



Designation: ~~C1819–15~~ C1819 – 21

## Standard Test Method for Hoop Tensile Strength of Continuous Fiber-Reinforced Advanced Ceramic Composite Tubular Test Specimens at Ambient Temperature Using Elastomeric Inserts<sup>1</sup>

This standard is issued under the fixed designation C1819; 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 ( $\epsilon$ ) indicates an editorial change since the last revision or reapproval.

### 1. Scope

1.1 This test method covers the determination of the hoop tensile strength including stress-strain response of continuous fiber-reinforced advanced ceramic tubes subjected to an internal pressure produced by the expansion of an elastomeric insert undergoing monotonic uniaxial loading at ambient temperature. This type of test configuration is sometimes referred to as an overhung tube. This test method is specific to tube ~~geometries~~geometries because flaw populations, fiber architecture, and specimen geometry factors are often distinctly different in composite tubes, as compared to flat plates.

1.2 In the test method a composite tube/cylinder with a defined gage section and a known wall thickness is loaded via internal pressurization from the radial expansion of an elastomeric insert (located midway inside the tube) that is longitudinally compressed from either end by pushrods. The elastomeric insert expands under the uniaxial compressive loading of the pushrods and exerts a uniform radial pressure on the inside of the tube. The resulting hoop stress-strain response of the composite tube is recorded until failure of the tube. The hoop tensile strength and the hoop fracture strength are determined from the resulting maximum pressure and the pressure at fracture, respectively. The hoop tensile strains, the hoop proportional limit stress, and the modulus of elasticity in the hoop direction are determined from the stress-strain data. Note that hoop tensile strength as used in this test method refers to the tensile strength in the hoop direction from the induced pressure of a monotonic, ~~uniaxially-loaded~~uniaxially loaded elastomeric insert, where ~~monotonic~~“monotonic” refers to a continuous, nonstop test rate without reversals from test initiation to final fracture.

1.3 This test method applies primarily to advanced ceramic matrix composite tubes with continuous fiber reinforcement: ~~uni-directional (1-D)~~unidirectional (1D, filament wound and tape lay-up), bidirectional (~~2-D~~(2D, fabric/tape lay-up and weave), and tridirectional (~~3-D~~(3D, braid and weave). These types of ceramic matrix composites can be composed of a wide range of ceramic fibers (oxide, graphite, carbide, nitride, and other compositions) in a wide range of crystalline and amorphous ceramic matrix compositions (oxide, carbide, nitride, carbon, graphite, and other compositions).

1.4 This test method does not directly address discontinuous fiber-reinforced, ~~whisker-reinforced~~whisker-reinforced, or particulate-reinforced ceramics, although the test methods detailed here may be equally applicable to these composites.

1.5 The test method is applicable to a range of test specimen tube ~~geometries~~ based on a ~~non-dimensional~~non-dimensional parameter that includes composite material property and tube radius. Lengths of the composite tube, ~~push-rods~~pushrods, and

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elastomeric insert are determined from this ~~non-dimensional~~ non-dimensional parameter so as to provide a gage length with ~~uniform, internal, uniform~~ internal radial pressure. A wide range of combinations of material properties, tube radii, wall thicknesses, tube lengths, and insert lengths are possible.

1.5.1 This test method is specific to ambient temperature testing. Elevated temperature testing requires ~~high-temperature~~ high-temperature furnaces and heating devices with temperature control and measurement systems and temperature-capable grips and loading fixtures, which are not addressed in this test standard.

1.6 This test method addresses tubular test specimen geometries, test specimen methods, testing rates (force rate, induced pressure rate, displacement rate, or strain rate), and data collection and reporting procedures in the following sections.

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

1.8 *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~~ safety, health, and health environmental practices and determine the applicability of regulatory limitations prior to use.* Specific hazard statements are given in Section 8 and **Note 1**.

1.9 *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:<sup>2</sup>

- [C1145 Terminology of Advanced Ceramics](#)
- [C1239 Practice for Reporting Uniaxial Strength Data and Estimating Weibull Distribution Parameters for Advanced Ceramics](#)
- [D3878 Terminology for Composite Materials](#)
- [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](#)
- [E177 Practice for Use of the Terms Precision and Bias in ASTM Test Methods](#)
- [E337 Test Method for Measuring Humidity with a Psychrometer \(the Measurement of Wet- and Dry-Bulb Temperatures\)](#)
- [E380 Practice for Use of the International System of Units \(SI\) \(the Modernized Metric System\) \(Withdrawn 1997\)<sup>3</sup>](#)
- [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](#)
- [SH0-02 IEEE/ASTM SI 10 American National Standard for Use of the International System of Units \(SI\): The Modern Metric System Metric Practice](#)

<sup>2</sup> 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.

### 3. Terminology

#### 3.1 Definitions:

3.1.1 The definitions of terms relating to hoop tensile strength testing appearing in Terminology E6 apply to the terms used in this test method. The definitions of terms relating to advanced ceramics appearing in Terminology C1145 apply to the terms used in this test method. The definitions of terms relating to ~~fiber-reinforced~~ fiber-reinforced composites appearing in Terminology D3878 apply to the terms used in this test method. Pertinent definitions as listed in Practice E1012, ~~Terminology and Terminologies C1145, Terminology D3878, and Terminology E6~~ are shown in the following with the appropriate source given in parentheses. Additional terms used in conjunction with this test method are defined in the following:

3.1.2 *advanced ceramic, n*—a highly engineered, ~~high performance~~ high-performance, predominantly nonmetallic, inorganic, ceramic material having specific functional attributes. (See Terminology C1145.)

3.1.3 *breaking force, n*—the force at which fracture occurs. (See Terminology E6.)

3.1.4 *ceramic matrix composite (CMC), n*—a material consisting of two or more materials (insoluble in one another), in which the major, continuous component (matrix component) is a ceramic, while the secondary component/s (reinforcing component) may be ceramic, glass-ceramic, glass, metal, or organic in nature. These components are combined on a macroscale to form a useful engineering material possessing certain properties or behavior not possessed by the individual constituents.

3.1.5 *continuous fiber-reinforced ceramic matrix composite (CFCC), n*—a ceramic matrix composite in which the reinforcing phase consists of a continuous fiber, continuous yarn, or a woven fabric.

3.1.6 *gage length, n*—the original length of that portion of the specimen over which strain or change of length is determined. (See Terminology E6.)

3.1.7 *hoop tensile strength, n*—the maximum tensile component of hoop stress which a material is capable of sustaining. Hoop tensile strength is calculated from the maximum internal pressure induced in a tubular test specimen.

3.1.8 ~~matrix-cracking~~ *matrix cracking stress, n*—the applied tensile stress at which the matrix cracks into a series of roughly parallel blocks normal to the tensile stress.

##### 3.1.8.1 Discussion—

In some cases, the matrix cracking stress may be indicated on the stress-strain curve by deviation from linearity (proportional limit) or incremental drops in the stress with increasing strain. In other cases, especially with materials which do not possess a linear region of the stress-strain curve, the matrix cracking stress may be indicated as the first stress at which a permanent offset strain is detected in the during unloading (elastic limit).

3.1.9 *modulus of elasticity, n*—the ratio of stress to corresponding strain below the proportional limit. (See Terminology E6.)

3.1.10 *modulus of resilience, n*—strain energy per unit volume required to elastically stress the material from zero to the proportional limit indicating the ability of the material to absorb energy when deformed elastically and return it when unloaded.

3.1.11 *modulus of toughness, n*—strain energy per unit volume required to stress the material from zero to final fracture indicating the ability of the material to absorb energy beyond the elastic range (that is, damage tolerance of the material).

##### 3.1.11.1 Discussion—

The modulus of toughness can also be referred to as the cumulative damage energy and as such is regarded as an indication of the ability of the material to sustain damage rather than as a material property. Fracture mechanics methods for the characterization of CMCs have not been developed. The determination of the modulus of toughness as provided in this test method for the characterization of the cumulative damage process in CMCs may become obsolete when fracture mechanics methods for CMCs become available.

3.1.12 *proportional limit stress, n*—the greatest stress that a material is capable of sustaining without any deviation from proportionality of stress to strain (Hooke's law).

##### 3.1.12.1 Discussion—

Many experiments have shown that values observed for the proportional limit vary greatly with the sensitivity and accuracy of the