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400 Commonwealth Dr., Warrendale, PA 15096

# AEROSPACE MATERIAL SPECIFICATION

Submitted for recognition as an American National Standard

AMS 4983A

Issued 4-1-84
Revised 1-1-87

Superseding AMS 4983

## TITANIUM ALLOY FORGINGS
## 10V - 2Fe - 3Al
## Consumable Electrode Melted, Single Solution Heat Treated and Aged
## 180,000 psi (1240 MPa) Tensile Strength

1. SCOPE:

1.1 Form: This specification covers a titanium alloy in the form of forgings under 1.00 in. (25 mm) in nominal cross-sectional thickness and of forging stock.

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 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 Materials
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





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

2.3.1 Military Specifications:

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

2.3.2 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:

| | 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 (3.1.2) | -- | 0.005 ( 50 ppm) |
| Residual Elements, each (3.1.2) | -- | 0.10 |
| Residual Elements, total (3.1.2) | -- | 0.30 |
| Titanium | remainder | |

3.1.1 Hydrogen shall be determined in accordance with ASTM E146, oxygen shall be Ø determined in accordance with ASTM E385, and other elements shall be determined by wet chemical methods in accordance with ASTM E120 or by spectrographic or other analytical methods approved by purchaser.

3.1.2 Determination not required for routine acceptance.

3.1.3 Check Analysis: Composition variations shall meet the applicable requirements of AMS 2249.

3.2 Condition: The product shall be supplied in the following condition:

3.2.1 Forgings: Descaled, pickled, solution heat treated, and aged.

3.2.2 Forging Stock: As ordered by the forging manufacturer.

3.3 Heat Treatment:

3.3.1 Forgings shall be single solution heat treated by heating to a temperature Ø 60 to 100 F (15 to 40 C) deg below the beta transus (See 8.2), holding at heat for not less than 30 min., and cooling at a rate equivalent to an air cool or faster; furnace surveys and calibration of temperature controllers and recorders shall be in accordance with MIL-H-81200.

3.3.1.1 Other solution heat treatments may be employed when agreed upon by purchaser and vendor.

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 3.4.1.2, the lot of forgings may be re-aged within the range 900° - 975°F (480° - 525°C) or held at heat for longer than 8 hours.

3.4 Properties: The product shall conform to the following requirements:

3.4.1 Forgings:

3.4.1.1 Tensile Properties: Shall be as follows, determined in accordance with
Ø 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 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 requirements apply in both the longitudinal and transverse directions but tests in the transverse direction need be made only on forgings from which a specimen not less than 2.50 in. (62.5 mm) in length can be taken; tests in the longitudinal direction are not required on forgings tested in the transverse direction.

| | |
|---|---|
| Tensile Strength, min | 180,000 psi (1240 MPa) |
| Yield Strength at 0.2% Offset, min | 160,000 psi (1105 MPa) |
| Elongation in 4D, min | 4% |
| Reduction of Area, min | Shall be reported except when flat sheet type specimens are used |

3.4.1.2 Fracture Toughness: $K_{IC}$ shall be not lower than 40 ksi$\sqrt{in.}$
Ø (44 MPa $\sqrt{m}$), determined in accordance with ASTM E399 for all specimen orientations.

3.4.1.2.1 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
Testing laboratory
Test machine
Operator

3.4.1.2.2 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.

3.4.1.3 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 purchaser and vendor.

3.4.1.4 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 areas are not designated by purchaser, 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 shall be used as the standard. Presence of laps, seams, folds, etc is not acceptable.

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

3.4.1.6 Ø Beta Transus Determination: The beta transus temperature shall be determined 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 ±10°F (±5°C).

3.4.2 Forging Stock: When a sample of stock is forged to a test coupon and heat Ø treated as in 3.3, specimens taken from the heat treated coupon shall conform to the requirements of 3.4.1.1. If specimens taken from the stock after heat treatment as in 3.3 conform to the requirements of 3.4.1.1 the tests shall be accepted as equivalent to tests of a forged coupon.

3.5 Quality:

3.5.1 Alloy shall be multiple melted; at least one of the melting cycles shall Ø be under vacuum. The first melt shall be made by consumable electrode, non-consumable electrode, electron beam, or plasma arc melting practice. The subsequent melt or melts shall be made using consumable electrode practice with no alloy additions permitted in the last consumable electrode melt.

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.

3.5.1.2 The electrode tip for non-consumable electrode melting shall be water-cooled copper.

3.5.2 The product, as received by purchaser, shall be uniform in quality and Ø condition, sound, and free from foreign materials and from imperfections detrimental to usage of the product.

3.5.3 Grain flow of die forgings, except in areas which contain flash-line end Ø grain, shall follow the general contour of the forgings, showing no evidence of re-entrant flow.

4. QUALITY ASSURANCE PROVISIONS:

4.1 Responsibility for Inspection: The vendor of the product shall supply all Ø samples for vendor's tests and shall be reponsible 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 product conforms to the requirements of this specification.

4.2 Classification of Tests:

4.2.1 Acceptance Tests: Tests to determine conformance to requirements for Ø composition (3.1), tensile properties (3.4.1.1), fracture toughness (3.4.1.2), microstructure (3.4.1.3), surface contamination (3.4.1.5), and beta-transus temperature (3.4.1.6) are classified as acceptance tests and shall be performed on each heat or lot as applicable.

4.2.2 Periodic Tests: Tests of forging stock to demonstrate ability to meet Ø specified requirements (3.4.2) are classified as periodic tests and shall be performed at a frequency selected by the vendor unless frequency of testing is specified by purchaser.

4.2.3 Preproduction Tests: Tests of forgings to determine conformance to all applicable 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, processing, or both requires reapproval as in 4.4, and when purchaser deems confirmatory testing to be required.

4.2.3.1 For direct U.S. Military procurement of forgings, 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 not less than 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 facture toughness specimens shall be as agreed upon by purchaser and vendor. If not defined by purchaser, vendor shall select test specimens from the heaviest section and shall select orientation in the following order of preference: transverse or longitudinal for tensile specimens and S-T, T-L, or L-T in accordance with ASTM E399 for fracture toughness specimens.

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 may be taken from any convenient location outside the machined part envelope for surface examination and from broken tensile specimens for general microstructure.