CMH-17 Durability & Damage Tolerance

Rev. H Updates

Prepared for

EASA – European Union Aviation Safety Agency

Composite Initiatives Involving EASA
Introduction to CMH-17 Updates

Webinar – March 26, 2025

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NSE Composites – Background & Experience

Company Overview

- NSE Composites is an engineering services company specializing in the field of advanced composite structures for the aerospace and wind energy sectors.
- Founded in 1996, locations in USA and Netherlands.

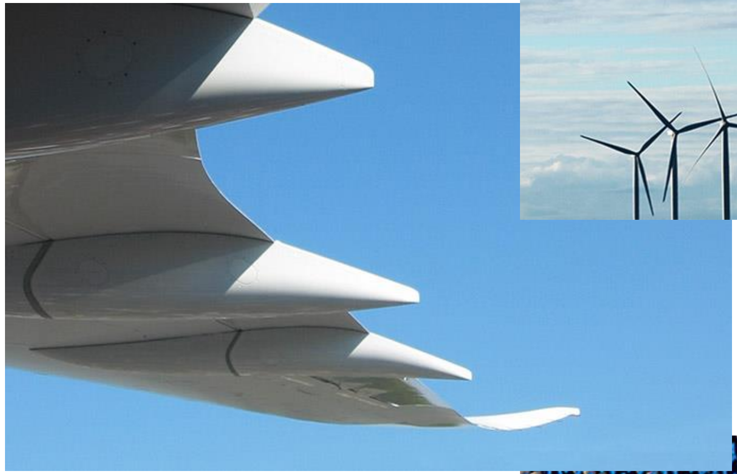
Aerospace Experience & Background

- Structural certification of transport aircraft, business jets, rotorcraft, and general aviation (including eVTOL).
- 30+ years of composite-specific experience on transport category certification programs.

FAA Safety Initiatives & CMH-17

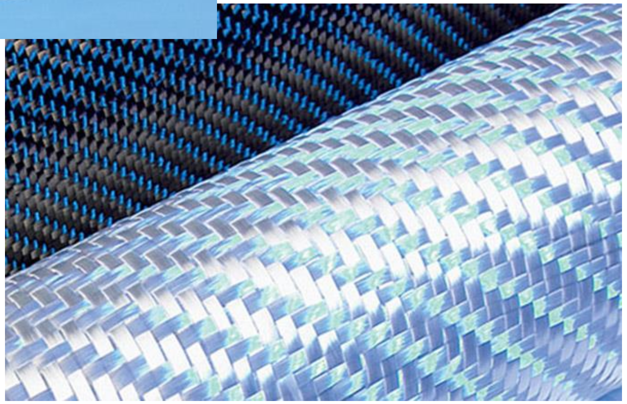
- Support to the FAA for 20+ years on composite safety initiatives related to damage tolerance and bonded joints.
- Active in CMH-17 since 1996, co-chairs of Damage Tolerance working group since 2001.
- Developed Module 4 of the FAA/NIAR CSET Course.

Wind Energy



Aerospace

CMH-17
COMPOSITE MATERIALS HANDBOOK



Composites R&D

Outline

- CMH-17 Durability & Damage Tolerance Overview
- REV H Updates by Technical Topic
  - Damage Threat Assessment
  - Categories of Damage & SDC
  - Hybrid Issues & Thermal Loads
  - Application Case Studies
  - Fatigue and Aging

CMH-17 Volumes for Polymer Matrix Composites (PMC)

Volume 1 – Guidelines for Characterization of Structural Materials

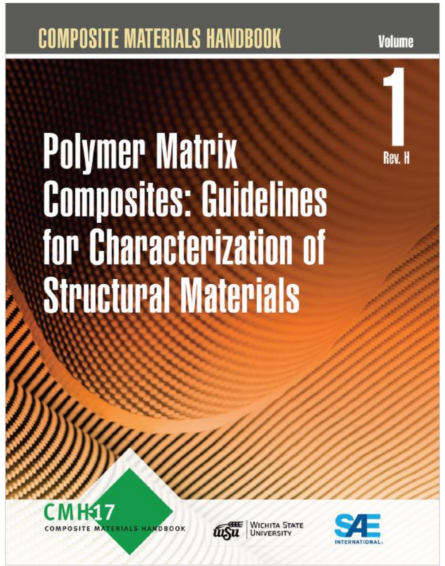
Volume 2 – Materials Properties

Volume 3 - Materials Usage, Design, and Analysis

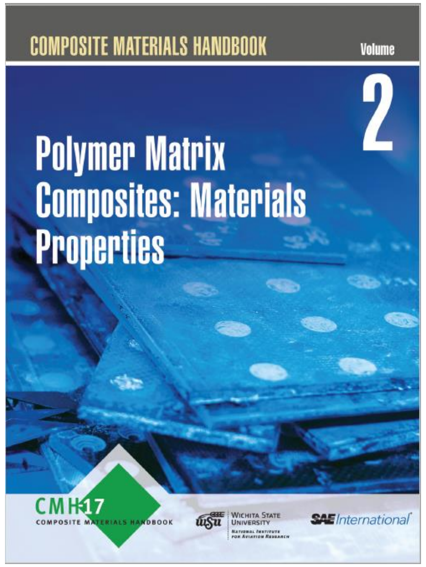
Volume 6 - Structural Sandwich Composites

Main D&DT content for Rev H (2025)

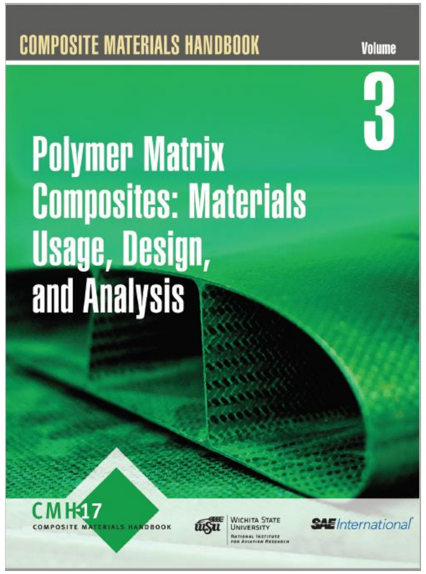
REV H (2022)



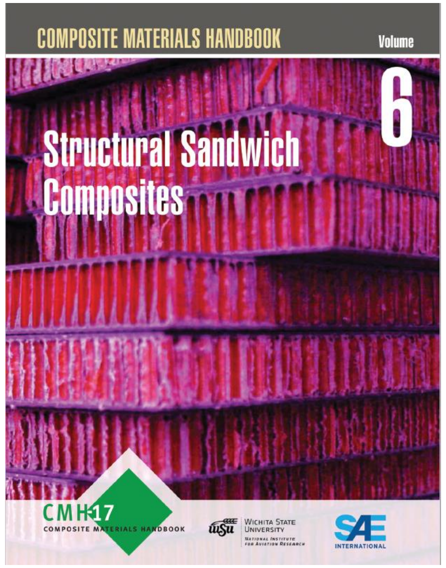
REV H (2018)



REV G (2012)



REV New (2013)



CMH-17 D&DT WG – Working Group Definition

Durability & Damage Tolerance (D&DT) Working Group Definition

- The group determines an overall strategy for the handbook to address durability and damage tolerance.
- The task group will examine methodologies in support of FAA AC20-107B (EASA AMC 20-29), FAA policy memos, ARAC material and other documentation focusing on polymer matrix composites.
- Benchmarking our approach includes the work done by the IRCWG (Industry Regulatory Composite Working Group) as well as industry best practices done at FAA/EASA/TCCA workshops over the years.
- The group will review the existing documents to assure that the sections related to durability and damage tolerance are up-to-date and provide maintenance for those sections.
- Appropriate interfaces will be made with existing groups to address identified gaps, in particular Bonding under Material and Process WG and the Disbonding and Delamination task group. The creation of new sections may be recommended if the current outline does not meet the needs of the strategic approach.

D&DT task group formed in 2001 – converted to Working Group in 2024.

Focus = benchmarking accepted industry practice and providing expanded guidance

CMH-17 Volume 3 Chapters

1. General Information
2. Introduction to Composite Structure Development
3. **Aircraft Structure Certification and Compliance** *
4. **Building Block Approach For Composite Structures**
5. Materials and Processes
6. Quality Control of Production Materials and Processes
7. Design of Composites
8. Analysis of Laminates
9. Structural Stability Analyses
10. Design and Analysis of Bonded Joints *
11. Design and Analysis of Bolted Joints
12. **Damage Resistance, Durability, and Damage Tolerance** ← **Main D&DT content**
13. **Defects, Damage, and Inspection** *
14. **Supportability, Maintenance, and Repair**
15. Thick-section Composites
16. Crashworthiness and Energy Management
17. Structural Safety Management
18. Environmental Management
19. Launch Vehicles and Spacecraft
20. Engine Applications

*Supporting discussions

Chapter 12: Damage Resistance, Durability, and Damage Tolerance

Chapter 12 Section Outline

Related Topics Covered Elsewhere

- Bonded joints and bonded repairs – Chapter 10
- Bonded joint M&P – Chapter 5
- Supportability and bonded repair – Chapter 14
- Sandwich disbond – Volume 6

Related topics in other chapters

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CMH-17 Durability & Damage Tolerance Overview

REV H Updates by Technical Topic

- Damage Threat Assessment
- Categories of Damage & SDC
- Hybrid Issues & Thermal Loads
- Application Case Studies
- Fatigue and Aging

CMH-17 D&DT – Key Accomplishments for Rev H

- **Aging, LOV, and Damage Accumulation**
  - *New section summarizing aging issues with input from ARAC, other new content including sections on environmental cycling and visco-elastic effects.*
- **Hybrid Issues & Thermal Loads**
  - *Extensive new sections for hybrid structure, large scale testing, and use of analysis for thermal load substantiation.*
  - *Two applications examples for addressing thermal loads.*
- **Repeated Load Tolerance & LEF Guidance**
  - *LEF guidance for complex structures and hybrids.*
  - *Test spectrum development, 5 x 5 blocking approach*
- **Damage Threat Assessment & Damage Resistance**
  - *New introduction relating damage threat assessment to criteria and substantiation.*
  - *Extensive new section covering all types of damage and defect threats.*
  - *Includes Part 25 and Part 23 application examples.*
  - *Updates to damage resistance sections.*
- **Categories of Damage & SDC**
  - *Updated design criteria and substantiation sections for Categories of Damage, including specific updates for bonded joints.*
  - *SDC and fail-safe design explained, minimum damage sizes discussed.*
  - *New section on relationship among categories.*
- **Category 5 & HEWABI***
  - *HEWABI policy statement incorporated with updated sections on addressing Category 5 damage, including damage resistance.*
- **Inspection for Defects & Damage**
  - *Inspection programs, EDR/ADR, MSG-3 and fleet leader programs discussed.*
  - *Chapter 13: Defects, Damage, and Inspection – updated.*
- **Additional Topics**
  - *Added discussion of AC 25.307-1 (level of testing needed).*
  - *Analysis – Added section on industry practices and limitations.*
  - *Residual Strength - Rewrite of analysis section.*
  - *Five application examples added, including Part 23 aircraft.*

**High Energy Wide Area Blunt Impact*

Outline

CMH-17 Durability & Damage Tolerance Overview

REV H Updates by Technical Topic

- **Damage Threat Assessment**
- Categories of Damage & SDC
- Hybrid Issues & Thermal Loads
- Application Case Studies
- Fatigue and Aging

CMH-17 D&DT Updates – Section 12.3.1 Damage Threat Assessment

12.3 Design Development and Substantiation

24 pages

12.3.1 Damage Threat Assessment

- **12.3.1.1 Damage and defect threats in manufacturing and repair**
- **12.3.1.2 Fatigue damage and other load-induced damage threats**
- **12.3.1.3 Environmental deterioration and time-related aging**
- **12.3.1.4 Accidental damage threats**
  - **12.3.1.4.1 Sources of accidental damage**
  - **12.3.1.4.2 Repetitive Impact**
  - **12.3.1.4.3 Structural impact surveys**
  - **12.3.1.4.4 Discrete source damage**
- **12.3.1.5 Inspection methods and conditional inspections**
- **12.3.1.6 Application examples**
  - **12.3.1.6.1 Boeing 787**
  - **12.3.1.6.2 Bombardier CSeries**
  - **12.3.1.6.3 Airbus A350**
  - **12.3.1.6.4 Part 23 Aircraft Example**

12.3.2 Damage design criteria

12.3.3 Substantiation

12.3.4 Addressing Category 5 damage

12.3.5 Additional design development guidance

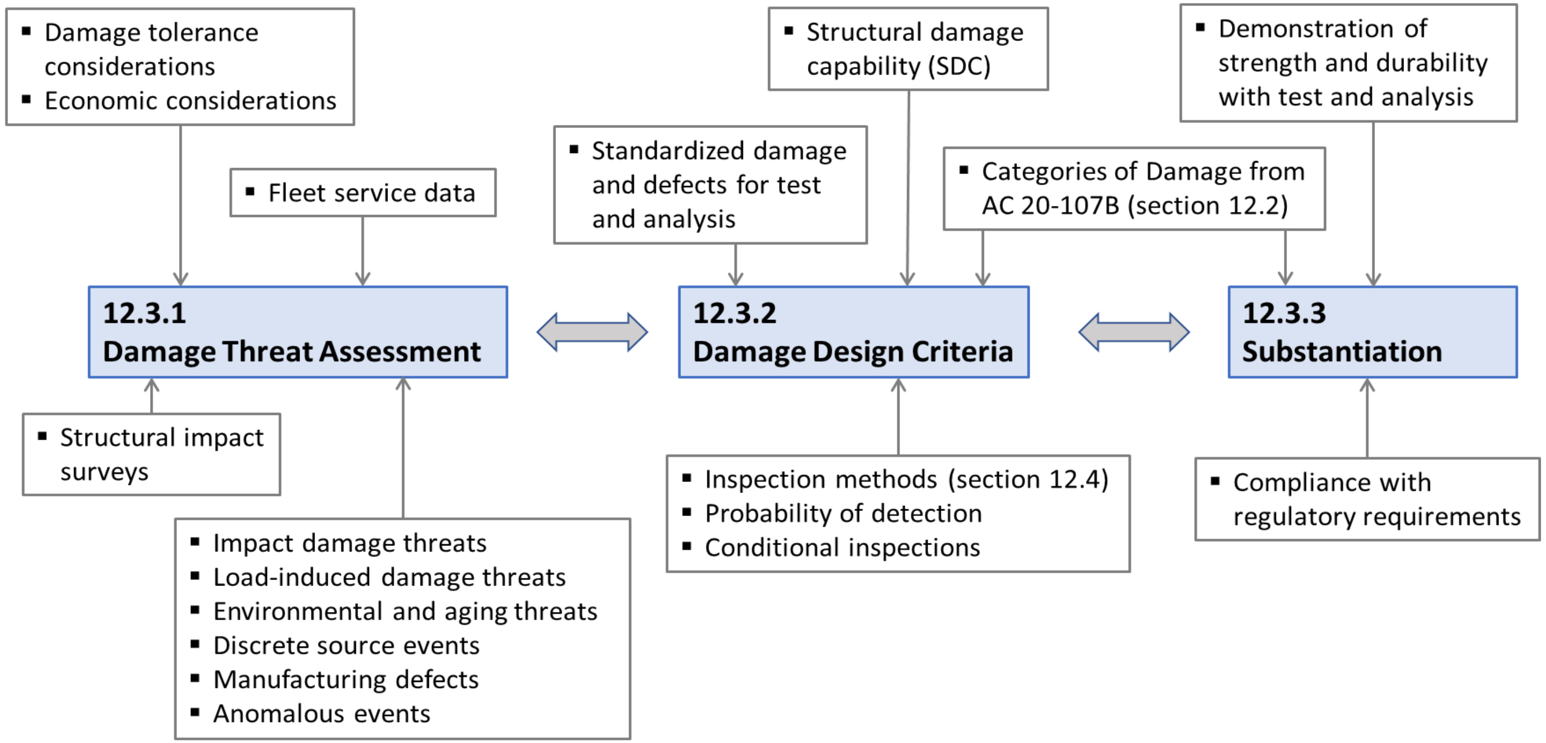
Rev H Updates

- New section

12.3 Design Development and Substantiation (Intro)

- "...the relationship between the damage threat assessment and the damage design criteria is complex and is dependent on many factors. Some damage and defects threats are addressed and avoided by design and material screening, while others are used to develop damage design criteria for damage tolerance evaluations."

New introduction including flowchart showing the relationship among damage threat assessment, damage design criteria, and substantiation.



Damage Threat Assessment – Introduction

12.3.1 Damage Threat Assessment (Intro)

New introduction including table of examples of potential threats (evolved from ARAC table)

- "...manufacturing and operational threats can be classified according to four broad areas as identified in AC 20-107B: manufacturing threats, fatigue damage (FD), environmental deterioration (ED), and accidental damage (AD)."

Structural Properties Degradation due to:						
Manufacturing Threats				Operational Threats		
Material Handling	**Part Fabrication**	**Assembly**	**Transportation / Storage**	**FD**	**ED**	**AD**
expired material (shelf life)	excessive ply gaps	out of tolerance surfaces, holes, edges, …	improper transport tooling fixtures	load-induced delamination	water entrapment	overheating due to system malfunction
expired out time (out of freezer)	defects related to the curing process	contamination of the bonding process	UV exposure prior to bonding and painting	load-induced disbond	thermally-induced stress	tire burst
improper storage (moisture, contaminants)	resin starvation, voids (porosity)	improper shimming (excessive pull-up stress)	chemical exposure affecting adhesion and strength		lightning strike	load-induced (heavy landing)
	weak bond, delamination, disbonding	contamination from drilling cooling fluids	Impact damage due to part transportation			
	machining marks	Impact damage from assembly tooling		**Time-related Aging**		**Impact Damage**
	heat damage caused by wrong cutting settings			repeated loads	chemical exposure	maintenance tools drop
	contamination from machining cooling fluids			hygrothermal cycling	erosion	hail (ground and in-flight)
	part warpage, spring-in, and spring-back				UV exposure	runway debris (including tire debris)
	fiber waviness				hygrothermal cycling	ground handling / cargo handling
					heat exposure	uncontained rotor
						bird strike

shaded: possible Conditional Inspections, see Section 12.3.1.5 for discussion.

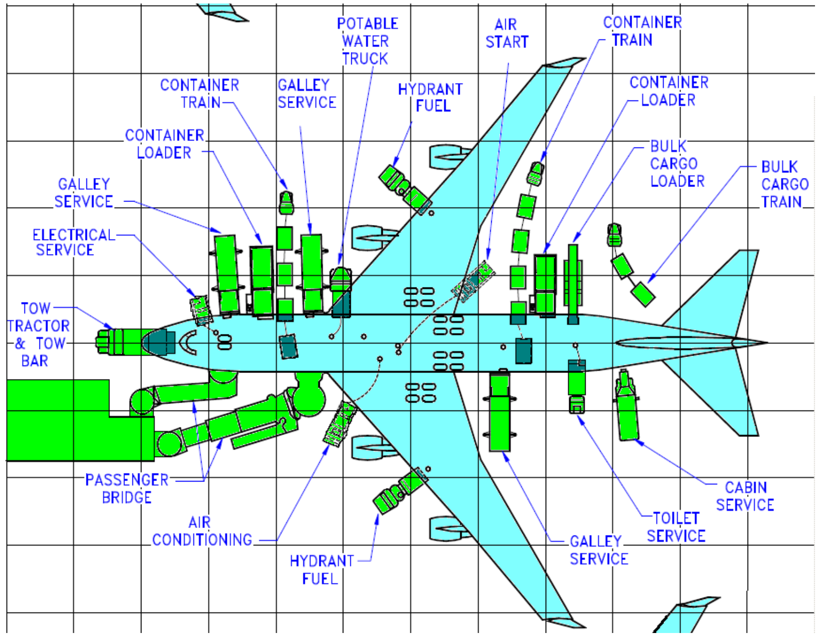
Damage Threat Assessment – Accidental Damage Threats

12.3.1.4 Accidental damage threats

- “Accidental damage refers to the wide variety of damage to aircraft structures that may occur during manufacturing and operations over their service life. While the threats associated with accidental damage remain consistent between metallic, composite, and hybrid structure, the resulting damage is different.”
- Sources of accidental damage
  - “Based on the identified impact threats, the characteristics of the identified threats are described, such as the physical properties of the threat source (e.g., geometry, material, mass) and the conditions of the structure or application when exposed to the threat (e.g., velocity, altitude).”
- Repetitive Impact
  - From AC 20-107B *“Multiple concentrated impact damage in the areas of the structure supported by a documented threat assessment. When using a visual inspection procedure, the impact damage is at the threshold of reliable detection and treated as BVID category 1 damage.”*

Example accidental damage threats and prone areas for a commercial aircraft

Threat	Prone Area
Tool Drop	Upper horizontal Surfaces
Runway Debris	Lower Surfaces Behind Landing gear
Ground Hail	Upper Horizontal Surfaces
Inflight Hail	Forward facing surfaces
Ground Vehicles Collision	Lower exterior surface, Doors and Panels
Work Stand Collision	Any Exterior Surface
Dropping of Part	Removable Doors, Panels and Control Surfaces
Bird Strike	Fwd Fuselage, wing leading edge, empennage
Passenger/Cargo boarding	Door surrounds
…	…

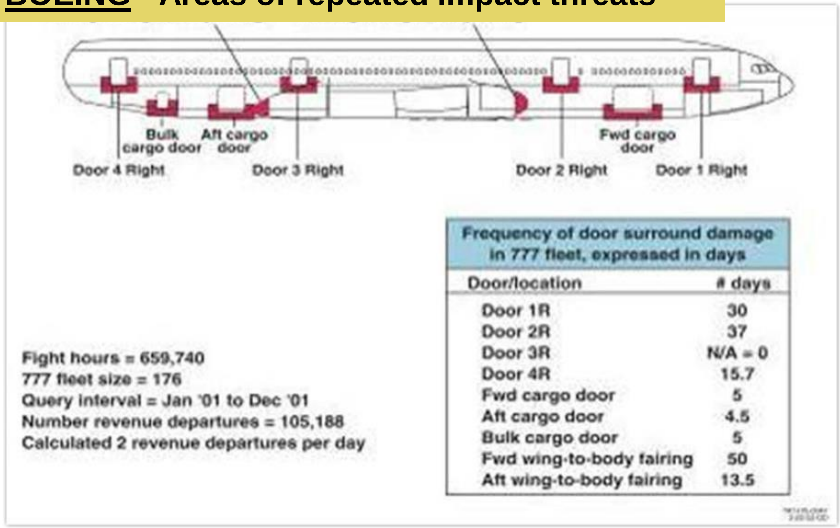


Damage Threat Assessment – Part 25 Example

12.3.1.6 Application examples (Part 25)

- Examples provided by three major OEMs of Part 25 transport category aircraft.
  - *Airbus A350 – extensive case study based on Airbus internal technical magazine article (2011).*
  - *Boeing 787 – fuselage fleet survey based on 777.*
  - *Bombardier CSeries – wing fleet survey based on CRJ.*

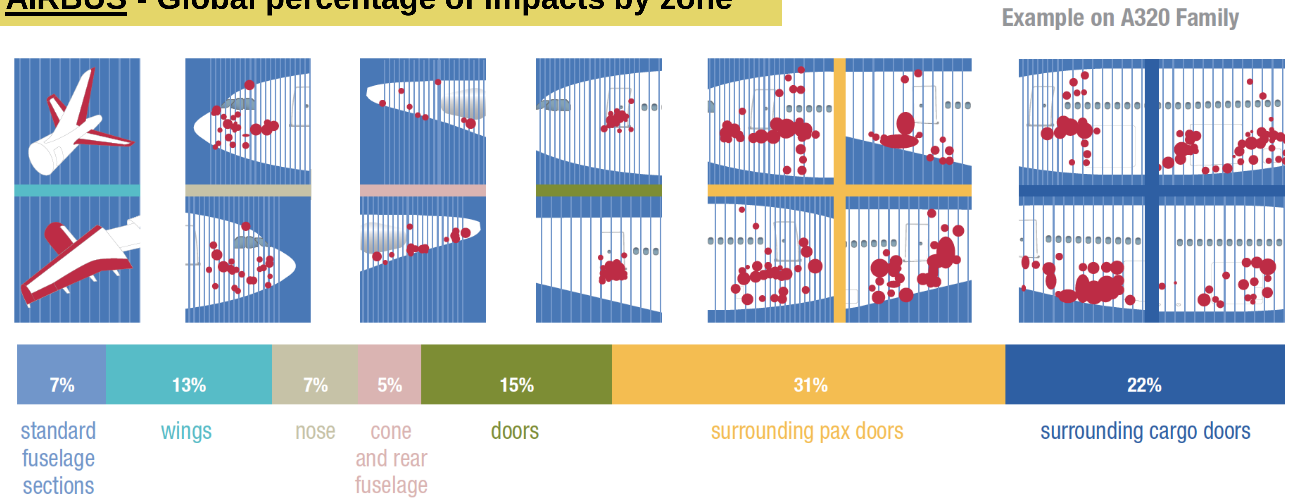
BOEING - Areas of repeated impact threats



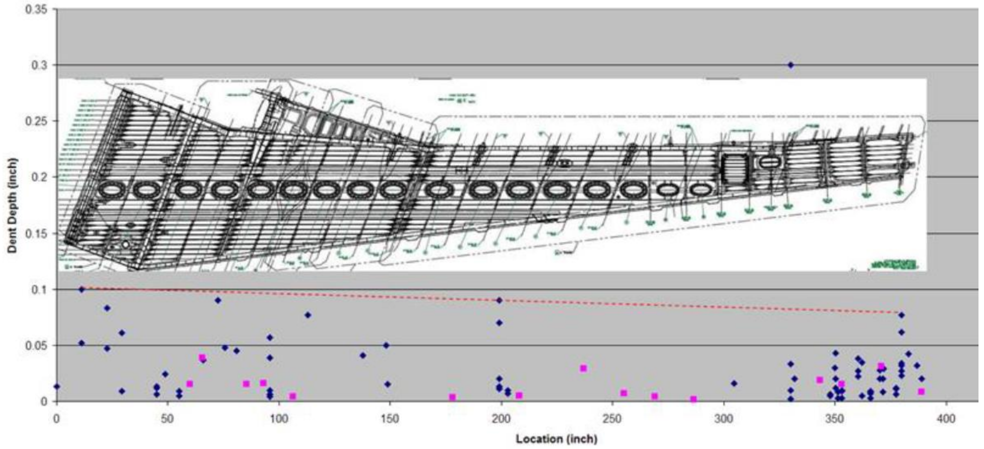
Frequency of door surround damage in 777 fleet, expressed in days

Door/location	# days
Door 1R	30
Door 2R	37
Door 3R	N/A = 0
Door 4R	15.7
Fwd cargo door	5
Aft cargo door	4.5
Bulk cargo door	5
Fwd wing-to-body fairing	50
Aft wing-to-body fairing	13.5

AIRBUS - Global percentage of impacts by zone



BOMBARDIER - Extract from wing impact survey (metallic) – CRJ

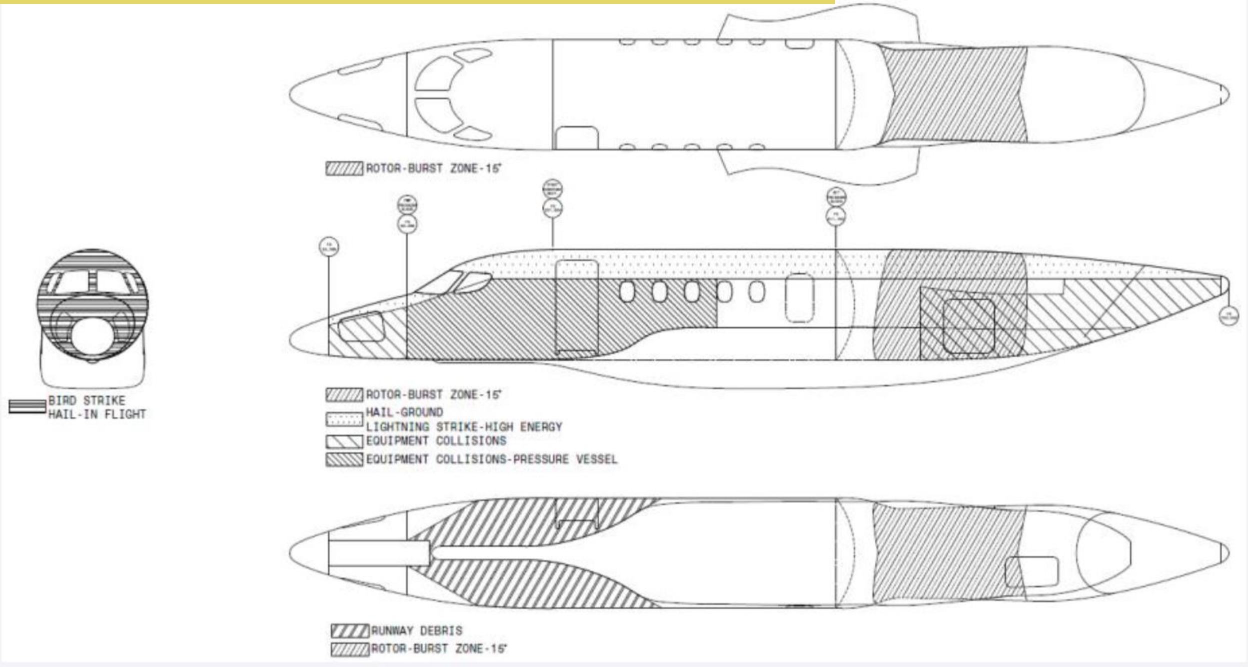


Damage Threat Assessment – Part 23 Example

12.3.1.6 Application examples (Part 23)

- Part 23 airplanes have limited commonality with their Part 25 counterparts with respect to the airline operational environment. Key differences are:
  - *Exposure areas, types of exposure events, threat sources, scale of structure, scale of (blunt) damage*

TEXTRON - Example threat zones for a Part 23 aircraft



DAMAGE THREATS: TYPICAL CATEGORIZATION and CHARACTERIZATION

Threat (Structure typically affected)		Damage Category: 1 - BVID	2 - Visual	3 - Obvious	4 - Discrete	5 - Anomalous	General Compliance (Damage progression, inspectability and residual strength)
Hail (upper surfaces, leading edges, side surfaces)	Ground Hail, Non-removable Structure		x				Above limit design strength, no moisture intrusion and no detrimental damage growth during inspection interval for small hail.
	Ground Hail, (NRS) Severe			x			Limit loading, no detrimental damage growth in support of inspection interval.
	In-Flight			x			Limit loading, no detrimental damage growth in support of inspection interval.
	In-Flight, Severe				x		Residual strength for "Get-Home" loads specified in the regulations
Runway Debris (lower surfaces, empennage)				x			Limit design strength and no detrimental damage growth in support inspection interval
Ground Ope[illegible] and Mainte[illegible] Equipment Collisions	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible] wth
	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible] d by
Lightning Str[illegible] (nose, tail, leading & trailing edges)	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible] f
	Dispatch			x			[illegible] material. Structural repair may be deferred to normal inspection. Limit load design strength.
	High Energy				x		Protection of systems for lightning attachment. Continued safe flight to landing.
Tool Drop (horizontal upper surfaces)	Small/Low Energy	x					No visible damage. No detrimental damage growth in support of inspection interval with Ultimate Design strength
	Large/High Energy			x			Up to obvious indicators with a high reliability of detection by operations or ramp maintenance personnel. No detrimental damage growth with Limit load residual strength in support of Inspection.
Bird Strike (nose and leading edges)					x		Residual strength for "Get Home" loads specified in regulations.
Rotor Burst, Threats from Rotating Machinery (wing and fuselage adjacent to engines, APUs, etc.)					x		Residual strength for "Get-Home" loads specified in the regulations.
Heat and fire (cabin interior and structure around engine/heat source)					x		Residual strength for "Get-Home" loads specified in the regulations.
Wear (moving surfaces)			x				Up to VID to be found @ scheduled maintenance. No damage growth for inspection interval with above limit load residual strength.
Incorrect re-assembly (bolted and bonded joints)			x				Up to VID to be found @ scheduled maintenance. No damage growth for inspection interval with above limit load residual strength.
Ballistic damage (military)					x		Known and/or severe damage and/or other indicators with a high reliability of detection by operations or ramp maintenance personnel. "Get home" residual strength.
Rain Erosion (nose and leading edges)			x				Up to VID to be found @ scheduled maintenance. No damage growth for inspection interval with above limit load residual strength.
UV Exposure (upper surfaces)			x				Up to VID to be found @ scheduled maintenance. No damage growth for inspection interval with above limit load residual strength.
Hygrothermal cycling (all structure, especially near heat source)				x			Up to obvious visual damage and/or other indicators with a high reliably detected by operations or ramp maintenance personnel. Limt load residual strength.
Oxidative degradation (structure near heat source)				x			Up to obvious visual damage and/or other indicators with a high reliably detected by operations or ramp maintenance personnel. Limt load residual strength.
Repeated loads (all structure)			x				Up to VID to be found @ scheduled maintenance. No damage growth for inspection interval with above limit load residual strength.
Fluid/Chemical ingression (structure exposed to fuel, hydraulic fluid, de-icing fluid, etc.)				x			Up to obvious visual damage and/or other indicators with a high reliably detected by operations or ramp maintenance personnel. Limit load residual strength.
Tire Burst (structure which forms the wheel wells and is adjacent to main landing gear)					x		Residual strength for "Get-Home" loads specified in the regulations.

Damage and defect threats were mapped to Categories of Damage and compliance approaches.

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- Hybrid Issues & Thermal Loads
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- Fatigue and Aging

CMH-17 D&DT Updates – Categories of Damage & SDC

12.3 Design Development and Substantiation

12.3.1 Damage Threat Assessment

12.3.2 Damage design criteria

- **12.3.2.1 Category 1**
- **12.3.2.2 Category 2**
- 12.3.2.3 Category 3
- 12.3.2.4 Category 4
- **12.3.2.5 Structural damage capability (SDC)**
- **12.3.2.6 Relationship among categories of damage**

12.3.3 Substantiation

- **12.3.3.1 Category 1**
- **12.3.3.2 Category 2**
- **12.3.3.3 Category 3**
- **12.3.3.4 Category 4**
- 12.3.3.5 Large-scale testing
- 12.3.3.6 Considerations for Metal/Composite Hybrid Structure

12.3.4 Addressing Category 5 damage

12.3.5 Additional design development guidance

Rev H Updates (12.3.2)

- Cat 1 updated to discuss conditional inspections for ground and in-flight hail
- Cat 2 updated based on ARAC bonded structure report
- SDC section added based on ARAC report
- New section added on relationship among categories and shape of residual strength curve

Rev H Updates (12.3.3)

- Cat 1 updated to discuss B-basis vs. typical design values
- Cat 2 updates related to fatigue scatter factors and environmental factors for fatigue testing
- Cat 3 updated to discuss time to detection
- Cat 4 updated to discuss environmental and material scatter factors

Categories of Damage and Defects – Definitions

Category	Examples (not inclusive of all damage types)
Category 1: Allowable damage that may go undetected by scheduled or directed field inspection (or allowable mfg defects)	Barely visible impact damage (BVID), scratches, gouges, minor environmental damage, and allowable mfg. defects that retain ultimate load for life
Category 2: Damage detected by scheduled or directed field inspection @ specified intervals (repair scenario)	VID (ranging small to large), deep gouges, mfg. defects/mistakes, major *local* heat or environmental degradation that retain limit load until found
Category 3: Obvious damage detected within a few flights by operations focal (repair scenario)	Damage obvious to operations in a “walk-around” inspection or due to loss of form/fit/function that must retain limit load until found by operations
Category 4: Discrete source damage known by pilot to limit flight maneuvers (repair scenario)	Damage in flight from events that are obvious to pilot (rotor burst, bird-strike, lightning, exploding gear tires, severe in-flight hail)
Category 5: Severe damage created by anomalous ground or flight events (repair scenario)	Damage occurring due to rare service events or to an extent beyond that considered in design, which must be reported by operations for immediate action

See FAA AC 20-107B and EASA AMC 20-29 for complete definitions and additional details.

Cat 1 and Cat 2 damage and defects are categorized based on damage detectability, selected inspection type, and allowable damage/defect limits

Cat 3 is “obvious” damage that will be found in a few flights (limited fatigue)

Cat 4 - Cat 5 will typically trigger conditional inspections (no fatigue)

Categories of Damage and Load Requirements

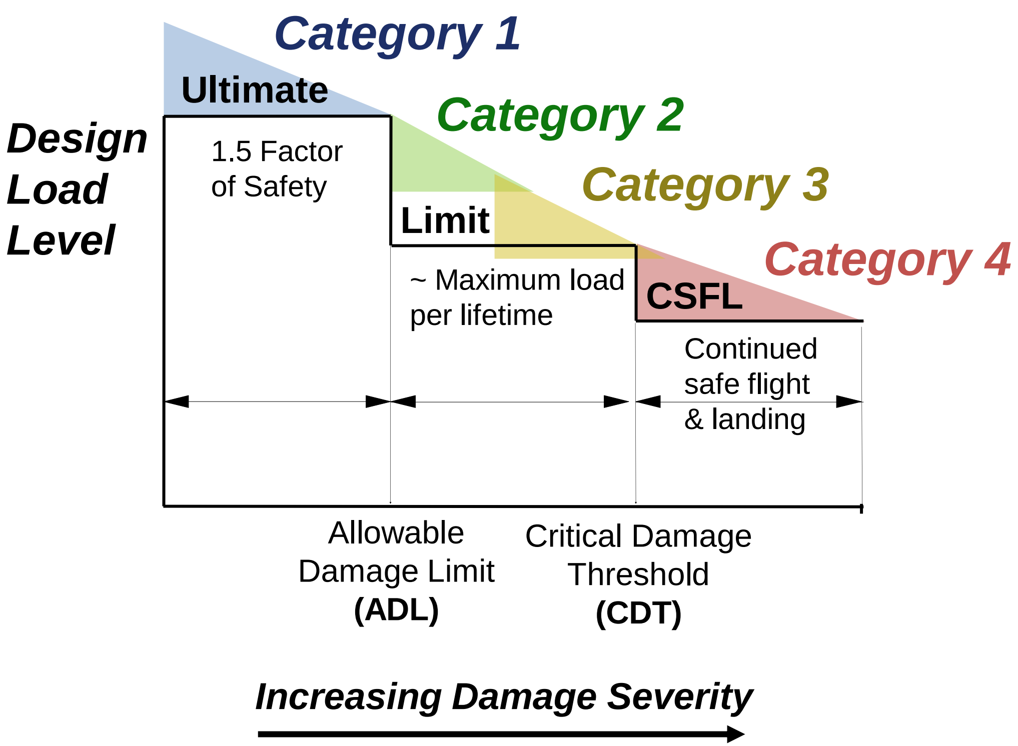
Categories of Damage (per AC 20-107B / AMC 20-29)

- Categories of Damage depend on damage or defect visibility and the ability to find it during inspection.
  - *Varies depending on configuration, material and inspection type*
- Other considerations (based on Category):
  - *Repeated loads (Cat 1, Cat 2, and limited Cat 3)*
  - *Stiffness and flutter (Cat 2, Cat 3, Cat 4 - CSFL)*
  - *Critical vs. typical environment*

Load Requirements by Category

- Category 1 – Ultimate load for life of aircraft
- Category 2 – Limit load until found with **scheduled inspection** and repaired
- Category 3 – Limit or "near limit" load until found during **walk around** or by ground service personnel (within a few flights)
- Category 4 – Continued safe flight and landing loads

Load Requirements for Categories of Damage*



***Applies to Principal Structural Elements (PSEs) and Critical Structure (per AC 20-107B)**

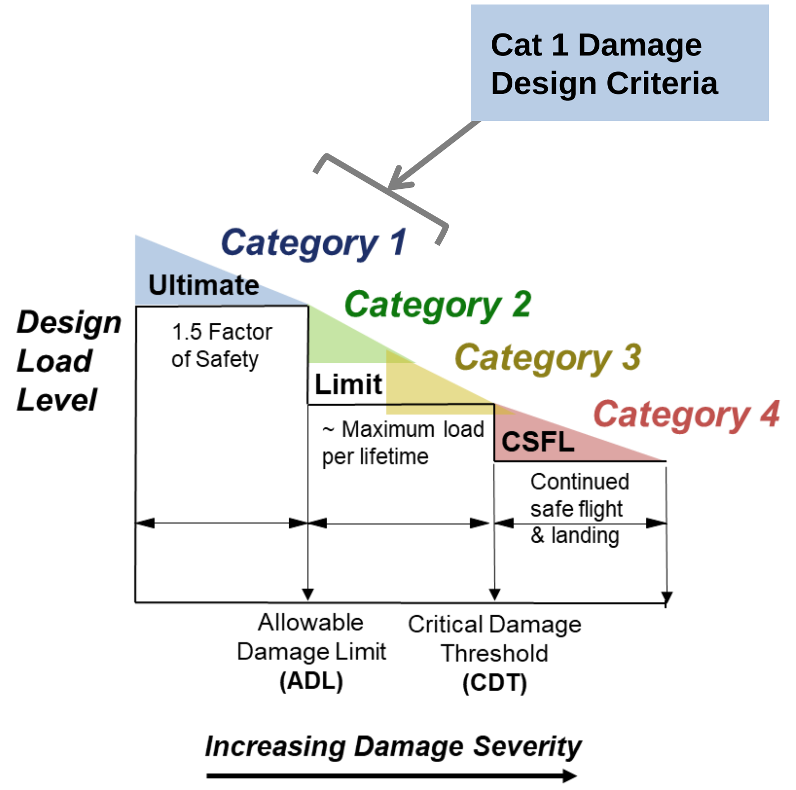
12.3.2 Damage Design Criteria – Category 1

12.3.2.1 Category 1

Rev H Updates

- **"Damages that would not be found during inspection are considered Category 1**; other damages would be addressed per the Structural Repair Manual (SRM) versus the allowable damage limits (ADLs)."
- **"Ground and in-flight hail** events are typically **addressed with "conditional" inspections.** When the event occurs, the airplane should be **inspected per the Aircraft Maintenance Manual (AMM). Inspections are typically visual**."
- "Therefore, **if conditional inspections are in place, damage from larger hail events (beyond Category 1) is found and assessed before flight.** In-flight hail beyond Category 1 will also be found before further flight."

Category 1 Damage



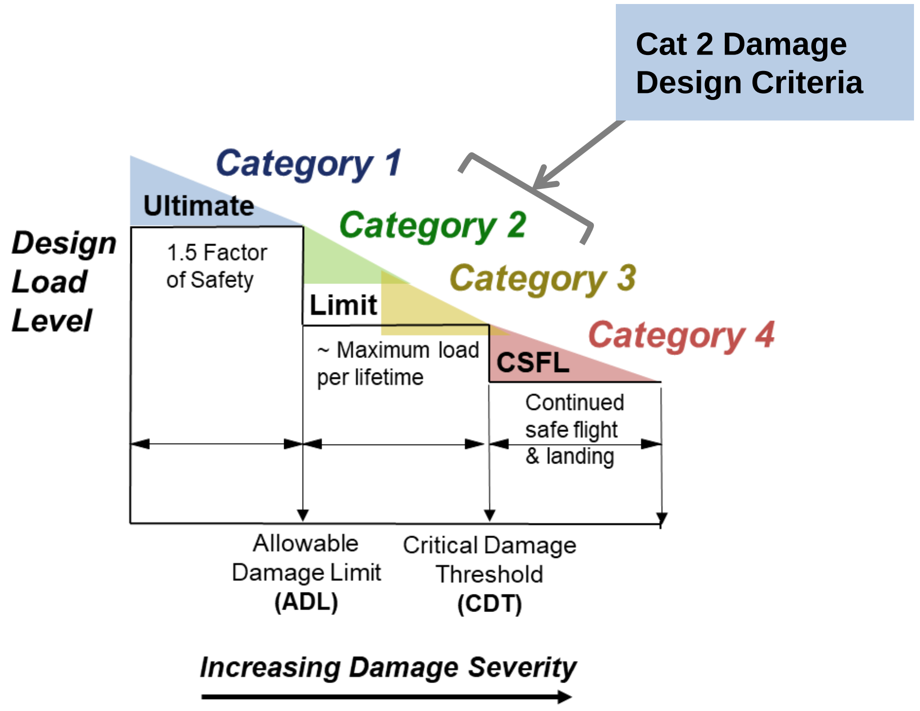
12.3.2 Damage Design Criteria – Category 2

12.3.2.2 Category 2

Rev H Updates

- "A **specific area of concern to address with Category 2 design criteria is a disbond or weak bond occurring due to a process breakdown** (or escapement) during the manufacture of bonded assemblies."
- "For commercial aircraft (Part 25), **weak bonds are consistent with the threat category of manufacturing defect and need consideration as part of the damage tolerance evaluation** required by 25.571(b). Similar considerations should be applied for other aircraft types (including Part 23, Part 27, and Part 29)."
- "**Category 2 design criteria may include disbonds of structural elements between arrestment features.** In many cases, disbonds between arrestment features can be **expected to be found during heavy maintenance and inspection and should maintain Limit Load residual strength until found and repaired.**"
- "**An internal General Visual inspection may be inadequate to find disbonds so a Detail inspection looking at the skin bond interface may be more appropriate**. In some cases, instrumental NDI may be needed where other factors reduce the effectiveness or validity of a Detailed inspection."

Category 2 Damage



12.3.2 Damage Design Criteria – Category 3 and Category 4

12.3.2.3 Category 3

Rev H Updates

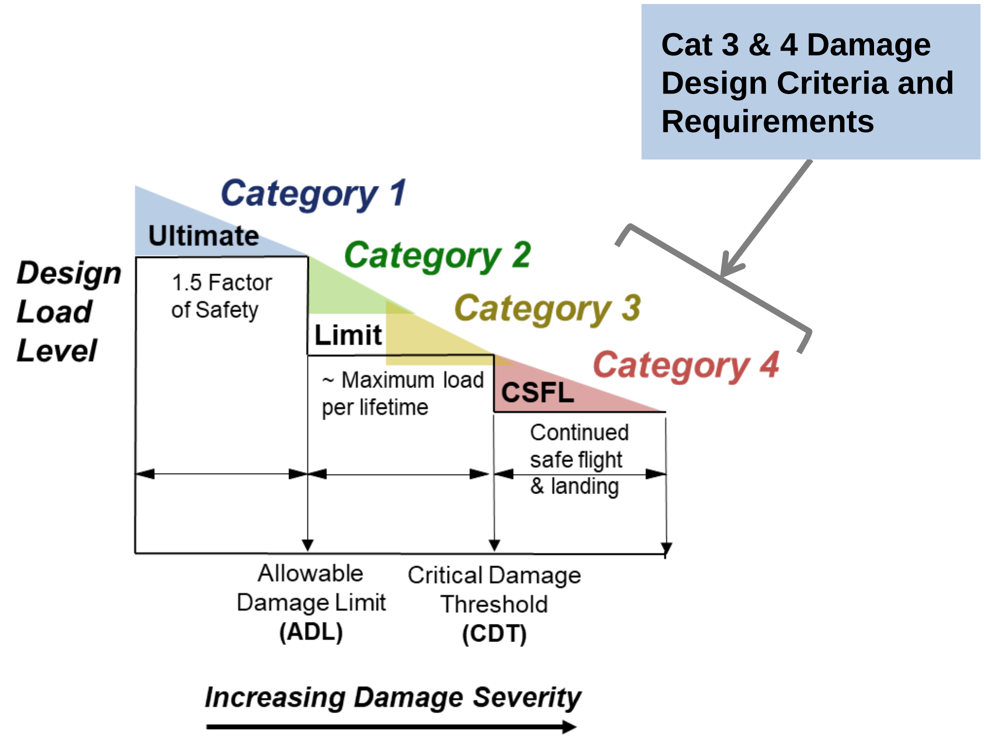
- "Note that **large damage criteria or Structural Damage Capability (SDC) are sometimes used to produce robust and fail-safe designs**."
- "In these cases, the resulting **large damage capability (based on damage scenarios without a defined source)** can be **used to cover the residual strength requirements for Category 3** damage that is associated with realistic damage scenarios identified as part of the **damage threat assessment**."

12.3.2.4 Category 4

Rev H Updates

- Added clarification of discrete source damage and added discussion on in-flight hail.

Categories 3 & 4 Damage



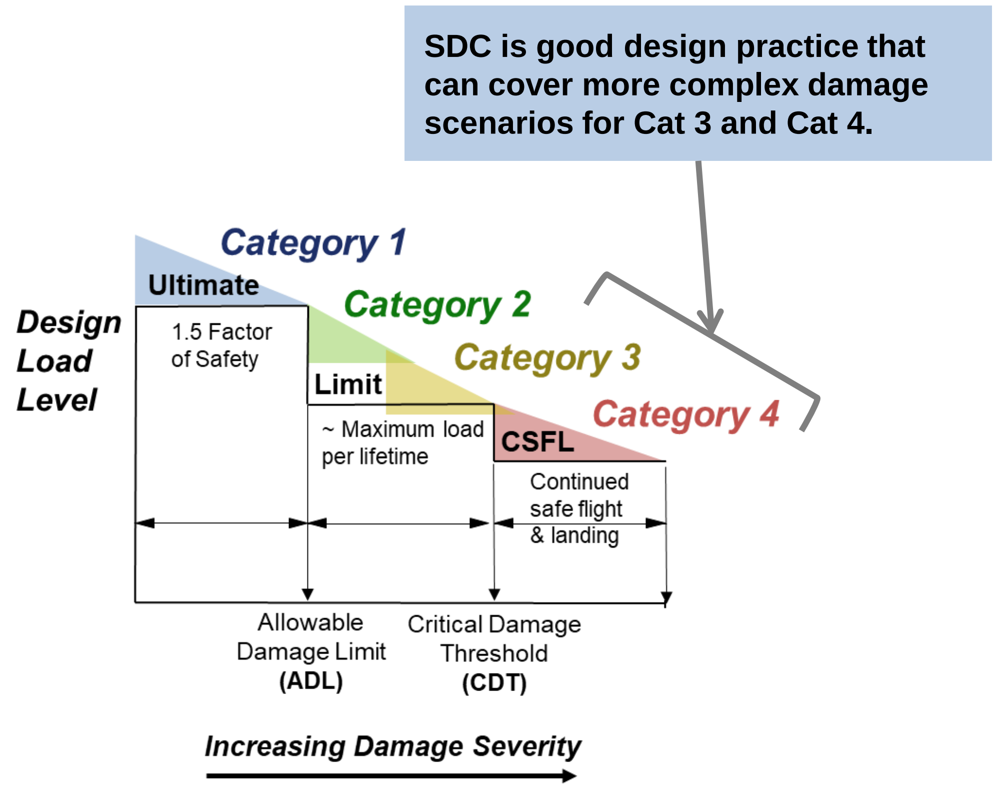
12.3.2 Damage Design Criteria – SDC & Fail-Safety

12.3.2.5 Structural damage capability (SDC)

New for Rev H

- **“SDC is good design practice** and has traditionally been achieved using Part 25 transport category primary structure **design criteria that go beyond regulatory requirements.**”
- “**This approach is intended to produce (or confirm) a robust, fail-safe design** that is referred to as “Large Damage Capability”, or “Structural Damage Capability (SDC)”.
- “...**SDC is not a replacement for damage tolerance**; SDC ensures that the structural design offers sufficient inherent robustness to address unforeseen damage. It **does not generate any additional inspection** or inspection threshold requirements...”
- “SDC is also used to: **1)** address the complexities and uncertainties of accidental impact damage (size vs. detectability, impactor variables, etc.), **2) ensure that very rare local weak bonds will not cause catastrophic failure**, and **3)** address possible interactions between damage threats.”
- “SDC design criteria can be used to **conservatively cover requirements for some categories of damage so that substantiation testing and analysis is simplified.”**

Structural Damage Capability (SDC) Criteria

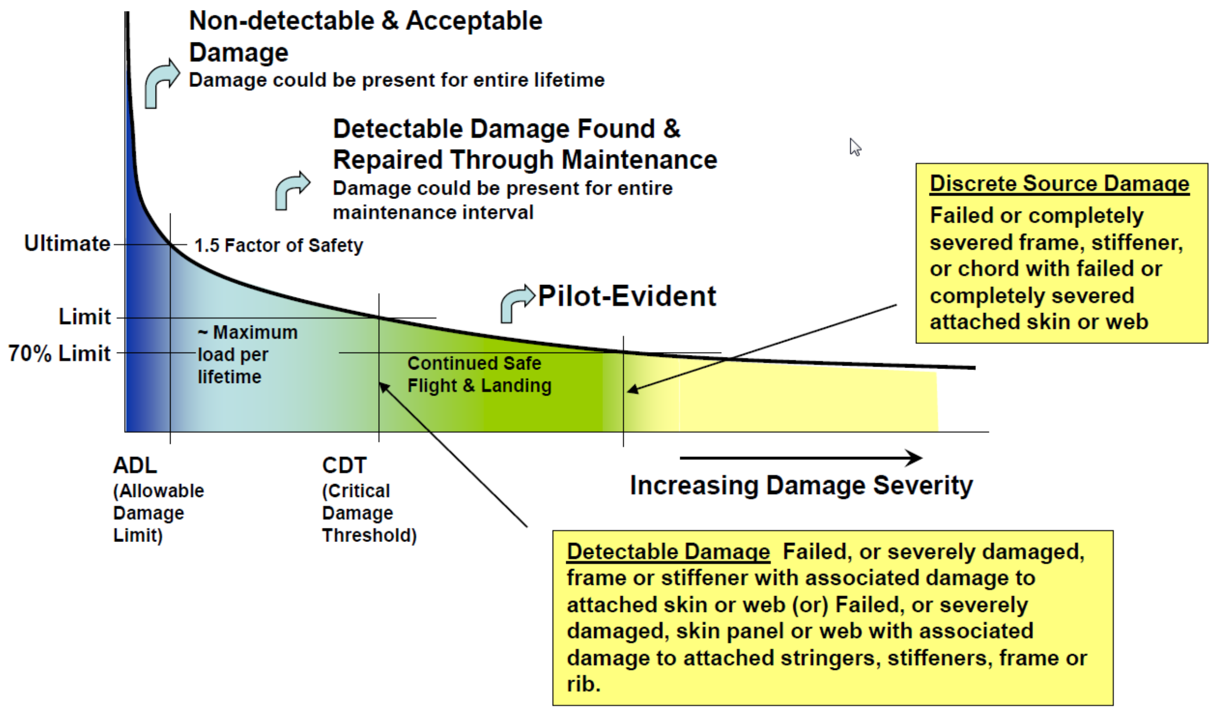


12.3.2 Damage Design Criteria – Relationships Among Categories

12.3.2.6 Relationships among categories of damage

New for Rev H

- "As shown in the figure, **the combination of damage design criteria used results in a <u>near "flat" residual strength curve for severe damage</u> such that a large increase in damage severity beyond the Critical Damage Threshold (CDT)** results in a small reduction in the residual strength capability."
- **"Since there are no standardized damage or defect metrics associated with each category of damage, the resulting relationship among the categories should be considered** as part of the design criteria development process."
- "In this example, this desired **shape of the residual strength curve is achieved by the application of a Limit Load requirement for "Detectable Damage"** (i.e., Structural Damage Capability (SDC) criterion).
- "However, **in other structure**, the same structural response (robustness through the shape of the residual strength curve) **may be achieved by the application of more severe Category 1 or 2 damage sizes** (possibly beyond regulatory requirements), **or through minimum gage** or other sizing requirements (e.g., stability)."



12.3.3 Substantiation – Category 1 and Category 2

12.3.3.1 Category 1

Rev H Updates

- "**For flaws**, when analysis supported by testing is used, **either Design Values (a reduced value per FAA AC 20-107B) or typical (mean) values can be appropriate** for use in the delamination or disbond analysis."
- "**The choice between Design Values and typical values depends on the flaw size chosen and its location** in the structure. If the largest acceptable flaw, by experience is known to be a rare event, then a typical value may be appropriate. For a more likely flaw size that is typical of the process, Design Values may be appropriate."
- "**Design values for Category 1 impact damage are established in a similar manner**, although subcomponent testing is typically used when the larger scale is needed to obtain a representative damage state and/or encompass load redistribution."

12.3.3.2 Category 2

Only Minor Rev H Updates

- "**Testing to obtain static strength design values is typically conducted at the element and/or subcomponent** scales, with validation conducted at the subcomponent, component, or higher levels."
- "**Component and higher-level tests are typically conducted at RTA conditions, with the environmental effects accounted for by analysis.**" [analysis validated by lower-level testing].
- "Repeated load capability of structure with Category 2 damage is usually substantiated by **demonstrating no detrimental damage growth in subcomponent or higher-level test articles.** Generally, the cyclic loading simulates one or more inspection intervals."
- "The large-scale **cyclic load tests are typically conducted at RTA conditions**....In some cases, additional environmental compensation factors (ECFs) are used when significant effects of environment on fatigue are identified by lower-level testing."

12.3.3 Substantiation – Category 3 and Category 4

12.3.3.3 Category 3

Rev H Updates

- "The primary differences between Category 2 and Category 3 damage are the **shorter time to detection for Category 3 and the associated residual strength (Limit or near Limit Load)** due to the shorter flight exposure time to the given damage state."
- "**Category 3 damage is usually applied through using conservative design criteria**, supported by substantiating data. Simpler damage scenarios (e.g., notches) can be shown to conservatively address more complex damage. Structural Damage Capability (SDC) criteria can also be used to cover the static strength aspects of some Category 3 damage scenarios."
- "Substantiation for Category 3 damage can be static residual strength only when damage detection can reliably be accomplished in only a few flights. However, **if potential damage growth is anticipated or suspected in a number of flights before detection, repeated loads should be considered** before residual static strength is demonstrated."

12.3.3.4 Category 4

Only Minor Rev H Updates

- "**Environment factors (considering structural temperature at time of event) are not typically needed for Category 4** damage as it is either considered pilot or ground crew evident with no further flights allowed."
- "Similar to testing for Category 2 and 3 damage, **material statistical scatter is not typically accounted for in the residual strength** assessment due to the large damage involved for this rare event. What is important is the damage state considered, where it is applied, and that the substantiating test data contains full scale features representative of the structure."

Outline

CMH-17 Durability & Damage Tolerance Overview

REV H Updates by Technical Topic

- Damage Threat Assessment
- Categories of Damage & SDC
- **Hybrid Issues & Thermal Loads**
- Application Case Studies
- Fatigue and Aging

CMH-17 D&DT Updates – Section 12.3

12.3 Design Development and Substantiation

12.3.1 Damage Threat Assessment

12.3.2 Damage design criteria

12.3.3 Substantiation

12.3.3.1 Category 1

12.3.3.2 Category 2

12.3.3.3 Category 3

12.3.3.4 Category 4

8 pages

12.3.3.5 Large-scale testing

12.3.3.6 Considerations for Metal/Composite Hybrid Structure

12.3.3.6.1 Environmentally-induced Loading

12.3.3.6.2 Differing Fatigue Sensitivities

12.3.3.7 Other considerations

12.3.4 Addressing Category 5 damage

12.3.5 Additional design development guidance

CMH-17 updates reflect current industry best practices and align with ARAC (industry) thinking regarding how thermally-induced loads are handled.

Rev H Updates

- Sections added in 2015-2017 based on IRCWG input.
- Minor updates made in April 2023.

12.3.3 Substantiation – Large Scale Testing

12.3.3.5 Large-scale testing

Rev H Updates

- "Typical large-scale test **limitations are associated with thermal gradients, thermal stresses, environmental effects on strength and stiffness,** variability of static and fatigue properties, fuel pressure, etc."
- "In addition, for the metallic structure, the test duration should be sufficient to demonstrate that the structure is free from widespread fatigue damage (WFD) prior to limit of validity (LOV) as outlined in AC 25.571-1D (Appendix 2), Section 3(d). In this case, **thermal loads associated with hybrid metal and composite assemblies are accounted for using analysis since thermal cycling is not practical in mechanically loaded fatigue testing at this scale."**

Tables of test requirements for composites and metals with link to CFRs and/or ACs

Testing requirements for composite structure

Substantiation Test Condition	Requirement/Source		Composite Damage Type	Fatigue Spectrum Type	Notes
Composite Parts					
Static-load validation of FE models via strain distributions and deflections	14CFR 2x.305/307		n/a	n/a	May be performed on one or more large-scale tests for "analysis supported by test" compliance approach
Limit static load without permanent deformation	14CFR 2x.305/307	AC20.107B	Cat 1	n/a	Category 1 damage may not be necessary if this capability has been demonstrated elsewhere in the test program
No/slow/arrested growth of Cat 1 damage for appropriate cycles (aircraft lifetime)	14CFR 23.573 14CFR 25.571 14CFR 27.573 14CFR 29.573	AC20.107B	Cat 1	Composite	Load/life factors associated with critical design details and failure modes should be addressed. This may involve multiple articles at different scales.
Ultimate static load following appropriate cycling (aircraft lifetime)	14CFR 2x.305/307 14CFR 2x.603 (env.) 14CFR 2x.613 (stats.)	AC20.107B	Cat 1	Composite	Category 1 damage may not be necessary if this capability has been demonstrated elsewhere in the test program. Load factors addressing environment and statistics may be needed, depending on the specific test objectives.
Destruct test following appropriate cycling (aircraft lifetime)	Final Validation and/or Economic		Cat 1	Composite	Not a certification requirement, but may be used for validation for analysis methods/factors. May also be used to provide supporting data for possible increased loading.
No/slow/arrested growth of Cat 2/3 damage for appropriate cycles (until detected)	14CFR 23.573(a) 14CFR 25.571(b) 14CFR 27.573(d) 14CFR 29.573(d)	AC 20.107B AC 25.571D AC 27-1B AC 29-2C	Cat 2/3	Composite	Load/life factors associated with critical design details and failure modes should be addressed. This may involve multiple articles at different scales. Cycling of Category 3 damage not required, but may be used to increase the reliability of detection.
Residual strength capability with Cat 2/3 damage following appropriate cycling	14CFR 23.573(a) 14CFR 25.571(b) 14CFR 27.573(d),(e) 14CFR 29.573(d),(e)	AC 20.107B AC 25.571D AC 27-1B AC 29-2C	Cat 2/3	n/a	Category 2 loading requirement is generally Limit load, but may include an appropriate factor on Limit load for probablistic approaches. Per AC20-107B, Category 3 residual strength loading for large damage capability is "Limit or near Limit". Load factors addressing environment may be needed for Category 2, depending on the length of time between inspection intervals.
Discrete-source static load capability	14CFR 23.573(a) 14CFR 25.571(e) 14CFR 27.573(a),(d) 14CFR 29.573(a),(d)	AC 20.107B AC 25.571D AC 27-1B AC 29-2C	Cat 4	n/a	Category 4 residual strength requirement is continued safe flight and landing loads.
Structural repairs - ultimate static load capability of repaired structure retained for lifetime of aircraft	same as original structure		Cat 1	Composite	Structural repairs typically require large-scale testing to achieve representative configurational details, loading and load redistribution. Substantiation of completed repair should consider Category 1 damage and defects (e.g., associated with bonded repair), based on size and location.
Structural repairs - damage tolerance of repaired structure	same as original structure (plus Policy Statement PS-AIR-100-14-130-001 for bonded repairs)		Cat 2/3/4	Composite	Repaired structure must meet the same requirements as original structure for Category 2/3/4 damage. For bonded repairs, design for Limit load capability with a failed bond may cover some damage types.

12.3.3 Substantiation – Environmentally-induced Loading

12.3.3.6.1 Environmentally-induced Loading

New for Rev H

Discusses industry practice for "analysis supported by test" approach for these loads.

- "The configurations and environmental conditions associated with many practical applications result in these **environmentally-induced loads primarily being of concern for the static compression strength of the composites and fatigue capability of the metals.**"
- "Current industry practice is to **address thermally-induced loading in structural substantiation by analysis with supporting tests**. **The static and fatigue sizing of the structure includes thermally-induced loading,** at both the local and global scale. Load cases are often evaluated with and without thermally-induced loading, to ensure that the most conservative combinations of mechanical and thermal loading are included. In addition, the induced loads due to **"extreme" temperatures are typically combined with static mechanical loads** and those due to **"typical/average" temperatures are combined with fatigue loads.**"
- "The **effect of local thermally-induced internal loads on fatigue life** and the analysis methods for predicting those internal loads are typically **validated using element and/or subcomponent tests.**"
- **"Analysis methods for predicting global thermally-induced loads are validated using large-scale tests** at environment and/or flight test articles, by comparing predicted and measured local temperatures and resultant strains."

12.3.3 Substantiation – Differing Fatigue Sensitivities

12.3.3.6.2 Differing Fatigue Sensitivities

- "...composites tend to be insensitive to repeated low-level loading, with their fatigue response being dominated by the high-load excursions. Metals, on the other hand, are very sensitive to low-load cycles, and high-load excursions can retard crack growth via crack-tip yielding. **These different fatigue sensitivities lead to different approaches for shortening repeated-load spectra.**"
- "For static strength testing, a single large-scale article is often sufficient. **For fatigue, however, current industry practice is to demonstrate metal and composite capability using separate articles**, particularly if the composite structure involves new and novel materials and/or designs."
- "...the critical fatigue loading conditions can differ for the two materials, since **metallic fatigue is controlled by tension loading, and composite materials are most sensitive to through-thickness and in-plane compression and/or shear loading**."
- "Emerging strategies that may enable the use of **single large-scale F&DT test articles** to properly address both the metallic and composite fatigue sensitivities are discussed in Section 12.6.3.4.4."

Includes considerations for how to address different sensitivities during large-scale testing.

See 12.6.3 (following slides)

CMH-17 D&DT Updates – Sections 12.6.3

12.6 Durability and Damage Growth Under Cyclic Loading

- 12.6.1 Influencing factors
- 12.6.2 Design issues and guidelines
- 12.6.3 Test issues
  - 12.6.3.1 Scatter analysis of composites
  - 12.6.3.2 Life Factor approach
  - 12.6.3.3 Load Factor approach
  - 12.6.3.4 Load Enhancement Factor approach
    - 12.6.3.4.1 Application of LEFs for aerospace structural component tests
    - 12.6.3.4.2 Testing Guidelines
    - **12.6.3.4.3 Considerations for Metal/Composite Hybrid Structure**
  - 12.6.3.5 Ultimate Strength approach
  - 12.6.3.6 Test spectrum development
  - 12.6.3.7 Test environment
  - 12.6.3.8 Damage growth
- 12.6.4 Analysis methods

Rev H Updates

- LEF guidance for complex structures and hybrids
- Emerging approaches and load sequencing
- Test spectrum development for hybrid structure

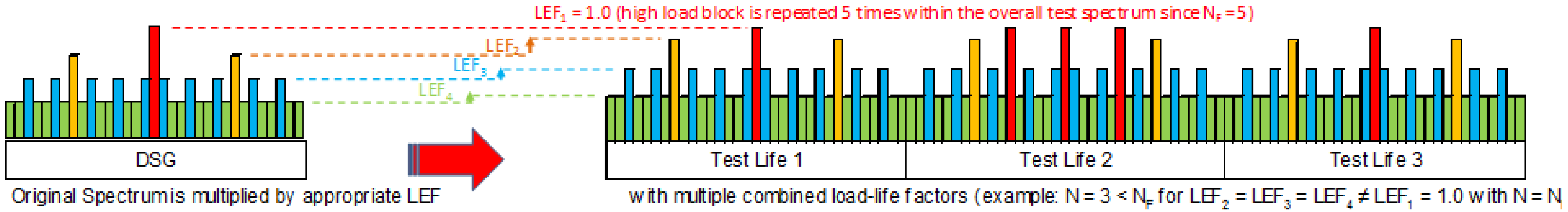
12.6.3 Test Issues – LEF Approaches

12.6.3.4.3 Considerations for Metal/Composite Hybrid Structure

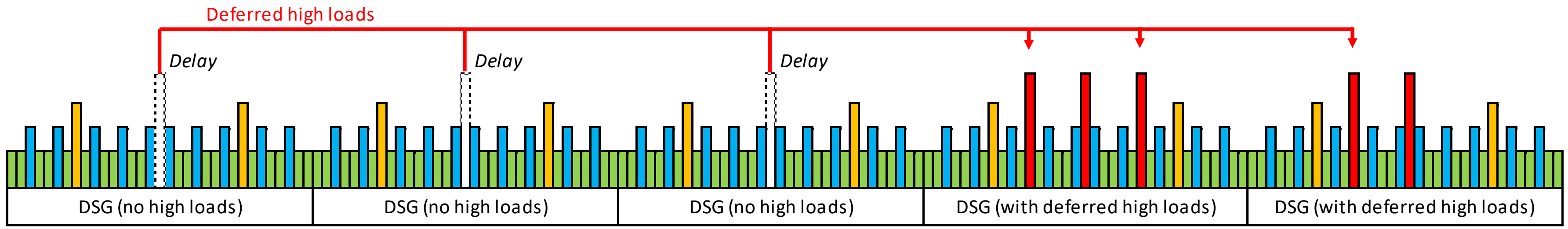
New LEF subsection on Metal/Composite Hybrid Structure

- Expands discussion about test issues and LEF usage
- Includes update to multi-LEF approach and addition of deferred severity spectrum (DSS) approach.
- Discusses possible use of "a **single full-scale article** can be used to substantiate both metallic and composite structures."

Multi-LEF Approach



Deferred Severity Spectrum Approach



Thermal Loads Application Examples

12.8 Application Examples

- 12.8.1 Rotorcraft (Sikorsky)
- 12.8.2 Commercial aircraft (Boeing 777 empennage torque boxes)
- 12.8.3 General aviation (Beech Starship)
- **12.8.4 Thermal loads in a business jet horizontal stabilizer** (designed by Fokker)
- **12.8.5 General aviation** (KC-100, KAI)
- **12.8.6 Primary Structure Technology Demonstrator** (Embraer)
- **12.8.7 Cirrus SR20 Life Extension** (Cirrus)
- **12.8.8 ILX-34 Wingbox Technology Demonstrator** (Warsaw Institute of Aviation)

Chapter 4 Building Block Approach for Composite Structures

- 4.1 Introduction and Philosophy
- 4.2 Rationale and Assumptions
- 4.3 Methodology
- 4.4 Considerations for Specific Applications
- 4.5 Building Block Methodology and Strategy Examples
  - 4.5.1 Aircraft wing box type structure - schedule-linked methodology guidance
  - **4.5.2 Strategies for building block approach development and optimization** (Bombardier)

Rev H Updates

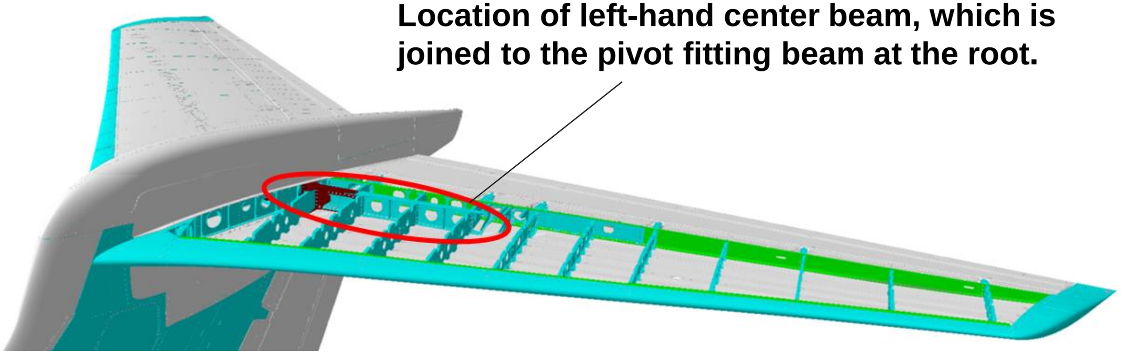
- Two new application examples specifically addressing thermal loads

Thermal Loads – Fokker Application Example

12.8.4 Thermal loads in a business jet horizontal stabilizer (designed by Fokker)

- The horizontal stabilizer of a large cabin business jet includes composite-to-metal hybrid structure that produces significant thermally-induced loads.
  - *The long aluminum center beam in combination with CFRP skins and spars produces thermal loads.*
- Full-scale thermal test performed for validation of FEM, especially at bolted joints.
- Certified by analysis supported by test using full-scale mechanical **fatigue** test (at room temperature) and validated analysis for thermal loads.
  - *"...**thermal loads were covered by analysis, validated by full-scale thermal-only testing."***
- Found that composite fatigue test with LEF = 1.15 enveloped predicted metallic fatigue damage in this case.

Location of left-hand center beam, which is joined to the pivot fitting beam at the root.

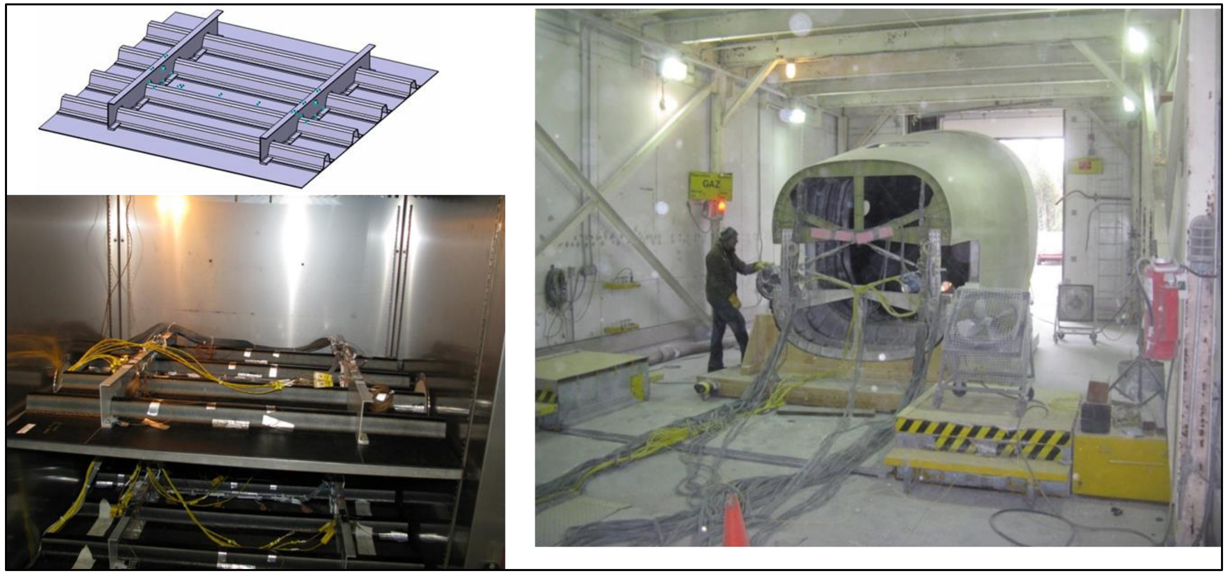


Thermal test on the instrumented horizontal stabilizer static and FDT component test article

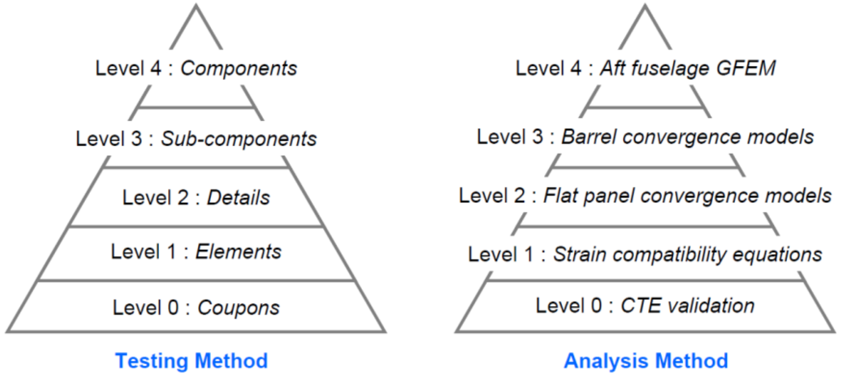
Thermal Loads – Bombardier Application Example

4.5.2 Strategies for building block approach development and optimization (Bombardier)*

- “An example where the anticipated thermally induced stresses were considered significant enough to justify large scale thermal load analysis calibration/validation is the CSeries Aft Fuselage hybrid structure (combining large metal and composite structural elements).”
- “.... thermally induced stresses were considered significant enough to justify large scale thermal load analysis calibration/validation...”
- “Instrumented flat stiffened plate and Aft-Fuselage hybrid structures were conditioned to temperatures from [-58ºF to 167ºF (-50ºC to 75ºC)].”
- “The strain gauge data was then used to establish correlations/validation between test results and FEA predictions which subsequently permitted to support FEA analyzes predictions combining internal thermal and maneuver loads for all the flight phases.”



Thermal stress methodology follow a building block approach with emphasis on understanding load and structure behavior rather than relying on a detail FEM for overall structure sizing (static and fatigue).



Outline

CMH-17 Durability & Damage Tolerance Overview

REV H Updates by Technical Topic

- Damage Threat Assessment
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- Application Case Studies
- Fatigue and Aging

CMH-17 D&DT Updates – Thermal Loads Application Examples

12.8 Application Examples

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- **12.8.7 Cirrus SR20 Life Extension** (Cirrus)
- **12.8.8 ILX-34 Wingbox Technology Demonstrator** (Warsaw Institute of Aviation)

56 pages

Rev H Updates

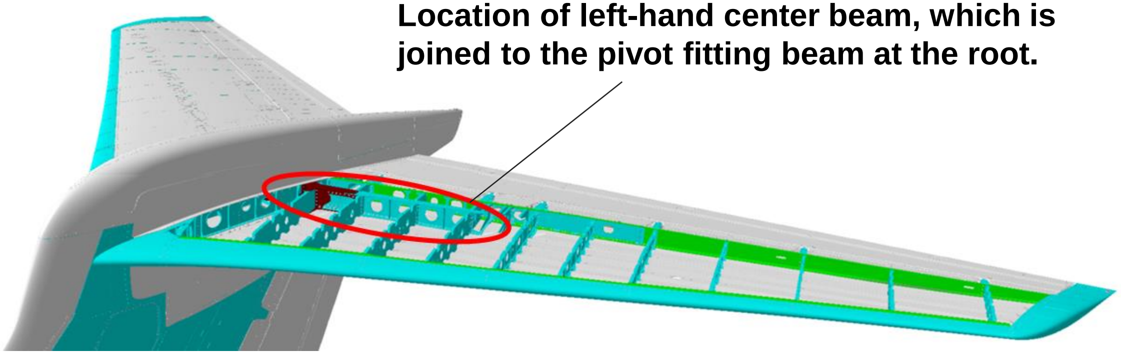
- Five new application examples, including general aviation and business jet examples

Thermal Loads – Fokker Application Example

12.8.4 Thermal loads in a business jet horizontal stabilizer (designed by Fokker)

- The horizontal stabilizer of a large cabin business jet includes composite-to-metal hybrid structure that produces significant thermally-induced loads.
  - *The long aluminum center beam in combination with CFRP skins and spars produces thermal loads.*
- Full-scale thermal test performed for validation of FEM, especially at bolted joints.
- Certified by analysis supported by test using full-scale mechanical **fatigue** test (at room temperature) and validated analysis for thermal loads.
  - *"...**thermal loads were covered by analysis, validated by full-scale thermal-only testing."***
- Found that composite fatigue test with LEF = 1.15 enveloped predicted metallic fatigue damage in this case.

Location of left-hand center beam, which is joined to the pivot fitting beam at the root.



Thermal test on the instrumented horizontal stabilizer static and FDT component test article

General Aviation Certification (KC-100, KAI)

12.8.5 General aviation (KC-100, KAI)

- Normal category aircraft type certified under Part 23 with its primary structure principally composed of composite materials with bonded skins and spars.
  - *Damage threat assessment*
  - *Damage characterization and locations*
  - *Categories of damage*
  - *Load enhancement factor (LEF) development*
  - *Fatigue and damage tolerance testing*

FIGURE 12.8.5.4(e). *KC-100 full-scale fatigue setup*

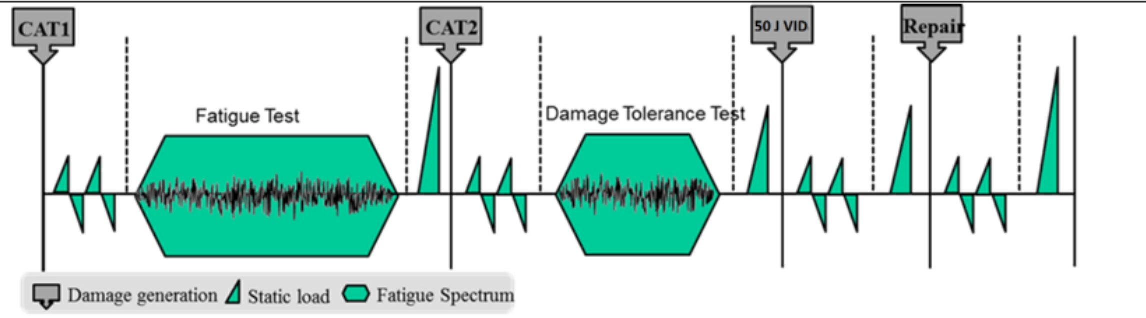


FIGURE 12.8.5.4(d). *Full-scale fatigue and damage tolerance test procedures*

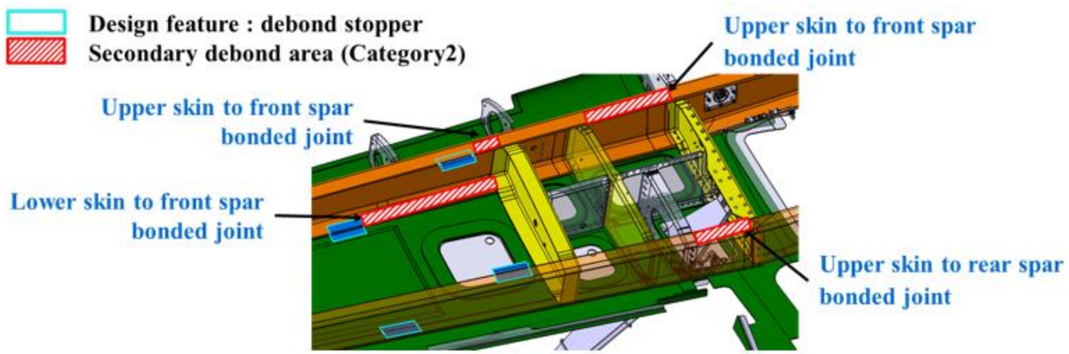


FIGURE 12.8.5.3(c). *Maximum debond locations of the KC-100 main wing test article*

12.8.6 Primary Structure Technology Demonstrator (Embraer)

- Part 25 principal structural element (PSE) technology demonstrator, including residual strength assessments for a range of damage scenarios were performed to complement the fatigue and damage tolerance substantiation.
  - *Damage threat assessment*
  - *Impact damage assessments*
  - *Categories of damage*
  - *Test and analysis building block for impacts, disbonds, and large notches*

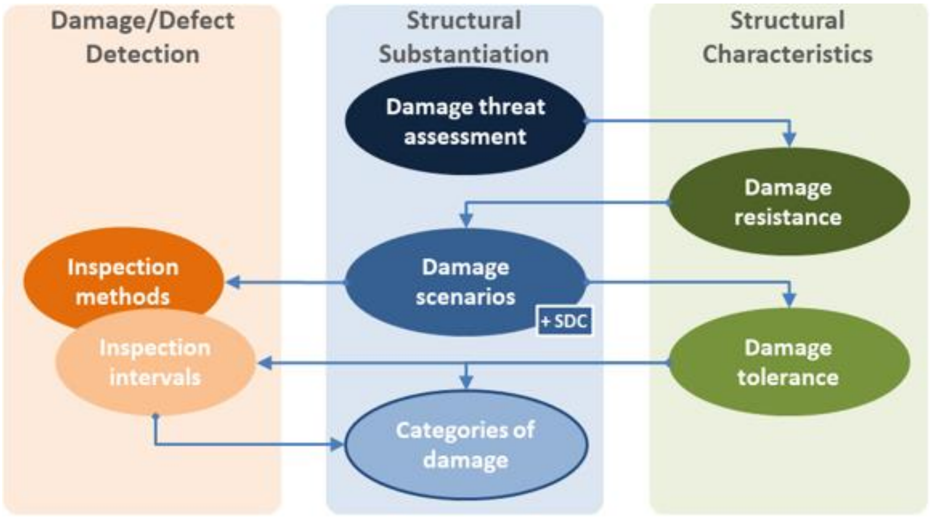


Figure 12.8.6.1(b). Damage categorization flow including SDC (Structural Damage Capability)

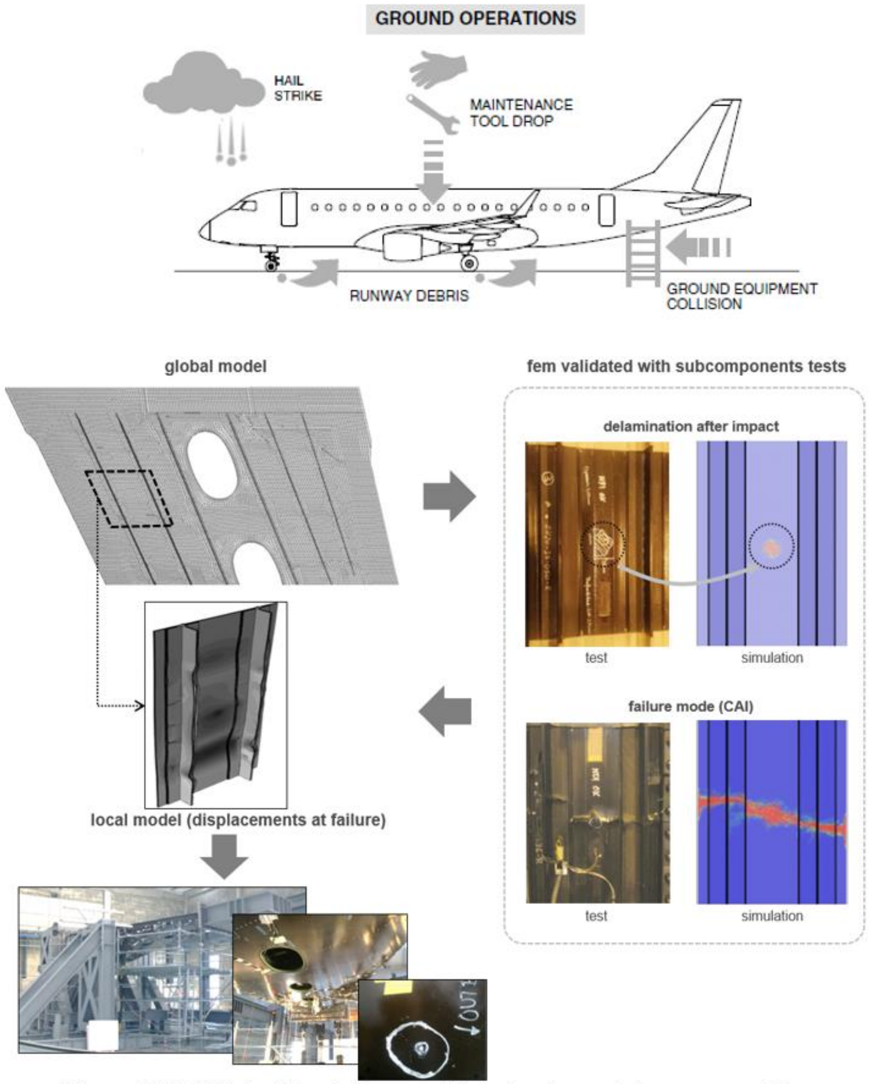


Figure 12.8.6.2(c) - Simulation workflow for impact damage - outline

12.8.7 Cirrus SR20 Life Extension (Cirrus)

- "....fiberglass/epoxy composite and bonded airframe, was certified to 14 CFR Part 23 in 1998 as a normal category..."
- "Cirrus later completed fatigue testing at the coupon/element level after the damage tolerance testing was completed. The data from these tests showed that a lower LEF could have been used for the cyclic testing, and that the selected values were conservative..."
- "...the use of conservative load enhancement factors (LEFs) during certification resulted in demonstrated lifetimes over 1.5 times the design life of 12,000 hrs (N_{dem} > 18,000)."

$$N_{dem} = \frac{N_{test}}{N_{req}}$$

- "The survey of fielded aircraft, with a cumulative service history of over 10 million flight hours, showed that there had been no fatigue related damage or failures with the composite components or structural bonds..."
- "To qualify each airframe for the service life extension, an inspection plan was required to verify there was no undetected field damage or damage growth in the candidate aircraft..."

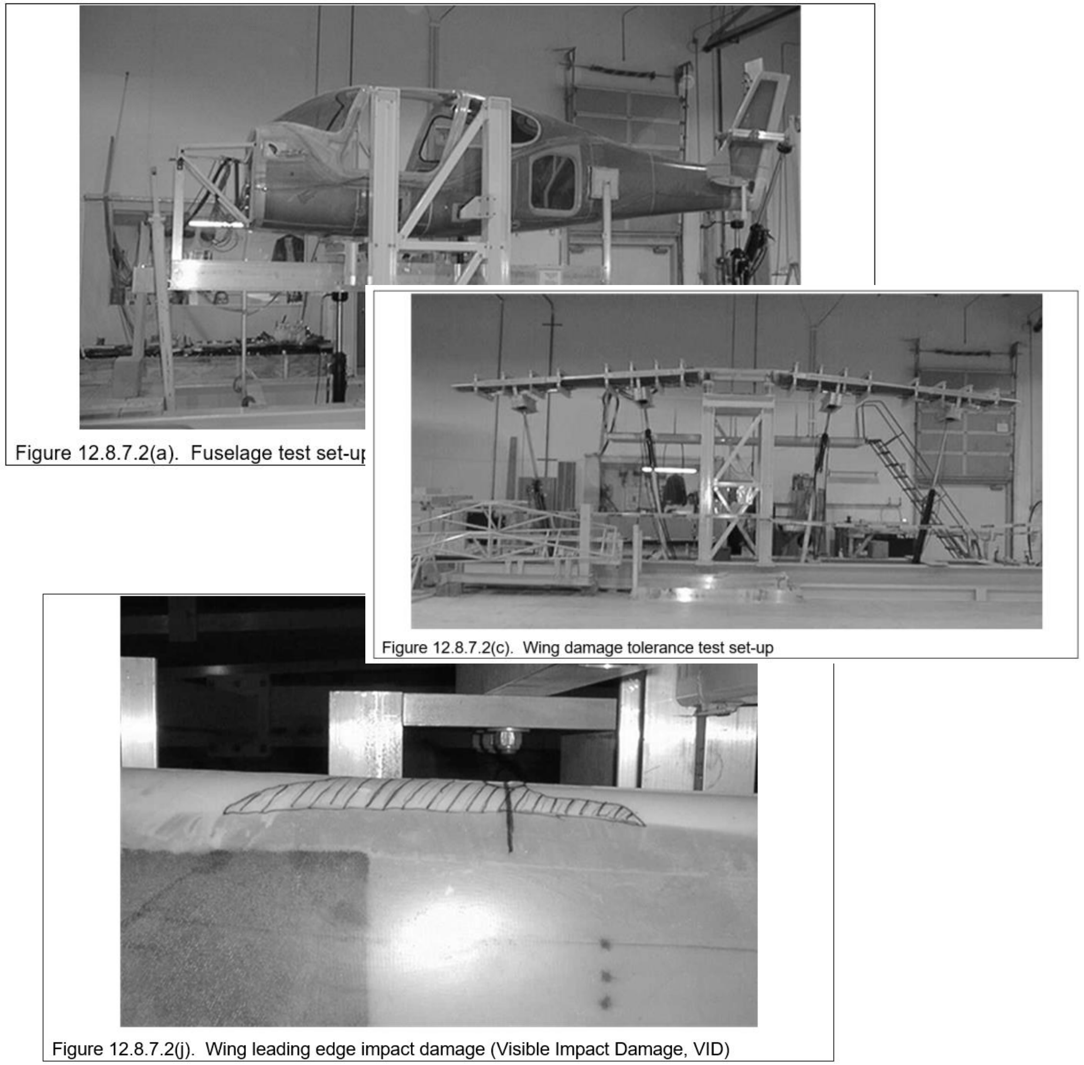


Figure 12.8.7.2(a). Fuselage test set-up

Figure 12.8.7.2(c). Wing damage tolerance test set-up

Figure 12.8.7.2(j). Wing leading edge impact damage (Visible Impact Damage, VID)

General Aviation Wingbox Demonstrator (Warsaw Institute of Aviation)

12.8.8 ILX-34 Wingbox Technology Demonstrator

- Wingbox component technology demonstrator for ILX-34, a 9-seater commuter airplane designed considering CS-23 regulations.
  - *Sandwich structure, carbon-epoxy composite in a two-stage out-of-autoclave (OoA) process.*
  - *AFP outer skin is cured then co-bonded to core and inner skin.*
- Building block testing – coupon to full-scale
- Load enhancement factor (LEF) development
- Full-scale fatigue and damage tolerance test

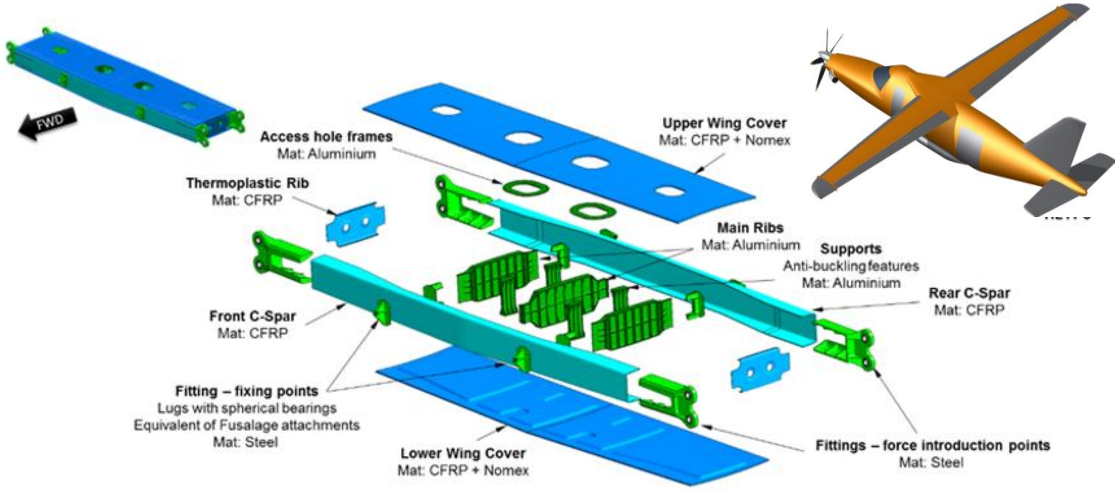


FIGURE 12.8.8.1(a) *Wingbox demonstrator architecture.*

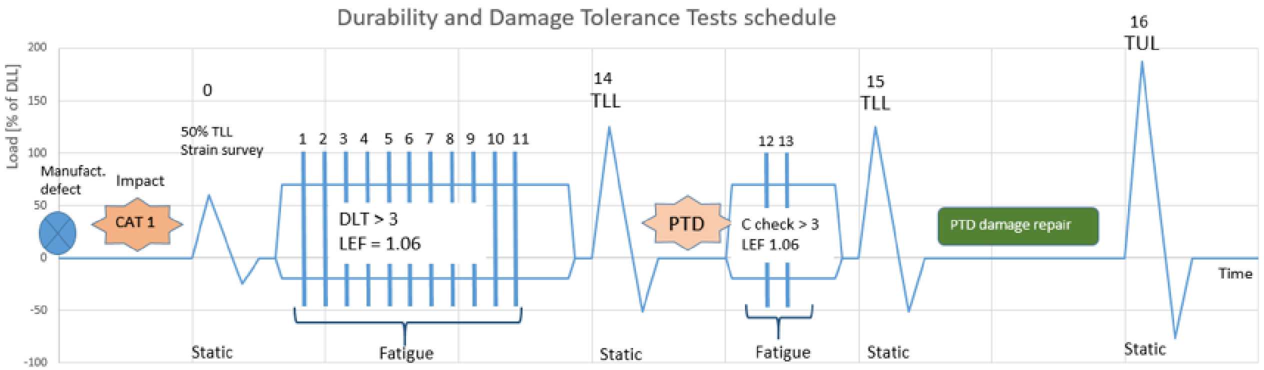


FIGURE 12.8.8.5.2(b) Wing demonstrator test schedule.

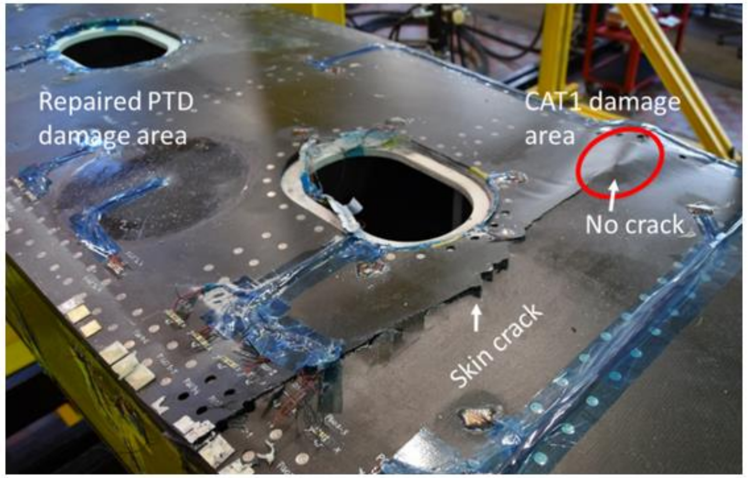


FIGURE 12.8.8.5.2(e) Upper skin damage in TUL test.

Outline

CMH-17 Durability & Damage Tolerance Overview

REV H Updates by Technical Topic

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- **Fatigue and Aging**

CMH-17 D&DT Updates – Sections 12.6.3

12.6 Durability and Damage Growth Under Cyclic Loading

12.6.3 **Test issues**

- 12.6.3.1 Scatter analysis of composites
  - 12.6.3.1.1 Individual Weibull method
  - 12.6.3.1.2 Joint Weibull method
  - 12.6.3.1.3 Sendeckyj equivalent static strength model
- 12.6.3.2 Life Factor approach
- 12.6.3.3 **Load Factor approach**
- 12.6.3.4 **Load Enhancement Factor approach**
  - 12.6.3.4.1 Application of LEFs for aerospace structural component tests
  - 12.6.3.4.2 Testing Requirements
  - 12.6.3.4.3 Considerations for Metal/Composite Hybrid Structure
- 12.6.3.5 **Ultimate Strength approach**
- 12.6.3.6 **Test spectrum development** — **13 pages**
  - **12.6.3.6.1 Overview**
  - **12.6.3.6.2 Cycle counting**
  - **12.6.3.6.3 5 x 5 matrix for composites**
  - **12.6.3.6.4 Spectrum truncation and clipping**
  - **12.6.3.6.5 Commercial aircraft flight segments and spectrum considerations**
- 12.6.3.7 Test environment
- 12.6.3.8 **Damage growth**

Rev H Updates (12.6.3)

- Update discussing use of "run-out" demonstration.

Rev H Updates (12.6.3.4 – 12.6.3.5)

- LEF guidance for complex structures and hybrids
- Emerging approaches and load sequencing.
- Update to Ultimate Strength approach

Rev H Updates (12.6.3.6)

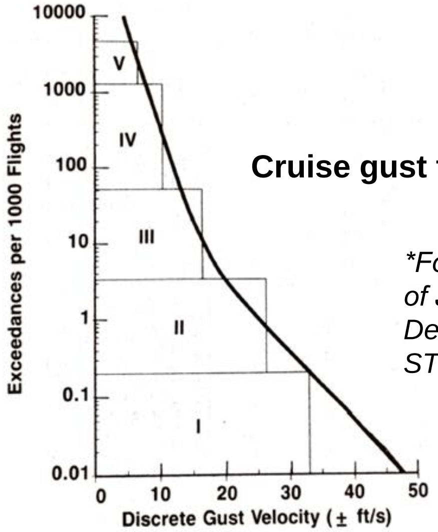
- New section expanding on previous spectrum and truncation section.

Repeated Load Tolerance & LEF – Spectrum Development (1 of 3)

12.6.3.6.3 5 x 5 matrix for composites

- "A 5 x 5 matrix (5 flight types and 5 loads levels) can be used for formulating the test spectra from the analysis exceedance curves. It typically consists of five flight types randomly sequenced in repeated one-tenth lifetime (DSG) blocks of flights. The five load levels are used in each segment of the spectrum to represent service usage. Each flight type can employ up to 25 flight segments with five load levels for major gust and maneuver segments or a more simplified approach depending on the type of loading (see table)."

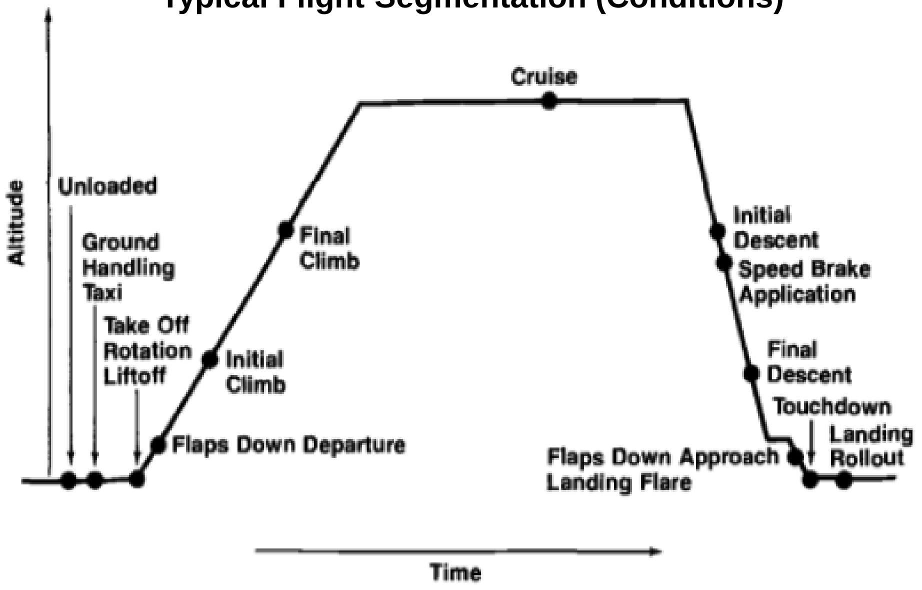
New section for 5 x 5 (6 pages)



Cruise gust test versus analysis spectra*

**Fowler, K.R. and Watanabe, R.T., "Development of Jet Transport Airframe Fatigue Test Spectra," Development of Fatigue Loading Spectra, ASTM STP 1006, 1989*

Typical Flight Segmentation (Conditions)



Example of alternating load allocation

Flight Type / Number of Flights in a 5000 Flight Block	Cruise Gust – Number of Peaks/Valleys at Five Amplitude Levels (±32.9 ft/s) I	(±26.4 ft/s) II	(±16.5 ft/s) III	(±10.4 ft/s) IV	(±6.64 ft/s) V	Number of Cycles in One Flight
A 1	1	3	6	56	61	127
B 13		1	2	32	40	75
C 215			1	12	23	36
D 1067				3	4	7
E 3704	4.74 Cycles per Flight Average				2	2
Number of Cycles in a 5000 Flight Block	1	16	247	6253	17202	

CMH-17 D&DT Updates – Sections 12.6.1, 12.6.2 and Vol. 1, 6.6.15

12.6 Durability and Damage Growth Under Cyclic Loading

- 12.6.1 Influencing factors
  - 12.6.1.1 Definitions for cyclic loading and S-N curves
  - 12.6.1.2 Cyclic stress ratio (R-ratio) and spectrum effects
  - **12.6.1.3 Environment and thermal cycling**
  - **12.6.1.4 Visco-elastic effects**
  - 12.6.1.5 Damage mechanisms
  - 12.6.1.6 High-cycle fatigue
- 12.6.2 Design issues and guidelines
  - **12.6.2.1 Design details**
  - 12.6.2.2 Damage tolerance considerations
  - **12.6.2.3 Aging considerations**

Rev H Updates

- Significant new content including sections on environmental cycling and visco-elastic effects, and fatigue sensitive design details.

Rev H Updates

- New section summarizing aging issues with input from ARAC.
- Thermal and moisture cycling content moved to Volume 1, Section 6.6.15 (through YPs)

Volume 1, Chapter 6

6.6 Thermal/Physical Property Tests

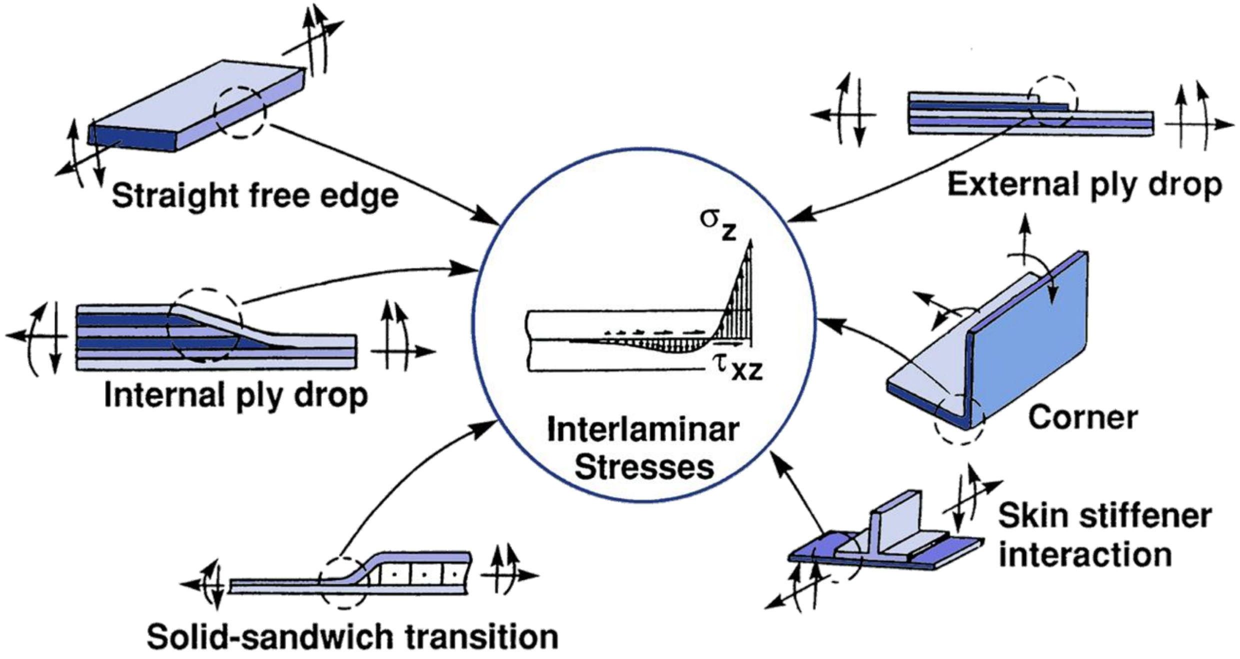
- 6.6.15 Thermal Cycling
  - 6.6.15.1 Introduction
  - **6.6.15.2 Accelerated thermal-moisture cycle screening test**

Rev H Updates

Durability and Damage Growth – Design Details

12.6.2.1 Design details

- "Experience has shown that certain composite design details may be susceptible to the onset (initiation) and growth of damage under significant repeated loading. Note that in many cases, these design details have similar adverse effects on static strength...design details resulting in high interlaminar stresses, stress concentrations and areas of high load transfer can result in potential durability and damage growth issues."
- Typical design guidelines that minimize the magnitude of the interlaminar stresses and stress concentrations.
- Design of arrestment features that may delay the damage initiation and contribute to limiting damage growth.



(courtesy of Christos Kassapoglou)

Section 12.6.2.1

- Provides discussion of fatigue-susceptible design details and guidelines to minimize fatigue stresses and arrest potential damage growth.

CMH-17 D&DT Updates – 12.6.2.3 Aging Considerations

12.6 Durability and Damage Growth Under Cyclic Loading

12.6.1 Influencing factors

12.6.2 Design issues and guidelines

12.6.2.1 Design details

12.6.2.2 Damage tolerance considerations

22 pages

12.6.2.3 Aging considerations

12.6.2.3.1 Background, history, and lessons learned

12.6.2.3.2 Industry best practices regarding aging threats

12.6.2.3.3 Regulatory guidance and ARAC recommendations

12.6.2.3.4 Service history and tear downs

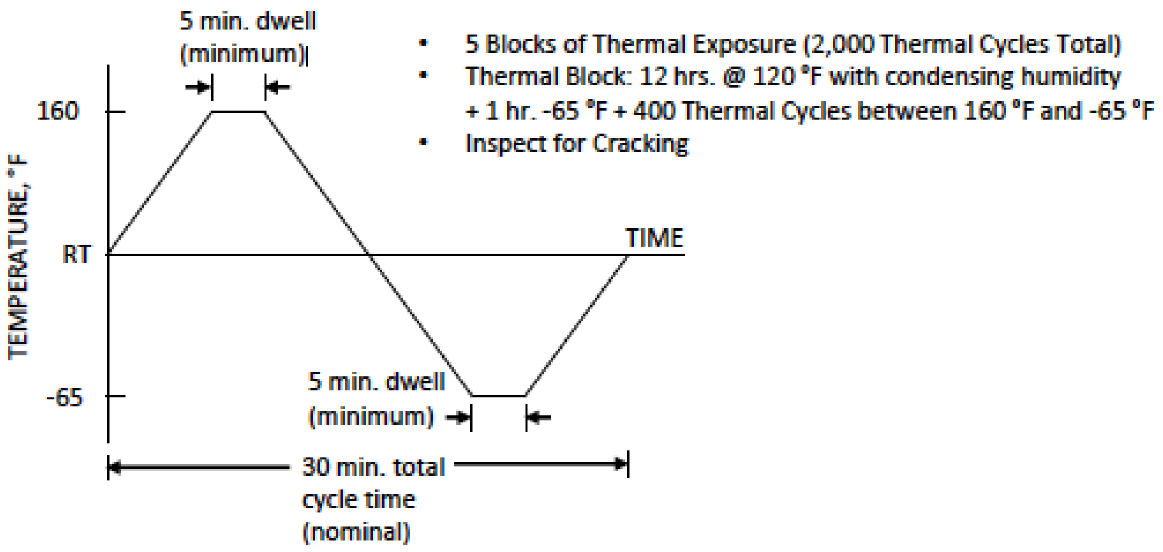
Rev H Updates

- New section summarizing aging issues with input from ARAC.
- Outline and content follows Boeing/Airbus/FAA/NSE presentation at AIAA conference.

Aging – Thermal-Moisture Cycle Screening Test (“Kevlar Cycle”)

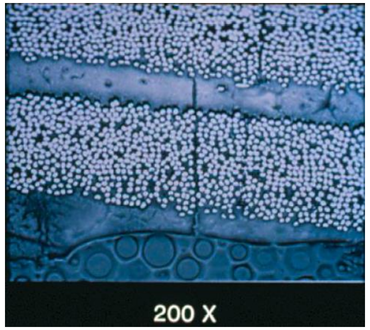
6.6.15.2 Accelerated thermal-moisture cycle screening test (Volume 1)

- “Accelerated thermal-moisture cycle (ATMC) screening testing is part of an environmental durability assessment. The test cycle has historically been referred to as the “Kevlar cycle” and has been used to assess the response of an aircraft structure’s material system to simulated long-term commercial in-service exposure environments.”
- Background of test origins - Aramid fiber composites with high thermal residual stresses, which in turn led to systematic matrix cracking caused by ground-air-ground (GAG) environmental cycling and a number of other contributing factors.
- Used primarily as a material screening test.
- Three examples of thermal-moisture cyclic tests and typical test specimens given, along with procedures and inspection methods to evaluate for microcracking.



Section 12.6.2.1

- Covers the “Kevlar” cycle and its usage for material screening.

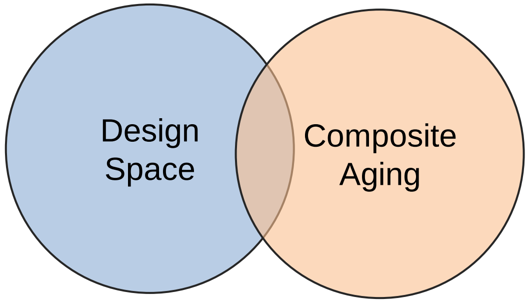


Aging – Industry Best Practices Overview

12.6.2.3.2 Industry best practices regarding aging threats

- "Current industry practices have generally enabled composite structures to avoid safety related aging mechanisms."
- "These practices are provided as guidance for the development of new and novel composite applications and structures developed by applicants with minimal or no experience with major composite components."

Current design practice and material choices generally avoid aging through careful evaluation of details that are known to be susceptible.



Needs careful evaluation!

Topics

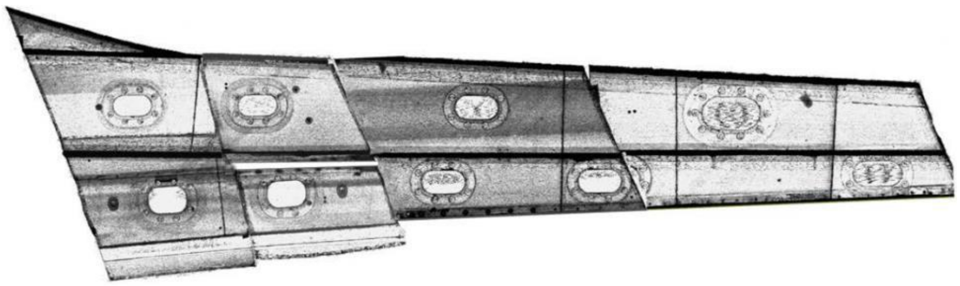
- Material Screening and Process Control
- Surface Protection
- Design Details
- Design Strains/Stresses and Thresholds
- Strength Allowables & Correction Factors
- Repetitive Impact Damage
- Repair Considerations

Aging – Service History, Tear Downs and Inspection

12.6.2.3.4 Service history and tear downs

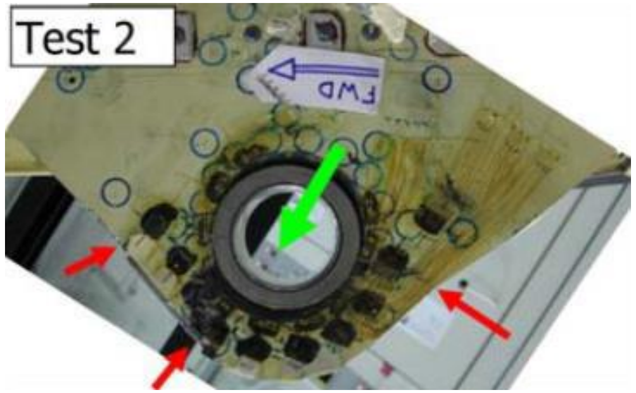
- Accelerated testing can’t cover all aspects of in-service environment, aging, or multi-site accidental damage over life of the aircraft.
- “A number of investigations have been performed on aircraft retired from service.”
  - *Flight hours vs. flight cycles vs. calendar time are considered for articles to evaluate*.
- “Overall results from teardown of in-service aircraft performed on aircraft retired from operations after long service histories reported no appreciable loss of strength, no obvious signs of structural material aging to the naked eye and no measurable degradation in material characteristics compared to baseline capability established at time of certification.”

V10F and ATR 72 Wings



Beechcraft Starship Wing

Boeing 737 Horizontal Stabilizers



Airbus A300-600 Vertical Stabilizer