Designation: E 1152 – 95

AMERICAN SOCIETY FOR TESTING AND MATERIALS
1916 Race St. Philadelphia, Pa 19103
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Standard Test Method for Determining *J-R* Curves[1]

This standard is issued under the fixed designation E 1152; 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[2] covers the determination of the *J*-integral versus crack growth resistance curves (*J-R* curve) for metallic materials.

1.2 The recommended specimens are the pin-loaded compact ($C(T)$) and the three-point bend ($SE(B)$) specimens. Both have in-plane dimensions of constant proportionality for all sizes. Specimen configurations other than those recommended in this test method may require different procedures and validity requirements.

1.3 This test method is intended to characterize the slow, stable crack growth resistance of bend-type specimens in such a manner that it is geometry insensitive within limits set forth in this test method.

1.4 The single specimen elastic compliance test method is detailed herein, but other techniques of measuring crack length are permissible if they equal or exceed the accuracy requirements of this test method.

1.5 The values stated in SI units are to be regarded as the standard. The values given in parentheses are for information only.

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

2. Referenced Documents

2.1 *ASTM Standards:*

E 4 Practices for Force Verification of Testing Machines[3]

E 8 Test Methods for Tension Testing of Metallic Materials[3]

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

E 616 Terminology Relating to Fracture Testing[3]

E 813 Test Method for J_{IC}, A Measure of Fracture Toughness[3]

3. Terminology

3.1 Terminology related to fracture testing contained in Terminology E 616 is applicable to this test method.

3.2 *Definitions:*

3.2.1 *J-integral, $J(FL^{-1})$*—a mathematical expression, a line or surface integral that encloses the crack front from one crack surface to the other, used to characterize the local stress strain field around the crack front. See Terminology E 616 for further discussion.

3.2.2 *R-curve*—a plot of resistance to stable crack extension, Δa_p.

Discussion—In this test method, the *J-R* curve is a plot of the far-field *J*-integral versus physical crack extension, Δa_p. It is recognized that the far-field value of *J* may not represent the stress-strain field local to a growing crack.

3.2.3 *effective yield strength, $\sigma_Y [FL^{-2}]$*—an assumed value of uniaxial yield strength that represents the influence of plastic yielding upon fracture test parameters.

Discussion—In this test method, σ_Y is the average of the 0.2 % offset tensile yield strength, σ_{ys}, and the ultimate tensile strength, σ_{TS}. See Test Methods E 8.

3.2.4 *specimen thickness, B[L]*—distance between the sides of the specimen.

3.2.5 *net thickness, $B_N[L]$*—distance between the roots of the side grooves in side grooved specimens.

3.2.6 *specimen width, W[L]*—distance from the reference plane to the back edge of the specimen.

3.2.7 *SE(B) specimen span, S[L]*—distance between specimen supports.

3.2.8 *physical crack size, $a_p[L]$*—the distance from a reference plane to the observed crack front. The reference plane depends on the specimen form. Normally it is taken to be either a specimen boundary, or a plane containing either the load line or the centerline of a specimen or plate. The reference plane in compact specimens is the plane normal to the sides and containing the load line. In three-point bend specimens, it contains the notched edge of the specimen.

3.2.9 *original crack size, $a_o[L]$*—the physical crack size at the start of testing.

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

3.2.11 *physical crack extension, $\Delta a_p[L]$*—an increase in physical crack size ($\Delta a_p = a_p - a_o$).

3.2.12 *remaining ligament, b[L]*—distance from the physical crack front to the back edge of the specimen ($b = W - a_p$).

4. Summary of Test Method

4.1 This test method describes a single specimen technique of determining the *J-R* curve for a metallic material. The *J-R* curve consists of a plot of *J* versus crack extension, in the region of *J*-controlled growth, and is valid provided that the criteria of Sections 7, 8, and 9 are satisfied.

4.2 For the procedure described in this test method, crack

[1] This test method is under the jurisdiction of ASTM Committee E-8 on Fatique and Fracture and is the direct responsibility of Subcommittee E 08.08 on Elastic-Plastic Fracture Mechanics Technology.

Current edition approved Sept. 10, 1995. Published November 1995. Originally published as E 1152 – 87. Last previous edition E 1152 – 87.

[2] Information on *R*-Curve round robin data is available from ASTM Headquarters, 1916 Race Street, Philadelphia, PA 19103. Request RR:E 24 – 1011.

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

length and crack extension are determined from elastic compliance measurements. These measurements are taken on a series of unloading/reloading segments spaced along the load-versus-displacement record.

5. Significance and Use

5.1 The *J-R* curve characterizes, within the limits set forth in this standard, the resistance of metallic materials to slow stable crack growth after initiation from a preexisting fatigue crack or other equally sharp flaw.

5.1.1 The *J-R* curve can be used as an index of material toughness for alloy design, material selection, and quality assurance.

5.1.2 The *J-R* curve from bend-type specimens defines the lower bound estimate of *J*-capacity as a function of crack extension, and has been observed to be conservative in comparison with those obtained with tensile loading specimen configurations.

5.1.3 The *J-R* curve can be used to assess the stability of cracks in structural details in the presence of ductile tearing, with awareness of the difference that may exist between laboratory test and field conditions.

5.2 The *J-R* curve is not intended to be used in the upper transition region for body-centered-cubic ferrous alloys where cleavage instability may follow ductile tearing.

6. Apparatus

6.1 Measurements of applied load and load-line displacement are needed to obtain the total energy absorbed by the specimen. Load versus load-line displacements may be recorded digitally for processing by computer or autographically with an *x-y* plotter.

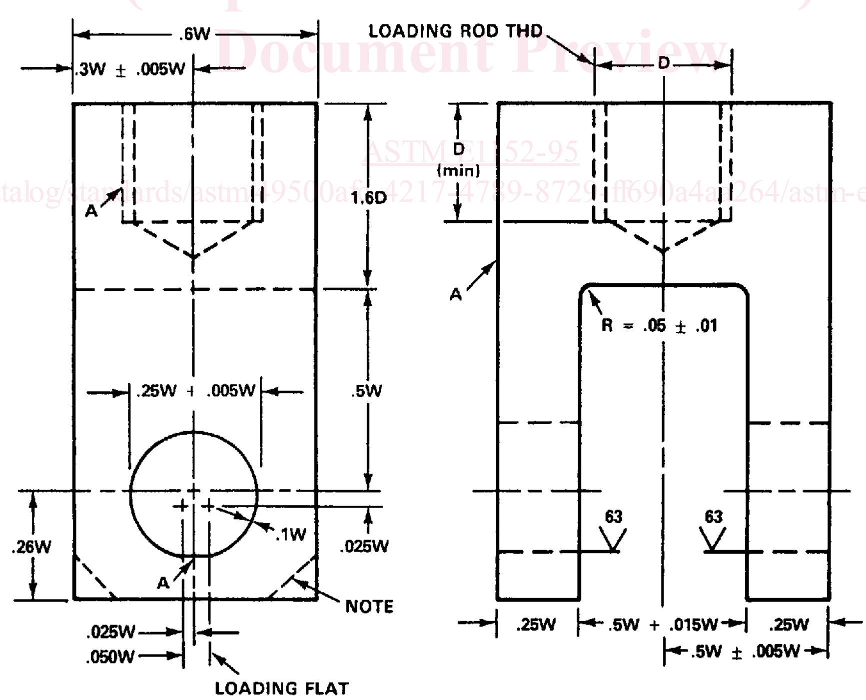
6.2 *Grips for C(T) Specimens*—A suggested clevis and pin arrangement for gripping compact specimens is shown in Fig. 1. It accommodates specimens have a thickness $B = 0.5\ W$. The flat-bottom holes minimize friction caused by loading pin rotation. Clevices and pins should be fabricated from steels of sufficient strength to elastically resist indentation loads (greater than 40 Rockwell Hardness, C scale [HRC]).

6.3 *Bend Test Fixture*—A suggested fixture for *SE*(*B*) specimen testing is shown in Fig. 2. It allows for roller pin rotation and minimizes friction effects during the test. Fixturing and rolls must be made of high hardness (greater than 40 HRC) steels.

6.4 *Displacement Gage:*

6.4.1 Displacement measurements are needed for two purposes: (*1*) to evaluate *J* from the area under the load-displacement record and, (*2*) for the elastic compliance method, to infer crack extension Δa_p from elastic compliance calculations.

6.4.2 In *C*(*T*), displacement measurements on the load line are recommended. As a guide, select a displacement gage that has a working range of not more than twice the displacement expected during the test. When the expected displacement is less than 3.75 mm (0.15 in.), the gage recommended in Test Method E 399 may be used. When a greater working range is needed, an enlarged gage such as the one shown in Fig. 3 is recommended. Accuracy shall be within ±1 % of the



A — SURFACES MUST BE FLAT, IN-LINE & PERPENDICULAR, AS APPLICABLE TO WITHIN 0.002 IN T.I.R. (.05 mm)

NOTE 1—Pin diameter = 0.24 W (+0.00 W/−0.005 W) for specimens with σ_{ys} 200 ksi (1379 MPa). The holes in the specimen and in the clevis may be 0.3 W (+0.005 W/−0.000 W) and the pin diameter 0.288 W (+0.000 W/−0.005 W).

NOTE 2—0.002 in. = 0.051 mm.

NOTE 3—Corners of the clevis may be removed as necessary to accommodate the clip gage.

FIG. 1 Clevis for C(T) Specimen Testing