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Standard Specification for Vacuum Treated Steel Forgings, Alloy, Differentially Heat Treated, for Turbine Rotors[1]

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1. Scope

1.1 This specification covers vacuum treated, alloy steel forgings, differentially heat treated for turbine rotors.

1.2 Differential heat treatment of a rotor forging involves subjecting two portions of the forging concurrently to two different austenitizing temperatures followed by two different cooling rates for normalizing and quenching, and then tempering, to achieve creep resistance in the high pressure (HP) portion and high toughness in the low pressure (LP) portion.[2]

1.3 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 275/A 275M Test Methods for Magnetic Particle Examination of Steel Forgings[3]

A 370 Test Methods and Definitions for Mechanical Testing of Steel Products[3]

A 418 Test Method of Ultrasonic Examination Inspection of Turbine and Generator Steel Rotor Forgings[3]

A 470 Specification for Vacuum-Treated Carbon and Alloy Steel Forgings for Turbine Rotors and Shafts[3]

A 472 Test Method for Heat Stability of Steam Turbine Shafts and Rotor Forgings[3]

A 751 Test Methods, Practices, and Terminology for Chemical Analysis of Steel Products[4]

A 788 Specification for Steel Forgings, General Requirements[3]

E 139 Practice for Conducting Creep, Creep-Rupture, and Stress-Rupture Tests of Metallic Materials[5]

3. Ordering Information

3.1 In addition to the ordering information required by Specification A 788, the purchaser shall include with the inquiry and order a detailed drawing, sketch, or written description of the forging, including the mechanical test locations, the portion of the forging to be included in the heating chamber during the stability test, and the minimum stability test temperature.

3.2 The purchaser shall specify if check tests for mechanical properties are required after stress relief or heat stability tests.

3.3 *Supplementary Requirements*—Supplementary requirements are provided. These requirements shall apply only when specified in the purchase order.

4. General Requirements

4.1 Material supplied to this specification shall conform to the requirements of Specification A 788, which outlines additional ordering information, manufacturing requirements, testing and retesting methods and procedures, marking, certification, product analysis variations, and additional supplementary requirements.

4.2 If the requirements of this specification are in conflict with the requirements of Specification A 788, the requirements of this specification shall prevail.

5. Manufacture

5.1 Melting processes of Specification A 788 shall be applicable, except that the open hearth or basic oxygen methods of primary melting shall not be used and the molten steel shall be vacuum treated during processing. When the ladle degassing process is used, the evacuation system shall be capable of reducing the system vacuum pressure to a low level (usually

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[2] *Symposium on Steel Forgings, ASTM STP 903*, ASTM, Philadelphia, PA, 1984, pp. 59-86.

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

[4] *Annual Book of ASTM Standards*, Vol 01.03.

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

less than 1000 µm). The molten metal shall be stirred adequately for a sufficient length of time to maximize exposure to the evacuated atmosphere. When this process is used, hydrogen testing per Supplementary Requirement S4 is mandatory.

5.1.1 If the ESR process is used, the electrodes shall have been produced from vacuum treated primary heat(s), and Supplementary Requirement S4 is mandatory.

5.2 In addition to the requirements of Specification A 788, it is important to maintain the axial center of the forging in common with the axial center of the original ingot.

5.3 *Differential Heat Treatment*—The heat treatment for mechanical properties shall consist of normalizing and tempering of the creep resistant portion, HP portion, and quenching and tempering of the high toughness portion, LP portion.

5.3.1 The preliminary heat treatment shall consist of normalizing well above the transformation temperature range.

5.3.2 The normalizing and quenching treatments shall be from above the transformation range but below the normalizing temperature described in 5.3.1. This treatment shall be performed after preliminary machining.

5.3.2.1 The heat treatment for the HP portion shall consist of normalizing, accelerated air cooling, and tempering.

5.3.2.2 For the high toughness LP portion, the heat treatment shall consist of water quenching (or water-spray quenching) and tempering.

5.3.3 The final tempering temperature for all zones shall not be below 1200°F (649°C).

5.3.4 After heat treatment and subsequent rough machining and boring, the forging shall be stress relieved at a temperature not more than 100°F (55°C) below the final tempering temperature, but not below 1100°F (593°C).

5.3.5 With the prior approval of the purchaser, the stress relieving temperature may approach, equal, or slightly exceed the final tempering temperature as a means of adjusting final strength or toughness. If the stress relieving temperature is within 25°F (14°C) of the final tempering temperature, or higher, acceptance tests shall be obtained after the stress relieving operation.

5.3.6 The method of cooling the HP and LP portions during the normalizing, quenching, tempering, and stress relieving heat treating cycles shall be reported.

5.4 *Machining*:

5.4.1 *Preliminary Rough Machining*—All exterior surfaces of the forging shall be machined prior to heat treatment for mechanical properties.

5.4.2 *Second Rough Machining*—After heat treatment for mechanical properties, all surfaces of the forging shall be rough machined prior to stress relief and the stability test.

5.4.3 *Boring*:

5.4.3.1 Forgings shall be bored to permissible bore size and tolerances when required by the purchaser's drawing.

5.4.3.2 Forgings may be bored to limits agreed to by the purchaser or indicated on the purchaser's drawing, to remove objectionable center conditions revealed by ultrasonic inspection.

5.4.3.3 Unless otherwise specified by the purchaser, the manufacturer may bore the forging at any time after quenching and prior to stress relief.

5.4.4 *Machining to Purchaser's Requirements for Shipment*—The forging, as shipped, shall conform to the finish and dimensions specified on the purchaser's drawing or order.

6. Chemical Composition

6.1 *Heat Analysis*—An analysis of each heat of steel shall be made by the manufacturer. This analysis shall be made from a test sample taken preferably during the pouring of the heat. The steel shall conform to the requirements for chemical composition prescribed in Table 1.

6.2 *Product Analysis*—The manufacturer shall make a product analysis from each forging. The chemical composition thus determined shall not vary from the requirements specified in Table 1 by more than the amounts prescribed in Specification A 788.

6.3 *Referee Analysis*—Test Methods, Practices, and Terminology A 751 shall be used.

7. Mechanical Properties

7.1 *Tension Test*:

7.1.1 The steel shall conform to the tensile requirements of Table 2.

7.1.2 The number and location of tension test specimens shall be as specified on the forging drawings furnished by the purchaser.

7.1.3 Final acceptance tests shall be performed after heat treatment of the forging for mechanical properties prior to stress relief. If the stress relief temperature is within 25°F (14°C) of the tempering temperature, or higher, check tests shall be made after the stress relief treatment and reported to the purchaser. The purchaser may require check tests after the completion of all heating cycles, including stress relief and the heat stability tests.

7.1.4 The yield strength prescribed in Table 2 shall be determined by the offset method of Test Methods and Definitions A 370.

7.2 *Impact Test*:

7.2.1 The steel shall conform to the requirements for notch toughness (both transition temperature and room temperature impact values) prescribed in Table 3.

7.2.2 The notch toughness specimens shall be machined from radial bars taken from the main body of the forging, as shown in the forging drawing. The specimens shall be Charpy V-notch, Type A, as shown in Test Methods and Definitions A 370. The notch direction of the Charpy bars shall be as prescribed in Specification A 470.

TABLE 1 Chemical Composition

	Composition, % Grade 1
Carbon	0.23–0.31
Manganese	0.50–1.00
Phosphorus, max	0.012
Sulfur, max	0.015
Silicon, max	0.10
Nickel	0.80–1.10
Chromium	0.90–1.50
Molybdenum	1.10–1.50
Vanadium	0.20–0.30
Columbium (Niobium)	0.01–0.05
Aluminum	0.010 max