Designation: C1499 − 19

Standard Test Method for Monotonic Equibiaxial Flexural Strength of Advanced Ceramics at Ambient Temperature[1]

This standard is issued under the fixed designation C1499; 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 equibiaxial strength of advanced ceramics at ambient temperature via concentric ring configurations under monotonic uniaxial loading. In addition, test specimen fabrication methods, testing modes, testing rates, allowable deflection, and data collection and reporting procedures are addressed. Two types of test specimens are considered: machined test specimens and as-fired test specimens exhibiting a limited degree of warpage. Strength as used in this test method refers to the maximum strength obtained under monotonic application of load. Monotonic loading refers to a test conducted at a constant rate in a continuous fashion, with no reversals from test initiation to final fracture.

1.2 This test method is intended primarily for use with advanced ceramics that macroscopically exhibit isotropic, homogeneous, continuous behavior. While this test method is intended for use on monolithic advanced ceramics, certain whisker- or particle-reinforced composite ceramics, as well as certain discontinuous fiber-reinforced composite ceramics, may also meet these macroscopic behavior assumptions. Generally, continuous fiber ceramic composites do not macroscopically exhibit isotropic, homogeneous, continuous behavior, and the application of this test method to these materials is not recommended.

1.3 The values stated in SI units are to be regarded as standard. No other units of measurement are included in this standard.

1.4 *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.*

1.5 *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

C1259 Test Method for Dynamic Young's Modulus, Shear Modulus, and Poisson's Ratio for Advanced Ceramics by Impulse Excitation of Vibration

C1322 Practice for Fractography and Characterization of Fracture Origins in Advanced Ceramics

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

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

F394 Test Method for Biaxial Flexure Strength (Modulus of Rupture) of Ceramic Substrates (Discontinued 2001) (Withdrawn 2001)[3]

IEEE/ASTM SI 10 American National Standard for Metric Practice

3. Terminology

3.1 *Definitions:*

3.1.1 The definitions of terms relating to biaxial testing appearing in Terminologies E6 and C1145 may apply to the terms used in this test method. Pertinent definitions are listed below with the appropriate source given in bold type. Additional terms used in conjunction with this test method are defined in the following section.

[1] This test method is under the jurisdiction of ASTM Committee C28 on Advanced Ceramics and is the direct responsibility of Subcommittee C28.01 on Mechanical Properties and Performance.

Current edition approved July 1, 2019. Published August 2019. Originally approved in 2001. Last previous edition approved in 2015 as C1499 – 15. DOI: 10.1520/C1499-19.

[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.

[3] The last approved version of this historical standard is referenced on www.astm.org.

3.1.2 *advanced ceramic, n*—highly engineered, high-performance, predominately non-metallic, inorganic, ceramic material having specific functional attributes. **C1145**

3.1.3 *breaking load, [F], n*—load at which fracture occurs. **E6**

3.1.4 *equibiaxial flexural strength, [FL^{-2}], n*—maximum stress that a material is capable of sustaining when subjected to flexure between two concentric rings. This mode of flexure is a cupping of the circular plate caused by loading at the inner load ring and outer support ring. The equibiaxial flexural strength is calculated from the maximum load of a biaxial test carried to rupture, the original dimensions of the test specimen, and Poisson's ratio.

3.1.5 *homogeneous, n*—condition of a material in which the relevant properties (composition, structure, density, etc.) are uniform, so that any smaller sample taken from an original body is representative of the whole. Practically, as long as the geometrical dimensions of a sample are large with respect to the size of the individual grains, crystals, components, pores, or microcracks, the sample can be considered homogeneous.

3.1.6 *modulus of elasticity, [FL^{-2}], n*—ratio of stress to corresponding strain below the proportional limit. **E6**

3.1.7 *Poisson's ratio, n*—negative value of the ratio of transverse strain to the corresponding axial strain resulting from uniformly distributed axial stress below the proportional limit of the material.

4. Significance and Use

4.1 This test method may be used for material development, material comparison, quality assurance, characterization, and design code or model verification.

4.2 Engineering applications of ceramics frequently involve biaxial tensile stresses. Generally, the resistance to equibiaxial flexure is the measure of the least flexural strength of a monolithic advanced ceramic. The equibiaxial flexural strength distributions of ceramics are probabilistic and can be described by a weakest-link failure theory (**1, 2**).[4] Therefore, a sufficient number of test specimens at each testing condition is required for statistical estimation or the equibiaxial strength.

4.3 Equibiaxial strength tests provide information on the strength and deformation of materials under multiple tensile stresses. Multiaxial stress states are required to effectively evaluate failure theories applicable to component design, and to efficiently sample surfaces that may exhibit anisotropic flaw distributions. Equibiaxial tests also minimize the effects of test specimen edge preparation as compared to uniaxial tests because the generated stresses are lowest at the test specimen edges.

4.4 The test results of equibiaxial test specimens fabricated to standardized dimensions from a particular material or selected portions of a component, or both, may not totally represent the strength properties in the entire full-size component or its in-service behavior in different environments.

4.5 For quality control purposes, results derived from standardized equibiaxial test specimens may be considered indicative of the response of the bulk material from which they were taken for any given primary processing conditions and post-processing heat treatments or exposures.

5. Interferences

5.1 Test environment (vacuum, inert gas, ambient air, etc.), including moisture content (for example, relative humidity), may have an influence on the measured equibiaxial strength. Testing to evaluate the maximum strength potential of a material can be conducted in inert environments or at sufficiently rapid testing rates, or both, so as to minimize any environmental effects. Conversely, testing can be conducted in environments, test modes, and test rates representative of service conditions to evaluate material performance under use conditions.

5.2 Fabrication of test specimens can introduce dimensional variations that may have pronounced effects on the measured equibiaxial mechanical properties and behavior (for example, shape and level of the resulting stress-strain curve, equibiaxial strength, failure location, etc.). Surface preparation can also lead to the introduction of residual stresses, and final machining steps might or might not negate machining damage introduced during the initial machining. Therefore, as universal or standardized methods of surface preparation do not exist, the test specimen fabrication history should be reported. In addition, the nature of fabrication used for certain advanced ceramic components may require testing of specimens with surfaces in the as-fabricated condition (that is, it may not be possible, desired, or required to machine some of the test specimen surfaces directly in contact with the test fixture). For very rough or wavy as-fabricated surfaces, perturbations in the stress state due to non-symmetric cross sections, as well as variations in the cross-sectional dimensions, may also interfere with the equibiaxial strength measurement. Finally, close geometric tolerances, particularly in regard to flatness of test specimen surfaces in contact with the test fixture components, are critical requirements for successful equibiaxial tests. In some cases it may be appropriate to use other test methods (for example, Test Method F394).

5.3 Contact and frictional stresses in equibiaxial tests can introduce localized failure not representative of the equibiaxial strength under ideal loading conditions. These effects may result in either over or under estimates of the actual strength (**1, 3**).

5.4 Fractures that consistently initiate near or just outside the load ring may be due to factors such as friction or contact stresses introduced by the load fixtures, or via misalignment of the test specimen rings. Such fractures will normally constitute invalid tests (see Note 14). Splitting of the test specimen along a diameter that expresses the characteristic size may result from poor test specimen preparation (for example, severe grinding or very poor edge preparation), excessive tangential stresses at the test specimen edges, or a very weak material. Such fractures will constitute invalid tests if failure occurred from the edge.

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