Composite Modification Workshop
Breakout Session: Fatigue and Damage Tolerance

Wichita, KS
August 22-23, 2017
Relevant Regulations for F&DT

Fatigue and Damage Tolerance

23.571 Metallic Pressurized Cabin Structures.
23.574 [Metallic damage tolerance and fatigue evaluation of commuter category airplanes.]
23.575 [Inspections and other procedures.]
23.627 Fatigue Strength

25.571 Damage Tolerance and Fatigue Evaluation of Structures
27.571 and 29.571 Fatigue evaluation of flight structure.
27.573 and 29.573 Damage Tolerance and Fatigue Evaluation of Composite Rotorcraft Structures

Bird Strike

23.775 Windows and windshields
25.631 Bird Strike Damage
29.631 Bird Strike
Example Text: Modifying Base Structure

Structural modifications on metallic baseline structure on transport category aircraft must be evaluated to determine if they affect principal structural elements (PSE), as identified by the TC holder, whose failure could lead to catastrophic failure of the aircraft. In addition, for transport category airplanes (part 25), the modification must also be evaluated to determine if it affects fatigue critical baseline structure (FCBS), a subset of the PSE list, or if it introduces fatigue critical alteration structure (FCAS). The modification should not adversely affect the fatigue performance of the aircraft locally or globally (i.e. Widespread Fatigue Damage). The evaluation must show that fatigue failure of the modification and/or that of the baseline metallic structure will be avoided throughout the design service goal or the Limit Of Validity (LOV) of the aircraft. The assurance of fatigue failure avoidance must be established by an evaluation that is based on test data or analysis supported by test evidence. The establishment of an inspection threshold and repeat inspection intervals to detect any cracks before they become critical while maintaining prescribed residual strength reserves are the main ingredients of a damage tolerance evaluation. In cases where damage tolerance based inspections of the modified area are impractical, replacement times or retirement life limits (safe life) must be identified. The modification should not invalidate the certification assumptions of the baseline structure. This implies that the instructions for continued airworthiness of the metallic baseline structure will have to be shown to still be effective in the presence of the modification or they will have to be supplemented by additional maintenance actions as determined by the fatigue and damage tolerance evaluation.
Example Text: Modifying Base Structure

The design of a structural modification on metallic structures should follow the industry accepted practices of minimizing the fatigue impact that a modification could introduce. These practices include the avoidance of introducing stress concentration factors and local peak stresses through the judicious selection of materials, fasteners and joint design details. Modifications that involve the process of metal bonding should be meticulously designed to the highest quality standards since the bond surface is the main load transfer mechanism. Additional fatigue enhancement measures could include cold working of critical holes and shot peening of fatigue critical details.
Base Structure: Metallic

- Thermal load considerations for metal base structure due to composites in composite parts of structural mod
  - Can be a significant challenge for metal fatigue and residual strength

- Challenges for base metallic structure relate to properly addressing changes in loads and consideration of:
  - Possible changes in analytical crack growth solution factors (relating to structural mod design details and load redistribution)
  - Unique inspection procedures needed for a specific modification (for ICA and related documentation)
  - Should we outline criteria when tests may be needed?

- Others?
The applicant must show that the modified composite structure continues to comply with applicable fatigue and damage tolerance requirements. The effects of changes in interface loads on fatigue spectrum loads must be considered together with any load redistribution or stress concentrations from modifying the structure (e.g., new cut-outs). This is particularly critical with modifications to rotorcraft, which commonly affect the fatigue spectrum. In most airplane structures, fatigue and durability can be enhanced by increasing the load-carrying capability of the structure by adding doublers or increasing the size. In helicopters, this approach – especially in the tail boom, vertical fin spar and elevators – does not work due to the fact that these operate in a displacement-driven environment. Increasing the stiffness of the tail boom or vertical fin may change the dynamic characteristics of the helicopter and may increase the loading and change loading in other components. Most helicopter airframe fatigue and durability issues are solved by enhancing the fatigue capability without changing the structural stiffness. If significant structural changes are implemented, the applicant must verify loads and strains in all critical components, not just those involved in the modification.
The general considerations for **composite** damage tolerance and durability demonstrations include:

- Acceptable manufacturing defects (acceptance criteria)
- Expected in-service **allowable** damage (un repaired) limited by threat, detectability or a maximum cut-off energy (1200 In.Lbs) (Comprehensive threat analysis is required to establish threat levels) whichever occurs first
- Manufacturing and Process variability
- Effects of environment on fatigue
- Effects of scatter on durability/life

All appropriate composite categories of damage, as defined in AC 20-107B, will need to be evaluated, within practical reason for the magnitude and size of structural modifications. Compliance options are to show no growth, slow growth, or arrested growth for damages. In most cases, element level testing can be sufficient for component and relatively small modifications. In well-analyzed structure, there is usually one or several critical details that drive or bound overall performance. Larger modifications may need full-scale testing.
Base Composite Structure Fatigue and DT*

- Changes in base structure loads or reinforcement may require fatigue and DT consideration
- Category 1 damage design criteria and test protocol (e.g., BVID, disbonds, porosity levels)
  - Allowable damage limits that differ from existing OEM documentation will require additional documentation
- Category 2 and 3 design criteria and test protocol
  - Conservative vs. rigorous approaches may be possible
  - Level of damage considered will depend on Mod dimensions
- Should we provide examples in the guidance?

* A need for structural tests may lead to: Can the modified composite base structure be reproduced to yield an acceptable result?
Composite Part Fatigue and DT

- **Composite part critical structure (PSE for transport)**
  - Similar to base structure (requiring loads dependent on the full aircraft details- see static discussions) → *Test dependence*
  - Damage threat assessment and test simulation
    - Accidental damage
    - Environmental damage (e.g., sandwich fluid ingression)
    - 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

- **STC to replace Metal composite rotor blades with composite rotor blades will require a separate meeting with experts in the area**
  - Other rotorcraft mods may also need future discussions
Other Composite Part Fatigue & DT Challenges

• Critical locations for damage and defects
  – Dependent on detailed knowledge of load paths (a role for analysis)
  – Manufacturing trials are necessary to understand the defects to cover in seeking allowable limits

• New content going into CMH-17 should help with other composite fatigue and damage tolerance challenges

• Document in ICA and other maintenance reports
  – Structural Mod AC will attempt to provide guidance that identifies all necessary procedures and tasks that should be documented to ensure continued airworthiness
  – Should we provide some other guidance on what is desired for ICA, incl. NDI procedures or special handling considerations?
  – Should we provide some guidance on structural mod design for other maintenance considerations (inspect-ability & repair-ability)?
Bird Strike Challenges

• Address potential that of modified part departing the aircraft (PDA)
  ➢ Exception: Demonstrate bird cannot strike the structure (shielded by other structure) or the PDA is no worst than a bird strike

• Process shared by Dave Stresing (see final presentation)
  • Possible use of “similarity” for similar radome designs (previously “calibrated” by tests) applied to similar aircraft ➤ see pitch with metal base
    ➢ Boeing noted that baseline metal structure differences may not be as critical as test data collected (interface loads from bird strike tests)

• Compliance by tests or analyses supported by tests
  ➢ Advantages of analysis supported by tests for design and test plans (particularly if tests indicate challenges need to be solved)
  ➢ Identify worst case bird strike locations and possible failure modes
  ➢ Specific antenna considerations (as related to mass, interface loads)

• Test simulation of modification installed on base structure (incl. failure modes of the base structure)