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400 COMMONWEALTH DRIVE WARRENDALE PA 15096

AEROSPACE MATERIAL SPECIFICATION

AMS 4146C
Superseding 4146B

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ALUMINUM ALLOY FORGINGS
1.0Mg - 0.60Si - 0.28Cu - 0.20Cr (6061 - T4)
Solution Heat Treated and Naturally Aged

UNS A96061

1. SCOPE:

1.1 Form: This specification covers an aluminum alloy in the form of die forgings, hand forgings, rolled rings, and forging stock.

1.2 Application: Primarily for forged parts which will be welded or brazed to assemblies and then given further heat treatment to develop the full strength of which the alloy is capable. Corrosion resistance of this alloy is superior to that of alloys having copper as the principal alloying element.

2. APPLICABLE DOCUMENTS: The following publications form a part of this specification to the extent specified herein. The latest issue of Aerospace Material Specifications shall apply. The applicable issue of other documents shall be as specified in AMS 2350.

2.1 SAE Publications: Available from SAE, 400 Commonwealth Drive, Warrendale, PA 15096.

2.1.1 Aerospace Material Specifications:

AMS 2201 - Tolerances, Aluminum and Aluminum Alloy Bar, Rod, Wire, and Forging Stock, Rolled or Cold Finished
MAM 2201 - Tolerances, Metric, Aluminum and Aluminum Alloy Bar, Rod, Wire, and Forging Stock, Rolled, Drawn, or Cold Finished
AMS 2350 - Standards and Test Methods
AMS 2375 - Control of Forgings Requiring First Article Approval
AMS 2645 - Fluorescent Penetrant Inspection
AMS 2770 - Heat Treatment of Aluminum Alloy Parts
AMS 2808 - Identification, Forgings

2.2 ASTM Publications: Available from American Society for Testing and Materials, 1916 Race Street, Philadelphia, PA 19103.

ASTM B557 - Tension Testing Wrought and Cast Aluminum- and Magnesium-Alloy Products
ASTM B594 - Ultrasonic Inspection of Aluminum-Alloy Products for Aerospace Applications
ASTM E10 - Brinell Hardness of Metallic Materials
ASTM E34 - Chemical Analysis of Aluminum and Aluminum Alloys

2.3 U.S. Government Publications: Available from Commanding Officer, Naval Publications and Forms Center, 5801 Tabor Avenue, Philadelphia, PA 19120.

2.3.1 Federal Standards:

Federal Test Method Standard No. 151 - Metals; Test Methods

2.3.2 Military Specifications:

MIL-H-6088 - Heat Treatment of Aluminum Alloys

2.3.3 Military Standards:

MIL-STD-649 - Aluminum and Magnesium Products, Preparation for Shipment and Storage

3. TECHNICAL REQUIREMENTS:

3.1 Composition: Shall conform to the following percentages by weight, determined by wet chemical methods in accordance with ASTM E34, by spectrographic methods in accordance with Federal Test Method Standard No. 151, Method 112, or by other analytical methods approved by purchaser:

	min	max
Magnesium	0.8	1.2
Silicon	0.40	0.8
Copper	0.15	0.40
Chromium	0.04	0.35
Iron	--	0.7
Zinc	--	0.25
Manganese	--	0.15
Titanium	--	0.15
Other Impurities, each	--	0.05
Other Impurities, total	--	0.15
Aluminum	remainder	

3.2 Condition: The product shall be supplied in the following condition:

3.2.1 Die Forgings, Hand Forgings, and Rolled Rings: Solution heat treated in accordance with MIL-H-6088 and naturally aged.

3.2.2 Forging Stock: As ordered by the forging manufacturer.

3.3 Properties: The product shall conform to the following requirements:

3.3.1 Die Forgings, Hand Forgings, and Rolled Rings:

3.3.1.1 As Solution Heat Treated and Naturally Aged:

3.3.1.1.1 Hardness: Shall be 50 - 80 HB/10/500 or 55 - 85 HB/10/1000, determined in accordance with ASTM E10.

3.3.1.2 After Precipitation Heat Treatment: Shall be as follows after being precipitation heat treated in accordance with AMS 2770:

3.3.1.2.1 Tensile Properties: Shall be as follows, determined in accordance with ASTM B557:

3.3.1.2.1.1 Test Specimens: Specimens machined from separately-forged coupons or from stock representing the forgings and, in either case, heat treated with the forgings, shall have the following properties:

Tensile Strength, min	38,000 psi (260 MPa)
Yield Strength at 0.2% Offset, min	35,000 psi (240 MPa)
Elongation in 4D, min	10%

3.3.1.2.1.2 Die Forgings:

3.3.1.2.1.2.1 With Grain Flow: Specimens, machined from forgings 4 in. (100 mm) and under in nominal thickness with the axis of specimen in the area of gage length varying not more than 15 deg from parallel to the forging flow lines, shall have properties as specified in 3.3.1.2.1.1 except that elongation may be as low as 7%.

3.3.1.2.1.2.2 Across Grain Flow: Specimens, machined from forgings 4 in. (100 mm) and under in nominal thickness with the axis of specimen in the area of gage length varying not more than 15 deg from perpendicular to the forging flow lines, shall have properties as specified in 3.3.1.2.1.1 except that elongation may be as low as 5%.

3.3.1.2.1.3 Hand Forgings: Specimens, machined from forgings 8 in. (200 mm) and under in nominal thickness shall have properties as specified in Table I; tests need not be made in the longitudinal direction unless specifically required by purchaser.

TABLE I

Nominal Thickness Inches	Specimen Orientation	Tensile Strength psi, min	Yield Strength at 0.2% Offset psi, min	Elongation in 4D %, min
Up to 4, incl	Longitudinal	38,000	35,000	10
	Long Trans.	38,000	35,000	8
	Short Trans.	37,000	33,000	5
Over 4 to 8, incl	Longitudinal	37,000	34,000	8
	Long Trans.	37,000	34,000	6
	Short Trans.	35,000	32,000	4

TABLE I (SI)

Nominal Thickness Millimetres	Specimen Orientation	Tensile Strength MPa, min	Yield Strength at 0.2% Offset MPa, min	Elongation in 5D %, min
Up to 100, incl	Longitudinal	260	240	9
	Long Trans.	260	240	7
	Short Trans.	255	230	4
Over 100 to 200, incl	Longitudinal	255	235	7
	Long Trans.	255	235	5
	Short Trans.	240	220	3

3.3.1.2.1.4 Rolled Rings:

3.3.1.2.1.4.1 Tangential: Specimens, machined from rings 2.50 in. (62.5 mm) and under in nominal thickness with axis of specimen tangential to ring OD (axis parallel to direction of rolling), shall have properties as specified in 3.3.1.2.1.1.

3.3.1.2.1.4.2 Axial: Specimens, machined from rings 2.50 in. (62.5 mm) and over in nominal thickness with axis of specimen approximately parallel to the axis of the ring (axis transverse to direction of rolling), shall have properties as specified in 3.3.1.2.1.1 except that elongation may be as low as 8%.

3.3.1.2.1.5 Other Forgings: Tensile property requirements for die forgings, hand forgings, and rolled rings having nominal thickness greater than specified above shall be as agreed upon by purchaser and vendor.

3.3.1.2.2 Hardness: Should be not lower than 80 HB/10/500 or 85 HB/10/1000 determined in accordance with ASTM E10, but the product shall not be rejected on the basis of hardness if the applicable tensile property requirements are met.

3.3.2 Forging Stock: When a sample of stock is forged to a test coupon and heat treated in the same manner as forgings, specimens taken from the heat treated coupon shall conform to the requirements of 3.3.1.2.1.1 and 3.3.1.2.2. If specimens taken from the stock after heat treatment in the same manner as forgings conform to the requirements of 3.3.1.2.1.1 and 3.3.1.2.2, the tests shall be accepted as equivalent to tests of a forged coupon.

3.4 Quality: The product, as received by purchaser, shall be uniform in quality and condition, sound, and free from foreign materials and from imperfections detrimental to usage of the product.

3.4.1 When specified, die forgings, hand forgings, and rolled rings shall be subjected to fluorescent penetrant inspection in accordance with AMS 2645 or to ultrasonic inspection in accordance with ASTM B594, or both. Standards for acceptance shall be as agreed upon by purchaser and vendor.

3.5 Tolerances: Unless otherwise specified, tolerances for forging stock shall conform to all applicable requirements of AMS 2201 or MAM 2201.

4. QUALITY ASSURANCE PROVISIONS:

4.1 Responsibility for Inspection: The vendor of the product shall supply all Ø samples for vendor's tests and shall be responsible for performing all required tests. Results of such tests shall be reported to the purchaser as required by 4.5. Purchaser reserves the right to sample and to perform any confirmatory testing deemed necessary to ensure that the product conforms to the requirements of this specification.

4.2 Classification of Tests:

4.2.1 Acceptance Tests: Test of the product to determine conformance to Ø requirements for composition (3.1); of forgings to determine conformance to requirements for hardness as solution heat treated (3.3.1.1.1), and tensile properties after precipitation heat treatment (3.3.1.2.1); and of forging stock to determine conformance to requirements for tolerances (3.5) are classified as acceptance tests and shall be performed on each lot.

4.2.2 Periodic Tests: Tests of forging stock to determine ability to develop Ø required properties (3.3.2) are classified as periodic tests and shall be performed at a frequency selected by the vendor unless frequency of testing is specified by purchaser.

4.2.3 Preproduction Tests: Tests of forgings and rolled rings to determine Ø conformance to all applicable technical requirements of this specification when AMS 2375 is specified are classified as preproduction tests and shall be performed prior to or on the first-article shipment of a forging or rolled ring to a purchaser, when a change in material or processing, or both, requires reapproval as in 4.4, and when purchaser deems confirmatory testing to be required.

4.2.3.1 For direct U.S. Military procurement of forgings, substantiating test data and, when requested, preproduction forgings shall be submitted to the cognizant agency as directed by the procuring activity, the contracting officer, or the request for procurement.

4.3 Sampling: Shall be as follows; a lot shall be all forgings or rolled rings of the same part number, size, or nominal cross-section and configuration heat treated in the same batch furnace load or in a continuous furnace consecutively during an 8-hr period.

4.3.1 Composition: At least one sample shall be taken by the producer from each group of ingots poured simultaneously from the same source of molten metal.

4.3.1.1 Unless compliance with 4.3.1 is established, an analysis shall be made for each 6,000 lb (2700 kg) or less comprising the lot except that not more than one analysis shall be required per piece.

4.3.2 Tensile Properties:

4.3.2.1 Die Forgings: Not less than one separately-forged coupon or one forging prolongation, heat treated with each lot of forgings.

4.3.2.1.1 In lieu of a prolongation or separately-forged coupon, tensile tests shall be conducted on specimens cut, in locations designated on the drawing, from a forging representing each lot.

4.3.2.2 Hand Forgings: Not less than two specimens taken from a forging or forging prolongation representing the lot. One specimen shall be taken in the long-transverse direction and the other in the short-transverse direction. When required by purchaser, an additional specimen shall be taken in the longitudinal direction.

4.3.2.3 Rolled Rings: Not less than two tensile specimens, taken from a ring or ring prolongation representing the lot. One specimen shall be taken tangetial to the ring OD and the other parallel to the axis of the ring.

4.4 Approval: When specified, approval and control of forgings shall be in accordance with AMS 2375.