Designation: C1291 – 18

Standard Test Method for Elevated Temperature Tensile Creep Strain, Creep Strain Rate, and Creep Time to Failure for Monolithic Advanced Ceramics[1]

This standard is issued under the fixed designation C1291; 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 tensile creep strain, creep strain rate, and creep time to failure for advanced monolithic ceramics at elevated temperatures, typically between 1073 and 2073 K. A variety of test specimen geometries are included. The creep strain at a fixed temperature is evaluated from direct measurements of the gage length extension over the time of the test. The minimum creep strain rate, which may be invariant with time, is evaluated as a function of temperature and applied stress. Creep time to failure is also included in this test method.

1.2 This test method is for use with advanced ceramics that behave as macroscopically isotropic, homogeneous, continuous materials. While this test method is intended for use on monolithic ceramics, whisker- or particle-reinforced composite ceramics as well as low-volume-fraction discontinuous fiber-reinforced composite ceramics may also meet these macroscopic behavior assumptions. Continuous fiber-reinforced ceramic composites (CFCCs) do not behave as macroscopically isotropic, homogeneous, continuous materials, and application of this test method to these materials is not recommended.

1.3 The values in SI units are to be regarded as the standard (see IEEE/ASTM SI 10). The values given in parentheses are mathematical conversions to inch-pound units that are provided for information only and are not considered 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
C1273 Test Method for Tensile Strength of Monolithic Advanced Ceramics at Ambient Temperatures
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
E139 Test Methods for Conducting Creep, Creep-Rupture, and Stress-Rupture Tests of Metallic Materials
E177 Practice for Use of the Terms Precision and Bias in ASTM Test Methods
E220 Test Method for Calibration of Thermocouples By Comparison Techniques
E230 Specification and Temperature-Electromotive Force (EMF) Tables for Standardized Thermocouples
E639 Test Method for Measuring Total-Radiance Temperature of Heated Surfaces Using a Radiation Pyrometer (Withdrawn 2011)[3]
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
IEEE/ASTM SI 10 American National Standard for Use of the International System of Units (SI): The Modern Metric System

3. Terminology

3.1 *Definitions*—The definitions of terms relating to creep testing which appear in Section E of Terminology E6 shall

[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.

apply to the terms used in this test method. For the purpose of this test method only, some of the more general terms are used with the restricted meanings given as follows.

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *axial strain, ε_a, [L/L], n*—average of the strain measured on diametrically opposed sides and equally distant from the test specimen axis.

3.2.2 *bending strain, ε_b [L/L], n*—difference between the strain at the surface and the axial strain.

3.2.2.1 *Discussion*—In general, it varies from point to point around and along the gage length of the test specimen. (**E1012**)

3.2.3 *creep rupture test, n*—test in which progressive test specimen deformation and the time to failure are measured. In general, deformation is greater than that developed during a creep test.

3.2.4 *creep strain, ε, [L/L], n*—time-dependent strain that occurs after the application of force which is thereafter maintained constant. Also known as engineering creep strain.

3.2.5 *creep test, n*—test that has as its objective the measurement of creep and creep rates occurring at stresses usually well below those that would result in fast fracture.

3.2.5.1 *Discussion*—Since the maximum deformation is only a few percent, a sensitive extensometer is required.

3.2.6 *creep time to failure, t_f, [T], n*—time required for a test specimen to fracture under constant force as a result of creep.

3.2.6.1 *Discussion*—This is also known as creep rupture time.

3.2.7 *gage length, l, [L], n*—original distance between fiducial markers on or attached to the test specimen for determining elongation.

3.2.8 *maximum bending strain, ε_{bmax}, [L/L], n*—largest value of bending strain along the gage length. It can be calculated from measurements of strain at three circumferential positions at each of two different longitudinal positions.

3.2.9 *minimum creep strain rate, $\dot{\varepsilon}_{min}$, $[T^{-1}]$, n*—minimum value of the strain rate prior to test specimen failure as measured from the strain-time curve. The minimum creep strain rate may not necessarily correspond to the steady-state creep strain rate.

3.2.10 *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, diffusive crack growth, or other mechanisms. (**C1145**)

3.2.11 *steady-state creep, ε_{ss}, [L/L], n*—stage of creep wherein the creep rate is constant with time.

3.2.11.1 *Discussion*—Also known as secondary creep.

3.2.12 *stress corrosion, n*—environmentally induced degradation that initiates from the exposed surface.

3.2.12.1 *Discussion*—Such environmental effects commonly include the action of moisture, as well as other corrosive species, often with a strong temperature dependence.

3.2.13 *tensile creep strain, ε_t, [L/L], n*—creep strain that occurs as a result of a uniaxial tensile-applied stress.

4. Significance and Use

4.1 Creep tests measure the time-dependent deformation under force at a given temperature, and, by implication, the force-carrying capability of the material for limited deformations. Creep rupture tests, properly interpreted, provide a measure of the force-carrying capability of the material as a function of time and temperature. The two tests complement each other in defining the force-carrying capability of a material for a given period of time. In selecting materials and designing parts for service at elevated temperatures, the type of test data used will depend on the criteria for force-carrying capability that best defines the service usefulness of the material.

4.2 This test method may be used for material development, quality assurance, characterization, and design data generation.

4.3 High-strength, monolithic ceramic materials, generally characterized by small grain sizes (<50 µm) and bulk densities near their theoretical density, are candidates for load-bearing structural applications at elevated temperatures. These applications involve components such as turbine blades which are subjected to stress gradients and multiaxial stresses.

4.4 Data obtained for design and predictive purposes shall be obtained using any appropriate combination of test methods that provide the most relevant information for the applications being considered. It is noted here that ceramic materials tend to creep more rapidly in tension than in compression (**1-3**).[4] This difference results in time-dependent changes in the stress distribution and the position of the neutral axis when tests are conducted in flexure. As a consequence, deconvolution of flexural creep data to obtain the constitutive equations needed for design cannot be achieved without some degree of uncertainty concerning the form of the creep equations, and the magnitude of the creep rate in tension vis-a-vis the creep rate in compression. Therefore, creep data for design and life prediction shall be obtained in both tension and compression, as well as the expected service stress state.

5. Interferences

5.1 *Time-Dependent Phenomena*—Other time-dependent phenomena, such as stress corrosion and slow crack growth, can interfere with determination of the creep behavior.

5.2 *Chemical Interactions with the Testing Environment*—The test environment (vacuum, inert gas, ambient air, etc.) including moisture content (for example, % relative humidity (RH)) may have a strong influence on both creep strain rate and creep rupture life. In particular, materials susceptible to slow crack growth failure will be strongly influenced by the test environment. Surface oxidation may be either active or passive and thus will have a direct effect on creep behavior by changing the material's properties. Testing shall be conducted in environments that are either representative of service conditions or inert to the materials being tested depending on the performance being evaluated. A controlled gas environment

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