WICHITA STATE UNIVERSITY

Discontinuous Fiber Thermoplastic Composite Qualification Framework Development

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Joint Centers of Excellence for Advanced Materials

Federal Aviation Administration

center of excellence for composites and advanced materials

DFC Research Team

NIAR

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- Royal Lovingfoss
- Brandon Saathoff
- Tomas Lorik

FAA

- Larry Ilcewicz, PhD
- Cindy Ashforth
- Ahmet Oztekin, PhD
- Dave Stanley (Technical Monitor)

Sekisui Aerospace

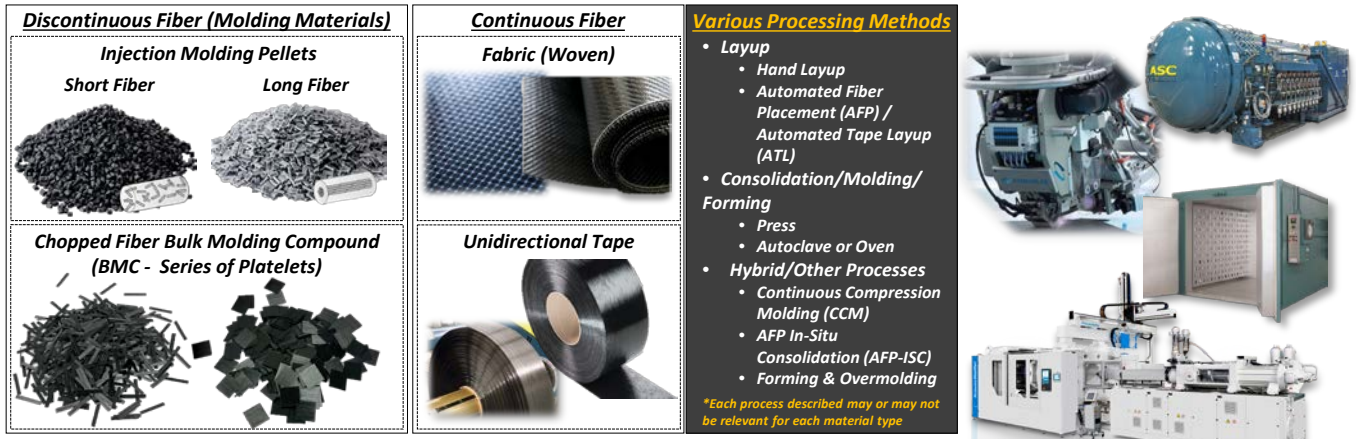
- Scott James
- Daniel Miranda



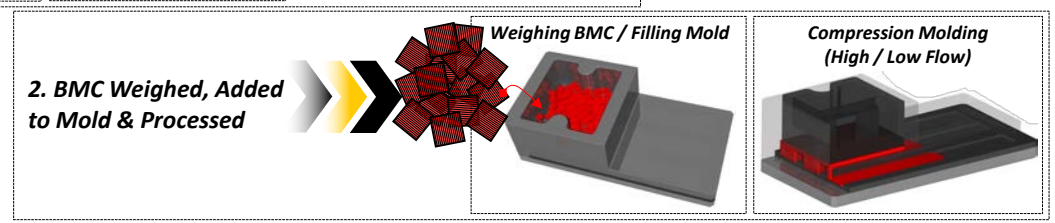

Research Partners:

DFC Background and Research Motivation

- **Thermoplastic composites** are an attractive material solution for accelerating the manufacturing production rate of aerospace structural parts/components
- **Thermoset** and **thermoplastic** polymers have been used in discontinuous fiber composite applications. Thermoplastic polymers are the most attractive due to:
  - Reduction of manufacturing cycle time
  - Increased performance (fracture toughness, chemical resistance, etc.)

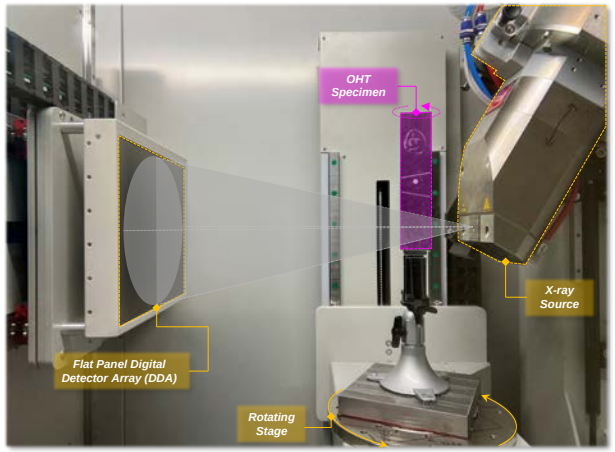


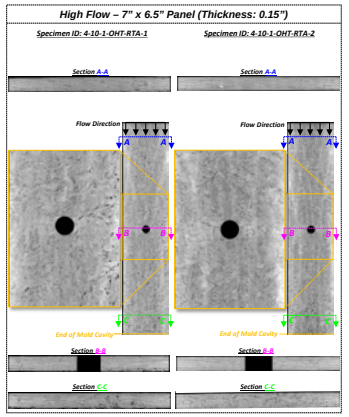
General DFC Compression Molding Process

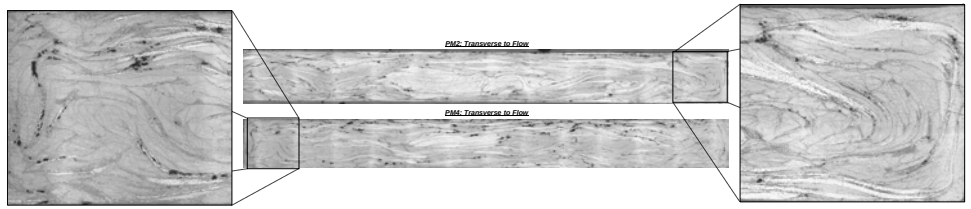


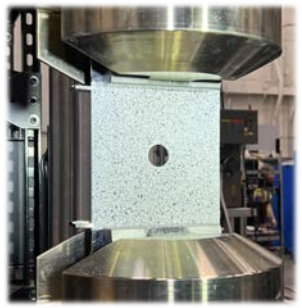
WSU-NIAR & University of Washington Collaboration

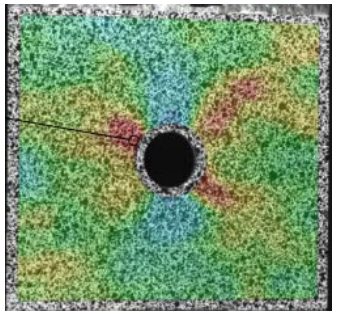
Experimental Testing





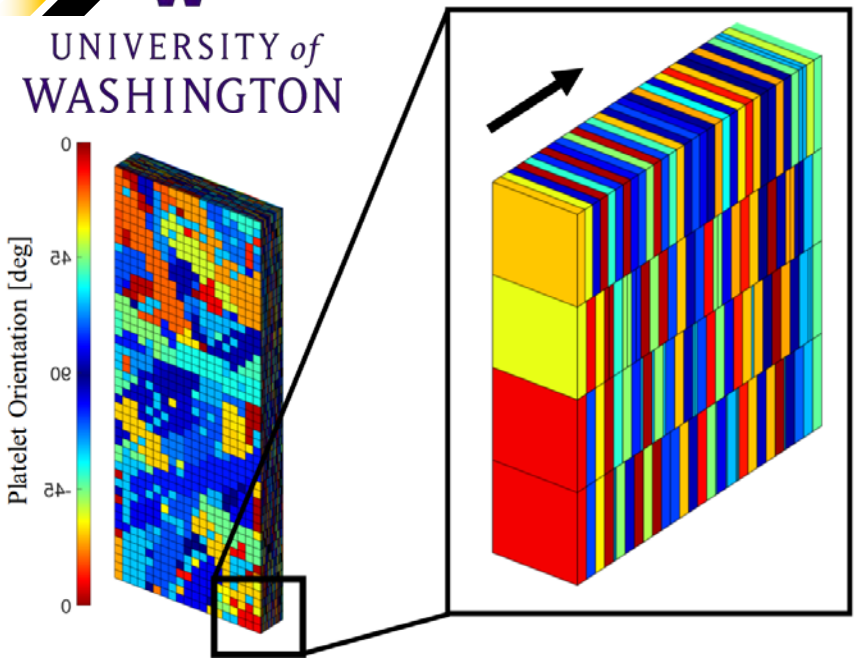


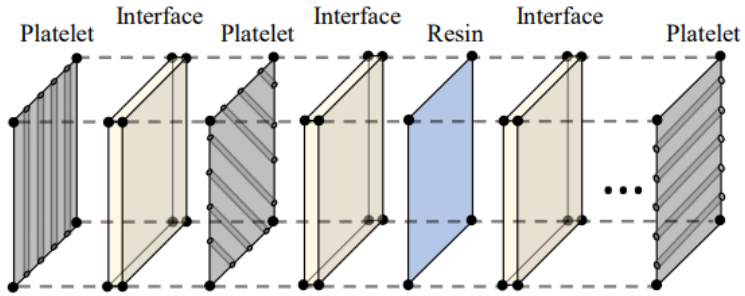




Analysis Tool Development

UNIVERSITY of WASHINGTON





*Platelet, Resin: 2D Shell, Interface: 3D Brick Cohesive Elements

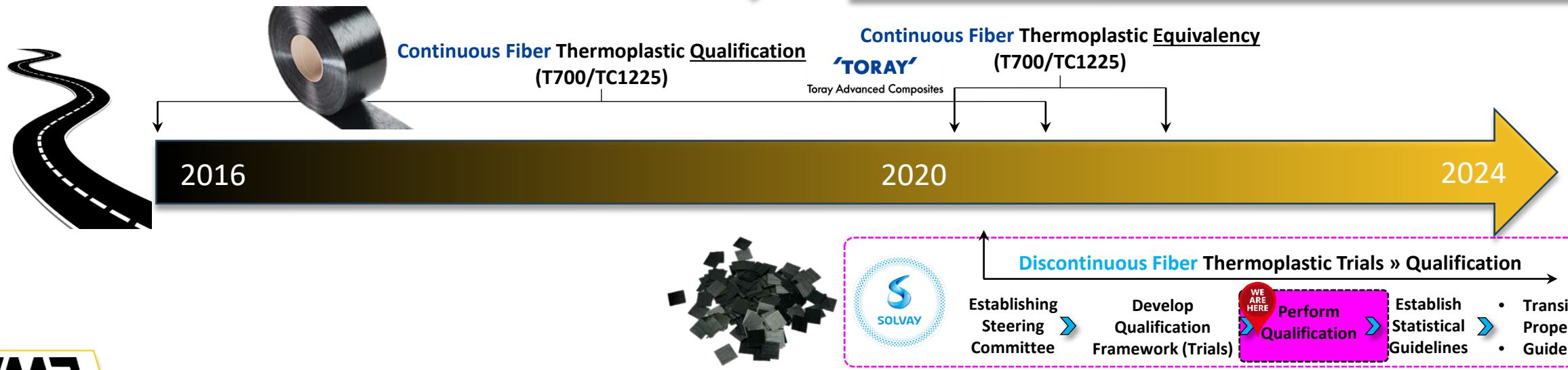
Project Overview

Overall Goals

- Develop a **framework for the qualification** of new and innovative **thermoplastic** composite material systems including guidelines and recommendations for their characterization, testing, design, and utilization.
- Second goal: To transition the test data and guidelines generated in this program into shared databases, such as **CMH-17.**

Research Outputs

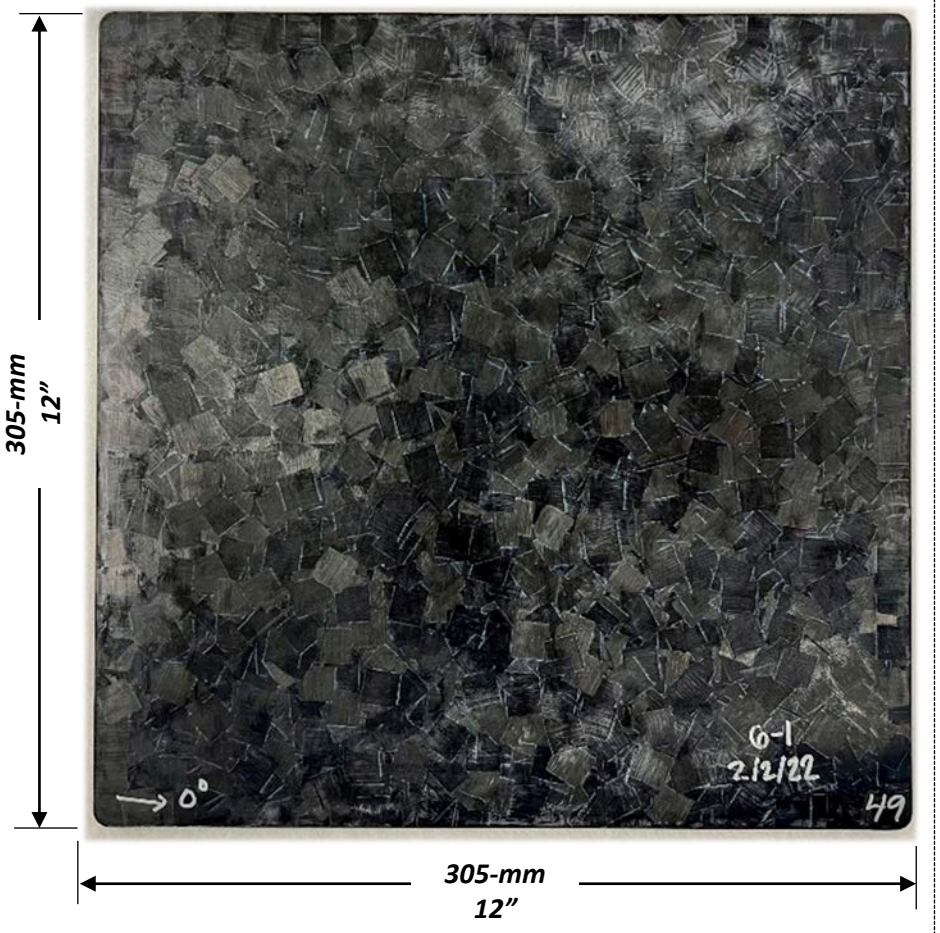
- **Trial tests** provide valuable lessons learned on temperature effects of key mechanical properties, test methods best suited for thermoplastic composites, and effects of key processing parameters
- **First public qualification of a continuous fiber thermoplastic composite** with material and process specifications
- Lessons learned, guidelines, and data made available to **CMH-17**
- **Qualification framework for chopped (discontinuous) fiber thermoplastic** composites



High Flow vs. Low Flow Panel Visual Comparison

Square Platelet – High Flow 13.5”x1.5” Panel

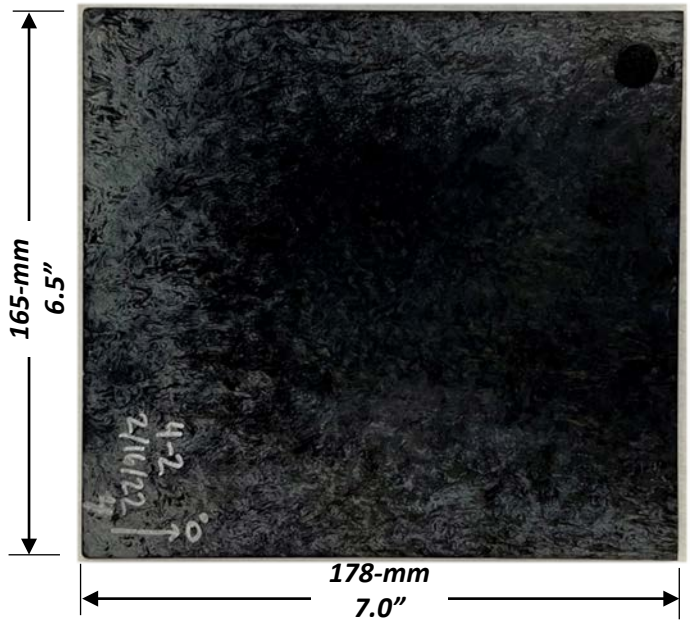
Square Platelet – Low Flow 12”x12” Panel



**panels not displayed to scale*

Flow	Platelet Size	Thickness
High Flow	Platelet Size 1	Thickness 1
		Thickness 2
	Platelet Size 2	Thickness 1
		Thickness 2
Low Flow	Platelet Size 1	Thickness 1
		Thickness 2
	Platelet Size 2	Thickness 1
		Thickness 2

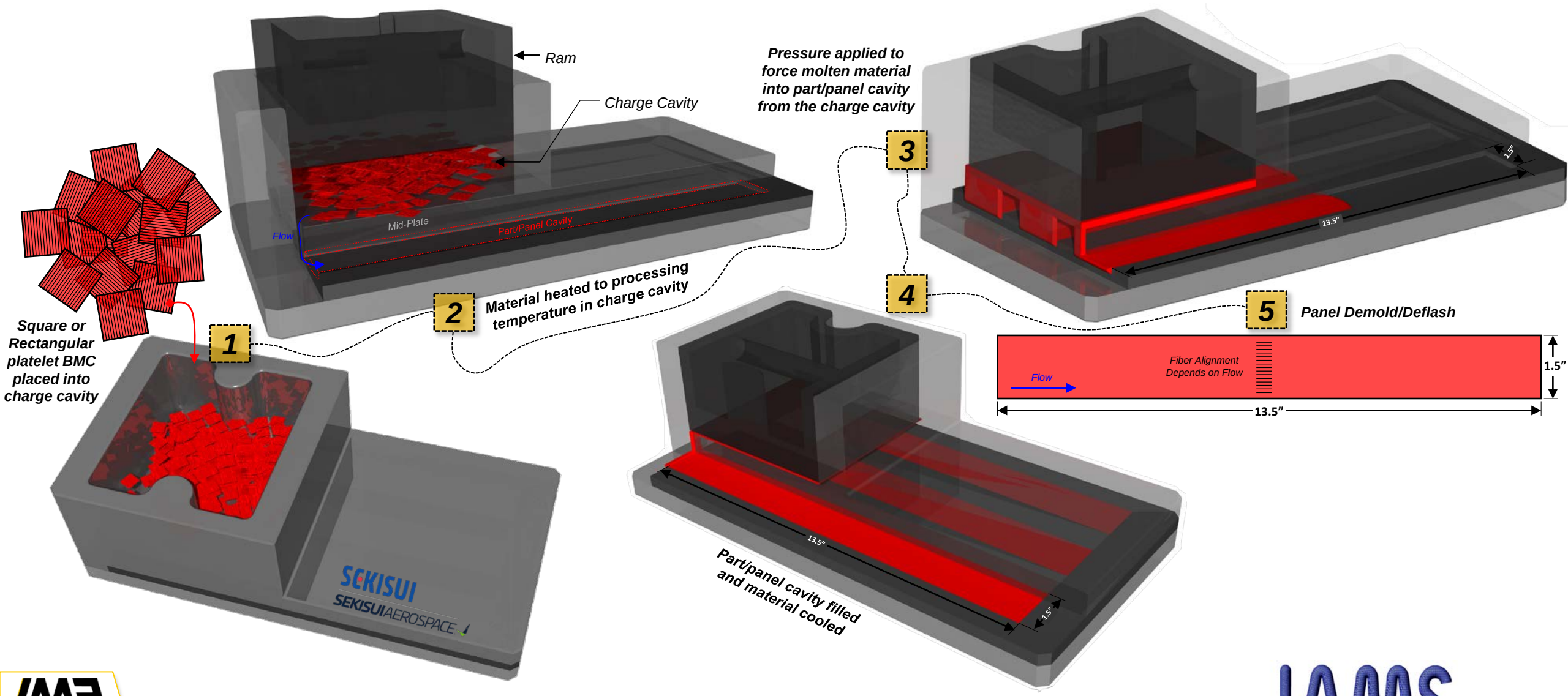
Square Platelet – High Flow 7”x6.5” Panel



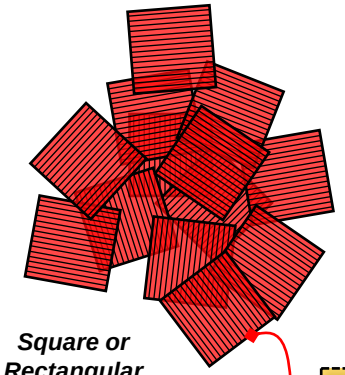
***Square* Platelet BMC**
0.5” x 0.5”

***Narrow* Platelet BMC**
0.5” x 0.0625”

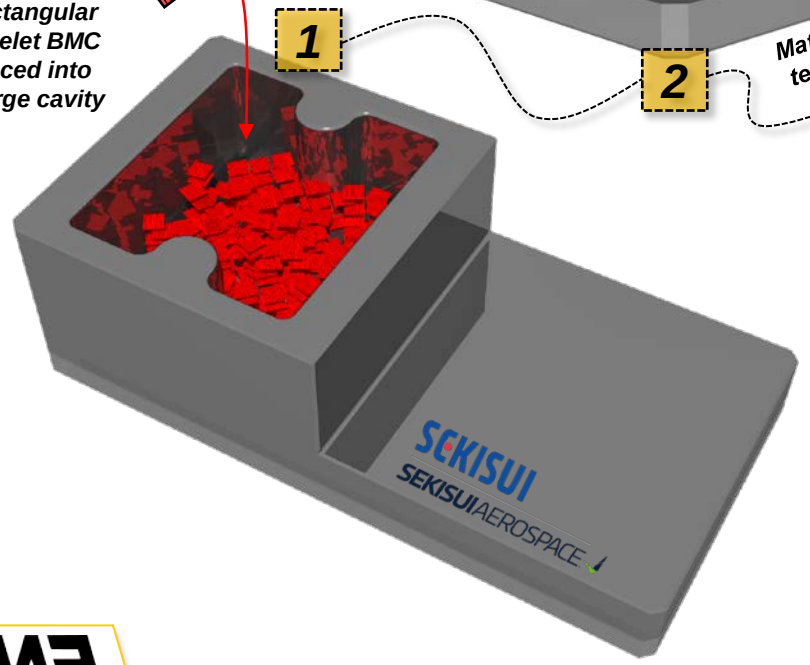
High Flow Panel Size Description – 13"x1.5"

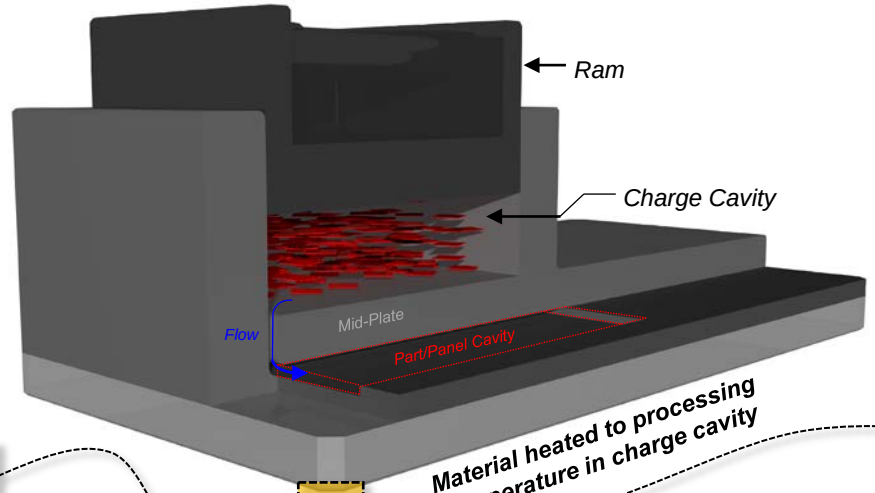


High Flow Panel Size Description – 7.0"x6.5"

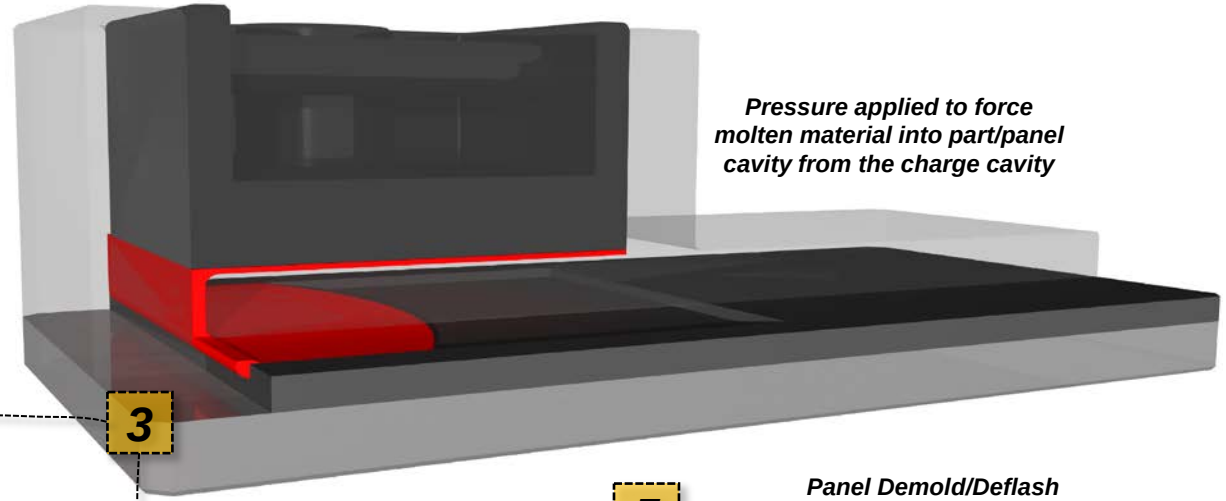


Square or Rectangular platelet BMC placed into charge cavity

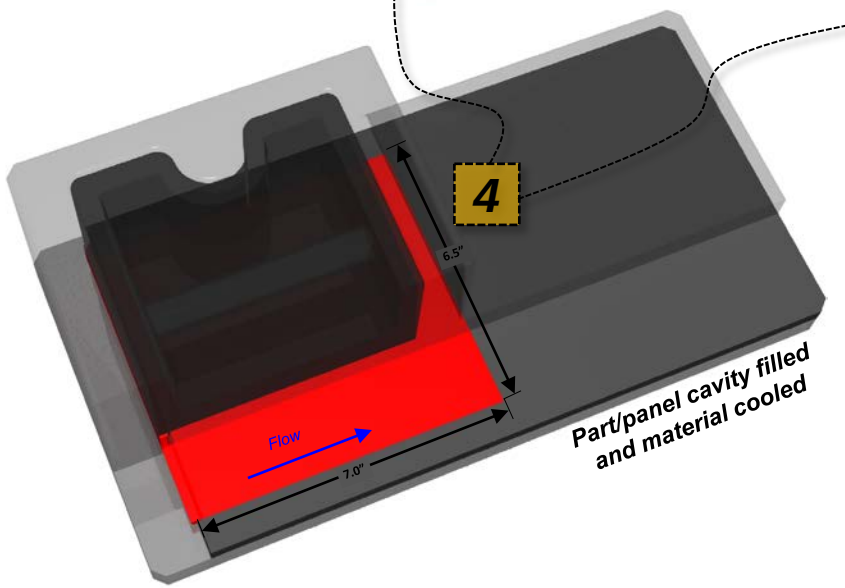




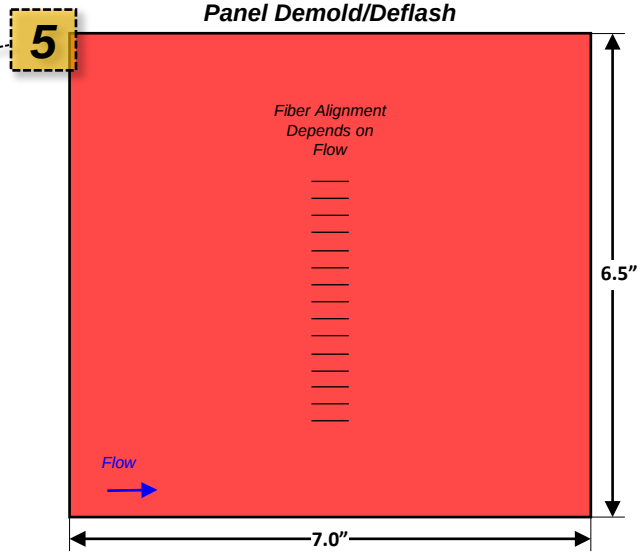
Material heated to processing temperature in charge cavity



Pressure applied to force molten material into part/panel cavity from the charge cavity

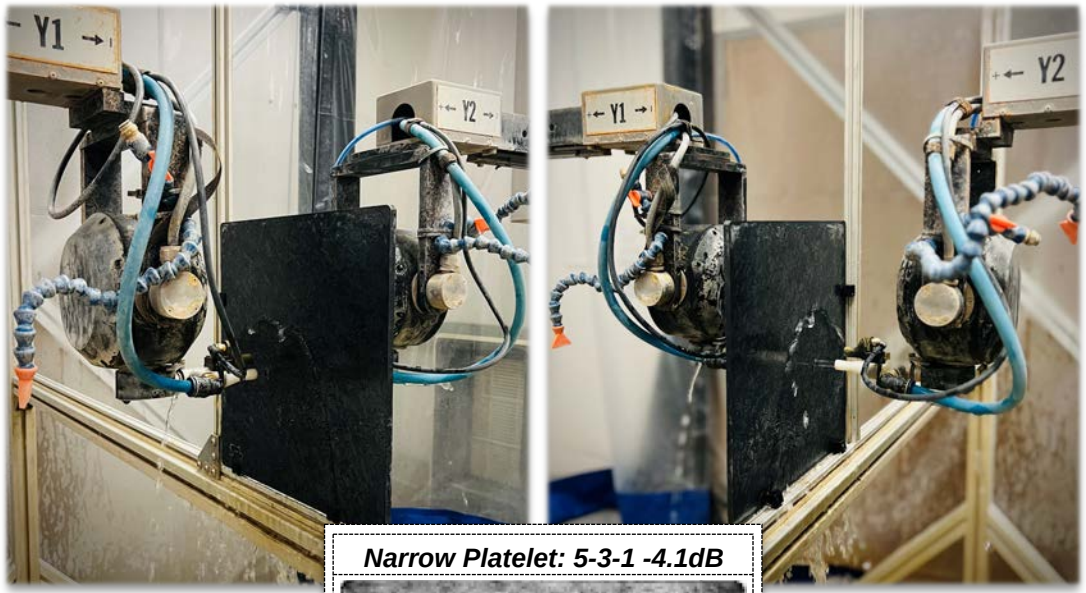


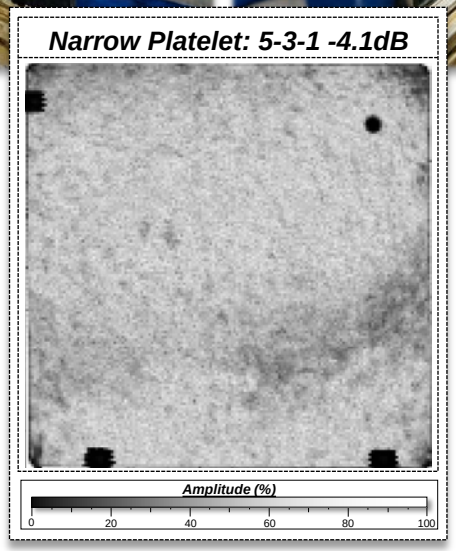
Part/panel cavity filled and material cooled



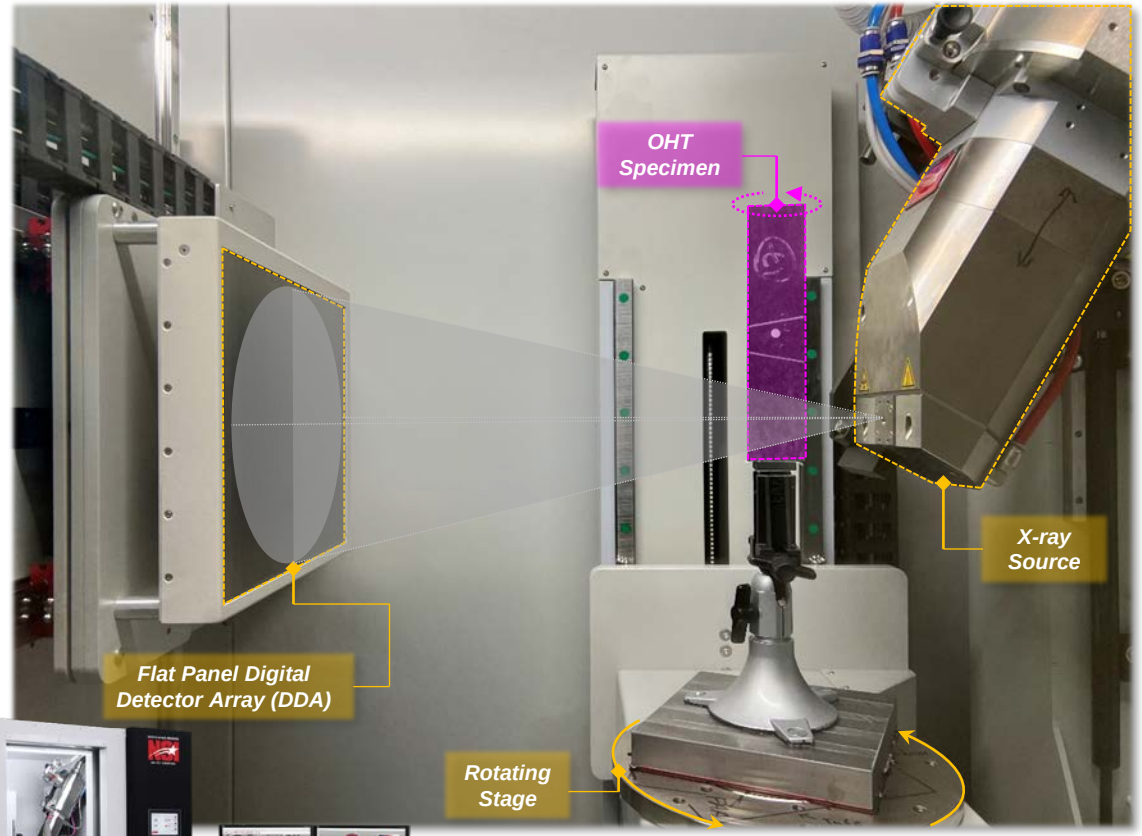
Non-Destructive Inspection Techniques

Through-Transmission Ultrasonic Inspections





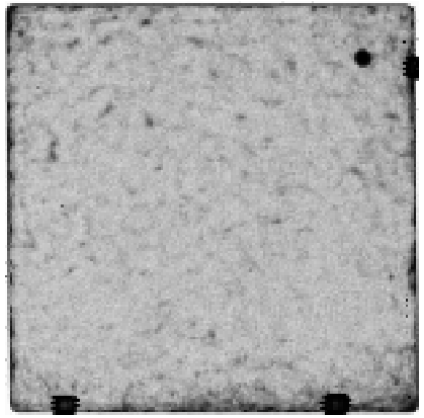
X-Ray Computed Tomography Inspection



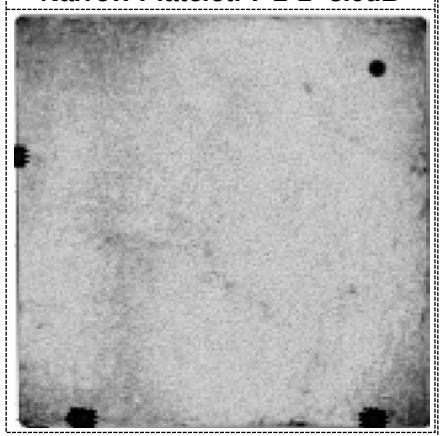
Summary of TTU C-Scan Results

Low Flow 12.0” x 12.0” Panel (Thickness: 0.15”)

Square Platelet: 8-1-3 -5.9dB



Narrow Platelet: 7-2-1 -5.9dB



High Flow 12.5” x 1.5” Panel (Thickness: 0.15”)

Square Platelet

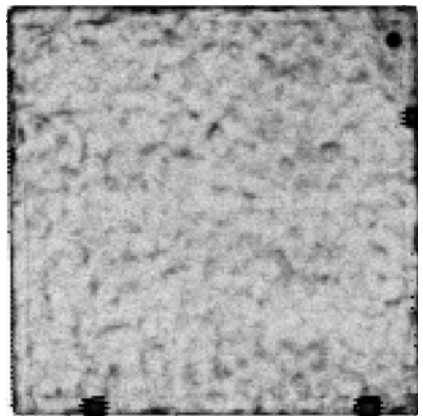
3-3-1-1 -5.9dB	3-3-1-1 7dB
	

Narrow Platelet

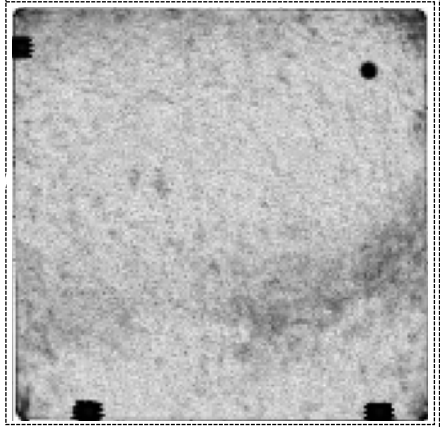
4-19-1-2 -5.9dB	4-19-1-2 7dB
	

Low Flow 12.0” x 12.0” Panel (Thickness: 0.25”)

Square Platelet: 6-1-1 -4.1dB

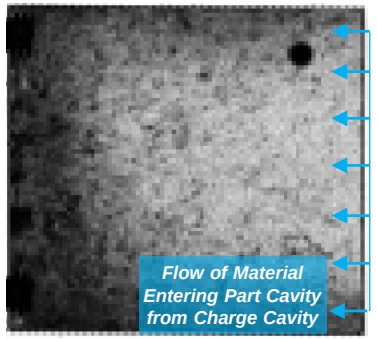


Narrow Platelet: 5-3-1 -4.1dB

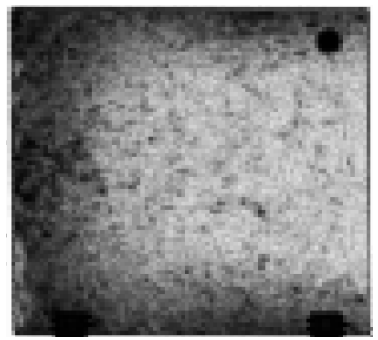


High Flow 7.0”x 6.5” Panel (Thickness: 0.15”)

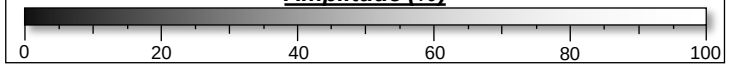
Square Platelet: 4-6-2 -5.9dB



Narrow Platelet: 3-8-2 -5.9dB



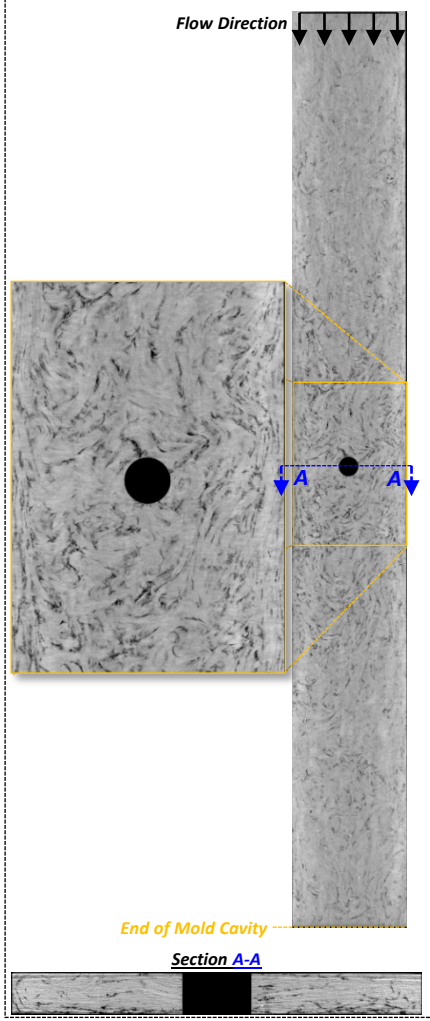
Amplitude (%)



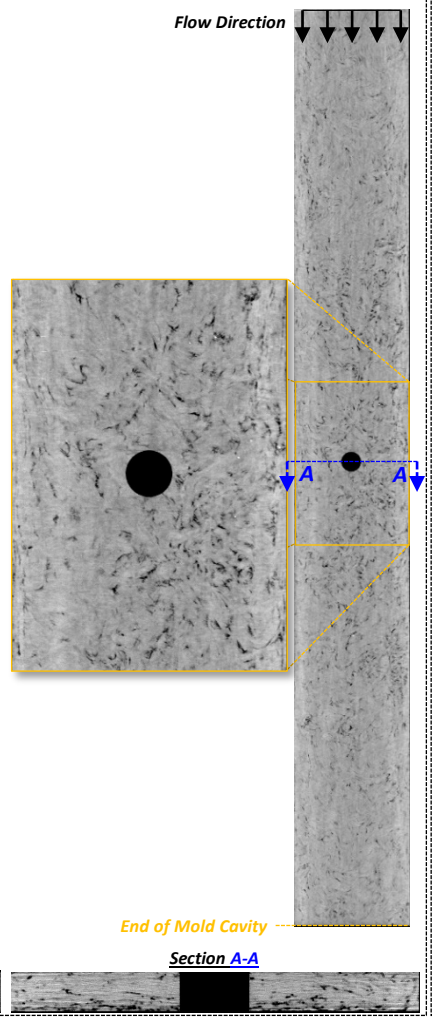
Square Platelet (0.5" x 0.5") – XRCT Process Comparisons

High Flow – 13.5" x 1.5" Panel (Thickness: 0.15")

Specimen ID: 4-9-1-OHT-RTA-1

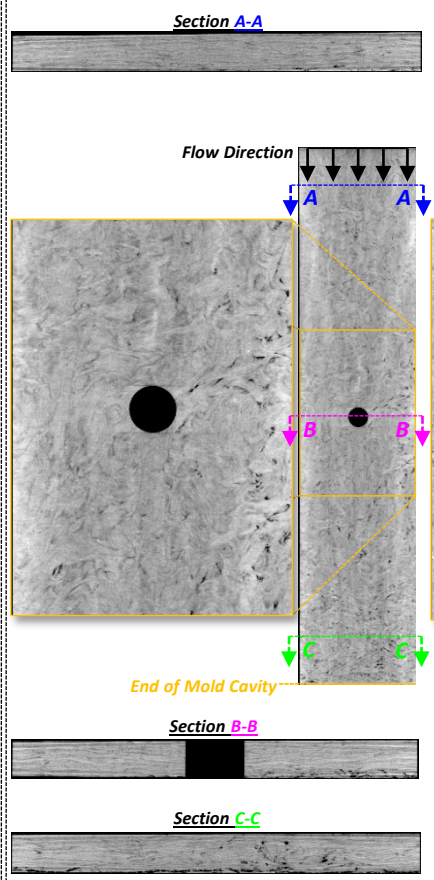


Specimen ID: 4-9-1-OHT-RTA-2

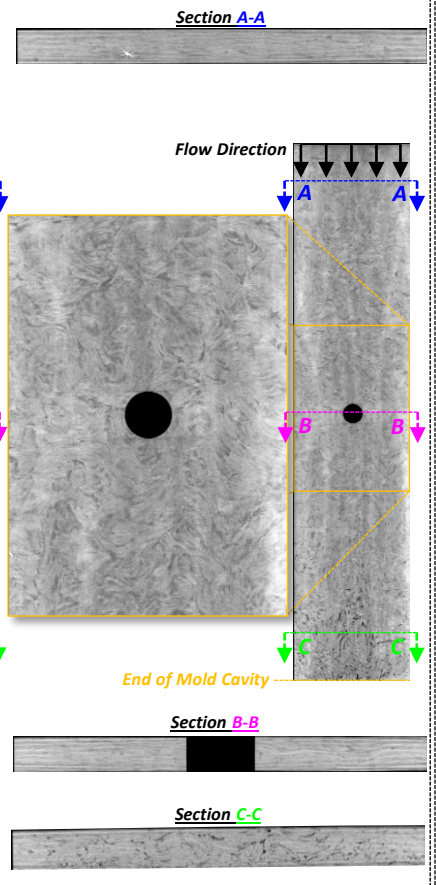


High Flow – 7" x 6.5" Panel (Thickness: 0.15")

Specimen ID: 4-10-1-OHT-RTA-1

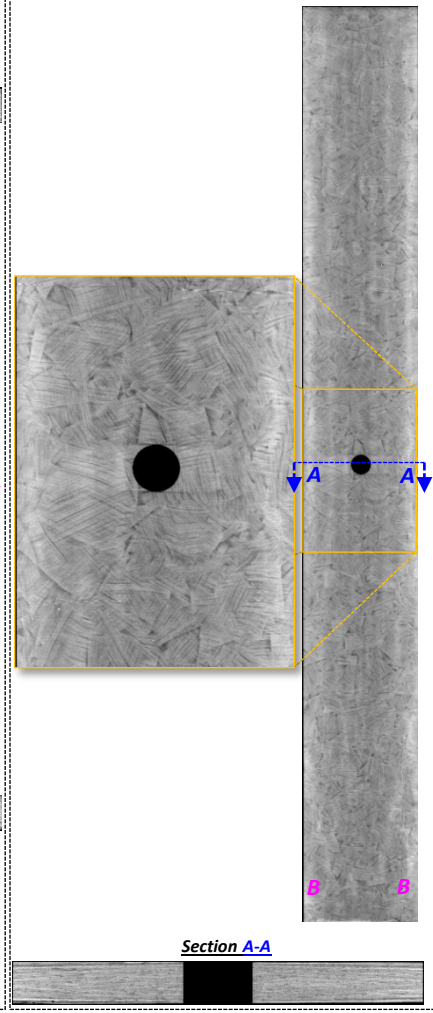


Specimen ID: 4-10-1-OHT-RTA-2

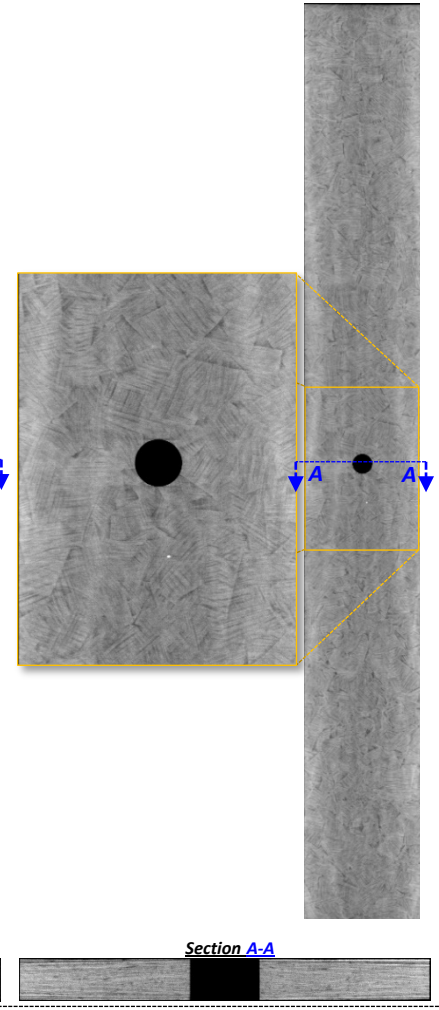


Low Flow – 12" x 12" Panel (Thickness: 0.15")

Specimen ID: 8-7-1-OHT-RTA-1

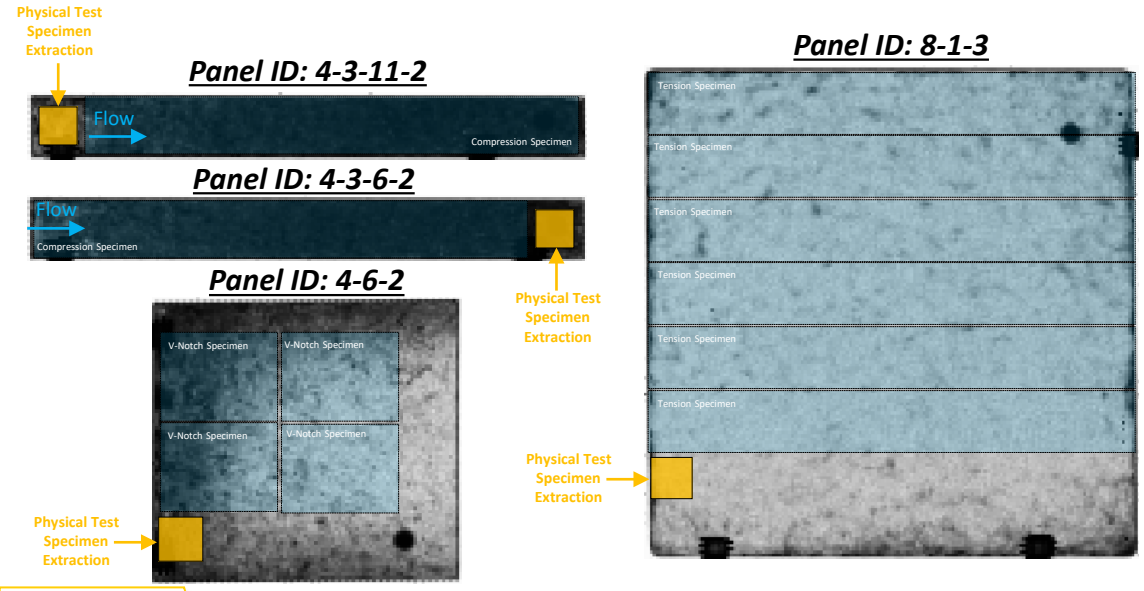


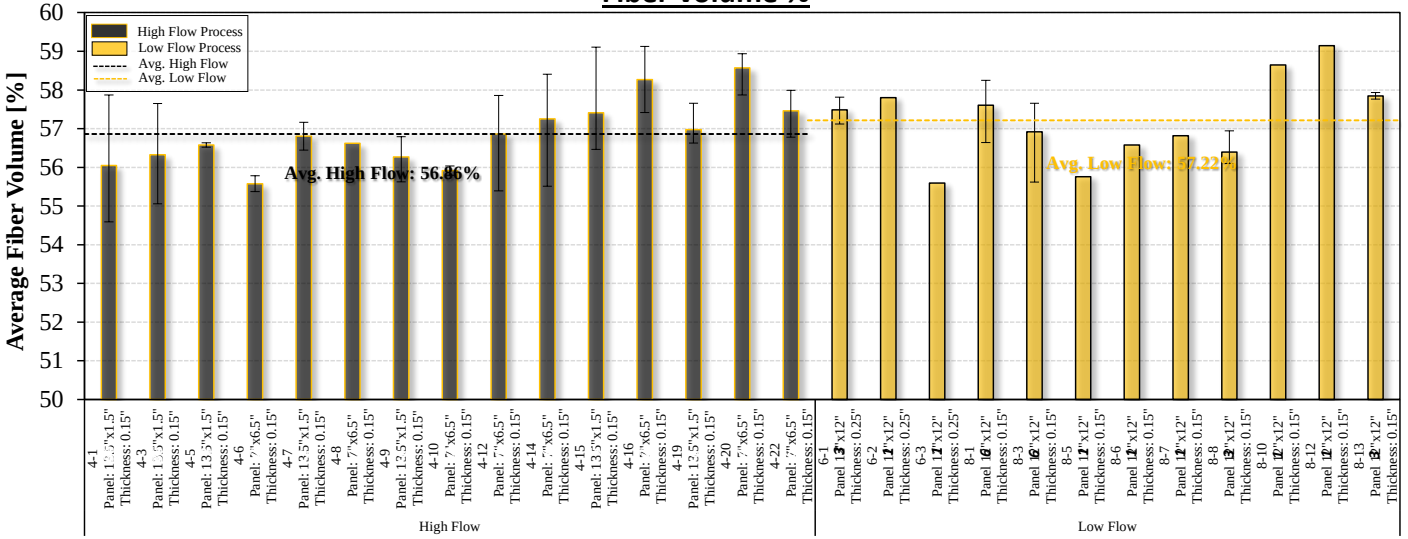
Specimen ID: 8-7-1-OHT-RTA-2

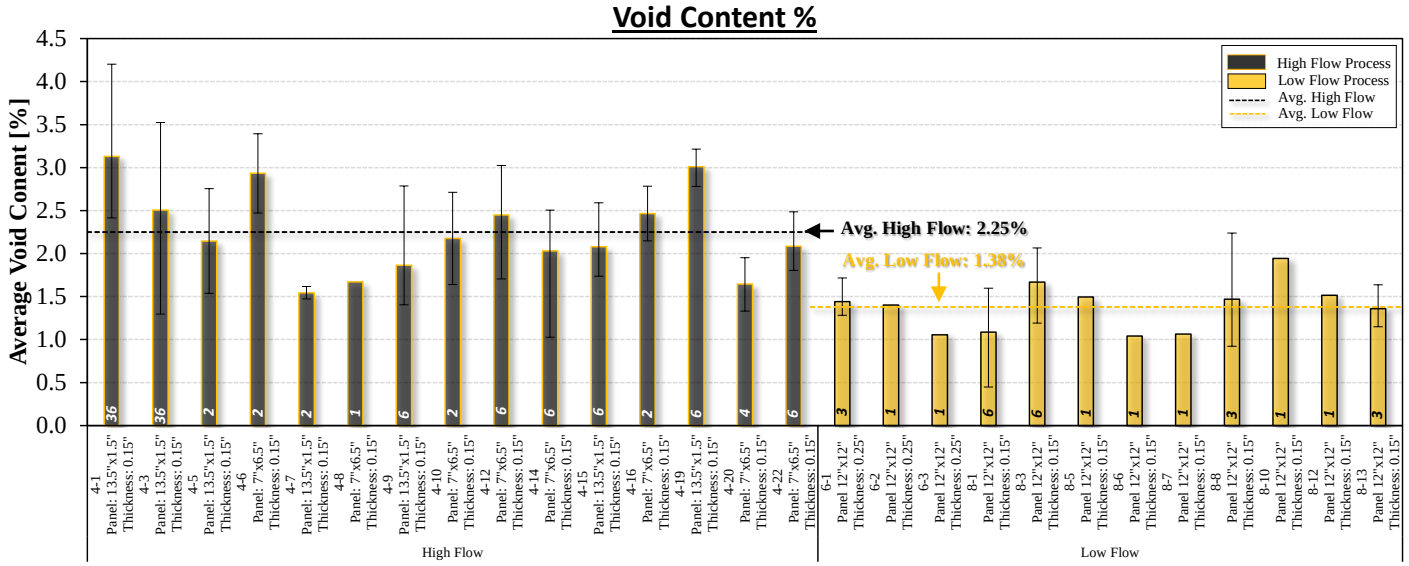


Square Platelet Panel Fiber Volume & Void Content

- Fiber & Void Content
  - ≈1” x 0.5” samples (*target≈1.5-grams*) extracted from each panel (locations documented for each panel)
    - ASTM D792-13 “*Standard Test Methods for Density and Specific Gravity (Relative Density) of Plastics by Displacement*”
    - ASTM D3171-15 “*Standard Test Methods for Constituent Content of Composite Materials*” (Method I, Procedure B)
    - ASTM D2734-16 “*Standard Test Methods for Void Content of Reinforced Plastics*”
  - Density:
    - **Resin: 1.31 g/cc** (%crystalline=30%)
    - **Fiber: 1.79 g/cc**







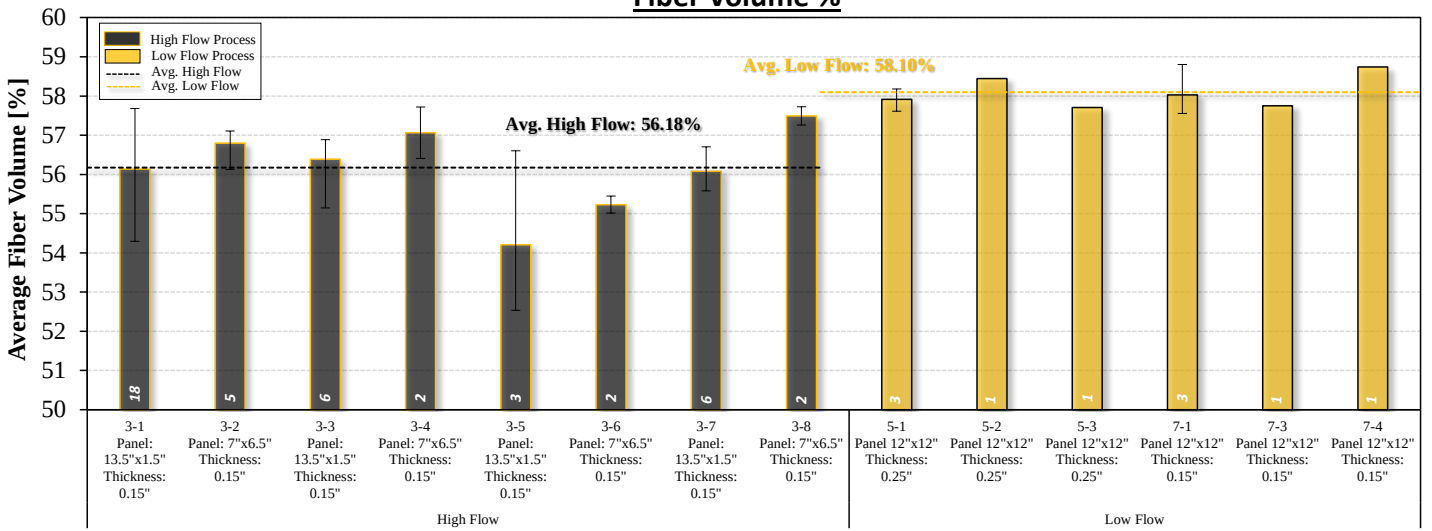
Narrow Platelet Panel Fiber Volume & Void Content

- Fiber & Void Content
  - ≈1” x 0.5” samples (*target≈1.5-grams*) extracted from each panel (locations documented for each panel)
    - ASTM D792-13 “*Standard Test Methods for Density and Specific Gravity (Relative Density) of Plastics by Displacement*”
    - ASTM D3171-15 “*Standard Test Methods for Constituent Content of Composite Materials*” (Method I, Procedure B)
    - ASTM D2734-16 “*Standard Test Methods for Void Content of Reinforced Plastics*”
  - Density:
    - **Resin: 1.31 g/cc** (%crystalline=30%)
    - **Fiber: 1.79 g/cc**

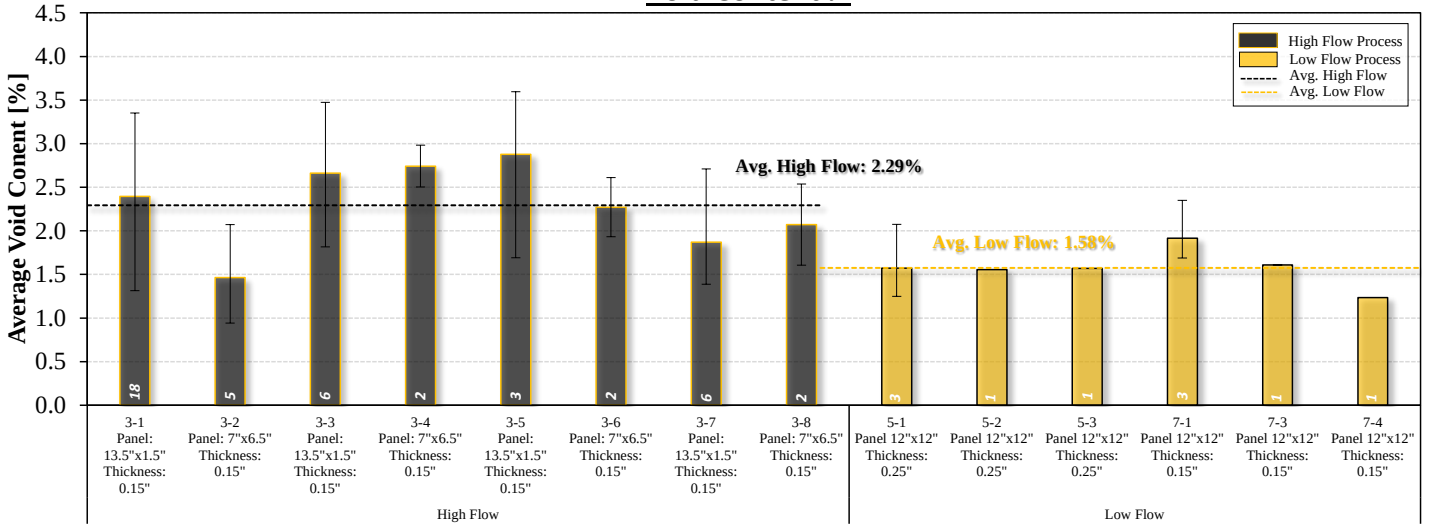
Square and Narrow Platelet Comparisons

Platelet	Flow	Property	Average	Specimen Qty
Square (0.5" x 0.5")	High	Fiber Volume [%]	56.863	123
		Void Content Volume [%]	2.249	
	Low	Fiber Volume [%]	57.216	28
		Void Content Volume [%]	1.378	
Narrow (0.5" x 0.0625")	High	Fiber Volume [%]	56.175	44
		Void Content Volume [%]	2.294	
	Low	Fiber Volume [%]	58.097	11
		Void Content Volume [%]	1.575	

Fiber Volume %



Void Content %



Mechanical Test Matrix

Square Platelets (0.5" x 0.5")													Narrow Platelets (0.5" x 0.0625")												
Flow	Thickness (in.)	Test Type	Flow Direction	Panel Size (in.)	Geometry (in.)	ASTM Method Description	CTA -65F	RTA	ETA1 180F	ETW1 180F	ETA2 350F	ETW2 350F	Flow	Thickness (in.)	Test Type	Flow Direction	Panel Size (in.)	Geometry (in.)	ASTM Method Description	CTA -65F	RTA	ETA1 180F	ETW1 180F	ETA2 350F	ETW2 350F
High	0.15"	UNT	Long.	13.5" x 1.5"	12.0" x 1.5"	D3039	6	6	6	6	6	6	High	0.15"	UNT	Long.	13.5" x 1.5"	12.0" x 1.5"	D3039		6	6		6	
		UNT	Trans.	7.0" x 6.5"	7.0" x 1.5"	D3039	6	6	6	6	6	6			UNT	Trans.	7.0" x 6.5"	7.0" x 1.5"	D3039		6	6		6	
		UNC	Long.	13.5" x 1.5"	12.0" x 1.5"	D8066	6	6	6	6	6	6			UNC	Long.	13.5" x 1.5"	12.0" x 1.5"	D8066		6				
		UNC	Trans.	7.0" x 6.5"	7.0" x 1.5"	D8066	6	6	6	6	6	6			UNC	Trans.	7.0" x 6.5"	7.0" x 1.5"	D8066		6				
		V-Notched Rail Shear	Long.	13.5" x 1.5"	3.0" x 1.5"	D7078		6							V-Notched Rail Shear	Long.	13.5" x 1.5"	3.0" x 1.5"	D7078		6				
		V-Notched Rail Shear	Trans.	7.0" x 6.5"	3.0" x 2.2"	D7078		6							V-Notched Rail Shear	Trans.	7.0" x 6.5"	3.0" x 2.2"	D7078		6				
		Flexural (3-Pt Bend)	Long.	13.5" x 1.5"	5.5" x 0.5"	D790, 3 pt bend		6							Open Hole Tension	Long.	13.5" x 1.5"	13.0" x 1.5"	D5766, Ø:0.25"		6				
		Flexural (3-Pt Bend)	Trans.	7.0" x 6.5"	5.5" x 0.5"	D790, 3 pt bend		6							Open Hole Tension	Trans.	7.0" x 6.5"	7.0" x 1.5"	D5766, Ø:0.25"		6				
		OHT	Long.	13.5" x 1.5"	12.0" x 1.5"	D5766, Ø:0.25"		6					Low	0.25"	UNT	N/A	12.0" x 12.0"	12.0" x 1.5"	D3039		6	6		6	
		OHT	Trans.	7.0" x 6.5"	7.0" x 1.5"	D5766, Ø:0.25"		6							UNC		12.0" x 12.0"	12.0" x 1.5"	D8066		6				
		OHT	Long.	7.0" x 6.5"	7.0" x 4.5"	D5766, Ø:0.75"		6							V-Notched Rail Shear		12.0" x 12.0"	3.0" x 2.2"	D7078		6				
		OHT	Trans.	7.0" x 6.5"	7.0" x 4.5"	D5766, Ø:0.75"		6							OHT		12.0" x 12.0"	12.0" x 1.5"	D5766, Ø:0.25"		6				
		OHT	Long.	7.0" x 6.5"	7.0" x 6.0"	D5766, Ø:1.0"		6						0.15"	UNT		12.0" x 12.0"	12.0" x 1.5"	D3039		6	6		6	
		OHT	Trans.	7.0" x 6.5"	7.0" x 6.0"	D5766, Ø:1.0"		6							UNC		12.0" x 12.0"	12.0" x 1.5"	D8066		6				
		OHC	Long.	13.5" x 1.5"	12.0" x 1.5"	D6484, Ø:0.25"		6							V-Notched Rail Shear		12.0" x 12.0"	3.0" x 2.2"	D7078		6				
		OHC	Trans.	7.0" x 6.5"	7.0" x 1.5"	D6484, Ø:0.25"		6							OHT		12.0" x 12.0"	12.0" x 1.5"	D5766, Ø:0.25"		6				
		SSB	Long.	13.5" x 1.5"	5.5" x 1.5"	D596,C, Ø:0.25"		6																	
		SSB	Trans.	7.0" x 6.5"	5.5" x 1.5"	D5961,C, Ø:0.25"		6																	
		CAI	Long.	7.0" x 6.5"	6.0" x 4.0"	D7136/D7137		6																	
		CAI	Trans.	7.0" x 6.5"	6.0" x 4.0"	D7136/D7137		6																	
Low	0.25"	UNT	N/A	12.0" x 12.0"	12.0" x 1.5"	D3039		6	6		6														
		UNC		12.0" x 12.0"	12.0" x 1.5"	D8066		6																	
		V-Notched Rail Shear		12.0" x 12.0"	3.0" x 2.2"	D7078		6																	
		OHT		12.0" x 12.0"	12.0" x 1.5"	D5766, Ø:0.25"		6																	
	0.15"	UNT		12.0" x 12.0"	12.0" x 1.5"	D3039	6	6	6	6	6	6													
		UNC		12.0" x 12.0"	12.0" x 1.5"	D8066	6	6	6	6	6	6													
		V-Notched Rail Shear		12.0" x 12.0"	3.0" x 2.2"	D7078		6																	
		Flexural (3-Pt Bend)		12.0" x 12.0"	5.5" x 0.5"	D790		6																	
		OHT		12.0" x 12.0"	12.0" x 1.5"	D5766, Ø:0.25"		6																	
		OHT		12.0" x 12.0"	12.0" x 4.5"	D5766, Ø:0.75"		6																	
		OHT		12.0" x 12.0"	12.0" x 6"	D5766, Ø:1.0"		6																	
		OHC		12.0" x 12.0"	12.0" x 1.5"	D6484, Ø:0.25"		6																	
		SSB		12.0" x 12.0"	5.5". x 4.0"	D5961,C, Ø:0.25"		6																	
		CAI		12.0" x 12.0"	6.0" x 1.5"	D7136/D7137		6																	

Total: 396 Square Platelet Specimens

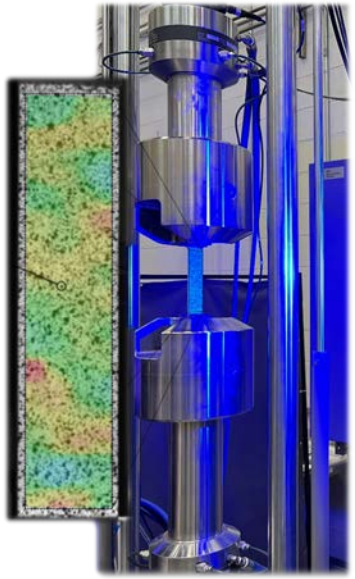
Total: 144 Narrow Platelet Specimens

Square & Narrow Platelet Tension Comparison

- In the majority of alike configurations, the narrow platelet material resulted in higher strengths and moduli in comparison to the square platelet material
  - High Flow (Long. To Flow) high C.V. and lower average strength
  - Significant difference in strength witnessed for low flow configurations
- High variability witnessed for ETA 350°F & ETW 350°F condition (strength and modulus)
- Similar strength and modulus witnessed for 0.25” & 0.15” thick specimens

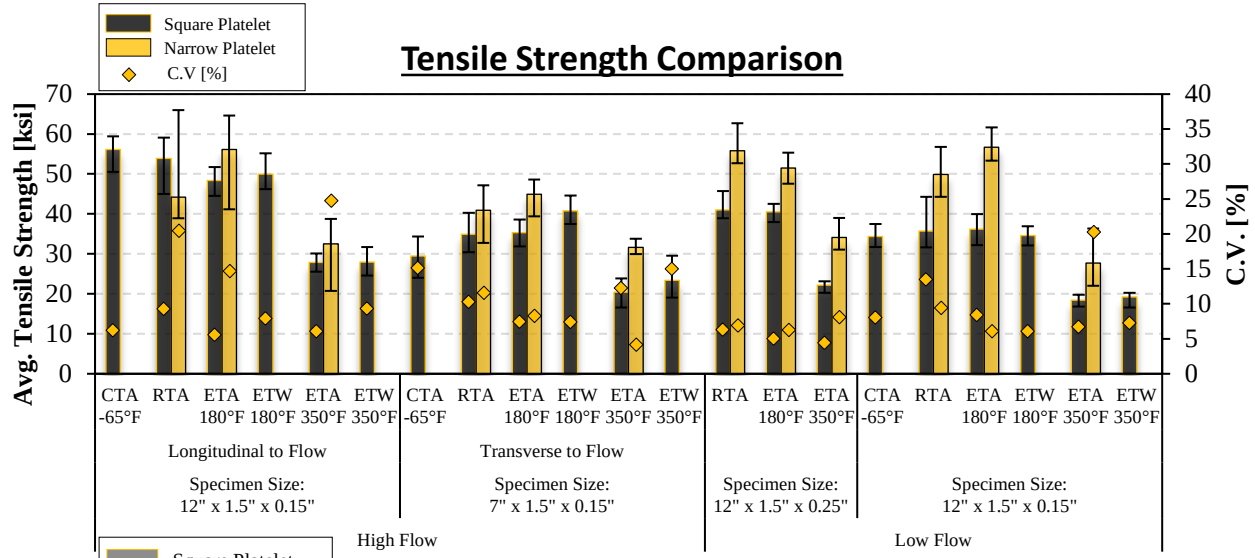
CTD (-65°F) / ETA (180°F)
Test Setup (Bi-Axial Ext)

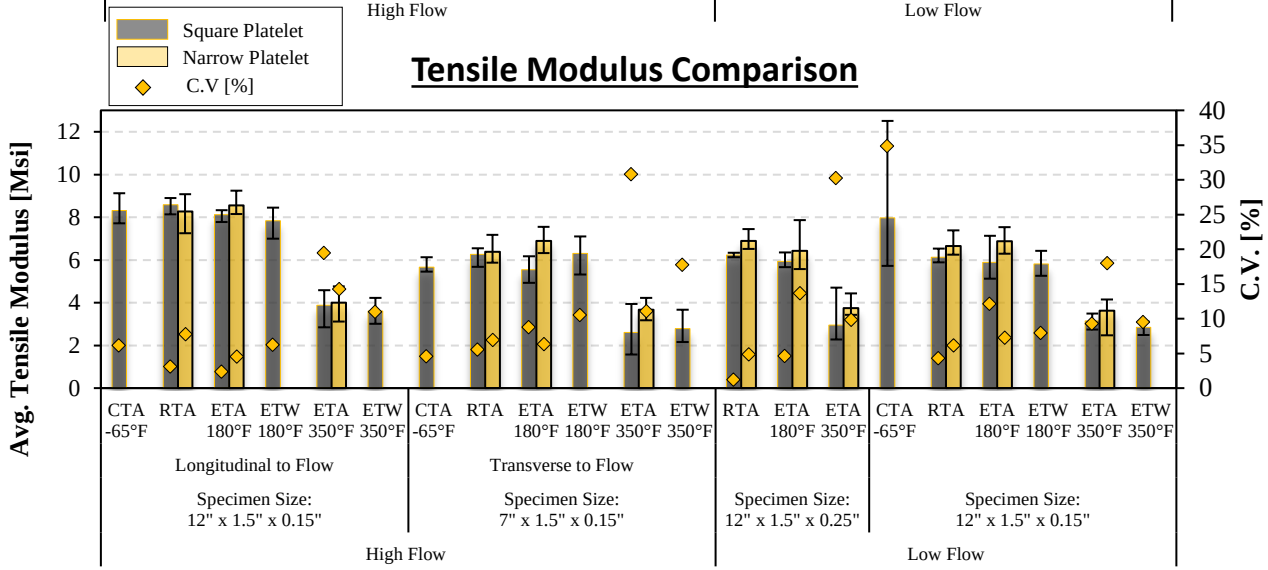
RTA
Test Setup (DIC)



ETA/ETW (350°F)
Test Setup (Uni-Axial Ext 2” GL)

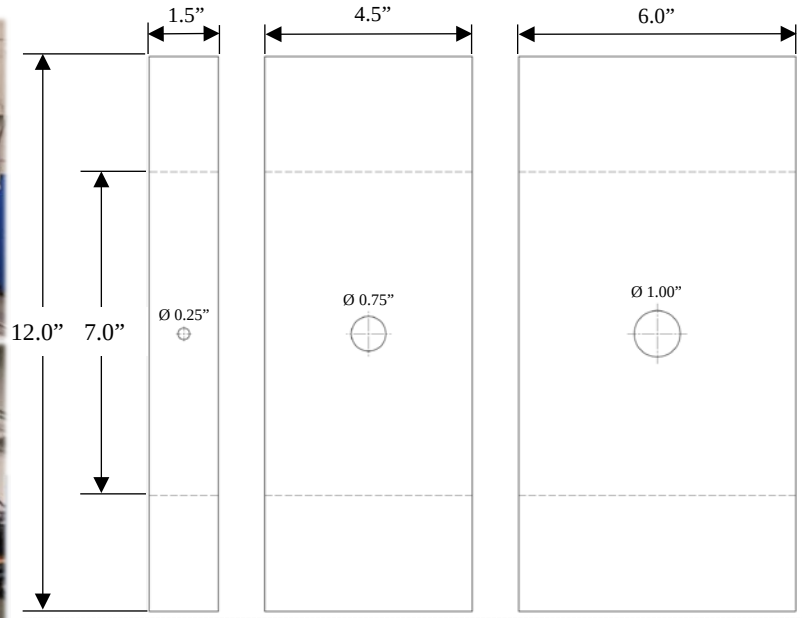
2” gage length used to encompass more platelets





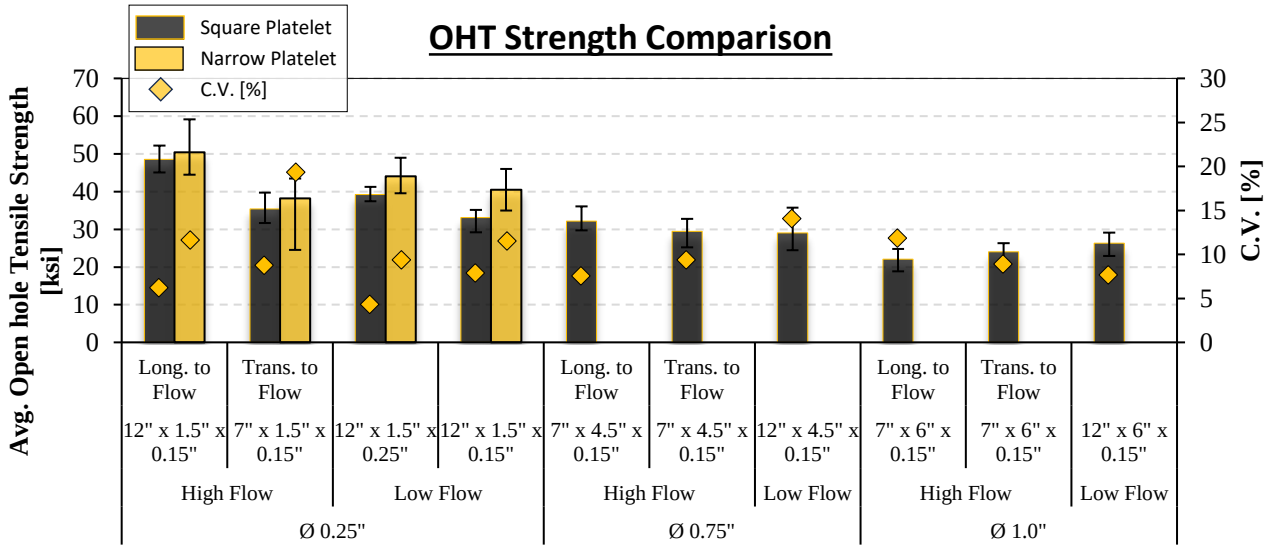
Square & Narrow Platelet Open Hole Tension (OHT) Comparison

- The propensity for failure away from the hole was high in the Ø0.25” hole.
  - Notched strength was similar to un-notched strength
- Ø0.75” & Ø1.0” specimen configurations had 100% failure through the hole.
  - Specimens with Ø0.75” experienced a knock down of approx. 20% (longitudinal 40%)
  - Specimens with Ø1.0” experienced a knock down of approx. 30% (longitudinal 60%)

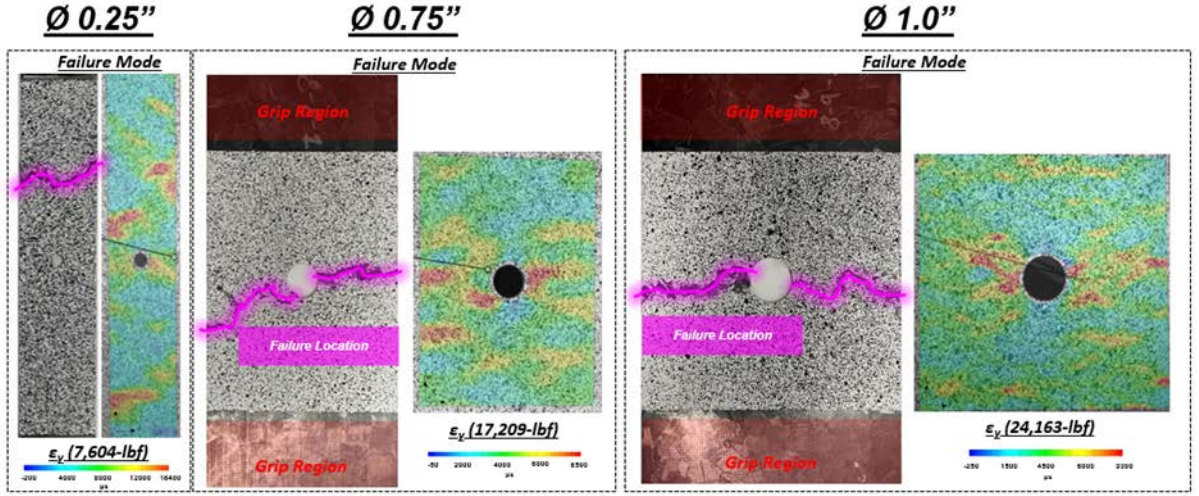


>> **12.0-in length** used for 13.5-in x 1.5-in High Flow panels & Low Flow 12.0-in x 12.0-in panels
>> **7.0-in length** used for 7.0-in x 6.5-in High Flow Panels

OHT Strength Comparison

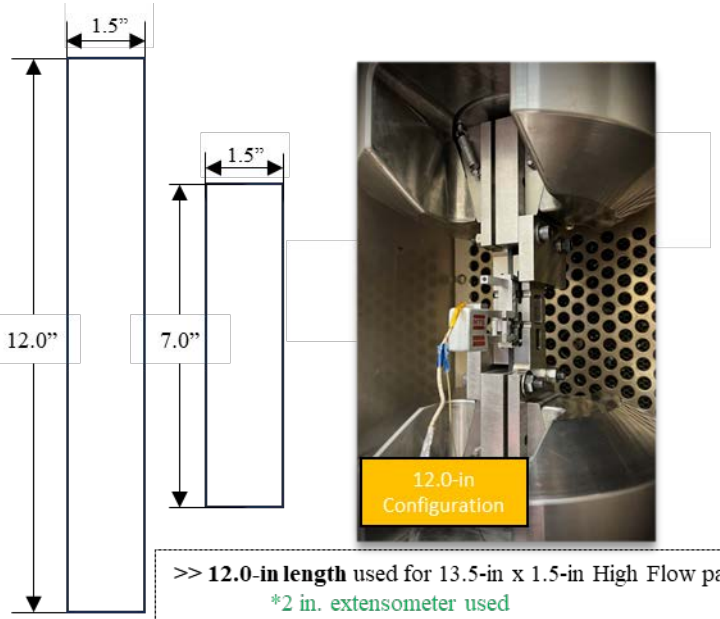


OHT Hole Diameter Comparison

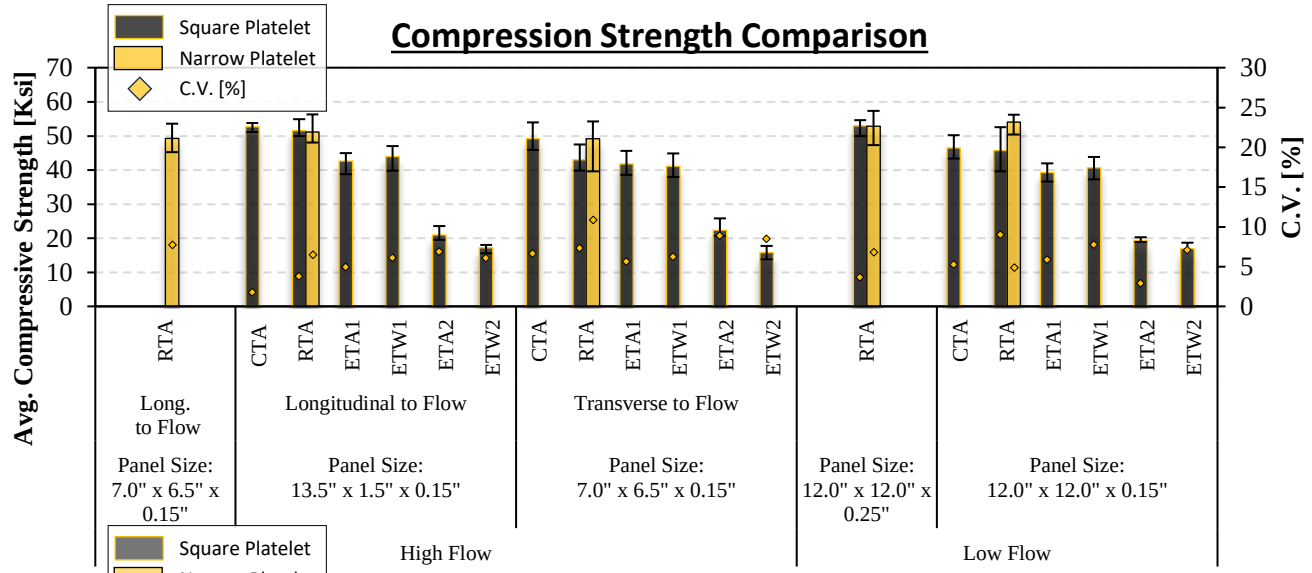


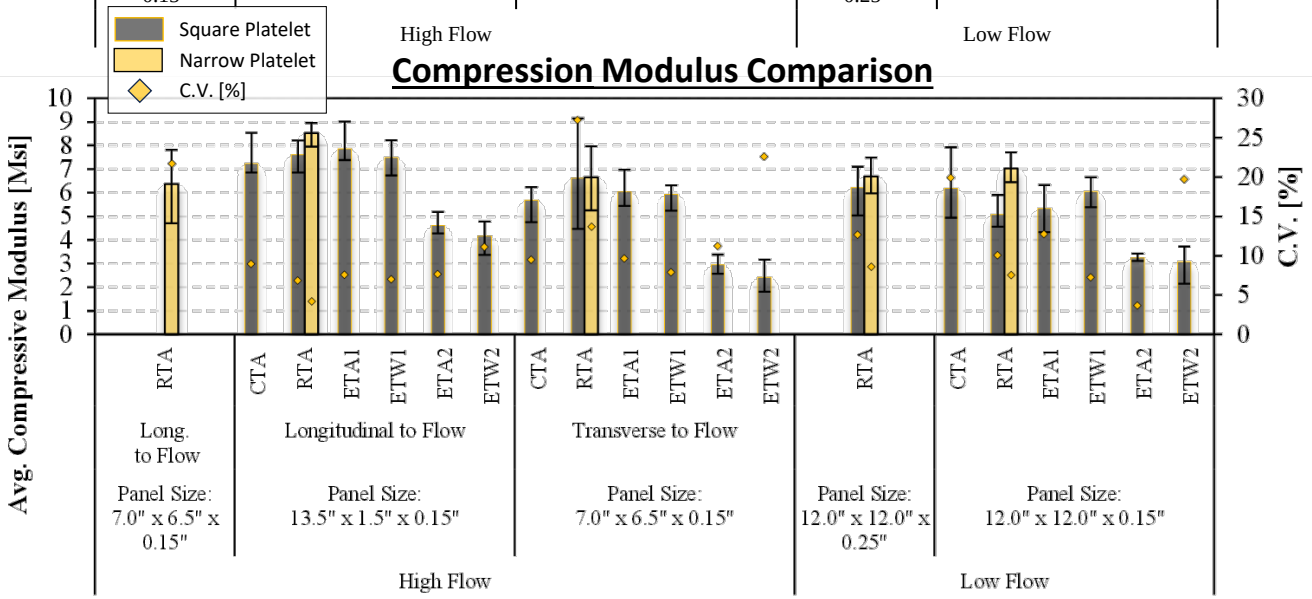
Square & Narrow Platelet Compression Comparison

- The square and narrow platelet specimens performed similarly in respective configurations
  - High Flow Square Platelet (Transverse To Flow) lower strength than expected
  - Similar strengths witnessed between both flow conditions
- Additional specimen batch used to compare compressive properties between different panel sizes



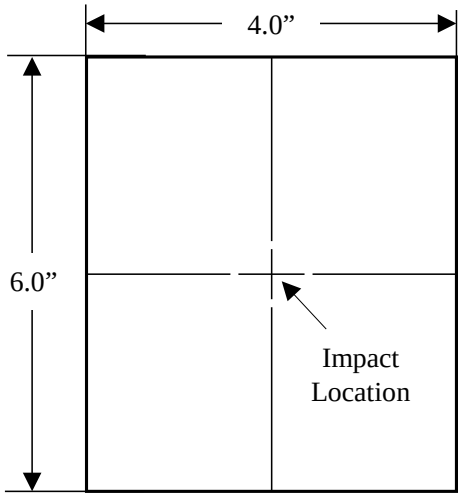
>> **12.0-in length** used for 13.5-in x 1.5-in High Flow panels & Low Flow 12.0-in x 12.0-in panels
*2 in. extensometer used
>> **7.0-in length** used for 7.0-in x 6.5-in High Flow Panels
*1 in. extensometer used



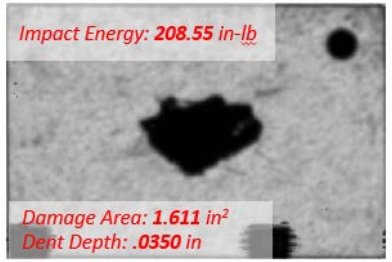


High & Low Flow Compression After Impact (CAI) Comparison

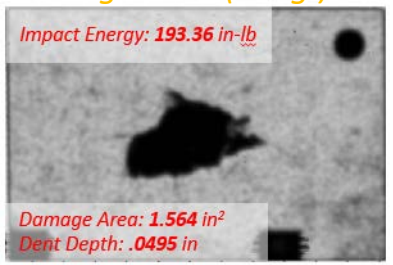
- All three configurations experienced varying sensitivity to the damage size.
  - Low flow specimens had the highest sensitivity to damage size.
  - Transverse to flow had the lowest sensitivity to damage size.
- All three configurations experienced knockdowns ranging from 15%-45%

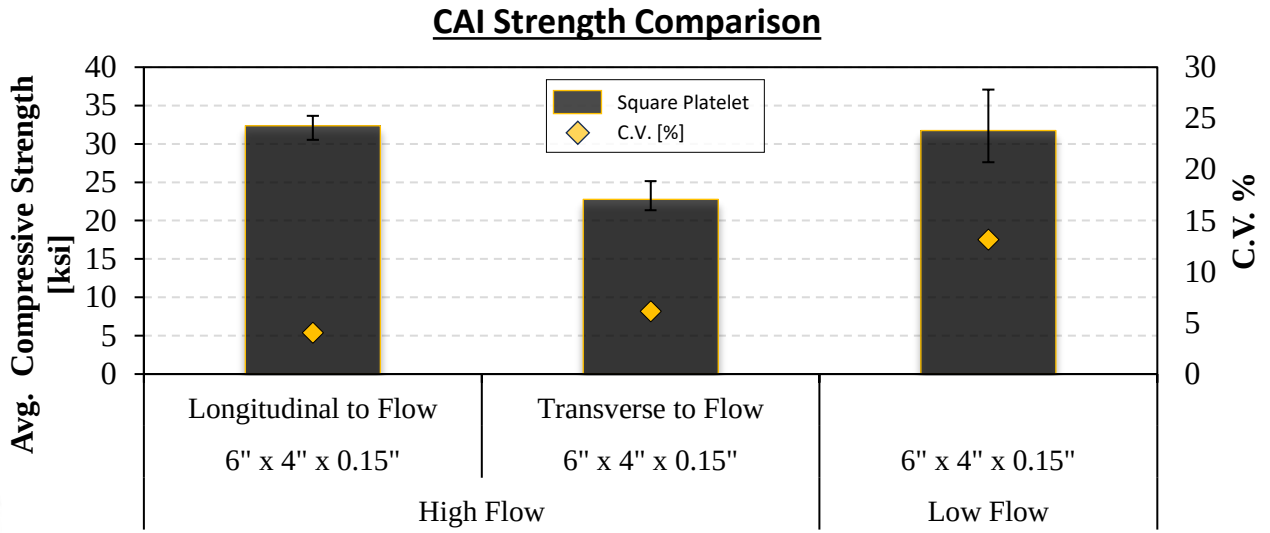


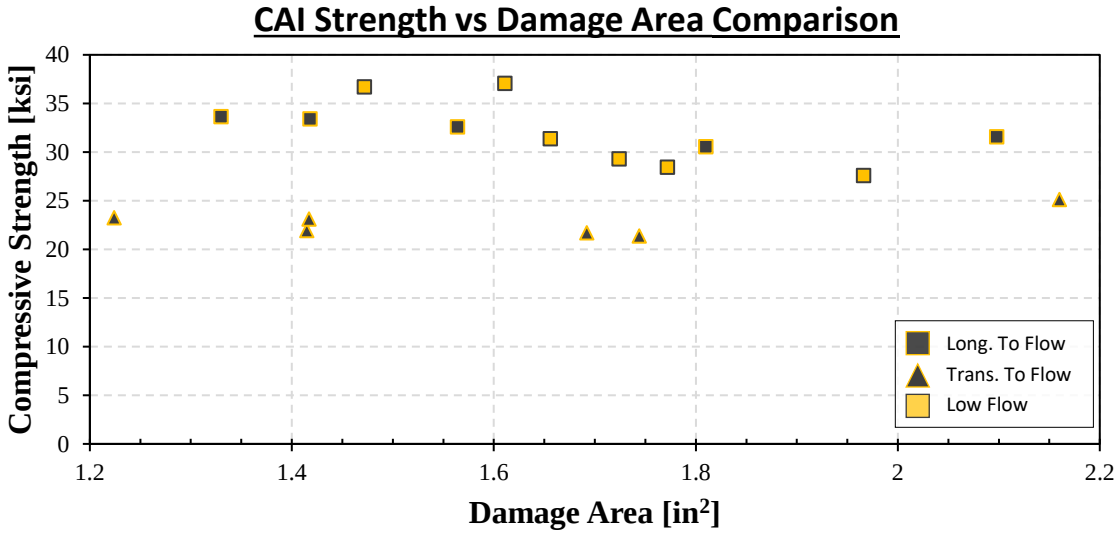
Low Flow



High Flow (Long.)

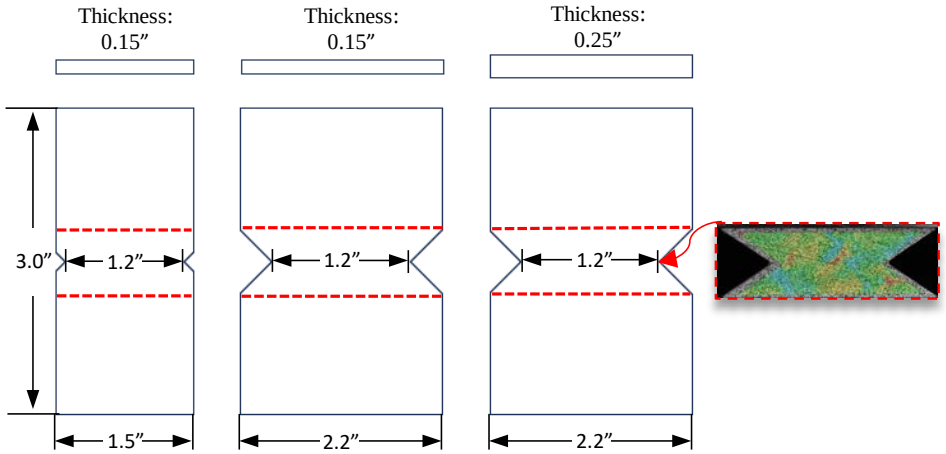


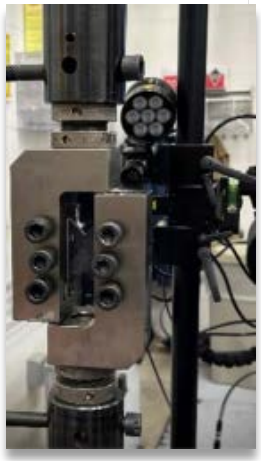


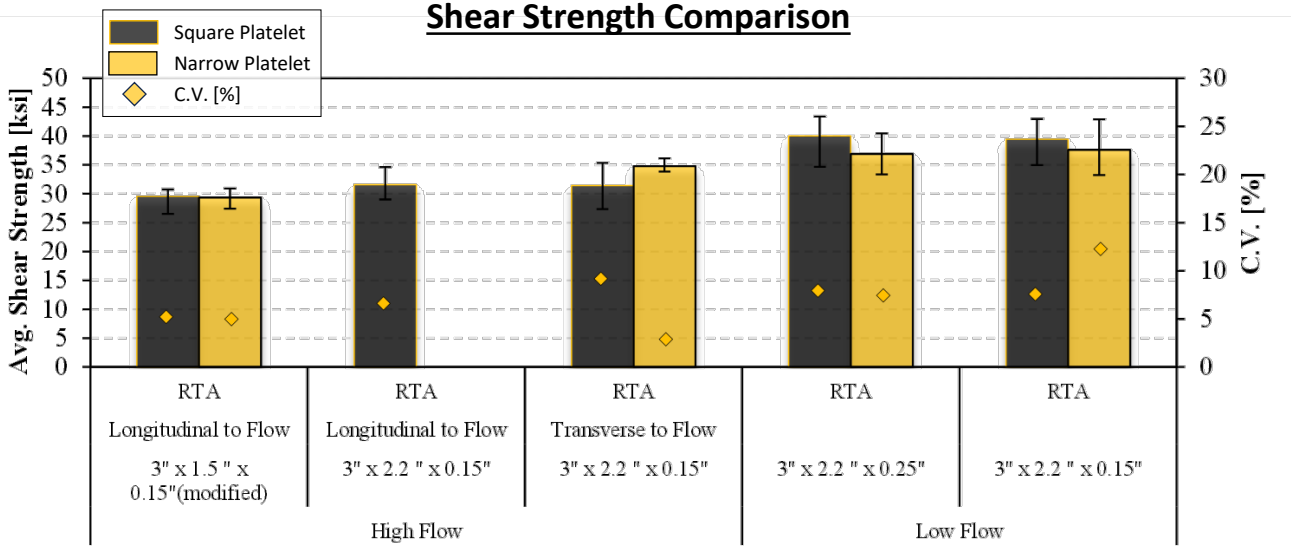


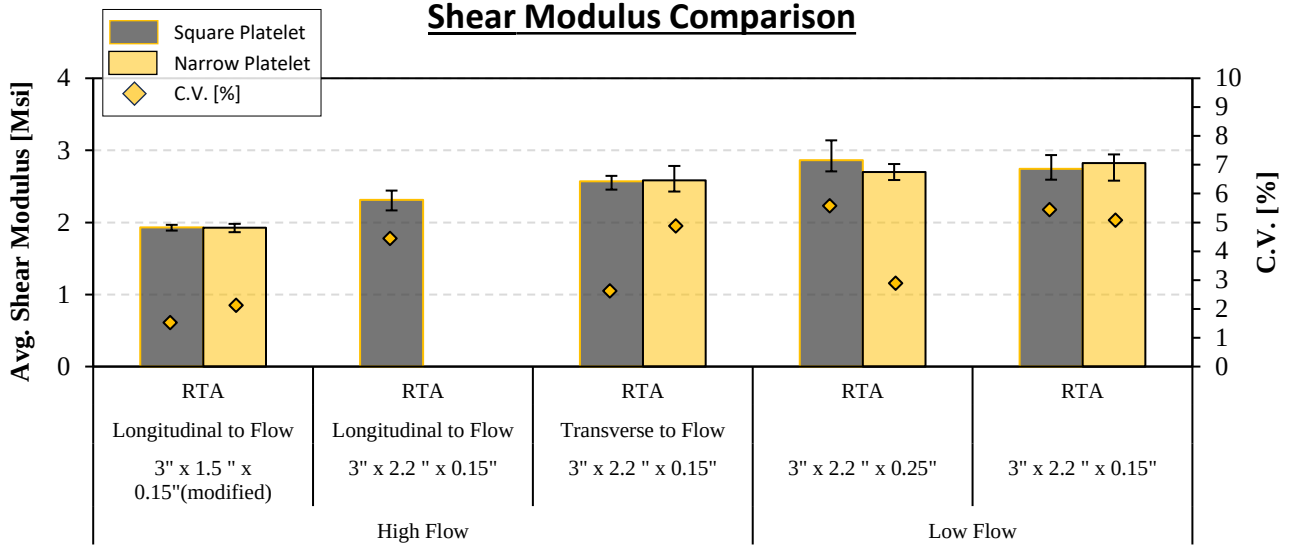
Square & Narrow Platelet V-Notch Rail Shear Comparison

- Specimens with similar manufacturing conditions experienced similar strength and modulus
  - Averages for low flow specimens of both thicknesses were within 5% of respective platelet type
- Knockdown for modified geometry is believed to be due to both the geometry and the flow characteristics
- The majority of low flow specimens did not reach the 0.2% offset strength



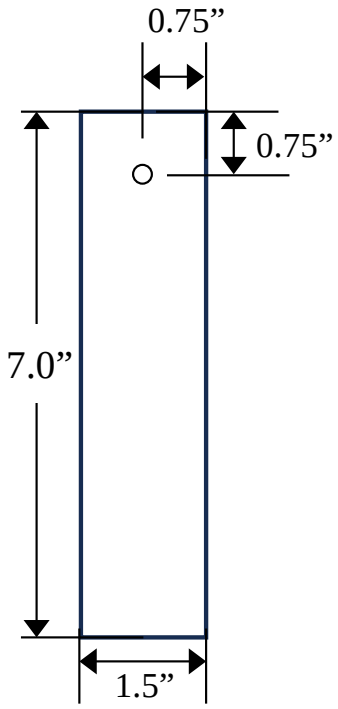




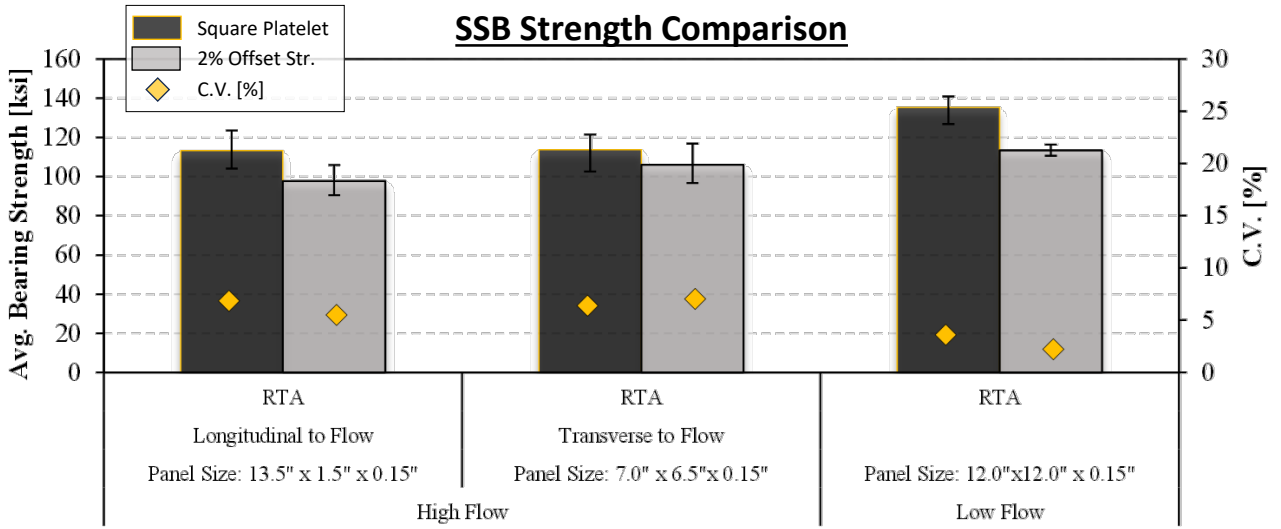


Square Platelet Single Shear Bearing (SSB) Comparison

- Each configuration of specimen had a different predominate failure mode.
  - High Flow (Long.): Mixed Mode Bearing/Cleavage
  - High Flow (Trans.): Net Tension
  - Low Flow: Bearing



SSB Strength Comparison



SSB Failure Mode Comparison

Qualification Framework for DFCs

Qualification Downselect

- **Low Flow** Process
- Narrow Platelet: **0.0625”x0.5”**
- **12” x 12”** Panel size
- Panel Thickness: **0.15”**
- Modified Geometry:
  - **Tension**
  - **Compression**
  - **In-Plane Shear**
  - **Flexure**
  - **Bearing**
  - **Tension After Impact**
- OHT specimen configuration with **Ø0.75” hole.**

Material Specs

- Base Spec NMS 145: **Solvay APC [PEKK/AS4D] 12K**
- NMS 145/1: **Wide Format Prepreg** (12” width)
- NMS 145/2: **Bulk Molding Compound** (.065” x 0.5”)
- **NPS 81450:** Fabrication of NMS 145 Qualification, Equivalency, and Acceptance Test Panels

NCAMP
NATIONAL CENTER FOR ADVANCED MATERIALS PERFORMANCE

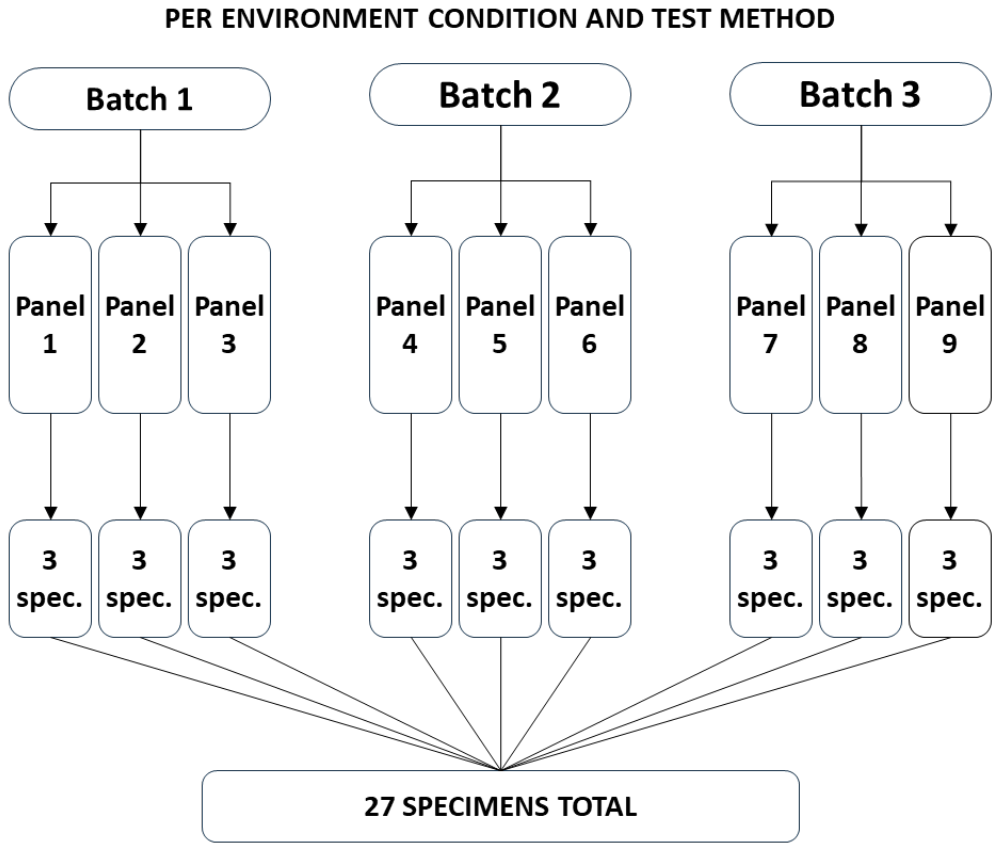
Test Plan

- **NTP 1450Q1**
- **Per Environmental Condition:**
  - 3 Material Batches
  - 3 panels per batch
  - 3 specimens per panel
- Use of Extensometers
- Mechanical Testing at **CTA, RTA, 300 °F, 250°F,** and **180°F**
- Fluid sensitivity screening using ASTM D3039 Tension
- Total of 219 panels required

Material Batch

Panel Manufacturing Process

Number of Specimens Required per Test Method & Environment



Qualification Mechanical Test Matrix

Test Type Abbreviation	Test Type Description	Test Specimen Geometry Length x Width x Thickness [in]	Property	Number of Batches x Number of Panels x Number of Test Specimens					
				Test Temperature/Moisture Condition					
				CTA	RTA	ETA1	ETW1	ETA2	ETA3
UNT	ASTM D3039 Un-notched Tension (1)	12 x 1.5 x 0.15	Strength and Modulus	3x3x3	3x3x3	3x3x3	1x3x3	1x3x3	1x3x3
UNC	ASTM D8066 Un-notched Compression (1)(2)	12 x 1.5 x 0.15	Strength and Modulus	1x3x3	3x3x3	3x3x3	1x3x3	1x3x3	1x3x3
IPS	ASTM D7078 V-Notch Shear (1)	3 x 2.2 x 0.15	Strength & Modulus	3x3x3	3x3x3	3x3x3	1x3x3	N/A	N/A
FLX	ASTM D790 Flexure	5.5 x 1.5 x 0.15	Strength and Modulus	3x3x3	3x3x3	3x3x3	1x3x3	N/A	N/A
OHT	ASTM D 5766 Open Hole Tension (1)(3)	12 x 4.5 x 0.15 (0.75 dia. Hole)	Strength	3x3x3	3x3x3	3x3x3	1x3x3	N/A	N/A
OHC	ASTM D6484 Open Hole Compression (1)	12 x 1.5 x 0.15 (0.25 dia. Hole)	Strength	1x3x3	3x3x3	3x3x3	1x3x3	N/A	N/A
SSB	ASTM D5961 Single Shear Bearing	5.5 x 1.5 x 0.15 (0.25 dia. Hole, e/D=3)	Strength & Deformation	1x3x3	3x3x3	3x3x3	1x3x3	N/A	N/A
CAI	ASTM D7136 & D7137 Compression After Impact (1500 in.lb/in)	6 x 4 x 0.15	Strength	1x3x3	3x3x3	3x3x3	1x3x3	N/A	N/A
TAI	ASTM D7136 & D5766 Tension After Impact (1500 in.lb/in)	12 x 4.5 x 0.15	Strength	1x3x3	3x3x3	3x3x3	1x3x3	N/A	N/A

Note 1: Coupon sized considering the bulk molding compound platelet width and length.
Note 2: UNC specimens tested using OHC compression fixture to stabilize specimen.
Note 3: Hole size modified for bulk molding compound platelet fiber length.
Note 4: ETA1/ETW1 is @ 180°F, ETA2 is a@ 250 °F, & ETA3 is @ 300 °F

Program Status and Summary

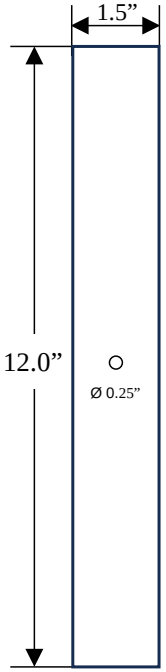
- **Pre-Qualification Trial Testing**
  - Completed trial test matrices to evaluate three key process parameters.
- **Qualification**
  - Currently have all NCAMP documents drafted and shared with material suppliers.
- **Benefit to Aviation**
  - Publicly available DFC data linked to M&P Specifications.
  - Lessons learned, guidelines for characterization, and data made available to **CMH-17.**

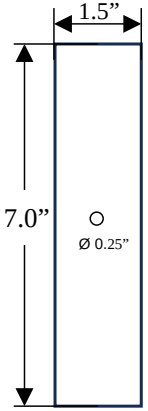
Thank you

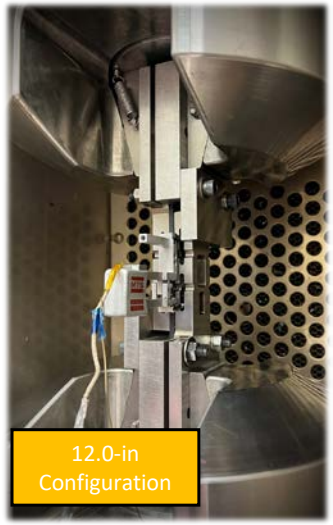
Questions?

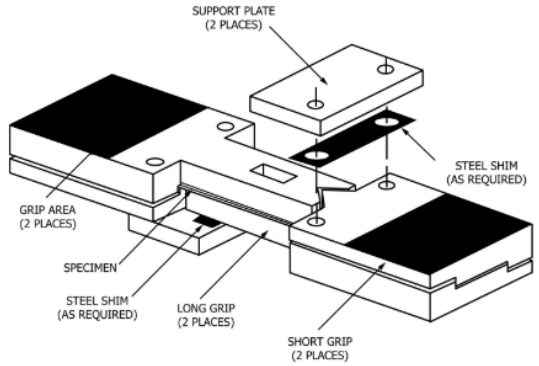
Square Platelet Open Hole Compression (OHC) Comparison

- Adequate failure modes through the hole were witnessed for all specimens except for one.
  - High Flow (long): Multi-mode failure above the hole.
- All specimen configurations experienced an approx. 10% knock down to strength

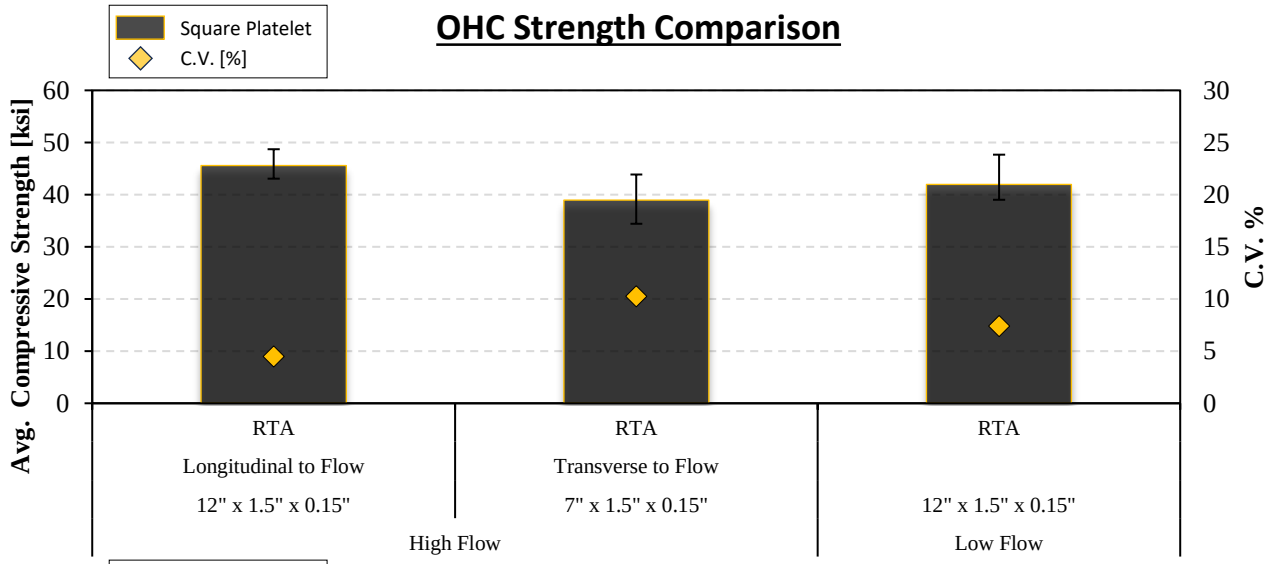


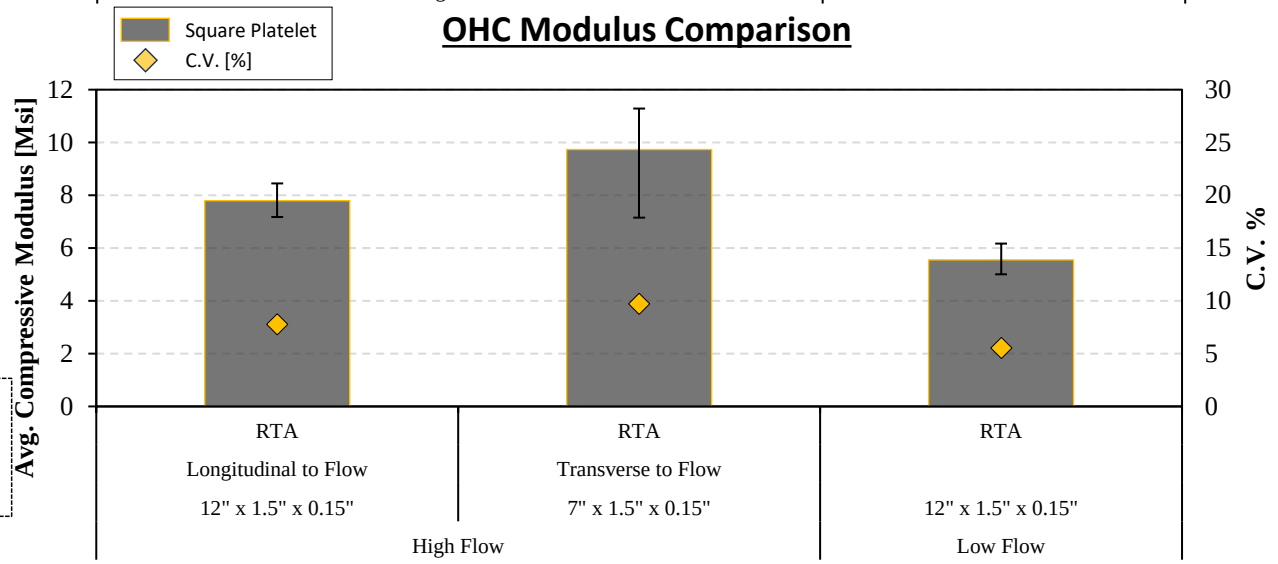






>> **12.0-in length** used for 13.5-in x 1.5-in High Flow panels & Low Flow 12.0-in x 12.0-in panels
*2 in. Extensometer used
>> **7.0-in length** used for 7.0-in x 6.5-in High Flow Panels
*2 in. Extensometer used





Thermal Analysis

ASTM D7028 – "Standard Test Method for Glass Transition Temperature (DMA Tg) of Polymer Matrix Composites by Dynamic Mechanical Analysis (DMA)"

Platelets	Flow	Thick-ness	Panel Size	Sample ID	Onset Storage Modulus Tg [°F]	Peak of Tangent Delta Tg [°F]
Square *0.5" x 0.5"*	High	0.15"	13" x 1.5"	4-1-1	289.11	331.86
				4-1-2	290.21	332.22
				4-1-3	288.72	330.94
			7" x 6.5"	8-13-1	286.52	331.70
				8-13-2	278.98	326.79
				8-13-3	284.65	331.93
	Low	0.25"	12" x 12"	6-1-1	289.35	333.43
		0.15"		8-1-1	288.57	332.62
				8-1-2	289.67	333.68
				8-1-3	286.93	331.74
Narrow *0.5" x 0.0625"*	High	0.15"	13" x 1.5"	3-5-1	278.47	326.17
			7" x 6.5"	3-6-2	283.73	325.54
	Low	0.15"	12" x 12"	7-3-1	282.27	324.36
				Average [°F]	**285.94**	**330.23**
				Stadard Deviation	4.02	3.25
				C.V. [%]	1.41%	0.99%

ASTM D3418 – "Standard Test Method for Transition Temperatures and Enthalpies of Fusion and Crystallization of Polymers by Differential Scanning Calorimetry"

Platelets	Flow	Thick-ness	Panel Size	Sample ID	Melting Peak Temperature [°F]	Enthalpy of Melting ΔHm [J/g]	Crystallization Peak Temperature [°F]	Enthalpy of Crystallization ΔHc [J/g]	Degree of Crystallinity [%]
Square *0.5" x 0.5"*	High	0.15"	13" x 1.5"	4-1-1	648.64	9.686	559.17	12.794	21.91
				4-1-2	645.04	8.557	560.48	12.095	19.36
				4-1-3	646.27	11.297	559.71	11.368	25.56
			7" x 6.5"	8-13-1	644.74	11.794	550.72	12.331	26.68
				8-13-2	651.54	13.586	550.24	12.766	30.74
				8-13-3	650.14	12.194	552.83	12.962	27.59
	Low	0.25"	12" x 12"	6-1-1	649.51	10.873	552.40	13.528	24.60
		0.15"		8-1-1	650.86	13.159	553.95	13.856	29.77
				8-1-2	651.20	12.577	553.89	12.997	28.45
				8-1-3	650.26	12.897	553.66	13.259	29.18
Narrow *0.5" x 0.0625"*	High	0.15"	13" x 1.5"	3-5-1	643.59	11.228	562.33	13.441	25.40
				3-5-2	648.07	11.732	562.59	13.235	26.54
				3-5-3	651.02	10.345	561.83	14.720	23.40
			7" x 6.5"	3-6-1	651.76	13.873	565.38	14.707	31.39
				3-6-2	653.29	13.032	565.32	13.435	29.48
				3-6-3	653.00	14.560	565.63	15.142	32.94
	Low	0.15"	12" x 12"	7-3-1	650.86	13.159	553.95	13.858	29.77
				7-3-2	651.20	12.577	553.89	12.997	28.45
				7-3-3	650.26	12.897	553.66	13.259	29.18
							Average [%]	**27.39**	
							Stadard Deviation	3.41	
							C.V. [%]	12.45%	