



Designation: C1869 – 18 (Reapproved 2023)

Standard Test Method for Open-Hole Tensile Strength of Fiber-Reinforced Advanced Ceramic Composites¹

This standard is issued under the fixed designation C1869; 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 open-hole (notched) tensile strength of continuous fiber-reinforced ceramic matrix composite (CMC) test specimens with a single through-hole of defined diameter (either 6 mm or 3 mm). The open-hole tensile (OHT) test method determines the effect of the single through-hole on the tensile strength and stress response of continuous fiber-reinforced CMCs at ambient temperature. The OHT strength can be compared to the tensile strength of an unnotched test specimen to determine the effect of the defined open hole on the tensile strength and the notch sensitivity of the CMC material. If a material is notch sensitive, then the OHT strength of a material varies with the size of the through-hole. Commonly, larger holes introduce larger stress concentrations and reduce the OHT strength.

1.2 This test method defines two baseline OHT test specimen geometries and a test procedure, based on Test Methods **C1275** and **D5766/D5766M**. A flat, straight-sided ceramic composite test specimen with a defined laminate fiber architecture contains a single through-hole (either 6 mm or 3 mm in diameter), centered by length and width in the defined gage section (**Fig. 1**). A uniaxial, monotonic tensile test is performed along the defined test reinforcement axis at ambient temperature, measuring the applied force versus time/displacement in accordance with Test Method **C1275**. Measurement of the gage length extension/strain is optional, using extensometer/displacement transducers. Bonded strain gages are optional for measuring localized strains and assessing bending strains in the gage section.

1.3 The open-hole tensile strength (S_{OHTx}) for the defined hole diameter x (mm) is the calculated ultimate tensile strength based on the maximum applied force and the gross cross-sectional area, disregarding the presence of the hole, per common aerospace practice (see **4.4**). The net section tensile

strength (S_{NSx}) is also calculated as a second strength property, accounting for the effect of the hole on the cross-sectional area of the test specimen.

1.4 This test method applies primarily to ceramic matrix composites with continuous fiber reinforcement in multiple directions. The CMC material is typically a fiber-reinforced, 2-D, laminated composite in which the laminate is balanced and symmetric with respect to the test direction. Composites with other types of reinforcement (1-D, 3-D, braided, unbalanced) may be tested with this method, with consideration of how the different architectures may affect the notch effect of the hole on the OHT strength and the tensile stress-strain response. This test method does not directly address discontinuous fiber-reinforced, whisker-reinforced, or particulate-reinforced ceramics, although the test methods detailed here may be equally applicable to these composites.

1.5 This test method may be used for a wide range of CMC materials with different reinforcement fibers and ceramic matrices (oxide-oxide composites, silicon carbide (SiC) fibers in SiC matrices, carbon fibers in SiC matrices, and carbon-carbon composites) and CMCs with different reinforcement architectures. It is also applicable to CMCs with a wide range of porosities and densities.

1.6 **Annex A1** and **Appendix X1** address how test specimens with different geometries and hole diameters may be prepared and tested to determine how those changes will modify the OHT strength properties, determine the notch sensitivity, and affect the stress-strain response.

1.7 The test method may be adapted for elevated temperature OHT testing by modifying the test equipment, specimens, and procedures per Test Method **C1359** and as described in **Appendix X2**. The test method may also be adapted for environmental testing (controlled atmosphere/humidity at moderate ($<300^\circ\text{C}$) temperatures) of the OHT properties by the use of an environmental test chamber, per **7.6**.

1.8 Values expressed in this test method are in accordance with the International System of Units (SI) and **IEEE/ASTM SI 10**.

1.9 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the*

¹ This test method is under the jurisdiction of ASTM Committee **C28** on Advanced Ceramics and is the direct responsibility of Subcommittee **C28.07** on Ceramic Matrix Composites.

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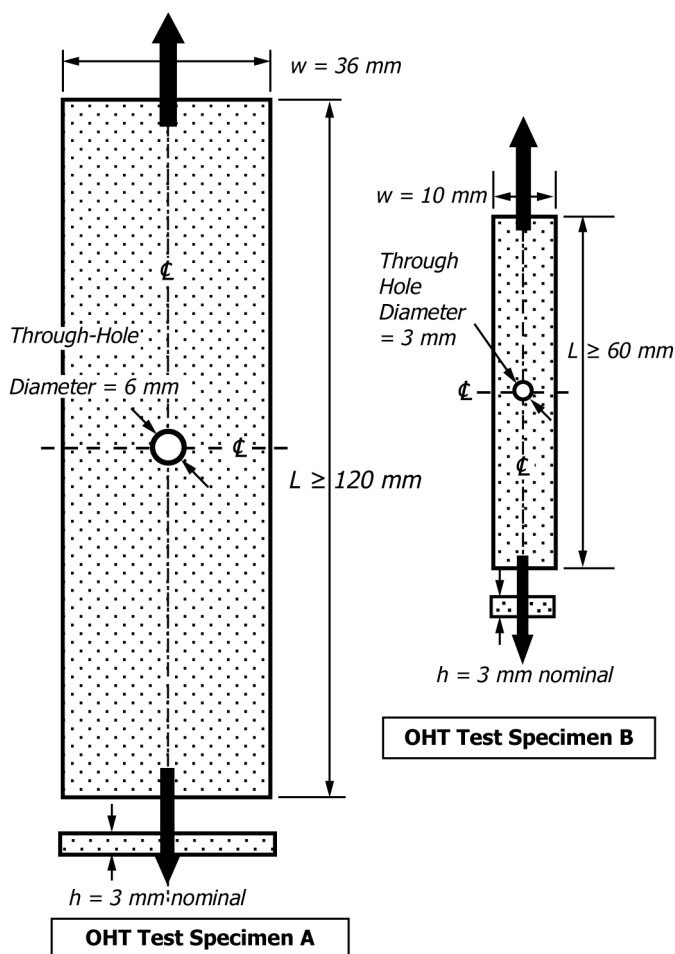


FIG. 1 OHT Test Specimens A and B

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.

1.10 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

- C373 Test Methods for Determination of Water Absorption and Associated Properties by Vacuum Method for Pressed Ceramic Tiles and Glass Tiles and Boil Method for Extruded Ceramic Tiles and Non-tile Fired Ceramic Whiteware Products
- C1145 Terminology of Advanced Ceramics

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.

- C1239 Practice for Reporting Uniaxial Strength Data and Estimating Weibull Distribution Parameters for Advanced Ceramics
- C1275 Test Method for Monotonic Tensile Behavior of Continuous Fiber-Reinforced Advanced Ceramics with Solid Rectangular Cross-Section Test Specimens at Ambient Temperature
- C1326 Test Method for Knoop Indentation Hardness of Advanced Ceramics
- C1327 Test Method for Vickers Indentation Hardness of Advanced Ceramics
- C1359 Test Method for Monotonic Tensile Strength Testing of Continuous Fiber-Reinforced Advanced Ceramics With Solid Rectangular Cross Section Test Specimens at Elevated Temperatures
- C1465 Test Method for Determination of Slow Crack Growth Parameters of Advanced Ceramics by Constant Stress-Rate Flexural Testing at Elevated Temperatures
- C1773 Test Method for Monotonic Axial Tensile Behavior of Continuous Fiber-Reinforced Advanced Ceramic Tubular Test Specimens at Ambient Temperature
- C1793 Guide for Development of Specifications for Fiber Reinforced Silicon Carbide-Silicon Carbide Composite Structures for Nuclear Applications
- D3039/D3039M Test Method for Tensile Properties of Polymer Matrix Composite Materials
- D3878 Terminology for Composite Materials
- D5766/D5766M Test Method for Open-Hole Tensile Strength of Polymer Matrix Composite Laminates
- D6856/D6856M Guide for Testing Fabric-Reinforced "Textile" Composite Materials
- E4 Practices for Force Calibration and Verification of Testing Machines
- E6 Terminology Relating to Methods of Mechanical Testing
- E83 Practice for Verification and Classification of Extensometer Systems
- E105 Guide for Probability Sampling of Materials
- E122 Practice for Calculating Sample Size to Estimate, With Specified Precision, the Average for a Characteristic of a Lot or Process
- E251 Test Methods for Performance Characteristics of Metallic Bonded Resistance Strain Gages
- E337 Test Method for Measuring Humidity with a Psychrometer (the Measurement of Wet- and Dry-Bulb Temperatures)
- E691 Practice for Conducting an Interlaboratory Study to Determine the Precision of a Test Method
- E1012 Practice for Verification of Testing Frame and Specimen Alignment Under Tensile and Compressive Axial Force Application
- E1402 Guide for Sampling Design
- E2208 Guide for Evaluating Non-Contacting Optical Strain Measurement Systems
- IEEE/ASTM SI 10 American National Standard for Metric Practice

3. Terminology

3.1 *Definitions*—Annex A2 lists pertinent general definitions from Practice E1012, Terminology C1145 (advanced