Accelerated Insertion of Materials –

Manufacturing and Producibility of Hat Stiffened Structure

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- Background and Problem Definition
- Hat Stiffened Panel Processing and Past Challenges
- Problem Solution Approach - AIM-C Methodology
- Materials Characterization
- AIM-C Producibility Heuristics
- Hat Structure Definition
- Tooling and Processing Approach
- First Round Results
- Second Round Results
- Summary

- **Background and Problem Definition**
  - **Hat Stiffened structure offers significant structural and fabrication advantages**

However…….

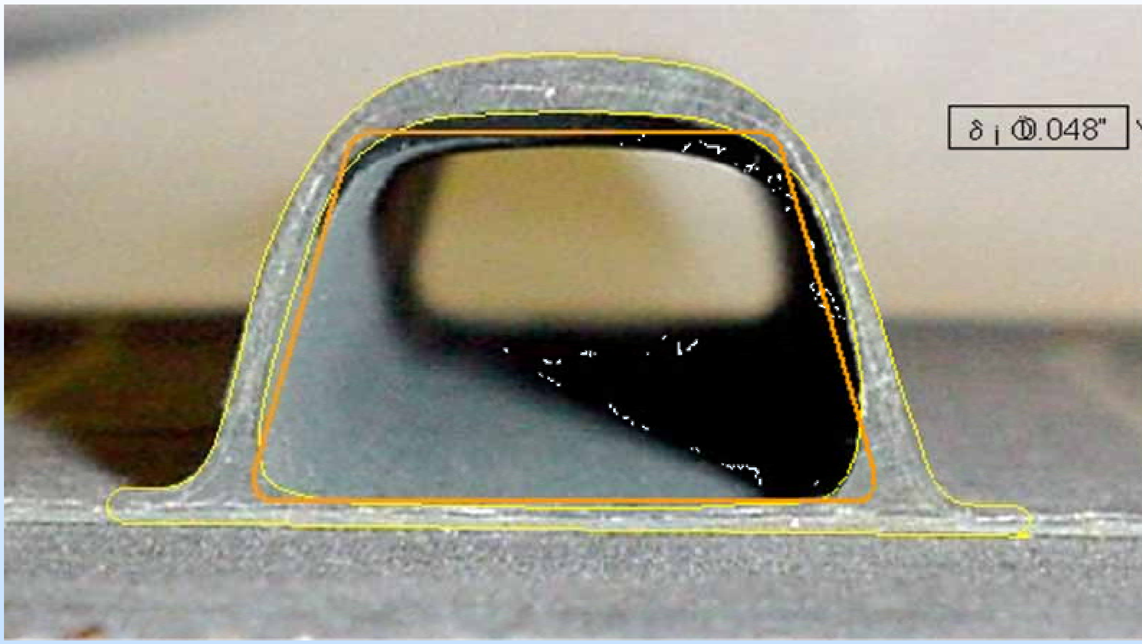
  - **Process development and fabrication of composite hat stiffened structure has proven problematic in the past**
    - **Trial and error without good knowledge of process bounds**
    - **Subsequent quality issues in production**

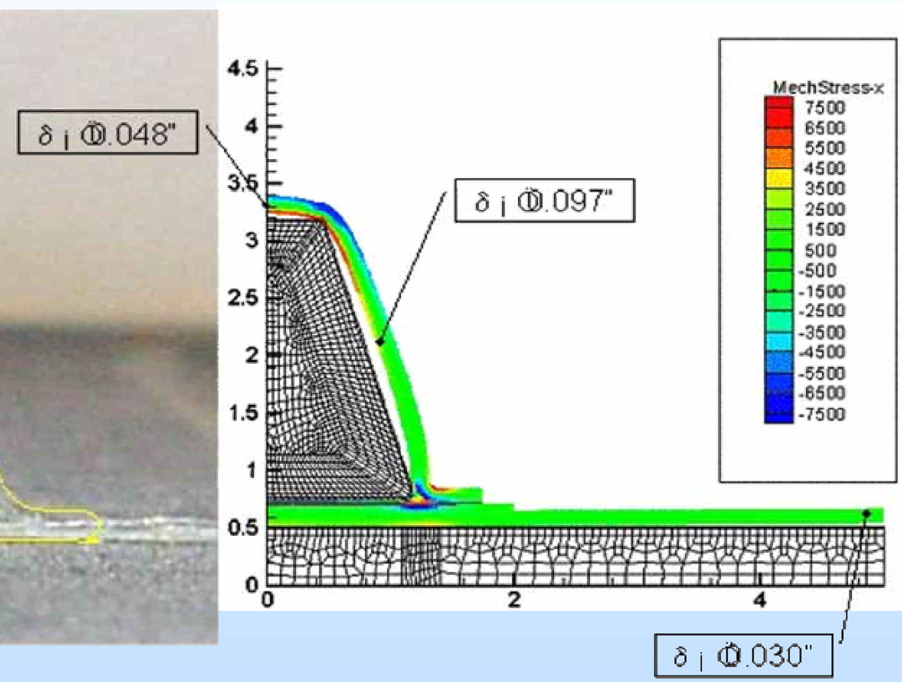
- Accelerate the process development of hat stiffened structure using AIM-C
- Successfully fabricate quality structure with as few iterations as possible

Hat Stiffened Panel Processing and Past Challenges

- Hat side wall/cap ballooning where the sidewalls are not flat
- Upper and lower radius thin-out (fiber movement and resin starvation)
- Hat miss-location (hat to hat spacing)
- Curved or snaking stiffener shape
- Stiffener sink where the skin under the stiffener is of less thickness than blueprint
- Other skin thickness variations between under the hat and adjacent to the hat (resin rich or resin poor areas)
- Adhesive migration if adhesive is used in the fillet area.
- Ply waviness around the radii
- Fillet porosity (hat to skin intersection)
- Skin out-of-plane waviness at the stiffener flange edges
- Resin rich areas at the stiffener termination if a net molded stiffener is used
- Trimming errors if the stiffener termination is trimmed after molding
- The typical array of flat panel manufacturing defects including porosity and delaminations

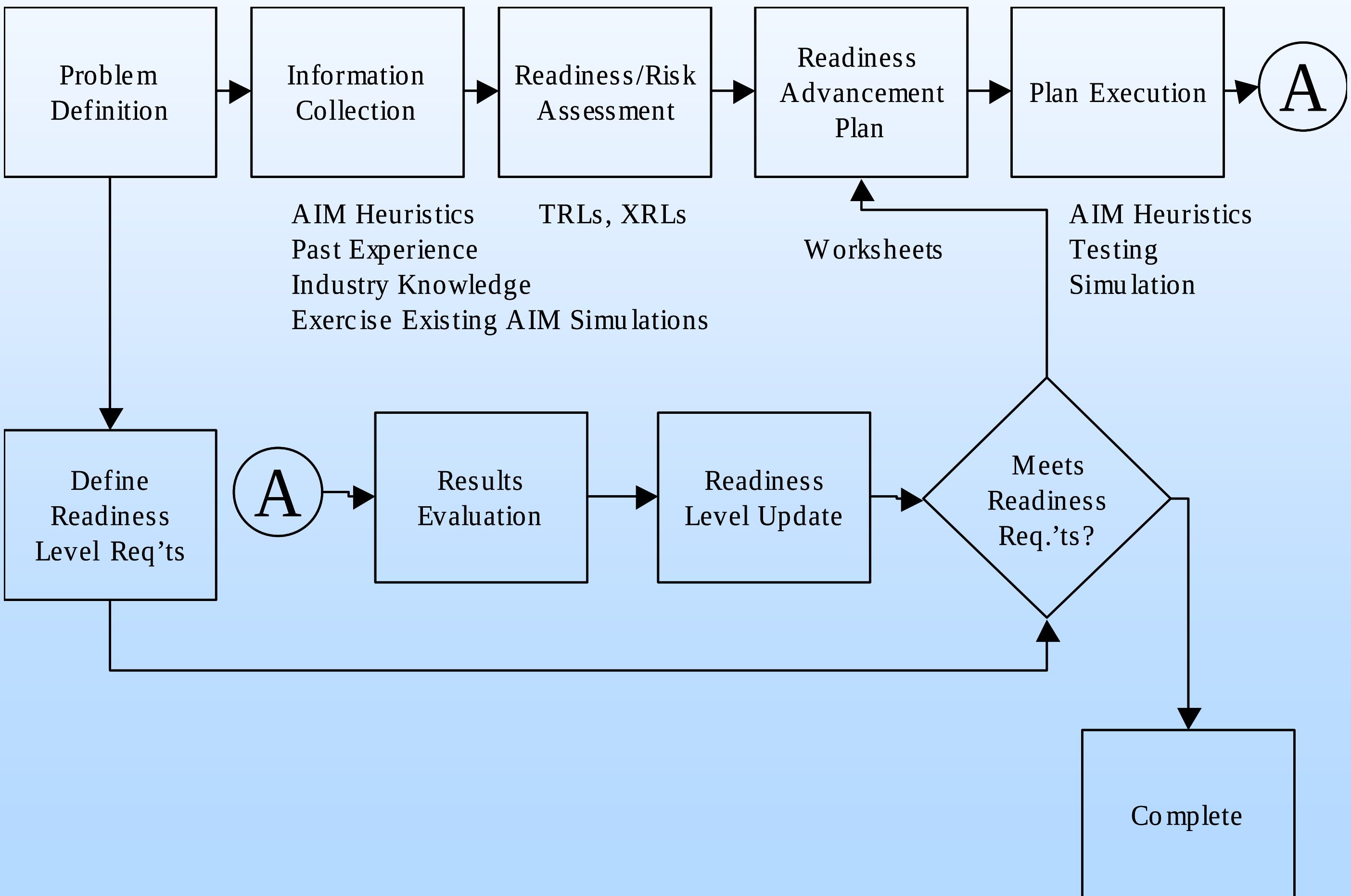
• Hat Stiffened Panel Processing and Past Challenges



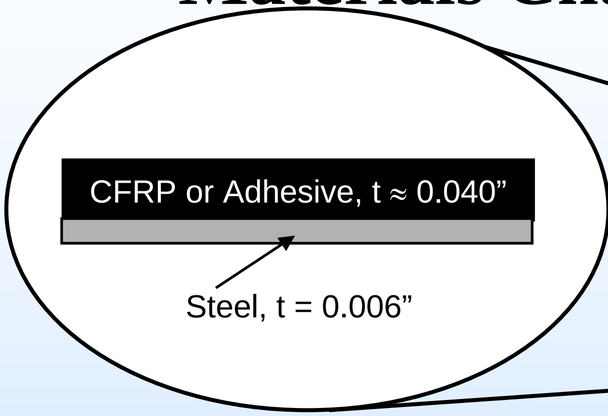


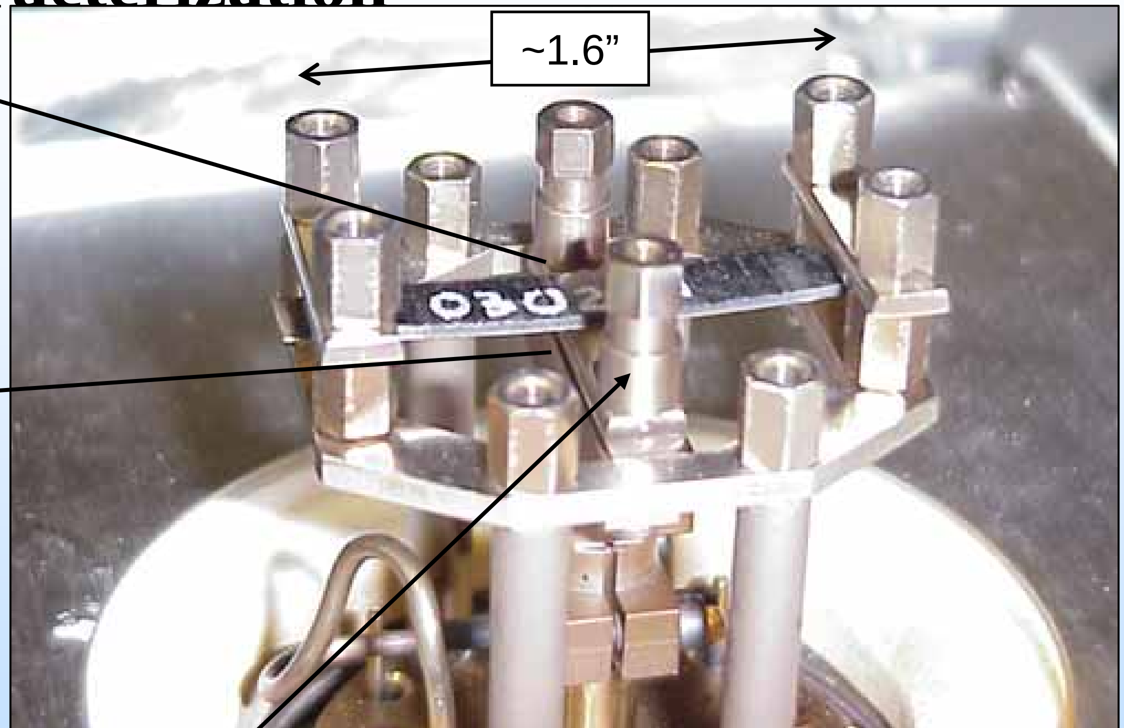
- Ballooning
- Lower radius thickening
- Upper radius thinning
- "Bow waves"
- Radius waviness
- Radius porosity

• AIM-C Methodology



• Materials Characterization

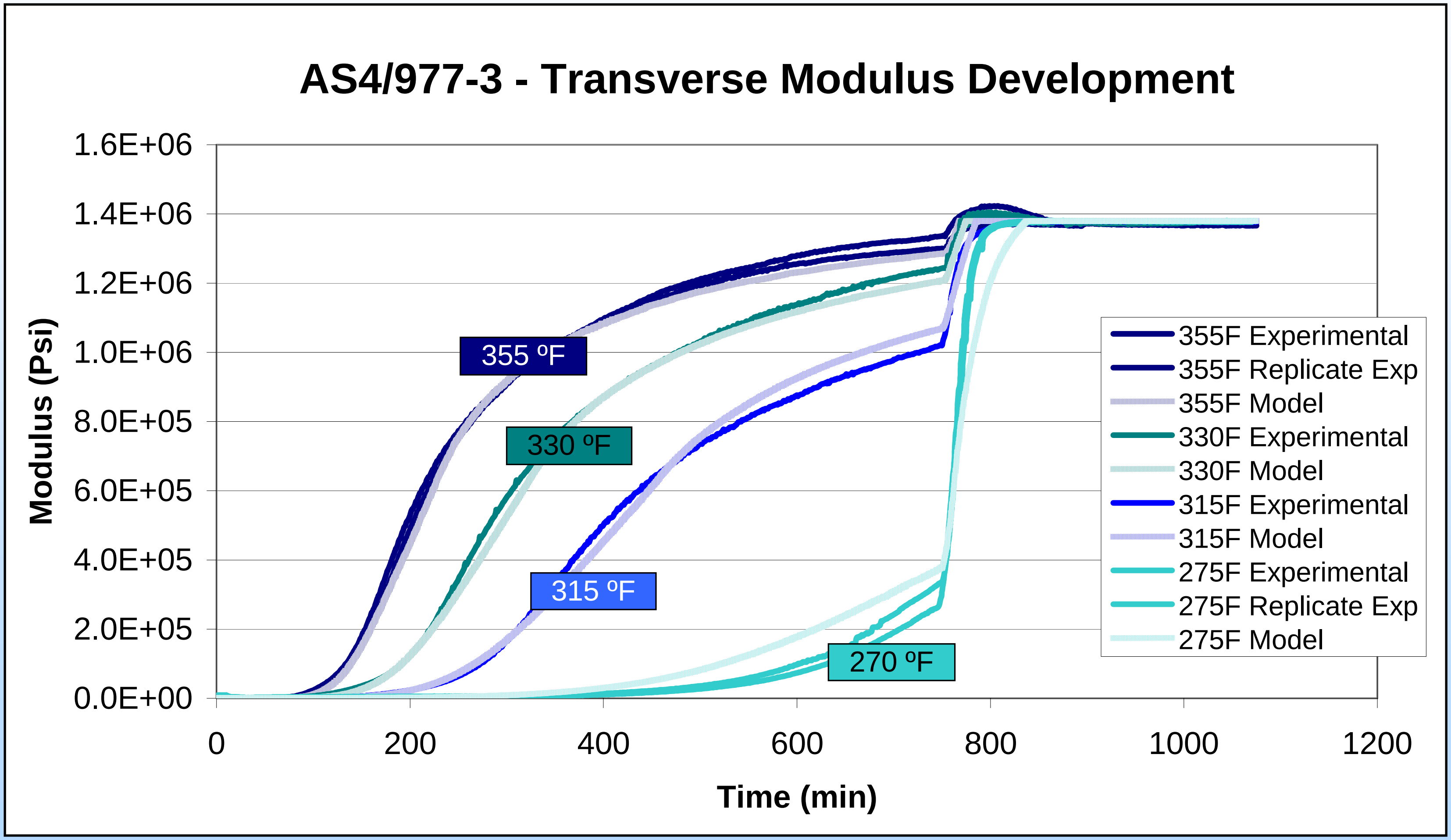




Dynamically oscillate (Dynamic Test) crosshead to measure modulus or apply constant force (Creep Test) and measure beam displacement due to cure shrinkage and CTE

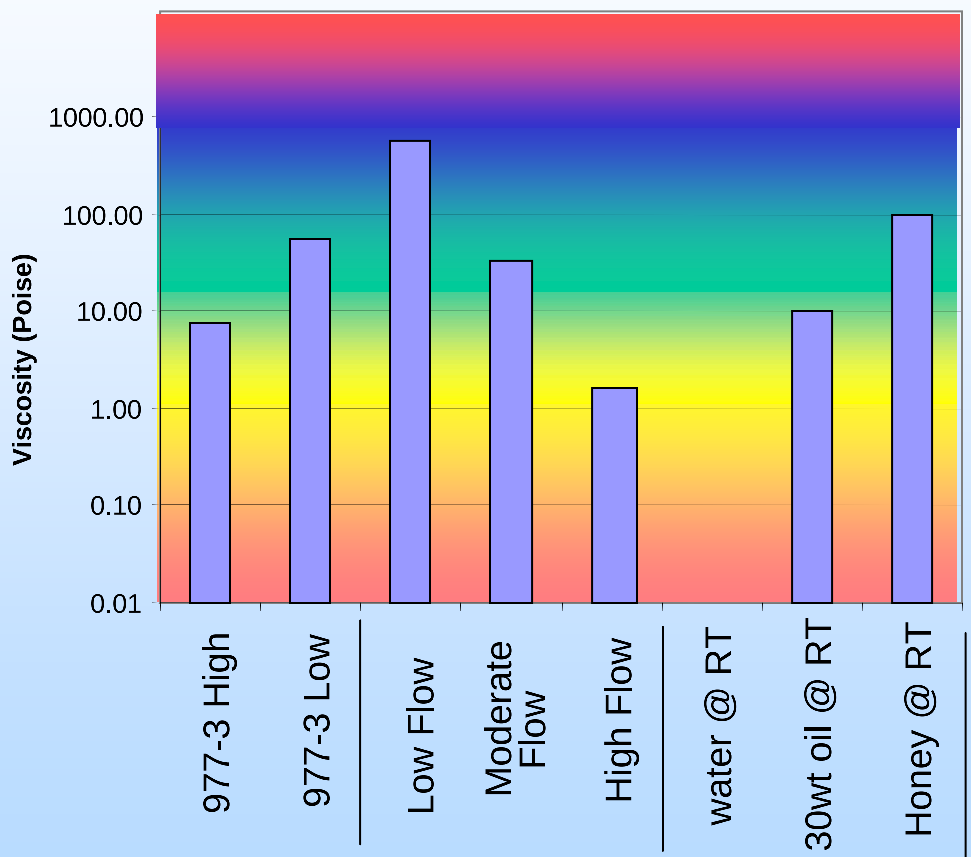
Supporting the curing material with the steel shim eliminates the need for staging of DMA specimens meaning <u>Accelerated Material Testing</u>

• Materials Characterization



• Materials Characterization

Minimum Viscosity Assessment



! Consolidation Challenges Due to High Viscosity

Autoclave Bagging Technique A

Autoclave Bagging Technique B

Autoclave Bagging Technique C

!

Use Bagging Method B

Data From Simulation

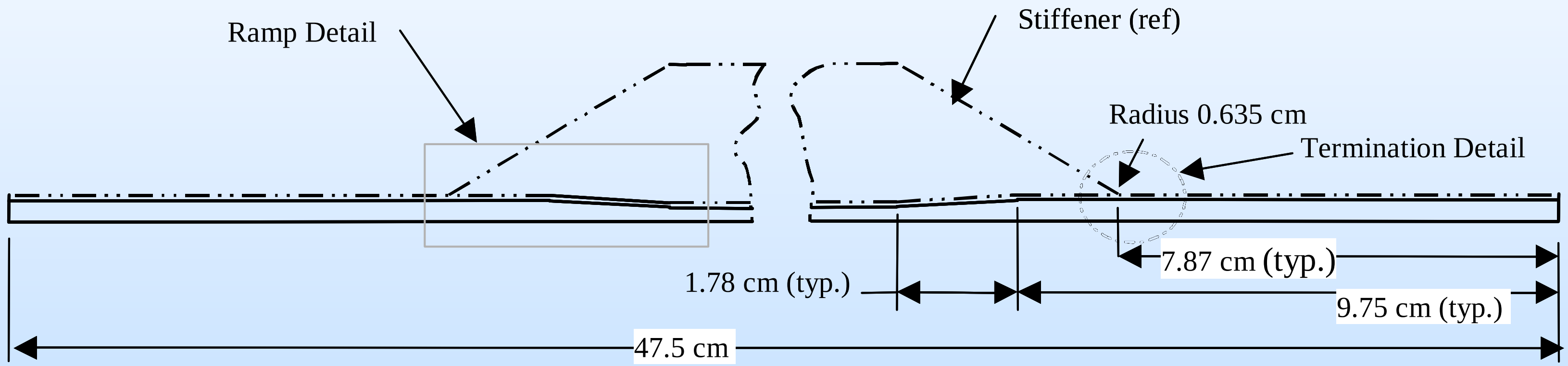
Historical Database Information

Reference Database Information

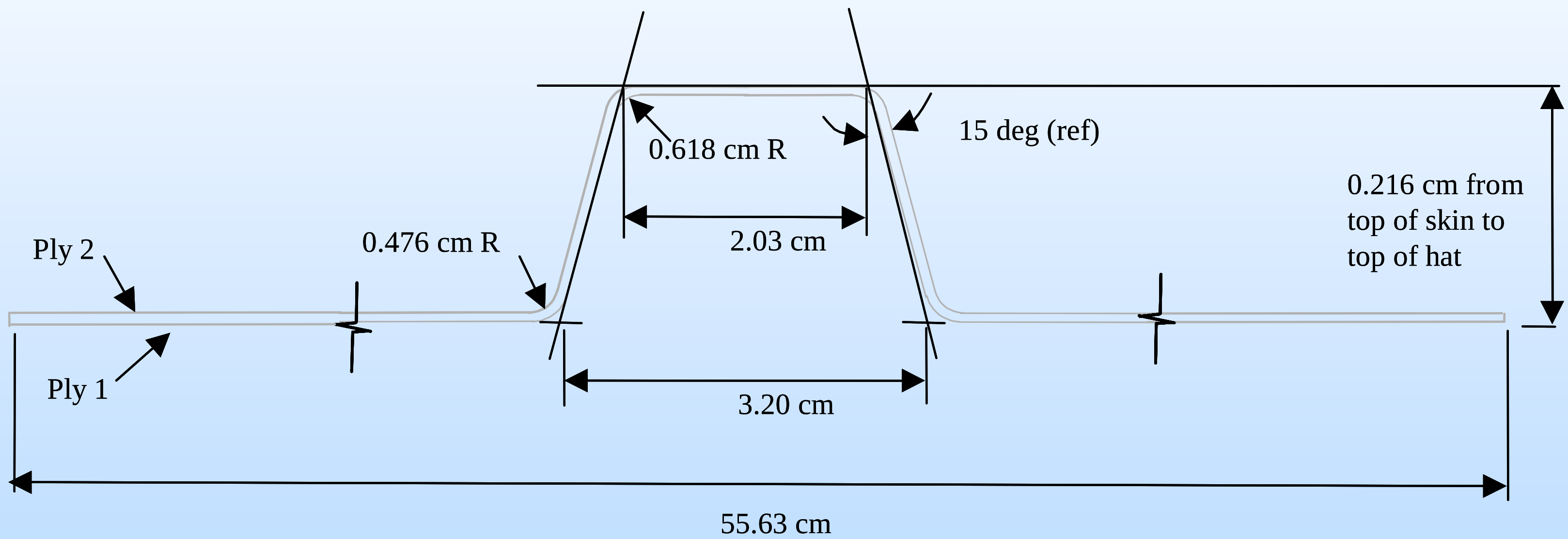
• AIM-C Producibility Heuristics

Issue	Semi-Rigid Cocure Tooling	Cobond with Wet Hats
Thick/Thin Flanges	Flange thickness is a minor problem assuming semi-rigid section extends into bay between stiffeners. (<10% flange thickness error). Assume flange and skin under flange experience the same fiber volume change.	Flange edge thickness more variable. Flanges typically 15% thin due to tooling pressure. (Fiber volume change in flanges and skins under the flanges. Resin flowed out toward midbay and noodle area.)
Skin Waviness Beyond the Hat	Typically not a significant issue. A slight (<5%) thickness increase may be noted beyond stiffener flange.	Not an issue with precured skins
Shim Induced delamination at hat termination	Tooling is rigid enough to be pinned in place and prevent undercut by the shim. Some slight flange fiber movement over the shim is possible but can be trimmed back to the required shape	No shim required.
High/Low fiber volume at flange termination	Low fiber volume is common in net formed hats for ply pull back. Tooling approach does not significantly affect this.	Low fiber volume is common in net formed hats for ply pull back. Tooling approach does not significantly affect this.
End of hat thick or thin flanges	Limited intensifier droop near the end of the panel (5%)	Tooling flexibility will allow a roll-off or pinching at the hat termination. Expect the flanges to taper to 15% thin at tooling termination. If the hats are not net shape, this in not much of an issue.
Skin Waviness beyond the hat	The hat mandrel can create markoff beyond the end of the hat. Since this is typically a mating surface, shims are used to reduce this effect. Expect a 10% thickness decrease with shims.	Not an issue with precured skins
Tool mark-off	Tool mark off can be reduced by terminating the inner stiffening member before the flexible coatings.	Not an issue with precured skins

• Hat Structure Definition



• Hat Structure Definition



• Tooling and Processing Approach

Studies with AIM Structures Tools indicated significant performance knockdowns if out of plane wrinkles occurred at hat termination.

AIM producibility heuristics indicated this could be an issue for co-cure structure

No heat-up rate or exotherm issues for any of the proposed tooling configurations based on simulation.

Co-bonding was selected over co-curing

- **First Round Results – Simulation configuration**

Cure Cycle Information

Pre Processor 1
HSP Geometry, Lay-up & Tooling Configuration

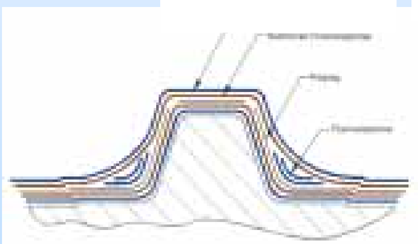
PATRAN

Pre Processor 2
Autoclave, Cure Cycle, Material Selection & Caul Plate Configuration

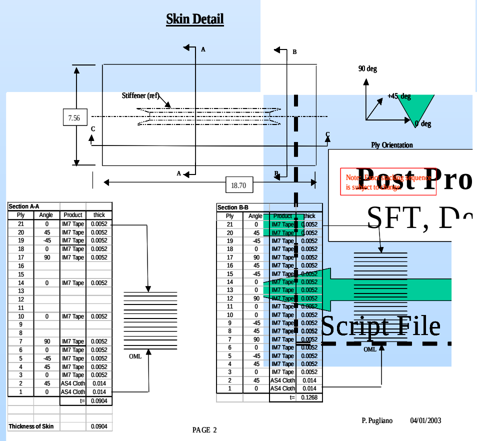
Tooling Configuration

Geometry & Lay-up from Structures

Processing Module
Using Resin, Fiber & Lamina



Tooling Configuration



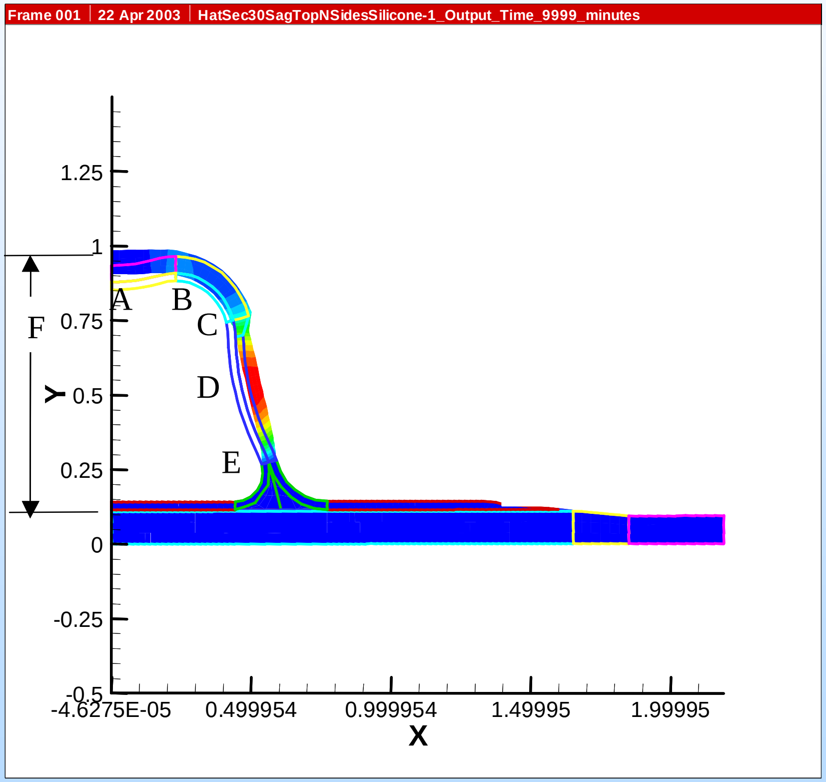
Post Pro
SFT, D

Script File

Detailed Data Output vs. Time

Structures information

- **First Round Results – Simulation Shape Prediction**



Predicted Mandrel Growth

A +0.109 cm in Y
B +0.048 cm in Y
C +0.025 cm in X
D +0.089 cm in X
E + 0.025 cm in X

Overall Height from Pre -cured Skin
F 2.21 cm

- Compensate mandrel to prevent ballooning