



Designation: D5450/D5450M – 93 (Reapproved 2006)

# Standard Test Method for Transverse Tensile Properties of Hoop Wound Polymer Matrix Composite Cylinders<sup>1</sup>

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 ( $\epsilon$ ) indicates an editorial change since the last revision or reapproval.

*This standard has been approved for use by agencies of the 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 values stated in either SI units or inch-pound units are to be regarded separately as standard. Within the text, the inch-pound units are shown in brackets. 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 *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:<sup>2</sup>

**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 Gauges

**E456** Terminology Relating to Quality and Statistics

**E691** Practice for Conducting an Interlaboratory Study to Determine the Precision of a Test Method

**E1012** Practice for Verification of Test Frame and Specimen Alignment Under Tensile and Compressive Axial Force Application

**E1237** Guide for Installing Bonded Resistance Strain Gages

## 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

<sup>1</sup> This test method is under the jurisdiction of ASTM Committee D30 on Composite Materials and is the direct responsibility of Subcommittee D30.04 on Lamina and Laminate Test Methods.

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<sup>2</sup> For referenced ASTM standards, visit the ASTM website, [www.astm.org](http://www.astm.org), or contact ASTM Customer Service at [service@astm.org](mailto:service@astm.org). For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

a conflict between terms, Terminology **D3878** shall have precedence over other standards.

### 3.2 Descriptions of Terms.<sup>3</sup>

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,  $E_{22}$  [ $MT^{-2}L^{-1}$ ]*, *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,  $\epsilon_{22}^u$  [nd]*, *n*—the value of strain, perpendicular to the reinforcing fibers in a unidirectional material, at failure when a tensile load is applied in the direction perpendicular to the reinforcing fibers.

3.2.5 *transverse tensile strength,  $\sigma_{22}^u$  [ $MT^{-2}L^{-1}$ ]*, *n*—the strength of a unidirectional material when a tensile load 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 load. The transverse tensile strength can be determined from the maximum load carried prior to failure. If the cylinder strain is monitored with strain gages, 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,  $\sigma_{22}^u$ ,*

5.1.2 *Transverse Tensile Strain at Failure,  $\epsilon_{22}^u$ ,*

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

5.1.4 *Poisson's Ratio,  $\nu_{21}$ .*

## 6. Interference

6.1 *Material and Specimen Preparation*—Poor material fabrication practices, lack of control of fiber alignment, and

damage induced by improper coupon 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 **12.2**.

## 7. Apparatus

7.1 *Micrometers*, suitable ball type for reading to within  $0.025 \pm 0.010$  mm [ $0.001 \pm 0.0004$  in.] of the specimen inner and outer diameters. Flat anvil type micrometer or calipers of similar resolution may be used for the overall specimen length and the gage length (the free length between the fixtures).

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 groove along the diameter of the other face, and a center hole through the thickness. Along the diameter perpendicular to the groove, three pairs of small eccentric holes are placed at three radial distances. The two 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 groove.

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

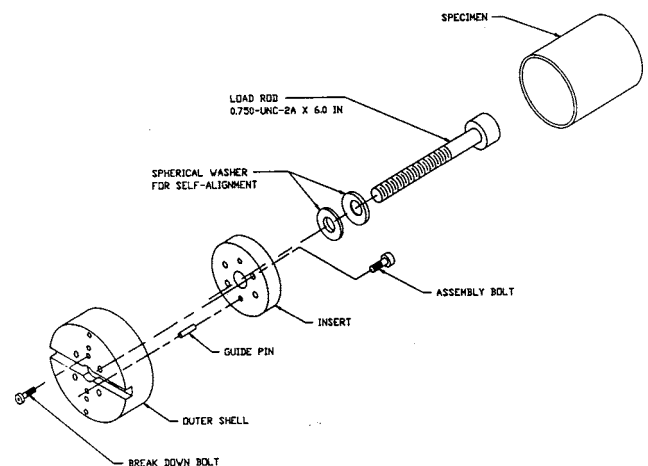


**FIG. 1 Assembly Drawing for Tension Fixture and Specimen**

<sup>3</sup> 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.

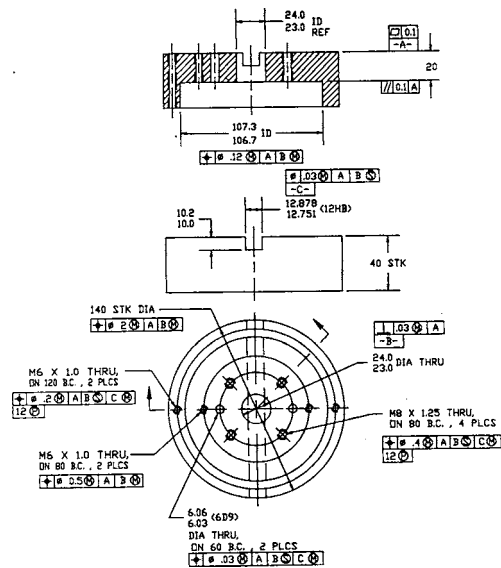


FIG. 2 The Outer Shell of the Tension Fixture in Metric Units

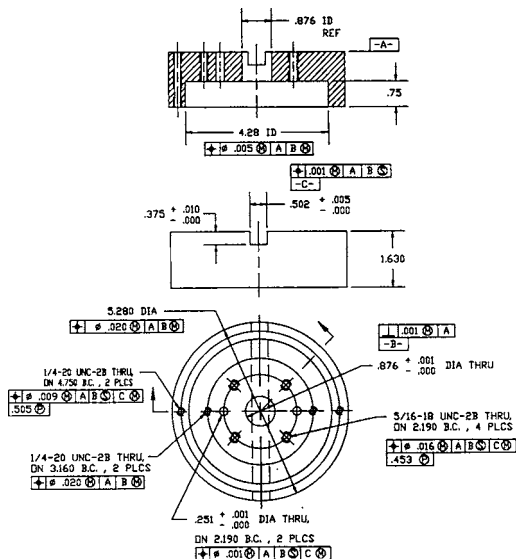


FIG. 3 The Outer Shell of the Tension Fixture in English Units

counterbored. The insert is fastened inside the hollow of the outer shell to form the concentric groove 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  $\times$  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.

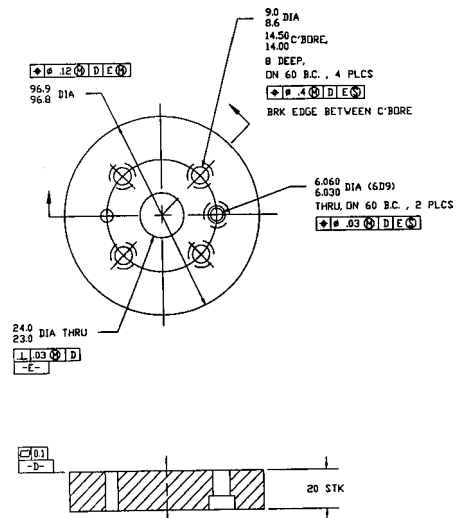


FIG. 4 The Insert of the Tension Fixture in Metric Units

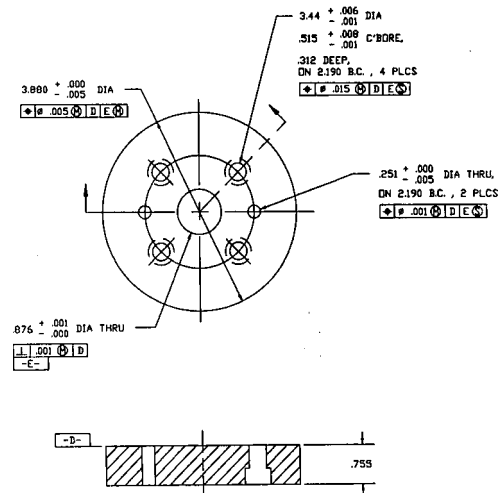


FIG. 5 The Insert of the Tension Fixture in English Units

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

**7.3.5 Construction Materials**—The fixed member, movable member, drive mechanism, and fixtures shall be constructed of such materials and in such proportions that the total longitudinal deformation of the system contributed by these parts is minimized.

**7.4 Strain-Indicating Device**—Load versus strain data shall be determined by means of bonded resistance strain gages. Each strain gage shall be 6.3 mm [0.25 in.] in length. The specimen shall be instrumented to measure strain in both the axial and circumferential directions to determine Poisson's ratio. Strain gage rosettes (0°/45°/90°) shall be used to