Designation: D 4762 – 04

Standard Guide for Testing Polymer Matrix Composite Materials[1]

This standard is issued under the fixed designation D 4762; 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.

1. Scope

1.1 This guide summarizes the application of ASTM standard test methods (and other supporting standards) to continuous-fiber reinforced polymer matrix composite materials. The most commonly used or most applicable ASTM standards are included, emphasizing use of standards of Committee D30 on Composite Materials.

1.2 This guide does not cover all possible standards that could apply to polymer matrix composites and restricts discussion to the documented scope. Commonly used but non-standard industry extensions of test method scopes, such as application of static test methods to fatigue testing, are not discussed. A more complete summary of general composite testing standards, including non-ASTM test methods, is included in the Composite Materials Handbook (MIL-HDBK-17).[2] Additional specific recommendations for testing textile (fabric, braided) composites are contained in Guide D 6856.

1.3 This guide does not specify a system of measurement; the systems specified within each of the referenced standards shall apply as appropriate. Note that the referenced standards of ASTM Committee D30 are either SI-only or combined-unit standards with SI units listed first.

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:* [3]

2.1.1 *Standards of Committee D30 on Composite Materials*

C 393 Test Method for Flexural Properties of Sandwich Constructions

C 480 Test Method for Flexure Creep of Sandwich Constructions

C 613/C 613M Test Method for Constituent Content of Composite Prepreg by Soxhlet Extraction

D 2344/D 2344M Test Method for Short Beam Strength of Composite Materials and Their Laminates

D 3039/D 3039M Test Method for Tensile Properties of Polymer Matrix Composite Materials

D 3171 Test Method for Constituent Content of Composite Materials

D 3410/D 3410M Test Method for Compressive Properties of Polymer Matrix Composite Materials with Unsupported Gage Section by Shear Loading

D 3479/D 3479M Test Method for Tension-Tension Fatigue of Polymer Matrix Composite Materials

D 3518/D 3518M Test Method for In-Plane Shear Response of Polymer Matrix Composite Materials by Tensile Test of a ±45 Laminate

D 3529/D 3529M Test Method for Matrix Solids Content and Matrix Content of Composite Prepreg

D 3530/D 3530M Test Method for Volatiles Content of Composite Material Prepreg

D 3531 Test Method for Resin Flow of Carbon Fiber-Epoxy Prepreg

D 3532 Test Method for Gel Time of Carbon Fiber-Epoxy Prepreg

D 3544 Guide for Reporting Test Methods and Results on High Modulus Fibers[4]

D 3800 Test Method for Density of High-Modulus Fibers

D 3878 Terminology of Composite Materials

D 4018 Test Methods for Properties of Continuous Filament Carbon and Graphite Fiber Tows

D 4102 Test Method for Thermal Oxidative Resistance of Carbon Fibers

D 4255/D 4255M Test Method for In-Plane Shear Properties of Polymer Matrix Composite Materials by the Rail Shear Method

D 5229/D 5229M Test Method for Moisture Absorption Properties and Equilibrium Conditioning of Polymer Matrix Composite Materials

D 5379/D 5379M Test Method for Shear Properties of Composite Materials by the V-Notched Beam Method

[1] This guide is under the jurisdiction of ASTM Committee D30 on Composite Materials and is the direct responsibility of Subcommittee D30.01 on Editorial and Resource Standards.

Current edition approved May 1, 2004. Published May 2004. Originally approved in 1988. Last previous edition approved in 2001 as D 4762 – 88 (2001).

[2] Available from ASTM, and also from the U.S. DoD Standardization Documents Order Desk, Bldg. 4 Section D, 700 Robbins Ave., Philadelphia, PA 19111-5094, Attn: NPODS.

[3] 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.

[4] Withdrawn.

D 5448/D 5448M Test Method for In-Plane Shear Properties of Hoop Wound Polymer Matrix Composite Cylinders
D 5449/D 5449M Test Method for Transverse Compressive Properties of Hoop Wound Polymer Matrix Composite Cylinders
D 5450/D 5450M Test Method for Transverse Tensile Properties of Hoop Wound Polymer Matrix Composite Cylinders
D 5467/D 5467M Test Method for Compressive Properties of Unidirectional Polymer Matrix Composites Using a Sandwich Beam
D 5528 Test Method for Mode I Interlaminar Fracture Toughness of Unidirectional Fiber-Reinforced Polymer Matrix Composites
D 5687/D 5687M Guide for Preparation of Flat Composite Panels With Processing Guidelines for Specimen Preparation
D 5766/D 5766M Test Method for Open Hole Tensile Strength of Polymer Matrix Composite Laminates
D 5961/D 5961M Test Method for Bearing Response of Polymer Matrix Composite Laminates
D 6115 Test Method for Mode I Fatigue Delamination Growth Onset of Unidirectional Fiber-Reinforced Polymer-Matrix Composites
D 6264 Test Method for Measuring the Damage Resistance of a Fiber-Reinforced Polymer-Matrix Composite to a Concentrated Quasi-Static Indentation Force
D 6415 Test Method for Measuring the Curved Beam Strength of a Fiber-Reinforced Polymer-Matrix Composite
D 6416/D 6416M Test Method for Two-Dimensional Flexural Properties of Simply Supported Sandwich Composite Plates Subjected to a Distributed Load
D 6484/D 6484M Test Method for Open-Hole Compressive Strength of Polymer Matrix Composite Laminates
D 6507 Practice for Fiber Reinforcement Orientation Codes for Composite Materials
D 6641/D 6641M Test Method for Determining the Compressive Properties of Polymer Matrix Composite Materials Using the Combined Loading Compression (CLC) Test Fixture
D 6671 Test Method for Mixed Mode I-Mode II Interlaminar Fracture Toughness of Unidirectional Fiber Reinforced Polymer Matrix Composites
D 6742/D 6742M Practice for Filled-Hole Tension and Compression Testing of Polymer Matrix Composite Laminates
D 6856 Guide for Testing Fabric Reinforced Textile Composite Materials
D 6873 Practice for Bearing Fatigue Testing of Polymer Matrix Composite Laminates
E 1309 Guide for the Identification of Fiber-Reinforced Polymer Matrix Composite Materials in Databases
E 1434 Guide for Recording Mechanical Test Data of Fiber-Reinforced Composite Materials in Databases
E 1471 Guide for the Identification of Fibers, Fillers, and Core Materials in Computerized Material Property Databases

2.1.2 *Standards of Committee D20 on Plastics*

C 581 Practice for Determining Chemical Resistance of Thermosetting Resins Used in Glass-Fiber-Reinforced Structures Intended for Liquid Service
D 256 Test Method for Determining the Izod Pendulum Impact Resistance of Plastics
D 543 Test Method for Evaluating the Resistance of Plastics to Chemical Reagents
D 618 Practice for Conditioning Plastics for Testing
D 638 Test Method for Tensile Properties of Plastics
D 648 Test Method for Deflection Temperature of Plastics Under Flexural Load in the Edgewise Position
D 671 Test Method for Flexural Fatigue of Plastics by Constant-Amplitude-of- Force[4]
D 695 Test Method for Compressive Properties of Rigid Plastics
D 696 Test Method for Coefficient of Linear Thermal Expansion of Plastics Between -30°C and 30°C With a Vitreous Silica Dilatometer
D 790 Test Methods for Flexural Properties of Unreinforced and Reinforced Plastics and Electrical Insulating Materials
D 792 Test Methods for Density and Specific Gravity (Relative Density) of Plastics by Displacement
D 953 Test Method for Bearing Strength of Plastics
D 1505 Test Method for Density of Plastics by the Density-Gradient Technique
D 1822 Test Method for Tensile-Impact Energy to Break Plastics and Electrical Insulating Materials
D 2471 Test Method for Gel Time and Peak Exothermic Temperature of Reacting Thermosetting Resins
D 2583 Test Method for Indentation Hardness of Rigid Plastics by Means of a Barcol Impressor
D 2584 Test Method for Ignition Loss of Cured Reinforced Resins
D 2734 Test Method for Void Content of Reinforced Plastics
D 2990 Test Methods for Tensile, Compressive, and Flexural Creep and Creep-Rupture of Plastics
D 3418 Test Method for Transition Temperatures of Polymers by Differential Scanning Calorimetry
D 3846 Test Method for In-Plane Shear Strength of Reinforced Plastics
D 4065 Practice for Plastics: Dynamical Mechanical Properties: Determination and Report of Procedures
D 4473 Test Method for Plastics: Dynamic Mechanical Properties: Cure Behavior
D 5083 Test Method for Tensile Properties of Reinforced Thermosetting Plastics Using Straight-Sided Specimens
D 6272 Test Method for Flexural Properties of Unreinforced and Reinforced Plastics and Electrical Insulating Materials by Four-Point Bending

2.1.3 *Standards of Other ASTM Committees*

E 228 Test Method for Linear Thermal Expansion of Solid Materials With a Vitreous Silica Dilatometer
E 289 Test Method for Linear Thermal Expansion of Rigid Solids with Interferometry
E 1269 Test Method for Determining Specific Heat Capacity by Differential Scanning Calorimetry

E 1461 Test Method for Thermal Diffusivity of Solids by the Flash Method

E 1922 Test Method for Translaminar Fracture Toughness of Laminated Polymer Matrix Composite Materials

3. Terminology

3.1 Definitions related to composite materials are defined in Terminology D 3878.

3.2 Symbology for specifying the orientation and stacking sequence of a composite laminate is defined in Practice D 6507.

3.3 For purposes of this document, "low modulus" composites are defined as being reinforced with fibers having a modulus ≤20 GPa (≤3.0 × 10^6 psi), while "high-modulus" composites are reinforced with fiber having a modulus >20 GPa (>3.0 × 10^6 psi).

4. Significance and Use

4.1 This guide is intended to aid in the selection of standards for polymer matrix composite materials. It specifically summarizes the application of standards from ASTM Committee D30 on Composite Materials that apply to continuous-fiber reinforced polymer matrix composite materials. For reference and comparison, many commonly used or applicable ASTM standards from other ASTM Committees are also included.

5. Standard Specimen Preparation

5.1 Preparation of polymer matrix composite test specimens is described in Guide D 5687.

6. Standard Test Methods

6.1 ASTM test methods for the evaluation of polymer matrix composites are summarized in Tables 1-5. Advantages, disadvantages, and other comments for each test method are included where appropriate. Where possible, a single preferred test method is identified.

TEST METHOD CATEGORY	TABLE
Lamina/Laminate Static Properties	Table 1
Lamina/Laminate Dynamic Properties	Table 2
Laminate/Structural Response	Table 3
Constituent/Precursor/Thermophysical Properties	Table 4
Environmental Conditioning/Resistance	Table 5

7. Standard Data Reporting

7.1 *Constituent Material Description*—Data reporting of the description of composite material constituents is documented in Guide E 1471.

7.2 *Composite Material Description*—Data reporting of the description of composite materials is documented in Guide E 1309.

7.3 *Composite Material Test Data*—Data reporting of mechanical test data results for composite materials is documented in Guide E 1434.

8. Keywords

8.1 bearing strength; coefficient of thermal expansion; composite materials; composites; compression; compressive strength; constituent content; crack-growth testing; creep; creep strength; CTE; curved-beam strength; damage; data recording; data records; delamination; density; elastic modulus; fatigue; fiber; fiber volume; filament; filled-hole compression strength; filled-hole tensile strength; flatwise tensile strength; flexural modulus; flexure; fracture; fracture toughness; gel time; glass transition temperature; hoop-wound; impact; impact strength; lamina; laminate; matrix content; mixed mode; mode I; mode II; mode III; modulus of elasticity; moisture content; moisture diffusivity; Poisson's ratio; OHC; OHT; open-hole compressive strength; open-hole tensile strength; out-of-plane compressive strength; out-of-plane shear strength; out-of-plane tensile strength; panel; plate; polymer matrix composites; prepreg; reinforcement; reinforcement content; reinforcement volume; resin; resin content; shear; shear modulus; shear strength; short-beam strength; specific heat; strain energy release rate; strength; structure; tensile strength; tension; thermal conductivity; thermal diffusivity; thermal expansion coefficient; tow; V-notched beam strength; void content; winding; yarn

TABLE 1 Lamina/Laminate Static Test Methods

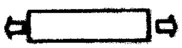
Test Method	Specimen	Measured Property	Description and Advantages	Disadvantages	Comments
		In-Plane Tensile Test Methods			
D 3039		Tensile Strength	Straight sided specimen. Suitable for both random, discontinuous and continuous-fiber composites. Tabbed and untabbed configurations available.	Tabbed configurations require careful adhesive selection and special specimen preparation. Certain laminate layups prone to edge delamination which can affect tensile strength results.	Preferred for most uses. Provides additional configurations, requirements, and guidance that are not found in D 5083. Limited to laminates that are balanced and symmetric with respect to the test direction.
		Tensile Modulus, Poisson's Ratio, Stress-Strain Response	Requires use of strain or displacement transducers. Modulus measurements do not require use of tabs.		Modulus measurements typically robust.
D 638		Tensile Strength, Tensile Modulus	"Dumbbell" shaped specimen. Ease of test specimen preparation.	Stress concentration at the radii. Unsuitable for highly oriented fiber composites.	Not recommended for high-modulus composites. Technically equivalent to ISO 527-1.
D 5083		Tensile Strength, Tensile Modulus	Straight-sided, untabbed specimen only.	Suitable for plastics and low-modulus composites.	A straight-sided alternative to D 638. Technically equivalent to ISO 527-4 except as noted below: (*a*) This test method does not include testing of the Type I dog-bone shaped specimen described in ISO 527-4. Testing of this type of specimen, primarily used for reinforced and unreinforced thermoplastic materials, is described in D 638. (*b*) The thickness of test specimens in this test method includes the 2 mm to 10 mm thickness range of ISO 527-4, but expands the allowable test thickness to 14 mm.
D 5450		Transverse (90°) Tensile Strength	Hoop wound cylinder with all 90° (hoop) plies loaded in axial tension. Develops data for specialized process/form.	Limited to hoop-wound cylinders. Limited to transverse tensile properties. Must bond specimen to fixture.	Must ensure adequate bonding to fixture.
		In-Plane Compression Test Methods			
D 6641		Compressive Strength	Untabbed, straight-sided specimen loaded via a combination of shear and end-loading. Smaller lighter, less expensive fixture than that of D 3410. Better also at non-ambient environments. Suitable for continuous fiber composites.	May be necessary to tab highly oriented fiber composites or laminates with 0° plies on the surface. Not recommended for determining compressive strength of unidirectional (0° ply orientation) tape or tow laminates.	Preferred method. Thickness must be sufficient to prevent column buckling. Limited to laminates that are balanced and symmetric and contain at least one 0° ply. For strength determination, the laminate is limited to a maximum of 50 % 0° plies, or equivalent.
		Compressive Modulus, Poisson's Ratio, Stress-Strain Response	Requires use of strain or displacement transducers.		Unidirectional tape or tow composites can be tested to determine unidirectional modulus and Poisson's ratio.

TABLE 1 *Continued*

Test Method	Specimen	Measured Property	Description and Advantages	Disadvantages	Comments
D 695		Compressive Strength, Compressive Modulus	“Dogbone” shaped specimen with loading applied at the ends via a platen. Tabs are optional.	Failure mode is often end-crushing. Stress concentrations at radii. Specimen must be dog boned and ends must be accurately machined. No assessment of alignment.	Not recommended for highly oriented or continuous fiber composites. Modified version of D 695 released as SACMA SRM 1 test method is widely used in aerospace industry, but ASTM D30 and MIL-HDBK-17 prefer use of D 6641 method.
D 3410		Compressive Strength	Straight sided specimen with load applied by shear via fixture grips. Suitable for random, discontinuous and continuous fiber composites. Tabbed and untabbed configurations available.	Strain gages required to verify alignment. Poor for non-ambient testing due to massive fixture.	Expensive and heavy/ bulky fixturing. Thickness must be sufficient to prevent column buckling.
		Compressive Modulus, Poisson’s Ratio, Stress-Strain Response	Requires use of strain or displacement transducers.		
D 5467		Compressive Strength, Compressive Modulus, Stress-Strain Response	Sandwich beam specimen loaded in 4-point bending. Intended result is a compression failure mode of the facesheet. Data is especially applicable to sandwich structures. Fixturing is simple compared to other compression tests.	An expensive specimen that is not recommended unless the structure warrants its use. Strain gages required to obtain modulus and strain-to-failure data. Narrow (1 in. wide) specimen may not be suitable for materials with coarse features, such as fabrics with large filament count tows (12K or more) or certain braided materials.	Must take care to avoid core failure modes. Limited to high-modulus composites. Due to the nature of the specimen construction and applied flexural loading these results may not be equivalent to a similar laminate tested by other compression methods such as D 3410 or D 6641.
D 5449		Transverse (90°) Compressive Strength	Hoop-wound cylinder with all 90° (hoop) plies loaded in compression. Develops data for specialized process/form.	Limited to hoop-wound cylinders. Limited to transverse compressive properties. Must bond specimen to fixture.	Must ensure adequate bonding to fixture.
		In-Plane Shear Test Methods			
D 3518		Shear Strength, Shear Modulus, Stress-Strain Response	Tensile test of [+45/-45]ns layup. Simple test specimen and test method.	Poor specimen for measuring ultimate shear strength due to large non-linear response. Limited to material forms/ processes that can be made in flat ±45° form. Biaxial transducers required to obtain modulus and strain-to-failure data.	Widely used due to its low cost and relationship to actual structural laminates.

TABLE 1 *Continued*

Test Method	Specimen	Measured Property	Description and Advantages	Disadvantages	Comments
D 5379		Shear Strength, Shear Modulus, Stress-Strain Response	V-notched specimen loaded in special bending fixture. Provides the best shear response of the standardized methods. Provides shear modulus and strength. Can be used to test most composite types. Produces a relatively pure and uniform shear stress state.	May be necessary to tab the specimen. Specimen can be difficult to machine. Biaxial strain gages required to obtain modulus and strain-to-failure data. Requires good strain-gage installation technique. In-plane tests not suitable for materials with coarse features, such as fabrics with large filament count tows (12K or more) or certain braided materials. Unacceptable failure modes, especially with high-strength laminates, can occur due to localized failure of the specimen at the loading points.	Recommended for quantitative data, or where shear modulus or stress/strain data are required. Enables correlation with out-of-plane properties. Must monitor strain data for specimen buckling. Limited to the following forms: (*a*) unidirectional tape or tow laminates with fibers parallel or perpendicular to loading axis. (*b*) woven fabric laminates with the warp direction parallel or perpendicular to loading axis. (*c*) laminates with equal numbers of 0° and 90° plies with the 0° plies parallel or perpendicular to loading axis. (*d*) short-fiber composites with majority of the fibers randomly distributed. The most accurate modulus measurements obtained from laminates of the [0/90] family.
D 4255		Shear Strength, Shear Modulus, Stress-Strain Response	Rail shear methods. Suitable for both random and continuous fiber composites.	Difficult test to run. Historically has had poor reproducibility. Stress concentrations at gripping areas. Strain gages required to obtain modulus and strain-to-failure data.	Expensive specimen. Best reserved for testing of laminates.
D 5448		Shear Strength, Shear Modulus, Stress-Strain Response	Hoop-wound cylinder with all 90° (hoop) plies loaded in torsion. Develops data for specialized process/form.	Limited to hoop-wound cylinders. Limited to in-plane shear properties. Must bond specimen to fixture.	Must ensure adequate bonding to fixture.
		Out-of-Plane Tensile Test Methods			
D 6415		Curved Laminate Strength	Right-angle curved laminate specimen loaded in 4-point bending. Suitable for continuous fiber composites.	A complex stress state is generated in the specimen that may cause an unintended complex failure mode. There is typically a large amount of scatter in the curved beam strength data. While the failure mode is largely out-of-plane, the result is generally considered a structural test of a curved beam rather than a material property.	Limited to composites with defined layers (no through-the-thickness reinforcement). For structural comparison, the same manufacturing process should be used for both the test specimen and the structure. Non-standard versions of the curved-beam test yield a different stress state that may affect the strength and failure mode.
		Interlaminar Tensile Strength	See above.	See above.	Tests for interlaminar tensile strength limited to unidirectional materials with fibers oriented continuously along the legs and around the bend.

TABLE 1 *Continued*

Test Method	Specimen	Measured Property	Description and Advantages	Disadvantages	Comments
Out-of-Plane Shear Test Methods					
D 2344		Short Beam Strength	Short rectangular beam specimen loaded in 3-point bending. Short Beam Strength is a good indicator of resin-dominated properties. Simple, inexpensive specimen and test configuration.	Short Beam Strength may be related to interlaminar shear strength, but the stress state is quite mixed, and so results are not recommended as an assessment of shear strength due to stress concentrations and high secondary stresses at loading points. Shear modulus cannot be measured.	Intended primarily for quality control, comparative data, and assessment of environmental effects.
D 5379		Interlaminar Shear Strength, Interlaminar Shear Modulus	V-notched specimen loaded in special bending fixture. Provides the best shear response of the standardized methods. Provides shear modulus and strength. Can be used to test most composites. Produces a relatively pure and uniform shear stress state.	May be necessary to tab the specimen. Specimen can be difficult to machine. Strain gages required to obtain modulus and strain-to-failure data. Requires good strain-gage installation technique. Requires a very thick laminate, 20 mm (0.75 in.) for out-of-plane properties.	Recommended for quantitative data, or where shear modulus or stress/strain data are required. Enables correlation with in-plane properties. Must monitor strain data for specimen buckling.
D 3846		Shear Strength	Specimen with two machined notches loaded in compression. Suitable for randomly dispersed and continuous fiber reinforced materials. May be preferable to D 2344 for materials with randomly dispersed fiber orientations.	Failures may be sensitive to accuracy of notch machining. Stress concentrations at notches. Failure may be influenced by the applied compression stress. Requires post-failure measurement of shear area. Shear modulus cannot be measured.	Specimen loaded in compression utilizing the D 695 loading/stabilizing jig. Shear loading occurs in a plane between two machined notches. Often a problematic test. Note that this is an out-of-plane shear test (using recognized terminology), despite the title that indicates in-plane shear loading.
Sandwich Flexural Test Methods					
C 393		Core Shear Strength, Core Shear Modulus, Sandwich Flexural Stiffness, Facesheet Compressive Strength, Facesheet Tensile Strength	Sandwich beam specimen for sandwich constructions. Ease of specimen construction and testing. Includes both 3-point and 4-point techniques, for different test objectives.	Method limited to 1D bending. Failures are often dominated by stress concentrations and secondary stresses at loading points, especially with specimens having low-density cores and thin face sheets. Care must be exercised when testing for core shear modulus to insure that the beam geometry is such that simple sandwich beam theory is valid. Specimen must be carefully designed to obtain the desired failure mode.	Since this method was developed for characterizing sandwich composite structures, results apply to a beam that could be made up of both composite and non-composite components. Therefore the failure may initiate in a non-composite element (core, adhesive) of the structure. Span-to-depth ratio >20:1 is recommended when testing for shear modulus. The ratio of face sheet thickness to core thickness (t/c) should be <0.10.

TABLE 1 *Continued*

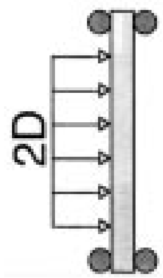
Test Method	Specimen	Measured Property	Description and Advantages	Disadvantages	Comments
D 5467		Facesheet Compressive Strength, Compressive Modulus, Stress-Strain Response	Sandwich beam specimen loaded in 4-point bending. Intended result is a compression failure mode of the facesheet. Data is especially applicable to sandwich structures. Fixturing is simple compared to other compression tests.	Limited to high-modulus composites. An expensive specimen that is not recommended unless the structure warrants its use. Strain gages required to obtain modulus and strain-to-failure data.	Must take care to avoid core failure modes. Narrow (1 in. wide) specimen may not be suitable for materials with coarse features, such as fabrics with large filament count tows (12K or more) or certain braided materials.
D 6416		Pressure-Deflection Response, Pressure-Strain Response, Sandwich Bending and Shear Stiffness	Two-dimensional plate flexure induced by a well-defined distributed load. Apparatus, instrumentation ensure applied pressure distribution is known. Failures typically initiate away from edges. Specimens are relatively large, facilitating study of manufacturing defects and process variables.	For studies of failure mechanics and other quantitative sandwich analyses, only small panel deflections are allowed. The test fixture is necessarily more elaborate, and some calibration is required to verify simply-supported boundary conditions. Results highly dependent upon panel edge boundary conditions and pressure distribution. Relatively large specimen and support fixture geometry.	The same caveats applying to C 393 (above) could apply to D 6416. However, this method is not limited to sandwich composites; D 6416 can be used to evaluate the 2-dimensional flexural properties of any square plate. Distributed load is provided using a water-filled bladder. Ratio of support span to average sandwich specimen thickness should be between 10 to 30.
Laminate Flexural Test Methods					
D 790		Flexural Strength, Flexural Modulus, Flexural Stress-Strain Response	Flat rectangular specimen loaded in 3-point bending. Suitable for randomly dispersed and continuous fiber reinforced materials. Ease of test specimen preparation and testing.	Stress concentrations and secondary stresses at loading points. Results sensitive to specimen and loading geometry, strain rate.	Failure mode may be tension, compression, shear, or combination.
D 6272		Flexural Strength, Flexural Modulus, Flexural Stress-Strain Response	Flat rectangular specimen loaded in 4-point bending. Suitable for randomly dispersed and continuous fiber reinforced materials. Ease of test specimen preparation and testing. Choice of two procedures enable adjustable tension/compression/shear load distribution.	Center-point deflection requires secondary instrumentation. Results sensitive to specimen and loading geometry, strain rate. Span-to-depth ratio must increase for laminates with high tensile strength with respect to in-plane shear strength.	The quarter-span version is recommended for high-modulus composites. Failure mode may be tension, compression, shear, or combination.
D 6416		Pressure-Deflection Response, Pressure-Strain Response, Plate Bending and Shear Stiffness	Two-dimensional plate flexure induced by a well-defined distributed load. Apparatus, instrumentation ensure applied pressure distribution is known. Failures typically initiate away from edges. Specimens are relatively large, facilitating study of manufacturing defects and process variables.	For studies of failure mechanics and other quantitative sandwich analyses, only small panel deflections are allowed. The test fixture is necessarily more elaborate, and some calibration is required to verify simply-supported boundary conditions. Results highly dependent upon panel edge boundary conditions and pressure distribution. Relatively large specimen and support fixture geometry.	The same caveats applying to C 393 (above) could apply to D 6416. However, this method is not limited to sandwich composites; D 6416 can be used to evaluate the 2-dimensional flexural properties of any square plate. Distributed load is provided using a water-filled bladder. Ratio of support span to average sandwich specimen thickness should be between 10 to 30.

TABLE 1 *Continued*

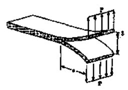
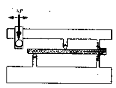
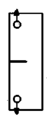
Test Method	Specimen	Measured Property	Description and Advantages	Disadvantages	Comments
		Fracture Toughness Test Methods			
D 5528		Mode I Interlaminar Fracture Toughness, G_{Ic}	Flat rectangular specimen with delamination insert loaded in tension. Suitable for unidirectional tape or tow laminates. Relatively stable delamination growth.	Specimens must be hinged at the loading points. Crack growth not always well behaved.	Calculations assume linear elastic behavior. Crack growth should be observed from both sides of the specimen.
D 6671		Mixed Mode I/II Interlaminar Fracture Toughness, G_c	Flat rectangular specimen with delamination insert loaded in bending. Suitable for unidirectional tape or tow laminates. Tests at most mode mixtures. Constant mode mixtures with crack growth. Can obtain initiation and propagation toughness values.	Specimens must be hinged at the loading points. Crack growth not always well behaved. Complicated loading apparatus.	Good alignment is critical. Calculations assume linear elastic behavior.
E 1922		Translaminar Fracture Toughness, K_{TL}	Flat rectangular specimen containing an edge notch loaded in tension. Simple test to perform.	Results are only valid for the particular laminate tested. Laminates producing large damage zones do not give valid values.	

TABLE 2 Lamina/Laminate Dynamic Test Methods

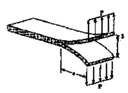
Test Method	Specimen	Measured Property	Description and Advantages	Disadvantages	Comments
In-Plane Tension/Tension Fatigue Test Methods					
D 3479		Tension-Tension Stress-Cycles (S-N) Data	Uses D 3039 tensile test specimen, with axial tension-tension cyclic loading. Suitable for both random and continuous-fiber composites.	Stress concentrations at the end tabs. End tab machining and bonding required.	Careful specimen preparation is critical. Appropriate specimen geometry may vary from material to material. User should be prepared to do preliminary fatigue tests to optimize tab configurations and materials.
In-Plane Flexural Fatigue Test Methods					
D 671		Flexural Stress-Cycles (S-N) Data	Constant-force cantilever specimen. Inexpensive high cycle fatigue (HCF) method.	Stress concentrations at notches. Results sensitive to specimen thickness. Not suitable for continuous-fiber composites.	This test method should not be used for continuous-fiber composites. Flexural tests are typically considered structural tests, not material property tests.
Fatigue Crack-Growth/Toughness Test Methods					
D 6115		Mode I Fatigue Delamination Initiation; Toughness-Cycles (G-N) Data	Uses D 5528 DCB specimen, with cyclic loading. Produces threshold fatigue data (G_{Imax} versus N).	Does not produce da/dN data. The limitations and comments for D 5528 also apply.	
Tensile Creep Test Methods					
D 2990		Tensile Strain versus Time	Uses D 638 tensile specimen, with long-duration loading. Ease of test specimen preparation.	Stress concentrations at specimen radii.	Not suitable for continuous fiber composites; instead use D 3039 type specimen.
Flexural Creep Test Methods					
D 2990		Flexural Deflection versus Time	Uses D 790 flexure specimen, with long-duration loading. Includes both 3 and 4-point bending test setups. Simple to set up and run.	Continuous-fiber flexural material response is complex, making results hard to interpret or generalize. Results sensitive to specimen and loading geometry. Failure mode may vary.	Not widely used in advanced composites industry.
C 480		Flexural Deflection versus Time	Sandwich beam specimen for sandwich construction loaded in 3-point bending.	Limited to sandwich panels.	
Tensile Impact Test Methods					
D 1822		Tensile Impact Energy of Rupture	Relatively inexpensive test machine.	Stress concentrations at the radii. Very small test specimens. Not instrumented.	Not suitable for continuous fiber composites.
Flexural Impact Test Methods					
D 256		Impact Energy of Rupture.	Notched specimen. Flexibility in testing methods.	Not instrumented. Varying failure modes. Sensitive to test specimen geometry variations.	This test provides a structural impact property, not a material impact property.

TABLE 3 Laminate/Structural Test Methods

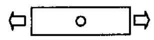
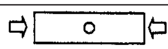
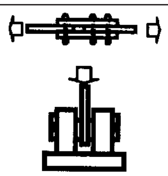
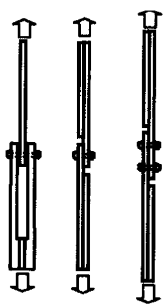
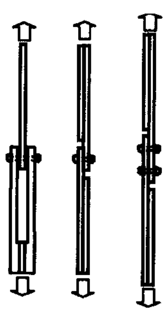
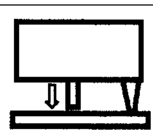
Test Method	Specimen	Measured Property	Description and Advantages	Disadvantages	Comments
Notched Laminate Tension Test Methods					
D 5766		Open Hole Tensile Strength	Straight-sided, untabbed, open hole configuration. Procedure nearly equivalent to D 3039.	Limited to multi-directional laminates with balanced and symmetric stacking sequences.	Provides requirements and guidance on specimen configuration and failure modes.
D 6742		Filled Hole Tensile Strength	Straight-sided, untabbed, filled hole configuration. Procedure and specimen nearly equivalent to D 3039, D 5766.	Same as D 5766.	Same as D 5766. Also provides guidance on hole tolerances, fastener torque/preload.
Notched Laminate Compression Test Methods					
D 6484		Open Hole Compressive Strength	Straight-sided, untabbed, open hole configuration. Fixture can be loaded using either hydraulic grips or end platens.	Limited to multi-directional laminates with balanced and symmetric stacking sequences.	Provides requirements and guidance on specimen configuration and failure modes.
D 6742		Filled Hole Compressive Strength	Straight-sided, untabbed, filled hole configuration. Procedure, specimen and apparatus nearly equivalent to D 6484.	Same as D 6484.	Same as D 6484. Also provides guidance on hole tolerances, fastener torque/preload.
Bolted Joint Test Methods					
D 953		Static Pin Bearing Strength	One fastener, double shear pin bearing specimen. Two methods available: tensile and compressive pin bearing. Monitors global load versus deformation behavior.	Focus is plastics. Does not account for various fastener geometries, torque/ preload levels. Deformation local to hole is not measured.	Some specimen geometric properties (for example, width/diameter ratio) vary from D 5961 guidelines. Not recommended for continuous fiber composites.
D 5961		Static Bearing Strength	One and two fastener double and single shear bearing specimens loaded in tension. Multiple specimen configurations provided to assess a variety of structural joint configurations. Procedures provided to monitor inelastic deformation behavior at hole.	Limited to multi-directional laminates with balanced and symmetric stacking sequences. Response highly dependent upon specimen configuration and fastener torque/ preload. Limited to bearing failure modes only. Some details of specimen configurations are not suitable for determining bypass failure strengths.	Provides requirements and guidance on specimen configuration, type of loading, hole tolerances, fastener torque/preload and failure modes.
D 6873		Bearing Stress-Cycles (S-N) Data	Specimen and apparatus equivalent to D 5961, with cyclic loading procedures provided to monitor hole elongation for a variety of joint configurations and fatigue loading conditions.	Same as D 5961. Certain tests may require fastener removal or a variant quasi-static loading ratio to monitor hole elongation.	Same as D 5961. Also provides guidance on fatigue loading ratio effects.
Static Indentation Test Methods					
D 2583		Indentation Hardness	Provides a relative measure of hardness based upon load versus indentation depth response. Barcol impressor is portable, and load is applied by hand.	Focus is plastics and low-modulus composites. Does not record force versus indentation depth response. Does not evaluate resulting damage state.	Uses flat-tipped indenter.

TABLE 3 *Continued*

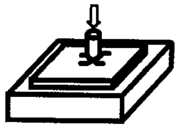
Test Method	Specimen	Measured Property	Description and Advantages	Disadvantages	Comments
D 6264		Force-Indenter Displacement Response, Dent Depth, Damage Characteristics	Flat rectangular laminated subject to a static point loading. Permits damage resistance testing of simply-supported and rigidly backed plate specimens. Uses a conventional testing machine. Contact force and indenter displacement data are obtained.	Limited to continuous fiber composites without through-the-thickness reinforcement. Test method does not address dynamic indentation effects. Narrow range of permissible specimen thicknesses.	Uses 12.7 mm (0.50 in.) diameter hemispherical indenter. Often used to approximate the damage state caused by a dynamic impact. Multi-directional fiber laminates with balanced and symmetric stacking sequences are usually used. The damage response is a function of the indentor geometry, support conditions and specimen configuration.
Trans-laminar Fracture Test Methods					
E 1922		Translaminar Fracture Toughness, K_{TL}	Flat rectangular specimen containing an edge notch loaded in tension. Simple test to perform	Results only valid for the particular laminate tested; laminates producing large damage zones do not give valid values	

TABLE 4 Constituent/Precursor/Thermophysical Test Methods

Test Method	Specimen	Measured Property	Description and Advantages	Disadvantages	Comments
		Reinforcement Property Test Methods			
D 3800		Fiber Density	Test method for density of high-modulus continuous and discontinuous fibers.		
D 4018		Carbon Fiber Tow Properties: -Tensile Modulus -Tensile Strength -Density -Mass per Unit Length -Sizing Content -Moisture Absorption	Provides test methods for continuous filament carbon and graphite yarns, rovings and tows. Tensile properties are determined using resin-impregnated fiber.	Tensile testing requires careful specimen preparation. The resin used to impregnate the fibers can affect the tensile test results.	
D 4102		Fiber Weight Loss	Test method for determining weight loss of carbon fibers exposed to hot ambient air. Exposure conditions are: -24 h at 375°C (707°F). -500 h at 315°C (600°F).		Determines oxidative resistance of carbon fibers for use in high-temperature applications.
		Matrix (Resin) Physical Property Test Methods			
D 792		Density	Test method for density of plastics using immersion methods. Ease of test specimen preparation and testing.	Some specimens may be affected by water; alternate immersion liquids are optional.	
D 1505		Density	Test method for density of plastics using density gradient method.		Typically used for film and sheeting materials
D 2471		Gel Time	Test method for determining gel time and peak exothermic temperature of reacting thermosetting resins		Used for testing neat resins. For composite prepregs, see D 3532 below.
D 4473		Cure Behavior	Test method for cure behavior of plastics by measuring dynamic mechanical properties.		
		Extent of Cure Test Methods			
D 3531		Resin Flow	Test method for resin flow of prepreg tape or sheet using square 2-ply specimen heated in a platen press.	Limited to carbon fiber-epoxy prepreg materials.	
D 3532		Gel Time	Test method for gel time of prepreg tape or sheet	Limited to carbon fiber-epoxy prepreg materials.	
		Constituent Content Test Methods			
C 613		Constituent Content	Test method for Soxhlet extraction procedure to determine the matrix content, reinforcement content, and filler content of composite material prepreg.	Limited to prepreg materials.	Not suitable for cured composites.
D 3171		Fiber, Resin, Void Content	Test method for fiber, resin, and void content of resin-matrix composites by either digestion of the matrix or by thickness of a material of known fiber areal weight (void content not determined). Includes methods for metal matrix composites as well.		The resin digestion methods are primarily intended for cured thermoset matrices but may also be suitable for some thermoplastics as well as prepreg resin content for materials that do not respond well to other methods.

TABLE 4 *Continued*

Test Method	Specimen	Measured Property	Description and Advantages	Disadvantages	Comments
D 3529		Resin Content	Test method for matrix solids content and matrix content using extraction by organic solvent.	Limited to prepreg materials. Resins that have started to cross-link (for example, B-staged resins) may be difficult to extract; D 3171 methods are recommended for these materials. Does not determine or require reporting of reinforcement content.	Not suitable for cured composites.
D 3530		Volatiles Content	Test method for volatiles content of epoxy-matrix prepreg tape and sheet	Limited to prepreg materials. Limited to reinforcement material types which are substantially unaffected by the temperature selected for use in removing volatiles from the matrix material.	Not suitable for cured composites.
D 2734		Void Content	Test methods for void content of reinforced plastics. Ease of test specimen preparation and testing.	Limited to composites for which the effects of ignition on the materials are known. May not be suitable for reinforcements consisting of metals, organic materials, or inorganic materials that may gain or lose weight. The presence of filler in some composites is not accounted for.	D 3171 is preferred for advanced composites. Void content of less than 1 % is difficult to measure accurately.
D 2584		Resin Content	Test method for ignition loss of cured reinforced resins. Ease of test specimen preparation and testing.	The presence of filler in some composites is not accounted for.	D 3171 is preferred for advanced composites. Result may be used as resin content under specified limitations.
		Thermo-Physical Test Methods			
D 696		Thermal Expansion versus Temperature Curves, Coefficients of Thermal Expansion	Test method for linear thermal expansion of plastic materials having coefficients of expansion greater than 1×10^{-6}/°C by use of a vitreous silica dilatometer. Ease of test specimen preparation and testing. Suitable for random and continuous fiber composites.	Limited to temperature range of -30°C to 30°C. Use E 228 for other temperatures.	This test method cannot be used for very low thermal expansion coefficient materials, such as unidirectional graphite fiber composites.
E 228		Thermal Expansion versus Temperature Curves, Coefficients of Thermal Expansion	Test method for linear thermal expansion over the temperature range of -180 to 900°C using vitreous silica push rod or tube dilatometers. Suitable for discontinuous or continuous fiber composites of defined orientation state.		Good for low values of thermal expansion. Precision greater than for D 696. Precision significantly lower than for E 289.
E 289		Thermal Expansion versus Temperature Curves, Coefficients of Thermal Expansion	Test method for linear thermal expansion of rigid solids using either a Michelson or Fizeau interferometer. Suitable for composites with very low values of thermal expansion.		Precision is listed as better than +40 nm/m/K.

TABLE 4 *Continued*

Test Method	Specimen	Measured Property	Description and Advantages	Disadvantages	Comments
E 1461		Thermal Diffusivity	Uses laser flash technique.		With specific heat measurement, can be used to calculate thermal conductivity indirectly.
E 1269		Specific Heat	Uses Differential Scanning Calorimetry.		
		Transition Temperature Test Methods			
D 648		Heat Deflection Temperature	Test method for determining temperature at which an arbitrary deformation occurs when specimen is subjected to an arbitrary set of testing conditions. Ease of test specimen preparation and testing.	Deflection temperature is dependent on specimen thickness and fiber reinforcement variables.	Test data used for material screening. Test data is not intended for design purposes.
D 3418		Glass Transition Temperature (Tg)	Test method for determination of transition temperatures of polymers by differential thermal analysis or differential scanning calorimetry (DSC). Ease of test specimen preparation and testing.	Not suitable for composites with low resin content.	The correlation between thermally measured transition temperatures and mechanical property transitions has not been suitably established.
D 4065		Transition Temperatures, Elastic Moduli, Loss Moduli	Practice for determining the transition temperatures, elastic, and loss moduli of plastics over a range of temperatures, frequencies, or time, by free vibration and resonant or nonresonant forced vibration techniques. Can use variety of test specimen geometries and loading methods.	Requires specialized equipment.	For best results, tests should be run on unreinforced resin.

TABLE 5 Environmental Conditioning/Resistance Test Methods

Test Method	Specimen	Measured Property	Description and Advantages	Disadvantages	Comments
		Equilibrium Moisture Content/Conditioning Test Methods			
D 5229		Through-Thickness Moisture Diffusivity, Equilibrium Moisture Content, Equilibrium Conditioning	Rigorous determination of moisture equilibrium for various exposure levels (including dry) as well as moisture absorption constants. Used for conditioning test coupons prior to use in other test methods	Requires long-conditioning times for many materials. Assumes 1-D Fickian behavior for material absorption constant determination.	A faster two-specimen approach documented in MIL-HDBK-17 has not yet been included in this standard.
		Non-Equilibrium Conditioning Test Methods			
D 618		None.	Test method for conditioning plastics prior to test.	No standard mechanical tests are specified. Weight gain is not monitored.	Not recommended for conditioning composites.
		Chemical Resistance Test Methods			
C 581		Changes to: Hardness, Weight, Thickness, Specimen Appearance Appearance of Immersion Media, Flexural Strength, Flexural Modulus.	Test method for chemical resistance of thermosetting resins. Ease of test specimen preparation and testing. Flexible exposure conditions.	The only mechanical tests specified are flexural. Weight gain is not monitored. No standard exposure times or temperatures are specified.	Exposure chemicals, times, temperatures are left to the user's discretion.
D 543		Changes to: Weight, Thickness, Specimen Appearance Tensile Strength, Tensile Modulus.	Practices for evaluating the resistance of plastics to chemical reagents. Standard exposure time and temperature set as a starting point.	The only mechanical loading type specified is tensile; others are optional	Longer exposure times may be desirable. Other mechanical loading types may be specified.