Designation: B 646 – 97

Standard Practice for Fracture Toughness Testing of Aluminum Alloys[1]

This standard is issued under the fixed designation B 646; 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 Department of Defense.

INTRODUCTION

Fracture toughness is a key property for a number of aluminum alloys utilized in aerospace and process industries, but at the current stage of development of fracture test techniques no standard methods exist to cover a number of the product lines or dimensional ranges involved. Plane-strain fracture toughness, K_{Ic}, is a keystone of the industry, but for the very tough alloys of principal interest, valid measurements can be made only for relatively thick sections. Thus it is necessary to provide this standard practice for uniform quality control test procedures for the industry, pointing out which current standards are utilized in specific cases, and providing guidelines where no standards exist.

1. Scope

1.1 This practice provides guidance for testing (*a*) thin products, of thicknesses equivalent to sheet that is, (|La0.249 in. (6.30 mm)), (*b*) intermediate thicknesses of plate, forgings, and extrusions, too thin for valid plane-strain fracture toughness testing but too thick for treatment as sheet, that is over 0.249 in. (6.30 mm) and up to 1 to 2 in. (25 to 50 mm), dependent upon toughness level, and (*c*) relatively thick products where Test Method E 399 is applicable. For changes to this specification since the last issue, refer to the Summary of Changes section at the end of the standard.

1.2 This practice addresses the problem of screening tests, recognizing the complexity and expense of making formal fracture toughness measurements on great quantities of production lots, and provides alternatives in the form of simpler, less expensive tests that may be carried out either in a research or production test laboratory.

1.3 The values stated in inch-pound units are to be regarded as the standard.

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 557 Test Methods of Tension Testing Wrought and Cast Aluminum- and Magnesium-Alloy Products[2]

B 645 Practice for Plane Strain Fracture Toughness Testing of Aluminum Alloys[2]

E 23 Test Methods for Notched Bar Impact Testing of Metallic Materials[3]

E 338 Test Method of Sharp-Notch Tension Testing of High-Strength Sheet Materials[3]

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

E 561 Practice for *R*-Curve Determination[3]

E 602 Test Method for Sharp-Notch Tension Testing with Cylindrical Specimens[3]

E 616 Terminology Relating to Fracture Testing[3]

E 1304 Test Method for Plane-Strain (Chevron Notch) Fracture Toughness of Metallic Materials[3]

2.2 *Other Document:*

Aluminum Association Bulletin T5, "Fracture Toughness Testing of Aluminum Alloys"[4]

3. Terminology

3.1 The terminology and definitions in the referenced documents are applicable to this practice.

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 For purposes of this practice, the following descriptions of terms are applicable in conjunction with Practice E 561 and use of the compact specimen:

3.2.2 $K_{R_{25}}$—A value of K on the R-curve based on a 25 % secant intercept of the load-crack opening displacement test record and the effective crack length at that point that otherwise satisfies the remaining-ligament criterion of Practice E 561.

3.2.3 $K_{R_{max}}$—A value of K on the R-curve based on the maximum load value of the load-crack opening displacement

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

Current edition approved Oct. 10, 1997. Published May 1998. Originally published as B 646 – 78. Last previous edition B 646 – 94.

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

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

[4] Available from The Aluminum Association, 750 3rd Ave., New York, NY 10017.

test record and the effective crack length at that point that otherwise satisfies the remaining-ligament criterion of Practice E 561. The $K_{R_{max}}$ value is used when the 25 % secant intercept occurs at a point after the maximum load is reached.

3.2.4 For purposes of this practice, the following descriptions of terms are applicable in conjunction with the chevron notch (short-rod and short-bar) Test Method E 1304.

4. Summary of Practice

4.1 This practice provides guidelines for the selection of tests for the evaluation of the fracture toughness properties of aluminum alloys, particularly for quality assurance and material release purposes, including:

4.1.1 Center-slotted panel testing of sheet products in accordance with Practice E 561, M(T) specimen procedures.

4.1.2 Screening tests of sheet products in accordance with Test Method E 338.

4.1.3 Plane-strain fracture toughness tests in accordance with Test Method E 399.

4.1.4 Intermediate thickness fracture toughness tests in accordance with Practice B 645 and Test Method E 399.

4.1.5 Intermediate thickness fracture toughness tests in accordance with Practice E 561 using the C(T) (compact specimen) and a 25 % secant-intercept value concept, designated as $K_{R_{25}}$, as a single value or discrete point evaluation of the crack-growth resistance curve (R-curve).

4.1.6 Screening tests of both intermediate and relatively thick materials using the chevron notch (short-rod or short-bar) Test Method E 1304.

4.1.7 Screening tests for a range of thickness from about 0.1-in. (2.54 mm) upward using the sharp notch Charpy test as covered in Test Methods E 23.

4.1.8 Screening tests of thick materials in accordance with Test Method E 602.

5. Significance and Use

5.1 This practice is provided to develop and maintain uniformity in practices for the evaluation of the toughness of aluminum alloys, particularly with regard to quality assurance and material release to specifications.

5.2 It is emphasized that the use of these procedures will not alter the validity of data determined with specific test methods, but provides guidance in the interpretation of test results (valid or invalid) and guidance in the selection of a reasonable test procedure in those instances where no standard exists today.

6. Selection of Test Procedures

6.1 The following methods are recommended for individual products and situations:

6.1.1 For products in sheet thicknesses, that is nominally |La0.249 in. (6.30 mm), the measurement of critical stress intensity factor (Kc) associated with a monotonically loaded center-slotted panel tested in general accordance with Practice E 561 for center-cracked tension (M(T)) specimens is recommended, as described in 7.2.

6.1.2 For products in sheet thicknesses, the use of tension tests of sharply edge-notched specimens in accordance with Test Method E 338, and the corresponding correlations of such data with the critical stress-intensity factors from tests of center-slotted panels in accordance with Practice E 561, as modified by this practice, are recommended for screening and quality control purposes as described in 7.3. The sharp notch Charpy screening test in accordance with Test Methods E 23 may also be applied for correlative purposes.

6.1.3 For relatively thick high-strength products, plane-strain fracture toughness tests in accordance with Test Method E 399 as supplemented by Practice B 645 are recommended. For further guidelines, refer to Practice B 645; no further description is covered herein.

6.1.4 For screening tests of relatively thick high-strength products, tension tests of sharply notched cylindrical specimens and the associated correlations with plane-strain fracture toughness as determined in accordance with Test Method E 399 and are recommended, as described in 8.2.3. Additional alternative screening tests that are recommended for relatively thick products are the chevron notch (short-rod and short-bar) test described in Test Method E 1304 and 8.2.1 and the sharp notch Charpy screening test in accordance with Test Methods E 23 and 8.2.4.

6.1.5 For intermediate thicknesses of high-strength products, too thin for valid plane-strain fracture toughness testing but too thick for large panel testing in accordance with Practice E 561, a modification of compact specimen testing in accordance with Test Method E 399 as described in Practice B 645 and Section 9 is recommended. For such intermediate thickness products, three additional alternative tests exist. They are as follows: a direct measure of fracture toughness using Practice E 561 and the $K_{R_{25}}$ concept as described in 9.2.1.1, the same screening tests suggested for thick products involving the chevron notch (short-rod or short-bar) test as described in Test Method E 1304 and 8.2.1 and the sharp notch Charpy test in accordance with Test Methods E 23 and 8.2.4.

6.2 It is pointed out that there are no current standard recommendations for toughness testing of relatively low-strength aluminum alloys which display large-scale yielding even in the presence of extremely large cracks in very thick sections. Such cases must be dealt with individually on a research basis using tests selected from program needs and anticipated design criteria. A typical case for general guidance is given in the literature.[5]

7. Fracture Toughness of Thin Sections

7.1 If a complete and precise measure of the fracture toughness of sheet or of sections of an extruded, welded, or forged shape equal to or less than 0.249 in. (6.30 mm) in thickness is required, the crack-resistance curve should be measured in accordance with Practice E 561.

7.2 For quality assurance or material release purposes, the critical (or maximum) stress intensity factor for monotonically loaded M(T) panels tested in general accordance with Practice E 561 is recommended as the index of fracture toughness. This value is designated K_c for purposes of this practice.

7.2.1 The recommended specimen size is 16 in. (405 mm)

[5] Kaufman, J. G., and Kelsey, R. A., "Fracture Toughness and Fatigue Properties of 5083-0 Plate and 5183 Welds for Liquefied Natural Gas Applications," *Properties of Materials for Liquefied Natural Gas Tankage, ASTM STP 579*, ASTM, 1975, pp. 138–158.