Resin Infusion as a Method of Manufacturing Composite Rocket Airframes

Team 93

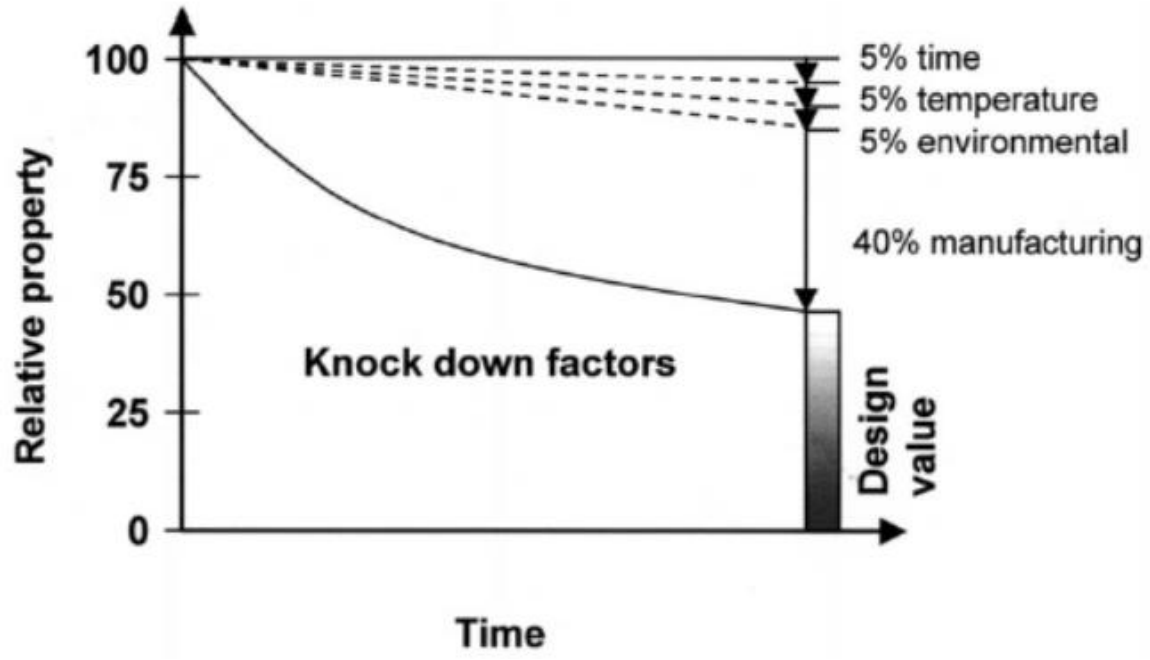
2018 Spaceport America Cup

Overview

- Introduction and Motivation
- Material Characterization
- Simulations and Implementation
- Manufacturing Results
- Conclusions, Future Work, and Acknowledgements

Introduction and Motivation

- The properties of a composite and its processing methodology are closely related



Comprehensive Composite Materials 1-26 Composite Processing and Manufacturing – An Overview

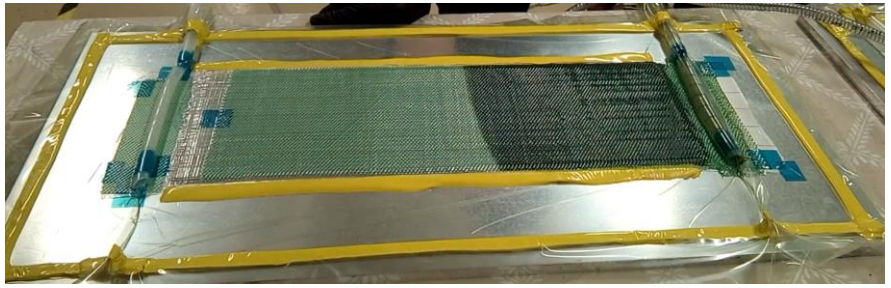
- Failing to properly process a composite component can lead to significant reductions in the material properties, or scrapping of large parts!

Introduction and Motivation

- What is Vacuum Assisted Resin Infusion (VARI)?

- Three stage composite manufacturing procedure
  - Preform is laid onto tool while dry and a vacuum bag is applied
  - Resin is pushed through preform by atmospheric pressure
  - The part cures under vacuum pressure

1) Pre-form is compacted under atmospheric pressure



2) Resin passes through part, impregnating the pre-form

3) The part cures under vacuum pressure as required

Introduction and Motivation

- Why use VARI though?

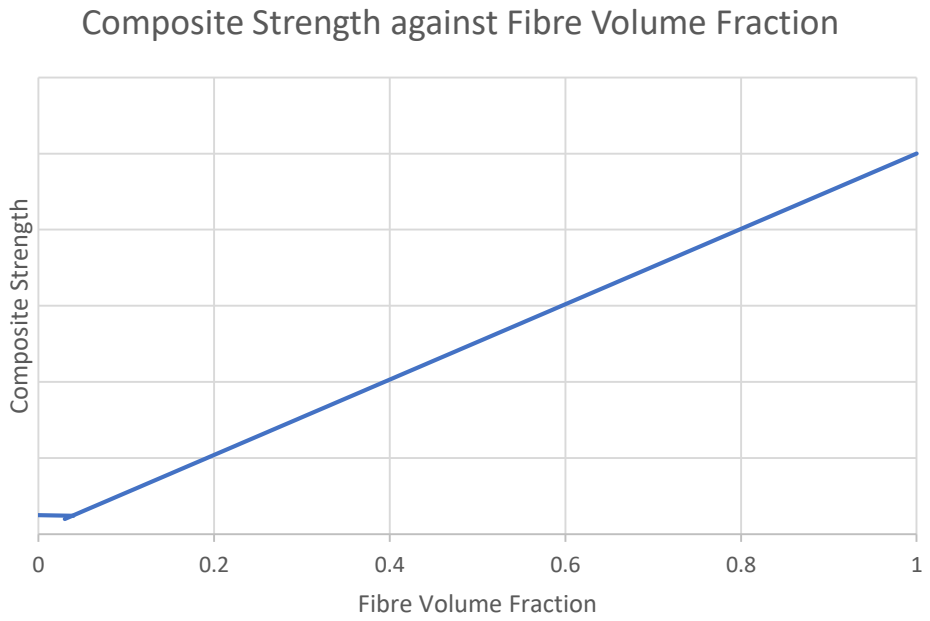
- Reduced lead times
  - A section of airframe can be produced in a few hours
- Low cost
  - No need for expensive tooling or high cost infrastructure
- Clean Process
  - Minimal exposure to resin during layup

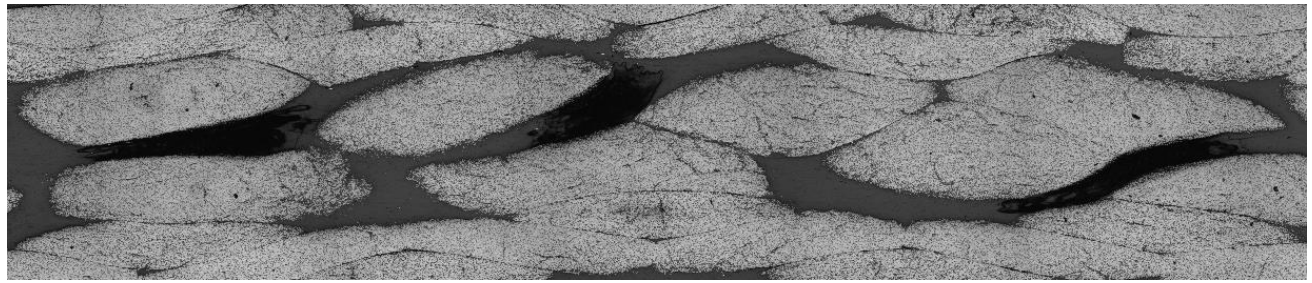
Introduction and Motivation

- Evaluating part quality is key in determining the success of the process

- Three key items evaluated on body tube samples
  - Dimensional accuracy
  - Fiber volume fraction
  - Void content

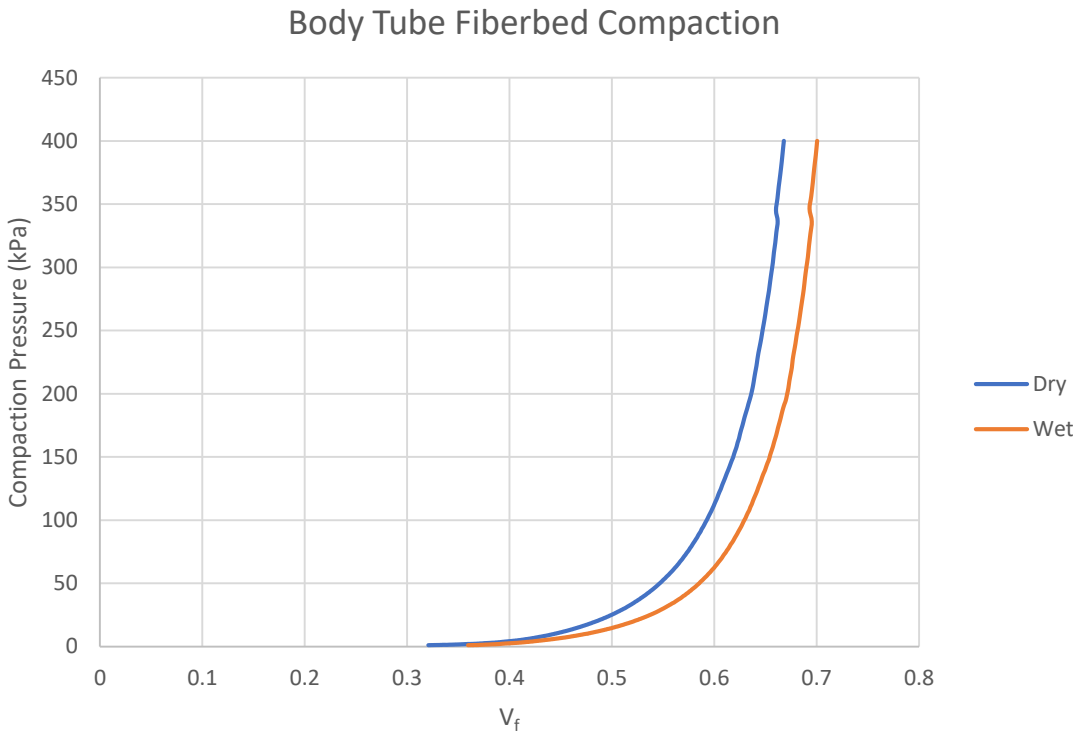
- Can we produce aerospace worthy components using VARI?





Material Characterization

- Fiber Bed Characterization
- Apply compaction pressure to fiber bed using an MTS 5kN machine and calculate fiber volume fraction
- Produces relationship between fiber volume and compaction pressure

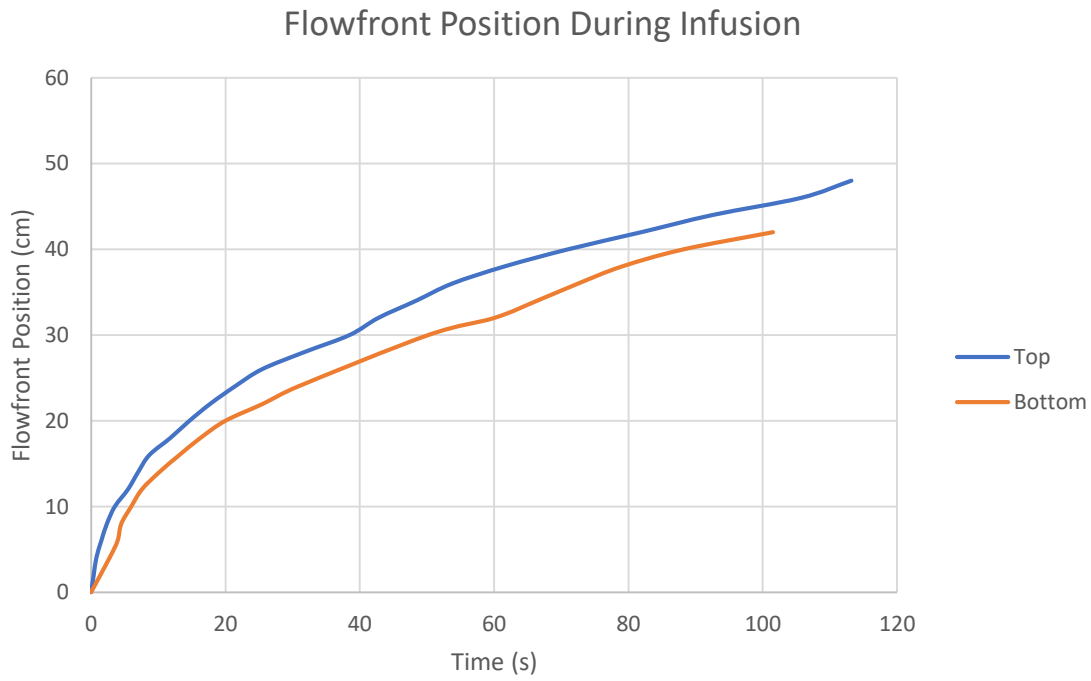


$$V_f = \frac{\sigma_f}{\rho_f \cdot t}$$

Material Characterization

- Permeability Measurements
- Permeability, *K*, measures the ability for the resin to flow through a preform
- Directly influences the fill time

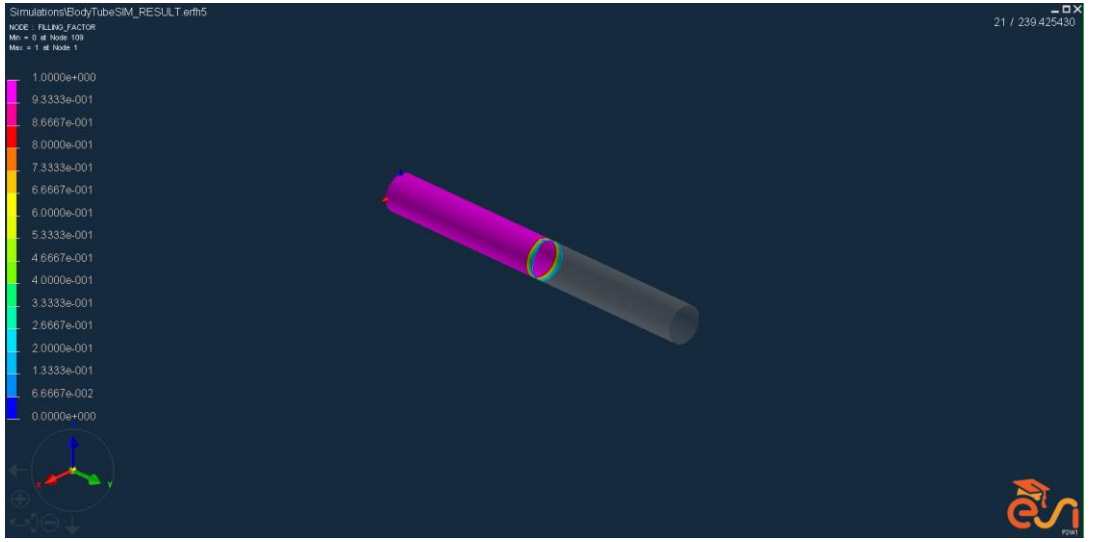
$$t_{fill} = \frac{x_{ff}^2 \phi \mu}{2(P_o - P_b)K}$$



Simulation and Implementation

- Body tube infusion simulated in PAM – RTM
- Simulated fill time: 942s
- Analytical fill time: 903s
- Results show that the process is implementable on full scale parts

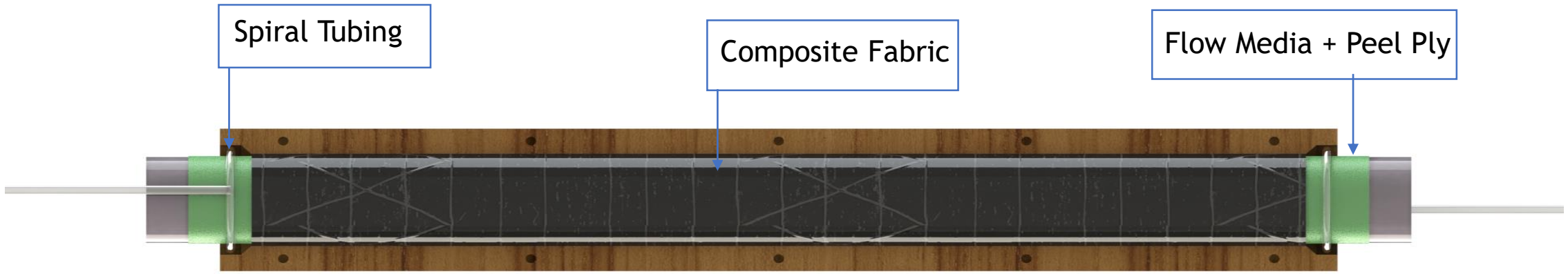
Simulation at 6s



Simulation at 239s

Simulation and Implementation

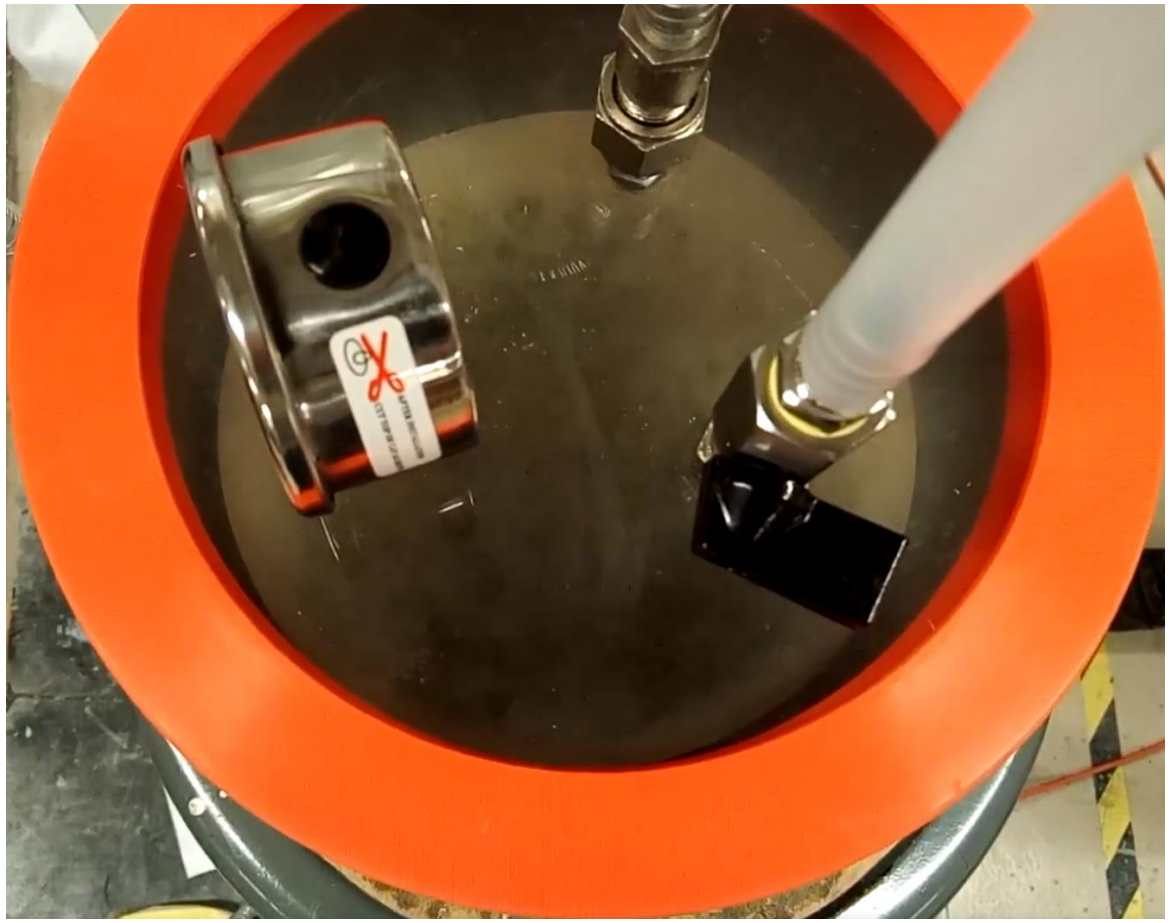
- Implemented using a female Renshape mold
  - Machined on a CNC router
  - Coated with polyester to create smooth surface
- Employs spiral tubing to create circular inlet and vent



Simulation and Implementation

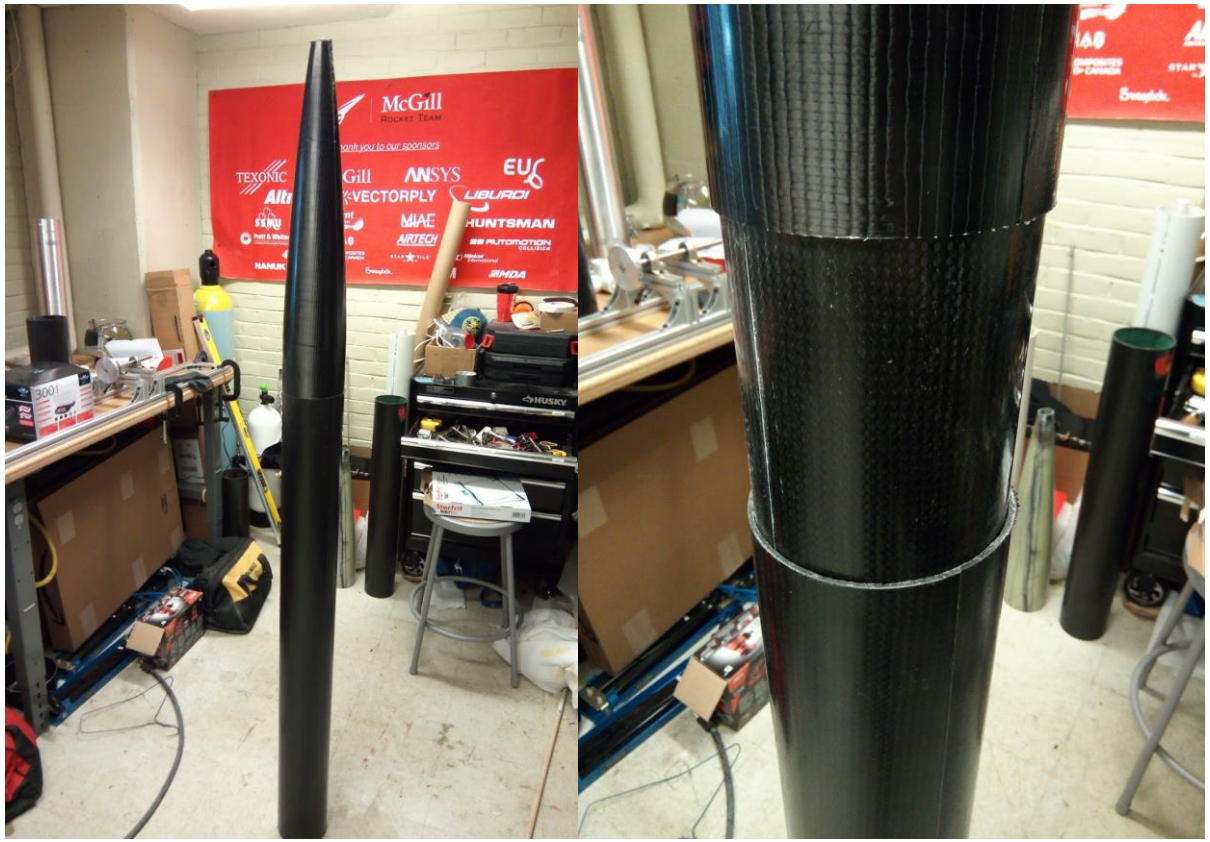
- Care must be taken to limit void content

- Resin is always de-gassed to remove as much entrapped air as possible before the part is infused



Manufacturing Results

- Measurements show the parts are within +/- 0.010” of target dimensions
- Parts successfully coupled without sanding
- Thickness variations apparent, measured values between 0.098”-0.108”
  - Airframe “Leaks”



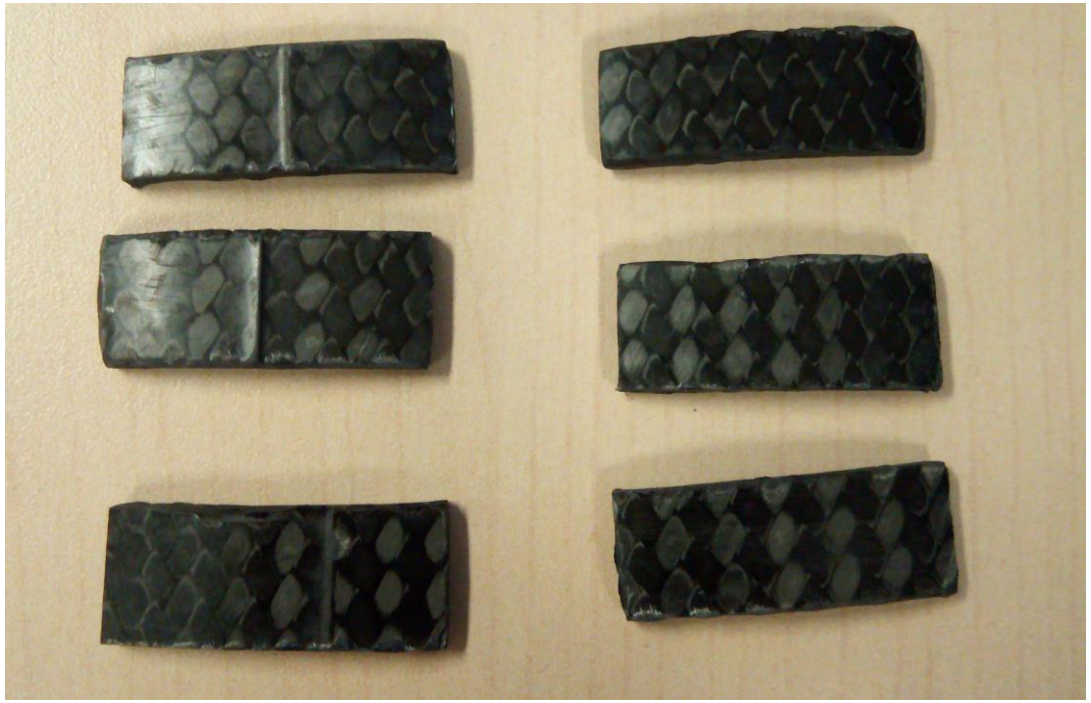
Manufacturing Results

- Samples cut from body tube samples to measure thickness locally, and calculate fiber volume fraction

$$V_f = \frac{\sigma_f}{\rho_f \cdot t}$$

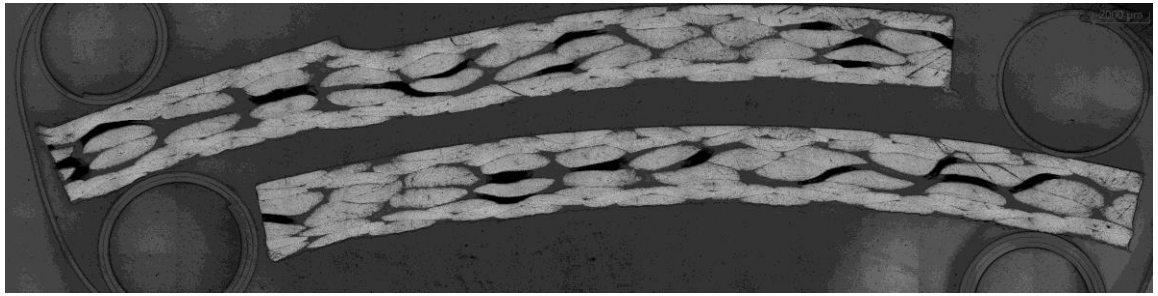
- Values between 50% - 53% were measured

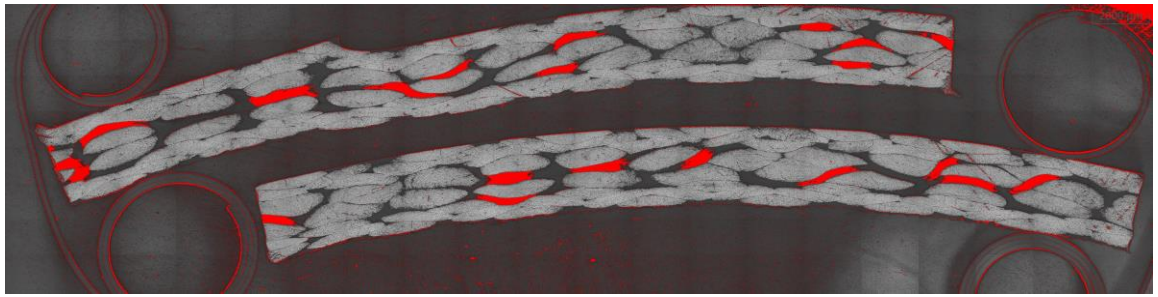
- Results just below maximum expected fiber volume of 55%



Manufacturing Results

- Samples were cast in resin, polished, and examined under a microscope
- Void content was analyzed using imageJ software
- Void content found to be ~5.4%
- Aerospace components require <2%





Conclusions and Future Work

- First ever fully SRAD composite airframe manufactured almost entirely with VARI
- Body tubes show reasonable tolerances and good fiber volume fractions, though improvements are possible on void content
- Resin characterization is necessary to further develop mechanical properties
- Improvements to the internal dimensions could be made

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