Designation: C1361 − 10 (Reapproved 2019)

Standard Practice for Constant-Amplitude, Axial, Tension-Tension Cyclic Fatigue of Advanced Ceramics at Ambient Temperatures[1]

This standard is issued under the fixed designation C1361; 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 practice covers the determination of constant-amplitude, axial, tension-tension cyclic fatigue behavior and performance of advanced ceramics at ambient temperatures to establish "baseline" cyclic fatigue performance. This practice builds on experience and existing standards in tensile testing advanced ceramics at ambient temperatures and addresses various suggested test specimen geometries, test specimen fabrication methods, testing modes (force, displacement, or strain control), testing rates and frequencies, allowable bending, and procedures for data collection and reporting. This practice does not apply to axial cyclic fatigue tests of components or parts (that is, machine elements with nonuniform or multiaxial stress states).

1.2 This practice applies primarily to advanced ceramics that macroscopically exhibit isotropic, homogeneous, continuous behavior. While this practice applies primarily to monolithic advanced ceramics, certain whisker- or particle-reinforced composite ceramics, as well as certain discontinuous fibre-reinforced composite ceramics, may also meet these macroscopic behavior assumptions. Generally, continuous fibre-reinforced ceramic composites (CFCCs) do not macroscopically exhibit isotropic, homogeneous, continuous behavior and application of this practice to these materials is not recommended.

1.3 The values stated in SI units are to be regarded as the standard and are in accordance with 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.* Refer to Section 7 for specific precautions.

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

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)

E467 Practice for Verification of Constant Amplitude Dynamic Forces in an Axial Fatigue Testing System

E468 Practice for Presentation of Constant Amplitude Fatigue Test Results for Metallic Materials

E739 Practice for Statistical Analysis of Linear or Linearized Stress-Life (***S-N***) and Strain-Life (ε-***N***) Fatigue Data

E1012 Practice for Verification of Testing Frame and Specimen Alignment Under Tensile and Compressive Axial Force Application

E1823 Terminology Relating to Fatigue and Fracture Testing

IEEE/ASTM SI 10 American National Standard for Metric Practice

2.2 *Military Handbook:*[3]

MIL-HDBK-790 Fractography and Characterization of Fracture Origins in Advanced Structural Ceramics

[1] This practice 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] Available from Army Research Laboratory-Materials Directorate, Aberdeen Proving Ground, MD 21005.

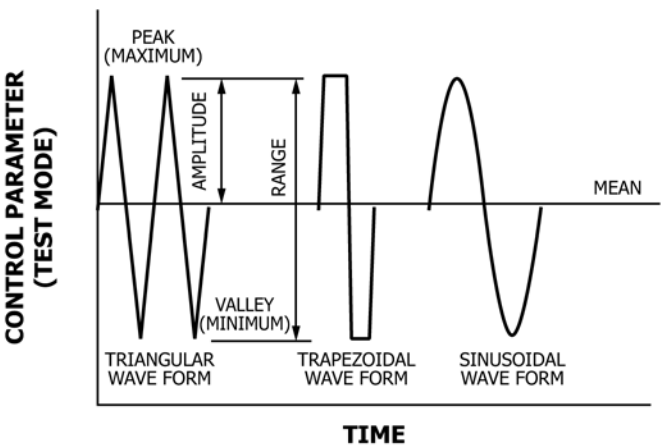

FIG. 1 Cyclic Fatigue Nomenclature and Wave Forms

3. Terminology

3.1 *Definitions*—Definitions of terms relating to advanced ceramics, cyclic fatigue, and tensile testing as they appear in Terminology C1145, Terminology E1823, and Terminology E6, respectively, apply to the terms used in this practice. Selected terms with definitions non-specific to this practice follow in 3.2, with the appropriate source given in parentheses. Terms specific to this practice are defined in 3.3.

3.2 *Definitions of Terms Non-Specific to This Standard:*

3.2.1 *advanced ceramic, n*—a highly engineered, high-performance, predominately non-metallic, inorganic, ceramic material having specific functional attributes. (See Terminology C1145.)

3.2.2 *axial strain* $[LL^{-1}]$, *n*—the average 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. (See Practice E1012.)

3.2.3 *bending strain* $[LL^{-1}]$, *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. (See Practice E1012.)

3.2.4 *constant amplitude loading, n*—in cyclic fatigue loading, a loading in which all peak loads are equal and all of the valley forces are equal. (See Terminology E1823.)

3.2.5 *cyclic fatigue, n*—the process of progressive localized permanent structural change occurring in a material subjected to conditions that produce fluctuating stresses and strains at some point or points and that may culminate in cracks or complete fracture after a sufficient number of fluctuations. (See Terminology E1823.) See Fig. 1 for nomenclature relevant to cyclic fatigue testing.

3.2.5.1 *Discussion*—In glass technology, static tests of considerable duration are called static fatigue tests, a type of test generally designated as stress-rupture.

3.2.5.2 *Discussion*—Fluctuations may occur both in load and with time (frequency) as in the case of random vibration.

3.2.6 *cyclic fatigue life,* N_f—the number of loading cycles of a specified character that a given test specimen sustains before failure of a specified nature occurs. (See Terminology E1823.)

3.2.7 *cyclic fatigue limit,* S_f, $[FL^{-2}]$, *n*—the limiting value of the median cyclic fatigue strength as the cyclic fatigue life, N_f, becomes very large (for example, $N > 10^6$-10^7). (See Terminology E1823.)

3.2.7.1 *Discussion*—Certain materials and environments preclude the attainment of a cyclic fatigue limit. Values tabulated as cyclic fatigue limits in the literature are frequently (but not always) values of S_f at 50 % survival at N_f cycles of stress in which the mean stress, S_m, equals zero.

3.2.8 *cyclic fatigue strength* S_N, $[FL^{-2}]$, *n*—the limiting value of the median cyclic fatigue strength at a particular cyclic fatigue life, N_f. (See Terminology E1823.)

3.2.9 *gage length, [L], n*—the original length of that portion of the test specimen over which strain or change of length is determined. (See Terminology E6.)

3.2.10 *load ratio, n*—in cyclic fatigue loading, the algebraic ratio of the two loading parameters of a cycle; the most widely used ratios (see Terminology E1823):

$$R = \frac{\text{minimum force}}{\text{maximum force}} \text{ or } R = \frac{\text{valley force}}{\text{peak force}}$$

and:

$$A = \frac{\text{force amplitude}}{\text{mean force}} \text{ or } A = \frac{(\text{maximum force} - \text{minimum force})}{(\text{maximum force} + \text{minimum force})}$$

3.2.11 *modulus of elasticity* $[FL^{-2}]$, *n*—the ratio of stress to corresponding strain below the proportional limit. (See Terminology E6.)

3.2.12 *percent bending, n*—the bending strain times 100 divided by the axial strain. (See Practice E1012.)

3.2.13 *S-N diagram, n*—a plot of stress versus the number of cycles to failure. The stress can be maximum stress, $S_{\max}$, minimum stress, $S_{\min}$, stress range, ΔS or S_r, or stress amplitude, S_a. The diagram indicates the *S-N* relationship for a specified value of S_m, A, *R*, and a specified probability of survival. For *N*, a log scale is almost always used, although a linear scale may also be used. For *S*, a linear scale is usually used, although a log scale may also be used. (See Terminology E1823 and Practice E468.)

3.2.14 *slow crack growth, n*—sub-critical crack growth (extension) that may result from, but is not restricted to, such mechanisms as environmentally assisted stress corrosion or diffusive crack growth.

3.2.15 *tensile strength* $[FL^{-2}]$, *n*—the maximum tensile stress which a material is capable of sustaining. Tensile strength is calculated from the maximum force during a tension test carried to rupture and the original cross-sectional area of the test specimen. (See Terminology E6.)

3.3 *Definitions of Terms Specific to This Standard:*

3.3.1 *maximum stress,* S_{max} $[FL^{-2}]$, *n*—the maximum applied stress during cyclic fatigue.

3.3.2 *mean stress,* S_{max} $[FL^{-2}]$, *n*—the average applied stress during cyclic fatigue such that

$$S_m = \frac{S_{max} + S_{min}}{2} \quad (1)$$