Cobonding Primary Structure – Processing Issues and Related Tests

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Background and Previous Experience

• 20 Years at Boeing Working CFRP Primary Structure

• R&D, 7J7 CFRP Emp, 767X Emp, 777 Emp and Wing High Lift & Control Surfaces, and Currently Working 7E7 Airframe

• DER from 777 and on
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777 Experiences with Peel Plies

• Peel Ply can work in a highly controlled environment

• Well trained workforce

• Single source adhesive, peel ply and substrate are used to reduce risk of quality escapements. NDI will not find weak bondlines!

• Peel Ply receiving inspection must be Intense. Testing every roll of every batch using drawing adhesive and CFRP substrate.

• Receiving tests must include a peel test (DCB)
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777 Experiences with Prebond Moisture

- Producing parts at typical commercial rates and in benign environments (Puget Sound) has not caused this to be an issue in the past

- Parts are dried when held for long periods after fabrication and before bonding

- Empennage structure and secondarily bonded facesheets have not worked the bondlines to their capability
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Current Experiences with Peel Plies

• Must consider multiple applications, partners and manufacturers

• Single source adhesive, peel ply and CFRP substrate are no longer viable for the long term, considering the use of bonded structure over the complete airframe.

• Not only are there multiple material systems to deal with but second sources are inevitable

• Chances for contaminated surfaces are increasing and NDI methods still can not detect weak bondlines.
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Current Experiences with Prebond Moisture

- Parts are to be manufactured in areas of high humidity

- Current bondlines are more highly loaded than typical empennage structure of the past and work to the capability of the adhesive. Reduction in peel and shear can not be tolerated
  - Fuel pressures
  - Cabin pressures
  - High shears resulting from much heavier structure

- Drying time required for in-service scarf repairs is unacceptable for large scale CFRP usage
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What Happens When a Bondline Fails In-Service

- Found Disbond During In-Service Inspection
  - Do Records Reveal Issue
    - No
      - No direct Issue is Related to Problem
        - Inspect the Fleet Immediately
    - Yes
      - Manufacturing Related Issue Found
        - Inspect the Effected Fleet Immediately
  - Yes
    - Disbond Found?
      - No
        - Inspect the Effected Fleet Immediately
      - Yes
        - Fix Disbond with Bolted Repair
          - Repeat NDI Inspection Until Permanent Repair - for Effected or Entire Fleet
          - Or
            - Immediate Permanent Repair for Effected or Entire Fleet
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What Happens When a Bondline Fails In-Service

• No current inspection available to find weak bondlines
• It is not acceptable to repair areas of high peel only
• This is an overall durability issue
• All effected or possibly effected bondlines must be repaired or repeatably inspected until a permanent can be done
• Instrumental NDI required for inspections
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**Conclusion**

- The primary structure bondline must have a *robust* processes

- The cost of developing adhesives that are insensitive to prebond moisture is a small price to pay for much better “wet” bondline strength and shorter drying times in-service

- Realize that adding an additional manufacturing step (grit blast, plasma etch, etc) after peel ply removal is an insignificant cost compared to having in-service bondline problems

- Continue education in the use of peel plies, their sensitivities and limitations, the importance of rigorous receiving tests and tight controls in the shop environment

- Structural bonding in highly loaded primary structure will not be a viable alternative in the future if this is not done correctly
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Testing Beyond the Typical Lap Shears and DCBs

• What are some tests done beyond the DCBs, lap shears, and fracture toughness tests characterizing adhesives, preps, and strain energies.

• Highly loaded bondlines with multiple types of loads and failure modes are difficult to size using point design values (tests) and in the past have been difficult to analyze

• Size by analysis supported by testing from simple through complex validation tests.

• Testing includes process defects at the simple level and BVID at the more complex subcomponent level

• VCCT approach utilizing detailed FEM shows promise for these complex failure modes
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Testing Beyond the Typical Lap Shears and DCBs

- Stringer pulloff with and without process defects
- Various geometries, support widths and environments
- Static and fatigue
- Statistical confidence established with pristine RT specimens

Location of defects
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Testing Beyond the Typical Lap Shears and DCBs

- Transverse load and transverse load with pulloff
- Tested with and without process defects
- Understand the effect of bow waves and combined loads on the analysis method
- Various geometries, support widths and environments – some fatigue
Testing Beyond the Typical Lap Shears and DCBs

- Bondline shear and rail shear with pulloff
- Tested with process defects
- Understand the effect of combine loads on the analysis method
- Various geometries, some fatigue
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*Testing Beyond the Typical Lap Shears and DCBs*

- Larger scale test with correct boundary conditions for stringer pulloff
- Understand load assumptions on the bondline
- Understand the effect of BVID and process defects
- Various geometries and environments – some fatigue
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**Testing Beyond the Typical Lap Shears and DCBs**

- Combine in-plane axial and chordwise loads with stringer pulloff
- Validation of analysis methods
- Correct boundary conditions and loading, with and without shear ties
- Tested with BVID and process defects, effect of multiple stringers understood
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Conclusion - Testing

- The first objective is to characterize the adhesive and bond prep and understand the fracture toughness properties to support an analysis method.

- Next step is to understand the design detail, simplified loads and the applicability of the analysis method with and without process defects.

- Now understand the effects of combine loading on the detail and the ability of the method to account for this.

- Look at larger subcomponents with correct boundary conditions to understand the true applied loads at the adhesive interface.

- Final verification of the analysis method and BVID knockdowns are established at the subcomponent level using combined loads.