NATIONAL INSTITUTE FOR AVIATION RESEARCH

WICHITA STATE UNIVERSITY

Resin Infused Fiber Reinforced Materials Guidelines for Aircraft Design and Certification

John Tomblin, Rachael Andrulonis, Royal Lovingfoss, Caleb Saathoff & Michelle Man

CECAM center of excellence for composites and advanced materials

JAMS JOINT ADVANCED MATERIALS & STRUCTURES CENTER OF EXCELLENCE

Federal Aviation Administration

Research Team & Project Objectives

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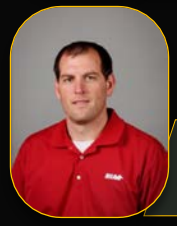

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Senior Technical Specialist for Advanced Composite Materials

TEIJIN SYENSQO FIBER DYNAMICS

PROJECT OVERVIEW

PROJECT OBJECTIVES

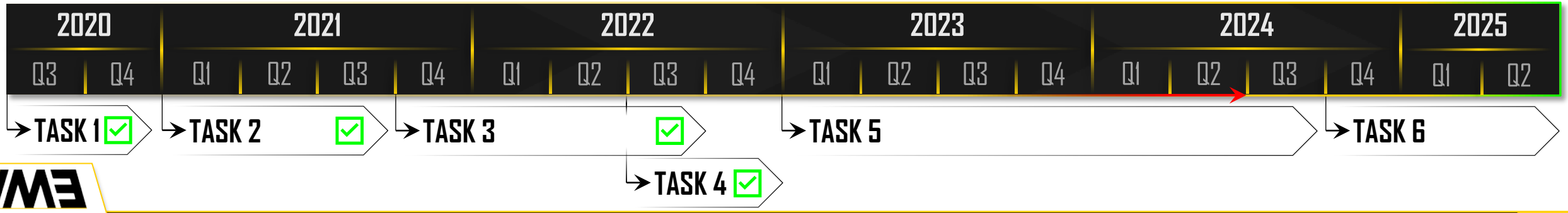
- To develop a framework for the qualification of resin infused fiber reinforced materials including guidelines and recommendations for their characterization, testing, design, and utilization using the National Center for Advanced Materials Performance (NCAMP) process.
- Transition of the test data and guidelines generated into shared databases such as Composite Materials Handbook-17 (CMH-17).

RESEARCH OUTCOME

- Vacuum Assisted Resin Transfer Molding (VARTM) trial test data and analysis published in FAA technical report.
- VARTM qualification material property test data, overview of results, and lessons learned published in an FAA technical report.
- Resin infusion material specification guidelines published in FAA technical report.
- VARTM material allowables submitted to CMH-17 and posted on the NCAMP Portal along with material and process specifications.

Project Plan & Tentative Timeline

1. **COORDINATION** — Establishment of an Industry Steering Committee (ISC).
2. **MATERIAL & PROCESS SELECTION** — Finalize resin and reinforcement materials and resin infusion method through manufacturing trials.
3. **QUAL. FRAMEWORK DEVELOPMENT** — Development of qualification framework leveraging lessons learned ensuring challenges and critical process parameters established on Task 2 are reflected and evaluated via trial testing.
4. **MATERIAL & PROCESS SPECs** — Development of base fabric, base resin, and base laminate material specifications and process specification for VARTM processing of test panels for qualification program.
5. **MATERIAL QUALIFICATION** — Performance of material qualification using framework established.
6. **STATISTICAL GUIDELINES** — Statistical analysis overview and guidelines.



Project Plan

ACCOMPLISHMENTS

- ✓ Survey OEM Designers, Manufacturers/User And Experts on Material Selection
- ✓ Committee Review Group Established – Industry Users, Suppliers, FAA
- ✓ Material Selection Narrowed
  - ✓ Reinforcement: Tenax™-E IMS65 Non-Crimp Reinforcement (Stitched):
    - UD Fabric, Bi-axial (0/90), Bi-diagonal (±45)
  - ✓ Resin: Solvay PRISM™ EP 2400
- ✓ Trials To Determine Project Needs, Challenges, Critical Process Control Parameters
- ✓ Processing Method: Vacuum Assisted Resin Transfer Molding (VARTM)
- ✓ Develop M&P Specifications
- ✓ Develop Mechanical, Physical, And Chemical Requirements
- ✓ Set Framework For Material Qualification
- ➢ Qualification Test Data Sufficient For Developing Statistical Guidelines And Allowables
- ○ Data And Guidelines

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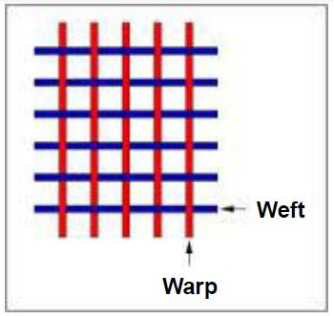
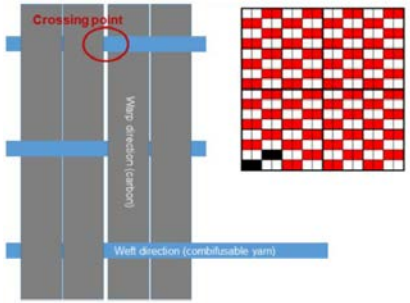
Task 2: Materials and Processing

REINFORCEMENT: Tenax™-E IMS65 Non-Crimp Reinforcement

- Material Forms:
  1. UD (woven with yarn)
  2. Bidiagonal (BD) – carbon fibers in +45°/-45° or -45°/+45° (also in ±30° and ±60°)
  3. Biaxial (BA) – carbon fibers in 0°/90° or 90°/0°
- Toughening Veil: TA1903s (polyamide veil) used to improve material toughness.
- Powder Binder: Hexion EP05311 binder.
- Stitching Yarns:
  - NCF: K-203 (EP1390) 33 dtex a co-polyamide yarn
  - UD Woven: polyester and co-polyamide Z-85 combi-fuseable bonding yarn, 200 dtex.

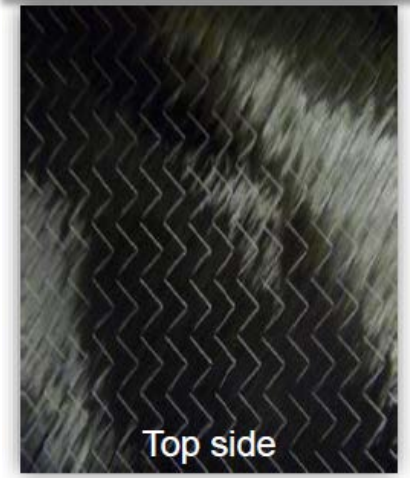
1 UNIDIRECTIONAL WOVEN





2 BIDIAGONAL NCF: PILLAR STITCH

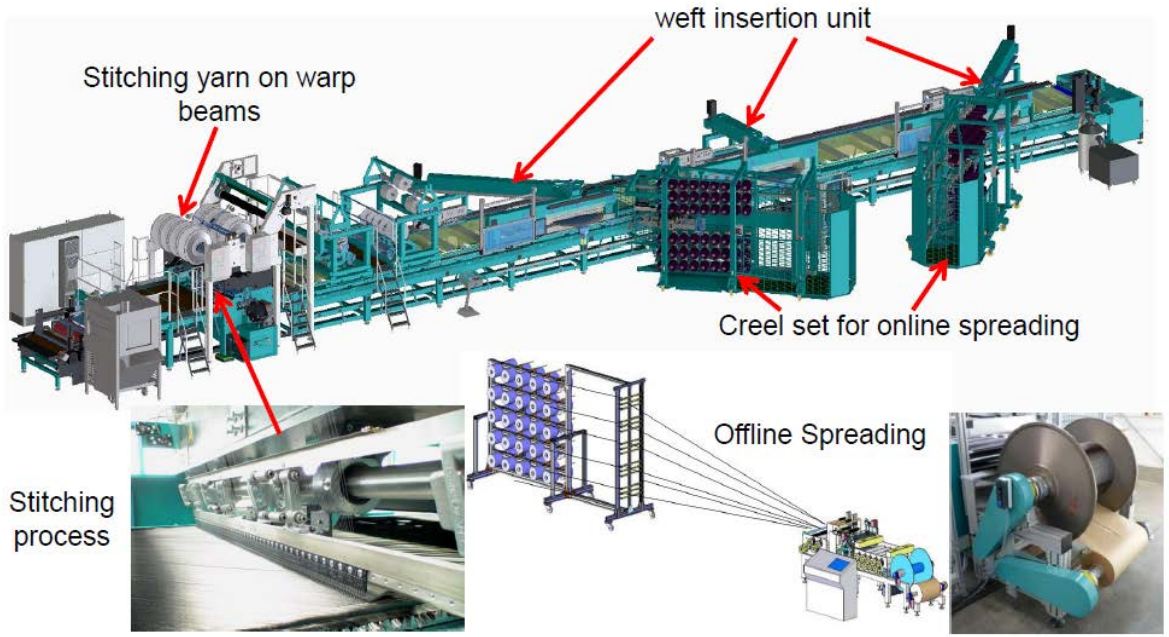
3 BIAXIAL NCF: TRICOT LOOP



Task 2: Materials and Processing

REINFORCEMENT cont.

Teijin NCF MANUFACTURING FACILITY



NON-CRIMP FABRIC: BIDIAGONAL EXAMPLE SHOWN

Veil (V) – Top layer
Carbon fiber (+45°)
Veil (V)
Carbon fiber (-45°)
Powder Binder (PB) – Bottom/first layer

WOVEN FABRIC

Veil (V) – Top layer
Carbon fiber (0°) – Bottom/first layer

RESIN

- Solvay PRISM™ EP 2400
- One-part toughened epoxy resin
- Intended service temp >250°F
- Superior toughness, low viscosity, and extended pot-life

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Task 3: Qualification Framework Development

Lamina Test Matrix								
Manufacturing Process	Type of Fabric	Stacking Sequence	Target Thickness (in)	# of Fabric Layers	Test Type	ASTM Method Description	Specimen Orientation*	# of Specimens
RTM	DRNF-BD	[45/-45]3s	0.087-0.090	6	UNT	D3039	45º	5
					CLC	D6641	45º	5
					CLC	D695	45º	5
					IPS	D3518	0º	5
					Flexural	D7264	0º	5
VARTM	DRNF-BD	[45/-45]3s	0.087-0.090	6	UNT	D3039	45º	5
					CLC	D6641	45º	5
					CLC	D695	45º	5
					IPS	D3518	0º	5
					Flexural	D7264	0º	5
RTM	DRNF-BA	[0/90]3s	0.087-0.090	6	UNT	D3039	0º	5
					CLC	D695	0º	5
					CLC	D695	90º	5
					IPS	D3518	0º	5
					Flexural	D7264	0º	5
VARTM	DRNF-BA	[0/90]3s	0.087-0.090	6	UNT	D3039	0º	5
					CLC	D695	0º	5
					CLC	D695	90º	5
					IPS	D3518	0º	5
					Flexural	D7264	0º	5
RTM	DRNF-BD	[45/-45]6s	0.174-0.181	12	SBS	D2344	0º	5
VARTM	DRNF-BD	[45/-45]6s	0.174-0.181	12	SBS	D2344	0º	5
RTM	DRNF-BA	[0/90]6s	0.174-0.181	12	SBS	D2344	0º	5
VARTM	DRNF-BA	[0/90]6s	0.174-0.181	12	SBS	D2344	0º	5
VARTM	DRWF	[45/-45]3s	.087-.090	12	IPS	D3518	0º	5
		[0/90]3s	0.087-0.090	12	UNT	D30398	0º	5
					CLC	D6641	0º	5
		[0]12	0.087-0.090	12	UNT	D3039	0º	5
					CLC	D6641	0º	5

* Specimen orientation: orientation of the specimen in reference to the fabricated panel 0º direction

TRIAL TESTING OBJECTIVES & MATRICIES

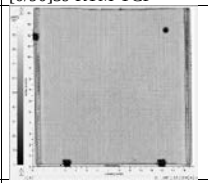
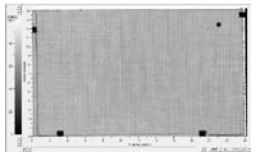
- Panel Fabrication
  - 26 Panels fabricated at Fiber Dynamics
- Properties Evaluated
  - Mechanical: *Tension, Compression, Flex, And Shear tests conducted.*
  - Physical: *Fiber Volumes, Resin Contents, Voids, etc.*
- General Processing Challenges
  - Identifying variables that need to be controlled.
- Manufacturing Process Differences
  - Vacuum Assisted Resin Transfer Molding Vs Resin Transfer Molding (VARTM vs RTM)
  - Qualification Vs. Equivalency: *Challenges, Feasibility*

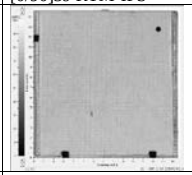
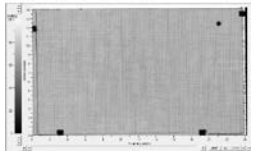
Laminate Test Matrix							
Manufacturing Process	Type of Fabric	Stacking Sequence	Target Thickness (in)	# of Fabric Layers	Test Type	ASTM Method Description	# of Specimens
RTM	DRNF -BD & BA	[45/-45,0/90]2s	0.116	8	OHC	D6484	5
					OHT	D5766	5
					CAI	D7136/D7137	5
VARTM	DRNF -BD & BA	[45/-45,0/90]2s	0.116	8	OHC	D6484	5
					OHT	D5766	5
					CAI	D7136/D7137	5

Task 3: Qualification Framework Development

PROCESSING METHOD DOWNSELECT via NDT

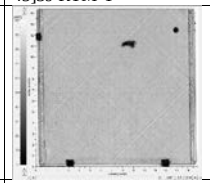
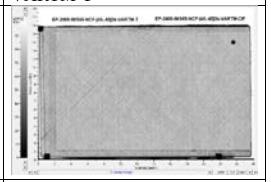
DRNF-BA: TEN, COMP, FLEX

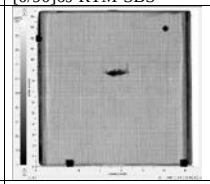
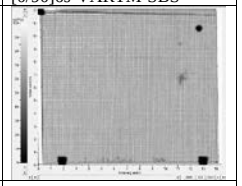
Panel Process	RTM Panel: EP-2400/IMS65-NCF-[0/90]3s-RTM-TCF	VARTM Panel: EP-2400/IMS65-NCF-[0/90]3s-VARTM-TCF
NDI Image		
Measured Properties	T = 0.088” FV = 53.7% Void: 0.89%	T=0.092” FV = 51.5% Void = 1.21%

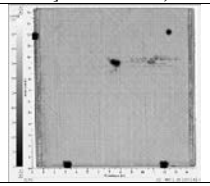
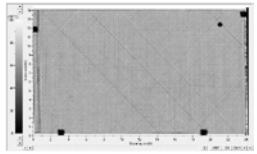
Panel Process	RTM Panel: EP-2400/IMS65-NCF-[0/90]3s-RTM-IPS	VARTM Panel: EP-2400/IMS65-NCF-[0/90]3s-VARTM-IPS
NDI Image		
Measured Properties	T = 0.085” FV = 57.5% Void = 1.04%	T= 0.094” FV = 50.9% Void = 1.17%

DRNF-BD: TENSION

DRNF-BA/BD: CAI

Panel Process	RTM Panel: EP-2400/IMS65-NCF-[45/-45]3s-RTM-T	VARTM Panel: EP-2400/IMS65-NCF-[45/-45]3s-VARTM-T
NDI Image		
Measured Properties	T = 0.085” FV = 55.3% Void = 0.79%	T=0.095” FV = 54.0% Void = 1.46%

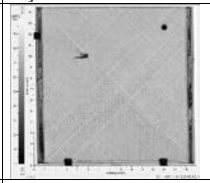
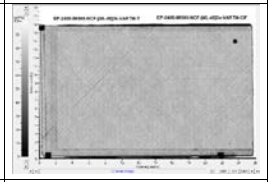
Panel Process	RTM Panel: EP-2400/IMS65-NCF-[0/90]6s-RTM-SBS	VARTM Panel: EP-2400/IMS65-NCF-[0/90]6s-VARTM-SBS
NDI Image		
Measured Properties	T = 0.175” FV = 55.9% Void = 2.05%	T=0.169” FV = 59.4% Void = 1.43%

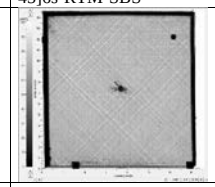
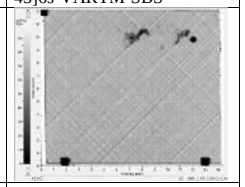
Panel Process	RTM Panel: EP-2400/IMS65-NCF-[45/-45/0/90]2s-RTM-OHC,CAI	VARTM Panel: EP-2400/IMS65-NCF-[45/-45/0/90]2s-VARTM-OHC,CAI
NDI Image		
Measured Properties	T = 0.111” FV = 56.1% Void = 0.87%	T=0.112” FV = 57.4% Void = 1.36%

DRNF-BD: COMP, IPS, FLEX

DRNF-BA: IPS

DRNF-BA: SBS

Panel Process	RTM Panel: EP-2400/IMS65-NCF-[45/-45]3s-RTM-CIF	VARTM Panel: EP-2400/IMS65-NCF-[45/-45]3s-VARTM-CIF
NDI Image		
Measured Properties	T = 0.089” FV = 53.2% Void = 1.16%	T= 0.095” FV = 55.1% Void = 0.94%

Panel Process	RTM Panel: EP-2400/IMS65-NCF-[45/-45]6s-RTM-SBS	VARTM Panel: EP-2400/IMS65-NCF-[45/-45]6s-VARTM-SBS
NDI Image		
Measured Properties	T = 0.165” FV = 59.4% Void = 1.53%	T=0.172” FV = 58.1% Void = 1.23%

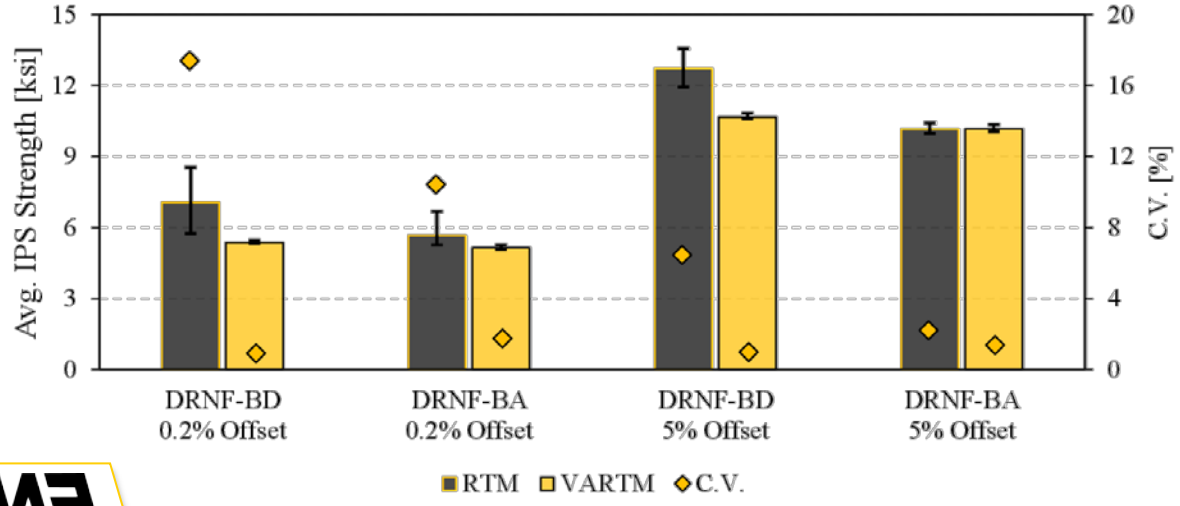
DRNF-BD: SBS

Task 3: Qualification Framework Development

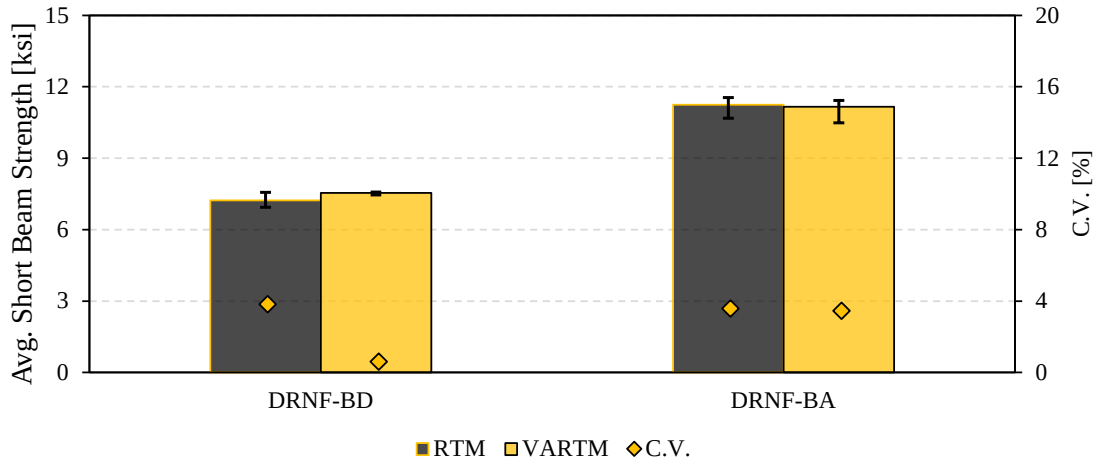
PROCESSING METHOD DOWNSELECT via MECHANICAL PERFORMANCE

- Select Sample Test Results Shown
  - Increased coefficient of variation (C.V.) in strength results for specimens manufactured with RTM when compared to VARTM
    - UNT, UNC, IPS exhibited this phenomenon
    - FLEX, SBS, OHT, OHC, CAI did not exhibit this phenomenon
- **VARTM Selected**: Improved consistency, process control, and panel quality with comparable results to RTM.

ASTM D3518: IN-PLANE SHEAR STRENGTH



ASTM D2344: SHORT BEAM STRENGTH



Task 3: Qualification Framework Development

PROCESSING METHOD CHALLENGES

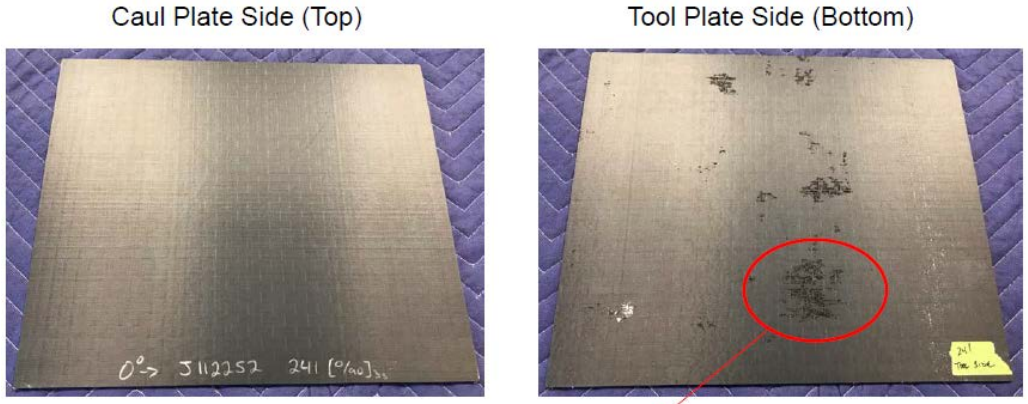
- Porosity
- Permeability – Infusion Times
- Fiber Volume Control

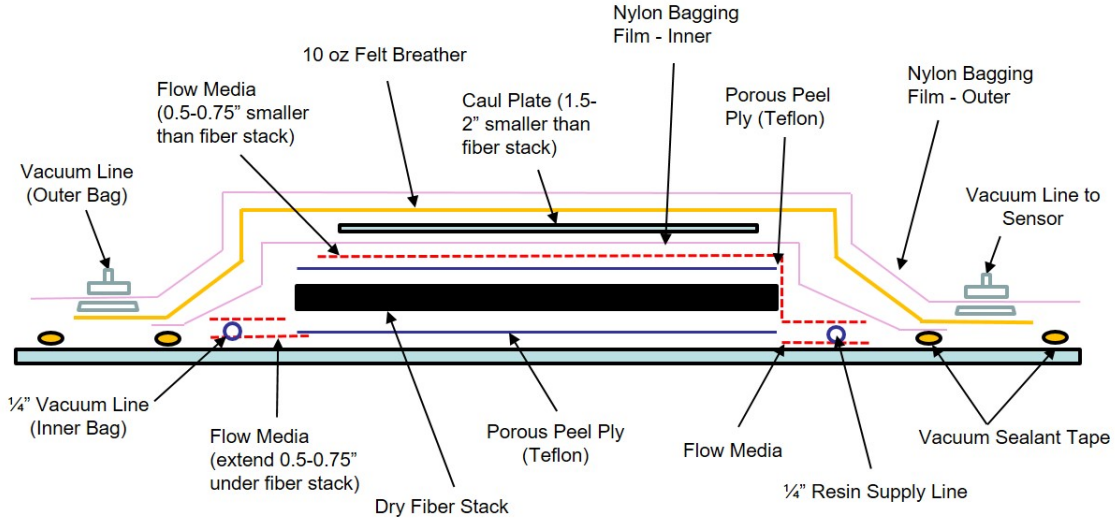
OPTIMIZATION [NIAR + Teijin at FDI]

- Varying Flow Media
- Increased Resin Infusion Temperature
- Port Adjustments
- Adjusted Tubing Placement
- Optimized Infusion Time

- **Result**: More Repeatable Fiber Volume; Goal: 57% ± 3%

VARTM UNI-FABRIC PANEL: COURTESY OF FIBER DYNAMICS, INC.



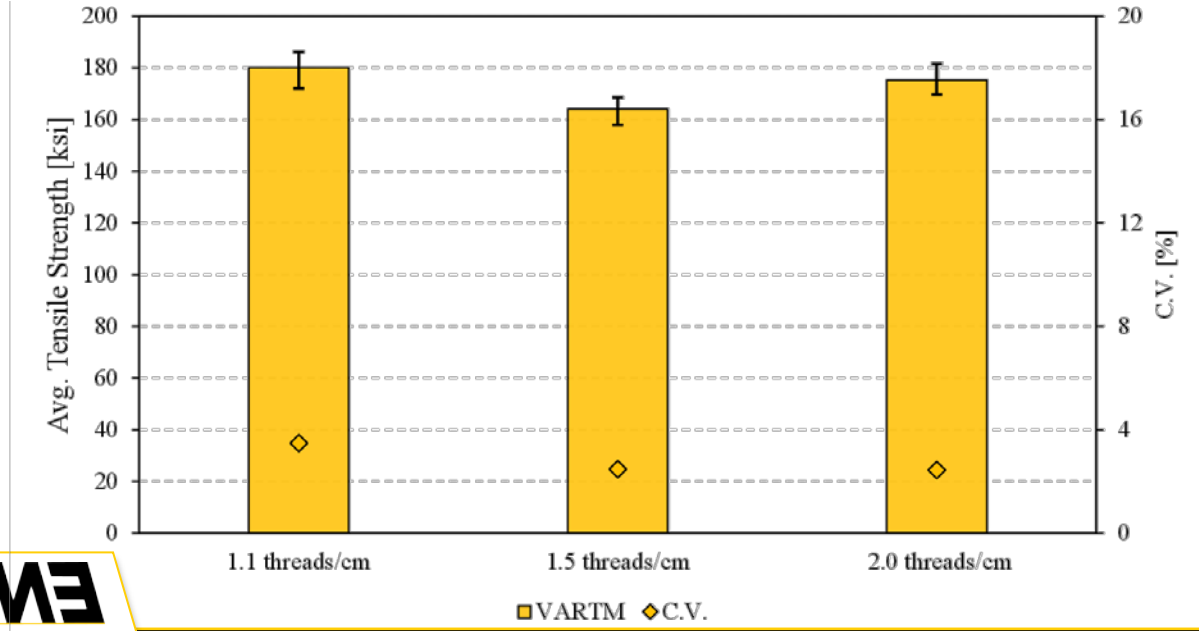


Task 3: Qualification Framework Development

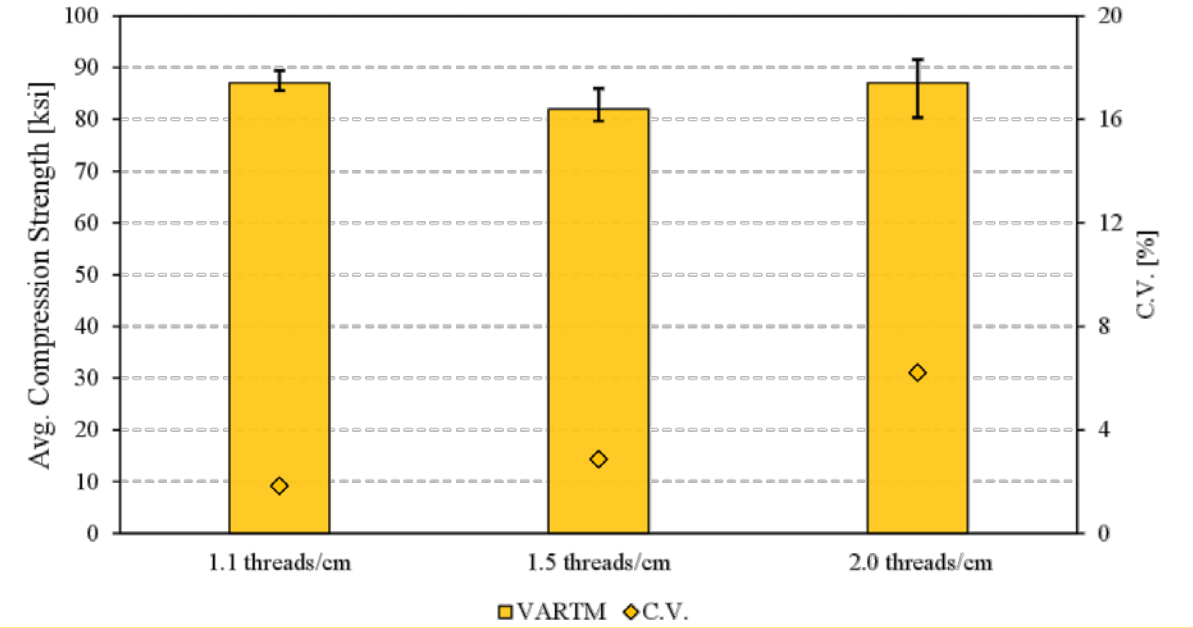
WEFT DENSITY SELECTION

- The first batch of UD woven fabric panels were fabricated utilizing the same parameter set as the DRNF panels with limited success.
  - Cause thought to be Weft Density: Challenges with permeability ➔ Porosity and high processing time
  - Teijin provided three material forms with varying weft densities: 1.1-threads/cm, 1.5-threads/cm, and 2.0-threads/cm
- **1.5-threads/cm Selected**: Balance between infusion time and panel quality.

ASTM D3039: TENSILE STRENGTH



ASTM D6641: COMPRESSIVE STRENGTH



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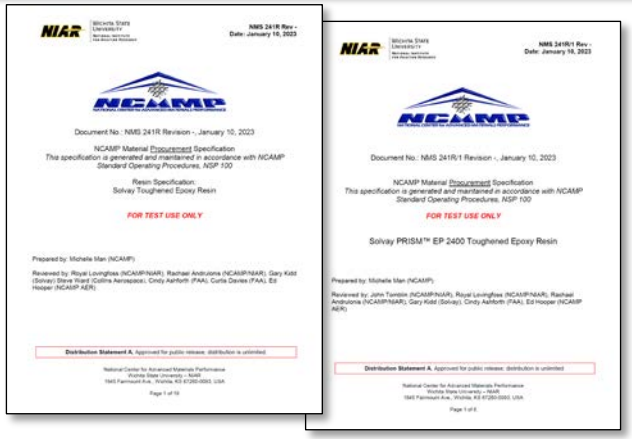
Task 4: Material and Process Specification(s)

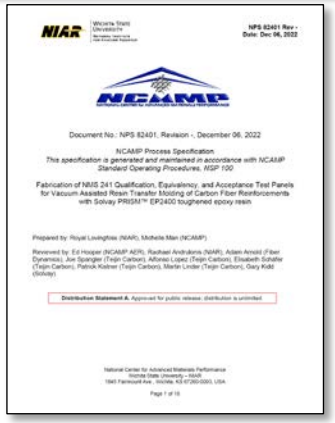
BASE FABRIC SPECIFICATION: DRY REINFORCEMENTS

BASE LAMINATE SPECIFICATION: FINISHED LAMINATES

BASE RESIN SPECIFICATION: RESIN



PROCESS SPECIFICATION: VARTM W/ PRISM™ EP2400 RESIN SYSTEM



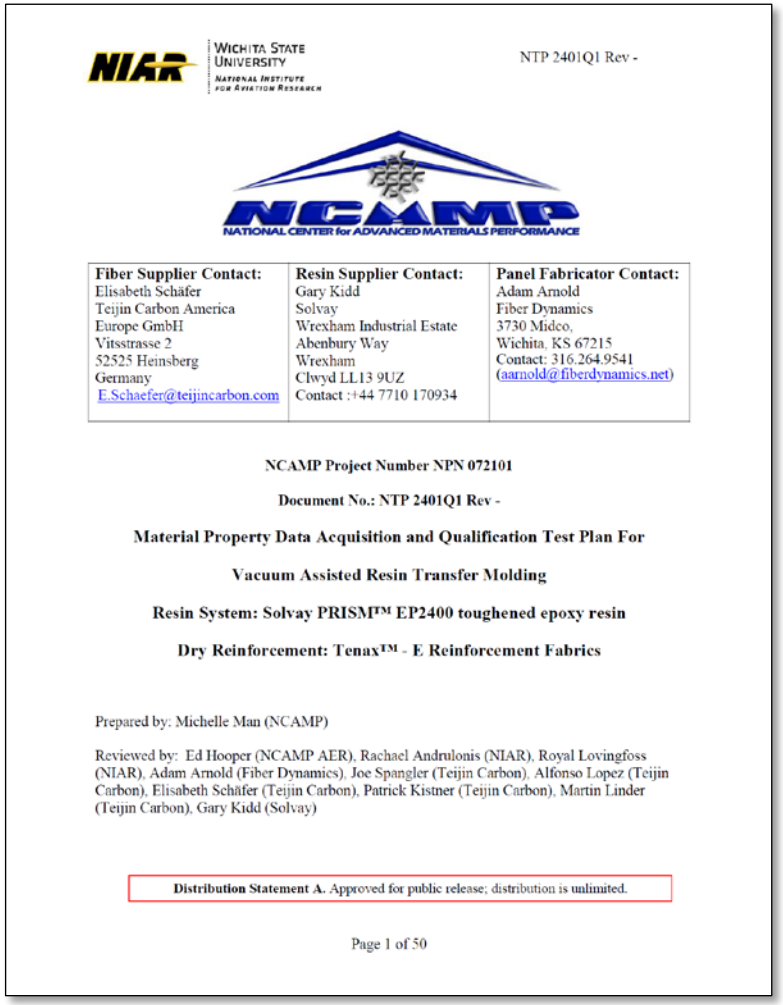
Project Plan

ACCOMPLISHMENTS

- ✓ Survey OEM Designers, Manufacturers/User And Experts on Material Selection
- ✓ Committee Review Group Established – Industry Users, Suppliers, FAA
- ✓ Material Selection Narrowed
  - ✓ Reinforcement: Tenax™-E IMS65 Non-Crimp Reinforcement (Stitched):
    - UD Fabric, Bi-axial (0/90), Bi-diagonal (±45)
  - ✓ Resin: Solvay PRISM™ EP 2400
- ✓ Trials To Determine Project Needs, Challenges, Critical Process Control Parameters
- ✓ Processing Method: Vacuum Assisted Resin Transfer Molding (VARTM)
- ✓ Develop M&P Specifications
- ✓ Develop Mechanical, Physical, And Chemical Requirements
- ✓ Set Framework For Material Qualification
- ➢ Qualification Test Data Sufficient For Developing Statistical Guidelines And Allowables
- ○ Data And Guidelines

Task 5: Material Qualification

TEST PLAN: LAMINA



NIAR Wichita State University National Institute for Aviation Research

NTP 2401Q1 Rev -

NCAMP National Center for Advanced Materials Performance

Fiber Supplier Contact:	Resin Supplier Contact:	Panel Fabricator Contact:
Elisabeth Schäfer Teijin Carbon America Europe GmbH Vitsstrasse 2 52525 Heinsberg Germany E.Schaefer@teijincarbon.com	Gary Kidd Solvay Wrexham Industrial Estate Abenbury Way Wrexham Clwyd LL13 9UZ Contact :+44 7710 170934	Adam Arnold Fiber Dynamics 3730 Midco, Wichita, KS 67215 Contact: 316.264.9541 (aarnold@fiberdynamics.net)

NCAMP Project Number NPN 072101

Document No.: NTP 2401Q1 Rev -

Material Property Data Acquisition and Qualification Test Plan For

Vacuum Assisted Resin Transfer Molding

Resin System: Solvay PRISM™ EP2400 toughened epoxy resin

Dry Reinforcement: Tenax™ - E Reinforcement Fabrics

Prepared by: Michelle Man (NCAMP)

Reviewed by: Ed Hooper (NCAMP AER), Rachael Andrulonis (NIAR), Royal Lovingfoss (NIAR), Adam Arnold (Fiber Dynamics), Joe Spangler (Teijin Carbon), Alfonso Lopez (Teijin Carbon), Elisabeth Schäfer (Teijin Carbon), Patrick Kistner (Teijin Carbon), Martin Linder (Teijin Carbon), Gary Kidd (Solvay)

Distribution Statement A. Approved for public release; distribution is unlimited.

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UD WOVEN

Fiber Layup	Test direction	Test Type	Property	Number of Batches x Number of Panels x Number of Test Specimens: Test Temperature/Moisture Condition				
				CTA (4)	RTA	ETA	ETW1	ETW2
$[0/90]_{4S}$	0°	ASTM D3039 Tension	Strength, Modulus, and Poisson's Ratio	3x2x3	3x2x3 (3)	3x2x3	3x2x3	
$[0/90]_{4S}$	0°	ASTM D6641 Compression	Strength and Modulus		3x2x3 (1)	3x2x3	3x2x3	1x2x3
$[0]_{8}$	0°	ASTM D3039 Tabbed Tension	Strength and Modulus	3x2x3	3x2x3 (3)	3x2x3	3x2x3	1x2x3
$[0]_{16}$	0°	ASTM D6641 Compression	Modulus		3x2x3 (1)	3x2x3	3x2x3	1x2x3
$[45/-45]_{3S}$	0°	ASTM D3518 In-Plane Shear (2)	Strength and Modulus	3x2x3	3x2x3	3x2x3	3x2x3	
[0]32	0°	ASTM D2344 Short Beam	Strength	3x2x3	3x2x3	3x2x3	3x2x3	1x2x3
$[0/90]_{4S}$	0°	ASTM D7264 Flex (5)	Strength and Modulus		3x2x3			

BIAXIAL

Fiber Layup	Test direction	Test Type	Property	Number of Batches x Number of Panels x Number of Test Specimens: Test Temperature/Moisture Condition				
				CTA (4)	RTA	ETA	ETW1	ETW2
$[0/90]_{4S}$	0°	ASTM D3039 Tension	Strength, Modulus, and Poisson's Ratio	3x2x3	3x2x3 (3)	3x2x3	3x2x3	
$[0/90]_{4S}$	0°	ASTM D6641 Compression	Strength and Modulus		3x2x3 (1)	3x2x3	3x2x3	1x2x3
$[0/90]_{4S}$	90°	ASTM D3039 Tension	Strength and Modulus	3x2x3	3x2x3 (3)	3x2x3	3x2x3	
$[0/90]_{4S}$	90°	ASTM D6641 Compression	Strength and Modulus		3x2x3 (1)	3x2x3	3x2x3	1x2x3
$[45/-45]_{3S}$ (rotated out of 0/90 and 90/0)	0°	ASTM D3518 In-Plane Shear (2)	Strength and Modulus	3x2x3	3x2x3 (3)	3x2x3	3x2x3	
$[0/90]_{8S}$	0°	ASTM D2344 Short Beam	Strength	3x2x3	3x2x3	3x2x3	3x2x3	1x2x3
$[0/90]_{4S}$	0°	ASTM D7264 Flex (5)	Strength and Modulus		3x2x3			

BIDIAGONAL

Fiber Layup	Test direction	Test Type	Property	Number of Batches x Number of Panels x Number of Test Specimens: Test Temperature/Moisture Condition				
				CTA (4)	RTA	ETA	ETW1	ETW2
$[0/90]_{4S}$ (BD rotated by 45°)	0°	ASTM D3039 Tension	Strength, Modulus, and Poisson's Ratio	3x2x3	3x2x3 (3)	3x2x3	3x2x3	
$[0/90]_{4S}$ (BD rotated by 45°)	0°	ASTM D6641 Compression	Strength and Modulus		3x2x3 (1)	3x2x3	3x2x3	1x2x3
$[45/-45]_{3S}$	0°	ASTM D3518 In-Plane Shear (2)	Strength and Modulus	3x2x3	3x2x3 (3)	3x2x3	3x2x3	
$[0/90]_{8S}$ (BD rotated by 45°)	0°	ASTM D2344 Short Beam	Strength	3x2x3	3x2x3	3x2x3	3x2x3	1x2x3
$[0/90]_{4S}$ (BD rotated by 45°)	0°	ASTM D7264 Flex (5)	Strength and Modulus		3x2x3			

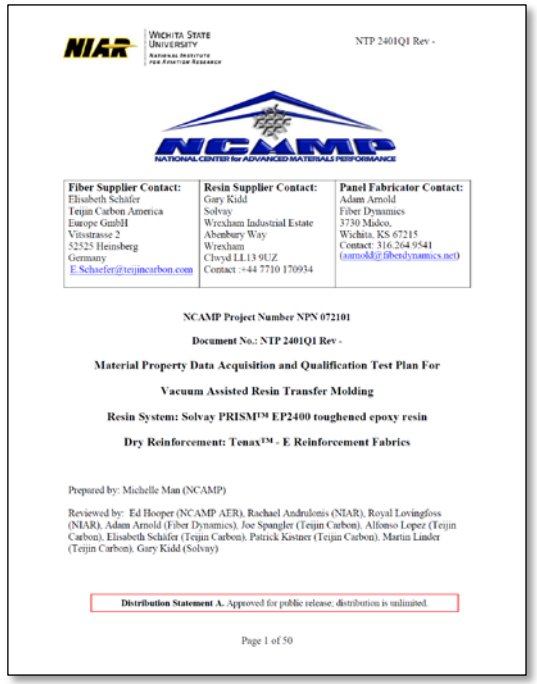
Task 5: Material Qualification

LAMINATE TESTING PROPERTIES

- Laminates use a combination of the non-crimp and woven fabric forms to produce the desired quasi, soft, and hard orientation(s).
- The layup angles 0/90, 90/0, 45/-45 and -45/45 refer to the specific DRNF, i.e. biaxial (0/90 or 90/0) and bidiagonal (45/-45 or -45/45) reinforcement fabric.
- The stacking sequences were chosen based on several factors:
  - Assess material properties from a soft, quasi and hard construction .
  - Assess the interactions of the different preforms during processing and subsequent performance.

LAMINATE TESTING PROPERTIES

- Unnotched Tension
- Unnotched Compression
- Short Beam Shear
- Open Hole Tension
- Filled Hole Tension
- Open Hole Compression
- Filled Hole Compression
- Single Shear Bearing
- Interlaminar Tension
- Compression After Impact
- Fluid Screening:
  - Woven Fabric
  - Short Beam Shear
  - 13 fluids + controls
  - RT and ET testing



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Task 5: Material Qualification

BIAXIAL: ORANGE (DATA IN REVIEW) GREEN (SCHEDULED)

Fiber Layup	Test direction	Test Type	Property	Number of Batches x Number of Panels x Number of Test Specimens				
				Test Temperature/Moisture Condition				
				CTA (4)	RTA	ETA	ETW1	ETW2
$[0/90]_{4S}$	0°	ASTM D3039 Tension	Strength, Modulus, and Poisson's Ratio	3x2x3	3x2x3 (3)	3x2x3	3x2x3	
$[0/90]_{4S}$	0°	ASTM D6641 Compression	Strength and Modulus		3x2x3 (1)	3x2x3	3x2x3	1x2x3
$[0/90]_{4S}$	90°	ASTM D3039 Tension	Strength and Modulus	3x2x3	3x2x3 (3)	3x2x3	3x2x3	
$[0/90]_{4S}$	90°	ASTM D6641 Compression	Strength and Modulus		3x2x3 (1)	3x2x3	3x2x3	1x2x3
$[45/-45]_{3S}$ (rotated out of 0/90 and 90/0)	0°	ASTM D3518 In-Plane Shear (2)	Strength and Modulus	3x2x3	3x2x3 (3)	3x2x3	3x2x3	
$[0/90]_{8S}$	0°	ASTM D2344 Short Beam	Strength	3x2x3	3x2x3	3x2x3	3x2x3	1x2x3
$[0/90]_{4S}$	0°	ASTM D7264 Flex (5)	Strength and Modulus		3x2x3			

BIDIAGONAL: ORANGE (DATA IN REVIEW) GREEN (SCHEDULED)

Fiber Layup	Test direction	Test Type	Property	Number of Batches x Number of Panels x Number of Test Specimens				
				Test Temperature/Moisture Condition				
				CTA (4)	RTA	ETA	ETW1	ETW2
$[0/90]_{4S}$ (BD rotated by 45°)	0°	ASTM D3039 Tension	Strength, Modulus, and Poisson's Ratio	3x2x3	3x2x3 (3)	3x2x3	3x2x3	
$[0/90]_{4S}$ (BD rotated by 45°)	0°	ASTM D6641 Compression	Strength and Modulus		3x2x3 (1)	3x2x3	3x2x3	1x2x3
$[45/-45]_{3S}$	0°	ASTM D3518 In-Plane Shear (2)	Strength and Modulus	3x2x3	3x2x3 (3)	3x2x3	3x2x3	
$[0/90]_{8S}$ (BD rotated by 45°)	0°	ASTM D2344 Short Beam	Strength	3x2x3	3x2x3	3x2x3	3x2x3	1x2x3
$[0/90]_{4S}$ (BD rotated by 45°)	0°	ASTM D7264 Flex (5)	Strength and Modulus		3x2x3			

UD WOVEN: ORANGE (DATA IN REVIEW) GREEN (SCHEDULED)

Fiber Layup	Test direction	Test Type	Property	Number of Batches x Number of Panels x Number of Test Specimens				
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$[0/90]_{4S}$	0°	ASTM D6641 Compression	Strength and Modulus		3x2x3 (1)	3x2x3	3x2x3	1x2x3
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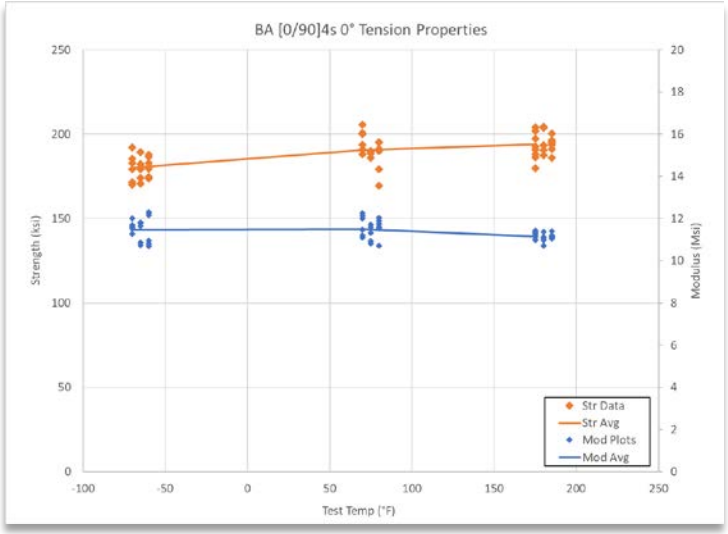
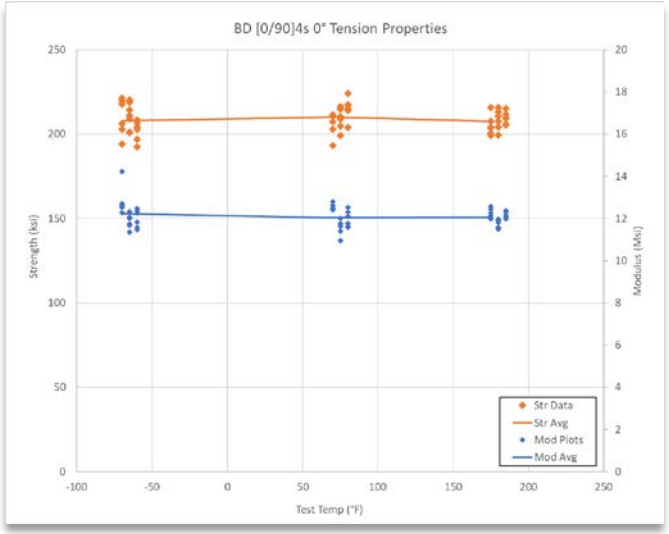
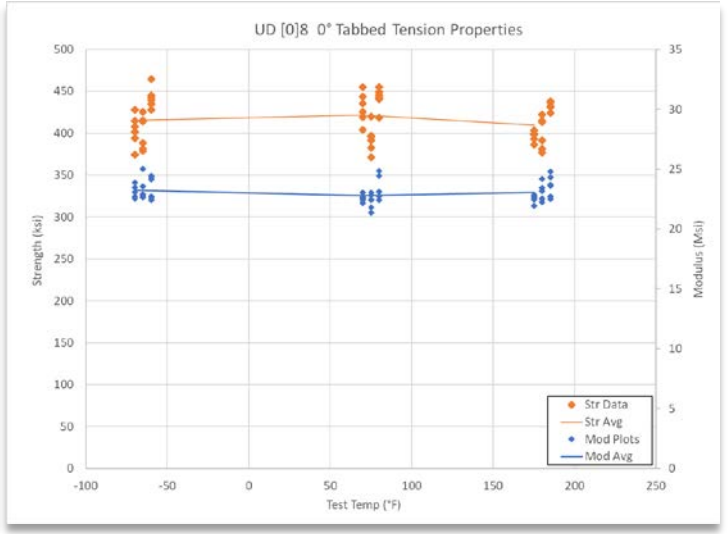
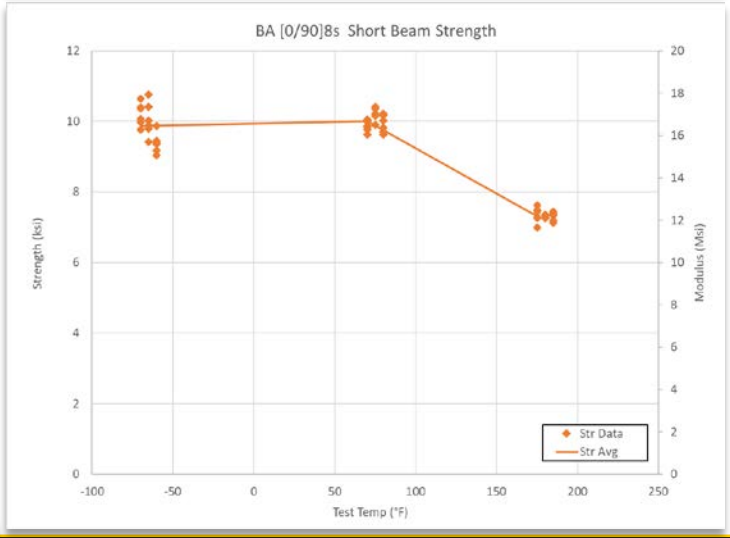
$[0/90]_{4S}$	0°	ASTM D7264 Flex (5)	Strength and Modulus		3x2x3			

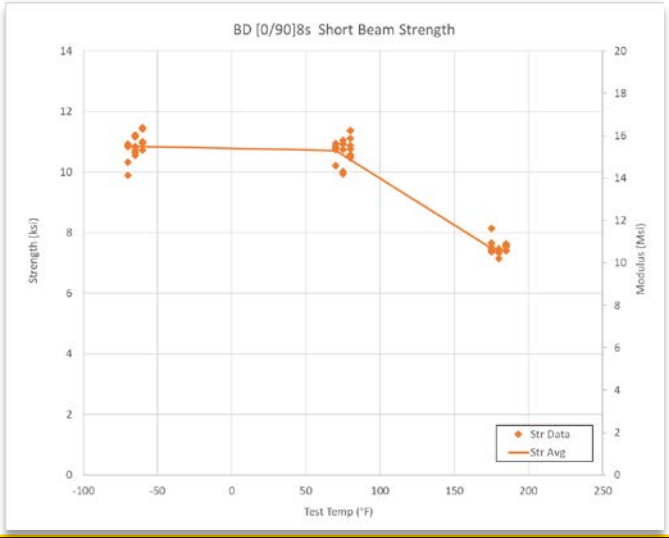
PRELIMINARY LAMINA DATA SAMPLES

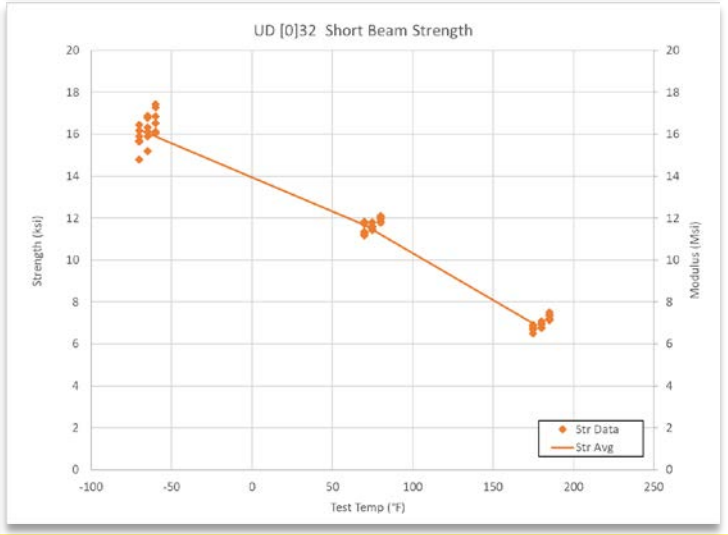












Task 5: Material Qualification

LAMINATE: ORANGE (DATA IN REVIEW) GREEN (SCHEDULED)

(%0º/%±45º/%90º) Actual Test Type	Test Type and Layup (5)	Property	Number of Batches x Number of Panels x Number of Test Specimens			
			Test Temperature/Moisture Condition			
			CTA	RTA	ETA	ETW1
(25/50/25 - QI) UNT1	ASTM D3039 Un-notched Tension [45/-45, 0/90], [45/-45, 90/0] | [0/90,-45/45], [90/0,-45/45]	Strength & modulus	3x2x3	3x2x3	3x2x3	3x2x3
(12.5/75/12.5) UNT2	ASTM D3039 Un-notched Tension [45/-45, 0/90, 45/-45, 45/-45] | [-45/45, -45/45, 90/0, -45/45]	Strength & modulus	3x2x3	3x2x3		3x2x3
(50/40/10) UNT3	ASTM D3039 Un-notched Tension [45/-45, 0, 0, 0/90, 45/-45, 0, 0] | [0, 0, -45/45, 90/0, 0, 0, -45/45]	Strength & modulus	3x2x3	3x2x3		3x2x3
(25/50/25 - QI) UNC1	ASTM D6641 Un-notched Compression [45/-45, 0/90], [45/-45, 90/0] | [0/90,-45/45], [90/0,-45/45]	Strength & modulus		3x2x3	3x2x3	3x2x3
(12.5/75/12.5) UNC2	ASTM D6641 Un-notched Compression [45/-45, 0/90, 45/-45, 45/-45] | [-45/45, -45/45, 90/0, -45/45]	Strength & modulus		3x2x3		3x2x3
(50/40/10) UNC3	ASTM D6641 Un-notched Compression [45/-45, 0, 0, 0/90, 45/-45, 0, 0] | [0, 0, -45/45, 90/0, 0, 0, -45/45]	Strength & modulus		3x2x3		3x2x3
(25/50/25 - QI) SBS1	ASTM D2344 Short Beam [45/-45, 0/90], [45/-45, 90/0] | [0/90,-45/45], [90/0,-45/45] (specimens may be taken from UNC1 panels)	Strength		3x2x3	3x2x3	3x2x3
(25/50/25 - QI) OHT1	ASTM D5766 Open Hole Tension (1) [45/-45, 0/90], [45/-45, 90/0] | [0/90,-45/45], [90/0,-45/45]	Strength	3x2x3	3x2x3	3x2x3	3x2x3
(12.5/75/12.5) OHT2	ASTM D5766 Open Hole Tension (1) [45/-45, 0/90, 45/-45, 45/-45] | [-45/45, -45/45, 90/0, -45/45]	Strength	3x2x3	3x2x3		3x2x3
(50/40/10) OHT3	ASTM D5766 Open Hole Tension (1) [45/-45, 0, 0, 0/90, 45/-45, 0, 0] | [0, 0, -45/45, 90/0, 0, 0, -45/45]	Strength	3x2x3	3x2x3		3x2x3
(37.5/25/37.5) OHT4	ASTM D5766 Open Hole Tension (1) [90/0, 45/-45, 0/90, 0/90 | 90/0, 90/0, -45/45, 0/90]	Strength			1x2x3	1x2x3
(25/50/25 - QI) FHT1	ASTM D6742 Filled Hole Tension (2) [45/-45, 0/90], [45/-45, 90/0] | [0/90,-45/45], [90/0,-45/45]	Strength	3x2x3	3x2x3	3x2x3	3x2x3
(12.5/75/12.5) FHT2	ASTM D6742 Filled Hole Tension (2) [45/-45, 0/90, 45/-45, 45/-45] | [-45/45, -45/45, 90/0, -45/45]	Strength	3x2x3	3x2x3		3x2x3
(50/40/10) FHT3	ASTM D6742 Filled Hole Tension (2) [45/-45, 0, 0, 0/90,45/-45 , 0, 0] | [0, 0, -45/45, 90/0, 0, 0, -45/45]	Strength	3x2x3	3x2x3		3x2x3
(25/50/25 - QI) OHC1	ASTM D6484 Open Hole Compression (1) [45/-45, 0/90], [45/-45, 90/0] | [0/90,-45/45], [90/0,-45/45]	Strength		3x2x3	3x2x3	3x2x3
(12.5/75/12.5) OHC2	ASTM D6484 Open Hole Compression (1) [45/-45, 0/90, 45/-45, 45/-45] | [-45/45, -45/45, 90/0, -45/45]	Strength		3x2x3		3x2x3
(50/40/10) OHC3	ASTM D6484 Open Hole Compression (1) [45/-45, 0, 0, 0/90, 45/-45, 0, 0] | [0, 0, -45/45, 90/0, 0, 0, -45/45]	Strength		3x2x3		3x2x3
(37.5/25/37.5) OHC4	ASTM D6484 Open Hole Compression (1) [90/0, 45/-45, 0/90, 0/90] | [90/0, 90/0, -45/45, 0/90]			1x2x3		1x2x3
(25/50/25 - QI) FHC1	ASTM D6742 Filled Hole Compression (2) [45/-45, 0/90], [45/-45, 90/0] | [0/90,-45/45], [90/0,-45/45]	Strength		3x2x3	3x2x3	3x2x3
(12.5/75/12.5) FHC2	ASTM D6742 Filled Hole Compression (2) [45/-45, 0/90, 45/-45, 45/-45] | [-45/45, -45/45, 90/0, -45/45]	Strength		3x2x3		3x2x3
(50/40/10) FHC3	ASTM D6742 Filled Hole Compression (2) [45/-45, 0, 0, 0/90, 45/-45 , 0, 0] | [0, 0, -45/45, 90/0, 0, 0, -45/45]	Strength		3x2x3		3x2x3
(25/50/25 - QI) SSB1	ASTM D5961 C Single Shear Bearing (3) [45/-45, 0/90], [45/-45, 90/0] | [0/90,-45/45], [90/0,-45/45]	Strength & Deformation		3x2x3	3x2x3	3x2x3
(12.5/75/12.5) SSB2	ASTM D5961 C Single Shear Bearing (3) [45/-45, 0/90, 45/-45, 45/-45] | [-45/45, -45/45, 90/0, -45/45]	Strength & Deformation		3x2x3		3x2x3
(50/40/10) SSB3	ASTM D5961 C Single Shear Bearing (3) [45/-45, 0, 0, 0/90, 45/-45 , 0, 0] | [0, 0, -45/45, 90/0, 0, 0, -45/45]	Strength & Deformation		3x2x3		3x2x3
(50/0/50) ILT	ASTM D6415 Interlaminar Tension $[0/90]_{10S}$ made from 0/90 biaxial RF	Strength	1x1x6	1x1x6		1x1x6
(50/0/50) ILT	ASTM D6415 Interlaminar Tension $[0/90]_{10S}$ made from rotated +45/-45 bidiagonal RF	Strength	1x1x6	1x1x6		1x1x6
(25/50/25 - QI) CAI	ASTM D7136 & D7137 Compression After Impact (1500 in.lb/in) (8) [45/-45, 0/90], [45/-45, 0/90], [45/-45, 90/0] | [0/90,-45/45], [90/0,-45/45], [90/0,-45/45]	Strength		1x1x6		1x1x6

Moving Forward

UPCOMING REPORTING

- MAY 2024: Resin Infused Fiber Reinforced Materials Guidelines for Aircraft Design and Certification: Volume 1 – Qualification Framework Development

QUALIFICATION TESTING

- Lamina Testing: Select ETW1 and ETW2 environmental conditioning is complete and awaiting testing.
- Laminate Testing: Awaiting environmental conditioning to be completed.

BENEFIT TO AVIATION

- Publicly available resin infused fiber reinforced materials data along with framework for qualification.
- Guidelines generated in this program will be transitioned into shared databases, such as CMH-17


DOT/FAA/TC-xx/xx

Federal Aviation Administration
William J. Hughes Technical Center
Aviation Research Division
Atlantic City International Airport
New Jersey 08405

Resin Infused Fiber Reinforced Materials Guidelines for Aircraft Design and Certification: Volume 1 – Qualification Framework Development

2024 Technical Report

DRAFT

May 2024

Technical Report

U.S. Department of Transportation
Federal Aviation Administration

Questions?

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NATIONAL INSTITUTE FOR AVIATION RESEARCH

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