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AMERICAN SOCIETY FOR TESTING AND MATERIALS
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Standard Practice for Plane–Strain Fracture Toughness Testing of Aluminum Alloys[1]

This standard is issued under the fixed designation B 645; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ϵ) indicates an editorial change since the last revision or reapproval.

INTRODUCTION

Plane-strain fracture toughness testing of aluminum alloys is performed essentially in accordance with Test Method E 399. However, there is a need, in the application of Test Method E 399 for quality assurance testing, to deal with the interpretation of the results for material qualification and release in cases where all requirements for valid measurements of plane-strain fracture toughness cannot be met. It is the purpose of this practice to provide consistent methods of dealing with those situations.

1. Scope

1.1 This practice is applicable to the fracture toughness testing of all aluminum alloys, tempers, and products, especially in cases where the tests are being made to establish whether or not individual lots meet the requirements of specifications and should be released to customers.

1.2 Test Method E 399 is the basic standard test method to be used for plane-strain fracture toughness testing of aluminum alloys. The purpose of this practice is to provide supplementary information for plane-strain fracture toughness of aluminum alloys in three main areas:

1.2.1 Specimen sampling,

1.2.2 Specimen size selection, and

1.2.3 Interpretation of invalid test results.

1.3 The values stated in inch-pound units are to be regarded as the standard. The values given in parentheses are provided for information only.

1.4 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

2. Referenced Documents

2.1 *ASTM Standards:*

B 646 Practice for Fracture Toughness Testing of Aluminum Alloys[2]

E 399 Test Method for Plane-Strain Fracture Toughness of Metallic Materials[3]

E 1823 Terminology Relating to Fatigue and Fracture Testing[3]

3. Terminology

3.1 *General*—Terms, definitions, symbols, and orientation designations in Test Method E 399 and Terminology E 1823 are applicable herein.

3.2 The following additional definitions are applicable:

3.2.1 *invalid plane-strain fracture toughness*—test result, Kq, that does not meet one or more of the validity requirements in Test Method E 399 and, where so characterized, is of no value in judging the true plain-strain fracture toughness of a material but may, under certain conditions, adequately guarantee the material's fracture toughness for lot release purposes.

3.2.2 *meaningful plane-strain fracture toughness*—test result, designated Kq, that does not meet one or more of the validity requirements in Test Method E 399, but for which there is experimental or analytical evidence that the departure from validity is small enough that the value of Kq is expected to be within 5 or 10 % of the value of K_{Ic} that would have been obtained had all the validity criteria been met.

3.2.3 *valid plane-strain, fracture toughness*—test result meeting all the validity requirements in Test Method E 399, that is, a value of K_{Ic}.

4. Summary of Practice

4.1 This practice supplements Test Method E 399 and Practice B 646 in three main areas:

4.1.1 Specimen sampling,

4.1.2 Specimen size selection, and

[1] This practice is under the jurisdiction of ASTM B-7 on Light Metals and Alloys , and is the direct responsibility of Subcommittee B07.05 on Testing.

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[2] *Annual Book of ASTM Standards*, Vol 02.02.

[3] *Annual Book of ASTM Standards*, Vol 03.01.

4.1.3 Interpretation of results which fail the validity requirements in Test Method E 399 in one of the following areas in order to determine if the invalid results are acceptable for lot release:

4.1.3.1 Pmax/Pq requirements,

4.1.3.2 Specimen size requirements, and

4.1.3.3 Fatigue precracking requirements.

5. Significance and Use

5.1 This practice for plane-strain fracture toughness testing of aluminum alloys may be used as a supplement to Test Method E 399. The application of this practice is primarily intended for quality assurance and material release in cases where valid plane-strain fracture toughness data cannot be obtained per Test Method E 399.

5.2 It must be understood that the interpretations and guidelines in this practice do not alter the validity requirements of Test Method E 399 or promote the designation of data that are invalid according to Test Method E 399 to a "valid" condition. This practice is primarily concerned with cases where it is not possible or practical to obtain valid data, but where material release judgments must be made against specified fracture toughness values. Where it is possible, by retesting, to obtain valid plane-strain fracture toughness according to Test Method E 399, that is the preferred approach.

6. Apparatus

6.1 All apparatus shall be in conformance with Test Method E 399.

7. Sampling

7.1 Sampling requirements shall be as stated in the individual material specifications. In the absence of specific requirements in the individual material specifications, specimens shall be taken at the following locations:

7.1.1 Specimens from plate shall be from the mid-thickness, until the plate thickness is twice the standard specimen thickness for that particular product (that is, the specimen thickness selected for lot release and quality assurance testing which typically yields a valid K_{Ic} for that particular alloy and product), at and beyond which the specimen shall be centered at the quarter-thickness location.

7.1.2 Specimens from forgings, extrusions, and rod shall be taken from the center of the cross section so far as is practical.

NOTE 1—Considerable care should be taken in specifying the location of specimens within the thickness of the thick plate, forgings, extrusions, or rod because fracture toughness may vary appreciably with location through the thickness.

8. Test Specimen Configuration and Dimensions

8.1 The specimen types, general configuration and size requirements in Test Method E 399 are applicable herein with the following supplemental recommendations and requirements:

8.1.1 For aluminum products, it is recommended that the thickness, *B*, and crack length, a, equal or exceed 5 $(Kq/\sigma ys)^2$ rather than the required minimum of 2.5 $(Kq/\sigma ys)^2$ in Test Method E 399.

NOTE 2—Experimental studies[4] have shown that more uniform values of Kq are obtained for high toughness aluminum alloys when $B,a \geq 5\ (Kq/\sigma ys)^2$.

8.1.2 When it is not possible to obtain a specimen thickness $B \geq 5\ (Kq/\sigma ys)^2$, it is recommended that the thickness be the maximum possible considering the basic product dimensions, and that crack length, *a*, be maintained at $\geq 5\ (Kq/\sigma ys)^2$ or as large as possible while still meeting the requirements of 8.1.4.

NOTE 3—Specimens having $B \geq 2.5\ (Kq/\sigma ys)^2$ and crack length, $a \geq 5\ (Kq/\sigma ys)^2$ may allow for a meaningful Kq to be obtained as described in 11.3.1 even though the Pmax/Pq requirement in Test Method E 399 is not met.

8.1.3 When the minimum size requirements of *B*, $a \geq 2.5\ (Kq/\sigma ys)^2$ in Test Method E 399 cannot be met due to product dimensional constraints, the specimen shall be machined such that the *B* dimension is maximized (for test orientations where it is the constrained dimension) up to an upper required limit of 2.5 in. (63.5 mm) for thick products (a thickness greater than 2.5 in. (63.5 mm) may be used at the discretion of the producer but is not required, see Note 5), or W is maximized (for test orientations where it is the constrained dimension) while still meeting the requirements of 8.1.4.

NOTE 4—A specimen which fails to satisfy the minimum size requirements in Test Method E 399 but meets the requirements in 8.1.3, is not valid per Test Method E 399 or this practice, or meaningful as defined in this practice, but may be acceptable for lot release purposes.

NOTE 5—An upper limit of 2.5 in. (63.5 mm) has been placed on specimen thickness for thick products in recognition that there are practical limitations on how large a specimen can be routinely machined and tested for lot release purposes in a production environment using standard test equipment. The producer may test thicker specimens provided the testing capability and sufficient material are available.

NOTE 6—For aluminum products where the size requirements $B,a \geq 2.5\ (Kq/\sigma ys)^2$ cannot be consistently met even when *B* is maximized or at the upper thickness limit of 2.5 in. (63.5 mm) and W is maximized, because of high toughness, other measures of fracture toughness such as KR25 as described in Practice B 646 or the R-curve as described in Practice E 561 should be considered for evaluating fracture toughness for lot release purposes.

8.1.4 In all cases, specimen *B/W* ratios shall be greater than or equal to 0.25 and less than or equal to 0.5 based on nominal specimen dimensions. Other dimensional proportions in Test Method E 399 shall also be maintained.

NOTE 7—Specimens meeting this requirement correspond to the standard ($B/W=0.5$) or alternative specimen geometries ($0.25 \leq B/W < 0.5$) in Test Method E 399.

9. Fatigue Precracking

9.1 Fatigue precracking shall be performed and fatigue crack front measurements shall be made in accordance with Test Method E 399.

10. Procedure

10.1 The test procedure, analysis of test record, and calculations shall be made in accordance with Test Method E 399.

[4] Kaufman, J. G., "Experience in Plane Strain Fracture Toughness per ASTM E 399," *Developments in Fracture Mechanics Test Methods Standardization, ASTM STP 632*,ASTM, 1977, pp. 3-24.