FAA Bonded Structure Workshop
June 2004

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Bell Experience with Bonded Structures

1950’s – Bell Model 47

Bonded main & tail rotors - Originally wood core with metallic skins.

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Bell Model 412 with experimental composite tailboom
BMI solid laminate/co-cured honeycomb sandwich structure.
Production rotor blades – bonded composite construction.

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Bell Model 427: Grey = Metal, remainder is bonded composite structure

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Bell Model 427 – detail part assembly view

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BA609 First Flight 2003
Bell Experience with Bonded Structure

Bonded Structures (Primary):

- Rotor Blades - Metallic and Composite (film adhesive/no fasteners)
- Bonded wing skin stiffeners - Co-bonded or Co-cured (Film adhesive)
- Bonded wing skin-to-rib structure - secondary bonded (Film adhesive).

Bonded Structures (Secondary):

- Co-cured sandwich structure – fairings, fuselage side of body panels (Film adhesive).
- Metal bond panels – sandwich and metal-to-metal (Film adhesive).
- Systems support – bonded brackets/standoffs ect. for electrical & hydraulic systems (paste adhesive or “composite bond”).

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**Bonded Structure Safety/Certification Issues**

✓ Surface preparation (well defined/controlled by process specs)
  * Time limits for prepared surfaces.
  * Storage requirements for prepared surfaces.

✓ Mechanical property characterization (well defined by material specs)
  * New designs often require testing of adherend combinations beyond what was done for basic qual (RI vs Design Reqm’ts).
  * Co-cure requires prepreg/adhesive compatibility testing.
  * Type of carrier used in adhesive can make a significant difference for certain applications.

✓ Damage tolerance (usually element and/or full scale part with known defects – fatigue test with static residual strength).
**Bonded Structure Safety/Certification Issues**

- Understand tolerances for mixing of paste adhesives.
  - Are scales with adequate capability clearly defined in the equipment section of the process specification for hand mixed adhesive? *(Example: mixing miss-match study)*
  - Is exotherm potential understood (maximum allowed mass/mix quantity defined in process spec)?
  - Have tests been performed to demonstrate that hand mixed vs. static mixed (kitted) adhesive produces the same result?.....does the QPL limit the kitted adhesive to approved kits/cartridges and specific approved mixing tips for each adhesive system?

- Material/Process Specs must provide the guidance necessary to ensure that design of the bonded structure assembly and associated tooling are consistent with adhesive processing limitations. *(Example: assembly time study)*
Example 1a: Mixing Mis-match (Lap Shear)

Adhesive System 1 - Lap Shear Response

Higher than nominal mix performance is not necessarily “better”.

Nominal Mix
Component A: Base Epoxy
Component B: Curing Agent

Component A, % Mismix
Strength Ratio

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Example 1b: Mixing Mis-match (Lap Shear)

Adhesive System 2 - Lap Shear

Component A: Base Epoxy
Component B: Curing Agent

Nominal Mix

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Example 1c: Mixing Mis-match (Peel)

Component A:
Base Epoxy

Component B:
Curing Agent

Adhesive System 1 - Metal/Metal Peel

Component A Mismatch, %

Peel Strength Ratio

Nominal Mix
Example 1d: Mixing Mis-match (Peel)

Adhesive System 2 - Metal/Metal Peel

Component A: Base Epoxy
Component B: Curing Agent

Nominal Mix

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Mixing Mis-match Conclusions

✓ Sensitivity to mixing ratio is adhesive system dependent.

✓ Sensitivity to mixing ratio should be considered when specifying minimum acceptable amount to mix and capability of weight measuring equipment.

✓ Mixing ratio effects should be addressed in training.

✓ Best solution is to qualify a metered/static mixed kit form when practical.
Example 2a: Bonded Joint Assembly Time

- 2 minute assembly time = 90% strength with 75F cure.
- 7 minute assembly time = 90% strength with 155F cure
Example 2b: Bonded Joint Assembly Time

- 6 minute assembly time = 90% strength with 75°F cure.
- 16 minute assembly time = 90% strength with 155°F cure

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Assembly Time Conclusions

✓ Perform enough tests during development to understand assembly time effects.

✓ Significance of assembly time effect is adhesive system dependent.

✓ Specify elevated temperature cure in production planning when practical to provide maximum assembly time window.

✓ Adhesive training program should include focus on assembly time in addition to pot life (working life) of mixed 2-part paste adhesives.

✓ Process specification should include upper limit on assembly time when applicable.

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Structural Adhesive Bonding

Biggest lessons learned – Clearly defined processes / Well trained personnel

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