Adhesive Bonding Experience at Cirrus Design

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Cirrus Products

**SRV**
- Powerplant: TCM IO-360ES
- 200 HP
- Gross Weight: 3000 lbs
- Cruise Speed: 150 KTAS
- Instrumentation: VFR

**SR20**
- Powerplant: TCM IO-360ES
- 200 HP
- Gross Weight: 3000 lbs
- Cruise Speed: 154 KTAS
- Instrumentation: IFR

**SR22**
- Powerplant: TCM IO-550N
- 310 HP
- Gross Weight: 3400 lbs
- Cruise Speed: 178 KTAS
- Instrumentation: IFR
Product History

- VK30 First Flight
- ST50 Development
- ST50 First Flight
- TUAV Program
- SR20 Development
- SR20 Certification
- SR20 First Flight
- SR20 T.C.
- SR20 Production
- SR20 G.W.I
- SR22 ICE
- SR22 Production
- SR22 T.C.
- SR22 First Flight
- SR22 PFD
- SR22 Certification
- SR22 Development
- SR22 ICE
- Fuse Redesign
- EASA Cert.
- SR20 ICE
- SR20 T.C.
Fuselage Construction
Wing and Stabilizer Construction

Horizontal Stabilizer Structural Assembly
- Fail-safe design
- Adhesively bonded fuselage installation
- Foam core stiffened skins

Wing Structural Assembly
- Single spar design
- One-piece C-section main spar
- Core stiffened skins
- Integral fuel tanks
Materials

- E- and S-Glass Prepreg
  - 250°F Cure
  - Oven/Vacuum processing
- Divinycell foam core sandwich
  - 3/8” and 1/4”
Materials

• Paste adhesive bonded
  – Low loads
  – Tolerant of laminate and tooling variation
  – Robust with good surface prep
  – Allow up to .080” thick
Adhesive Bonding – What Are The Issues?

• The design and substantiation process is pretty well understood:
  – Process selection
  – Process development
  – Detail design
  – Structural substantiation

• Then come the other things:
  – Production scale up issues
  – Product in service issues
  – Process evolution
  – Design evolution

Does the substantiation and cert work support this?

Certification
Substantiation Issues

• Bonding Issues for Substantiation
  – Damage tolerance and defects
  – Environment – changes in strength and stiffness
  – Mixed and competing failure modes
  – Overloading and geometric nonlinear effect
Damage Tolerance and Defects

• Can you predict the future?
  – What kind?
  – How many?
  – How close together?
  – How can you describe them and their limitations in an inspection spec?

• The applicant must anticipate and select “acceptable” manufacturing and service defects

• Selection requires a priori knowledge of failure modes, hot spots, and manufacturing limitations

• The real guidance is experience and judgment…
Damage Tolerance and Defects

- Considerations
  - Have an NDE plan and understand its limitations
  - Have a plan to be able both interpolate and extrapolate size and proximity effects
  - Understand that everything is a stress concentration
    - Use the building block approach to understand stress concentration details
    - Consider multiple full scale test articles
    - Accomplish sensitivity evaluation for unique defect and repair schemes

- If you don’t, every “non-standard” production defect is a crisis
Environment – Changes In Strength and Stiffness

• Is ETW or CTD your real enemy with thick bonds?

• For the 418/L418 paste system Cirrus tested for a particular joint
Environment – Changes In Strength and Stiffness

• ETW Bonds
  – Modulus is reduced
    • Elastic peak stress is reduced…..
  – Plastic strain capability is often improved
  – Failure strength is reduced
  – But, more load redistribution occurs in the structure…..

• CTD Bonds
  – Modulus is increased
    • Elastic peak stress is increased…..
  – Plastic strain capability is reduced
  – Failure strength is increased

• So, what can you infer from RTD testing?
Competing Failure Modes

- Structural test overloads to account for “worst case” environmental material properties are difficult
  - Do you pick laminate strength, laminate stiffness, adhesive strength, adhesive stiffness, or some other parameter for the overload criteria?
- Test overloads result in unnecessarily high strains
  - Geometric nonlinear effects and secondary loading can cause failure that is not achievable in the operating or ultimate envelope
- Is the answer to accomplish the full-scale test at each environmental condition????

  Or

- Do you over-design to pass the worst environmental factor for your selected test condition and pay the weight/cost penalty?

  Or

- Can you design a building block program supported by analysis with the necessary confidence in extrapolating analysis to conditions that are difficult to test?
The Things After Initial Certification

- Production scale up issues
- Product in service issues
- Process evolution
- Design evolution

- These issues challenge the substantiation basis of the product every day
- Remember…..they are all positive in terms of customer value and profitability!
Production Scale Up

Deliveries

- 1999: 7
- 2000: 90
- 2001: 183
- 2002: 402
- 2003: 472
- 2004: 501 Planned

Yearly delivery growth trend.
Production Scale Up

• Facility controls and changes
  – Growth requires facility changes and operational realignments
  – How does your test data and analysis methods support changes in
    • Particulates and ventilation?
    • Contaminants?
    • Temperature and humidity?
    • Part staging?
    • Batching and delays?
  – Can you tell when these factors might be affected?

• Personnel issues
  – How sensitive is your process to training and operator skill?
  – Adequate and continuous training and monitoring is crucial
Production Scale Up

• Scaling up purchasing
  – Can you supplier provide the material quantities you need for your business plan?
  – Are your materials single source?
    • How will you deal with second source or alternate material qualification?
    • Will it push you back into full scale test?
    • This should play a significant role in material selection

• Scaling up Supplier Quality Assurance
  – Moving to large quantities requires effective supplier SPC
  – Balancing JIT inventory and rate production requires an understanding of “go/no-go” decisions on materials that may be non-conforming but still acceptable
    • This can and should be addressed at the substantiation level
Product In Service Issues

• The is little general experience at the small field FBO level with bonded structures for service damage assessment
• Damage assessment and repair must be included in the substantiation plan
Product In Service Issues

• Here is one approach to having confidence in ferry flights…

Fractured compression skin bond
Process Evolution

- Every intended manufacturing process changes
- Continuous Improvement means:
  - Manufacturing will never remain at steady state
  - Cycle time reduction efforts will inevitably try to chip away at perceived process “margins”
  - This concept is successful in all other industries….
- If your company is well run, you will be challenged to reduce direct material, labor, and overhead costs on a regular basis
- Management changes
  - Significant leadership changes in a company can actually wipe out an existing culture and replace it
  - The substantiation approach needs to be flexible so that changes can be assimilated without requiring extensive new test programs
Process and Design Evolution

- As an example, our fuselage bonding process went from this….
  - 5 subassy stages
  - 2 complete tool sets
  - 5 initial cure oven runs per unit
  - 24 technicians on 3 shifts to produce 10 units per week
Process and Design Evolution

• To this….
  – 2 subassy stages
  – One tool set
  – Initial cure in tooling
  – 6 technicians on one shift to produce 10 units per week
Thank You!

CIRRUS
DESIGN CORPORATION