Designation: D 3379 – 75 (Reapproved 1989)$^{\epsilon 1}$

Standard Test Method for Tensile Strength and Young's Modulus for High-Modulus Single-Filament Materials[1]

This standard is issued under the fixed designation D 3379; 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 Department of Defense.

ϵ^1 NOTE—Editorial changes were made throughout in May 1989.

1. Scope

1.1 This test method covers the preparation, mounting, and testing of high-modulus single-filament materials [over > 21×10^9 Pa (> 3×10^6 psi)] for the determination of tensile strength and Young's modulus, at room temperature.

1.2 This test method is limited to single filaments utilizing a fixed gage length at least 2000 times longer than the nominal filament diameter.

1.3 *This standard may involve hazardous materials, operations, and equipment. This standard does not purport to address all of the safety concerns 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:*

D 638 Test Method for Tensile Properties of Plastics[2]

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

E 6 Terminology Relating to Methods of Mechanical Testing[3]

3. Terminology

3.1 *Definitions:*

3.1.1 *mounting tab*—a thin paper, compliant metal, or plastic strip with a longitudinal slot of fixed gage length. The mounting tab should be as thin as practicable to minimize filament misalignment.

3.1.2 *system compliance*—that portion of the indicated elongation contributed by the load train system and the specimen gripping system. This compliance must be determined experimentally for a given combination of test machine conditions, grip system and mounted specimen. It must be subtracted from the indicated elongation to yield true specimen elongation in the gage length (Note 1). System compliance correction will not apply when elongation in the specimen gage length is determined by direct measurement.

NOTE 1—The magnitude of the system compliance can be a significant portion of the indicated compliance. Extreme care must be exercised in the determination of this correction as outlined in 8.2.

3.2 Definitions of terms and symbols relating to this test method appear in Terminology E 6, and the Appendix to Test Method D 638.

4. Summary of Test Method

4.1 A random selection of single filaments is made from the material to be tested. The filaments are center-line mounted on special slotted tabs. The tabs are gripped so that the test specimen is aligned axially in the jaws of a constant-speed movable-crosshead test machine. The filaments are then stressed to failure at a constant strain rate.

4.2 For this test method, filament cross-sectional areas are determined by planimeter measurements of a representative number of filament cross sections as displayed on highly magnified photomicrographs. Alternative methods of area determination such as optical gages, image-splitting microscope, linear weight-density method, etc, may also be used.

4.3 Tensile strength and Young's modulus are calculated from the load-elongation records and the cross-sectional area measurements.

5. Significance and Use

5.1 Properties determined by this test method are very useful in the evaluation of new materials at the research and development levels. Very short filaments, such as whiskers of nonuniform cross section, call for highly specialized test techniques not covered by this test method.

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[1] This test method is under the jurisdiction of ASTM Committee C-28 on Advanced Ceramics and is the direct responsibility of Subcommittee C28.07 on Ceramic Matrix Composites.

Current edition approved Feb. 28, 1975. Published April 1975.

[2] *Annual Book of ASTM Standards,* Vol 08.01.

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

6. Apparatus

6.1 Tensile strength and Young's modulus properties of single-filament specimens may be determined by several established testing procedures. The apparatus described herein shall use a constant-strain-rate tensile testing machine with a test specimen bonded to a suitable tab.

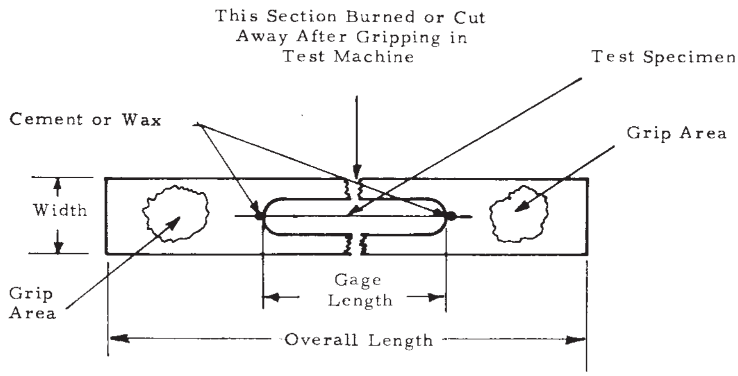

FIG. 1 Tab Showing Typical Specimen Mounting Method

6.2 *Stationary Member*—This member shall be rigidly fixed to the test machine frame and shall contain a housing, located on the machine centerline, for a load cell and part of the specimen grip assembly.

6.3 *Movable Member*—This member, also called the crosshead, shall be driven at a constant preset strain rate. It shall contain an adaptor, on the machine centerline, for the other part of the specimen grip assembly.

6.4 *Load Cell*—The load-sensing device shall have sufficient capacity to accept and transmit load signals above the highest anticipated loads. Its accuracy shall be verified in accordance with Practices E 4.

6.5 *Grips*—The gripping system shall be of a design such that axial alignment may be easily accomplished without damaging the specimens.

6.6 *Load- and Elongation-Measuring System*—A record of test load to failure, with corresponding indicated elongation, shall be provided. For this test method, chart and crosshead speeds shall be provided to produce acceptable data.

6.7 *Mounting Tabs*—A typical test specimen mounting tab is shown in Fig. 1. Alternative methods of specimen mounting may be used.

6.8 *Metallographic Capability*—This test area should have the following capabilities:

6.8.1 *Sample Preparation and Encapsulation in Potting Compound*.

6.8.2 *Metallographic Polishing Units*.

6.8.3 *Metallograph Unit*, with high magnification capabilities (to 3000×).

6.9 *Area Planimeter*.

6.10 Other methods of measuring specimen cross-sectional areas may be used (see 4.1).

7. Test Specimens

7.1 *Selection of Test Specimens*—Special care shall be taken to assure obtaining representative strand or single-filament segments. A statistically significant number of single-filament test specimens are gently separated from the strand bundle. Selection should be random. The critical considerations are that the filament be not visibly damaged or attached to another filament, and have sufficient length.

7.2 Segments used for area determinations shall represent the same population as those used for tensile testing.

8. Procedure

8.1 *Test Specimen Mounting*:

8.1.1 Loosely place a strand bundle from the material to be tested on a suitable work surface.

8.1.2 Randomly choose and carefully separate a suitable single-filament specimen from the strand bundle.

8.1.3 The specimen gage length shall be the same for a given test group. Determine the length to the nearest ±0.1 mm.

NOTE 2—For this test method, the specimen gage length shall be between 20 and 30 mm. The tab shape should be proportioned as shown in Fig. 1, with an overall length about three times the specimen gage length and a width of about one half the gage length.

8.1.4 Use a tab (Fig. 1) for specimen mounting. Center the specimen over the tab slot with one end taped to the tab.

8.1.5 Lightly stretch the filament and tape its opposite end to the tab.

8.1.6 Carefully place a small amount of suitable adhesive[4] on the filament at each edge of the slot and bond the filament to the mounting tab.

8.1.7 Repeat 8.1.2-8.1.6 to complete the test group.

8.2 *Filament Specimen Testing*:

8.2.1 Stabilize the tensile test machine in accordance with the manufacturer's instructions.

8.2.2 Calibrate the test machine before testing begins and at 4-h intervals throughout the work period.

8.2.3 Set the crosshead and chart recorder speeds to provide a test time to specimen fracture of about 1 min. Make load scale range selection such that specimen fracture occurs above 25 % of full scale.

8.2.4 Grasp a mounted test specimen in one tab grip area by the faces of the stationary jaws.

[4] H. Courtwright No. 70 cement crystals, melted by a microtorch flame, have been found satisfactory for this test method. Ordinary sealing wax has proven equally effective.

8.2.5 Position the crosshead so that the other tab grip area may be grasped as in 8.2.4. Visually check the axial specimen alignment.

8.2.6 With the mounting tab unstrained, cut both sides of the tab or burn it away very carefully at mid-gage as shown in Fig. 1. If specimen damage occurs, discard the specimen.

8.2.7 Tension the specimen with the chart continuously recording the test load to failure and the indicated elongation.

8.2.8 Follow 8.2.4-8.2.7 for each specimen of the test group.

9. Calculation

9.1 *Measurement of Cross-Sectional Area*—Determine the average specimen area for a test group by planimetering a representative number of filament cross sections (minimum of ten), as shown on photomicrographs as prepared by the metallographic facility (9.3.1). Where doubt exists as to the cross-sectional area of a test specimen, prepare and measure its broken ends by this method. Use a magnification of 2000× to 3000× on the photomicrographs for this technique.

9.2 *Determination of System Compliance*:

9.2.1 *Elongation*—The specimen fragility prevents the use of normal strain-sensing devices, such as strain gages, extensometers, etc. However, an optical method may be used to detect gage section elongation directly. Use an alternative means for determining the true gage length elongation from analysis of the chart speed, crosshead speed, and the system compliance.

9.2.2 *System Compliance*—This compliance must be determined experimentally for a given test machine and grip system. It must be subtracted from the chart indicated compliance to yield the actual specimen elongation in the gage length.

9.2.3 Use a test material of the same elemental structure as the materials to be evaluated, which exhibits a constant Young's modulus of comparable magnitude, to determine the system compliance.

9.2.4 Mount a group of single-filament specimens by the specified tab method, 8.1.1-8.1.7, at several different gage lengths (minimum of three samples each). These tabs must be made of the same material as that used in the procedure outlined herein. Determine the gage length to the nearest ±0.1 mm.

9.2.5 Carry out standard tensile testing (8.2) of these specimens.

9.2.6 Analyze the recorder charts as follows: Draw a line through the initial straight line section of the generated load-time curve to the extremes of the chart records (see Fig. 2). Measure the chart extension in millimetres as shown. Calculate the indicated compliance, C_a, for each sample as in 9.5.1.

9.2.7 On Cartesian coordinate paper, plot each indicated compliance on the *Y*-axis and its gage length on the *X*-axis for all specimens (Fig. 3). Draw the best fit line through each set of points to intersect the zero gage length axis. The vertical displacement indicated shall be called the zero gage length intercept or the system compliance, C_s.

9.2.8 Determine the true compliance, C, by subtracting the system compliance, C_s, from the indicated compliance, C_a.

9.3 *Area*—Calculate the area as follows:

$$A = \frac{\Sigma a_f \times 10^{-6}}{N(M_f)^2} \tag{1}$$

where:

A = average filament area, m^2(or in.^{2}),
a_f = area of one filament, mm^2(or in.^{2}),
N = number of filaments measured, and
M_f = photomicrograph magnification factor.

NOTE 3—Eq 1 is applicable only to SI units. A suitable conversion factor must be used for inch-pound units.

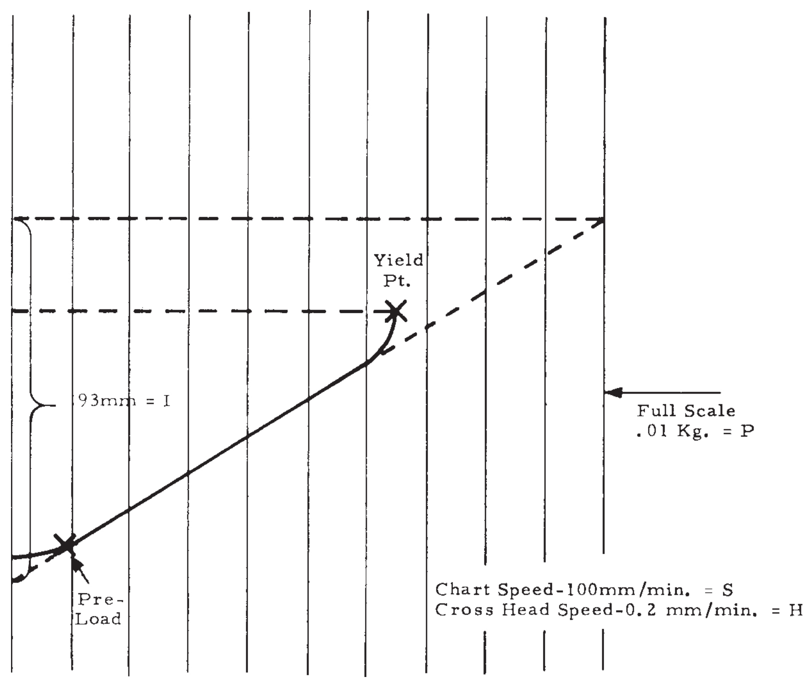

FIG. 2 Typical Load-Time Curve

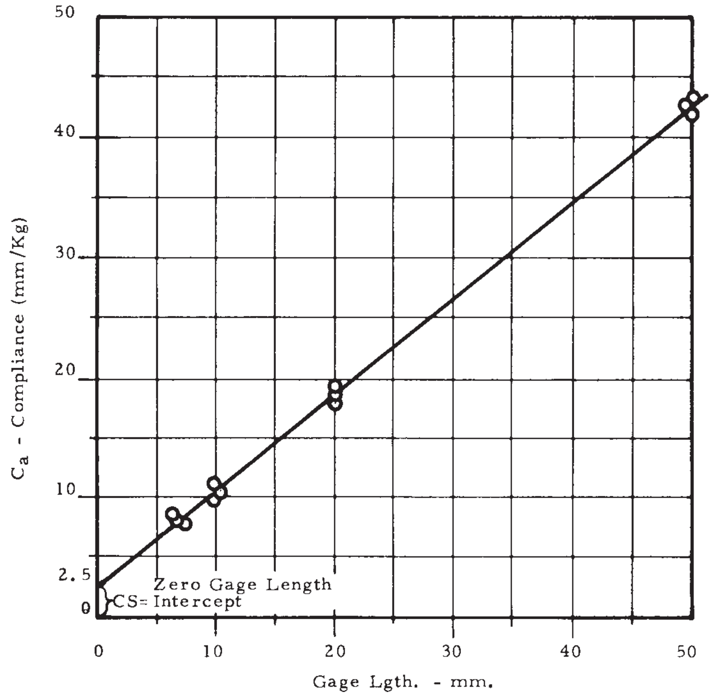

FIG. 3 Typical System Compliance

9.4 *Tensile Strength*—Calculate the tensile strength as follows:

$$T = F/A \quad (2)$$

where:
T = tensile strength, Pa (or psi),
F = force to failure, N (or lbf), and
A = average filament area, m^2(or in.^{2}).

9.5 *True Compliance*:

9.5.1 *Indicated Compliance*—Calculate the indicated compliance as follows:

$$C_a = I/P \times H/S \quad (3)$$

where:
C_a = indicated compliance, mm/N (or in./lbf),
I = total extension for straight line section of load-time curve, extrapolated across full chart scale, mm (or in.),
H = crosshead speed, mm/s (or in./min),
P = full scale force, N (or lbf), and
S = chart speed, mm/s (or in./min).

9.5.2 *True Compliance*—Calculate the true compliance as follows:

$$C = C_a - C_s \quad (4)$$

where:
C = true compliance, mm/N (or in./lbf), and
C_s = system compliance, mm/N (or in./lbf).

9.6 *Young's Modulus*—Calculate Young's modulus as follows:

$$Y_m = L/CA \quad (5)$$

where:
Y_m = Young's modulus, Pa (or psi),
L = specimen gage length, mm (or in.),
C = true compliance, mm/N (or in./lbf), and
A = average filament area, m^2 (or in.^{2}).

10. Report

10.1 The report shall include the following:

10.1.1 Complete identification of the test specimens, including material type, source, manufacturer's name and code number, previous history, etc.,

10.1.2 Method of selecting specimens,

10.1.3 Number of specimens for each test series,

10.1.4 Method of mounting test specimens,

10.1.5 Method used for specimen cross-section area determination, including measured cross-sectional areas,

10.1.6 Specimen gage length,

10.1.7 System compliance, if required,

10.1.8 Test machine parameters; crosshead speed, chart speed, load cell used, etc.,

10.1.9 Method used for determination of gage length elongation,

10.1.10 Individual filament breaking loads,

10.1.11 Tensile strength of each specimen, average and standard deviation for series,

10.1.12 Young's modulus of each specimen, average and standard deviation for series,

10.1.13 Atmospheric conditions of test room (temperature and relative humidity), and

10.1.14 Date of test.