Metallic Materials Properties Development and Standardization (MMPDS)

MMPDS-08

Chapter 5 – TITANIUM ALLOYS

April 2013

Scientific Source:
Metallic Materials design data acceptable to Government procuring or certification agencies.

A joint effort of government, industrial, educational, and international aerospace organizations.

FOREWORD

The Metallic Materials Properties Development and Standardization (MMPDS) Handbook, is an accepted source for metallic material and fastener system allowables recognized by the Federal Aviation Administration (FAA), all Departments and Agencies of the Department of Defense (DoD), and the National Aeronautics and Space Administration (NASA) within the limitations of the certification requirements of the specific government agency. Some of these limitations are noted below.

Federal Aviation Administration:
Per guidance provided by FAA Advisory Circular (AC) 25.613-1 and FAA policy memorandum PS-AIR100-2006-MMPDS, the 'A' and 'B' basis values published for materials in the MMPDS have been determined by the FAA to satisfy the material strength probability levels required by Title 14 of the Code of Federal Regulations (14 CFR) §§ 27.613(d), § 29.613(d), §25.613(b) and § 23.613(b). These values can be used to demonstrate compliance with the static strength requirements of 14 CFR without further showing. Other data provided (e.g. S-basis properties, fatigue, crack growth, stress-strain curves) in the Handbook might be used for design following FAA ACs and policy. The final determination on their applicability rests with the civil aviation authority responsible for finding compliance for the particular aircraft system on a case-by-case basis.

DoD:
Per guidance provided in the Joint Service Specification Guide (JSSG) 2006 and MIL-STD-1530, the "A" and "B" basis design allowables published for materials in the MMPDS have been determined by Department of Defense (DoD) services to satisfy the strength and statistical variability requirements for airframe metallic materials. Other data (e.g. S-basis properties, fatigue, crack growth, stress-strain curves) in the Handbook may be used for design. However, the final determination of the acceptability of data rests with the cognizant design authority responsible for finding compliance for the particular aircraft system.

MMPDS-08 supersedes MMPDS-07 and prior editions of the MMPDS Handbook as well as all editions of MIL-HDBK-5, Metallic Materials and Elements for Aerospace Vehicle Structures Handbook that was maintained by the U.S. Air Force. The last edition, MIL-HDBK-5J was cancelled by the U.S. Air Force in March 2006.

This document contains design information on the mechanical and physical properties of metallic materials and joints commonly used in aircraft and aerospace vehicle structures. All information contained in this Handbook has been reviewed and approved using a standardized process. The development and ongoing maintenance process involves certifying agencies, including the FAA, DoD, and NASA, and major material suppliers and material users worldwide. The information and procedures in this Handbook are continuously reviewed, and modified or removed as determined to be appropriate. With advances in materials and fastener systems, and with the review process of existing information, periodic updates of the MMPDS should be expected. As such, it is recommended that the latest version of the MMPDS be used.

The allowables contained in the published document, or from approved minutes of the Metallic Materials Properties Development and Standardization (MMPDS) handbook coordination meetings, are

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Beneficial comments (recommendations, additions, deletions) and any pertinent data that may be of use in improving this document should be addressed to Secretariat, MMPDS Coordination Activity (614-424-6496 voice or bcommpds@battelle.org email), Battelle, MMPDS, 505 King Avenue, Columbus, OH 43201. You may also contact the Secretariat through the handbook website, www.mmpds.org.

This Handbook has been approved for public release with unlimited distribution.

Preparing activity:
FAA - William J. Hughes Technical Center

EXPLANATION OF NUMERICAL CODE

For chapters containing materials properties, a deci-numeric system is used to identify sections of text, tables, and illustrations. This system is explained in the examples shown below. Variations of this deci-numerical system are also used in Chapters 1, 8, and 9.

Example A 2.4.2.1.1

General material category (in this case, steel)

A logical breakdown of the base material by family characteristics (in this case, intermediate alloy steels); or for element properties

Particular alloy to which all data are pertinent. If zero, section contains comments on the family characteristics

If zero, section contains comments specific to the alloy; if it is an integer, the number identifies a specific temper or condition (heat treatment)

Type of graphical data presented on a given figure (see following description)

Example B 3.2.3.1.X

Aluminum

2000 Series Wrought Alloy

2024 Alloy

T3, T351, T3510, T3511, T4, and T42 Tempers

Specific Property as Follows

Tensile properties (ultimate and yield strength)	1
Compressive yield and shear ultimate strengths	2
Bearing properties (ultimate and yield strength)	3
Modulus of elasticity, shear modulus	4
Elongation, total strain at failure, and reduction of area	5
Stress-strain curves, tangent-modulus curves	6
Creep	7
Fatigue	8
Fatigue-Crack Propagation	9
Fracture Toughness	10

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REGISTERED TRADEMARKS

Trademark	Registered by	Chemistry	UNS Number
15-5PH®	AK STEEL CORP.	15Cr - 4.6Ni - 0.22Cb - 2.8Cu	J92110
		15Cr - 4.5Ni - 0.30Cb - 3.5Cu	S15500
17-4-PH® [1]	ARMCO INC. CORP.	16Cr - 4.1Ni - 0.28Cb - 3.2Cu	J92200
		16.5Cr - 4.0Ni - 4.0Cu - 0.30Cb	S17400
17-7PH®	ARMCO INC. CORP	17Cr-7.1Ni-1.1Al	J17700
ACRES® sleeves	CLICK BOND, INC.	NA	NA
AerMet® 100	CRS HOLDINGS INC.	3.1Cr-11.5Ni-13.5Co-1.2Mo (0.21 - 0.25C)	K92580
AM-350™	ALLEGHENY LUDLUM CORP.	16.5Cr - 4.5Ni - 2.9Mo - 0.10N	S35000
AM-355™	ALLEGHENY LUDLUM CORP.	15.5Cr - 4.5Ni - 2.0Mo - 0.10N	S35500
Cherry®	TEXTRON FASTENING SYSTEMS, INC.	NA	NA
Cherrybucks®	TEXTRON FASTENING SYSTEMS, INC.	NA	NA
Custom450®	CRS HOLDINGS INC.	15Cr - 6.5Ni - 0.75Mo - 0.30 (Cb + Ta) - 1.5Cu	S45000
Custom455®	CRS HOLDINGS INC.	12Cr-8.5Ni-2.0Cu-1.1Ti	S45500
Custom465®	CRS HOLDINGS INC.	6A1- 6V - 2SN	none
Ferrium® S53®	QUES TEK INNOVATIONS LLC	10Cr-5.5Ni-14Co-2Mo-1W (0.19-0.23C)	S10500
Ferrium® M54™	QUES TEK INNOVATIONS LLC	1Cr-10Ni-7Co-2Mo-1.3W (0.28-0.32C)	K91973
Hastelloy® X	HAYNES INTERNATIONAL, INC.	47.5Ni-22Cr-1.5Co-9.0Mo	N06002
Elektron® 21	MAGNESIUM ELEKTRON	EV31A	Similar to M12310
HAYNES®	HAYNES INTERNATIONAL, INC.	NA	NA
230®	HAYNES INTERNATIONAL, INC.	59Ni-22Cr-2Mo-14W-0.35Al	N06230
Hi-Lok®	HI-SHEAR CORP.	NA	NA
Hi-Shear®	HI-SHEAR CORP.	NA	NA
HR-120®	HAYNES INTERNATIONAL, INC.	35Fe - 24Cr - 37Ni - 0.65Cb - 0.2N	N08120
HSL180™	HITACHI METALS AND SUMITOMO PRECISION PRODUCTS	12.5Cr-1.0Ni-15.5Co-2.0Mo	NA

[1] Shown in the customary form of 17-4PH in the Handbook.

Trademark	Registered by	Chemistry	UNS Number
INCONEL®	HUNTINGTON ALLOYS CORP.	NA	NA
MP159®	SPS TECHNOLOGY	19Cr - 36Co - 25Ni - 7.0Mo - 0.50Cb - 2.9Ti - 0.20Al - 9.0Fe	R30159
MP35N®	SPS TECHNOLOGY	20Cr - 35Ni - 35Co - 10Mo	R30035
PH13-8® Mo	ARMCO INC. CORP.	13Cr-8.0Ni-2.2Ni-1.1Al	S13800
PH15-7® Mo	ARMCO INC. CORP.	15Cr - 7.1Ni - 2.5Mo - 1.1A1	S15700
RENE´ ® 41	TELEDYNE INDUSTRIES INC.	54Ni - 19Cr - 11Co - 9.8Mo - 3.2Ti - 1.5Al - 0.006B	N0704
ToughMet® 3	MATERION BRUSH INC.	77Cu-15Ni-8Sn	C72900

CHAPTER 5 - CONTENTS

CONTENTS

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CHAPTER 5

TITANIUM

5.1 GENERAL

This chapter contains the engineering properties and related characteristics of titanium and titanium alloys used in aircraft and missile structural applications.

General comments on engineering properties and the considerations relating to alloy selection are presented in Section 5.1. Mechanical- and physical-property data and characteristics pertinent to specific alloy groups or individual alloys are reported in Sections 5.2 through 5.5.

Titanium is a relatively lightweight, corrosion-resistant structural material that can be strengthened greatly through alloying and, in some of its alloys, by heat treatment. Among its advantages for specific applications are: good strength-to-weight ratio, low density, low coefficient of thermal expansion, good corrosion resistance, good oxidation resistance at intermediate temperatures, good toughness, and low heat-treating temperature during hardening, and others.

5.1.1 TITANIUM INDEX — The coverage of titanium and its alloys in this chapter has been divided into four sections for systematic presentation. The system takes into account unalloyed titanium and three groups of alloys based on metallurgical differences which in turn result in differences in fabrication and property characteristics. The sections and the individual alloys covered under each are shown in Table 5.1.

Table 5.1. Titanium Alloys Index

Section	Alloy Designation
5.2	**Unalloyed Titanium**
5.2.1	Commercially Pure Titanium
5.3	**Alpha and Near-Alpha Titanium Alloys**
5.3.1	Ti-5A1-2.5Sn (Alpha)
5.3.2	Ti-8A1-1Mo-1V (Near-Alpha)
5.3.3	Ti-6A1-2Sn-4Zr-2Mo (Near-Alpha)
5.4	**Alpha-Beta Titanium Alloys**
5.4.1	Ti-6A1-4V
5.4.2	Ti-6A1-6V-2Sn
5.4.3	Ti-4.5Al-3V-2Fe-2Mo
5.4.4	Ti-4Al-2.5V-1.5Fe
5.5	**Beta, Near-Beta, and Metastable Titanium Alloys**
5.5.1	Ti-13V-11Cr-3A1
5.5.2	Ti-15V-3Cr-3Sn-3A1
5.5.3	Ti-10V-2Fe-3A1

5.1.2 MATERIAL PROPERTIES — The material properties of titanium and its alloys are determined mainly by their alloy content and heat treatment, both of which are influential in determining the allotropic forms in which this material will be bound. Under equilibrium conditions, pure titanium has an "alpha" structure up to 1620°F, above which it transforms to a "beta" structure. The inherent properties of these two structures are quite different. Through alloying and heat treatment, one or the other or a combination of these two structures can be made to exist at service temperatures, and the properties of the material vary