



Designation: ~~A471/A471M—09 (Reapproved 2014)~~ A471/A471M – 19

Standard Specification for Vacuum-Treated Alloy Steel Forgings for Turbine Rotor Disks and Wheels¹

This standard is issued under the fixed designation A471/A471M; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ϵ) indicates an editorial change since the last revision or reapproval.

1. ~~Scope~~ 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 either SI units or inch-pound units are to be regarded separately as standard. The values stated in each system ~~may~~ are not ~~be~~ necessarily exact equivalents; therefore, to ensure conformance with the standard, each system shall be used independently of the other. ~~Combining other, and~~ values from the two systems ~~may result in non-conformance with the standard; shall not be combined.~~

1.3 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate ~~safety~~ safety, health, and health environmental practices and determine the applicability of regulatory limitations prior to use.*

1.4 *This international standard was developed in accordance with internationally recognized principles on standardization established in the Decision on Principles for the Development of International Standards, Guides and Recommendations issued by the World Trade Organization Technical Barriers to Trade (TBT) Committee.*

2. Referenced Documents

2.1 *ASTM Standards:*²

[A275/A275M Practice for Magnetic Particle Examination of Steel Forgings](#)

[A370 Test Methods and Definitions for Mechanical Testing of Steel Products](#)

[A388/A388M Practice for Ultrasonic Examination of Steel Forgings](#)

[A751 Test Methods, Practices, and Terminology for Chemical Analysis of Steel Products](#)

[A788/A788M Specification for Steel Forgings, General Requirements](#)

[E139 Test Methods for Conducting Creep, Creep-Rupture, and Stress-Rupture Tests of Metallic Materials](#)

3. Ordering Information

3.1 Material supplied to this specification shall conform to the requirements of Specification [A788/A788M](#), which outlines additional ordering information, manufacturing methods and procedures, marking, certification, production analysis variations, and additional supplementary requirements.

3.2 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](#), ~~Section 7.4~~, and ~~Section 15.7~~).

3.3 *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.

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

4. Materials and Manufacture

4.1 *Melting Process:*

4.1.1 The steel shall be made by the basic electric-furnace process, with additional ladle refining being optional.

¹ This specification is under the jurisdiction of ASTM 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 For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the ~~standard's~~ standard's Document Summary page on the ASTM website.

*A Summary of Changes section appears at the end of this standard

4.1.2 Provisions for subsequent secondary melting of the steel by the consumable electrode-electroslag or vacuum-arc remelting processes are included in Supplementary Requirement S4.

4.2 The vacuum degassing requirements of Specification **A788/A788M** are mandatory.

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

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 [595°C]~~, 1100 °F [595 °C], and for Class 10 not less than ~~1200°F [650°C]~~, 1200 °F [650 °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 [55°C]~~, 100 °F [55 °C] below the final tempering temperature but in no case below ~~1025°F [550°C]~~, 1025 °F [550 °C] for Classes 1 to 6 and 11 through 14 and ~~1150°F [620°C]~~, 1150 °F [620 °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 $\frac{3}{16}$ in. [5 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 the 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.

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	_B	_B	_B	_B
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
Aluminum ^D	0.015 max	0.015 max	0.015 max	0.015 max

^A 0.35 % C max for Classes 4 and 5; 0.40 % C, max, for Class 6.

^B 0.10 % max unless an alternative value, not in excess of 0.35 %, is specified in the purchase order.

^C To be reported for information only.

^D Total of soluble and insoluble.

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~~ requested 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 1 of Specification **A788/A788M**.

5.3 *Test Methods of Analysis*—Test Methods, Practices, and Terminology **A751** 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 2** when tested in accordance with Test Methods and Definitions **A370**. Tension test specimens shall be the standard round, ~~1/2-in. [12.5 mm]~~ diameter, ~~2-in. [50 mm]~~ in. [12.5 mm] diameter, 2 in. [50 mm] gauge length as shown in Test Methods and Definitions **A370**. The yield strength prescribed in **Table 2** shall be determined by the 0.2 % offset method of Test Methods and Definitions **A370**. The offset shall be 0.2 % unless 0.02 % is specified in the ordering information.

6.2 *Impact Test*—The material shall conform to the requirements for impact (both transition-temperature and room-temperature impact value) as prescribed in **Table 2**. The impact tests shall be performed in accordance with Test Methods and Definitions **A370** using standard full-size specimens.

6.3 *Hardness*—Forgings made from Classes 11 to 14 and subjected to group testing in accordance with **6.4.1** shall conform to the Brinell hardness requirements prescribed in **Table 2** when tested in accordance with Test Methods and Definitions **A370**.

6.4 *Location and Number of Tests*—Classes 1 through 10 tension and impact test specimen shall be identified and taken from the locations as specified by the purchaser and agreed to by the producer. One tension test and a transition-temperature determination, including room-temperature impact strength shall be considered a minimum number of tests conducted on forgings made to this specification.

6.4.1 For Classes 11 through 14 unless otherwise specified by the purchaser, tests shall be made as follows:

6.4.1.1 Forgings 30 in. [750 mm] and under in diameter may be group tested. One tension test and one Charpy V-notch test shall be considered representative of each lot of forgings manufactured from the same heat of material and heat treated together. When group tested two Brinell tests, 180° apart, shall be made on the same face of each forging near the rim.

6.4.1.2 For forgings over 30 in. [750 mm] in diameter, at least one rim tension test and one Charpy V-notch test shall be made from each forging.

TABLE 2 Tensile and Charpy Impact Requirements

	Class 1	Class 2	Class 3	Class 4	Class 5	Class 6
Tensile strength, min, ksi [MPa]	100 [690]	105 [725]	110 [760]	120 [830]	130 [900]	140 [965]
Yield strength, ksi [MPa]						
0.2 % offset	80–100 [550–690]	90–110 [620–760]	100–120 [690–825]	110–130 [760–895]	120–140 [825–965]	130–150 [895–1035]
0.02 % offset	75–95 [520–655]	85–105 [585–725]	95–115 [655–790]	105–125 [725–860]	115–135 [790–930]	125–145 [860–1000]
Elongation in 2 in. or 50 mm, min, %	20	19	18	17	16	15
Reduction of area, min, %	50	50	47	45	43	43
Charpy V-notch impact, room temperature, ft·lbf [J], min	50 [68]	50 [68]	45 [61]	45 [61]	40 [54]	40 [54]
Transition temperature, FATT ₅₀ , °F [°C], max	0 [–18]	0 [–18]	0 [–18]	0 [–18]	10 [–12]	10 [–12]
Brinell hardness number	...	...	...	...	...	...
	Class 10	Class 11	Class 12	Class 13	Class 14	
Tensile strength, min, ksi [MPa]	105 [725]	100 [690]	110 [760]	125 [860]	125 [860]	
Yield strength, ksi [MPa]						
0.2 % offset	90–105	...	...	...	...
0.2 % offset	90–105 [620–725]	...	...	...	...
0.02 % offset	85–100 [585–690]	75–95 [515–655]	85–105 [585–725]	105–125 [725–860]	105–125 [725–860]	
Elongation in 2 in. or 50 mm, min, %	15	20.0	18.0	16.0	18.0	
Reduction of area, min, %	30	50.0	48.0	45.0	45.0	
Charpy V-notch impact, room temperature, ft·lbf [J], min	10 [14]	15 [20] ^A	15 [20] ^A	15 [20] ^A	15 [20] ^A	
Transition temperature, FATT ₅₀ , °F [°C], max	200 [95]					
Brinell hardness number	...	207–255	229–269	255–302	255–302	

^A Not required.