Designation: D5450/D5450M – 16

Standard Test Method for Transverse Tensile Properties of Hoop Wound Polymer Matrix Composite Cylinders[1]

This standard is issued under the fixed designation D5450/D5450M; 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 determines the transverse tensile properties of wound polymer matrix composites reinforced by high-modulus continuous fibers. It describes testing of hoop wound (90°) cylinders in axial tension for determination of transverse tensile properties.

1.2 The technical content of this standard has been stable since 1993 without significant objection from its stakeholders. As there is limited technical support for the maintenance of this standard, changes since that date have been limited to items required to retain consistency with other ASTM D30 Committee standards, including editorial changes and incorporation of updated guidance on specimen preconditioning and environmental testing. The standard, therefore, should not be considered to include any significant changes in approach and practice since 1993. Future maintenance of the standard will only be in response to specific requests and performed only as technical support allows.

1.3 The values stated in either SI units or inch-pound units are to be regarded separately as standard. The values stated in each system are not exact equivalents; therefore, each system must be used independently of the other. Combining values from the two systems may result in nonconformance with the standard.

1.3.1 Within the text, the inch-pound units are shown in brackets.

1.4 *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.*

2. Referenced Documents

2.1 *ASTM Standards:*[2]

D792 Test Methods for Density and Specific Gravity (Relative Density) of Plastics by Displacement
D883 Terminology Relating to Plastics
D2584 Test Method for Ignition Loss of Cured Reinforced Resins
D2734 Test Methods for Void Content of Reinforced Plastics
D3171 Test Methods for Constituent Content of Composite Materials
D3878 Terminology for Composite Materials
D5229/D5229M Test Method for Moisture Absorption Properties and Equilibrium Conditioning of Polymer Matrix Composite Materials
D5448/D5448M Test Method for Inplane Shear Properties of Hoop Wound Polymer Matrix Composite Cylinders
D5449/D5449M Test Method for Transverse Compressive Properties of Hoop Wound Polymer Matrix Composite Cylinders
E4 Practices for Force Verification of Testing Machines
E6 Terminology Relating to Methods of Mechanical Testing
E111 Test Method for Young's Modulus, Tangent Modulus, and Chord Modulus
E122 Practice for Calculating Sample Size to Estimate, With Specified Precision, the Average for a Characteristic of a Lot or Process
E132 Test Method for Poisson's Ratio at Room Temperature
E177 Practice for Use of the Terms Precision and Bias in ASTM Test Methods
E251 Test Methods for Performance Characteristics of Metallic Bonded Resistance Strain Gages
E456 Terminology Relating to Quality and Statistics
E691 Practice for Conducting an Interlaboratory Study to Determine the Precision of a Test Method
E1237 Guide for Installing Bonded Resistance Strain Gages

[1] This test method is under the jurisdiction of ASTM Committee D30 on Composite Materialsand is the direct responsibility of Subcommittee D30.04 on Lamina and Laminate Test Methods.

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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.

3. Terminology

3.1 *Definitions*—Terminology D3878 defines terms relating to high-modulus fibers and their composites. Terminology D883 defines terms relating to plastics. Terminology E6 defines terms relating to mechanical testing. Terminology E456 and Practice E177 define terms relating to statistics. In the event of a conflict between terms, Terminology D3878 shall have precedence over other standards.

NOTE 1—If the term represents a physical quantity, its analytical dimensions are stated immediately following the term (or letter symbol) in fundamental dimension form, using the following ASTM standard symbology for fundamental dimensions, shown within square brackets: [M] for mass, [L] for length, [T] for time, [θ] for thermodynamic temperature, and [nd] for non-dimensional quantities. Use of these symbols is restricted to analytical dimensions when used with square brackets, as the symbols may have other definitions when used without the brackets.

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *hoop wound, n*—a winding of a cylindrical component where the filaments are circumferentially oriented.

3.2.2 *specimen, n*—a single part cut from a winding. Each winding may yield several specimens.

3.2.3 *transverse tensile elastic modulus, E_{22} $[ML^{-1}T^{-2}]$, n*—the tensile elastic modulus of a unidirectional material in the direction perpendicular to the reinforcing fibers.

3.2.4 *transverse tensile strain at failure, ε_{22}^{ut} [nd], n*—the value of strain, perpendicular to the reinforcing fibers in a unidirectional material, at failure when a tensile force is applied in the direction perpendicular to the reinforcing fibers.

3.2.5 *transverse tensile strength, σ_{22}^{ut}, $[ML^{-1}T^{-2}]$, n*—the strength of a unidirectional material when a tensile force is applied in the direction perpendicular to the reinforcing fibers.

3.2.6 *winding, n*—an entire part completed by one winding operation and then cured.

4. Summary of Test Method

4.1 A thin walled hoop wound cylinder nominally 100 mm [4 in.] in diameter and 140 mm [5.5 in.] in length is bonded into two end fixtures. The specimen/fixture assembly is mounted in the testing machine and monotonically loaded in tension while recording force. The transverse tensile strength can be determined from the maximum force carried prior to failure. If the cylinder strain is monitored with strain gauges, then the stress-strain response of the material can be determined. From the stress-strain response the transverse tensile strain at failure, transverse tensile modulus of elasticity, and Poisson's ratio can be derived.

5. Significance and Use

5.1 This test method is used to produce transverse tensile property data for material specifications, research and development, quality assurance, and structural design and analysis. Factors which influence the transverse tensile response and should, therefore, be reported are: material, methods of material preparation, specimen preparation, specimen conditioning, environment of testing, specimen alignment and gripping, speed of testing, void content, and fiber volume fraction. Properties, in the test direction, which may be obtained from this test method include:

5.1.1 *Transverse Tensile Strength,* σ_{22}^{ut},

5.1.2 *Transverse Tensile Strain at Failure,* ε_{22}^{ut},

5.1.3 *Transverse Tensile Modulus of Elasticity,* E_{22}, and

5.1.4 *Poisson's Ratio,* υ_{21}.

6. Interference

6.1 *Material and Specimen Preparation*—Poor material fabrication practices, lack of control of fiber alignment, and damage induced by improper specimen machining are known causes of high material data scatter in composites.

6.2 *Bonding Specimens to Test Fixtures*—A high percentage of failures in or near the bond between the test specimen and the test fixtures, especially when combined with high material data scatter, is an indicator of specimen bonding problems. Specimen to fixture bonding is discussed in 11.5.

6.3 *System Alignment*—Excessive bending may cause premature failure, as well as highly inaccurate modulus of elasticity determination. Every effort should be made to eliminate excess bending from the test system. Bending may occur due to misaligned grips, misaligned specimens in the test fixtures, or from departures of the specimen from tolerance requirements. The alignment should always be checked as discussed in 13.2.

7. Apparatus

7.1 *Micrometers and Calipers*—A micrometer with a 4 to 7 mm [0.16 to 0.28 in.] nominal diameter ball-interface or a flat anvil interface shall be used to measure the specimen wall thickness, inner diameter, and outer diameter. A ball interface is recommended for these measurements when at least one surface is irregular (e.g. a course peel ply surface, which is neither smooth nor flat). A micrometer or caliper with a flat anvil interface shall be used for measuring the overall specimen length, the gauge length (the free length between the fixtures) and other machined surface dimensions. The use of alternative measurement devices is permitted if specified (or agreed to) by the test requestor and reported by the testing laboratory. The accuracy of the instruments shall be suitable for reading to within 1 % of the sample dimensions. For typical specimen geometries, an instrument with an accuracy of ±0.0025 mm [±0.0001 in.] is adequate for wall thickness measurements, while an instrument with an accuracy of ±0.025 mm [±0.001 in.] is adequate for measurement of the inner diameter, outer diameter, overall specimen length, gauge length, and other machined surface dimensions.

7.2 *Tension Fixture*—The tension fixture consists of a steel outer shell, insert, load rod, and spherical washer. An assembly drawing for these components and the test fixture is seen in Fig. 1.

7.2.1 *Outer Shell*—The outer shell (metric units Fig. 2, english units Fig. 3) is circular with a concentric circular hollow in one face, a grove along the diameter of the other face, and a center hole through the thickness. Along the diameter perpendicular to the grove, three pairs of small eccentric holes are placed at three radial distances. The two

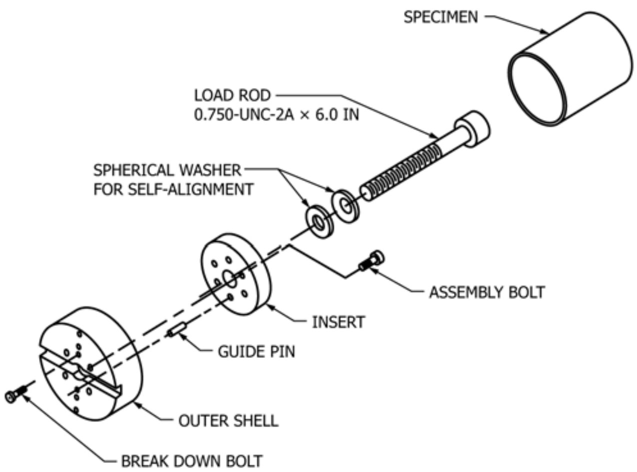

FIG. 1 Assembly Drawing for Tension Fixture and Specimen

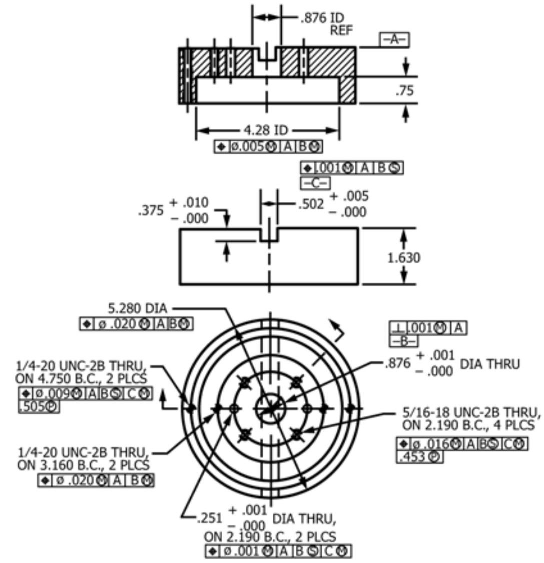

FIG. 3 The Outer Shell of the Tension Fixture in English Units

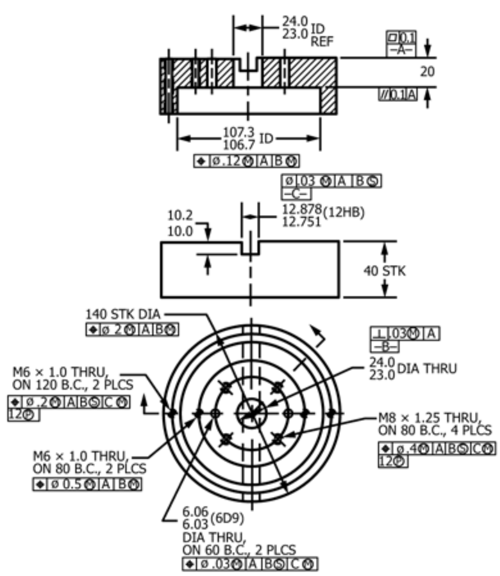

FIG. 2 The Outer Shell of the Tension Fixture in Metric Units

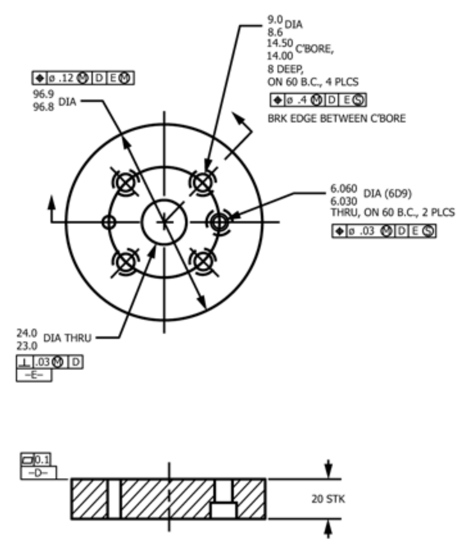

FIG. 4 The Insert of the Tensile Fixture in Metric Units

outer pairs of holes are threaded. Four additional threaded holes are placed at the same radial distance as the innermost pair of holes, at ninety degree intervals starting forty-five degrees from the diameter that passes through the center grove.

7.2.2 *Insert*—The fixture insert is circular with a center hole through the thickness (metric units Fig. 4, english units Fig. 5). Two sets of holes are placed along a concentric centerline. These holes align with the innermost set of holes in the outer shell. The set of four holes at ninety degree intervals are counterbored. The insert is fastened inside the hollow of the outer shell to form the concentric grove used to put the specimen in the fixture (Fig. 1).

7.2.3 *Load Rod and Spherical Washers*—Two spherical washers for self alignment are placed over a 0.750-UNC-2A × 6.0 inch load rod. The load rod is then slid through the center hole of the outer shell and insert assembly as illustrated in Fig. 1.

7.2.4 The outer shell and insert for the tension fixture are the same outer shell and insert used for the fixtures in Test Methods D5448/D5448M and D5449/D5449M.

7.3 *Testing Machine,* comprised of the following:

7.3.1 *Fixed Member*—A fixed or essentially stationary member to which one end of the tension specimen/fixture assembly, shown in Fig. 1, can be attached.

7.3.2 *Movable Member*—A movable member to which the opposite end of the tension specimen/fixture assembly, shown in Fig. 1, can be attached.

7.3.3 *Drive Mechanism,* for imparting to the movable member a uniform controlled velocity with respect to the fixed member, this velocity to be regulated as specified in 11.6.

7.3.4 *Force Indicator*—A suitable force-indicating mechanism capable of showing the total tensile force carried by the test specimen. This mechanism shall be essentially free of inertia-lag at the specified rate of testing and shall indicate the force within an accuracy of ±1 % of the actual value, or better. The accuracy of the testing machine shall be verified in accordance with Practice E4.