



AEROSPACE MATERIAL SPECIFICATION

AMS6412™

REV. N

Issued 1940-01

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Revised 2015-12

Superseding AMS6412M

Steel, Bars and forgings
0.80Cr - 1.8Ni - 0.25Mo (0.35 - 0.40C) (4337)
(Composition similar to UNS G43370)

RATIONALE

AMS6412N results from a Five Year Review and update of this document that revises macrostructure, grain size, decarburization testing methods and reporting.

1. SCOPE

1.1 Form

This specification covers an aircraft-quality, low-alloy steel in the form of bars, forgings, and forging stock.

1.2 Application

These products have been used typically for parts, 0.875 inch (22.22 mm) and under in nominal section thickness at time of heat treatment, requiring a through-hardening steel capable of developing hardness as high as 50 HRC and for parts of greater thickness but requiring proportionately lower hardness, but usage is not limited to such applications.

2. APPLICABLE DOCUMENTS

The issue of the following documents in effect on the date of the purchase order forms a part of this specification to the extent specified herein. The supplier may work to a subsequent revision of a document unless a specific document issue is specified. When the referenced document has been cancelled and no superseding document has been specified, the last published issue of that document shall apply.

2.1 SAE Publications

Available from SAE International, 400 Commonwealth Drive, Warrendale, PA 15096-0001, Tel: 877-606-7323 (inside USA and Canada) or +1 724-776-4970 (outside USA), www.sae.org.

AMS2251 Tolerances, Low-Alloy Steel Bars

AMS2259 Chemical Check Analysis Limits, Wrought Low-Alloy and Carbon Steels

AMS2301 Steel Cleanliness, Aircraft Quality, Magnetic Particle Inspection Procedure

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AMS2370	Quality Assurance Sampling and Testing, Carbon and Low-Alloy Steel, Wrought Products and Forging Stock
AMS2372	Quality Assurance Sampling and Testing, Carbon and Low-Alloy Steel forgings
AMS2806	Identification Bars, Wire, Mechanical Tubing, and Extrusions, Carbon and Alloy Steels and Corrosion and Heat Resistant Steels and Alloys
AMS2808	Identification forgings
AS1182	Standard Stock Removal Allowance, Aircraft-Quality and Premium Aircraft-Quality Steel Bars and Mechanical Tubing

2.2 ASTM Publications

Available from ASTM International, 100 Barr Harbor Drive, P.O. Box C700, West Conshohocken, PA 19428-2959, Tel: 610-832-9585, www.astm.org.

ASTM A255	Determining Hardenability of Steel
ASTM A370	Mechanical Testing of Steel Products
ASTM E112	Determining Average Grain Size
ASTM E350	Chemical Analysis of Carbon Steel, Low-Alloy Steel, Silicon Electrical Steel, Ingot Iron, and Wrought Iron
ASTM E381	Macroetch Testing Steel Bars, Billets, Blooms, and forgings
ASTM E384	Knoop and Vickers Hardness of Materials

3. TECHNICAL REQUIREMENTS

3.1 Composition

Shall conform to the percentages by weight shown in Table 1, determined by wet chemical methods in accordance with ASTM E350, by spectrochemical methods, or by other analytical methods acceptable to purchaser.

Table 1 - Composition

Element	min	max
Carbon	0.35	0.40
Manganese	0.65	0.85
Silicon	0.15	0.35
Phosphorus	--	0.025
Sulfur	--	0.025
Chromium	0.70	0.90
Nickel	1.65	2.00
Molybdenum	0.20	0.30
Copper	--	0.35

3.1.1 Aluminum, vanadium and columbium are optional grain refining elements and need not be determined or reported unless used to satisfy average grain size requirements of 3.3.2.

3.1.2 Check Analysis

Composition variations shall meet the applicable requirements of AMS2259.

3.2 Condition

The product shall be supplied in the following condition; hardness and tensile strength shall be determined in accordance with ASTM A370.

3.2.1 Bars

Bar shall not be cut from plate.

3.2.1.1 Bars 0.500 Inch (12.70 mm) and Under in Nominal Diameter or Least Distance Between Parallel Sides

Cold finished having tensile strength not higher than 130 ksi (896 MPa) or equivalent hardness (see 8.2).

3.2.1.2 Bars Over 0.500 Inch (12.70 mm) in Nominal Diameter or Least Distance Between Parallel Sides

Hot finished and annealed, unless otherwise ordered, having hardness not higher than 229 HB, or equivalent (see 8.3). Bars ordered cold finished may have hardness as high as 248 HB, or equivalent (see 8.3).

3.2.2 forgings

As ordered.

3.2.3 Forging Stock

As ordered by the forging manufacturer.

3.3 Properties

The product shall conform to the following requirements; hardness testing shall be performed in accordance with ASTM A370:

3.3.1 Macrostructure

Visual examination of transverse full cross-sections from bars, billets, and forging stock, etched in hot hydrochloric acid in accordance with ASTM E381, shall show no pipe or cracks. Porosity, segregation, inclusions, and other imperfections shall be no worse than the macrographs of ASTM E381 shown in Table 2.

Table 2 - Macrostructure limits

Cross-Sectional Area Square Inches	Cross-Sectional Area Square Centimeters	Macrographs
Up to 36, incl	Up to 232, incl	S2 - R1 - C2
Over 36 to 100, incl	Over 232 to 645, incl	S2 - R2 - C3
Over 133	Over 858	Note 1

Note 1: Limits for larger sizes shall be agreed upon by purchaser and producer. The purchaser shall have written approval of the agreement from the cognizant engineering organization.

3.3.2 Average Grain Size of Bars and forgings

Average grain size shall be determined by either 3.3.2.1 or 3.3.2.2.

3.3.2.1 Shall be ASTM No. 5 or finer, determined in accordance with ASTM E112

3.3.2.2 The product of a heat shall be considered to have an ASTM No. 5 or finer austenitic grain size if one or more of the following are determined by heat analysis (see 8.6).

3.3.2.2.1 A total aluminum content of 0.020% to 0.050%.

- 3.3.2.2.2 An acid soluble aluminum content of 0.015% to 0.050%.
- 3.3.2.2.3 A vanadium content of 0.02 to 0.08%.
- 3.3.2.2.4 A columbium content of 0.02 to 0.05%.

3.3.3 Hardenability of each heat

Shall be J10/16 inch (15.9 mm) = 50 HRC minimum and J18/16 inch (28.6 mm) = 44 HRC minimum, determined on the standard end-quench test specimen in accordance with ASTM A255 except that the steel shall be normalized at 1700 °F ± 25 °F (927 °C ± 14 °C) and the test specimen austenitized at 1500 °F ± 25 °F (816 °C ± 14 °C).

3.3.4 Decarburization

- 3.3.4.1 Bars ordered ground, turned, or polished shall be free from decarburization on the ground, turned, or polished surfaces.
- 3.3.4.2 Allowable decarburization of bars and billets ordered for redrawing or forging or to specified microstructural requirements shall be as agreed upon by purchaser and producer.
- 3.3.4.3 Decarburization of bars that 3.3.4.1 or 3.3.4.2 is not applicable shall be not greater than shown in Table 3.

Table 3A - Maximum decarburization, inch/pound units

Nominal Diameter or Distance Between Parallel Sides Inches	Total Depth of Decarburization Inch
Up to 0.375, incl	0.010
Over 0.375 to 0.500, incl	0.012
Over 0.500 to 0.625, incl	0.014
Over 0.625 to 1.000, incl	0.017
Over 1.000 to 1.500, incl	0.020
Over 1.500 to 2.000, incl	0.025
Over 2.000 to 2.500, incl	0.030
Over 2.500 to 3.000, incl	0.035
Over 3.000 to 4.000, incl	0.045

Table 3B - Maximum decarburization, SI units

Nominal Diameter or Distance Between Parallel Sides Millimeters	Total Depth of Decarburization Millimeters
Up to 9.52, incl	0.25
Over 9.52 to 12.70, incl	0.30
Over 12.70 to 15.88, incl	0.36
Over 15.88 to 25.40, incl	0.43
Over 25.40 to 38.10, incl	0.51
Over 38.10 to 50.80, incl	0.64
Over 50.80 to 63.50, incl	0.76
Over 63.50 to 76.20, incl	0.89
Over 76.20 to 101.60, incl	1.14

- 3.3.4.4 Decarburization shall be evaluated by one of the two methods of 3.3.4.4.1 or 3.3.4.4.2.

3.3.4.4.1 Metallographic Method

A cross section taken perpendicular to the surface shall be prepared, etched, and visually examined metallographically at a magnification not to exceed 100X. Optical indications of decarburization (including complete decarburization [ferrite] plus partial decarburization shall not exceed the limits of Table 3.

3.3.4.4.2 Hardness Traverse Method

The total depth of decarburization shall be determined by a traverse method using microhardness testing in accordance with ASTM E384, at a magnification not exceeding 100X, conducted on a hardened but untempered specimen protected during heat treatment to prevent changes in surface carbon content. Depth of decarburization is defined as the perpendicular distance from the surface to the depth under that surface where there is not further increase in hardness. Such measurements shall be far enough away from any adjacent surface to be uninfluenced by any decarburization on the adjacent surface. Acceptance shall be as listed in Table 3.

3.3.4.5 When determining the depth of decarburization, it is permissible to disregard local areas provided the decarburization of such areas does not exceed the above limits by more than 0.005 inch (0.13 mm) and the width is 0.065 inch (1.65 mm) or less.

3.3.4.6 In case of dispute, the total depth of decarburization determined using the microhardness traverse method shall govern.

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 Steel shall be aircraft quality conforming to AMS2301.

3.4.2 Bars ordered hot rolled or cold drawn, or ground, turned, or polished shall, after removal of the standard stock removal allowance in accordance with AS1182, be free from seams, laps, tears, and cracks open to the machined, ground, turned, or polished surfaces.

3.4.3 Grain flow of die forgings, except in areas that contain flash line end grain, shall follow the general contour of the forgings showing no evidence of reentrant grain flow.

3.5 Tolerances

Bars shall conform to all applicable requirements of AMS2251.

4. QUALITY ASSURANCE PROVISIONS

4.1 Responsibility for Inspection

The producer of the product shall supply all samples for producer's tests and shall be responsible for the performance of all required tests. Purchaser reserves the right to sample and to perform any confirmatory testing deemed necessary to ensure that the product conforms to specified requirements.

4.2 Classification of Tests

4.2.1 Acceptance Tests

Composition (3.1), condition/hardness (3.2), macrostructure (3.3.1), average grain size (3.3.2), hardenability (3.3.3), decarburization (3.3.4), quality (3.4), frequency-severity cleanliness rating (3.4.1), and tolerance (3.5) are acceptance tests and shall be performed on each heat or lot as applicable. If grain refining elements (3.3.2.2) are not present, the ASTM E112 grain size test (3.3.2.1) shall be conducted on each lot.

4.2.2 Periodic Tests

If grain refining elements (3.3.2.2) are present, the ASTM E112 grain size test (3.3.2.1) shall be conducted on a periodic basis and shall be performed at a frequency selected by the producer (not to exceed one year) unless frequency of testing is specified by purchaser. Grain flow of die forgings (3.4.3) is a periodic test and shall be performed at a frequency selected by the producer unless frequency of testing is specified by purchaser.