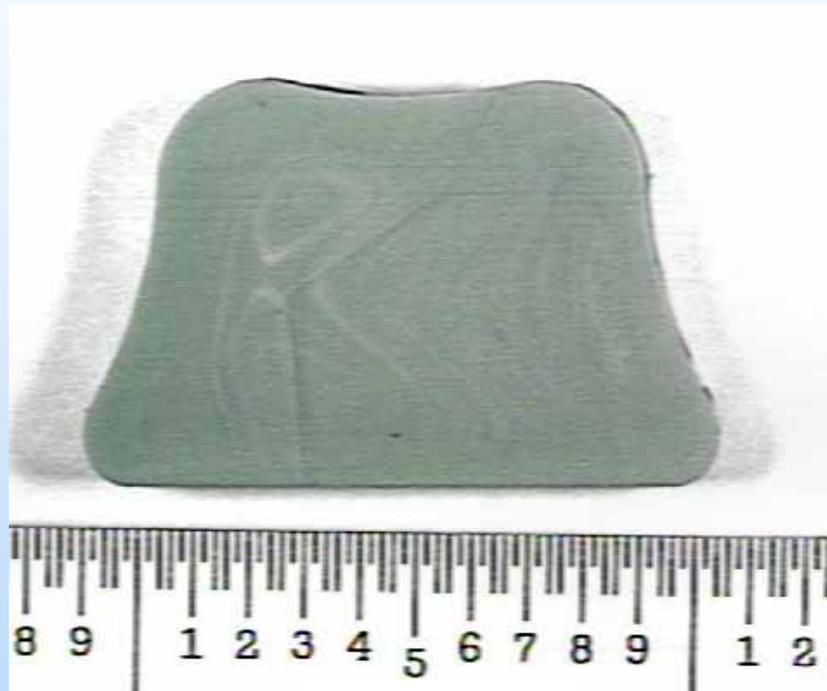




Accelerated Insertion of Materials – Manufacturing and Producibility of Hat Stiffened Structure

- **First Round Results – Silicone Elastomeric Mandrel with compensated sides and top**

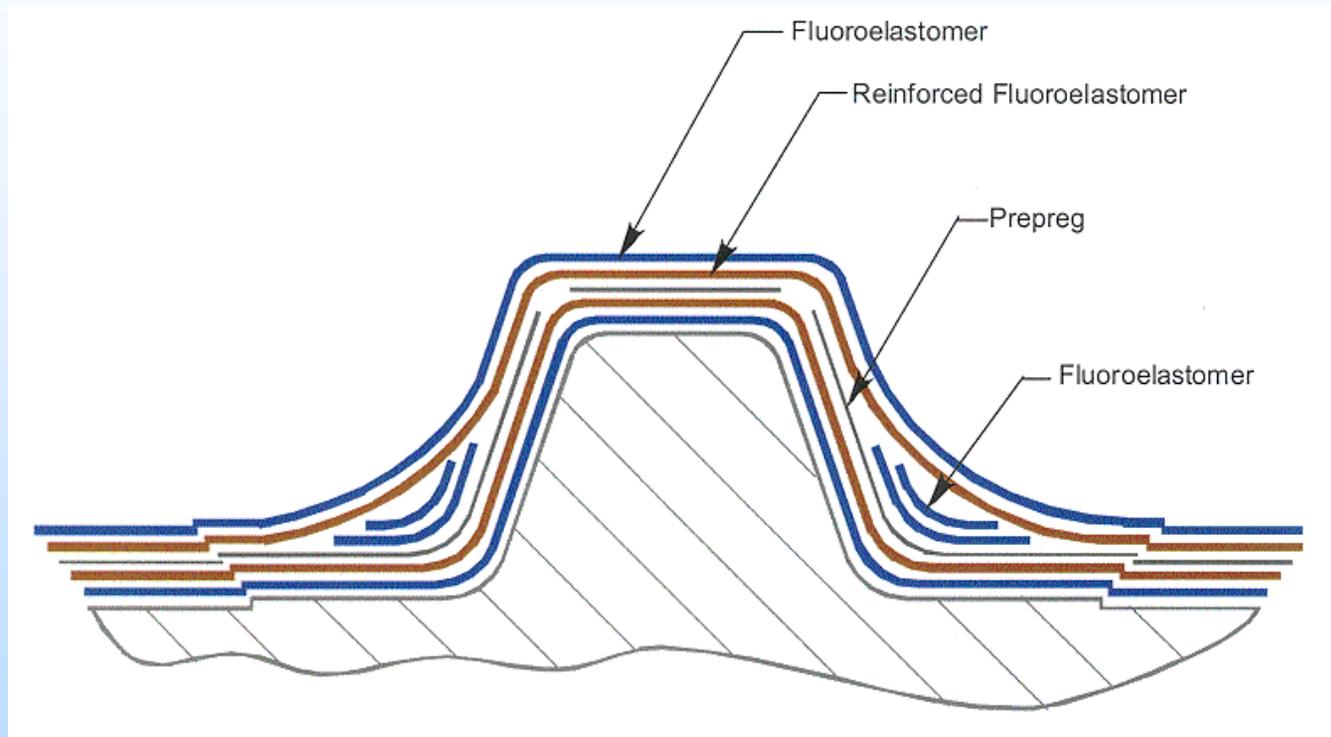


← 2.54 cm →



**Accelerated Insertion of Materials –
Manufacturing and Producibility of Hat Stiffened Structure**

- **Tooling and Processing Approach – Caul sheet**

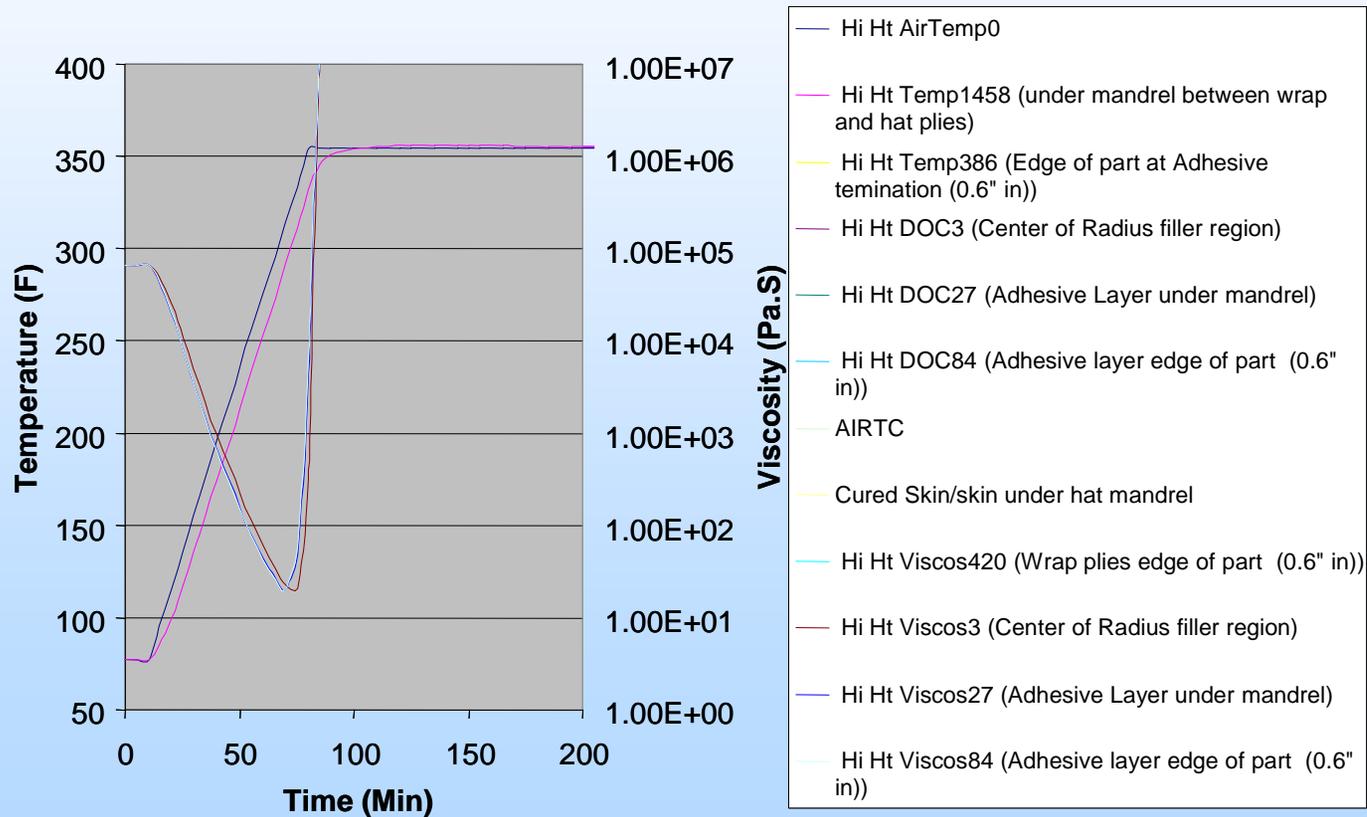


- Use semi rigid reinforcement in caul sheet to maintain radius control



Accelerated Insertion of Materials – Manufacturing and Producibility of Hat Stiffened Structure

• First Round Results – Viscosity Predictions



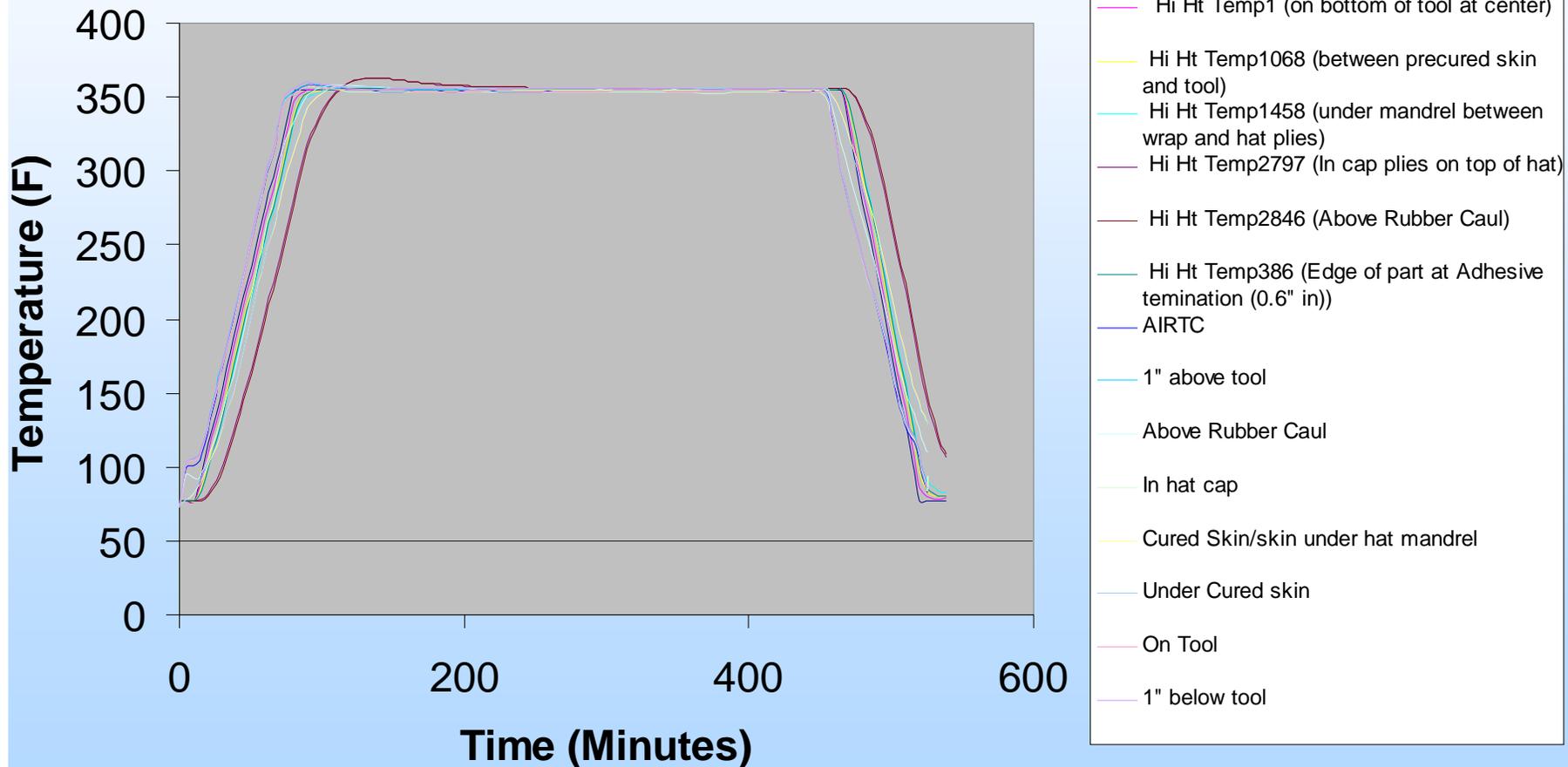
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Accelerated Insertion of Materials – Manufacturing and Producibility of Hat Stiffened Structure

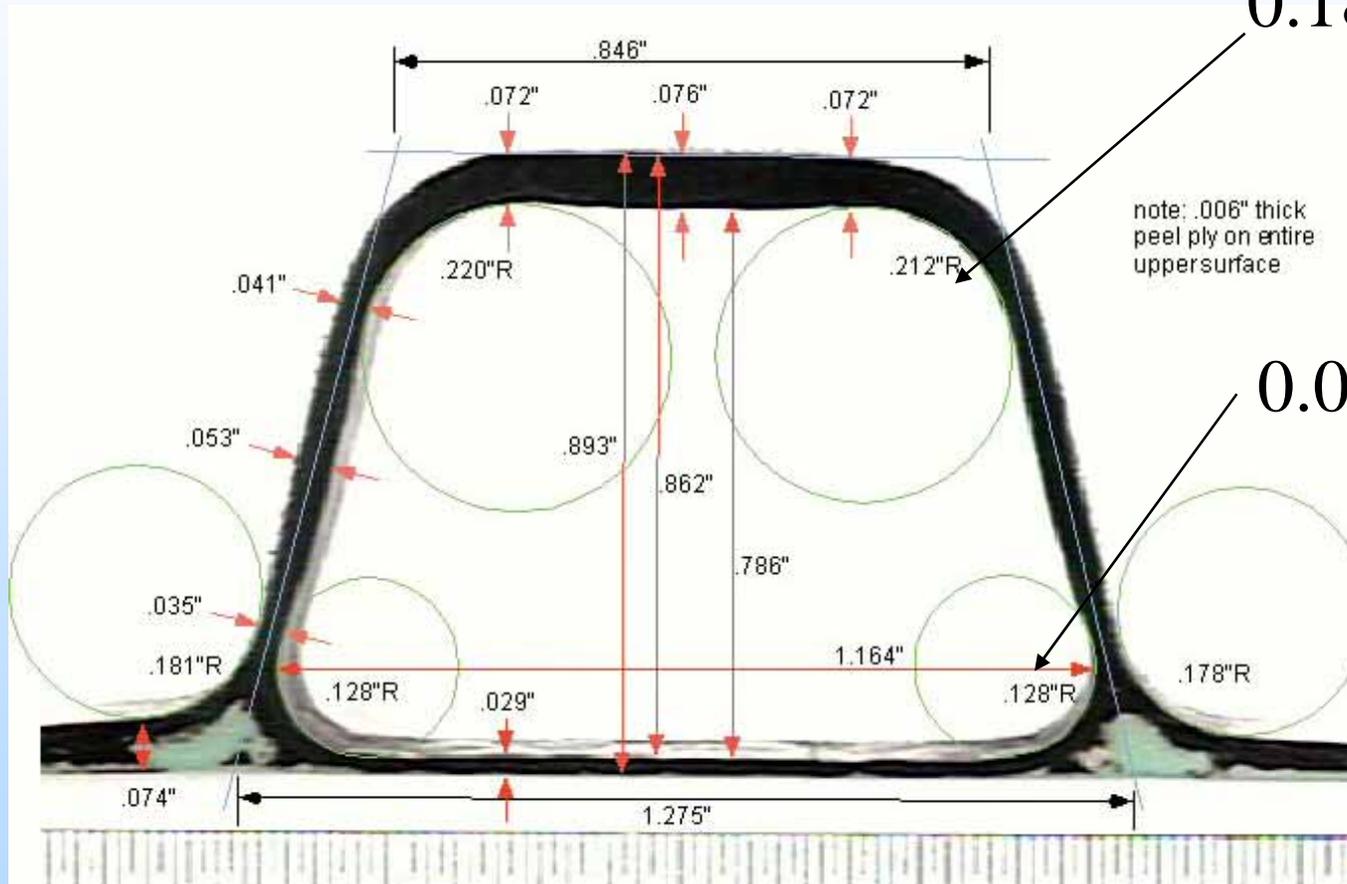
• First Round Results – Temperature predictions vs. actual





Accelerated Insertion of Materials – Manufacturing and Producibility of Hat Stiffened Structure

- **First Round Results**



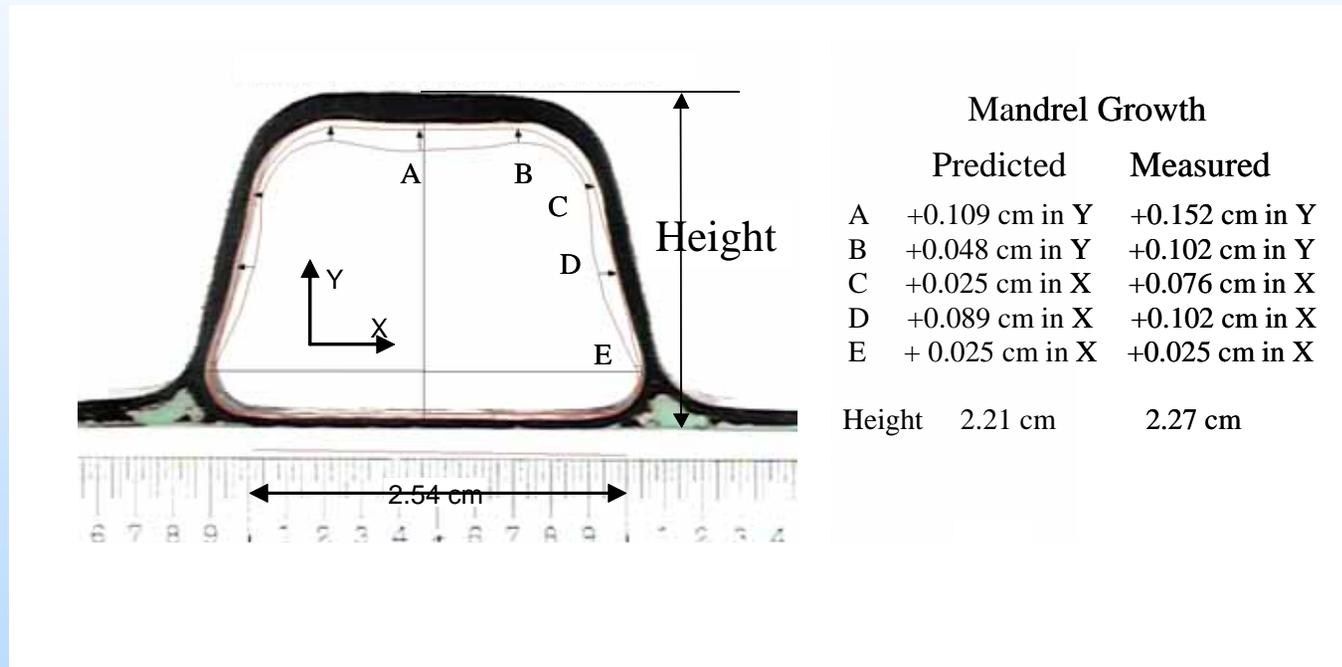
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Accelerated Insertion of Materials – Manufacturing and Producibility of Hat Stiffened Structure

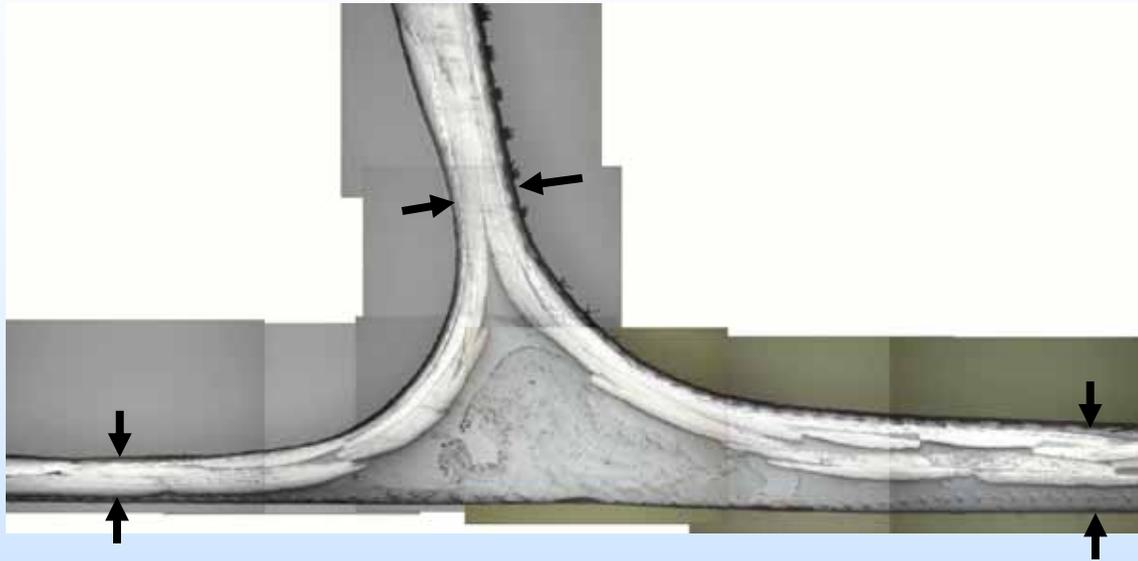
- **First Round Results Shape Predictions vs. Actual**





Accelerated Insertion of Materials – Manufacturing and Producibility of Hat Stiffened Structure

• First Round Results



- Excessive Radius thinning at top of lower radii
- Thickness mismatch between plies under hat and outside hat
- While possibly acceptable additional goal was to match geometry of structural prediction
- Interaction between shape compensated mandrel and semi rigid caul sheet
- Team decided to redesign mandrels to reduce radius thinning



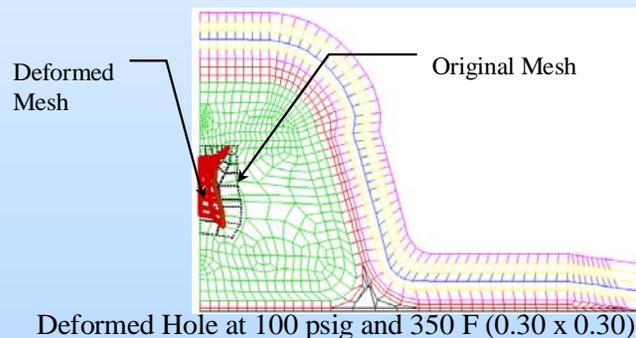
• Second Round

Mandrel Redesign Effort performed using simulation guided design of Mandrel with:

Plane stress design assumption – Expansion in 2D, 3rd dimension extrudes mandrel out ends (experience based)

Plane strain design assumption – Bulk behavior due to friction between mandrel and prepreg (Simulation based)

Plain stress with open space to mitigate bulk behavior and help control shape (Simulation based)

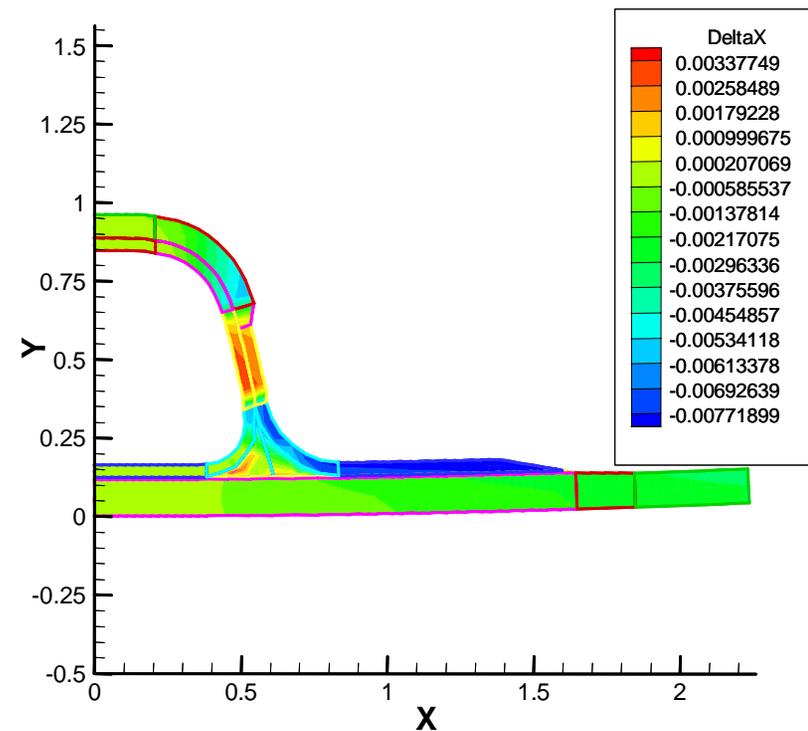
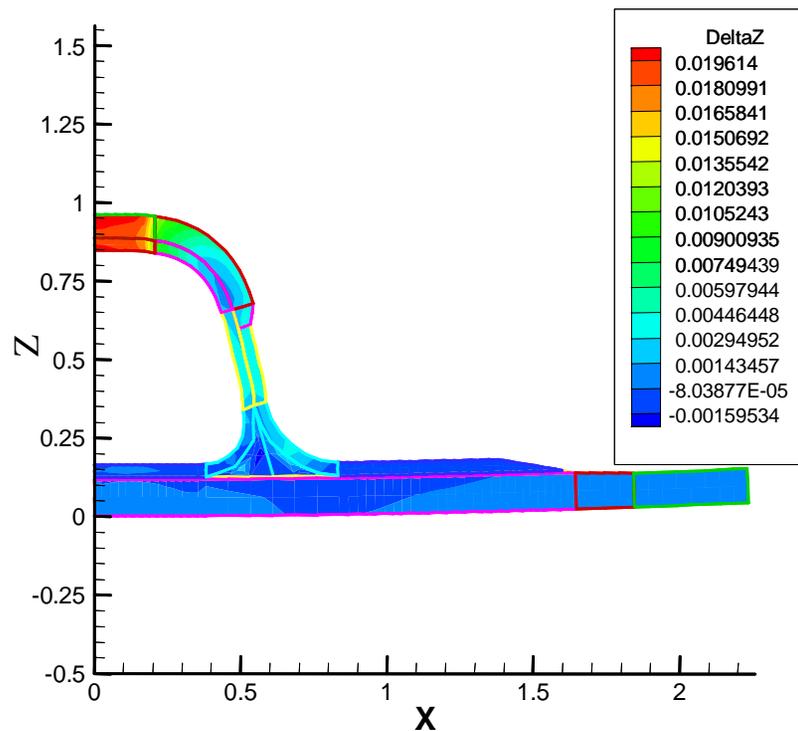


Fabrication trials performed with all three designs to reduce schedule risk



Accelerated Insertion of Materials – Manufacturing and Producibility of Hat Stiffened Structure

- **Second Round Results**



- Updated simulation without mandrel compensation and rigid caul sheet



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**Accelerated Insertion of Materials –
Manufacturing and Producibility of Hat Stiffened Structure**

- Second Round Results**

Spec #	Between Hats (L side)		Under Hat			Between Hats (R side)	
	Mid bay	Radius	L Radius	Center	R Radius	Radius	Midbay
Target	0.040	0.040	0.040	0.040	0.040	0.040	0.040
Plain Strain	0.038	0.042	0.035	0.032	0.042	0.037	0.039
Hole-2	0.040	0.062	0.035	0.037	0.035	0.062	0.042
Hole-1	0.041	0.070	0.032	0.042	0.040	0.067	0.042
Plain Stress-2	0.041	0.050	0.037	0.035	0.040	0.052	0.042
Plain Stress-1	0.041	0.050	0.040	0.035	0.039	0.048	0.036



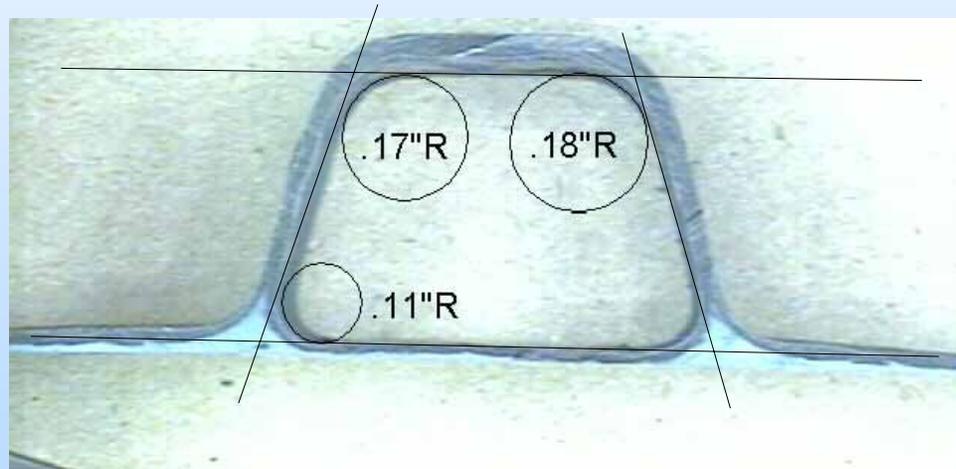
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• Second Round Results

Plane Stress assumption designed mandrel provided best results
All radii and thickness within tolerance
Successful fabrication of all parts to date

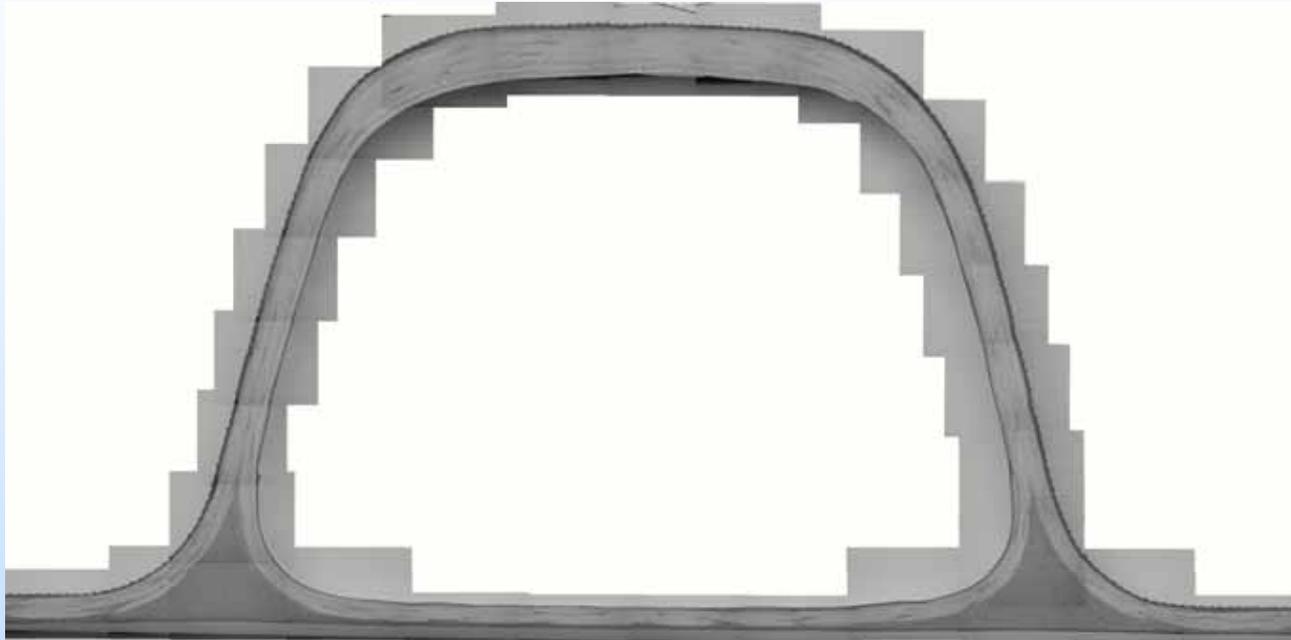




**Accelerated Insertion of Materials –
Manufacturing and Producibility of Hat Stiffened Structure**



- **Second Round Results**



Plain Strain Assumption Mandrel Sizing

A little Ballooning but otherwise nailed it on 2nd iteration



Accelerated Insertion of Materials – Manufacturing and Producibility of Hat Stiffened Structure



• Summary

- Temperature – Thermal response within range of predictions with exception of plies on top of hat. Most probable cure assumptions did prove conservative, All heat up rate and hold times met.
- Viscosity- All areas gelled near or at final hold temperature. Cure cycle modification to increase minimum heat-up rate may be wise to avoid premature adhesive gelation
- Degree of Cure – All parts reached desired degree of cure per simulation, experimental confirmation pending. Pre-cured skin did not advance beyond acceptable DOC range during co-bond.
- Shape – While initial trial offered production type quality parts, deviations from as designed geometry complicated strength prediction efforts. Therefore AIM tools and experience were used to redesign the hat mandrel shape. The second fabrication trial produced a part meeting all tolerance requirements. This successful mandrel design was based on analysis rather than experience. It should be noted that ALL parts fabricated were of typical or better quality for hat stiffened panels.



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Accelerated Insertion of Materials – Acknowledgements



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Certification Advisory Team – Air Force, Army, Federal Aviation Administration, NASA (Langley), and NAVAIR



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