The Composite Materials Handbook

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1. Abstract

The Composite Materials Handbook-17 (CMH-17) is both an organization and a collection of volumes on composites and non-metallic additively manufactured materials. The organization creates, publishes, and maintains pedigreed material data as well as proven engineering information. The Handbook provides information and guidance regarding design and fabrication of composite and non-metallic additively manufactured materials.

The Handbook provides industry best practices for design, manufacturing, substantiation, and sustainability for aerospace applications. CMH-17 covers material characterization, design and analysis, processing, certification, and sustainment of parts and structures made from polymer, ceramic, and metal matrix composites, and non-metallic AM materials, including bonded and bolted joints, and sandwich construction.

The CMH-17 organization and Handbook play a key role in advanced materials knowledge transfer including examples, on applications, lessons learned, and supporting engineering guidelines that outline limitations, strengths and weaknesses of composites and non-metallic AM materials and structures.

Wichita State University's National Institute for Aviation Research serves as secretariat for CMH-17, which holds regular meetings to create, publish, and maintain proven material data and engineering information. This material, subjected to thorough technical review, supports the development and use of advanced materials and structures in aerospace applications.

2. Introduction

Composite materials are indispensable in aerospace and high-performing engineering. Composites have good strength-to-weight ratios, tailorability, corrosion resistance, and fatigue performance. However, variability in constituent materials, processing, laminate architectures, and test methods create challenges for constituent design, certification, and structural substantiation. CMH-17

(Composite Materials Handbook) compiles industry guidelines and validated datasets for polymer matrix composites, metal matrix composites, ceramic matrix composites, and nonmetallic additively manufactured materials.[1]

The Handbook bridges material characterization with engineering usage and certification needs. CMH-17's role is synergistic with regulatory policy (e.g., FAA AC 20-107B for composite aircraft structure)[2] and test standardization like ASTM D3039 for tension testing [3], enabling repeatable property generation, rigorous data reduction, and traceable allowables that underpin safe design and airworthiness demonstrations. CMH-17 has a long history of industry, government, and academia collaboration. This paper provides an overview of CMH-17 including the organizational governance, technical scope, and contributions to data quality and allowables, its industry impact and regulatory alignment, and current projects in work.

3. History and Evolution of CMH-17

The Composite Materials Handbook originated as MIL-HDBK-17, a U.S. military handbook designed to harmonize composite methodologies and provide vetted material properties for defense applications. In 1978, as composites proliferated beyond dense into commercial aerospace and other sectors, the handbook transitioned to a broader audience with the introduction of coordination groups. In 2006, the Federal Aviation Administration (FAA) took over stewardship of the document. The evolution of coordination groups, the addition of multiple composite material systems, and the stewardship of the FAA reflect the practical need to bridge research, industry, and regulatory perspectives in order to achieve certifiable, repeatable, and safe composite structures.

Key milestones include the formalization of data quality levels, statistical allowables, and standardized terminology; the expansion from polymer matrix composites to include metal and ceramic matrix systems; and the establishment of working groups that maintain, curate, and update guidelines to align ASTM and SAE standards, FAA policy, and prevailing industry practices [1,2]. The transition from MIL-HDBK-17 to CMH-17 also placed emphasis on consensus governance and international collaboration, increasing adoption across aerospace OEMs, suppliers, and certification authorities.

The Handbook consists of 7 volumes, Volumes 1-3 focus on Polymer Matrix Composites, Volume 4 is on Metal Matrix Composites, Ceramic Matrix Composites are covered in Volume 5, Sandwich Structures are covered in Volume 6, and Volume 7 which is preparing for initial release, is focused on nonmetallic additively manufactured materials. The Volumes are available for purchase through SAE International, the publisher for CMH-17. The volunteer organization is working on many updates to the volume set.

4. Organizational Structure and Governance

CMH-17 operates with a Leaders Group, and domain-specific working groups that draft, review, and publish guidelines and datasets. Participation spans industry, government, and academia to ensure balanced perspectives. Draft content undergoes structured review cycles, data vetting, and methodological consistence checks before publication – reflecting CMH-17's emphasis on consensus and quality content.

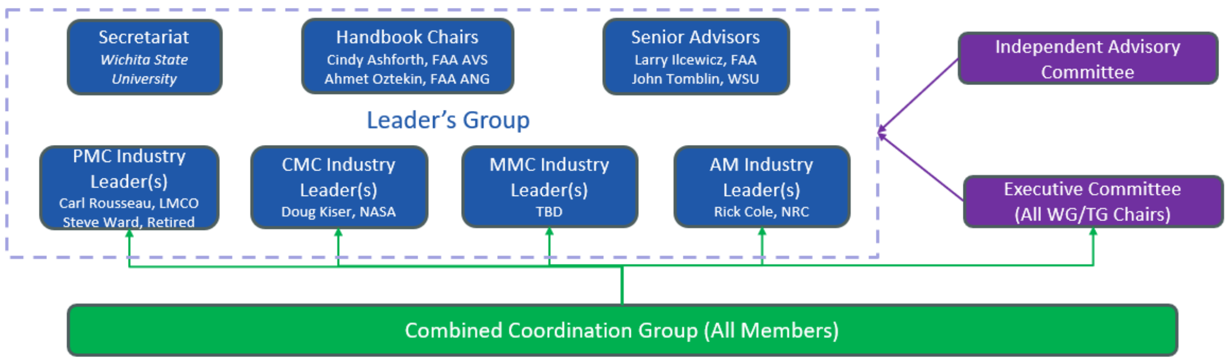

Figure 1: Diagram of the CMH-17 Organizational Structure

The Handbook Chairs lead CMH-17 decision making on technical, logistical and financial budgets, including organizational structure, handbook initiatives, contracts, meetings, secretariat tasks, and related challenges, striving for what's best to advance the organization. Senior advisors support decision making on organizational structure, technical, logistical, and financial needs. These needs include special projects, organizational coordination and any related challenges. The Senior advisors directly help the Handbook Chairs and the Secretariat. The final set of advisors is the Independent Advisory Committee. This committee supports CMH-17 leadership with advice at regular IAC meetings on technical, logistical and financial interests or challenges, including review of organizational decisions, CMH-17 content, and IAC studies to identify application needs.

Industry leaders represent their specific material domain and help Working groups and Task groups with any challenges in their areas of specialty. Industry leaders are critical to the Leaders Group and help to create technical direction for the volumes.

Working Groups (WG) are supported by Task Groups (TG). Task Groups support discrete tasks that require interdisciplinary support to tackle difficult problems, write necessary content, and address industry needs. Task Groups draw members from across the organization (or new members) with the required skill and knowledge to develop the content, regardless of their existing WG membership. The chairs of these two groups make up the Executive Committee. The Committee supports CMH-17 with identification/proposal/approval of initiatives that follow the content development process, yielding updated, merged and new content for the seven volumes of technical information that comprise CMH-17 Handbooks.

The content is developed by the membership. Membership comprises the resources needed to recommend, develop, review and maintain CMH-17 handbook content. Members may join selected WG and TG to participate in the interdisciplinary teams that perform CMH-17 Handbook tasks.

All CMH-17 members are supported by the Secretariat. The Secretariat conducts specified CMH-17 technical, logistical and financial tasks, including handbook publication, website maintenance, organize meetings, continuous outside interfaces, and related challenges, performing work authorized within the FAA and other sponsor contracts.

This governance model mirrors successful standards bodies wherein impartiality, reproducibility, and documented provenance are paramount. CMH-17 also coordinates with ASTM subcommittees relevant to composite test methods (e.g., D30 Committee on Composite Materials), enabling alignment between handbook guidance and the test standards practitioners use to generate engineering data [4]. The result is a coherent ecosystem: CMH-17 defines data quality and allowables methodologies; ASTM provides standardized test procedures; and FAA policy defines certification expectations for composite structures [2,1].

5. Purpose and Scope of CMH-17

The central objective is to provide reliable, traceable, and certifiable composite material data and guidelines. The Handbook includes significant information for aerospace applications, with benefit to other applications as well. It constitutes an overview of advanced composite and additive materials technology and engineering. Its scope includes:

- **Standardized terminology and methodologies:** Common definitions, symbols, and procedures that reduce ambiguity in documentation and certification packages [1].
- **Testing and characterization guidance:** Harmonized approaches to coupon testing, laminate construction, environmental conditioning, and data reduction to increase reproducibility across laboratories [1,3,4,5].
- **Data quality levels and statistical rigor:** Frameworks to classify data quality and derive A-basis and B-basis material allowables consistent with principles of statistical tolerance limits and certification usage [1,2].
- **Material property data and databases:** Curated datasets with clear provenance, conditioning, and test methods, enabling engineers to select properties and understand variability [1].
- **Design, analysis, and recommendations:** Guidelines on ply-level and laminate analysis, failure criteria, notched behavior, impact and compression after impact (CAI), fatigue, and environmental effects [1, 9, 10]. CMH-17 provides Proven methodologies, engineering solutions, best practices, lessons learned, and case studies for the design, analysis,

certification, manufacture, and field support of parts and structures made from advanced materials.

6. Technical Contents

The handbook aligns with ASTM composite test standards to ensure consistent specimen geometry, grips/fixtures, conditioning, and data reduction protocols—for example, tensile (ASTM D3039/D3039M)[3], compression (ASTM D6641/D6641M[4] and D3410/D3410M[5]), shear (ASTM D5379/D5379M[6]), short-beam shear/interlaminar (ASTM D2344/D2344M[7]), open-hole tension/compression (ASTM D5766/D5766M[8] and D6484/D6484M[9]), CAI after impact (ASTM D7136/D7136M[10] and D7137/D7137M[11]), and elevated/low-temperature conditioning requirements (ASTM D5229/D5229M[12]) (ASTM Standards; CMH-17, Vol. 1). CMH-17 maps these methods to common property needs (e.g., E1, E2 moduli, F1t/F2t strengths, interlaminar shear, notch sensitivity), and provides guidance on data reduction (e.g., chord moduli, offset yields, Poisson's ratio) to achieve comparability across programs.

CMH-17 defines strategies for building material qualification datasets: selecting representative prepreg lots, process routes, laminate stacks, and environmental conditions; ensuring sufficient sample sizes and batch-to-batch coverage; and coordinating process control documentation [1]. This approach recognizes that composite properties depend on fiber/resin constituents, cure cycles, layup architecture, defect sensitivity, and environmental exposure. The methodology tightly couples materials engineering with manufacturing process control to create robust, transferable allowables suitable for static strength, stability, and durability analyses [1,2].

CMH-17 formalizes data quality levels (e.g., screening vs. qualification datasets) and provides statistical methodologies for deriving A-basis and B-basis allowables—lower tolerance bounds used in certification to ensure conservative design. A-basis typically represents a 99% lower confidence bound for a property, while B-basis represents a 95% lower confidence bound, assuming appropriate sample sizes and distributions; CMH-17 details the requirements for dataset construction, outlier handling, and distribution checks to support these derivations [1,2]. Such rigor elevates the credibility of composite property values in airworthiness substantiation.

CMH-17 provides engineering guidance on ply-level and laminate analysis, classical lamination theory, failure criteria (e.g., maximum stress/strain, Tsai-Hill, Tsai-Wu), and damage tolerance topics such as open-hole behavior, bearing/bypass load distribution, impact resistance, and compression after impact (CAI). It addresses environmental effects (temperature, moisture) and fatigue behavior, emphasizing the need to supplement coupon data with sub-element and element testing when structural complexities or load interactions exceed coupon-level representativeness [1, 9, 11]. This philosophy underpins certification strategies that blend analysis and progressive-level testing (coupon → sub-component → full-scale).

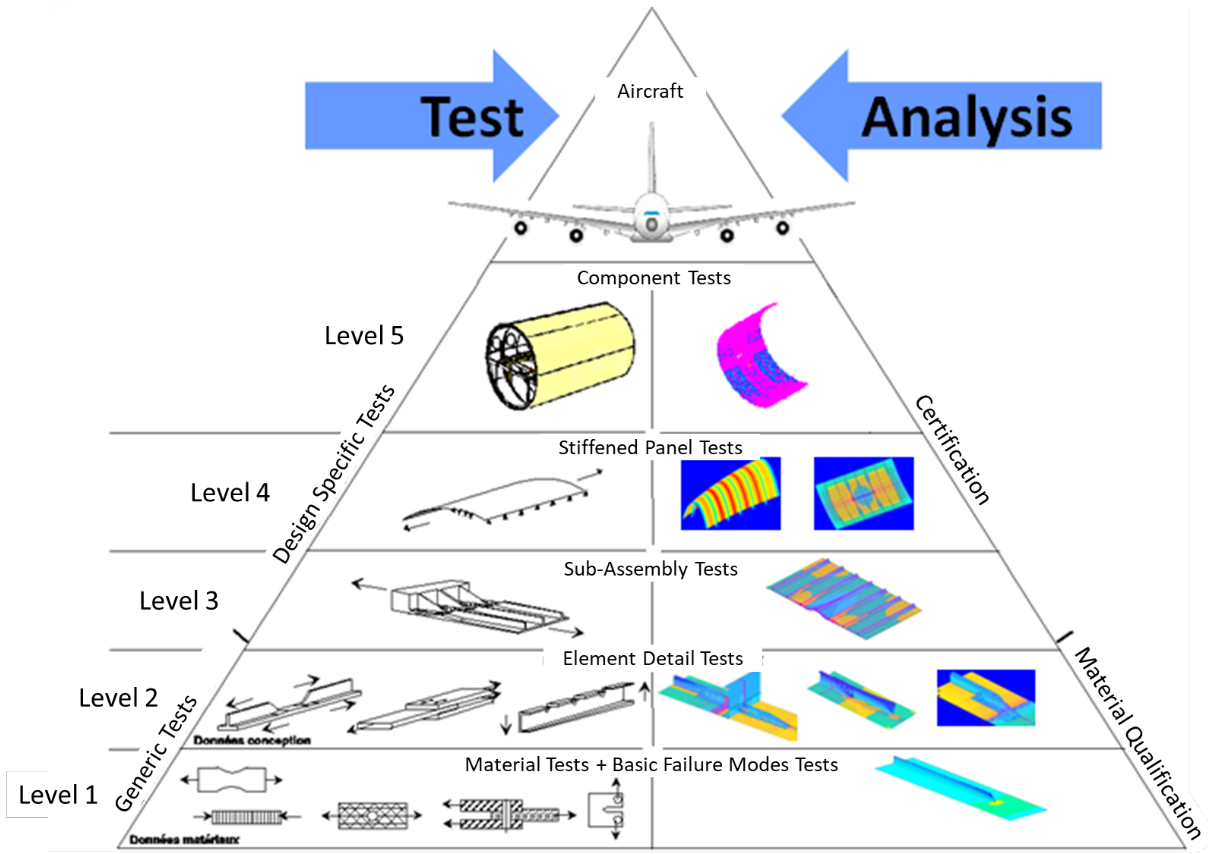

Figure 2: Building Block Approach

Recently, the publication of Volume 3 Revision H for "Polymer Matrix Composites: Materials Usage, Design and Analysis". The new revision is available for purchase in print or digital format through SAE International (Warrendale, Pa., U.S.).

Volume 3 discusses usage of data for material procurement, quality control, design, structural analysis, and reliability. Volume 3 has undergone extensive revisions and expansions on critical topics such as damage tolerance, crashworthiness, spacecraft and engine applications. The new print version will be made in 4 bindings to manage over 2,000 pages of peer-reviewed and balloted technical content.

Changes to Volume 3 occurred over the last 13 years and doubled the length of the Volume, adding new case studies, new sections, and a new chapter on engine applications. The primary purpose of this volume is to expand on the industry's best practices for using the data generated with the engineering methodologies outlined in Volume 1. Volume 3 is a critical tool worldwide for engineers designing and using composite parts throughout an applications life cycle (including sustainment and repair).

7. Applications and Industry Impact

In aerospace, CMH-17 undergirds material selection, allowables derivation, and structural substantiation for primary and secondary composite structures. OEMs and suppliers rely on CMH-17 to harmonize test plans and data reduction; to define qualification protocols; and to compile certification-ready datasets for regulatory submissions [1,2]. The alignment with ASTM standards facilitates cross-laboratory comparability, while the statistical frameworks reduce ambiguity in safety margins. This has material implications for airframe weight reduction, structural integrity, and lifecycle cost.

Regulatory bodies (e.g., FAA) reference the need for conservative material property bases and robust damage tolerance demonstrations for composite structures. CMH-17's data quality frameworks and methodological guidance directly support compliance with expectations in AC 20-107B and related policy, notably for bonded joints, disbonds, impact damage, and environmental conditioning [2,1]. CMH-17 helps applicants and regulators align on common technical baselines, reducing certification risk and streamlining reviews.

CMH-17's influence is evident in its synergy with ASTM test methods for composites and it's conceptual parallel to metal property handbooks such as MMPDS. While MMPDS focuses on metallic allowables, CMH-17 provides a composite-specific framework for analogous rigor in data curation and statistical allowables. Together, these resources support mixed-material structures and holistic certification approaches [13, 1].

8. Future Projects

Volume 5, on Ceramic Matrix Composites (CMC), is in the process of completing Revision B. This new Revision includes new content on Environmental Barrier Coatings, Engine Applications, increased information on melt infiltrated (MI) SiC/SiC, Attachments, and Testing Methodologies. It also includes the first CMC Data set included in the Handbook. The Axiom AX-7800-DF11-5FS3000D satin weave fabric prepreg interim dataset was tested by Wichita State University's National Institute for Aviation Research – NCAMP.

Volume 2, the Polymer Matrix Composite Data Volume is also in the process of Revision. This new revision will include new data sets, updated definitions, and an update to a dataset with additional data.

The newest CMH-17 Volume, Volume 7 is in production and expected to be released late in 2026 or early 2027. The Non-metallic Additive Manufacturing Volume will include information covering Selective Laser Sintering, Powder Bed Fusion, and Fused Filament Fabrication. The Volume also includes approved data sets for several materials. Some topics include Material and Machine Qualification, Process Controls, Sources of Variation, Quality and Inspection, Analysis methods, In-situ inspection, and test matrices for new materials and processes.

The National Institute for Aviation Research is also working on developing new supporting software for the CMH-17 statistical methods. The existing software is CPU locked, Excel based software. The new software is python coded and it has finished beta testing and software equivalency testing. The user interface is in development. The new software will continue to generate A- and B-basis values and test statistics for material equivalency and acceptance testing (modified coefficient of variation (MOD CV)).

The continued adoption of CMH-17 depends on knowledgeable practitioners who understand data quality, statistical allowables, and certification needs. Academic programs and industry training that integrate CMH-17 methodologies with hands-on ASTM testing and regulatory context will strengthen the ecosystem and enhance the reproducibility of composite property data [1, 14].

9. Conclusion

CMH-17 provides the foundational methodology and curated data that make composite materials engineering reproducible, certifiable, and safe across demanding applications. Its evolution from MIL-HDBK-17 into a consensus international organization has positioned it as a pivotal bridge between materials science, structural engineering, manufacturing, and regulation. By codifying data quality, allowables, standardized testing, and design/analysis guidance, CMH-17 reduces ambiguity and supports conservative, traceable property usage.

Looking forward, advances in digital data infrastructure, manufacturing technologies, and model-based engineering will benefit from CMH-17's consensus processes, extending its utility to new materials and certification paradigms. Continued collaboration among industry, academia, and regulators will ensure CMH-17 remains a reliable, rigorous foundation for the next generation of composite structures. The organization and the Handbook will only continue to thrive with the contributions of volunteers, like you, who can participate in any of the Working Groups and Task Groups to ensure the documentation of best practices for advanced material systems.

10. Acknowledgments

The author acknowledges the role of CMH-17 working groups, ASTM committees, and regulatory guidance in shaping the methodology described, and the broader composites community—including OEMs, research institutes such as NIAR, and certification authorities—for ongoing contributions to data quality and safety.

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[4] ASTM D6641/D6641M: Standard Test Method for Compressive Properties of Polymer Matrix Composite Materials Using a Combined Loading Compression (CLC) Test Fixture.

[5] ASTM D3410/D3410M: Compressive Properties of Polymer Matrix Composite Materials with Unsupported Gage Section by Shear Loading.

[6] ASTM D5379/D5379M: Shear Properties of Composite Materials by the V-Notched Beam Method.

[7] ASTM D2344/D2344M: Short-Beam Strength of Polymer Matrix Composite Materials and Their Laminates.

[8] ASTM D5766/D5766M: Open-Hole Tensile Strength of Polymer Matrix Composite Laminates.

[9] ASTM D6484/D6484M: Open-Hole Compressive Strength of Polymer Matrix Composite Laminates.

[10] ASTM D7136/D7136M: Drop-Weight Impact Damage of Fiber-Reinforced Polymer Matrix Composites.

[11] ASTM D7137/D7137M: Compressive Residual Strength of Damaged Polymer Matrix Composite Plates (CAI).

[12] ASTM D5229/D5229M: Moisture Absorption Properties and Equilibrium Conditioning for Polymer Matrix Composites.

[13] MMPDS – Metallic Materials Properties Development and Standardization.

[14] ASTM Committee D30 on Composite Materials.