pfRICH End Ring – Manufacturing Updates

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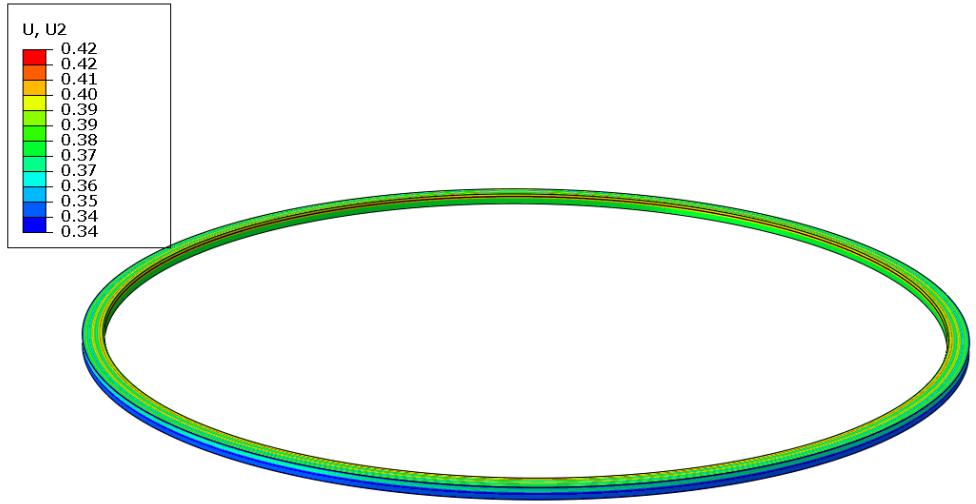
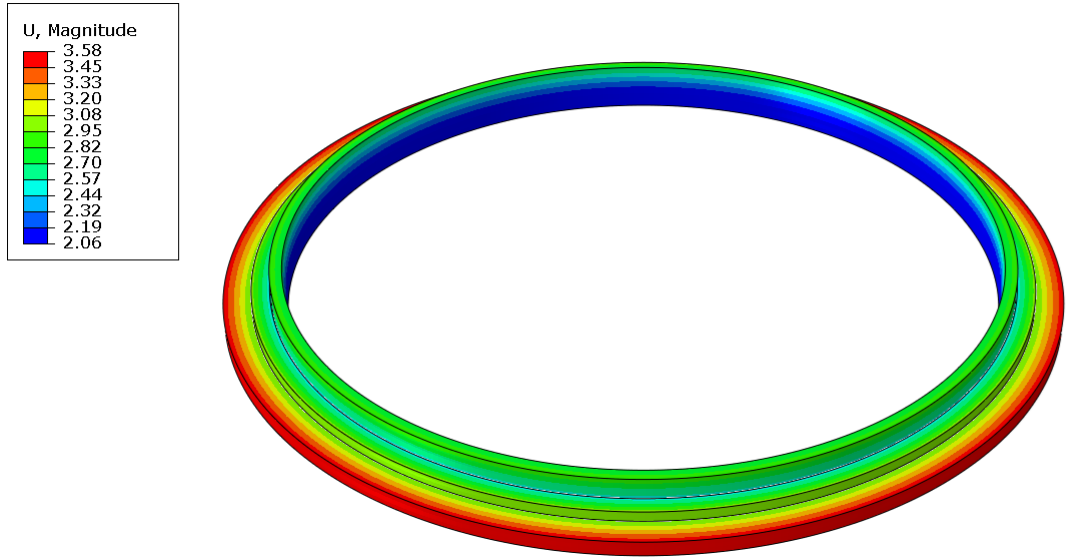
Recap

- We were looking at manufacturing the End Ring in parts to save on cost, time and dependence on CNC machines (still inside Purdue CMSC) but outside pfRICH team.
- We know we can manufacture this in full ring – can we make this in parts and join ?

Unit mm

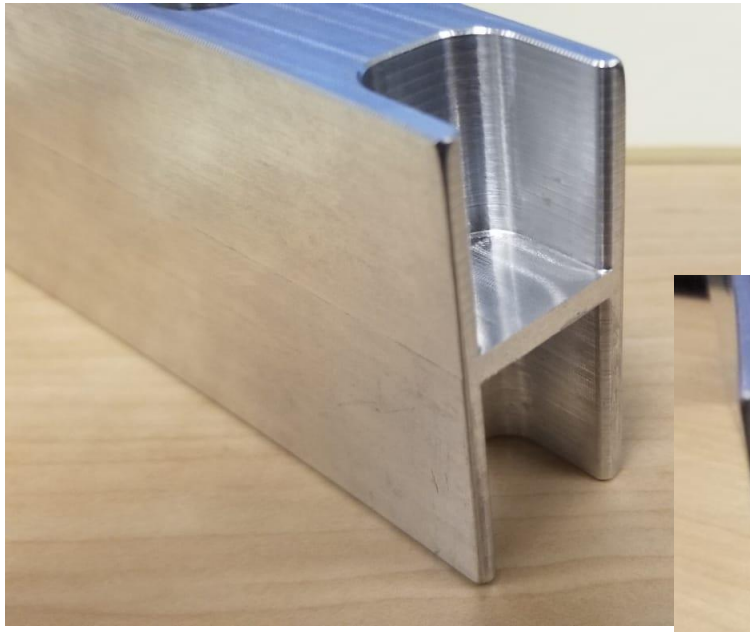


Unit mm



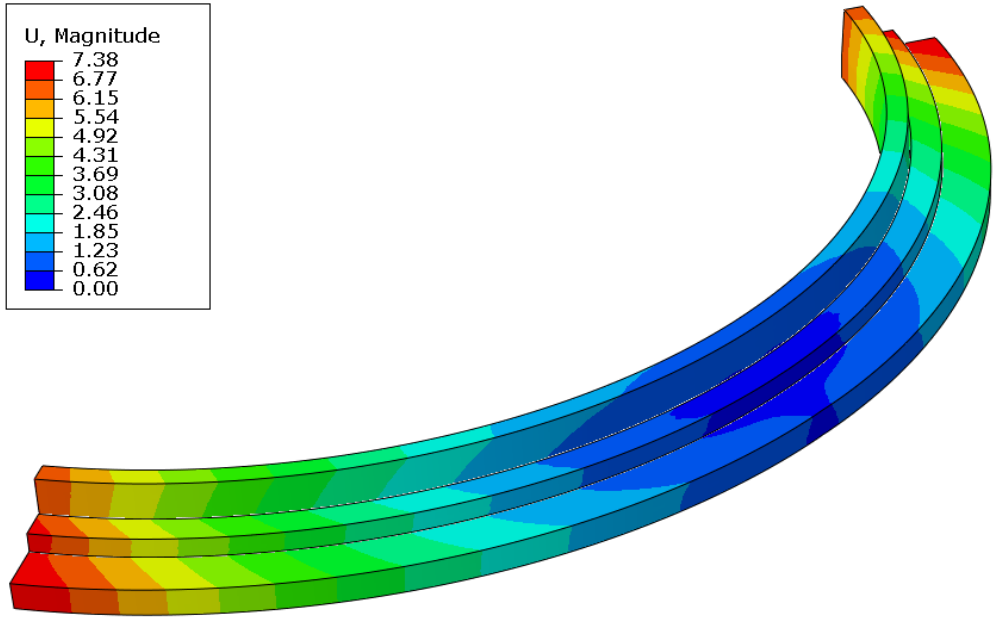
Half Ring Simulation

- Yes, we can make this and compensate for the deformation from the layup and curing process to get a quarter ring that is close to the nominal dimensions
- Layup and cure 120-degree parts and machine down the edges using a **mortise and tenon curved joint** to bond the 4 parts together



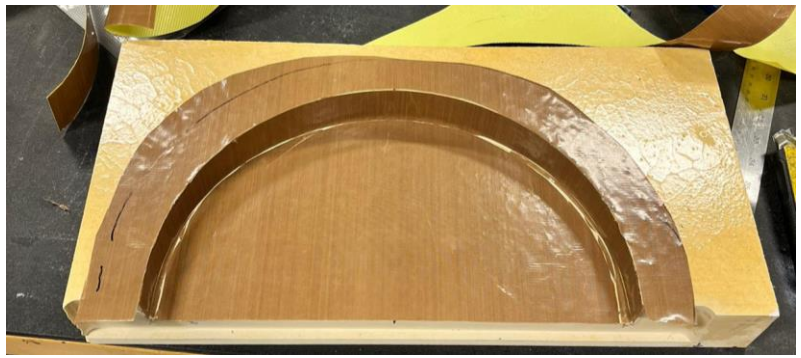
Aluminum for representational purpose only - this will be made from composites

Unit mm



Manufacturing Trials

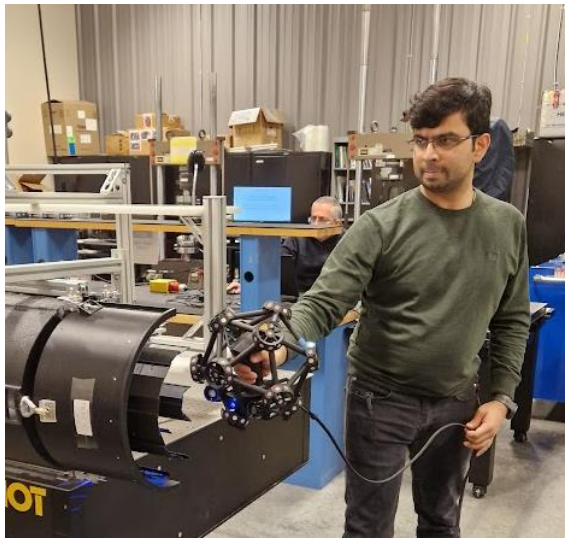
- We are using Proof Research AS4 plain weave p2si-250p Epoxy pre-preg – will a concave or convex curve be better ?

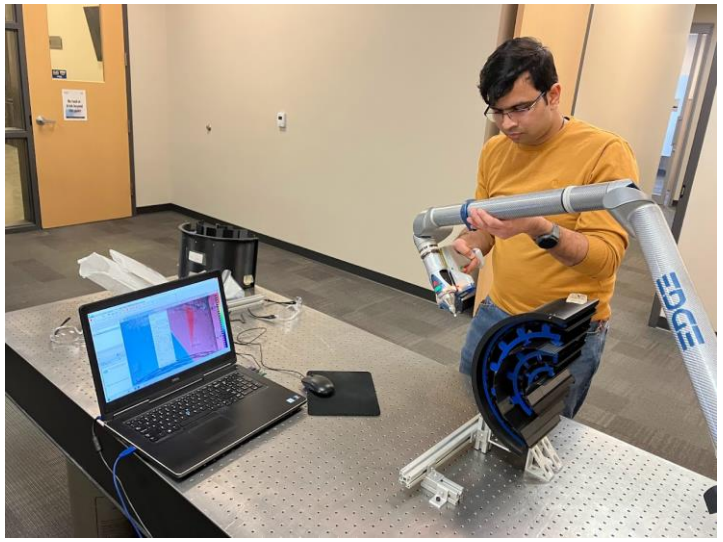


- Layups on-going
- The thickness we are using 32 mm that will me machined to 25 mm and have all the grooves and inserts – this ends up being a 150-layer stack up ! So takes a bit of time to layup

Manufacturing Trial – expected outcomes/ learnings

- Does the simulation that we are using give us accurate spring –in values for this layup ? – We will repeat the simulation and then laser scan the part using MetraSCAN 3D OR Faro EDGE
- Machining of insert holes – bonding of inserts
- Metrology needed for the end ring
- Check joining mechanisms and flatness after joining.

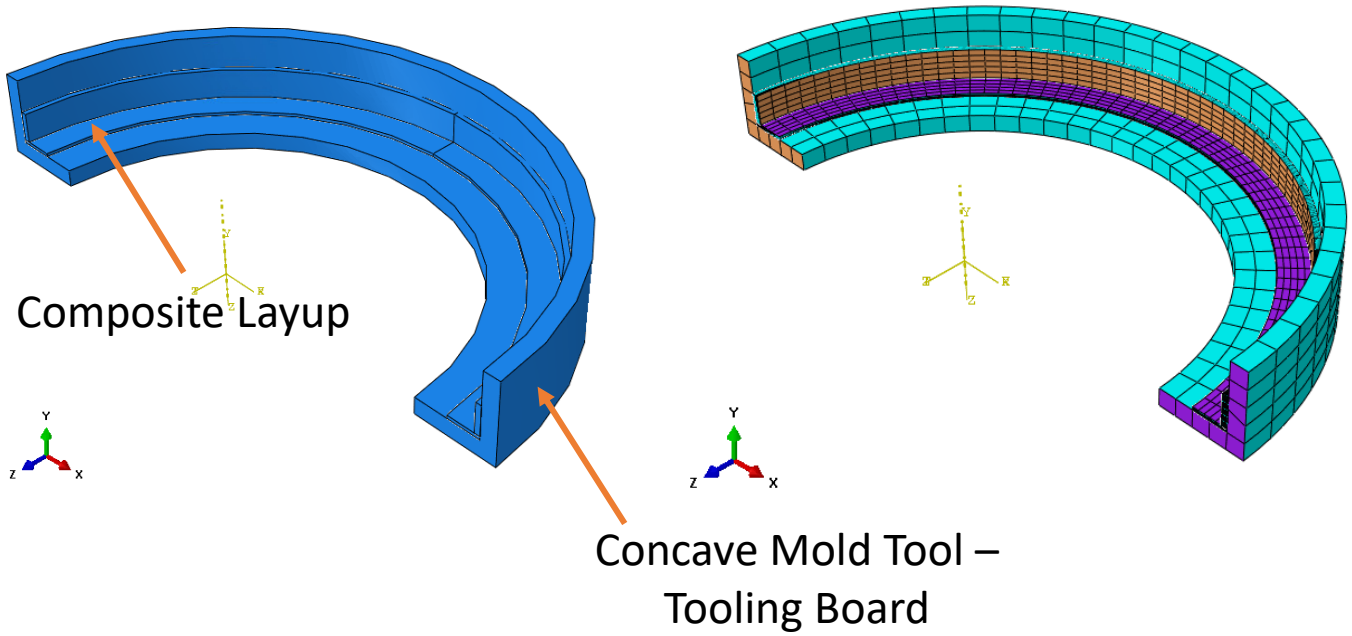




What is tool shape compensation and how is it done?

The geometry used is for representational purpose only. This is to show the simulation and work-flow needed to come to the final part of the End Ring.

Spring-in Simulation Work Flow



1. MODEL SET-UP

part geometry, nominal tool geometry & ply cut out, assign local material orientation, initial/boundary conditions

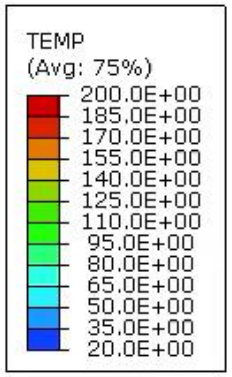
CATIA **Geometry**

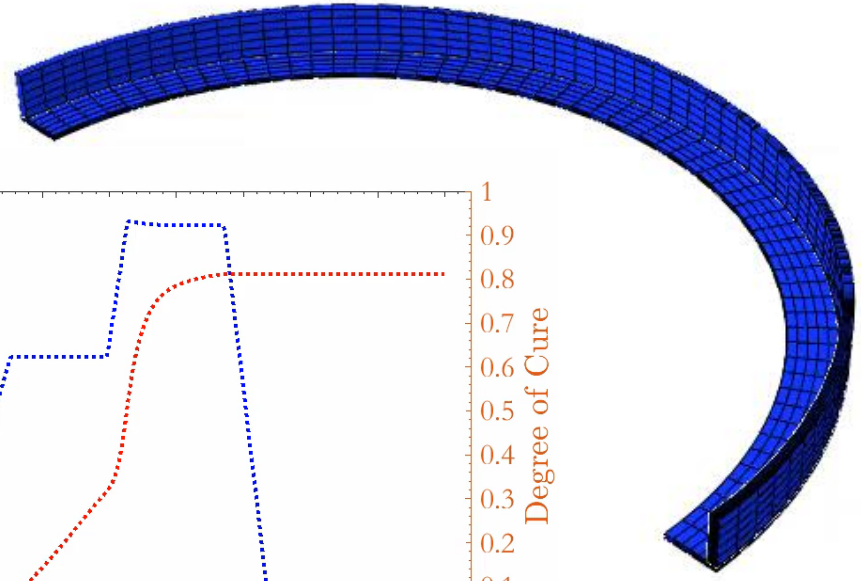
SIMULIA **Set up FE Model**

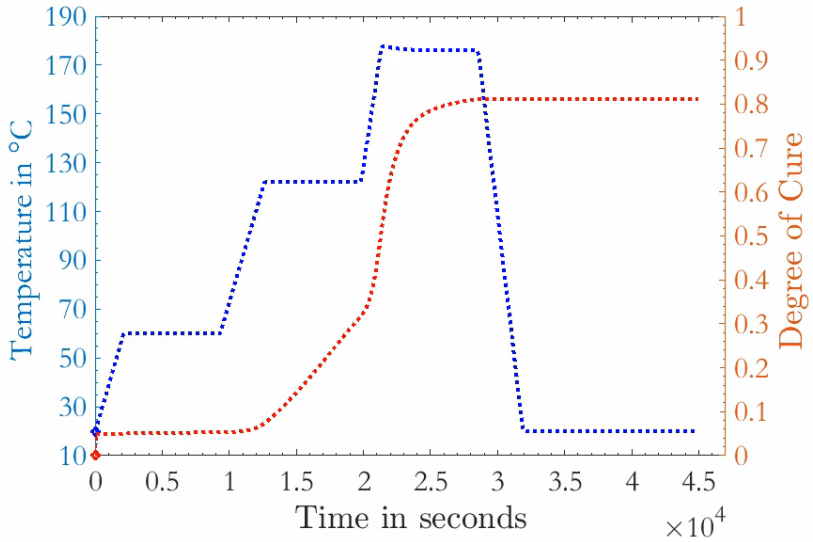
Model Setup | Thermo-Chemical | Flow Compaction | Stress Deformation | Tool Shape Compensation

Spring-in Simulation Work Flow

Unit : °C







CONVERGENT MANUFACTURING TECHNOLOGIES

2. THERMO-CHEMICAL ANALYSIS

cure kinetics, heat transfer between ambient & the tool-part assembly, heat generation -chemical cure reaction

SIMULIA

Define Cure Conditions

SIMULIA

Thermal History & Degree of Cure

Model Setup → Thermo-Chemical → Flow Compaction → Stress Deformation → Tool Shape Compensation

Spring-in Simulation Work Flow

CONVERGENT MANUFACTURING TECHNOLOGIES

3. FLOW-COMPACTION ANALYSIS

resin (Darcy) flow relative to elastic porous fiber-bed, pressure load development in resin, change in laminate thickness

SIMULIA

Fiber Volume Fraction Computation

CONVERGENT MANUFACTURING TECHNOLOGIES

4. STRESS-DEFORMATION ANALYSIS

process induced deformations & residual stress, mismatch of thermal-mechanical properties, cure shrinkage & tool part interaction

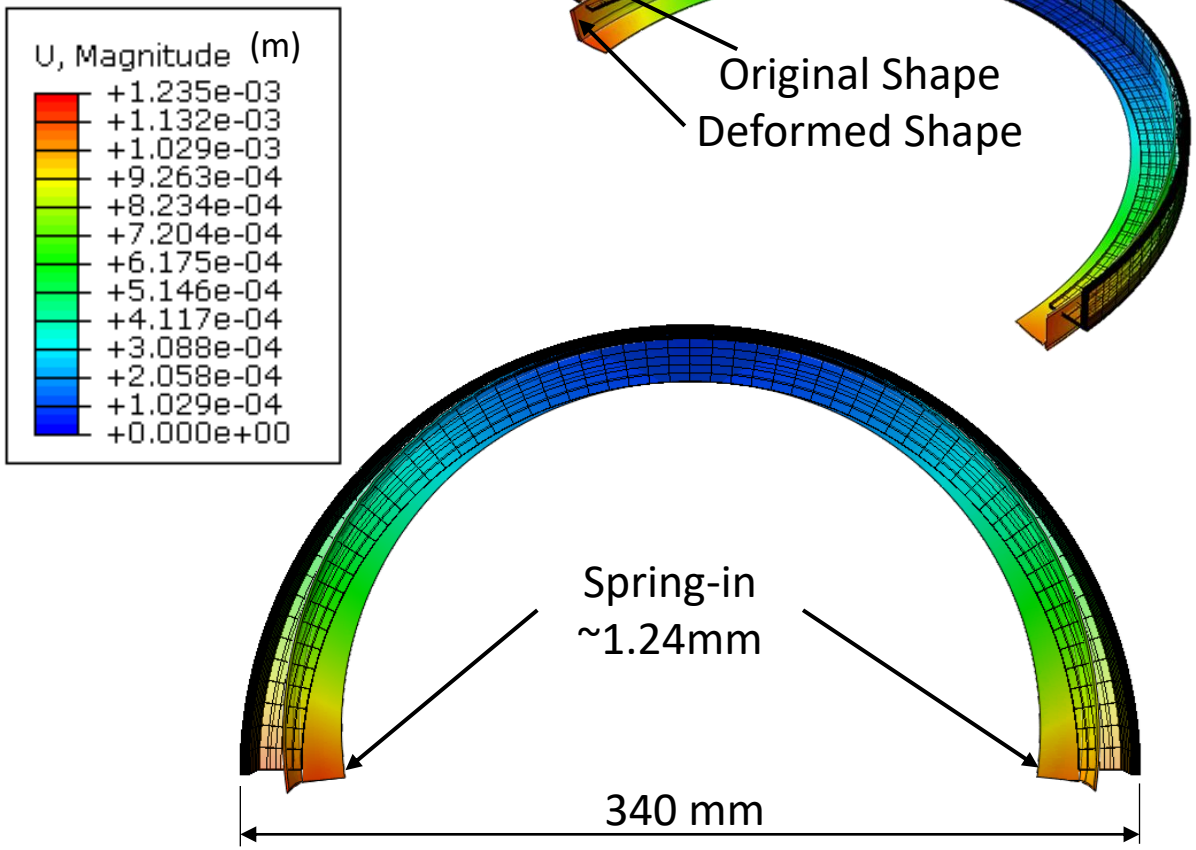
SIMULIA

Deformed Shape & Residual Stress State

Material properties are updated at each solution step to account for the progression of cure and the subsequent change in thermal properties.

Model Setup → Thermo-Chemical → Flow Compaction → Stress Deformation → Tool Shape Compensation

Tool Shape Compensation for Radial Stiffeners



Visual deformation scaling 20x

5. COMPENSATED TOOL SHAPE GENERATION

deformed shape inverted about nominal

SOLIDWORKS SIMULIA

Tool Shape used for Thermal Deformation Analysis of the Tooling Material

material properties (tool)

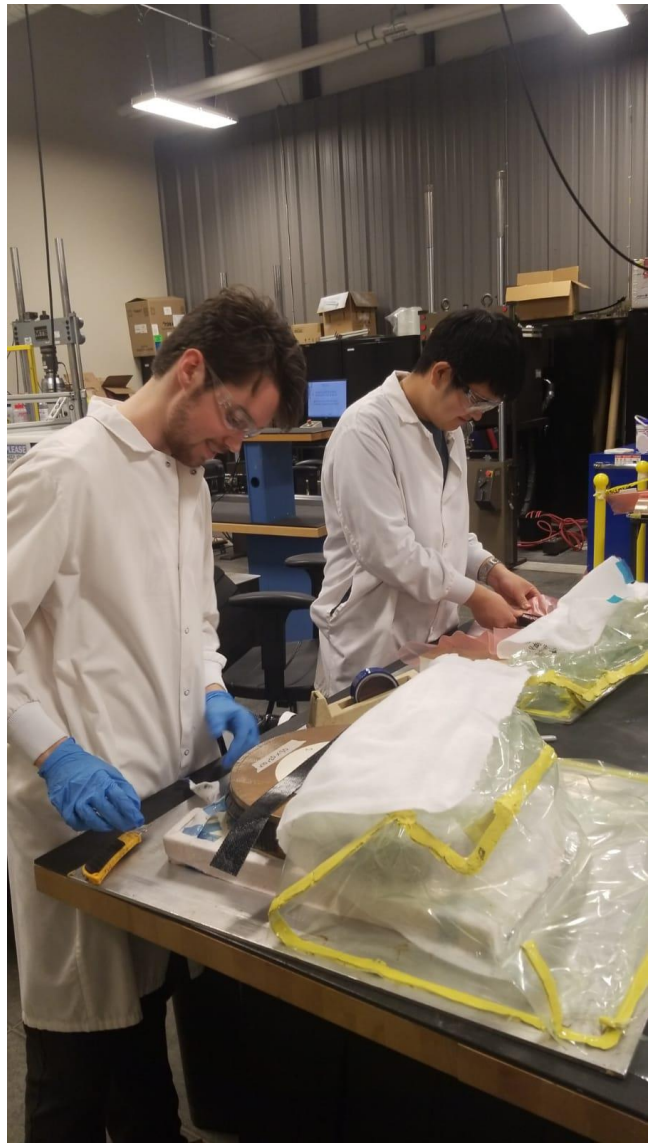
SOLIDWORKS SIMULIA

Compensated Tool Shape

5a. TOOLING BOARD TOOL (isotropic material properties)

Model Setup → Thermo-Chemical → Flow Compaction → Stress Deformation → Tool Shape Compensation

Thank you



… pictures for work update from 5 Feb 2024 at 13:20 hours EST

UG students –
Samuel Langley-Hawthorne and Xuli (Henry) You