AIRBUS Composite fatigue & damage tolerance Sessions
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Sept 2015: FAA/Bombardier Composite Transport DT & Maintenance Workshop

Airbus Composite Fatigue and Damage Tolerance certification experiences.
Long History of Composite Technologies in Primary Airframe Structure

Fleet experience, on Airbus programs, show more than 200 millions of Flight Hours now been cumulated.

Design & analysis & validation methodology benefit of 50 years of experiences, since A300 to A380,

Hundreds of large Sub components to full scale Components Tested

Good reliability & durability established that should benefit to A350 Fatigue and damage tolerance validation.
The challenge: Hybrid Fatigue Full scale Cells?

Current scenarios: Tests cells duplication ➔ schedule & cost impact...

Metal test scenario
- Fatigue sensitive areas: all stress concentration areas
- Fatigue mainly driven by local tension loading, \( R = 0.1 \)
- Scatter covered by Test Life factor: 2 …3

Composite test scenario
- Fatigue sensitive features: Feature with out-of-plane stresses, Shear and Tensile inter lamina strength
- Compression: Mainly driven by compression and alternative loading, \( R = -1 \)
- Scatter covered by LEF Load Enhancement Factor: 1.17* from Northrop approach

\*from Northrop approach

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FAA/Bombardier Industry Composite Transport Damage Tolerance & Maintenance Workshop ESCAC
The challenge: Hybrid Fatigue Full scale Cells?

Adapted scenarios: Consolidate composite Fatigue sensitive feature, Converge on LEF (metal/composite):

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Adapted scenarios: Consolidate composite Fatigue sensitive feature, Converge on LEF (metal/composite).
The principle: Large testing background capitalized on a building block approach used to consolidate the fatigue insensitive threshold of the material.

- Comprehensive tests program developed for the fatigue scatter characteristic from key design/strength:
- Consolidate the fatigue insensitivity thresholds, through coupon and element testing
- Validating the approach at higher levels when required

Dedicated A350 tests developed
Goal: Establish Suitability and Durability of materials after repeated loading (as per CS25.603 & AC20.107B (8) b)

How: Determine on selected feature failure mode & material:
- Damage onset and residual strength capability
- Variability in fatigue results (scatter characteristics)
- Environment effect (wet exposure)
- Relationship stress – life (SN curve and slope)
- Load sequence: spectrum / constant amplitude loading effect

→ No material degradation from repeated loading was demonstrated.
LEF definition: Northrop’s analysis

Load Enhancement Factor has been introduced on fatigue composite full scale test as a response to the higher scatter observed on fatigue composite tests.

Composite standard approach:
1986-Northrop’s report proposed a 2 parameters Weibull law analysis.

Resulting from a large number of coupon tests,

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Remarks: Test campaign with all failure mode (not focused on sizing criteria)

\[
\text{LEF} = \left( \frac{N_F}{N} \right)^{\frac{\alpha_R}{\alpha_L}}
\]

\[
N_F = \frac{\Gamma \left( \frac{\alpha_L + 1}{\alpha_L} \right)}{\left[ -\ln(p) \right]^{\frac{1}{\alpha_L}}} 
\]

\[N_F\] is the resulting life factor for LEF=1
\[\alpha_R\] Weibull shape parameter for the scatter on residual strength properties
\[\alpha_L\] Weibull shape parameter for the scatter on fatigue life properties
\[p\] Survival probability (90% for the B-value definition)
\[g\] Confidence (95%)
\[N\] Coefficient applied on the life (N = Life Factor when LEF = 1)
\[n\] Number of test articles (usually one for a full-scale test)
Load Enhancement Factor has been introduced on fatigue composite full scale test as a response to the higher scatter observed on fatigue composite tests.

Composite standard approach:
AIRBUS Applied LEF.

Resulting from a large number of coupon tests,

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LEF = \left( \frac{N_f}{N} \right)^{\frac{\alpha_R}{\alpha_L}}
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N_f = \frac{\Gamma \left( \frac{\alpha_L + 1}{\alpha_L} \right)}{\left[ -\ln(p) \right]^{\frac{1}{\alpha_L}}}
\]

**Inputs**
- Alpha R (LEF=1)
- Alpha L
- \(N_f\)
- 0.55
- 0.67
- 1
- 2
- 3

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<th>Alpha L</th>
<th>(N_f)</th>
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**Equation Notes:**
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Conclusions

Extensive works performed to understand Composite Fatigue performance

- Current composite material show no fatigue degradation
- Fatigue Design sensitivity address by Coupons to Element test specimen
- Failure mode with higher LEF may-be accomplished at sub-component test level

Demonstrator principle tests properly support durability, combining impact damage demonstration and no detrimental fatigue propagation

- Potential to reduce testing at full scale level, using ‘conventional ‘ metallic tests specimens