Designation: E2818 – 11

Standard Practice for Determination of Quasistatic Fracture Toughness of Welds[1]

This standard is issued under the fixed designation E2818; 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 provides methods for preparing specimens from welds in metallic materials and interpreting subsequent test results when used in conjunction with standards Test Methods E1290 and E1820 for the determination of fracture toughness. The fatigue pre-cracking procedures included in this practice may also be used to aid in preparing straight pre-cracks for weld specimens in accordance with Test Method E1681.

1.2 This practice draws heavily from ISO 15653: Metallic materials – Method of test for the determination of quasistatic fracture toughness of welds. All references to ISO 12135 in that test method should be replaced with the applicable ASTM Test Methods (E1820, E1290 or E1681).

1.3 The recommended specimen is a single-edge bend [SE(B)] with width, W, equal to twice the specimen thickness, B. An alternate SE(B) specimen with W/B equal to one and a span, S, to W ratio of 4 may be used but may produce different toughness values. A compact tension [C(T)] specimen may be used if it can be demonstrated that the analysis of results properly accounts for weld-to-base metal strength mismatch effects on fracture toughness.

1.4 The recommended limitation on weld-to-base metal yield strength ratio is

$$0.5 < \frac{\sigma_{ys}^{weld}}{\sigma_{ys}^{base}} < 1.5 \quad (1)$$

Undermatching within this limitation leads to conservative estimates of fracture toughness, while overmatching may lead to an overestimation of the fracture toughness by up to 10%.

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]

E8/E8M Test Methods for Tension Testing of Metallic Materials

E1290 Test Method for Crack-Tip Opening Displacement (CTOD) Fracture Toughness Measurement (Withdrawn 2013)[3]

E1681 Test Method for Determining Threshold Stress Intensity Factor for Environment-Assisted Cracking of Metallic Materials

E1820 Test Method for Measurement of Fracture Toughness

E1823 Terminology Relating to Fatigue and Fracture Testing

2.2 *ISO Standard:*[4]

ISO 12135 Metallic materials – Unified method of test for the determination of quasistatic fracture toughness

ISO 15653 Metallic materials–Method of test for the determination of quasistatic fracture toughness of welds

3. Terminology

3.1 Terminology of E1823 and ISO 15653 are applicable to this test practice with the following additions.

3.2 *Definitions:*

3.2.1 *base metal yield strength*—The base metal 0.2% offset yield strength (σ_{ys}^{base}) is defined by testing tensile specimens per Test Method E8/E8M.

3.2.1.1 *Discussion*—ISO 15653 uses $R_{p0,2b}$ to represent the base metal yield strength.

3.2.2 *overmatched*—Any weldment having $\frac{\sigma_{ys}^{weld}}{\sigma_{ys}^{base}} > 1$

3.2.3 *test temperature*—The test temperature for tensile specimens shall either be identical to the test temperature for the fracture toughness specimens, or evidence shall be provided to demonstrate that there is not an appreciable change in

[1] This practice 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] 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.

[4] Available from International Organization for Standardization (ISO), 1, ch. de la Voie-Creuse, Case postale 56, CH-1211, Geneva 20, Switzerland, http://www.iso.ch.

the yield strength between the test temperature used for the tensile and fracture toughness tests.

3.2.4 *undermatched*—Any weldment having $\frac{\sigma_{ys}^{weld}}{\sigma_{ys}^{base}} < 1$

3.2.5 *weld metal yield strength*—The weld metal 0.2% offset yield strength (σ_{ys}^{weld}) is defined by testing tensile specimens per Test Method E8/E8M.

3.2.5.1 *Discussion*—ISO 15653 uses $R_{p0,2w}$ to represent the weld metal yield strength.

4. Summary of Practice

4.1 This test practice complements ISO 15653 for the quasistatic fracture toughness testing of welds. When testing welds, it is important that the crack tip sample the region and microstructure of interest. Procedures given in ISO 15653 for selecting a specimen orientation, positioning of the fatigue precrack relative to the weld or heat affected zone (HAZ), and verifying that the resulting measured fracture toughness is representative of the target region or microstructure apply to this practice.

4.2 This test practice references ISO 15653 for recommendations for relieving non-uniform residual stresses ahead of notch tips in weld fracture toughness specimens to allow for an improvement in the straightness of fatigue precracks. Where thermal stress relief treatments are found inadequate, the local compression technique, which involves indenting the sides of the specimens to encompass the notch tip, is the recommended procedure.

4.3 This practice follows the guidance provided in ISO 15653 for relaxation in crack front straightness requirements provided in the applicable fracture toughness test method; however, this relaxation is valid only for SE(B) specimens evaluated in terms of J or CTOD (not for K_{Ic} evaluation).

5. Significance and Use

5.1 This test practice provides a recommended procedure for preparing fracture toughness specimens from welds to improve the likelihood of obtaining useful fracture toughness values.

5.1.1 The subsequent fracture toughness values, that have significance and use as stated in the applicable ASTM test method, may allow for flaw tolerance assessments of welded structures. Flaw tolerance assessments require an understanding and compensation for the differences that may exist between laboratory test results and field conditions.

5.1.2 The shallow-notched specimen testing procedures described in Annex E of ISO 15653 may be used by agreement between the parties involved as long as it is understood that Annex E is "Informative" and the result is a geometry dependent measurement of toughness that is not validated by the applicable test standard.

6. Apparatus

6.1 The apparatus for specimen preparation and testing is as described in ISO 15653 and the applicable ASTM fracture toughness test method.

7. Specimen Configuration, Dimensions, and Preparation

7.1 The following sections override ISO 15653 where applicable.

7.1.1 *Specimen:*

7.1.1.1 *Standard Configuration*—A single edge notch bend, SE(B), specimen having a ratio of width W to thickness B (W/B) of two and a span S to W ratio of four is the standard configuration.

7.1.1.2 *Alternative Configuration*—A specimen having W/B=1 may also be tested with a S/W=4. However, this configuration may produce different toughness values than the standard configuration.

7.1.1.3 *Shallow-crack SE(B) specimen testing*—When the microstructure of interest in a weld occurs only at a location where the precrack in a SE(B) specimen must be placed at a/W < 0.45, conducting a fracture test will sample the toughness of that microstructure; however, it is subject to low constraint conditions that will elevate the measured toughness. If this microstructure only occurs at this a/W, then the measured fracture toughness is representative of the weld. On the other hand, if the microstructure could occur at deep crack locations in some applications, then the measured fracture toughness could be non-conservative. Consequently, the shallow-notched specimen testing procedures described in Annex E of ISO 15653 may be used by agreement between the parties involved as long as it is understood that Annex E is "Informative" and the result is a geometry dependent measurement of toughness.

7.1.1.4 *Alternative Specimen*—The compact tension, C(T), specimen, which is routinely used to measure fracture toughness for base materials, is not recommended for fracture toughness testing of weldments due to a lack of experience with both the testing and analysis of welded C(T) specimens. The C(T) specimen may be used if the user demonstrates that the equations for interpreting the results appropriately account for weld-to-base metal strength mismatch effects on fracture toughness.

7.1.1.5 *Notch Orientation*—ISO 15653 provides orientation codes for weld and parent metal specimens. The parent metal directions designated X, Y, and Z correspond to directions L, T and S in Test Method E1823.

7.2 *Pretest Hydrogen Release Heat Treatment:*

7.2.1 *Applicability to Service Conditions*—The presence of diffusible hydrogen in a weld can reduce fracture toughness, especially when the rate of straining is low. If the time between welding and testing is shorter than the time between welding and the structure experiencing its first major loading, it may be necessary to carry out hydrogen release heat treatment on the test weldment. Conversely, when the time between welding and the structure entering service is short, heat treatment of the welded test panel for hydrogen release would be inappropriate.

7.2.2 *Comparability of Multiple Test Weldments*—Heat treatment may also be required when it is necessary to compare the fracture toughness of different weldments and it is not possible to ensure that the time between welding and testing is the same. The purpose of the heat treatment is to ensure that the level of diffusible hydrogen is the same as that in the structural weld, or that consistent hydrogen levels are obtained in different panels.