Experience and lessons learned of a Composite Aircraft

30th CONGRESS
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Airbus
Ch Fualdes: Head of Airframe certification
A350 XWB – All new efficient design shaping the future

- 810 Orders
- 43 Customers
- 30 Deliveries
- 25% Lower operating cost

end July 2016
Experience & Lessons Learned of a Composite Aircraft

Content

• A350 Composite Technologies & Design
  • Overall design

• Certification & Testing approach
  • Regulatory & advisory material
  • Overall Full Scale Tests

• Key criteria for Maintainability
Composites use in Airbus aircraft – growing

During the last 40 years, Airbus has continuously and progressively introduced composite technologies in aircraft.
A350XWB: The lighter Aircraft
70% of advanced materials

**Material Breakdown (%)**
- **Composite**: 53%
- **Al/Al-Li**: 19%
- **Steel**: 6%
- **Titanium**: 14%
- **Misc.**: 8%

**A350-900**
Material Breakdown (%)
Including Landing Gear

**Titanium**
- High load frames
- Door surroundings
- Landing gear
- Pylons

**CFRP**
- Wings
- Centre wing box and keel beam
- Empennage & Tail cone
- Fuselage Skin panels
- Frames, stringers and doublers
- Doors (Passenger & Cargo)
Why Composite?

Integration of functions
• Bonding replaces riveting
• Reduction of number of parts

Fiber orientation to fit structural needs
• Better weight optimization
• Better stiffness control (wing shape)

Reduced maintenance cost
• No need for specific corrosion (re-)protection
• No fatigue behavior

<table>
<thead>
<tr>
<th>1990</th>
<th>Today</th>
</tr>
</thead>
<tbody>
<tr>
<td>Flight cycles</td>
<td>48,000</td>
</tr>
<tr>
<td>Scheduled Maintenance Tasks</td>
<td>4 years</td>
</tr>
<tr>
<td>Design Service Goal</td>
<td>20 years</td>
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</tbody>
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Higher residual value on 2nd hand market
• Major airlines renew fleets every 6-8 years
• Composite repairs / re-build without patches
A350XWB – Composite Parts
A350XWB: Composite Technologies & design
Fuselage Status

Panels / bonded stringers
CFRP

Pax Doors
CFRP

Design for efficiency
A350XWB: Wing Status
Design for Performance

- Single Droop Nose
- 6 Sealed slats
- Winglet updated
- 7 Spoilers & 1 upper droop panel
- Engine pylon Attachment
- Metallic Ribs
A350XWB: Wing Status

• One piece Cover 32m long,
• Co-bonded process, ATL, pre-cured skin, Tee section stringers ‘wet’
• Copper foil for lightning protection
A350XWB Empennage Status
Proven maturity

HTP & VTP: Improved communality

Covers: Monolithic construction with “T” shape stringers
  • Material: CFRP Tape (ATL skins)
  • Manufacturing process: Hard stringers co-bonded to wet skins

Root Joint: Continuous with tension bolts and shear angles
A350XWB Structure & Technologies

3 keys challenges:

• Assess our Airbus “route of the art” with Composite technologies.
  • Certification rules ‘adapted’
  • Need new baseline and re-evaluation (Tail strike, ESN, crash..)

• Reduce Maintenance cost: 12 years maintenance target threshold
  • Fatigue & Corrosion free
  • Design robustness equivalent or better that A330 one

• Design for weight maintaining aggressive industrial ramp up.
  • New technologies with proven maturity (TRL&MRL,...)
  • Engineering & Manufacturing consolidation up to Extended Enterprise

Standardization was a must to ensure program objectives
Content

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• **Key criteria for Maintainability**
A350XWB CERTIFICATION & TESTING APPROACH

Regulatory & Means of Compliance Basis updated for Composite Airframe Structure…

- Crash Survivability for Composite structure:
- Static, F& DT for Composite structure
- Post-crash fire resistance of CFRP materials:
- Lightning protection CFRP fuel tanks
- Rotor burst small fragment impact on CFRP fuel tank:
- Tyre debris for fuel tank Structural
- Substantiation of CFRP, Materials & manufacturing processes variability…

→ Extensive use of established Standard to develop equivalent safety level:
  - Building block approach for Tests
  - Advanced numerical computing methods
CERTIFICATION & TESTING APPROACH

Overall Approach

→ Tests methodology developed on a building block approach

- Block approach used to establish Composite sizing criteria & analysis process

- Comprehensive tests program developed for Wing & Fuselage design validation:
  
  - 25.0307: proof of structure (max strain level) & 25.571: F&D
    - Validate design & assembly concepts
    - Calibrate global FEM
    - Verify global FEM predicted stress/strain distribution

  - 25.307 & 25.571: consolidation of methods applicability
    - Establish analysis methods and computing process from generic up to specific features (combined effects)
    - Demonstrate accuracy of the methods against predicted failure mode (generic single characteristics)
    - Validate EKDF applicability
    - Establish manufacturing process capabilities (assembly/parts vs inspection methods)

  - Composite:
    - Material qualification database (five batches & 6 specimens)
    - Composite: 
      - Generic characteristics vs DP (ply drops off, joints...) 
      - characteristics dependant to manufacturing technology (bonding joints durability...)
      - Intrinsic properties characterisation (stress concentration, impact damage...)

  - Composite:
    - Material qualification database (five batches & 6 specimens)
    - Generic characteristics vs DP (layup, bolt diameter...) (1 batch & 3 to 6 specimens)

  - Composite:
    - Generic characteristics vs DP / design allowables

Building block Test methodology (static/Fatigue)

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CERTIFICATION & TESTING APPROACH
Large demonstrators methodology

• From Physical tests to Computer models
  • All physical tests (Details, Sub-component to demonstrators) are supported by computed models,
  • Extensive measurement on all test levels.
  • Verified predicted performance and understand combined load

• Objective is to have calibrated methods & computer models to run predictions’ Virtual testing’ in anticipation to full scale test: partial wing (EW), fuselage section (Barrels) and full aircraft (ES and EF)
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CERTIFICATION & TESTING APPROACH
Large demonstrator methodology

Demonstrators developed when design concept doesn’t encompass previous experience

• For Fuselage: 3 Barrels
  • 2 fuselage Demonstrators
  • 1 Pre-development test

• For Wing: 2 Outer Wing Box
  • 1 Wing Demonstrator test
    on top of A400M Wing & Partial wing Box tests
    & CWB test from A380
  • 1 Pre-development Wing Box (E-wing)

• For Empennage: 1 Root Joint Demonstrator
  for Vertical Fin joint attachment towards Tail cone

➡️ Consolidate Design, Modelling principles & Manufacturing processes
CERTIFICATION & TESTING APPROACH
Numerical Simulation

Finite Element Modelling

Example: Virtual Full-Scale Test

- 68 million degrees of freedom
- Risk mitigation, secure static test campaign
CERTIFICATION & TESTING APPROACH
Full-Scale Fatigue Tests

Nose Fuselage

Toulouse, France
Fatigue Campaign started 22/10/13
>10,000 simulated flights achieved in May 2014
Test ended in Q4 2015

Center Fuselage

Erding, Germany
Fatigue Campaign started 24/04/14
<1,000 simulated flights achieved in May 2014
Test ended in Q2 2016

Rear Fuselage

Hamburg, Germany
Fatigue Campaign started 12/03/14
>5,000 simulated flights achieved in May 2014
Test ended in Q3 2015
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• **Key criteria for Maintainability**
Benefits of composites to the users

Improved performance and reduced maintenance with a big step as most of the external structure is in CFRP

A KEY CRITERIA FOR MAINTAINABILITY
DESIGN & ROBUSTNESS EQUIVALENT TO A330

- Alu alloy
- CFRP Monolithic
- CFRP Sandwich
- Quartz, Glass
A KEY CRITERIA FOR MAINTAINABILITY
Robustness

- Accidental dent assessment from in service data
  - Statistical analysis for equivalent robustness between LR program

- Aircraft zoning for impact resistance
  - Translation of LR metal dents into A350XWB CFRP dent

77 Aircrafts
1324 impacts
A KEY CRITERIA FOR MAINTAINABILITY
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77 Aircrafts
1324 impacts

Damage distribution of the complete aircraft
Number of impacts by zone

High threat
Medium threat
A KEY CRITERIA FOR MAINTAINABILITY
Robustness

Ground Operation Risks
• Short turnaround times
• Simultaneous operations, multiple vehicles

A350XWB Maintenance
• -52% structure tasks compared with A330
• Structure task interval significantly increased compared with A330
• -45% scheduled maintenance hours over heavy maintenance cycle (12 years) than on A330
A KEY CRITERIA FOR MAINTAINABILITY
Primary Structure Composite Repairs

Extensive experience to repair regardless whether it’s metal or composite

• Majority of events involved secondary structure like belly fairing panels, nacelles...

• Primary structure

  • Empennages (since A300), ATR72 Wing, A380 Rear Fuselage

  • Example on Recent event of tail cone damage

    • Tail cone cut by winglet of passing aircraft

    • Repaired in situ
A KEY CRITERIA FOR MAINTAINABILITY
Primary Structural Bonded Repairs

Concept

• Flush Bonded repair (permanent, no inspection) bonded repair on **Principal Structural Elements**.

• Current focus on most likely damage scenarios & locations:
  • **Fuselage skin** delamination and perforation.
  • **Fuselage stringer** delamination & disbond.

• Selected repair material set
  • Material selection & Qualification in the framework of the CACRC (Civil Aircraft Composite Repair Committee).
A KEY CRITERIA FOR MAINTAINABILITY
Primary Structural Bonded Repairs

Embodiemnt process

• **Environment conditions.** A/C in hangar. Preparation of prepreg plies in a humidity & temperature controlled environment.

• **Stepping** *either* by hand *or* with portable automated machining GSE

• **Curing.** Conventional hot bonder & heating blanket and single vacuum bag cover most damage scenarios & locations.

• **Checks & inspection:**
  • Water break test.
  • Conventional ultrasonic method.
Conclusions

• Airbus has accumulated a unique experience in Composite technologies. Especially the numerical simulation of composite structures has evolved significantly.

• The progressive introduction approach used by Airbus for new technologies and especially composites, in very close cooperation with the airlines, has proven to be very efficient.

• The in-service experience has validated the designs as well as the certification approach and the maintenance concept of these structure technologies.

• Many opportunities remain, composite not yet at “saturation level”.

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