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THE MMPDS DATA, A REVIEW

The information presented in this document is offered on a best effort basis. Accordingly, recipients are hereby urged to consult with the appropriate authorities / organizations.

1.0 Methods for Generating Design Values (AKA Allowables)

The MMPDS utilizes two methods for generating the mechanical property values listed in the various Tables; viz., the direct and indirect methods. It is always preferable to use the direct method, in spite of the fact that it requires a considerably larger number of data points. Frequently, however, only few data points exist and the cost of generating the required database by the direct method is prohibitive. In such cases, the indirect method has to be used.

1.1 The direct method: The direct method relies solely on actual test results, obtained by material producers, users and / or independent test facilities. Generating A or B design values by this method requires a large number of data points from several heats, to enable the adequate statistical characterization of property variability; 100-299 data points would be required, depending on the statistical distribution of the property in question. Generating S values, by contrast, requires considerably fewer (around 30) data points. [(1)] For specific requirements, the reader is referred to the MMPDS.

1.2 The indirect method: The indirect method requires only as few as 10 data points (10 lots from 2 heats). In this method, F_{cy}, F_{su}, F_{bru} and F_{bry} are "paired" with the tensile properties, F_{tu} or F_{ty}, determined in the same region of the product, to produce a ratio. Statistical analyses of these ratios are conducted to obtain lower bound estimates of the relationship between the primary property (F_{tu} or F_{ty}) and the ratiod property. These ratios are then multiplied by the appropriate Handbook allowable (F_{tu} or F_{ty}) to obtain the F_{cy}, F_{su}, F_{bru} or F_{bry}, as applicable. [(2)] The property values determined by the indirect method are referred to as "derived values," and they have the same basis (A, B or S) as the primary property used for their determination. For specific requirements, the reader is referred to the MMPDS.

2.0 Property Values in the MMPDS

The following is a comprehensive summary of the types of property values (A, B and S) listed in the various MMPDS Tables and the data presented in the various MMPDS graphs, together with the methods by which they are generated. The information presented is oriented towards wrought alloys. Where appropriate, however, information on cast alloys is inserted.

2.1 The primary strength properties (F_{tu}, F_{ty}, F_{cy}, F_{su}, F_{bru} and F_{bry}) listed in the various Tables are minimum room temperature values, established on A, B and / or S basis.

2.1.1 Due to the large database available, it is possible, in most cases, to generate A and B values for F_{tu} and F_{ty} in the longitudinal direction, using the direct method (1.1); see sidebar titled "Material Specifications & Property Database." In general, therefore, the longitudinal F_{tu} and F_{ty} values listed in the Tables are A and B values. Where the database is not large enough to generate A and B values, S values are listed instead. This is generally the case for cast alloys [(3)] and for the less frequently used wrought alloys. Occasionally, however, S values are listed side-by-

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[(1)] This procedure was adopted ~ 1975, by SAE, for AMS specifications. It is described in part F of the SAE / AMS Editorial Style Manual for the Preparation of Aerospace Material Specifications (AMS) Metals and Processes and Nonmetallic Materials. The procedure provides a level of statistical significance to S-Basis property values contained within Mil-HDBK-5 and then the MMPDS. Prior to ~ 1975, the S-values listed in Mil-HDBK-5 were generally the minimum values specified in the referenced specifications; these were generally negotiated with supplies, before incorporation in specifications. The statistical significance to these S values is typically not known. To this day, however, some of the S-values in the MMPDS are specification minima.

[(2)] *Note that the compression, shear and bearing property values listed in the MMPDS are considerably lower than the raw data obtained in actual testing, by virtue of (a) the statistical treatment of the ratios to obtain lower bounds, and (b) the fact that the primary properties used (F_{tu} or F_{ty}) are taken from the MMPDS, meaning that they have been themselves statistically treated.*

[(3)] *For example, the S values listed for cast Inconel 718 (AMS 5383) and cast aluminum alloys (Mil-A-21180 / AMS-A-21180) are specification minima. Unfortunately, however, not all the cast materials specifications referenced in the MMPDS were available for a detailed review. It is important to note here that Mil-A-21180 / AMS-A-21180, now inactive, required that production lot acceptance be based on testing of specimens excised from castings. As to AMS 5383, the use of specimens excised from castings is required only for preproduction testing. For lot acceptance, separately or integrally cast specimens are used. No tensile testing is required for periodic testing.*

side with A and / or B values. This is the case for many wrought alloys and for D357.0 and E357.0 cast aluminum alloys. [(4)] More information on casting alloys can be found in the sidebar titled "Casting Alloys in the MMPDS."

2.1.2 Some of the long and short transverse F_{tu} and F_{ty} data listed in the Tables are derived, whereas others are determined by the direct method (1.1), depending on the number of data points available for each particular case; see sidebar titled "Material Specifications & Property Database."

2.1.3 Due to a certain lack of data, F_{cy}, F_{su}, F_{bru} and F_{br} values listed in the Tables are derived values, determined by the indirect method (1.2); see sidebar titled "Material Specifications & Property Database."

2.2 The strength properties at temperatures other than ambient, presented in the various graphs, are derived properties, determined by the indirect method (1.2), and presented as fractions of the room temperature values.

2.3 All derived properties are regarded as having the same basis as the property that they were derived from.

2.4 The tensile e% and RA% properties listed in the Tables are minimum room temperature values, except that they are presented on an S basis only. This is because the determination of these properties is generally performed by approximate means that can lead to excessive scatter.

2.5 The tensile e% and RA% properties at temperatures other than ambient, the elastic (E, E_c, G, and μ), and physical (ω, C, K, and α), fatigue, creep, and fracture toughness properties listed in Tables or presented in graphs, are typical values, unless a basis is specifically indicated.

Material Specifications & Property Database

For quality conformance purposes, material specifications normally impose room temperature tensile property requirements (particularly for F_{tu}, F_{ty}). This is due to fact that tensile properties are easy and inexpensive to perform, and they are also good indicators of many other mechanical properties. Typically, material specifications list tensile requirements in the longitudinal direction. Thus, there is an abundant, ever increasing supply of room temperature tensile data in the longitudinal (L) direction. It is because of this that the MMPDS mandates the use of the direct method for the usual (typically the longitudinal) tensile test direction. By contrast, only few specifications require testing in the long and / or short transverse directions. Thus, in anticipating situations where sufficient data will be lacking, the MMPDS allows the use of the indirect method for the long and short transverse directions. This being so, some of the long and short transverse strength data presented in the MMPDS are derived, whereas others are direct. A distinction as to which values are derived and which are direct, however, requires referral to MMPDS historical files. In addition to room temperature tensile requirements, specifications covering special purpose materials frequently impose some special property; e.g., elevated temperature properties (high temperature alloys) or fracture toughness requirements (fracture critical applications). The databases available for such special properties, however, are generally not sufficient to enable the generation of A and B property values. The same is true for bearing, shear and compressive properties, since material specifications seldom impose requirements for such properties. In those cases, where an insufficient database exists, the MMPDS relies on typical, derived or S values, as the case might be.

The MMPDS Tables almost exclusively list AMS specifications. For some wrought alloy product forms, however, other types of specification are listed:

(1) ASTM specifications: Aluminum alloys 2014, 5052, 5083, 5086, 5454, and 5456; Magnesium alloys AZ31B, AZ61A, and AK60A; Inconel 600, and; C 172 (Be-Cu).

(2) Mil-Specs: Aluminum alloy 2519 (no AMS listed); CP Titanium; Ti-5Al-2.5 Sn, and; Ti-6Al-6V-2Sn.

3.0 A note on A, B, and S Values:

Some design organizations are reluctant to utilize S values in design analyses, in favor of using A and B values. This appears to be the result of a mistaken belief that using A and B values is reason to waive the tests required for quality assurance. Nothing could be farther from the truth. These tests would still be required to verify that the properties of each lot of wrought stock (or each casting heat) are equal to or greater than the A or B values utilized in the design analyses.

Design organizations should abandon their reluctance to utilize S values in design analyses. S values may be used in these analyses, provided that the properties of each lot of wrought stock (or each casting heat) are verified to be equal to or greater than the S values utilized in the design analyses. Regulating agencies should also be more amenable to accepting the use of S values by applicants in design analyses.

[(4)] In addition to D357.0 and E357.0, the MMPDS lists "A" and "B" values for three more cast alloys. The first, an aluminum alloy (205/TiB_2/3P), the second a magnesium alloy (EV31A, AKA Elektron 21) and the third, a titanium alloy (Ti-6Al-4V, HIP); no S values are listed for these three alloys.

4.0 Materials not Covered by the MMPDS

Often, design requirements mandate the use of materials that are not covered by the MMPDS. In such cases, the applicant should contact the cognizant FAA organization in the geographic location, to get an accurate reading as to what constitutes acceptable means of compliance with CFR requirements. It is important to recognize that the ultimate responsibility for the design rests with the applicant, not the FAA or the undersigned. With the above in mind, the following suggestions are offered.

4.1 Room Temperature Tensile Strength Values

Two options, applicable to wrought and cast alloys, are available for the determination of F_{tu} and F_{ty} values.

Option 1: Generate the required F_{tu} and F_{ty} values (A, B, or S basis) in the desired direction, according to the procedures set forth in the MMPDS for the direct method (section 1.1). The number of data points required will range from about 30 to about 300, depending on the basis selected, and the statistical distribution of the data points.

Casting Alloys in the MMPDS

Insofar as casting alloys in the MMPDS are involved, "A" and "B" allowables are listed only for five alloys: aluminum alloys 205/TiB_2/3P, D357.0 and E357.0; magnesium alloy, EV31A (AKA Elektron 21), and; titanium alloy, (Ti-6Al-4V, HIP). For D357.0 and E357.0, S values are also listed. No S values are listed for the remaining alloys.

The MMPDS does not explicitly define specific requirements for generating cast alloy allowables. Accordingly, and for lack of a better choice, it is assumed that the same wrought alloy requirements (1.1 and 1.2) also apply to cast alloys (castings). Cast alloy allowables may be determined in one of three ways: (a) from specimens excised from castings; (b) from integrally cast specimens, or; (c) from separately cast specimens. Typically, the MMPDS does not indicate the type of specimen used to generate the listed allowables. The exception is alloy E357.0 where it is indicated that the A, B and S values were obtained from separately cast specimens (investment cast plates or step geometry). As to all the other cast alloys, the MMPDS does not indicate the type of specimen used to generate the listed values. However, according to report ANM-112N-13-05, A and B values were likely determined from separately cast test specimens.

As to the S values, the MMPDS does not indicate whether these values were statistically derived (1.1) or they are simply specification minima. Of course, the exception is alloy E357.0, where the S values were determined from separately cast specimens. It turns out that the S values listed in the MMPDS for this alloy are the property minima listed in the casting material specification (AMS 4288) for investment and sand castings, both listed under "non-designated area;" the same holds true for cast aluminum alloy D357.0 (AMS 4241).

Option 2: If the applicable material specification lists minimum F_{tu} and F_{ty} values, as most do, and if these properties are in the direction required for the design analysis, then these values maybe considered S values. The cognizant FAA organization, however, should approve of this approach. Upon approval, the applicant should verify that each lot of material conforms to the subject minimum values, by performing suitable receiving, in- process, and / or final inspections / tests, and maintaining adequate records. The frequency of the inspections / tests, and the number of specimens required, should be as agreed upon between the applicant and the cognizant FAA organization. If the property values listed in the applicable specification are not in the direction required for the design analysis, then the required data should be generated according to option 1.

4.2 Room Temperature Bearing, Shear, and Compressive Strength Values

To obtain F_{bru}, F_{br}, F_{su}, and F_{cy} values, use is made of the F_{tu} and F_{ty} Values determined in 4.1. Again, two options, applicable to wrought and cast alloys, are available for the determination of these properties.

Option 1: Generate the required values by testing and the use of the indirect method (section 1.2), as set forth in the MMPDS.

Option 2: Use some company or industry empirical expression for the property in question, subject to approval by the cognizant FAA organization. This is the option frequently adopted by design organizations. The undersigned is familiar with the following expressions used in the space program.

Bearing

e/D = 2: $F_{bru} / F_{tu} = 1.8$, and; $F_{bry} / F_{ty} = 1.6$.

e/D = 1.5: $F_{bru} / F_{tu} = 1.4$ and; $F_{bry} / F_{ty} = 1.3$.

Shear & Compression

$F_{su} = 0.58\ F_{tu}$ (brittle materials); $F_{su} = 0.62\ F_{tu}$ (ductile materials).

$F_{cy} = F_{ty}$ (absent Bauschinger effect).

Justification for the empirical approach stems from the fact that the subject properties are not ordinarily used for primary structural analyses. Rather, they are used to perform “spot checks” on specific details; e.g., fasteners, flanges.

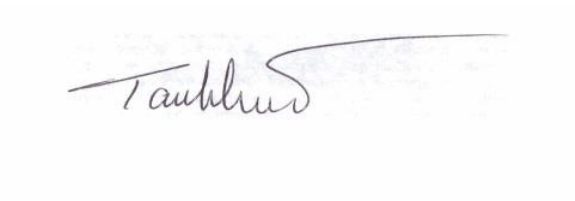
4.3 Other Properties

4.3.1 Tensile e% and RA% are seldom used in design analysis.

4.3.2 Elastic properties (E, E_c, G, and μ) and physical properties (ω, C, K, and α) are not ordinarily used in design analysis. In some cases, however, some, or all, of these properties may be deemed necessary for special analyses. Typical values from the literature maybe used in such cases. Note that the MMPDS lists typical values for these properties; see section 2.5.

4.3.3 Occasionally, fatigue, creep, and / or fracture toughness properties are required for design analysis. Typical values, from the literature maybe used in such cases. Note that the MMPDS data for these properties are typical; see section 2.5.

4.3.4 Occasionally, strength properties at temperatures other than ambient are required for design analysis. In such cases, the required properties should be derived, using the indirect method of section 1.2. This is because the values listed in the MMPDS for these properties are derived by the indirect method; see section 2.2.



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