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## Standard Test Method for Shear Properties of Composite Materials by the V-Notched Beam Method<sup>1</sup>

This standard is issued under the fixed designation D5379/D5379M; 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.

### 1. Scope

1.1 This test method covers the shear properties of composite materials reinforced by high-modulus fibers. The composite materials are limited to continuous-fiber or discontinuous-fiber-reinforced composites in the following material forms:

1.1.1 Laminates composed only of unidirectional fibrous laminae, with the fiber direction oriented either parallel or perpendicular to the loading axis.

1.1.2 Laminates composed only of woven fabric filamentary laminae with the warp direction oriented either parallel or perpendicular to the loading axis.

1.1.3 Laminates composed only of unidirectional fibrous laminae, containing equal numbers of plies oriented at 0 and 90° in a balanced and symmetric stacking sequence, with the 0° direction oriented either parallel or perpendicular to the loading axis.

1.1.4 Short-fiber-reinforced composites with a majority of the fibers being randomly distributed.

NOTE 1—This shear test concept was originally developed without reference to fiber direction for use on isotropic materials such as metals or ceramics.

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~~ may not be exact equivalents; therefore, each system ~~must~~ shall be used independently of the other. Combining values from the two systems may result in ~~nonconformance~~ 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](#)

[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](#)

[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](#)

<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.

[E456 Terminology Relating to Quality and Statistics](#)

[E1237 Guide for Installing Bonded Resistance Strain Gages](#)

2.2 *Other Documents:*

[ANSI Y14.5M-1982 Geometric Dimensioning and Tolerancing](#)<sup>3</sup>

[ANSI/ASME B 46.1-1985 Surface Texture \(Surface Roughness, Waviness, and Lay\)](#)<sup>3</sup>

2.3 *ASTM Adjuncts:*

V-Notched Beam Shear Fixture Machining Drawings<sup>4</sup>

### 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 the other standards.

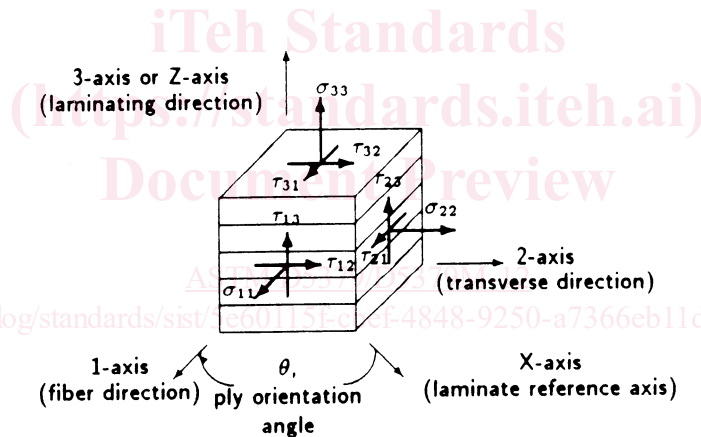
3.2 *Definitions of Terms Specific to This Standard:*

NOTE 2—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 nondimensional 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.

3.2.1 *in-plane shear, n*—any of the shear properties describing the response resulting from a shear load or deformation applied to the 1-2 material plane. (See also *material coordinate system*.)

3.2.2 *interlaminar shear, n*—any of the shear properties describing the response resulting from a shear load or deformation applied to the 1-3 or 2-3 material planes. (See also *material coordinate system*.)

3.2.3 *material coordinate system, n*—a Cartesian coordinate system describing the principal material coordinate system, using 1, 2, and 3 for the axes, as shown in [Fig. 1](#).



**FIG. 1 Material Coordinate System**

3.2.4 *nominal value, n*—a value, existing in name only, assigned to a measurable property for the purpose of convenient designation. Tolerances may be applied to a nominal value to define an acceptable range for the property.

3.2.5 *shear strength, n*—the shear stress carried by a material at failure under a pure shear condition.

3.2.5.1 *Discussion*—There are no standard test methods that are capable of producing a perfectly pure shear stress condition to failure for every material, although some test methods can come acceptably close for a specific material for a given engineering purpose.

3.3 *Symbols:*

3.3.1 *A*—minimum cross-sectional area of a coupon.

3.3.2 *CV*—coefficient of variation statistic of a sample population for a given property (in percent).

3.3.3 *F<sup>su</sup>*—ultimate shear strength in the test direction.

3.3.4 *F<sup>u</sup>*—ultimate strength in the test direction.

3.3.5 *F<sup>o</sup> (offset)*—the value of the shear stress at the intersection of the shear chord modulus of elasticity and the stress strain curve when the modulus is offset along the engineering shear strain axis from the origin by the reported strain offset value.

<sup>3</sup> Available from American National Standards Institute (ANSI), 25 W. 43rd St., 4th Floor, New York, NY 10036.

<sup>4</sup> Available from ASTM International Headquarters. Order Adjunct No. [ADJD5379](#).

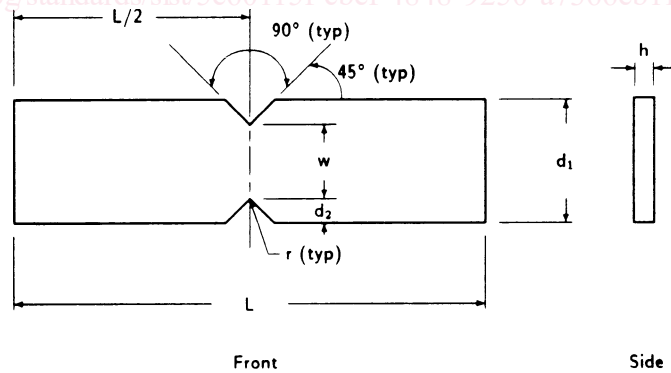
- 3.3.6  $G$ —shear modulus of elasticity in the test direction.
- 3.3.7  $h$ —coupon thickness.
- 3.3.8  $n$ —number of coupons per sample population.
- 3.3.9  $P$ —load force carried by test coupon.
- 3.3.10  $P^f$ —load force carried by test coupon at failure.
- 3.3.11  $P^{max}$ —maximum load force carried by test coupon before failure.
- 3.3.12  $s_{n-1}$ —standard deviation statistic of a sample population for a given property.
- 3.3.13  $w$ —coupon width.
- 3.3.14  $x_i$ —test result for an individual coupon from the sample population for a given property.
- 3.3.15  $\bar{x}$ —mean or average (estimate of mean) of a sample population for a given property.
- 3.3.16  $\gamma$ —shear  $\gamma$ —engineering shear strain.
- 3.3.17  $\epsilon$ —general symbol for strain, whether normal strain or shear strain.
- 3.3.18  $\epsilon$ —indicated normal strain from strain transducer or extensometer.
- 3.3.19  $\sigma$ —normal stress.
- 3.3.20  $\tau$ —shear stress.
- 3.3.21  $\theta$ —ply orientation angle.

**4. Summary of Test Method**

4.1 A material coupon in the form of a rectangular flat strip with symmetrical centrally located v-notches, shown schematically in Fig. 2, is loaded in a mechanical testing machine by a special fixture (shown schematically in Fig. 3 and in more detail in the machining drawings of ASTM Adjunct ADJD5379.<sup>5</sup>

4.2 The specimen is inserted into the fixture with the notch located along the line of action of loading by means of an alignment tool that references the fixture. The two halves of the fixture are compressed by a testing machine while monitoring load force. The relative displacement between the two fixture halves loads the notched specimen. By placing two strain gage elements, oriented at  $\pm 45^\circ$  to the loading axis, in the middle of the specimen (away from the notches) and along the loading axis, the shear response of the material can be measured.

<sup>5</sup> The specimen and fixture are based upon work at the University of Wyoming Composite Materials Research Group (1, 2), and were subsequently modified by the group (3, 4) into the configuration used by this test method. The Wyoming investigations referred to the earlier work of Arcan (5-7) and Iosipescu (8-10), and the later work of a number of other researchers, including Refs (11-16) (early historical perspectives are given in Refs (1, 17)). The boldface numbers in parentheses refer to the list of references at the end of this standard.



Nominal Specimen Dimensions

$d_1$	=	20.0 mm [0.75 in.]
$d_2$	=	19 mm [0.75 in.]
$d_2$	=	4.0 mm [0.15 in.]
$d_2$	=	3.8 mm [0.15 in.]
$h$	=	as required
$L$	=	76.0 mm [3.0 in.]
$L$	=	76 mm [3.0 in.]
$r$	=	1.3 mm [0.05 in.]
$w$	=	12.0 mm [0.45 in.]
$w$	=	11.4 mm [0.45 in.]

**FIG. 2 V-Notched Beam Test Coupon Schematic**

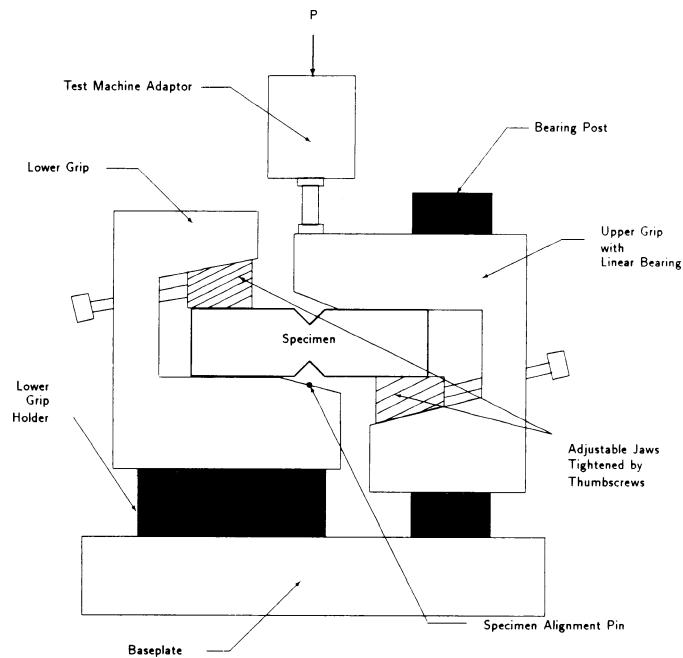


FIG. 3 V-Notched Beam Test Fixture Schematic

4.3 The loading can be idealized as asymmetric flexure, as shown by the shear and bending moment diagrams of Fig. 4.<sup>6</sup> The notches influence the shear strain along the loading direction, making the distribution more uniform than would be seen without the notches. While the degree of uniformity is a function of material orthotropy, the best overall results, when testing in the 1-2 plane, have been obtained on  $[0/90]_{ns}$ -type laminates.

## 5. Significance and Use

5.1 This test method is designed to produce shear property data for material specifications, research and development, quality assurance, and structural design and analysis. Either in-plane or interlaminar shear properties may be evaluated, depending upon the orientation of the material coordinate system relative to the loading axis. Factors that influence the shear response and should therefore be reported include the following: material, methods of material preparation and lay-up, specimen stacking sequence, specimen preparation, specimen conditioning, environment of testing, specimen alignment and gripping, speed of testing, time at temperature, void content, and volume percent reinforcement.

5.2 In anisotropic materials, properties may be obtained in any of the six possible shear planes by orienting the testing plane of the specimen with the desired material plane (1-2 or 2-1, 1-3 or 3-1, 2-3 or 3-2). Only a single shear plane may be evaluated for any given specimen. Properties, in the test direction, which may be obtained from this test method, include the following:

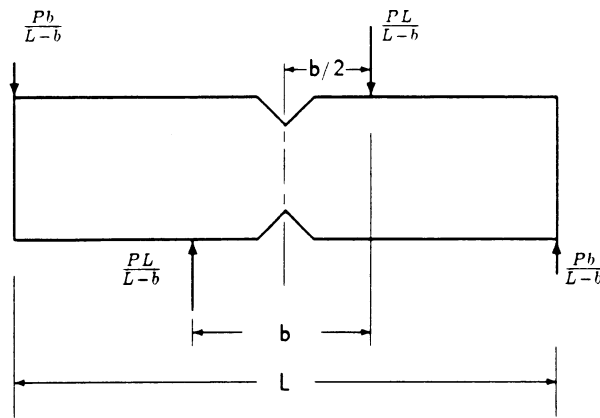
- 5.2.1 Shear stress/strain response,
- 5.2.2 Ultimate strength,
- 5.2.3 Ultimate strain, and
- 5.2.4 Shear chord modulus of elasticity, and elasticity.
- ~~5.2.5 Transition strain.~~

## 6. Interferences

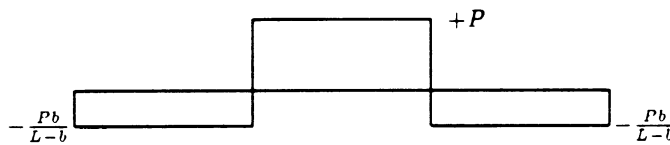
6.1 *Material and Specimen Preparation*—Poor material fabrication practices, lack of control of fiber alignment, and damage induced by improper coupon machining are known causes of high material data scatter in composites.

6.2 *Materials and Coarse Structure*—One of the fundamental assumptions of this test method is that the material must be relatively homogeneous with respect to the size of the test section. Materials that have relatively coarse features with respect to the test section dimensions, such as fabrics using large filament count tows (such as tows of 12 000 filaments or more) or certain braided structures, should not be tested with this specimen size. Scale-up of the specimen and the fixturing to accommodate such materials is possible, but is beyond the scope of this test method.

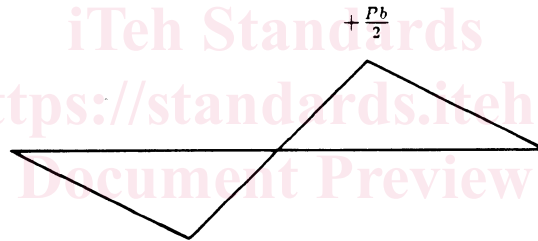
<sup>6</sup> While the idealization indicates constant shear loading and zero bending moment in the specimen at the notches, the actual load application is distributed and imperfect, which contributes to asymmetry in the shear strain distribution and to a component of normal stress that is particularly deleterious to  $[90]_n$  specimens (16).



Force Diagram



Shear Diagram



Moment Diagram

NOTE 1—The value of the dimension  $b$  is not critical to the concept.

FIG. 4 Idealized Force, Shear, and Moment Diagrams

**6.3 Elastic Modulus Measurement**—The calculations in this test method assume a uniform shear stress state between the notches. The actual degree of uniformity varies with the level of material orthotropy and the direction of loading. Both analysis and full-field experimental strain measurement have shown that when testing in the  $I$ -2 plane,  $[0]_n$  specimens result in an elastic modulus estimate that is too high (about 10 % too high for carbon/epoxy), while  $[90]_n$  specimens of the same material result in a value that is about 20 % too low. The most accurate measurements of in-plane shear modulus for unidirectional materials have been shown to result from the  $[0/90]_{n,s}$  specimen. The use of specialized shear strain gauges, which span the length of the test section between the notch roots, allows the average shear strain to be measured even with a nonuniform shear stress state present, and thus are recommended.

**6.4 Load Force Eccentricity**—Twisting of the specimen during loading can occur, affecting strength results, and especially, elastic modulus measurement. Twisting may occur due to an out-of-tolerance fixture, or from specimens that are too thin (unstable), improperly installed in the fixture, out-of-tolerance because of poor specimen preparation, or of a material configuration with an extremely low tolerance to twist. It is recommended that at least one specimen of each sample be tested with back-to-back rosettes to evaluate the degree of twist. Evaluate the percent twist for the specimen by substituting the shear modulus from each side,  $G_a$  and  $G_b$ , into  $|(G_a - G_b)/(G_a + G_b)| \times 100$ , evaluated at 0.004 absolute strain. If the amount of twist is greater than 3 %, then the specimens should be examined for cause of the twisting, and corrected, if possible. If no cause is apparent or correction possible, and the twisting persists, then the shear modulus measurement should be made using the average response of back-to-back rosettes.

NOTE 3—Twisting as a result of minor tolerance variations can be mitigated by use of a thin compliant interface, such as a plastic-backed adhesive tape, between the fixture and the load-bearing surface of the specimen.

**6.5 Specimen Geometry Modifications**—Detailed stress analysis of the v-notch specimen has shown that adjustments to the notch dimensions (notch angle, depth, and radius) can minimize non-uniformity in the shear-stress distribution as a result of

material orthotropy. Recommendations for notch dimensions versus degree of material orthotropy are still being developed. In the interim, and in order to minimize the complexity of this test method, a single standard geometry has been adopted. However, variations to the notch angle, depth, and radius for the purpose of optimizing the specimen performance for a particular material are acceptable when the variations are clearly noted in the report.

6.6 Determination of Failure:

6.6.1  $[0]_n$  Materials—In  $[0]_n$  specimens tested in the 1-2 plane, a visible crack typically develops at the notch root, causing a small drop in loadforce before ultimate failure, as shown in Fig. 5. The small loadforce drop accompanying the notch root crack is not considered the failure loadforce; rather the loadforce that accompanies failure in the test section shall be used as the failure loadforce.

6.6.2  $[90]_n$  Materials—In  $[90]_n$  specimens tested in the 2-1 plane, the ultimate failure loadforce is clearly defined by the maximum loadforce attained on the load-deflectionforce-deflection curve.

6.6.3  $[0/90]_{n,s}$ ,  $[0/90]_{n,s}$ , SMC, Toughened Materials—For  $[0/90]_{n,s}$ , SMC, or toughened materials, the shear failure loadforce may be lower than the maximum loadforce attainable during the test. In such materials, the fibers may reorient following shear failure, subsequently allowing the fibers to carry a major portion of the loadforce. This reorientation is more likely to occur in composites with tough matrix materials that are very nonlinear in shear or in laminates containing off-axis fibers. In such cases, the shear failure loadforce can often be determined by correlating visual observation of failure in the test section with a loadforce drop or by a significant change in the slope of the load-displacementforce-displacement plot, as shown in Fig. 5. Additionally, some toughened materials may deform to such an extent that shear failure does not occur at all; rather the specimen ultimately fails in a mixed-mode failure. Consequently, to avoid the reporting of results that are not representative of shear strength, this test method terminates data reporting at an engineering shear strain of 5%.

7. Apparatus

7.1 Micrometers—Micrometers and Calipers—A micrometer with a 4- to 5-mm [0.16- to 0.20-in.] nominal diameter double-ball interface shall be used to measure the thickness of the specimen. A micrometer with a suitable size diameter ball-interface on irregular surfaces such as the bag-size of a laminate, and a flat anvil interface shall be used to measure the width of the specimen on machined edges or very smooth tooled surfaces. A caliper of suitable size can also be used on machined edges or very smooth tooled surfaces. The accuracy of these instruments shall be suitable for reading to within 1% of the sample width and thickness. For typical specimen geometries, an instrument with an accuracy of  $\pm 2.5 \mu\text{m}$  [ $\pm 0.0001$  in.] is adequate desirable for thickness measurement, while an instrument with an accuracy of  $\pm 25 \mu\text{m}$  [ $\pm 0.001$  in.] is adequate desirable for width measurement.

7.2 Angle Measuring Device—For measuring the specimen notch angle, accurate to within  $\pm 0.5^\circ$ .

7.3 Radius Measuring Device—For measuring the specimen notch radius, accurate to within  $\pm 25 \mu\text{m}$  [ $\pm 0.001$  in.].

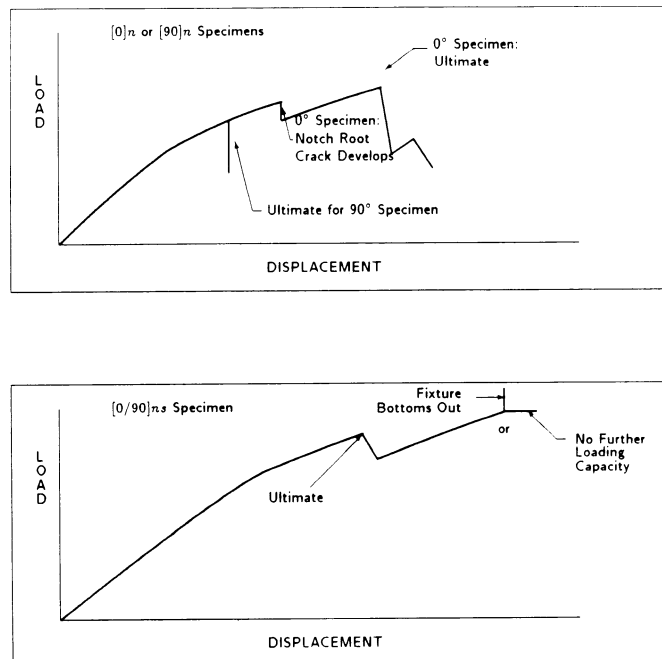


FIG. 5 Typical V-Notched Beam Load-DisplacementForce-Displacement Plots