Space Shuttle Stiffener Ring Foam Failure Analysis, a Non-conventional Approach.

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Shuttle Legacy Flight Hardware will Fly on the Space Launch System
Space Shuttle on Ascent
SRB Recovery
Stiffener Ring
SRB Foam Buildup

- 1/8 bond coat
- Coating Buildup
- Pull
- Test
- >20psi
ATK define the foam failures qualitatively by visual inspection of the presence or absence of foam residue on the de-bonded surface.

Foam Failures fall into two categories:

- Adhesive
- Cohesive
- Mixture of both
Solid Rocket Booster Stiffener Ring Foam Failure
The classical methods of analysis failed to provide a root cause into this foam failures for the last 25 years.

- Chemistry-extraction of residues
- Bulk property test
- Fracture analysis
- No known nondestructive analysis
- 10,000’s of hours testing “process” variables

**A new approach was needed**

**How would a microscopist look at this?**

Cell morphology determines the mechanical strength of the foam.

Foam is the ideal media to preserve its own failure.

Cross sectioning to observe the cell morphology.
Foam Chemistry

• A/B Ratio- mechanical strength and flexibility

• Blowing agent function of vapor pressure and temperature

• Exothermic reaction –driving the reaction rate

• Moisture
Application parameters

• Optimum two part ratio
  – Viscosities
  – Delivery Pressures

• Temperature
  – Substraight temperature – infinite heat sink
  – Exothermic reaction ~140 F
  – Ambient - outdoor conditions

• Operator application technique
  – Spray pattern

• Formulation changes
  – Blowing agent
  – Catalyst

• Humidity-dew point
  – Cure rate
  – Substraight
Polarized Light Microscopy

Cells at Failure
Polarized Light Microscopy of Foam

Exemplar

Failed Surface
Cross Sectioning of Foam

- Plastic slide with double-sided tape

1\textsuperscript{st} cut 1 mm section single edge razor

2\textsuperscript{nd} cut 0.5-1 mm section double edge razor
Cross Section of SRB Foam Failure

Second layer knit line

Distorted cells contained in bond coat

Chief SRB Engineer – we have never looked at foam like this
SRB Foam Failure

- Adhesive failure at RT-455
- Attachment ligament
SRB Foam Failure
The foam bond coat displayed two modes of failure:

- >80 percent application failed
- Cohesive failure was observed due to severely deformed foam cells in the bond coat
- Adhesive failure was observed at the RT-455 Epoxy interface.

The observed morphology indicates that the bond coat was not fully cured before other forces were applied, e.g. the expansion forces of the second coat distorted the bonding cells.
Process Changes

- Develop spray hardware to apply micro bond layers (< 1/8” layers)

- The bond coat should be allowed to completely dry/cure
  Never apply over wet uncured layers

- Smaller Soup can (1/2 inch) inspection plugs for SEM analysis should be developed
Sunset on International Space Station Expedition 15
A View from Above!
• 30% adhesive failure
50 PSI
78 PSI