

# CMH-17 Durability & Damage Tolerance

## Roadmap to Rev. G Content and Rev. H Updates as Related to Workshop Topics

Prepared for

FAA/Bombardier/TCCA/EASA  
Composite Transport Workshop on Damage Tolerance  
and Maintenance

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# Introduction

## ■ Background

- Many updates have been made to CMH-17 over the past 10+ years focused on key safety-related areas identified by the regulators (FAA/EASA/TCCA) and industry leaders.
- One main goal has been to benchmark accepted industry practice relative to regulations and associated guidance.

## ■ Objectives

- Provide a roadmap of CMH-17 content related to workshop topics.
- Outline relevant industry guidelines currently published in CMH-17 **(Rev. G)**
- Outline additional content in-work or planned for next revision **(Rev. H)**.
- Identify key updates needed for Rev. H that are not currently being worked.

## ■ Focus

- Focus on the specific workshop topics for Composite Fatigue & Damage Tolerance.
- Include priorities established by the Industry/Regulatory Working Group.
  - *Generally in line with technical areas being studied by the Part 25 F&DT ARAC committee.*

# Workshop Subtopics – Fatigue & Damage Tolerance

- **Composite Fatigue & Damage Tolerance – Session 4**
  - Aging aircraft (LOV, other constraints)
  - Design criteria and objectives for Cat 2-4
  - Large-scale structural analysis & test protocol
  - Repeated load tolerance (fatigue & damage tolerance)
  - Design requirements & criteria
- **Damage Tolerance (Special Subjects) – Sessions 5 & 6**
  - Building blocks for “Analysis Supported by Test”
  - Hybrid issues for composite-metal assemblies
  - Thermal loads (analysis and sufficient test evidence)
- **Other Related Subjects – Sessions 5, 6, & 7**
  - Flights with known damage (substantiation)
  - Substantiation of maintenance inspection technology
  - Use of probabilistic methods

Roadmap to cover key sub-topics from F&DT sessions.




Limited discussion

# Priorities from Industry/Regulatory Working Group

## ■ Priorities from Industry/Regulatory Working Group

Priorities and workshop topics line up except for Damage Threat Assessment.

- “Key components of composite fatigue and damage tolerance and related maintenance practice that are typically addressed during type certification”
- Priorities generally line up with workshop subtopics with the exception of Damage Threat Assessment. 
- Agreed on several “**key aspects**” to focus on for each priority topic relative to safety and certification.
- The key aspects were rated by importance:
  - *Most Important*
  - *Needed*
  - *Desired in Time*

Added to Roadmap Topics

# CMH-17 Roadmap Topics

## ■ CMH-17 F&DT Roadmap Topics

- Categories of Damage
- Repeated Load Tolerance
- Building Blocks for Analysis Supported by Test
- Hybrid Issues for Composite-Metal Assemblies
- Damage Threat Assessment
- Other Topics
  - *Flights with Known Damage and Defects*
  - *Maintenance Inspection Technology*
  - *Application of Probabilistic Methods*

**For each topic:** Review “key aspects” for each and provide summary of existing, in-work, and needed content.

## ■ Roadmap of CMH-17 Content for Each Topic

- Key aspects from Industry/Regulatory WG
- Rev G. – Existing
- Rev H. – In-Work / Needed

# Outline



## CMH-17 Overview

Categories of Damage

Repeated Load Tolerance

Building Blocks for Analysis Supported by Test

Hybrid Issues for Composite-Metal Assemblies

Damage Threat Assessment

Other Topics

Flights with Known Damage and Defects

Maintenance Inspection Technology

Application of Probabilistic Methods

# 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

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
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



# Ch. 12: Damage Resistance, Durability, and Damage Tolerance

12.1 Introduction

**12.2 Rules, Requirements and Compliance for Aircraft\***

**12.3 Design Development and Substantiation\***

12.4 Inspection for Defects and Damage

12.5 Damage Resistance

**12.6 Durability and Damage Growth Under Cyclic Loading\***

12.7 Residual Strength

12.8 Application/Examples

12.9 Supporting Discussions

**\* Content on most workshop topics is contained in these sections.**

# Outline

CMH-17 Overview



Categories of Damage

Repeated Load Tolerance

Building Blocks for Analysis Supported by Test

Hybrid Issues for Composite-Metal Assemblies

Damage Threat Assessment

Other Topics

Flights with Known Damage and Defects

Maintenance Inspection Technology

Application of Probabilistic Methods

- Key Aspects From Industry/Regulatory Working Group
  - Categories of Damage (and Defects)
    - **Category 1 Damage**  
*within allowable damage limits for the airplane life*
    - **Category 2 Damage**  
*ties to the scheduled maintenance program*
    - **Category 3 Damage**  
*minimum damage sizes for large damage capability*
    - **Category 4 Damage**  
*acceptable simulations for discrete source events*
    - **Category 5 Damage**  
*set by the criteria applied for Category 2 through 4*

# Categories of Damage – CMH-17 Rev. G

## ▪ Rev. G – Existing Content

- Categories of Damage defined in 12.2.2.
  - 12.2, “Rules, Requirements And Compliance For Aircraft”
  - Definitions are based on **AC 20-107B**.
- Design criteria by Category discussed in 12.3.1.
- Substantiation by Category discussed in 12.3.2.

## ▪ Rev. G – Missing & Inconsistent Content

- Does not adequately reflect industry practice in some areas.
- Discussion of HEWABI and Category 5 damage is inconsistent and does not reflect latest thinking in all areas.

**Rev. G:** Good coverage but need update for current industry practices in some areas.

# Categories of Damage – CMH-17 Rev. H

## ■ Rev. H – In-Work Content

- Major update to 12.3.3, Substantiation section
  - *Substantiation of Categories 1-4*
  - *Includes extensive input from Industry working group and CMH-17 D&DT task group.*
- Update planned for Category 5 content
  - *New Policy Statement on HEWABI*
  - *More on industry practice and latest research findings (UCSD, EASA)*
  - *Planned update spans several subsections in 12.2, 12.3, and 12.5.*

**Rev. H:** Some updates already in-work, HEWABI update is planned, but more focus needed on other key aspects.

## ■ Rev H – Needed Content?

- Minimum damage sizes for large damage capability?
- Relationship between Categories of Damage?
  - *Set design criteria for Category 2 and 3 that ensure the magnitude of damage becomes extremely unlikely as load requirements become more likely (relationship with residual strength curve).*
  - *Category 5 Damage set by the criteria applied for Category 2 through 4*
- Acceptable simulations for discrete source events?

← Make higher priority?

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Categories of Damage



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Hybrid Issues for Composite-Metal Assemblies

Damage Threat Assessment

Other Topics

Flights with Known Damage and Defects

Maintenance Inspection Technology

Application of Probabilistic Methods

- Key Aspects From Industry/Regulatory Working Group
  - Repeated load tolerance (Fatigue & DT)
    - *Load and life enhancement factors (e.g., LEF) to address statistical scatter*
      - Acceptance of combined load and life enhancement approaches (aka “Multi-LEF”).
    - *Truncation and clipping (supporting data)*
    - *Experimental data to establish the fatigue spectrum and LEF*
    - *What is the minimum number of Lifetimes that needs to be demonstrated?*
      - Repeated load cycles have been reduced below 2 lifetimes with a higher LEF for the composite part of demonstrations.
    - *What is the composite equivalent of WFD and how does it relate to LOV?*

# Repeated Load Tolerance – CMH-17 Rev. G

## ▪ Rev. G – Existing Content

### ▪ Good coverage in 12.6.3 (“Test Issues”)

- *Scatter analysis, shape parameters*
  - Individual Weibull, Joint Weibull, Sendeckyj
- *Load enhancement factor (LEF) development and usage*
- **LEF test guidelines**, *batches, design details, loading*
- *Considerations for metal-composite hybrids*
- *Combined load-life approach (“Multi-LEF” approach)*
- **Spectrum truncation** *(low loads) and clipping (high loads), including determining truncation levels from fatigue thresholds based on S-N data*
- *Test environment*

**Rev. G:** Good coverage but not complete in all areas and needs update for new research.

## ▪ Rev. G – Missing Content

- LEF and spectrum development content is incomplete in some areas.
- Needs update for new research findings and latest industry thinking.
- LOV and WFD (or composite equivalent) is not addressed.



# Repeated Load Tolerance – CMH-17 Rev. H

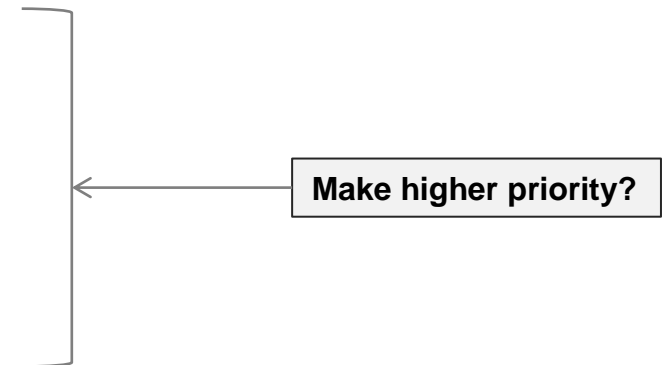
## ▪ Rev. H – In-Work Content (12.6.3)

- Additional test guidance for LEFs
  - *Minimum testing to use Whitehead values (i.e., LEF = 1.15)*
  - *Testing required to use new values for specific material and design*
- Improvements to existing LEF section
- Test spectrum development
  - *5 x 5 blocking strategy*
- Minimum number of lifetimes (considerations)
- Deferred spectrum approaches and load sequencing effects

**Rev. H:** Significant updates planned but may need more focus on LOV and related testing.

## ▪ Rev H – Needed Content

- Aging and limits of validity (LOV) for composites
  - *WFD equivalent?*
  - *Multiple impacts or repairs over lifetime interacting?*
  - *Other material degradation?*
- Additional guidance on use of data for setting truncation levels?



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Repeated Load Tolerance



Building Blocks for Analysis Supported by Test

Hybrid Issues for Composite-Metal Assemblies

Damage Threat Assessment

Other Topics

Flights with Known Damage and Defects

Maintenance Inspection Technology

Application of Probabilistic Methods

- Key Aspects From Industry/Regulatory Working Group
  - Acceptance of building block details, including full-scale test evidence for composite fatigue and damage tolerance
    - **What constitutes large-scale test evidence to support “analysis supported by test” certification approaches**
    - **Protocol for analysis and test correlation/structural substantiation**
    - **Introduction of damages (simulation, locations, magnitude, spacing, etc.)**
    - **Repair test and analysis substantiation**
    - *Statistical design values for impact-damaged structure*
    - *Combined load analysis and test demonstration of structural capability*
    - *How to deal with environmental effects and possible time-related issues for unique design details (e.g., co-cured splices)?*

## ■ Rev. G – Existing Content

- Usage of building block tests is covered in 12.3.
  - *Design criteria for damages (simulation and magnitude) discussed in 12.3.1.*
  - *Substantiation (testing) for each Category of Damage discussed in 12.3.2.*
  - *Full-scale testing discussed in 12.3.2.5.*
- Building Block Approach is covered in Chapter 4.
  - *Extensive content (62 pages) discussing all levels of building block.*
  - *Includes a parallel discussion on some F&DT topics.*

**Rev. G:** Building block testing is well-covered but relationship with analysis and design criteria needs improvement.

## ■ Rev. G – Needed Content & Harmonization

- More content needed on industry practice and practical limitations of analysis.
- Content in Chapter 12 has not been adequately harmonized with Chapter 4.

## ■ Rev. H – Planned & In-Work Content

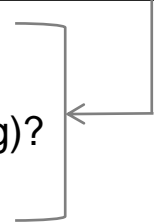
- New sections are in-work on industry practice regarding the role of design criteria and analysis vs. test during design substantiation.
  - Section 12.3.2 “Design Criteria” (*in-work*).
  - Section 12.3.3 “Substantiation” (*ready for YPs*).
  - Section 12.5.4 “Damage Resistance” (*planned*)
  - Section 12.6.4 “Durability & Damage Growth Under Cyclic Loading” (*submitted to YPs*)
  - Section 12.7.4 “Residual Strength” (*in-work*)

**Rev. H:** New sections are in-work but additional content may be needed for other topics.

## ■ Rev H – Needed Content?

- Additional content on protocol for analysis and test correlation?
- Add to existing content on introduction of damages (for locations and spacing)?
- Review and update of 14.6.2 for repair test and analysis substantiation?
- Other new content over time:
  - *Statistical design values for impact-damaged structure*
  - *Combined-load analysis and test demonstration of structural capability*
  - *Environmental effects and possible time-related issues for unique design details*

Identify specific needs?



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Maintenance Inspection Technology

Application of Probabilistic Methods

- Key Aspects From Industry/Regulatory Working Group
  - Hybrid issues for composite and metal assemblies
    - *What is achieved in the full-scale “airplane” test (typically used for metal fatigue test substantiation) vs. subcomponent and demonstrator/pre-production test articles (typically used for repeated load parts of composite substantiation).*
    - *Airplane temperature distributions and thermal load validation of analyses in large scale tests*
    - *Is it necessary to address thermal loads in large scale fatigue tests? (e.g., added cycles)*
    - *Differences in composite and metal repeated load / fatigue spectrums*

## ▪ Rev. G – Existing Content

- Full-Scale testing covered in 12.3.2.5 (substantiation)
  - *Example test sequences given for transport and rotorcraft*
  - *Limited discussion of composite-metal hybrids, but includes discussion on use of separate composite-specific testing*
- Differing fatigue sensitivities discussed in 12.6.3 (test issues)
  - *LEF application for hybrid structures (including “multi-LEF” approach)*
  - *Considerations for spectrum truncation (low loads, composites) and clipping (high loads, metals)*

**Rev. G:** Only limited coverage for testing of composite-metal assemblies.

## ▪ Rev. G – Missing/Incomplete Content

- Content is incomplete with regard to industry practice and differing test requirements for composites and metals.
- Thermally-induced loading due to CTE mismatch is not addressed.



# Hybrid Issues for Composite-Metal Assemblies – CMH-17 Rev. H

## ▪ Rev. H – In-Work

**Rev. H:** Extensive update is in-work to address all major priority items.

- Extensive update to 12.3.3, Substantiation section
  - *Based on significant input from industry working group and CMH-17 D&DT Task Group.*
  - *New subsection on “Large-Scale Testing”*
    - Includes tables of test requirements for composites and metals with link to CFRs and/or ACs.
  - *New subsection on “Environmentally-Induced Loading”*
    - Discusses industry practice for “analysis supported by test” approach for these loads.
  - *New subsection on “Differing Fatigue Sensitivities”*
    - Includes considerations for how to address different sensitivities during large-scale testing.
- Updates to 12.6.3 (“Test Issues” for repeated loading)
  - *New subsection on “Considerations for Metal/Composite Hybrid Structure”*
    - Expands discussion about test issues and LEF usage, and to include mention of evolving concepts (e.g., deferred spectrum approach)

## ▪ Rev H – Needed Content?

- Other new content identified during workshop?



Anything else needed?

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Damage Threat Assessment

Other Topics

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Maintenance Inspection Technology

Application of Probabilistic Methods

- Key Aspects From Industry/Regulatory Working Group
  - Damage threat assessment, including considerations as a function of structural locations
    - *Accidental damage types*
    - *Environmental damage types*
    - *Manufacturing defect types*
    - *Other defect and damage types*
    - *Discrete source damage threats*
    - *Large damage capability*
      - Relationships with selected inspection procedures, design criteria and categories of damage
    - *Identification of damage threats beyond Damage Tolerance Assessments (i.e., Cat 5)*

## ▪ Rev. G – Existing Content

Rev. G: No significant content

- Brief mention only
  - *Section 12.2 (“Rules, Requirements and Compliance for Aircraft”)*
  - *“The assessment must include consideration of probable locations, types, and sizes of damage allowing for fatigue, environmental effects, intrinsic/discrete flaws, and impact or other accidental damage.”*
- Industry practice relative to rules and guidance is not documented.

# Damage Threat Assessment – CMH-17 Rev. H

## ■ Rev. H – Planned Content

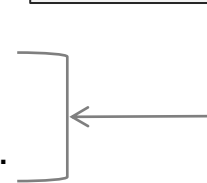
- New section planned at beginning of 12.3
  - *Will benchmark industry practice*
  - *Will leverage content in AC 20-107B and CSET Course*
  - *Will include relevant content from HEWABI Policy Statement for Category 5*
- Draft outline follows CSET course
  - *12.3.1.1 Foreign object impact damage threats*
  - *12.3.1.2 Load-induced damage threats*
  - *12.3.1.3 Environmental and time-related aging*
  - *12.3.1.4 Discrete source damage threats*
  - *12.3.1.5 Manufacturing defect threats*
  - *12.3.1.6 Case studies on Category 5 damage of safety note*

Rev. H: New section planned but not started.

## ■ Rev. H – Status

- Good outline and content identified but no draft has been started.
- Needs more focus in CMH-17 Working Group if priority item for Rev. H.

Make higher priority?



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Other Topics

Flights with Known Damage and Defects

Maintenance Inspection Technology

Application of Probabilistic Methods

- Key Aspects From Industry/Regulatory Working Group
  - *Flight with known composite damage and defects (within allowable limits)*
    - *As related to the “no damage growth” compliance approach*

# Flights with Known Damage and Defects – CMH-17

## ■ Rev. G – Existing Content

- Section 12.2.3 “Load and damage relationships” discusses need to develop allowable damage limits (ADLs) as a function of structural location.
  - *Also mentions relationship with maintenance costs and the possibility of “cosmetic repair” for damage within the ADL.*
- Section 14.9.1 covers ADL development and use of “simple maintenance actions (e.g., sealing)” for damage within ADL.

**Rev. G:** Some content related to ADLs and “cosmetic” repairs but may need more on industry practice for composites vs. metals.

## ■ Rev. H – Needed Content?

- Add discussion to clarify the different approaches for composites and metals?
  - *In composites, it is often better to clean up the damage and seal it than to remove ALL damage.*
  - *In metals, all damage is often removed to avoid crack starters.*



- **Key Aspects From Industry/Regulatory Working Group**
  - Demonstration maintenance inspection technology details related to F&DT
    - *Validation of inspection methods used for detection (Category 1 - 3 damages), including the minimum number of inspection cycles*
    - *Validation of full extent/characterization of damage as related to allowable damage limits and repair size limits (e.g., the 2 BRSL criteria)*
    - **Protocol for ICA as applied to scheduled composite maintenance**
    - **Conditional inspection details for HEWABI and other Category 5 damage types**
    - *Guidelines for MSG-3 (accidental and environmental damage threats)*

## ▪ **Rev. G – Existing Content**

- Section 12.4.4 covers environmental deterioration and accidental damage ratings (EDR/ADR) and related “MSG-3” process.
- Section 12.4.5 covers fleet leader programs.
- Section 12.4.6 covers probability of detection (POD) studies, which can be used to validate inspection methods and guide the minimum number of inspection cycles needed during testing.
- Section 14.9 (Maintenance documentation) covers characterizing the extent of damage as related to allowable damage limits (ADLs) and repair size limits (RSLs).

**Rev. G:** Some content on MSG-3 and EDR/ADR, and on using POD studies to validate inspection methods.

## ▪ **Rev. H – Needed Content?**

- Protocol for Instructions for Continued Airworthiness (ICA) as applied to scheduled composite maintenance?
- Conditional inspection details for HEWABI and other Category 5 damage types?

- Key Aspects From Industry/Regulatory Working Group
  - Application of probabilistic methods to different aspects of composite F&DT
    - *Damage threat assessments*
    - *Setting inspection intervals*
    - *Use of metallic damage data for composite applications*
    - *Justification of conservative design criteria*

## ■ Rev. G – Existing Content

- Section 12.2.4 (compliance approaches) covers probabilistic and semi-probabilistic approaches (essentially documents Airbus approach).
  - *Includes discussion of probability of impact threats and the relationship with the probability of detection within the inspection program.*
- Probabilistic compliance approaches are also discussed with respect to design criteria (12.3.1) and substantiation (12.3.2).
- Section 12.9.1 discusses development of probability-of-occurrence relationships for impact events.

**Rev. G:** Good coverage on current industry practice but may need additional content on related topics and as methods evolve.

## ■ Rev. H – Needed Content?

- Need more on damage threat assessments (field data) to support probabilistic approaches?
- Add discussion on using metallic damage data for composite applications?

# Questions and Comments?

