Discontinuous Fiber Thermoplastic Composite Qualification Framework Development

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Royal Lovingfoss & Brandon Saathoff

April 19th, 2023

Wichita State University
NIAR

Federal Aviation Administration

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Joint Advanced Materials & Structures Center of Excellence

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AMTAS
Advanced Materials in Transport Aircraft Structures

Presented by:

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JAMS 2023 Technical Review – Seattle, WA

DFC Research Team

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Sekisui Aerospace

- Scott James
- Daniel Miranda

SEKISUI
SEKISUI AEROSPACE

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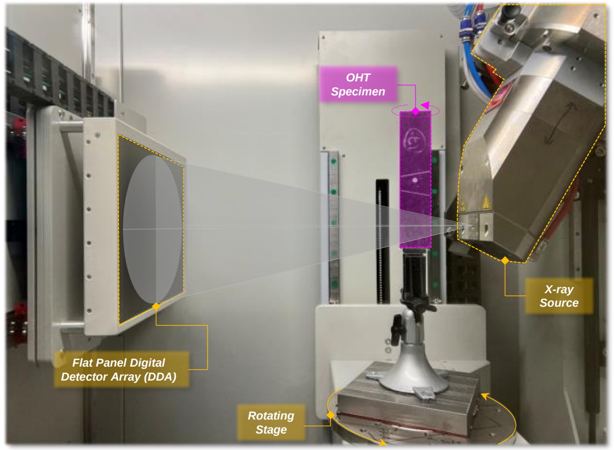
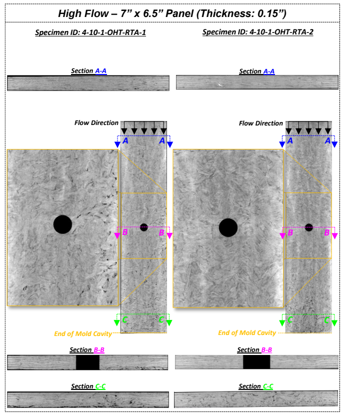
Research Partners:

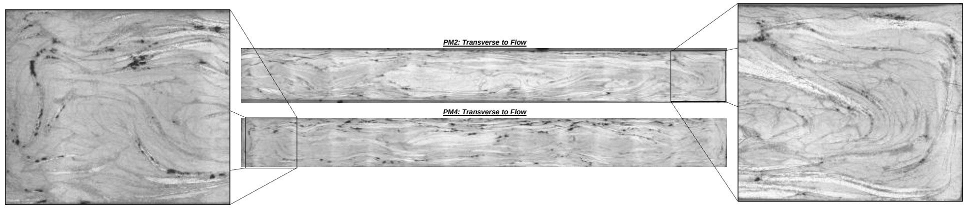
SOLVAY
W UNIVERSITY of WASHINGTON

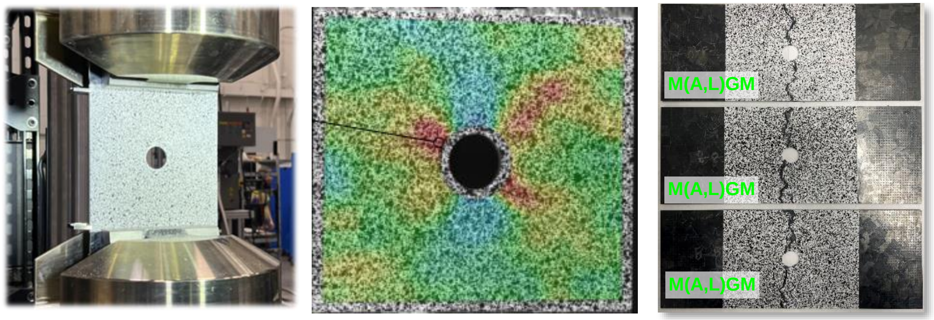
WSU-NIAR & University of Washington Collaboration

Experimental Testing



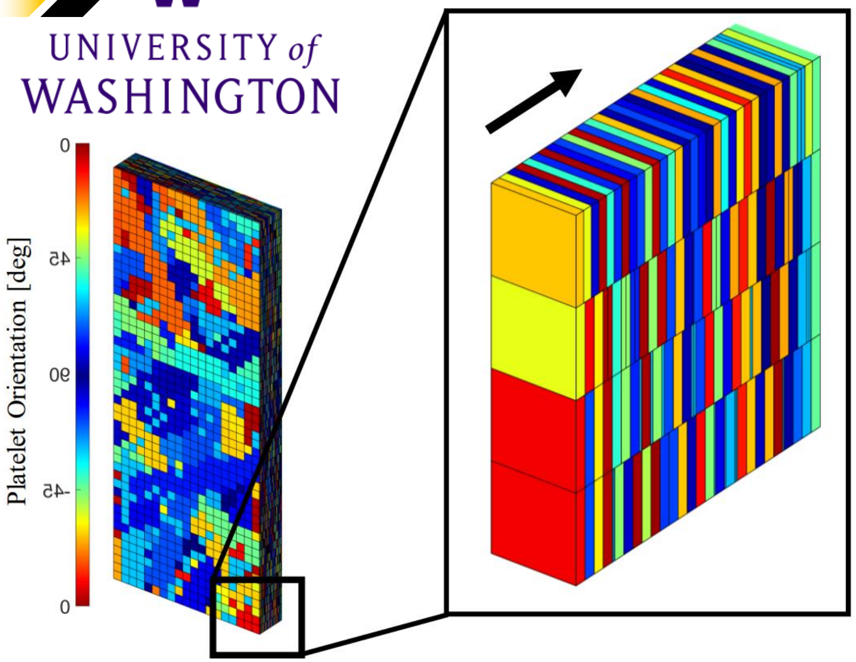


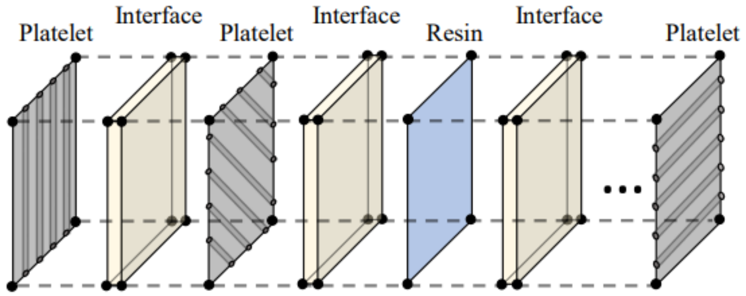




Analysis Tool Development

UNIVERSITY of WASHINGTON





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

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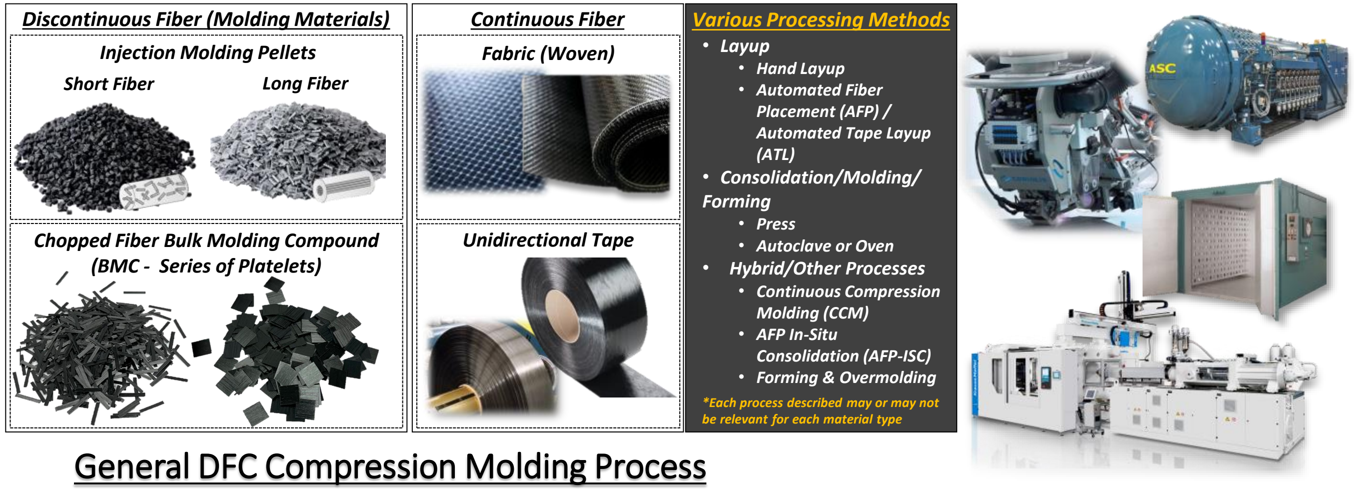
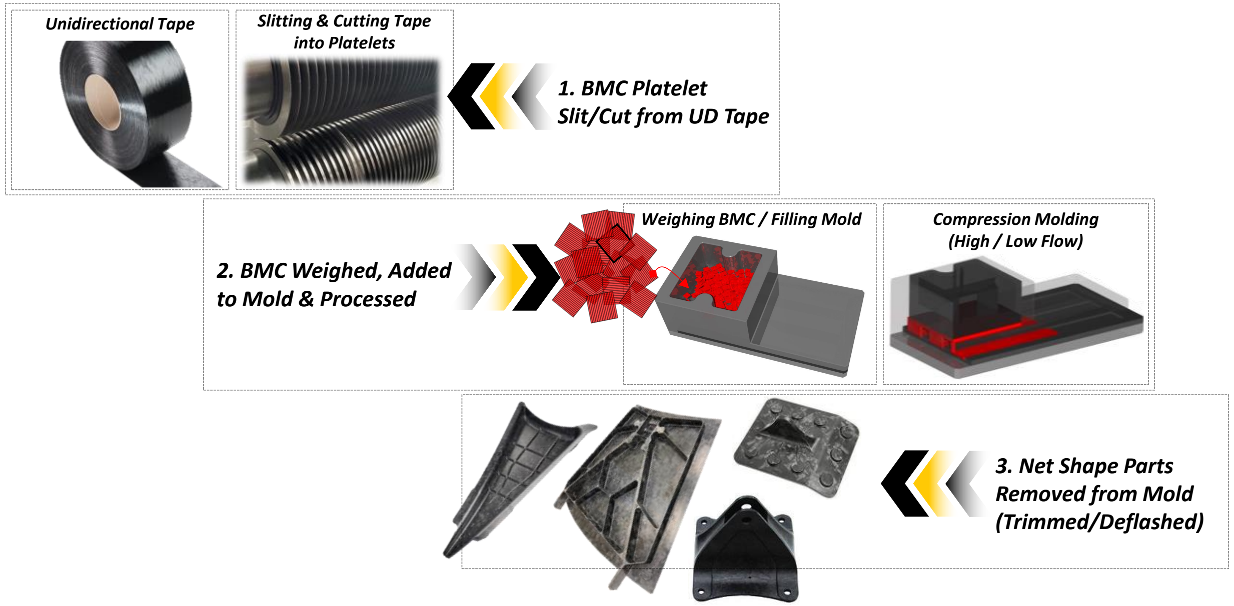
DFC Background and Research Motivation

- **DFCs are attractive for manufacturing low cost complex parts.**
- **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.)
- Widespread adoption of discontinuous fiber composites for structural applications is limited:
  - **Inherent challenges with predicting and characterizing the material properties**
  - **Lack of statistically meaningful material property data used for design – especially with various flow behaviors**
    - **Level of conservatism in design unknown**



General DFC Compression Molding Process



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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.**

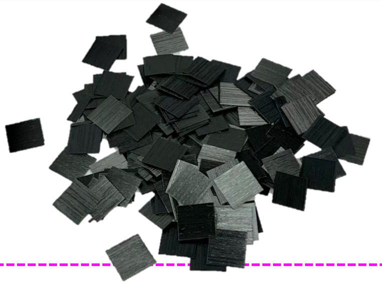
CMH-17
COMPOSITE MATERIALS HANDBOOK

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

Continuous Fiber Thermoplastic Qualification
(T700/TC1225) & Equivalency

TORAY
Toray Advanced Composites



Discontinuous Fiber Thermoplastic Trials » Qualification

SOLVAY

Establishing Steering Committee » Develop Qualification Framework (Trials) [WE ARE HERE] » Perform Qualification » Establish Statistical Guidelines »
- Transition Material Property Data
- Guidelines

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Development of Qualification Framework for DFCs

Preliminary Trials

- Three Suppliers
- Platelet size: **0.5"x0.5"**
- **12" x 12" panels**
- **C-Scan**
- **Density and Void Content**
- Mechanical Testing at **CTA, RTA, 250°F/A** and **180°F/A**

Material Selection

- **Solvay APC selected**
  - **Synergy with JAMS partner UW**
  - **Consistent Quality**
  - **Lowest CV in comparison to other materials**
  - **Industry Relevance**

APC by Solvay

Test Types & Geometries

- **Coupon widths sized with respect to platelet size**
  - Low flow process considered
- Strain gage considerations for use on DFCs
  - Use of DIC / Extensometers
- Thickness effect saturates after approx. 0.1"
  - Considered in test matrix planning

Key Process Parameters

- **Flow**
  - High: Individual platelets disperse during pressure application
  - Low: Platelets remain intact and relatively small relative moments occur
- **Platelet Size**
  - **Size 1: 0.5" x 0.0625"**
  - **Size 2: 0.5" x 0.5"**
- **Thickness**
  - **Thickness 1: 0.25"**
  - **Thickness 2: 0.15"**

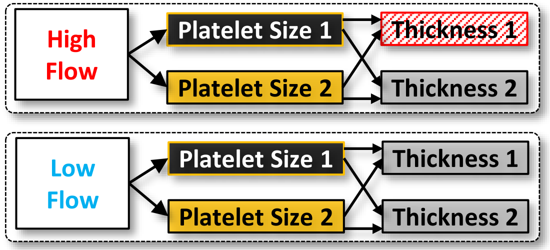
Industry Survey

3 Question Survey

1. **Properties of interest for the trial test matrix**
2. **Environmental conditions**
3. **Parameters of Interest**
   - **Low versus High Flow – Highest interest to respondents**
   - Platelet Size
   - Thickness

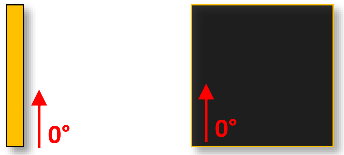
Trial Test Matrix

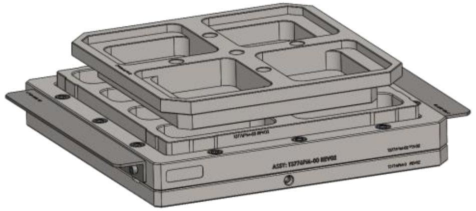
WE ARE HERE

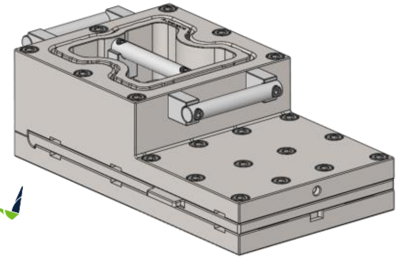


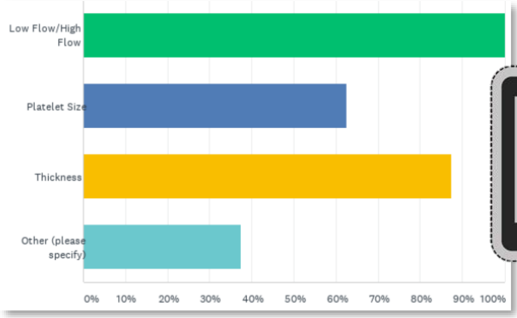
Platelet Size 1
0.5" x 0.0625"

Platelet Size 2
0.5" x 0.5"









Primary Objectives for Trial Testing:

- *Understand effects of key processing parameters to establish process spec*
- *Realize variability & associated specimen quantity needed*
- *Evaluate appropriate test methods, specimen sizes, environments, and failure modes*

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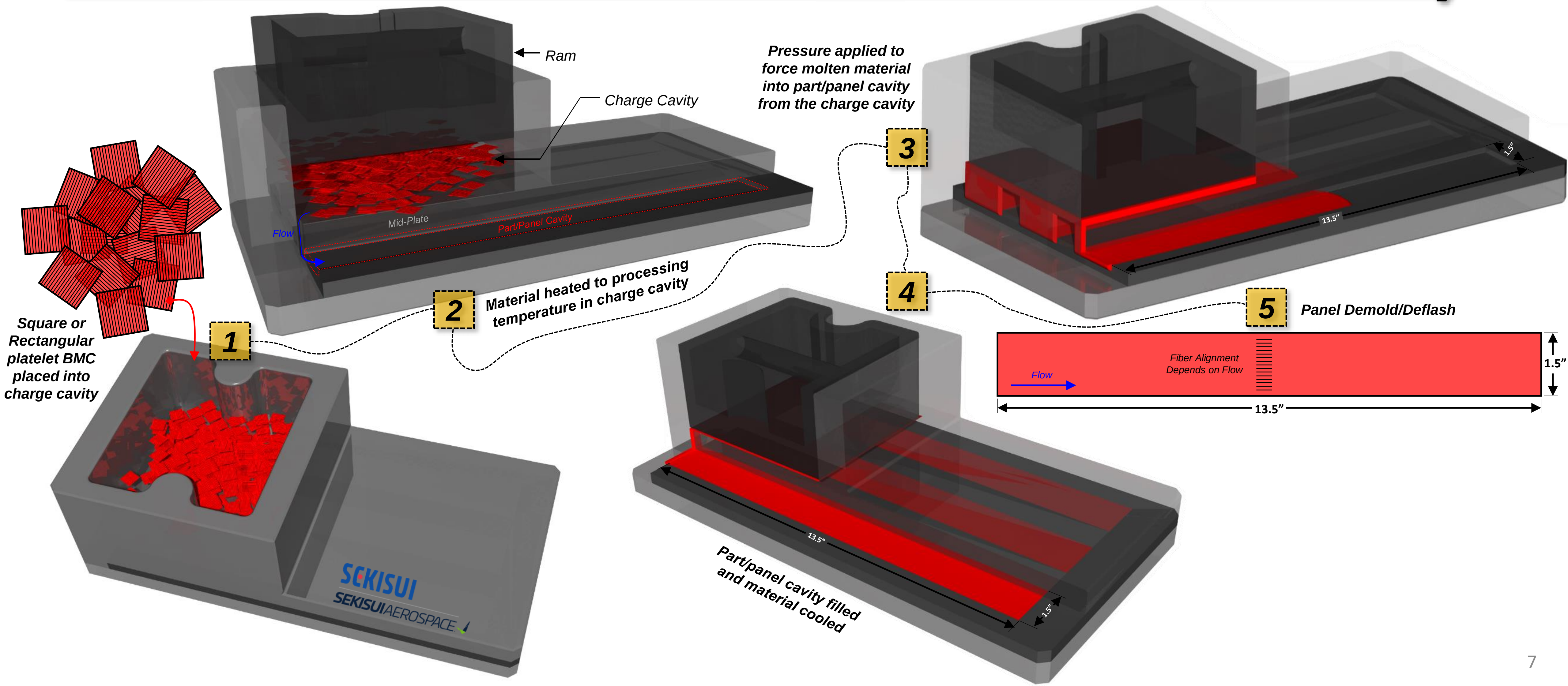
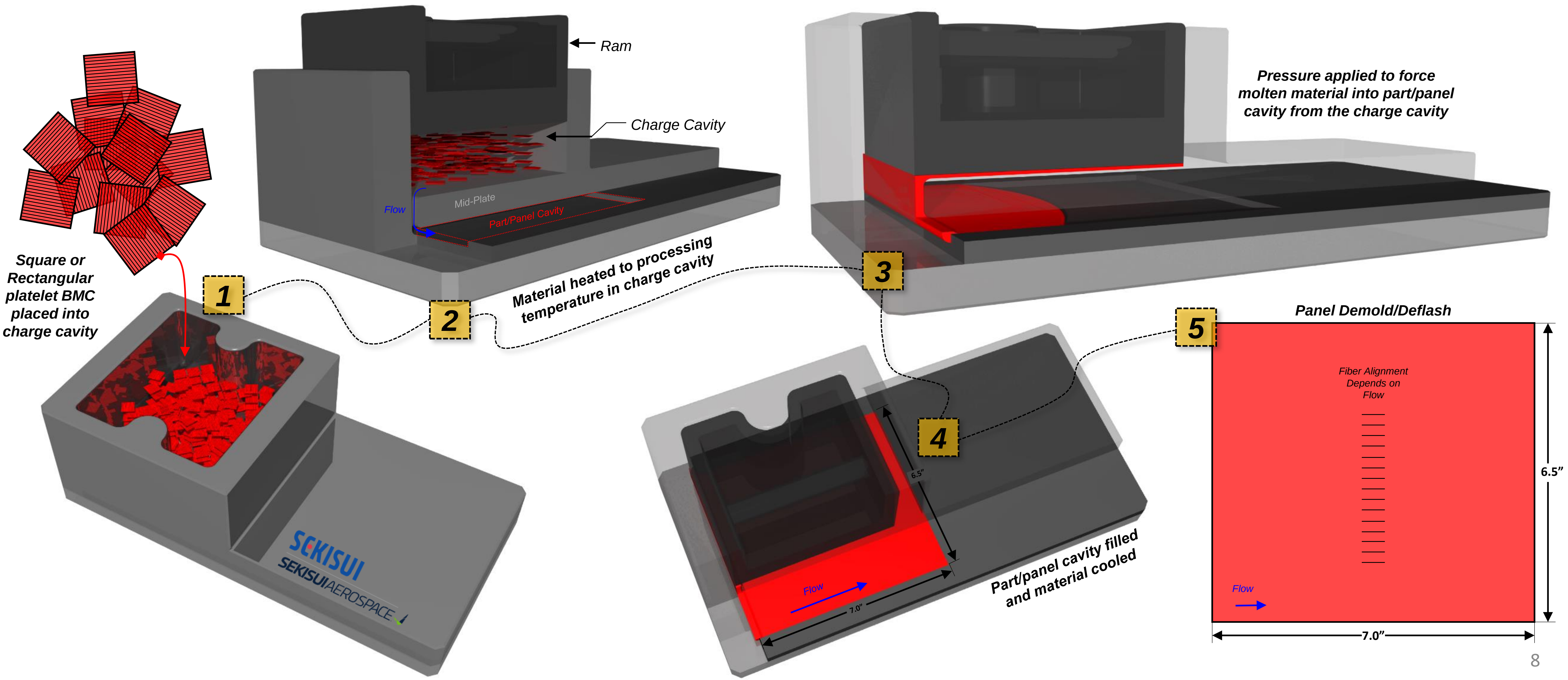
High Flow Panel Size Description – 13.5”x1.5”



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



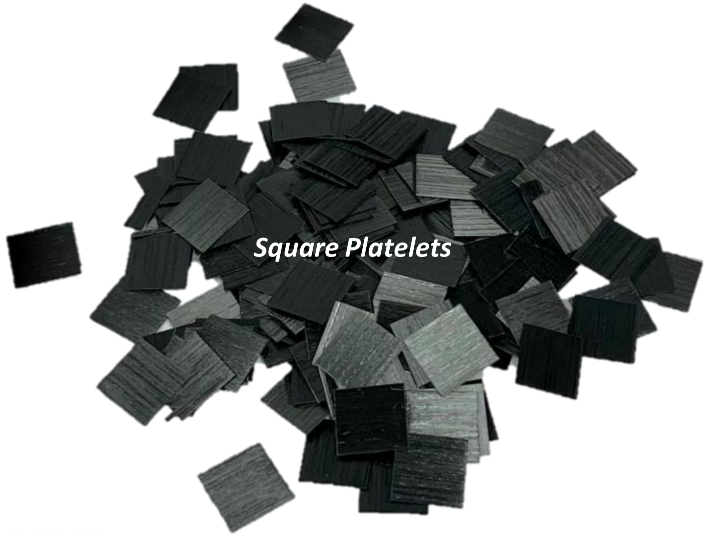
High Flow vs. Low Flow Panel Visual Comparison

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

38.1-mm
1.5”

343-mm
13.5”

*panels not displayed to scale



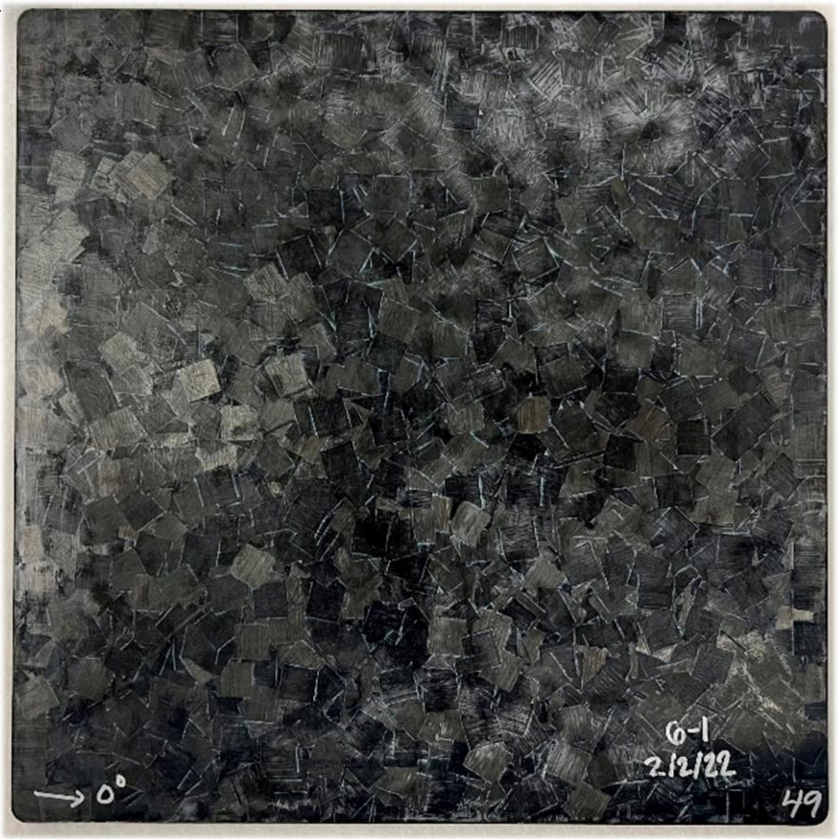
Square Platelet – High Flow 7”x6.5” Panel

165-mm
6.5”

178-mm
7.0”

Square Platelet – Low Flow 12”x12” Panel

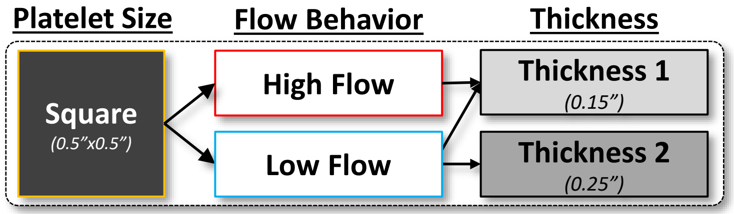
305-mm
12”

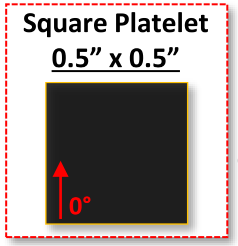


305-mm
12”

Trial Test Matrix – _Square_ Platelet

- Solvay APC PEKK-FC AS4 Unitape Prepreg Material
  - Areal Weight: 145 gsm
  - Resin Content: 34%
- Panel Fabrication at Sekisui Aerospace
  - Qforge™ Process





0.5" x 0.5" Platelet Test Matrices

Test Matrix	Flow	Thick-ness	Platelet Size	Coupon Group	Test Type	Geometry	Test Method	CTA -65F	RTA	ETA 180F	ETW 180F	ETA 350F	ETW 350F	Panel Size	Total # of Panels	Panels Received
Iteration 4	High	0.15"	0.5" x 0.5"	1	Tension	12" x 1.5"	ASTM D3039 (DIC at RT)	6	6	6	6	6	6	13" x 1.5"	36	36
				2	Tension (L)	7" x 1.5"	ASTM D3039 (DIC at RT)	6	6	6	6	6	6	7" x 6.5"	9	9
				2*	Tension (T)	6.5" x 1.5"	ASTM D3039 (DIC at RT)		6					7" x 6.5"		
				3	Compression	12" x 1.5"	ASTM D6484 with no hole	6	6	6	6	6	6	13" x 1.5"	36	36
				4	Compression (L)	7" x 1.5"	ASTM D6484 with no hole	6	6	6	6	6	6	7" x 6.5"	9	9
				4*	Compression (T)	6.5" x 1.5"	ASTM D6484 with no hole		6					7" x 6.5"		
				5	Shear	3" x 1.5 " (mod)	ASTM D7078 with DIC		6					13" x 1.5"	2	2
				6	Shear (L)	3" x 2.2 "	ASTM D7078 with DIC		6					7" x 6.5"	2	2
				6*	Shear (T)	3" x 2.2 "	ASTM D7078 with DIC		6					7" x 6.5"		
				7	Flex	5.5" x 0.5"	ASTM D790, 3 pt bend		6					13" x 1.5"	3	3
				8	Flex (Wide)	5.5" x 1.5"	ASTM D790, 3 pt bend		6					13" x 1.5"		
				8	Flex	5.5" x 0.5"	ASTM D790, 3 pt bend		6					7" x 6.5"	1	1
				8*	Flex (Wide)	5.5" x 1.5"	ASTM D790, 3 pt bend		6					7" x 6.5"		
				9	OHT	12" x 1.5"	ASTM D5766, hole: 0.25"		6					13" x 1.5"	6	6
				10	OHT	7" x 1.5"	ASTM D5766, hole: 0.25"		6					7" x 6.5"	2	2
				11	OHT	12" x 1.5"	ASTM D5766, hole: 0.75"		6					13" x 1.5"	6	6
				12	OHT	7" x 4.5"	ASTM D5766, hole: 0.75"		6					7" x 6.5"	6	6
				13	OHT	12" x 1.5"	ASTM D5766, hole: 1"		6					13" x 1.5"	6	6
				14	OHT	7" x 6"	ASTM D5766, hole: 1"		6					7" x 6.5"	6	6
				15	OHC	12" x 1.5"	ASTM D6484, hole: 0.25"		6					13" x 1.5"	6	6
				16	OHC	7" x 1.5"	ASTM D6484, hole: 0.25"		6					7" x 6.5"	3	3
				19	SSB	5.5" x 1.5"	ASTM D5961 pr. C, 0.25"d		6					13" x 1.5"	4	4
				20	SSB	5.5" x 1.5"	ASTM D5961 pr. C, 0.25"d		6					7" x 6.5"	4	4
				21	CAI	6" x 4"	ASTM D7136/D7137		6					7" x 6.5"	6	6* (6)
				22	CAI	6" x 4"	ASTM D7136/D7137		6					7" x 6.5"	6	6
Iteration 6	Low	0.25"	0.5" x 0.5"	1	Tension	12" x 1.5"	ASTM D3039 (DIC at RT)		6	6		6		12"x12"	3	3
				2	Compression	12" x 1.5"	ASTM D6484 with no hole		6					12"x12"	1	1
				3	Shear	3" x 2.2 "	ASTM D7078		6					12"x12"	1	1
				4	OHT	12" x 1.5"	ASTM D5766, hole: 0.25"		6					12"x12"	1	1
Iteration 8	Low	0.15"	0.5" x 0.5"	1	Tension	12" x 1.5"	ASTM D3039 (DIC at RT)	6	6	6	6	6	6	12"x12"	6	3 (3)
				3	Compression	12" x 1.5"	ASTM D6484 with no hole	6	6	6	6	6	6	12"x12"	6	8
				5	Shear	3" x 2.2 "	ASTM D7078		6					12"x12"	1	1
				6	Flex	5.5" x 0.5"	ASTM D790		6					12"x12"	1	1
				7	Flex (Wide)	5.5" x 1.5"	ASTM D791		6					12"x12"		
				7	OHT	12" x 1.5"	ASTM D5766, hole: 0.25"		6					12"x12"	1	1
				8	OHT	12" x 4.5"	ASTM D5766, hole: 0.75"		6					12"x12"	3	3
				9	OHT	12" x 6"	ASTM D5766, hole: 1"		6					12"x12"	3	3
				10	OHC	12" x 1.5"	ASTM D6484, hole: 0.25"		6					12"x12"	1	1
				12	SSB	5.5" x 1.5"	ASTM D5961 pr. C, 0.25"d		6					12"x12"	1	1
				13	CAI	6" x 4"	ASTM D7136/D7137		6					12"x12"	3	3

Test Completed
In-Progress
On-Hold / Pending Review
Not Started
Additional Testing Outlined Blue

March Shipment	*51*
April Shipment	*68*
May Shipment	*50*
June Shipment	*18*
August Shipment	*6*
High Flow Extra Panels	*3*
Low Flow Extra Panels	*2*

Trial Test Matrix – *Narrow* Platelet

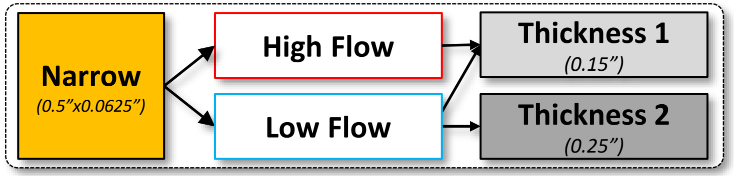
- Solvay APC PEKK-FC AS4 Unitape Prepreg Material
  - Areal Weight: 145 gsm
  - Resin Content: 34%
- Panel Fabrication at Sekisui Aerospace
  - Qforge™ Process

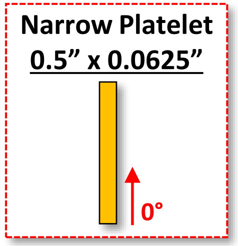
0.5" x 0.0625" Platelet Test Matrices

Test Matrix	Flow	Thick-ness	Platelet Size	Coupon Group	Test Type	Geometry	Test Method	CTA -65F	RTA	ETA 180F	ETW 180F	ETA 350F	ETW 350F	Panel Size	Total # of Panels	Panels Received
Iteration 3	High	0.15"	0.5" x 0.0625"	1	Tension	12" x 1.5"	ASTM D3039 (DIC at RT)		6	6		6		13" x 1.5"	19	21
				2	Tension (T)	6.5" x 1.5"	ASTM D3039 (DIC at RT)		6	6		6		7" x 6.5"	5	5
				2*	Tension (L)	7" x 1.5"	ASTM D3039 (DIC at RT)		4					7" x 6.5"	1	1
				3	Compression	12" x 1.5"	ASTM D6484 with no hole		6					13" x 1.5"	6	6
				4	Compression (T)	6.5" x 1.5"	ASTM D6484 with no hole		6					7" x 6.5"	2	2
				4*	Compression (L)	7" x 1.5"	ASTM D6484 with no hole		4					7" x 6.5"	2	2
				5	Shear	3" x 1.5 " (mod)	ASTM D7078 with DIC		6					13" x 1.5"	2	6
				6	Shear	3" x 2.2 "	ASTM D7078 with DIC		6					7" x 6.5"	2	2
				7	OHT	13" x 1.5"	ASTM D5766, hole size 1 (0.25")		6					13" x 1.5"	6	6
				8	OHT (Tranv.)	6.5" x 1.5"	ASTM D5766, hole size 1 (0.25")		6					7" x 6.5"	2	2
Iteration 5	Low	0.25"	0.5" x 0.0625"	1	Tension	12" x 1.5"	ASTM D3039 (DIC at RT)		6	6		6		12"x12"	3	3
				2	Compression	12" x 1.5"	ASTM D6484 with no hole		6					12"x12"	1	1
				3	Shear	3" x 2.2 "	ASTM D7078 with DIC		6					12"x12"	1	1
				4	OHT	12" x 1.5"	ASTM D5766, hole size 1 (0.25")		6					12"x12"	1	1
Iteration 7	Low	0.15"	0.5" x 0.0625"	1	Tension	12" x 1.5"	ASTM D3039 (DIC at RT)		6	6		6		12"x12"	3	4
				2	Compression	12" x 1.5"	ASTM D6484 with no hole		6					12"x12"	1	1
				3	Shear	3" x 2.2 "	ASTM D7078		6					12"x12"	1	1
				4	OHT	12" x 1.5"	ASTM D5766, hole size 1 (0.25")		6					12"x12"	1	1

Test Completed	
In-Progress	
On-Hold / Pending Review	
Not Started	
Additional Testing Outlined Blue	

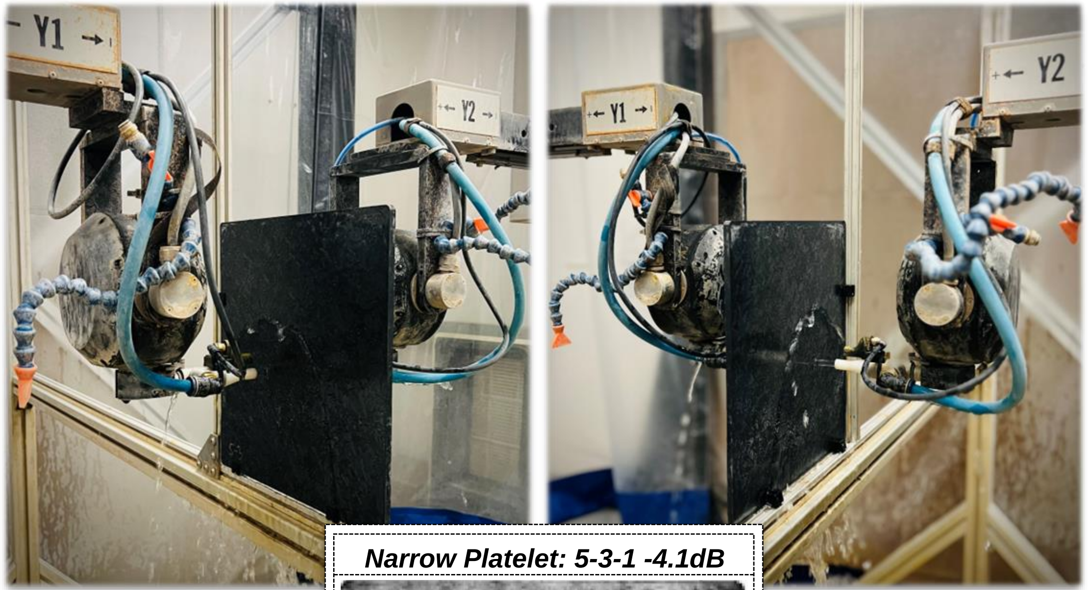
August Shipment	*66*
High Flow Extra Panels	*6*
Low Flow Extra Panels	*1*

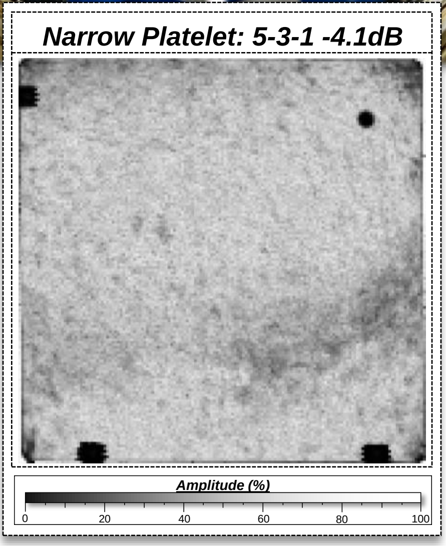




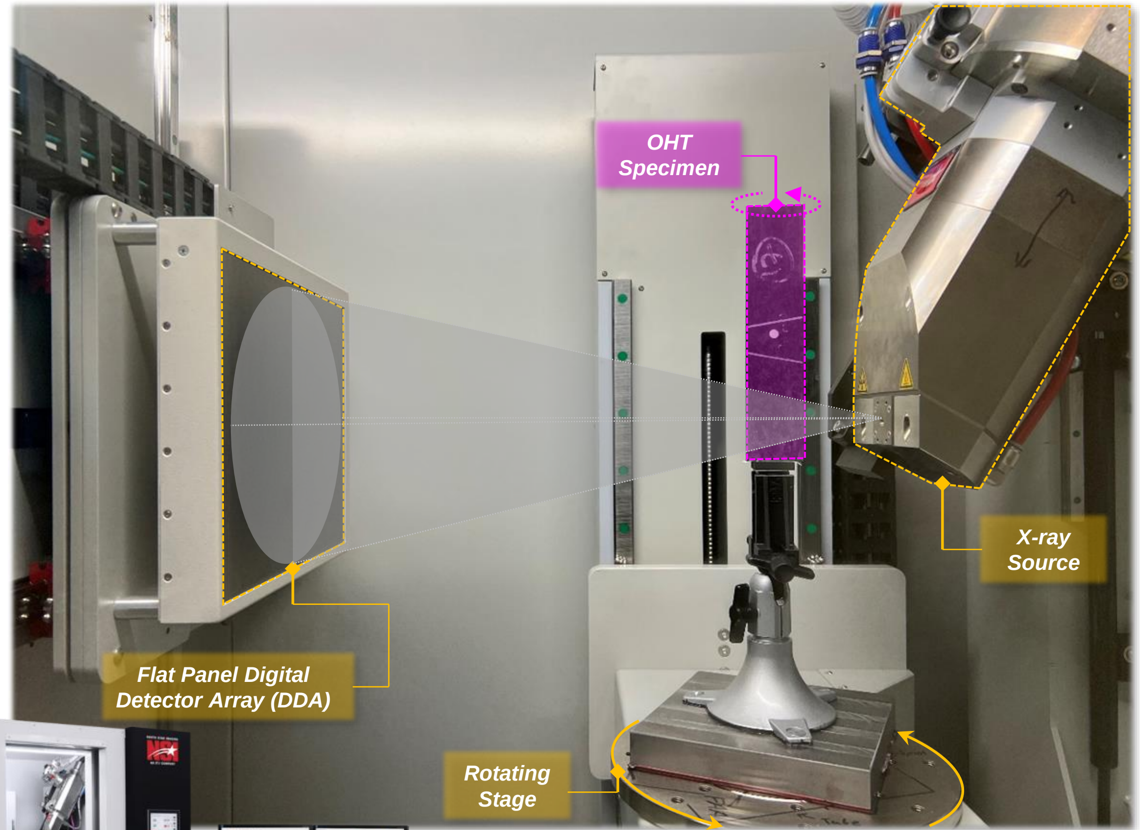
Non-Destructive Inspection Techniques

Through-Transmission Ultrasonic Inspections



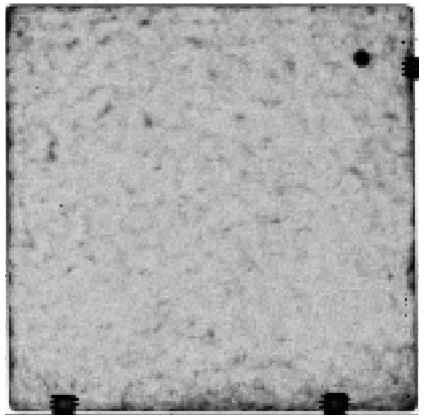
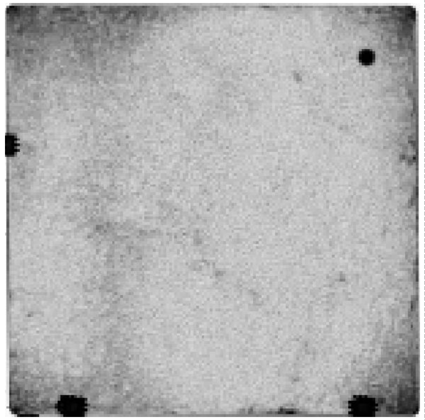


X-Ray Computed Tomography Inspection



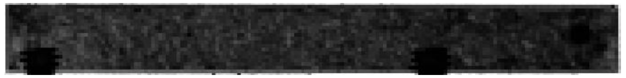
Summary of TTU C-Scan Results

Low Flow 12” x 12” Panel (Thickness: 0.15”)

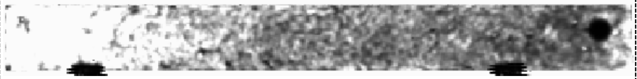
Square Platelet: 8-1-3 -5.9dB	Narrow Platelet: 7-2-1 -5.9dB
	

High Flow 13.5” x 1.5” Panel (Thickness: 0.15”)

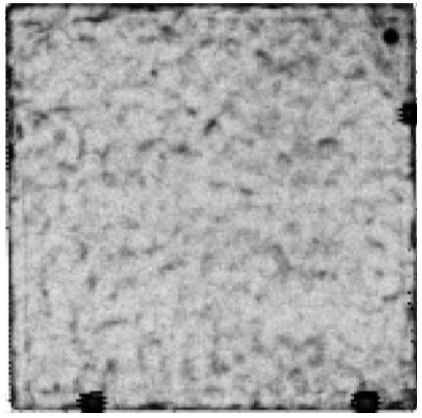
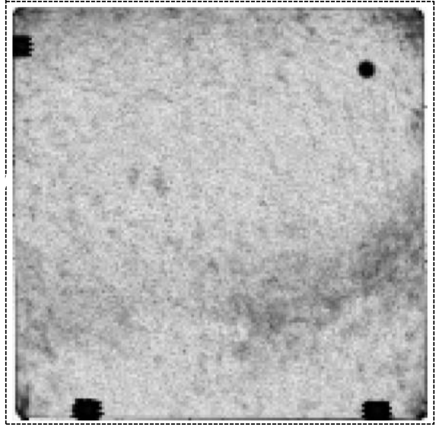
Square Platelet

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

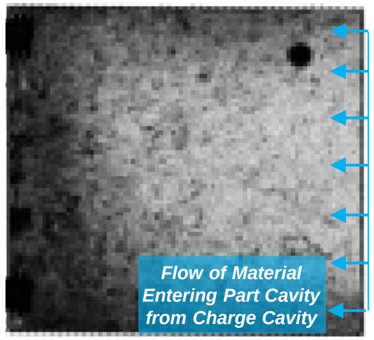
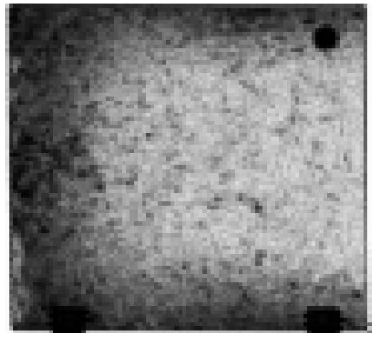
Narrow Platelet

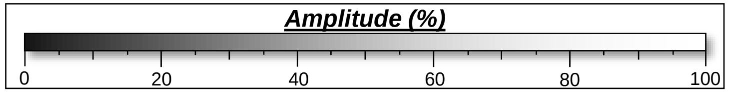
4-19-1-2 -5.9dB	4-19-1-2 7dB
	

Low Flow 12” x 12” Panel (Thickness: 0.25”)

Square Platelet: 6-1-1 -4.1dB	Narrow Platelet: 5-3-1 -4.1dB
	

High Flow 7” x 6.5” Panel (Thickness: 0.5”)

Square Platelet: 4-6-2 -5.9dB	Narrow Platelet: 3-8-2 -5.9dB
	



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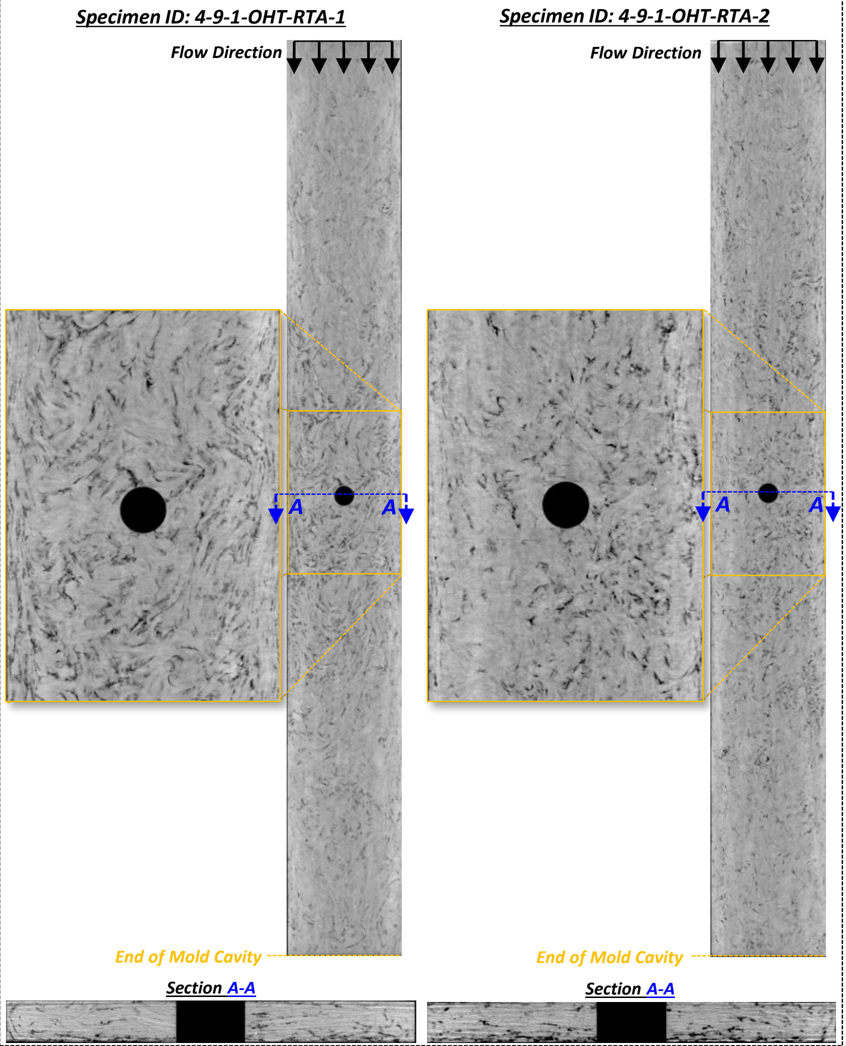
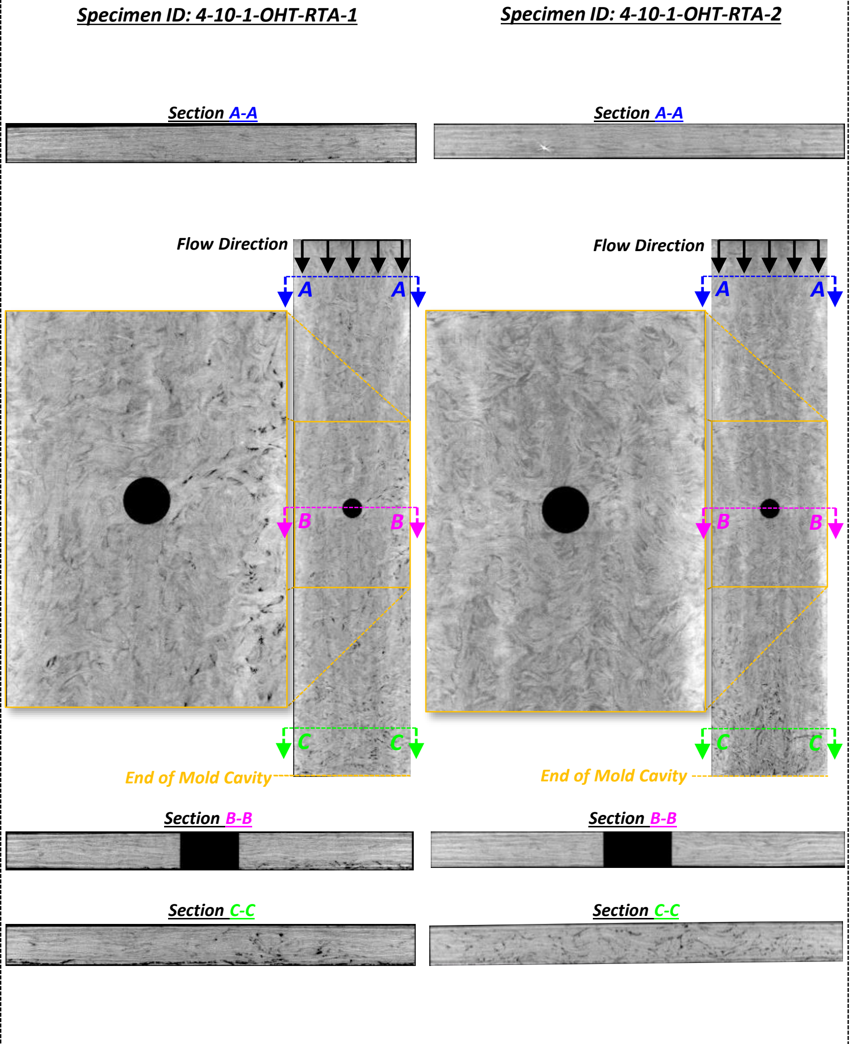
Square Platelet (0.5” x 0.5”) – XRCT Process Comparisons

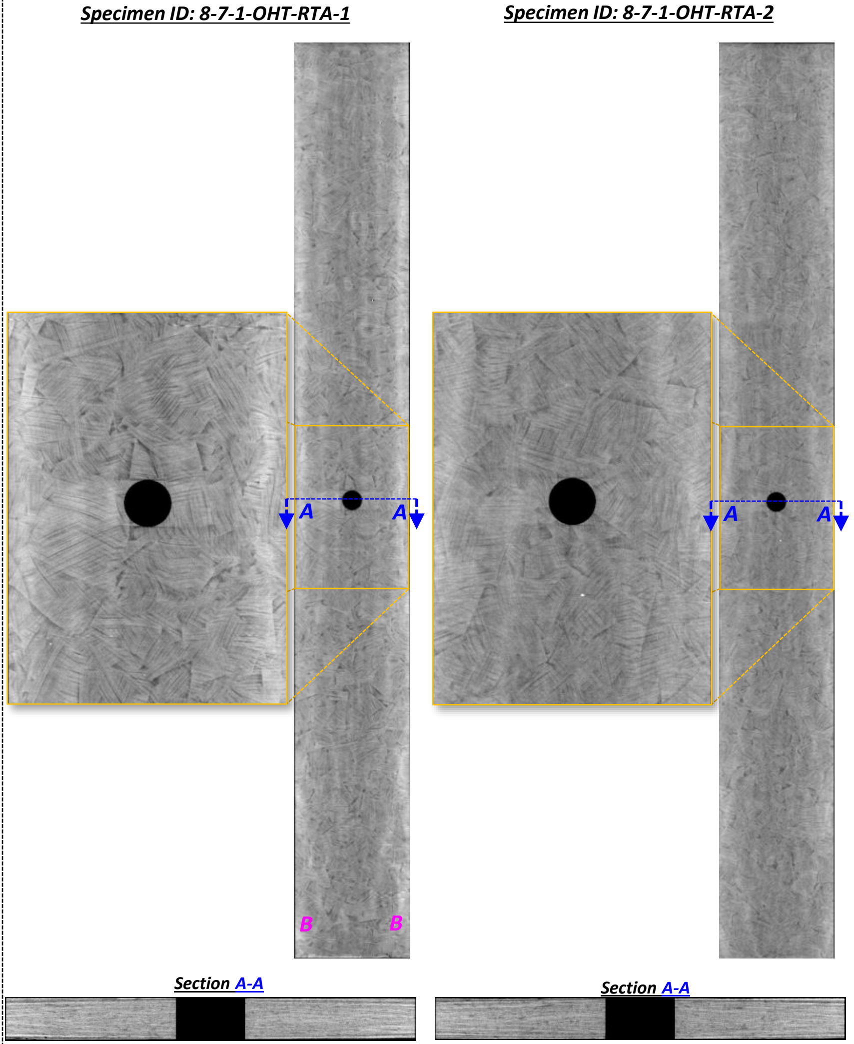
High Flow – 13.5” x 1.5” Panel (Thickness: 0.15”)



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

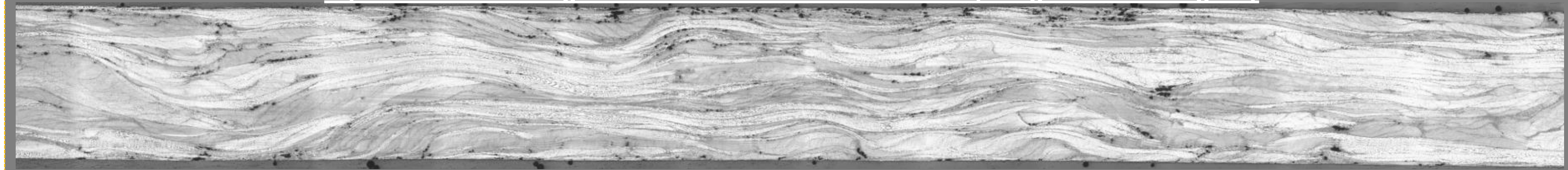


Low Flow – 12” x 12” Panel (Thickness: 0.15”)

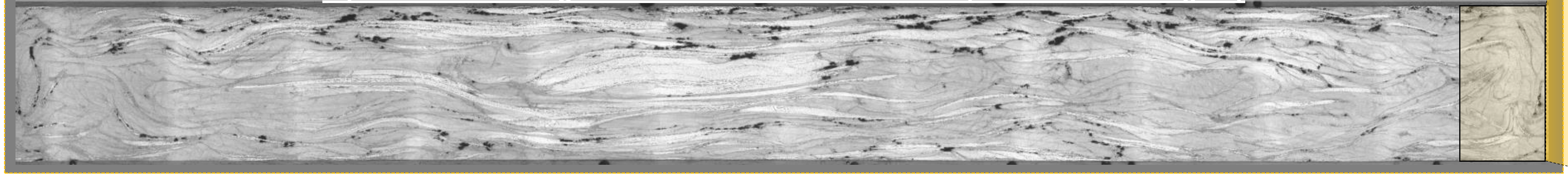


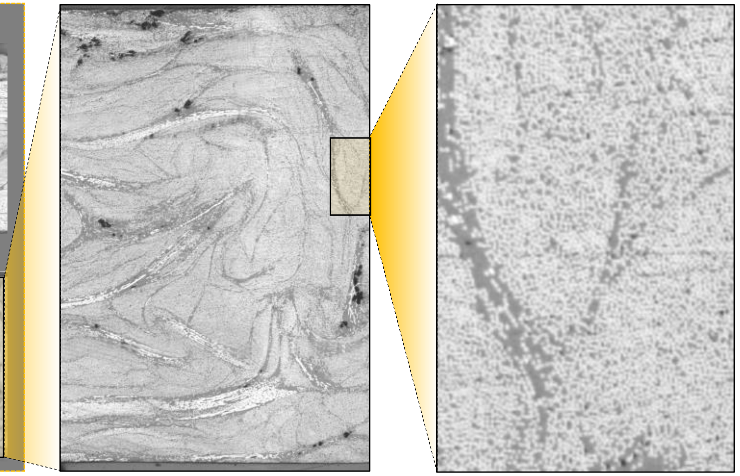
Square and Narrow Platelet High Flow Micrograph Comparison

Square Platelet – High Flow 13.5” x 1.5” Panel – 4-7-2 (Longitudinal 0-degree)



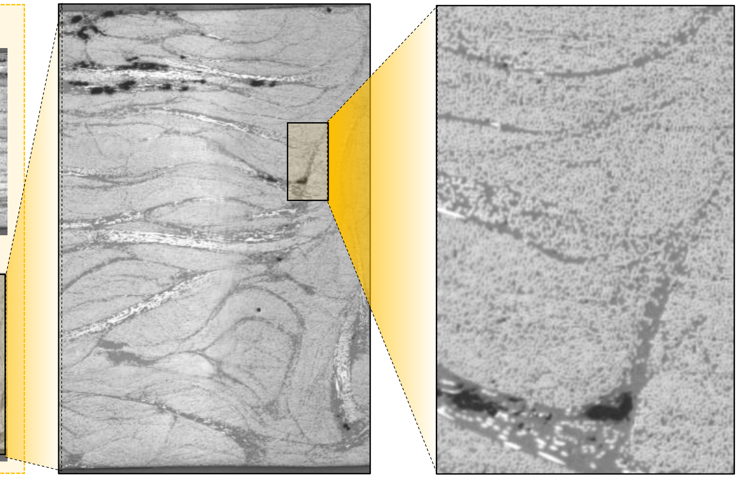
Square Platelet – High Flow 13.5” x 1.5” Panel – 4-7-2 (Transverse 90-degree)





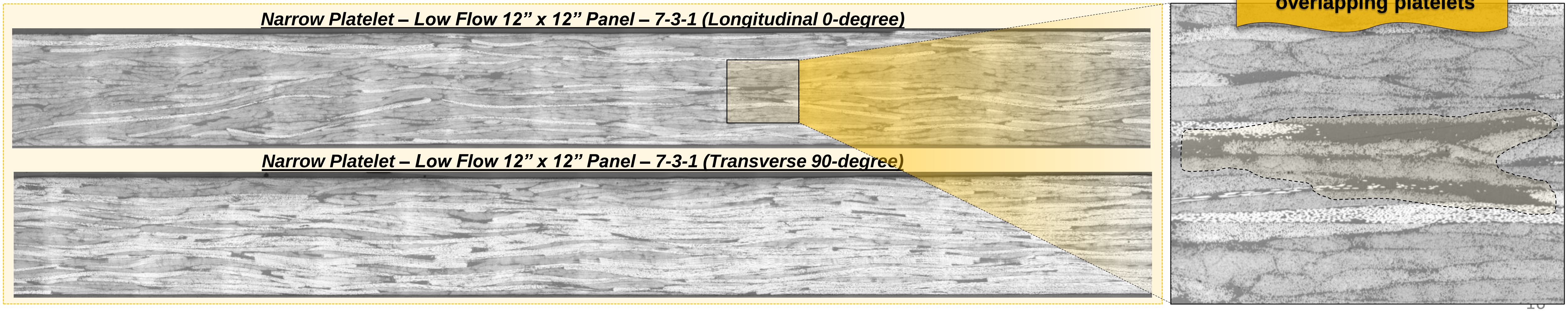
Narrow Platelet – High Flow 13.5” x 1.5” Panel – 3-5-1-3 (Longitudinal 0-degree)

Narrow Platelet – High Flow 13.5” x 1.5” Panel – 3-5-1-3 (Transverse 90-degree)



Fiber alignment in flow direction at edge of specimen

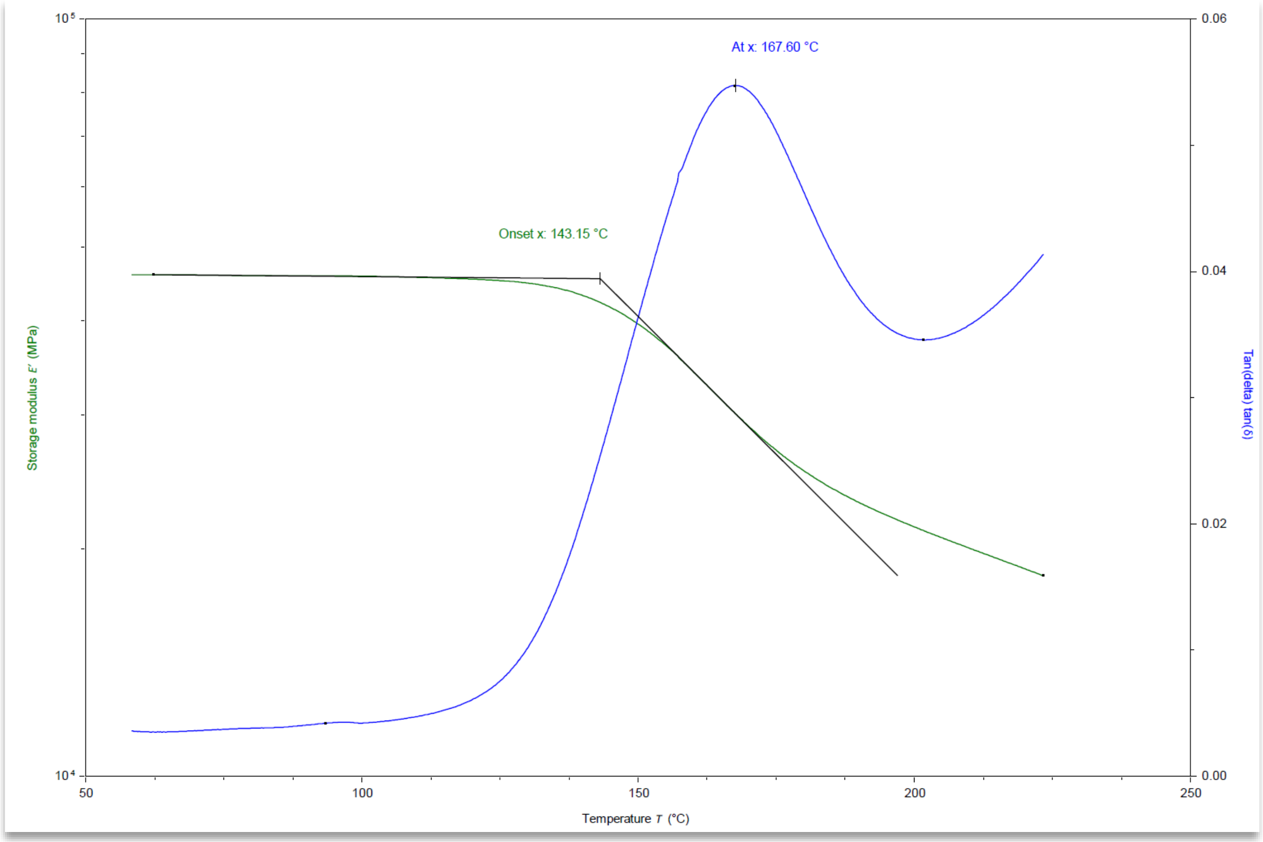
Square and Narrow Platelet Low Flow Micrograph Comparison



Thermal Analysis – Glass Transition Temperature

- **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%



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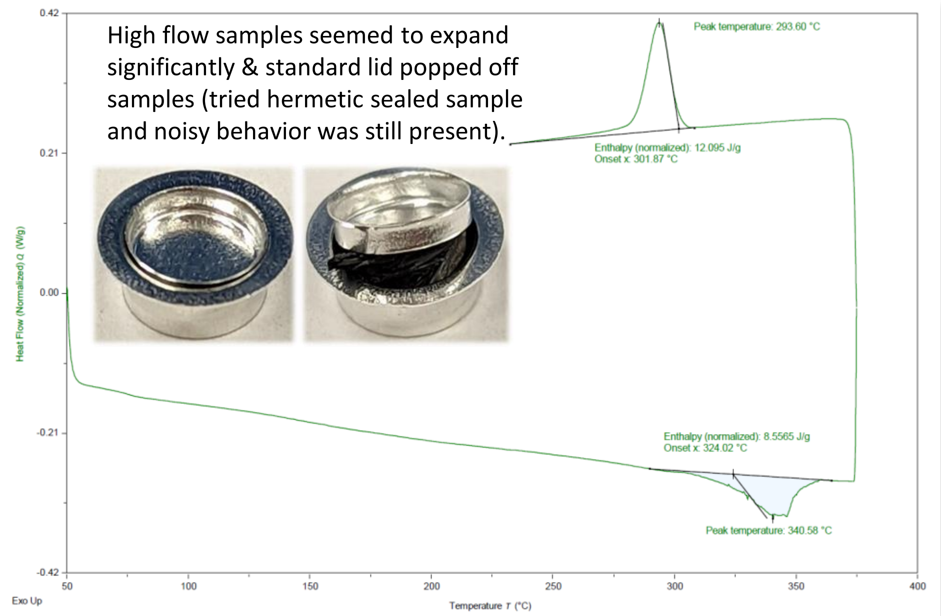
Thermal Analysis – Crystallinity

- **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%



$$\%Crystallinity = \frac{\Delta H_f - \Delta H_{cc}}{\Delta H_f{}^o \times R_c} \times 100$$

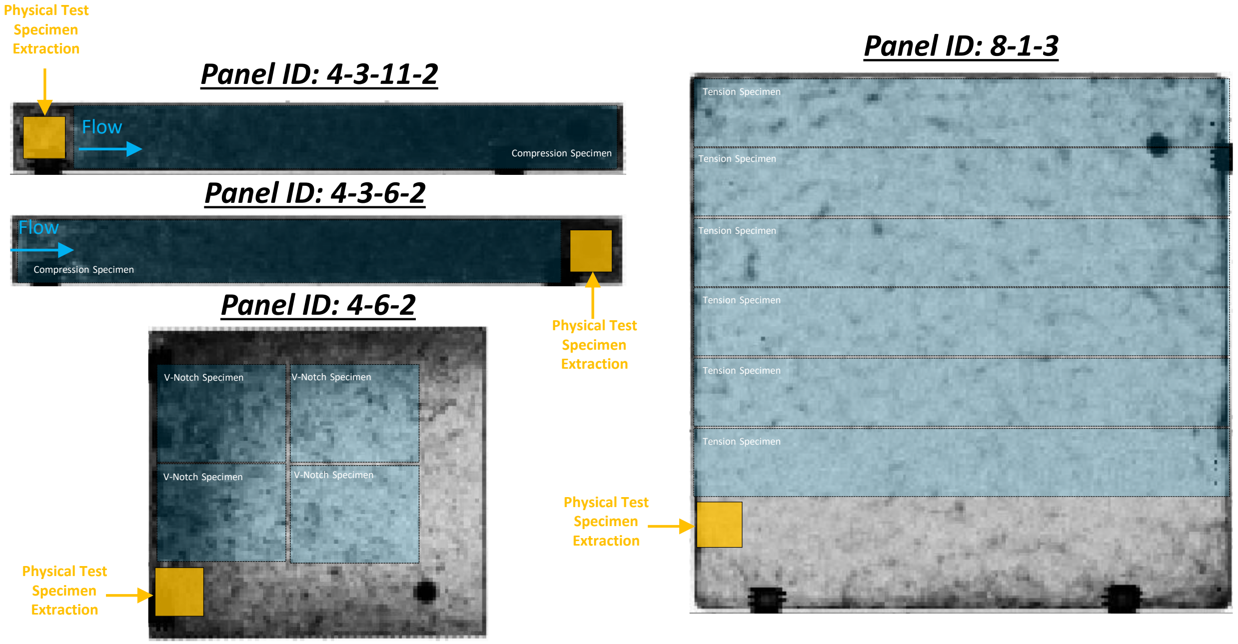
ΔH_f: Enthalpy of Fusion / Melting
ΔH_{cc}: Enthalpy of Cold Crystallization
$\Delta H_f{}^o$: Theoretical Maximum Enthalpy of Fusion for Fully Crystalline Sample (**130 J/g**)
R_c: Resin Content (**34%**)

Summary of 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**

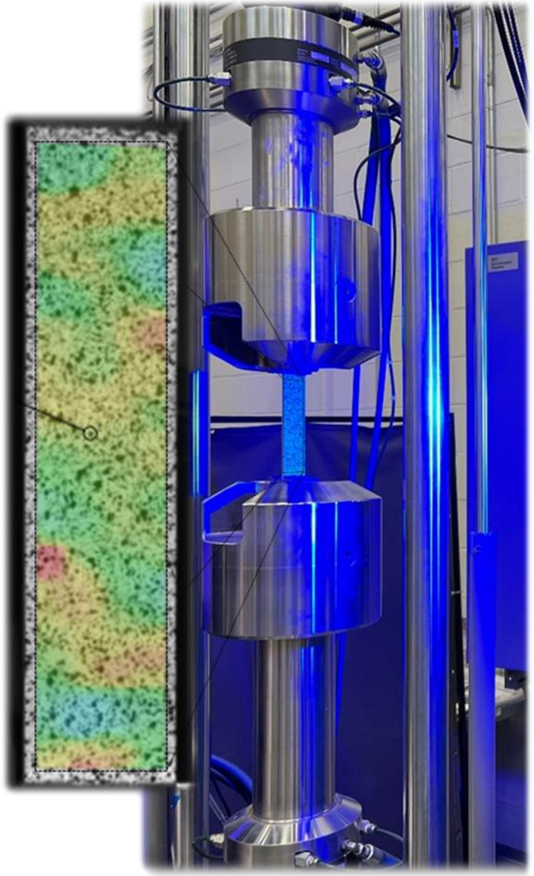
Square and Narrow Platelet Comparisons

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	



Mechanical Test Methods

Tension

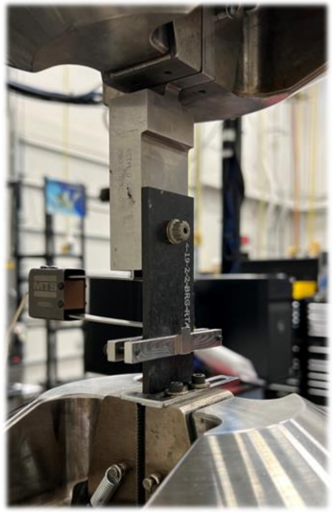


Compression (12" Length)

Compression (7" Length)

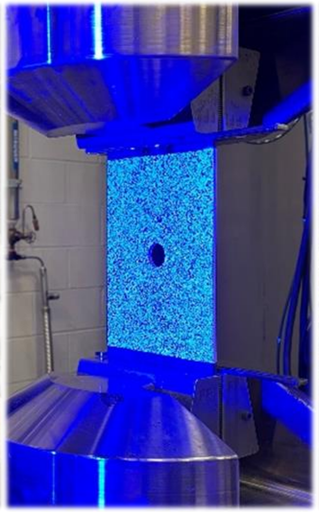
V-Notched Rail Shear

Bearing (SSB)

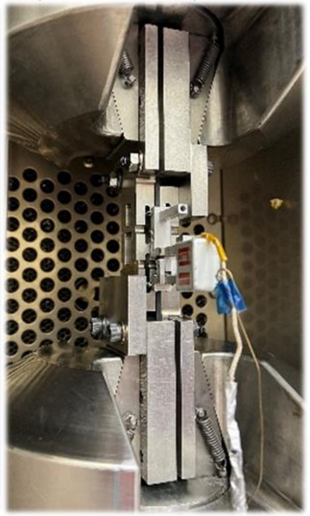


Flexural

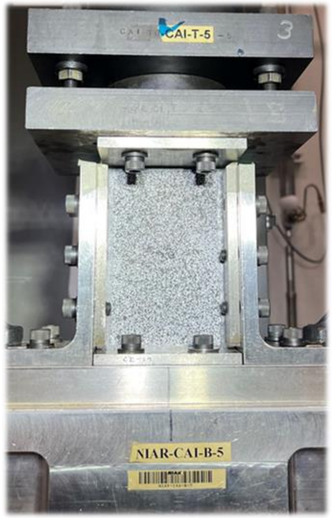
Open Hole Tension



Open Hole Compression



Compression After Impact



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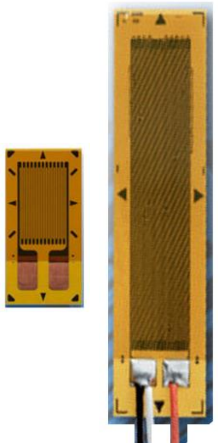
Mechanical Testing – Key Takeaways

- **General:**
  - **Specimen Sizing**
    - Cross sectional area must be sized considering platelet size
    - Tension/Compression sized with 3X platelet size (0.5” platelet size ⟶ 1.5” coupon width)
  - **Strain Measurement Techniques**
    - Large strain gradients associated with DFCs
    - Strain Gauge grid length of the strain gauge must be significantly larger than the inhomogeneity present in the strain field
    - All work focused on DIC and Extensometers
      - Maximize gage length when using extensometers
  - **Flow behavior** largely drives fiber orientation within part/panel and significantly effects mechanical performance
    - Varies for each mold

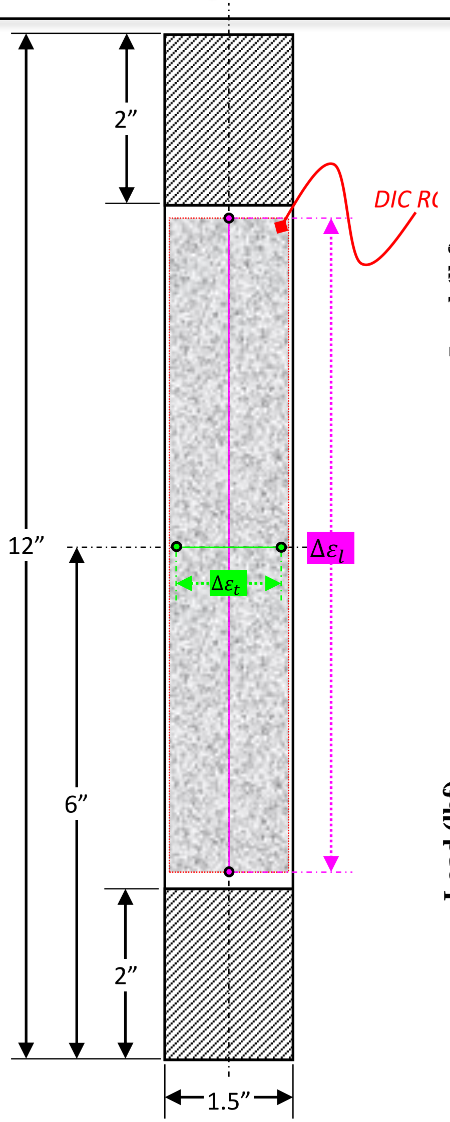


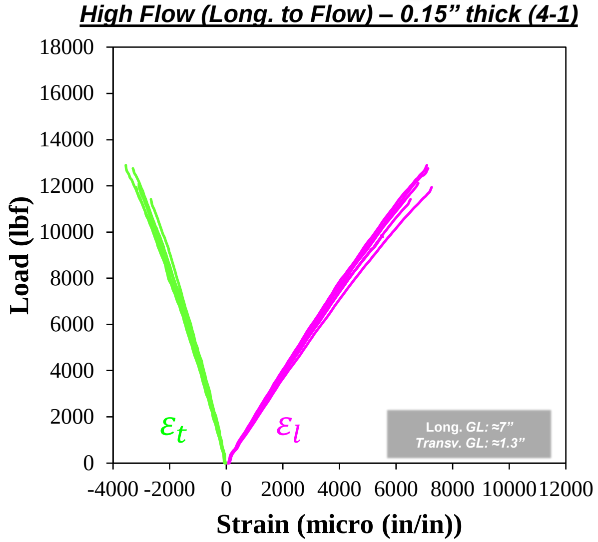
$$\nu = -\frac{\Delta\varepsilon_t}{\Delta\varepsilon_l}$$

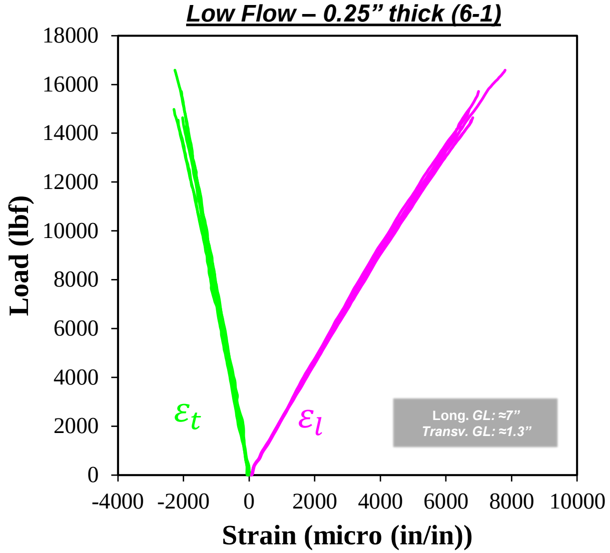
ν: Poisson’s Ratio

$\Delta\varepsilon_t$: **Average** difference in lateral strain between two strain points

$\Delta\varepsilon_l$: **Average** Difference between two longitudinal strain points

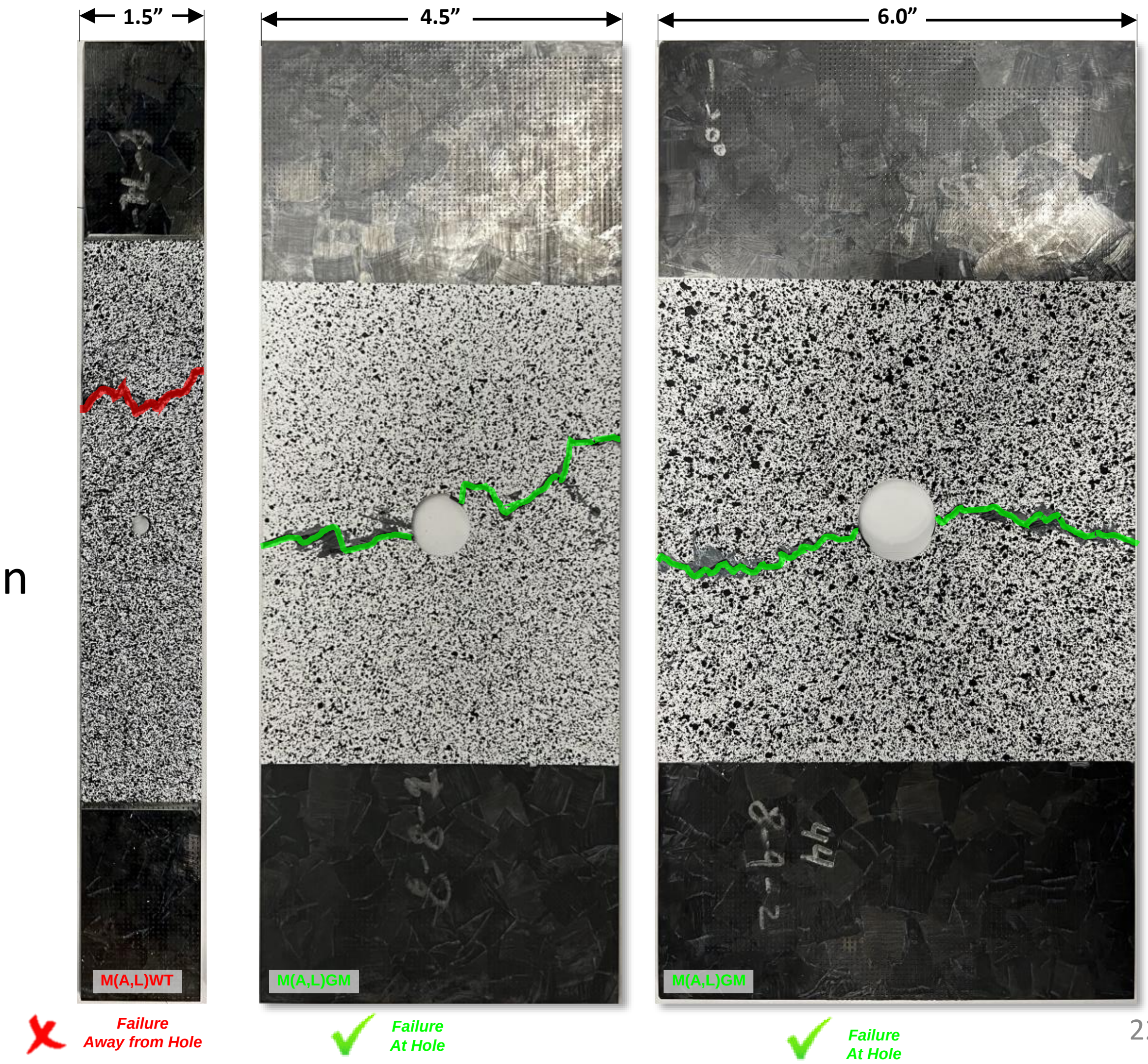






Mechanical Testing – Key Takeaways Cont.

- **Tension**
  - In the majority of the alike configurations tested, the narrow platelet material resulted in higher (average) strengths and moduli in comparison to the square platelet material
    - **Most significant change in tensile strength and modulus for low flow panels**
- **Open Hole Tension**
  - Standard hole diameter of 0.25” (ASTM D5766) insignificant as stress concentrations inherent to the material were higher than stress concentration at hole
    - As hole diameter is increased beyond fiber length » stress concertation around hole more significant
- **Bearing**
  - **Significant change in strength and failure mode between flow behaviors**



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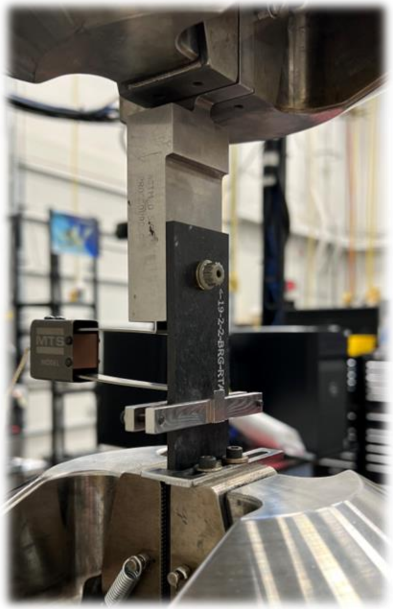
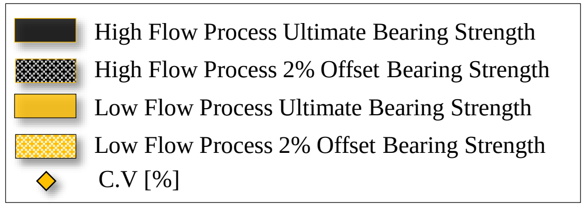
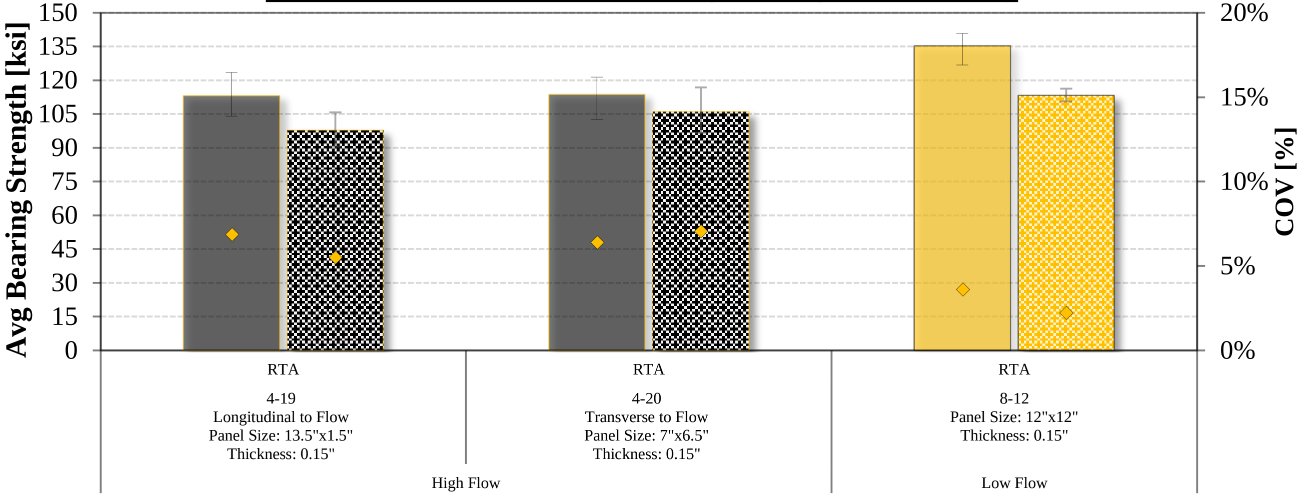
Single-Shear Bearing Testing – (Square Platelet)

- ASTM D5961 “Standard Test Method for Bearing Response of Polymer Matrix Composite Laminates”
  - Procedure C SSB Testing
    - **Fastener: MS21297-04003**
    - **Torque: 30 + P.T. in-lb**
    - **Head Washer: MS21206-C4**
    - **Nut Washer: MS21206-4**
    - **Collar: MS21084L04**

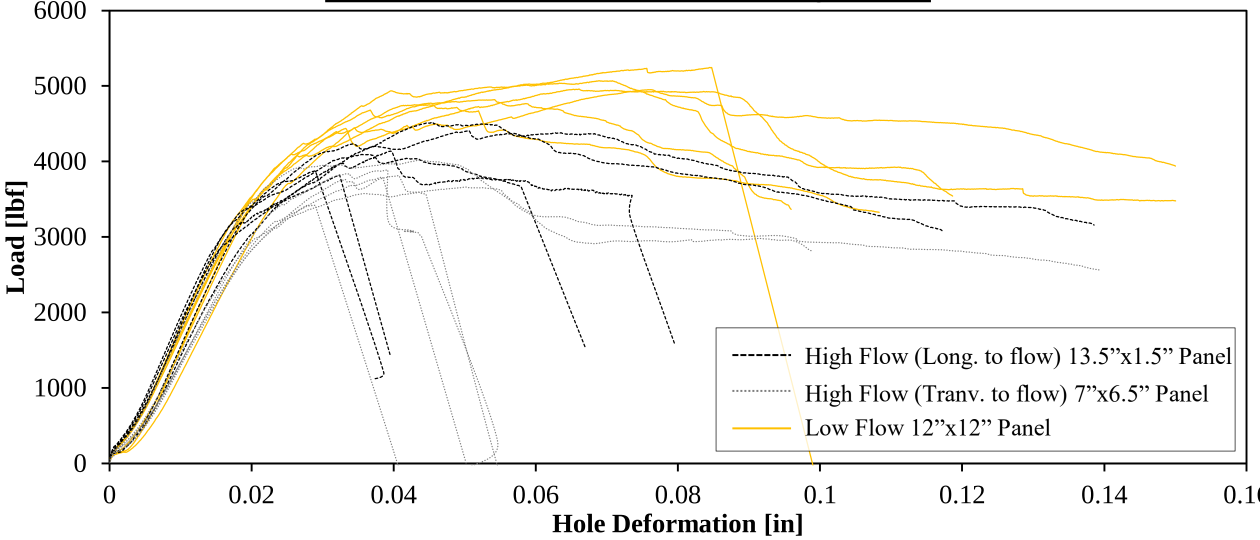



Ultimate & 2% Offset Bearing Strength Summary



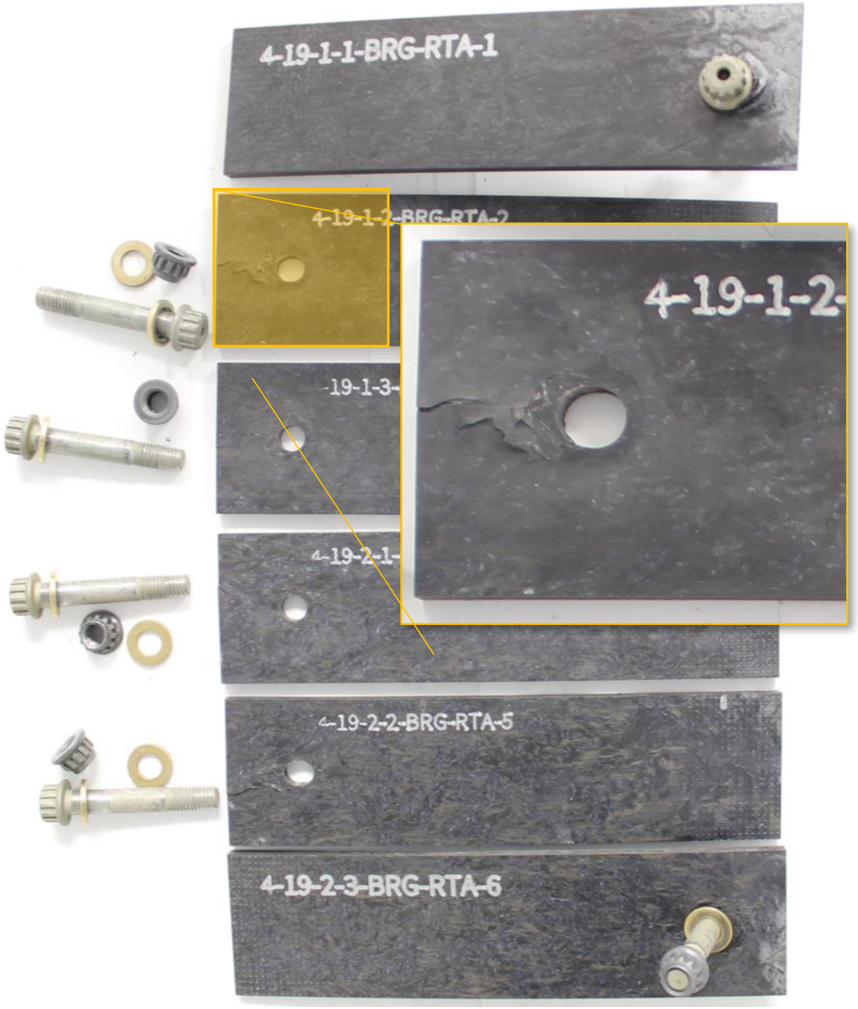


Load vs. Hole Deformation Comparison

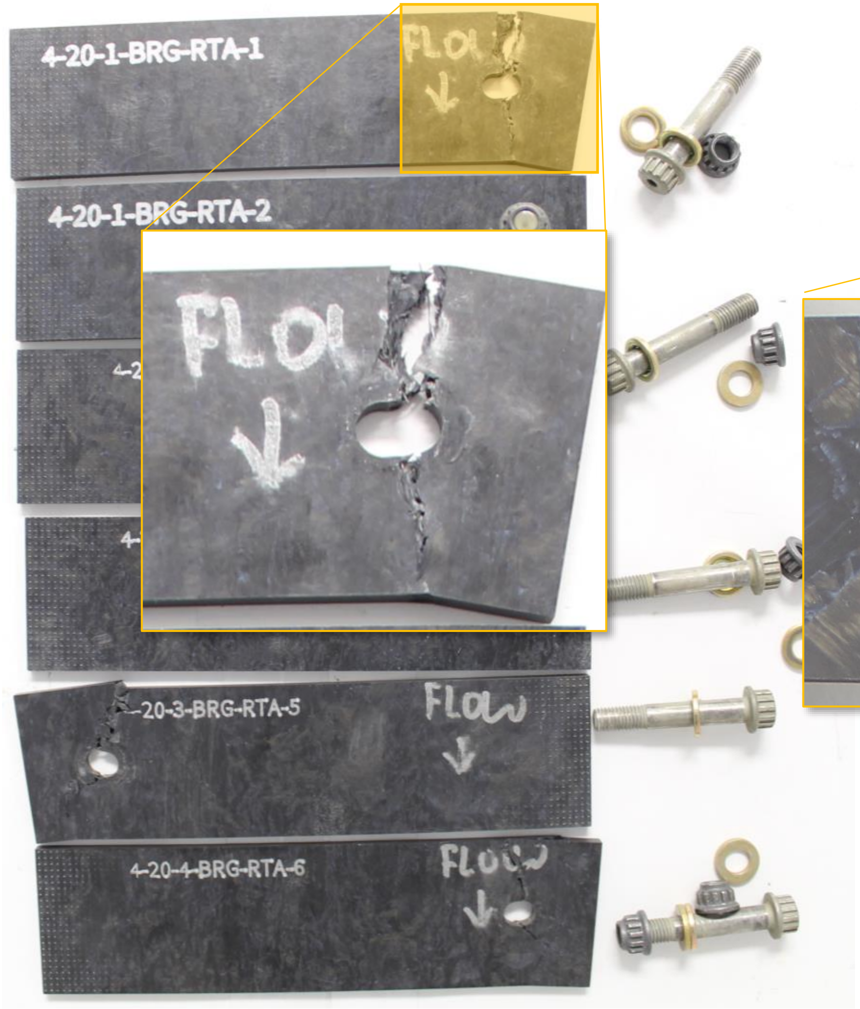


SSB Failure Mode Summary

High Flow (Long. to Flow)



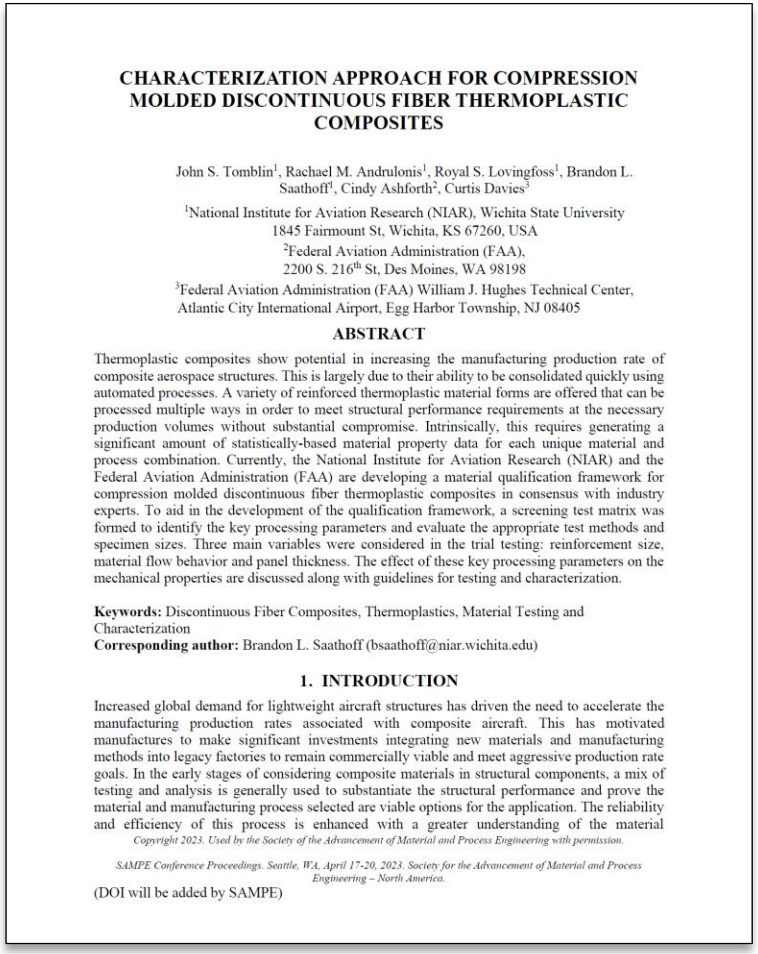
High Flow (Transverse to Flow)



Low Flow

Program Status & Summary

- **Pre-Qualification Trial Testing**
  - Completed trial test matrices for square and narrow platelet DFC material
  - Load/Strain rate sensitivity testing in-progress (DFC versus continuous fiber composite laminate)
  - Facilitating the transfer of test data to University of Washington. A shared file transfer portal was created and has been used for transferring test data.
- **Qualification**
  - Currently outlining test matrices and specifications to move toward qualification program
- **Benefit to Aviation**
  - Publicly available DFC data linked to M&P Specifications.
  - Lessons learned, guidelines for characterization, and data made available to **CMH-17.**



CHARACTERIZATION APPROACH FOR COMPRESSION MOLDED DISCONTINUOUS FIBER THERMOPLASTIC COMPOSITES

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ABSTRACT

Thermoplastic composites show potential in increasing the manufacturing production rate of composite aerospace structures. This is largely due to their ability to be consolidated quickly using automated processes. A variety of reinforced thermoplastic material forms are offered that can be processed multiple ways in order to meet structural performance requirements at the necessary production volumes without substantial compromise. Intrinsically, this requires generating a significant amount of statistically-based material property data for each unique material and process combination. Currently, the National Institute for Aviation Research (NIAR) and the Federal Aviation Administration (FAA) are developing a material qualification framework for compression molded discontinuous fiber thermoplastic composites in consensus with industry experts. To aid in the development of the qualification framework, a screening test matrix was formed to identify the key processing parameters and evaluate the appropriate test methods and specimen sizes. Three main variables were considered in the trial testing: reinforcement size, material flow behavior and panel thickness. The effect of these key processing parameters on the mechanical properties are discussed along with guidelines for testing and characterization.

Keywords: Discontinuous Fiber Composites, Thermoplastics, Material Testing and Characterization
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1. INTRODUCTION

Increased global demand for lightweight aircraft structures has driven the need to accelerate the manufacturing production rates associated with composite aircraft. This has motivated manufactures to make significant investments integrating new materials and manufacturing methods into legacy factories to remain commercially viable and meet aggressive production rate goals. In the early stages of considering composite materials in structural components, a mix of testing and analysis is generally used to substantiate the structural performance and prove the material and manufacturing process selected are viable options for the application. The reliability and efficiency of this process is enhanced with a greater understanding of the material

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Track: Composites Certification and Qualification
Title: Characterization Approach for Compression Molded Discontinuous Fiber Thermoplastic Composites
Date: Thursday, 4/20/2023
Time: 11:30 AM - 11:55 AM
Room: 337

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