Designation: D8387/D8387M – 21

Standard Test Method for High Bypass – Low Bearing Interaction Response of Polymer Matrix Composite Laminates[1]

This standard is issued under the fixed designation D8387/D8387M; 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 test method determines the uniaxial high bypass - low bearing interaction response of multi-directional polymer matrix composite laminates reinforced by high-modulus fibers using a two-fastener hard point joint specimen. The scope of this test method is limited to net section (bypass) failure modes. Standard specimen configurations using fixed values of test parameters are described for this procedure. A number of test parameters may be varied within the scope of the standard, provided that the parameters are fully documented in the test report. The composite material forms are limited to continuous-fiber or discontinuous-fiber (tape or fabric, or both) reinforced composites for which the laminate is balanced and symmetric with respect to the test direction. The range of acceptable test laminates and thicknesses are described in 8.2.1. This test method was previously published under Test Method D7248/D7248M-17 Procedure C.

1.2 This test method is consistent with the recommendations of Composite Materials Handbook, CMH-17, which describes the desirable attributes of a bearing/bypass interaction response test method.

1.3 The two-fastener test configurations described in this test method are intended to provide data in the relatively high bypass, low bearing part of the composite bolted joint bearing-bypass interaction diagram. This data complements the data from filled hole tension and compression (Practice D6742/D6742M), bearing (Test Method D5961/D5961M), and low bypass/high bearing interaction (Test Method D7248/D7248M) tests.

1.4 This test method requires careful specimen design, instrumentation, data measurement, and data analysis. The use of this test method requires close coordination between the test requestor and the test lab personnel. Test requestors need to be familiar with the data analysis procedures of this test method and should not expect test labs who are unfamiliar with this test method to be able to produce acceptable results without close coordination.

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-pound 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
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

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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 D30.05 on Structural 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.

D5687/D5687M Guide for Preparation of Flat Composite Panels with Processing Guidelines for Specimen Preparation
D5766/D5766M Test Method for Open-Hole Tensile Strength of Polymer Matrix Composite Laminates
D5961/D5961M Test Method for Bearing Response of Polymer Matrix Composite Laminates
D6484/D6484M Test Method for Open-Hole Compressive Strength of Polymer Matrix Composite Laminates
D6742/D6742M Practice for Filled-Hole Tension and Compression Testing of Polymer Matrix Composite Laminates
D7248/D7248M Test Method for Bearing/Bypass Interaction Response of Polymer Matrix Composite Laminates Using 2-Fastener Specimens
E4 Practices for Force Verification of Testing Machines
E6 Terminology Relating to Methods of Mechanical Testing
E83 Practice for Verification and Classification of Extensometer Systems
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 *Other Document:*[3]

CMH-17 Composite Materials Handbook-17, Polymer Matrix Composites, Vol 1, Section 7

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 documents.

NOTE 1—If the term represents a physical quantity, its analytical dimensions are stated immediately following the term (or letter symbol) in fundamental dimension form, using the following ASTM standard symbology for fundamental dimensions, shown within square brackets: [*M*] for mass, [*L*] for length, [*T*] for time, [θ] for thermodynamic temperature, and [*nd*] for non-dimensional quantities. Use of these symbols is restricted to analytical dimensions when used with square brackets, as the symbols may have other definitions when used without the brackets.

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *bearing area,* $[L^2]$, *n*—the area of that portion of a specimen used to normalize applied loading into an effective bearing stress; equal to the diameter of the fastener multiplied by the thickness of the specimen.

3.2.2 *bearing force, P* $[MLT^{-2}]$, *n*—the in-plane force transmitted by a fastener to a specimen at the fastener hole.

3.2.3 *bearing strain,* ε^{br} [*nd*], *n*—the normalized hole deformation in a specimen, equal to the deformation of the bearing hole in the direction of the bearing force, divided by the diameter of the hole.

3.2.4 *bearing strength,* $F_x^{br\_byp}$ $[ML^{-1}T^{-2}]$, *n*—the value of bearing stress occurring at the point of bypass (net section) failure.

3.2.5 *bearing stress,* σ^{br} $[ML^{-1}T^{-2}]$, *n*—the bearing force divided by the bearing area.

3.2.6 *diameter to thickness ratio, D/h* [*nd*], *n—in a bearing specimen*, the ratio of the hole diameter to the specimen thickness.

3.2.6.1 *Discussion*—The diameter to thickness ratio may be either a nominal value determined from nominal dimensions or an actual value determined from measured dimensions.

3.2.7 *edge distance ratio, e/D* [*nd*], *n—in a bearing specimen*, the ratio of the distance between the center of the hole and the specimen end to the hole diameter.

3.2.7.1 *Discussion*—The edge distance ratio may be either a nominal value determined from nominal dimensions or an actual value determined from measured dimensions.

3.2.8 *gross bypass stress,* f^{gr_byp} $[ML^{-1}T^{-2}]$, *n*—the gross bypass stress for tensile loadings is calculated from the total force bypassing the fastener hole.

3.2.9 *net bypass stress,* f^{net_byp} $[ML^{-1}T^{-2}]$, *n*—the net bypass stress for tensile loading is calculated from the force bypassing the fastener hole minus the force reacted in bearing at the fastener.

3.2.9.1 *Discussion*—For compressive loadings, the gross and net bypass stresses are equal and are calculated using the force that bypasses the fastener hole (since for the compressive loading case, the bearing stress reaction is on the same side of the fastener as the applied force, the force reacted in bearing does not bypass the fastener hole).

3.2.9.2 *Discussion*—Several alternate definitions for gross and net bypass stress have been used historically in the aerospace industry. Comparison of data from tests conforming to this test method with historical data may need to account for differences in the bypass definitions.

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

3.2.11 *ultimate bearing strength,* F_x^{bru} $[ML^{-1}T^{-2}]$, *n*—the value of bearing stress, in the direction specified by the subscript, at the maximum force capability of a bearing specimen.

3.2.12 *ultimate gross bypass strength,* $F_x^{gr\_byp}$ $[ML^{-1}T^{-2}]$, *n*—the value of gross bypass stress, in the direction specified by the subscript, at the maximum force capability of the specimen.

3.2.13 *ultimate net bypass strength,* $F_x^{net\_byp}$ $[ML^{-1}T^{-2}]$, *n*—the value of net bypass stress, in the direction specified by the subscript, at the maximum force capability of the specimen.

3.2.14 *width to diameter ratio, w/D* [*nd*], *n—in a bearing specimen*, the ratio of specimen width to hole diameter.

3.2.14.1 *Discussion*—The width to diameter ratio may be

[3] Available from SAE International (SAE), 400 Commonwealth Dr., Warrendale, PA 15096, http://www.sae.org.

either a nominal value determined from nominal dimensions or an actual value, determined as the ratio of the actual specimen width to the actual hole diameter.

3.3 *Symbols:*

A = gross cross-sectional area (disregarding hole) mm^2 [in.^{2}]

C_F = fastener flexibility (Ref **1**)[4]

C_P = plate (specimen) flexibility

C_S = doubler plate flexibility

CV = sample coefficient of variation, %

d = fastener diameter, mm [in.]

D = hole diameter, mm [in.]

e/D = actual edge distance ratio

E_F = fastener modulus, MPa [psi]

E_{xP} = test specimen laminate modulus, MPa [psi]

E_{xS} = doubler plate modulus in axial (x) direction, MPa [psi]

$F_x^{gr\_byp\_t}$ = ultimate tensile gross bypass strength, MPa [psi].

$F_x^{net\_byp\_t}$ = ultimate tensile net bypass strength, MPa [psi]

$F_x^{gr\_byp\_c}$ = ultimate compressive gross bypass strength, MPa [psi]

$F_x^{net\_byp\_c}$ = ultimate compressive net bypass strength, MPa [psi]

F^{br_byp} = bearing stress at ultimate bypass strength, MPa [psi]

g = distance from hole edge to specimen end, mm [in.]

h = specimen thickness near hole (nominal or actual, as specified), mm [in.]

k_D = proportion of total force transferred through doubler plates

k_E = estimate of proportion of total force transferred through fasteners to doubler plates

k_S = proportion of total force transferred through specimen

L = distance between fastener centerlines, mm [in.]

n = number of strain gages on the doubler plate

n = number of tested specimens

P = total force applied to specimen, N [lbf]

P_{D1}, P_{D2} = force in doubler plates, N [lbf]

P_i = force at i-th data point, N [lbf]

P_{max} = maximum force prior to failure, N [lbf]

P_S = force in specimen between fasteners, N [lbf]

s_{n-1} = sample standard deviation

t_P = test specimen laminate thickness, mm [in.]

t_S = doubler plate thickness, mm [in.]

ν_F = fastener Poisson's ratio

w = width of specimen across hole, mm [in.]

w_P = test specimen width, mm [in.]

w_S = doubler plate width, mm [in.]

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

x_i = measured or derived property

δ_{1i} = extensometer-1 displacement at i-th data point, mm [in.]

δ_{2i} = extensometer-2 displacement at i-th data point, mm [in.]

ε_i^{br} = bearing strain, microstrain

σ_i^{br} = bearing stress at i-th data point, MPa [psi]

[4] The boldface numbers in parentheses refer to the list of references at the end of this standard.

4. Summary of Test Method

4.1 *Bearing/Bypass Test Procedures*—Definition of the uniaxial bearing/bypass interaction response requires data for varying amounts of bearing and bypass forces at a fastener hole. Fig. 1 shows a typical composite laminate bearing/bypass interaction diagram (Refs **1-3**), along with illustrative data from various test types. Data from Practice D6742/D6742M and Test Method D5961/D5961M define the 100 % bypass and bearing ends of the interaction diagram. Test Method D7248/D7248M Procedures A and B provide data in the low bypass/high bearing region. This test method provides data in the high bypass/low bearing region. More complicated test setups have been used to develop data across the full range of bearing/bypass interaction. This test method is limited to cases where the bearing and bypass loads are aligned in the same direction. It is also limited to uniaxial tensile or compressive bypass loads. Test procedures for cases where the bearing and bypass loads act at different directions, or cases with biaxial or shear bypass loads are outside the scope of this test method.

4.1.1 Ultimate strength for all procedures is calculated based on the specimen gross cross-sectional area, disregarding the presence of the hole. While the hole causes a stress concentration and reduced net section, it is common industry practice to develop notched design allowable strengths based on gross section stress to account for various stress concentrations (fastener holes, free edges, flaws, damage, and so forth) not explicitly modeled in the stress analysis. This is consistent with the ASTM D30 test methods for open and filled hole tension and compression strength (Test Methods D5766/D5766M, D6484/D6484M, and Practice D6742/D6742M).

4.2 *High Bypass/Low Bearing Double Shear:*

4.2.1 A flat, constant rectangular cross-section test specimen with two centerline holes located in the middle of the specimen, as shown in the test specimen drawing of Fig. 2, is axially loaded. Two doubler plates, Fig. 3, are attached to the specimen as shown in Fig. 4 to act as a "hardpoint" which induces bearing forces in the test specimen and plates. The ends of the test specimen are gripped in the jaws of a test machine and loaded in tension or compression.

4.2.1.1 *Unstabilized Configuration (No Support Fixture)*—The ends of the test specimen are gripped in the jaws of a test machine and loaded in tension.

4.2.1.2 *Stabilized Configuration (Using Support Fixture)*—The test specimen is face-supported in a multi-piece bolted support fixture, as shown in Fig. 5. The test specimen/fixture assembly is clamped in hydraulic wedge grips and the force is sheared into the support fixture and then sheared into the specimen. Tensile or compressive force is applied. The stabilization fixture is required for compressive loading and is optional for tensile loading.

4.2.2 The amount of force that is transferred through the doubler plates is determined from the measurement of strain in the plates and test specimen. The force-strain response of the doubler plates and test specimen must be determined using a determinant test setup prior to the bearing/bypass test. Due to uncertainties in the hole tolerances and fastener flexibilities, calculation of the doubler plate forces is not sufficiently

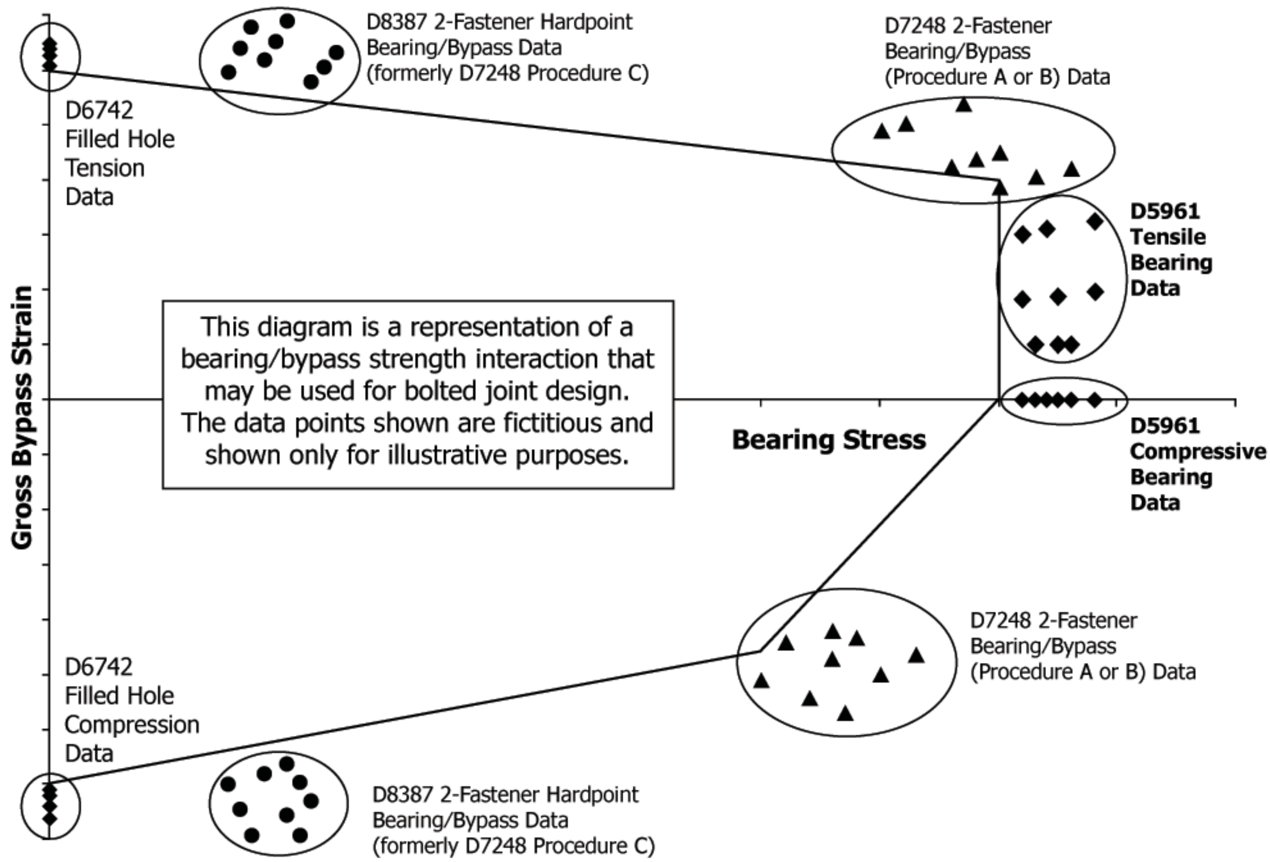

FIG. 1 Illustration of FHT, FHC, Bearing and Bearing/Bypass Bolted Joints Data and Bearing/Bypass Interaction Diagram (Refs 1-3)

reliable for data reduction (equations are provided in this test method for estimating the fastener loads for the purposes of specimen design).

4.2.3 Both the applied force and the associated deformation of the hole(s) are monitored. The applied force is normalized by the projected hole area to yield an effective bearing stress. The specimen is loaded until a two part failure is achieved.

4.2.4 The standard test configuration for this procedure has defined values for the major test parameters. However, the following variations in configuration are allowed and can be considered as being in accordance with this test method as long as the values of all variant test parameters are prominently documented with the results. The standard specimen width has a w/d = 6, as bearing failures for this specimen configuration are not common, unlike that for the 2-fastener Test Method D7248/D7248M bypass specimen. This avoids having to put spacers into the support fixture for narrow specimens.

Parameter	Standard	Variation
Loading condition	double-shear	none
Loading type	tensile	compressive
Doubler plate material	steel	yes, if documented
Number of holes	2	none
Countersunk holes	no	none
Hole fit	tight	any, if documented
Fastener torque	9.0-10.7 N·m [80-95 lbf-in.] for tensile load 2.2-3.4 N·m [20-30 lbf-in.] for compressive load	any, if documented
Laminate	quasi-isotropic	any, if documented
Fastener diameter	6 mm [0.250 in.]	any, if documented
w/D ratio	6	any, if documented
D/h ratio	1.2-2	any, if documented

5. Significance and Use

5.1 This test method is designed to produce low bearing / high bypass interaction response data for research and development, and for structural design and analysis. The