

Evaluation of Large Thermoplastic Welded Structure

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Evolution of Thermoplastic Technology

ASPERA

- 4'x6'
- Constant curvature
- Constant thickness
- HS (AS4) fiber

- AS4 fiber
- Constant thickness
- Made at NIAR

- AS4 fiber
- Constant thickness
- Made at NIAR

Skin

Laser
AFP

Stringers

AFP +
Stamp
CoFusion

Frames

AFP +
Stamp
Induction
Weld

WICHITA

- 4'x8.5'
- Compound curvature
- Variable thickness
- Shape compensated layup tool
- IM+ (T1100) Fiber

- T1100 fiber
- Variable thickness
- Made by HiCAM partner

- IM8 fiber
- Variable thickness
- Tooling exceeded US equipment limits, NRC- Montreal

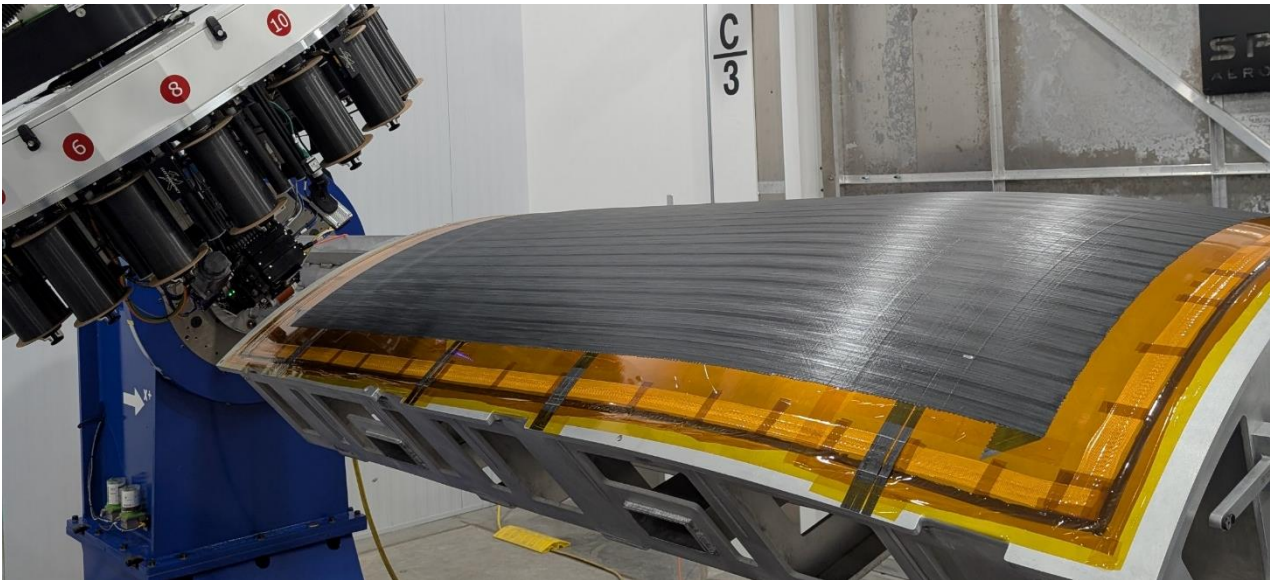


Laser Assisted Automated Fiber Placement

- Make skin and stamping blanks
- Laser heating
- 1/4" tows
- Temperature and speed influences tack, level of repairability

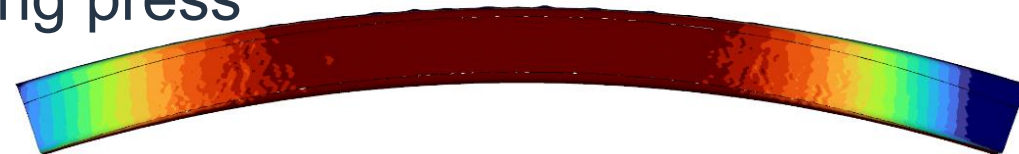
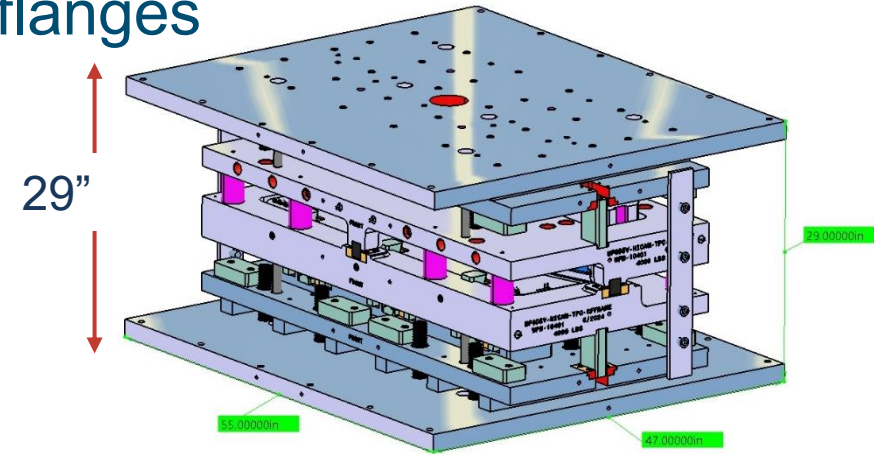
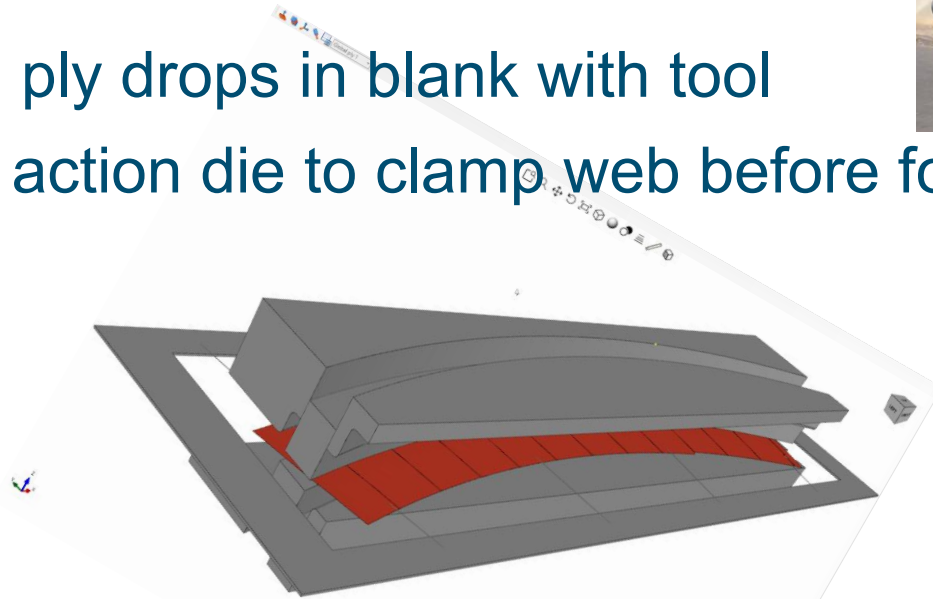
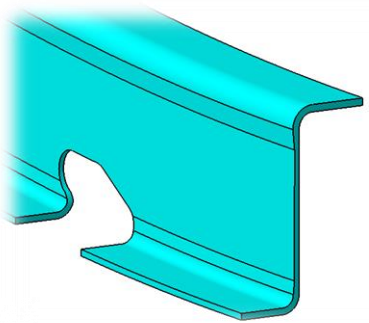
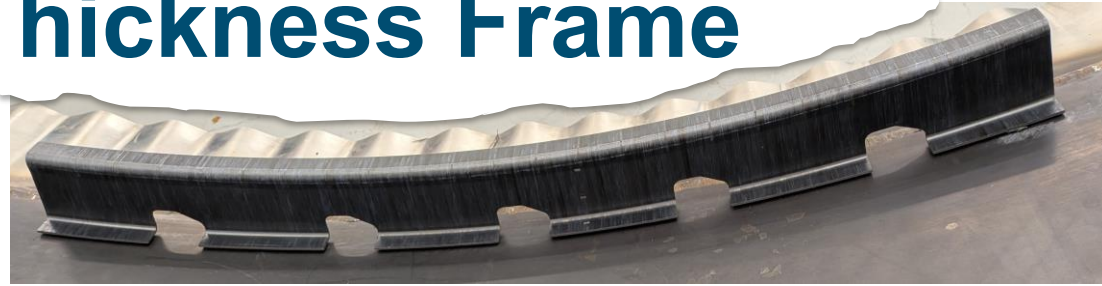


- Allowed angular deviation to reduce laps & gaps
- 8 lbs/ hr with 5 lanes
- Shape compensation of mandrel



Stampforming of Variable Thickness Frame

- Difficult to align ply drops in blank with tool
- Designed multi action die to clamp web before forming flanges



- Size of tool eliminated use of any domestic stamping press
- Aniform used to predict distortions
 - Predicted movement of 0° plies during stamping
 - Showed effect of mouse holes and trim on wrinkling

CoFusion Tooling (patent pending)

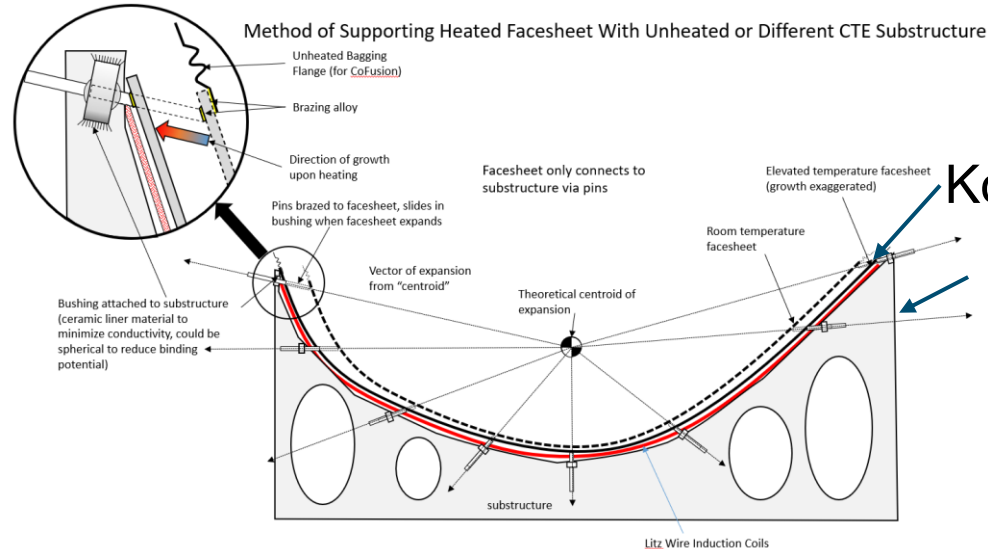


Sliding stems allow stress-free face-sheet expansion



Litz wire induction coils

Thermally isolated perimeter

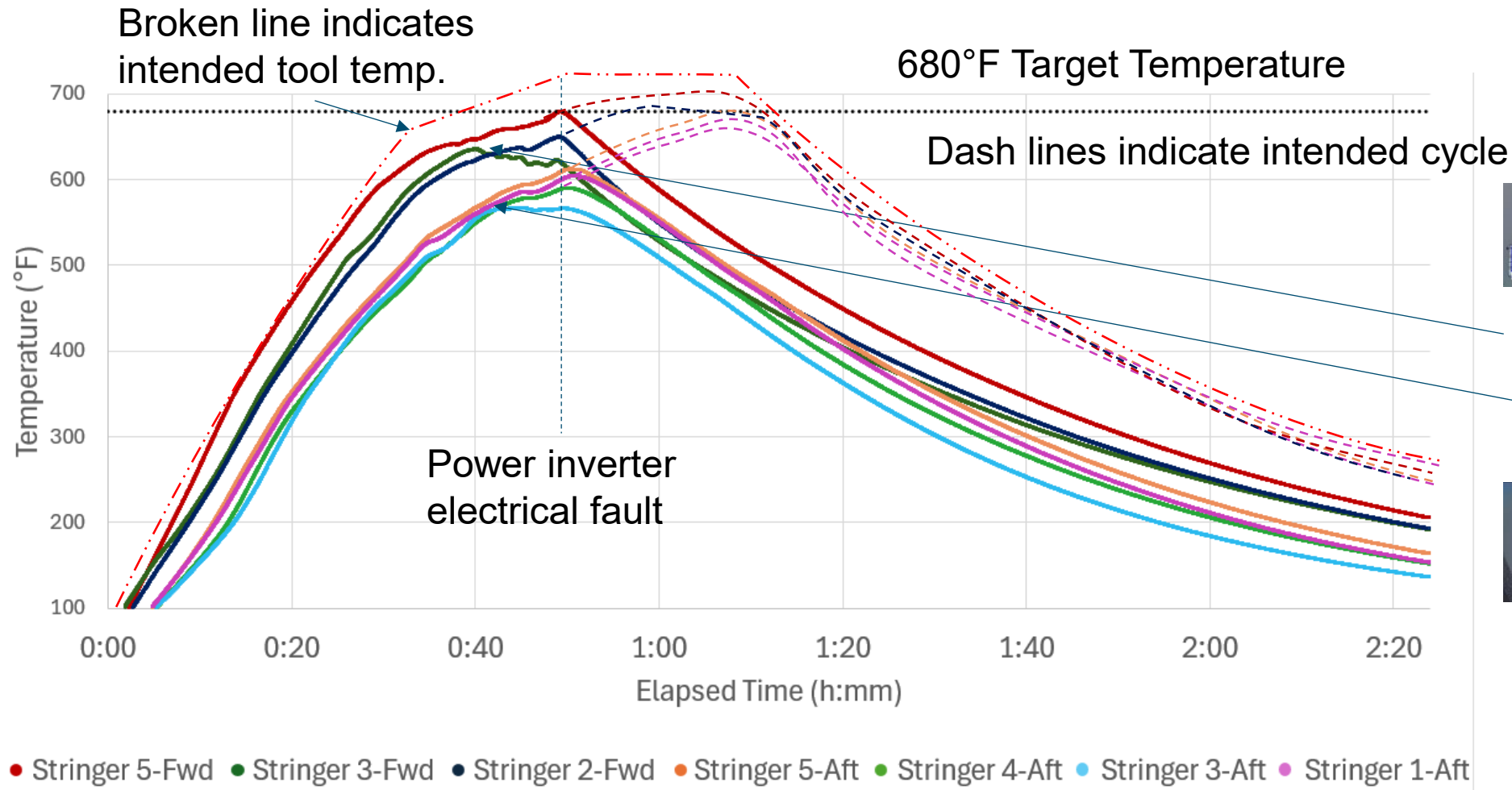


Kovar face-sheet

Steel substructure

All stem axis project to same point

Co-Fusion Temperature Profile

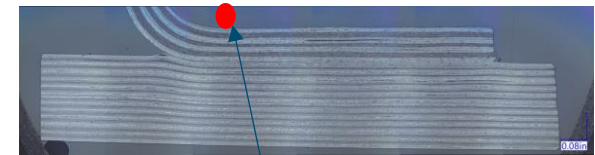


Thermocouple location



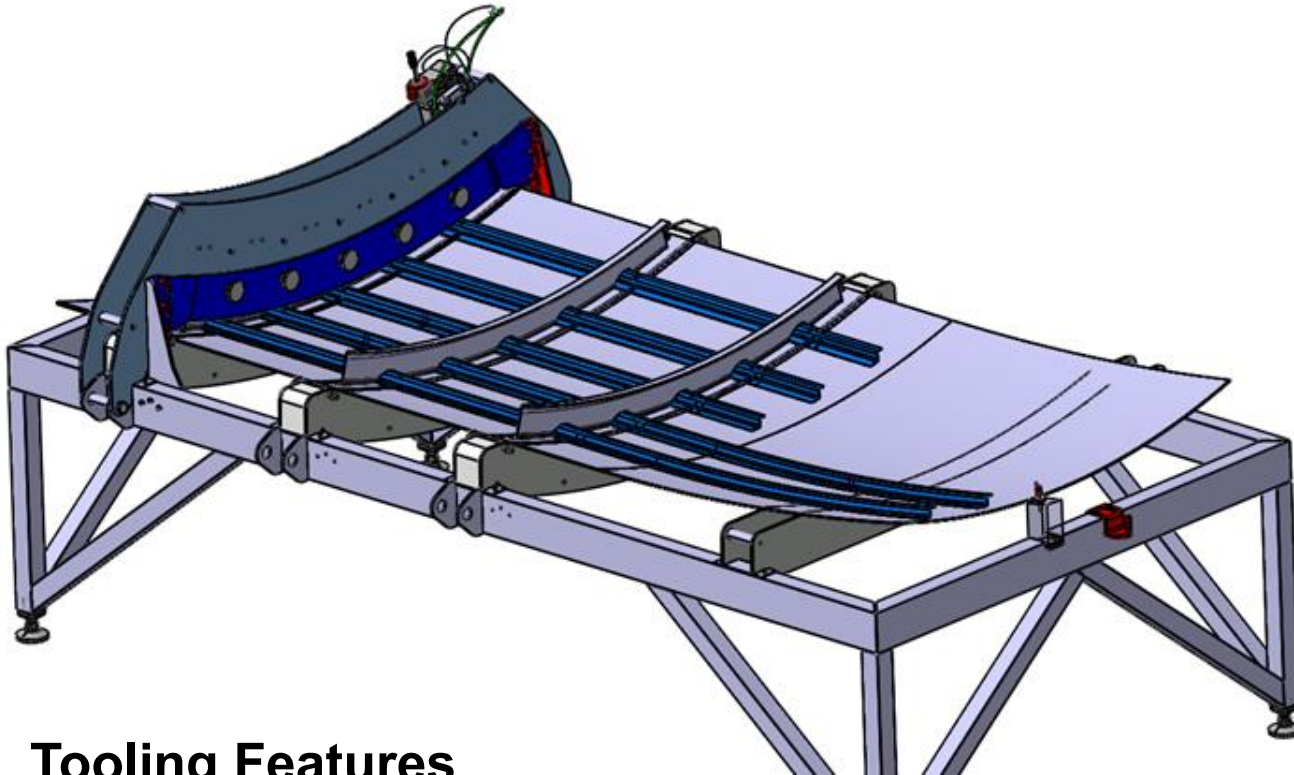
30 Ply T/C's

70 Ply T/C's



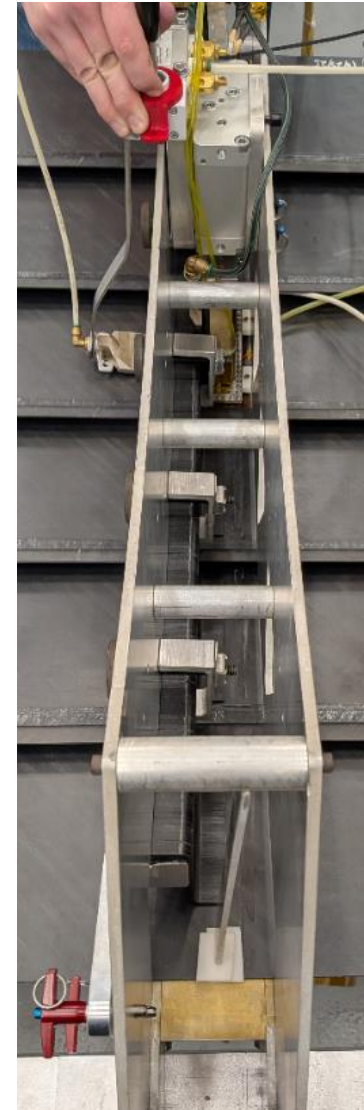
Thermocouple location

Induction Welding Tooling

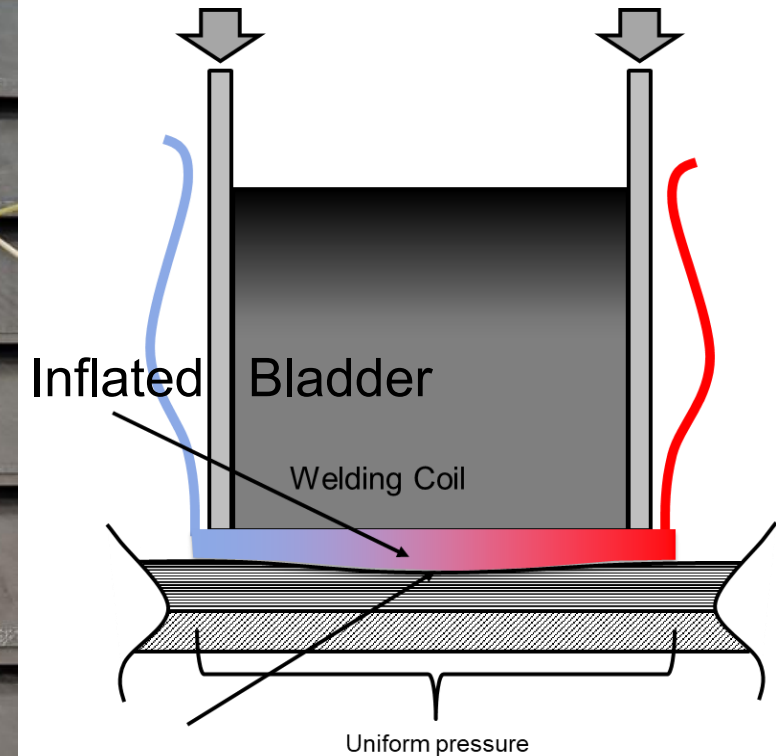


Tooling Features

- Gantry to position coil in each stringer bay
- Backup support serves as heat sink
- Air cylinder on coil and bladder must work in harmony



Reaction force from manipulator



Heat removed from surface

Induction Welding Process Development



More uniform pressure than compliant layer



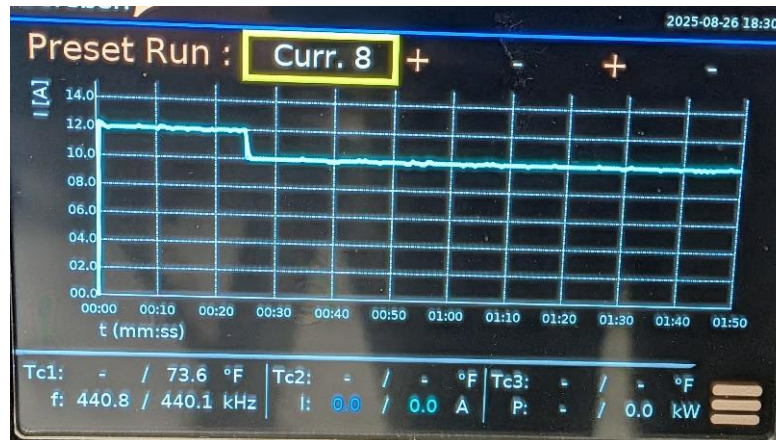
Overheating of shear tie & skin ply squeeze out



Optimized balance of weld area & defects



Bladder during welding



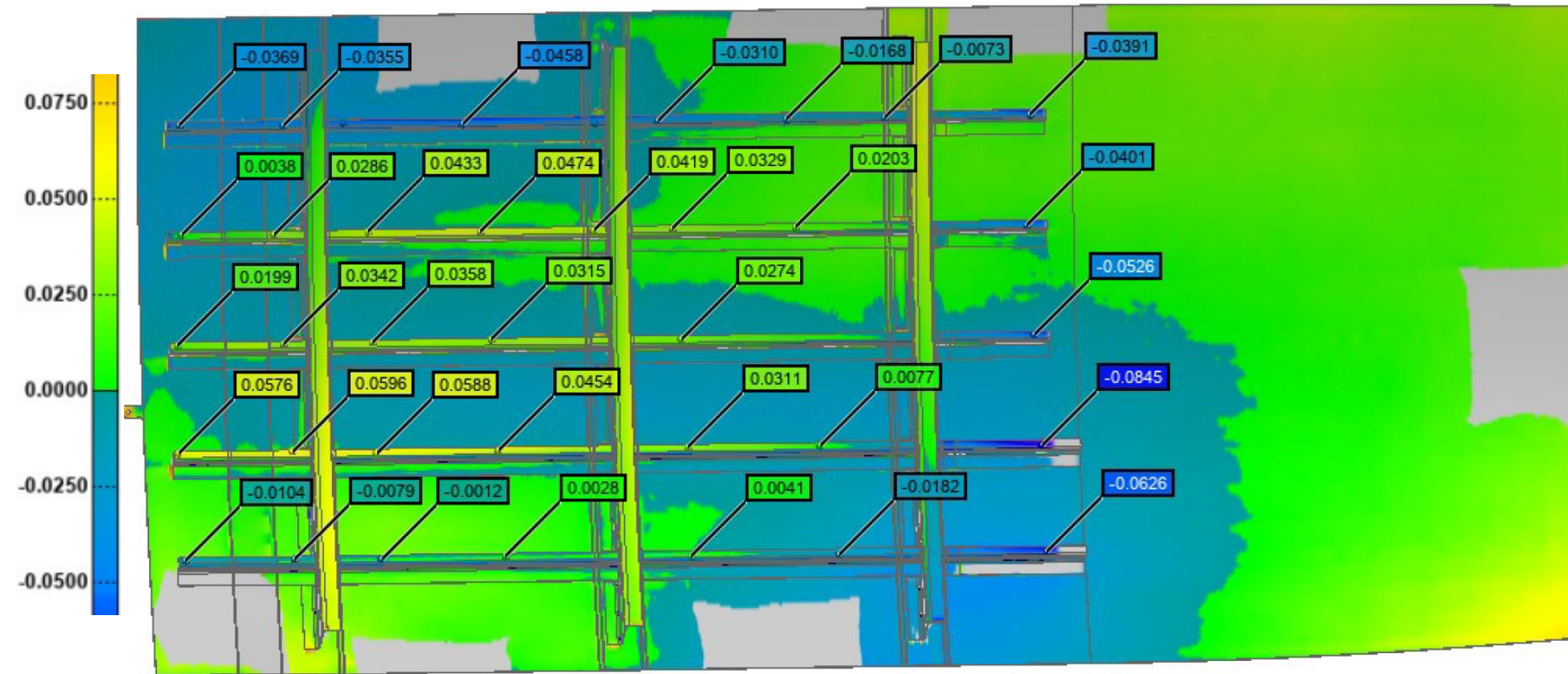
2 step recipe



Guarding against radius melting

WICHITA: Dimensional Inspection

WICHITA-REV2

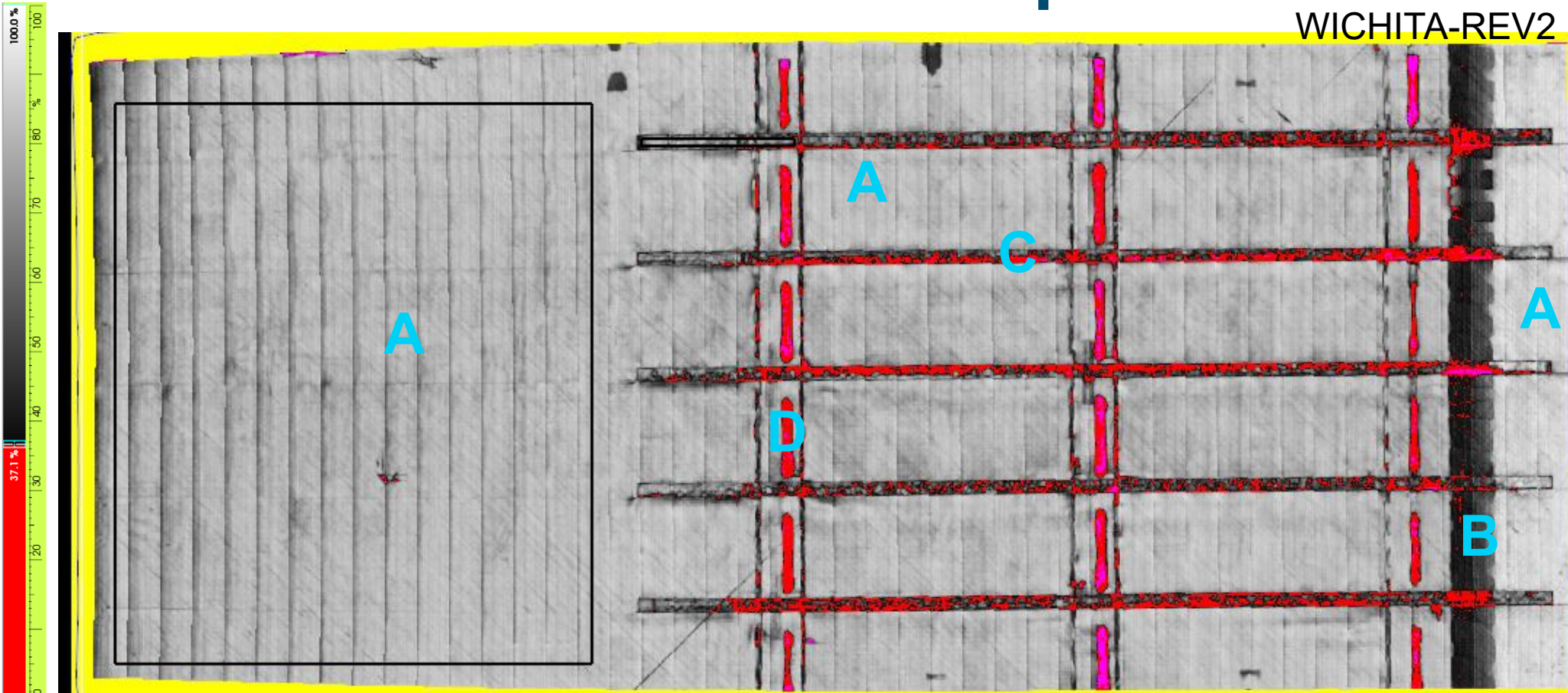


- Goal was 0.060" surface profile
- OOT after just AFP largely eliminated
- Most of skin fits within -0.02" / +0.04"

Call outs are for stringer caps, color applies to all

Pulse Echo Ultrasonic Inspection

WICHITA-REV2



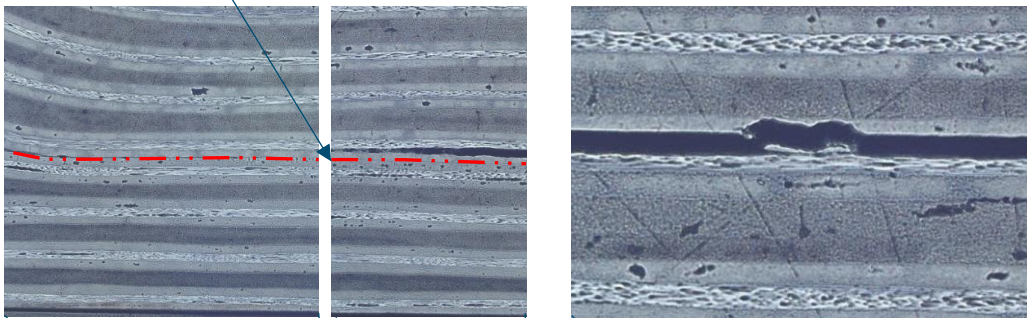
Red: >6dB loss
Pink: no signal
A: skin
B: ramp
C: stringer weld
D: frame weld

- Stringer OOT may have exceeded capability of Co-Fusion process
- **Good consolidation in skin, mixed results on welds. Need weld standards for further analysis**

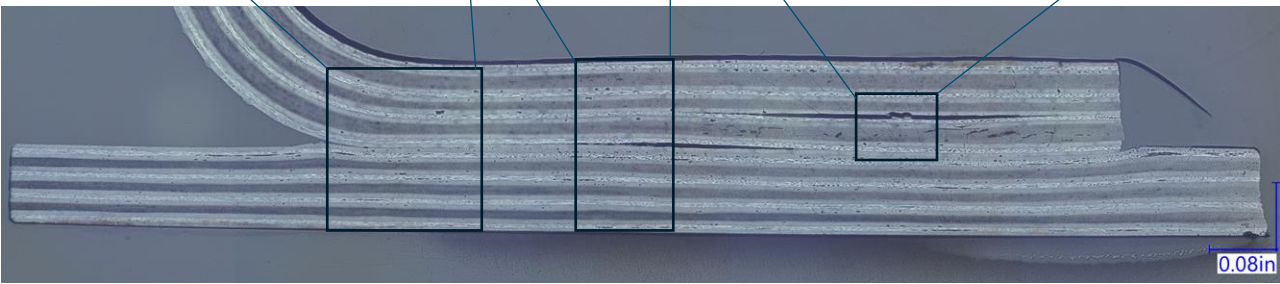
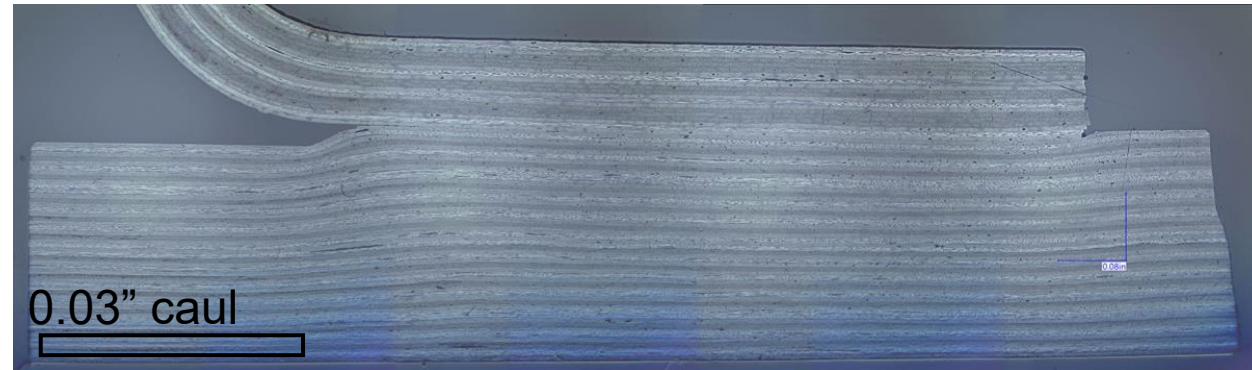
Stringer Weld Photomicros

**Thick stringer on thin skin:
high attenuation**

Weld Line

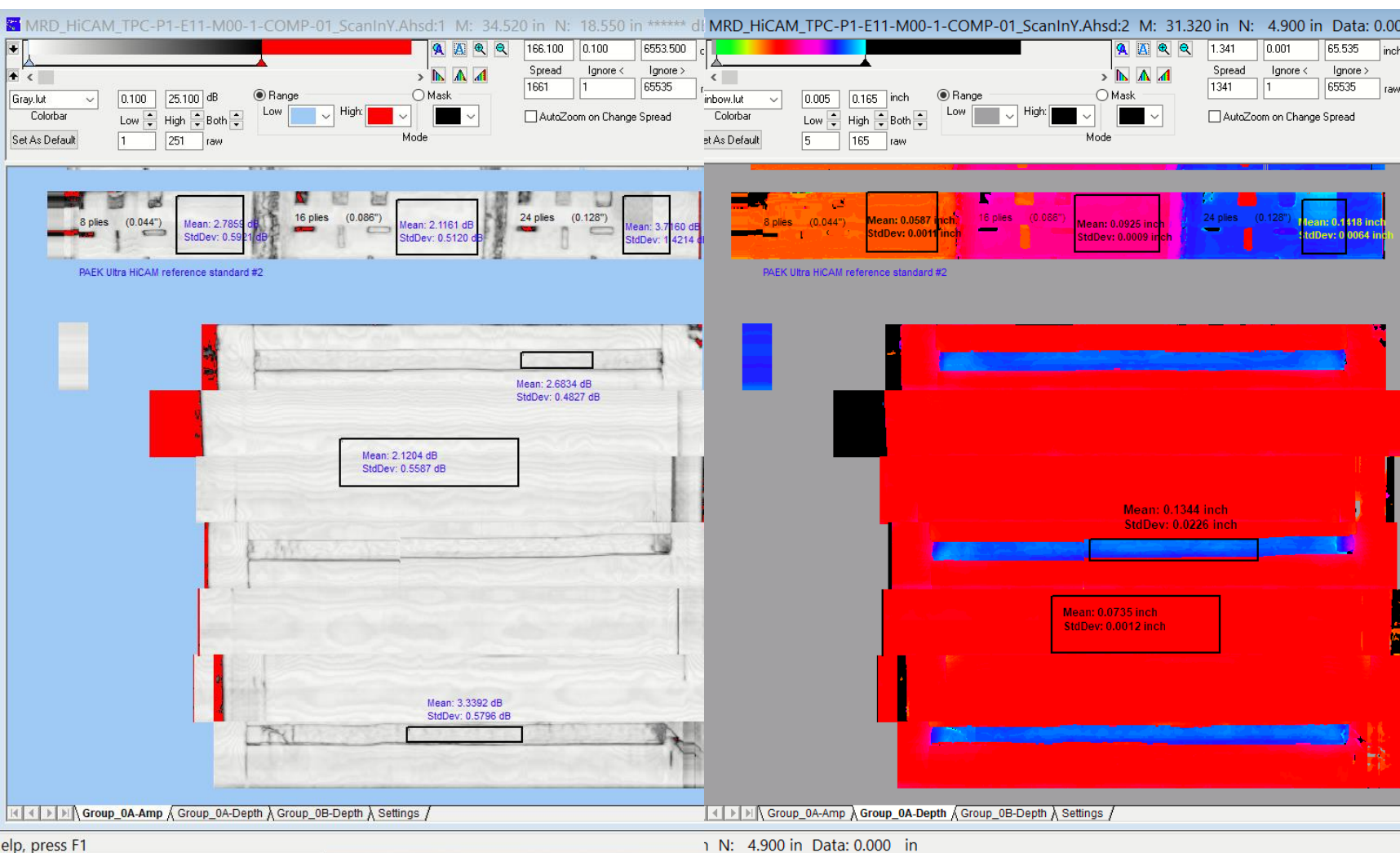


**Thick stringer on thick skin:
low attenuation**



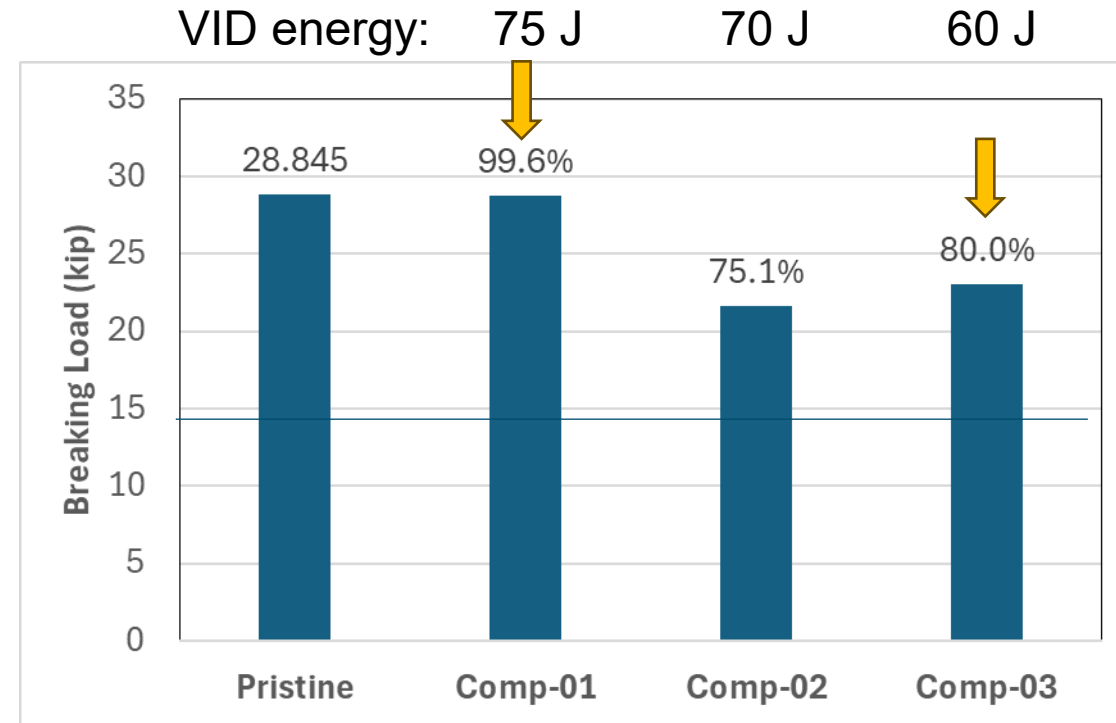
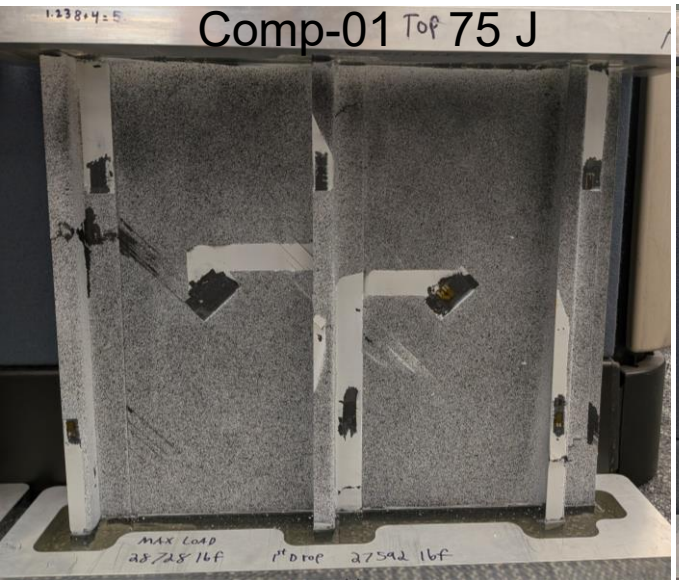
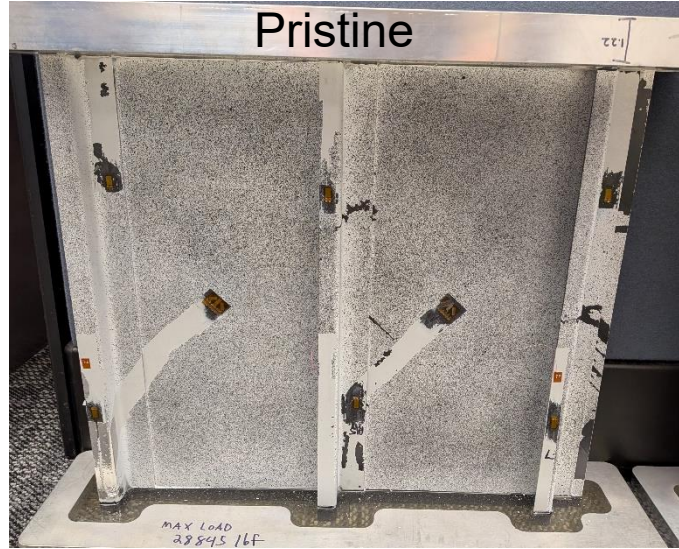
Component Testing

No indications and highly uniform welds on all 5, 3-stringer panels



IMP-01

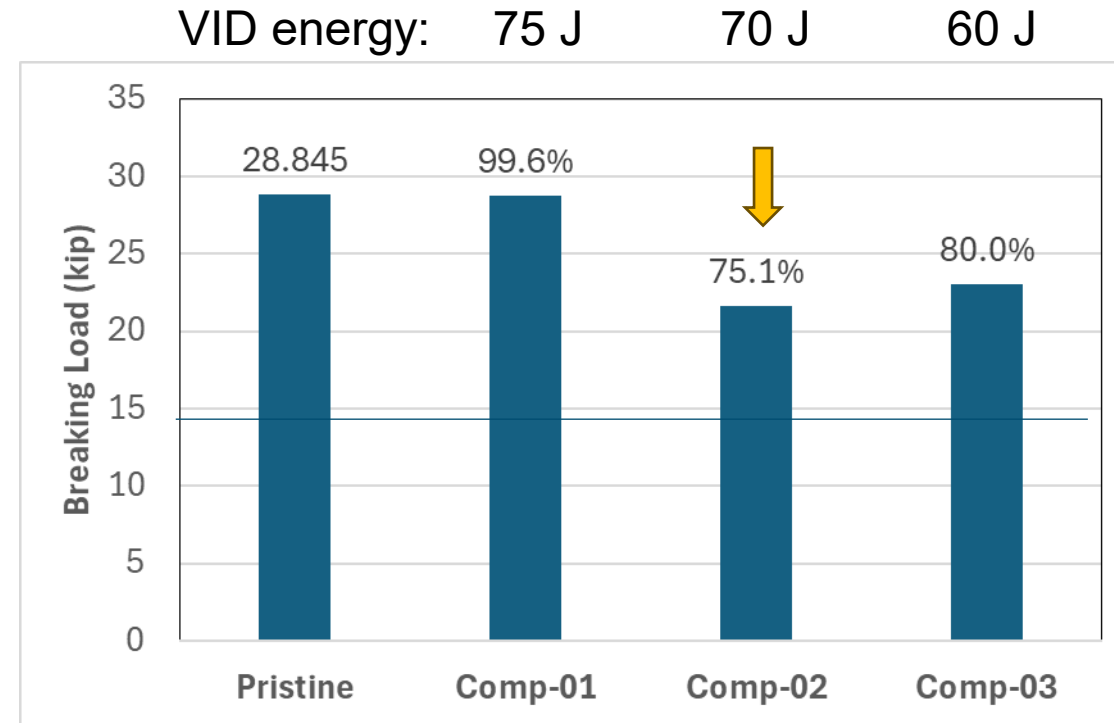
Compression After Impact



Skin impact to cause stringer disweld

Compression After Impact

Impact to OML to cause stringer cracking



High Rate Aircraft Manufacturing

- WICHITA used to demonstrate technologies and processes that could be used to build a single aisle fully thermoplastic fuselage
- Benefits (compared to current thermoset practices) are expressed in flow time, labor cost, material cost, and factory floor space

KPPs	Savings from baseline	Savings
Net Cost/shipset*	\$ 0.68M	43%
Non-Recurring Cost	\$ 1.30B	49%
Recurring Cost	\$ 0.31M	37%
Factory Area	0.35M ft ²	44%
Weight	216 lbs	13%

* Assuming 3600 units

Acknowledgement

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