•Federal Aviation
•Administration

FAA / CAAs "Composite Meeting"

- Illustration: CSET Flutter Section -

Larry Ilcewicz
Lester Cheng
FAA Composite Team

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Structural Engineering Technology (CSET)
Illustration – Content for Flutter Section

- **Course Outline**
  - 1.0 Introduction
  - 2.0 Challenges of Composite Applications
  - 3.0 Design, Material and Fabrication Development
  - 4.0 Proof of Structure
  - 5.0 Quality Control of Composite Manufacturing Process
  - 6.0 Maintenance Interface Issues
  - 7.0 Additional Considerations
    - 7.1 Proof of Structure – Flutter +
    - 7.2 Crashworthiness
    - 7.3 Fire safety and fuel tank issues
    - 7.4 Lightning protection

AC 20-107B Outline

AC 20-107A 11 pages
AC 20-107B 37 pages
(new sections highlighted by blue)

1. Purpose
2. To Whom This AC Applies
3. Cancellation
4. Related Regulations & Guidance
5. General
6. Material and Fabrication Development
7. Proof of Structure – Static
8. Proof of Structure – Fatigue & Damage Tolerance
9. Proof of Structure – Flutter & Other Aeroelastic Instabilities
10. Continued Airworthiness
11. Additional Considerations

Appendix 1. Applicable Regulations & Relevant Guidance
Appendix 2. Definitions
Appendix 3. Change of Composite Material and/or Process
(EASA CS 25.603, AMC No. 1, Para. 9 and No. 2: *Change of Material*)

Physics – Aeroelasticity and Aeroelastic Instabilities

- Aeroelasticity – The interaction between inertial, elastic, and aerodynamic forces

Aeroelastic Instabilities:

- Static Instabilities- Divergence and control reversal
  - Wing divergence is when the aerodynamic load creates deflection or twist of the wing in a manner that increases the aerodynamic load, thus creating more deflection, and subsequently more load, until failure occurs.
  - Aileron reversal is when the flexibility of the wing is such that aerodynamic forces on the aileron will cause wing twist in a direction that eliminates or reverses the intended aileron effect.

Physics – Aeroelasticity and Aeroelastic Instabilities (cont.)

Aeroelastic Instabilities:

- Dynamic Instability – Flutter
  - Flutter is a structural oscillation that is self-exciting or self-sustaining
  - These oscillations occur at certain frequencies and mode shapes
  - During these oscillations, energy that is extracted from the airstream keeps the amplitude of the oscillations constant or increasing until the structure fails
  - Onset can occur with little or no warning. From onset to complete failure can be very quick

Physics – Aeroelasticity and Aeroelastic Instabilities (cont.)

- Flutter- Physical Parameters
  - Classical flutter involves the coupling of two or more vibration modes of the structure
  - Vibration modes are determined by the <u>mass distribution</u>, <u>stiffness distribution</u>, <u>geometry</u>, and <u>damping</u> of structure
  - Vibration modes are excited by external forces that are <u>independent</u> of motion of structure
  - Flutter is a self-excited phenomena where energy is extracted from the airstream due to the motion of structure

Regulations – Aeroelastic Stability Requirements

- Part 23 [14 CFR 23.629]: Flutter
  - Includes: flutter, divergence, and control reversal
- Part 25 [14 CFR 25.629]: Aeroelastic Stability Requirements
  - Includes: flutter, divergence, and control reversal
- Part 27 [14 CFR 27.629]: Flutter
- Part 29 [14 CFR 29.629]: Flutter and Divergence

FAA Compliance Guidance – Aeroelastic Stability Requirements

- Part 23: AC 23.629-1B, Means of Compliance with Section 23.629, “Flutter”, Amdt 23-48 (Mar/1996)
- Part 25: AC 25.629-1A, Aeroelastic Stability Substantiation of Transport Category Airplanes
- Part 27: AC 27-1, Certification of Normal Category Rotorcraft
- Part 29: AC 29-2, Certification of Transport Category Rotorcraft

Type Certification - Show Compliance for Flutter

- Structural Model created
- GVT (Ground Vibration Test) [validation of model]
- Frequencies & Modes determined
- Unsteady Aerodynamic Model created
- Flutter Model (combining structural & unsteady aerodynamic models)
- Flutter Analysis Results Evaluated (for critical modes, speeds, and trends)
- Flight Flutter Test with excitation at and around flutter frequencies obtained from analysis

Type Certification - Show Compliance for Flutter (cont.)

- Design Changes (e.g., STC) May Affect Flutter Characteristics:
  - Changes to the Mass and Mass Distribution (*e.g.*, *gross weight changes*, *structural redesign*)
  - Changes to the Airframe Stiffness and Stiffness Distribution (*e.g.*, *additions of cutouts*, *adding structural reinforcement*, *weight reduction campaigns resulting in stiffness changes*)
  - Profile Changes in Aerodynamic Shapes of Lifting Surfaces (*e.g.*, *radome*, *camera pod*)

Concerns for Composite Structures

- Structural properties (i.e., mass, stiffness, damping) may change during operation:
  - Repeated Loading (*e.g., sandwich damage growth under GAG-cycle*)
  - Environmental Exposure (*e.g., sandwich panel water ingression*)
  - Proximity of Heat Sources
  - Manufacturing Flaws

Concerns for Composite Structures (cont.)

- Structural Properties (i.e., mass, stiffness, damping) may change during operation:
  - Disbond / delamination
  - Accidental damage
  - Multiple layers of paint on control surfaces and winglets
  - Damage repair

Large Category 3 & 4 Damage for Flutter Consideration

- Large damage can change flutter characteristics (stiffness, mass, & damping)
  - **Category 3 Damage:** Obvious damage found within a few flights of occurrence, requiring immediate repair
  - **Category 4 Damage:** Discrete source damage, obvious to flight crew, requiring repair after flight

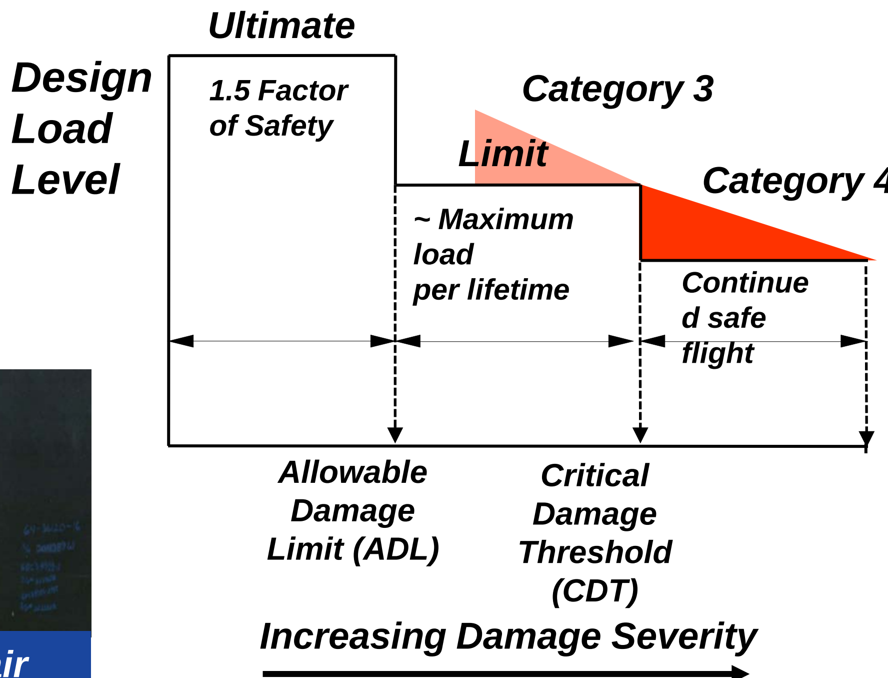
Category 3 & 4 Damage

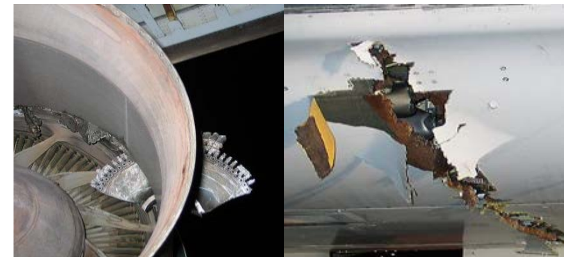
Category 3: ***Obvious damage detected within a few flights by operations focal*** ***(repair scenario)***

Category 4: ***Discrete source damage known by pilot to limit flight maneuvers*** ***(repair scenario)***

Accidental Damage to Lower Fuselage

Lost Bonded Repair Patch





Rotor Disk Cut Through the Aircraft Fuselage Belly and Wing Center Section to Reach Opposite Engine

Severe Rudder Lightning Damage

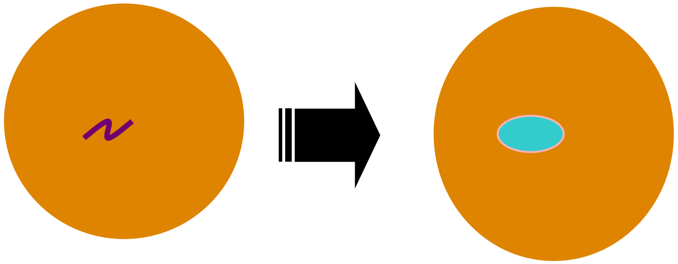
Large Category 3 & 4 Damage for Flutter Consideration (cont.)

- After large damage, some flight control surfaces may retain adequate residual strength margin, but may lose stiffness or incur mass increase (*e.g.*, *sandwich panel disbond and/or water ingression*)
- Sandwich flight control surfaces or other critical structures have individual layers critical to torsion and bending stiffness
- Any repair to a flight control panel will need to be considered for the effects (*e.g.*, *mass and/or mass distribution*) on flutter characteristics

Case Study- Potential Flutter Problems with Minimum Gage Control Surface

- Highlights of Airbus presentation from the 2009 FAA Workshop in Tokyo, Japan
  1. A Composite growth phenomena (root cause and engineering solution) not previously available
  2. Minimum-gage sandwich growth under GAG cycles [$Growth\ rates = f(disbond\ size)$]
  3. Potential bonded repair problem (*see below*)

Blunt Impact of Sandwich Part With Sharp Penetration Near Center



Followed by Poorly Bonded Repair Patch to Penetration Zone Only

Air Transat Flight 961

New CMH-17 Disbond & Delam TG Initiative