INTERNATIONAL

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Standard Test Method for Creep-Fatigue Testing[1]

This standard is issued under the fixed designation E2714; 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 mechanical properties pertaining to creep-fatigue deformation or crack formation in nominally homogeneous materials, or both by the use of test specimens subjected to uniaxial forces under isothermal conditions. It concerns fatigue testing at strain rates or with cycles involving sufficiently long hold times to be responsible for the cyclic deformation response and cycles to crack formation to be affected by creep (and oxidation). It is intended as a test method for fatigue testing performed in support of such activities as materials research and development, mechanical design, process and quality control, product performance, and failure analysis. The cyclic conditions responsible for creep-fatigue deformation and cracking vary with material and with temperature for a given material.

1.2 The use of this test method is limited to specimens and does not cover testing of full-scale components, structures, or consumer products.

1.3 This test method is primarily aimed at providing the material properties required for assessment of defect-free engineering structures containing features that are subject to cyclic loading at temperatures that are sufficiently high to cause creep deformation.

1.4 This test method is applicable to the determination of deformation and crack formation or nucleation properties as a consequence of either constant-amplitude strain-controlled tests or constant-amplitude force-controlled tests. It is primarily concerned with the testing of round bar test specimens subjected to uniaxial loading in either force or strain control. The focus of the procedure is on tests in which creep and fatigue deformation and damage is generated simultaneously within a given cycle. It does not cover block cycle testing in which creep and fatigue damage is generated sequentially. Data that may be determined from creep-fatigue tests performed under conditions in which creep-fatigue deformation and damage is generated simultaneously include *(a)* cyclic stress-strain deformation response *(b)* cyclic creep (or relaxation) deformation response *(c)* cyclic hardening, cyclic softening response *(d)* cycles to formation of a single crack or multiple cracks in test specimens.

NOTE 1—A crack is believed to have formed when it has nucleated and propagated in a specimen that was initially uncracked to a specific size that is detectable by a stated technique. For the purpose of this standard, the formation of a crack is evidenced by a measurable increase in compliance of the specimen or by a size detectable by potential drop technique. Specific details of how to measure cycles to crack formation are described in 9.5.1.

1.5 This test method is applicable to temperatures and strain rates for which the magnitudes of time-dependent inelastic strains (creep) are on the same order or larger than time-independent inelastic strain.

NOTE 2—The term *inelastic* is used herein to refer to all nonelastic strains. The term *plastic* is used herein to refer only to time independent (that is, non-creep) component of inelastic strain. A useful engineering estimate of time-independent strain can be obtained when the strain rate exceeds some value. For example, a strain rate of 1×10^{-3} sec^{-1} is often used for this purpose. This value should increase with increasing test temperature.

1.6 The values stated in SI units are to be regarded as standard. No other units of measurement are included in this standard.

1.7 *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.*

1.8 *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]

E4 Practices for Force Verification of Testing Machines

[1] This test method 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.

E8/E8M Test Methods for Tension Testing of Metallic Materials
E83 Practice for Verification and Classification of Extensometer Systems
E111 Test Method for Young's Modulus, Tangent Modulus, and Chord Modulus
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 for Temperature-Electromotive Force (emf) Tables for Standardized Thermocouples
E467 Practice for Verification of Constant Amplitude Dynamic Forces in an Axial Fatigue Testing System
E606 Test Method for Strain-Controlled Fatigue Testing
E647 Test Method for Measurement of Fatigue Crack Growth Rates
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
E1823 Terminology Relating to Fatigue and Fracture Testing
E2368 Practice for Strain Controlled Thermomechanical Fatigue Testing

2.2 *BSI Standards:*[3]
BS 7270: 2000 Method for Constant Amplitude Strain Controlled Fatigue Testing
BS 1041-4:1992 Temperature measurement – Part 4: Guide to the selection and use of thermocouples

2.3 *CEN Standards:*[4]
EN 60584-1–1996 Thermocouples – Reference tables (IEC 584-1)
EN 60584 -2– 1993 Thermocouples – Tolerances (IEC 584-2)
PrEN 3874–1998 Test methods for metallic materials – constant amplitude force-controlled low cycle fatigue testing
PrEN 3988–1998 Test methods for metallic materials – constant amplitude strain-controlled low cycle fatigue testing

2.4 *ISO Standards:*[5]
ISO 12106–2003 Metallic materials – Fatigue testing - Axial strain-controlled method
ISO 12111–2005 (Draft) Strain-controlled thermo-mechanical fatigue testing method
ISO 7500-1–2004 Metallic materials – Verification of static uniaxial testing machines – Part 1. Tension/compression testing machines – Verification and calibration of the force measuring system
ISO 9513–1999 Metallic materials – Calibration of extensometers used in axial testing
ISO 5725–1994 Accuracy (trueness and precision) of measurement methods

2.5 *JIS Standard:*[6]
JIS Z 2279–1992 Method of high temperature low cycle fatigue testing for metallic materials

3. Terminology

3.1 The definitions in this test method that are also included in Terminology E1823 are in accordance with Terminology E1823.

3.2 Symbols, standard definitions, and definitions specific to this standard are in 3.2.1, 3.3, and 3.4, respectively.

3.2.1 *Symbols:*

Symbol	Term
d [L]	Diameter of gage section of cylindrical test specimen
D_g, [L]	Diameter of grip ends
E, E_o, E_N , [FL^{-2}]	Elastic modulus, initial modulus of elasticity, modulus of elasticity at cycle
E_T, E_C [FL^{-2}]	Tensile modulus, compressive modulus
P [F]	Force
l, l_o [L]	Extensometer gage length, original extensometer gage length
L, L_o, [L]	Length of parallel section of gage length, original length of parallel section of gage length
N, N_f	Cycle number, cycle number to crack formation
r,[L}	Transition radius (from parallel section to grip end)
$\varepsilon_{min} / \varepsilon_{max}$, R_ε	Strain ratio
$\sigma_{min} / \sigma_{max}$, R_σ	Stress ratio
τ	Time
T [θ]	Specimen temperature
T_i [θ]	Indicated specimen temperature
N versus σ_{max}	Crack formation or end-of-life criterion is expressed as a percentage reduction in maximum stress from the cycles, N versus σ_{max} curve when the stress falls sharply (see Fig. 1), or a specific percentage decrease in the modulus of elasticity ratios in the tensile and compressive portions of the hysteresis diagrams, or as a specific increase in crack size as indicated by an electric potential drop monitoring instrumentation.
ε, ε_{max}, ε_{min}	Strain, maximum strain in the cycle, minimum strain in the cycle
ε_{ea}, ε_{pa}, ε_{ta}	Elastic strain amplitude, plastic strain amplitude, total strain amplitude

[3] Available from British Standards Institute (BSI), 389 Chiswick High Rd., London W4 4AL, U.K., http://www.bsi-global.com.

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

[5] Available from International Organization for Standardization (ISO), 1, ch. de la Voie-Creuse, Case postale 56, CH-1211, Geneva 20, Switzerland, http://www.iso.ch.

[6] Available from Japanese Standards Organization (JSA), 4-1-24 Akasaka Minato-Ku, Tokyo, 107-8440, Japan, http://www.jsa.or.jp..

$\Delta\varepsilon_e$, $\Delta\varepsilon_p$, $\Delta\varepsilon_t$	Elastic strain range, plastic strain range, total strain range (see Fig. 2)
$\Delta\varepsilon_{in}$	Inelastic strain range, (see Fig. 2) is the sum of the plastic strain range and the creep strains during the cycle; it is the distance on the strain axis between points of intersections of the strain axis and the extrapolated linear regions of the hysteresis loops during tensile and compressive unloadings
σ, σ_{max}, σ_{min}	Stress, maximum stress in the cycle, minimum stress in the cycle
$\Delta\sigma$	Stress range

3.3 *Definitions:*

3.3.1 *cycle*—In fatigue, one complete sequence of values of force (strain) that is repeated under constant amplitude loading (straining)

3.3.2 *hold-time, τ_h [T]*—In fatigue testing, the amount of time in the cycle where the controlled test variable (force, strain, displacement) remains constant with time (Fig. 3).

3.3.2.1 *Discussion*—Hold- time(s) are typically placed at peak stress or strain in tension and/or compression, but can also be placed at other positions within the cycle.

3.3.3 *total cycle period, τ_t [T],*—The time for completion of one cycle. The parameter τ_t can be separated into hold (τ_h) and non-hold (τ_{nh}) (that is, steady and dynamic) components, where the total cycle time is the sum of the hold time and the non-hold time.

3.3.4 *hysteresis diagram*—The stress-strain path during one cycle (see Fig. 2).

3.3.5 *initial modulus of elasticity, E_o , [FL^{-2}]* —The modulus of elasticity determined during the loading portion of the first cycle.

3.3.6 *modulus of elasticity at cycle N, (E_N, [FL^{-2}]* —The average of the modulus of elasticity determined during increasing load portion (see E_c in Fig. 2) and the decreasing load portion (E_T in Fig. 2) of the hysteresis diagram for the N_{th} cycle.

3.3.7 *stress range, $\Delta\sigma$, [FL^{-2}]*—The difference between the maximum and minimum stresses.

3.3.7.1 *Discussion*—For creep-fatigue tests, the difference between the maximum and minimum stresses is called the "peak stress range" and for tests conducted under strain control, the difference between the stresses at the points of reversal of the control parameter is called the "relaxed stress range" (see Fig. 2b).

3.4 *Definitions of Terms Specific to This Standard:*

3.4.1 *DCPD and ACPD*—Direct current and alternating current electrical potential drop crack monitoring instrumentation.

3.4.2 *homologous temperature*—The specimen temperature in °K divided by the melting point of the material also in °K.

3.4.3 *crack formation*—A crack is believed to have formed when it has nucleated and propagated in a specimen that was initially un-cracked to a size that is detectable by a stated technique.

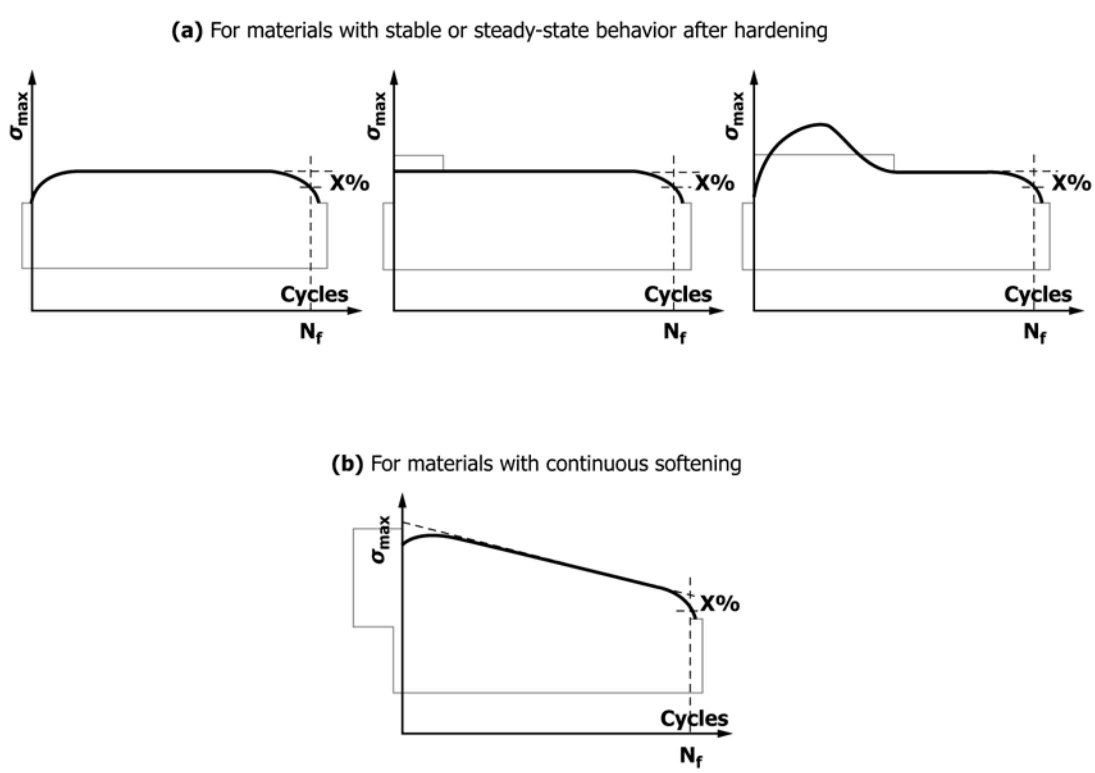

FIG. 1 Crack Formation and End-of-Test Criterion based on Reduction of Peak Stress for (a) Hardening and (b) Softening Materials