COMPOSITE MATERIALS HANDBOOK

Volume

1

Rev. H

Polymer Matrix Composites: Guidelines for Characterization of Structural Materials

CMH-17

COMPOSITE MATERIALS HANDBOOK

WSU | WICHITA STATE UNIVERSITY

SAE INTERNATIONAL

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CMH-17-1H
Volume 1 of 6
AUGUST 2022

Superseding
CMH-17-1G
MARCH 2012

COMPOSITE MATERIALS HANDBOOK

POLYMER MATRIX COMPOSITES
GUIDELINES FOR CHARACTERIZATION OF STRUCTURAL MATERIALS

VOLUME 1. Revision H

The underlying data from the work conducted under Cooperative Agreement Number 12-C-AM-WISU is publicly available and accessible at from the Defense Logistics Agency (DLA) Document Services, 700 Robbins Avenue, Philadelphia, PA 19111-5094.

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 to support new applications. As a result, the document will be continually revised as sections are added or modified to reflect advances in best industry practices.

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 the 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 dialog 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), and sandwich composites are covered in Volumes 4, 5, and 6, respectively. The organization is also developing a new Volume 7 for non-metallic additive manufacturing.

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, and deletions) and any pertinent data which may be of use in improving this document should be addressed to: CMH-17 Secretariat, Wichita State University, 1845 Fairmount, Wichita, KS 67260, by letter or email, info@cmh17.org.

ACKNOWLEDGEMENT

Committee members from government, industry, and academia develop, coordinate, and review all the information provided in this handbook. The time and effort of the members and the support of their respective departments, companies, and universities make it possible to ensure the handbook reflects completeness, accuracy, and industry best practices.

Support necessary for the development and maintenance of the Composite Materials Handbook (CMH-17) is provided by the Handbook Secretariat, Wichita State University. 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	Cover	CMH-17 Leadership Committee
	Foreword	Foreword	CMH-17 Leadership Committee
1		**Objectives**	
	1.4.1	Roadmaps for use of Volumes 1 - 3	Revision / Virtual (7/20)
	1.7.1.2	Laminae and laminates	Revision / Salt Lake City (3/15)
	1.8	Definitions	Revision and New / Salt Lake City (3/15, 3/17), Charleston (7/18), Salt Lake City (3/19)
2		**Guidelines for Property Testing of Composites**	
	ALL	Complete chapter revision	Revision / Salt Lake City (2/17), Charleston (7/18), Salt Lake City (3/19), virtual (7/20)
3		**Evaluation of Reinforcement Fibers**	
	ALL	Complete chapter revision	Revision / Salt Lake City (3/19), Wichita (10/19)
4		**Matrix Characterization**	
	ALL	Complete chapter revision	Revision / Salt Lake City (3/19), Virtual (7/20)
5		**Prepreg Material Characterization**	
	Chapter 5	Complete chapter revision	Revision / Wichita (11/17), Salt Lake City (3/19)
6		**Lamina, Laminate, and Special Form Characterization**	
	6.2	Specimen Preparation	Revision / Virtual (7/20)
	6.3	Conditioning and Environmental Exposure	Revision / Wichita (10/19), Virtual (7/20)
	6.4	Instrumentation and Calibration	Revision / Virtual (7/20)
	6.5	Testing Environments	Revision / Virtual (7/20)
	6.6	Thermal/Physical Property Tests	Revision / Wichita (11/17 and 10/19), Virtual (7/20)
	6.8	Static Uniaxial Mechanical Property Tests	Revision / Virtual (7/20)
	6.8.6	Fracture Toughness	revision / Virtual (7/20)
	6.11	Viscoelastic Properties Tests	Revision / Virtual (7/20)

Chapter	Section	Title	Change type / Proceedings
7		**Structural Element Characterization**	
	ALL	Complete chapter revision	Revision / Salt Lake City (3/19)
	7.6	Bonded joint tests	Revision / Virtual (7/20)
	7.8	High Load Rate and Dynamic Testing	New / Virtual (7/20)
8		**Statistical Methods**	
	8	References and examples to CMH-17 STATS updated throughout	
	8.3.7	Calculation of basis values for structured data using regression analysis	Revision / Salt Lake City (3/19), Virtual (7/20)
	8.4	Statistical Methods	Revision / Virtual (7/20)
	8.4.1	Methods to set material specification limits or determine equivalency between an existing database and a new dataset for the same material	Revision / Salt Lake City (3/19)
	8.4.2.2	Test method induced variability in comparing two groups	New / Virtual (3/21)
	8.4.7	General linear statistical models	Revision / Salt Lake City (3/19)

Contents

COMPOSITE MATERIALS HANDBOOK

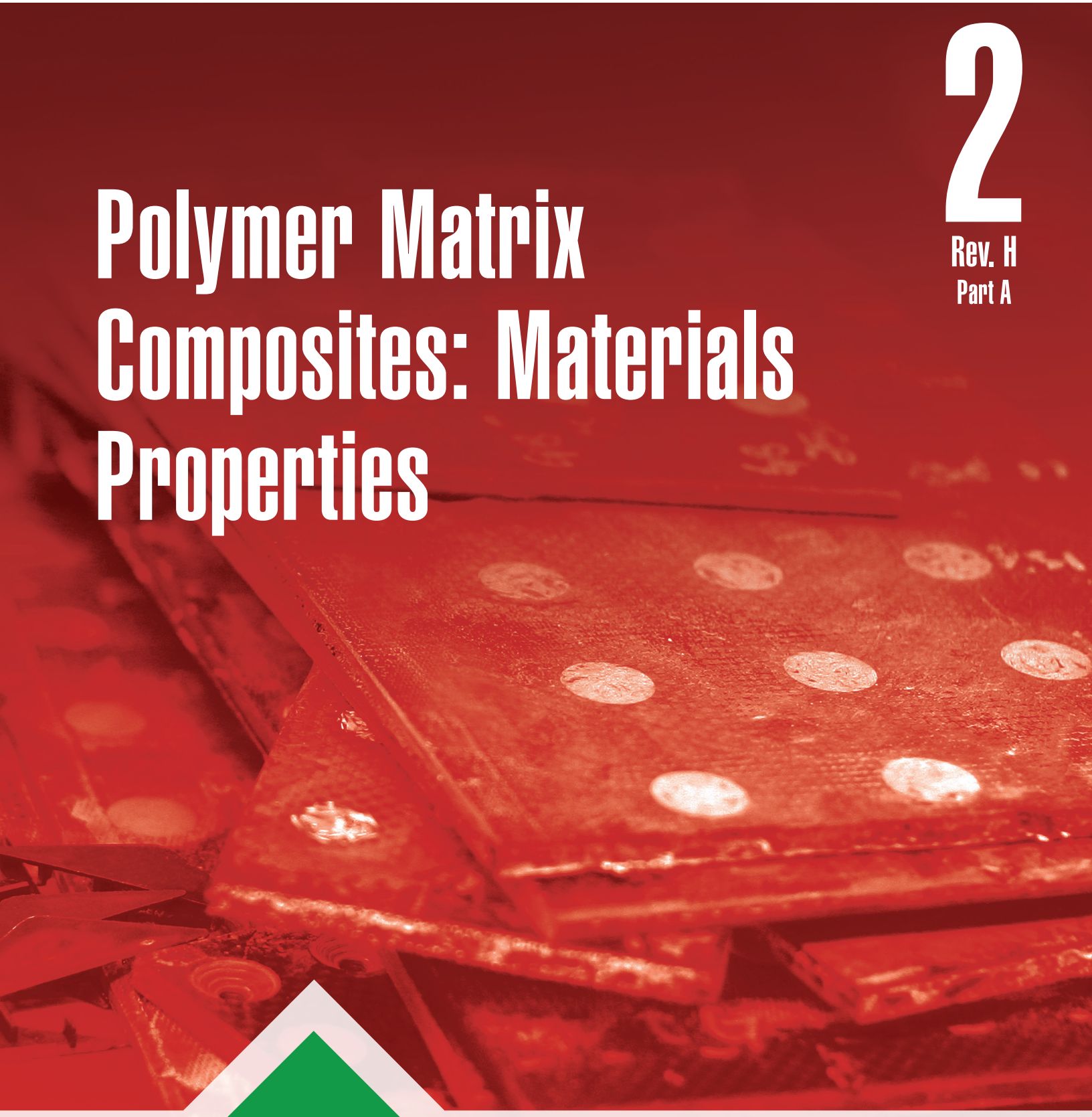
Volume

2

Rev. H

Part A

Polymer Matrix Composites: Materials Properties



CMH-17

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WSU Wichita State University

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CMH-17-2H
Volume 2 of 6
FEBRUARY 2018

SUPERSEDING
CMH-17-2G
Volume 2 of 6
17 JUNE 2012

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POLYMER MATRIX COMPOSITES: MATERIALS PROPERTIES

VOLUME 2. Rev. H/Part A

ISBN-Print 978-0-7680-9481-7

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TABLE OF CONTENTS

Page

Page

TABLE

FIGURE

Page

Page

SUMMARY OF CHANGES

Chapter	Section [old section #]	Title	Change type
1		**General Information**	
	1.7.1.2	Laminae and laminates	Revision/Salt Lake City (3/2015)
	1.8	Definitions	Revision and new/Salt Lake City (3/2015 and 3/2017)
	1.10 [Volume 1, Section 2.4]	Data Reduction and Documentation	Reorganization/Wichita (12/2013)
	1.11 [Volume 1, Section 2.5]	Material Testing for Submission of Data to CMH-17	Reorganization/Wichita (12/2013)
	1.12 [Volume 1, Section 2.3.7]	Data Substantiation for Use of Basis Values from CMH-17 or Other Large Databases	Reorganization/Wichita (12/2013)
2		**Carbon Fiber Properties**	
	2.2.1.3	AS4 12k/8552 Unidirectional Tape	New/Boston (8/2012)
	2.2.1.4	IM7 12k/8552 Unidirectional Tape	New/Supplemental YPs (3/2015)
	2.2.1.5	T650 6k/5320 Unidirectional Tape	New/Wichita (10/2015)
	2.2.1.6	IM7 12k/MTM45-1 Unidirectional Tape	New/Salt Lake City (3/2015)
	2.2.1.7	HTS40 12k/MTM45-1 Unidirectional Tape	New/Salt Lake City (3/2015)
	2.2.1.8	AS4 12k/MTM45-1 Unidirectional Tape	New/Salt Lake City (3/2015)
	2.2.1.9	IM7 12k/EP2202 Unidirectional Tape	New/Salt Lake City (3/2017)
	2.2.1.10	IM7 GP 12k/BT250E-6 Unidirectional Tape	New/St. Paul (8/2016)
	2.2.2.5	AS4 3k/8552 Plain Weave Fabric	New/Wichita (12/2013)
	2.2.2.6	HTS40 E13 3k/MTM45-1 Plain Weave Fabric	New/Miami (8/2014)
	2.2.2.7	T650 3k/5320-1 Plain Weave Fabric	New/Supplemental YPs (3/2015)
	2.2.2.8	HTS40/TC250 Plain Weave Fabric	New/Salt Lake City (3/2015)
	2.2.2.9	AS4C 3k/BT250-E Plain Weave Fabric	New/St. Paul (8/2016)
	2.2.2.10	T650/EP2202 Plain Weave Fabric	New/Salt Lake City (3/2017)

CHAPTER 1 GENERAL INFORMATION

Table of Contents

COMPOSITE MATERIALS HANDBOOK

Volume

2

Rev. H

Part B

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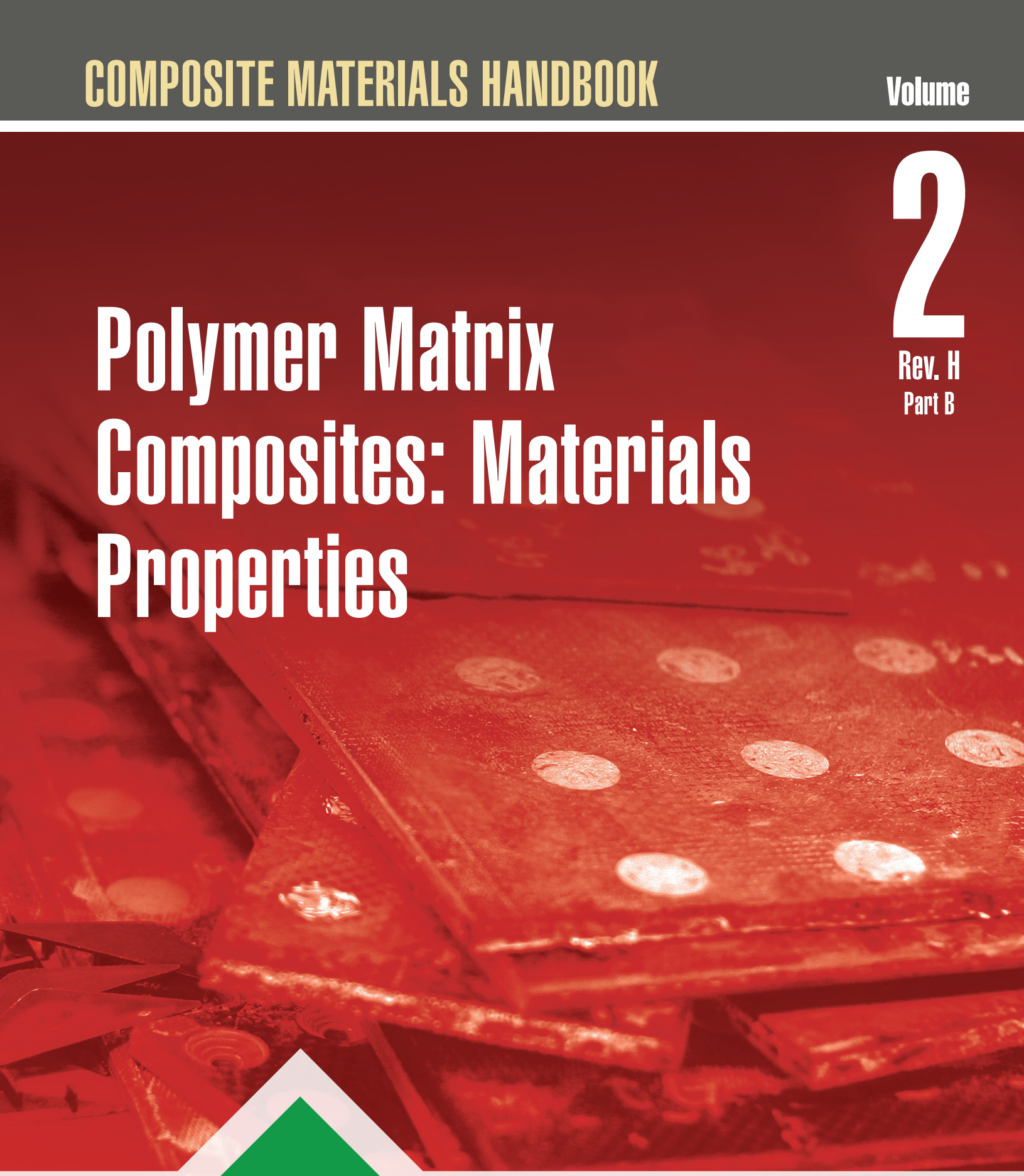

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TABLE OF CONTENTS

Page

SUMMARY OF CHANGES

Chapter	Section [old section #]	Title	Change type
2		**Carbon Fiber Properties**	
	2.3.2.15 [2.2.2.4]	AS4C 3k/HTM45 8-Harness Satin Fabric	Reorganization
	2.3.2.16 [2.2.2.5]	AS4C 3k/HTM45 Plain Weave Fabric	Reorganization
4		**Glass Fiber Composites**	
	4.2.1.1	S-2 Glass/BT250E-6 Unidirectional Tape	New/St. Paul (8/2016)
	4.2.2.2	6781 S-2 Glass/MTM45-1 8-Harness Satin Weave Fabric	New/Miami (8/2014)
	4.2.2.3	E-Glass 7781/MTM45-1 8-Harness Satin Weave Fabric	New/Supplemental YPs (3/2015)

CHAPTER 2B CARBON FIBER COMPOSITES

Table of Contents

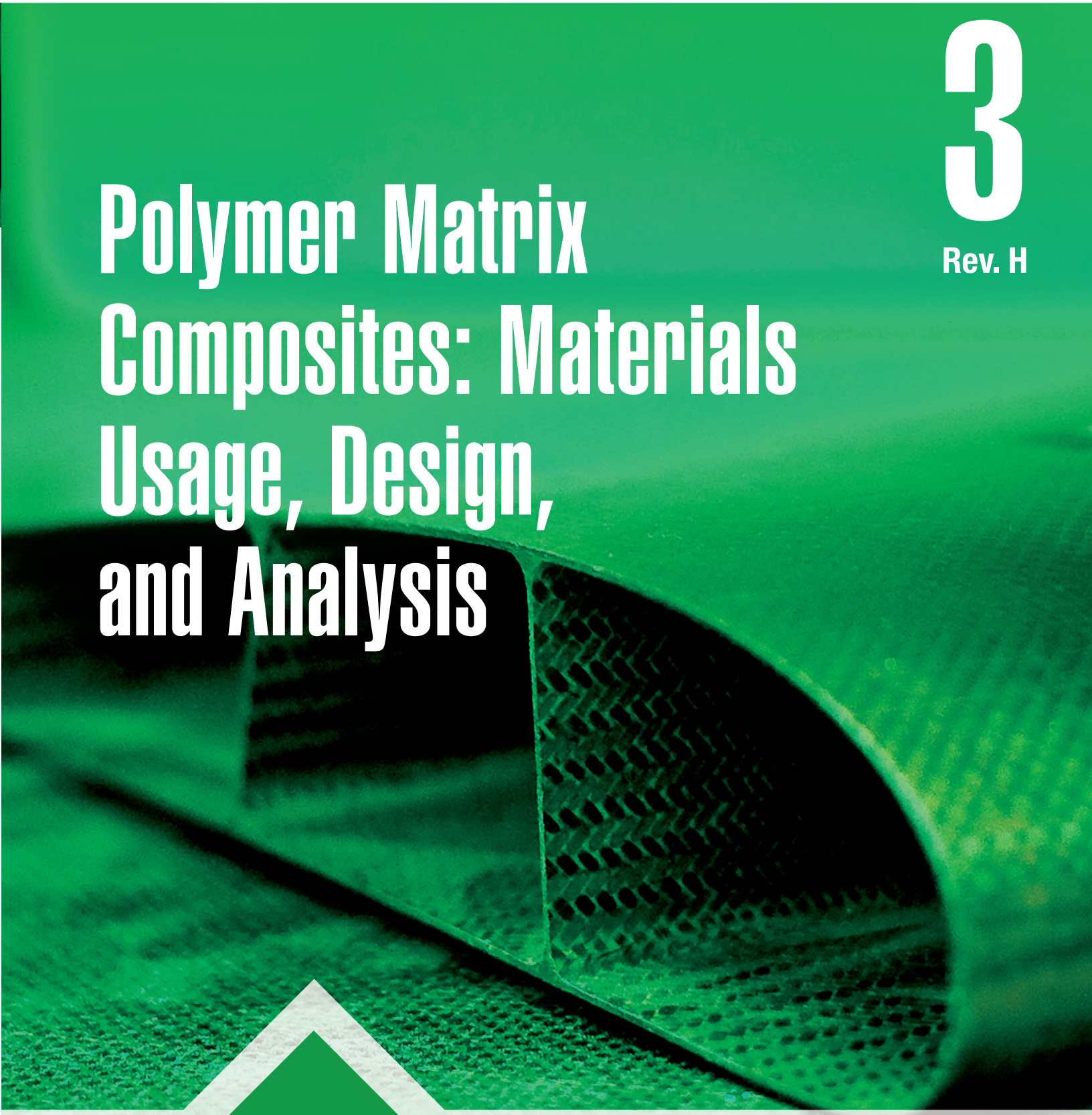
COMPOSITE MATERIALS HANDBOOK

Volume

3

Rev. H

Polymer Matrix Composites: Materials Usage, Design, and Analysis



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COMPOSITE MATERIALS HANDBOOK

VOLUME 3. POLYMER MATRIX COMPOSITES MATERIALS USAGE, DESIGN AND ANALYSIS

FOREWORD

The Composite Materials Handbook (CMH-17) provides information and guidelines necessary to design, fabricate, and maintain components from composite and non-metallic additively manufactured (AM) materials. Its primary purposes are to provide:

a) Rigorously reviewed material property data linked to publicly available material and process specifications,

b) Guidelines and recommendations for material and process controls and methods for testing, data reduction, and reporting material data, and

c) 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.

In support of these purposes, the handbook is written for aerospace applications, although other applications can benefit as well. This handbook constitutes an overview of the field of advanced materials technology and engineering. It is continually updated to reflect industry advancements.

SUMMARY

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 constructions.

CMH-17 ORGANIZATION

The Composite Materials Handbook organization creates, publishes, and maintains pedigreed material data as well as proven engineering information, subjected to thorough technical review, to support the development and use of advanced materials and structures in aerospace applications.

VISION

The Composite Materials Handbook is the authoritative worldwide focal point for technical information on composite and non-metallic additively manufactured materials and structures in aerospace applications.

GOALS AND OBJECTIVES

- Provide comprehensive, practical engineering guidelines that have proven reliable for the design, fabrication, characterization, test, and maintenance of composites and non-metallic AM in aerospace applications
- Provide reliable data, linked to control of processes and raw materials, thereby being a source of material property basis values and design information that satisfies the needs of the aerospace industry
- Provide content, 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
- Promote safe use of composites and non-metallic AM in aerospace applications
- Promote efficient methods for design, test, analysis, and quality assurance of composite and non-metallic AM materials and structures
- Provide educational resources through both the handbook content and in-person training/content review
- Establish relationships with other standards organizations and engineering handbooks with similar goals to jointly develop and maintain consistent information

ACKNOWLEDGEMENT

Committee members from government, industry, and academia develop, coordinate, and review all the information provided in this handbook. The time and effort of the members and the support of their respective departments, companies, and universities make it possible to ensure the handbook reflects completeness, accuracy, and industry best practices.

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OVERVIEW OF HANDBOOK CONTENT

Composite Materials Handbook 17 is composed of a series of seven volumes.

Volume 1: Polymer Matrix Composites - Guidelines for Characterization of Structural Materials

Volume 1 contains guidelines for determining the properties of polymer matrix composite material systems and their constituents, as well as the properties of 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. Volume 1 contains guidelines for general development of material characterization data as well as specific requirements for publication of material data in CMH-17.

Volume 2: Polymer Matrix Composites - Material Properties

Volume 2 contains statistically-based data for polymer matrix composites that meets specific CMH-17 population sampling and data documentation requirements. As of the publication of Revision G, data published in Volume 2 are under the jurisdiction of the Data Review Working Group and are approved by the overall CMH-17 Coordinating Committee. New material systems will be included and additional material data for existing systems will be added as data becomes available and are approved. Selected historical data from

previous versions of the handbook that do not meet current data sampling, test methodology, or documentation requirements, but that still are of potential interest to industry are also included in this volume.

Volume 3: Polymer Matrix Composites - Materials Usage, Design, and Analysis

Volume 3 provides proven methodologies and lessons learned for the design, analysis, manufacture, and field support of fiber-reinforced, polymeric-matrix composite structures. It also provides guidelines on material and process specifications and procedures for utilization of the data presented in Volume 2. The information provided is consistent with the guidance provided in Volume 1 and is an extensive compilation of the current knowledge and experiences of the engineers and scientists who are active in composites from industry, government, and academia.

Volume 4: Metal Matrix Composites

Volume 4 publishes properties on metal matrix composite material systems for which data meeting the specific requirements of the handbook are available. In addition, it provides selected guidance on other technical topics related to this class of composites, including material selection, material specification, processing, characterization testing, data reduction, design, analysis, quality control, and repair of typical metal matrix composite materials.

Volume 5: Ceramic Matrix Composites

Volume 5 publishes properties on ceramic matrix composite material systems for which data meeting the specific requirements of the handbook are available. In addition, it provides selected guidance on other technical topics related to this class of composites, including material selection, material specification, processing, characterization testing, data reduction, design, analysis, quality control, and repair of typical ceramic matrix composite materials.

Volume 6: Polymer Matrix Composites - Sandwich Structures

Volume 6 is an update to the cancelled Military Handbook 23, which was prepared for use in the design of structural sandwich polymer composites, primarily for flight vehicles. The information presented includes test methods, material properties, design and analysis techniques, fabrication methods, quality control and inspection procedures, and repair techniques for sandwich structures in both military and commercial vehicles. As of the time of this writing, this volume is undergoing extensive revision to add content on design, material properties, testing, and case studies.

Volume 7: Non-Metallic Additive Manufacturing

Volume 7 provides the best technical guidance available on properties, design, manufacture, and use of non-metallic AM parts. It includes material properties data meeting the specific requirements of the handbook where such data is available and provides practical technical information on the design and manufacture of non-metallic AM parts. The volume focusses on the use of non-metallic AM parts in regulated applications such as civil aviation. At the time of this writing, Volume 7 is in final preparation and publication.

Volume 3 Contents

CHAPTER 1 GENERAL INFORMATION

CHAPTER 2 INTRODUCTION TO COMPOSITE STRUCTURE DEVELOPMENT

CHAPTER 3 AIRCRAFT STRUCTURE CERTIFICATION AND COMPLIANCE

CHAPTER 4 BUILDING BLOCK APPROACH FOR COMPOSITE STRUCTURES

CHAPTER 5 MATERIALS AND PROCESSES – THE EFFECTS OF VARIABILITY ON COMPOSITE PROPERTIES

CHAPTER 6 QUALITY CONTROL OF PRODUCTION MATERIALS AND PROCESSES

CHAPTER 7 DESIGN OF COMPOSITE STRUCTURES

CHAPTER 8 ANALYSIS OF LAMINATES

CHAPTER 9 STRUCTURAL STABILITY ANALYSIS

CHAPTER 10 DESIGN AND ANALYSIS OF BONDED JOINTS

CHAPTER 11 DESIGN AND ANALYSIS OF BOLTED JOINTS

CHAPTER 12 DAMAGE RESISTANCE, DURABILITY, AND DAMAGE TOLERANCE

CHAPTER 13 DEFECTS, DAMAGE AND INSPECTION

CHAPTER 14 SUPPORTABILITY, MAINTENANCE, AND REPAIR

CHAPTER 15 THICK-SECTION COMPOSITES

CHAPTER 16 CRASHWORTHINESS AND ENERGY MANAGEMENT

CHAPTER 17 STRUCTURAL SAFETY MANAGEMENT

CHAPTER 18 ENVIRONMENTAL MANAGEMENT

CHAPTER 19 LAUNCH VEHICLES AND SPACECRAFT

CHAPTER 20 ENGINE APPLICATIONS

Contents

COMPOSITE MATERIALS HANDBOOK

Volume

4

Metal Matrix Composites

CMH-17

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COMPOSITE MATERIALS HANDBOOK

VOLUME 4. METAL MATRIX COMPOSITES

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PARAGRAPH PAGE

TABLE OF CONTENTS

PARAGRAPH PAGE

PARAGRAPH PAGE

PARAGRAPH PAGE

PARAGRAPH PAGE

PARAGRAPH PAGE

PARAGRAPH PAGE

PARAGRAPH PAGE

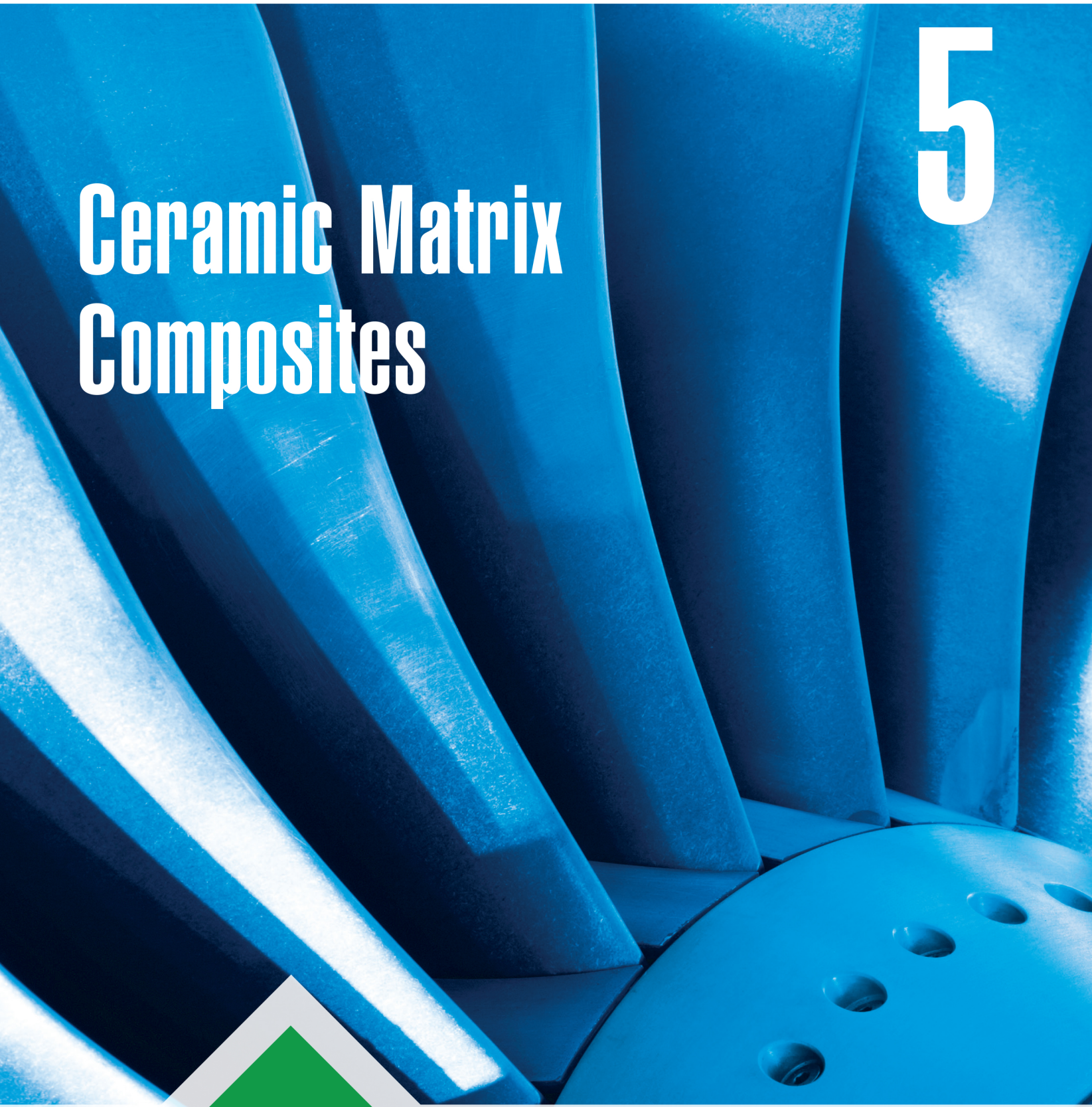
PARAGRAPH PAGE

COMPOSITE MATERIALS HANDBOOK

Volume

5

Ceramic Matrix Composites



CMH-17

COMPOSITE MATERIALS HANDBOOK

WICHITA STATE UNIVERSITY
NATIONAL INSTITUTE FOR AVIATION RESEARCH

SAE INTERNATIONAL®

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CMH-17-5A
Volume 5 of 6
1 JUNE 2017

Superseding
MIL-HDBK-17-5
17 JUNE 2002

COMPOSITE MATERIALS HANDBOOK

VOLUME 5. CERAMIC MATRIX COMPOSITES

WICHITA STATE UNIVERSITY
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SAE INTERNATIONAL

Published by SAE International on behalf of CMH-17,
a division of Wichita State University

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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.
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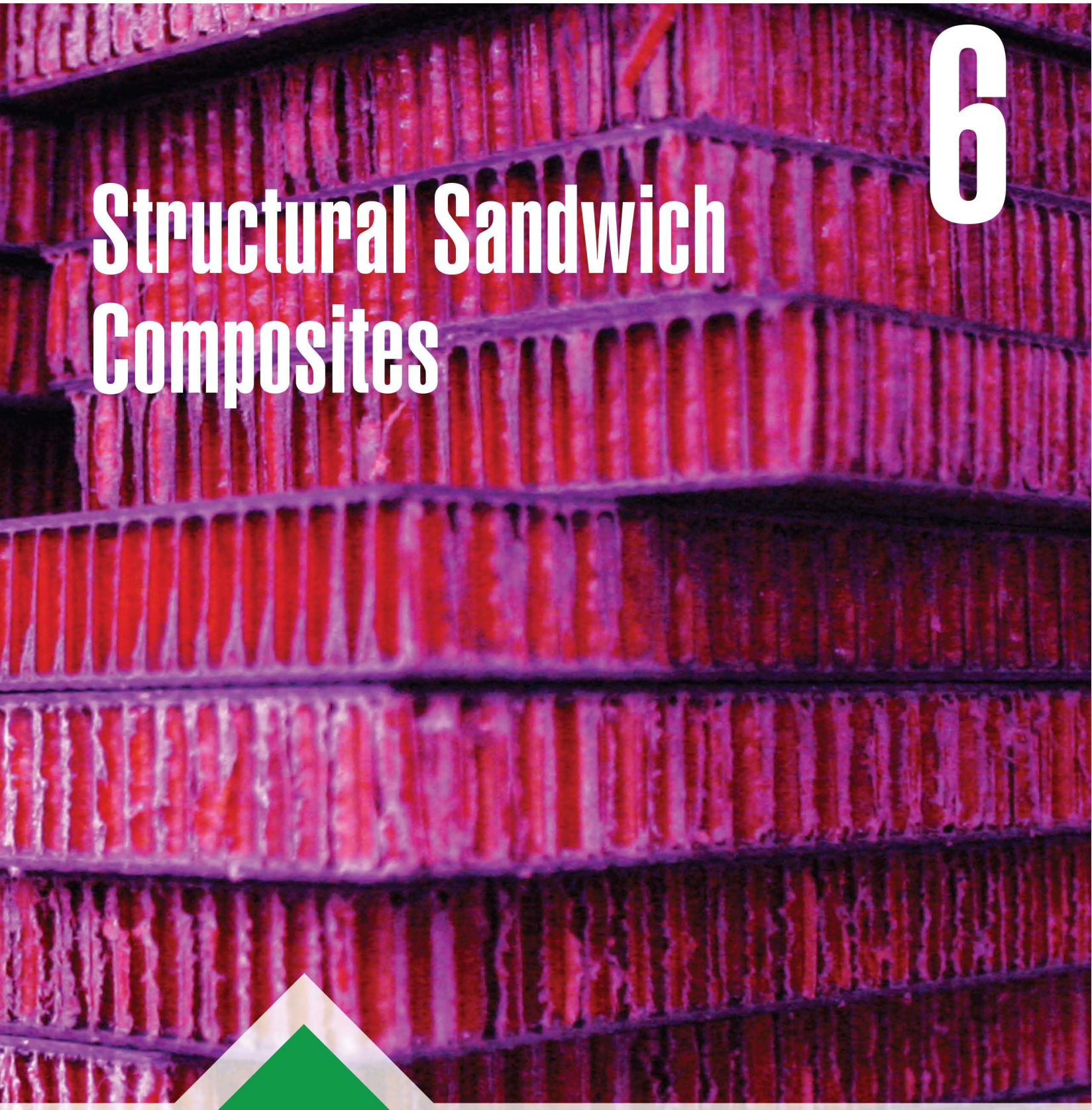
CONTENTS

COMPOSITE MATERIALS HANDBOOK

Volume

6

Structural Sandwich Composites



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COMPOSITE MATERIALS HANDBOOK

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CMH-17-6
Volume 6 of 6
July 2013

COMPOSITE MATERIALS HANDBOOK

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TABLE OF CONTENTS

Page