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Standard Specification for Steel, Closed-Impression Die Forgings for General Industrial Use[1]

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1. Scope*

1.1 This specification covers untreated and heat-treated steel, closed-impression die forgings (Note 1) for general industrial use.

NOTE 1—For the definition of a forging, refer General Requirements Specification A788/A788M.

1.2 The Grades of forgings are as follows, the choice depending on design and stress or service to be imposed:

1.2.1 *Grade CA*—Untreated, carbon steel forgings,

1.2.2 *Grades CC, CC1, and CE*—Annealed, normalized and tempered, carbon steel forgings,

1.2.3 *Grade CF*—Normalized and tempered carbon steel forgings,

1.2.4 *Grade CF1*—Double normalized and tempered carbon steel forgings,

1.2.5 *Grade CG*—Quenched and tempered, or normalized, quenched and tempered carbon steel forgings,

1.2.6 *Grade AA*—Annealed, normalized, or normalized and tempered alloy steel forgings,

1.2.7 *Grades AB and AC*—Normalized and tempered alloy steel forgings, and

1.2.8 *Grades AD, AE, AF, AG, and AH*—Normalized, quenched, and tempered alloy steel forgings.

1.3 Unless the order specifies the applicable "M" specification designation, the forgings shall be furnished with the inch-pound units.

1.4 The values stated in either inch-pound units or SI (metric) units are to be regarded separately as standard. Within the text and tables, the SI units are shown in brackets. The values stated in each system are not exact equivalents; therefore, each system shall be used independently of the other. Combining values from the two systems may result in nonconformance with the specification.

2. Referenced Documents

2.1 *ASTM Standards:*[2]

A29/A29M Specification for Steel Bars, Carbon and Alloy, Hot-Wrought, General Requirements for

A275/A275M Practice for Magnetic Particle Examination of Steel Forgings

A322 Specification for Steel Bars, Alloy, Standard Grades

A370 Test Methods and Definitions for Mechanical Testing of Steel Products

A388/A388M Practice for Ultrasonic Examination of Steel Forgings

A576 Specification for Steel Bars, Carbon, Hot-Wrought, Special Quality

A788/A788M Specification for Steel Forgings, General Requirements

A921/A921M Specification for Steel Bars, Microalloy, Hot-Wrought, Special Quality, for Subsequent Hot Forging

E3 Guide for Preparation of Metallographic Specimens

E45 Test Methods for Determining the Inclusion Content of Steel

E94 Guide for Radiographic Examination

E112 Test Methods for Determining Average Grain Size

E340 Test Method for Macroetching Metals and Alloys

E381 Method of Macroetch Testing Steel Bars, Billets, Blooms, and Forgings

E407 Practice for Microetching Metals and Alloys

3. Ordering Information and General Requirements

3.1 Material supplied to this specification shall conform to the requirements of Specification A788/A788M, which outlines additional ordering information, manufacturing requirements, testing and retesting methods and procedures, product analysis variations, marking, certification, and additional

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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.**

supplementary requirements. Failure to comply with the requirements of Specification A788/A788M constitutes nonconformance with this specification

3.2 In addition to the ordering information required by Specification A788/A788M, the purchaser may require that the tolerances stated in the appendices to this specification shall apply.

3.3 If the requirements of this specification should conflict with the requirements of A788/A788M, then the requirements of this specification shall prevail.

4. Forging Manufacture

4.1 Sufficient discard shall be taken from the ingot or forging stock to secure freedom from piping and undue segregation.

4.2 Manufacturing practice shall be in accordance with accepted commercial procedures designed to produce forgings free from harmful surface discontinuities, roughness, excessive scale, fins, indications of overheating, burning, or other injurious conditions. The manufacturer may be required to certify that furnaces used for all heating operations for forging and heat treating are controlled to minimize scaling and decarburization.

4.3 Heat treatment, if required, shall be in accordance with the ordered Grade description.

5. Chemical Requirements

5.1 Depending on the forging size, type of heat treatment, and the requirements of the purchaser, the chemical composition shall be as specified by the purchaser. To assist in this choice attention is drawn to the chemical requirements of Specification A576 for carbon steels, Specification A322 for alloy steels, and Specification A29/A29M for both carbon and alloy steels; however, the purchaser may wish to specify more restrictive sulfur and phosphorous limits than are provided in these specifications.

5.2 For microalloyed forgings, forging stock to Specification A921/A921M may be used.

5.3 Attention is drawn to the supplementary requirements included in Specification A788/A788M regarding special chemical requirements.

5.4 The heat and product analyses requirements of Specification A788/A788M shall apply.

6. Metallurgical Requirements

6.1 Provision has been made, through the use of supplementary requirements in Specification A788/A788M and this specification, for the purchaser to specify preferred grain flow and limits for grain size as well as any microscopic examination requirements.

7. Dimensional Tolerances

7.1 The purchaser may specify tolerances for impression die forgings according to Appendix X1 or Appendix X2 as appropriate.

8. Tensile Properties

8.1 The material shall conform to the requirements for tensile properties prescribed in Table 1 when tested in accordance with the latest issue of Test Methods and Definitions A370.

8.2 The yield strength shall be determined by the offset method, using an offset value of 0.2 % of the gauge length, or by the total extension under load method, using an extension value of 0.005 in./in. [0.005 mm/mm] (0.5 %) for Grades AD and AE, 0.006 in./in. [0.006 mm/mm] (0.6 %) for Grades AF and AG, and 0.007 in./in. [0.007 mm/mm] (0.7 %) for Grade AH.

8.3 Tests for acceptance shall be made after final heat treatment of the forgings.

9. Number of Tests and Orientation

9.1 Unless otherwise specified, one tension test shall be made for each heat of steel for each heat treat charge. For untreated forgings (Grade CA) no tension tests need be made unless when specified in the purchase order, when one tension test shall represent each heat.

9.2 For the purpose of tests of heat-treated forgings, the necessary extra forgings shall be provided. When it is impracticable to provide extra forgings for test purposes, test bars may be made from the same billet or bar material, provided they represent the maximum cross section of the forging, do not exceed the production forging reduction, and are heat treated with the forgings they represent.

9.3 Unless otherwise specified, the axis of the specimen shall be located at any point midway between the center and the surface of solid forgings or at any point midway between the inner and outer surfaces of the wall of hollow forgings, and shall be parallel to the direction of maximum metal flow.

10. Test Specimen

10.1 Location, size, and number of test specimens shall be specified by the purchaser. Unless otherwise stated in the contract or purchase order, test bars may be separately forged or swaged from the same bars, billets, or blooms used in manufacture of the forgings. The percentage reduction given the forged tests bars shall not be greater than the minimum amount of reduction given the forging itself. The test bars shall be heat treated with the forgings they represent. The manufacturer may elect to submit an extra forging in lieu of forged test bars.

10.2 Unless otherwise specified, the axis of the specimen shall be located at any point midway between the center and the surface of solid forgings or at any point midway between the inner and outer surfaces of the wall of hollow forgings, and shall be parallel to the direction of maximum metal flow.

10.3 The specimens shall be machined to the form and dimensions shown in Test Methods and Definitions A370 for the standard or subsize round tension test specimens.

11. Cleaning

11.1 The forgings shall be furnished in a scale-free condition. Unless otherwise specified, the manufacturer may clean by acid pickling, grit blasting, sand blasting, or other abrasive method.

TABLE 1 Tensile Requirements

Grade	Solid Diameter or Thickness, in. [mm]		Bored Wall Thickness in. [mm]				Tensile Strength, min, ksi [MPa]	Yield Strength, min, ksi [MPa]	Elongation in 2 in. or 50 mm, min, %	Reduction of Area, min, %
	Over	Not Over	Over		Not Over					
AA (Annealed, normalized, or	...	12 [300]	...		...		80 [550]	50 [345]	24	40
normalized, and tempered)	12 [300]	20 [500]	...		...		80 [550]	50 [345]	22	38
AB (Normalized and tempered)	...	7 [175]	...		4	[100]	80 [550]	55 [380]	26	52
	7 [175]	20 [500]	4	[100]	7½	[190]	80 [550]	55 [380]	24	50
AC (Normalized and tempered)	...	7 [175]	...		4	[100]	90 [620]	60 [415]	22	44
	7 [175]	20 [500]	4	[100]	7½	[190]	90 [620]	58 [400]	21	42
AD (Normalized, quenched, and	...	7 [175]	...		3½	[85]	96 [655]	70 [485]	20	50
tempered)	7 [175]	10 [250]	3½	[85]	5	[125]	90 [620]	65 [450]	20	50
AE (Normalized, quenched, and	...	7 [175]	....		3½	[85]	105 [725]	80 [550]	20	50
tempered)	7 [175]	10 [250]	3½	[85]	5	[125]	100 [690]	75 [520]	19	50
	10 [250]	20 [500]	5	[125]	8	[200]	95 [655]	70 [485]	19	50
AF (Normalized, quenched, and	...	4 [100]	...		2	[50]	125 [860]	105 [725]	16	50
tempered)	4 [100]	7 [175]	2	[50]	3½	[85]	115 [795]	96 [655]	16	45
	7 [175]	10 [250]	3½	[85]	5	[125]	110 [760]	85 [585]	16	45
AG (Normalized, quenched, and	...	4 [100]	...		2	[50]	145 [1000]	120 [830]	15	45
tempered)	4 [100]	7 [175]	2	[50]	3½	[85]	140 [965]	115 [795]	14	40
	7 [175]	10 [250]	3½	[85]	5	[125]	135 [930]	110 [760]	13	40
AH (Normalized, quenched, and	...	4 [100]	...		2	[50]	170 [1175]	140 [965]	13	40
tempered)	4 [100]	7 [175]	2	[50]	3½	[85]	165 [1140]	135 [930]	12	35
	7 [175]	10 [250]	3½	[85]	5	[125]	160 [1105]	130 [895]	11	35
CA (Untreated)	No tensile requirement except as covered by 8.1									
CC (Annealed, normalized, or	...	12 [300]	...		...		60 [415]	30 [205]	25	36
normalized, and tempered)	12 [300]	...	...		...		60 [415]	30 [205]	24	36
CC1 (Annealed, normalized, or	...	12 [300]	...		...		66 [455]	33 [230]	23	36
normalized and tempered)	12 [300]	20 [500]	...		...		66 [455]	33 [230]	22	34
CE (Annealed, normalized, or	...	8 [200]	...		...		75 [520]	37 [290]	24	40
normalized and tempered)	8 [200]	12 [300]	...		...		75 [520]	37 [290]	22	35
	12 [300]	20 [500]	...		...		75 [520]	37 [290]	20	32
	20 [500]	...	...		...		75 [520]	37 [290]	19	30
CF (Normalized and tempered)	...	8 [200]	...		...		80 [550]	40 [275]	22	36
	8 [200]	12 [300]	...		...		80 [550]	40 [275]	21	33
	12 [300]	20 [500]	...		...		80 [550]	40 [275]	20	31
CF1 (Double normalized and tempered)	...	8 [200]	...		...		85 [585]	44 [300]	25	40
	8 [200]	12 [300]	...		...		83 [570]	43 [295]	23	37
	12 [300]	20 [500]	...		...		83 [570]	43 [295]	22	35
CG (Quenched, and tempered or	...	4 [100]	...		2	[50]	90 [620]	55 [380]	20	39
normalized, quenched and tempered)	8 [200]	7 [175]	2	[50]	3½	[85]	85 [585]	50 [345]	20	39
	7 [175]	10 [250]	3½	[85]	5	[125]	85 [585]	50 [345]	19	37
	...	...	5	[125]	10	[250]	82 [565]	48 [330]	19	36

12. Keywords

12.1 alloy steel; carbon steel; closed die; forging tolerances; heat treated; impression die; Steel Forgings

SUPPLEMENTARY REQUIREMENTS

One or more of 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 specified by purchaser.

S1. Magnetic Particle Test

S1.1 When magnetic particle inspection of forgings is required, the areas to be inspected, and the acceptance standards shall be specified by purchaser.

S1.2 Unless otherwise required by the purchaser, Test Method A275/A275M shall be used.

S2. Grain Flow

S2.1 When a specific pattern of grain flow is required by the purchaser, a sample forging shall be sectioned as specified. The section shall be ground and subjected to acid etching, using the type of acid, temperature, and time of etching agreed upon to reveal flow lines. The section may be preserved using a coating of mineral oil or clear lacquer.

S2.2 Unless otherwise specified by the purchaser, Method E381 or Test Method E340 shall be used.

S3. Microscopic Examination

S3.1 When microscopical examination is specified, the steel shall be inspected by utilizing samples cut from the undistorted

portion of tension test specimens. Requirements for number of microscopical tests, grain size, cleanliness, or microstructure shall be specified by purchaser.

S3.2 For grain size determination Test Methods E112 or the grain size provisions of Specification A29/A29M shall be used, and the grain size requirement shall be as specified by the purchaser.

S3.3 For non-metallic inclusion rating Test Methods E45 shall be used, and the acceptance limits shall be specified by the purchaser.

S3.4 Guide E3 and Practice E407 shall be used for the determination of the microstructure. Acceptance criteria shall be specified by the purchaser.

S4. Impact Test

S4.1 Impact testing in accordance with Test Methods A370 shall be done on specimens taken adjacent to the tension test. The test temperature and acceptance criteria shall be as specified by the purchaser.

S5. Ultrasonic Examination

S5.1 Ultrasonic examination shall be conducted in accordance with Practice A388/A388M unless otherwise specified by the purchaser who will also specify the acceptance criteria.

S6. Radiographic Tests

S6.1 When radiographic tests are required, the number of tests, location, and ASTM standards of acceptance shall be specified by the purchaser. Reference shall be made to Guide E94.

S7. Brinell Hardness

S7.1 When hardness is required, Brinell hardness tests taken in accordance with Test Methods A370 shall be made of sample forgings from each furnace charge of heat-treated forgings, or from an 8 h shift for continuous furnaces. The number of samples per charge and location of the hardness impressions shall be specified by the purchaser.

S7.2 The acceptance criteria shall be specified by the purchaser, but shall be consistent both with the tensile properties specified in Table 1, and the relative locations of the tension test specimens and the specified surfaces to be hardness tested.

APPENDIXES

(Nonmandatory Information)

X1. FORGINGS PRODUCED ON HAMMERS AND PRESSES

X1.1 Units of Measure

X1.1.1 Where direct tolerances are not provided, use Table X1.1 in converting to fractional units of measure after making computations.

X1.2 Length and Width Tolerances

X1.2.1 Length and width tolerances represent variations in dimensions measured parallel to the fundamental parting line of the dies. Normally, they are combined with tolerances for die wear.

X1.2.1.1 *Tolerance*—The length and width tolerance is ±0.003 in./in. [±0.003 mm/mm] and applies to all dimensions of length and width including diameters. This tolerance includes allowance for shrinkage, die sinking, and die polishing variations.

X1.2.1.2 *Units of Measure*—Length and width tolerances, normally combined with tolerances for die wear, are expressed as fractions of an inch [millimetre], in units of 1/32 in. [0.75 mm] or greater as shown in Table X1.1. Decimals used in computing tolerances are totaled, rounded off to two places after the decimal point, then converted to the next higher fractional unit of measure.

X1.3 Die Wear Tolerances

X1.3.1 Die wear varies according to the material forged and the shape of the forging. Consequently, die wear tolerances for various materials are applied in addition to length and width tolerances on dimensions pertaining to forged surfaces only. Die wear tolerances do not apply on center-to-center dimensions.

X1.3.1.1 *Tolerance*—Die wear tolerances for all *external* length, width, and diameter dimensions are computed by multiplying the *greatest external length or outside diameter* (measured parallel to the fundamental parting line of the dies) by the appropriate factor in Table X1.2 and are then combined

TABLE X1.1 Units of Measure

Dimensions, ft [m]		Units of Measure to the Closest
Over	Under	
...	2 [0.6]	1/32 in. [0.75 mm]
2 [0.6]	5 [1.5]	1/16 in. [1.5 mm]
5 [1.5]	10 [3]	1/8 in. [3 mm]
10 [3]	...	1/4 in. [6 mm]

TABLE X1.2 Die Wear Tolerances

Materials	Factor per inch or millimetre
Carbon	0.004
Low Alloy	0.005
400 Series Stainless	0.006
300 Series Stainless	0.007
Super Alloy	0.008