



Standard Test Methods for Bend Testing of Material for Ductility¹

This standard is issued under the fixed designation E290; 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.

This standard has been approved for use by agencies of the U.S. Department of Defense.

1. Scope*

1.1 These test methods cover bend testing for ductility of materials. Included in the procedures are four conditions of constraint on the bent portion of the specimen; a guided-bend test using a mandrel or plunger of defined dimensions to force the mid-length of the specimen between two supports separated by a defined space; a semi-guided bend test in which the specimen is bent, while in contact with a mandrel, through a specified angle or to a specified inside radius (r) of curvature, measured while under the bending force; a free-bend test in which the ends of the specimen are brought toward each other, but in which no transverse force is applied to the bend itself and there is no contact of the concave inside surface of the bend with other material; a bend and flatten test, in which a transverse force is applied to the bend such that the legs make contact with each other over the length of the specimen.

1.2 After bending, the convex surface of the bend is examined for evidence of a crack or surface irregularities. If the specimen fractures, the material has failed the test. When complete fracture does not occur, the criterion for failure is the number and size of cracks or surface irregularities visible to the unaided eye occurring on the convex surface of the specimen after bending, as specified by the product standard. Any cracks within one thickness of the edge of the specimen are not considered a bend test failure. Cracks occurring in the corners of the bent portion shall not be considered significant unless they exceed the size specified for corner cracks in the product standard.

1.3 The values stated in SI units are to be regarded as standard. Inch-pound values given in parentheses were used in establishing test parameters and are for information only.

1.4 *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*

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

2. Referenced Documents

2.1 *ASTM Standards:*²

- E6 Terminology Relating to Methods of Mechanical Testing
- E8/E8M Test Methods for Tension Testing of Metallic Materials
- E18 Test Methods for Rockwell Hardness of Metallic Materials
- E190 Test Method for Guided Bend Test for Ductility of Welds

3. Summary of Test Methods

3.1 Four methods for ductility testing employing bending are included in these test methods. Three methods have subgroups with specific procedures.

3.1.1 *Guided Bend:*

- 3.1.1.1 Guided Bend, No Die,
- 3.1.1.2 Guided Bend, U-Bend,
- 3.1.1.3 Guided Bend, V-Bend,
- 3.1.1.4 Guided Bend, V-Bend for cold rolled sheet,

3.1.2 *Semi-guided Bend:*

- 3.1.2.1 *Arrangement A*, specimen held at one end.
- 3.1.2.2 *Arrangement B*, for thin material.
- 3.1.2.3 *Arrangement C*, mandrel contact force in the bend.

3.1.3 *Free-Bend:*

- 3.1.3.1 *Type 1*, 180° bend.
- 3.1.3.2 *Type 2*, bend flat on itself.

3.1.4 *Bend and Flatten:*

3.2 A guided-bend test for ductility of welds is described in Method E190 and may be used for flat-rolled materials when specified by the product standard. The essential features of this bending method are employed in 3.1.1.2, Guided Bend, U-Bend.

3.3 Bend tests are made in one of two directions relative to the principal working direction employed in production processing of the material.

¹ This test method is under the jurisdiction of ASTM Committee E28 on Mechanical Testing and is the direct responsibility of Subcommittee E28.02 on Ductility and Formability.

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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.

*A Summary of Changes section appears at the end of this standard

3.3.1 Longitudinal tests use a specimen with its long dimension aligned with the processing direction such that the bend is formed across the processing direction, as shown in Fig. 1.

3.3.2 Transverse tests use a specimen with the long dimension perpendicular to the processing direction so that the bend axis is aligned with the processing direction, as shown in Fig. 2. The axis of bend is the center of the bend radius.

3.3.3 Thin sheet products are generally produced by reducing the thickness of stock in rolling mills and from this the term rolling direction is used to identify the principal processing direction. Similarly, a product produced in coil form may have the processing direction referred to as the coiling direction.

3.4 The location of the force application to the specimen relative to the bend itself and the amount of bending differentiate the four methods of bending covered in these test methods. The two semi-guided bend test procedures provide radiused surfaces over which the bend is formed. The results obtained by different test procedures may not be the same, especially for material with a tendency to crack or fracture.

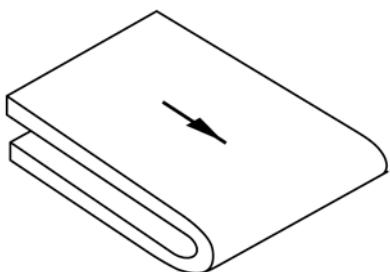
3.5 The test is completed when the designated angle of bend, or other specified condition, has been reached.

3.5.1 If a defined amount of cracking is permitted by the product standard, the convex surface of the bend region is examined for cracks and surface irregularities.

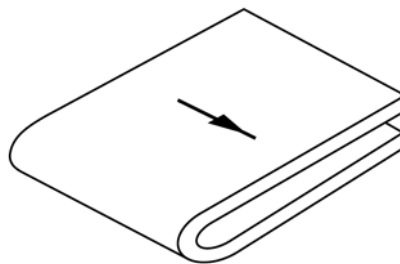
3.5.2 Surface irregularities, such as orange peel, loss of coating adherence, or imperfections resulting from the bend, shall be noted as required by the product specification.

3.6 *Guided Bend*—The guided-bend test is made by supporting the specimen near each end on pins, rollers, or flat surfaces with appropriate end radii and applying a force through a pin, mandrel, plunger, or male die midway between two supports, as shown schematically in Fig. 3, Fig. 4, Fig. 5, and Fig. 6 until the desired bend is formed. No force is applied directly to the outer face of the bend when no female die is used (3.1.1.1). Some force may be applied by the female die to the outer face of the bend in the case of U-bend (3.1.1.2) and V-bends (3.1.1.3 and 3.1.1.4). In some cases, for U-bend and V-bends it may be necessary for the specimen to bottom out in the female die to ensure the correct amount of bending.

3.6.1 The radii of the plunger and of the two supports shall be defined in the product specification as related to the thickness (t) of the specimen being tested. A clearance of three thickness with a tolerance of one half thickness shall be provided between the pins, plunger, and specimen in the initial bend fixture.



NOTE 1—Arrow indicates direction of processing.
FIG. 1 Longitudinal Bend Test



NOTE 1—Arrow indicates direction of processing.
FIG. 2 Transverse Bend Test

3.6.1.1 The distance between supports (C) shall be three thicknesses plus twice the plunger radius, with a tolerance of one-half thickness, as shown in Fig. 3.

3.6.1.2 When female dies are used for U-bend and V-bend, they shall conform approximately to the geometries shown in Fig. 4, Fig. 5, and Fig. 6.

3.6.2 The surfaces of the supports and plunger shall be hard enough to resist plastic deformation and wear that can be observed after the test. If visible flattening, wear, or other permanent deformation of the test fixtures does occur, the test is invalid.

NOTE 1—Supports and plungers hardened to at least 20 HRC have been found to be generally suitable for this test. It is recommended that checking by the unaided eye for flattening, wear, or other deformation of the test fixtures take place after testing different and potentially harder materials than usual.

3.6.3 The supports can be fixed or free to rotate. A lubricant may be applied to the supports and plunger.

3.6.4 The width of the guided-bend fixture, including the supports and plunger, shall be such that the bend region of the specimen is subject to the bending force across its width (w) during bending.

3.6.5 When the thickness or strength of the specimen, or capacity of the guided-bend test fixture (shown in Fig. 3) does not produce the required amount of bending, the specimen can be removed from the fixture and the bend completed by applying force against the ends of the specimen, as shown schematically in Fig. 7. A spacer with a thickness equal to twice the required bend radius is inserted at the location of the bend. The edges at the ends shall be constrained so the specimen cannot eject from the fixture under the bending force.

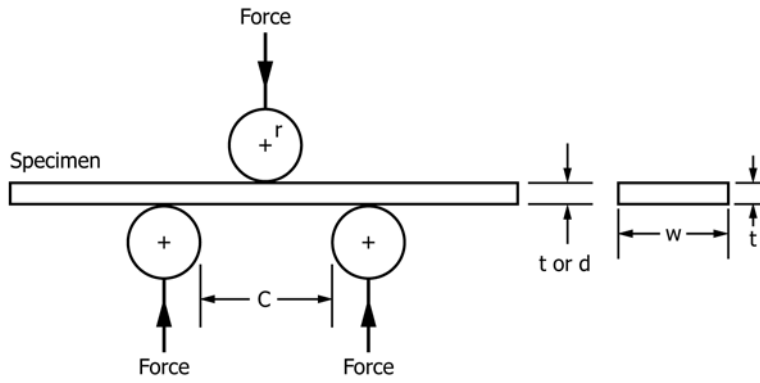
3.6.6 Surface cracks and imperfections resulting from the bend shall be evaluated and reported.

3.7 *Semi-guided Bend*—The semi-guided bend test employs a constraining force on the inside of the bend during the initiation of the bending and continuing until the final bend condition is achieved.

3.7.1 The semi-guided bend test is made by applying a force transversely to the specimen's long axis in the portion that is being bent.

3.7.2 The angle of bend in the semi-guided bend test is measured while the specimen is held stationary under the force forming the bend.

3.7.3 The location of the bend along the length of the specimen is unimportant. The specimen is clamped or supported by one of the methods shown schematically in Figs.



$$C = 2r + 3t \pm t/2$$

NOTE 1— C = distance between lower supports,
 r = radius of the end of the mandrel or plunger,
 t = sheet specimen thickness,
 d = round specimen diameter, and
 w = sheet specimen width.

FIG. 3 Schematic Fixture for the Guided Bend, No Die Test

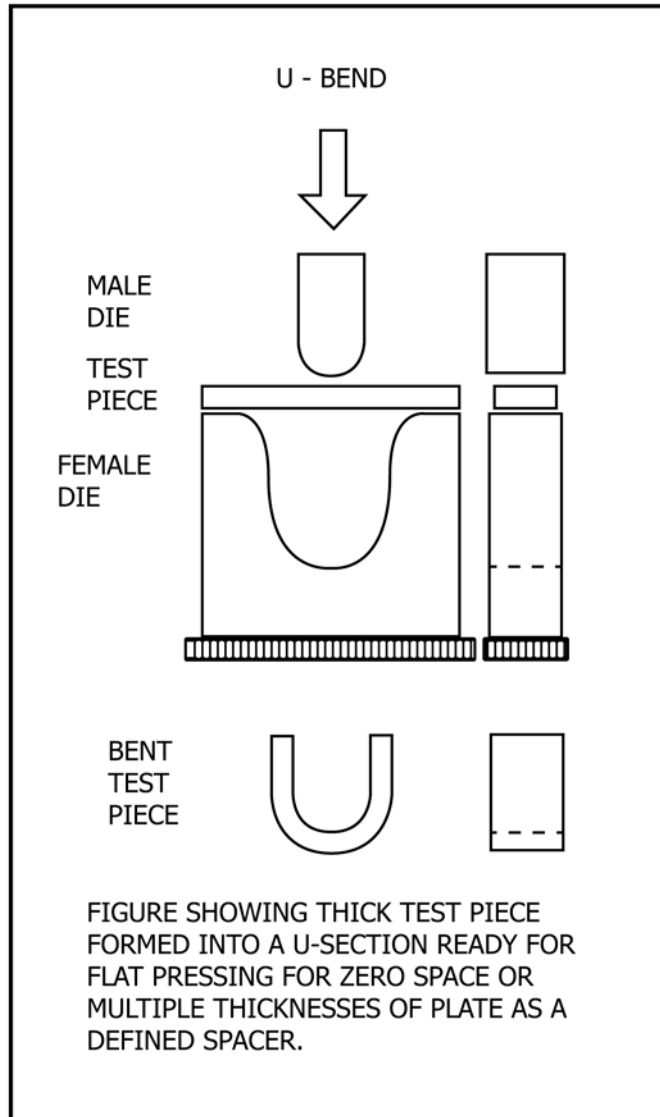


FIG. 4 Schematic Fixture for the Guided Bend, U-bend Test