

**Material Specification;  
Forged bar of Titanium blades  
Ti-6Al-2Sn-4Zr-2Mo  
(UNSR54620)**

<b>Document Title:</b> Material Specification; Forged bar of Titanium blades Ti-6Al-2Sn-4Zr-2Mo(UNSR54620)	<b>Engineering Reference Document</b>		<a href="#">Index</a>
	<b>Doc. No:</b> MTS53502	<b>Rev:</b> 02	<b>Page 1 of 14</b>

**Revision:**

Rev. No	Date	Description
0	31/08/2019	First issue
01	21/11/2019	Second issue: Added the room temp. rupture test
02	17/12/2019	Third issue: revised on standard of NDT

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11	X	X														
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**Document Title:**

Material Specification; Forged bar of Titanium blades  
Ti-6Al-2Sn-4Zr-2Mo(UNSR54620)

Engineering Reference Document

[Index](#)

Doc. No: MTS53502

Rev: 02

Page 2 of 14

## Contents

<b>1. SCOPE</b> .....	<b>4</b>
<b>2. NORMATIVE REFERENCE</b> .....	<b>4</b>
<b>3. GENERAL REQUIREMENT</b> .....	<b>5</b>
3.1 PROCESS QUALIFICATION .....	5
<b>4. MANUFACTURING PROCESS</b> .....	<b>6</b>
4.1. MATERIAL REQUIREMENTS .....	6
4.2. MELTING PROCESS .....	6
4.3. HEAT TREATMENT .....	7
<b>5. CHEMICAL COMPOSITION</b> .....	<b>7</b>
<b>6. SAMPLING</b> .....	<b>8</b>
<b>7. MECHANICAL PROPERTIES</b> .....	<b>8</b>
7.1 AT ROOM TEMPERATURE .....	8
7.2 AT ELEVATED TEMPERATURE .....	9
7.3 ROOM-TEMPERATURE NOTCHED STRESS-RUPTURE PROPERTIES:.....	10
7.4 CREEP PROPERTIES AT 950 °F (510 °C).....	10
7.5 DEVIATION IN MECHANICAL PROPERTIES .....	10
<b>8. MICROSTRUCTURE TESTING</b> .....	<b>10</b>
8.1 SURFACE CONTAMINATION .....	11
<b>9. NON DESTRUCTIVE TESTING</b> .....	<b>11</b>
9.1. ULTRASONIC TESTING .....	11
9.2. DYE PENETRANT TEST .....	11
<b>10. DIMENSIONS AND TOLERANCES/SURFACE QUALITY</b> .....	<b>11</b>
<b>11. DOCUMENTATION</b> .....	<b>12</b>
<b>12. PACKING &amp; MARKING</b> .....	<b>12</b>
<b>13. FINAL INSPECTION</b> .....	<b>13</b>
<b>14. SHIPMENT</b> .....	<b>13</b>
<b>ANNEX. A: SAMPLING REQUIREMENTS</b> .....	<b>14</b>

**Document Title:**

Material Specification; Forged bar of Titanium blades  
Ti-6Al-2Sn-4Zr-2Mo(UNSR54620)

Engineering Reference Document

[Index](#)

Doc. No: MTS53502

Rev: 02

Page 3 of 14

## 1. Scope

This specification covers compressor blades forged bar requirements made of Ti-6Al-2Sn-4Zr-2Mo (UNSR54620).

## 2. Normative Reference

The following standards contain provisions which, through reference in this text, constitute provisions of this procedure. For dated references, subsequent amendments to, or revisions of, any of these publications do not apply.

AMS4976J: Titanium Alloy, Forgings 6.0Al-2.0Sn-4.0Zr-2.0Mo-0.08Si Solution and Precipitation Heat Treated;

AMS2750: Pyrometry

ASTM E10-12: Standard Test Method for Brinell Hardness of Metallic Materials;

ASTM E 8 / E 8M: Tension Testing of Metallic Materials

ASTM E 21: Elevated Temperature Tension Tests of Metallic Materials

ASTM E 139: Conducting Creep, Creep-Rupture, and Stress-Rupture Tests of Metallic Materials;

ASTM E 1447 Determination of Hydrogen in Titanium and Titanium Alloys by the Inert Gas Fusion Thermal Conductivity/Infrared Detection Method;

ASTM E 1941 Determination of Carbon in Refractory and Reactive Metals and Their Alloys by Combustion Analysis;

ASTM A370-12: Standard Test Methods and Definitions for Mechanical Testing of Steel Products;

AMS2241: Tolerances, Corrosion and Heat-Resistant Steel, Iron Alloy, Titanium, and Titanium Alloy Bars and Wire

EN 10204: Metallic Products- Types of Inspection Documents,

EN ISO 9001:2008: Quality Management Systems-Requirements,

ASTM E165: Standard Practice for Liquid Penetrant Examination for General Industry,

ASME sec V article 6: Nondestructive Examination.

<b>Document Title:</b>  Material Specification; Forged bar of Titanium blades Ti-6Al-2Sn-4Zr-2Mo(UNSR54620)	<b>Engineering Reference Document</b>		<a href="#">Index</a>
	<b>Doc. No:</b> MTS53502	<b>Rev:</b> 02	<b>Page 4 of 14</b>

AMS 2361D: Ultrasonic Inspection Titanium and Titanium Alloy Bar, Billet and Plate

**TUGA internal procedure:**

- EPS6007: Preservation, Packaging, Storage and Shipping (General requirement);
- EPS9009: Instruction of Marking and Stamping;

In case of conflict between this specification and any other references, the information included in this specification shall govern.

### **3. General Requirement**

#### **3.1 Process Qualification**

The supplier shall possess a quality management system which complies with the standards of EN ISO 9001:2008.

For a new product performing a standard method of PPQ (Product / Process Qualification) is necessary, and following documents shall be submitted to customer/purchaser by manufacturer for approving process: Manufacturing process, Manufacturing plan, heat treatment and test sequence plan.

Manufacturer shall prepare QCP (Quality Control Plan) according to TUGA's ITP (Inspection and Test Plan). Also Manufacturer shall receive QCP approval from TUGA prior of manufacturing process.

The approved documents are obligatory for production and any change in approved documents shall be submitted for permission.

The manufacturer has to inform the purchaser about every change in the manufacturing or inspection process. The purchaser decides if a new qualification process is necessary.

The PPQ for first productions is "Frozen" method and shall not be changed with supplier without approval new or revised PPQ.

It shall be the responsibility of the Supplier to understand thoroughly the work scope and all documentation needed to complete the work.

<b>Document Title:</b>  Material Specification; Forged bar of Titanium blades Ti-6Al-2Sn-4Zr-2Mo(UNSR54620)	<b>Engineering Reference Document</b>		<a href="#"><u>Index</u></a>
	<b>Doc. No:</b> MTS53502	<b>Rev:</b> 02	<b>Page 5 of 14</b>

## 4. Manufacturing Process

The parts classified according to this specification may be made by any suitable raw material that will produce the parts that meets the requirements of this specification.

Material shall be supplied Solution and precipitation heat treated, and descaled condition.

Forging stock shall be ordered by the forging manufacturer.

Hot finished with or without subsequent cold reduction, solution and precipitation heat treated, and descaled. The product shall be processed to the final thickness/diameter by metallurgical working operations prior to any straightening, dimensional sizing or surface finishing operations. Bar shall not be cut from plate.

### 4.1. Material Requirements

Material supplied to this specification shall be uniform in quality and condition, clean, sound, free from inclusions and internal and external defects detrimental to the application.

There must be sufficient discard from each ingot to secure freedom from piping and excessive segregation and non-metallic inclusions.

A certificate of test is required for all material to the requirements of the applicable Material Specification.

All grinding, machining, and abrasive wheel cutting operations shall be controlled so that they do not cause burning and discoloration. Machining operations shall be documented and approved in the Process Plan.

### 4.2. Melting Process

Alloy shall be multiple melted. The first melt shall be made by vacuum consumable electrode, non-consumable electrode, electron beam cold hearth, or plasma arc cold hearth melting practice. The subsequent melt or melts shall be made under vacuum using vacuum arc remelting (VAR) practice. Alloy additions are not permitted in the final VAR melt.

The atmosphere for non-consumable electrode melting shall be vacuum or shall be argon and/or helium at an absolute pressure not higher than 1000 mm of mercury.

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

<b>Document Title:</b>  Material Specification; Forged bar of Titanium blades Ti-6Al-2Sn-4Zr-2Mo(UNSR54620)	<b>Engineering Reference Document</b>		<a href="#">Index</a>
	<b>Doc. No:</b> MTS53502	<b>Rev:</b> 02	<b>Page 6 of 14</b>

### 4.3. Heat treatment

Forgings shall be solution heat treated by heating to a temperature 25 to 50 °F (14 to 28 °C) degrees below the beta transus determined on each heat of alloy, holding at the selected temperature within  $\pm 15$  °F ( $\pm 8$  °C) for 60 minutes  $\pm 5$ , and cooling at a rate equivalent to an air cool or faster and precipitation heat treated by heating to 1100 °F  $\pm 15$  (593 °C  $\pm 8$ ), holding at heat for 8 hours  $\pm 0.25$ , and cooling in air. Pyrometry shall be in accordance with AMS2750.

### 5. Chemical Composition

Shall conform to the percentages by weight shown in Table 1; carbon shall be determined in accordance with ASTM E 1941, hydrogen in accordance with ASTM E 1447, oxygen and nitrogen in accordance with ASTM E 1409, and other elements in accordance with ASTM E 2371. Other analytical methods may be used if acceptable to the purchaser.

Table.1- Chemical composition

Element	Weight Percent
Aluminum	5.50-6.50
Zirconium	3.60-4.40
Molybdenium	1.80-2.20
Tin	1.80-2.20
Silicon	0.06-0.1
Oxygen(max)	0.15
Iron(max)	0.10
Carbon( max)	0.05
Nitrogen(max)	500ppm
Hydrogen(max)	125ppm
Yttrium(max)	50ppm
Other Elements	0.10
Other Elements, total	0.40

**Document Title:**

Material Specification; Forged bar of Titanium blades  
Ti-6Al-2Sn-4Zr-2Mo(UNSR54620)

**Engineering Reference Document**

[Index](#)

**Doc. No:** MTS53502

**Rev:** 02

**Page 7 of 14**

Titanium	Remainder
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Hydrogen content of rings may be as high as 0.0150 (150 ppm).

For hydrogen analysis, conducted in accordance with ASTM E 1447, sample size may be as large as 0.35 gram.

Determination not required for routine acceptance.

Composition variations shall meet the applicable requirements of AMS2249.

## 6. Sampling

The mechanical properties shall be determined on the hardest and softest bar (by hardness testing) per melt and heat treatment batch (= test unit). If the reliability of the manufacturing process is proven then the test of the mechanical properties may only be tested at the softest bar of one test unit if this is agreed to by the purchaser in writing.

The hardness tests shall be performed on 100% of each bar on test unit.

One tensile test in longitudinal direction, one tensile test in transverse direction, one elevated tensile test in longitudinal direction and one creep test in longitudinal are required for each batch.

Test conditions shall be according to section 7.

The location of samples, direction and requirements shall be according to Annex. A.

## 7. Mechanical Properties

### 7.1 At Room Temperature

Mechanical properties (tensile test) shall be tested at room temperature ( $23 \pm 5^{\circ}\text{C}$ ). The following properties shall be achieved at room temperature (Table2):

<b>Document Title:</b> Material Specification; Forged bar of Titanium blades Ti-6Al-2Sn-4Zr-2Mo(UNSR54620)	<b>Engineering Reference Document</b>		<a href="#">Index</a>
	<b>Doc. No:</b> MTS53502	<b>Rev:</b> 02	Page <b>8</b> of <b>14</b>



Table2- Mechanical Properties

Tensile strength MPa	Yield strength at 0.2% offset MPa	Elongation in 50.8 mm or 4D %	Reduction Of Area %
896	827	10	25

Tensile test shall be in accordance with E 8M on specimens as in 6 with the rate of strain set at 0.005 mm/mm/minute and maintained within a tolerance of 0.002 mm/mm/minute through the 0.2% offset yield strain.

Hardness test shall be performed according to ASTM E10 and ASTM A370 all bars. The surface of parts shall be prepared for measuring the hardness. The depth of cleaning shall ensure the entire removal of alloying elements denuded and decarburized depletion layer from the part surface.

## 7.2 At elevated Temperature

Material shall be as specified in Table 3, determined in accordance with ASTM E 21 on specimens heated to 900 °F ± 10 (482 °C ± 6), held at heat for 20 to 30 minutes before testing, and tested at 900 °F ± 10 (482 °C ± 6) using strain rates as specified in 7.1.

Table.3 - elevated mechanical properties

Tensile strength MPa	Yield strength at 0.2% offset MPa	Elongation in 50.8 mm or 4D %	Reduction Of Area %
621	483	15	35

### Document Title:

Material Specification; Forged bar of Titanium blades  
Ti-6Al-2Sn-4Zr-2Mo(UNSR54620)

### Engineering Reference Document

Doc. No: MTS53502

Rev: 02

### [Index](#)

Page 9 of 14

### 7.3 Room-Temperature Notched Stress-Rupture Properties:

A standard cylindrical notched specimen, conforming to ASTM E 292, maintained at room temperature while a load sufficient to produce an initial axial stress of (1172 MPa) is applied continuously, shall not rupture in less than 5 hours. The initial stress may be less than (1172 MPa) and increased to (1172 MPa), based on the initial diameter at root of notch, in increments of (69 MPa) at intervals of not less than 5 hours. Test shall be conducted in accordance with ASTM E 292.

### 7.4 Creep Properties at 950 °F (510 °C)

An unnotched tensile specimen, maintained at 950 °F ± 3 (510 °C ± 2) while an axial stress of 35.0 ksi (241 MPa) is applied continuously, shall not exceed 0.1% plastic strain in less than 35 hours. Test shall be conducted in accordance with ASTM E 139.

### 7.5 Deviation in mechanical properties

If any specimen used in the above tests fails to meet the specified requirements, disposition of the product may be based on the results of testing three additional specimens for each original nonconforming specimen. Failure of any retest specimen to meet the specified requirements shall be cause for rejection of the product represented. Results of all tests shall be reported. Testing conditions and requirements shall be according to AMS 4976.

## 8. Microstructure Testing

Shall be that structure resulting from processing within the alpha-beta phase field. Microstructure shall conform to below items.

- Equiaxed and/or elongated primary alpha in a transformed beta matrix with no continuous network of alpha at prior beta grain boundaries.
- Essentially complete field of equiaxed and/or elongated alpha with or without intergranular beta and with no continuous network of alpha at prior beta grain boundaries.

<b>Document Title:</b>  Material Specification; Forged bar of Titanium blades Ti-6Al-2Sn-4Zr-2Mo(UNSR54620)	<b>Engineering Reference Document</b>		<a href="#">Index</a>
	<b>Doc. No:</b> MTS53502	<b>Rev:</b> 02	Page <b>10</b> of <b>14</b>

## 8.1 Surface Contamination

The product shall be free of any oxygen-rich layer, such as alpha case, or other surface contamination, determined by microscopic examination at not lower than 400X magnification or by other method acceptable to purchaser.

## 9. Non Destructive Testing

### 9.1. Ultrasonic testing

Ultrasound test of internal defects must be carried out according to AMS 2631D.

#### Requirements:

Testing shall be carried out after heat treatment. The finish shall be such that it permits unrestricted testing. The Ra value should not exceed 16 µm. Impurities on the surface are not permissible.

#### Acceptance criteria:

The evaluation of defects has to be made according to ASM 2361D. The maximum allowable quality grade value of an entire part is quality class AA.

### 9.2. Dye penetrant test

Dye penetrant test shall be carried out on all forged bars ready for delivery according to (ASTM E165 alt, ASME sec V article 6) and following acceptance limits should be followed.

**Acceptance:** All defects at the surfaces of forgings subjected to machining should be reported and permitted if the depth of the defect does not exceed 75 % of the actual unilateral allowance for machining.

## 10. Dimensions and Tolerances/Surface Quality

Bars shall conform to all applicable requirements of AMS2241.

<b>Document Title:</b>  Material Specification; Forged bar of Titanium blades Ti-6Al-2Sn-4Zr-2Mo(UNSR54620)	<b>Engineering Reference Document</b>		<a href="#">Index</a>
	<b>Doc. No:</b> MTS53502	<b>Rev:</b> 02	Page <b>11</b> of <b>14</b>

## 11. Documentation

Prior to, but in no case later than the delivery of the material, an inspection certificate 3.1 per EN 10204 in National language and in English shall be provided to the purchaser in duplicate; this certificate must contain the following data:

- Order No,
- Material designation.
- Heat number, heat analysis and melting method.
- Results of non-destructive and destructive examinations,
- Complete information on all heat treatments performed.
- Confirmation of the quality ordered, certified by records on the NDE performed.
- Confirmation of the dimensional and visual check.

The certificate shall be sent to the address given in the order.

## 12. Packing & Marking

Marking shall be according to EPS9009. Each bars has to be mark with the individual identification number (serial number or Kenn number), which is given in the order. Serial (Kenn) number, material number and drawing number shall be stamped at specified location which indicated in part drawing. Otherwise, if no identification No. is obtained, the marking has to be carried out with the pattern No. and the heat No.

Packaging and preservation shall be according to EPS6007. Packing and conservation of parts shall be sufficient to protect them from damage during transit from point of manufacturer and storage at shop under conditions which may involve multiple handling, extended storage, exposure to moisture and many other issues.

The act of preservation shall protect equipment and components by filling air spaces, displacing water and providing a barrier against deterioration and corrosion. In addition to deterioration, activities preserving must also be concerned with physical damage during handling, shipping, or storage. For avoiding the cover bag damage, the packed unit shall be protected by transportation container or safety Box which will be fastened carefully.

<b>Document Title:</b>  Material Specification; Forged bar of Titanium blades Ti-6Al-2Sn-4Zr-2Mo(UNSR54620)	<b>Engineering Reference Document</b>		<a href="#">Index</a>
	<b>Doc. No:</b> MTS53502	<b>Rev:</b> 02	Page <b>12</b> of <b>14</b>

### 13. Final Inspection

Supplier shall invite the representatives of the TUGA at least 4 weeks in advance. At the date of inspection all mentioned documents in section 11 shall be available for review. Customer inspector shall control final documents.

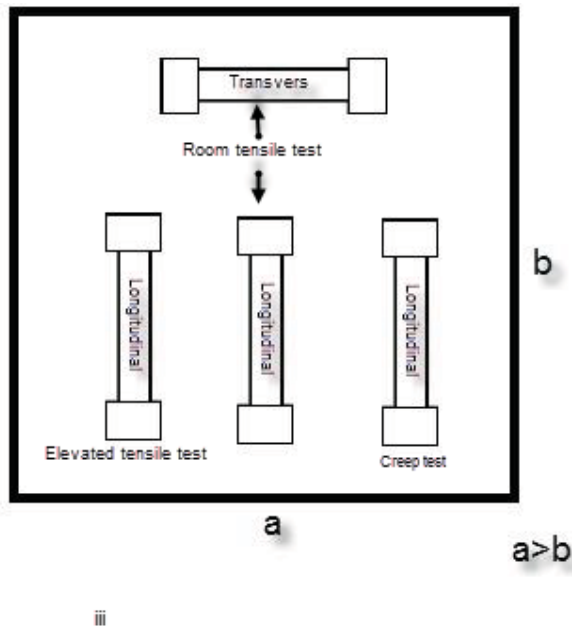
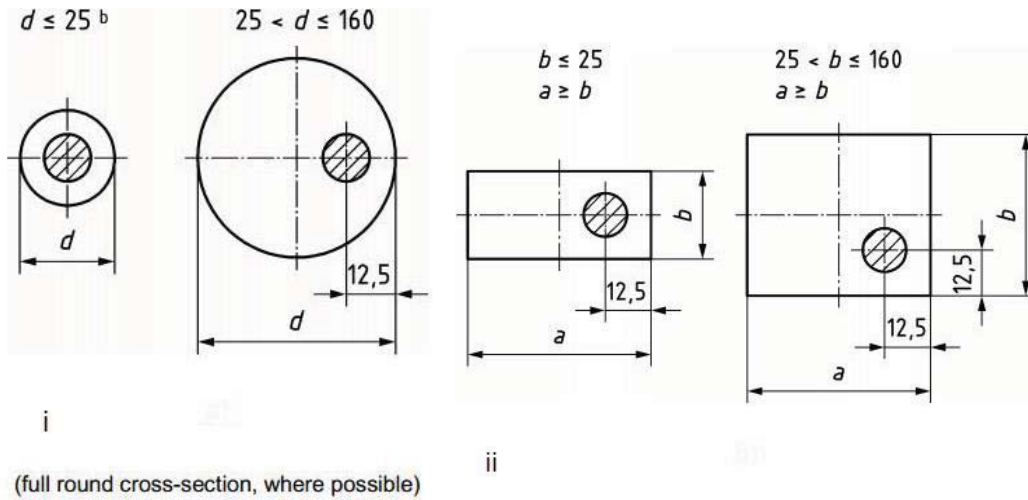
The acceptance does not relieve of manufacturer's responsibility for hidden defects that will discover later time. Difficulties which might lead to delays in delivery must be reported to the TUGA immediately.

### 14. Shipment

The product shall be prepared for shipment in accordance with commercial practice and in compliance with applicable rules and regulations pertaining to the handling, packaging, and transportation of the product to ensure carrier acceptance and safe delivery.

<b>Document Title:</b>  Material Specification; Forged bar of Titanium blades Ti-6Al-2Sn-4Zr-2Mo(UNSR54620)	<b>Engineering Reference Document</b>		<a href="#">Index</a>
	<b>Doc. No:</b> MTS53502	<b>Rev:</b> 02	Page <b>13</b> of <b>14</b>

## Annex. A: Sampling requirements



- i) Round Cross section products
- ii) Rectangular cross section products
- iii) Schematic of longitudinal and transverse sample

**Document Title:**

Material Specification; Forged bar of Titanium blades  
 Ti-6Al-2Sn-4Zr-2Mo(UNSR54620)

Engineering Reference Document

[Index](#)

Doc. No: MTS53502

Rev: 02

Page 14 of 14