



Designation: E1681 – 23^{ε1}

Standard Test Method for Determining Threshold Stress Intensity Factor for Environment-Assisted Cracking of Metallic Materials¹

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^{ε1} NOTE—Section 3.1.9 was editorially corrected in April 2024.

1. Scope

1.1 This test method covers the determination of the environment-assisted cracking threshold stress intensity factor parameters, K_{IEAC} and K_{EAC} , for metallic materials from constant-force testing of fatigue precracked beam or compact fracture specimens and from constant-displacement testing of fatigue precracked bolt-load compact fracture specimens.

1.2 This test method is applicable to environment-assisted cracking in aqueous or other aggressive environments.

1.3 Materials that can be tested by this test method are not limited by thickness or by strength as long as specimens are of sufficient thickness and planar size to meet the size requirements of this test method.

1.4 A range of specimen sizes with proportional planar dimensions is provided, but size may be variable and adjusted for yield strength and applied force. Specimen thickness is a variable independent of planar size.

1.5 Specimen configurations other than those contained in this test method may be used, provided that well-established stress intensity calibrations are available and that specimen dimensions are of sufficient size to meet the size requirements of this test method during testing.

1.6 *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, health, and environmental practices and determine the applicability of regulatory limitations prior to use.*

1.7 *This international standard was developed in accordance with internationally recognized principles on standardization established in the Decision on Principles for the Development of International Standards, Guides and Recommendations issued by the World Trade Organization Technical Barriers to Trade (TBT) Committee.*

¹ This test method is under the jurisdiction of ASTM Committee E08 on Fatigue and Fracture and is the direct responsibility of Subcommittee E08.06 on Crack Growth Behavior.

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2. Referenced Documents

2.1 ASTM Standards:²

- D1141 Practice for Preparation of Substitute Ocean Water
- E8/E8M Test Methods for Tension Testing of Metallic Materials
- E399 Test Method for Linear-Elastic Plane-Strain Fracture Toughness of Metallic Materials
- E647 Test Method for Measurement of Fatigue Crack Growth Rates
- E1823 Terminology Relating to Fatigue and Fracture Testing
- G1 Practice for Preparing, Cleaning, and Evaluating Corrosion Test Specimens
- G5 Reference Test Method for Making Potentiodynamic Anodic Polarization Measurements
- G15 Terminology Relating to Corrosion and Corrosion Testing (Withdrawn 2010)³

3. Terminology

3.1 Definitions:

3.1.1 For definitions of terms relating to fracture testing used in this test method, refer to Terminology E1823.

3.1.2 For definitions of terms relating to corrosion testing used in this test method, refer to Terminology G15.

3.1.3 *stress-corrosion cracking (SCC)*—a cracking process that requires the simultaneous action of a corrosive and sustained tensile stress.

3.1.4 *stress intensity factor threshold for plane strain environment-assisted cracking (K_{IEAC} [$FL^{-3/2}$])*—the highest value of the stress intensity factor (K) at which crack growth is not observed for a specified combination of material and environment and where the specimen size is sufficient to meet requirements for plane strain as described in Test Method E399.

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.

³ The last approved version of this historical standard is referenced on www.astm.org.

3.1.5 *stress intensity factor threshold for environment-assisted cracking* (K_{EAC} [$FL^{-3/2}$])—the highest value of the stress intensity factor (K) at which crack growth is not observed for a specified combination of material and environment and where the measured value may depend on specimen thickness.

3.1.6 *physical crack size* ($a_p[L]$)—the distance from a reference plane to the observed crack front. This distance may represent an average of several measurements along the crack front. The reference plane depends on the specimen form, and it is normally taken to be either the boundary or a plane containing either the loadline or the centerline of a specimen or plate. The reference plane is defined prior to specimen deformation.

3.1.7 *original crack size* ($a_o[L]$)—the physical crack size at the start of testing.

3.1.8 *original uncracked ligament* ($b_o[L]$)—distance from the original crack front to the back edge of the specimen ($b_o = W - a_o$).

3.1.9 *specimen thickness* (B)[L])—the distance between the parallel sides of a test specimen.

3.1.10 *tensile strength* (σ_{TS} [FL^{-2}])—the maximum tensile stress that a material is capable of sustaining. Tensile strength is calculated from the maximum force during a tension test carried to rupture and the original cross-section area of the specimen.

3.2 Definitions of Terms Specific to This Standard:

3.2.1 *environment-assisted cracking (EAC)*—a cracking process in which the environment promotes crack growth or higher crack growth rates than would occur without the presence of the environment.

3.2.2 *normalized crack size* (a/W)—the ratio of crack size, a , to specimen width, W . Specimen width is measured from a reference position such as the front edge in a bend specimen or the loadline in the compact specimen to the back edge of the specimen.

3.2.3 *yield strength* (σ_{YS} [FL^{-2}])—the stress at which a material exhibits a specific limiting deviation from the proportionality of stress to strain. This deviation is expressed in terms of strain.

NOTE 1—In this test method, the yield strength determined by the 0.2 % offset method is used.

3.2.4 *effective yield strength* (σ_Y [FL^{-2}])—an assumed value of uniaxial yield strength that represents the influences of plastic yielding upon fracture test parameters. For use in this method, it is calculated as the average of the 0.2 % offset yield strength σ_{YS} , and the ultimate tensile strength, σ_{TS} , or

$$\sigma_Y = (\sigma_{YS} + \sigma_{TS})/2 \quad (1)$$

3.2.5 *notch length* ($a_n(L)$)—the distance from a reference plane to the front of the machined notch. The reference plane depends on the specimen form and normally is taken to be either the boundary or a plane containing either the loadline or the centerline of a specimen or plate. The reference plane is defined prior to specimen deformation.

4. Summary of Test Method

4.1 This test method involves testing of single-edge notched [SE(B)] specimens, compact [C(T)] specimens, or bolt-load compact [MC(W)] specimens, precracked in fatigue. The single-edge notched beam specimen is tested by dead weight loading. An environmental chamber is either attached to the specimen, or the specimen is contained within the chamber. The chamber must enclose the portion of the specimen where the crack tip is located. Prescribed environmental conditions must be established and maintained within the chamber at all times during the test.

4.1.1 Specimens shall be deadweight loaded or otherwise held under constant force or held under constant displacement (defined in 6.2) for a prescribed length of time, during which failure by crack growth leading to fracture may or may not occur. K_{IEAC} and K_{EAC} are defined as the highest value of stress intensity factor at which neither failure nor crack growth occurs. The stress intensity factor (K) is calculated from an expression based on linear elastic stress analysis. To establish a suitable crack-tip condition for constant force tests, the stress-intensity level at which the fatigue precracking of the specimen is conducted is limited to a value substantially less than the measured K_{IEAC} or K_{EAC} values. For constant displacement tests, the stress-intensity level at which the fatigue precracking of the specimen is conducted is limited to the requirements of Test Method E399. The validity of the K_{IEAC} value determined by this test method depends on meeting the size requirements to ensure plane strain conditions, as stated in Test Method E399. The validity of the K_{EAC} value depends on meeting the size requirements for linear elastic behavior, as stated in the Test Method E647.

4.1.2 This test method can produce information on the onset of environment-assisted crack growth. Crack growth rate information can be obtained after crack nucleation, but the method for obtaining this information is not part of this test method (1).⁴

4.2 The mechanisms of environment-assisted cracking are varied and complex. Measurement of a K_{EAC} or K_{IEAC} value for a given combination of material and environmental provides no insight into the particular cracking mechanism that was either operative or dominant. Two prominent theories of environment-assisted cracking are anodic reaction and hydrogen embrittlement (2). The data obtained from this test method may be interpreted by either theory of environment-assisted cracking.

4.3 Specimen thickness governs the proportions of plane strain and plane stress deformation local to the crack tip, along with the environmental contribution to cracking. Since these chemical and mechanical influences cannot be separated in some material/environment combinations, thickness must be treated as a variable. In this test method, however, the stress in the specimen must remain elastic. For these reasons, two threshold values of EAC are defined by this test method. The measurement of K_{IEAC} requires that the thickness requirements

⁴ The boldface numbers in parentheses refer to the list of references at the end of this standard.