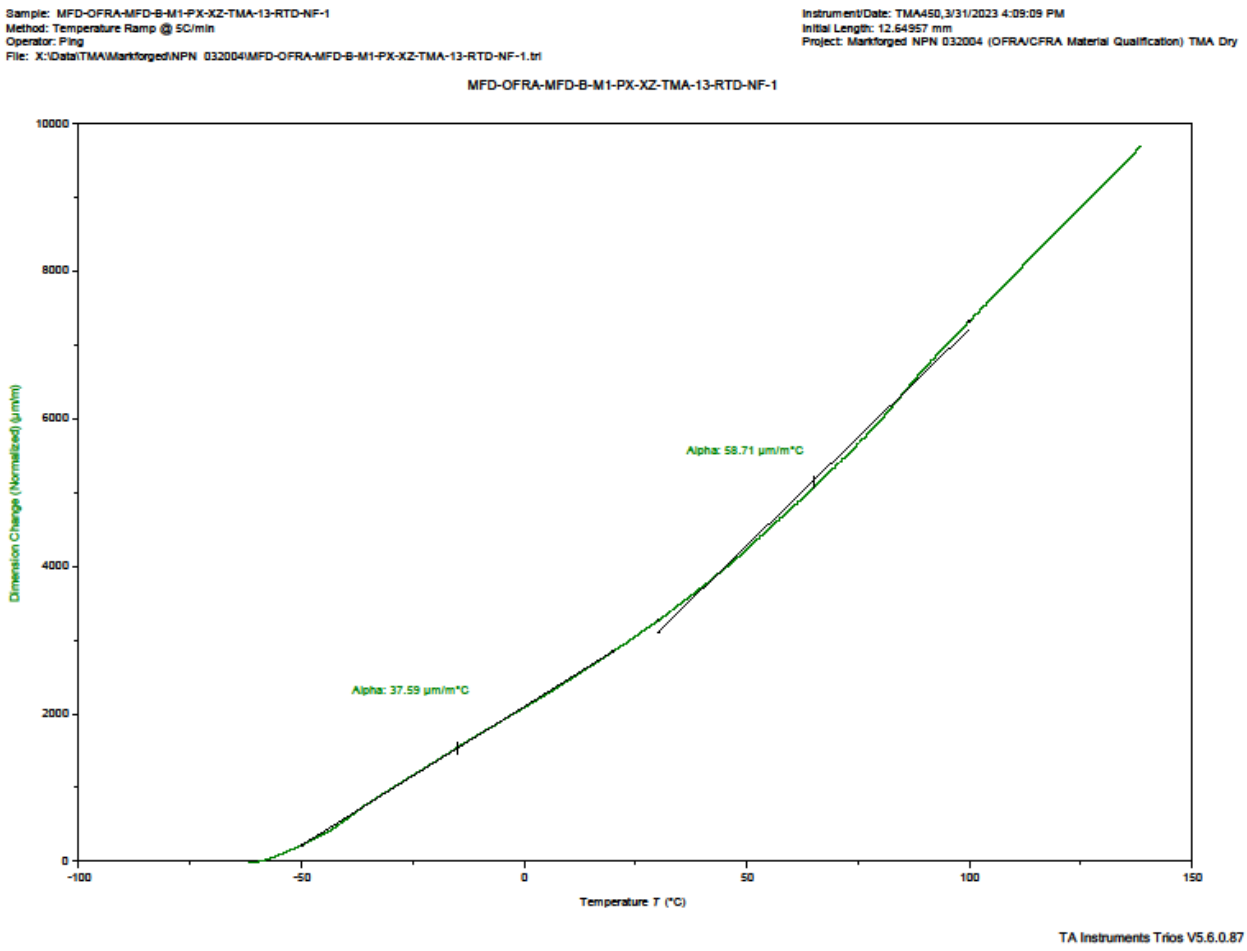
9.2.21 **XZ PF TMA Batch B**



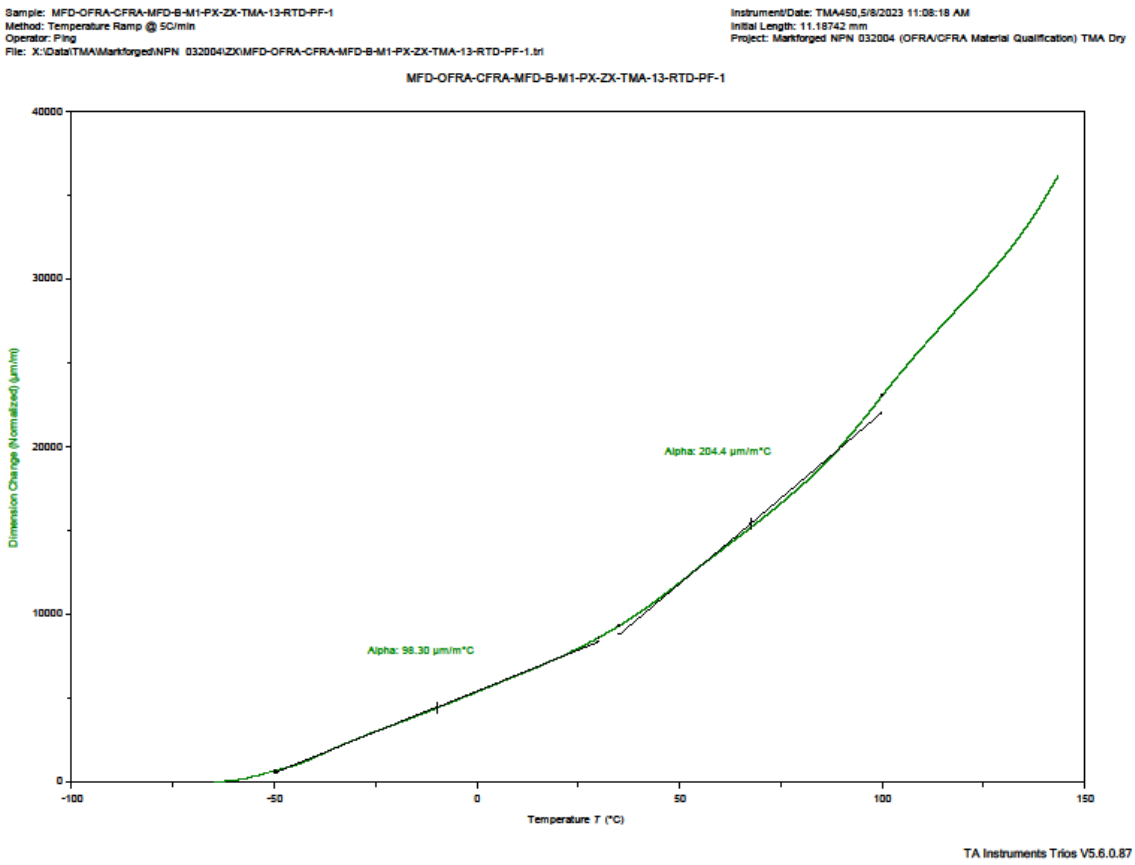
9.2.22 **XZ FF TMA Batch B**



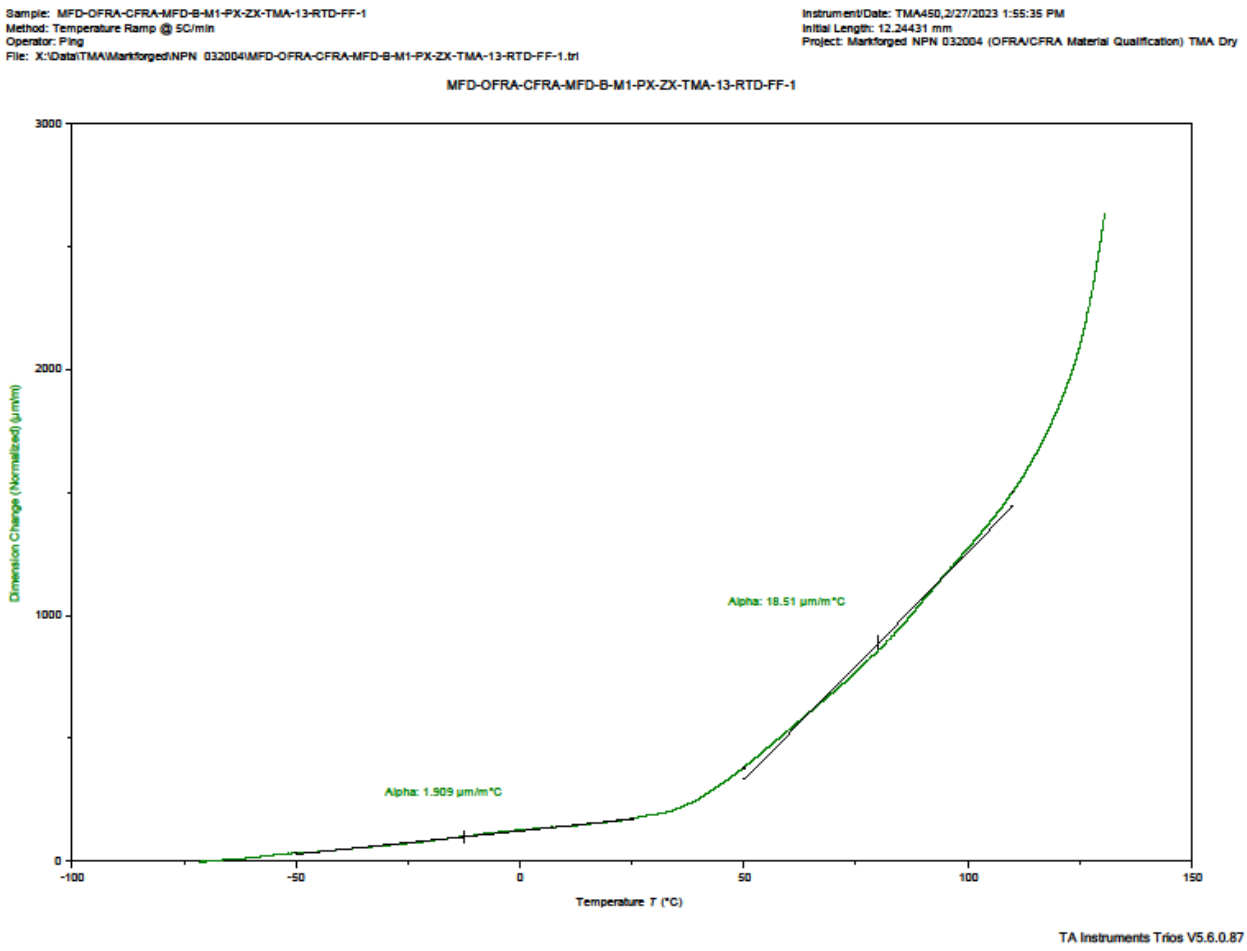
9.2.23 **XZ NF TMA Batch B**



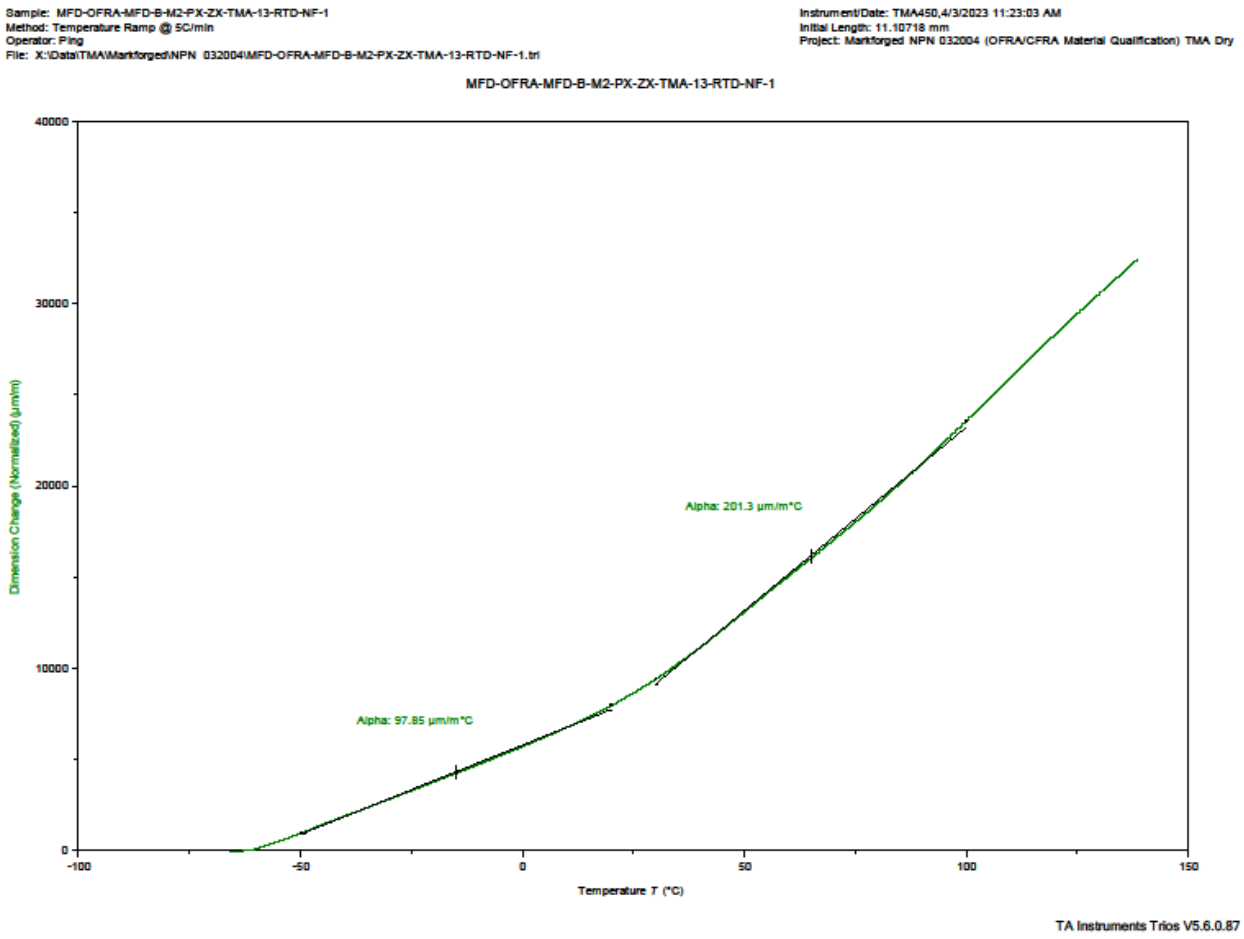
9.2.24 **ZX PF TMA Batch B**



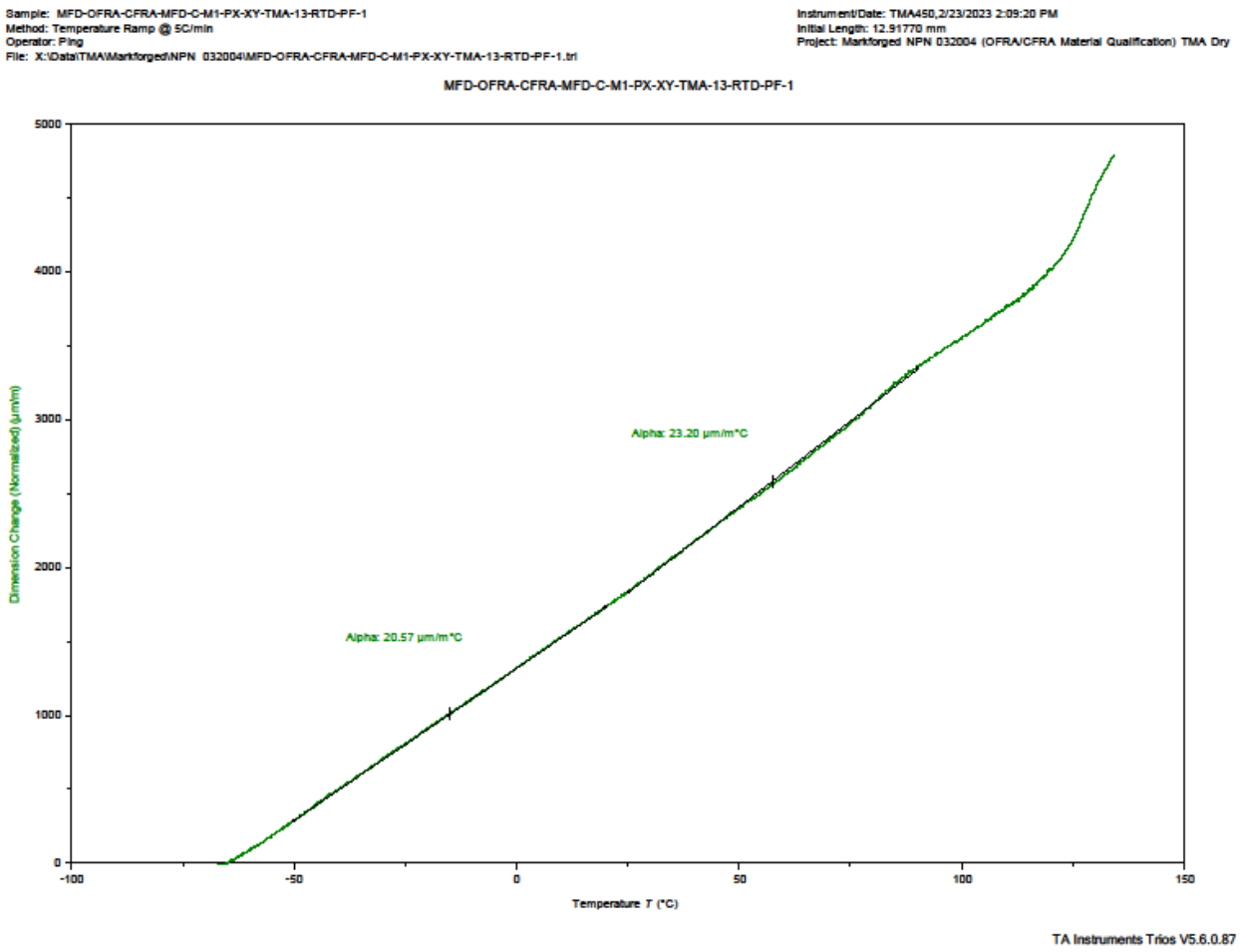
9.2.25 **ZX FF TMA Batch B**



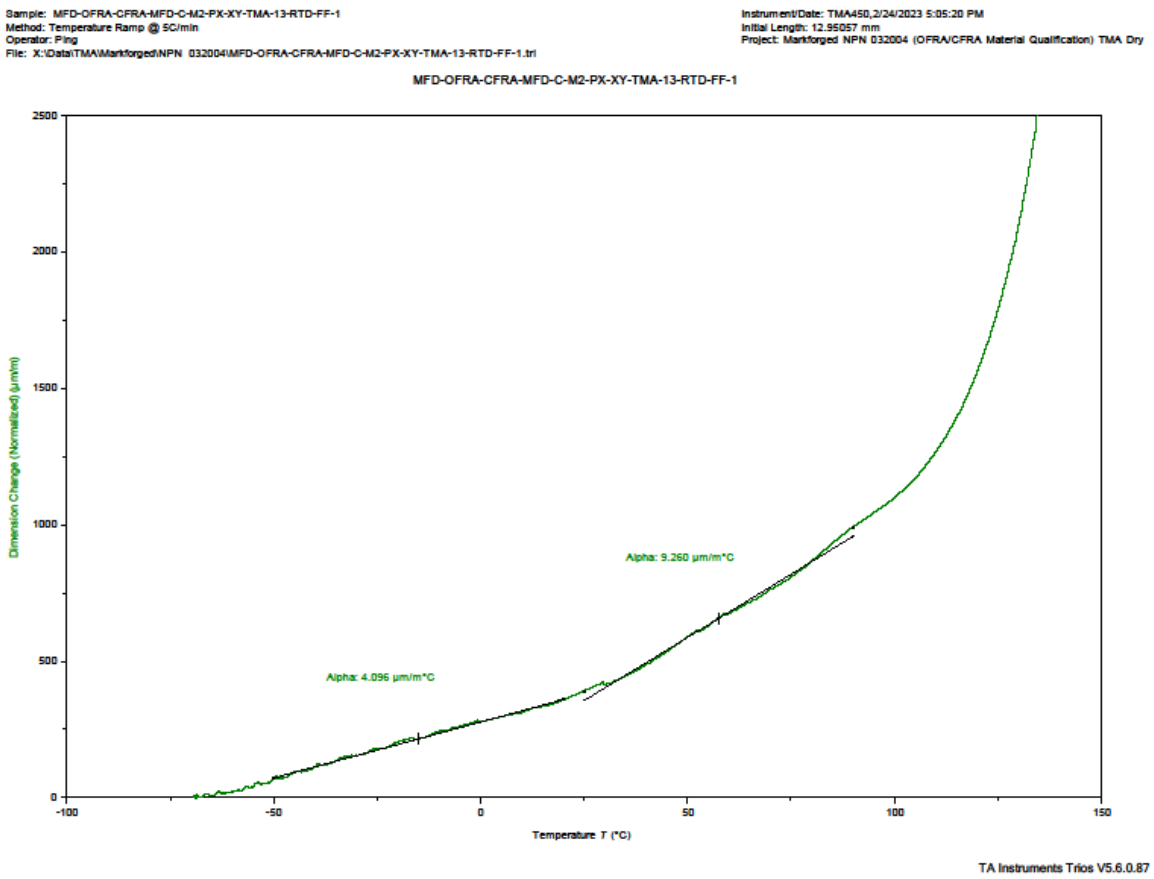
9.2.26 **ZX NF TMA Batch B**



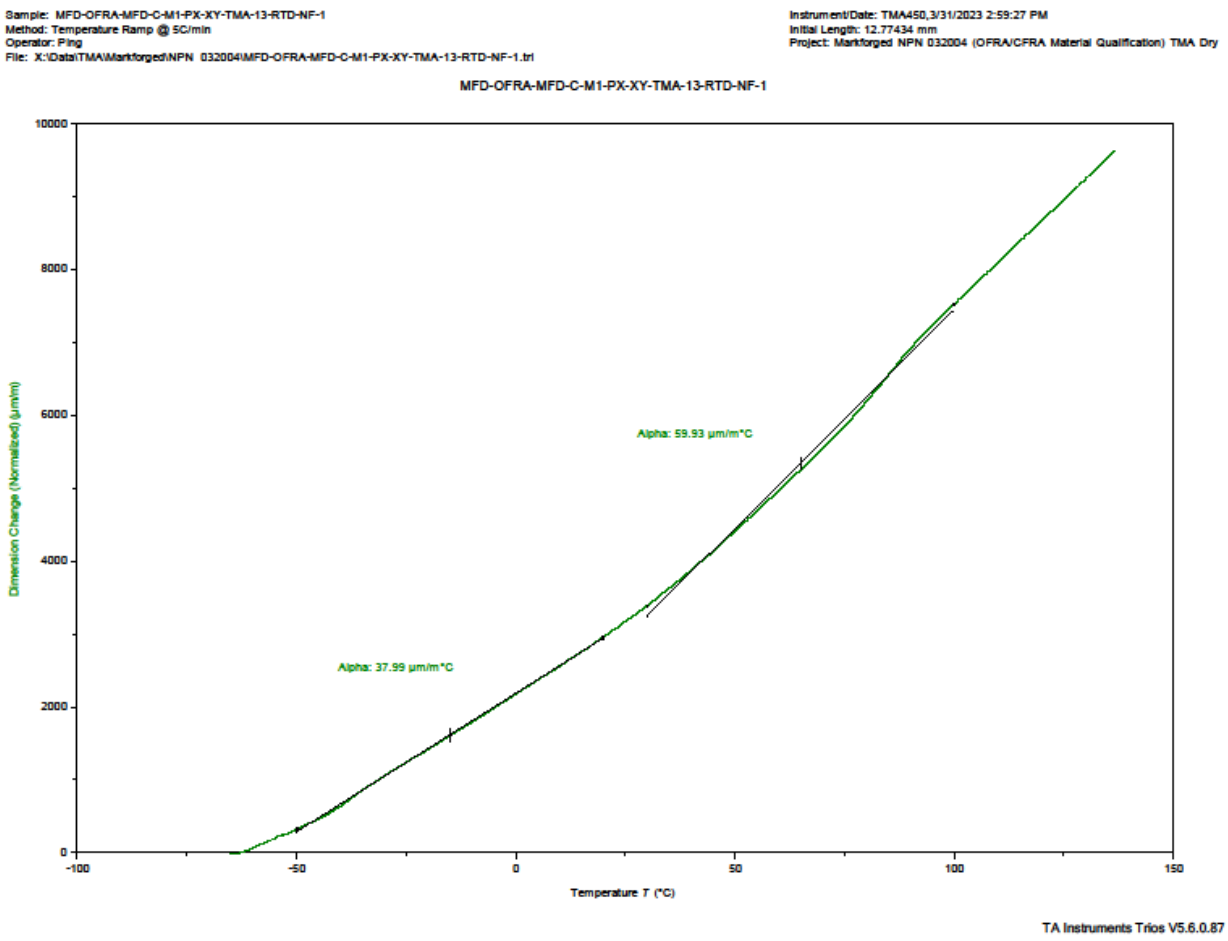
9.2.27 **XY PF TMA Batch C**



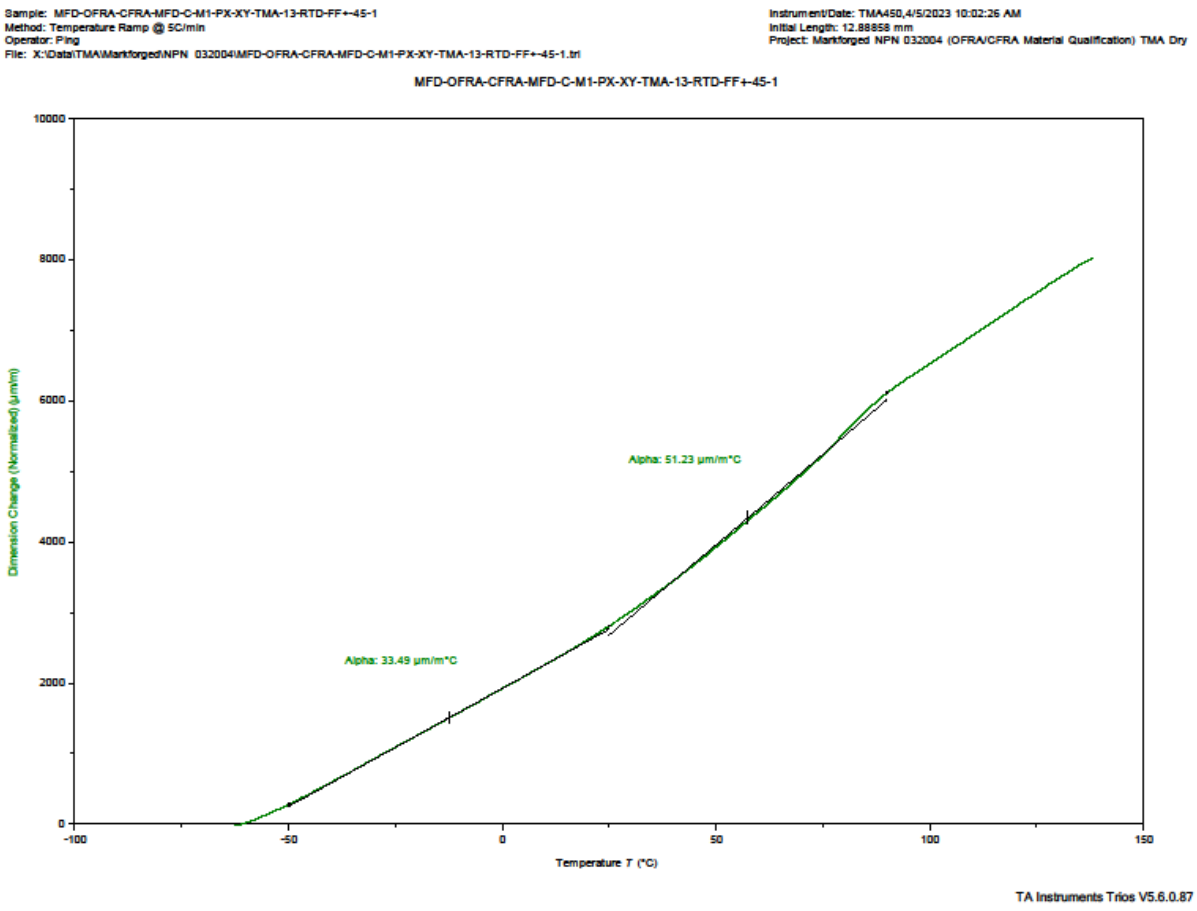
9.2.28 **XY FF TMA Batch C**



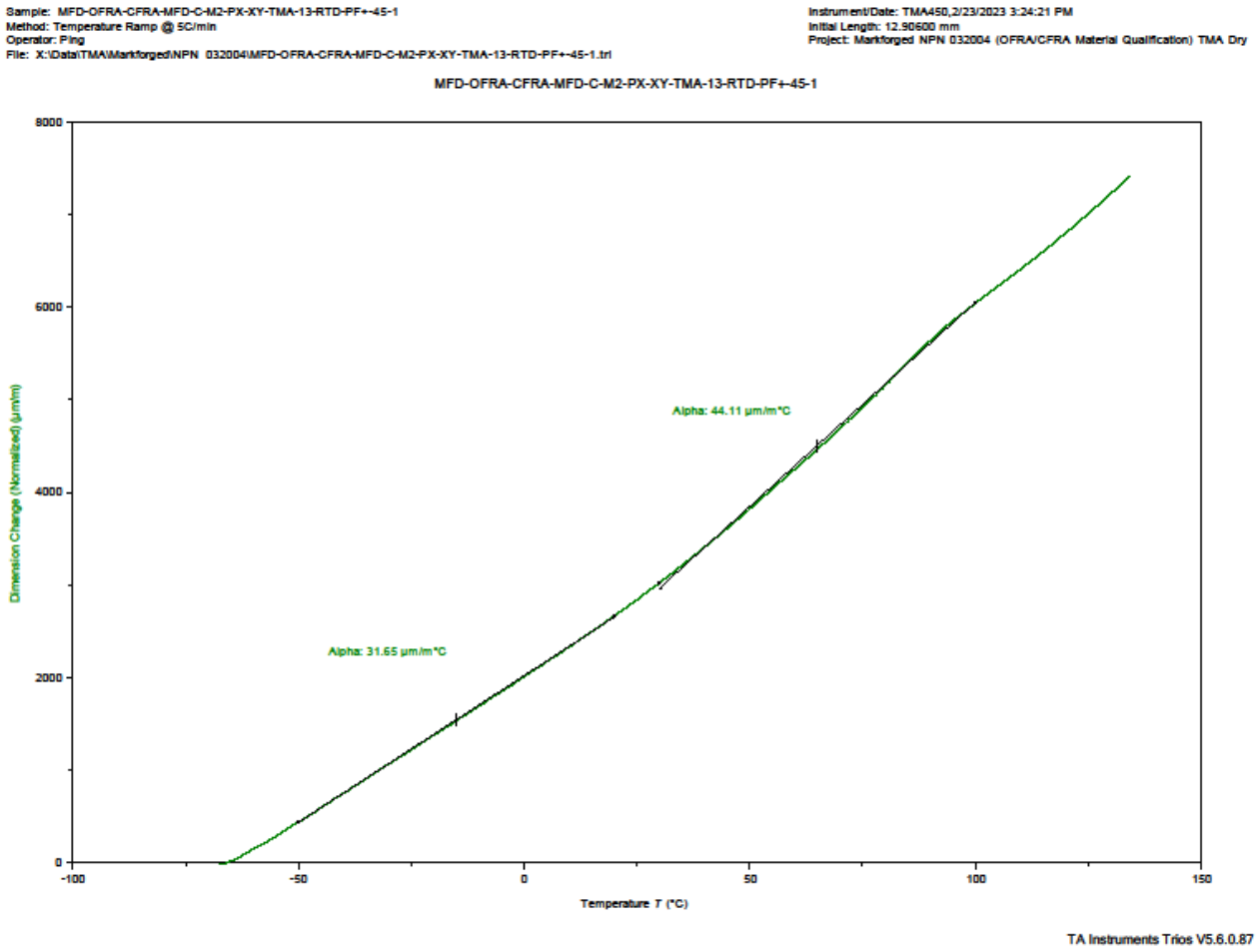
9.2.29 **XY NF TMA Batch C**



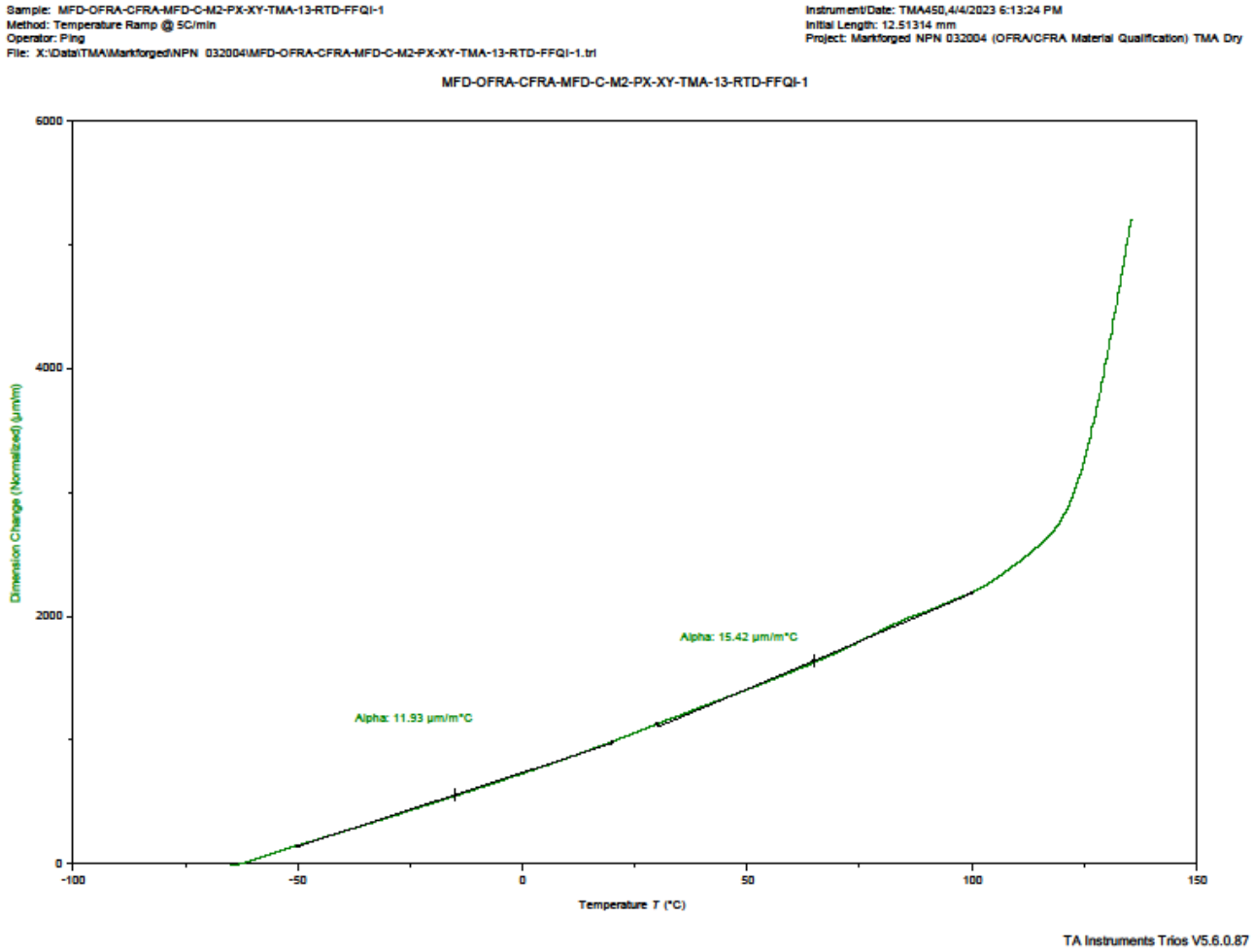
9.2.30 **XY FF±45 TMA Batch C**



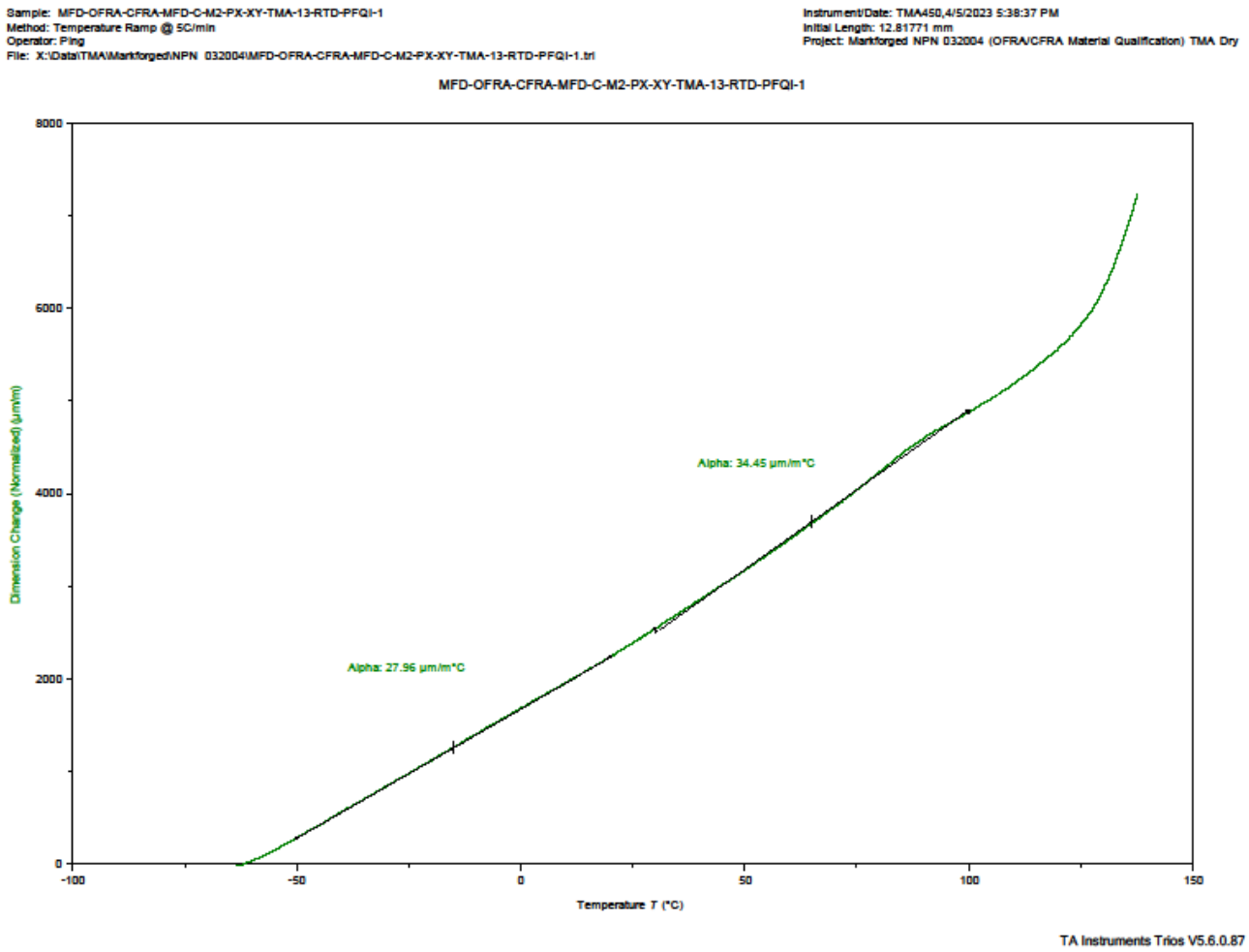
9.2.31 **XY PF±45 TMA Batch C**



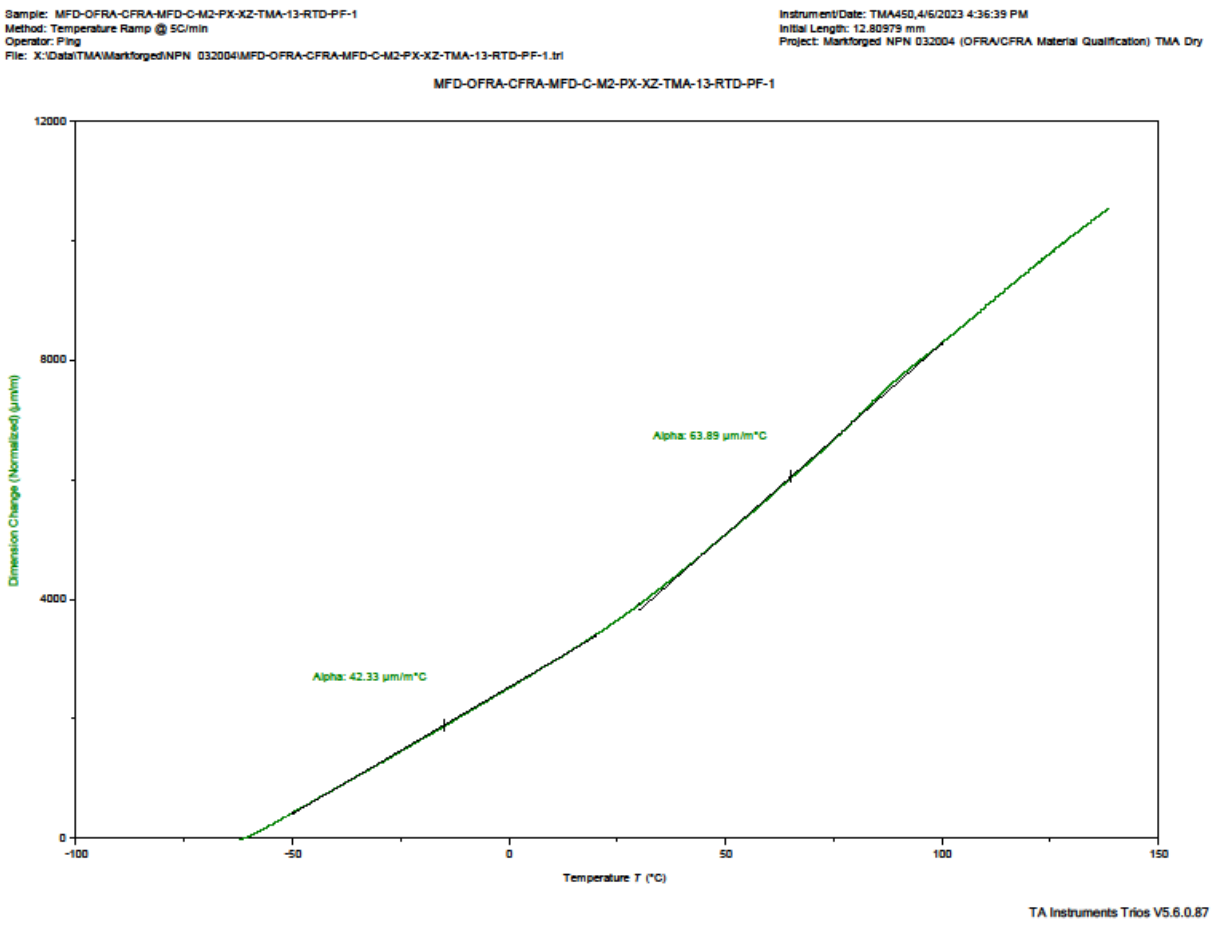
9.2.32 **XY FF Quasi TMA Batch C**



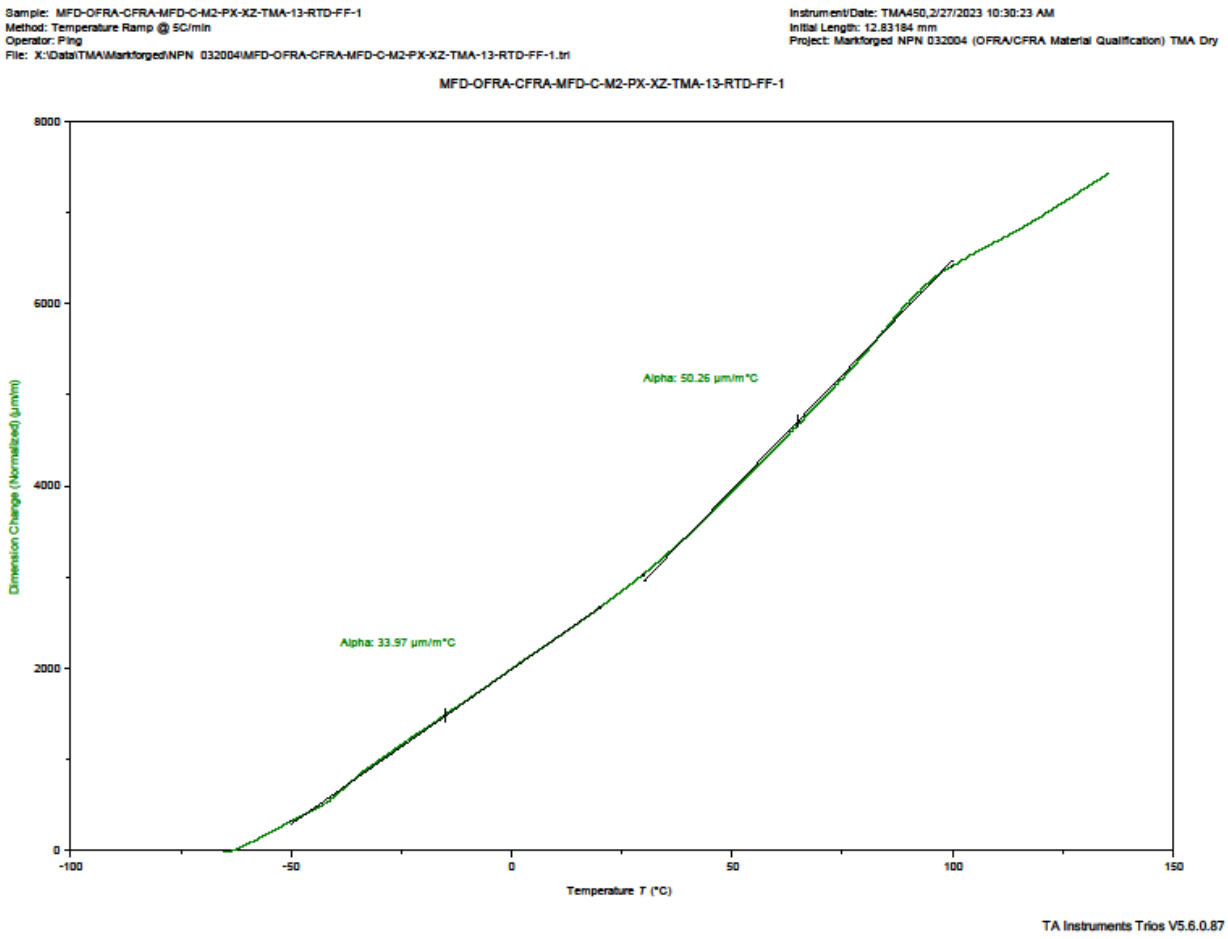
9.2.33 **XY PF Quasi TMA Batch C**



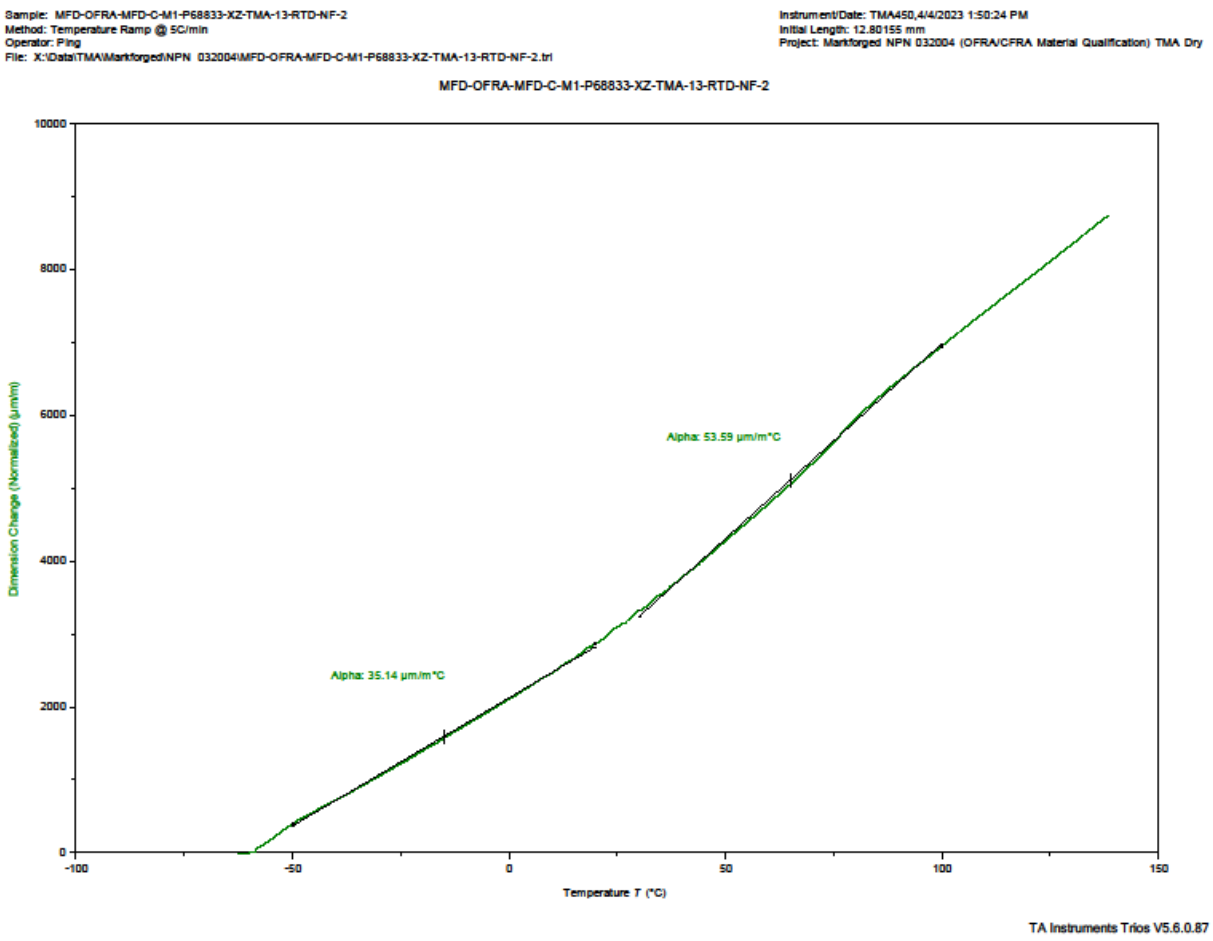
9.2.34 **XZ PF TMA Batch C**



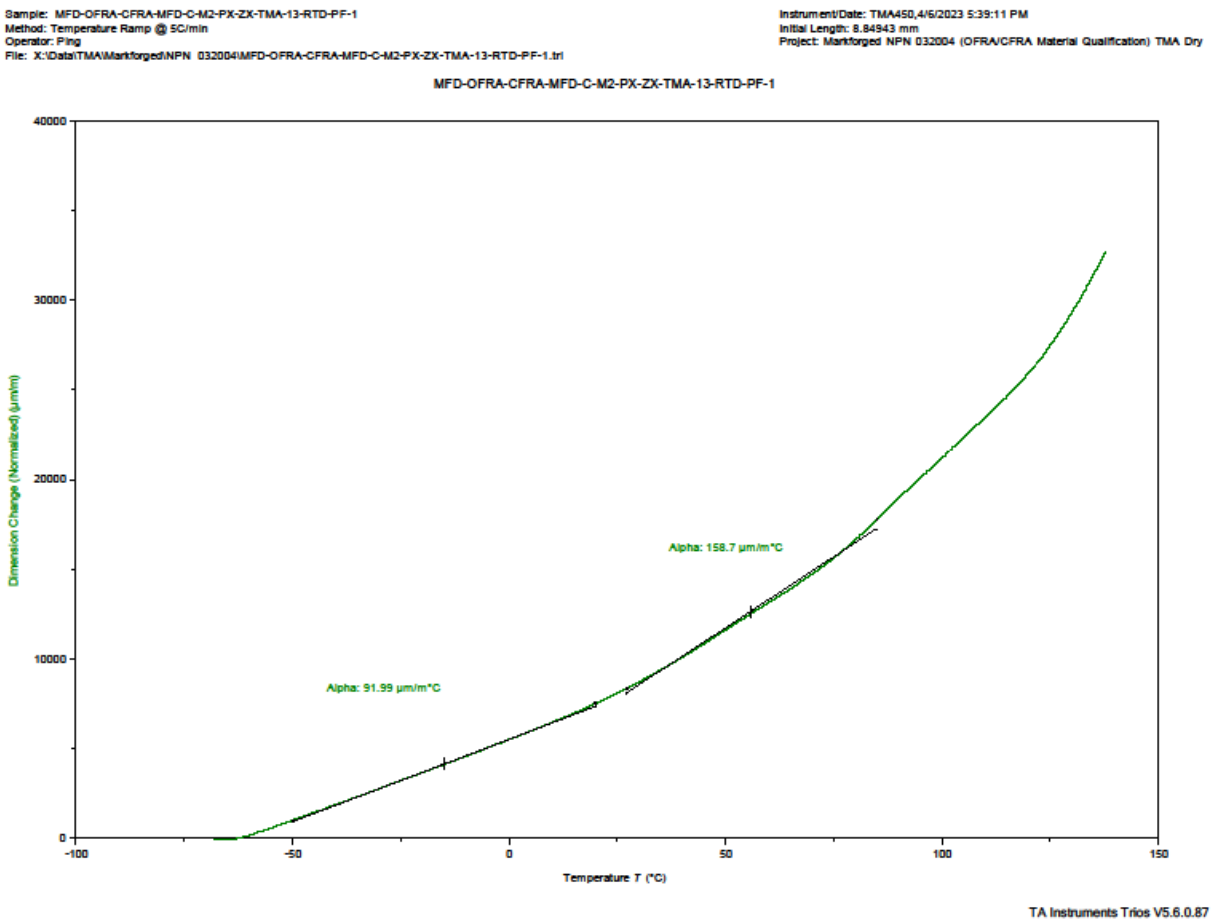
9.2.35 **XZ FF TMA Batch C**



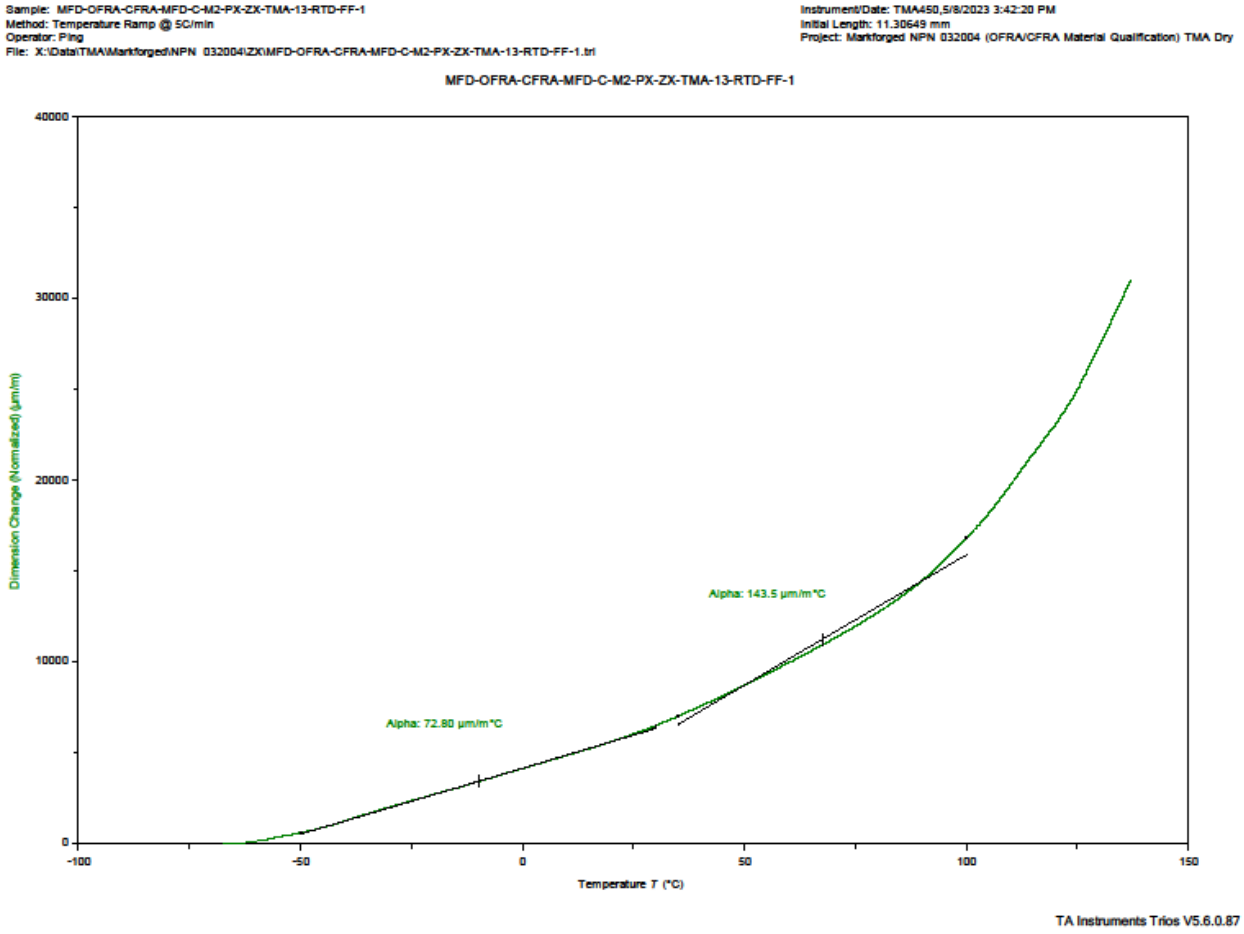
9.2.36 **XZ NF TMA Batch C**



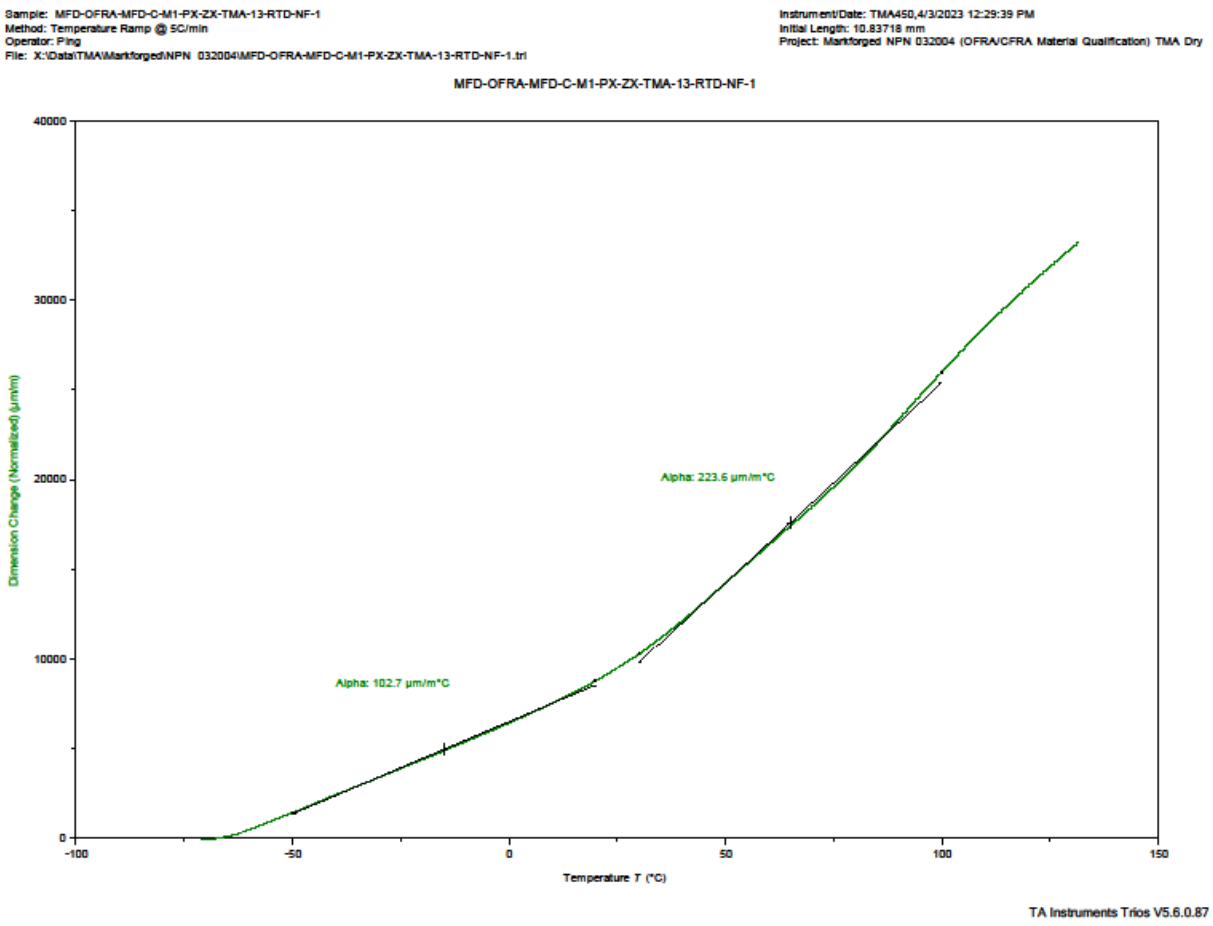
9.2.37 **ZX PF TMA Batch C**



9.2.38 **ZX FF TMA Batch C**



9.2.39 **ZX NF TMA Batch C**



9.3 Flammability Results

9.3.1 XY PF Vertical Burn Flammability Test

FAR 25.853 (a) Appendix F, Part I, (a) 1, (i): 60 sec,
Vertical Burn Flammability Test
Markforged OFRA-CFRA Qualification

Specimen Number	Burning Time (sec)	Burning Length (in)	Longest Burning Particle (sec)	Pass/Fail
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M1-P41767-XY-FLM-11-RTD-PF-1	7	4	0	Pass
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M1-P45491-XY-FLM-12-RTD-PF-2	0	4.4	0	Pass
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M1-P54259-XY-FLM-13-RTD-PF-3	1	3.9	0	Pass
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M1-P45491-XY-FLM-13-RTD-PF-SP				
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M2-P41693-XY-FLM-11-RTD-PF-1	0	4.3	0	Pass
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M2-P43600-XY-FLM-12-RTD-PF-2	0	3	0	Pass
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M2-P54704-XY-FLM-13-RTD-PF-3	0	4.6	0	Pass
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M2-P43600-XY-FLM-13-RTD-PF-SP				
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-B-M1-P39169-XY-FLM-11-RTD-PF-1	18	3.6	0	Fail
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-B-M1-P39520-XY-FLM-12-RTD-PF-2	7	3.8	0	Pass
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-B-M1-P56493-XY-FLM-13-RTD-PF-3	0	3.8	0	Pass
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-B-M1-P39520-XY-FLM-13-RTD-PF-SP				
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-B-M2-P39084-XY-FLM-11-RTD-PF-1	0	3	0	Pass
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-B-M2-P41419-XY-FLM-12-RTD-PF-2	0	3.6	0	Pass
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-B-M2-P65963-XY-FLM-13-RTD-PF-3	6	3.6	0	Pass
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-B-M2-P41419-XY-FLM-13-RTD-PF-SP				
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-C-M1-P65580-XY-FLM-11-RTD-PF-1	3	2.9	0	Pass
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-C-M1-P56820-XY-FLM-12-RTD-PF-2	0	2.4	0	Pass
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-C-M1-P51329-XY-FLM-13-RTD-PF-3	16	2.7	0	Fail
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-C-M1-P56820-XY-FLM-13-RTD-PF-SP				
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-C-M2-P48189-XY-FLM-11-RTD-PF-1	0	3.6	0	Pass
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-C-M2-P47926-XY-FLM-12-RTD-PF-2	1	4	0	Pass
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-C-M2-P51557-XY-FLM-13-RTD-PF-3	22	4.8	0	Fail
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-C-M2-P47926-XY-FLM-13-RTD-PF-SP				

Passing Criteria:
Maximum Burn Time: 15 sec
Maximum Burn Length: 6 in
Maximum Longest Burning: 3 sec

9.3.2 XZ PF Vertical Burn Flammability Test

FAR 25.853 (a) Appendix F, Part I, (a) 1, (i): 60 sec,
Vertical Burn Flammability Test
Markforged OFRA-CFRA Qualification

Specimen Number	Burning Time (sec)	Burning Length (in)	Longest Burning Particle (sec)	Pass/Fail
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M1-P41637-XZ-FLM-11-RTD-PF-1	0	2.2	0	Pass
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M1-P42023-XZ-FLM-12-RTD-PF-2	2	2.4	0	Pass
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M1-P42422-XZ-FLM-13-RTD-PF-3	1	2.8	0	Pass
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M1-P42103-XZ-FLM-13-RTD-PF-SP	0	2.4	0	Pass
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M2-P41808-XZ-FLM-11-RTD-PF-1	4	3	0	Pass
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M2-P41854-XZ-FLM-12-RTD-PF-2	1	3	0	Pass
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M2-P42422-XZ-FLM-13-RTD-PF-3	0	3.1	0	Pass
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M2-P42102-XZ-FLM-13-RTD-PF-SP	0	2.3	0	Pass
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-B-M1-P37587-XZ-FLM-11-RTD-PF-1	1.54	2.5625	0	Pass
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-B-M1-P37047-XZ-FLM-12-RTD-PF-2	0	2.6875	0	Pass
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-B-M1-P37704-XZ-FLM-13-RTD-PF-3	9.54	3	0	Pass
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-B-M1-P38483-XZ-FLM-13-RTD-PF-SP				
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-B-M2-P37430-XZ-FLM-11-RTD-PF-1	1	2.375	0	Pass
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-B-M2-P37084-XZ-FLM-12-RTD-PF-2	4.46	2.75	0	Pass
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-B-M2-P37392-XZ-FLM-13-RTD-PF-3	2.75	2.625	0	Pass
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-B-M2-P37360-XZ-FLM-13-RTD-PF-SP				
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-C-M1-P47123-XZ-FLM-11-RTD-PF-1	0	3.8	0	Pass
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-C-M1-P47919-XZ-FLM-12-RTD-PF-2	3	3.6	0	Pass
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-C-M1-P49205-XZ-FLM-13-RTD-PF-3	1	4.2	0	Pass
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-C-M1-P51593-XZ-FLM-13-RTD-PF-SP				
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-C-M2-P47465-XZ-FLM-11-RTD-PF-1	0	3.4	0	Pass
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-C-M2-P47567-XZ-FLM-12-RTD-PF-2	0	3.8	0	Pass
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-C-M2-P48538-XZ-FLM-13-RTD-PF-3	1	3.4	0	Pass
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-C-M2-P49084-XZ-FLM-13-RTD-PF-SP				

Passing Criteria:
Maximum Burn Time: 15 sec
Maximum Burn Length: 6 in
Maximum Longest Burning: 3 sec

9.3.3 ZX PF Vertical Burn Flammability Test

FAR 25.853 (a) Appendix F, Part I, (a) 1, (i): 60 sec,
Vertical Burn Flammability Test
Markforged OFRA-CFRA Qualification

Specimen Number	Burning Time (sec)	Burning Length (in)	Longest Burning Particle (sec)	Pass/Fail
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M1-P45710-ZX-FLM-11-RTD-PF-1	0	3.3	0	Pass
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M1-P44408-ZX-FLM-12-RTD-PF-2	0	3.4	0	Pass
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M1-P44497-ZX-FLM-13-RTD-PF-3	0	3.4	0	Pass
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M1-P44549-ZX-FLM-13-RTD-PF-SP				Pass
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M2-P44452-ZX-FLM-11-RTD-PF-1	0	2.5	0	Pass
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M2-P44804-ZX-FLM-12-RTD-PF-2	7	2.3	0	Pass
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M2-P44623-ZX-FLM-13-RTD-PF-3	13	2.1	0	Pass
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M2-P44949-ZX-FLM-13-RTD-PF-SP	5	2.4	0	Pass
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-B-M1-P37474-ZX-FLM-11-RTD-PF-1	1	2.6	0	Pass
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-B-M1-P37788-ZX-FLM-12-RTD-PF-2	9	3	0	Pass
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-B-M1-P55446-ZX-FLM-13-RTD-PF-3	9	3.1	0	Pass
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-B-M1-P38269-ZX-FLM-13-RTD-PF-SP				
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-B-M2-P37467-ZX-FLM-11-RTD-PF-1	0	1.6875	0	Pass
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-B-M2-P37749-ZX-FLM-12-RTD-PF-2	1.38	1.75	0	Pass
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-B-M2-P40760-ZX-FLM-13-RTD-PF-3	0	1.4375	0	Pass
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-C-M1-P49381-ZX-FLM-11-RTD-PF-1	15	3.4	0	Pass
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-C-M1-P49381-ZX-FLM-12-RTD-PF-2	0	3.6	0	Pass
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-C-M1-P51398-ZX-FLM-13-RTD-PF-3	0	2.8	0	Pass
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-C-M1-P52335-ZX-FLM-13-RTD-PF-SP				
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-C-M2-P49354-ZX-FLM-11-RTD-PF-1	0	2.6	0	Pass
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-C-M2-P50010-ZX-FLM-12-RTD-PF-2	8	3.3	0	Pass
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-C-M2-P50783-ZX-FLM-13-RTD-PF-3	0	3.6	0	Pass
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-C-M2-P53150-ZX-FLM-13-RTD-PF-SP				

Passing Criteria:
Maximum Burn Time: 15 sec
Maximum Burn Length: 6 in
Maximum Longest Burning: 3 sec

9.3.4 XY PF Smoke Density Test

FAR 25.853 (d) Appendix F, Part V,
Smoke Density Test
Markforged OFRA-CFRA Qualification

Specimen Number	Ds @ 1.5m	Ds @ 4.0m	Ds Max	Dmax Time	Pass/Fail
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M1-P45918-XY-NBS-11-RTD-PF-1	15	167	167	240	Pass
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M1-P46349-XY-NBS-12-RTD-PF-2	9	108	108	240	Pass
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M1-P46121-XY-NBS-13-RTD-PF-3	17	162	162	240	Pass
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M1-P54708-XY-NBS-13-RTD-PF-SP					
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M2-P44993-XY-NBS-11-RTD-PF-1	8	94	94	240	Pass
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M2-P44328-XY-NBS-12-RTD-PF-2	10	92	92	240	Pass
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M2-P44246-XY-NBS-13-RTD-PF-3	9	61	61	240	Pass
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M2-P53540-XY-NBS-13-RTD-PF-SP					
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-B-M1-P40434-XY-NBS-11-RTD-PF-1	9	130	134	245	Pass
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-B-M1-P40767-XY-NBS-12-RTD-PF-2	11	104	104	240	Pass
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-B-M1-P40042-XY-NBS-13-RTD-PF-3	22	131	131	240	Pass
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-B-M1-P54969-XY-NBS-13-RTD-PF-SP					
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-B-M2-P40435-XY-NBS-11-RTD-PF-1	16	80	80	240	Pass
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-B-M2-P46338-XY-NBS-12-RTD-PF-2	19	98	98	240	Pass
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-B-M2-P40598-XY-NBS-13-RTD-PF-3	6	78	78	240	Pass
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-B-M2-P58063-XY-NBS-13-RTD-PF-SP					
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-C-M1-P47645-XY-NBS-11-RTD-PF-1	17	104	104	240	Pass
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-C-M1-P47474-XY-NBS-12-RTD-PF-2	18	96	96	240	Pass
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-C-M1-P47735-XY-NBS-13-RTD-PF-3	26	150	150	240	Pass
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-C-M1-P56904-XY-NBS-13-RTD-PF-SP					
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-C-M2-P47413-XY-NBS-11-RTD-PF-1	17	94	94	240	Pass
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-C-M2-P47269-XY-NBS-12-RTD-PF-2	13	79	79	240	Pass
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-C-M2-P50575-XY-NBS-13-RTD-PF-3	15	104	104	240	Pass
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-C-M2-P51396-XY-NBS-13-RTD-PF-SP					

Passing Criteria:
Ds Max <200

9.3.5 XZ PF Smoke Density Test

FAR 25.853 (d) Appendix F, Part V,
Smoke Density Test
Markforged OFRA-CFRA Qualification

Specimen Number	Ds @ 1.5m	Ds @ 4.0m	Ds Max	Dmax Time	Pass/Fail
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M1-P54708-XZ-NBS-11-RTD-PF-1	6	101	101	240	Pass
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M1-P54234-XZ-NBS-12-RTD-PF-2	10	128	128	240	Pass
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M1-P54110-XZ-NBS-13-RTD-PF-3	8	97	97	240	Pass
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M1-P54234-XZ-NBS-13-RTD-PF-SP					
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M2-P53540-XZ-NBS-11-RTD-PF-1	5	100	100	240	Pass
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M2-P54218-XZ-NBS-12-RTD-PF-2	6	86	86	240	Pass
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M2-P53977-XZ-NBS-13-RTD-PF-3	8	92	92	240	Pass
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M2-P54218-XZ-NBS-13-RTD-PF-SP					
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-B-M1-P54969-XZ-NBS-11-RTD-PF-1	6	96	96	240	Pass
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-B-M1-P56434-XZ-NBS-12-RTD-PF-2	9	210	210	240	Fail
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-B-M1-P55693-XZ-NBS-13-RTD-PF-3	5	134	134	240	Pass
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-B-M1-P56434-XZ-NBS-13-RTD-PF-SP					
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-B-M2-P58063-XZ-NBS-11-RTD-PF-1	5	113	113	240	Pass
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-B-M2-P55707-XZ-NBS-12-RTD-PF-2	4	68	68	240	Pass
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-B-M2-P55043-XZ-NBS-13-RTD-PF-3	4	112	112	240	Pass
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-B-M2-P55707-XZ-NBS-13-RTD-PF-SP					
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-C-M1-P56904-XZ-NBS-11-RTD-PF-1	3	70	70	240	Pass
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-C-M1-P50990-XZ-NBS-12-RTD-PF-2	7	113	113	240	Pass
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-C-M1-P51485-XZ-NBS-13-RTD-PF-3	7	109	109	240	Pass
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-C-M1-P50990-XZ-NBS-13-RTD-PF-SP					
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-C-M2-P51396-XZ-NBS-11-RTD-PF-1	6	170	170	240	Pass
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-C-M2-P51184-XZ-NBS-12-RTD-PF-2	19	199	199	240	Pass
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-C-M2-P65562-XZ-NBS-13-RTD-PF-3	6	131	131	240	Pass
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-C-M2-P51184-XZ-NBS-13-RTD-PF-SP					

Passing Criteria:
Ds Max <200

9.3.6 ZX PF Smoke Density Test

FAR 25.853 (d) Appendix F, Part V,
Smoke Density Test
Markforged OFRA-CFRA Qualification

Specimen Number	Ds @ 1.5m	Ds @ 4.0m	Ds Max	Dmax Time	Pass/Fail
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M1-P54144-ZX-NBS-11-RTD-PF-1	8	109	109	240	Pass
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M1-P54234-ZX-NBS-12-RTD-PF-2	8	119	119	240	Pass
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M1-P53990-ZX-NBS-13-RTD-PF-3	6	114	114	240	Pass
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M1-P54632-ZX-NBS-13-RTD-PF-SP					
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M2-P53725-ZX-NBS-11-RTD-PF-1	8	156	156	240	Pass
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M2-P54218-ZX-NBS-12-RTD-PF-2	7	202	202	240	Fail
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M2-P53618-ZX-NBS-13-RTD-PF-3	6	120	120	240	Pass
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M2-P54722-ZX-NBS-13-RTD-PF-SP					
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-B-M1-P58774-ZX-NBS-11-RTD-PF-1	8	140	140	240	Pass
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-B-M1-P56434-ZX-NBS-12-RTD-PF-2	6	128	128	240	Pass
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-B-M1-P55625-ZX-NBS-13-RTD-PF-3	15	199	199	240	Pass
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-B-M1-P56531-ZX-NBS-13-RTD-PF-SP					
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-B-M2-P58165-ZX-NBS-11-RTD-PF-1	6	97	97	240	Pass
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-B-M2-P55707-ZX-NBS-12-RTD-PF-2	7	108	108	240	Pass
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-B-M2-P66022-ZX-NBS-13-RTD-PF-3	27	179	179	240	Pass
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-B-M2-P56225-ZX-NBS-13-RTD-PF-SP					
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-C-M1-P51459-ZX-NBS-11-RTD-PF-1	6	113	113	240	Pass
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-C-M1-P50990-ZX-NBS-12-RTD-PF-2	12	189	189	240	Pass
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-C-M1-P51179-ZX-NBS-13-RTD-PF-3	7	85	85	240	Pass
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-C-M1-P51009-ZX-NBS-13-RTD-PF-SP					
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-C-M2-P57299-ZX-NBS-11-RTD-PF-1	21	230	230	240	Fail
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-C-M2-P51184-ZX-NBS-12-RTD-PF-2	13	178	178	240	Pass
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-C-M2-P50982-ZX-NBS-13-RTD-PF-3	15	341	341	240	Fail
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-C-M2-P57305-ZX-NBS-13-RTD-PF-SP					

Passing Criteria:
Ds Max <200

9.3.7 ZX FF Smoke Density Test

FAR 25.853 (d) Appendix F, Part V,
Smoke Density Test
Markforged OFRA-CFRA Qualification

Specimen Number	Ds @ 1.5m	Ds @ 4.0m	Ds Max	Dmax Time	Pass/Fail
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-B-M2-P69381-ZX-NBS-11-RTD-FF-1	4	147	147	240	Pass
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-B-M2-P69381-ZX-NBS-12-RTD-FF-2	6	107	107	240	Pass
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-B-M2-P69381-ZX-N8S-13-RTD-FF-3	4	156	156	240	Pass

Passing Criteria:
Ds Max <200

9.3.8 ZX NF Smoke Density Test

FAR 25.853 (d) Appendix F, Part V,
Smoke Density Test
Markforged OFRA-CFRA Qualification

Specimen Number	Ds @ 1.5m	Ds @ 4.0m	Ds Max	Dmax Time	Pass/Fail
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-C-M2-P67114-ZX-NBS-11-RTD-NF-1	15	167	167	240	Pass
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-C-M2-P67114-ZX-NBS-12-RTD-NF-2	9	108	108	240	Pass
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-C-M2-P67114-ZX-NBS-13-RTD-NF-3	17	162	162	240	Pass

Passing Criteria:
Ds Max <200

9.3.9 XY PF Heat Release Test

FAR 25.853 (d) Appendix F, Part IV,
Heat Release Test
Markforged OFRA-CFRA Qualification

Specimen Number	Total HR at 2 min (kWmin/m^2)	Peak HR (kW/m^2)	Peak Time (sec)	Pass/Fail
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M1-P54259-XY-HRP-11-RTD-PF-1	150	180	298	Fail
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M1-P54708-XY-HRP-12-RTD-PF-2	139	165	276	Fail
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M1-P53990-XY-HRP-13-RTD-PF-3	138	145	288	Fail
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M1-P54110-XY-HRP-13-RTD-PF-SP				
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M2-P54704-XY-HRP-11-RTD-PF-1	169	143	281	Fail
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M2-P53540-XY-HRP-12-RTD-PF-2	152	141	262	Fail
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M2-P53618-XY-HRP-13-RTD-PF-3	139	154	293	Fail
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M2-P53977-XY-HRP-13-RTD-PF-SP				
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-B-M1-P56493-XY-HRP-11-RTD-PF-1	170	134	269	Fail
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-B-M1-P54969-XY-HRP-12-RTD-PF-2	134	147	292	Fail
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-B-M1-P55625-XY-HRP-13-RTD-PF-3	140	143	271	Fail
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-B-M1-P55693-XY-HRP-13-RTD-PF-SP				
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-B-M2-P65963-XY-HRP-11-RTD-PF-1	163	150	282	Fail
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-B-M2-P58063-XY-HRP-12-RTD-PF-2	121	149	285	Fail
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-B-M2-P66022-XY-HRP-13-RTD-PF-3	135	123	288	Fail
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-B-M2-P55043-XY-HRP-13-RTD-PF-SP				
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-C-M1-P51329-XY-HRP-11-RTD-PF-1	158	147	271	Fail
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-C-M1-P56904-XY-HRP-12-RTD-PF-2	154	114	263	Fail
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-C-M1-P51179-XY-HRP-13-RTD-PF-3	142	129	278	Fail
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-C-M1-P51485-XY-HRP-13-RTD-PF-SP				
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-C-M2-P51557-XY-HRP-11-RTD-PF-1	149	153	278	Fail
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-C-M2-P51396-XY-HRP-12-RTD-PF-2	127	111	260	Fail
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-C-M2-P50982-XY-HRP-13-RTD-PF-3	152	118	276	Fail
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-C-M2-P65562-XY-HRP-13-RTD-PF-SP				

Passing Criteria:
Total HR at 2 min <65 kWmin/m^2
Peak HR <65 kW/m^2

9.3.10 XZ PF Heat Release Test

FAR 25.853 (d) Appendix F, Part IV,
Heat Release Test
Markforged OFRA-CFRA Qualification

Specimen Number	Total HR at 2 min ($kWmin/m^2$)	Peak HR (kW/m^2)	Peak Time (sec)	Pass/Fail
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M1-P42220-XZ-HRP-11-RTD-PF-1	147.3	153.9	239	Fail
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M1-P42825-XZ-HRP-12-RTD-PF-2	118.3	143.2	225	Fail
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M1-P43128-XZ-HRP-13-RTD-PF-3	116.8	126.8	292	Fail
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M1-P44799-XZ-HRP-13-RTD-PF-SP				
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-B-M1-P55370-XZ-HRP-11-RTD-PF-1	132	130	81	Fail
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-B-M1-P55575-XZ-HRP-12-RTD-PF-2	120	127	260	Fail
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-B-M1-P55914-XZ-HRP-13-RTD-PF-3	118	111	287	Fail
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-B-M1-P56349-XZ-HRP-13-RTD-PF-SP				
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-C-M1-P46937-XZ-HRP-11-RTD-PF-1	132	144	295	Fail
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-C-M1-P50721-XZ-HRP-12-RTD-PF-2	112	126	234	Fail
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-C-M1-P51227-XZ-HRP-13-RTD-PF-3	160	143	78	Fail
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-C-M1-P49085-XZ-HRP-13-RTD-PF-SP				
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M2-P42290-XZ-HRP-11-RTD-PF-1	142.8	141.2	286	Fail
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M2-P42771-XZ-HRP-12-RTD-PF-2	123.2	123	238	Fail
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M2-P44313-XZ-HRP-13-RTD-PF-3	124.4	113.9	217	Fail
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M2-P43083-XZ-HRP-13-RTD-PF-SP				
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-B-M2-P41254-XZ-HRP-11-RTD-PF-1	120	136	187	Fail
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-B-M2-P46390-XZ-HRP-12-RTD-PF-2	119	124	207	Fail
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-B-M2-P38625-XZ-HRP-13-RTD-PF-3	105	110	284	Fail
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-B-M2-P56024-XZ-HRP-13-RTD-PF-SP				
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-C-M2-P46936-XZ-HRP-11-RTD-PF-1	120	131	219	Fail
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-C-M2-P47763-XZ-HRP-12-RTD-PF-2	105	119	219	Fail
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-C-M2-P48530-XZ-HRP-13-RTD-PF-3	137	141	228	Fail
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-C-M2-P49206-XZ-HRP-13-RTD-PF-SP				

Passing Criteria:
Total HR at 2 min <65 $kWmin/m^2$
Peak HR <65 kW/m^2

9.3.11 ZX PF Heat Release Test

FAR 25.853 (d) Appendix F, Part IV,
Heat Release Test
Markforged OFRA-CFRA Qualification

Specimen Number	Total HR at 2 min ($kWmin/m^2$)	Peak HR (kW/m^2)	Peak Time (sec)	Pass/Fail
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M1-P53539-ZX-HRP-11-RTD-PF-1	128	132	250	Fail
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M1-P43741-ZX-HRP-12-RTD-PF-2	104	132	250	Fail
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M1-P43192-ZX-HRP-13-RTD-PF-3	122	129	240	Fail
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M1-P45326-ZX-HRP-13-RTD-PF-SP				
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-B-M1-P55312-ZX-HRP-11-RTD-PF-1	119.8	137.5	242	Fail
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-B-M1-P55870-ZX-HRP-12-RTD-PF-2	118.5	114.8	297	Fail
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-B-M1-P56023-ZX-HRP-13-RTD-PF-3	123	132.5	244	Fail
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-B-M1-P56193-ZX-HRP-13-RTD-PF-SP				
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-C-M1-P47059-ZX-HRP-11-RTD-PF-1	132	136	270	Fail
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-C-M1-P50788-ZX-HRP-12-RTD-PF-2	114	120	207	Fail
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-C-M1-P52698-ZX-HRP-13-RTD-PF-3	131	175	193	Fail
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-C-M1-P53030-ZX-HRP-13-RTD-PF-SP				
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M2-P42218-ZX-HRP-11-RTD-PF-1	123	141	204	Fail
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M2-P42638-ZX-HRP-12-RTD-PF-2	107	122	230	Fail
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M2-P43194-ZX-HRP-13-RTD-PF-3	109	125	191	Fail
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-A-M2-P43729-ZX-HRP-13-RTD-PF-SP				
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-B-M2-P54897-ZX-HRP-11-RTD-PF-1	121	138	261	Fail
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-B-M2-P55618-ZX-HRP-12-RTD-PF-2	126	167	226	Fail
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-B-M2-P55445-ZX-HRP-13-RTD-PF-3	102	105	228	Fail
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-B-M2-P56186-ZX-HRP-13-RTD-PF-SP				
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-C-M2-P47648-ZX-HRP-11-RTD-PF-1	124.5	137.2	252	Fail
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-C-M2-P48080-ZX-HRP-12-RTD-PF-2	94.8	131.4	236	Fail
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-C-M2-P48719-ZX-HRP-13-RTD-PF-3	142.7	129.1	263	Fail
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-C-M2-P49951-ZX-HRP-13-RTD-PF-SP				

Passing Criteria:
Total HR at 2 min <65 $kWmin/m^2$
Peak HR <65 kW/m^2

9.4 Relative Density

D792-20 Specific Gravity (Relative Density)							
Sample Name	W1 [g]	W2 [g]	Water Temp. [°C]	Water Density at Temp. [g/cc]	Specific Gravity	Specimen Density [g/cc]	Specimen Density [lbm/in3]
NTPAM6754Q1-MFD-OFRA-MFD-A-M1-P31429-ZX-DEN-13-RTD-NF-1	2.7993	0.4568	21.8000	0.99782	1.1950	1.1924	0.0431
NTPAM6754Q1-MFD-OFRA-MFD-A-M1-P31429-ZX-DEN-13-RTD-NF-2	2.7580	0.4312	21.8000	0.99782	1.1853	1.1827	0.0427
NTPAM6754Q1-MFD-OFRA-MFD-A-M1-P31429-ZX-DEN-13-RTD-NF-3	2.7605	0.4586	21.8000	0.99782	1.1992	1.1966	0.0432
NTPAM6754Q1-MFD-OFRA-MFD-A-M1-P31429-ZX-DEN-13-RTD-NF-4	2.7441	0.4421	21.8000	0.99782	1.1921	1.1895	0.0430
NTPAM6754Q1-MFD-OFRA-MFD-A-M1-P31429-ZX-DEN-13-RTD-NF-5	2.7486	0.4494	21.8000	0.99782	1.1955	1.1929	0.0431
NTPAM6754Q1-MFD-OFRA-MFD-A-M2-P31576-ZX-DEN-11-RTD-NF-1	2.8135	0.4760	21.8000	0.99782	1.2036	1.2010	0.0434
NTPAM6754Q1-MFD-OFRA-MFD-A-M2-P31576-ZX-DEN-11-RTD-NF-2	2.7897	0.4667	21.8000	0.99782	1.2009	1.1983	0.0433
NTPAM6754Q1-MFD-OFRA-MFD-A-M2-P31576-ZX-DEN-11-RTD-NF-3	2.7803	0.4704	21.8000	0.99782	1.2036	1.2010	0.0434
NTPAM6754Q1-MFD-OFRA-MFD-A-M2-P31576-ZX-DEN-11-RTD-NF-4	2.7582	0.4665	21.8000	0.99782	1.2036	1.2009	0.0434
NTPAM6754Q1-MFD-OFRA-MFD-A-M2-P31576-ZX-DEN-11-RTD-NF-5	2.7630	0.4654	21.9000	0.99780	1.2026	1.1999	0.0433
NTPAM6754Q1-MFD-OFRA-MFD-B-M1-P33521-ZX-DEN-11-RTD-NF-1	2.7112	0.3838	21.9000	0.99780	1.1649	1.1623	0.0420
NTPAM6754Q1-MFD-OFRA-MFD-B-M1-P33521-ZX-DEN-11-RTD-NF-2	2.7092	0.3828	21.9000	0.99780	1.1645	1.1620	0.0420
NTPAM6754Q1-MFD-OFRA-MFD-B-M1-P33521-ZX-DEN-11-RTD-NF-3	2.6407	0.3843	22.0000	0.99778	1.1703	1.1677	0.0422
NTPAM6754Q1-MFD-OFRA-MFD-B-M1-P33521-ZX-DEN-11-RTD-NF-4	2.6321	0.3791	22.0000	0.99778	1.1683	1.1657	0.0421
NTPAM6754Q1-MFD-OFRA-MFD-B-M1-P33521-ZX-DEN-11-RTD-NF-5	2.6024	0.3651	22.0000	0.99778	1.1632	1.1606	0.0419
NTPAM6754Q1-MFD-OFRA-MFD-B-M2-P33520-ZX-DEN-11-RTD-NF-1	2.7221	0.4179	22.0000	0.99778	1.1814	1.1787	0.0426
NTPAM6754Q1-MFD-OFRA-MFD-B-M2-P33520-ZX-DEN-11-RTD-NF-2	2.7061	0.4072	22.0000	0.99778	1.1771	1.1745	0.0424
NTPAM6754Q1-MFD-OFRA-MFD-B-M2-P33520-ZX-DEN-11-RTD-NF-3	2.7082	0.4119	22.0000	0.99778	1.1794	1.1768	0.0425
NTPAM6754Q1-MFD-OFRA-MFD-B-M2-P33520-ZX-DEN-11-RTD-NF-4	2.6884	0.3987	22.0000	0.99778	1.1741	1.1715	0.0423
NTPAM6754Q1-MFD-OFRA-MFD-B-M2-P33520-ZX-DEN-11-RTD-NF-5	2.6475	0.3899	22.0000	0.99778	1.1727	1.1701	0.0423
NTPAM6754Q1-MFD-OFRA-MFD-C-M1-P49599-ZX-DEN-12-RTD-NF-1	2.7738	0.4425	22.1000	0.99776	1.1898	1.1871	0.0429
NTPAM6754Q1-MFD-OFRA-MFD-C-M1-P49599-ZX-DEN-12-RTD-NF-2	2.7603	0.4315	22.1000	0.99776	1.1853	1.1826	0.0427
NTPAM6754Q1-MFD-OFRA-MFD-C-M1-P49599-ZX-DEN-12-RTD-NF-3	2.7280	0.4482	22.1000	0.99776	1.1966	1.1939	0.0431
NTPAM6754Q1-MFD-OFRA-MFD-C-M1-P49599-ZX-DEN-12-RTD-NF-4	2.7092	0.4379	22.1000	0.99776	1.1928	1.1901	0.0430
NTPAM6754Q1-MFD-OFRA-MFD-C-M1-P49599-ZX-DEN-12-RTD-NF-5	2.6670	0.4200	22.1000	0.99776	1.1869	1.1843	0.0428
NTPAM6754Q1-MFD-OFRA-MFD-C-M2-P46611-ZX-DEN-11-RTD-NF-1	2.7013	0.4200	22.1000	0.99776	1.1841	1.1814	0.0427
NTPAM6754Q1-MFD-OFRA-MFD-C-M2-P46611-ZX-DEN-11-RTD-NF-2	2.7145	0.4280	22.1000	0.99776	1.1872	1.1845	0.0428
NTPAM6754Q1-MFD-OFRA-MFD-C-M2-P46611-ZX-DEN-11-RTD-NF-3	2.7199	0.4313	22.1000	0.99776	1.1885	1.1858	0.0428
NTPAM6754Q1-MFD-OFRA-MFD-C-M2-P46611-ZX-DEN-11-RTD-NF-4	2.7212	0.4261	22.1000	0.99776	1.1857	1.1830	0.0427
NTPAM6754Q1-MFD-OFRA-MFD-C-M2-P46611-ZX-DEN-11-RTD-NF-5	2.6780	0.4136	22.1000	0.99776	1.1827	1.1800	0.0426
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-B-M1-P41475-ZX-DEN-11-RTD-PF-1	2.6636	0.4016	22.1000	0.99776	1.1775	1.1749	0.0424
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-B-M1-P38524-ZX-DEN-13-RTD-PF-2	2.6487	0.4111	22.1000	0.99776	1.1837	1.1811	0.0427
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-B-M1-P38524-ZX-DEN-13-RTD-PF-3	2.6625	0.4229	22.1000	0.99776	1.1888	1.1862	0.0429
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-B-M1-P38524-ZX-DEN-13-RTD-PF-4	2.6422	0.4654	22.1000	0.99776	1.2138	1.2111	0.0438
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-B-M1-P38524-ZX-DEN-13-RTD-PF-5	2.6975	0.4616	22.1000	0.99776	1.2064	1.2037	0.0435
NTPAM6754Q1-MFD-OFRA-MFD-B-M1-P41475-ZX-DEN-11-RTD-FF-1	2.6949	0.3669	22.1000	0.99776	1.1576	1.1550	0.0417
NTPAM6754Q1-MFD-OFRA-MFD-B-M1-P41475-ZX-DEN-11-RTD-FF-2	2.6881	0.3832	22.1000	0.99776	1.1663	1.1636	0.0420
NTPAM6754Q1-MFD-OFRA-MFD-B-M1-P41475-ZX-DEN-11-RTD-FF-3	2.6348	0.4579	22.1000	0.99776	1.2103	1.2076	0.0436
NTPAM6754Q1-MFD-OFRA-MFD-B-M1-P41475-ZX-DEN-11-RTD-FF-4	2.6433	0.4653	22.1000	0.99776	1.2136	1.2109	0.0437
NTPAM6754Q1-MFD-OFRA-MFD-B-M1-P41475-ZX-DEN-11-RTD-FF-5	2.6381	0.4217	22.1000	0.99776	1.1903	1.1876	0.0429
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-B-M2-P40435-ZX-DEN-12-RTD-PF-1	2.6761	0.4172	22.0000	0.99778	1.1847	1.1821	0.0427
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-B-M2-P40435-ZX-DEN-12-RTD-PF-2	2.6708	0.4025	22.0000	0.99778	1.1774	1.1748	0.0424
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-B-M2-P40435-ZX-DEN-12-RTD-PF-3	2.6639	0.3930	22.0000	0.99778	1.1731	1.1705	0.0423
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-B-M2-P40435-ZX-DEN-12-RTD-PF-4	2.6572	0.3844	22.0000	0.99778	1.1691	1.1665	0.0421
NTPAM6754Q1-MFD-OFRA-MFD-B-M2-P33520-ZX-DEN-11-RTD-PF-5	2.7372	0.4922	22.0000	0.99778	1.2192	1.2165	0.0440
NTPAM6754Q1-MFD-OFRA-MFD-B-M2-P40435-ZX-DEN-12-RTD-FF-1	2.6614	0.3560	22.0000	0.99778	1.1544	1.1519	0.0416
NTPAM6754Q1-MFD-OFRA-MFD-B-M2-P40435-ZX-DEN-12-RTD-FF-2	2.6463	0.3820	22.0000	0.99778	1.1687	1.1661	0.0421
NTPAM6754Q1-MFD-OFRA-MFD-B-M2-P40435-ZX-DEN-12-RTD-FF-3	2.6436	0.3830	22.0000	0.99778	1.1694	1.1668	0.0422
NTPAM6754Q1-MFD-OFRA-MFD-B-M2-P40435-ZX-DEN-12-RTD-FF-4	2.6876	0.4698	22.0000	0.99778	1.2118	1.2091	0.0437
NTPAM6754Q1-MFD-OFRA-MFD-B-M2-P40435-ZX-DEN-12-RTD-FF-5	2.6785	0.4623	22.0000	0.99778	1.2086	1.2059	0.0436
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-C-M1-P47735-ZX-DEN-13-RTD-PF-1	2.7060	0.4241	22.0000	0.99778	1.1859	1.1832	0.0427
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-C-M1-P47735-ZX-DEN-13-RTD-PF-2	2.7140	0.4452	22.0000	0.99778	1.1962	1.1936	0.0431
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-C-M1-P47735-ZX-DEN-13-RTD-PF-3	2.7029	0.4398	22.0000	0.99778	1.1943	1.1917	0.0431
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-C-M1-P47735-ZX-DEN-13-RTD-PF-4	2.7081	0.4346	22.0000	0.99778	1.1912	1.1885	0.0429
NTPAM6754Q1-MFD-OFRA-MFD-C-M1-P49599-ZX-DEN-12-RTD-PF-5	2.7680	0.5071	22.0000	0.99778	1.2243	1.2216	0.0441
NTPAM6754Q1-MFD-OFRA-MFD-C-M1-P47735-ZX-DEN-13-RTD-FF-1	2.7632	0.4765	21.2000	0.99796	1.2084	1.2059	0.0436
NTPAM6754Q1-MFD-OFRA-MFD-C-M1-P47735-ZX-DEN-13-RTD-FF-2	2.7542	0.4533	21.2000	0.99796	1.1970	1.1946	0.0432
NTPAM6754Q1-MFD-OFRA-MFD-C-M1-P47735-ZX-DEN-13-RTD-FF-3	2.7606	0.4579	21.2000	0.99796	1.1989	1.1964	0.0432
NTPAM6754Q1-MFD-OFRA-MFD-C-M1-P47735-ZX-DEN-13-RTD-FF-4	2.7151	0.4750	21.2000	0.99796	1.2120	1.2096	0.0437
NTPAM6754Q1-MFD-OFRA-MFD-C-M1-P47735-ZX-DEN-13-RTD-FF-5	2.7083	0.4754	21.2000	0.99796	1.2129	1.2104	0.0437
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-C-M2-P47269-ZX-DEN-11-RTD-PF-1	2.7777	0.4844	21.2000	0.99796	1.2112	1.2087	0.0437
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-C-M2-P47269-ZX-DEN-11-RTD-PF-2	2.7571	0.4659	21.3000	0.99793	1.2033	1.2009	0.0434
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-C-M2-P47269-ZX-DEN-11-RTD-PF-3	2.7513	0.4788	21.3000	0.99793	1.2107	1.2082	0.0436
NTPAM6754Q1-MFD-OFRA-CFRA-MFD-C-M2-P47269-ZX-DEN-11-RTD-PF-4	2.7459	0.4889	21.3000	0.99793	1.2166	1.2141	0.0439
NTPAM6754Q1-MFD-OFRA-MFD-C-M2-P46611-ZX-DEN-11-RTD-PF-5	2.7612	0.4947	21.3000	0.99793	1.2183	1.2157	0.0439
NTPAM6754Q1-MFD-OFRA-MFD-C-M2-P47269-ZX-DEN-11-RTD-FF-1	2.7646	0.4626	21.3000	0.99793	1.2010	1.1985	0.0433
NTPAM6754Q1-MFD-OFRA-MFD-C-M2-P47269-ZX-DEN-11-RTD-FF-2	2.7720	0.4868	21.3000	0.99793	1.2130	1.2105	0.0437
NTPAM6754Q1-MFD-OFRA-MFD-C-M2-P47269-ZX-DEN-11-RTD-FF-3	2.7829	0.4856	21.3000	0.99793	1.2114	1.2089	0.0437
NTPAM6754Q1-MFD-OFRA-MFD-C-M2-P47269-ZX-DEN-11-RTD-FF-4	2.7843	0.5066	21.3000	0.99793	1.2224	1.2199	0.0441
NTPAM6754Q1-MFD-OFRA-MFD-C-M2-P47269-ZX-DEN-11-RTD-FF-5	2.7789	0.5014	21.3000	0.99793	1.2202	1.2176	0.0440
NTPAM6754Q1-MFD-OFRA-MFD-A-M1-P44799-ZX-DEN-13-RTD-FF-1	2.7222	0.4254	21.3000	0.99793	1.1852	1.1828	0.0427
NTPAM6754Q1-MFD-OFRA-MFD-A-M1-P44799-ZX-DEN-13-RTD-FF-2	2.7407	0.4841	21.3000	0.99793	1.2145	1.2120	0.0438
NTPAM6754Q1-MFD-OFRA-MFD-A-M1-P44799-ZX-DEN-13-RTD-FF-3	2.7656	0.5233	21.3000	0.99793	1.2334	1.2308	0.0445
NTPAM6754Q1-MFD-OFRA-MFD-A-M1-P44799-ZX-DEN-13-RTD-FF-4	2.7524	0.5023	21.3000	0.99793	1.2232	1.2207	0.0441
NTPAM6754Q1-MFD-OFRA-MFD-A-M1-P44799-ZX-DEN-13-RTD-FF-5	2.7363	0.4651	21.5000	0.99789	1.2048	1.2022	0.0434
NTPAM6754Q1-MFD-OFRA-MFD-A-M1-P44799-ZX-DEN-13-RTD-PF-1	2.7317	0.4691	21.5000	0.99789	1.2073	1.2048	0.0435
NTPAM6754Q1-MFD-OFRA-MFD-A-M1-P44799-ZX-DEN-13-RTD-PF-2	2.7139	0.4471	21.5000	0.99789	1.1972	1.1947	0.0432
NTPAM6754Q1-MFD-OFRA-MFD-A-M1-P44799-ZX-DEN-13-RTD-PF-3	2.7072	0.4316	21.5000	0.99789	1.1897	1.1872	0.0429
NTPAM6754Q1-MFD-OFRA-MFD-A-M1-P44799-ZX-DEN-13-RTD-PF-4	2.6740	0.4154	21.5000	0.99789	1.1839	1.1814	0.0427
NTPAM6754Q1-MFD-OFRA-MFD-A-M1-P44799-ZX-DEN-13-RTD-PF-5	2.7026	0.4357	21.5000	0.99789	1.1922	1.1897	0.0430

NTPAM6754Q1-MFD-OFRA-MFD-A-M2-P43729-ZX-DEN-13-RTD-FF-1	2.7496	0.4115	21.5000	0.99789	1.1760	1.1735	0.0424
NTPAM6754Q1-MFD-OFRA-MFD-A-M2-P43729-ZX-DEN-13-RTD-FF-2	2.7129	0.4147	21.5000	0.99789	1.1804	1.1780	0.0426
NTPAM6754Q1-MFD-OFRA-MFD-A-M2-P43729-ZX-DEN-13-RTD-FF-3	2.6994	0.4129	21.5000	0.99789	1.1806	1.1781	0.0426
NTPAM6754Q1-MFD-OFRA-MFD-A-M2-P43729-ZX-DEN-13-RTD-FF-4	2.7861	0.4752	21.5000	0.99789	1.2056	1.2031	0.0435
NTPAM6754Q1-MFD-OFRA-MFD-A-M2-P43729-ZX-DEN-13-RTD-FF-5	2.7375	0.4585	21.6000	0.99787	1.2012	1.1986	0.0433
NTPAM6754Q1-MFD-OFRA-MFD-A-M2-P43729-ZX-DEN-13-RTD-PF-1	2.7760	0.4605	21.6000	0.99787	1.1989	1.1963	0.0432
NTPAM6754Q1-MFD-OFRA-MFD-A-M2-P43729-ZX-DEN-13-RTD-PF-2	2.7199	0.4287	21.6000	0.99787	1.1871	1.1846	0.0428
NTPAM6754Q1-MFD-OFRA-MFD-A-M2-P43729-ZX-DEN-13-RTD-PF-3	2.7002	0.4206	21.6000	0.99787	1.1845	1.1820	0.0427
NTPAM6754Q1-MFD-OFRA-MFD-A-M2-P43729-ZX-DEN-13-RTD-PF-4	2.6809	0.4128	21.6000	0.99787	1.1820	1.1795	0.0426
NTPAM6754Q1-MFD-OFRA-MFD-A-M2-P43729-ZX-DEN-13-RTD-PF-5	2.7830	0.4971	21.6000	0.99787	1.2175	1.2149	0.0439
				AVERAGE (composite)	**1.1935**	**1.1909**	**0.0430**
				STANDARD DEVIATION	**0.0172**	**0.0172**	**0.0006**
				COEFF. OF VARIATION	**1.4447**	**1.4484**	**1.4484**
				Minimum	**1.1544**	**1.1519**	**0.0416**
				Maximum	**1.2334**	**1.2308**	**0.0445**
				Number of Specimens	**90**	**90**	**90**

10. X-Ray CT scan Results

10.1 Tension X-ray CT Summary

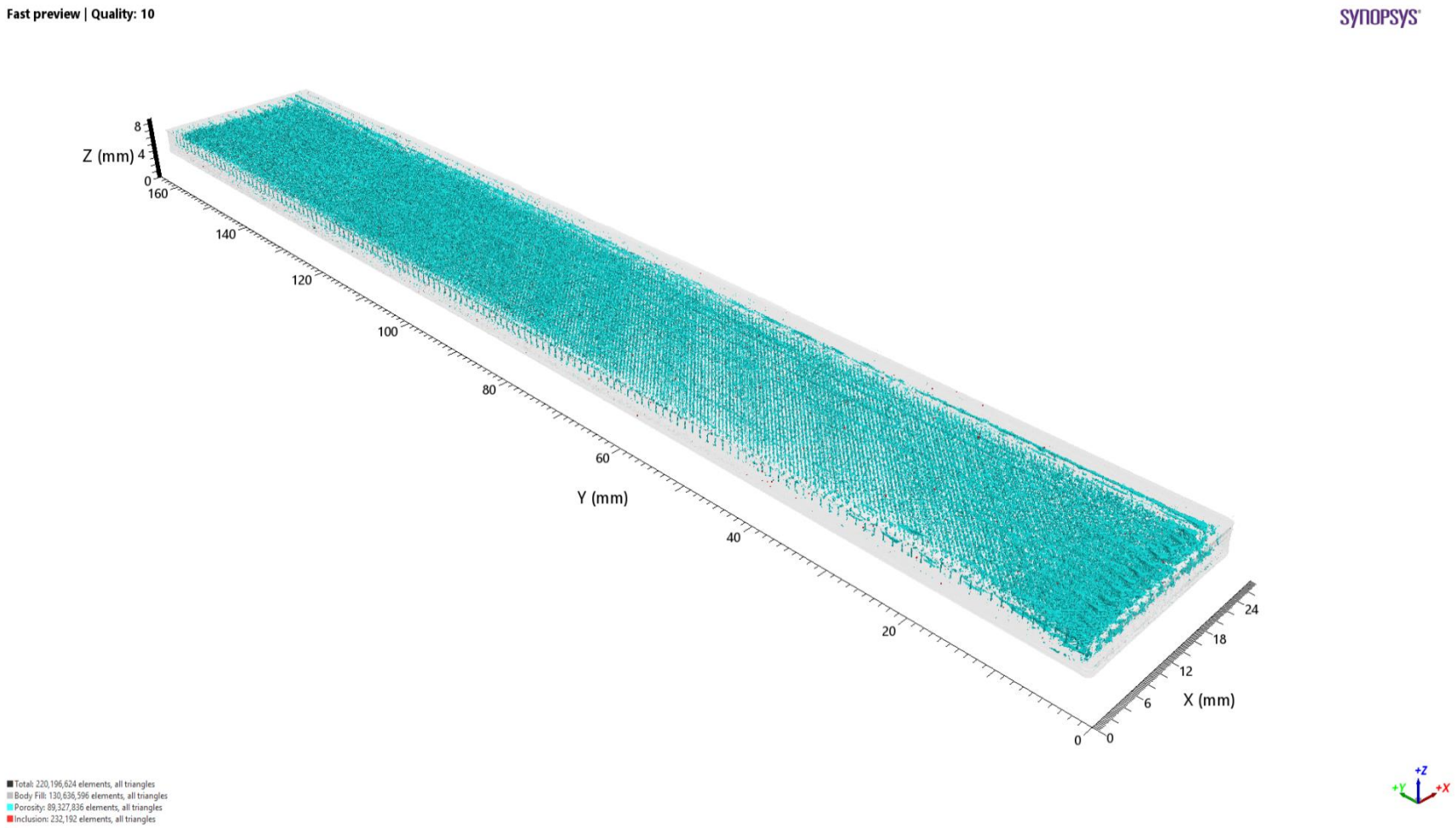
Material:	Markforged Onyx FR-A™ - Carbon Fiber FR-A™
Material Specification:	NMS 754-1
Process Specification:	NPS 86754
Printer:	Markforged X7

Markforged Onyx FR-A™ - Carbon Fiber FR-A™/ Markforged X7
X-ray CT Summary

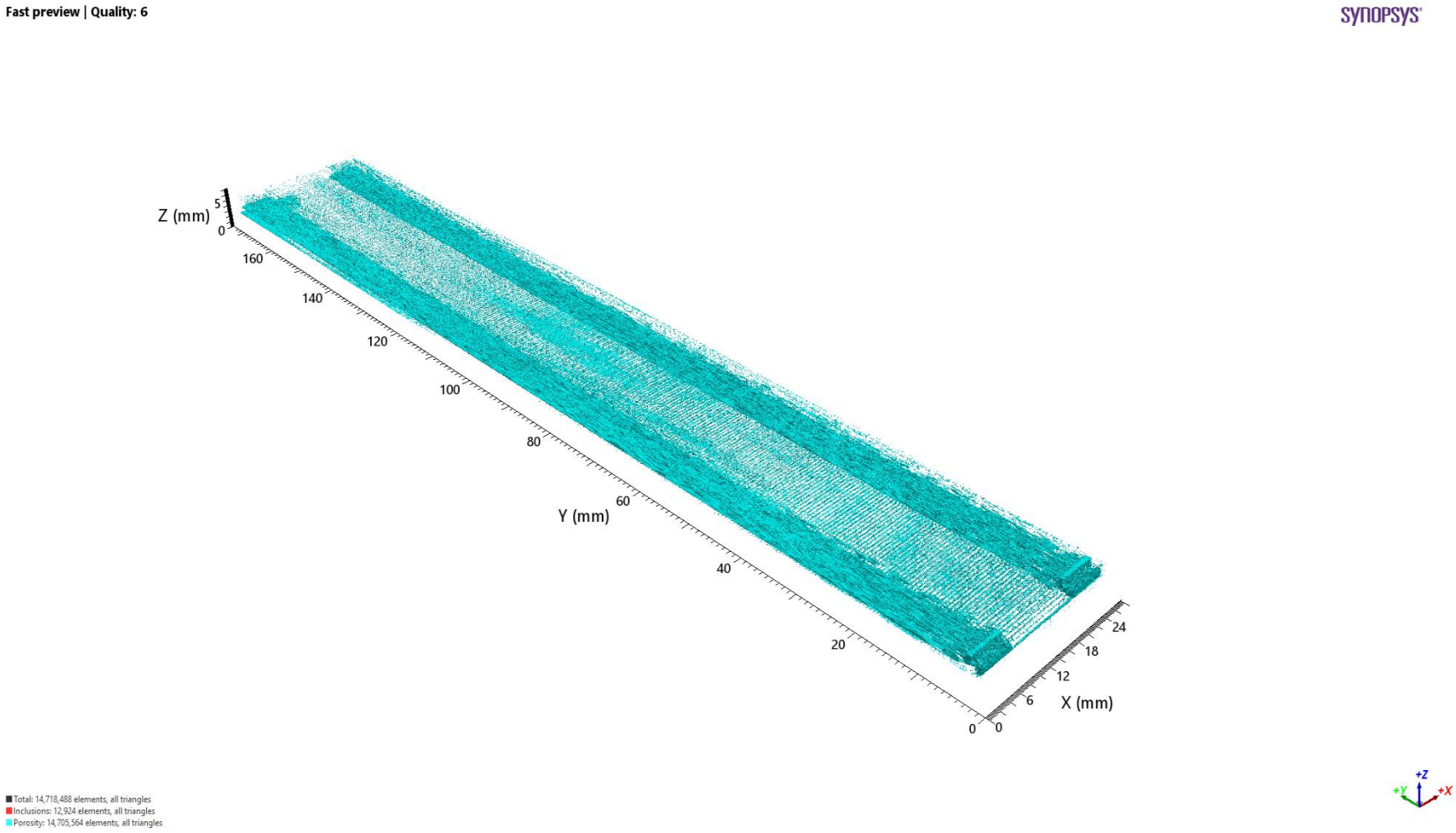
Specimen Orientation	Scan Resolution (µm)
XY	25
XZ	26
ZX	25

Test Type	Fiber Fill	Specimen Orientation		Percentage Porosity (%)	Percentage Inclusions (%)	Minimum Porosity Length (mm)	Maximum Porosity Length (mm)	Minimum Inclusion Length (mm)	Maximum Inclusion Length (mm)
D3039	PF	XY	Mean	4.597	0.013	0.048	153.987	0.048	0.789
			Minimum	2.812	0.002	0.046	94.102	0.046	0.043
			Maximum	7.138	0.064	0.050	173.657	0.050	4.844
			Standard Deviation	1.439	0.018	0.002	25.775	0.002	1.352
			C.V.(%)	31.308	139.359	3.871	16.738	3.871	171.389
			No. Specimens	11					
			No. Material Batches	3					
		XZ	Mean	4.680	0.005	0.054	167.361	0.054	0.446
			Minimum	3.090	0.000	0.046	140.260	0.046	0.230
			Maximum	5.575	0.010	0.060	173.860	0.060	0.808
			Standard Deviation	0.863	0.004	0.007	11.996	0.007	0.237
			C.V.(%)	18.446	92.327	13.036	7.168	13.036	53.283
			No. Specimens	7					
			No. Material Batches	3					
		ZX	Mean	1.419	0.255	0.050	29.019	0.050	0.390
			Minimum	0.946	0.005	0.050	15.466	0.050	0.351
			Maximum	1.786	0.991	0.050	43.597	0.050	0.464
			Standard Deviation	0.362	0.491	0.000	12.427	0.000	0.052
			C.V.(%)	25.540	192.499	0.000	42.825	0.000	13.298
			No. Specimens	4					
			No. Material Batches	3					

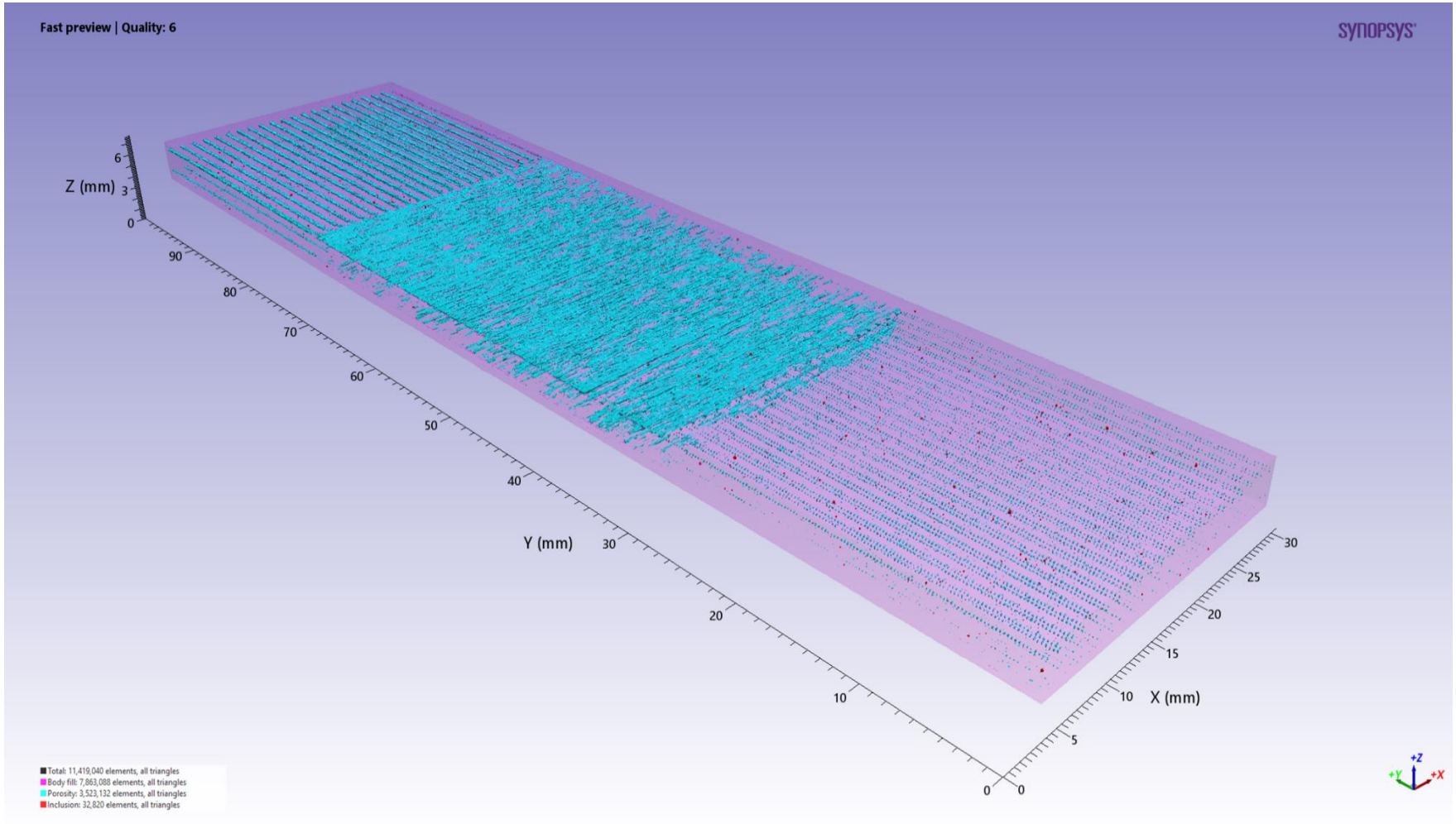
10.1.1 **XY Tension X-Ray CT scan**



10.1.2 **XZ Tension X-Ray CT scan**



10.1.3 **ZX Tension X-Ray CT scan**



10.2 **Compression X-ray CT Summary**

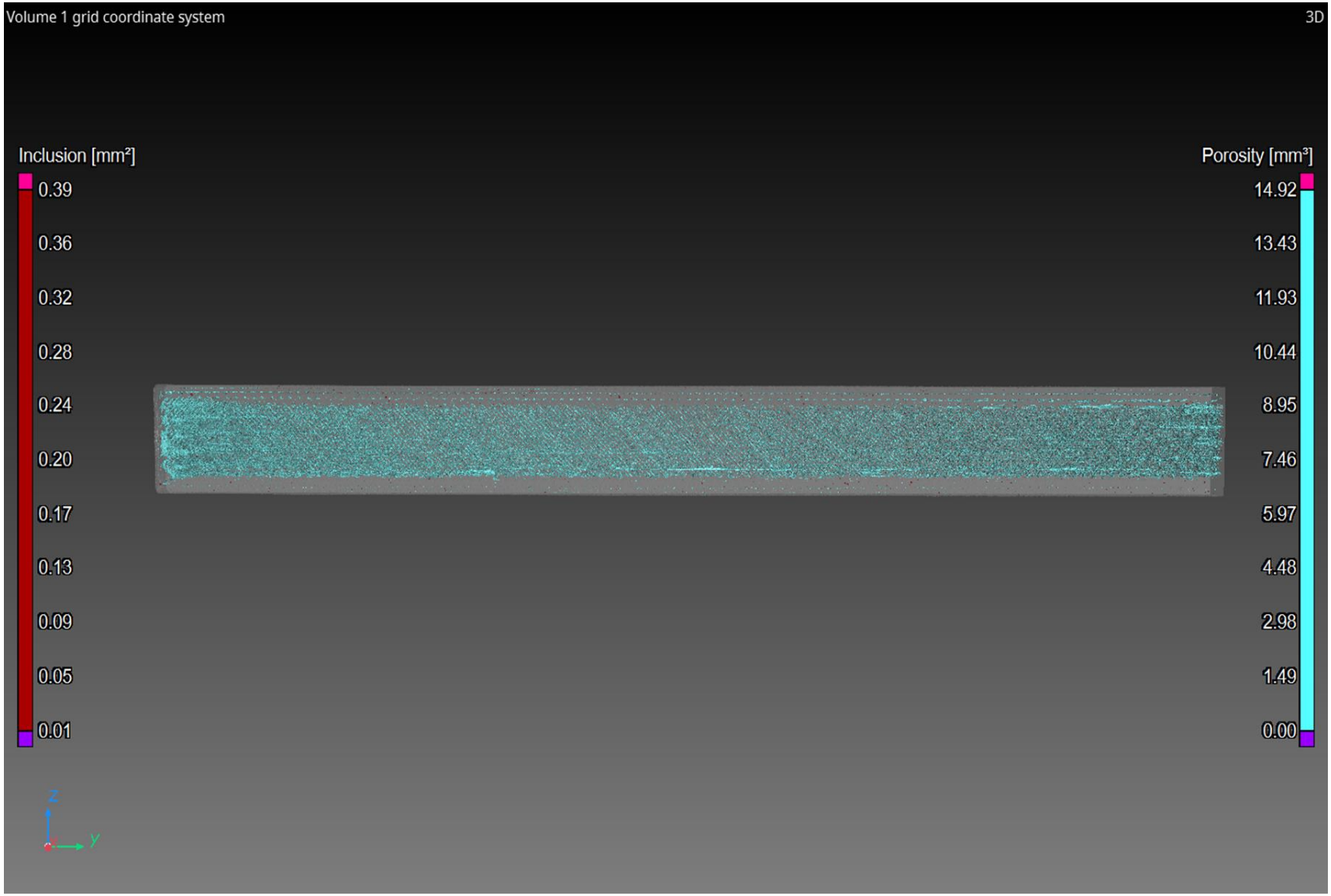
Material: Markforged Onyx FR-A™ - Carbon Fiber FR-A™
Material Specification: NMS 754-1
Process Specification: NPS 86754
Printer: Markforged X7

Markforged Onyx FR-A™ - Carbon Fiber FR-A™/ Markforged X7 X-ray CT Summary

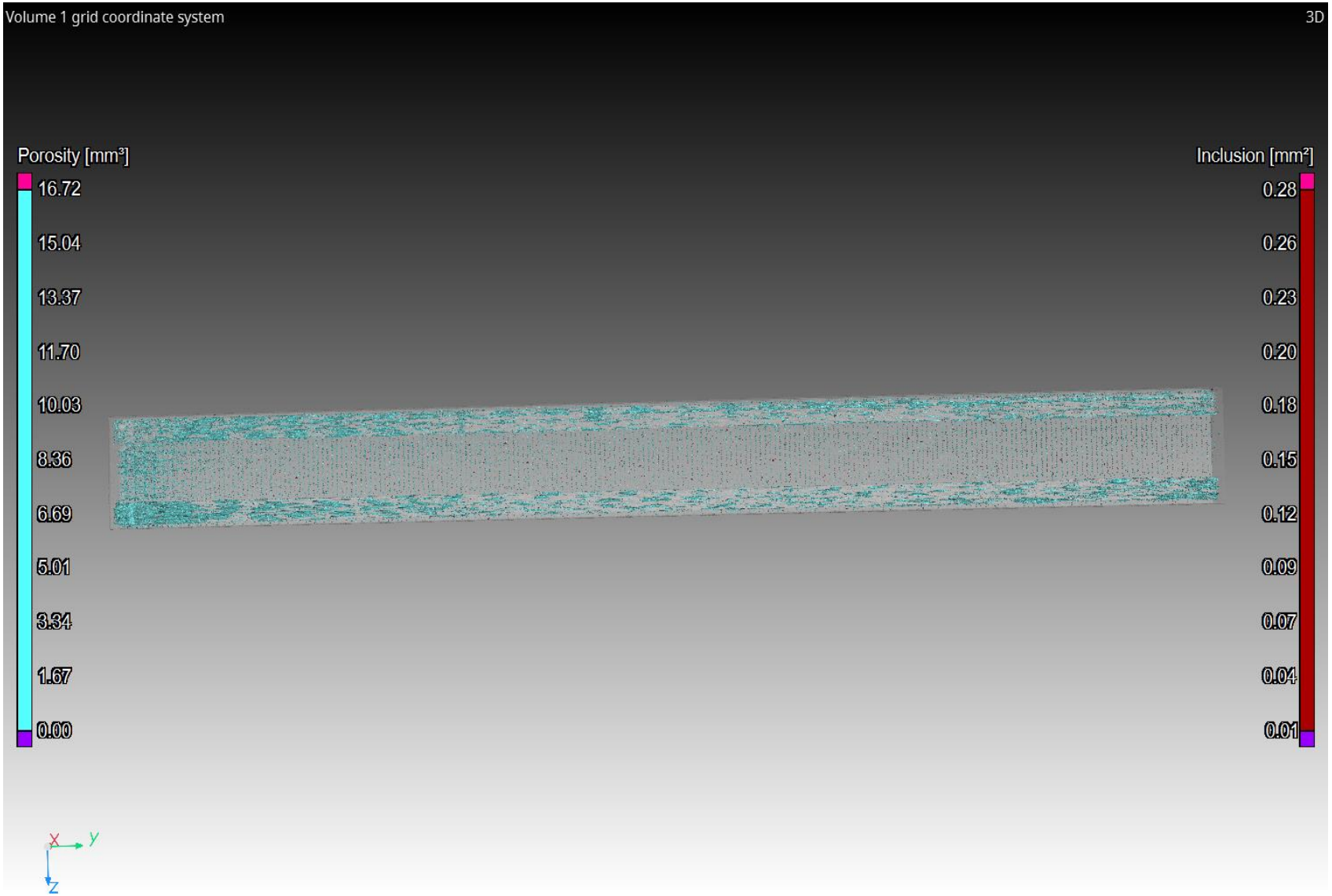
Specimen Orientation	Scan Resolution (µm)
XY	29
XZ	29
ZX	13

Test Type	Fiber Fill	Specimen Orientation		Percentage Porosity (%)	Percentage Inclusions (%)	Minimum Porosity Length (mm)	Maximum Porosity Length (mm)	Minimum Inclusion Length (mm)	Maximum Inclusion Length (mm)
D6641	PF	XY	Mean	3.947	0.009	0.054	70.439	0.054	0.356
			Minimum	1.360	0.002	0.041	17.690	0.041	0.282
			Maximum	8.500	0.020	0.070	136.499	0.070	0.446
			Standard Deviation	2.607	0.006	0.015	61.499	0.015	0.063
			C.V.(%)	66.051	61.803	27.568	87.309	27.568	17.624
			No. Specimens	7					
			No. Material Batches	3					
		XZ	Mean	2.865	0.014	0.058	116.440	0.058	0.351
			Minimum	1.290	0.000	0.041	25.930	0.041	0.276
			Maximum	3.759	0.049	0.070	136.216	0.070	0.470
			Standard Deviation	0.913	0.017	0.014	38.481	0.014	0.067
			C.V.(%)	31.874	118.740	23.122	33.048	23.122	19.189
			No. Specimens	8					
			No. Material Batches	3					
		ZX	Mean	4.177	0.005	0.027	17.892	0.027	0.266
			Minimum	3.233	0.004	0.027	13.141	0.027	0.235
			Maximum	4.787	0.006	0.027	24.211	0.027	0.308
			Standard Deviation	0.829	0.001	0.000	5.699	0.000	0.038
			C.V.(%)	19.852	26.455	0.000	31.853	0.000	14.368
			No. Specimens	3					
			No. Material Batches	3					

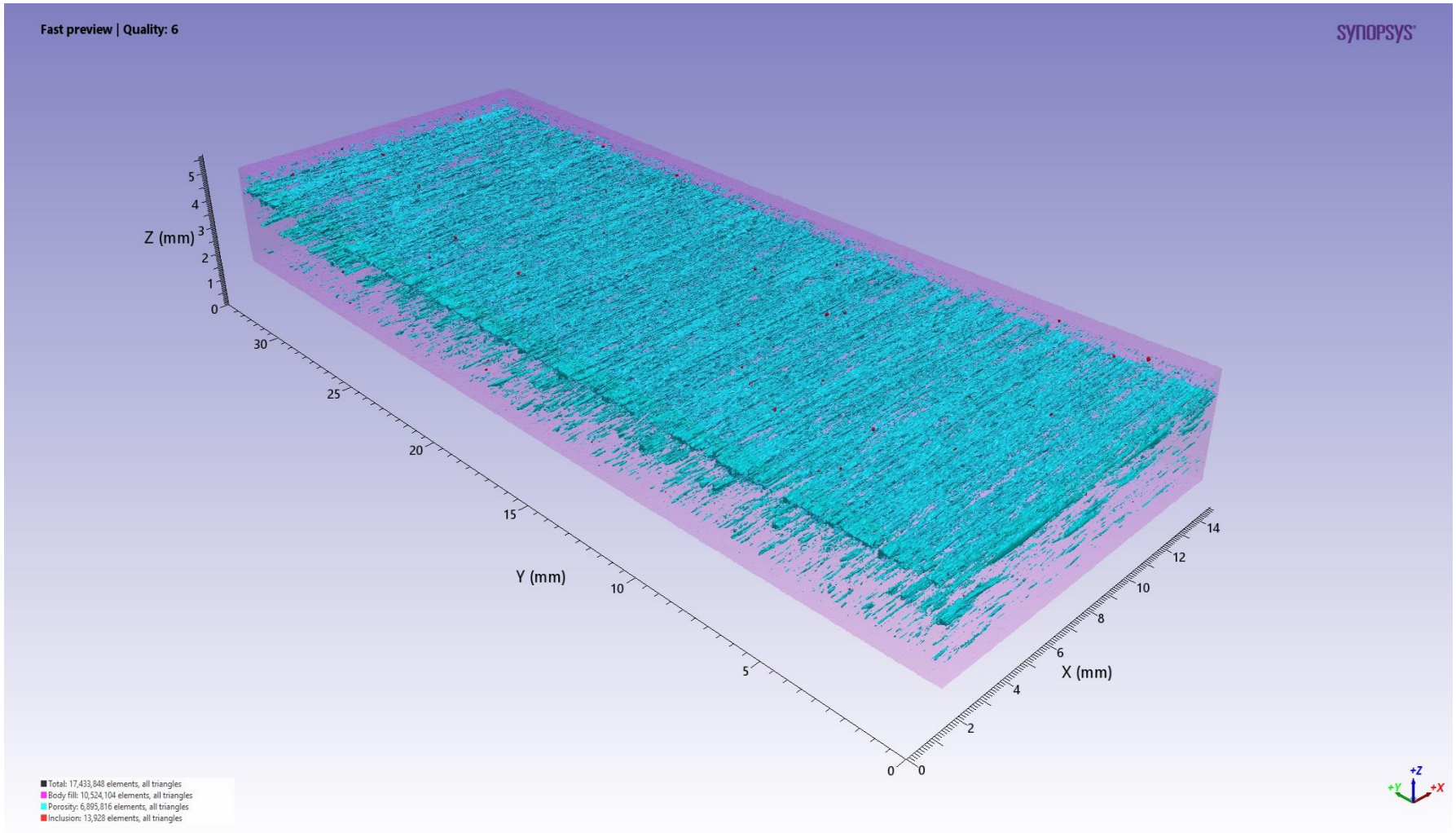
10.2.1 **XY Compression X-Ray CT scan**



10.2.2 **XZ Compression X-Ray CT scan**



10.2.3 **ZX Compression X-Ray CT scan**



10.3 **Flex X-ray CT Summary**

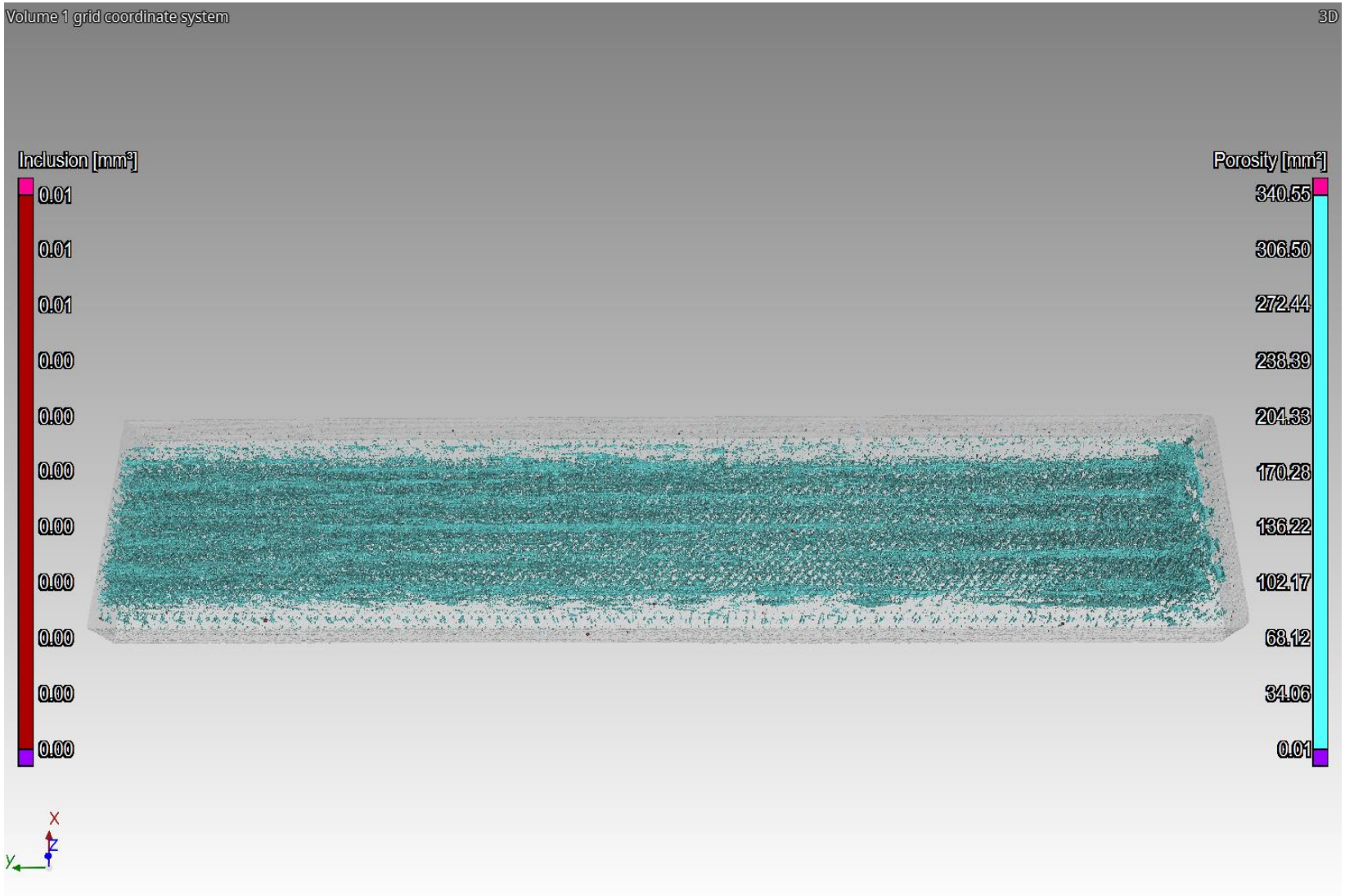
Material:	Markforged Onyx FR-A™ - Carbon Fiber FR-A™
Material Specification:	NMS 754-1
Process Specification:	NPS 86754
Printer:	Markforged X7

Markforged Onyx FR-A™ - Carbon Fiber FR-A™/ Markforged X7 X-ray CT Summary

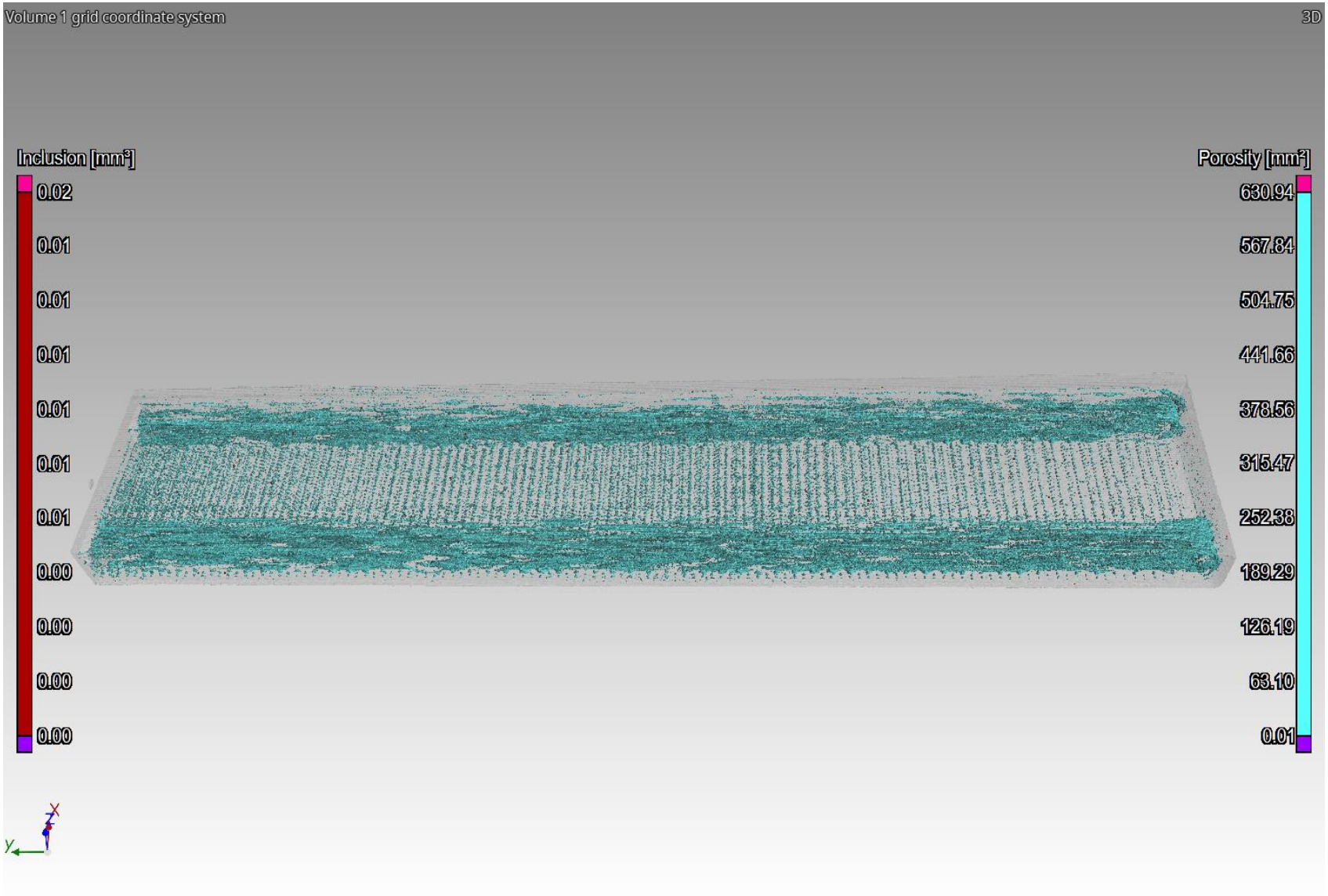
Specimen Orientation	Scan Resolution (µm)
XY	21
XZ	21
ZX	13

Test Type	Fiber Fill	Specimen Orientation		Percentage Porosity (%)	Percentage Inclusions (%)	Minimum Porosity Length (mm)	Maximum Porosity Length (mm)	Minimum Inclusion Length (mm)	Maximum Inclusion Length (mm)
D790	PF	XY	Mean	3.896	0.014	0.045	59.055	0.045	0.332
			Minimum	2.500	0.000	0.041	28.470	0.041	0.266
			Maximum	6.343	0.056	0.050	72.175	0.050	0.405
			Standard Deviation	1.290	0.020	0.005	17.274	0.005	0.057
			C.V.(%)	33.108	140.667	11.326	29.250	11.326	17.206
			No. Specimens	7					
			No. Material Batches	3					
		XZ	Mean	2.956	0.010	0.600	60.798	0.046	0.341
			Minimum	1.392	0.000	0.041	28.384	0.041	0.265
			Maximum	4.273	0.022	0.150	71.580	0.050	0.409
			Standard Deviation	1.064	0.008	0.040	16.817	0.005	0.058
			C.V.(%)	35.985	85.513	6.659	27.661	10.629	16.931
			No. Specimens	7					
			No. Material Batches	3					
		ZX	Mean	4.318	0.010	0.027	12.863	0.027	0.271
			Minimum	2.977	0.004	0.027	12.648	0.027	0.200
			Maximum	5.571	0.014	0.027	13.121	0.027	0.337
			Standard Deviation	1.077	0.004	0.000	0.227	0.000	0.056
			C.V.(%)	24.935	43.298	0.000	1.762	0.000	20.731
			No. Specimens	4					
			No. Material Batches	3					

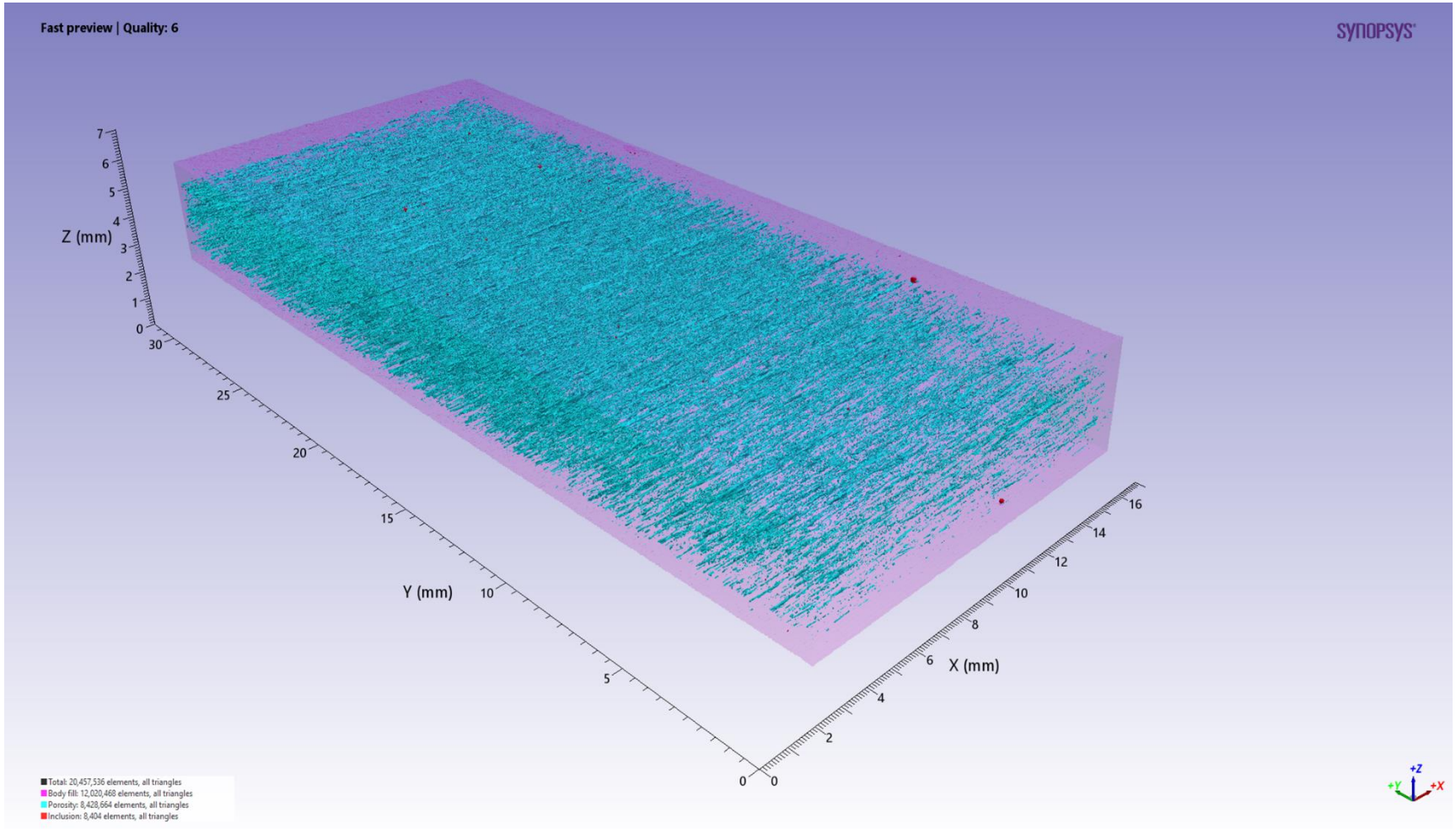
10.3.1 **XY Flex X-Ray CT scan**



10.3.2 **XZ Flex X-Ray CT scan**



10.3.3 **ZX Flex X-Ray CT scan**



10.4 **In-Plane Shear X-ray CT summary**

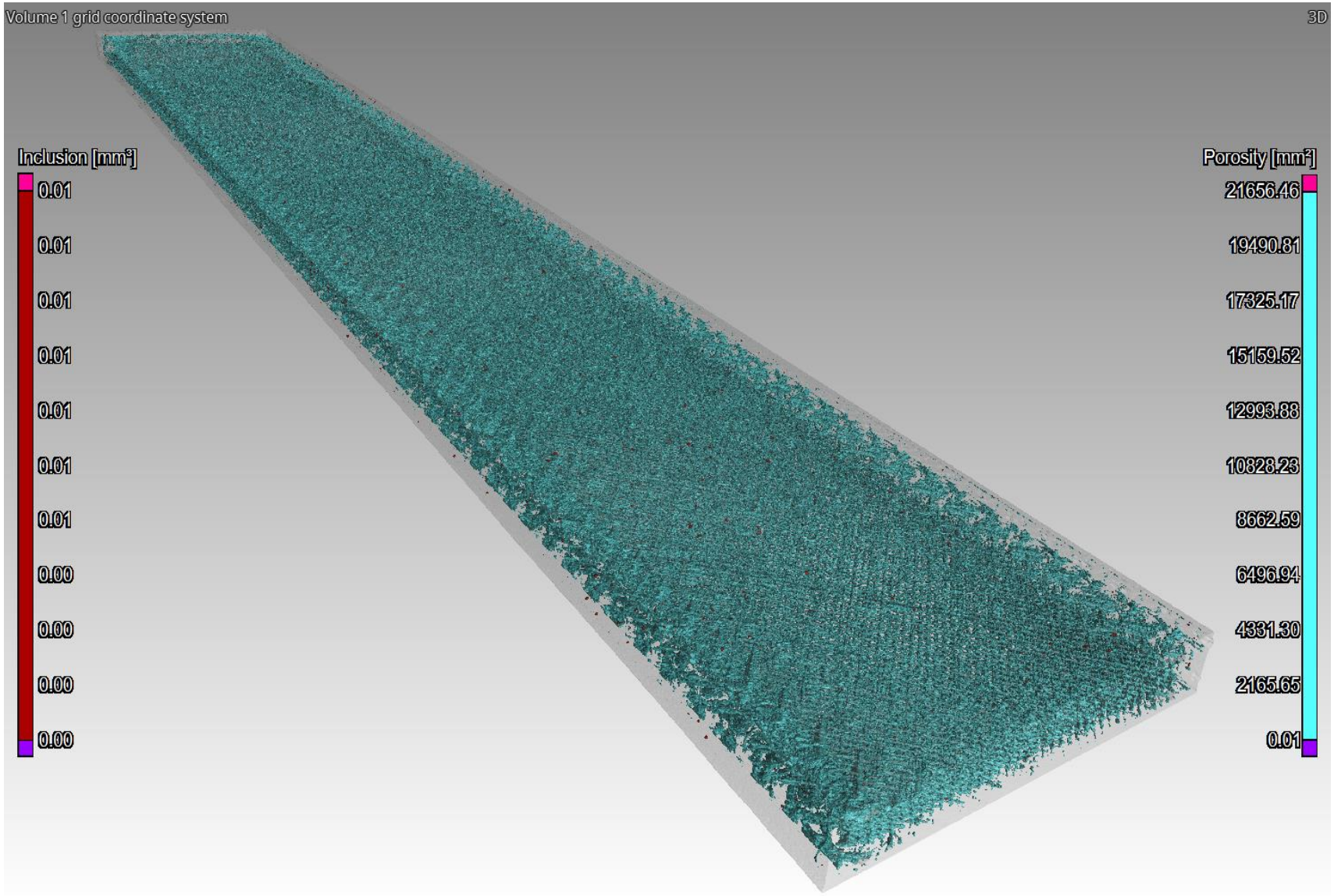
Material: Markforged Onyx FR-A™ - Carbon Fiber FR-A™
Material Specification: NMS 754-1
Process Specification: NPS 86754
Printer: Markforged X7

Markforged Onyx FR-A™ - Carbon Fiber FR-A™/ Markforged X7
X-ray CT Summary

Specimen Orientation	Scan Resolution (µm)
XY	26

Test Type	Fiber Fill	Specimen Orientation		Percentage Porosity (%)	Percentage Inclusions (%)	Minimum Porosity Length (mm)	Maximum Porosity Length (mm)	Minimum Inclusion Length (mm)	Maximum Inclusion Length (mm)
D3518	PF	XY	Mean	5.657	0.003	0.048	161.623	0.048	0.432
			Minimum	5.059	0.000	0.046	103.732	0.046	0.317
			Maximum	7.147	0.006	0.060	172.822	0.060	0.692
			Standard Deviation	0.789	0.002	0.005	25.547	0.005	0.141
			C.V.(%)	13.939	79.879	10.594	15.806	10.594	32.589
			No. Specimens	7					
			No. Material Batches	3					

10.4.1 **XY In-Plane Shear X-Ray CT scan**



10.5 Short Beam Shear X-ray CT summary

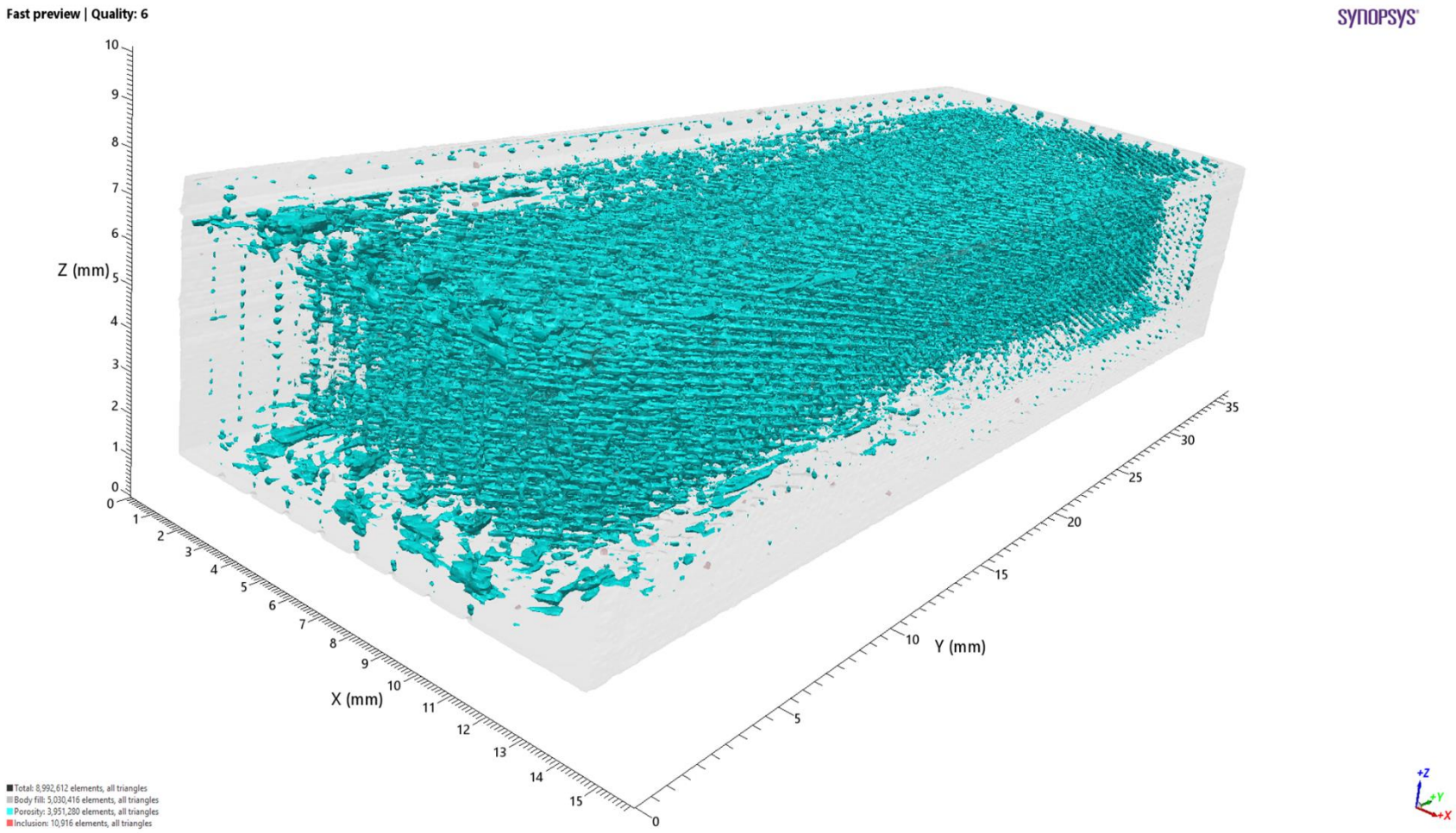
Material: Markforged Onyx FR-A™ - Carbon Fiber FR-A™
Material Specification: NMS 754-1
Process Specification: NPS 86754
Printer: Markforged X7

Markforged Onyx FR-A™ - Carbon Fiber FR-A™/ Markforged X7
X-ray CT Summary

Specimen Orientation	Scan Resolution (µm)
XY	27

Test Type	Fiber Fill	Specimen Orientation		Percentage Porosity (%)	Percentage Inclusions (%)	Minimum Porosity Length (mm)	Maximum Porosity Length (mm)	Minimum Inclusion Length (mm)	Maximum Inclusion Length (mm)
D2344	PF	XY	Mean	5.429	0.014	0.055	27.881	0.055	0.371
			Minimum	3.260	0.000	0.054	15.020	0.054	0.260
			Maximum	9.241	0.031	0.060	35.967	0.060	0.487
			Standard Deviation	2.501	0.012	0.003	10.852	0.003	0.093
			C.V.(%)	46.055	88.010	4.905	38.924	4.905	25.199
			No. Specimens	5					
			No. Material Batches	3					

10.5.1 **XY Short Beam Shear X-Ray CT scan**



10.6 **Open-Hole Tension X-ray CT summary**

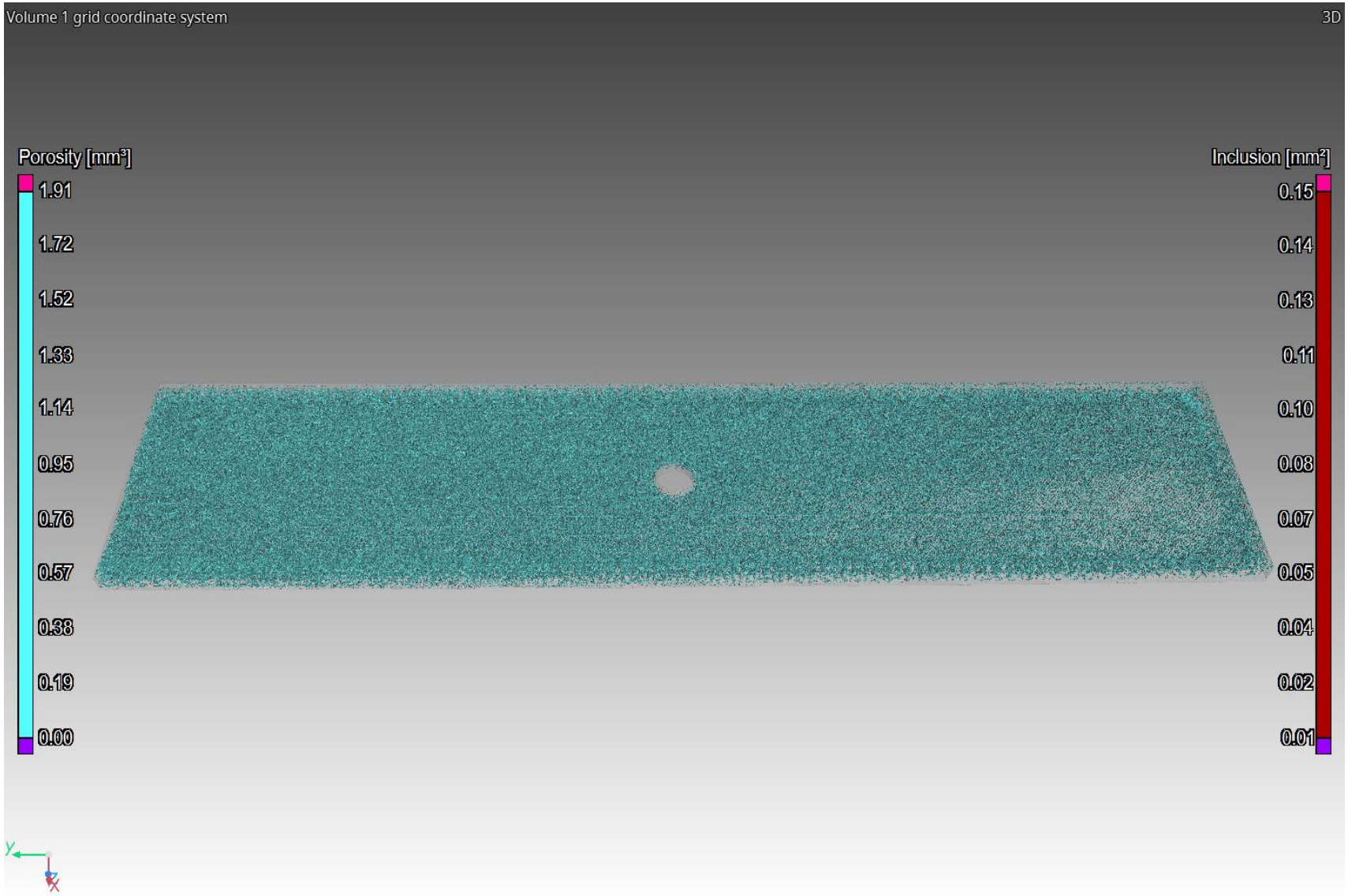
Material:	rkforged Onyx FR-A™ - Carbon Fiber FR-A
Material Specification:	NMS 754-1
Process Specification:	NPS 86754
Printer:	Markforged X7

Markforged Onyx FR-A™ - Carbon Fiber FR-A™/ Markforged X7
X-ray CT Summary

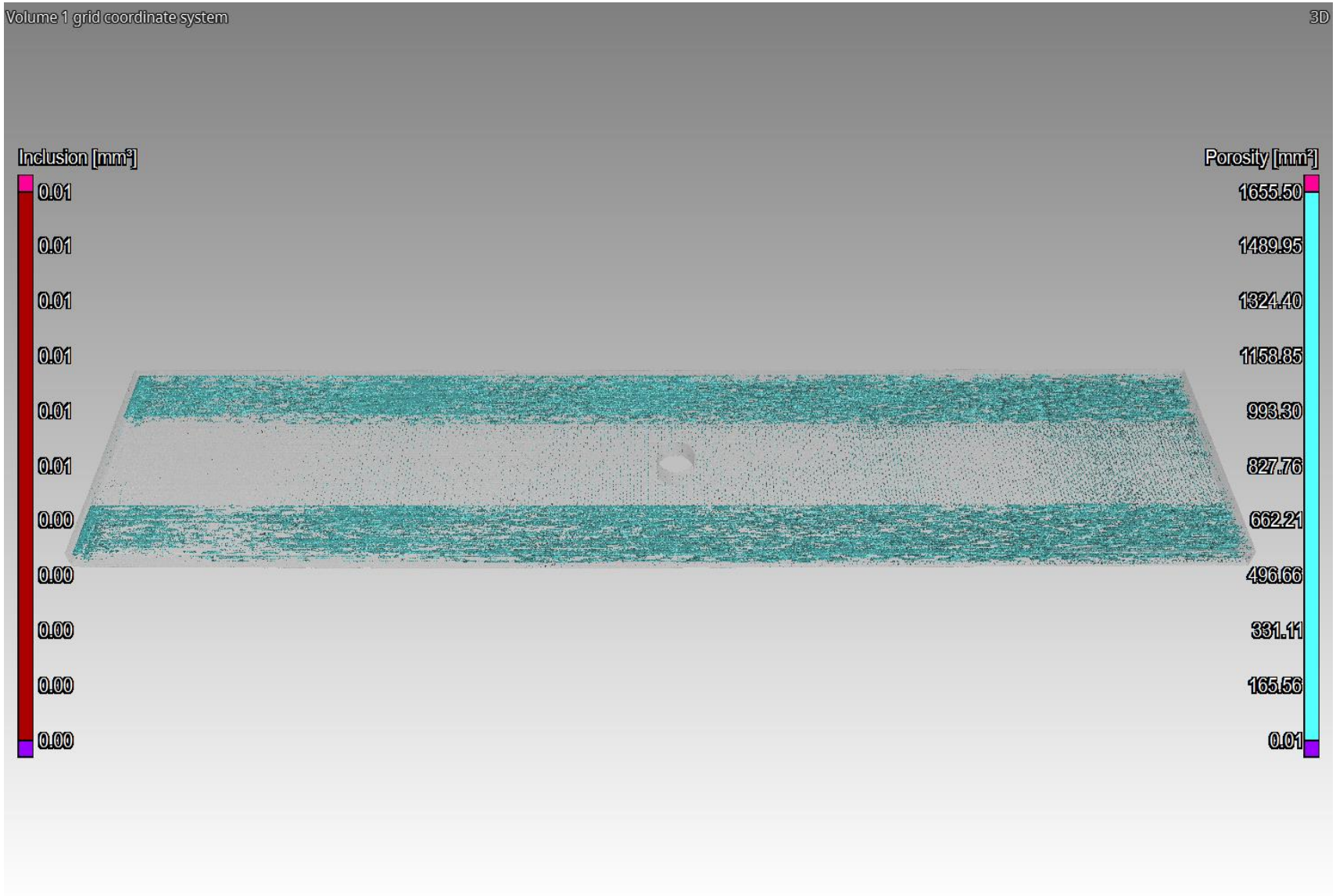
Specimen Orientation	Scan Resolution (µm)
XY	29
XZ	29
ZX	26

Test Type	Fiber Fill	Specimen Orientation		Percentage Porosity (%)	Percentage Inclusions (%)	Minimum Porosity Length (mm)	Maximum Porosity Length (mm)	Minimum Inclusion Length (mm)	Maximum Inclusion Length (mm)
D5766	PF	XY	Mean	4.682	0.003	0.061	99.734	0.061	0.447
			Minimum	1.940	0.000	0.048	19.840	0.048	0.210
			Maximum	7.569	0.010	0.070	191.625	0.070	0.640
			Standard Deviation	2.169	0.004	0.011	76.859	0.011	0.160
			C.V.(%)	46.323	128.832	17.457	77.064	17.457	35.803
			No. Specimens	6					
			No. Material Batches	3					
		XZ	Mean	3.211	0.009	0.061	153.851	0.061	0.395
			Minimum	1.610	0.000	0.048	49.000	0.048	0.300
			Maximum	6.325	0.038	0.070	189.470	0.070	0.502
			Standard Deviation	1.779	0.012	0.011	52.771	0.011	0.070
			C.V.(%)	55.390	132.218	17.962	34.300	17.962	17.702
			No. Specimens	9					
			No. Material Batches	3					
		ZX	Mean	2.026	0.019	0.053	38.914	0.053	0.439
			Minimum	1.987	0.015	0.053	38.459	0.053	0.432
			Maximum	2.064	0.023	0.053	39.368	0.053	0.446
			Standard Deviation	0.054	0.006	0.000	0.643	0.000	0.010
			C.V.(%)	2.688	29.182	0.013	1.652	0.013	2.335
			No. Specimens	2					
			No. Material Batches	1					

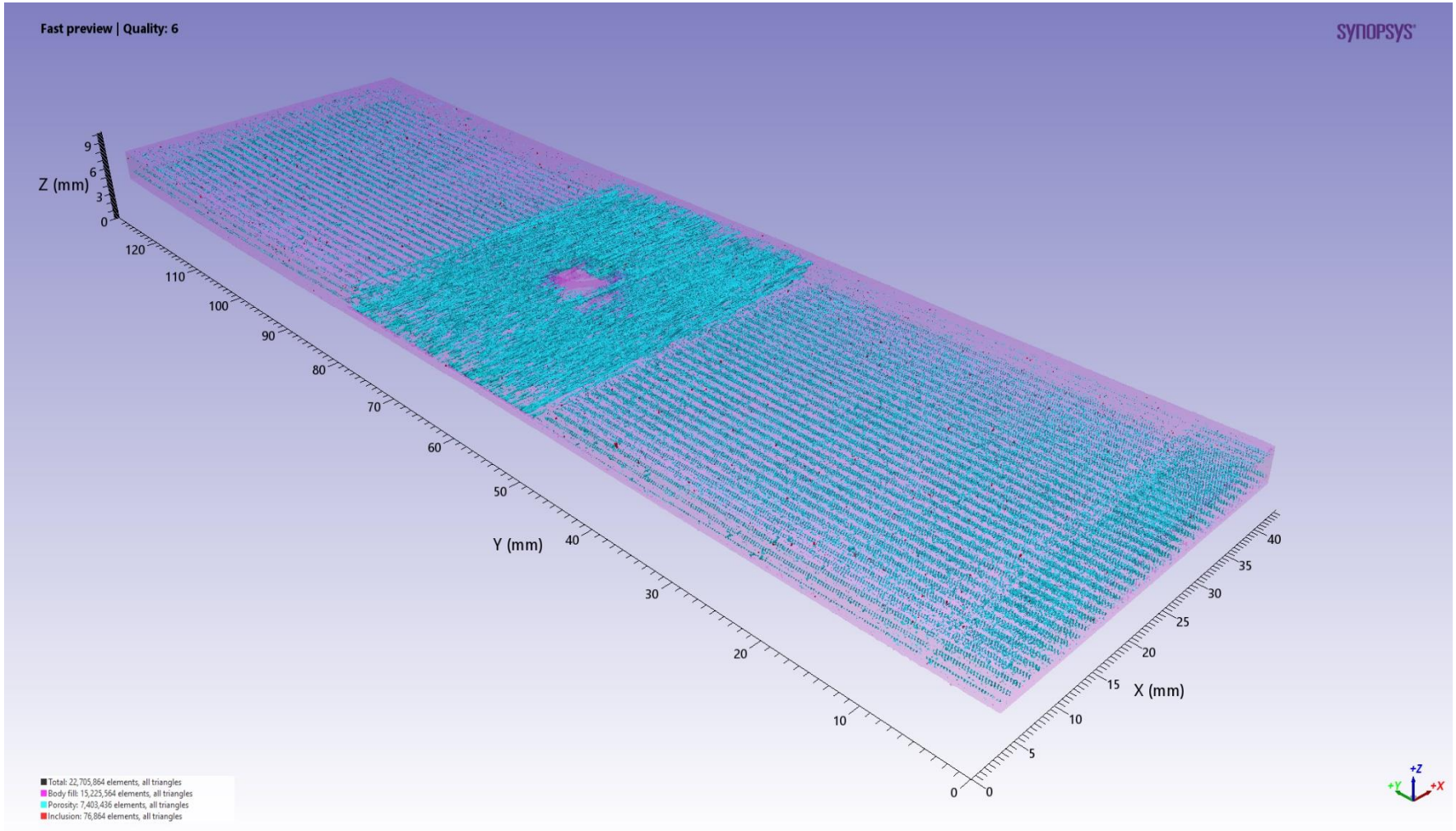
10.6.1 **XY Open-Hole Tension X-Ray CT scan**



10.6.2 **XZ Open-Hole Tension X-Ray CT scan**



10.6.3 **ZX Open-Hole Tension X-Ray CT scan**



10.7 **Filled-Hole Tension X-ray CT summary**

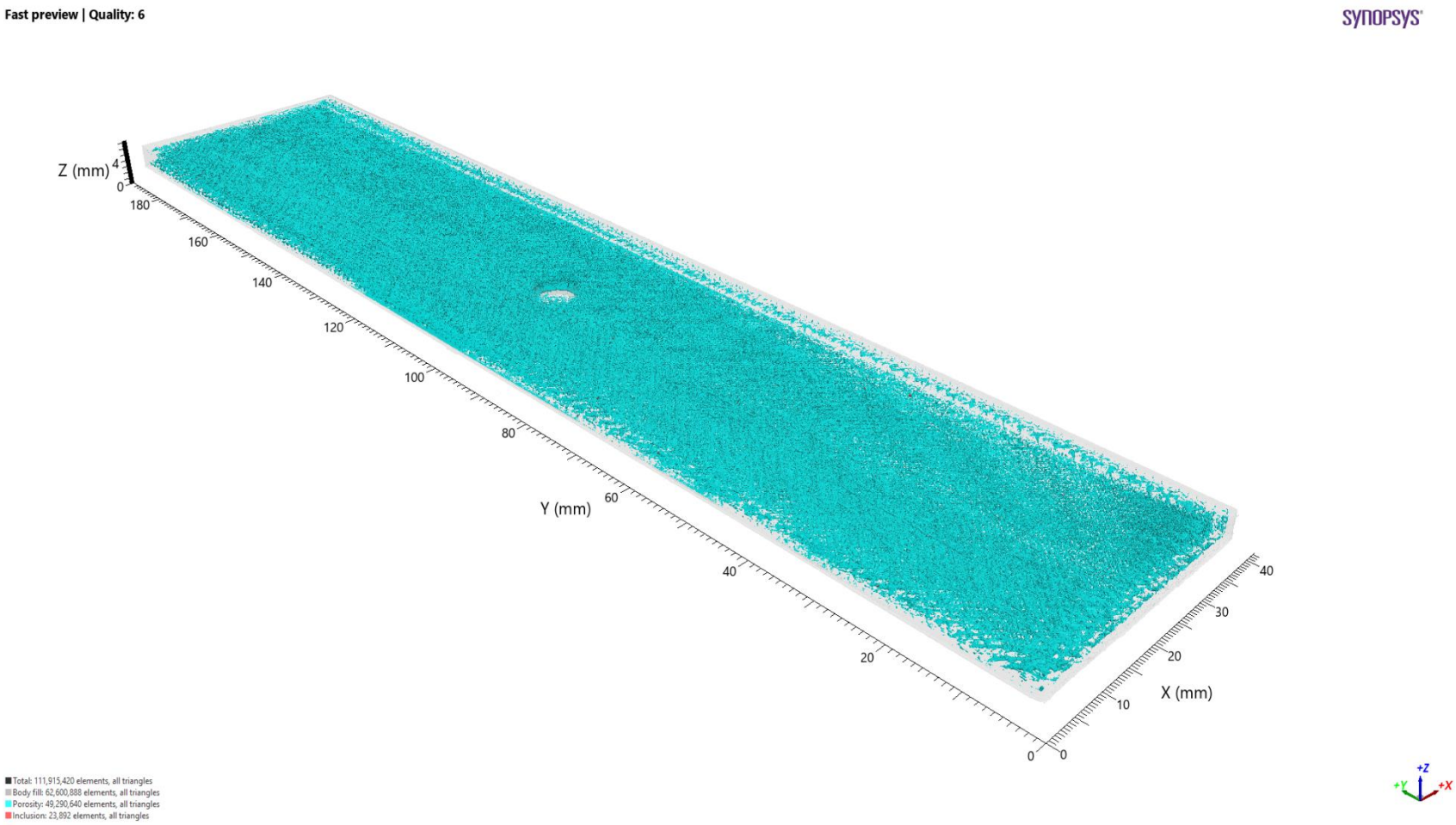
Material: Markforged Onyx FR-A™ - Carbon Fiber FR-A™
Material Specification: NMS 754-1
Process Specification: NPS 86754
Printer: Markforged X7

Markforged Onyx FR-A™ - Carbon Fiber FR-A™/ Markforged X7
X-ray CT Summary

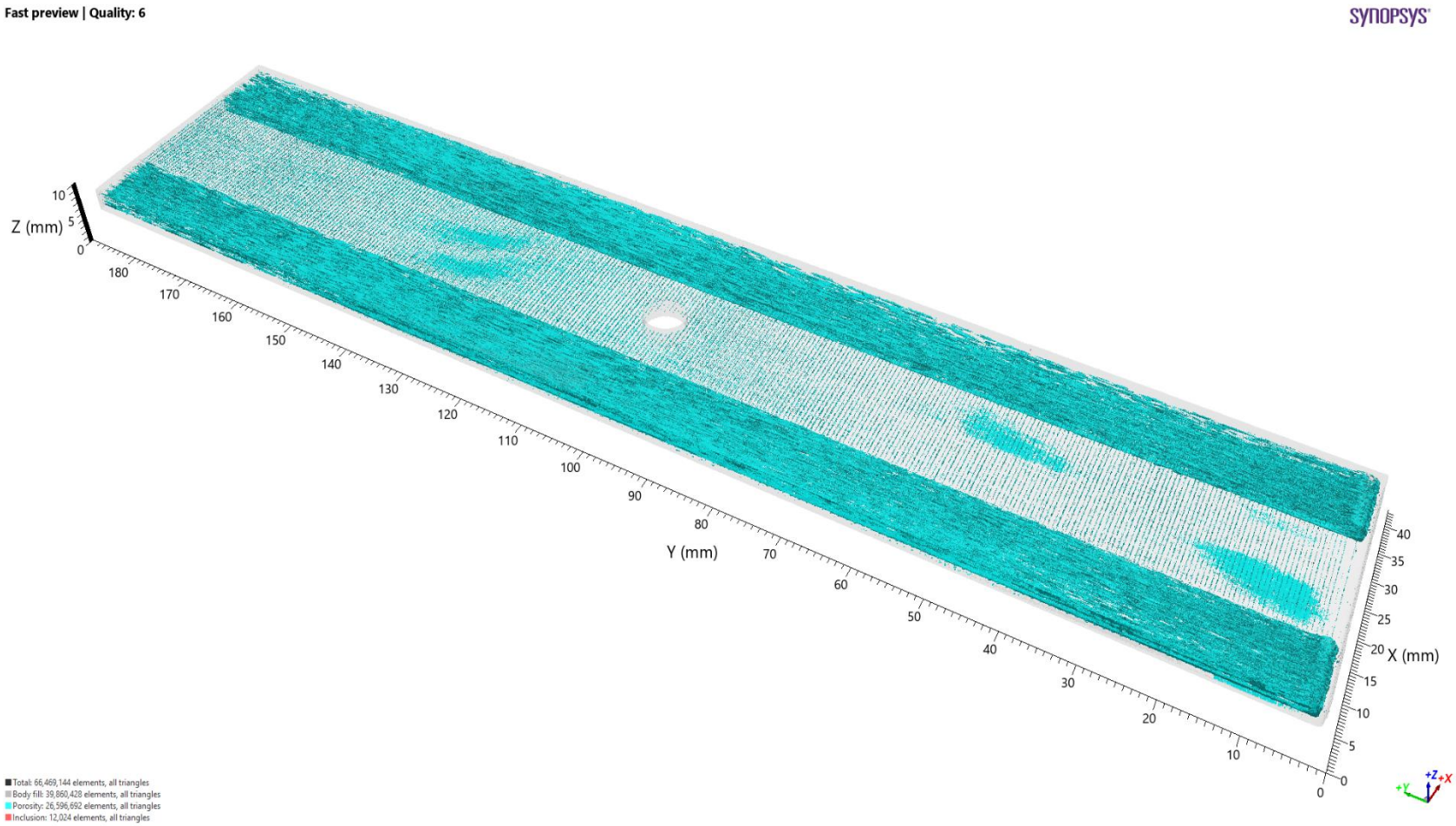
Specimen Orientation	Scan Resolution (µm)
XY	29
XZ	

Test Type	Fiber Fill	Specimen Orientation		Percentage Porosity (%)	Percentage Inclusions (%)	Minimum Porosity Length (mm)	Maximum Porosity Length (mm)	Minimum Inclusion Length (mm)	Maximum Inclusion Length (mm)
D6742	PF	XY	Mean	5.119	0.005	0.055	161.018	0.055	0.447
			Minimum	2.649	0.001	0.048	107.988	0.048	0.330
			Maximum	10.569	0.017	0.058	188.900	0.058	0.566
			Standard Deviation	3.165	0.006	0.005	41.100	0.005	0.106
			C.V.(%)	61.839	130.043	9.352	25.525	9.352	23.637
			No. Specimens	6					
			No. Material Batches	2					
		XZ	Mean	6.816	0.001	0.059	189.341	0.059	0.368
			Minimum	5.003	0.000	0.048	186.064	0.048	0.308
			Maximum	10.080	0.003	0.070	193.870	0.070	0.450
			Standard Deviation	2.304	0.001	0.013	3.277	0.013	0.063
			C.V.(%)	33.798	120.804	21.227	1.731	21.227	17.202
			No. Specimens	4					
			No. Material Batches	3					

10.7.1 **XY Filled-Hole Tension X-Ray CT scan**



10.7.2 **XZ Filled-Hole Tension X-Ray CT scan**



10.8 **Single-Shear Bearing X-ray CT summary**

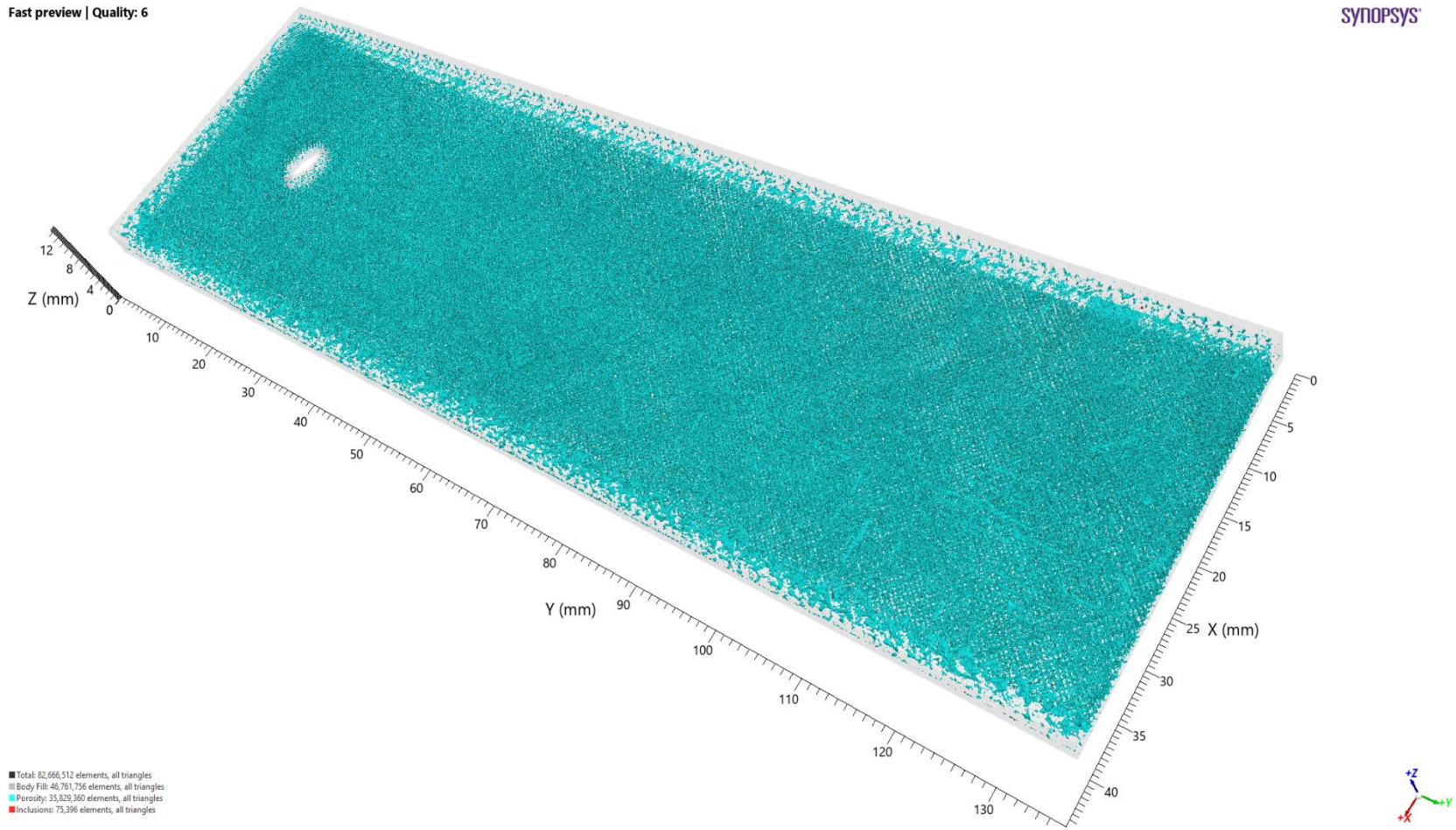
Material: Markforged Onyx FR-A™ - Carbon Fiber FR-A™
Material Specification: NMS 754-1
Process Specification: NPS 86754
Printer: Markforged X7

Markforged Onyx FR-A™ - Carbon Fiber FR-A™/ Markforged X7
X-ray CT Summary

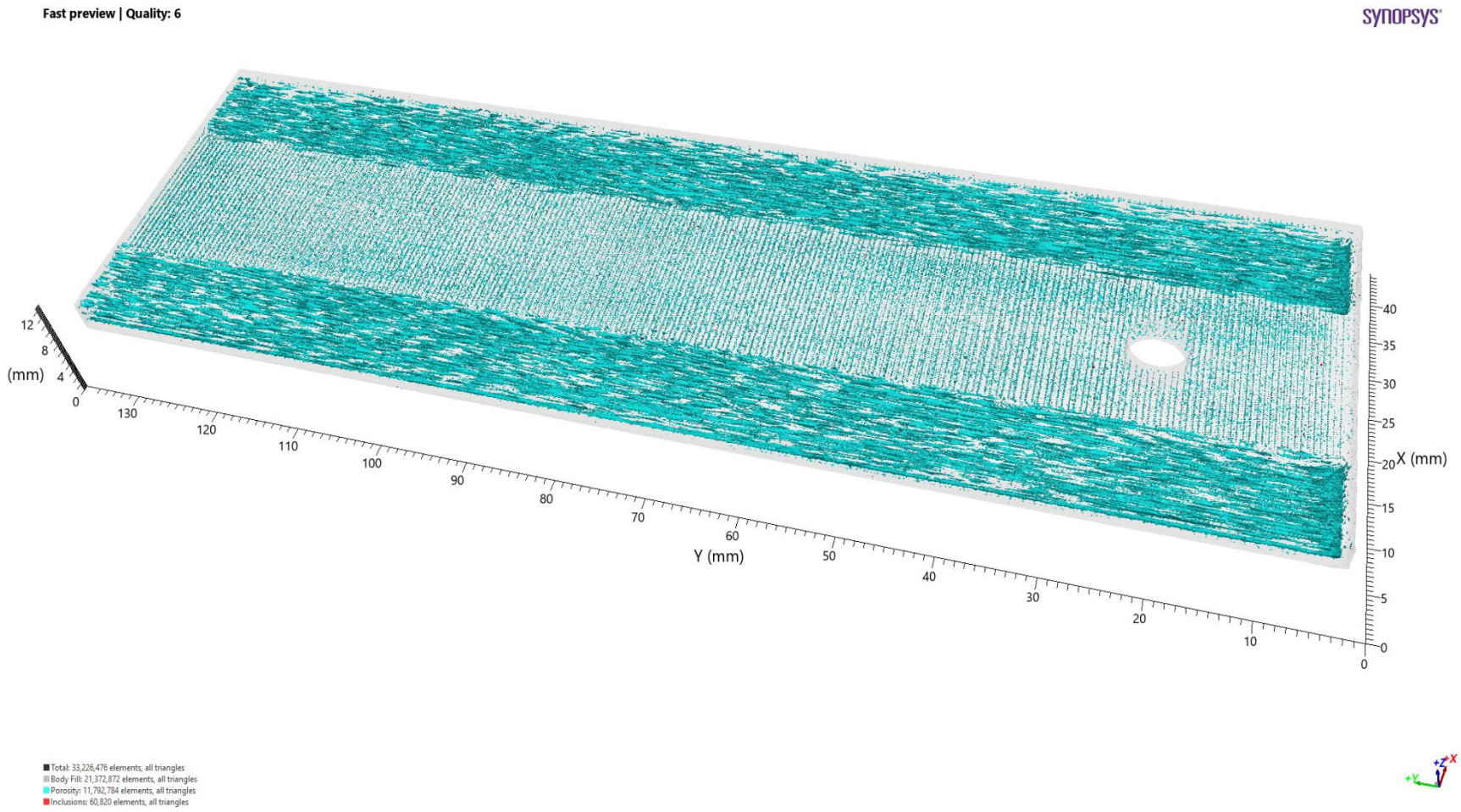
Specimen Orientation	Scan Resolution (µm)
XY	29
XZ	

Test Type	Fiber Fill	Specimen Orientation		Percentage Porosity (%)	Percentage Inclusions (%)	Minimum Porosity Length (mm)	Maximum Porosity Length (mm)	Minimum Inclusion Length (mm)	Maximum Inclusion Length (mm)
D5961	PF	XY	Mean	3.473	0.009	0.058	94.043	0.058	0.409
			Minimum	1.230	0.004	0.048	26.010	0.048	0.340
			Maximum	6.403	0.016	0.070	136.333	0.070	0.466
			Standard Deviation	1.872	0.004	0.012	51.526	0.012	0.042
			C.V.(%)	53.895	47.482	20.183	54.790	20.183	10.169
			No. Specimens	7					
			No. Material Batches	3					
		XZ	Mean	2.872	0.009	0.061	118.183	0.061	0.525
			Minimum	1.540	0.000	0.048	58.150	0.048	0.328
			Maximum	4.614	0.013	0.070	134.614	0.070	0.760
			Standard Deviation	1.367	0.005	0.012	33.582	0.012	0.180
			C.V.(%)	47.595	58.047	19.424	28.416	19.424	34.257
			No. Specimens	5					
			No. Material Batches	3					

10.8.1 **XY Single-Shear Bearing X-Ray CT scan**



10.8.2 **XZ Single-Shear Bearing X-Ray CT scan**



11. Deviations/Program Test Notes

a. The conditioning process was adjusted to first dry the specimens before machining the holes to prevent deviations in hole geometry. This adjustment was applied to all the ASTM D6742, D5961, and D5766 specimens.
b. The DO-160G Category A, standard humidity environment conditioning method with a reduced temperature of 120°F was utilized for the qualification project.
c. The test temperatures for ETW and Elevated Temperature Dry (ETD) specimens were reduced from 160°F to 130°F due to softening of the material near the glass transition temperature (Tg) of nylon in the OFRA material during prequalification testing.
d. The test speed for ASTM D6641 specimens were set to a speed of 0.05 in/min to achieve test consistency and eliminate test speed as a source of variability.
e. The ASTM D5961 Procedure C test type utilized the Constant Head Speed of the test at a fixed rate of 0.05 in/min to eliminate further variance in the data
f. Open-hole compression (ASTM D6484) and filled-hole compression (ASTM D6742) were removed from the initial test plan due to consistent improper failures of bending and buckling during the prequalification stage.
g. ASTM D2344 testing was reduced to XY orientation only due to improper failure modes when tested in the XZ and ZX orientation.
h. Due to material shrinkage, the ZX-PF test specimens were substituted with ZX-NF specimens for all mechanical testing except ASTM D3518 and D2344 testing, which were limited to XY orientation only.
i. Test results for Thermomechanical Analysis (ASTM E831) will report two values for coefficient of thermal expansion due to presence of an inflection point as presented in section 9.2.
j. X-ray CT scans for ZX no fiber and IZOD (ASTM D256) specimens were not carried out.