Designation: A 291/A 291M – 05

Standard Specification for Steel Forgings, Carbon and Alloy, for Pinions, Gears and Shafts for Reduction Gears[1]

This standard is issued under the fixed designation A 291/A 291M; 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 normalized and tempered carbon steel and quenched and tempered alloy steel forgings for pinions, gears, and shafts.

1.2 Several grades of steel are covered as follows:

1.2.1 *Grade 1, Class A,* is normalized and tempered carbon steel.

1.2.2 *Grade 2, Class B, Grade 3, Class C, Grade 3A, Class D, Grades 4 to 7, Classes E, F, G, and H, Grade 8, Class I, and Grade 9, Class J,* are liquid quenched and tempered alloy steel.

1.3 All grades and classes are considered weldable under proper conditions. Welding technique is of fundamental importance and it is presupposed that welding procedure and inspection shall be in accordance with approved methods for the class of material used.

1.4 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 not be exact equivalents; therefore, each system shall be used independently of the other. Combining values from the two systems may result in non-conformance with the standard.

1.5 *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 and health practices and determine the applicability of regulatory limitations prior to use.*

2. Referenced Documents

2.1 *ASTM Standards:*

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

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

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

3. Ordering Information

3.1 Instructions for purchasing forgings to this specification should be in accordance with Specification A 788. In addition, a detailed drawing, sketch, or written description of the forging should be included with the inquiry or order.

3.2 Supplementary requirements are provided and shall apply only when specified in the purchase order.

4. Heat Treatment

4.1 *Preliminary Heat Treatment*:

4.1.1 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 austenitization and shall be suitably cooled to bring about complete transformation.

4.1.2 Forgings may be immediately treated for mechanical properties after preliminary heat treatment or may be rough turned prior to treatment for mechanical properties.

4.2 *Heat Treatment for Mechanical Properties*—The forging shall be reheated to a temperature above the upper critical temperature and held a sufficient length of time for complete austenitization. Grade 1 shall be air cooled while Grades 2 through 9 shall be liquid quenched.

4.3 *Tempering*—The forgings shall be tempered to develop the specified properties. Minimum tempering temperatures shall be as follows:

		Minimum Tempering Temperature	
Grade	Class	°F	[°C]
1 and 2	A and B	1150	[620]
3, 3A, and 4	C, D, and E	1075	[580]
5, 6, 7	F, G, and H	1050	[565]
8	I	1100	[595]
9	J	1000	[540]

The charge shall be cooled under uniform conditions in the furnace at a maximum rate of 100°F [55°C] per h to 600°F [315°C].

4.4 *Stress Relief*—If the manufacturer elects to heat treat for mechanical properties prior to machining, the forgings shall be stress relieved after machining (see 4.5) at a temperature that is 50 to 100°F [30 to 55°C] below the last previous tempering

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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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temperature but in no case below 1000°F [540°C]. The forgings shall be cooled under uniform conditions in the furnace at a maximum rate of 100°F [55°C]/h to 600°F [315°C].

4.5 *Machining*:

4.5.1 Rough machining before heat treatment for mechanical properties may be performed at the option of the manufacturer.

4.5.2 If the producer elects to heat treat for mechanical properties prior to machining, the forgings shall be stress relieved after machining.

4.5.3 *Boring*—Forgings, after being heat treated for mechanical properties and subsequently bored, shall be stress relieved.

5. General Requirements

5.1 Unless otherwise specified herein, the requirements of Specification A 788 shall apply to forgings supplied to this specification.

6. Chemical Requirements

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

6.2 The limits for elements other than carbon, manganese, phosphorus, sulfur, and silicon in Grade 2 alloy shall be agreed upon between the manufacturer and purchaser.

7. Mechanical Requirements

7.1 *Tensile and Impact Requirements*:

7.1.1 The material shall conform to the requirements for tensile and impact properties prescribed in Table 2 and impact properties (see S2) when agreed upon between the purchaser and the supplier.

7.1.2 *Classification*—The nominal or specified rough-machined diameter or thickness of solid forgings, disregarding large ends, collars and flanges, or the nominal rough-machined wall thickness of bored forgings shall determine the size classification.

7.1.3 *Number, Location, and Orientation of Test Specimens*:

7.1.3.1 At least one tension test specimen either longitudinal or tangential at the option of the manufacturer shall be taken from each forging unless a number of forgings are forged and treated in multiple, in which case one tension test specimen shall be taken from each end of the multiple forging. When impact tests are specified in accordance with Supplementary Requirement S2, one set of impact tests shall also be taken from each end of the multiple forging. When agreed upon between the manufacturer and the purchaser, forgings weighing less than 500 lb [225 kg] each (rough-machined weight) may be tested in lots; the number of forgings to make up a lot shall be by mutual agreement.

7.1.3.2 Tension and impact test specimens shall be taken from an extension of the main body of the forging, or from a full-size prolongation left on one end of each individual forging or on both ends of the multiple forging if the forgings are made in multiple. The nominal or specified outside rough-machined diameter or thickness of the forgings, disregarding large ends, collars and flanges, shall determine the size of prolongations for test specimens.

7.1.3.3 The axis of the longitudinal tension test specimen shall be located at any point 1¼ in. [32 mm] below the surface of the forging. The axis of the tangential test specimen shall be located as near to the surface of the forging as practicable.

7.2 *Brinell Hardness*:

7.2.1 The material shall conform to the requirements for hardness as prescribed in Table 2. Brinell hardness tests shall be made on prepared areas on the forgings after machining to the sizes ordered by the purchaser and after stress relieving if stress relieving is required.

7.2.2 *Number and Location of Tests*—On each forging 8 in. [200 mm] and over in diameter, four Brinell hardness tests shall be made on the outside surface of that portion of the forging on which teeth will be cut, two tests being made on each helix 180° apart and the tests on the two helices shall be 90° apart. On each forging under 8 in. [200 mm] in diameter, two Brinell hardness tests shall be made, one on each helix 180° apart. Hardness tests shall be performed at the quarter-face width of the tooth portion diameter. On shaft forgings, two hardness tests shall be made on each end 180° apart.

8. Retreatment

8.1 If the results of the mechanical tests of any forging do not conform to the specified requirements, the manufacturer

TABLE 1 Chemical Requirements

Element	Composition, %						
	Grade 1 Class A	Grade 2 Class B	Grade 3 Class C	Grade 3A Class D	Grades 4 to 7 Classes E, F, G, and H	Grade 8 Class I	Grade 9 Class J
Carbon	0.55 max	0.50 max	0.45 max	0.45 max	0.35–0.50	0.38–0.45	0.25–0.39
Manganese	0.60–0.90	0.40–0.90	0.40–0.90	0.40–0.90	0.40–0.90	0.40–0.70	0.20–0.60
Phosphorus, max	0.040	0.040	0.040	0.040	0.040	0.040	0.015
Sulfur, max	0.040	0.040	0.040	0.040	0.040	0.040	0.015
Silicon[A], max	0.35	0.35	0.35	0.35	0.35	0.40	0.35
Nickel	0.30 max	[B]	0.50 max	1.00–3.00	1.65 min	0.30 max	3.25–4.00
Chromium	0.25 max	[B]	1.25 max	1.50 max	0.60 min	1.40–1.80	1.25–1.75
Molybdenum	0.10 max	[B]	0.15 min	0.15 min	0.20–0.60	0.30–0.45	0.30–0.70
Vanadium, max	0.06	0.10	0.05	0.10	0.10	0.03	0.05–0.15
Copper, max	0.35	0.35	0.35	0.35	0.35	0.35	0.35
Aluminum	. . .	. . .	. . .	. . .	. . .	0.85–1.30	. . .

[A] When vacuum carbon deoxidation is used, silicon maximum shall be 0.10 %.
[B] Optional with manufacturer and purchaser.

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TABLE 2 Mechanical Properties

Grade	Class	Size, Solid Diameter or Thickness, in.[A]		Tensile Strength, min		Yield Strength, 0.2% Offset, min		Elongation in 2 in. [50 mm], min, %		Reduction of Area, min, %		Charpy V-notch Ftlb [J]	Brinell Hardness Number Range
		Over	Not Over	ksi	[MPa]	ksi	[MPa]	Longi-tudinal	Transverse (Tangential)	Longi-tudinal	Transverse (Tangential)		
1	A	...	10	85	[585]	50	[345]	22	...	45	...	. . .	170 - 223
		10	...	80	[550]	45	[310]	20	16	37	30		
2	B	...	10	95	[655]	70	[485]	20	...	45	...	. . .	201 - 241
		10	20	95	[655]	70	[485]	20	18	45	34		
		20	...	95	[655]	70	[485]	18	16	38	30		
3, 3A	C, D	...	10	105	[725]	80	[550]	19	...	45	...	. . .	223 - 262
		10	20	105	[725]	80	[550]	19	16	45	32		
		20	...	105	[725]	80	[550]	18	14	38	30		
4	E	...	10	120	[825]	95	[655]	16	...	40	...	. . .	248 - 293
		10	20	120	[825]	95	[655]	14	12	35	30		
		20	...	115	[795]	90	[620]	13	10	33	25		
5	F	...	10	140	[965]	115	[795]	16	...	40	...	. . .	285 - 331
		10	20	135	[930]	110	[760]	14	12	35	30		
		20	...	130	[905]	105	[725]	12	10	30	25		
6	G	...	10	145	[1000]	120	[825]	15	...	40	...	. . .	302 - 352
		10	20	140	[965]	115	[795]	14	12	35	30		
		20	...	135	[930]	110	[760]	12	10	30	25		
7	H	...	10	170	[1375]	140	[960]	14	...	35	...	. . .	341 - 415
		10	20	165	[1140]	135	[930]	12	10	30	25		
		20	...	160	[1105]	130	[905]	10	10	25	25		
8	I	...	10	120	[825]	85	[585]	15	...	40	...		255 - 302
9	J	20	. . .	170	[1175]	140	[960]	10	10	30	30	25 [30]	352 - 401

[A] 10 in. = 250 mm. 20 in. = 500 mm.

may retreat the forging one or more times, but not more than three additional times without approval of the purchaser.

9. Dimensions and Tolerance

9.1 The forgings shall conform to the dimensions and tolerances specified on the purchaser's drawing or order.

10. Certification and Reports

10.1 Material test reports as specified in Specification A 788 are required and shall include the final austenitizing and tempering temperatures, holding times, and methods of cooling.

11. Marking, Packaging, and Loading

11.1 Each forging shall be legibly stamped by the manufacturer with the manufacturer's name or trademark, the manufacturer's serial number, ASTM designation A 291, followed by the appropriate class number. The purchaser may indicate the desired location of such identification information.

11.2 Packaging and loading shall be done so the forging is not damaged during shipment to the purchaser.

12. Keywords

12.1 alloy steel forgings; carbon steel forgings; gear forgings; gear shaft forgings; heat-treated; pinion forgings

SUPPLEMENTARY REQUIREMENTS

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

S1. Rough Turning and Boring

S1.1 The position of rough turning and boring in the sequence of manufacturing operations is specified.

S2. Impact Tests

S2.1 Impact tests shall be made. The specimens shall be machined and tested with minimum properties and test temperatures specified as follows.

Grade	Class	Charpy V-Notch, ft·lbf [J], 70 to 80°F [20 to 25°C] min	
		Longitudinal	Transverse (Tangential)
1	A	10 [13]	8 [11]
2	B	10 [13]	8 [11]
3	C	30 [40]	20 [27]
3A	D	30 [40]	20 [27]

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Grade	Class	Charpy V-Notch, ft·lbf [J], 70 to 80°F [20 to 25°C] min	
		Longitudinal	Transverse (Tangential)
4	E	30 [40]	20 [27]
5	F	25 [34]	15 [20]
6	G	25 [34]	15 [20]
7	H	20 [27]	10 [13]
8	I	8 [11]	. . .

S3. Nondestructive Examination

S3.1 Magnetic particle examination may be specified in accordance with Test Method A 275/A 275M.

S3.2 Ultrasonic examination may be specified in accordance with Practice A 388/A 388M.

S4. Phosphorus

S4.1 Phosphorus shall not exceed 0.015 %, and sulfur shall not exceed 0.018 % for all classes.

S5. Vacuum Degassing

S5.1 The molten steel shall be vacuum treated prior to, or during, pouring of the ingot, to remove objectionable gases, particularly hydrogen.

APPENDIX

(Nonmandatory Information)

X1. PREVIOUS CLASSES AND CORRESPONDING CURRENT GRADES

Previous Class	Current Grade	Current Class
Class 1	Grade 1	Class A
Class 2	Grade 2	Class B
Class 3	Grade 3	Class C
Class 3A	Grade 3A	Class D
Class 4	Grade 4	Class E
Class 5	Grade 5	Class F
Class 6	Grade 6	Class G
Class 7	Grade 7	Class H
Class 8	Grade 8	Class I
Class 9	Grade 9	Class J

SUMMARY OF CHANGES

Committee A01 has identified the location of selected changes to this standard since the last issue (A 291 – 02) that may impact the use of this standard (approved Apr. 10, 2003).

(1) Converted standard to dual unit format..

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