Composite Production Work Cell Enabling Rapid Innovation

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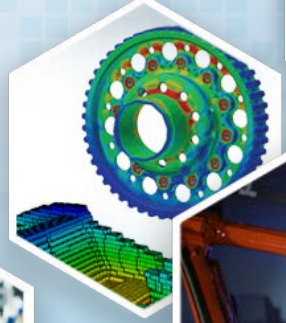


THE COMPOSITES iacmi INSTITUTE

Composite Production Work Cell Objectives

Coordinate with industry supply chain partners to demonstrate the ability to utilize key processing elements to rapidly design and manufacture composite parts.

The work cell is comprised of the following key elements:

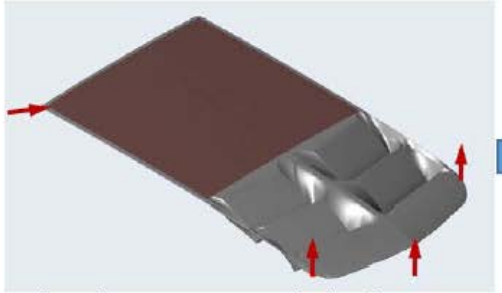
1) Design and simulation tools,

2) Agile tooling concepts focused on additive manufacturing,

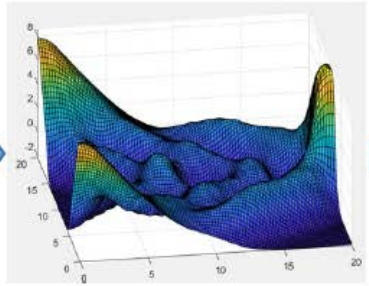
3) Automated preforming using continuous or chopped fiber,

4) Rapid consolidation and cure using a modified RapidClave®

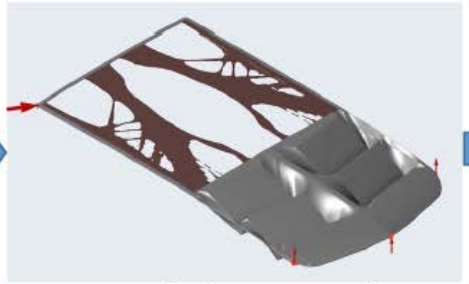
Topology Optimization Applied to TFP



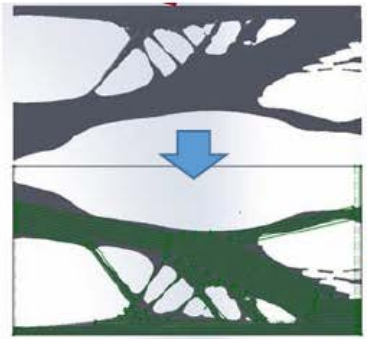
Loads and constraints are applied to the geometry.



Design loads are analyzed.



Load paths are optimized.



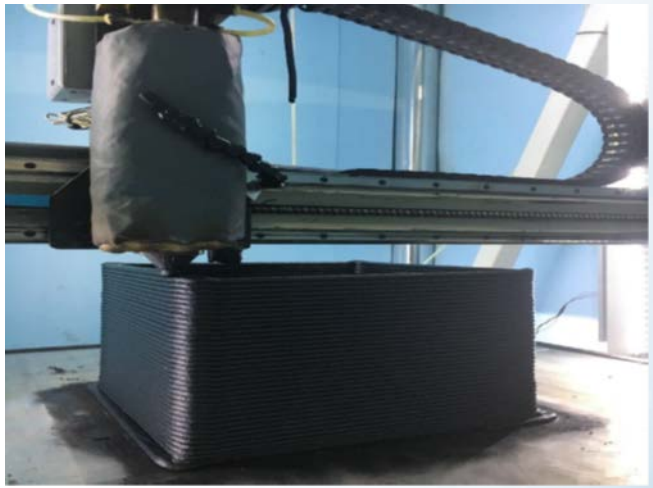
Stitch paths and pattern is created.

Data is sent to automated TFP stitching machine.

TFP preform is stitched and ready to move to the infusion and cure process.

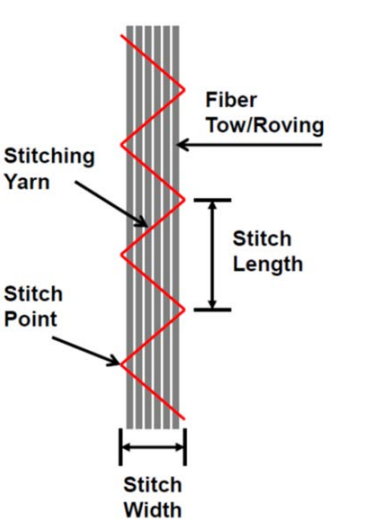
AM Tooling Technology – Pellets to Part

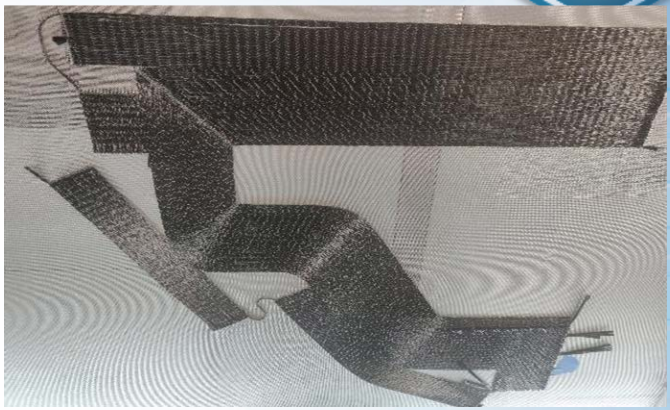
Extruder: 0.6, 0.8, 1, 1.2, 1.5, 2, 4, 6, 8 mm
3 – 30 lbs/hr
Heated Build Volume: 1m x 1m x1.2m



Tailored Fiber Placement – Automated Preforming

TFP, commercial, automated process, net shape preforms with minimal set-up and near zero scrap.





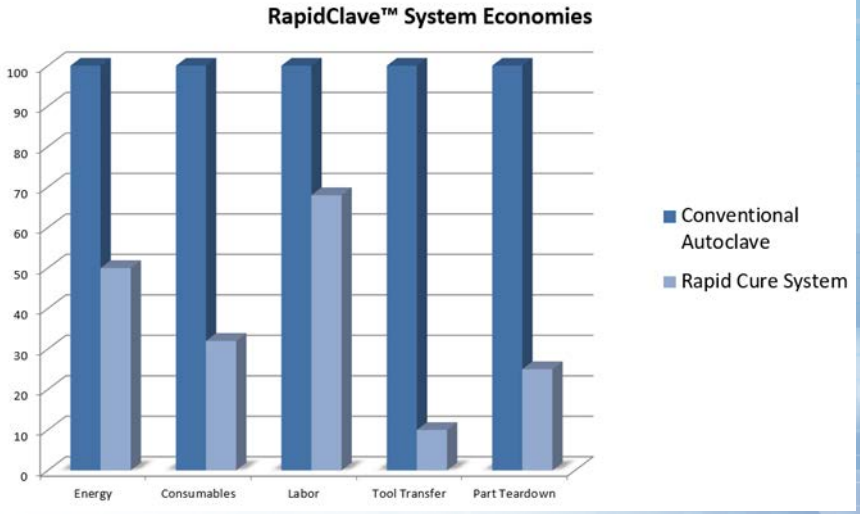
RapidClave® Technology

Globe Composites Technology Innovation
Getting Out of the Autoclave…

Conventional Autoclave System
Antiquated Process Control

…Evolution

Globe RapidClave® System
"High Fidelity" Process Control
& Automation



RapidClave® Technology Into Production

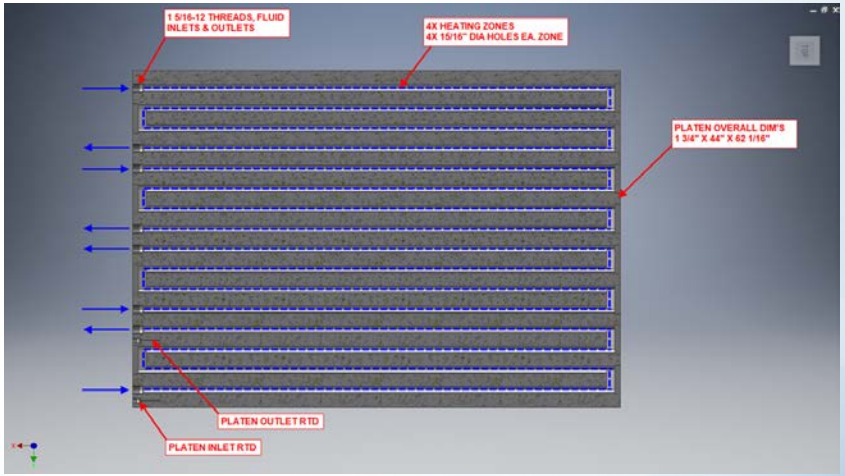
RapidClave® Gen-I Concept/Development began in 2008

- Carbon fiber, prepreg body panels for all **C7** base model & variants required new rapid consolidation method
- 2008-Plasan Carbon Composites and Globe Machine Manufacturing Company installed 7 RapidClave® systems
- Rapid heating and cooling required expensive and complex tooling.

Modified RapidClave®: Heated Process Air and Tool Plate

Temperature controlled process air (bag side) and circulating fluid-filled tool base allow for use of simple aluminum or polymeric tooling, supporting rapid cure up to 350°F, 100 psi.

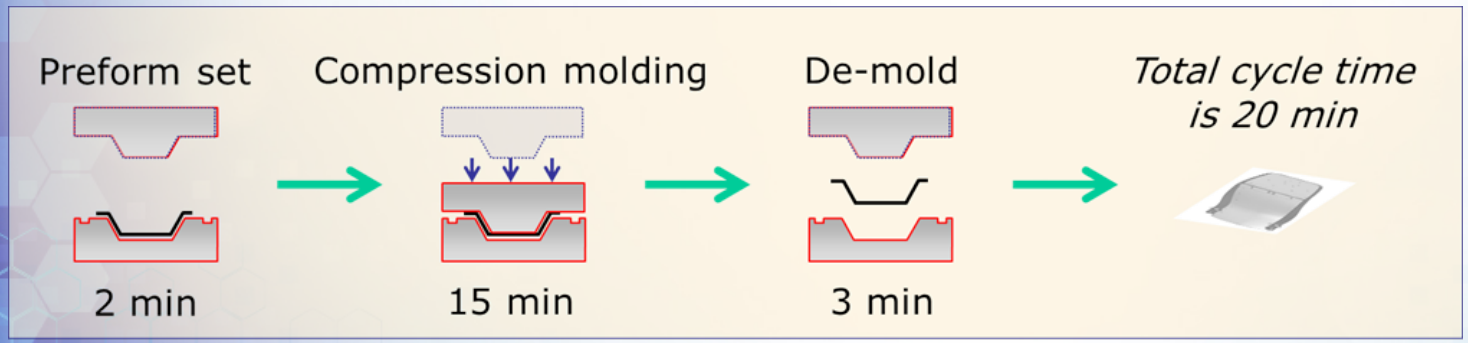
Tool plate working area: 61” x 44”



Hat Stiffener Compression Molding Versus RapidClave®

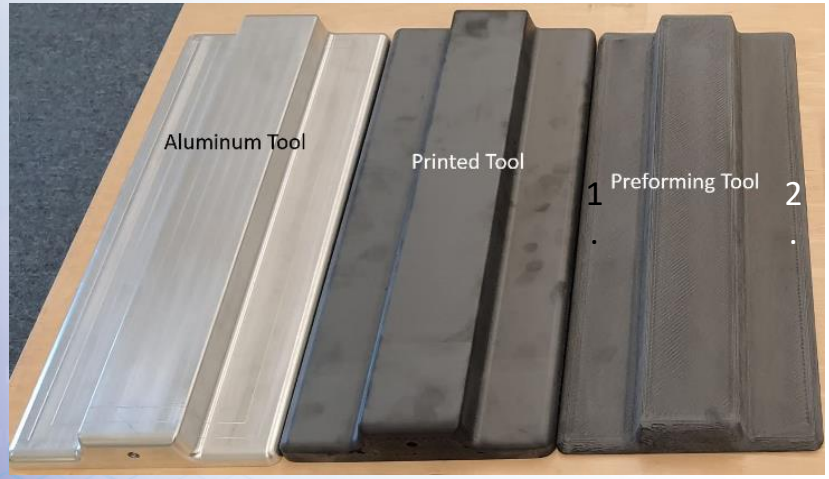
- RapidClave molding demonstration using Teijin Q-183 prepreg developed for compression molding of aerospace components

Cure: 160°C, 20 minutes
Tg: 180-190°C



Tooling Design

- Three hat stiffener tools were produced:
  1. CNC machined M1 aluminum tool
  2. Polymeric tool with a 20% carbon fiber filled polyetherimide feedstock.
  3. Preforming tool printed to net shape of the tool



Cost Analysis

- Additive hat stiffener tool achieved a cost savings of 90% compared to matched steel tooling.
  - Further development is needed to reduce additive tooling cost even more

Hat Stiffener			
Material	Compression Molding	M1 Aluminum	**Titan Atlas – 20% CF PEI (ULTEM)**
Total Costs	$24,000	$2,530	**$2,435**

Task	Labor Hours	Labor Costs ($75/hr)	Machine Hours	Machine Usage Costs ($80/hr)	Material (lbs)	Material Costs ($25/lb)	Total Costs	Notes
AM Tool Print	4	$300	15.75	$1,260	8	$200	$1,760	Costs $80/hr for print time on a Titan printer (as quoted by Titan Robotics).
Machining	N/A	$	N/A	$	N/A	N/A	$600	Machine usage hourly rate will need adjusted appropriately depending on commercial rate (assumed $80/hr).
Benching	1	$75	N/A	N/A	N/A	N/A	$75	This could vary depending on the individual and how much of this cost is rolled into the total machining costs.
Sealing	N/A	$0	N/A	N/A	N/A	$0	$0	Labor hours reported by operator. 600g of sealer used on the tool set.
						Total:	$2,435	Labor hour cost was set at $75 but could vary depending on the individual performing the work.

Preforming Step

- Solvay's Cycom®EP2750: Epoxy prepreg system, 30 min. cure time at 330°F.
- Preform used three 5 minutes debulks at each section (3 bottom plies, 2 middle plies, 3 top plies)
- Kits were pre-shaped so they could be immediately placed on a pre-heated tool for cure.
- Preform tool is much cheaper than cure tool allowing for multiple preforms perdebulk cycle

Additively Manufactured Polymeric Draping Tool

Debulking of Ply Stack

Pre-shaped Ply Stack

Part Fabrication

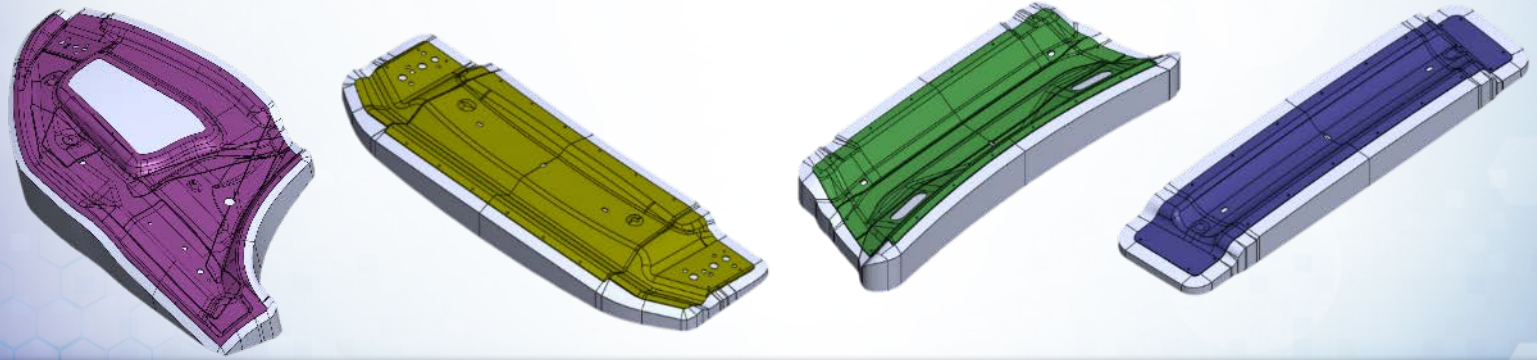
- Pre-shaped ply stacks were positioned onto tools pre-heated to 330°F
- A reusable silicone vacuum bag was placed over the part and tool.
- Hot plate was shuttled into RapidClave® for cure.
- Cured part is removed from the hot tool and ready to receive next preform.

New RapidClave® approach
100 psi hydrostatic pressure
Position preform on hot tool,
demold hot, conserves time and energy
Cycle time 20-30 minutes

Tooling Cost Comparison

Matched steel tool set (~1000 psi) vs. single sided aluminum (100 psi)

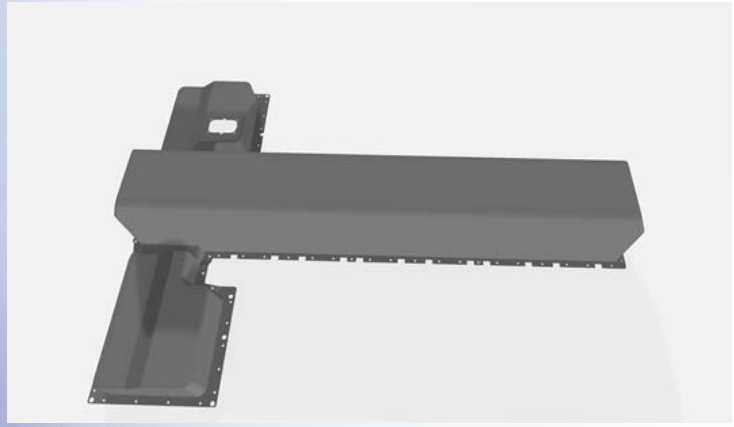
	Compression Tool	RapidClave® Tool
Tool #1	$92,000	$12,100
Tool #2	$65,500	$6,600
Tool #3	$65,500	$6,300
Tool #4	$54,000	$4,500
TOTAL	**$277,000**	**$29,500**

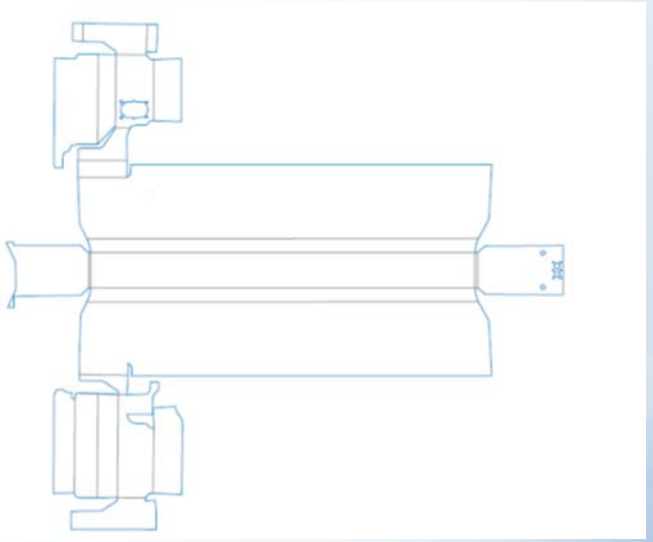


Dry Fiber Preforming Demonstrations

Using origami approach, design a flat preform that can be shipped to a molding site near OEM. Preform must readily drape into RTM-Light tool.

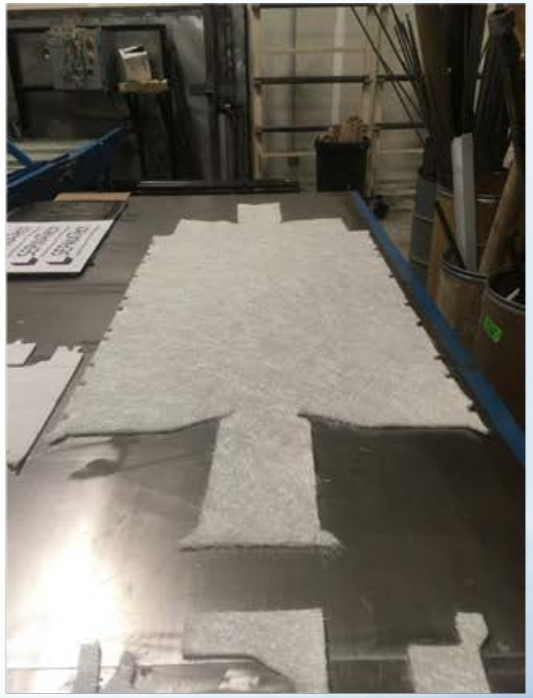
Part is approximately 4 feet long





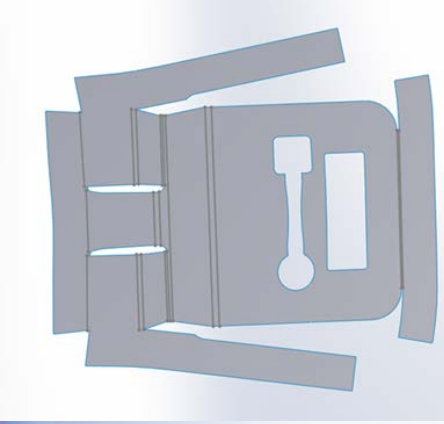
Preforming Demonstrations

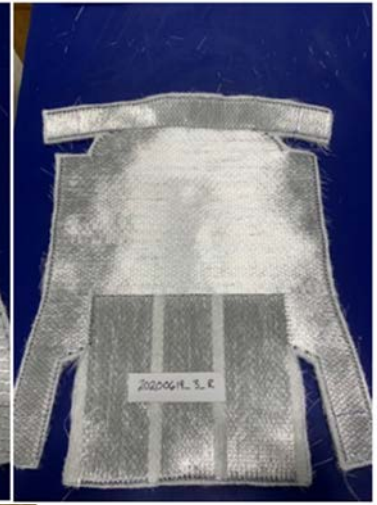
Preform is cut from Owens Corning Chopped Strand Mat

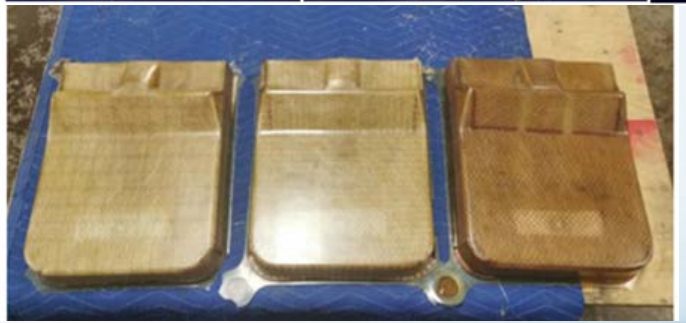


AM Printed Polymeric Tool Used to Validate Preform

Hybrid Preform Demonstration: CSM & TFP



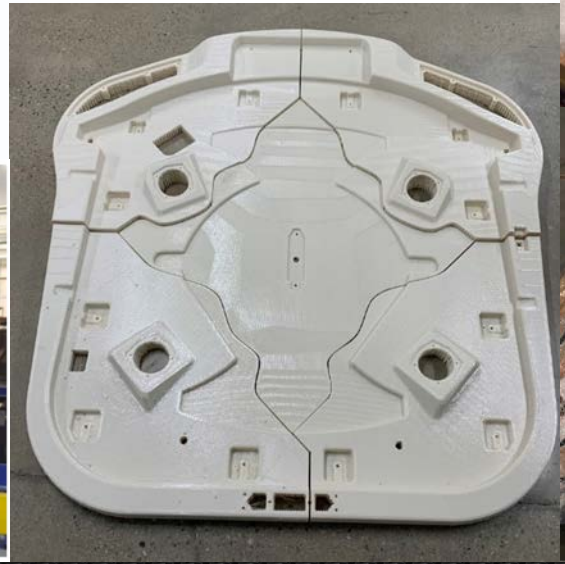




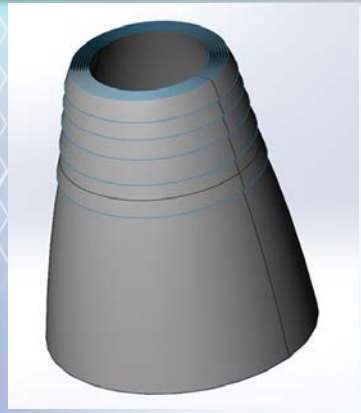
Flat Preform VS. P4A Net Shape Approach

Construction vehicle cab roof typically uses expensive SMC process – tooling cost too expensive to change design
Flat, chopped fiber preform enables low cost tooling for RTM-Light
Robotic chopper allows for FAW optimization
Vacuum bag of preform to tool allows for conformance validation.

In best cases no preforming tool is required

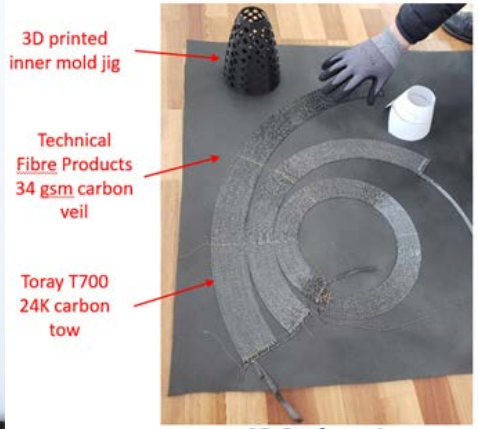


TFP Preforms for Complex Net Shape Structure



Side

2D Preform 1



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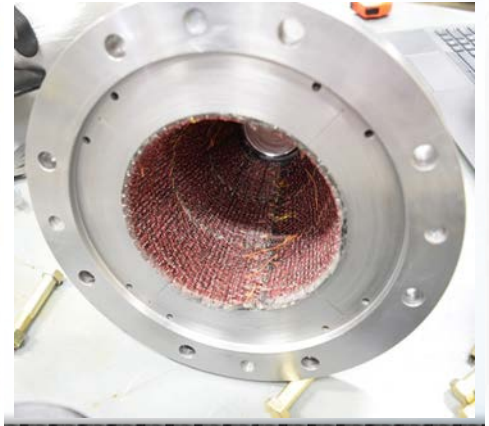
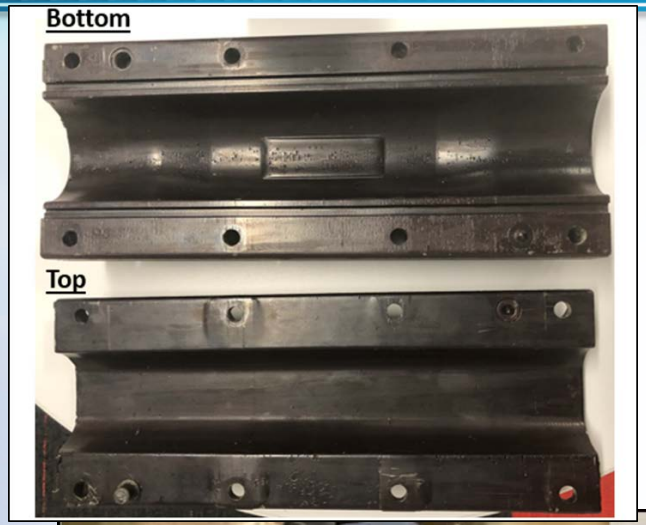
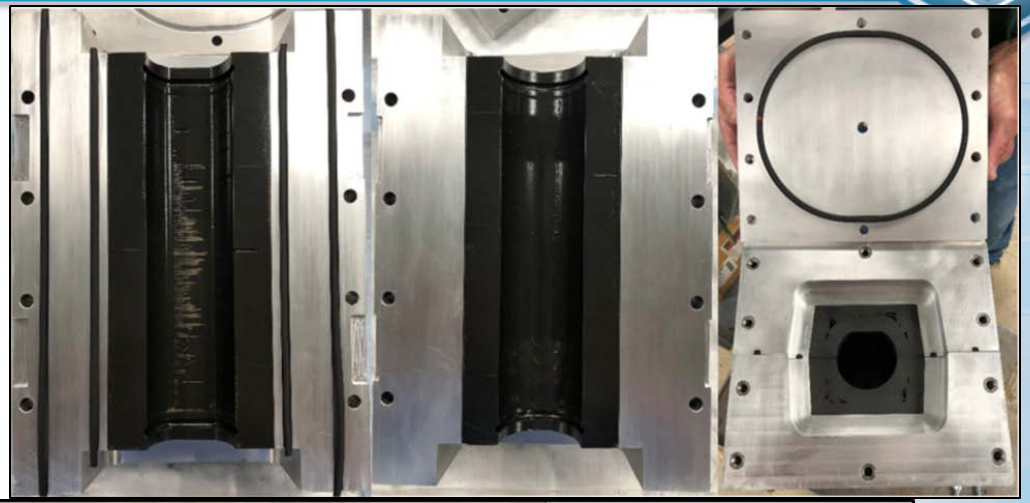


Oblique

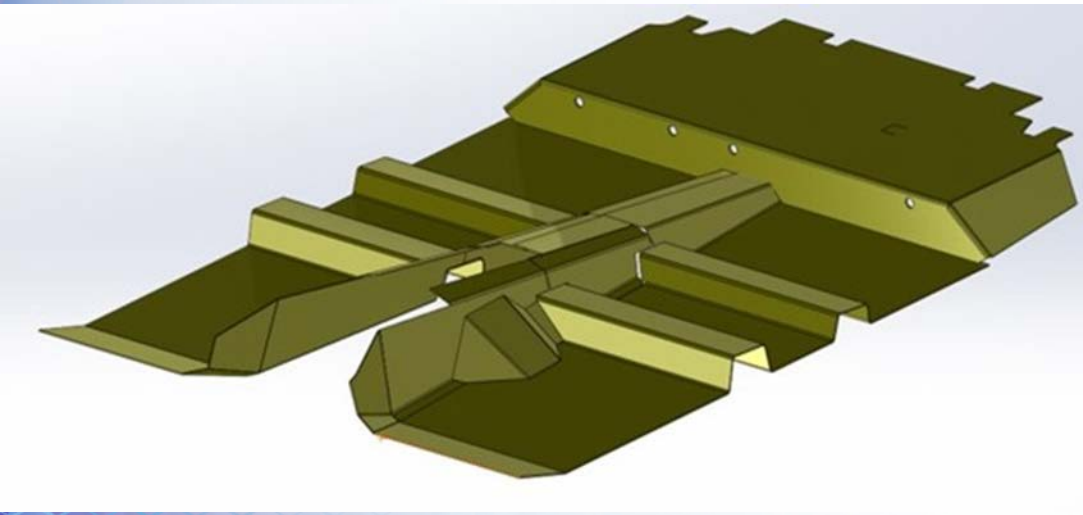
AM Tooling Master for Spintech Smart Tooling





Preforming Process for Vehicle Composite Floor

Developed ply kitting strategy to minimize waste and preforming time
Utilized AM tooling for preform, decoupled from expensive steel consolidation tooling
Demonstrated consolidation in RapidClave with 75% reduction in cycle time



Conclusions

Demonstrated up to 90% tooling cost reduction for high rate manufacturing process demonstration

Demonstrated novel automated low waste preforming approaches

Demonstrated new operational methodology for RapidClave

Fostered technology exchange and problem solving with over a dozen industry partners serving multiple market segments

Acknowlegements

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Industry Partners:
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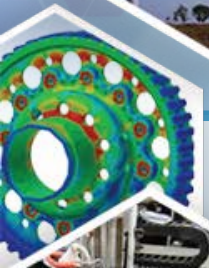

Thank you for attending!!