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DENDRITE ARM SPACING OF STRUCTURAL AIRCRAFT QUALITY D357 ALUMINUM ALLOY CASTINGS, DETERMINATION AND ACCEPTANCE OF

1. SCOPE:

1.1 This document covers the recommended practice for determining the acceptability of the dendrite arm spacing (DAS) of D357-T6 aluminum alloy castings required to have tensile strength not lower than 50,000 psi (345 MPa).

1.2 To apply this method, at least two coupons used for DAS measurement and tensile testing, shall be attached to the casting.

1.3 Critical areas of the casting which require DAS control must be accessible for surface DAS measurements.

1.4 Safety - Hazardous Materials: While the materials, methods, applications, and processes described or referenced in this specification may involve the use of hazardous materials, this specification does not address the hazards which may be involved in such use. It is the sole responsibility of the user to ensure familiarity with the safe and proper use of any hazardous materials and to take necessary precautionary measures to ensure the health and safety of all personnel involved.

2. APPLICABLE DOCUMENTS: The following publications form a part of this document to the extent specified herein. The latest issue of SAE publications 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 2350 - Standards and Test Methods

2.2 ASTM Publications: Available from ASTM, 1916 Race Street, Philadelphia, PA 19103.

ASTM B 557 - Tension Testing Wrought and Cast Aluminum- and Magnesium-Alloy Products
ASTM B 557M - Tension Testing Wrought and Cast Aluminum- and Magnesium-Alloy Products (Metric)

3. SUMMARY OF METHOD: It has been shown that a linear correlation can be established between the ultimate tensile strength (UTS) and the spacing between the secondary dendrite arms of D357-T6 castings of high quality. The relationship, however, varies with the heat treatment process and chemical composition of the alloy; therefore, a preliminary evaluation using attached coupons on the casting is necessary before actual DAS measurements on the casting are meaningful. By determining the UTS and DAS of attached coupons, the effect of composition and heat treatment on the DAS/UTS relationship is determined. This relationship is used to evaluate the DAS measured in critical areas of the casting.

4. REFERENCE INFORMATION: Information relative to this method may be found in section 8.

5. DEFINITIONS:

5.1 Dendrite arm spacing (DAS) refers to the spacing between the secondary arms of the dendrite structure.

5.2 Particle intercepted distance (PID) refers to the spacing between the silicon particles that are intercepted by a straight line drawn in a random manner across the microstructure.

6. TEST PROCEDURE:

6.1 Attached Coupon Testing:

6.1.1 The average DAS and tensile strength of the attached coupons shall be determined. The attached coupons shall exhibit a minimum difference of 0.0010 inch (0.025 mm) DAS and a UTS of 47,000 - 57,000 psi (324 - 393 MPa).

6.1.2 The DAS of the attached coupons may be determined on the surface of the coupon as described in 6.2.3 or by examining a metallographic specimen excised from the tensile specimen.

6.1.3 The UTS of the attached coupons shall be determined in accordance with ASTM B 557 or ASTM B 557M.

6.2 Determination of Maximum DAS (DAS max):

6.2.1 Calculation Method:

6.2.1.1 The maximum acceptable DAS of the casting shall be determined using the following equation:

$$DAS_{max} = \frac{(DA5_2 - DAS_1)(UTS_1 - UTS_3)}{(UTS_1 - UTS_2)} + DAS_1$$

Where:

DAS_{max} = Maximum size DAS in 0.0001 inch (2.5 μm) acceptable to meet minimum tensile properties

DAS_1 = Size of DAS in 0.0001 inch (2.5 μm) of coupon with smallest structure

DAS_2 = Size of DAS in 0.0001 inch (2.5 μm) of coupon with largest structure

UTS_1 = Tensile strength of coupon with smallest DAS (ksi)

UTS_2 = Tensile strength of coupon with largest DAS (ksi)

UTS_3 = Minimum tensile strength required (ksi)

6.2.2 Graphic Method: The maximum DAS may be determined graphically in the following manner (See Figure 1).

6.2.2.1 Establish a graph using UTS units as the ordinate and DAS units as the abscissa.

6.2.2.2 Plot the UTS and DAS values from tests of the attached coupons and draw a line connecting the two points.

6.2.2.3 The maximum DAS is determined by projecting the intersection of the 50 ksi (345 MPa) UTS and the related DAS value.

6.3 Casting Acceptance:

6.3.1 The DAS shall be determined at each test location on the casting.

6.3.2 The DAS in all test locations shall be equal to or less than the maximum acceptable size determined in 6.2.1.

6.4 DAS Test Procedure:

6.4.1 Prepolishing:

6.4.1.1 Test locations shall be prepolished using 100 grit paper followed by 400 or 600 grit paper.

6.4.1.2 Prepolishing shall be sufficient to produce an outline of the secondary arm structure after etching.

6.4.1.3 Metal removal during polishing shall not exceed 0.005 inch (0.13 mm) thickness.

6.4.2 Final Polishing and Etching:

6.4.2.1 Final polishing can be accomplished using mechanical or electro-polishing equipment.

6.4.2.2 The electro-polishing and electro-etching solution shall be made up as follows:

Distilled Water	120 mL
Tartaric Acid	50 g
Ethyl Alcohol	100 mL
Butyl Cellosolve	100 mL
Perchloric Acid (60%)	78 mL

6.4.2.3 Current density and times should be sufficient to reveal the dendrite structure of the material.

6.4.2.4 Chemical etching may be used by carefully swabbing the polished area with Keller's etch or other suitable etch to reveal the dendrite structure. Care must be exercised to not allow the etchant to spread to other areas of the casting.

6.4.2.5 After etching, the casting shall be cleaned to remove all etchant.

6.4.3 Microstructure Replication:

6.4.3.1 The microstructure shall be transferred from the etched surface to a plastic replica for viewing by an optical microscope.

6.4.3.2 Each replica shall be identified for traceability to the test location of the casting being evaluated.

6.4.3.3 A photograph at 100X magnification which clearly delineates the dendritic structure shall be obtained from the replica.

6.4.3.4 The microstructure shall clearly distinguish the secondary arm spacing from the casting surface. Improper polishing, under-etching, or over-etching can produce a misleading microstructure.

6.4.3.5 If the microstructure is improperly polished, under-etched, or over-etched, the test location shall be repolished very lightly using 400 to 600 grit paper, repolished, and re-etched. Under-etched locations shall not be re-etched without repolishing.

6.4.3.6 The test casting shall be rinsed in running water to remove the etching solution after the examination has been completed.

6.4.4 Photomicrograph:

6.4.4.1 A photomicrograph shall be made at 100X magnification in the area which most clearly defines the general microstructure.

6.4.4.2 Areas of the photomicrograph selected for DAS count shall be identified either directly on the original photomicrograph or on a copy of the photomicrograph.

6.4.5 Microstructure Evaluation:

6.4.5.1 Either of the following methods for evaluation is acceptable; however, the measurement of clearly defined secondary dendrite arm spacing (DAS) is preferred. When this is not possible, the alternate procedure of measuring the distance between silicon particles located in a random manner along a single line shall be used.

6.4.5.2 All measurements used in the evaluation of a casting for acceptability shall be made by the same method.

6.4.5.3 Preferred Measurement Method: Extend a straight line across an area of well-defined structure such as illustrated in Figure 2. The line is drawn perpendicular to the growth direction of the secondary arms. The average distance between intercepts of silicon particles along the line shall be used to define the DAS of the structure. By measuring the total length of drawn line and counting the number of interceptions, the average DAS value can be determined in the following manner:

$$\text{DAS, inch (mm)} = \frac{\text{Length of Intercept Line Inch (mm)}}{\text{Number of Interceptions X Magnification}}$$

6.4.5.3.1 At least two areas of the microstructure shall be evaluated. The average of the two areas shall be considered to be the DAS of that test site.

6.4.5.4 Alternate Measurement Method: This alternate procedure consists of drawing a straight line of known length across the microstructure and counting the number of times the line is intercepted by silicon particles (See Fig. 3). The average distance between silicon particles is then used to quantify the structure. Particle intercept distance (PID) is determined by the following:

$$\text{PID, inch (mm)} = \frac{\text{Length of Intercept Line Inch (mm)}}{\text{Number of Intercepts X Magnification}}$$

6.4.5.5 At least two lines with a minimum length of 3 inches (76 mm) shall be drawn which vary in their orientation to each other as much as practical. The average PID of the two lines shall be reported.

6.4.5.6 Caution should be used when using this procedure for measuring coarse dendritic structures. These structures may exhibit large amounts of interdendritic material which reduce the accuracy of the measurement.

6.4.5.7 In other sections of this recommended practice, PID may be interchanged with DAS without changing its technical intent.

7. TEST REPORTS:

7.1 The test results shall be itemized as average values from each test site on the casting or integrally-attached coupon.

7.1.1 A photograph or copy of the photograph of the microstructure at each test site shall be furnished clearly delineating the lines drawn for microstructure measurements.

7.1.2 The test laboratory shall maintain on file, for not less than 90 days, the replica plate or tape used in the evaluation.

8. REFERENCES:

8.1 Spear, R. E. and Gardner, G. R., "Dendrite Cell Size", Transactions of the American Foundrymen's Society, Vol. 71, 1963, pp. 209-215.

8.2 Bossing, E. N., and Hall, J. J., "Predicting Properties of Al-Si-Mg Casting with NDT, "Foundry, Vol. 102, Oct. 1974, pp. 82-87.

8.3 Oswalt, K. J. and Misra, M. S., "Dendritic Arm Spacings (DAS) - a Nondestructive Test to Evaluate Tensile Properties of Premium Quality Aluminum Alloy (Al-Si-Mg) Casting, "AFS Transactions, 1980, pp. 845-862.

8.4 Levy, S. A., Hughes, R. E., and Kemppinens, A. I., "Quantitative Metallography of As-Cast Aluminum Microstructures" AFS Cast Metals Research Journal, June 1969, pp. 93-96.

8.5 Flemings, M. C., Uram, S. Z., and Taylor, H. F., "Solidification of Aluminum Casting", AFS Transactions, Vo. 68, 1960, pp. 670-684.

8.6 Flemings, M. C., "Casting Metals, "Science and Technology", Dec. 1968, pp. 13-24.

9. NOTES:

9.1 Marginal Indicia: The phi (Ø) symbol is used to indicate technical changes from the previous issue of this specification.

9.2 This recommended practice is under the jurisdiction of AMS Committee "D".