
This standard is issued under the fixed designation D 3822; 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 covers the measurement of tensile properties of natural and man-made single textile fibers of sufficient length to permit mounting test specimens in a tensile testing machine.

1.2 This test method is also applicable to continuous (filament) and discontinuous (staple) fibers or filaments taken from yarns or tow. When the fibers to be tested contain crimp, or if the tow or yarns have been subjected to bulkling, crimping, or texturing process, the tensile properties are determined after removal of the crimp.

Note 1—Testing of filaments taken from yarns or tow, included in this test method was originally covered in Test Method D 2101, that is discontinued.

1.3 The words “fiber” and “filament” are used interchangeably throughout this test method.

1.4 This test method is also applicable to fibers removed from yarns, or from yarns processed further into fabrics. It should be recognized that yarn and manufacturing processes can influence or modify the tensile properties of fibers. Consequently, tensile properties determined on fibers taken from yarns, or from yarns that have been processed into fabrics, may be different than for the same fibers before being subjected to yarn or fabric manufacturing processes.

1.5 Test methods provide directions for measuring the breaking force and elongation at break of single textile fibers and for calculating breaking tenacity, initial modulus, chord modulus, tangent modulus, tensile stress at specified elongation, and breaking toughness.

1.6 Procedures for measuring the tensile properties of both conditioned and wet single fibers are included. The test method is applicable to testing under a wide range of conditions.

1.7 As the length of the test specimen decreases, the tenacity strength is likely to increase, but the accuracy of the tensile properties determined may decrease, which may require the need to increase the number of test specimens. This is particularly true for those properties dependent on the measurement of elongation, since the shorter lengths increase the relative effect of slippage and stretching of the test specimens within the jaws of either clamp.

2. Referenced Documents

2.1 ASTM Standards:

D 76 Specification for Tensile Testing Machine for Textiles
D 1776 Practice for Conditioning Textiles for Testing D 2101 Test Method for Tensile Properties of Single Man-Made Fibers Taken from Yarns and Tow
D 2258 Practice for Sampling Yarn for Testing D 3333 Practice for Sampling Man-Made Staple Fibers Sliver, or Tow for Testing
D 4448 Terminology Relating to Force and Deformation Properties of Textiles
E 178 Practice for Dealing with Outlying Observations

3. Terminology

3.1 Definitions:

3.1.1 breaking force, n—maximum force applied to a material carried to rupture.

3.1.1.1 Discussion—The observed breaking force for fiber and filaments is generally expressed as millinewtons (mN) or gram-force (gf).

3.1.2 breaking tenacity, n—the tenacity at the breaking force.

3.1.2.1 Discussion—Breaking tenacity is commonly expressed as centinewton per tex (cN/tex) or gram-force per denier (gf/denier). The breaking tenacity is calculated from the breaking force and the linear density of the unstrained specimen or obtained directly from tensile testing machines that can be suitably adjusted to indicate tenacity instead of force for purposes of known tonnage or linear density.

3.1.3 breaking toughness, n—toughness up to the breaking force.

3.1.3.1 Discussion—Breaking toughness is proportional to the area under the force-elongation curve from the origin to the breaking force. In textile strands, it is expressed as work (joules) per unit linear density.

3.1.4 chord modulus, n—in a stress-strain curve, the ratio of change in stress to the change in strain between two specified points on the curve.

3.1.4.1 Discussion—The chord modulus is expressed in millinewton per tex (cN/tex) or in gram-force per denier (gf/denier).

3.1.5 corresponding elongation, n—see elongation at specified force.

3.1.6 corresponding force, n—see force at specified elongation.

3.1.7 elongation, n—the ratio of the extension of a material to the length of the material prior to stretching, expressed as a percent.

3.1.7.1 Discussion—Elongation may be measured at any specified force or at rupture.

3.1.8 elongation at break, n—the elongation corresponding to the breaking force. (Syn: breaking elongation)

3.1.9 elongation at specified force, (EASF) n—the elongation associated with a specified force on the force-elongation curve. (Syn: corresponding force)

3.1.10 fiber, n—in textiles, a generic term for any of the various types of matter that form the basic elements of a textile article that is characterized by having a length at least 100 micrometers in diameter.

3.1.11 Discussion—Refer to D 123 definitions for man-made fiber and natural fiber, and Annex A1 and Annex A2 for additional information.

3.1.12 filament, n—in textiles, continuous fibers of indefinite length.

3.1.13 flaxen yarn, n—a yarn composed of (continuous) filaments assembled with or without twist.

3.1.14 force at specified elongation (FAE), n—the force associated with a specified elongation on the force-elongation or stress-elongation curve. (Syn: corresponding force)

3.1.15 initial modulus, n—in a stress-strain curve, the slope of the initial straight portion of the curve.

3.1.16 tangent modulus, n—decreased term in textile terminology. Use the preferred term in this method.

3.1.17 tangent modulus, n—in a stress-strain curve, the slope of change in stress to change in strain derived from the tangent to any point on the curve.

3.1.18 tenacity, n—in a tensile test, the force exerted on the specimen based on the linear density of the unstrained material.

3.1.19 tow, n—in man-made fibers, a twistless multifoil bundle suitable for conversion into staple fibers or diver, or for direct using into yarn.

3.1.20 yield point, n—in a stress-strain curve, the point beyond which work is not completely recoverable and permanent deformation takes place.

3.1.21 Discussion—In textile fibers, an exact proportionality does not exist between force and extension and there is not a true yield point. The point on the force-extension curve beyond which the force-extension ratio changes from that existing in the linear region to a second straight line or curve is frequently called the yield point of a textile strand or fiber. With animal fibers, permanent deformation does not occur until the extension reaches about 30%, or when the rate of extension is extremely slow or the fiber is held under tension for a long time. In fact, if animal fiber is stretched in water, or at high humidity conditions, to as much as 30% of the original length and allowed to relax for 24 h, the original force-extension curves may be reproduced.

3.1.22 Discussion—In tensile testing machines, a tensile testing machine at a predetermined gage length and rate of extension. Using the force-extension curve, the breaking force and elongation at break are determined. The force-elongation curve and linear density are used to calculate breaking tenacity, initial modulus, chord modulus, tangent modulus, tensile stress at specified elongation, and breaking toughness.

5. Significance and Use

5.1 Test Method D 3822 using test specimens having gage lengths of 10 mm (0.4 in.) or greater is considered satisfactory for acceptance testing of commercial shipments since the test method has been used extensively in the trade for acceptance testing. Critical discrepancies noted in Tables 1 and 2 were obtained from man-made fibers having a gage length of 25.4 mm (1.0 in.) and 254 mm (10 in.). Natural fibers or fibers having lesser or greater gage lengths may provide different values and may require comparative testing. (See 5.1.1.)

5.1.1 In cases of dispute arising from differences in reported test results when using Test Method D 3822 for acceptance testing of commercial shipments, the purchaser and the supplier should conduct comparative tests to determine if there is a real difference between their laboratories. Competent statistical assistance is recommended for the investigation of bias. As a minimum, the two parties should take a group of test specimens which are as homogeneous as possible and which are from a lot of material of the type in question. The test specimens should then be randomly assigned in equal numbers to each laboratory for testing. The average results from the two
laboratories should be compared using Student's t-test for unpaired data and an acceptable probability level chosen by the two parties before the testing begins. If a bias is found, either its cause must be found and corrected or the purchaser and supplier must agree to interpret future test results in view of test results with consideration to the known bias.

5.2 The breaking tenacity, calculated from the breaking force and the linear density, and the elongation at break are fundamental properties that are widely used to establish limitations on fiber processing or conversion and in their end-use applications. Initial modulus is a measure of the resistance of the fiber to extension at forces below the yield point. The tangent modulus and tenacity at specified elongation may be used to differentiate between the probable performance of fibers in processing and end-use performance. The breaking toughness is an indication of the durability of materials produced from the fiber.

5.3 It is recognized that computerized results are used extensively in the industry. When comparing results from the laboratories using computerized tensile testers, the algorithms used to derive results must be examined for parity, that is, be

---

**TABLE 1 Fiber Tenacity Properties Using 25.4 mm (1 in.) Gauge Length**

<table>
<thead>
<tr>
<th>Properties, Limits of Measurement and Materials</th>
<th>Number of Observations in Each Average</th>
<th>Single-Operator Processing</th>
<th>Within-Laboratory Laboratory Processing</th>
<th>Between-Laboratory Laboratory Processing</th>
</tr>
</thead>
<tbody>
<tr>
<td>Acetate</td>
<td>25.4 mm (1 in.)</td>
<td>0.94</td>
<td>0.96</td>
<td>0.97</td>
</tr>
<tr>
<td>Nylon</td>
<td>21.39</td>
<td>0.90</td>
<td>0.92</td>
<td>0.93</td>
</tr>
<tr>
<td>Aramid</td>
<td>20.34</td>
<td>0.98</td>
<td>0.99</td>
<td>0.99</td>
</tr>
<tr>
<td>Polyester</td>
<td>20.25</td>
<td>0.95</td>
<td>0.96</td>
<td>0.97</td>
</tr>
</tbody>
</table>

---

**TABLE 2 Fiber Tenacity Properties Using 254 mm (10 in.) Gauge Length**

<table>
<thead>
<tr>
<th>Properties, Limits of Measurement and Materials</th>
<th>Number of Observations in Each Average</th>
<th>Single-Operator Processing</th>
<th>Within-Laboratory Laboratory Processing</th>
<th>Between-Laboratory Laboratory Processing</th>
</tr>
</thead>
<tbody>
<tr>
<td>Acetate</td>
<td>2.05</td>
<td>0.94</td>
<td>0.96</td>
<td>0.97</td>
</tr>
<tr>
<td>Nylon</td>
<td>2.03</td>
<td>0.90</td>
<td>0.92</td>
<td>0.93</td>
</tr>
<tr>
<td>Aramid</td>
<td>2.02</td>
<td>0.98</td>
<td>0.99</td>
<td>0.99</td>
</tr>
<tr>
<td>Polyester</td>
<td>2.01</td>
<td>0.95</td>
<td>0.96</td>
<td>0.97</td>
</tr>
</tbody>
</table>

---

6.1 Constant-Rate of Extension (CRE) Type Tensile Testing Machine, conforming to Specification D 76, having adequate response characteristics to properly record the characteristics of the force-elongation curve, or the stress-strain curve of the fibers under test at the rate of extension specified in Table 3. The capacity of the machine must be selected for the break on the recorded curve to fall within 50 to 90% of full scale, preferably within 50 to 90% of full scale. It is permissible to use tensile testing machines that have a means of calculating and displaying the required results without the use of an electromagnetic recorder. The tensile testing machine must be equipped with a tank to provide for breaking fibers immersed in liquid, if tests on wet immersed specimens are required.

---

7.1 Distilled or Deionized Water, for use in wet specimen testing.

7.1.4 Wetting Agent, Nonionic—For wet specimen testing, for example, Triton X-100 to make 0.1% aqueous solution using water described in 6.7.
8.2 If fibers are to be tabbed, select a technique from Annex A1 or some other technique agreed upon by the purchaser and supplier.

8.3 For testing wet specimens without immersion, place the specimens in a container and immerse in a 1 % aqueous solution of a nonionic wetting agent in distilled or deionized water at ambient temperature until thoroughly soaked. (See 8.3.1 and 8.3.2.)

8.3.1 The time of immersion must be sufficient to completely wet out the specimens, as indicated by no significant changes in breaking force, or elongation at break when followed for a period of at least 10 min (0.1 h) and, when applicable, 250 min (10 h) or more. The most common gage lengths are 10, 20, 25, and 250 mm (0.4, 0.8, 1.0 and 10 in.).

Note 5—The results obtained are normally subject to less error if the gage length is selected to be at least portable, consistent with the length of fibers to be tested. When comparisons are to be made between different fibers or between fibers of the same species, it is desirable to use the same gage length for all tests, selecting it to accommodate the shortest fibers of interest.

9.1 Select the appropriate force range for the fiber to be tested.

9.2 Verify that the tensile tester is within calibration as specified in the manufacturer’s instructions.

9.3 Adjust the distance between the clamps to obtain the selected gage length of at least 10 mm (0.4 in.) and, when applicable, 250 mm (10 in.) or more. The most common gage lengths are 10, 20, 25, and 250 mm (0.4, 0.8, 1.0 and 10 in.).

10. Conditioning

10.1 Precondition the specimens by bringing them to approximate moisture equilibrium in the standard atmosphere for preconditioning textiles as directed in Practice D 1776 or, if applicable, in the specified atmosphere in which the testing is to be performed.

10.2 After preconditioning, bring the test specimens to moisture equilibrium for testing in the standard atmosphere for testing textiles as directed in Practice D 1776 or, if applicable, in the specified atmosphere in which the testing is to be performed.

11. Procedure

11.1 Test the conditioned specimens in the standard atmosphere for testing textiles, which is 21 ± 1°C (70 ± 2°F) and 65 ± 2 % relative humidity.

11.2 Mount a test specimen in the jaws of the clamps, removing slack without stretching the specimen. The specimen must be straight within the jaws and extreme care must be taken to ensure that the fiber specimen lies on the line of action between the force-measuring device and the point where the fiber leaves the test specimen. Any deformation that tends to produce transverse motion of the clamps and jaws will introduce errors in measurements of elongation and may contribute to premature failure.

11.2.1 For testing wet specimens without immersion, remove a specimen from the water and immediately mount it in the clamps as directed in 11.1 and 11.2. Perform the test within two minutes after removal of the specimen from the water at ambient temperature until thoroughly soaked. (See 8.3.1 and 8.3.2.) Test while the specimen is immersed in the water bath.

Note 6—In general, it will be found that no one type of fiber mounting will be suitable for all types and sizes of fibers and experience may show that some mounting techniques are much more efficient than others. Experience and experiment will be the key factors to be considered in selecting the most satisfactory mounting method for a given laboratory.

11.3 For specimens having crimp, use a pretension of 0.3 to 1.0 % of the gage length to remove the crimp while the fiber is placed in the clamps. If certain fibers with a high degree of crimp require greater pretensioning than the amount specified, determine the minimum pretension as directed in Appendix X3. Notwithstanding the results of test or visual examination, the specimen is considered to have had no crimp if the crimp is not completely removed even at these greater force applications, record this fact.

11.4 Start the tensile testing machine and any associated auxiliary equipment, extending the fiber specimen to break at the selected extension speed and record the data of interest. For fibers of low stiffness, it may be advisable to first back off the moving jaw of the testing machine to allow the fiber to be slack at the time the testing machine is started.

11.5 After breaking the specimen, return the testing machine to its starting condition and remove all remains of the broken specimen from the clamp faces. Pieces of broken fiber remaining in the jaws may adversely affect the reliability of the results from properly held the succeeding specimens.

11.6 Test successive specimens as directed in 11.1-11.5 until the remaining specimens have been broken. If the number of fiber specimens breaks in a row of tests is 5 % of the number tested, repeat the test after adjusting the jaw and clamping mechanism as described in 11.6.1-11.6.3.

11.6.1 If a specimen slips in the jaws, breaks at the edge of the jaws, or, if any reason attributable to faulty machine operation the result falls 20 % below the average of the breaking force set of specimens, discard the result and test another specimen. Continue until the required number of acceptable breaks have been obtained.

11.6.2 The decision to discard the results of a break shall be based on observation of the specimen during the test and upon the inherent variability of the fiber. It is difficult to determine the precise reason for certain specimens breaking near the edge of the jaws. If a jaw break is caused by damage to the specimen by the jaws, the results should be discarded. If, however, it is merely due to randomly distributed weak places, it is a permissible minor result. Refer to Practice E 178 for treatment of outlying data points.

11.6.3 If a fiber manifests any slippage in the jaws or if the percent of the specimens break at a point within 3 mm (1/8 in.) of the edge of the edge, only the jaw faces may be padded. (2) the fiber may be cured under the jaw face area, or (3) the surface of the jaw face may be modified. If any of the modifications listed above are used, state the method of modification in the report.

11.7 Obtain the elongation data by means of a suitable recording device, or computer, at the same time as the breaking force is determined unless otherwise agreed upon, as provided for in an applicable material specification.

12. Calculation

12.1 Breaking Force—Record the breaking force of individual specimens to three significant digits as read directly from the testing machine expressed in kN (g). The breaking force of a single specimen is the maximum force at which a fiber specimen breaks under force.

12.2 Breaking Tensile Strength—Calculate the breaking tensile strength of individual specimens to three significant digits, using Eq 1:

\[ S = \frac{F}{A} \]  

where:

- \( F \) = breaking force of a single specimen (N or lbf),
- \( A \) = effective cross-sectional area of the specimen (mm² or in²).

12.3 Effective Specimen Length—Calculate the effective specimen length of individual specimens to three significant digits, using Eq 2. (See Annex A2 and Figs. X1.1 and X1.2.)

\[ L_e = L_d \times \frac{R}{S} \]

where:

- \( L_e \) = effective specimen length, mm (in.),
- \( L_d \) = initial distance between clamps (gage length), mm (in.),
- \( R \) = effective strength of the fiber, N/mm² or lbf/in².

12.4 Elongation—From XY type recorders, calculate the elongation at break, or other specified elongation, of individual specimens to three significant digits, using Eq 3:

\[ \varepsilon = \frac{L - L_e}{L_d} \]

where:

- \( \varepsilon \) = elongation percent, at the specified force,
- \( L \) = distance along the zero-stress axis from the point corresponding to the tensile load line to the point where the load line intersects the zero-stress axis, to a point corresponding to the breaking stress, or other specified stress,
- \( L_e \) = effective specimen length, mm (in.),
- \( L_d \) = initial distance between clamps (gage length), mm (in.),
- \( R \) = effective strength of the fiber, N/mm² or lbf/in².

12.5 Initial Modulus—Locate the tangent portion of the stress-strain curve between the tangent point for the zero-stress line and the proportional elastic limit through the zero-stress axis. Measure the stress and the corresponding elongation with respect to the stress axis. Calculate initial modulus in cN/mm (g/den) to three significant digits, using Eq 4 (see Appendix X2 and Figs. X1.1 and X1.2).

\[ E = \frac{R}{\varepsilon} \]

where:

- \( E \) = initial modulus, cN/mm (g/den),
- \( R \) = stress at the tangent line on the stress-strain curve, cN/mm (g/den),
- \( \varepsilon \) = corresponding strain with respect to the tangent line and determined stress.

12.6 Chord Modulus—Determine the stress for a specified elongation, such as 10 % and label that point on the stress-strain curve as \( P_{10} \), Likewise, label a second point, \( P_{S} \), at a specified elongation, such as 5 % elongation. Draw a straight line through points \( P_{10} \) and \( P_{S} \), intersecting the zero-stress axis. Other elongation values may be used, for example, when provided for in an applicable material specification. Calculate chord modulus in cN/mm (g/den) to three significant digits, using Eq 5 (see Appendix X2 and Fig. X2.1):

\[ E \times \varepsilon = \frac{R}{\varepsilon} \]

where:

- \( E \) = chord modulus between specified elongations, cN/mm (g/den),
- \( \varepsilon \) = specified stress on the chord, cN/mm (g/den),
- \( R \) = corresponding strain with respect to the constructed line and the determined stress.
13. Report

13.1 State that the specimen were tested as directed in ASTM Test Method D 3822. Describe the material or product sampled and the method of sampling used.

13.2 Report the following information for both, the laboratory sampling units and the lot average as applicable to a material specification or contract order.

13.2.1 Average breaking tension or breaking elongation.

13.2.2 Average breaking tension or breaking elongation at a specific elongation.

13.2.3 Average elongation at break or other specified force.

13.2.4 Average initial modulus.

13.2.5 Average chord modulus and the two elongations used in the calculation.

13.2.6 Average tensile modulus and the point on the stress-strain curve at which it was calculated.

13.2.7 Tensile stress and the specified elongation.

13.2.8 Breaking toughness, and whether or not the work-to-remove cannot be expressed as a single point.

13.2.9 Standard deviation, coefficient of variation, or both, for each property, if calculated.

13.2.10 Effective specimen length, when applicable.

13.2.11 Testing temperature and percent relative humidity if the test was performed on specimens conditioned at other than the standard conditions for testing textiles.

13.2.12 For wet specimens, whether specimens were tested wet in air, or while immersed, and the temperature of the water bath, if applicable.

13.2.13 If requested, include a force-elongation curve, with chart units and speed indicated, as part of the report.

13.2.14 Number of specimens tested.

13.2.15 Protocols applied, if any.

13.2.16 Make and model of tensile testing machine.

13.2.17 Type of clamps used.

13.2.18 Type of padding used in jigs, technique for fastening specimens gripped in the jaws, or modification of jaw faces if used.

13.2.19 Nominal gauge length, clamp error, rate of specimen extension and full-scale range force used for testing.

13.2.20 For computer derived data, identity new slope and breaking points were determined and identify the program (software) used.

14. Precision and Bias

14.1 Interlaboratory Test Data — An interlaboratory test was run in 1983 in which randomly-drawn samples of four materials were tested in each of six laboratories. Two operators in each laboratory each tested ten specimens of each material using a 10-in. gauge length and a 1-in. gauge length. The components of variance for tension, initial modulus and elongation at break expressed as standard deviations were calculated to be the values listed in Table 5 for gauge lengths of 1 in. and Table 5 for gauge lengths of 10 in. The four classes of fibers were: 42 denier low tenacity; 30 denier medium tenacity, high modulus; nylon; and 15 denier high tenacity, high modulus.

14.2 Precision — For the components of variance reported in Tables 5 and 6, two averages of observed values should be considered significantly different at the 95% confidence level if the difference equals or exceeds the critical differences listed in Tables 1 and 2, respectively.

14.3 Bias — The values of the tenacity, initial modulus, and elongation at break can only be defined in terms of a specific test method. Within this limitation, the procedures in Test Method D 3822 for measuring these properties has no known bias.

15. Keywords

15.1 tension (tensile) property/property: textile fibers
A2.1 The effective specimen length can be determined by adding the initial length between the clamp faces (nominal gage length) and adding the length contributed by the clamp error (see Fig. A2.1).

A2.1.1 The fiber clamps used in tensile testing can affect the apparent fiber properties observed. The customary method of determining specimen elongation, by measuring clamp separation, assumes that the stresses applied to the specimen during the test are confined by the clamps to the original specimen length. Most fiber clamps do not completely confine the stresses, and therefore, an erroneously high elongation may be measured as the result of being based on a nominal gage length which is shorter than the effective gage length.

A2.1.2 Clamp errors may occur in nondestructive testing, such as tests for elastic performance, modulus, etc., as well as in destructive testing. In all cases, the procedure for estimation of effective gage length should employ stresses comparable to those experienced in the corresponding tensile testing.

A2.1.3 The magnitude of the error determined for any one clamping system may vary according to the surface characteristics, linear density, test environment, breaking force, and extensibility of the material. Accordingly, changes in any of these factors will require a re-evaluation of the error.

A2.2 Determine the clamp error as follows:

A2.2.1 Mount the fibers in the clamps in the normal manner using a pretension of 10 to 50 cN/mm (0.01 to 0.05 g/d). (See Note A2.1.)

A2.2.2 Mark the recorder chart to locate the crosshead in reference to chart position (Note A2.2).

Note A2.2—The marking of the crosshead position in reference to the chart position allows observation of any slack caused by the extensibility of the fiber specimens from the clamps during tightening of the clamps.

A2.2.3 Break the representative groups of fibers at three or more different nominal gage lengths (Note A2.3). Maintain the same rate of extension at each gage length.

Note A2.3—Limits within which the gage lengths are chosen will be dictated by the accuracy with which the shortest gage length can be determined, and in the case of a destructive test, the maximum length of specimens which will not be affected by flaws distribution. The latter point is of importance when, by increasing the gage length, the probability of including a major flaw (causing premature fiber failure) in the test length is increased. Fiber inclusion may be suspected when the average elongation does not increase proportionally with increase in gage length. This will be indicated when the straight line portion (Fig. A2.7) curves downward the curve at longer gage lengths.

A2.2.4 Break ten specimens in each representative group of fibers. If the variation in average breaking tenacity among data obtained at different gage lengths is greater than ±3 percent, break additional specimens until the variation in average breaking tenacity among groups does not exceed ±3 percent.

A2.2.5 Calculate the average apparent elongation at break in denormation units, for each nominal gage length. Plot the apparent elongation versus the nominal gage length (for example see Fig. A2.2.1). Draw a straight line (Note A2.2) through the plotted points to the nominal gage length axis, point C, and extrapolate to zero elongation (BC, Fig. A2.1).

The distance between the intersection of this line and zero nominal gage length, along the gage length axis (CD), represents the average clamp error.

Note A2.4—The preferred procedure for drawing the line is by least mean squares method, although in many cases visual inspection is adequate.

A2.3 Calculate the Effective Gage Length as follows:

\[
\text{Effective Gage Length} = \frac{\text{Clamp Error Length} + \text{Nominal Gage Length}}{\text{Clamp Error}} \quad (A2.2)
\]

\[
\text{Effective Gage Length} = \frac{\text{Clamp Error Length}}{\text{Clamp Error}} + \text{Nominal Gage Length} \quad (A2.3)
\]

X1.1 In the case of a fiber exhibiting a region that obeys Hooke's law (Fig. X1.1), a discontinuity of the linear region of the stress-strain curve is constructed through the zero-stress axis. This intersection point B is the zero-extension point from which strain is measured.

X1.1.1 The initial modulus can be determined by dividing the stress at any point along the line BD (or its extension) by the strain at the same point (measured from point B, defined as zero-strain). Point C, the point where line BD first touches the stress-strain curve is the tangent point.

X1.2 In the case of a fiber that does not exhibit any linear region (Fig. X1.2), a tangent K' is constructed to the maximum slope and its extension intersecting the zero-stress axis at point B. This intersection point B is the zero point from which strain is measured. Point C, the point where line K' first touches the stress-strain curve, is the tangent point.

X1.2.1 The initial modulus may be determined by dividing the stress at any point along line B' (or its extension) by the strain at the same point (measured from point B', defined as zero-strain).

X2.1 In a typical stress-strain curve (Fig. X2.1), a straight line is constructed through the zero-stress axis, such as zero-strain point A' and a second point, such as 10% strain, point M'. The intersection point A' is the zero strain point from which the specimen strain is measured.

X2.1.1 The chord modulus can be calculated by dividing the stress at any point along line A'M' (or its extension) by the specimen stress at the same point (measured from point A', defined as zero-strain).

X2.1.2 Fig. X2.1 also represents a straight line constructed through any two specified points, point O' and point R' other than zero and 10% strain. In this case, the line extends through the zero stress axis at point B. This intersection is the zero strain point from which specimen strain is measured. The chord modulus can be determined by dividing the stress at any point along the line O'R' (or its extension) by the specimen strain at the same point (measured from point B', defined as zero-strain).
A2.1 The effective specimen length can be determined by adding the initial length between the clamp faces (nominal gage length) and adding the length contributed by the clamp error (see Fig. A2.1).

A2.2.1 The fiber clamps used in tensile testing can affect the apparent fiber properties observed. The customary method of determining specimen elongation, by measuring clamp separation, assumes that the stresses applied to the specimen during the test are confined by the clamps to the original specimen length. Most fiber clamps do not completely confine the stresses, and therefore, an erroneously high elongation may be measured as the result of being tested on a nominal gage length which is shorter than the effective gage length.

A2.2.2 Mark the recorder chart to locate the crosshead in reference to chart position (Note A2.2).

Note A2.2—The marking of the crosshead position in reference to the chart position allows observation of any slack caused by the extension of the fiber specimens from the clamp during tightening of the clamp.

A2.2.3 Break the representative groups of fibers at three or more different nominal gage lengths (Note A2.3). Maintain the same rate of extension at each gage length.

Note A2.3—Limits within which the gage lengths are chosen will be dictated by the accuracy with which the shortest gage length can be determined, and in the case of a destructive test, the maximum length of specimens which will not be affected by flaw distribution. The latter point is of importance when, by increasing the gage length, the probability of including a major flaw (causing premature fiber failure) in the test length is increased. The inclusion may be suspected when the average elongation does not increase proportionately with increase in gage length. This will be indicated when the straight line portion (Fig. A2.7) curves toward the abscissa at longer gage lengths.

A2.2.4 Break ten specimens in each representative group of fibers. If the variation in average breaking tenacity among data obtained at different gage lengths is greater than ±3 percent, break additional specimens until the variation in average breaking tenacity among groups does not exceed ±5 percent.

A2.2.5 Calculate the average apparent elongation at break in denoticum units, for each nominal gage length. Plot the apparent elongation versus the nominal gage length (for example see Fig. A2.2.1). Draw a straight line (Note A2.4) through the plotted points to the nominal gage length axis, point C, and extrapolate to zero elongation (BC, Fig. A2.1). The distance between the intersection of this line and zero nominal gage length, along the gage length axis (CD), represents the average clamp error.

Note A2.4—The preferred procedure for drawing the line is by means of the least squares method, although in many cases visual inspection is adequate.

A2.3 Calculate the Effective Gage Length as follows:

\[
\text{Effective Gage Length} = \text{Clamp Error Length} + \text{Nominal Gage Length}
\]

A2.4 The use of a precut specimen is shown in the example graph for the determination of the effective gage length.

---

X1.1.1 In the case of a fiber exhibiting a region that obeys Hooke's law (Fig. X1.1), a continuation of the linear region of the stress-strain curve is constructed through the zero-stress axis. This intersection point B is the zero-stress strain point from which strain is measured.

X1.1.2 The initial modulus can be determined by dividing the stress at any point along the line BD (or its extension) by the strain at the same point (measured from point B, defined as zero-strain). Point C, the point where line BD first touches the stress-strain curve, is the tangent point.

X1.2.1 In the case of a fiber that does not exhibit any linear region (Fig. X1.2), a tangent KB is constructed to the maximum slope and its extension intersecting the zero-stress axis at point B. This intersection point B is the zero point from which strain is measured. Point C, the point where line KB first touches the stress-strain curve, is the tangent point.

X1.2.2 The initial modulus may be determined by dividing the stress at any point along line KB (or its extension) by the strain at the same point (measured from point B, defined as zero-strain).

---

X1.2 CHORD MODULUS

---

X2.1.1 In a typical stress-strain curve (Fig. X2.1), a straight line is constructed through the zero-stress axis, such as zero-strain point A and a second point, such as 10% strain, point M. The intersection point A' is the zero strain point from which the specimen strain is measured.

X2.1.2 The chord modulus may be calculated by dividing the stress at any point along line A'M (or its extension) by the specimen stress at the same point (measured from point A', defined as zero strain).

X2.1.2.1 Fig. X2.1 also represents a straight line constructed through any two specified points, point O and point R' other than zero and 10% strain. In this case, the line extends through the zero stress axis at point B'. This intersection is the zero strain point from which specimen strain is measured. The chord modulus can be determined by dividing the stress at any point along the line OR' (or its extension) by the specimen strain at the same point (measured from point B', defined as zero-strain).
A2. EFFECTIVE SPECIMEN LENGTH

A2.1 The effective specimen length can be determined by adding the initial length between the clamp faces (nominal gage length) and adding the length contributed by the clamp error (see Fig. A2.1).

A2.1.1 The fiber clamps used in tensile testing can affect the apparent fiber properties observed. The customary method of determining specimen elongation, by measuring clamp separation, assumes that the stresses applied to the specimen during the test are confined by the clamps to the original specimen length. Most fiber clamps do not completely confine the stresses, and therefore, an erroneously high elongation may be indicated as the result of being based on a nominal gage length which is shorter than the effective gage length.

A2.1.2 Clamp errors may occur in nondestructive testing, such as tests for elastic performance, modulus, etc., as well as in destructive testing. In all cases, the procedure for estimation of gage length should employ stresses comparable to those experienced in the corresponding tensile testing.

A2.1.3 The magnitude of the error determined for any one clamping system may vary according to the surface characteristics, linear density, test environment, breaking force, and extensibility of the material. Accordingly, changes in any of these factors will require a re-evaluation of the error.

A2.2 Determine the clamp error as follows:

A2.2.1 Mount the fibers in the clamps in the normal manner using a pretension of 10 to 50 cN/m (0.01 to 0.05 g/d). (See Note A2.1.)

Note A2.1—The use of a pretension eliminates slack in the specimen. Any slack would be erroneously computed as clamp error by the testing procedure.

A2.2.2 Mark the recorder chart to locate the crosshead in reference to chart position (Note A2.2).

Note A2.2—The marking of the crosshead position in reference to the chart position allows observation of any slack caused by the extrusion of the fiber specimen from the clamp during tightening of the clamp.

A2.2.3 Break the representative groups of fibers at three or more different nominal gage lengths (Note A2.3). Maintain the same rate of extension at each gage length.

Note A2.3—Limits within which the gage lengths are chosen will be dictated by the accuracy with which the shortest gage length can be determined, and in the case of a destructive test, the maximum length of specimen which will not be affected by flaw distribution. The upper limit is of importance when, by increasing the gage length, the probability of including a major flaw (causing premature fiber failure) in the test length is increased. Flaw inclusion may be suspected when the average elongation does not increase proportionally with increase in gage length. This will be indicated when the straight line plot (Fig. A2.1) curves toward the abscissa at longer gage lengths.

A2.2.4 Break ten specimens in each representative group of fibers. If the variation in average breaking tenacity among data obtained at different gage lengths is greater than ± 5 percent, break additional specimens until the variation in average breaking tenacity among groups does not exceed ± 3 percent.

A2.2.5 Calculate the average apparent elongation at break in den. units, for each nominal gage length. Plot the apparent elongation versus the nominal gage length (for example see Fig. A2.1). Draw a straight line (Note A2.4) through the plotted points to the normal gage length axis point C, and extrapolate to zero elongation (BC, Fig. A2.1). The distance between the intersection of this line and zero nominal gage length, along the gage length axis (CD), represents the clamp error.

Note A2.4—The preferred procedure for drawing the line is by means of the least squares method, although in many cases visual inspection is adequate.

A2.3 Calculate the Effective Gage Length as follows:

\[
\text{Effective Gage Length} = (\text{gage length} + \text{nominal gage length})
\]

X1. INITIAL MODULUS

X1.1 In the case of a fiber exhibiting a region that obeys Hooke's law (Fig. X1.1), a continuation of the linear region of the stress-strain curve is constructed through the zero-stress axis. This intersection point B is the zero extension point from which strain is measured.

X1.1.1 The initial modulus can be determined by dividing the stress at any point along the line BD (or its extension) by the strain at the same point (measured from point B, defined as zero-strain). Point C, the point where line BD first touches the stress-strain curve is the tangent point.

X1.2 The case of a fiber that does not exhibit any linear

\[\text{Fig. X1.1: Example of Material with Hookean Region} \]

\[\text{Fig. X1.2: Example of Material with No Hookean Region} \]

X2. CHORD MODULUS

X2.1 In a typical stress-strain curve (Fig. X2.1), a straight

\[\text{Fig. X2.1: Example of Construction for Chord Modulus} \]

line is constructed through the zero-stress axis, such as zero-strain point A" and a second point, such as 10% strain, point M". The intersection point A' is the zero strain point from which the specimen strain is measured.

X2.1.1 The chord modulus may be calculated by dividing the stress at any point along line A'M" (or its extension) by the specimen stress at the same point (measured from point A", defined as zero-strain).

X2.1.2 Fig. X2.1 also represents a straight line constructed through any two specified points, point C' and point B", other than zero and 10% strain. In this case, the line extends through the zero stress axis at point R'. This intersection is the zero strain point from which specimen strain is measured. The chord modulus can be determined by dividing the stress at any point along the C'R' (or its extension) by the specimen strain at the same point (measured from point B", defined as zero-strain).