Designation: F3001 – 14

Standard Specification for Additive Manufacturing Titanium-6 Aluminum-4 Vanadium ELI (Extra Low Interstitial) with Powder Bed Fusion[1]

This standard is issued under the fixed designation F3001; 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 additively manufactured titanium-6aluminum-4vanadium with extra low interstitials (Ti-6Al-4V ELI) components using full-melt powder bed fusion such as electron beam melting and laser melting. The components produced by these processes are used typically in applications that require mechanical properties similar to machined forgings and wrought products. Components manufactured to this specification are often, but not necessarily, post processed via machining, grinding, electrical discharge machining (EDM), polishing, and so forth to achieve desired surface finish and critical dimensions.

1.2 This specification is intended for the use of purchasers or producers or both of additively manufactured Ti-6Al-4V ELI components for defining the requirements and ensuring component properties.

1.3 Users are advised to use this specification as a basis for obtaining components that will meet the minimum acceptance requirements established and revised by consensus of the members of the committee.

1.4 User requirements considered more stringent may be met by the addition to the purchase order of one or more supplementary requirements, which may include, but are not limited to, those listed in S1-S4 and S1-S16 in Specification F2924.

1.5 The values stated in SI units are to be regarded as standard. No other units of measurement are included in this standard.

2. Referenced Documents

2.1 *ASTM Standards:*[2]

B214 Test Method for Sieve Analysis of Metal Powders

B243 Terminology of Powder Metallurgy

B600 Guide for Descaling and Cleaning Titanium and Titanium Alloy Surfaces

B769 Test Method for Shear Testing of Aluminum Alloys

D3951 Practice for Commercial Packaging

E3 Guide for Preparation of Metallographic Specimens

E8/E8M Test Methods for Tension Testing of Metallic Materials

E9 Test Methods of Compression Testing of Metallic Materials at Room Temperature

E11 Specification for Woven Wire Test Sieve Cloth and Test Sieves

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

E238 Test Method for Pin-Type Bearing Test of Metallic Materials

E407 Practice for Microetching Metals and Alloys

E539 Test Method for Analysis of Titanium Alloys by X-Ray Fluorescence Spectrometry

E1409 Test Method for Determination of Oxygen and Nitrogen in Titanium and Titanium Alloys by Inert Gas Fusion

E1447 Test Method for Determination of Hydrogen in Titanium and Titanium Alloys by Inert Gas Fusion Thermal Conductivity/Infrared Detection Method

E1820 Test Method for Measurement of Fracture Toughness

E1941 Test Method for Determination of Carbon in Refractory and Reactive Metals and Their Alloys by Combustion Analysis

E2371 Test Method for Analysis of Titanium and Titanium Alloys by Direct Current Plasma and Inductively Coupled Plasma Atomic Emission Spectrometry (Performance-Based Test Methodology)

F136 Specification for Wrought Titanium-6Aluminum-4Vanadium ELI (Extra Low Interstitial) Alloy for Surgical Implant Applications (UNS R56401)

F2792 Terminology for Additive Manufacturing Technologies

F2924 Specification for Additive Manufacturing Titanium-6 Aluminum-4 Vanadium with Powder Bed Fusion

2.2 *ISO/ASTM Standards:*[2]

52915 Specification for Additive Manufacturing File Format (AMF) Version 1.1

[1] This specification is under the jurisdiction of ASTM Committee F42 on Additive Manufacturing Technologies and is the direct responsibility of Subcommittee F42.05 on Materials and Processes.

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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.

52921 Terminology for Additive Manufacturing—Coordinate Systems and Test Methodologies

2.3 *ASQ Standard:*[3]

ASQ C1 Specification of General Requirements for a Quality Program

2.4 *ISO Standards:*[4]

ISO 5832-3 Implants for Surgery—Metallic Materials—Part 3: Wrought Titanium 6-Aluminum 4-Vanadium Alloy Third Edition

ISO 6892 Metallic Materials—Tensile Testing at Ambient Temperature

ISO 9001 Quality Management System—Requirements

ISO 9044 Industrial Woven Wire Cloth – Technical Requirements and Testing

ISO 13485 Medical devices—Quality management systems—Requirements for regulatory purposes

2.5 *SAE Standards:*[5]

AMS 2249 Chemical Check Analysis Limits Titanium and Titanium Alloys

AMS 2801 Heat Treat of Titanium Alloys

AMSH81200 Heat Treatment of Titanium and Titanium Alloys

AS1814 Terminology for Titanium Microstructures

AS9100 Quality Systems—Aerospace—Model for Quality Assurance in Design, Development, Production, Installation and Servicing

3. Terminology

3.1 Terminology relating to titanium microstructure in AS1814 shall apply.

3.2 Terminology relating to additive manufacturing in Terminology F2792 shall apply.

3.3 Terminology relating to coordinate systems in Terminology 52921 shall apply.

3.4 Terminology relating to powder metallurgy in Terminology B243 shall apply.

3.5 Terminology relating to powder bed fusion in Specification F2924 shall apply.

4. Classification

4.1 Unless otherwise specified herein, all classifications shall meet the requirements in each section of this standard.

4.1.1 Class A components shall be stress relieved or annealed per Section 12.

4.1.2 Class B components shall be annealed per Section 12.

4.1.3 Class C components shall be hot isostatically pressed per Section 13.

4.1.4 Class D components shall be solution heat treated and aged per Section 12.

4.1.5 For Class E components all thermal post processing shall be optional.

4.1.6 Class F components shall be stress relieved or annealed per Section 12.

5. Ordering Information

5.1 Orders for components compliant with this specification shall include the following to describe the requirements adequately:

5.1.1 This specification designation,

5.1.2 Description or part number of product desired,

5.1.3 Quantity of product desired,

5.1.4 Classification,

5.1.5 SI or SAE units,

5.1.5.1 *Discussion*—The STL file format used by many powder bed fusion machines does not contain units of measurement as metadata. When only STL files are provided by the purchaser, ordering information should specify the units of the component along with the electronic data file. More information about data files can be found in ISO/ASTM 52915.

5.1.6 Dimensions and tolerances (Section 14),

5.1.7 Mechanical properties (Section 11),

5.1.8 Methods for chemical analysis (Section 9),

5.1.9 Sampling methods (S11 in F2924),

5.1.10 Post-processing sequence of operations,

5.1.11 Thermal processing,

5.1.12 Allowable porosity (S8 in F2924),

5.1.13 Component marking such as labeling the serial or lot number in the CAD file prior to the build cycle, or product tagging,

5.1.14 Packaging,

5.1.15 Certification,

5.1.16 Disposition of rejected material (Section 15), and

5.1.17 Supplementary requirements.

6. Manufacturing Plan

6.1 Class A, B, C, D, and F components manufactured to this specification shall have a manufacturing plan that includes, but is not limited to, the following:

6.1.1 A machine, and manufacturing control system, qualification procedure as agreed between component supplier and purchaser;

NOTE 1—Qualification procedures typically require qualification build cycles in which mechanical property test specimens are prepared and measured in accordance with Section 11 or other applicable standards. Location, orientation on the build platform, number of test specimens for each machine qualification build cycle, and relationship between specimen test results and component quality shall be agreed upon between component supplier and purchaser.

6.1.2 Feedstock that meets the requirements of Section 7;

6.1.3 The machine identification, including machine software version, manufacturing control system version (if automated), build chamber environment, machine conditioning, and calibration information of the qualified machine;

6.1.4 Predetermined process as substantiated by the qualification procedure;

6.1.5 Safeguards to ensure traceability of the digital files, including design history of the components;

[3] Available from American Society for Quality (ASQ), 600 N. Plankinton Ave., Milwaukee, WI 53203, http://www.asq.org.

[4] Available from American National Standards Institute (ANSI), 25 W. 43rd St., 4th Floor, New York, NY 10036, http://www.ansi.org.

[5] Available from SAE International (SAE), 400 Commonwealth Dr., Warrendale, PA 15096-0001, http://www.sae.org.

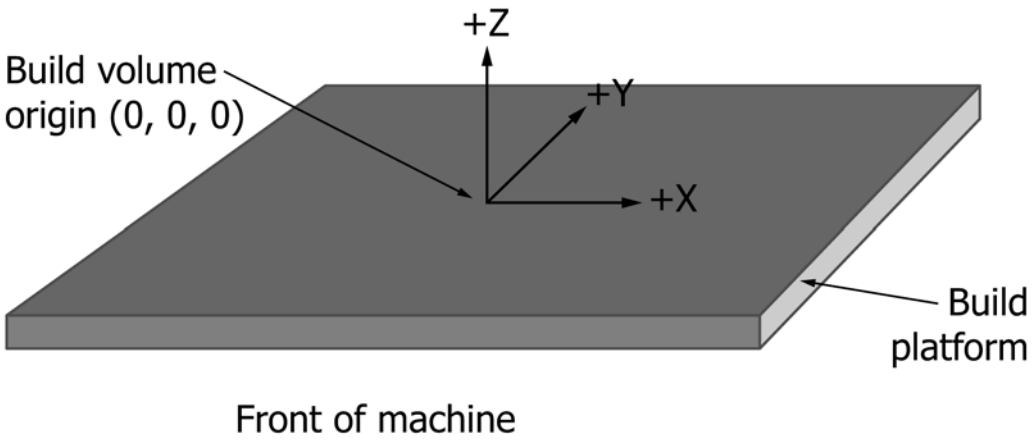

FIG. 1 Build Platform Coordinates for Test Specimens (for reference only)

6.1.6 All the steps necessary to start the build process, including build platform selection, machine cleaning, and powder handling;

6.1.7 The requirements for approving machine operators;

6.1.8 Logging of machine build data files, upper and lower limits of the parameters affecting component quality and other process validation controls;

6.1.9 The number of components per build cycle, their orientation and location on the build platform, and support structures, if required;

6.1.10 Process steps including, but not limited to, Section 8;

6.1.11 Post-processing procedure, including sequence of the post-processing steps and the specifications for each step;

6.1.12 Thermal processing including furnace anneal, hot isostatic pressing, heat treat, and aging; and

6.1.13 Inspection requirements as agreed between the purchaser and component supplier, including any supplementary requirements.

7. Feedstock

7.1 The feedstock for this specification shall be metal powder, as defined in Terminology B243, that has the powder type, size distribution, shape, tap density, and flow rate acceptable for the process as determined by the component supplier.

7.2 The metal powder shall be free from detrimental amounts of inclusions and impurities and its chemical composition shall be adequate to yield, after processing, the final material chemistry listed in Table 1.

TABLE 1 Composition

Element	min	max
Aluminum	5.50	6.50
Vanadium	3.50	4.50
Iron	...	0.25
Oxygen	...	0.13
Carbon	...	0.08
Nitrogen	...	0.05
Hydrogen	...	0.012
Yttrium	...	0.005
Other elements, each	...	0.10
Other elements, total	...	0.40
Titanium	remainder	

7.3 Powder blends are allowed unless otherwise specified between the component supplier and component purchaser, as long as all powder used to create the powder blend meets the requirements in Table 1 and lot numbers are documented and maintained.

7.4 Used powder is allowed. The proportion of virgin powder to used powder shall be recorded and reported for each production run. The maximum number of times used powder can be used as well as the number of times any portion of a powder lot can be processed in the build chamber should be agreed upon between component supplier and purchaser for Class A, B, C, D, and F. There are no limits on the number of build cycles for used powder for Class E components. After a build cycle, any remaining used powder may be blended with virgin powder to maintain a powder quantity large enough for the next build cycle. The chemical composition of used powders shall be analyzed regularly, as agreed upon between component supplier and purchaser. Powder not conforming to Table 1 or 7.7 shall not be further processed in the machine to manufacture Class A, B, C, D and F components.

7.4.1 All used powder shall be sieved with a sieve having a mesh size appropriate for removing any agglomerates or contaminants from the build cycle.

7.5 All powder sieves used to manufacture Class A, B, C, D and F components shall have a certificate of conformance that they were manufactured to ISO 9044 or all powder sieving shall be in conformance with Specification E11.

7.6 Sieve analysis of used powder or powder lots during incoming inspection or in-process inspection shall be made in accordance with Test Method B214 or as agreed between component supplier and purchaser.

7.7 The maximum percentage of aluminum in Table 1 may be increased for virgin powder, used powder and powder blends when agreed upon between component supplier and purchaser. When component supplier and purchaser agree to an increase in the maximum percentage of aluminum, 9.2 shall apply.

7.8 Any powder lot or powder blend containing any used powder shall be considered used powder.