Designation: G168 – 00 (Reapproved 2013)

Standard Practice for
Making and Using Precracked Double Beam Stress Corrosion Specimens[1]

This standard is issued under the fixed designation G168; 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 practice covers procedures for fabricating, preparing, and using precracked double beam stress corrosion test specimens. This specimen configuration was formerly designated the double cantilever beam (DCB) specimen. Guidelines are given for methods of exposure and inspection.

1.2 The precracked double beam specimen, as described in this practice, is applicable for evaluation of a wide variety of metals exposed to corrosive environments. It is particularly suited to evaluation of products having a highly directional grain structure, such as rolled plate, forgings, and extrusions, when stressed in the short transverse direction.

1.3 The precracked double beam specimen may be stressed in constant displacement by bolt or wedge loading or in constant load by use of proof rings or dead weight loading. The precracked double beam specimen is amenable to exposure to aqueous or other liquid solutions by specimen immersion or by periodic dropwise addition of solution to the crack tip, or exposure to the atmosphere.

1.4 This practice is concerned only with precracked double beam specimen and not with the detailed environmental aspects of stress corrosion testing, which are covered in Practices G35, G36, G37, G41, G44, and G50.

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]

D1193 Specification for Reagent Water

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

E1823 Terminology Relating to Fatigue and Fracture Testing

G15 Terminology Relating to Corrosion and Corrosion Testing (Withdrawn 2010)[3]

G35 Practice for Determining the Susceptibility of Stainless Steels and Related Nickel-Chromium-Iron Alloys to Stress-Corrosion Cracking in Polythionic Acids

G36 Practice for Evaluating Stress-Corrosion-Cracking Resistance of Metals and Alloys in a Boiling Magnesium Chloride Solution

G37 Practice for Use of Mattsson's Solution of pH 7.2 to Evaluate the Stress-Corrosion Cracking Susceptibility of Copper-Zinc Alloys

G41 Practice for Determining Cracking Susceptibility of Metals Exposed Under Stress to a Hot Salt Environment

G44 Practice for Exposure of Metals and Alloys by Alternate Immersion in Neutral 3.5 % Sodium Chloride Solution

G49 Practice for Preparation and Use of Direct Tension Stress-Corrosion Test Specimens

G50 Practice for Conducting Atmospheric Corrosion Tests on Metals

3. Terminology

3.1 *Definitions of Terms Specific to This Standard:*

3.1.1 *stress corrosion cracking (SCC) threshold stress intensity, K_{Iscc}*—the stress intensity level below which stress corrosion cracking does not occur for a specific combination of material and environment when plane strain conditions are satisfied.

3.1.1.1 *Discussion*—Terms relative to this subject matter can be found in Terminologies G15 and E1823.

4. Summary of Practice

4.1 This practice covers the preparation and testing of precracked double beam specimens for investigating the resistance to SCC (see Terminology G15) of metallic materials in various product forms. Precracking by fatigue loading and by mechanical overload are described. Procedures for stressing

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[1] This practice is under the jurisdiction of ASTM Committee G01 on Corrosion of Metals and is the direct responsibility of Subcommittee G01.06 on Environmentally Assisted Cracking.

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[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.

specimens in constant displacement with loading bolts are described, and expressions are given for specimen stress intensity and crack mouth opening displacement. Guidance is given for methods of exposure and inspection of precracked double beam specimens.

5. Significance and Use

5.1 Precracked specimens offer the opportunity to use the principles of linear elastic fracture mechanics (**1**)[4] to evaluate resistance to stress corrosion cracking in the presence of a pre-existing crack. This type of evaluation is not included in conventional bent beam, C-ring, U-bend, and tension specimens. The precracked double beam specimen is particularly useful for evaluation of materials that display a strong dependence on grain orientation. Since the specimen dimension in the direction of applied stress is small for the precracked double beam specimen, it can be successfully used to evaluate short transverse stress corrosion cracking of wrought products, such as rolled plate or extrusions. The research applications and analysis of precracked specimens in general, and the precracked double beam specimen in particular, are discussed in Appendix X1.

5.2 The precracked double beam specimen may be stressed in either constant displacement or constant load. Constant displacement specimens stressed by loading bolts or wedges are compact and self-contained. By comparison, constant load specimens stressed with springs (for example, proof rings, discussed in Test Method G49, 7.2.1.2) or by deadweight loading require additional fixtures that remain with the specimen during exposure.

5.3 The recommendations of this practice are based on the results of interlaboratory programs to evaluate precracked specimen test procedures (**2,3**) as well as considerable industrial experience with the precracked double beam specimen and other precracked specimen geometries (**4-8**).

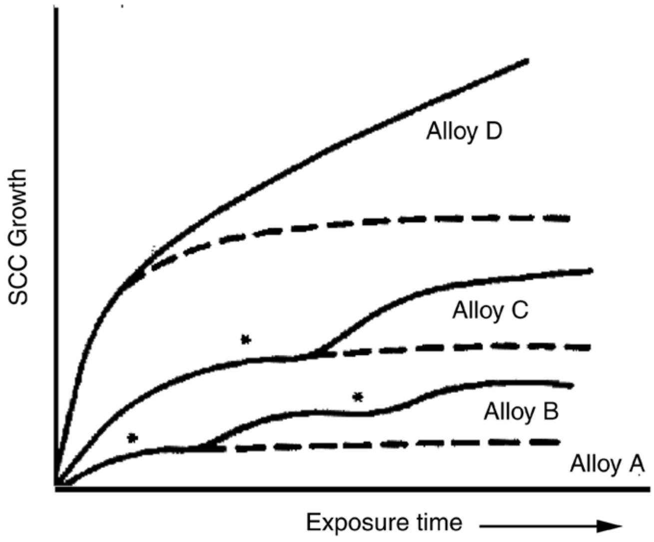
6. Interferences

6.1 *Interferences in Testing:*

6.1.1 The accumulation of solid corrosion products or oxide films on the faces of an advancing stress corrosion crack can generate wedge forces that add to the applied load, thereby increasing the effective stress intensity at the crack tip (**6-9**). This self-loading condition caused by corrosion product wedging can accelerate crack growth and can prevent crack arrest from being achieved. The effect of corrosion product wedging on crack growth versus time curve is shown schematically in Fig. 1 (**9**). When wedging forces occur, they can invalidate further results and the test should be ended.

6.1.2 Crack-tip blunting or branching out, or both, of the plane of the precrack can invalidate the test. For valid tests, the crack must remain within ±10° of the centerline of the specimen.

6.1.3 Drying or contamination of the corrodent in the crack during interim measurements of the crack length may affect the cracking behavior during subsequent exposure.



NOTE 1—Schematic of the influence of corrosion product wedging on SCC growth versus time curves in a decreasing K (constant displacement) test. Solid lines: actually measured curve for case of corrosion product wedging that results in increase in crack growth with time; asterisks indicate temporary crack arrest. Dashed lines: true crack growth curve excluding the effect of corrosion product wedging (**9**).

FIG. 1 Effect of Corrosion Product Wedging on Growth Crack Versus Time Curve

NOTE 1—Do not allow corrodent in the crack to dry during periodic measurements to avoid repassivation at the crack tip and the resulting change in corrosion conditions. Remove one specimen at a time from corrodent. For tests conducted in deaerated test environments or in environments that contain readily oxidizable species or corrosion products, interim crack length examinations may produce changes in the conditions at the crack tip that can, in turn, affect cracking behavior during the subsequent exposure period.

6.2 *Interferences in Visual Crack Length Measurements:*

6.2.1 Corrosion products on the side surfaces of the specimen can interfere with accurate crack length measurements. Corrosion products on these surfaces may be removed by careful scrubbing with a nonmetallic abrasive pad. However, for interim measurements, a minimum area of surface should be cleaned to allow for visual crack length measurements if reexposure is planned.

6.2.2 Measurement on side grooved specimens may be difficult if the advancing crack travels up the side of the groove. This is especially difficult with V-shaped grooves. Adjustment of the direction and intensity of the lighting may highlight the location of the crack tip.

6.2.3 Often the crack length measured at the specimen surface is less than in the interior, due to decreased stress triaxiality at the specimen surface. Alternatively, some conditions produce an increase in crack length at the surface due to availability of the corrodent. Ultrasonic methods can be used to obtain interim crack length measurements at the interior of the specimen but not near the specimen surface.

6.2.4 Transport of species in solution in the through-thickness direction can be important for precracked double beam specimens. This may affect measurement of crack length since it can produce curvature of the crack front (that is, variation in crack length from the edge to the center of the specimen).

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

7. Specimen Size, Configuration, and Preparation

7.1 *Specimen Dimensions and Fabrication:*

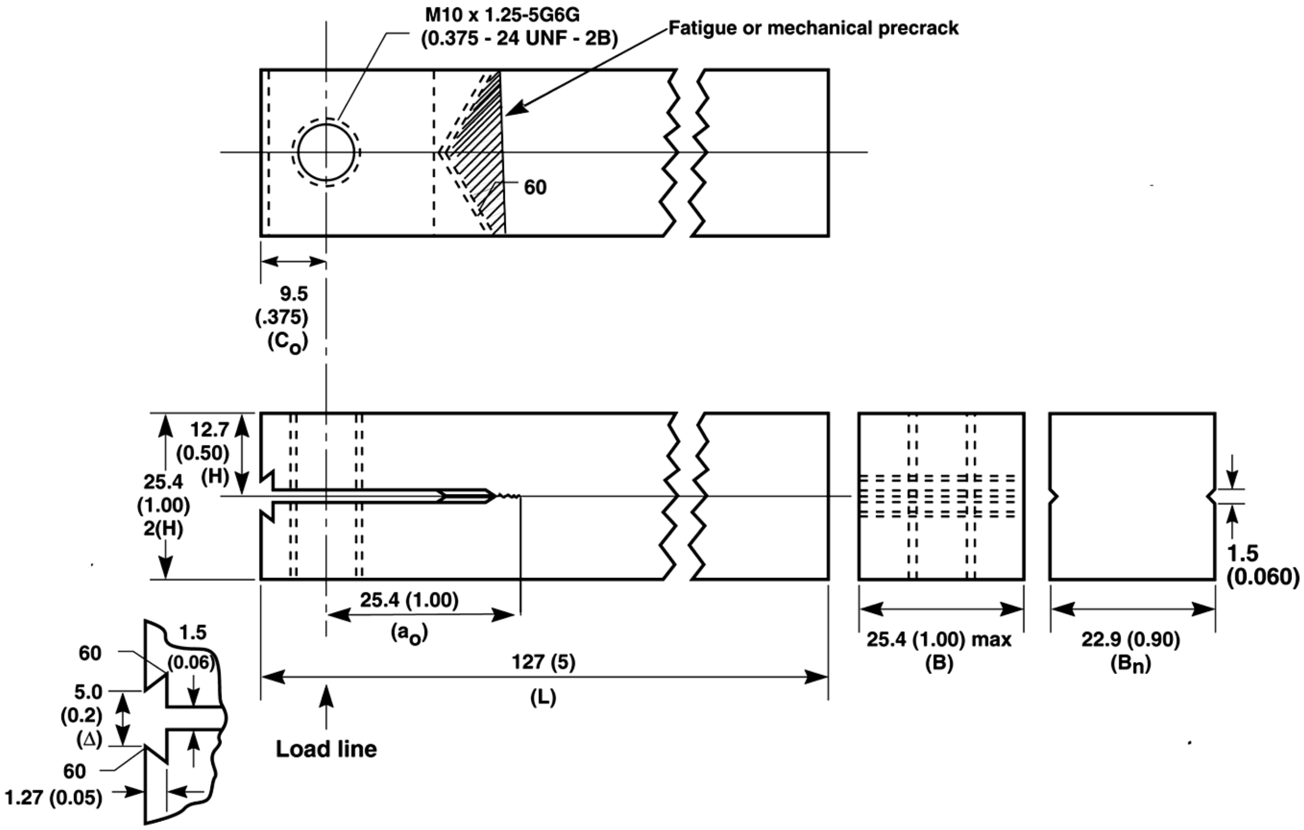
7.1.1 Dimensions for the recommended specimen are given in Figs. 2 and 3. As a general guideline, specimen dimensions should ensure that plane strain conditions are maintained at the crack tip (**1**,**10**). While there are no established criteria for ensuring adequate constraint for a plane strain SCC test, some guidelines are given herein regarding specimen dimensions (see 7.1.3).

7.1.2 Specimen machining shall be in accordance with the standards outlined in Test Method E399. The principal considerations in machining are that the sides, top, and bottom of the specimen should be parallel; the machined notch should be centered; and the bolt holes should be aligned and centered. A typical bolt loaded specimen is shown in Fig. 4.

7.1.3 Recommendations for determining the minimum specimen thickness, *B*, which will ensure that plane strain conditions are maintained at the tip of an SCC crack, are discussed in Brown (**1**) and Dorward and Helfrich (**8**). A conservative estimate for the specimen thickness shall be made by adopting the thickness criteria for plane strain fracture toughness testing, as described in Test Method E399. For bolt loaded precracked double beam specimens, the thickness, B, may also be influenced by the size of the loading bolts and the minimum thickness needed to support the bolt loading.

7.1.4 The specimen half-height, *H*, may be reduced for material under 25 mm (1 in.) thick. The minimum *H* that can be used is constrained by the onset of plastic deformation upon precracking or stresses in the leg of the specimen since this influences the calculation of *K*. Outer fiber stresses shall not exceed the yield strength of the test material during precracking or stressing.

NOTE 2—The effect of notch geometry on specimen compliance and stress intensity solutions, noted in 7.3.4.4, Note 4, 8.1.3, and Note 5, is



NOTE 1—All dimensions in mm (in.). Top and front views are shown for smooth specimen only; side view is shown for both smooth and side grooved configuration.

NOTE 2—For Chevron notch crack starter, cutter tip angle 90° max.

NOTE 3—Radius at notch bottom to be 0.25 mm (0.01 in.) or less.

NOTE 4—Crack starter to be perpendicular to specimen length and thickness to within ±2°.

NOTE 5—Initial COD (Δ) may be increased to 12.7 mm (0.5 in.) to accomodate COD gage.

NOTE 6—All surfaces 32 µin. or better, tolerances not specified ±0.127 (0.005).

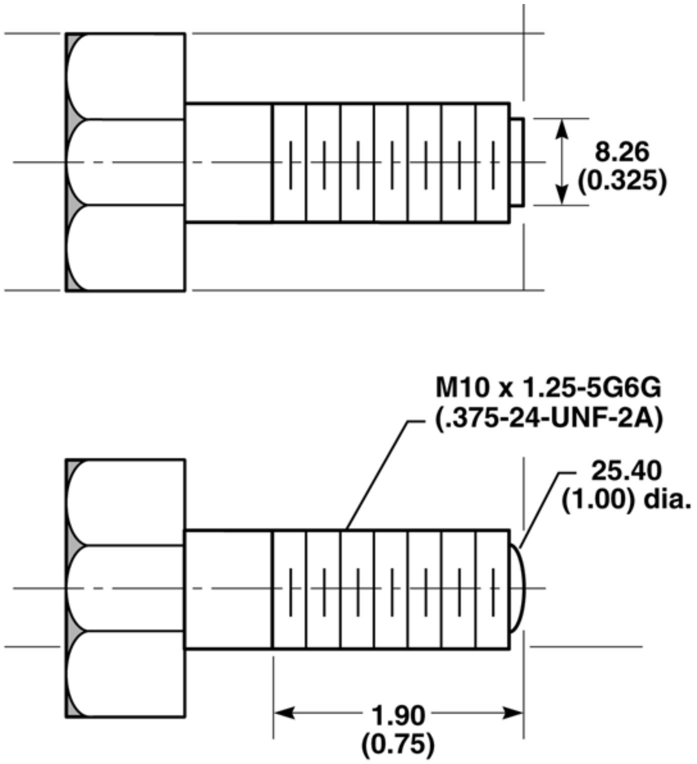
NOTE 7—Continue with Chevron cutter on surface to machine grooves.

NOTE 8—Loading bolt holes shall be perpendicular to specimen center lines within ±5°.

NOTE 9—Center line of holes shall be parallel and perpendicular to specimen surfaces within ±2°.

NOTE 10—Center line of holes shall be coincident within ±0.127 mm (0.005 in.).

FIG. 2 Detailed Machine Drawing for Smooth and Face Grooved DCB Specimen



Note 1—All dimensions in mm (in). Tolerances not specified ±0.127 (±0.005).

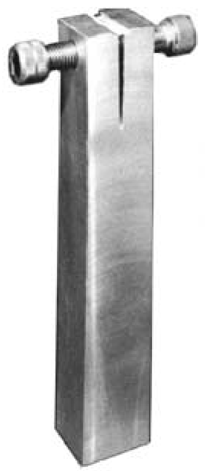
Note 2—Suggested material: Strong enough not to fail in tension during loading or mechanical precracking.

Note 3—Bolt head design optional. Commercial stainless steel socket head cap screws or hex head bolts are satisfactory.

Note 4—Use one rounded end and one flat end bolt for loading each specimen. Commercial bolts or screws should be modified accordingly.

Note 5—To avoid galvanic corrosion between dissimilar bolt and specimen metals, see 8.2.

FIG. 3 Machine Drawing for DCB Loading Bolts



Note 1—An optional bolt is shown which has a recessed hexagonal socket to accept an Allen wrench.

FIG. 4 Bolt Loaded Precracked Double Beam Specimen

magnified as H is reduced.

7.1.5 The overall length of the specimen, L, can be increased to allow for more crack growth. Specimens of SCC susceptible material that are loaded in constant deflection to high starting stress intensities may require additional crack growth to achieve crack arrest as defined in 10.1.

7.2 *Specimen Configuration:*

7.2.1 The recommended specimen configuration includes a sharp starter notch, which may be either a straight through or chevron configuration. The chevron configuration is recommended for both the fatigue and the mechanical overload precracking operations (see Fig. 2).

7.2.2 The use of side grooves is optional. They may be helpful if any difficulty is experienced in keeping the crack in the center of the specimen. The side groove configuration may be machined with the chevron V-shaped cutter or with a U-shaped cutter. The depth of each side groove should not exceed 5 % of B, such that the net thickness, B_n, will be at least 90 % of B.

7.2.3 Specimens machined from rectangular product can have six possible orientations (see Test Method E399) relative to the direction of loading and the direction of crack propagation, namely, S-L, S-T, T-L, T-S, L-T, and L-S. In wrought products, the S-L orientation is usually the most critical and is the most frequently used to avoid crack branching

7.2.4 More detailed discussions of the factors described in this section are given in Brown (**1**), Sprowls et al (**6**), and Sprowls (**9**).

7.3 *Specimen Preparation:*

7.3.1 Specimen surfaces along the path of expected crack propagation may be polished to assist in crack measurement.

7.3.2 Specimens shall be cleaned and degreased prior to precracking and testing. Successive ultrasonic cleaning in acetone and methyl alcohol is suggested. Specimens shall not be recleaned after precracking to prevent contamination of the crack with cleaning or degreasing chemicals. If cleaning of the side surfaces of the specimen following precracking is necessary, then this should be performed by lightly wiping these surfaces and not by immersion of the specimen into the cleaning or degreasing media.

Note 3—Only chemicals appropriate for the metal or alloy of interest shall be used. All chemicals shall be of reagent grade purity.

7.3.3 Specimens shall be fully machined, including surface grooves, prior to precracking. Precracked specimens shall be stored in a dry atmosphere prior to environmental exposure.

7.3.4 *Fatigue Precracking:*

7.3.4.1 Fatigue precracking shall be performed under sinusoidal cyclic loading with a stress ratio $0.05 < R < 0.2$, where $R = P_{min}/P_{max}$. Any convenient cyclic load frequency may be used for precracking.

7.3.4.2 The maximum stress intensity factor (K_{max}) to be applied during fatigue precracking shall not exceed two thirds of the target starting stress intensity for the environmental exposure.

7.3.4.3 The fatigue precrack shall extend 2.5 to 3.8 mm (0.10 to 0.15 in.) from the tip of the machined notch at the specimen surface. The plane of the crack shall be within ±10°

of the centerline of the specimen. The resulting crack length, a_o, shall be measured on both specimen surfaces, and the two values averaged. The measuring instrument shall have an accuracy of 0.025 mm (0.001 in.).

7.3.4.4 The stress intensity factor during precracking shall be computed from the following equation (**2,11**):

$$K_I = [3.464\, P\, a\, (1+0.673(H/a))]/[(B_n)^{1/2}\, H^{3/2}] \tag{1}$$

where:

K_I = stress intensity factor, MPa-m$^{1/2}$ (ksi-in.$^{1/2}$),
P = applied load, MN (klbf),
a = crack length, m (in.),
B = specimen thickness, m (in.),
B_n = specimen thickness at the machined notch for face grooved specimens, m (in.) (B_n = B for smooth face specimens), and
H = specimen half height, m (in.).

NOTE 4—The stress intensity solutions provided by Eq 1, Eq 2, and Eq X1.2 are based on theoretical compliance of specimens of the recommended configuration in Fig. 2. They have been validated by the work of Fichter (**11**). However, significant deviation in starter notch geometry and specimen half height may result in inaccurate K_I values (**12,13**).

7.3.5 *Mechanical Precracking:*

7.3.5.1 Specimens that are precracked by mechanical overload shall be precracked immediately prior to, and as the initial step of, the environmental exposure test initiation. It may be convenient to support the specimen in a vise during the mechanical precracking procedure. Mechanical precracking may be difficult on higher toughness materials; for example, aluminum alloys with $K_{IC} > 25$ MPa-m$^{1/2}$. Regardless of the material toughness, mechanical precracking is also difficult for specimens that are machined with the crack propagation direction normal to predominant grain orientation; for example, L-T or S-T (see Test Method E399) orientations in rolled plate.

7.3.5.2 Crack mouth opening displacement, V_o, shall be monitored with a clip-on crack mouth opening displacement (COD) gage during precracking. A typical COD gage is described in Test Method E399, Annex A1.

7.3.5.3 The mechanical precrack shall be extended 2.5 to 3.8 mm (0.10 to 0.15 in.) from the tip of the machined notch at the specimen surface. The resulting crack length, a_o, shall be measured on both specimen surfaces, and the two values averaged. The measuring instrument shall have an accuracy of 0.025 mm (0.001 in.).

7.3.5.4 The resulting stress intensity after mechanical precracking will be K_{Ia}, the stress intensity for mechanical crack arrest. If K_{Ia} is greater than the target starting stress intensity, then K_{Ia} shall be used as the starting stress intensity for the stress corrosion test (that is, K_{io}). If a mechanically precracked specimen is inadvertently overloaded, no attempt shall be made to reduce the initial stress by partially unloading the specimen. This will produce compressive stresses at the crack tip, which will retard or prevent crack initiation. If K_{Ia} is less than the target starting stress intensity, then adjustment of crack mouth opening, V_o, should be made following procedures provided in 8.1 (Eq 3).

7.3.5.5 The resulting stress intensity factor, K_{Ia}, should be computed from the following equation (**11**):

$$K_{Ia} = (V_o\ E)/\{2.309\, H^{1/2}\ (a_o/H+0.673)^2\ [1+1.5(C_o/a_o) - 1.15(C_o/a_o)^2]\} \tag{2}$$

where:

K_{Ia} = stress intensity factor at crack arrest, Mpa-m$^{1/2}$ (ksi-in.$^{1/2}$),
V_o = crack mouth opening displacement, m (in.),
E = Young's Modulus, MPa (ksi),
a_o = starting crack length at start of exposure test, m (in.),
C_o = distance from load line to COD gage attachment location, m (in.), and
H = specimen half height, m (in.).

7.4 *Residual Stress Effects*—Residual stresses can have an influence on SCC. The effect can be significant when test specimens are removed from material in which complete stress relief is impractical, such as weldments, as-heat treated materials, complex wrought parts, and parts with intentionally produced residual stresses. Residual stresses superimposed on the applied stress can cause the local crack-tip stress intensity factor to be different from that calculated from externally applied forces or displacements. Irregular crack growth during precracking, such as excessive crack front curvature or out-of-plane crack growth, often indicates that residual stresses will affect subsequent SCC growth behavior. Changes in the zero-force value of crack mouth opening displacement as a result of precrack growth is another indication that residual stresses will affect the subsequent SCC growth.

8. General Procedure

8.1 *Stressing Procedure:*

8.1.1 Precracked double beam specimens may be stressed either in constant displacement or constant load. The constant displacement condition may be achieved by a wedge inserted in the machined notch or by loading bolts. The constant load condition may be achieved through the use of dead weight loading or approximated with the use of proof rings with adequate compliance to minimize load reduction that will occur during the test due to crack growth in the specimen (**3**).

8.1.2 Suggested loading bolts are shown in Fig. 3. A precracked double beam specimen stressed in constant displacement with two bolts is shown in Fig. 4. The loading bolts shall be tightened until the crack mouth opening displacement (V_o) reaches a value corresponding to the desired target starting stress intensity value for the measured precrack length. The bolts shall be tightened in small increments, alternating between the two, such that the specimen is deflected symmetrically about the centerline. Another approach is to mount the nonstressed end of the specimen in a vice and use two wrenches, turning both wrenches simultaneously and attempting similar movement of both wrenches.

8.1.3 The required crack mouth opening displacement to achieve the target starting stress intensity level is calculated with the following relationship (**11**). Crack mouth opening displacement during loading shall be measured with a clip-on crack opening displacement (COD) gage.

$$V_o = 2.309\, (K_{Io}/E)\, H^{1/2}\ (a_o/H+0.673)^2\ [1+1.5(C_o/a_o) - 1.15(C_o/a_o)^2] \tag{3}$$

where:

V_o = crack mouth opening displacement, m (in.),
K_{Io} = starting stress intensity, MPa-m$^{1/2}$ (ksi-in.$^{1/2}$),
a_o = starting crack length, m (in.),
C_o = distance from load line to COD gage attachment location, m (in.),
H = specimen half height, m (in.), and
E = Young's Modulus, MPa (ksi).

NOTE 5—Eq 3 does not account for starter notch geometry effects (chevron notches, and so forth); however, specimen dimensions have been selected that minimize errors in specimen compliance. Significant deviation in starter notch geometry and specimen half height may increase compliance errors (**12**, **13**).

8.2 *Exposure Conditions:*

8.2.1 The environmental testing conditions will depend on the intent of the test but, ideally, shall be similar to those prevailing for the intended use of the alloy or comparable to the anticipated service conditions. Ideally, the specimens should be stressed in the test environment. However, if this is not possible, the stressed specimens shall be exposed to the test environment, either gaseous or liquid, as soon as possible after stressing. Multiple, and preferably replicate, specimen should be used where possible.

8.2.2 For the specimens precracked by mechanical overload, the specimens can be precracked with the corrodent already present. In some cases for naturally aerated environments, this can be achieved by affixing strips of tape to both surfaces of the specimen and then adding solution dropwise while performing the mechanical precrack. This procedure can also be used during stressing of the fatigue precracked specimens.

8.2.3 If the corrodent is introduced during the precracking operation, the time at the end of the load application shall be considered as the starting time for environmental exposure. For other cases, the starting time for the test shall be when the specimens are exposed to the test environment.

8.2.4 For atmospheric and other vapor phase exposures, the bolt loaded end of the specimen shall be coated with an electrically insulating coating prior to exposure to prevent degradation of the knife edges and to prevent any galvanic interaction between dissimilar metals (specimen and loading bolts). The coating must not be so stiff that it would restrict movement of the specimen arms. This coating may not be required during exposure to very mild environments, such as indoor, inland, or rural atmospheres.

8.2.5 Specimens may be exposed to aqueous and nonaqueous corrosion solutions either by constant immersion, alternate immersion, or by periodic dropwise application of the solution on a regular, predetermined schedule, whichever is deemed appropriate for the test exposure. Coating of the bolt, wedge, or stressing fixture is not necessary for dropwise application. Where appropriate, dropwise addition of solution reduces corrosion on the faces of the specimen, which facilitates visual or ultrasonic inspection for crack growth. It may be necessary to periodically clean the specimen surfaces with a mild, noncorrosive polish to facilitate detection of the crack tip (see 6.2).

8.2.5.1 During constant immersion exposure, the specimens should be immersed such that the tip of the mechanical precrack is at least 6 mm (¼ in.) below the solution surface. Bolts or wedges made from electrochemically similar materials are recommended. However, if dissimilar materials are utilized for bolting or wedges, then these items shall not be in contact with the test solution or they shall be coated to isolate them from the test solution.

8.2.5.2 The level of solution must be monitored to ensure that the corrosive environment is reaching the crack tip region of the specimen. If the test solution consists of an aqueous electrolyte and is in an open container, for example, synthetic seawater or other aqueous solution exposed to air, it is necessary to periodically provide additional water to compensate for evaporation.

NOTE 6—Make up water shall be reagent water as defined by Type IV of Specification D1193.

8.2.5.3 Replacement, aeration, deaeration, or gas saturation of the aqueous test solution will depend on the intended purpose of the test. In general, aqueous solutions should be replaced weekly. Alternatively, the solution can be monitored for solution evaporation, contamination by corrosion products, depletion of reactive species, changes in pH, and periodic or continuous replenishment implemented (see 8.3). For some applications in which it is critical to maintain certain test conditions, it may be desirable to provide a replenishment system to ensure adequate aeration, deaeration, gas saturation, or otherwise preparation and maintenance of the bulk solution.

8.3 *Environmental Monitoring:*

8.3.1 Environmental parameters are of vital importance in stress corrosion testing; therefore, careful monitoring and control is required. Temperature, pH, conductivity, dissolved oxygen content, concentration of reactive species, and electrode potential are variables that can affect stress-corrosion cracking processes and should be monitored where appropriate.

8.3.2 For aqueous solutions, the solution temperature and pH shall be measured and recorded with each crack length measurement. Other environmental parameters may also be monitored as appropriate to the purpose of the specific test.

9. Interim Specimen Inspection

9.1 Crack length measurements should be made periodically to establish crack growth behavior. The frequency of these interim measurements will depend upon the particular test requirements and the material-environment combination as crack growth kinetics are different in each case. For constant displacement exposure, the crack growth rate decreases as the test progresses, requiring more frequent measurements at the start of the test and less frequent measurements as exposure continues. Once a familiarity with crack growth rate is obtained, measurement frequency can be adjusted such that measurements are made for a constant crack growth interval.

9.1.1 If needed, interim crack length measurements should be made by means of a visual, or equivalent, technique capable of resolving crack extensions of 0.025 mm (0.001 in.). Techniques have been developed to ultrasonically measure crack length at various positions across the specimen width, and to continuously monitor crack length by electrical resistance (potential drop) or by mechanical devices. The validity of these techniques should be verified by destructive examination of specimens of the same materials with stress corrosion cracks of varying length prior to using these techniques for actual test measurements.

9.1.2 Interim crack length measurements made by visual inspection shall be made on both sides of the specimen, and the crack length defined as the average value of these measurements. Crack lengths are to be determined from measurements of the distance from the loading point to the noncracked ligament.

10. Duration of Exposure

10.1 This practice is concerned primarily with procedures used with a variety of precracked double beam specimens and methods of applying stress. Exposure times, criteria of failure, and so forth, are variable depending on the application and are not specified herein.

10.2 Test duration for specimens loaded in constant displacement will be different for each alloy-heat treatment/environment combination, and should be determined by evaluation of the interim crack growth during specimen exposure, where possible. Test termination should be considered when crack length measurements indicate the crack growth rate has decreased to near 10^{-9} cm/s (10^{-6} in./h), or less (**3**). For materials qualification purposes, the final crack growth rate for test termination may be agreed upon between the user and the material vendor.

NOTE 7—Corrosion product wedging usually prevents adequate deceleration of an advancing crack and will invalidate the result from any continued exposure. This is particularly true if increasing crack growth rate is noted during the exposure.

10.3 For constant load specimens, the end of the test should be when the specimen fractures or when the period of exposure has been sufficiently long to characterize the cracking behavior of the material.

10.4 In some cases in which hydrogen embrittlement cracking is being evaluated with the precracked double beam specimen, the time required to charge the specimen with hydrogen in the test environment may be an important consideration in determining the appropriate test duration, which may depend on the diffusivity of hydrogen in the material at the test temperature and other factors.

11. Post Test Examination

11.1 *Constant Displacement Tests:*

11.1.1 The specimen shall be removed from the solution and the loading bolts or wedges removed.

11.1.2 The specimen may be placed in a test machine and subjected to cyclic load to mark the end of the stress corrosion crack. Fatigue marking should continue until the crack has been extended by 1 mm (0.05 in.) on both surfaces. The specimen shall then be loaded to failure to expose the crack faces. Final fatigue crack marking may not be necessary for aluminum alloys and certain other materials where there is a distinct difference in appearance between the stress corrosion fracture surface and the final mechanical fracture surface. In some cases, it may be necessary to cool the specimens in liquid nitrogen and then pull them to failure, thus differentiating the stress corrosion crack from the low temperature mechanical fracture.

11.2 *Constant Load Test*—The specimen shall be removed from solution and from the stressing hardware. If the sample is not fractured, then the specimen shall be handled and crack length measured by the same procedures given for constant displacement specimens.

11.3 *Final Crack Length Measurement:*

11.3.1 The final stress corrosion crack length, a_f, shall be measured on the fracture surface. Final crack length shall be the average of five measurements taken at the specimen center line, midway between the centerline and each side surface, and on each side surface. For face grooved specimens, the surface is defined as the base of the surface groove. Crack lengths shall be determined by measuring the final overload fracture ligament and subtracting $L - C_o - a_f$. The measuring instrument shall have an accuracy of 0.025 mm (0.001 in.).

11.3.2 Symmetry of the crack front shall be evaluated based on measurements made in accordance with 11.3.1. The crack shall be considered symmetric if (*1*) the difference between any two measurements is within 10 % and (*2*) each surface measurement is within 10 % of the average crack length. Deviations greater than these shall be included in the specimen report.

NOTE 8—Asymmetry in crack growth indicates nonuniform crack driving force, which may be related to eccentricities in specimen loading, residual stresses in the material, anisotropy of material properties or resistance to stress corrosion cracking, or to errors in specimen machining.

12. Report

12.1 The results of stress corrosion tests with precracked specimens shall be considered unique for a specific material-environment combination, but should be independent of the methods used for precracking, stressing, introduction of corrodent, and inspection. Report the following information for each specimen:

12.1.1 Specimen identification number;

12.1.2 Material name or specification code, chemical composition, heat treatment, and mechanical properties, product type, and dimensions of starting material;

12.1.3 Specimen orientation;

12.1.4 A summary of precracking parameters;

12.1.5 Method of stress application, test type (that is, constant load or constant deflection), and starting stress intensity level;

12.1.6 Type of corrodent (for example, aqueous NaCl), nominal composition, and mode of exposure. Other information necessary to adequately characterize the exposure conditions, such as temperature, pH, active aeration, deaeration, gas saturation, concentration of reactive species, flow velocity, and replenishment, should be recorded as appropriate;

12.1.7 Test duration;

12.1.8 Interim crack length measurements and measurement technique used (if made) and time period during the test when the measurements were made;

12.1.9 Final crack length, including both the five measurements, and the average value;

12.1.10 Any variations of conditions specified herein.

13. Keywords

13.1 crack growth rate; double cantilever beam specimen; K_{ISCC}; plateau velocity; precracked double beam specimen; precracked specimens; stress corrosion cracking; threshold stress intensity

APPENDIX

(Nonmandatory Information)

X1. RESEARCH APPLICATION AND ANALYSIS OF PRECRACKED DOUBLE BEAM SPECIMENS

X1.1 Precracked specimens offer the opportunity to use the principles of linear elastic fracture mechanics to evaluate resistance to stress corrosion cracking. Precracked specimens may be used to determine threshold stress intensity level, K_{Iscc}, stress corrosion crack growth rate, *da/dt* as a function of stress intensity, and plateau velocity (*K*-independent crack growth range), as illustrated in Fig. X1.1. K_{Iscc} provides a means to predict combinations of material flaw size and service stresses, which could result in stress corrosion cracking (**1, 9**). All results should be considered unique for a given material-environment combination.

X1.1.1 Crack growth rate decreases until crack arrest occurs during exposure for specimens stressed in constant displacement (see Fig. X1.1, *a*), which defines a threshold value for stress corrosion cracking, K_{Iscc}. During constant load exposure, crack growth rate increases until specimen fracture occurs at K_{If}, (see Fig. X1.1, *b* and *c*). Estimates of K_{If} and K_{Iscc}, based on knowledge of the material-environment combination of interest, will facilitate selection of starting stress levels to

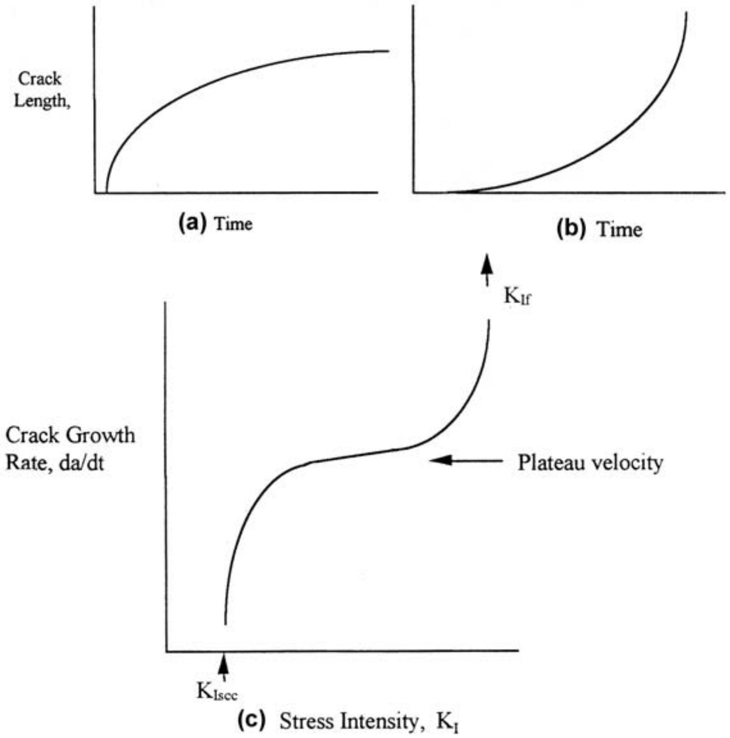


FIG. X1.1 Schematic Representation of Crack Growth Data Obtained From Prescribed Double Beam Specimen (a) constant displacement test (b) constant load test) (c) crack growth rate as a function of stress intensity) optimize the range of da/dt versus K, which can be determined, and to define the threshold stress intensity. In the constant deflection test, the starting stress intensity level should be high enough to define the plateau velocity but low enough to allow for crack growth deceleration within the specimen length, and definition of K_{Iscc}. For the constant load test, the starting stress intensity level should minimize crack growth in the very low da/dt regime while attaining plateau velocity before specimen fracture. Although the da/dt - K curve must include an inflection point, a crack plateau velocity may not occur in certain combinations of material, environment, and starting stress intensity (K_{Io}).

X1.2 Test Results

X1.2.1 The results obtained from precracked specimens are based on measurements of crack length at specific times and correlation with stress intensity for each crack length. Crack length measurements should be made at scheduled time intervals, depending on how rapidly the crack is expected to grow while in test. Exposure time should be recorded when measurements are taken.

X1.2.2 The rate of crack growth, *da/dt*, associated with a particular crack length, a_i, should be determined from the slope of the crack length versus time curve (Fig. X1.1, *a* or *b*) generated from the interim crack length measurements. Various approaches are discussed in Sprowls, p. 260, (**9**) for calculating the slopes, with the object of determining the *da/dt* - K curve (Fig. X1.1, *c*), from which plateau velocities and threshold stress intensities are derived.

X1.2.3 For the constant displacement test, the stress intensity, K_{Ii}, should be based on V_{LL}, the total initial displacement at the load line, as this is the only displacement that does not change with increasing crack length (assuming rigid bolt analysis). The load line displacement should be determined from the following relationship (**9**):

$$V_{LL} = (V_o)/[1+1.5(C_o/a_o) - 1.15\,(C_o/a_o)^2] \qquad (X1.1)$$

where:

V_{LL} = load line crack opening displacement, m (in.),
V_o = crack mouth opening displacement at COD gage attachment location, m (in.),
a_o = starting crack length, m (in.), and
C_o = distance from load line to COD gage attachment location, m (in.).

The stress intensity level, K_{Ii}, associated with the interim crack length, a_i, should be calculated from the following relationship (**9**):

$$K_{Ii} = [1.732\,E\,V_{LL}]/[4\,H^{1/2}\,(a_i/H+0.673)^2] \qquad (X1.2)$$

where:

a_i = interim crack length, m (in.),
K_{Ii} = stress intensity level associated with the measured crack length, MPa-m$^{1/2}$ (ksi-in.$^{1/2}$),
V_{LL} = load line crack opening displacement, m (in.),
H = specimen half height, m (in.), and
E = Young's Modulus, MPa (ksi).

X1.2.3.1 The final stress intensity level, K_{If}, should be calculated with Eq X1.2, based on the final crack length, a_f, measured, as described in 11.2. The final stress intensity level calculated at test termination is considered an indication of the threshold value only if the crack growth rate is within the range described in 10.2. Results apply to a specific combination of material, its metallurgical condition, and corrodent.

X1.2.4 Linear fracture mechanics has been well established as a basis for materials characterization, including stress corrosion cracking. In practice, it is most practical to define K_{ISCC} as the level of stress intensity associated with some generally acceptable and definably low rate of crack growth that is commensurate with the design service life. Such characterization requires that linear elastic fracture mechanics and plane-strain conditions be satisfied. However, for certain low-strength (or high toughness, or both) materials, existing data show that stress corrosion cracking can occur under conditions that deviate from plane strain conditions, and that stress corrosion cracking is by no means limited to, or is most severe under, plane strain loading conditions (**5,9**). In these cases, the application of linear elastic fracture mechanics is no longer valid, and the parameter K_{ISCC} is no longer meaningful. Similarly, when testing materials with a high resistance to stress corrosion cracking, loading to high percentages of K_{Ic} may cause a relaxation of stress due to creep. In this case, the apparent K_{ISCC} values can also be meaningless. The symbol K_{th} has been used to identify threshold stress intensity factors developed under test conditions that do not satisfy all of the requirements for plane strain conditions. Design calculations, using such values, should not be employed unless it is clear that the laboratory tests exhibit the same stress state as that for the intended application. Nevertheless, properly determined K_{th} values can be useful for ranking materials for resistance to stress corrosion cracking.

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