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Designation: D 3916 – 02

An American National Standard

Standard Test Method for Tensile Properties of Pultruded Glass-Fiber-Reinforced Plastic Rod[1]

This standard is issued under the fixed designation D 3916; 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 describes a procedure for determining the tensile properties of pultruded, glass-fiber-reinforced thermosetting plastic rod of diameters ranging from 3.2 mm (⅛ in.) to 25.4 mm (1 in.). Little test specimen preparation is required; however, reusable aluminum tab grip adapters (Fig. 1) of appropriate size are required to prevent premature failure of the specimens at the grips.

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

1.3 *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.* Specific hazards statements are given in Note 3 and Note 4.

NOTE 1—There is no known ISO equivalent to this test method.

2. Referenced Documents

2.1 *ASTM Standards:*

D 618 Practice for Conditioning Plastics for Testing[2]

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

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

E 83 Practice for Verification and Classification of Extensometers[3]

3. Significance and Use

3.1 The high axial-tensile strength and the low transverse-compressive strength of pultruded rod combine to present some unique problems in determining the tensile strength of this material with conventional test grips. The high transverse-compressive forces generated in the conventional method of gripping tend to crush the rod, thereby causing premature failure. In this test method, aluminum-alloy tabs contoured to the shape of the rod reduce the compressive forces imparted to the rod, thus overcoming the deleterious influence of conventional test grips.

3.2 Tensile properties are influenced by specimen preparation, strain rate, thermal history, and the environmental conditions at the time of testing. Consequently, where precise comparative results are desired, these factors must be carefully controlled.

3.3 Tensile properties provide useful data for many engineering design purposes. However, due to the high sensitivity of these properties to strain rate, temperature, and other environmental conditions, data obtained by this test method should not, by themselves, be considered for applications involving load-time scales or environmental conditions that differ widely from the test conditions. In cases where such dissimilarities are apparent, the sensitivities to strain rate, including impact and creep, as well as to environment, should be determined over a wide range of conditions as dictated by the anticipated service requirements.

4. Apparatus

4.1 *Water-Cooled Diamond or Tungsten-Carbide Saw*, for cutting rod to size.

4.2 *Micrometer*, reading to at least 0.025 ± 0.000 mm (0.001 ± 0.000 in.), for measuring the width and thickness of the test specimens. The thickness of nonrigid plastics should be measured with a dial micrometer that exerts a pressure of 25 ± kPa (3.6 ± 0.7 psi) on the specimen and measures the thickness to within 0.025 mm (0.001 in.). The anvil of the micrometer shall be at least 30 mm (1.4 in.) in diameter and parallel to the face of the contact foot.

4.3 *Universal Testing Machine*, verified in accordance with Practices E 4, having a capacity of at least 530 kN (120 000 lbf) to permit the testing of 25.4 mm (1 in.) diameter rod. Smaller-diameter rod may be tested on lower-capacity equipment, commensurate with the anticipated tensile strength of such rod.

4.4 *Extensometer*—A suitable instrument for determining the distance between two designated points located within the gage length of the test specimen as the specimen is stretched. It is desirable, but not essential, that this instrument automatically record this distance (or any change in it) as a function of the load on the test specimen or of the elapsed time from the start of the test, or both. If only the latter is obtained, load-time

[1] This test method is under the jurisdiction of ASTM Committee D20 on Plastics and is the direct responsibility of Subcommittee D20.18 on Reinforced Thermosetting Plastics.

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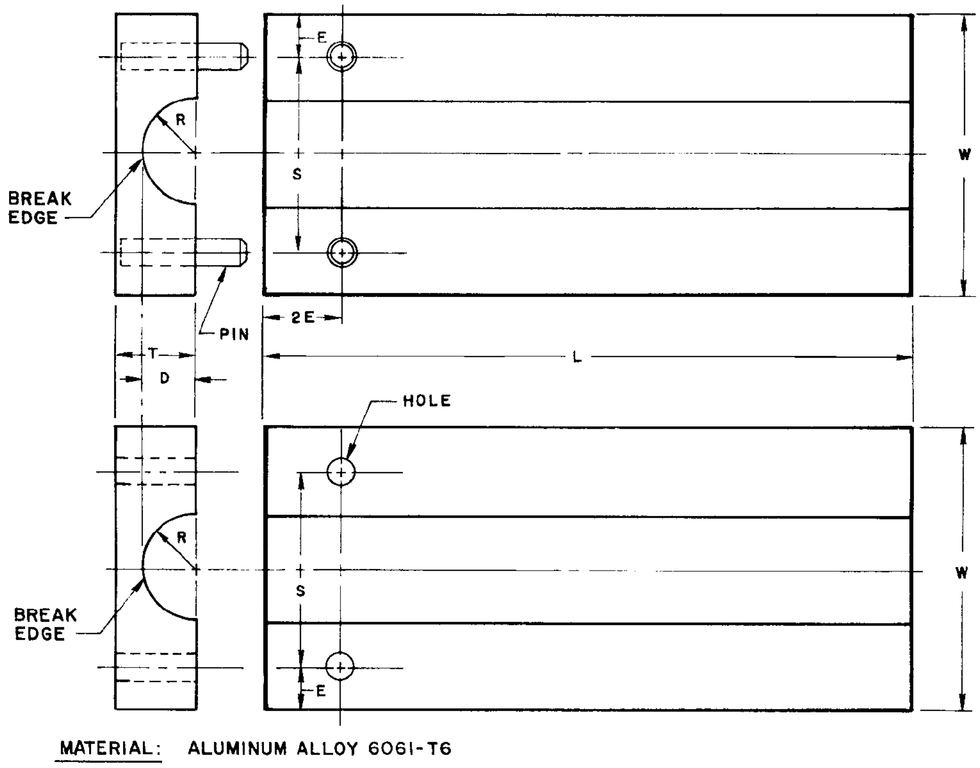
[2] *Annual Book of ASTM Standards*, Vol 08.01.

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



NOTE 1—Sandblast Clamp Face with 100-mesh Carbide at 100 psi.

FIG. 1 General Schematic of Tab Grip Adapters

data must also be taken. This instrument shall be essentially free of inertia lag at the specified speed of testing and shall be accurate to ±1 % of strain or better.

NOTE 2—Reference is made to Practice E 83.

4.5 *One Pair of 6061 – T6 Aluminum-Alloy Tab Grip Adapters*, as described in Fig. 1 and Table 1, to fit in split wedge-type action jaws of the testing machine.

4.6 *Solvent*, such as methylene chloride, for cleaning the gripping surfaces of the aluminum-alloy tab grip adapters to remove any mold release, oil, or other foreign material that might act as a lubricant. The improper use of solvents can present hazardous conditions. Use of proper equipment, ventilation, and training of personnel in proper techniques should be practiced to minimize hazards associated with the use of any volatile solvent.

5. Test Specimens

5.1 At least five specimens shall be cut from the rod sample of interest. Specimen length shall be as great as possible, commensurate with the physical limitations of the testing machine.

NOTE 3—**Caution:** When fabricating composite specimens by machining operations, a fine dust consisting of particles of fibers or the matrix material, or both, may be formed. These fine dusts can be a health or safety hazard, or both. Adequate protection should be afforded operating personnel and equipment. This may require adequate ventilation or dust collecting facilities, or both, at a minimum.

6. Conditioning

6.1 Standard conditioning shall be in accordance with Procedure A of Practice D 618.

6.2 Tests at other than standard laboratory atmospheric conditions should be described, including time (hours), temperature, and test environment, such as watersoak, and so forth. Tests should be made as near to these conditions as possible.

7. Number of Test Specimens

7.1 At least five specimens shall be tested for each sample. When specimens are preconditioned (for example, water-boiled or oven-aged) prior to test, five specimens per sample shall be tested for each condition employed.

8. Procedure

8.1 Measure and record the diameter of the rod specimen at several points along its length with a micrometer, noting both the minimum and average values of these measurements.

8.2 Wipe the ends of the specimen and the gripping surfaces of the aluminum tabs with a cloth saturated with a suitable solvent to remove any foreign material that might act as a lubricant.

8.3 Assemble the aluminum tabs to the ends of the specimen, allowing 10 to 20 mm (0.4 to 0.8 in.) of the specimen to extend beyond the tabs at each end, and mount this assembly in the grips of the testing machine, taking care to align the long axis of the specimen with that of the grips of the machine.

8.4 If values of the modulus of elasticity are being determined, proceed as follows:

8.4.1 Attach the extensometer.

8.4.2 Start the machine and operate it at a nominal cross-head speed of 5 mm (0.20 in.)/min.

TABLE 1 Dimensions of Tab Grip Adapters for Rods of Various Diameters

SI Units

Dimension[A] (see Fig. 1)	Rod Diameter					
	3.2	6.4	12.7	19	22.2	25.4
R	$1.6^{+0.1}_{-0}$	$3.2^{+0.1}_{-0}$	$6.4^{+0.1}_{-0}$	$9.5^{+0.1}_{-0}$	$11.1^{+0.1}_{-0}$	$12.7^{+0.1}_{-0}$
D	1.4	3.0	6.1	9.0	10.1	11.4
L(min)	50	50	152	152	178	229
W(min)	25	25	50	57	64	67
T	4	6.4	19	19	19	19
E	5.6	5.6	9.5	9.5	9.5	9.5
2*E*	11.1	11.1	19.5	19.5	19.5	19.5
S	14.3	14.3	31.8	38.1	44.4	47.6
Pin diameter	3.2	3.2	6.4	6.4	6.4	6.4
Hole diameter	3.6	3.6	6.7	6.7	6.7	6.7
Typical maximum load, kN	8 to 10	30 to 40	135 to 160	300 to 360	400 to 500	530 to 675
Minimum specimen length	305	457	914	1070	1170	1220

Inch-Pound Units

Dimension[B] (see Fig. 1)	Rod Diameter					
	⅛	¼	½	¾	⅞	1
R	$0.062^{+0.004}_{-0.000}$	$0.125^{+0.0004}_{-0.000}$	$0.250^{+0.0004}_{-0.000}$	$0.375^{+0.0004}_{-0.000}$	$0.438^{+0.0004}_{-0.000}$	$0.500^{+0.0004}_{-0.000}$
D	0.057	0.120	0.240	0.355	0.415	0.475
L(min)	2	2	6	6	7	9
W(min)	1	1	2	2¼	2½	2⅝
T	0.155	¼	¾	¾	¾	¾
E	7⁄32	7⁄32	⅜	⅜	⅜	⅜
2*E*	7⁄16	7⁄16	¾	¾	¾	¾
S	9⁄16	9⁄16	1¼	1½	1¾	1⅞
Pin diameter	⅛	⅛	¼	¼	¼	¼
Hole diameter	9⁄64	9⁄64	17⁄64	17⁄64	17⁄64	17⁄64
Typical maximum load, lbf	1800 to 2200	7000 to 8000	30 000 to 35 000	65 000 to 80 000	90 000 to 110 000	120 000 to 150 000
Minimum specimen length	12	18	36	42	46	48

[A] All dimensions in millimetres, except where noted.
[B] All dimensions in inches, except where noted.

8.4.3 Unless an automatic recorder is used, record loads and corresponding extensions at uniform intervals of extension or load so that not less than ten load-extension readings are obtained prior to the termination of the test.

NOTE 4—**Caution:** When testing composite materials, it is possible to store considerable energy in the test specimen which can be released with considerable force on rupture. This can release small high velocity particles and dust consisting of fractured fibers and matrix materials. The particles and fine dust can potentially be a health or safety hazard, or both. Adequate protection should be afforded operating personnel, bystanders, and the equipment. This may require shielding or dust collection facilities, or both, at a minimum.

8.5 Determine the tensile strength and the elongation (if required) by the following procedure:

8.5.1 Start the machine and operate it at a nominal cross-head speed of 5 mm (0.20 in.)/min.

8.5.2 Allow the test to continue until the specimen breaks, and record the breaking load and the extension. If elongation is desired, measure by an extensometer or strain gage at the moment of break.

8.5.3 Only failures which initiate in the free length of the specimen shall be considered valid for the determination of tensile strength.

9. Calculation

9.1 *Tensile Strength*—Calculate the tensile strength in MPa (psi) by dividing the breaking load in newtons (pounds-force) by the original minimum cross-sectional area of the specimen in square millimetres (square inches). Report the result to three significant figures.

$$\text{Tensile strength, } S = 4P/\pi D^2$$

where:

S = tensile strength in MPa (or psi),
P = maximum load in N (or lbf), and
D = minimum diameter of rod in mm (or in.).

9.2 *Modulus of Elasticity*—Calculate the modulus of elasticity by extending the initial linear portion of the load-extension curve and dividing the difference in stress, corresponding to a segment of this line, by the corresponding difference in strain. This calculation shall be performed using the average initial cross-sectional area within the gage length of the test specimen. Express the result in gigapascals (or psi) and report to three significant figures.

$$\text{Modulus of elasticity, } E = 4mg/\pi D^2$$

where:

E = modulus of elasticity in GPa (or psi),
m = slope of the tangent to the initial straightline portion of the load-extension curve in kN/mm (or lbf/in.) of extension,

g = original gage length in mm (or in.), and
D = average diameter of rod in mm (or in.).

9.3 *Percent Elongation*—Calculate the percent elongation by dividing the extension at rupture of the specimen by the original gage length and multiplying by 100. Report the percentage elongation to two significant figures as percentage elongation at break.

$$\text{elongation }\% = [(\Delta/g)]\ 100$$

where:
Δ = extension at maximum load in mm (or in.), and
g = original gage length in mm (or in.).

9.4 For each series of tests, calculate the arithmetic mean of all values obtained and report it as the "average value" for the particular property determined.

9.5 *Wet-Strength Retention*—Calculate the wet-strength retention (if specimens are tested after water boil or soak) by dividing the average wet strength by the average dry strength of the specimens for each sample. Report the wet-strength retention as a percent to two significant figures.

9.6 *Coefficient of Variation*—Calculate the coefficient of variation (COV) for each set of test values by dividing the respective standard deviations by the corresponding arithmetic mean. Report the result to two significant figures as "percent COV" by multiplying by 100. The formula for standard deviation is in 11.5 of Test Method D 638.

10. Report

10.1 Report the following information:

10.1.1 Complete identification of the material tested, including type, source, manufacturer's code numbers, form, principal dimensions, previous history, etc.,

10.1.2 Dimensions of test specimens,

10.1.3 Conditioning procedure used,

10.1.4 Atmospheric conditions in test room,

10.1.5 Number of specimens tested,

10.1.6 Speed of testing,

10.1.7 Tensile strength: average value and percent coefficient of variation,

10.1.8 Modulus of elasticity (if required): average value and percent coefficient of variation,

10.1.9 Percentage elongation at break (if required): average value and percent coefficient of variation,

10.1.10 Wet-strength retention (if applicable), expressed as a percent, and

10.1.11 Date of test.

11. Precision and Bias

11.1 *Precision*:

11.1.1 *Precision Repeatability* (Single Laboratory)—Testing in a single laboratory of a sample of 1-in. diameter pultruded rod resulted in a within-laboratory coefficient of variation of 4.0% for strength and 2.9% for modulus. The within-laboratory critical interval (c_r) between two test results is 11.2% for strength and 8.1% for modulus (2.8 × Vr). Two results obtained within one laboratory on the same material shall be judged not equivalent if they differ by more than the critical interval (c_r). Attempts to develop a full precision and bias statement for this test method have not been successful due to the limited number of machines of the needed capacity to perform this test. For this reason, data on precision and bias cannot be given. Because this test method does not contain a round robin based numerical precision and bias statement, it shall not be used as a referee method in case of dispute. Anyone wishing to participate in the development of precision and bias data should contact the Chairman, Subcommittee D20.18 (Section 20.18.02), ASTM, 100 Barr Harbor Drive, West Conshohocken, PA 19428.

11.2 *Bias*—A statement of bias cannot be made for this test method since no standard or control material exists.

12. Keywords

12.1 glass reinforced plastic; pultruded rods; tensile properties