



Designation: C1773 – 21

Standard Test Method for Monotonic Axial Tensile Behavior of Continuous Fiber-Reinforced Advanced Ceramic Tubular Test Specimens at Ambient Temperature¹

This standard is issued under the fixed designation C1773; 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 axial tensile strength and stress-strain response of continuous fiber-reinforced advanced ceramic composite tubes at ambient temperature under monotonic loading. This test method is specific to tube geometries, because 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 fitted/bonded into a loading fixture. The test specimen/fixture assembly is mounted in the testing machine and monotonically loaded in uniaxial tension at ambient temperature while recording the tensile force and the strain in the gage section. The axial tensile strength and the fracture strength are determined from the maximum applied force and the fracture force. The strains, the proportional limit stress, and the tensile modulus of elasticity are determined from the stress-strain data.

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 are 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 describes a range of test specimen tube geometries based on past tensile testing of ceramic composite

tubes. These geometries are applicable to tubes with outer diameters of 10 to 150 mm and wall thicknesses of 1 to 25 mm, where the ratio of the outer diameter-to-wall thickness (d_o/t) is typically between 5 and 30.

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 grips and loading fixtures, which are not addressed in this test method.

1.6 The test method addresses test equipment, gripping methods, testing modes, allowable bending stresses, interferences, tubular test specimen geometries, test specimen preparation, test procedures, data collection, calculation, reporting requirements, and precision/bias in the following sections.

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1.7 *Units*—The values stated in SI units are to be regarded as standard.

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 precautionary statements are given in Section 8.

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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*A Summary of Changes section appears at the end of this standard

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
- C1273 Test Method for Tensile Strength of Monolithic Advanced Ceramics at Ambient Temperatures
- C1557 Test Method for Tensile Strength and Young's Modulus of Fibers
- D3878 Terminology for Composite Materials
- D5450 Test Method for Transverse Tensile Properties of Hoop Wound Polymer Matrix Composite Cylinders
- 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
- 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

3. Terminology

3.1 Definitions:

3.1.1 Pertinent definitions, as listed in Terminology C1145, Practice E1012, Terminology D3878, and Terminology E6, are shown in the following with the appropriate source in bold type. 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, predominantly nonmetallic, inorganic, ceramic material having specific functional attributes. **C1145**

3.1.3 *axial strain, n*—the average of the longitudinal strains measured at the surface on opposite sides of the longitudinal axis of symmetry of the test specimen by two strain-sensing devices located at the mid length of the reduced section. **E1012**

3.1.4 *bending strain, n*—the difference between the strain at the surface and the axial strain. In general, the bending strain varies from point to point around and along the reduced section of the test specimen. **E1012**

3.1.5 *ceramic matrix composite, 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**

3.1.6 *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**

3.1.7 *fracture (breaking) force, $P_{fracture}$, n*—the force at which the test specimen ruptures, breaking into two or more pieces.

3.1.8 *fracture strength, S_f , n*—the tensile stress at which the test specimen ruptures, breaking into two or more pieces or where the applied force drops off significantly. Typically, a 10 % force drop off is considered significant.

3.1.9 *gage length, l_o , n*—the original length of that portion of the test specimen over which strain or change of length is determined. **E6**

3.1.10 *matrix cracking stress, n*—the applied tensile stress at which the matrix in the composite cracks into a series of roughly parallel blocks normal to the tensile stress.

3.1.10.1 *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 portion 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 unloading stress-strain (elastic limit).

3.1.11 *modulus of elasticity, E , n*—the ratio of stress to corresponding strains below the proportional limit. **E6**

3.1.12 *modulus of resilience, U_r , 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.

3.1.13 *modulus of toughness, U_t , 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).

3.1.13.1 *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 CFCCs have not been developed. The determination of the modulus of toughness as

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.