Composite Modification Workshop
Discussion of Challenges: Fatigue and Damage Tolerance (plus ICA)

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Fatigue & Damage Tolerance Challenges

- Decisions on what critical structure in the Mod requires full damage tolerance
  - PSE for transport category aircraft
  - Likely no difference in decision for composite or metal

- More difficult to determine what is needed for base structure (metal or composite) when it is critical structure but parts in the mod are not
  - More difficult for composites (likely need for tests, after proving base structure can be reproduced as equivalent at structural scale)

- Still a challenge even when considering Mods that have all secondary structures
  - Allowable damage limits for even base structure are no longer valid if loads have changed
Fatigue & Damage Tolerance Challenges

• **Base metal PSE structure fatigue and DT**
  – Affected by complex interface loads, inspectability with Mod details and workmanship
  – Analysis is such that tests may not be needed

• **Base composite structure fatigue and DT***
  – Category 1 damage design criteria and test protocol (e.g., BVID, disbonds, porosity levels)
  – Category 2 and 3 design criteria and test protocol
    - Conservative versus rigorous approaches possible
    - Level of damage considered will depend on Mod dimensions

• **Composite part PSE*** (e.g., rotor blades)
  – Similar to base structure
    (requiring loads dependent on the full aircraft details)

* A need for structural tests may lead to: Can the modified composite base structure be reproduced to yield an acceptable result?
### Table X: Material and Fabrication Prerequisites for Base Structure Used in STC or Other Major Mod Test Substantiation

<table>
<thead>
<tr>
<th>Application</th>
<th>Approved Data*</th>
<th>Material and Process Specifications</th>
<th>Base structure remanufacturing instructions and assembly details (for modified structural components used for substantiation)</th>
</tr>
</thead>
<tbody>
<tr>
<td>(Eng. Judgment: to facilitate efficient industry practices)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Critical Structure (e.g., Transport PSE)</td>
<td>Design values &amp; DT data with analyses</td>
<td>Yes</td>
<td>Yes, incl. qual. for bonding</td>
</tr>
<tr>
<td>Non-critical Structure that may cause flight difficulties</td>
<td>Design values coupled with analyses + other</td>
<td>Yes</td>
<td>Yes, incl. qual. for bonding</td>
</tr>
<tr>
<td>Non-critical Structure that can’t cause flight difficulties</td>
<td>Design values coupled with analyses</td>
<td>Yes</td>
<td>Precise controls</td>
</tr>
<tr>
<td>Interior Structures Subjected to Fire or Crash Regulations</td>
<td>Design values with analyses &amp; fire tests</td>
<td>Yes but less rigor</td>
<td>Yes, incl. qual. for bonding</td>
</tr>
<tr>
<td>Secondary Transport Structure</td>
<td>Design values coupled with analyses</td>
<td>Yes but less rigor</td>
<td>Yes, incl. qual. for bonding</td>
</tr>
<tr>
<td>Secondary GA or RC Structure</td>
<td>Design values or other proof of structure</td>
<td>Yes but less rigor</td>
<td>Yes, incl. qual. for bonding</td>
</tr>
<tr>
<td>Tertiary Structures</td>
<td>Other proof of structure</td>
<td>Control w/o qualification data rigor</td>
<td>Yes, incl. qual. for bonding</td>
</tr>
</tbody>
</table>

* Note: Approved data may come from previous sources (e.g., OEM) and can support or reduce the development of equivalent materials, processes or other procedures needed in re-manufacturing base structural test elements or components for structural substantiation.
Fatigue & Damage Tolerance Challenges

• Damage threat assessment
  – Accidental damage
  – Environmental damage (e.g., sandwich fluid ingestion)
  – Manufacturing defects (e.g., weak bonds)

• Load enhancement factors (LEF) + other info
  – Element tests to justify lower (realistic) LEF and identify truncation load levels (reducing larger scale test costs)
  – Minimum tests to justify conservative LEF

• Thermal load considerations for metal and composite components of Structural Mod
  – Can be a significant challenge for metal fatigue and composite or metal residual strength
  – Validated temperature profiles for insulated boxes on the top of a fuselage, where defaults aren’t accurate
Fatigue & Damage Tolerance Challenges

• Critical locations for damage and defects
  – Can depend on detailed knowledge of load paths (a role for analysis, which can be validated in DT tests)
  – Manufacturing trials are necessary to understand the defects you will need to seek allowable limits with

• Document in ICA & other maintenance reports
  – Just a reminder of the final goal (see subsequent charts)

• New content going into CMH-17/CSET should help get up a learning curve
  – Future efforts seeking composite advantages for structure known to be very damage tolerant

• Negotiating some knowledge from the OEM (thru customers) may be best/cheapest option
Fatigue & Damage Tolerance Challenges

Some suggestions from contractors

1. Much of the challenge in work comes with composites, although metallic base structure can drive Mod design
2. Would like more AC definition of damage threats (this is conceivable but would be conservative)
3. MRB actions will require “effects of defects/damage” knowledge regardless of structural classification
4. Don’t forget to evaluate obvious damage and possible remote damage for any high energy events (including bird strike)
5. Fairing/radome deflection may contact antenna, causing damage to light gage composite parts
6. Composite truncation loads can be quite high versus metal (but depend on a level of stress/strains, not 30% of Limit load)
7. What would it take for an applicant to substitute significant static overload for a composite fatigue test?
8. Be careful with rules of thumb on damage sizes and fatigue cycles
9. Metal damage tolerance standard industry practices exist – desirable for composites
Bird Strike Challenges

- Address potential of a modified part departing the aircraft (PDA)
- Consider all flight phases (sea level to 8,000 feet, up to required speed within design weight & CG limits)
  - Exception: Demonstrate bird cannot strike the structure (shielded by other structure) or the PDA is no worst than a bird strike
- Must show that modified structure will survive required bird strike and successfully complete the flight
- Compliance by tests or analyses supported by tests
  - Identify worst case bird strike locations
  - Evaluate all possible failure modes of the modified structure attached to the base structure
- Analysis supporting design and test plans
  - Worst case impact locations
  - Avoid undesirable failure modes
- Test simulation of modification installed on base structure
Instructions for Continued Airworthiness

• §21.50 Instructions for continued airworthiness and manufacturer's maintenance manuals having airworthiness limitations sections.

• ICA’s must include among other items:
  – d) Details for the application of special inspection techniques including radiographic and ultrasonic testing where such processes are specified
  – 1) Each mandatory modification time, replacement time, structural inspection interval, and related structural inspection procedure approved under §25.571.

These are often neglected or poorly documented!!
Examples of ICA’s

<table>
<thead>
<tr>
<th>Detail</th>
<th>Critical Crack Length</th>
<th>Cycles to Failure</th>
<th>Inspection Method</th>
<th>Inspection Interval (Cycles)</th>
</tr>
</thead>
<tbody>
<tr>
<td>External Skin, First Fastener Row</td>
<td>.66 inch (link up to next fastener hole)</td>
<td>67,471</td>
<td>Eddy current inspection of each fastener in the first fastener row around the doubler using high frequency surface probe method, from the inside skin surface around the rivet tail. Required Probability of Detection is 90% for .06” exposed crack.</td>
<td>At no less 18,823 cycle intervals after installation,</td>
</tr>
<tr>
<td>External Skin or Doubler, Connector Penetration</td>
<td>1.157 inch (link up to the second adjacent fastener hole)</td>
<td>53,135</td>
<td>Eddy current inspection around the periphery of the connector penetration, from the exterior side using high frequency method, antenna removed. Required Probability of Detection is 90% for .06” crack extending from hole edge.</td>
<td>At no less 16,711 cycle intervals after installation</td>
</tr>
</tbody>
</table>
Review Comments

- Inspection areas are described but no diagrams
- No open up or close up procedures
- Describes critical crack length and cycles to failure derived from DT evaluation (good)
- States to do a HFEC but no setup procedure;
  - Size and frequency range of eddy current probe not included
  - No calibration standard called out, material and notch size
  - No accept/reject criteria
  - Provided an interval but not a threshold
  - Two separate intervals (operator will probably do both at same time)
Concluding Remarks on ICAs

• The modifier of a metallic baseline structure is **required** to furnish Instructions for Continued Airworthiness (ICA) of the proposed change to the type design.

• Inspections for composite structure **must support** the damage tolerance criteria used during certification, including any deviations needed for the unique installation design detail.

• These maintenance actions **should identify** all the necessary procedures and tasks that are either recommended or required to maintain airworthiness.

• If **required**, they need to be annotated in the Airworthiness Limitations Sections (ALS) of the ICA document and be FAA approved.

• It may be possible that a structural modification could be adequately covered by the existing ICA of the baseline structure. Otherwise, the modifier needs to provide supplemental ICAs.