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An American National Standard

Standard Specification for Precipitation Hardening Iron Base Superalloy Forgings for Turbine Rotor Disks and Wheels[1]

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1. Scope

1.1 This specification covers precipitation hardening iron base superalloy forgings which are primarily intended for use as turbine rotor disks and wheels.

1.2 Two heat treatments are covered. Selection will depend upon design, service conditions, mechanical properties, and elevated temperature characteristics.

1.3 All of the provisions of Specification A 788, apply, except as amended herein.

1.4 The values stated in inch-pound units are to be regarded as the standard. The values given in parentheses are for information only.

2. Referenced Documents

2.1 *ASTM Standards:*

A 788 Specification for Steel Forgings, General Requirements[2]

E 112 Test Methods for Determining the Average Grain Size[3]

E 139 Test Methods for Conducting Creep, Creep-Rupture, and Stress-Rupture Tests of Metallic Materials[3]

E 165 Test Methods for Liquid Penetrant Examination[4]

E 292 Test Methods for Conducting Time-for-Rupture Notch Tension Tests of Materials[3]

3. Ordering Information

3.1 Orders for material under this specification shall include the information specified in Specification A 788 and the following:

3.1.1 *Condition*—See Section 4.

3.1.2 *Stress Rupture Test*—Parameters for material furnished in condition 2 of 8.3.3.

3.1.3 *Forging Drawing*—Each forging shall be manufactured in accordance with a drawing furnished by the purchaser showing the dimensions of the forging and the location of mechanical test specimens.

4. Condition

4.1 The forgings covered in this specification may be ordered in two different solution treated and aged conditions:

4.1.1 *Type 1*:

4.1.1.1 Solution anneal at 1650 ± 25°F (900 ± 14°C) for 2 to 5 h at temperature liquid quench.

4.1.1.2 Precipitation harden at 1420 ± 15°F (770 ± 8°C) for 16 h at temperature air cool; 1200 ± 15°F (650 ± 8°C) for 16 h at temperature air cool.

4.1.2 *Type 2*:

4.1.2.1 Solution anneal at 1800 ± 25°F (980 ± 14°C) for 2 to 5 h at temperature liquid quench.

4.1.2.2 Precipitation harden at 1420 ± 15°F (770 ± 8°C) for 16 h at temperature air cool; 1200 ± 15°F (650 ± 8°C) for 16 h at temperature air cool.

5. Manufacture

5.1 The material shall be made by vacuum melting followed by consumable electrode vacuum arc or electroslag remelting as agreed upon between producer and user.

5.2 The forgings shall be upset forged so that the axis of the disk corresponds with that of the ingot.

6. Chemical Requirements

6.1 *Heat Analysis*—Each heat shall be analyzed by the manufacturer in accordance with Specification A 788. The chemical composition shall conform to the requirements specified in Table 1.

7. Heat Treatment

7.1 The forgings shall be heat treated in accordance with 4.1.

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[1] This specification is under the jurisdiction of Committee A01 on Steel, Stainless Steel, and Related Alloys and is the direct responsibility of Subcommittee A01.06 on Steel Forgings and Billets.

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[2] *Annual Book of ASTM Standards*, Vol 01.05.

[3] *Annual Book of ASTM Standards*, Vol 03.01.

[4] *Annual Book of ASTM Standards*, Vol 03.03.

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TABLE 1 Chemical Composition

Element	Heat and Product Analyses Range, Percentage	Product Analysis Tolerance—Over or Under
Carbon	0.05 max	0.01
Manganese	0.50 max	0.03
Silicon	0.50 max	0.05
Phosphorus	0.025 max	0.005
Sulfur	0.015 max	0.005
Chromium	13.50–16.00	0.20
Nickel	24.00–27.00	0.20
Molybdenum	1.00–1.50	0.05
Titanium	1.90–2.35	0.07
Boron	0.003–0.010	0.001 over 0.0004 under
Vanadium	0.10–0.50	0.03
Aluminum	0.35 max	0.05
Iron	remainder	

8. Mechanical Properties

8.1 The forgings shall conform to the mechanical property requirements specified in Table 2 after heat treatment as prescribed in 4.1.

8.2 *Tension and Hardness*—Tension and hardness testing shall be conducted in accordance with Specification A 788.

8.3 *Stress Rupture*:

8.3.1 Combination smooth and notched bar specimens using 0.252 in. (6.4 mm) diameter bars shall be tested to rupture in accordance with Practice E 292. Rupture must occur in the smooth section of each specimen. After 100 h, samples may be uploaded in 5-ksi (35-MPa) increments in 8 to 16 h intervals.

8.3.2 Material supplied as Type 1 shall meet the stress rupture requirements specified in Table 3.

8.3.3 Material supplied as Type 2 shall meet the stress rupture requirements of either Test A or Test B of Table 3 as specified by the purchaser.

8.4 *Creep*:

8.4.1 A creep test shall be performed in accordance with Practice E 139 on a 0.252 in. (6.4 mm) diameter smooth bar.

8.4.2 The material shall meet the requirements specified in Table 4 after heat treatment as prescribed in 4.1.

8.5 *Number of Tests*—The testing frequency shall be as follows with a lot being defined as not more than 50 pieces of the same part made from the same heat of material to the same forging parameters, forged within an 8 h period, and heat treated together:

8.5.1 For forgings weighing less than 500 lb (227 kg) each, one tension, stress rupture, and creep test shall be made on one forging per lot. In addition, two hardness tests shall be made on each piece in the lot.

8.5.2 For forgings weighing 500 lb to 2000 lb (227 kg to 907 kg) one tension, stress rupture, and creep test, and two hardness tests shall be made on each forging.

TABLE 2 Mechanical Property Requirements

	Type 1	Type 2
Tensile Strength, min, ksi [MPa]	140 (965)	130 (895)
0.2 % Offset Yield Strength, min, ksi [MPa]	95 (655)	85 (585)
Elongation in 4, min, %	12	15
Reduction of Area, min, %	15	20
Hardness, HB	277–363	248–341

TABLE 3 Stress Rupture Requirements

	Test Temp, °F (°C)	Stress, ksi (MPa)	Min, h	Min, Elongation in 4, %
Type 1	1200 (649)	56 (385)	100	15
Type 2				
Test A	1200 (649)	56 (385)	100	8
Test B	1200 (649)	65 (450)	30	10

TABLE 4 Creep Requirements

Temperature, °F (°C)	Stress, ksi (MPa)	Time, h	Creep Strain, %
1000 (538)	85 (585)	100	0.1–2.0

8.5.3 For forgings weighing over 2000 lb (907 kg) testing shall be performed as covered in 8.5.1.2 or in Supplementary Requirement S1. In addition, one tangential tension, stress rupture, and creep test shall be run on material taken from the forging hub.

8.6 *Test Location*:

8.6.1 The tension, stress rupture, and creep specimens covered in 8.5.1 and 8.5.2 shall be machined from tangential bars taken from the forging rim.

8.6.2 Hardness tests shall be taken on both the rim and hub.

9. Microstructure

9.1 The forgings shall have an average grain size of number 4 or finer as determined in accordance with Test Methods E 112. The material shall be of a uniform microstructure, free of phase or compound formations such as a continuous grain boundary film.

9.2 One test per lot is required for forgings weighing less than 500 lb (227 kg) each. One test per forging is required on all other forgings.

9.3 The microstructural examination may be performed on material taken from the non-deformed grip section of a peripheral tensile test specimen or on a separate sample taken from the peripheral area of a forging.

10. Non-Destructive Examinations

10.1 *Ultrasonic Examination*:

10.1.1 Each forging shall be subjected to ultrasonic examination.

10.1.2 The method of ultrasonic examination and acceptance level shall be agreed upon between the purchaser and manufacturer.

10.2 *Liquid Penetrant Examination*—Each forging shall be subjected to liquid penetrant examination using one of the methods outlined in Practice E 165. The specific test procedure and acceptance level shall be as agreed upon by the purchaser and manufacturer.

11. Quality

11.1 The forgings shall be uniform in quality and condition, clean, sound, and free of cracks, seams, laps, shrinkage, and other injurious imperfections.

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12. Retests

12.1 If any test specimen fails to meet specified requirements because of defective machining or a flaw other than a rupture, crack, or flake, a single retest shall be allowed.

12.2 If the results of any test lot are not in conformance with the requirements of this specification, such lots may be retreated by the manufacturer with the agreement of the purchaser. The material shall be acceptable if the results of the retests on the retreated material are within the requirements of this specification.

13. Certification and Reports

13.1 Certifications shall be furnished in accordance with Specification A 788.

13.2 The report shall include the results of the chemical analysis(ses), microstructural examination, the date, drawing number, melt practice used, ingot number and position or serial number and the name of the manufacturer. It shall also include the test parameters and results of the tensile, creep, stress-rupture, and hardness testing as well as the ultrasonic and liquid penetrant examination results.

14. Product Marking

14.1 Each forging shall be legibly stamped by the manufacturer in accordance with Specification A 788. Markings shall include the ingot number and position or serial number, part number, and purchase order number.

15. Keywords

15.1 age hardened; creep; elevated temperature service; forging; alloy steel—turbine disk; forging; alloy steel—turbine wheel; precipitation hardened; stress rupture; superalloy

SUPPLEMENTARY REQUIREMENTS

The following supplemental requirements shall apply only when specified by the purchaser on the order and agreed to by the manufacturer.

S1. Number of Test

S1.1 Two tension and stress rupture tests shall be made on each forging weighing less than 2000 lb (907 kg). Each set of tests shall be machined from tangential bars located 180° apart on the forging rim.

S1.2 One creep test shall be made on each forging weighing less than 2000 lb (907 kg). Test material shall be taken from the same location as that for one of the sets of test bars covered in S1.1.

S1.3 One microstructural examination shall be performed on each forging in accordance with 9.1.

S1.4 A product analysis of each forging shall be made by the manufacturer in accordance with Specification A 788 and shall conform to the requirements of Table 1.

S2. Stress Rupture

S2.1 The stress rupture tests conditions shall be 1200°F (650°C), 65 ksi (450 MPa), 30 h minimum, no upload, with a 15 % minimum elongation.

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