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Standard Specification for Vacuum-Treated Alloy Steel Forgings for Turbine Rotor Disks and Wheels[1]

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1. Scope

1.1 This specification covers vacuum-treated alloy steel forgings intended for use as turbine rotor disks and wheels.

1.2 The values stated in inch-pound units are to be regarded as the standard.

2. Referenced Documents

2.1 *ASTM Standards:*

A 275/A 275M Test Method for Magnetic Particle Examination of Steel Forgings[2]

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

A 388/A 388M Practice for Ultrasonic Examination of Heavy Steel Forgings[2]

E 30 Test Methods for Chemical Analysis of Steel, Cast Iron, Open-Hearth Iron, and Wrought Iron[4]

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

3. Ordering Information

3.1 The purchaser shall specify in the inquiry and order the class of steel desired and test and purchase options (see 4.5.5, 5.2.2, 6.1, 6.3, 7, and 15.1).

3.2 *Forging Drawing*—Each forging shall be manufactured in accordance with a purchaser-supplied drawing showing the finished dimensions and the locations of mechanical test specimens.

3.3 Supplementary requirements are provided and shall apply only when specified in the purchaser's order.

4. Materials and Manufacture

4.1 *Melting Process*—The steel shall be made by one or more of the following processes: electric-arc, electric-induction, or consumable-electrode.

4.2 *Vacuum Degassing*:

4.2.1 The molten steel shall be vacuum treated prior to or during the pouring of the ingot, in order to remove objectionable gases, particularly hydrogen.

4.2.1.1 When the vacuum stream degassing process[6] is used, the vacuum system must be of sufficient capacity to effect a blank-off pressure low enough (usually less than 1000 µm) to break up the normal tight, rope-like stream of molten metal into a wide-angled conical stream of relatively small droplets. The capacity of the system must also be sufficiently high to reduce the initial surge pressure at the start of the pour to a low level within 2 min.

4.2.1.2 When the vacuum-lift process[6] is utilized, the molten metal shall be repeatedly drawn into the evacuated vessel to give a recirculation factor (Note 1) of at least 2.5 to ensure thorough degassing and mixing of the entire heat. The evacuation system shall be capable of reducing the pressure surges, which occur each time a new portion of steel is admitted to the vessel, to increasingly lower levels until a blank-off pressure (usually less than 1000 µm) is achieved.

NOTE 1—The recirculation factor is obtained as follows:

$$\frac{\text{tons of steel lifted per cycle} \times \text{number of cycles}}{\text{heat weight in tons}}$$

4.2.1.3 When the ladle degassing process is used, the evacuation system shall be capable of reducing the system vacuum pressure to a low level (usually less than 1000 µm). The molten metal shall be adequately stirred for a sufficient length of time to maximize exposure to the evacuated atmosphere. When this process is used, hydrogen testing per Supplemental Requirement S2 is mandatory.

4.2.1.4 Other methods of degassing may be used if the supplier can demonstrate their adequacy to the satisfaction of the purchaser. When other processes are used, hydrogen testing per the supplemental requirement S2 is mandatory.

4.3 *Discard*—Sufficient discard shall be taken from each ingot to secure freedom from pipe and undue segregation in the finished forging.

[1] This specification is under the jurisdiction of ASTM Committee A-1 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 01.03.

[4] *Annual Book of ASTM Standards*, Vol 03.05.

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

[6] Details of the vacuum stream degassing process may be found in the *Journal of the Iron and Steel Institute*, Vol 191, January 1959; "Vacuum Pouring of Ingots for Heavy Forgings" by J. H. Stoll.

4.4 *Forging Process*—The forgings shall receive their hot mechanical work under a press, hammer, or mill of sufficient power to work the metal throughout its section. The forgings shall be upset by forming from a block having an axial length before upsetting of at least two times the thickness of the forging after upsetting.

4.4.1 The as-forged dimensions of each forging shall be planned so the metal is shaped by forging as close as is practical to the dimensions shown on the purchaser's drawing so as to keep subsequent machining to a minimum.

4.4.2 The axial center of the forging shall be maintained in common with the axial center of the ingot.

4.5 *Heat Treatment*:

4.5.1 *Cooling Prior to Heat Treatment*— After forging and before reheating for heat treatment, the forging shall be allowed to cool in a manner to prevent damage and to accomplish transformation.

4.5.2 *Preliminary Heat Treatment*—The forgings shall be given such preliminary heat treatment as is proper for the design and composition. The forgings shall be heated to a suitable temperature for a sufficient length of time for complete austenitization and shall be suitably cooled to bring about complete transformation.

4.5.3 *Heat Treatment for Mechanical Properties*—The forgings shall be reheated to a temperature above the upper critical temperature, held a sufficient length of time for complete austenitization, and liquid quenched.

4.5.4 *Tempering Temperature*—The forgings shall be tempered to develop the specified properties. The final tempering temperature for Class 1 to 6 and 11 through 14 shall be not less than 1100°F (593°C), and for Class 10 not less than 1200°F (649°C). The forgings shall be cooled under suitable conditions from the tempering temperature.

4.5.5 *Stress Relief*—Unless otherwise specified by the purchaser, the forgings shall be stress relieved after machining (see 4.6.2) by heating slowly to a temperature within 100°F (56°C) below the final tempering temperature but in no case below 1025°F (552°C) for Classes 1 to 6 and 11 through 14 and 1150°F (621°C) for Class 10. They shall be held for a sufficient length of time and then cooled under suitable conditions. This stress-relief temperature may be omitted provided the metal removed in accordance with 4.6.2, excluding test metal, does not exceed 3⁄16 in. (4.8 mm) on any surface.

4.6 *Machining*:

4.6.1 *Preliminary Machining*—The forgings shall be preliminarily machined on all surfaces prior to heat treatment for mechanical properties (see 4.5.3).

4.6.2 *Machining to Purchaser's Requirements for Shipment*—After heat treatment for mechanical properties (see 4.5.3), the forgings shall be machined to the dimensions of the purchaser's forging drawing or instructions on his order.

5. Chemical Composition

5.1 The steel shall conform to the requirements for chemical composition prescribed in Table 1.

5.2 *Chemical Analysis*:

5.2.1 *Heat Analysis*—An analysis of each heat of steel shall be made by the manufacturer to determine the percentages of those elements specified in Table 1. This analysis shall be made from a test ingot taken during the pouring of the heat.

5.2.1.1 If the test sample taken for the ladle analysis is lost or declared inadequate for chemical determinations, the manufacturer may take alternative samples from appropriate locations near the surface of the ingot or forging as necessary to establish the analysis of the heat in question.

5.2.2 *Product Analysis*—A product analysis may be made by the purchaser on each forging. Sample for an analysis may be taken from the forging at any point from the mid-radius to the outside diameter or from a full-size prolongation, or turnings may be taken from a test specimen. The chemical composition thus determined shall not vary from the requirements specified in Table 1 more than the amounts prescribed in Table 2.

5.3 *Test Methods of Analysis*—Test Methods E 30 shall be used for referee purposes.

6. Mechanical Properties

6.1 *Tension Test*—The material shall conform to the requirement for tensile properties prescribed in Table 3 when tested in accordance with Test Methods and Definitions A 370. Tension test specimens shall be the standard round, ½ -in. (12.7-mm) diameter, 2-in. (50.8-mm) gage length as shown in Test Methods and Definitions A 370. The yield strength prescribed in Table 3 shall be determined by the 0.2 % offset method of Test Methods and Definitions A 370. The offset shall be 0.2 % unless 0.02 % is specified in the ordering information.

TABLE 1 Chemical Requirements

	Composition, %			
	Classes 1 to 6, incl	Class 10	Classes 11 to 13, incl	Class 14
Carbon	0.28 max[A]	0.27–0.37	0.38–0.43	0.45 max
Manganese	0.70 max	0.70–1.00	0.60–1.00	0.60–1.00
Phosphorus	0.012 max	0.012 max	0.012 max	0.012 max
Sulfur	0.015 max	0.015 max	0.015 max	0.015 max
Silicon[B]	0.15–0.35	0.20 min	0.15–0.35	0.15–0.35
Nickel	2.00–4.00	0.50 max	0.50 max	1.65–3.50
Chromium	0.75–2.00	0.85–1.25	0.80–1.10	0.50–1.25
Molybdenum	0.20–0.70	1.00–1.50	0.15 min	0.20 min
Vanadium	0.05 min	0.20–0.30	0.06 max	optional
Antimony	C	C	C	C

[A] 0.35 % C max for Classes 4 and 5; 0.40 % C, max, for Class 6.
[B] When vacuum deoxidation is specified, silicon content shall be 0.10 max.
[C] To be reported for information only.