Designation: C1465 – 26

Standard Test Method for Determination of Slow Crack Growth Parameters of Advanced Ceramics by Constant Stress-Rate Flexural Testing at Elevated Temperatures[1]

This standard is issued under the fixed designation C1465; 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 slow crack growth (SCG) parameters of advanced ceramics by using constant stress-rate flexural testing in which flexural strength is determined as a function of applied stress rate in a given environment at elevated temperatures. The strength degradation exhibited with decreasing applied stress rate in a specified environment is the basis of this test method which enables the evaluation of slow crack growth parameters of a material.

NOTE 1—This test method is frequently referred to as "dynamic fatigue" testing **(1-3)**[2] in which the term "fatigue" is used interchangeably with the term "slow crack growth." To avoid possible confusion with the "fatigue" phenomenon of a material which occurs exclusively under cyclic loading, as defined in Terminology E1823, this test method uses the term "constant stress-rate testing" rather than "dynamic fatigue" testing.

NOTE 2—In glass and ceramics technology, static tests of considerable duration are called "static fatigue" tests, a type of test designated as stress-rupture (Terminology E1823).

1.2 This test method is intended primarily to be used for *negligible* creep of test specimens, with specific limits on creep imposed in this test method.

1.3 This test method applies primarily to advanced ceramics that are macroscopically homogeneous and isotropic. This test method may also be applied to certain whisker- or particle-reinforced ceramics that exhibit macroscopically homogeneous behavior.

1.4 This test method is intended for use with various test environments such as air, vacuum, inert, and any other gaseous environments.

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

1.6 *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.*

1.7 *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:*[3]

C1145 Terminology of Advanced Ceramics
C1211 Test Method for Flexural Strength of Advanced Ceramics at Elevated Temperatures
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
C1368 Test Method for Determination of Slow Crack Growth Parameters of Advanced Ceramics by Constant Stress Rate Strength Testing at Ambient Temperature
D1239 Test Method for Resistance of Plastic Films to Extraction by Chemicals
E4 Practices for Force Calibration and Verification of Testing Machines
E6 Terminology Relating to Methods of Mechanical Testing
E220 Test Method for Calibration of Thermocouples by Comparison Techniques
E230 Specification for Temperature-Electromotive Force (emf) Tables for Standardized Thermocouples
E337 Test Method for Measuring Humidity with a Psychrometer (the Measurement of Wet- and Dry-Bulb Temperatures)

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

[3] 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.

E616 Terminology Relating to Fracture Testing (Withdrawn 1996)[4]
E1150 Definitions of Terms Relating to Fatigue (Withdrawn 1996)[4]
E1823 Terminology Relating to Fatigue and Fracture Testing
IEEE/ASTM SI 10 American National Standard for Metric Practice

3. Terminology

3.1 *Definitions:*

3.1.1 The terms described in Terminologies C1145, E6, and E1823 are applicable to this test method. Specific terms relevant to this test method are as follows:

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

3.1.3 *constant stress rate,* $\dot{\sigma}$[FL^{-2} t^{-1}], *n*—a constant rate of increase of maximum flexural stress applied to a specified beam by using either a constant load or constant displacement rate of a testing machine.

3.1.4 *environment, n*—the aggregate of chemical species and energy that surrounds a test specimen. **E1150**

3.1.5 *environmental chamber, n*—a container surrounding the test specimen and capable of providing controlled local environmental condition.

3.1.6 *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.

3.1.7 *flexural strength-stress rate curve*—a curve fitted to the values of flexural strength at each of several stress rates, based on the relationship between flexural strength and stress rate:

$\log \sigma_f = [1/(n + 1)] \log \dot{\sigma} + \log D$ (see Appendix X1)

3.1.7.1 *Discussion*—In the ceramics literature, this is often called a "dynamic fatigue" curve.

3.1.8 *flexural strength-stress rate diagram*—a plot of flexural strength as a function of stress rate. Flexural strength and stress rate are both plotted on logarithmic scales.

3.1.9 *fracture toughness,* K_{IC} [FL$^{-3/2}$], *n*—a generic term for measures of resistance to extension of a crack. **E616**

3.1.10 *inert flexural strength* [FL^{-2}], *n*—a measure of the strength of a specified beam specimen in bending as determined in an appropriate inert condition whereby no slow crack growth occurs.

3.1.10.1 *Discussion*—An inert condition at near room temperature may be obtained by using vacuum, low temperatures, very fast test rates, or any inert media. However, at elevated temperatures, the definition or concept of an inert condition is unclear since temperature itself acts as a degrading environment. It has been shown that for some ceramics, one approach to obtain an inert condition (thus, inert strength) at elevated temperatures is to use very fast (ultra-fast) test rates $\geq 3 \times 10^4$ MPa/s, where the time for slow crack growth would be minimized or eliminated (**4**).

3.1.11 *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.

3.1.12 *stress intensity factor,* K_I [FL$^{-3/2}$], *n*—the magnitude of the ideal-crack-tip stress field (stress-field singularly) subjected to Mode I loading in a homogeneous, linear elastic body. **E616**

3.1.13 *R-curve, n*—a plot of crack-extension resistance as a function of stable crack extension. **E616**

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *slow crack growth parameters, n and D, n*—the parameters estimated as constants in the flexural strength (in megapascals)-stress rate (in megapascals per second) equation, which represent a measure of susceptibility to slow crack growth of a material (see Appendix X1). For the units of *D*, see 9.3.1.

4. Significance and Use

4.1 For many structural ceramic components in service, their use is often limited by lifetimes that are controlled by a process of slow crack growth. This test method provides the empirical parameters for appraising the relative slow crack growth susceptibility of ceramic materials under specified environments at elevated temperatures. This test method is similar to Test Method C1368 with the exception that provisions for testing at elevated temperatures are given. Furthermore, this test method may establish the influences of processing variables and composition on slow crack growth as well as on strength behavior of newly developed or existing materials, thus allowing tailoring and optimizing material processing for further modification. In summary, this test method may be used for material development, quality control, characterization, and limited design data generation purposes.

NOTE 3—Data generated by this test method do not necessarily correspond to crack velocities that may be encountered in service conditions. The use of data generated by this test method for design purposes may entail considerable extrapolation and loss of accuracy.

4.2 In this test method, the flexural stress computation is based on simple beam theory, with the assumptions that the material is isotropic and homogeneous, the moduli of elasticity in tension and compression are identical, and the material is linearly elastic. The average grain size should be no greater than one fiftieth (1/50) of the beam thickness.

4.3 In this test method, the test specimen sizes and test fixtures were chosen in accordance with Test Method C1211, which provides a balance between practical configurations and resulting errors, as discussed in Refs (**5, 6**). Only the four-point test configuration is used in this test method.

4.4 In this test method, the slow crack growth parameters (*n* and *D*) are determined based on the mathematical relationship between flexural strength and applied stress rate, $\log \sigma_f = [1/(n + 1)] \log \dot{\sigma} + \log D$, together with the measured experimental data. The basic underlying assumption on the derivation of this relationship is that slow crack growth is governed by an empirical power-law crack velocity, $v = A[K_I / K_{IC}]^n$ (see Appendix X1).

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