Designation: E 1012 – 99

Standard Practice for Verification of Specimen Alignment Under Tensile Loading[1]

This standard is issued under the fixed designation E 1012; 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 Included in this practice are methods covering the determination of the amount of bending that occurs during the loading of notched and unnotched tensile specimens in the elastic range and to plastic strains less than 0.002. These methods are particularly applicable to the force application rates normally used for tension testing, creep testing, and uniaxial fatigue testing.

2. Referenced Documents

2.1 *ASTM Standards:*

E 6 Terminology Relating to Methods of Mechanical Testing[2]

3. Terminology

3.1 The terms in Terminology E 6 apply. Other terms used in connection with specimen alignment are defined as follows:

3.2 *Definitions:*

3.2.1 *alignment*—the condition of a testing machine and load train (including the test specimen) which influences the introduction of bending moments into a specimen during tensile loading.

3.2.2 *apparatus*—the load-train, strain gages, and other details of the equipment to be used for testing, excluding the test specimen.

3.2.3 *axial strain*—the average of the longitudinal strains measured at the surface on opposite sides of the longitudinal axis of symmetry of the specimen by two strain-sensing devices located at the mid-length of the reduced section.

3.2.4 *bending strain*—the difference between the strain at the surface and the axial strain (see Fig. 1). In general, the bending strain varies from point to point around and along the reduced section of the specimen. Bending strain is calculated as shown in Section 11.

3.2.5 *eccentricity*—the distance between the line of action of the applied force and the axis of symmetry of the specimen in a plane perpendicular to the longitudinal axis of the specimen.

3.2.6 *maximum bending strain*—the largest value of bending strain at the position along the length of the reduced section of a straight unnotched specimen at which bending is measured. (For notched specimens, see 4.9.)

3.2.7 *notched section*—the section perpendicular to the longitudinal axis of symmetry of the specimen where the cross-sectional area is intentionally at a minimum value in order to serve as a stress raiser.

3.2.8 *nominal percent bending in notched specimens*—the percent bending in a hypothetical (unnotched) specimen of uniform cross section—equal to the minimum cross section of the notched specimen, the eccentricity of the applied force in the hypothetical, and the notched specimens being the same. (See 11.5.) (This definition is not intended to define strain at the root of the notch.)

3.2.9 *percent bending*—the bending strain times 100 divided by the axial strain.

3.2.10 *rated force*—a force at which the alignment is being measured.

3.2.11 *reduced section*—that part of the specimen length between the fillets.

4. Significance and Use

4.1 It has been shown that bending stresses that inadvertently occur due to misalignment between the applied force and the specimen axes during tensile forces can affect the test results. In recognition of this effect, some test methods include a statement limiting the misalignment which is permitted. The purpose of this practice is to provide a reference for test methods and practices that require tensile loading under conditions where alignment is important. The objective is to implement the use of common terminology and methods for verification of alignment of loading fixtures and test specimens.

4.2 Axiality requirements and verifications should be *optional* when testing is performed for acceptance of materials for minimum strength and ductility requirements. This is because the effects, if any, especially excessive bending, would be expected to reduce strength and ductility properties and give conservative results. There may be no benefit from improved axiality when testing high ductility materials to determine conformance with minimum properties. Whether or not to improve axiality, should be a matter of negotiation between the material producer and the user.

[1] This practice is under the jurisdiction of ASTM Committee E-28 on Mechanical Testing and is the direct responsibility of Subcommittee E28.04 on Uniaxial Testing.

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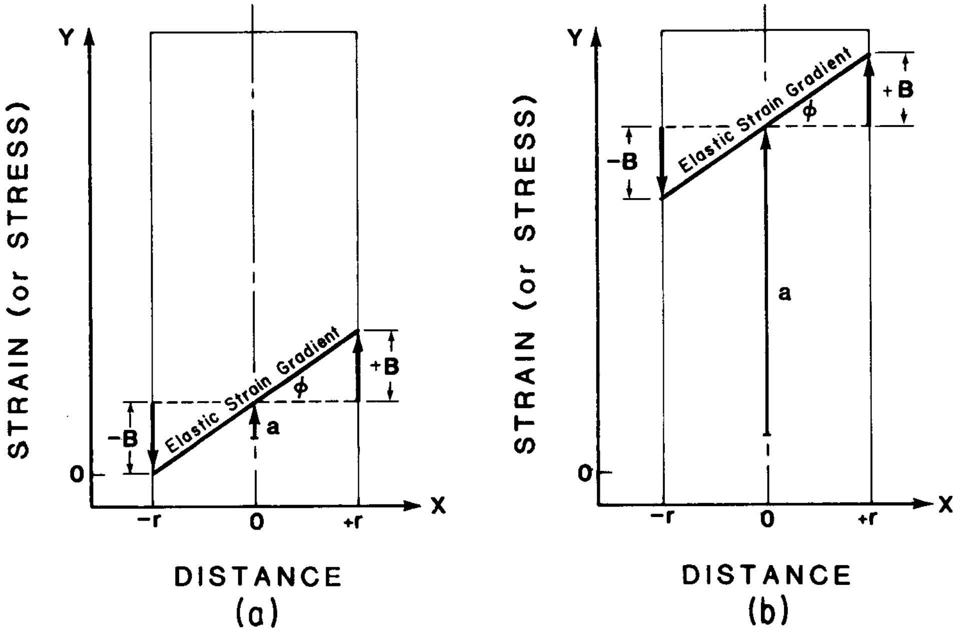
[2] *Annual Book of ASTM Standards,* Vol 03.01.



NOTE 1—A bending strain, $\pm B$, is superimposed on the axial strain, *a*, for low-axial strain (or stress) in (*a*) and high-axial strain (or stress) in (*b*). For the same bending strain $\pm B$, a high-percent bending is indicated in (*a*) and a low-percent bending is indicated in (*b*).

FIG. 1 Schematic Representations of Bending Strains (or Stresses) That May Accompany Uniaxial Loading

5. Verification of Alignment

5.1 For ease of reference in other practices, test methods, and product specifications, the most commonly used methods for verifying alignment are listed in Section 6.

5.2 A numerical requirement for alignment should specify the force, specimen dimensions, and temperature at which the measurement is to be made.

5.2.1 The force at which the bending strain is specified may be stated in terms of a yield strength or other nominal specimen stress.

NOTE 1—For an offset-load train, percent bending decreases with increasing applied force. (See Curves A, B, and C in Fig. 2.) However, in some instances, percent bending may increase with increasing applied force. (See Curve D in Fig. 2.)

5.3 Alignment requirements can refer to the apparatus (Type A) or to a single test (Type T). Those applied to the test apparatus should be referred to as follows: ASTM Standard Practice E 1012, Type A, Method (followed by the suitable number from 6.1). Those applied to a specific test should be similar with a "T" substituted for the "A."

5.3.1 Verifications of Type A shall be made using a specimen and apparatus made to the same drawing and of the same materials as those that will be used during testing, except that any specimen notches be eliminated. The same specimen may be used for successive verifications. The materials and design should be such that only elastic strains occur at the rated force.

NOTE 2—To avoid damage to the verification specimen, the sum of the axial strain (see section 4.4) and the maximum bending strain (see section 4.8) should not exceed the elastic limit.

5.3.2 Verifications of Type T shall be made on the specimen to be tested just prior to or during the testing and without removing the specimen from the testing machine or making any other adjustments that would affect alignment during the period between verification and testing.

NOTE 3—Maintaining a small force on the specimen between verification and testing is necessary to retain alignment.

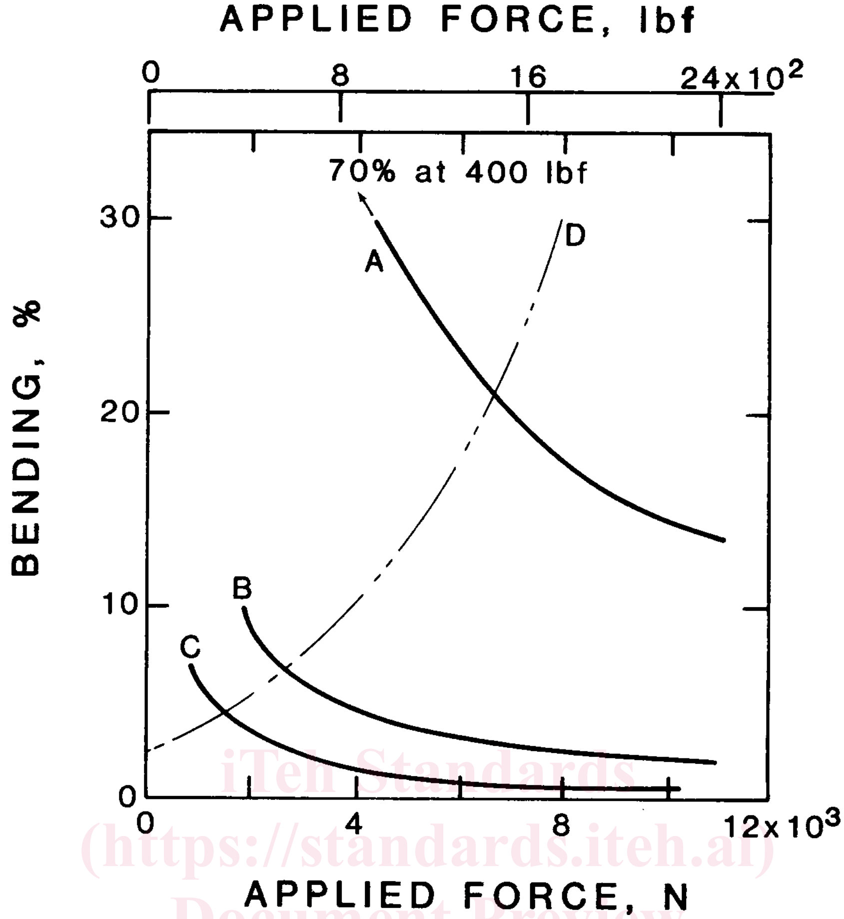
6. Methods of Verification of Alignment

6.1 The following methods may be applied to either the verification of alignment of the apparatus or during a specific test. (In general, they are in order of decreasing rigor and cost.)

6.1.1 *Method 1*—The specification measure of alignment is determined either at the test conditions (Type A) or during the test (Type T). This requires an array of strain sensors (for example, see Fig. 3 and 10.6) at two or more longitudinal positions along the reduced section. The strain sensors or components of the strain sensors must be attached to the specimen. Position the strain sensors so as to minimize the portion of the measured strain due to notches or fillets. (If a specific specimen configuration is required, specify the location of the strain sensors.)

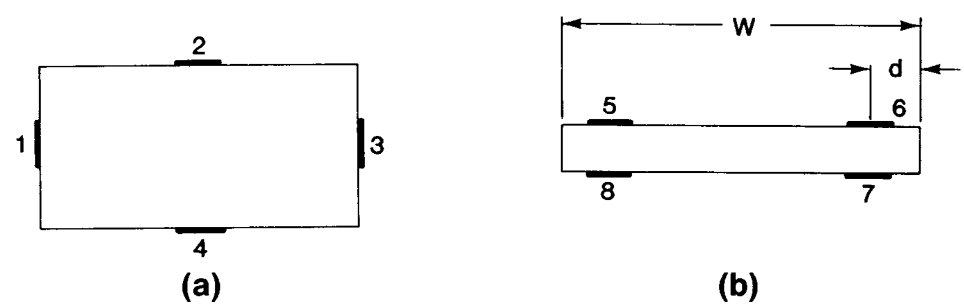
NOTE 4—When verifying alignment for apparatus (Type A), bending values may be considered to vary linearly with temperature at temperatures between those at which alignment was measured.

6.1.2 *Method 2*—Identical to Method 1, with the following exceptions:



NOTE 1—Curve A: Machine 1, threaded grip ends (**11**)
NOTE 2—Curve B: Machine 2, buttonhead grip ends (**11**)
NOTE 3—Curve C: Machine 3, grips with universal couplings (**7**)
NOTE 4—Curve D: schematic representation of a possible response from an offset load train (**16**)

FIG. 2 Effects of Applied Force on Percent Bending for Different Testing Machines and Gripping Methods



NOTE 1—*w* equals width of specimen.
NOTE 2—*d* equals distance from edge of specimen to centerline of strain sensor.

FIG. 3 Locations of Strain Sensors on Specimens of Rectangular Cross Section (Numbers Indicate Positions of Strain Sensors)

6.1.2.1 An array of strain sensors are centered at the mid-length of the reduced section of an unnotched specimen, or over the notch of a notched specimen (Note 2 applies).

6.1.2.2 If an extensometer is used on a notched specimen, the gage length should be at least 1.5 times the distance from the notch to the nearest fillet, but no closer to the tangent point of the nearest fillet than one-half of the reduced section diameter or width.

6.1.2.3 Note 4 does not apply.

6.1.3 *Method 3*—Test fixtures, machine, and specimens are dimensionally inspected for compatibility with good alignment and are examined visually or with suitable instrumentation to establish that wear, distortion, or other damage do not significantly affect alignment.

NOTE 5—When there is disagreement over the results of this test, Methods 1 or 2 for verifying alignment are recommended as the preferred method.

7. Apparatus

7.1 The readings from the individual strain sensors shall be repeatable at the rated force within 10 % of the permitted bending strain, during five successive force applications made after the first force application without reducing the applied force to less than 5 % of the rated force.

7.2 When multiple strain sensors are used as in 6.1.1 and 6.1.2, specimen size limitations may dictate the use of electrical resistance strain gages rather than extensometers employing mechanical linkages. Strain sensors, such as mechanical, optical, or electrical extensometers, as well as wire resistance or foil strain gages, can provide useful displacement data. The sensitivity of displacement measurement required by an applicable standard or specification depends on the amount of bending permitted.

7.3 For verification by Method 2, a single *extensometer* of the nonaveraging type may be used by rotating it to various positions around the perimeter during successive force applications and repeating the measurements as described in 10.5. In general, repeated force applications are not permitted in Type T tests (see 5.3) because they may affect the subsequently measured results.

NOTE 6—Repositioning the extensometer around the specimen does not usually give highly precise and reproducible results, but nevertheless is a technique which is useful for detecting large amounts of bending.

7.4 For determining maximum bending strain during Type T Tests (see 5.3), the use of three or four separate extensometers or an extensometer with multiple strain sensors which reads strain at three or more positions about the perimeter is recommended.

7.5 In most cases, the strain sensors will reference displacements between points on the specimen surfaces. However, it is also possible to reference displacements of surfaces attached to the specimen. Such an arrangement might consist of two plates firmly fixed to each end of the gage length of a specimen which is free of initial bending. Displacement measurements are made between corresponding pairs of points on these plates. Each pair of points is in a plane containing the specimen axis and is equally distant from this axis. For specimens of circular cross section, it is recommended that three or four pairs of points be used. A suitable extensometer may then be used to measure the displacement of the pairs of points as force is applied to the specimen. The strain at the specimen surface in the plane containing the pairs of points may, for small displacements, be taken equal to the strain computed at the measurement points multiplied by the ratio of the distance between the specimen applied force axis and the specimen surface to the distance from this axis to the measurement points. An apparatus that measures displacements at points external to the specimen surfaces should be qualified by showing that the bending strains calculated from these measurements agree with those calculated from strains measured directly on the specimen surface using the same application of force.

NOTE 7—When multiple extensometers are used, the strain may be determined by arithmetically averaging outputs. Electrical outputs are thought to be more accurate and reproducible than mechanical outputs.

8. Test Specimen

8.1 This practice refers to cylindrical specimens, thick rectangular specimens, and thin rectangular specimens.

8.2 This practice is valid for metallic and nonmetallic test specimens.

8.3 Quality of machining of test specimens is critical, for example, straightness, concentricity, flatness, and surface finish.

NOTE 8—Geometry and dimensions of test specimens taken from different product forms are described in the Test Specimen section of Test Methods E 8.

9. Calibration and Standardization

9.1 When three or more strain measurements are made at one or more longitudinal positions, the bending strains are determined from ratios of strain measurements. Consequently, the absolute accuracies of the extensometers are not significant. The sensitivities and reproducibilities of the instruments used are significant. All sensors should be calibrated by the same means (see Method E 83) and correction factors should be applied, if necessary, to bring their readings into agreement.

10. Procedure

10.1 Temperature variations during the verification test should be within the limits specified in the methods or practices which require the alignment verification.

10.2 The zero-force reference value of the strain sensors should be measured at a force no greater than approximately 1 % of that force at which the alignment verification is to be made.

10.3 To verify the alignment of the testing apparatus, repeated force applications are necessary. The amount of bending introduced by the load-train depends on the relative position of the various components which transmit force to the specimen and also on the care with which these parts are machined and assembled. Aspects of the test specimen, such as straightness and concentricity, are critical.

10.4 Repeated force should include assembly and disassembly of the components of the load-train, including the test specimen. Rotation in 90° increments (0°, 90°, 180°, 270°, repeat 0°) are recommended for a systematic study of the effects of rotational position of components of the load-train. Calculate the bending value for each combination of the components of the load-train. The maximum value should not exceed the specified values in the standard practices, testing methods, or material specifications.

10.5 When using a single, nonaveraging extensometer to evaluate apparatus (Type A), move the extensometer from one side of the specimen to the opposite at the rated force, then rotate 90° at the lower force limit (see 10.2), and repeat the process. Calculate a bending value from the four readings, that is, the readings from two applications of force and two removals of force. Remove the specimen from the grips, and repeat the loading force application sequence for systematic rotations of the components of the load-train as described in