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Standard Test Method for Hoop Tensile Strength of Continuous Fiber-Reinforced Advanced Ceramic Composite Tubular Test Specimens at Ambient Temperature Using Direct Pressurization¹

This standard is issued under the fixed designation C1863; 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 covers the determination of the hoop tensile strength, including stress-strain response, of continuous fiber-reinforced advanced ceramic tubes subjected to direct internal pressurization that is applied monotonically at ambient temperature. This type of test configuration is sometimes referred to as “tube burst test.” This test method is specific to tube geometries, because flaw populations, fiber architecture, material fabrication, and test 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 gauge section and a known wall thickness is loaded via internal pressurization from a pressurized fluid applied either directly to the material or through a secondary bladder inserted into the tube. The monotonically applied uniform radial pressure on the inside of the tube results in hoop stress-strain response of the composite tube that 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 introduction of a monotonically applied internal pressure where ‘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: unidirectional (1D, filament wound and tape lay-up), bidirectional (2D, fabric/tape lay-up and weave), and tridirectional (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, 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 the intended application that includes composite material property and tube radius. Lengths of the composite tube, length of the pressurized section, and length of tube overhang are determined so as to provide a gauge length with uniform internal radial pressure. A wide range of combinations of material properties, tube radii, wall thicknesses, tube lengths, and lengths of pressurized section are possible.

1.5.1 This test method is specific to ambient temperature testing. Elevated temperature testing requires high-temperature furnaces and heating devices with temperature control and measurement systems and temperature-capable pressurization methods which are not addressed in this test method.

1.6 This test method addresses tubular test specimen geometries, test specimen preparation methods, testing rates (that is, induced pressure 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) and **IEEE/ASTM SI 10**.

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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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, health, and environmental practices and determine the applicability of regulatory limitations prior to use. Specific hazard statements are given in Section 8.

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:²

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 Calibration and Verification of Testing Machines

E6 Terminology Relating to Methods of Mechanical Testing

E83 Practice for Verification and Classification of Extensometer Systems

E337 Test Method for Measuring Humidity with a Psychrometer (the Measurement of Wet- and Dry-Bulb Temperatures)

E1012 Practice for Verification of Testing Frame and Specimen Alignment Under Tensile and Compressive Axial Force Application

IEEE/ASTM SI 10 American National Standard for Metric Practice

3. Terminology

3.1 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 composites appearing in Terminology **D3878** apply to the terms used in this test method. Pertinent definitions as listed in Practice **E1012** and Terminologies **C1145**, **D3878**, and **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:

3.2 Definitions:

3.2.1 *advanced ceramic*, *n*—a highly engineered, high-performance, predominantly nonmetallic, inorganic, ceramic material having specific functional attributes. **C1145**

3.2.2 *breaking force (F)*, *n*—the force at which fracture occurs. **E6**

3.2.3 *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. **C1145**

3.2.4 *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. **C1145**

3.2.5 *gauge length (L)*, *n*—the original length of that portion of the specimen over which strain or change of length is determined. **E6**

3.2.6 *hoop fracture strength (FL⁻²)*, *n*—the tensile component of hoop stress at the point when the structural integrity of the material is compromised and the tubular test specimen ruptures. Hoop fracture strength is calculated from the internal pressure induced at rupture of the tubular test specimen.

3.2.7 *hoop stress (FL⁻²)*, *n*—the tensile stress in the circumferential direction of a tube or pipe due to internal hydrostatic pressure.

3.2.8 *hoop tensile strength (FL⁻²)*, *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.

3.2.9 *matrix cracking stress (FL⁻²)*, *n*—the applied tensile stress at which the matrix cracks into a series of roughly parallel blocks normal to the tensile stress.

3.2.9.1 *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).

3.2.10 *modulus of elasticity (FL⁻²)*, *n*—the ratio of stress to corresponding strain below the proportional limit. **E6**

3.2.11 *modulus of resilience (FLL⁻³)*, *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.

3.2.12 *modulus of toughness (FLL⁻³)*, *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).

3.2.12.1 *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

² For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at www.astm.org/contact. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.