Designation: D4255/D4255M – 20

Standard Test Method for In-Plane Shear Properties of Polymer Matrix Composite Materials by the Rail Shear Method[1]

This standard is issued under the fixed designation D4255/D4255M; 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 in-plane shear properties of high-modulus fiber-reinforced composite materials by either of two procedures. In Procedure A, laminates clamped between two pairs of loading rails are tested. When loaded in tension, the rails introduce shear forces in the specimen. In Procedure B, laminates clamped on opposite edges with a tensile or compressive force applied to a third pair of rails in the center are tested.

1.2 Application of this test method is limited to continuous-fiber or discontinuous-fiber-reinforced polymer matrix composites in the following material forms:

1.2.1 Laminates composed only of unidirectional fibrous laminae, with the fiber direction oriented either parallel or perpendicular to the fixture rails.

1.2.2 Laminates composed only of woven fabric filamentary laminae with the warp direction oriented either parallel or perpendicular to the fixture rails.

1.2.3 Laminates of balanced and symmetric construction, with the 0° direction oriented either parallel or perpendicular to the fixture rails.

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

NOTE 1—Additional test methods for determining in-plane shear properties of polymer matrix composites may be found in Test Methods D3518/D3518M, D5379/D5379M, D5448/D5448M, and D7078/D7078M.

1.3 The reproducibility of this test method can be affected by the presence of shear stress gradients in the gage section and stress concentrations at the gripping areas. Test Methods D5379/D5379M and D7078/D7078M provide superior shear response in comparison to this test method, as their specimen configurations produce a relatively pure and uniform shear stress state in the gage section.

1.4 The technical content of this standard has been stable since 2001 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 micrometers and calipers, strain gage requirements, speed of testing, specimen preconditioning and environmental testing. Future maintenance of the standard will only be in response to specific requests and performed only as technical support allows.

1.5 *Units*—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.

1.5.1 Within the text the inch-pounds units are shown in brackets.

1.6 *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.*

1.7 *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

[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.

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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.

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
D3518/D3518M Test Method for In-Plane Shear Response of Polymer Matrix Composite Materials by Tensile Test of a ±45° Laminate
D3878 Terminology for Composite Materials
D5229/D5229M Test Method for Moisture Absorption Properties and Equilibrium Conditioning of Polymer Matrix Composite Materials
D5379/D5379M Test Method for Shear Properties of Composite Materials by the V-Notched Beam Method
D5448/D5448M Test Method for Inplane Shear Properties of Hoop Wound Polymer Matrix Composite Cylinders
D7078/D7078M Test Method for Shear Properties of Composite Materials by V-Notched Rail Shear Method
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

2.2 *ASTM Adjunct:*
Adjunct No. ADJD4255, Rail Shear Fixtures Machining Drawings[3]

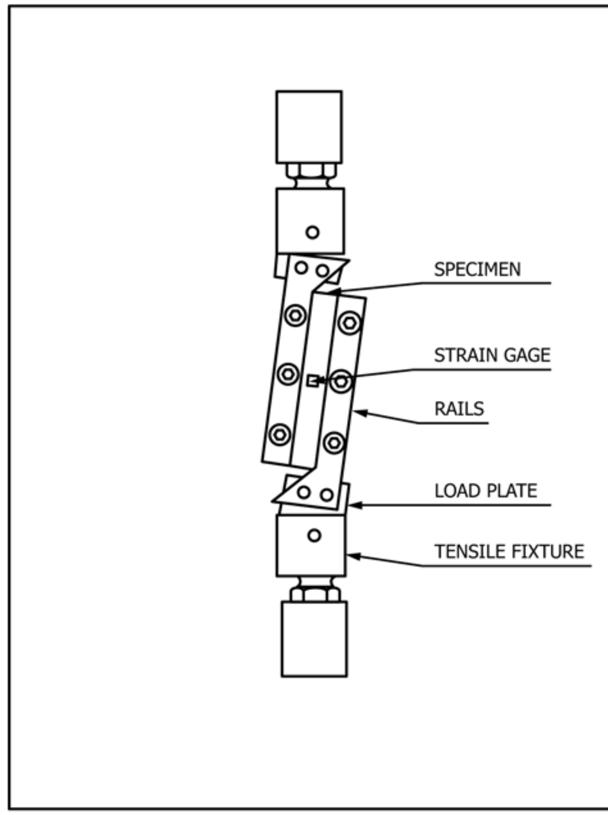

FIG. 1 Procedure A Assembly Rail Shear Apparatus

3. Terminology

3.1 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 terminology standards.

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 *Definitions of Terms Specific to This Standard:*

3.2.1 *in-plane shear, n*—shear associated with shear forces applied to the edges of the laminate so that the resulting shear deformations occur in the plane of the laminate rather than through the thickness.

3.2.2 *offset shear stress* [$M/(LT^2)$], *n*—the shear stress associated with an offset of the shear chord modulus of elasticity line along the strain axis (see 13.5).

3.2.3 *shear strength* [$M/(LT^2)$], *n*—the shear stress carried by a material at failure under a pure shear condition.

3.2.4 *transition region, n*—a strain region of a stress-strain or strain-strain curve over which a significant change in the slope of the curve occurs within a small strain range.

3.2.4.1 *Discussion*—Many filamentary composite materials exhibit a nonlinear response during loading, such as seen in plots of either longitudinal stress versus longitudinal strain or transverse strain versus longitudinal strain. In certain cases, the nonlinear response may be conveniently approximated by a bilinear fit. There are several physical reasons for the existence of a transition region. Common examples include matrix cracking under tensile loading and ply delamination.

3.2.5 *traveler, n*—a small piece of the same material as, and processed similarly to, the test specimen, used for example to measure moisture content as a result of conditioning. This is also sometimes termed as a reference sample.

3.3 *Symbols:*

A = cross-sectional area of test specimen
B_y = percent bending of specimen
CV = coefficient of variation statistic of a sample population for a given property, %

[3] A copy of the detailed drawing for the construction of the fixtures shown in Figs. 1 and 2 is available at a nominal cost from ASTM Headquarters. Request Adjunct No. ADJD4255.

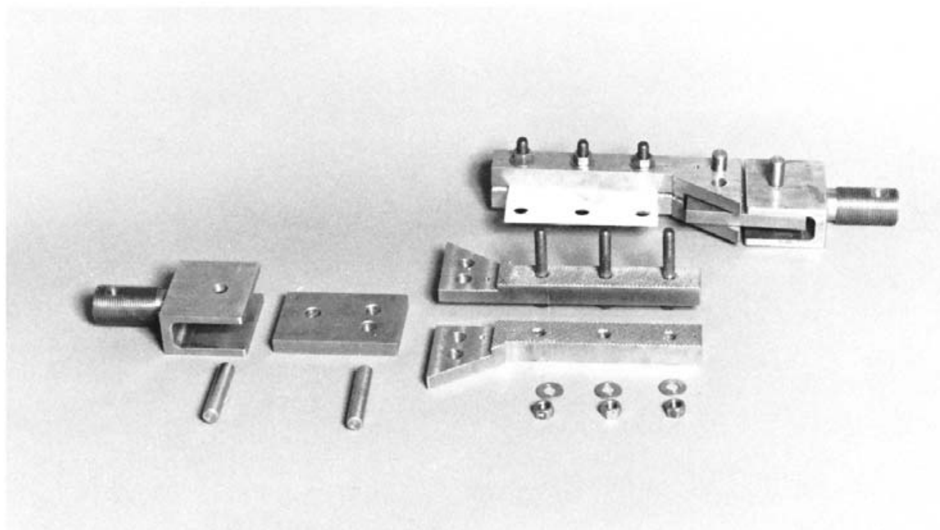

FIG. 2 Procedure A Partially Assembled Typical Test Fixture

F_{12}^{o} = offset shear stress, the value of the shear stress at the intersection of the stress-strain plot with a line passing through the offset strain value at zero stress and with a slope equal to the shear chord modulus of elasticity

F^{u} = ultimate shear stress

G = shear modulus of elasticity

h = specimen thickness

l = specimen length, the dimension parallel to the rails in the gage section

n = number of specimens

P_i = force carried by test specimen at ith data point

P^{max} = force carried by a test specimen that is the lesser of (*1*) the maximum force before failure, (*2*) the force at 5 % engineering shear strain, or (*3*) the force at the bending limit (see 11.8.1)

S_{n-1} = sample standard deviation

x_i = measured or derived property for an individual specimen from the sample population

$\bar{\chi}$ = sample mean (average)

γ = engineering shear strain

ε = indicated normal strain from strain transducer

$\mu\varepsilon = 10^{-6}$ m/m (10^{-6} in./in.)

τ_i = shear stress at ith data point

4. Summary of Test Method

4.1 *Procedure A: Two-Rail Shear Test*—A flat panel with holes along opposing edges is clamped, usually by through bolts, between two pairs of parallel steel loading rails; see Figs. 1 and 2. When loaded in tension, this fixture introduces shear forces in the specimen that produce failures across the panel. This test method is typical but not the only configuration usable. The two-rail shear fixtures can also be compression loaded. The force may be applied to failure.

4.1.1 If force-strain data are required, the specimen may be instrumented with strain gages. Biaxial strain gage rosettes are installed at corresponding locations on each face of the specimen.

4.2 *Procedure B: Three-Rail Shear Test*—A flat panel, clamped securely between pairs of rails on opposite edges and in its center, is loaded by supporting the side rails while loading the center rails. See Figs. 3-5. A force on the center rail of either tension or compression produces a shear force in each section of the specimen. The force may be applied to failure.

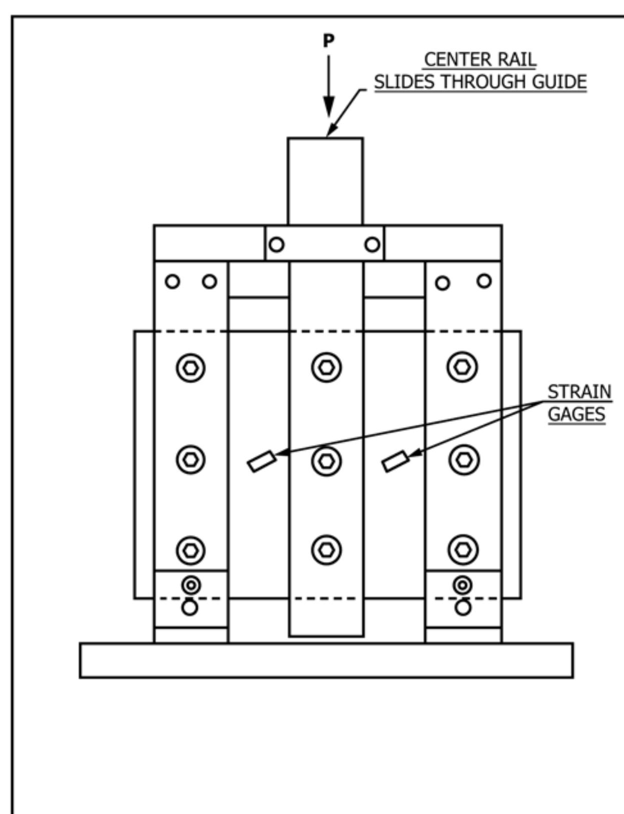

FIG. 3 Procedure B Assembly Rail Shear Fixture