Designation: B645 – 10 (Reapproved 2015)

Standard Practice for Linear-Elastic Plane–Strain Fracture Toughness Testing of Aluminum Alloys[1]

This standard is issued under the fixed designation B645; 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.

This standard has been approved for use by agencies of the U.S. Department of Defense.

INTRODUCTION

Linear-elastic plane-strain fracture toughness testing of aluminum alloys is performed essentially in accordance with Test Method E399. However, there is a need, in the application of Test Method E399 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 E399 is the basic 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 SI units are to be regarded as standard. No other units of measurement are included in this standard.

1.3.1 *Exception*—Certain inch-pound values given in parentheses are provided for information only.

1.4 This standard is currently written to accommodate only C(T) specimens.

1.5 *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:*[2]

B646 Practice for Fracture Toughness Testing of Aluminum Alloys

E29 Practice for Using Significant Digits in Test Data to Determine Conformance with Specifications

E399 Test Method for Linear-Elastic Plane-Strain Fracture Toughness K_{Ic} of Metallic Materials

E561 Test Method for ***K-R*** Curve Determination

E1823 Terminology Relating to Fatigue and Fracture Testing

3. Terminology

3.1 *General*—Terms, definitions, symbols, and orientation designations in Test Method E399 and Terminology E1823 are applicable herein.

3.2 *Definitions:*The following additional definitions are applicable:

3.2.1 *invalid plane-strain fracture toughness*—test result, K_Q, that does not meet one or more of the validity requirements in Test Method E399 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.

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

Current edition approved Dec. 1, 2015. Published December 2015. Originally approved in 1978. Last previous edition approved in 2010 as B645 – 10. DOI: 10.1520/B0645-10R15.

[2] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

***A Summary of Changes section appears at the end of this standard**

3.2.2 *valid plane-strain, fracture toughness*—test result meeting all the validity requirements in Test Method E399, that is, a value of K_{Ic}.

4. Summary of Practice

4.1 This practice supplements Test Method E399 and Practice B646 in three main areas:

4.1.1 Specimen sampling,

4.1.2 Specimen size selection, and

4.1.3 Interpretation of results that fail the validity requirements in Test Method E399 in one of the following areas in order to determine if the invalid results are usable for lot release:

4.1.3.1 P_{max}/P_Q 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 E399. 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 E399.

5.2 It must be understood that the interpretations and guidelines in this practice do not alter the validity requirements of Test Method E399 or promote the designation of data that are invalid according to Test Method E399 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 to obtain a valid plane-strain fracture toughness value by replacement testing according to Test Method E399, that is the preferred approach.

6. Apparatus

6.1 All apparatus shall be in conformance with Test Method E399.

7. Sampling

7.1 Sampling requirements stated in the individual material specifications shall be followed. 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 as 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 Specimen size requirements stated in the individual material specifications shall be followed. In the absence of specific requirements, the specimen types, general configuration, and size requirements in Test Method E399 are applicable herein with the following supplemental recommendations and requirements:

8.1.1 For aluminum products, the recommended minimum specimen ligament length is:

$$(W - a) \geq 5 \cdot \left(\frac{K_Q}{\sigma_{YS}} \right)^2 \quad (1)$$

rather than the required minimum of:

$$(W - a) \geq 2.5 \cdot \left(\frac{K_Q}{\sigma_{YS}} \right)^2 \quad (2)$$

in Test Method E399.

NOTE 2—Experimental studies[3] have shown that more uniform values of K_Q are obtained for high toughness aluminum alloys when the conditions of Eq 1 are met.

8.1.2 In all cases, the specimen *W/B* ratio shall be greater than or equal to 2 and less than or equal to 4 based on nominal specimen dimensions. Other specimen dimensional proportions in Test Method E399 shall also be maintained.

NOTE 3—Specimens meeting this requirement correspond to the standard ($W/B = 2$) or alternative specimen geometries ($2 \leq W/B \leq 4$) in Test Method E399.

8.1.3 When the minimum size requirement of:

$$(W - a) \geq 2.5 \cdot \left(\frac{K_Q}{\sigma_{YS}} \right)^2$$

in Test Method E399 cannot be met due to product dimensional constraints, the specimen shall be machined such that the *W* dimension is maximized to the nearest 12.7 mm (0.5 in.) at the specified test location while still meeting the requirements of 8.1.2 up to the specimen width required in the applicable material specification, or if no width is specified, up to an upper required limit of 127 mm (5.0 in.).

NOTE 4—It is not practical for *W* to vary continuously (that is, non-discretely) since many C(T) specimen dimensions are proportional to *W*. Each change in *W* requires a different machining or testing setup. Therefore, it is required that *W* be maximized to the nearest 12.7 mm (0.5 in.).

8.1.4 When the requirement $P_{max}/P_Q \leq 1.1$ cannot be met due to product dimensional constraints, the specimen shall be machined such that the *B* dimension is maximized up to a required maximum thickness of 63.5 mm (2.5 in.) at the specified test location. The specimen ligament length should be maintained at:

$$(W - a) \geq 2.5 \cdot \left(\frac{K_Q}{\sigma_{YS}} \right)^2 \quad (3)$$

or as large as possible while still meeting the requirements of 8.1.2, up to the specimen width required in the applicable material specification, or if no width is specified, up to an upper required limit of 127 mm (5.0 in.).

NOTE 5—The upper limit on specimen thickness and width have been established because of practical limitations on how large a specimen can

[3] Kaufman, J. G., "Experience in Plane Strain Fracture Toughness per ASTM E399," *Developments in Fracture Mechanics Test Methods Standardization, ASTM STP 632*, ASTM, 1977, pp. 3-24.