Designation: A 982/A 982M – 05

Standard Specification for Steel Forgings, Stainless, for Compressor and Turbine Airfoils[1]

This standard is issued under the fixed designation A 982/A 982M; 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*

1.1 This specification covers stainless steel forgings for compressor and turbine bucket, blade, and airfoil applications.

1.2 This specification is expressed in both inch-pound units and in SI units; however, unless the purchase order or contract specifies the applicable *M* designation (SI units), the inch-pound units shall apply. The values stated in either inch-pound units or SI units are to be regarded separately as standard. Within the text, the SI units are shown in brackets. The values stated in each system may not be exact equivalents; therefore, each system shall be used independently of the other. Combining values from the two systems may result in nonconformance with the standard.

2. Referenced Documents

2.1 *ASTM Standards:* [2]

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

A 788 Specification for Steel Forgings, General Requirements

A 994 Guide for Editorial Procedures and Form of Product Specifications for Steel, Stainless Steel, and Related Alloys

E 381 Method of Macroetch Testing Steel Bars, Billets, Blooms, and Forgings

E 562 Test Method for Determining Volume Fraction by Systematic Manual Point Count

3. Ordering Information

3.1 In addition to the ordering information required by Specification A 788, the purchaser shall include a sketch or written description of the forging with the inquiry and order.

4. General Requirements

4.1 Materials 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 Process*—All melting processes of Specification A 788 are permitted unless Supplementary Requirement S1 is invoked by the purchaser.

5.2 *Forging Process*—Either the closed impression die or the open die forging processes may be utilized unless the purchaser specifies one or the other.

5.2.1 *Forging Temperature*—The maximum part temperature during forging shall be 2150°F [1175°C].

5.3 *Heat Treatment*—Heat treating all forgings is required in accordance with Table 1 to develop the required mechanical properties.

5.3.1 *Number of Heat Treatments*—Two complete heat treatments, consisting of an austenitize, quench, and temper, are permitted. Purchaser approval is required prior to any additional heat treatments.

5.3.2 *Temperature Variation*—Heat treating temperatures shall be controlled in the range of ±25°F [±14°C].

5.4 *Stress Relief*—When heat treatment for mechanical properties is followed by straightening, a stress-relieving heat treatment is required at a temperature meeting the requirements of Table 1.

5.4.1 *Quenching after Stress Relief*—Water or oil quenching of stress-relieved forgings is prohibited.

6. Chemical Composition

6.1 The steel shall conform to the requirements for chemical composition prescribed in Table 2.

[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 Document Summary page on the ASTM website.

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

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TABLE 1 Heat Treatment, °F [°C]

	Grade A	Grade B	Grade C		Grade D	Grade E		Grade F
	Classes 1 & 2	Class 1	Class 1	Class 2	Classes 1 & 2	Class 1	Class 2	Class 1
Austenitizing	1725-1775 [940-970]	1600-1750 [870-955]	1825-1875 [995-1025]	1725-1875 [940-1025]	1875-1925 [1025-1050]	2075-2125 [1135-1165]	1725-1775 [940-970]	1875-1925 [1025-1050]
Quenching	Air or liquid	Air or liquid	Air or liquid	Air or liquid	Air or liquid	Air or liquid	Air or liquid	Air or liquid
Single tempering	1050 min [565 min]	1050 min [565 min]	1050 min [565 min]	1050 min [565 min]	1150 min [620 min]	1250 min [675 min]	1100 min [595 min]	. . .
Double tempering	. . .	. . .	1025 min [550 min]	1025 min [550 min]	. . .	. . .	. . .	. . .
Aging	. . .	. . .	. . .	. . .	. . .	. . .	. . .	1135-1165 [615-630]
Stress Relieving	1025 min [550 min]	1025 min [550 min]	1000 min [540 min]	1000 min [540 min]	1100 min [595 min]	1200 min [650 min]	1050 min [565 min]	1100 min [595 min]

TABLE 2 Chemical Requirements

	Composition %					
	Grade A	Grade B	Grade C	Grade D	Grade E	Grade F
UNS Designation	S41000	S41005	S41428	S42225	S41041	S17400
Carbon	0.15 max	0.10-0.15	0.10-0.17	0.20-0.25	0.13-0.18	0.07 max
Manganese	1.0 max	0.25-0.80	0.65-1.05	0.5-1.0	0.4-0.6	1.0 max
Phosphorus, max	0.018	0.018	0.020	0.020	0.030	0.040
Sulfur, max	0.015	0.015	0.015	0.010	0.030	0.030
Silicon	0.5 max	0.5 max	0.10-0.35	0.20-0.50	0.5 max	1.0 max
Nickel	0.75 max	0.75 max	2.25-3.25	0.5-1.0	0.5 max	3.0-5.0
Chromium	11.5-13.0	11.5-13.0	11.25-12.75	11.0-12.5	11.5-13.0	15.0-17.5
Molybdenum	0.5 max	0.5 max	1.5-2.0	0.9-1.25	0.20 max	. . .
Vanadium	. . .	Report only	0.25-0.40	0.20-0.30	. . .	. . .
Tungsten	. . .	0.10 max	0.10 max	0.9-1.25	. . .	. . .
Nitrogen	. . .	0.08 max	0.020-0.045	Report only	. . .	. . .
Aluminum	. . .	0.025 max	0.025 max	0.025 max	0.05 max	. . .
Columbium	. . .	0.20 max	. . .	0.05 max	0.15-0.45	0.15-0.45
Cobalt	. . .	. . .	. . .	0.20 max	. . .	. . .
Titanium	. . .	0.05 max	0.05 max	0.025 max	. . .	. . .
Copper	. . .	0.15 max	0.15 max	0.15 max	. . .	3.0-5.0
Tin	. . .	0.05 max	0.05 max	0.02 max	. . .	. . .

7. Mechanical Properties

7.1 *Tension, Impact, and Hardness Tests*—All testing shall be performed after heat treatment and stress relief, as applicable. The test specimens shall meet the requirements of Table 3.

7.1.1 *Number of Tests*—A minimum of two forgings from each lot shall be randomly selected for longitudinal tensile, impact, and hardness testing. Hardness values of the tension test specimen shall be reported with the tensile data.

7.1.1.1 *Lot Size*—A lot shall consist of all forgings of the same size from one electric furnace heat of steel and heat treated either in the same charge in either a batch furnace or a continuous type furnace.

7.1.1.2 *Continuous Heat Treating Furnaces*—Test forgings shall be taken from each of the first and last push or tray to exit the furnace. Additional forgings shall be taken so that the maximum time between samples is 4 h.

7.1.1.3 *Test Locations*—One tension test specimen and one set of three impact test specimens shall be machined from the center portion of the air foil vane section.

TABLE 3 Tensile, Impact, and Hardness Requirements

	Grade A		Grade B	Grade C		Grade D		Grade E		Grade F
	Class 1	Class 2	Class 1	Class 1	Class 2	Class 1	Class 2	Class 1	Class 2	Class 1
Tensile strength, min, ksi [MPa]	100 [690]	110 [760]	110 [760]	145 [1000]	160 [1105]	140 [965]	140 [965]	115 [795]	110 [760]	135 [935]
Yield strength, min, ksi [MPa], 0.2 % offset	70 [485]	80 [555]	90 [620]	115 [795]	120 [825]	90 [620]	100 [690]	75 [515]	80 [555]	105 [725]
Elongation in 2 in., min, %	20	18	18	15	16	13	13	15	18	16
Reduction of area, min, %	60	50	50	30	50	30	35	50	55	50
Impact strength, min, av., Cv [J], Rt, ft-lb	30 [40]	25 [33]	30 [40]	30 [40]	40 [55]	8 [11]	13 [18]	20 [27]	25 [34]	41 [55]
Hardness, Brinell, max	255	269	269	352	375	331	331	277	262	341

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7.1.2 *Forging Hardness Testing*:

7.1.2.1 *Batch Type Furnaces*—A minimum of 10 % of the forgings in each lot shall be hardness tested.

7.1.2.2 *Continuous Type Furnaces*—Samples for hardness testing shall be taken from every other tray or push.

8. Nondestructive Examination

8.1 *General Requirements*—All forgings shall be free of cracks, seams, laps, shrinkage, and similar discontinuities.

8.2 *Nondestructive Tests*—Nondestructive testing and corresponding acceptance criteria shall be as specified by the purchaser.

9. Certification and Reports

9.1 All tests required by this specification shall be made by the manufacturer and reported on a certificate of test to the purchaser. Each test certificate shall include the following items:

9.1.1 Purchase order number,

9.1.2 Forging identification number,

9.1.3 Specification number and yeardate of issue, grade, and class,

9.1.4 Heat number,

9.1.5 Lot number and size,

9.1.6 Mechanical properties including tension, impact, and hardness,

9.1.7 Hardness data tabulation for each forging tested,

9.1.8 Heat-treating and stress-relieving temperature and times,

9.1.9 Results of any specified supplementary requirements, and

9.1.10 Statement that the forgings were manufactured, sampled, tested, and inspected in accordance with this specification and that the results satisfied the requirements.

10. Marking

10.1 The part number and a unique lot control designator, or heat number, shall be stenciled or legibly painted on each forging. Material shall be segregated according to drawing, heat, and lot numbers.

11. Keywords

11.1 compressor airfoils; stainless steel forgings; turbine airfoils

SUPPLEMENTARY REQUIREMENTS

The following supplementary requirements shall apply only when specified by the purchaser in the inquiry, contract, and order. Details of these supplementary requirements shall be agreed upon by the manufacturer and purchaser.

S1. Secondary Melting and Refining

S1.1 ESR or VAR is required. Use of either is permitted unless otherwise specified.

S2. Ingot Chemical Analysis

S2.1 If consumable electrode remelting is used, then chemical analyses of each remelted ingot shall meet the chemical composition requirements listed and shall be reported.

S3. Macrostructure

S3.1 Samples shall be taken from the top and bottom of the first and last ingot of each heat. The structure of the starting billets shall meet the criteria of Method E 381, S-3, R-2, C-3 ≤ 36 in.^{2} [230 cm^2] and S-3, R-3, C-3 > 36 in.^{2} [230 cm^2].

S4. Root Attachment Zone Mechanical Properties

S4.1 Testing for mechanical properties of the root attachment area is required. The type, number, location, and orientation of the tests shall be specified by the purchaser.

S5. Magnetic Particle Inspection

S5.1 Each forging shall be magnetic particle inspected in accordance with Test Method A 275/A 275M. The maximum acceptable indication size shall be ⅛ in. [3 mm] unless otherwise specified by the purchaser.

S6. Ultrasonic Inspection

S6.1 Ultrasonic inspection is required. The test method, location, and acceptance criteria shall be as agreed upon by the purchaser and producer.

S7. Microstructure

S7.1 The microstructure shall be uniformly fine grain tempered martensite with no more than 1 % delta ferrite.

S7.2 Metallographic inspection shall be performed at 100x magnification to determine the metallurgical structure, grain size, decarburization, and delta ferrite content. Visual estimation for the volume fraction of delta ferrite of various representative areas of examination is acceptable. When the visual estimation method indicates the delta ferrite content is greater than the allowed limit, the manufacturer may employ Test Method E 562 for determining the acceptability of a lot.

S7.3 A specimen shall be removed from the airfoil section on one test forging per heat treat lot. The plane of polish of the specimen shall be parallel to the axial centerline of the forging. The area examined shall include both the concave and convex vane surfaces.

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S7.4 Surface decarburization of forgings shall not exceed 0.06 in. [1.5 mm].

S8 Hardness Testing

S8.1 One hardness test is required on the surface of the turbine rotor attachment portion on each forging. When specified by the purchaser, forgings shall be hardness tested for surface hardness on the air foil vane section.

S9. Minimum Hardness Requirements

S9.1 When agreed upon by the purchaser and producer, a minimum hardness value is required.

SUMMARY OF CHANGES

Committee A01 has identified the location of the following changes to this standard since A 982/A 982M - 02 that may impact the use of this standard (Approved March 1, 2005).

(1) Added dual units to title, new 1.2, rationalized metric values in Table 1 and Table 3 per Guide A 994. Added metric values to S3, S5, and S7.

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