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400 COMMONWEALTH DRIVE WARRENDALE, PA 15096

AEROSPACE MATERIAL SPECIFICATION

AMS 4983

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Revised

TITANIUM ALLOY FORGINGS
10V - 2.0Fe - 3.0Al
Solution Heat Treated and Aged

1. SCOPE:

1.1 Form: This specification covers a titanium alloy in the form of forgings.

1.2 Application: Primarily for parts in high stress and stress-corrosion-resistant applications.

2. APPLICABLE DOCUMENTS: The following publications form a part of this specification to the extent specified herein. The latest issue of Aerospace Material Specifications (AMS) shall apply. The applicable issue of other documents shall be as specified in AMS 2350.

2.1 SAE Publications: Available from SAE, 400 Commonwealth Drive, Warrendale, PA 15096.

2.1.1 Aerospace Material Specifications:

AMS 2249 - Chemical Check Analysis Limits, Titanium and Titanium Alloys
AMS 2350 - Standards and Test Methods
AMS 2375 - Control of Forgings Requiring First Article Approval
AMS 2808 - Identification, Forgings

2.2 ASTM Publications: Available from American Society for Testing and Materials, 1916 Race Street, Philadelphia, PA 19103.

ASTM E8 - Tension Testing of Metallic Materails
ASTM E120 - Chemical Analysis of Titanium and Titanium Alloys
ASTM E146 - Chemical Analysis of Zirconium and Zirconium Alloys
ASTM E385 - Oxygen Content Using a 14-MeV Neutron Activation and Direct Counting Technique
ASTM E399 - Plane-Strain Fracture Toughness of Metallic Materials

2.3 U.S. Government Publications: Available from Commanding Officer, Naval Publications and Forms Center, 5801 Tabor Avenue, Philadelphia, PA 19120.

2.3.1 Federal Standards:

Federal Test Method Standard No. 151 - Metals; Test Methods

2.3.2 Military Specifications:

MIL-H-81200 - Heat Treatment of Titanium and Titanium Alloys

2.3.3 Military Standards:

MIL-STD-163 - Steel Mill Products, Preparation for Shipment and Storage

3. TECHNICAL REQUIREMENTS:

3.1 Composition: Shall conform to the following percentages by weight, determined by wet chemical methods in accordance with ASTM E120 or by spectrographic methods in accordance with Federal Test Method Standard No. 151, Method 112, except that hydrogen shall be determined in accordance with ASTM E146 and oxygen in accordance with ASTM E385; other methods of analysis may be used when approved by purchaser:

	min	max
Vanadium	9.0	11.0
Aluminum	2.6	3.4
Iron	1.6	2.2
Oxygen	--	0.13
Carbon	--	0.05
Nitrogen	--	0.05 (500 ppm)
Hydrogen	--	0.015 (150 ppm)
Yttrium (3.1.1)	--	0.005 (50 ppm)
Residual Elements, each (3.1.1)	--	0.10
Residual Elements, total (3.1.1)	--	0.30
Titanium	remainder	

3.1.1 Determination not required for routine acceptance.

3.1.2 Check Analysis: Composition variations shall meet the applicable requirements of AMS 2249; no variation over maximum will be permitted for yttrium, unless otherwise agreed upon by purchaser and vendor.

3.2 Condition: Solution heat treated and aged. The majority of forging work shall be done above the beta transus. Finish or final forging shall be performed below the beta transus and shall be limited to 10 - 25% reduction.

3.3 Heat Treatment:

3.3.1 Forgings shall be single solution heat treated in accordance with 3.3.1.2 unless duplex solution heat treatment in accordance with 3.3.1.1 and 3.3.1.2 is specified by purchaser. Heat treating furnaces and controls shall be in accordance with MIL-H-81200 as applicable.

3.3.1.1 Forgings shall be heated to a temperature 60F to 100F (15C to 40C) deg below the beta transus (See 8.1) determined for the lot of forgings, held at heat for not less than 30 min., and either furnace or air cooled to room temperature.

3.3.1.2 Forgings shall be heated to a temperature 60F to 100F (15C to 40C) deg below the beta transus (See 8.1) determined for the lot of forgings, held at heat for not less than 30 min., and quenched in water.

3.3.2 Aging Heat Treatment: Heat to a temperature within the range 900° - 950°F (480° - 510°C), hold at the selected temperature within ±10°F (±5°C) for not less than 8 hr, and cool to room temperature.

3.3.2.1 If a lot of forgings does not meet the minimum fracture toughness requirement of 3.4.2, the lot of forgings may be re-aged at 900°F to 975°F (480°C to 525°C) or held at heat for longer than 8 hours.

3.4 Properties: Forgings shall conform to the following requirements:

3.4.1 Tensile Properties: Shall be as follows for forgings with nominal section thickness up to 3.50 in. (87.5 mm), determined in accordance with ASTM E8 with the rate of strain maintained at 0.003 - 0.007 in./in. per min. (0.003 - 0.007 mm/mm per min.) through the yield strength and then increased so as to produce failure in approximately one additional minute. When a dispute occurs between purchaser and vendor over the yield strength values, a referee test shall be performed on a machine having a strain rate pacer, using a rate of 0.005 in./in. per min. (0.005 mm/mm per min.) through the yield strength and a minimum cross head speed of 0.10 in. (2.5 mm) per min. above the yield strength. Tensile property requirements for forgings 3.50 in. (87.5 mm) and over in nominal cross-sectional thickness shall be as agreed upon by purchaser and vendor.

Tensile Strength, min	180,000 psi (1250 MPa)
Yield Strength at 0.2% Offset, min	160,000 psi (1100 MPa)
Elongation in 4D, min	4%
Reduction of Area, min	Shall be reported

3.4.2 Fracture Toughness: K_{IC} shall be not lower than 40 ksi $\sqrt{in.}$ (44 MPa $\sqrt{mm}$), determined in accordance with ASTM E399.

3.4.2.1 Test Data: At time of testing, the following data shall be recorded on the load-displacement test record:

Date
Specimen identification
Specimen orientation
Load scale calibration
Displacement scale calibration
Loading rate in terms of K_I in accordance with ASTM E399
PQ
Pmax
Temperature
Relative humidity
Testing laboratory
Test machine
Operator

3.4.2.2 Reduction of Test Data: Test data shall be reduced in accordance with ASTM E399 to calculate a K_Q value and to determine if a valid K_{IC} value has been measured. Tensile coupons shall be provided for validity verification wherever fracture toughness coupons are specified. In checking for validity, the yield strength value used shall be yield strength measured for the same forging from which the fracture toughness specimen was obtained. Not less than one tensile specimen taken immediately adjacent to the location of the fracture toughness specimen is required. Fracture planes of tensile and K_{IC} specimen shall be in the same direction.

3.4.3 Microstructure: Shall consist of primary alpha in a matrix of aged beta, determined at 500X magnification. Microstructure shall not be cause for rejection unless standards have been agreed upon by the purchaser and vendor except that microstructure with continuous grain boundary alpha will not be acceptable.

3.4.4 Macrostructure and Grain Flow: The grain flow pattern of macroetch sections taken from designated areas of a forging during initial evaluation shall generally conform to the part shape. If no areas are designated, two sections shall be taken normal to the parting line in areas having the greatest section variation. If standards are not established, photomacrographs of acceptable macrostructure of a forging from the first production lot may be used as a basis for acceptance of subsequent lots. Presence of laps, seams, folds, etc is not acceptable.

3.4.5 Surface Contamination: Forgings shall be free of any oxygen-rich layer, such as alpha case, or other surface contamination, determined by microscopic examination.

3.5 Quality:

3.5.1 Alloy shall be multiple melted using consumable electrode practice; the final melting cycle shall be under vacuum.

3.5.1.1 The melting atmosphere shall be vacuum or shall be inert gas at a pressure not higher than 250 mm of mercury.

3.5.2 Forgings, as received by purchaser, shall be uniform in quality and condition, sound, and free from foreign material and from internal and external imperfections detrimental to usage of the forgings.

4. QUALITY ASSURANCE PROVISIONS:

4.1 Responsibility for Inspection: The vendor of forgings shall supply all samples for vendor's tests and shall be responsible for performing all required tests. Results of such tests shall be reported to the purchaser as required by 4.2. Purchaser reserves the right to sample and to perform any confirmatory testing deemed necessary to ensure that the forgings conform to the requirements of this specification.

4.2 Classification of Tests:

4.2.1 Acceptance Tests: Tests to determine conformance to requirements for composition (3.1), tensile properties (3.4.1), fracture toughness (3.4.2), microstructure (3.4.3), and surface contamination (3.4.5), are classified as acceptance tests and shall be performed on each heat or lot as applicable.

4.2.2 Preproduction Tests: Tests to determine conformance to all technical requirements of this specification when AMS 2375 is specified are classified as preproduction tests and shall be performed prior to or on the first article shipment of a forging to a purchaser, when a change in material or processing, or both, requires reapproval as in 4.4, and when purchaser deems confirmatory testing to be required.

4.2.2.1 For direct U.S. Military procurement, substantiating test data and, when requested, preproduction forgings shall be submitted to the cognizant agency as directed by the procuring activity, the contracting officer, or the request for procurement.

4.3 Sampling: Shall be in accordance with the following; a lot shall be all forgings of the same nominal size and configuration from the same heat processed at the same time under the same fixed conditions and presented for vendor's inspection at one time:

4.3.1 For Acceptance Tests:

4.3.1.1 Composition: One sample from each ingot except that for hydrogen determinations one sample from each lot, obtained after thermal and chemical processing is completed.

4.3.1.2 Tensile and Fracture Toughness Properties:

4.3.1.2.1 Two samples from a forging or forging prolongations from each lot.

4.3.1.2.2 Location and orientation of tensile and fracture toughness specimens shall be as agreed upon by purchaser and vendor. If not defined by purchaser, the vendor shall select the test specimens from the heaviest section and shall select orientation in the following order of preference: S-T, T-L, or L-T in accordance with ASTM E399.

4.3.1.2.3 If a K_Q value is invalid solely on the basis of either B is less than 2.5 $(K_Q/TYS)^2$ or P_{max}/PQ is greater than 1.10, the K_Q value may be used as K_{IC} to satisfy the requirements of 3.4.2. K_Q values invalid on the basis of criteria other than listed above (e.g., crack front curvature, etc) shall not be used. Retests shall be conducted on additional forgings.

4.3.1.2.4 Tensile and fracture toughness properties shall be retested on forgings re-aged in accordance with 3.3.2.1.

4.3.1.3 Microstructure and Surface Contamination: At least one sample from each lot. Microstructural evaluations required on a lot basis may be taken from any convenient location outside the mmachined part envelope for surface examination and from broken test specimens for general microstructure.

4.3.2 For Preproduction Tests: As agreed upon by purchaser and vendor and as follows:

4.3.2.1 Beta Transus Determination: The beta transus shall be determined for each heat by any method approved by purchaser. Thermal controls and readouts shall be calibrated to an accuracy of ±5°F (±3°C). Beta transus accuracy shall be ±15°C (±8°C).

4.4 Approval: When specified, approval and control of forgings shall be in accordance with AMS 2375.

4.5 Reports:

4.5.1 The vendor of forgings shall furnish with each shipment a report showing the results of tests for chemical composition of each heat, for hydrogen content, tensile and fracture toughness properties, and macrographs of grain flow and micrographs of microstructure as applicable, and beta transus temperature of each lot. This report shall include the purchase order number, heat number, AMS 4983, size, lot number, quantity from each heat, heat-treat cycle, part number, and the size and melt source of stock used to make the forgings.