Designation: E2207 – 15

Standard Practice for Strain-Controlled Axial-Torsional Fatigue Testing with Thin-Walled Tubular Specimens[1]

This standard is issued under the fixed designation E2207; 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 The standard deals with strain-controlled, axial, torsional, and combined in- and out-of-phase axial torsional fatigue testing with thin-walled, circular cross-section, tubular specimens at isothermal, ambient and elevated temperatures. This standard is limited to symmetric, completely-reversed strains (zero mean strains) and axial and torsional waveforms with the same frequency in combined axial-torsional fatigue testing. This standard is also limited to characterization of homogeneous materials with thin-walled tubular specimens and does not cover testing of either large-scale components or structural elements.

1.2 *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 and health practices and determine the applicability of regulatory limitations prior to use.*

2. Referenced Documents

2.1 *ASTM Standards:*[2]

E3 Guide for Preparation of Metallographic Specimens
E4 Practices for Force Verification of Testing Machines
E6 Terminology Relating to Methods of Mechanical Testing
E8/E8M Test Methods for Tension Testing of Metallic Materials
E9 Test Methods of Compression Testing of Metallic Materials at Room Temperature
E83 Practice for Verification and Classification of Extensometer Systems
E111 Test Method for Young's Modulus, Tangent Modulus, and Chord Modulus
E112 Test Methods for Determining Average Grain Size
E143 Test Method for Shear Modulus at Room Temperature
E209 Practice for Compression Tests of Metallic Materials at Elevated Temperatures with Conventional or Rapid Heating Rates and Strain Rates
E467 Practice for Verification of Constant Amplitude Dynamic Forces in an Axial Fatigue Testing System
E606/E606M Test Method for Strain-Controlled Fatigue Testing
E1012 Practice for Verification of Testing Frame and Specimen Alignment Under Tensile and Compressive Axial Force Application
E1417/E1417M Practice for Liquid Penetrant Testing
E1444/E1444M Practice for Magnetic Particle Testing
E1823 Terminology Relating to Fatigue and Fracture Testing
E2624 Practice for Torque Calibration of Testing Machines and Devices

3. Terminology

3.1 *Definitions*—The terms specific to this practice are defined in this section. All other terms used in this practice are in accordance with Terminologies E6 and E1823.

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *axial strain*—refers to engineering axial strain, ε, and is defined as change in length divided by the original length ($\Delta L_g/L_g$).

3.2.2 *shear strain*—refers to engineering shear strain, γ, resulting from the application of a torsional moment to a cylindrical specimen. Such a torsional shear strain is simple shear and is defined similar to axial strain with the exception that the shearing displacement, ΔL_s is perpendicular to rather than parallel to the gage length, L_g, that is, $\gamma = \Delta L_s / L_g$ (see Fig. 1).

3.2.2.1 *Discussion*—γ= is related to the angles of twist, θ and Ψ as follows:

$\gamma = \tan \Psi$, where Ψ is the angle of twist along the gage length of the cylindrical specimen. For small angles expressed in radians, tan Ψ approaches Ψ and γ approaches Ψ.

$\gamma = (d/2)\theta/L_g$, where θ expressed in radians is the angle of twist between the planes defining the gage length of the cylindrical specimen and d is the diameter of the cylindrical specimen.

[1] This practice is under the jurisdiction of ASTM Committee E08 on Fatigue and Fracture and is the direct responsibility of Subcommittee E08.05 on Cyclic Deformation and Fatigue Crack Formation.

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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.

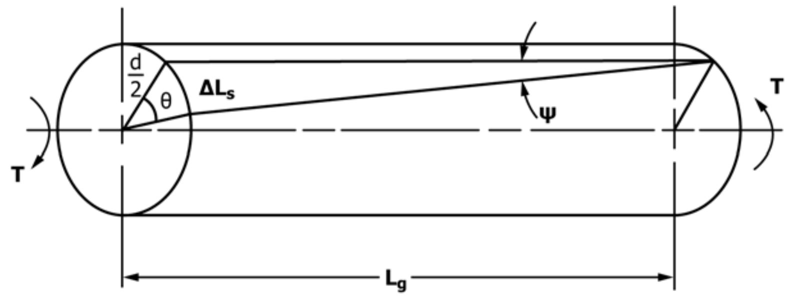

FIG. 1 Twisted Gage Section of a Cylindrical Specimen Due to a Torsional Moment

3.2.2.2 *Discussion*—ΔL_s is measurable directly as displacement using specially calibrated torsional extensometers or as the arc length $\Delta L_s = (d/2)\theta$, where θ is measured directly with a rotary variable differential transformer.

3.2.2.3 *Discussion*—The shear strain varies linearly through the thin wall of the specimen, with the smallest and largest values occurring at the inner and outer diameters of the specimen, respectively. The value of shear strain on the outer surface, inner surface, and mean diameter of the specimen shall be reported. The shear strain determined at the outer diameter of the tubular specimen is recommended for strain-controlled torsional tests, since cracks typically initiate at the outer surfaces.

3.2.3 *biaxial strain amplitude ratio*—in an axial-torsional fatigue test, the biaxial strain amplitude ratio, λ is defined as the ratio of the shear strain amplitude (γ_a) to the axial strain amplitude (ε_a), that is, γ_a/ε_a.

3.2.4 *phasing between axial and shear strains*— in an axial-torsional fatigue test, phasing is defined as the phase angle, φ, between the axial strain waveform and the shear strain waveform. The two waveforms must be of the same type, for example, both must either be triangular or both must be sinusoidal.

3.2.4.1 *in-phase axial-torsional fatigue test*— for completely-reversed axial and shear strain waveforms, if the maximum value of the axial strain waveform occurs at the same time as that of the shear strain waveform, then the phase angle, φ = 0° and the test is defined as an "in-phase" axial-torsional fatigue test (Fig. 2(a)). At every instant in time, the shear strain is proportional to the axial strain.

NOTE 1—Proportional loading is the commonly used terminology in plasticity literature for the in-phase axial-torsional loading described in this practice.

3.2.4.2 *out-of-phase axial-torsional fatigue test*— for completely-reversed axial and shear strain waveforms, if the maximum value of the axial strain waveform leads or lags the maximum value of the shear strain waveform by a phase angle φ ≠ 0° then the test is defined as an "out-of-phase" axial-torsional fatigue test. Unlike in the in-phase loading, the shear strain is not proportional to the axial strain at every instant in

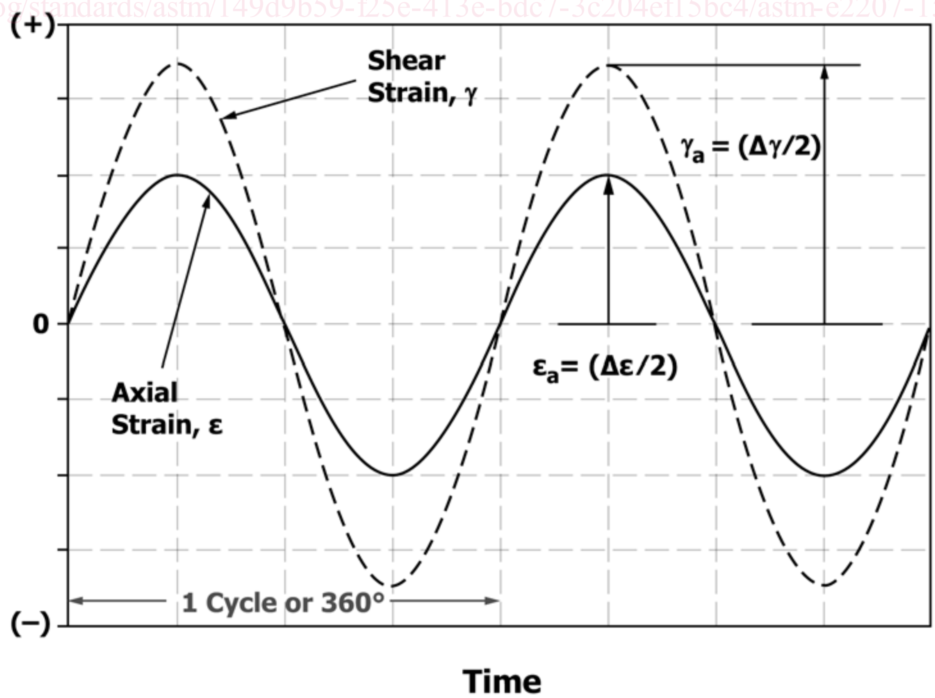

FIG. 2 Schematics of Axial and Shear Strain Waveforms for In- and Out-of-Phase Axial-Torsional Tests