INTERNATIONAL

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Standard Specification for Materials for Aluminum Powder Metallurgy (PM) Structural Parts[1]

This standard is issued under the fixed designation B595; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope

1.1 This specification covers aluminum powder metallurgy structural parts made using admixed materials.

1.2 This specification covers a material designation code that includes the chemical composition of the material, its guaranteed minimum 0.2 % offset yield strength or ultimate tensile strength, and the temper condition of the material.

1.3 *Units*—With the exception of density values for which the g/cm^3 unit is the industry standard, property values stated in inch-pound units are to be regarded as standard. Values in SI units result from conversion, are only for information, and are not considered standard.

1.4 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety, health, and environmental practices and determine the applicability of regulatory limitations prior to use.*

1.5 *This international standard was developed in accordance with internationally recognized principles on standardization established in the Decision on Principles for the Development of International Standards, Guides and Recommendations issued by the World Trade Organization Technical Barriers to Trade (TBT) Committee.*

2. Referenced Documents

2.1 *ASTM Standards:*[2]

B243 Terminology of Powder Metallurgy

B962 Test Methods for Density of Compacted or Sintered Powder Metallurgy (PM) Products Using Archimedes' Principle

B963 Test Methods for Oil Content, Oil-Impregnation Efficiency, and Surface-Connected Porosity of Sintered Powder Metallurgy (PM) Products Using Archimedes' Principle

E8/E8M Test Methods for Tension Testing of Metallic Materials

E29 Practice for Using Significant Digits in Test Data to Determine Conformance with Specifications

E466 Practice for Conducting Force Controlled Constant Amplitude Axial Fatigue Tests of Metallic Materials

E606/E606M Test Method for Strain-Controlled Fatigue Testing

E1269 Test Method for Determining Specific Heat Capacity by Differential Scanning Calorimetry

E1416 Practice for Radioscopic Examination of Weldments

2.2 *MPIF Standards:*[3]

MPIF Standard 10, Method for Determination of the Tensile Properties of Powder Metallurgy (PM) Materials

MPIF Standard 35-SP, Materials Standards for PM Structural Parts

MPIF Standard 72, Guide to Sample Preparation of Aluminum Powder Metallurgy (PM) Materials for Cross-sectional Metallographic Evaluation

3. Terminology

3.1 *Definitions*—Definitions of powder metallurgy terms can be found in Terminology B243. Additional descriptive information is available under "General Information on PM" on the ASTM B09 web page.

4. Ordering Information

4.1 Materials for parts covered under this specification shall be ordered by material designation code.

4.2 Orders for parts under this specification may include the following information:

4.2.1 Certification, if required (see Section 13),

4.2.2 Dimensions (see Section 9),

4.2.3 Chemical composition (see 6.1, 10.1, and Table 1),

4.2.4 Test methods and mechanical properties (see Section 8, Table 2, Table 3, Table X1.1, and Table X1.2),

4.2.5 Density (see Section 7, Table X1.1, and Table X1.2),

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[2] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

[3] Available from Metal Powder Industries Federation (MPIF), 105 College Rd. East, Princeton, NJ 08540, http://www.mpif.org.

TABLE 1 Chemical Composition Requirements (wt.%)^{A,B}

Material Designation Code	Al	Cu	Si	Mg	Element
AC-2014	Balance	3.5	0.5	0.2	Minimum
	Balance	5.5	1.2	1.0	Maximum

^{A} Other elements: 1.5 wt.% max.
^{B} For the purpose of determining conformance with this specification, measured values shall be rounded "to the nearest unit" in the last right-hand digit used in expressing the specification limit, in accordance with the rounding-off method of Practice E29.

TABLE 2 Minimum Tensile Strength Values (inch-pound)

NOTE 1—Processing parameters used to generate these data; other conditions may be used.

Material Designation Code^{C}	Minimum Strength^{A,B,D}	
	Yield	Ultimate
	10^3 psi	
AC-2014-23-T2	23	
AC-2014-25-T2	25	
AC-2014-32-T8		32
AC-2014-38-T8		38

^{A} Suffix numbers represent minimum strength values in 10^3 psi
^{B} Mechanical property data derived from laboratory prepared test specimens sintered under commercial manufacturing conditions
^{C} Thermal Treatment:
-T2: Cold worked (sized) and then naturally aged (room temperature)
-T8: Solution treated at 935 ºF for 70 min at temperature, immediately water quenched, cold worked (sized), overall length (OAL) reduced by approximately 2 %, and artificially aged at 320 ºF for 18 h and air cooled
^{D} Tensile properties determined on machined round specimens

TABLE 3 Minimum Tensile Strength Values (SI)

NOTE 1—Processing parameters used to generate these data, other conditions may be used.

Material Designation Code^{C}	Minimum Strength^{A,B,D}	
	Yield	Ultimate
	MPa	
AC-2014-23-T2	160	
AC-2014-25-T2	170	
AC-2014-32-T8		220
AC-2014-38-T8		265

^{A} Suffix numbers represent minimum strength values in 10^3 psi
^{B} Mechanical property data derived from laboratory prepared test specimens sintered under commercial manufacturing conditions
^{C} Thermal Treatment:
-T2: Cold worked (sized) and then naturally aged (room temperature)
-T8: Solution treated at 502 ºC for 70 min at temperature, immediately water quenched, cold worked (sized), overall length (OAL) reduced by approximately 2 %, and artificially aged at 160 ºC for 18 h and air cooled
^{D} Tensile properties determined on machined round specimens

4.2.6 Special packaging, if required.

5. Materials and Manufacture

5.1 Structural parts shall be made by compacting, sintering, and sizing followed by either a T2 or T8 temper to produce finished parts in conformance with this specification.

6. Chemical Composition

6.1 The material shall conform to the requirements provided in Table 1.

6.2 Chemical analysis shall be performed in accordance with the methods prescribed in Vol. 03.05 of the *Annual Book of ASTM Standards* or by any other approved method agreed between the producer and the purchaser.

7. Physical Properties

7.1 Density shall be determined in accordance with Test Method B962.

7.1.1 The producer and purchaser may agree upon a minimum average density for the part and minimum densities for specific regions of the part. Typical density values may be found in Table X1.1 and Table X1.2.

8. Mechanical Properties

8.1 For material in the T2 condition, the minimum guaranteed 0.2 % offset yield strength as shown in Table 2 and Table 3 is a numerical suffix to the material designation code and is read as 10^3 psi. The code is adopted from MPIF Standard 35-SP. All tensile yield strengths are defined as the 0.2 % offset yield strengths.

8.2 For material in the T8 condition, the minimum guaranteed ultimate tensile strength as shown in Table 2 and Table 3 is a numerical suffix to the material designation code and is read as 10^3 psi. The code is adopted from MPIF Standard 35-SP.

8.3 The producer and purchaser shall agree upon the method to be used to verify the minimum strength characteristics of the finished parts. Since it is generally impossible to machine tensile test specimens from these parts, alternative strength tests are advisable. An example would be measuring the force needed to break teeth off a gear with the gear properly fixtured.

8.4 The tensile properties shall be measured using machined round specimens prepared in accordance with MPIF Standard 10 and tested in accordance with Test Methods E8/E8M and MPIF Standard 10.

8.5 Typical mechanical property values may be found in Table X1.1 and Table X1.2.

9. Permissible Variations in Dimensions

9.1 Permissible variations in dimensions shall be within the limits specified in the drawings provided by the purchaser, which describe the structural parts that accompany the order, or variations shall be within the limits specified in the order.

10. Sampling

10.1 *Chemical Analysis*—When requested on the purchase order, at least one sample for chemical analysis shall be taken from each lot. A sample of chips may be obtained by dry-milling, or crushing at least two pieces with clean, dry tools without lubrication. In order to obtain oil-free chips, the parts selected for test shall have the oil extracted from them in accordance with Test Methods B963, if necessary.

10.2 *Mechanical Tests*—The producer and the purchaser shall agree upon a representative number of specimens for mechanical tests.

11. Inspection

11.1 Inspection of the material shall be agreed upon between the producer and purchaser as part of the purchase order or contract.

12. Rejection and Rehearing

12.1 Material that fails to conform to the requirements of this specification may be rejected. Rejection should be reported to the producer promptly and in writing. In the case of dissatisfaction with test results, the producer may make claim for a rehearing.

13. Certification

13.1 When specified in the purchase order or contract, the purchaser shall be furnished certification stating samples representing each lot have been tested and inspected as indicated in this specification and the requirements have been met. When specified in the purchase order or contract, a report of the test results shall be furnished. Test reports may be transmitted to the purchaser by electronic services. The content of the electronically transmitted document shall conform to any existing agreement between the producer and purchaser.

14. Keywords

14.1 aluminum alloys; nonferrous powder metallurgy; nonferrous structural parts; powder metallurgy (PM); PM structural parts

SUPPLEMENTARY REQUIREMENTS

S1. Metallographic Examination

S1.1 *Microstructure*—The Al-Cu alloy system is the most popular production material and displays a matrix of alpha-aluminum, with some precipitates. The GP zones (Cu-rich regions on the {100} planes of the fcc aluminum matrix that are the precursors to the $CuAl_2$ theta phase) cannot be resolved using the light microscope. The presence of coarse $CuAl_2$ precipitates is indicative of an over-aged condition; such precipitates are visible by optical metallography.

S1.1.1 When specified in the purchase order or contract, either or both of the following supplementary requirements may be applied. Details of these supplementary requirements shall be agreed upon in writing between the producer or supplier and purchaser. Supplementary requirements shall in no way negate any requirement of the specification itself. Metallographic samples should be prepared in accordance with MPIF Standard 72.

S1.2 *Sintering*—Requirements for the uniformity and quality of sintering may be agreed upon.

S1.3 *Porosity*—Requirements excluding excessively large pores may be included when specified and agreed upon in writing.

APPENDIXES

(Nonmandatory Information)

X1. USE OF THIS SPECIFICATION

X1.1 PM Material Code Designation:

X1.1.1 The PM material code designation, or identifying code for structural PM parts, defines a specific material as to chemical composition and minimum strength expressed in 10^3 psi (6.895 MPa (6.895 N/mm^2)). For example, AC-2014-23-T2 is an aluminum PM material containing nominally 4 % copper, 0.8 % silicon, and 0.5 % magnesium. It has a minimum yield strength of 23 x 10^3 psi (23 000 psi) in the T2 condition.

X1.1.2 The system offers a convenient means of designating both the chemical composition and minimum strength value of any standard PM material. For each standard material, the density is given as one of the typical values and is no longer a requirement of the specification.

X1.1.3 Code designations in this specification and revisions thereof apply only to PM materials for which specifications have been adopted. In order to avoid confusion, the PM material designation coding system is intended for use only with such materials, and it should not be used to create nonstandard materials. The explanatory notes, property values, and other contents of this specification have no application to any other materials.

X1.1.4 In this coding system, the prefix letters denote the general type of material. For example, the prefix AC represents an aluminum alloy that contains copper (A for aluminum and C for copper). The prefix four-digit code designates the actual alloy, the composition of which is specified in the chemical composition table (see Table X1.1 and Table X1.2).

TABLE X1.1 Typical Properties of Aluminum PM Materials (Inch-pound)^{A,B}

NOTE 1—Processing parameters used to generate these data; other conditions may be used.

Material Designation Code^{C}	Tensile Properties^{D}			Elastic Constants		Compressive Yield Strength (0.1%)	Apparent Hardness	Density
	Ultimate Strength	Yield Strength (0.2 %)	Elongation (in 1 in.)	Young's Modulus	Poisson's Ratio			
	10^3 psi	10^3 psi	%	10^6 psi		10^3 psi	HRE	g/cm^3
AC-2014-23-T2	29	25	1	8	0.32	24	60	2.50
AC-2014-35-T2	33	27	2	8.5	0.33	25	70	2.60
AC-2014-32-T8	38	38	<1	8	0.32	39	75	2.50
AC-2014-38-T8	45	45	<1	8.5	0.33	43	83	2.60

^{A} Suffix numbers represent minimum strength values in 10^3 psi.
^{B} Mechanical property data derived from laboratory prepared test specimens sintered under commercial manufacturing conditions
^{C} Thermal Treatment:
-T2: Cold worked (sized) and then naturally aged (room temperature)
-T8: Solution treated at 935 ºF for 70 min at temperature, immediately water quenched
^{D} Tensile properties determined on machined round specimens

TABLE X1.2 Typical Properties of Aluminum PM Materials (SI)^{A,B}

NOTE 1—Processing parameters used to generate these data; other conditions may be used.

Material Designation Code^{C}	Tensile Properties^{D}			Elastic Constants		Compressive Yield Strength (0.1%)	Apparent Hardness	Density
	Ultimate Strength	Yield Strength (0.2 %)	Elongation (in 25 mm)	Young's Modulus	Poisson's Ratio			
	MPa	MPa	%	GPa		MPa	HRE	g/cm^3
AC-2014-23-T2	200	170	1	55	0.32	165	60	2.50
AC-2014-35-T2	225	185	2	60	0.33	170	70	2.60
AC-2014-32-T8	265	265	<1	55	0.32	270	75	2.50
AC-2014-38-T8	310	310	<1	60	0.33	300	83	2.60

^{A} Suffix numbers represent minimum strength values in 10^3 psi
^{B} Mechanical property data derived from laboratory prepared test specimens sintered under commercial manufacturing conditions
^{C} Thermal Treatment:
-T2: Cold worked (sized) and then naturally aged (room temperature)
-T8: Solution treated at 502 ºC for 70 min at temperature, immediately water quenched
^{D} Tensile properties determined on machined round specimens

X2. THERMAL CONDUCTIVITY

The thermal conductivity of PM aluminum materials is a function of their density, thermal treatment, and microstructure. Thermal diffusivity was determined in accordance with Test Method E1416, thermal flash method, and specific heat capacity in accordance with Test Method E1269, differential scanning calorimetry. Thermal conductivity (k) was calculated from the relationship

$$k = \alpha \rho \; C_p \qquad (X2.1)$$

where:

α = thermal diffusivity,
ρ = density, and
C_p = specific heat capacity.

A typical range for AC-2014 materials in the T2 or T8 condition is 125–145 W/(m-K).

X3. FATIGUE PROPERTIES

X3.1 *Axial Fatigue*—The fully reversed (R = -1) axial fatigue strength at 10^7 cycles was determined for AC-2014-T2 material in accordance with Practice E466. The results are summarized in Table X3.1 and Table X3.2.

TABLE X3.1 Mean Axial Fatigue Strength of AC-2014-T2 (inch-pound)

Material	Mean Fatigue Strength 10^7 Cycles (10^3 psi)	Density (g/cm^3)
AC-2014-T2	8	2.50
AC-2014-T2	9	2.60

X3.2 *Low-Cycle Fatigue*—Strain-controlled fatigue testing, also known as low-cycle fatigue (LCF) was conducted per Test Method E606/E606M in a closed-loop, servo-controlled, electro-hydraulic testing machine. A process control computer controlled fully reversed (R = -1) constant strain or stress amplitude in a sinusoidal or triangular waveform. Each test started in strain-control mode with a frequency of 0.05 – 3.0 Hz. After the stress-strain loops exhibited constant stress peaks, the control mode was changed to load control at