This international standard was developed in accordance with internationally recognized principles on standardization established in the Decision on Principles for the Development of International Standards, Guides and Recommendations issued by the World Trade Organization Technical Barriers to Trade (TBT) Committee.

INTERNATIONAL

Designation: D3916 − 22

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

This standard is issued under the fixed designation D3916; 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 This test method describes a procedure for determining the tensile properties of a pultruded, glass-fiber-reinforced thermosetting plastic rod of diameters ranging from 2.03 mm (0.08 in.) to 12.7 mm (0.5 in.). Test Method D7205/D7205M is an alternative test method to determine tensile properties of fiber-reinforced composite rods of diameters bigger than 12.7 mm (0.5 in.).

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, health, and environmental practices and determine the applicability of regulatory limitations prior to use.* Specific hazards statements are given in 6.1 and 8.4.3.

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

1.4 *This international standard was developed in accordance with internationally recognized principles on standardization established in the Decision on Principles for the Development of International Standards, Guides and Recommendations issued by the World Trade Organization Technical Barriers to Trade (TBT) Committee.*

2. Referenced Documents

2.1 *ASTM Standards:*[2]

D618 Practice for Conditioning Plastics for Testing
D883 Terminology Relating to Plastics
D7205/D7205M Test Method for Tensile Properties of Fiber Reinforced Polymer Matrix Composite Bars
E4 Practices for Force Calibration and Verification of Testing Machines
E83 Practice for Verification and Classification of Extensometer Systems
E177 Practice for Use of the Terms Precision and Bias in ASTM Test Methods
E691 Practice for Conducting an Interlaboratory Study to Determine the Precision of a Test Method

3. Terminology

3.1 For definitions of terms used in this standard and associated with plastics issues refer to the terminology contained in D883 unless otherwise specified.

4. Significance and Use

4.1 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.

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

4.3 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 shall 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 the environment, shall be

[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] 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

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determined over a wide range of conditions as dictated by the anticipated service requirements.

5. Apparatus

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

5.2 *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 (reinforced pultruded products are rigid) 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.

5.3 *Universal Testing Machine,* verified in accordance with Practices E4, having a capacity greater than the anticipated tensile strength of such rod.

5.4 *Extensometer*—A suitable instrument for determining the distance between two designated points located within the gauge 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 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 E83.

5.5 *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. Sandblast clamp face with 100-mesh carbide at 100 psi.

5.6 *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 will present hazardous conditions. The use of proper equipment, ventilation, and training of personnel in proper techniques minimizes hazards associated with the use of any volatile solvent.

6. Test Specimens

6.1 At least five specimens shall be tested from the rod sample of interest. Specimen length shall be as given in Table 1, commensurate with the physical limitations of the testing machine. When specimens are preconditioned (for example, water-boiled or oven-aged) prior to the test, five specimens per sample shall be tested for each condition employed. (**Warning—**When fabricating composite specimens by machining operations, fine dust consisting of particles of fibers or the matrix material, or both, may be formed. This fine dust can be a health or safety hazard or both. Adequate protection should be afforded to operating personnel and equipment. This may require adequate ventilation or dust collecting facilities, or both, at a minimum.)

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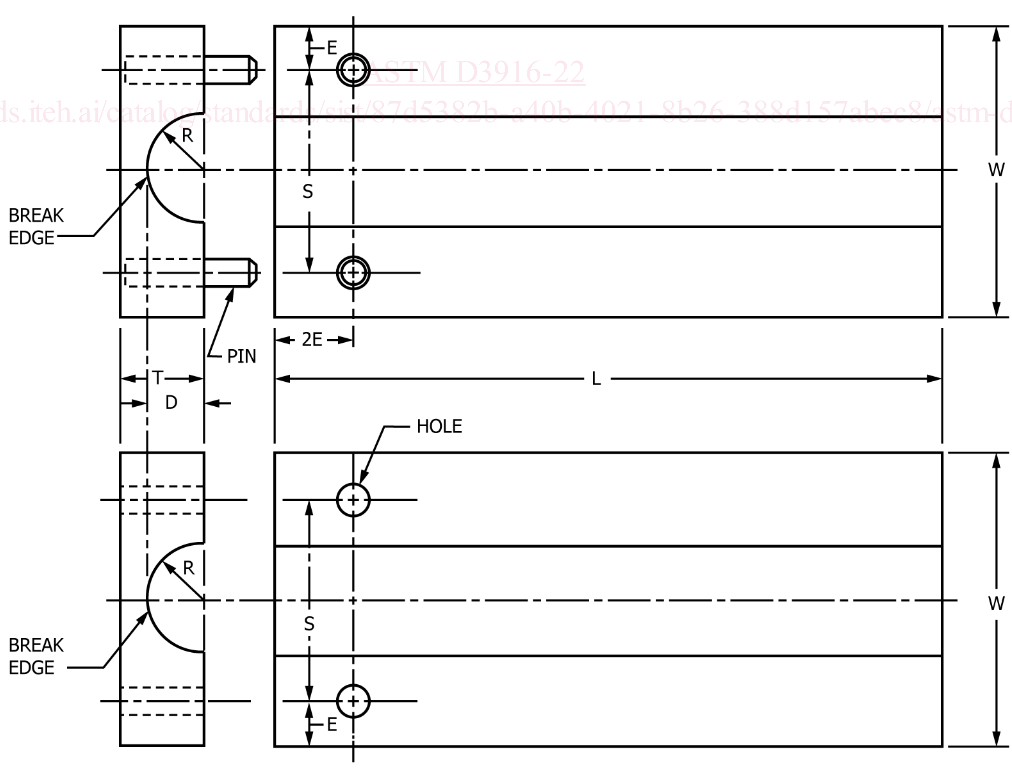

FIG. 1 General Schematic of Tab Grip Adapters

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

SI Units				
Dimension[A] (see Fig. 1)	Rod Diameter			
	2.03	3.2	6.4	12.7
R	$1.01_{-0}^{+0.1}$	$1.6^{+0.1}_{-0}$	$3.2^{+0.1}_{-0}$	$6.4^{+0.1}_{-0}$
D	0.94	1.4	3.0	6.1
L(min)	50	50	50	152
W(min)	25	25	25	50
T	4	4	6.4	19
E	5.6	5.6	5.6	9.5
2*E*	11.1	11.1	11.1	19.5
S	14.3	14.3	14.3	31.8
Pin diameter	3.2	3.2	3.2	6.4
Hole diameter	3.6	3.6	3.6	6.7
Typical maximum load, kN	4 to 5	8 to 10	30 to 40	135 to 160
Minimum Specimen Length, kN	254	305	457	915

Inch-Pound Units				
Dimension[B] (see Fig. 1)	Rod Diameter			
	0.08	1/8	1/4	1/2
R	0.04	$0.062^{+0.004}_{-0.000}$	$0.125^{+0.0004}_{-0.000}$	$0.250^{+0.0004}_{-0.000}$
D	0.037	0.057	0.120	0.240
L(min)	2	2	2	6
W(min)	1	1	1	2
T	0.155	0.155	1/4	3/4
E	7/32	7/32	7/32	3/8
2*E*	7/16	7/16	7/16	3/4
S	9/16	9/16	9/16	1 1/4
Pin diameter	1/8	1/8	1/8	1/4
Hole diameter	9/64	9/64	9/64	17/64
Typical Maximum Load, lbf	900 to 1100	1800 to 2200	7000 to 8000	30 000 to 35 000
Minimum Specimen Length	10	12	18	36

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

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7. Conditioning

7.1 Standard conditioning shall be in accordance with Procedure A of Practice D618.

7.2 Tests at other than standard laboratory atmospheric conditions shall be described, including time (hours), temperature, and test environment, such as water-soak, and so forth. Tests shall be made as near to these conditions as possible.

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 dampened with a suitable solvent to remove any foreign material that might act as a lubricant. Wipe off any leftover solvent on the surface of the rod immediately using a clean cloth to avoid any chemical interaction with the rod.

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 crosshead speed of 10 mm (0.40 in.)/min.

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. (**Warning—**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 to 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 10 mm (0.40 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 gauge 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 gauge 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 straight-line portion of the load-extension curve in kN/mm (or lbf/in.) of extension,
g = original gauge 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 gauge 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 gauge 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.

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.

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11. Precision and Bias

11.1 The precision of this test method is based on an interlaboratory study of ASTM D3916, Test Method for Tensile Properties of Pultruded Glass-Fiber-Reinforced Plastic Rod, conducted in 2021. A single laboratory participated in this study, testing two different materials. Every "test result" represents an individual measurement. Ten replicate test results were reported. Except for the number of participating laboratories, Practice E691 was followed for the design of study and analysis of the data; the details are given in ASTM Research Report No. [RR # – D20-2006].[3]

11.1.1 *Repeatability limit (r)*—The difference between repetitive results obtained by the same operator in a given laboratory applying the same test method with the same apparatus under constant operating conditions on identical test material within short intervals of time would in the long run, in the normal and correct operation of the test method, exceed the determined values only in one case in 20.

11.1.1.1 Repeatability limit can be interpreted as the maximum difference between two results, obtained under repeatability conditions, that is accepted as plausible due to random causes under normal and correct operation of the test method.

11.1.1.2 Repeatability limits are listed in Tables 2 and 3.

11.1.2 *Reproducibility limit (R)*—The difference between two single and independent results obtained by different

[3] Supporting data have been filed at ASTM International Headquarters and may be obtained by requesting Research Report RR:D20-2006. Contact ASTM Customer Service at service@astm.org.