

Metal Matrix Composites

CMH17

COMPOSITE MATERIALS HANDBOOK



WICHITA STATE
UNIVERSITY
NATIONAL INSTITUTE
FOR AVIATION RESEARCH

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COMPOSITE MATERIALS HANDBOOK

VOLUME 4. METAL MATRIX COMPOSITES

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FOREWORD

The Composite Materials Handbook, CMH-17, provides information and guidance necessary to design and fabricate structural components from composite materials. Its primary purposes are a) the standardization of engineering data development methodologies related to testing, data reduction, and data reporting of property data for current and emerging composite materials, b) guidance on material and process specifications and procedures for utilization of the material data presented in the handbook, and c) methodologies for the design, analysis, certification, manufacture, and field support of composite structures. In support of these objectives, the handbook includes composite materials properties that meet specific data requirements. The Handbook therefore constitutes an overview of the field of composites technology and engineering, an area that is advancing and changing rapidly. As a result, the document will be continually revised as sections are added or modified to reflect advances in the state-of-the-art.

CMH-17 Mission

The Composite Materials Handbook organization creates, publishes and maintains proven, reliable engineering information and standards, subjected to thorough technical review, to support the development and use of composite materials and structures.

CMH-17 Vision

The Composite Materials Handbook will be the authoritative worldwide focal point for technical information on composite materials and structures.

Goals and Objectives to Support CMH-17 Mission

- To periodically meet with experts from the field to discuss critical technical issues for composite structural applications, with an emphasis on increasing overall product efficiency, quality and safety.
- To provide comprehensive, practical engineering guidance that has proven reliable for the design, fabrication, characterization, test and maintenance of composite materials and structures.
- To provide reliable data, linked to control of processes and raw materials, thereby being a comprehensive source of material property basis values and design information that can be shared within the industry.
- To provide a resource for composite material and structure education with examples, applications and references to supporting engineering work.
- To establish guidelines for use of information in the Handbook, identifying the limitations of the data and methods.
- To provide guidance on references to proven standards and engineering practices.
- To provide for periodic updates to maintain the all-inclusive nature of the information.
- To provide information in formats best-suited for user needs.
- To serve the needs of the international composites community through meetings and dialogue between member industries, which use teamwork and the diverse member engineering skills to provide information for the handbook.

Notes

1. Every effort has been made to reflect the latest information on polymer (organic), metal, and ceramic composites. The handbook is continually reviewed and revised to ensure it is complete and current.
2. CMH-17 provides guidelines and material properties for polymer (organic), metal, and ceramic matrix composite materials. The first three volumes of this handbook currently focus on, but are not limited to, polymeric composites intended for aircraft and aerospace vehicles. Metal matrix composites (MMC), ceramic matrix composites (CMC) including carbon-carbon composites (C-C), and sandwich composites are covered in Volumes 4, 5, and 6, respectively.
3. The information contained in this handbook was obtained from materials producers, industry companies and experts, reports on Government sponsored research, the open literature, and by contract with research laboratories and those who participate in the CMH-17 coordination activity. The information in this handbook has undergone vigorous technical review and was subject to membership vote.
4. Beneficial comments (recommendations, additions, deletions) and any pertinent data which may be of use in improving this document should be addressed to: CMH-17 Secretariat, Materials Sciences Corporation, 135 Rock Road, Horsham, PA 19044, by letter or email, handbook@materials-sciences.com.

ACKNOWLEDGEMENT

Volunteer committee members from government, industry, and academia develop, coordinate and review all the information provided in this handbook. The time and effort of the volunteers and the support of their respective departments, companies, and universities make it possible to insure the handbook reflects completeness, accuracy, and state-of-the-art composite technology.

Support necessary for the development and maintenance of the Composite Materials Handbook (CMH-17) are provided by the handbook Secretariat, Materials Sciences Corporation. The primary source of funding for the current Secretariat contract is the Federal Aviation Administration.

SUMMARY OF CHANGES

Chapter	Section	Title	Change type / Proceedings
		Cover and Foreword	Ottawa Accelerated YPs (8/08)
1		<u>Guidelines</u>	
	1.1.6.1	Figure 1.1.6.1 Mechanical Property Notation	Ottawa Accelerated YP (8/08)
	1.1.7	Definitions: Batch (or lot), Lot	New/Revised - Ottawa PMC Accelerated YPs (8/08)
	1.2.3	Matrix materials Sections 1.2.3.3.2 and 1.3.3.3.4 are new	Revision - Monterey (2/03)
	1.2.4	Reinforcement materials Section 1.2.4.3 is new	Revision - Monterey (2/03)
	1.2.6.2.4	Squeeze casting and squeeze infiltration	Revision - Monterey (2/03)
	1.3.2.5	Data documentation requirements checklist	Revision - Monterey (2/03)
	1.3.4	Continuous fiber reinforced MMC constituent material properties	New – 7/2013
	1.3.4.1	Screening	New - Monterey (2/03)
	1.3.4.2	Acceptance testing of composite materials	Revised heading - Monterey (2/03)
	1.3.5.1	Screening	New - Monterey (2/03)
	1.3.5.2	Acceptance testing of composite materials	New - Monterey (2/03)
	1.3.5.2	Composite corrosion properties test	New - Monterey (2/03)
	1.4.2.2	Compression	Addition - Cleveland (7/02)
	1.4.8	Environmental effects test methods	New outline - Monterey (2/03)
	1.4.8.1	Corrosion and corrosion test methods 1.4.8.1.1 Static neutral spray salt 1.4.8.1.2 Corrosion testing, cyclic	Revised - Atlanta (11/05)
	1.6.2.1	Tensile tests	Revision - Cleveland (7/02)
	1.9.2.5	Fatigue crack growth	New -7/2013
2		<u>Design Guidelines for Metal Matrix Composites</u>	
	2.3.3.1.3	Residual stresses	New - Atlanta (11/05)
	2.3.3.1.4	Fiber-matrix bond strength	New - Atlanta (11/05)
	2.3.3.1.5	Overall inelastic strain	New - Atlanta (11/05)
	2.3.3.3	Macromechanics 2.3.3.3.1 Effective elastic properties 2.3.3.3.2 Effective strength 2.3.3.3.3 Creep	New - Atlanta (11/05)
3		<u>Materials Properties Data</u>	
	3.2.6.2	SCS-6 Fibers	New - Cleveland (7/02)

Chapter	Section	Title	Change type / Proceedings
	3.2.6.3	SCS-6 Fibers	New – 7/2013
	3.8.1	Introduction	Revision – 7/2013
	3.8.2.2	TRIMARC-1/Ti-6Al-2Sn-4Zr-2MO wire/fiber wound plate	Revision - Monterey (2/03)
	3.8.2.3	SCS-6/Ti-6Al-4V	New – 7/2013

Appendix A**Typical Pushout Test Data****Appendix B****Raw Data Tables for Matrix Materials****Appendix C****Raw Data Tables for Metal Matrix Composite Materials**

C4.2	TRIMARC-1/Ti6-2-4-2 (Section 3.8.2.2)	Revision - Monterey (2/03)
C4.3	SCS-6/Ti-6Al-4V (Section 3.8.2.3)	New – 7/2013

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1. GUIDELINES

1.1 GENERAL INFORMATION

This handbook documents engineering methodologies for the development of standardized, statistically-based material property data for continuous and discontinuous metal matrix composite (MMC) materials. Also provided are data summaries for a number of relevant composite material systems for which available data meets specific CMH-17 requirements for publication. Additionally, supporting engineering and manufacturing technologies and common practices related to composite materials are summarized.

1.1.1 INTRODUCTION

It is generally understood that standardized, statistically-based, material property data are essential to an efficient engineering development process; such data are needed by material suppliers, engineering users, and system end-users alike. Since the inherent properties of materials are independent of specific applications, data development methodologies and material property data are applicable to a wide variety of industries; they also form much of the technical basis for establishment of statistically-based design values acceptable to procuring or certifying agencies.¹ This evaluation of the inherent properties of composite materials, as shown in Figure 1.1.1, is the focus of CMH-17.

1.1.2 PURPOSE

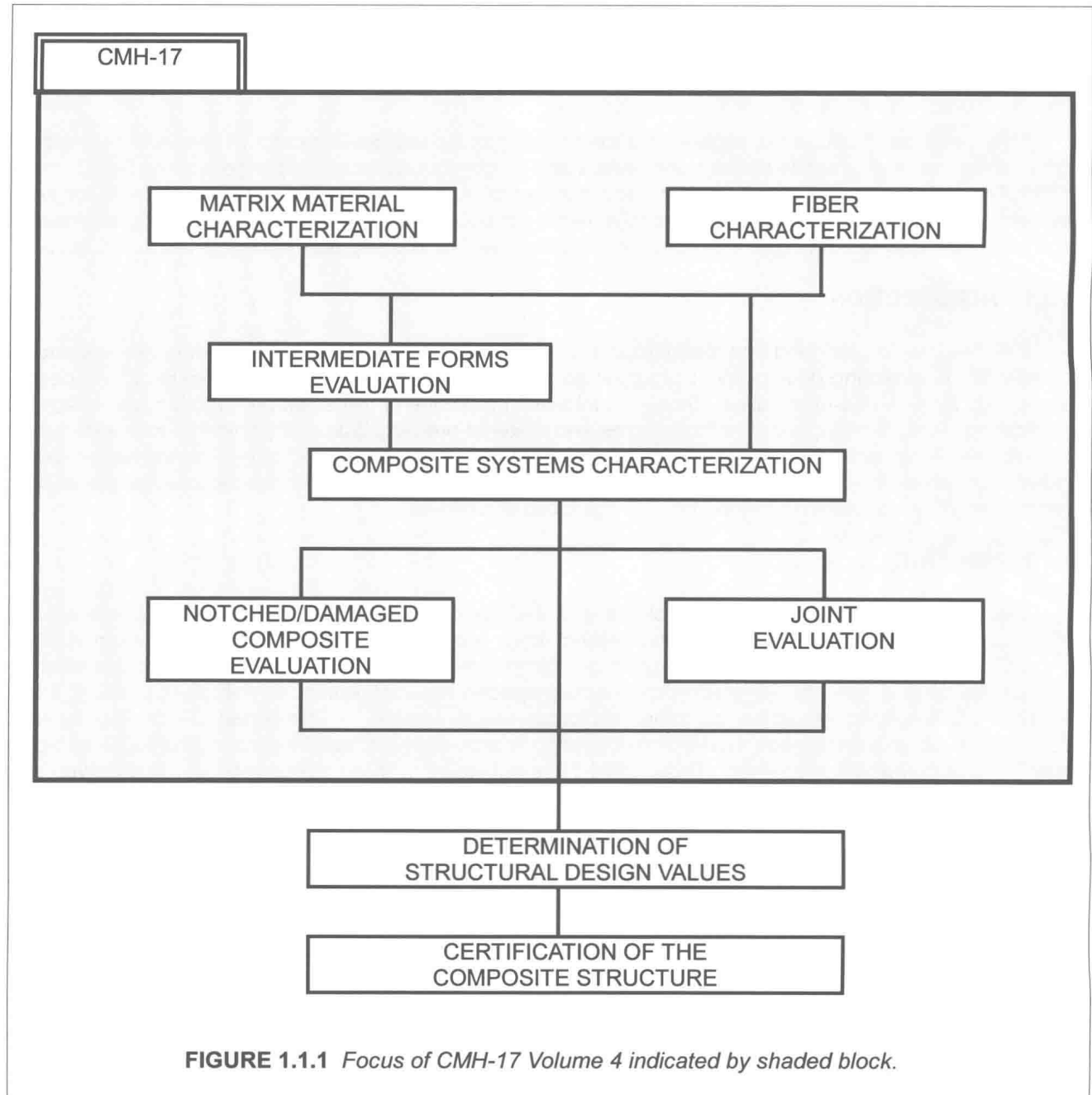
The primary purpose of CMH-17 Volume 4 is the standardization of engineering data development methodologies related to characterization testing, data reduction, and data reporting of properties for metal matrix composite materials. In support of this objective CMH-17 Volume 4 publishes properties on composite material systems for which data meeting specific requirements is available. In addition, CMH-17 provides selected guidance on other technical topics related to composites, including material selection, material specification, material processing, design, analysis, quality control, and repair of typical metal matrix composite materials. Thus, CMH-17 is published in three major sections, and serves as a source for the following:

- Section 1 - Guidelines: Documents material characterization data development methodology guidelines adaptable to a wide variety of needs, as well as specific requirements to be met by data published in the handbook. Most procuring and certifying agencies prefer, and some may require, that composite material systems used in critical applications either be characterized in accordance with Section 1 guidelines or selected from material systems published in Section 3.
- Section 2 – Design Guidelines for Metal Matrix Materials: This section provides guidance on statistical analysis of metal matrix composite data. In addition, methodologies and recommendations for design, modeling, joining, structural reliability, and repair are given.
- Section 3 - Material Property Data: Provides a repository of potential design data. The documented property summaries for material systems provide data meeting the criteria for any of the two CMH-17 data documentation classes, screening and fully approved.

1.1.3 SCOPE

Volume 4 of CMH-17 serves as a general Reference source for technical information on metal matrix composites, including:

¹An example of a procuring agency is a branch of the U.S. Department of Defense (DoD). An example of a certifying agency is an office of the Federal Aviation Administration (FAA).



1.1.3.1 Section 1: Guidelines

This Volume contains guidelines for determining the properties of composite material systems, their constituents, and generic structural elements, including test planning, test matrices, sampling, conditioning, test procedure selection, data reporting, data reduction, statistical analysis, and other related topics. Special attention is given to the statistical treatment and analysis of data. Section 1 contains guidelines for general development of material characterization data as well as specific requirements for publication of metal matrix composite material data in CMH-17.

It must be emphasized that this handbook differentiates between material basis values (material allowables) and design allowable values. Material basis values, being an intrinsic property of a composite material system, are the focus of this handbook. Design allowable values, while often rooted in material basis values, are application dependent, and consider and include specific additional considerations that