BEECHCRAFT

CMH-17 Sandwich Working Group

Donald Wernert

John Splichal

June 14, 2013

We build aircraft you can believe in.

Agenda

Beechcraft
We build aircraft you can believe in.®

I. Process Stabilization (Materials and Process Controls)

II. Basic Design Strength

III. Balanced Sandwich Design

IV. Area or Damage Specific Design Strengths

V. Residual Strength

I. Process Stabilization (Materials and Process Controls)

I. Process Stabilization (Materials and Process Controls)

Beechcraft
We build aircraft you can believe in.®

I. Receiving Inspections

- Replicate the Supplier Specifications and Test Data
- Statistical Sampling Basis After Production Process Stabilization

II. Core

- Baked Core (Twice)
- Bagging
- Clean Room; Environmental Controls
- Solvent Exclusion
- Build Times Must be Recorded and Limits Observed

III. Pre-preg / Adhesive Film Sheets / Foaming Adhesives

- Replicate Supplier Qualification Data Upon Receipt/Use
- Total Out-Time for the Roll must be Observed
- Build Times Must be Recorded and Limits Observed

I. Process Stabilization (Materials and Process Controls)

Beechcraft
We build aircraft you can believe in®

IV. Assembly Process

- Ply Assembly Controls
- Rigorous Repeated Compaction Planning
- Build Times Recorded and Limitations Observed
- Surface Preparation for Partially Cured or Cured Components

V. Autoclave Process

- Inert Gas Pressurization Required
- Optimizing Toughness Requires High Temperature Resin Curing and Maximum Sustainable Pressure Consistent with Core Density
- Porosity Limitations, Un-bonded Areas, Ply Wrinkling, Resin Content, Core and Cured Component Shifting

VI. Routine Re-Qualification

- Manufacturing Excess for Qualification and MRB action Required for each Cured Component
- 100% Ultrasonic Inspection of Sandwich Assemblies

II. Basic Design Strength

II. Basic Design Strength

Beechcraft
We build aircraft you can believe in.®

I. Gross Area Strength Limitations

- Open Hole Compression Typical
- Environmental Effects Must be Included
- Elevated Temperature w/Moisture Saturation
- Cold Temperature without Moisture (Critical for Toughness)
- Operating Temperature Limitations (INCLUDING SOLAR EFFECTS!)

II. Damages Included in Design Allowables Baseline

- BVID
- Non-Visible Damage Allowables

III. Damage Growth Studies

- Detail and Component Cyclic Testing of BVID, Manufacturing Permitted Defects Critical in Compression
- Representative Undetected/Unrepaired Damage Cyclic Testing

IV. Laminate Failure Modes

- Two Dimensional Finite Element Modeling is Required for Broad Area Evaluation
- Three Dimensional Finite Element Modeling/Analysis Required for Core Ramp and Core Termination Details
- Ply by Ply Analysis Required for In-Plane Modes of Failure
- Interlaminar Shear Usually not Critical for Poisson's Effect, but Significant for Laminate Bending

V. Sandwich Failure Modes

- Core Shear ~ Off Axis Usually Critical and Usually Overlooked
- Face Sheet Wrinkling ~ Face Sheet Shear/Compression Interaction Critical
  - Core Density/Rigidity
  - Cell Size is second order function
- Face Sheet Crimping ~ Face Sheet Shear/Compression Interaction Critical
  - Core Density/Rigidity
  - Cell Size is second order function
- Face Sheet Dimpling ~ Core Size/Compression Stress Interaction

III. Balanced Sandwich Design

III. Balanced Sandwich Design

Beechcraft
We build aircraft you can believe in.®

I. Basic Flat-wise Strengths

- Allowables Development and In-Process Test Failures Must Result in Core Fracture
  - Cohesive Failures not Adhesive Failures
  - Small Cell Sizes and Medium Densities are Preferable
- Facesheet Separation from the Core is Not Permissible
- Flat-wise Fracture Growth Must be in the Core
- Sheets Must be able to Resist Boiling Water Vapor to 225 Degree F

II. Flat-wise Strength Pressure Loading

- Sheets ingle Sheet with Damaged or Missing Core Must be Able to Resist Residual Strength Pressure
- Sheets ingle Sheet with Damaged or Missing Core Must be Able to Resist Fatigue Pressure Loads

IV. Area or Damage Specific Design Strengths

IV. Area or Damage Specific Design Strengths

Beechcraft
We build aircraft you can believe in.®

I. Threat and Vulnerability Studies

- Scuffs, Scratches and Abrasions
- Small Impacts
  - Small Engine Debris
  - Runway Debris
  - Service and Manufacturing Handling Impacts
- Hail Impact
  - In-Flight Hail Assessment and Testing (See UCSD)
  - Ground Hail Impact Assessment
- Lightning Damage
  - Zonal Analysis
  - Unreported Strikes
  - Reported Strikes

IV. Area or Damage Specific Design Strengths

Beechcraft
We build aircraft you can believe in.®

II. UV Damage

- Unpainted, Worn or Depleted Paint
  - Damage Can Occur in 24 Hours or Less!!
  - Improper Storage

III. Blunt Impact Damage

- Threat Analysis Must Include Ground, Runway, Thrust Reverser, Tire Tread, Maintenance and Flight Damage
- Objective: Ensure Face Sheet and Core Design Exhibit Visible Face Sheet Damage in Lieu of Delamination or Core Failure
- If this is not Achievable, a rigorous threat Analysis and test program is required
- Non-Visible Damage May Reduce Component Allowables By up to 40%!

IV. Area or Damage Specific Design Strengths

Beechcraft
We build aircraft you can believe in.®

IV. Large Discrete Source Damage

- Rotor Burst
- Birdstrike
- Rouge Hailstone
- High Energy Lightning
- Ice Shedding
- Tire Burst and/or Rim Release
- Ground Vehicle and Large Animal Impact

V. Expected Damages and Abuses, Point Allowables

- Development of sandwich structure response with Three Dimensional Finite Element Modeling/Analysis
- Component testing required to evaluate residual strength

VI. Damage Growth Arrest

- Defense against growth at the next cell wall
  - Smaller cell size advantageous
- Damage will typically grow to a minimum energy configuration
  - Circular or oval
  - Burn or lightning damage
- Gross Area Redistribution of Loads in the Sandwich Structure
  - Can be estimated analytically
  - Requires extensive test background for meaningful prediction
- Exceeding laminate or sandwich allowables will result in propagation of failure
  - Invariant with panel size
  - Facesheet stiffening typically does not arrest growth

V. Residual Strength

V. Residual Strength

Beechcraft
We build aircraft you can believe in.®

I. "Yep, I felt that one! Let's call it a day."

- Birdstrike
  - Gelatin impact testing is representative
  - Analytical basis can be developed based upon 3D FEM modeling
  - Sacrificial OML facesheet design
- Rouge Hail
  - Develop an empirical basis using UCSD type projectiles and methods
  - Six inch hailstone
  - Smaller sizes may be more critical
  - The aerial density of impact decreases with hailstone size
- Lightning
  - Design for six inch damage to the OML facesheet and Core
  - Perforation of the IML facesheet is possible
  - Edges typicall resistance to failure propigation

II. Damage Containment Philosophy

– Initial ~ At Occurrence

- High toughness resin system
- Pressurized structure protect the IML facesheet
- Use of adhesive film between facesheets and core is essential to preclude dynamic separation of the sandwich

– Post Damage ~ Continued Flight