INTERNATIONAL

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Standard Test Method for Determination of Thermal Shock Resistance for Advanced Ceramics by Water Quenching[1]

This standard is issued under the fixed designation C1525; 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 describes the determination of the resistance of advanced ceramics to thermal shock by water quenching. The method builds on the experimental principle of rapid quenching of a test specimen at an elevated temperature in a water bath at room temperature. The effect of the thermal shock is assessed by measuring the reduction in flexural strength produced by rapid quenching of test specimens heated across a range of temperatures. For a quantitative measurement of thermal shock resistance, a critical temperature interval is determined by a reduction in the mean flexural strength of at least 30 %. The test method does not determine thermal stresses developed as a result of a steady-state temperature difference within a ceramic body or of thermal expansion mismatch between joined bodies. The test method is not intended to determine the resistance of a ceramic material to repeated shocks. Since the determination of the thermal shock resistance is performed by evaluating retained strength, the method is not suitable for ceramic components; however, test specimens cut from components may be used.

1.2 The test method is intended primarily for dense monolithic ceramics, but may also be applicable to certain composites such as whisker- or particulate-reinforced ceramic matrix composites that are macroscopically homogeneous.

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

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]

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

C1161 Test Method for Flexural Strength of Advanced Ceramics at Ambient Temperature

C1239 Practice for Reporting Uniaxial Strength Data and Estimating Weibull Distribution Parameters for Advanced Ceramics

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

E616 Terminology Relating to Fracture Testing (Discontinued 1996) (Withdrawn 1996)[3]

IEEE/ASTM SI 10 American National Standard for Metric Practice

2.2 *European Standard:*[4]

EN 820-3 Advanced Technical Ceramics—Monolithic Ceramics—Thermomechanical Properties—Part 3: Determination of Resistance to Thermal Shock by Water Quenching

3. Terminology

3.1 *Definitions:*

[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.

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[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.

[4] Available from European Committee for Standardization (CEN), 36 rue de Stassart, B-1050, Brussels, Belgium, http://www.cenorm.be.

3.1.1 The terms described in Terminologies C1145, E6, and E616 are applicable to this standard test method. Specific terms relevant to this test method are as follows:

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

3.1.3 *critical temperature difference, ΔT_c, [θ], n*—temperature difference between the furnace and the ambient temperature water bath that will cause a 30 % drop in the average flexural strength.

3.1.4 *flexural strength, σ_f, $[FL^{-2}]$, n*—a measure of the ultimate strength of a specified beam specimen in bending, determined at a given stress rate in a particular environment.

3.1.5 *fracture toughness, n*—a generic term for measures of resistance to extension of a crack. **E616**

3.1.6 *slow crack growth (SCG), n*—subcritical crack growth (extension) which may result from, but is not restricted to, such mechanisms as environmentally assisted stress corrosion or diffusive crack growth. **C1145**

3.1.7 *thermal shock, n*—a large and rapid temperature change, resulting in large temperature differences within or across a body. **C1145**

3.1.8 *thermal shock resistance, n*—the capability of material to retain its mechanical properties after exposure to one or more thermal shocks.

4. Summary of Test Method

4.1 This test method indicates the ability of an advanced ceramic product to withstand the stress generated by sudden changes in temperature (thermal shock). The thermal shock resistance is measured by determining the loss of strength (as compared to as-received specimens) for ceramic test specimens quickly cooled after a thermal exposure. A series of rectangular or cylindrical test specimen sets is heated across a range of different temperatures and then quenched rapidly in a water bath. After quenching, the test specimens are tested in flexure, and the average retained flexural strength is determined for each set of specimens quenched from a given temperature. The "critical temperature difference" for thermal shock is established from the temperature difference (exposure temperature minus the water quench temperature) that produces a 30 % reduction in flexural strength compared to the average flexural strength of the as-received test specimens.

5. Significance and Use

5.1 The high temperature capabilities of advanced ceramics are a key performance benefit for many demanding engineering applications. In many of those applications, advanced ceramics will have to perform across a broad temperature range with exposure to sudden changes in temperature and heat flux. Thermal shock resistance of the ceramic material is a critical factor in determining the durability of the component under transient thermal conditions.

5.2 This test method is useful for material development, quality assurance, characterization, and assessment of durability. It has limited value for design data generation, because of the limitations of the flexural test geometry in determining fundamental tensile properties.

5.3 Appendix X1 (following EN 820-3) provides an introduction to thermal stresses, thermal shock, and critical material/geometry factors. The appendix also contains a mathematical analysis of the stresses developed by thermal expansion under steady-state and transient conditions, as determined by mechanical properties, thermal characteristics, and heat transfer effects.

6. Interferences

6.1 Time-dependent phenomena such as stress corrosion or slow crack growth may influence the strength tests. This might especially be a problem if the test specimens are not properly dried before strength testing.

6.2 Surface preparation of test specimens can introduce machining flaws, which may have a pronounced effect on the measured flexural strength. The surface preparation may also influence the cracking process due to the thermal shock procedure. It is especially important to consider surface conditions in comparing test specimens and components.

6.3 The results are given in terms of a temperature difference between furnace and quenching bath (ΔT). However, it is important to notice that results may be different for the same ΔT but different absolute temperatures. It is therefore specified in this test method to quench to room temperature.

6.4 The formulae presented in this test method apply strictly only to materials that do not exhibit R-curve behavior, but have a single-valued fracture toughness. If the test material exhibits a strong R-curve behavior, that is, increase in fracture toughness with increasing crack length, caution must be taken in interpreting the results.

6.5 Test data for specimens of different geometries are not directly comparable because of the effect of geometry on heat transfer and stress gradients. Quantitative comparisons of thermal shock resistance for different ceramic compositions should be done with equivalent test specimen geometries.

7. Apparatus

7.1 *Test Apparatus:*

7.1.1 The test method requires a thermal exposure/quenching system (consisting of a furnace, specimen handling equipment, and a quench bath) and a testing apparatus suitable for measuring the flexural strength of the test specimens.

7.1.2 The test method requires a furnace capable of heating and maintaining a set of test specimens at the required temperature to ±5 K (±5 °C). The temperature shall be measured with suitable thermocouples located no more than 2 mm from the midpoint of the specimen(s) in the furnace. Furnaces will usually have an open atmosphere, because air exposure is common during the transfer to the quench bath.

NOTE 1—If air exposure is detrimental, a special furnace-quench system can be set up in which both the furnace and the quench unit are contained within an inert atmosphere container. A common design for such a system consists of a tube furnace positioned vertically above the quench tank, so that the test specimen drops directly into the tank from the furnace.