Designation: E2899 – 15

Standard Test Method for Measurement of Initiation Toughness in Surface Cracks Under Tension and Bending[1]

This standard is issued under the fixed designation E2899; 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.

1. Scope

1.1 This test method describes the method for testing fatigue-sharpened, semi-elliptically shaped surface cracks in rectangular flat panels subjected to monotonically increasing tension or bending. Tests quantify the crack-tip conditions at initiation of stable crack extension or immediate unstable crack extension.

1.2 This test method applies to the testing of metallic materials not limited by strength, thickness, or toughness. Materials are assumed to be essentially homogeneous and free of residual stress. Tests may be conducted at any appropriate temperature. The effects of environmental factors and sustained or cyclic loads are not addressed in this test method.

1.3 This test method describes all necessary details for the user to test for the initiation of crack extension in surface crack test specimens. Specific requirements and recommendations are provided for test equipment, instrumentation, test specimen design, and test procedures.

1.4 Tests of surface cracked, laboratory-scale specimens as described in this test method may provide a more accurate understanding of full-scale structural performance in the presence of surface cracks. The provided recommendations help to assure test methods and data are applicable to the intended purpose.

1.5 This test method prescribes a consistent methodology for test and analysis of surface cracks for research purposes and to assist in structural assessments. The methods described here utilize a constraint-based framework (**1**, **2**)[2] to evaluate the fracture behavior of surface cracks.

NOTE 1—*Constraint-based framework*. In the context of this test method, constraint is used as a descriptor of the three-dimensional stress and strain fields in the near vicinity of the crack tip, where material contractions due to the Poisson effect may be suppressed and therefore produce an elevated, tensile stress state (**3**, **4**). (See further discussions in Terminology and Significance and Use.) When a parameter describing this stress state, or constraint, is used with the standard measure of crack-tip stress amplitude (K or J), the resulting two-parameter characterization broadens the ability of fracture mechanics to accurately predict the response of a crack under a wider range of loading. The two-parameter methodology produces a more complete description of the crack-tip conditions at the initiation of crack extension. The effects of constraint on measured fracture toughness are material dependent and are governed by the effects of the crack-tip stress-strain state on the micromechanical failure processes specific to the material. Surface crack tests conducted with this test method can help to quantify the material sensitivity to constraint effects and to establish the degree to which the material toughness correlates with a constraint-based fracture characterization.

1.6 This test method provides a quantitative framework to categorize test specimen conditions into one of three regimes: (I) a linear-elastic regime, (II) an elastic-plastic regime, or (III) a field-collapse regime. Based on this categorization, analysis techniques and guidelines are provided to determine an applicable crack-tip parameter for the linear-elastic regime (K or J) or the elastic-plastic regime (J), and an associated constraint parameter. Recommendations are provided to assess the test data in the context of a toughness-constraint locus (**2**). The user is directed to other resources for evaluation of the test specimen in the field-collapse regime when extensive plastic deformation in the specimen eliminates the identifiable crack-front fields of fracture mechanics.

1.7 The specimen design and test procedures described in this test method may be applied to evaluation of surface cracks in welds; however, the methods described in this test method to analyze test measurements may not be applicable. Weld fracture tests generally have complicating features beyond the scope of data analysis in this test method, including the effects of residual stress, microstructural variability, and non-uniform strength. These effects will influence test results and must be considered in the interpretation of measured quantities.

1.8 This test method is not intended for testing surface cracks in steel in the cleavage regime. Such tests are outside the scope of this test method. A methodology for evaluation of cleavage fracture toughness in ferritic steels over the ductile-to-brittle region using C(T) and SE(B) specimens can be found in Test Method E1921.

1.9 *Units*—The values stated in SI units are to be regarded as the standard. The values given in parentheses are for information only.

[1] This test method is under the jurisdiction of ASTM Committee E08 on Fatigue and Fracture and is the direct responsibility of Subcommittee E08.07 on Fracture Mechanics.

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[2] The boldface numbers in parentheses refer to the list of references at the end of this test method.

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1.10 This practice may involve hazardous materials, operations, and equipment. *This standard does not purport to address all of the safety problems associated with its use. It is the responsibility of the users of this standard to establish appropriate safety and health practices and to determine the applicability of regulatory limitations prior to use.*

2. Referenced Documents

2.1 *ASTM Standards:*[3]

C1421 Test Methods for Determination of Fracture Toughness of Advanced Ceramics at Ambient Temperature

E4 Practices for Force Verification of Testing Machines

E6 Terminology Relating to Methods of Mechanical Testing

E8/E8M Test Methods for Tension Testing of Metallic Materials

E111 Test Method for Young's Modulus, Tangent Modulus, and Chord Modulus

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

E647 Test Method for Measurement of Fatigue Crack Growth Rates

E740 Practice for Fracture Testing with Surface-Crack Tension Specimens

E1012 Practice for Verification of Testing Frame and Specimen Alignment Under Tensile and Compressive Axial Force Application

E1820 Test Method for Measurement of Fracture Toughness

E1823 Terminology Relating to Fatigue and Fracture Testing

E1921 Test Method for Determination of Reference Temperature, T_o, for Ferritic Steels in the Transition Range

[3] 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.

3. Terminology

3.1 For definitions of terms used in this Test Method, Terminologies E6 and E1823 apply.

3.2 *Symbols:*

3.2.1 *crack depth, a [L]*—see Terminology E1823 and Fig. 1 in this test method.

3.2.1.1 *Discussion*—In this test method, the term a_o is the original surface crack depth, as determined in subsection 8.4, used in the evaluation of the test.

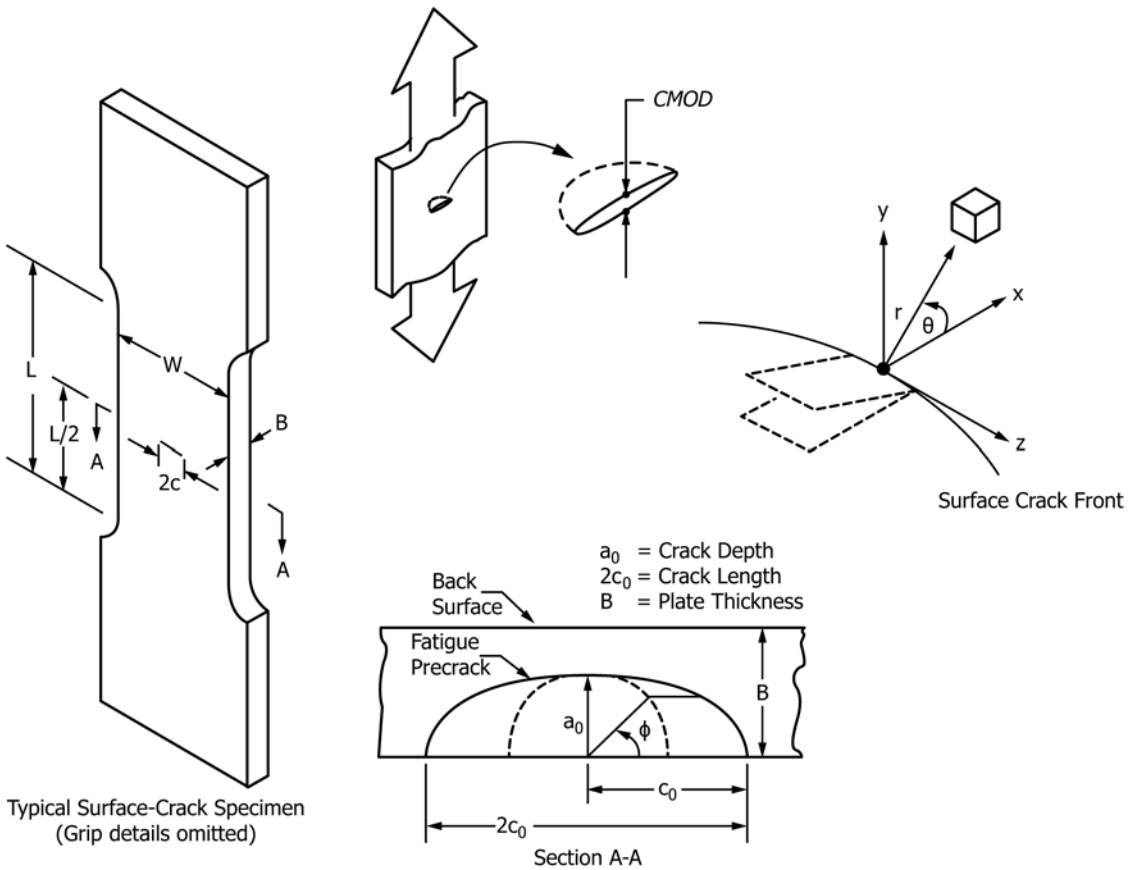

FIG. 1 Test Specimen and Crack Configurations

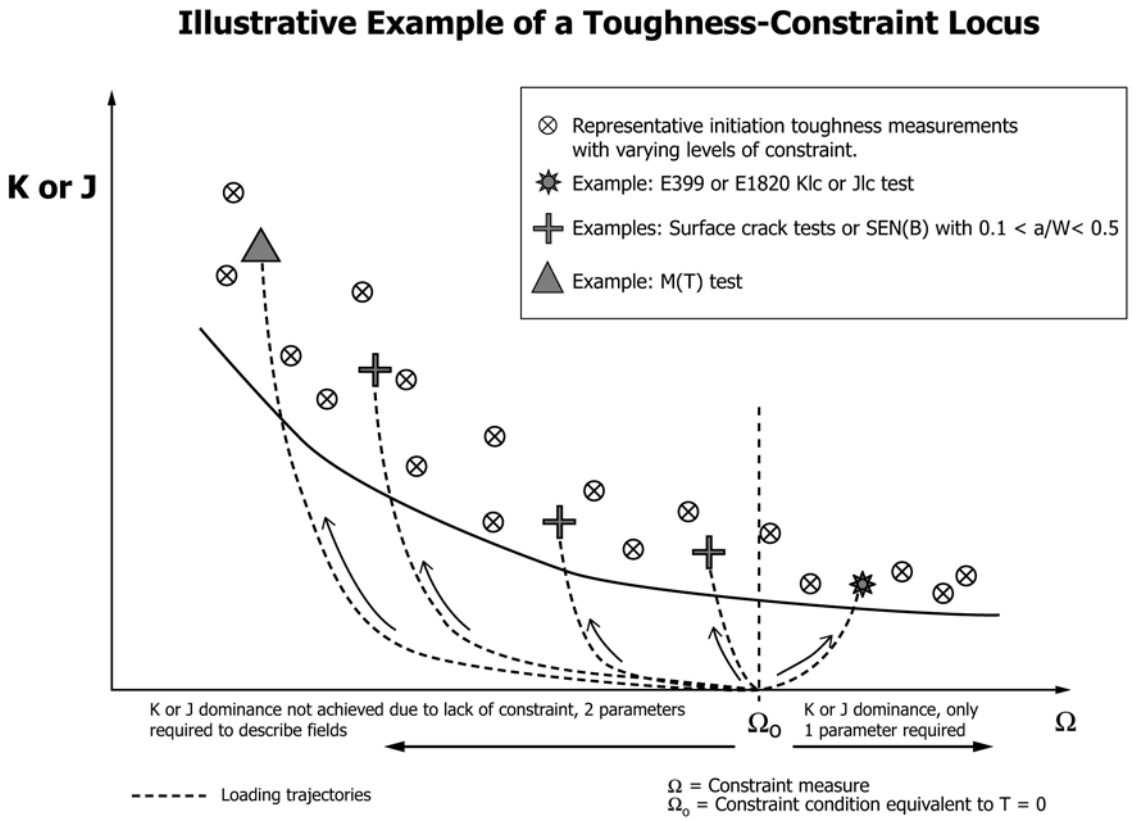

FIG. 2 Toughness-Constraint Locus with Example Trajectories

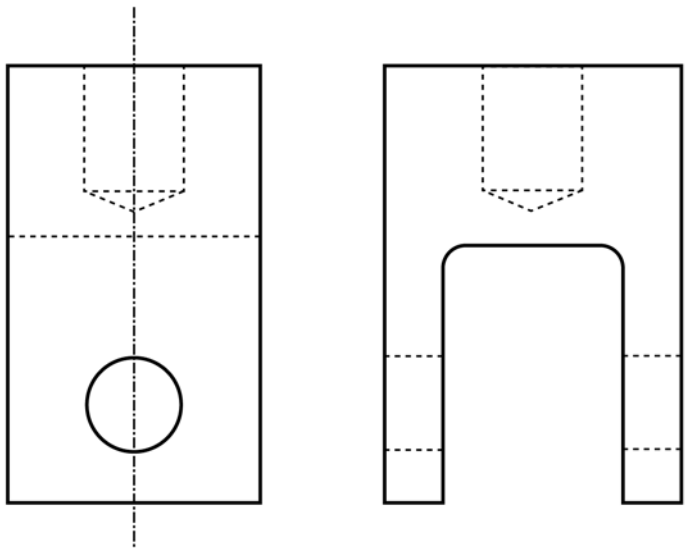

FIG. 3 Recommended Configuration of Tension Testing Clevis

NOTE 1—Flat bottomed holes are not required, but may be used in configurations found in Test Methods E399 or E1820.

3.2.2 *crack-mouth opening displacement, CMOD [L]*—see Terminology E1823 and Fig. 1 in this test method.

3.2.3 *force, P [F]*—see Terminology E1823.

3.2.4 *J-integral, J [FL^{-1} or FLL^{-2}]*—see Terminology E1823.

3.2.5 *modulus of elasticity, E [FL^{-2}]*—see Terminology E1823.

3.2.6 *net section area, A_N [L^2]*—see Terminology E1823. For surface cracks $A_N = WB - \pi a_0 c_0/2$.

3.2.7 *plane-strain fracture toughness, K_{Ic} [$FL^{-3/2}$]*—see Terminology E1823.

3.2.8 *Poisson's ratio,* ν—see Terminology E6.

3.2.9 *specimen thickness, B [L]*—see Terminology E1823 and Fig. 1 from this test method.