Designation: D5379/D5379M – 19$^{\varepsilon 1}$

Standard Test Method for Shear Properties of Composite Materials by the V-Notched Beam Method[1]

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 (ε) indicates an editorial change since the last revision or reapproval.

ε^1 NOTE—Editorial corrections were made to the adjunct information in March 2021.

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. The values stated in each system are not necessarily exact equivalents; therefore, to ensure conformance with the standard, each system shall be used independently of the other, and values from the two systems shall not be combined.

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

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.*

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]

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 Gages
E456 Terminology Relating to Quality and Statistics
E1237 Guide for Installing Bonded Resistance Strain Gages

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[1] 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.

Current edition approved Oct. 15, 2019. Published October 2019. Originally approved in 1993. Last previous edition approved in 2012 as D5379/D5379M – 12. DOI: 10.1520/D5379_D5379M-19E01.

[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.

2.2 *Other Documents:*[3]

ANSI Y14.5M-1982 Geometric Dimensioning and Tolerancing

ANSI/ASME B 46.1-1985 Surface Texture (Surface Roughness, Waviness, and Lay)

2.3 *ASTM Adjuncts:*

V-Notched Beam Shear Fixture Machining Drawings[4]

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 force 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 force 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.

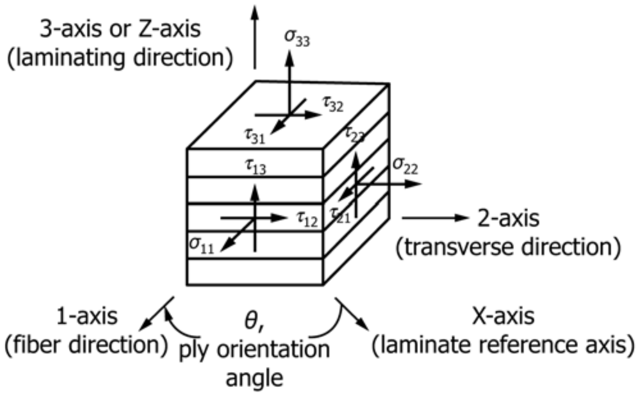

FIG. 1 Material Coordinate System

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^{su}—ultimate shear strength in the test direction.

3.3.4 F^{u}—ultimate strength in the test direction.

3.3.5 F^{o} *(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.

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*—force carried by test coupon.

3.3.10 P^{f}—force carried by test coupon at failure.

3.3.11 P^{max}—maximum 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 γ—engineering shear strain.

3.3.17 ε—general symbol for strain, whether normal strain or shear strain.

3.3.18 ε—indicated normal strain from strain transducer or extensometer.

3.3.19 σ—normal stress.

3.3.20 τ—shear stress.

3.3.21 θ—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

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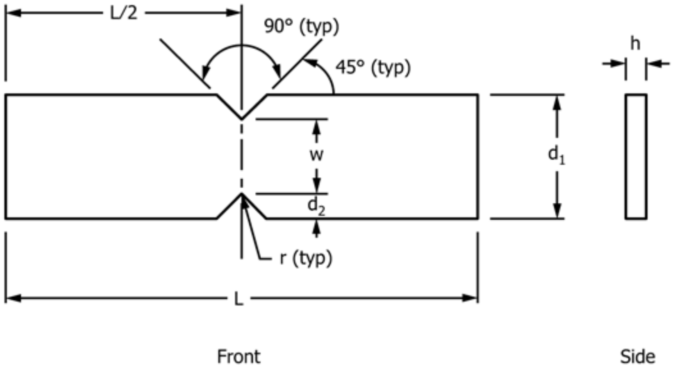
[3] Available from American National Standards Institute (ANSI), 25 W. 43rd St., 4th Floor, New York, NY 10036.

[4] Available from ASTM International Headquarters, www.astm.org. Order Adjunct No. ADJD5379-E-PDF.



Nominal Specimen Dimensions

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

FIG. 2 V-Notched Beam Test Coupon Schematic

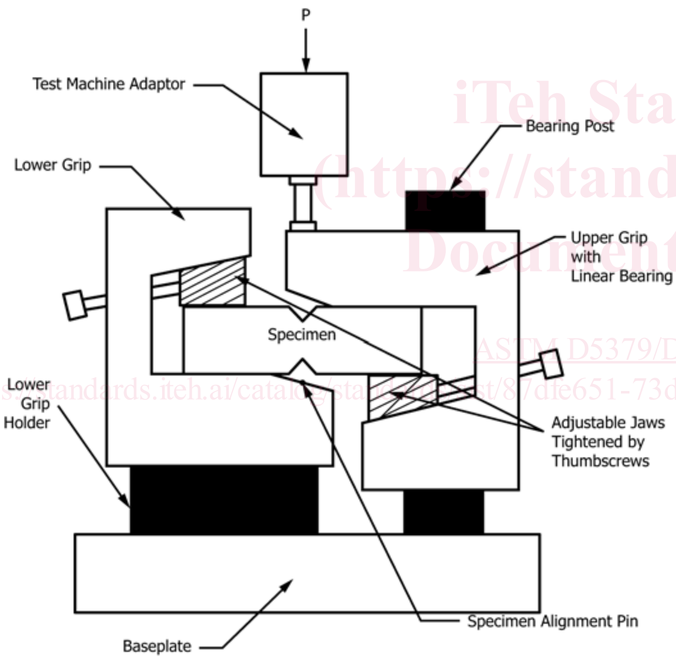
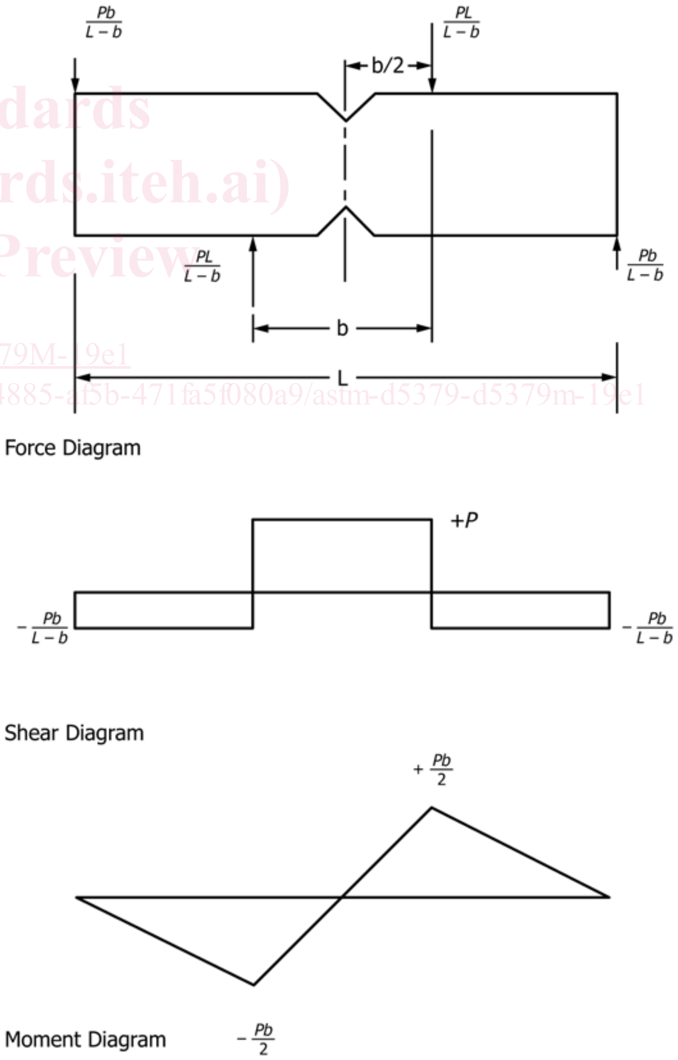


FIG. 3 V-Notched Beam Test Fixture Schematic

ADJD5379-E-PDF.[5]

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 force. The relative displacement between the two fixture halves loads the notched specimen. By placing two strain gage elements, oriented at ±45° 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.

4.3 The loading can be idealized as asymmetric flexure, as shown by the shear and bending moment diagrams of Fig. 4.[6] 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.



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

FIG. 4 Idealized Force, Shear, and Moment Diagrams

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[5] 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.

[6] While the idealization indicates constant shear loading and zero bending moments 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**).

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 layup, 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.

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.

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 *1-2* 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 $[0/90]_{ns}$ specimen. The use of specialized shear strain gages, 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 is recommended.

6.4 *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. 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 force before ultimate failure, as shown in Fig. 5. The small force drop accompanying the notch root crack is not considered the failure force; rather the force that accompanies failure in the test section shall be used as the failure force.

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

6.6.3 *$[0/90]_{ns}$, SMC, Toughened Materials*—For $[0/90]_{ns}$, SMC, or toughened materials, the shear failure force may be lower than the maximum force 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 force. 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 force can often be determined by correlating visual observation of failure in the test section with a force drop or by a significant change in the slope of the force-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

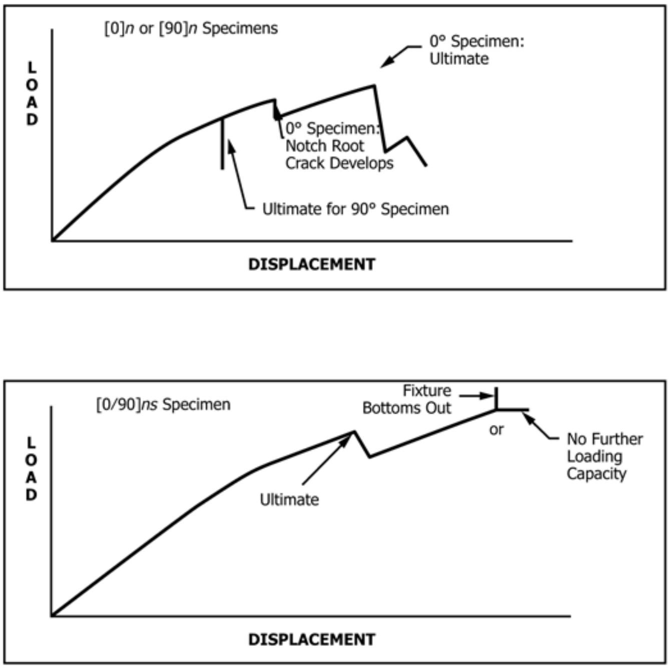

FIG. 5 Typical V-Notched Beam Force-Displacement Plots

not representative of shear strength, this test method terminates data reporting at an engineering shear strain of 5 %.

7. Apparatus

7.1 *Micrometers and Calipers*—A micrometer with a 4 to 8 mm [0.16 to 0.32 in.] nominal diameter ball-interface or a flat anvil interface shall be used to measure the specimen thickness. A ball interface is recommended for thickness measurements when at least one surface is irregular (for example, a coarse peel ply surface which is neither smooth nor flat). A micrometer or caliper with a flat anvil interface shall be used for measuring length, shoulder width, and other machined surface dimensions. A blade micrometer or non-contact device such as an optical comparator shall be used for measuring the width between notches. 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 instrument(s) shall be suitable for reading to within 1 % of the specimen dimensions. For typical specimen geometries, an instrument with an accuracy of ±0.0025 mm [±0.0001 in.] is adequate for thickness measurements, while an instrument with an accuracy of ±0.025 mm [±0.001 in.] is adequate for measurement of length, width, and other machined surface dimensions.

7.2 *Angle Measuring Device,* for measuring the specimen notch angle, accurate to within ±0.5°.

7.3 *Radius Measuring Device,* for measuring the specimen notch radius, accurate to within ±25 µm [±0.001 in.].

7.4 *Testing Machine*—The testing machine shall be in conformance with Practices E4 and shall satisfy the following requirements:

7.4.1 *Testing Machine Heads*—The testing machine shall have both an essentially stationary head and a movable head.

7.4.2 *Drive Mechanism*—The testing machine drive mechanism shall be capable of imparting to the movable head a controlled velocity with respect to the stationary head. The velocity of the movable head shall be capable of being regulated as specified in 11.3.

7.4.3 *Force Indicator*—The testing machine force-sensing device shall be capable of indicating the total force being carried by the test specimen. This device shall be essentially free from inertia lag at the specified rate of testing and shall indicate the force with an accuracy over the force range(s) of interest of within ±1 % of the indicated value. The force range(s) of interest may be fairly low for modulus evaluation, much higher for strength evaluation, or both, as required.

NOTE 4—Obtaining precision force data over a large range of interest in the same test, such as when both elastic modulus and ultimate force are being determined, places extreme requirements on the load cell and its calibration. For some equipment, a special calibration may be required. For some combinations of material and load cell, simultaneous precision measurement of both elastic modulus and ultimate strength may not be possible, and measurement of modulus and strength may have to be performed in separate tests using a different load cell range for each test.

7.4.4 *Platens/Adapter*—One of the testing machine heads shall be capable of supporting the lower half of the v-notched beam test fixture (see 7.4.5) and the other head shall be capable of being attached to the upper half of the fixture, using an adapter or platen interface as required. If required, one of the interfaces may be capable of relieving minor misalignments between the heads, such as a hemispherical ball joint.

7.4.5 *Fixturing*—The fixture used shall be a four-point asymmetric flexure fixture[7] shown schematically in Fig. 3, and in more detail in the machining drawings of ASTM Adjunct ADJD5379-E-PDF. Each half of the fixture contains a wedge-action grip which lightly clamps one half of the test specimen across the specimen width and supports the specimen on its back face. One of the grips, normally the lower half, is mounted on a base plate which also supports a linear bearing shaft, while the other grip, normally in the upper position, contains a linear bearing which mounts over the shaft on the base. Each element is attached to or supported by one of the testing machine heads. A 13 mm [0.5 in.] span is left unsupported between fixture halves. An alignment tool is provided to ensure that the specimen notch is aligned with the line of action of the loading fixture.

7.5 *Strain Indicating Device*—Bonded resistance strain gages shall be used to measure strain. A minimum of two gage elements is required, centered about the loading axis in the gage section of the specimen, as shown in Fig. 6, and mounted at +45° and −45° to the loading axis. If specimen twisting is a concern, then two gage elements on each side of the specimen should be simultaneously measured to allow for a correction as a result of any twisting of the specimen, as discussed in Section 6. The output from each pair may be monitored individually and the outputs summed following the test, or each pair may be wired as a half-bridge so that the recorded strain is the sum of the absolute value of the response of each gage-yielding the shear strain response directly.

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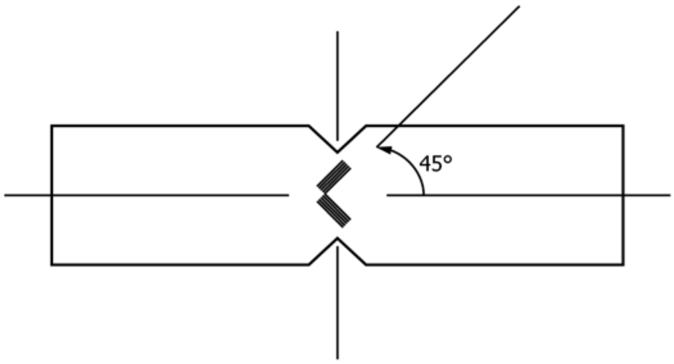
[7] Available from several commercial test fixture suppliers or testing equipment companies.



NOTE 1—The active elements of two orthogonal strain gages are centered between the notch roots at the angle shown. The elements may be independent, or in a stacked or unstacked rosette.

FIG. 6 Strain Gage Locations

7.5.1 *Bonded Resistance Strain Gage Selection*—Strain gage selection is a compromise based on the type of material. The use of specialized shear strain gages, which feature a thin active gage section that spans the length of the test section between the notch roots, generally is recommended. Otherwise, an active gage length of 1.5 mm [0.062 in.] is recommended for most materials, although larger sizes may be more suitable for some woven fabrics. The active gage section area should not be so large as to extend significantly beyond the area in which shear strain is relatively uniform.[8] Gage calibration certification shall comply with Test Methods E251. Strain gages with a minimum normal strain range of approximately 3 % (yielding 6 % engineering shear strain) are recommended. When testing woven fabric laminates, gage selection should consider the use of an active gage length that is at least as great as the characteristic repeating unit of the weave. Some guidelines on the use of strain gages on composites follow. A general reference on the subject is Tuttle and Brinson (**18**).

7.5.1.1 Surface preparation of fiber-reinforced composites in accordance with Guide E1237 can penetrate the matrix material and cause damage to the reinforcing fibers, resulting in improper coupon failures. Reinforcing fibers should not be exposed or damaged during the surface preparation process. The strain gage manufacturer should be consulted regarding surface preparation guidelines and recommended bonding agents for composites, pending the development of a set of standard practices for strain gage installation surface preparation of fiber-reinforced composite materials.

7.5.1.2 Consideration should be given to the selection of gages having larger resistances to reduce heating effects on low-conductivity materials. Resistances of 350 Ω or higher are preferred. Additional consideration should be given to the use of the minimum possible gage excitation voltage consistent with the desired accuracy (1 to 2 V is recommended) to reduce the power consumed further by the gage. Heating of the coupon by the gage may affect the performance of the material directly or it may affect the indicated strain as a result of a difference between the gage temperature compensation factor and the coefficient of thermal expansion of the coupon material.

7.5.1.3 Consideration of some form of temperature compensation is recommended, even when testing at standard laboratory atmosphere. Temperature compensation is required when testing in non-ambient temperature environments.

7.5.1.4 Consideration should be given to the transverse sensitivity of the selected strain gage. The strain gage manufacturer should be consulted for recommendations on transverse sensitivity corrections and effects on composites.

7.6 *Conditioning Chamber*—When conditioning materials at non-laboratory environments, a temperature-vapor-level-controlled environmental conditioning chamber is required that shall be capable of maintaining the required temperature to within ±3 °C [±5 °F] and the required relative vapor level to within ±3 %. Chamber conditions shall be monitored either on an automated continuous basis or on a manual basis at regular intervals.

7.7 *Environmental Test Chamber*—An environmental test chamber is required for test environments other than ambient testing laboratory conditions. This chamber shall be capable of maintaining the gage section of the test specimen at the required test environment during the mechanical test.

8. Sampling and Test Specimens

8.1 *Sampling*—Test at least five specimens per test conditions unless valid results can be gained through the use of fewer specimens, such as in the case of a designed experiment. For statistically significant data, consult the procedure outlined in Practice E122. Report the method of sampling.

NOTE 5—If specimens are to undergo environmental conditioning to equilibrium, and are of such type or geometry that the weight change of the material cannot be properly measured by weighing the specimen itself (such as a tabbed mechanical coupon), then another *traveler* coupon of the same nominal thickness and appropriate size (but without tabs) shall be used to determine when equilibrium has been reached for the specimens being conditioned.

8.2 *Geometry*—The special coupon is a rectangular flat strip with symmetrical centrally located v-notches. The mandatory requirements are described in 8.2.1. Recommendations on parameters that are not required are discussed in 8.2.2.

8.2.1 *Specimen Requirements:*

8.2.1.1 *Shape, Dimensions, Tolerances, and Configuration*—The required specimen shape, dimensions, and tolerances are described in Fig. 7 (SI) and Fig. 8 (inch-pound). If required, adjust the standard notch angle of 90°, notch depth of 20 %, and notch radius of 1.3 mm [0.050 in.] to meet special material requirements, but any deviation from these values must be recorded with the test results, and the standard tolerances on these features still apply. As discussed in Section 6 and 15.1, when testing laminated materials in the *1-2* material plane, the $[0/90]_{ns}$ specimen has been found to provide a more accurate modulus determination, shows less variation in the strength results, and is generally preferred over either the $[0]_n$ or $[90]_n$ specimens.

8.2.2 *Specific Recommendations:*

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[8] A typical gage would have a 0.062 to 0.125 in. active gage length, 350 Ω resistance, a strain rating of 3 % or better, and the appropriate environmental resistance and thermal coefficient.