SAE INTERNATIONAL

AEROSPACE RECOMMENDED PRACTICE

ARP1947™ REV. D

Issued 1985-10
Reaffirmed 1996-07
Revised 2024-05

Superseding ARP1947C

Dendrite Arm Spacing of Structural Aircraft Quality D357 Aluminum Alloy Castings, Determination and Acceptance of

RATIONALE

ARP1947D results from an SAE Five-Year Review and update of this specification with changes to relocate Definitions (see 2.3), correct typographical errors (see Title and 2.3.2) and strength units consistent with related material specifications (see 1.1 and 4.1.1), and update Applicable Documents (see Section 2).

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 ksi (345 MPa).

1.2 To apply this method, at least two coupons used for DAS measurement and two tensile specimens shall be attached in locations defined by the cognizant engineering organization.

1.3 Areas of the casting that require DAS control must be accessible for surface DAS measurements, or if internal locations are to be tested, such locations shall be defined by the cognizant engineering organization.

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 that 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. REFERENCES

2.1 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 publications shall be the issue in effect on the date of the purchase order. In the event of conflict between the text of this document and references cited herein, the text of this document takes precedence. Nothing in this document, however, supersedes applicable laws and regulations unless a specific exemption has been obtained.

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2.1.1 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.

AS7766 Terms Used in Aerospace Metals Specifications

2.1.2 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 B557/B557M Tension Testing Wrought and Cast Aluminum- and Magnesium-Alloy Products

2.2 Related Publications

The following publications are provided for information purposes only and are not a required part of this SAE Technical Report.

Spear, R.E. and Gardner, G.R. (1963). Dendrite cell size. *Transactions of the American Foundrymen's Society, 15*, 209-215.

Bossing, E.N. and Hall, J.J. (1974). Predicting properties of Al-Si-Mg casting with NDT. *Foundry, 102*, 82-87.

Oswalt, K.J. and Misra, M.S. (1980). Dendritic arm spacings (DAS): A nondestructive test to evaluate tensile properties of premium quality aluminum alloy (Al-Si-Mg) casting. *AFS Transactions, 80*(51), 845-862.

Levy, S.A., Hughes, R.E., and Kemppinens, A.I. (1969). Quantitative metallography of as-cast aluminum microstructures. *AFS Cast Metals Research Journal*, 93-96.

Flemings, M.C., Uram, S.Z., and Taylor, H.F. (1960). Solidification of aluminum casting. *AFS Transactions*, *68*, 670-684.

Flemings, M.C. (1968). Casting metals. *Science and Technology*, 13-24.

2.3 Definitions

Terms used in AMS are defined in AS7766, except as defined below:

2.3.1 DENDRITE ARM SPACING (DAS)

Refers to the spacing between the secondary arms of the dendrite structure.

2.3.2 PARTICLE INTERCEPT 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.

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 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. TEST PROCEDURE

4.1 Attached Coupon Testing

4.1.1 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 to 57 ksi (324 to 393 MPa). The DAS of the attached coupons may be determined on the untested grip or gauge length surface of the coupon as described in 4.4 or by examining a metallographic specimen excised from the tensile specimen in any location not deformed by strain.

4.1.2 The UTS of the attached coupons shall be determined in accordance with ASTM B557/B557M.

4.2 Determination of Maximum DAS (DAS Maximum)

4.2.1 Calculation Method

4.2.1.1 The maximum acceptable DAS of the casting shall be determined using Equation 1.

$$DAS_{1max} \frac{(DAS_2 - DAS_1)(UTS_1 - UTS_3)}{(UTS_1 - UTS_2)} \quad \text{(Eq. 1)}$$

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)

4.2.2 Graphic Method

The maximum DAS may be determined graphically following the example in Figure 1.

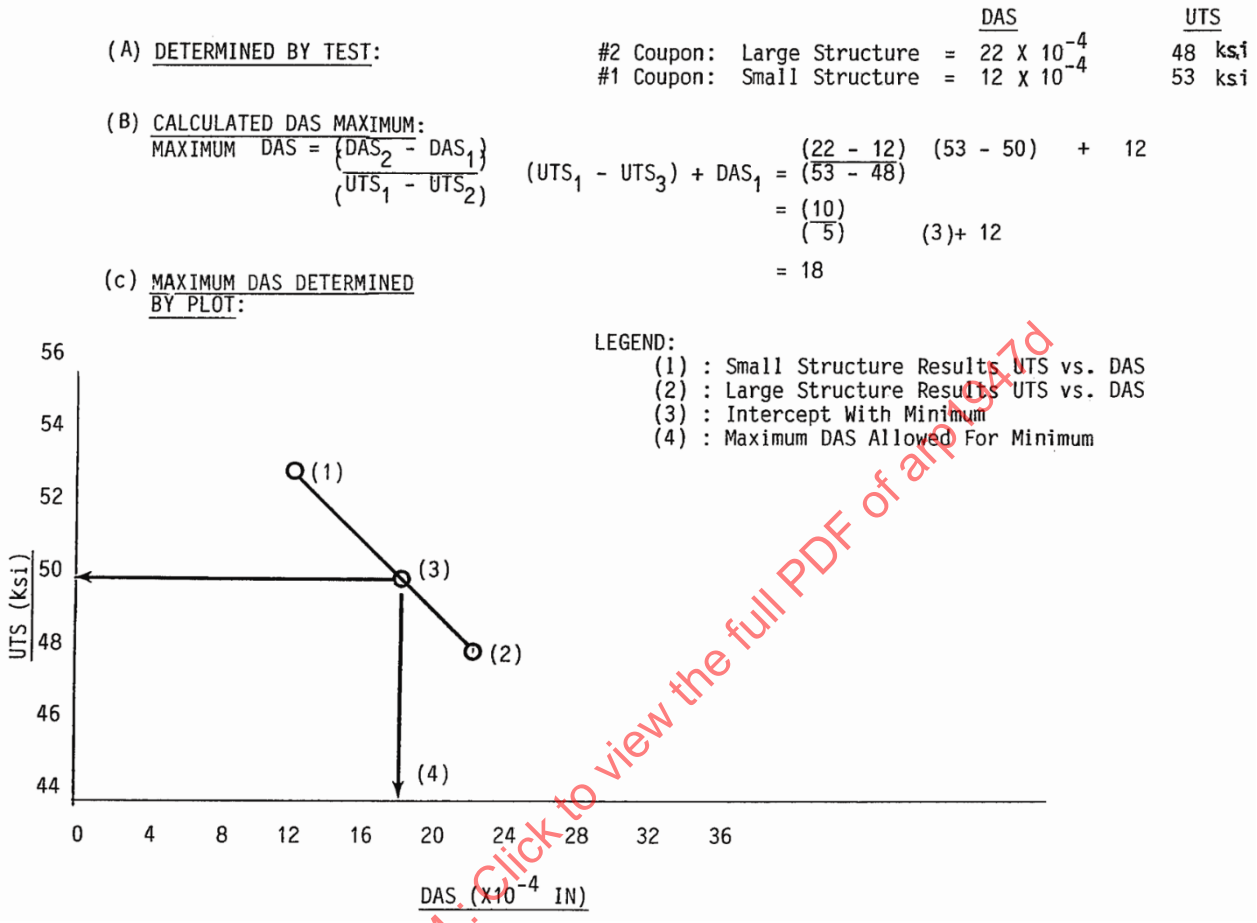

Figure 1 - Maximum DAS determination

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

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

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

4.3 Casting Acceptance

4.3.1 The DAS shall be determined at each test location on the casting as defined by the cognizant engineering organization.

4.3.2 The DAS in all test locations shall be equal to or less than the maximum acceptable DAS determined in 4.2.

4.4 Metallographic DAS Test Procedure

4.4.1 Test locations shall be mechanically polished or electro-polished. Polishing and etching shall be sufficient to produce a clear outline of the secondary arm structure when examined at 100X magnification.

4.4.1.1 Where surface DAS measurements are made, metal removal during polishing shall not exceed 0.005-inch (0.13-mm) thickness.

4.4.2 Microstructure Replication

4.4.2.1 Where surface measurements are made, the microstructure shall be transferred from the etched surface to a plastic replica for viewing by an optical microscope.

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

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

4.4.2.4 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.

4.4.2.5 If the microstructure is improperly polished, under-etched, or over-etched, the test location shall be repolished and re-etched. Where applicable, the test casting shall be rinsed in running water to remove the etching solution after the examination has been completed.

4.4.3 Photomicrograph

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

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

4.4.4 Microstructure Evaluation

4.4.4.1 Either of the following methods for evaluation is acceptable; however, the measurement of clearly defined secondary 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.

4.4.4.2 All measurements used in the evaluation of a casting for acceptability shall be made by the same 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:

$$DAS, inch(mm) = \frac{\text{Length of Intercept Line Inch (mm)}}{\text{Number of Interceptions x Magnification}}\ ^{(1)} \qquad \text{(Eq. 2)}$$

(1) Some microscopes and laboratories use calibrated scales or slides superimposed or adjacent to the microstructure that provide a direct measurement of, for example, actual true Length of Intercept. In this case, it is not required to divide by the microscope magnification.

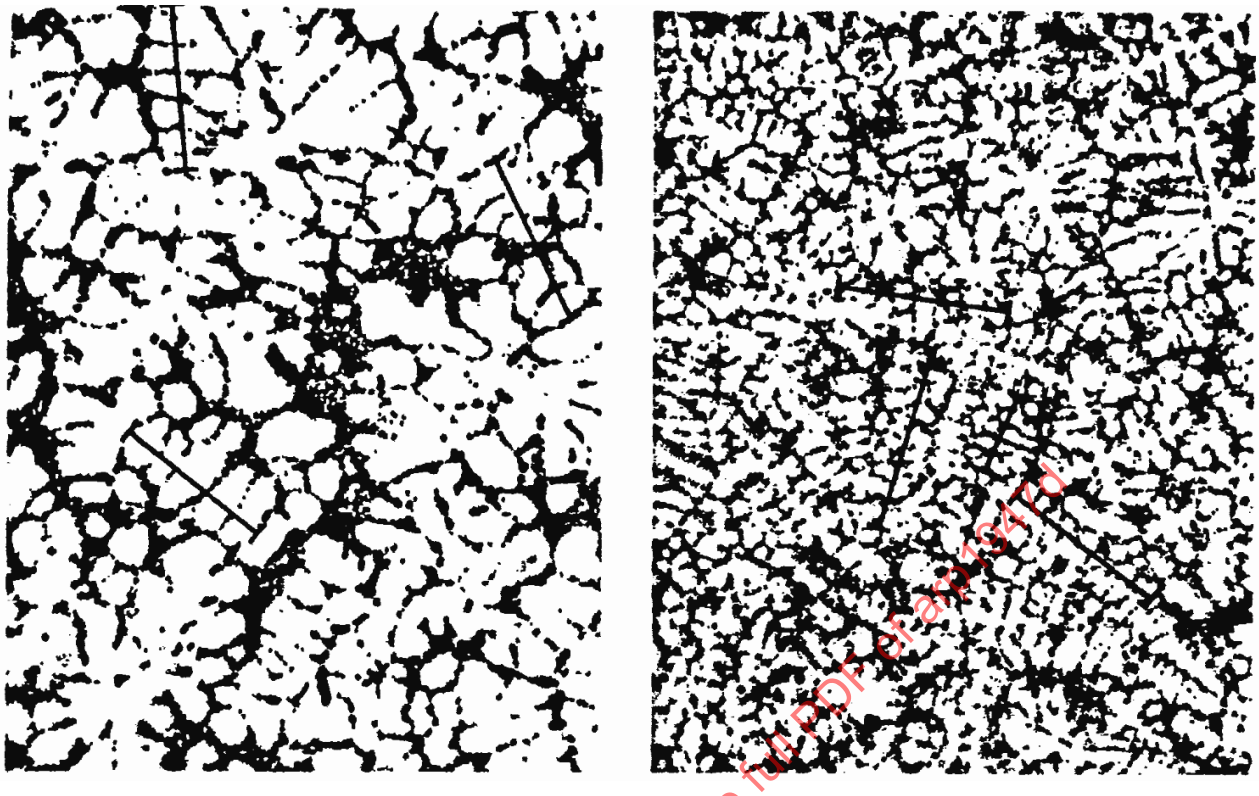

Figure 2 - Example of measurement of DAS taken in selected areas

4.4.4.2.1 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.

4.4.4.3 Alternate Method B: PID 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 Figure 3). The average distance between silicon particles is then used to quantify the structure. Particle intercept distance (PID) is determined by the following:

$$\text{PID, inch (mm)} = \frac{\text{Length of Intercept Line Inch (mm)}}{\text{Number of Intercepts x Magnification}} \quad \text{(Eq. 3)}$$