



Designation: **E1823 – 12e E1823 – 13**

## Standard Terminology Relating to Fatigue and Fracture Testing<sup>1</sup>

This standard is issued under the fixed designation E1823; 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 reappraisal. A superscript epsilon ( $\epsilon$ ) indicates an editorial change since the last revision or reappraisal.

### 1. Scope

1.1 This terminology contains definitions, definitions of terms specific to certain standards, symbols, and abbreviations approved for use in standards on fatigue and fracture testing. The definitions are preceded by two lists. The first is an alphabetical listing of symbols used. (Greek symbols are listed in accordance with their spelling in English.) The second is an alphabetical listing of relevant abbreviations.

1.2 This terminology includes [Annex A1](#) on Units and [Annex A2](#) on Designation Codes for Specimen Configuration, Applied Loading, and Crack or Notch Orientation.

### 2. Referenced Documents

#### 2.1 *ASTM Standards:*<sup>2</sup>

- [E6 Terminology Relating to Methods of Mechanical Testing](#)
- [E23 Test Methods for Notched Bar Impact Testing of Metallic Materials](#)
- [E28 Test Methods for Softening Point of Resins Derived from Naval Stores by Ring-and-Ball Apparatus](#)
- [E208 Test Method for Conducting Drop-Weight Test to Determine Nil-Ductility Transition Temperature of Ferritic Steels](#)
- [E338 Test Method of Sharp-Notch Tension Testing of High-Strength Sheet Materials \(Withdrawn 2010\)<sup>3</sup>](#)
- [E399 Test Method for Linear-Elastic Plane-Strain Fracture Toughness  \$K\_{Ic}\$  of Metallic Materials](#)
- [E436 Test Method for Drop-Weight Tear Tests of Ferritic Steels](#)
- [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](#)
- [E561 Test Method for  \$K-R\$  Curve Determination](#)
- [E602 Test Method for Sharp-Notch Tension Testing with Cylindrical Specimens \(Withdrawn 2010\)<sup>3</sup>](#)
- [E604 Test Method for Dynamic Tear Testing of Metallic Materials](#)
- [E606 Practice for Strain-Controlled Fatigue Testing](#)
- [E647 Test Method for Measurement of Fatigue Crack Growth Rates](#)
- [E739 Practice for Statistical Analysis of Linear or Linearized Stress-Life \( \$S-N\$ \) and Strain-Life \( \$\epsilon-N\$ \) Fatigue Data](#)
- [E740 Practice for Fracture Testing with Surface-Crack Tension Specimens](#)
- [E813 Test Method for  \$J\_{Ic}\$ , A Measure of Fracture Toughness](#)
- [E992 Practice for Determination of Fracture Toughness of Steels Using Equivalent Energy Methodology](#)
- [E1049 Practices for Cycle Counting in Fatigue Analysis](#)
- [E1152 Test Method for Determining  \$J-R\$  Curves](#)
- [E1221 Test Method for Determining Plane-Strain Crack-Arrest Fracture Toughness,  \$K\_{Ia}\$ , of Ferritic Steels](#)
- [E1290 Test Method for Crack-Tip Opening Displacement \(CTOD\) Fracture Toughness Measurement \(Withdrawn 2013\)<sup>3</sup>](#)
- [E1304 Test Method for Plane-Strain \(Chevron-Notch\) Fracture Toughness of Metallic Materials](#)
- [E1450 Test Method for Tension Testing of Structural Alloys in Liquid Helium](#)
- [E1457 Test Method for Measurement of Creep Crack Growth Times in Metals](#)
- [E1681 Test Method for Determining Threshold Stress Intensity Factor for Environment-Assisted Cracking of Metallic Materials](#)
- [E1737 Test Method for  \$J\$ -Integral Characterization of Fracture Toughness \(Withdrawn 1998\)<sup>3</sup>](#)

<sup>1</sup> This terminology is under the jurisdiction of ASTM Committee E08 on Fatigue and Fracture and is the direct responsibility of Subcommittee E08.02 on Standards and Terminology.

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<sup>2</sup> For referenced ASTM standards, visit the ASTM website, [www.astm.org](http://www.astm.org), or contact ASTM Customer Service at [service@astm.org](mailto:service@astm.org). For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

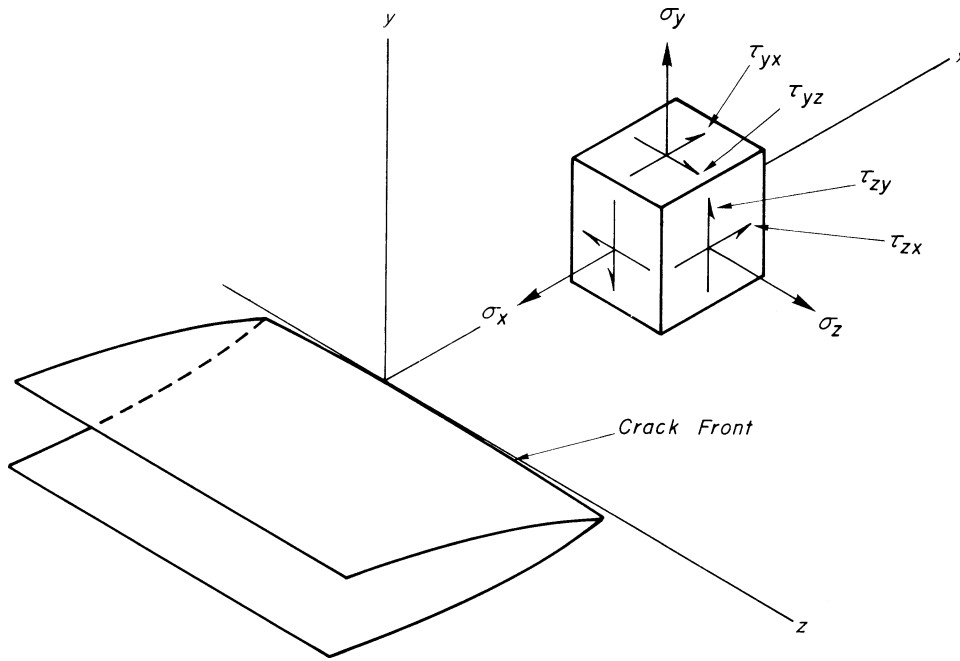
<sup>3</sup> The last approved version of this historical standard is referenced on [www.astm.org](http://www.astm.org).

- [E1820 Test Method for Measurement of Fracture Toughness](#)  
[E1921 Test Method for Determination of Reference Temperature,  \$T\_o\$ , for Ferritic Steels in the Transition Range](#)  
[E1942 Guide for Evaluating Data Acquisition Systems Used in Cyclic Fatigue and Fracture Mechanics Testing](#)  
[E2207 Practice for Strain-Controlled Axial-Torsional Fatigue Testing with Thin-Walled Tubular Specimens](#)  
[E2208 Guide for Evaluating Non-Contacting Optical Strain Measurement Systems](#)  
[E2298 Test Method for Instrumented Impact Testing of Metallic Materials](#)  
[E2443 Guide for Verifying Computer-Generated Test Results Through The Use Of Standard Data Sets](#)  
[E2472 Test Method for Determination of Resistance to Stable Crack Extension under Low-Constraint Conditions](#)  
[E2714 Test Method for Creep-Fatigue Testing](#)  
[E2760 Test Method for Creep-Fatigue Crack Growth Testing](#)  
[G15 Terminology Relating to Corrosion and Corrosion Testing \(Withdrawn 2010\)<sup>3</sup>](#)

### 3. Terminology

#### 3.1 Alphabetical Listing of Principal Symbols Used in This Terminology:

Symbol	Term
$a$	crack depth, crack length, crack size, estimated crack size
$a_e$	effective crack size
$a_n$	notch length
$a_o$	original crack size
$a_p$	physical crack size
$a/W$	normalized crack size
$A$	force ratio ( $P_a/P_m$ )
$A_N$	net-section area
$b$	remaining ligament
$b_o$	original uncracked ligament
$B$	specimen thickness
$B_e$	effective thickness
$B_N$	net thickness
$2c$	surface-crack length
$C$	normalized $K$ -gradient
$D$	cycle ratio ( $n/N_f$ )
$C^*(t)$	$C^*(t)$ – Integral
$da/dN$	fatigue-crack-growth rate
$\delta$	crack-tip opening displacement ( $CTOD$ )
$\delta d$	specimen gage length
$\Delta a$	crack extension, estimated crack extension
$\Delta K$	stress-intensity-factor range
$\Delta K_{th}$	fatigue-crack-growth threshold
$\Delta P$	force range
$\varepsilon_a$	strain amplitude
$\varepsilon_{in}$	inelastic strain
$\varepsilon_m$	mean force
$G$	crack-extension force
$G_R$	crack-extension resistance
$H^*$	specimen center of pin hole distance
$\Gamma$	the path of the $J$ -integral
$J$	$J$ -integral
$J_{IC}$	plane-strain fracture toughness
$J_R$	crack-extension resistance
$k_f$	fatigue notch factor
$k_t$	theoretical stress concentration factor (sometimes abbreviated stress concentration factor)
$K, K_1, K_2, K_3,$ $K_I, K_{II}, K_{III}$	stress-intensity factor (see mode)
$K_a$	crack-arrest fracture toughness
$K_c$	plane-stress fracture toughness
$K_{EAC}$	stress intensity factor threshold for environment-assisted cracking
$K_{Ia}$	plane-strain crack-arrest fracture toughness
$K_{IEAC}$	stress intensity factor threshold for plane strain environment-assisted cracking
$K_{Ic}$	plane-strain fracture toughness
$K_{IVM}, K_{IV}, K_{IVj}$	plane-strain (chevron-notch) fracture toughness
$K_{max}$	maximum stress-intensity factor
$K_{min}$	minimum stress-intensity factor
$K_o$	stress-intensity factor at crack initiation
$K_R$	crack-extension resistance
$n$	cycles endured
$N_f$	fatigue life
$P$	force
$P_a$	force amplitude



Symbol
$P_m$
$P_M$
$P_{max}$
$P_{min}$
$q$
$r$
$r_c$
$r_y$
$R$
$s$
$s^2$
$S$
$S_a$
$S_f$
$S_m$
$S_N$
$\sigma_c$
$\sigma_N$
$\sigma_r$
$\sigma_s$
$\sigma_{TS}$
$\sigma_x, \sigma_y, \sigma_z$
$\sigma_Y$
$\sigma_{YS}$
$T$
$t_T$
$t_t$
$\tau_{xy}, \tau_{yz}, \tau_{zx}$
$u$
$v$
$2v_m$
$V_c$
$w$
$W$
$Y^*$
$Y_m^*$

Term
mean force
precrack force
maximum force
minimum force
fatigue notch sensitivity
effective unloading slope ratio
critical slope ratio
plastic-zone adjustment
force ratio ( $P_{min}/P_{max}$ )
sample standard deviation
sample variance
specimen span
force amplitude
fatigue limit
mean force
fatigue strength at $N$ cycles
crack strength
nominal (net-section) stress
residual strength
sharp-notch strength
tensile strength
normal stresses (refer to )
effective yield strength
yield strength
specimen temperature
transition time
total cycle period
shear stresses (refer to Fig. 1)
displacement in x direction
displacement in y direction
crack-mouth opening displacement
force-line displacement due to creep
displacement in z direction
specimen width
stress-intensity factor coefficient
minimum stress-intensity factor coefficient

iTeh Standards  
 (https://standards.iteh.ai)  
 Document

ASTM E1823-13  
<https://standards.iteh.ai/catalog/standards/sist/d82491f7-4aca2-351aa633c215/astm-e1823-13>

3.2 Alphabetical Listing of Abbreviations Used:

<i>CMOD</i>	crack-mouth opening displacement
<i>COD</i>	see <i>CTOD</i>
<i>CTOD</i>	crack-tip opening displacement
<i>DT</i>	dynamic tear
<i>DWTT</i>	drop-weight tear test

NOTE 1—See definition of mode.

<i>EAC</i>	environment-assisted cracking
<i>K-EE</i>	equivalent-energy fracture toughness
<i>NTS</i>	notch tensile strength
<i>PS</i>	part-through surface
<i>SCC</i>	stress corrosion cracking
<i>SZW</i>	stretch zone width

3.3 *Definitions*—Each definition is followed by the designation(s) of the standard(s) of origin. The listing of definitions is alphabetical.

*alternating force*—See **loading amplitude**.

**accuracy—accuracy**—The quantitative difference between a test measurement and a reference value. **E467, E2208**

**applied-K curve**—a curve (a fixed-force or fixed-displacement crack-extension-force curve) obtained from a fracture mechanics analysis for a specific configuration. The curve relates the stress-intensity factor to crack size and either applied force or displacement.

DISCUSSION—

The resulting analytical expression is sometimes called a *K* calibration and is frequently available in handbooks for stress-intensity factors. **E647**

**block**—*in fatigue loading*, a specified number of constant amplitude loading cycles applied consecutively, or a spectrum loading sequence of finite length that is repeated identically. **E1823**

**C\*(t) integral, C\*(t)[FL<sup>-1</sup> T<sup>-1</sup>]**—a mathematical expression, a line or surface integral that encloses the crack front from one crack surface to the other, used to characterize the local stress-strain rate fields at any instant around the crack front in a body subjected to extensive creep conditions. **E1457, E2760**

DISCUSSION—

1 The C\*(t) expression for a two-dimensional crack, in the *x-z* plane with the crack front parallel to the *z*-axis, is the line integral:

$$C^*(t) = \int_{\Gamma} \left( W^*(t) dy - T \frac{\partial \dot{u}}{\partial x} ds \right) \quad (1)$$

where:

- $W^*(t)$  = instantaneous stress-power or energy rate per unit volume,
- $\Gamma$  = path of the integral, that encloses (that is, contains) the crack tip contour (see **Fig. 2**),
- $ds$  = increment in the contour path,
- $T$  = outward traction vector on  $ds$ ,
- $\dot{u}$  = displacement rate vector at  $ds$ ,
- $x, y, z$  = rectangular coordinate system, and
- $T \frac{\partial \dot{u}}{\partial x} ds$  = rate of stress-power input into the area enclosed by  $\Gamma$  across the elemental length,  $ds$ .

DISCUSSION—

2 The value of C\*(t) from this equation is path-independent for materials that deform according to a constitutive law that may be separated into single-value time and stress functions or strain and stress functions of the forms:

$$\dot{\epsilon} = f_1(t) f_2(\sigma) \text{ or,}$$

$$\dot{\epsilon} = f_3(\epsilon) f_4(\sigma)$$

Where  $f_1$ – $f_4$  represent functions of elapsed time,  $t$ , strain,  $\epsilon$ , and applied stress,  $\sigma$ , respectively;  $\dot{\epsilon}$  is the strain rate.

DISCUSSION—

3 For materials exhibiting creep deformation for which the above equation is path independent, the C\*(t)-integral is equal to the value obtained from two, stressed, identical bodies with infinitesimally differing crack areas. This value is the difference in the stress-power per unit difference in crack area at a fixed value of time and displacement rate or at a fixed value of time and applied force.

FIG. 1 Customary Coordinate System and Stress on a Small Volume Element Located on the x Axis Just Ahead of the Crack Front

DISCUSSION—

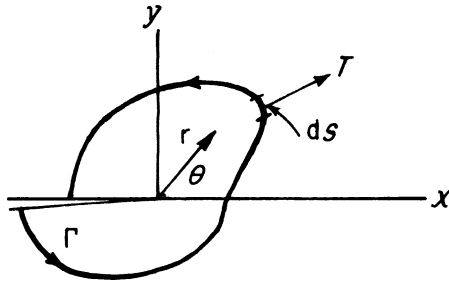


FIG. 2 Contour and Symbolism for Path-Independent Crack Tip Integrals

4 The value of  $C^*(t)$  corresponding to the steady-state conditions is called  $C^*_s$ . Steady-state is said to have been achieved when a fully developed creep stress distribution has been produced around the crack tip. This occurs when secondary creep deformation characterized by the following equation dominates the behavior of the specimen.

$$\dot{\epsilon}_{ss} = A \sigma^n$$

DISCUSSION—

5 This steady state in  $C^*$  does not necessarily mean steady state crack growth rate. The latter occurs when steady state damage develops at the crack tip. For Test Method E1457 this behavior is observed as “tails” at the early stages of crack growth. Test Method E1457 deals with this region as the initial crack extension period defined as time  $t_{0,2}$ , measured for an initial crack growth of 0.2 mm after first loading.

**$C_t$  parameter,  $C_t$ , [ $FL^{-1}T^{-1}$ ]**—parameter equal to the value obtained from two identical bodies with infinitesimally differing crack areas, each subjected to stress, as the difference in the stress-power per unit difference in crack area at a fixed value of time and displacement rate or at a fixed value of time and applied force for an arbitrary constitutive law. **E1457, E2760**

DISCUSSION—

The value of  $C_t$  is path-independent and is identical to  $C^*(t)$  for extensive creep conditions when the constitutive law described in Discussion 2 of  $C^*(t)$ -integral definition applies.

DISCUSSION—

Under small-scale creep conditions,  $C^*(t)$  is not path-independent and is related to the crack tip stress and strain fields only for paths local to the crack tip and well within the creep zone boundary. Under these circumstances,  $C_t$  is related uniquely to the rate of expansion of the creep zone size. There is considerable experimental evidence that the  $C_t$  parameter which extends the  $C^*(t)$ -integral concept into the small-scale creep and the transition creep regime correlates uniquely with creep crack growth rate in the entire regime ranging from small-scale to extensive creep regime.

DISCUSSION—

for a specimen with a crack subject to constant force,  $P$

$$C_t = \frac{P \dot{V}_c}{BW} (f'/f)$$

and

$$f' = \frac{df}{d(a/W)}$$

**circulation rate [ $L^3 T^{-1}$ ]**—in fatigue testing, the volume rate of change of the environment chamber volume. **E1823**

**clipping**—in fatigue spectrum loading, the process of decreasing or increasing the magnitude of all loads (strains) that are, respectively, above or below a specified level, referred to as clipping level; the loads (strains) are decreased or increased to the clipping level (see Fig. 3). **E1823**

**compliance ( $LF^{-1}$ )**— the ratio of displacement increment to force increment. **E1820**

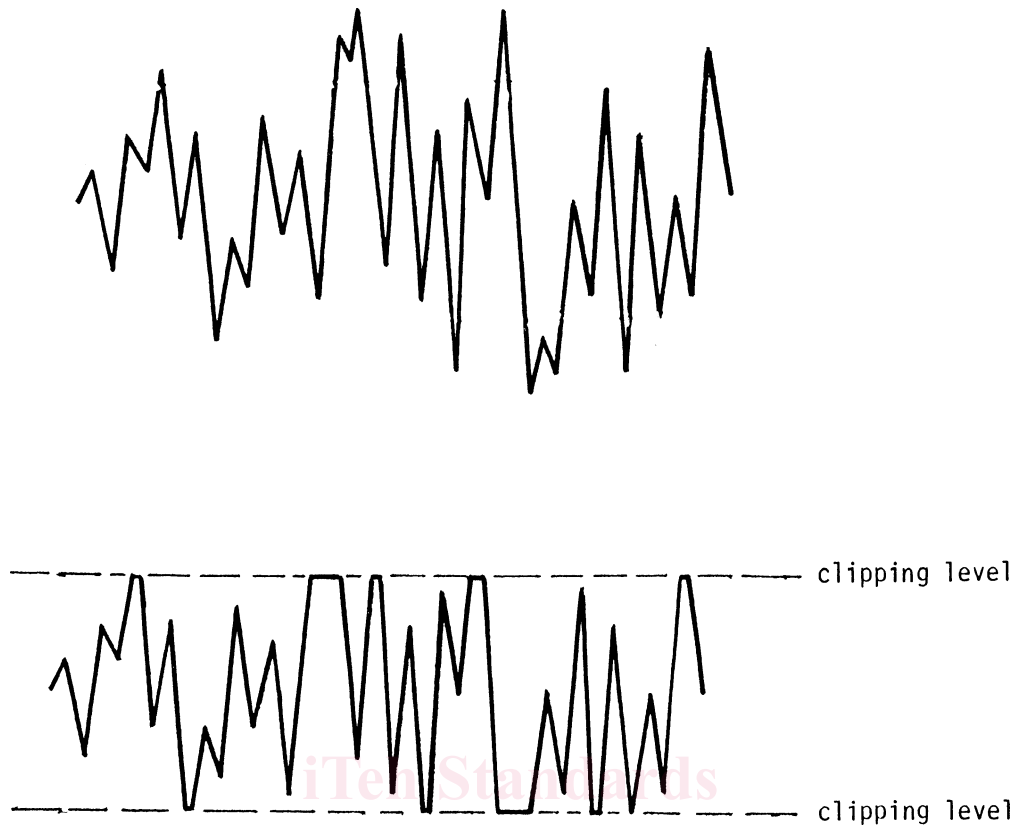


FIG. 3 Clipping of Fatigue Spectrum Loading

**confidence interval**—an interval estimate of a population parameter computed so that the statement “the population parameter included in this interval” will be true, on the average, in a stated proportion of the times such computations are made based on different samples from the population. **E1823**

**confidence level (or coefficient)**—the stated proportion of the times the confidence interval is expected to include the population parameter. **E1823**

**confidence limits**—the two statistics that define a confidence interval. **E1823**

**constant amplitude loading**— *in fatigue loading*, a loading (straining) in which all of the peak forces (strains) are equal and all of the valley forces (strains) are equal. **E1049**

**constant life diagram**— *in fatigue*, a plot (usually on rectangular coordinates) of a family of curves each of which is for a single fatigue life,  $N$ , relating stress amplitude,  $S_a$ , to mean stress,  $S_m$ , or maximum stress,  $S_{max}$ , or both, to minimum stress,  $S_{min}$ . The constant life fatigue diagram is usually derived from a family of  $S-N$  curves each of which represents a different stress ratio ( $A$  or  $R$ ) for a 50 % probability of survival. **E1820**

**control force,  $P_m$  [F]**—a calculated value of maximum force to stipulate allowable precracking limits. **E1820, E1921**

**corrosion fatigue**—the process by which fracture occurs prematurely under conditions of simultaneous corrosion and repeated cyclic loading at lower stress levels or fewer cycles than would be required in the absence of the corrosive environment. **G15**

**counting method**—*in fatigue spectrum loading*, a method of counting the occurrences and defining the magnitude of various loading parameters from a load-time history; (some of the counting methods are: level crossing count, peak count, mean crossing peak count, range count, range-pair count, rain-flow count, racetrack count). **E1049**

**crack opening displacement (COD)[L]**—force-induced separation vector between two points at a specified gage length. The direction of the vector is normal to the crack plane. **E399, E1221, E1290, E1820, E2472**

**crack extension,  $\Delta a$  [L]**—an increase in crack size.

For example, in Practice **E561**,  $\Delta a_p$  or  $\Delta a_e$  is the difference between the crack size, either  $a_p$  (physical crack size) or  $a_e$  (effective crack size), and  $a_o$  (original crack size). **E561**

**crack-extension force,  $G$  [ $\text{FL}^{-1}$  or  $\text{FLL}^{-2}$ ]**—the elastic energy per unit of new separation area that is made available at the front of an ideal crack in an elastic solid during a virtual increment of forward crack extension.

DISCUSSION—

This force concept implies an analytical model for which the stress-strain relations are regarded as elastic. The preceding definition of  $G$  applies to either static cracks or running cracks. From past usage,  $G$  is commonly associated with linear-elastic methods of analysis, although the  $J$  (see **J-integral**) also may be used for such analyses. **E1823**

**crack-extension resistance,  $K_R$  [ $\text{FL}^{-3/2}$ ],  $G_R$  [ $\text{FL}^{-1}$ ] or  $J_R$  [ $\text{FL}^{-1}$ ]**—a measure of the resistance of a material to crack extension expressed in terms of the stress-intensity factor,  $K$ ; crack-extension force,  $G$ ; or values of  $J$  derived using the  $J$ -integral concept.

DISCUSSION—

See definition of  $R$ -curve. **E561**

**crack initiation**—the onset of crack propagation from a preexisting macroscopic crack created in the specimen by a stipulated procedure. **E1921**

**crack-mouth opening displacement (CMOD),  $V_m, 2v_m$  [L]**—the Mode I (also called opening-mode) component of crack crack opening displacement resulting from the total deformation (elastic plus plastic), measured under force at the location on a crack surface that has the ~~greatest elastic~~ largest displacement per unit force.

DISCUSSION—

In part-through surface-crack (PS) specimens,  $CMOD$  is measured on the specimen surface at the midpoint of the crack length. **E399, E647, E740, E1221, E1457, E1681, E1820** **E740**

**crack opening displacement (COD)[L]**—force-induced separation vector between two points at a specified gage length. The direction of the vector is normal to the crack plane. **E399, E1221, E1290, E1820, E2472**

**crack-plane orientation**—an identification of the plane and direction of fracture or crack extension in relation to product configuration. This identification is designated by a hyphenated code with the first letter(s) representing the direction normal to the crack plane and the second letter(s) designating the expected direction of crack propagation. **E1823-13**

DISCUSSION—

See also E1823 Annex A2, (A2.4 on crack or notch orientation). **E399, E1457**

**crack size,  $a$  [L]**—principal lineal dimension used in the calculation of fracture mechanics parameters for through-thickness cracks as defined in the applicable standard. See Fig. A2.2 for schematic representations.

DISCUSSION—

For example, in the C(T) specimen  $a$  is the average measurement from the line connecting the bearing points of force application; in the M(T) specimen,  $a$  is the average measurement from the perpendicular bisector of the central crack.

DISCUSSION—

In practice, the value of  $a$  is obtained from procedures for measurement of physical crack size,  $a_p$ , original crack size,  $a_o$ , and effective crack size,  $a_e$ , as appropriate to the situation being considered.

DISCUSSION—

For part-through cracks see crack depth ( $a$ ) and surface crack length ( $2c$ ) in *Definitions of Terms* (Specific to the indicated standards.)

DISCUSSION—

In Test Method **E1457**, the physical crack size is represented as  $a_p$ . The subscript  $p$  is everywhere implied.

**E1457**

**crack strength,  $\sigma_c$  [ $\text{FL}^{-2}$ ]**—the maximum value of the nominal stress that a cracked structure is capable of sustaining.

DISCUSSION—

1 Crack strength is calculated on the basis of the maximum force and the original minimum cross-sectional area (net cross section or ligament). Thus, it takes into account the original size of the crack but ignores any crack extension that may occur during the test.

DISCUSSION—

2 Crack strength is analogous to the ultimate tensile strength, as it is based on the ratio of the maximum force to the minimum cross-sectional area at the start of the test.

**E338, E602**

**crack-tip opening displacement (CTOD),  $\delta$ , [L]**—the crack displacement resulting from the total deformation (elastic plus plastic) at variously defined locations near the original (prior to force application) crack tip.

DISCUSSION—

In common practice,  $\delta$  is estimated for Mode I by inference from observations of crack displacement nearby or away, or both, from the crack tip.

**E1290**

**crack-tip plane strain**—a stress-strain field (near the crack tip) that approaches plane strain to the degree required by an empirical criterion.

DISCUSSION—

For example, in Mode I, the criterion for crack-tip plane strain given by Test Method **E399** requires that plate thickness,  $B$ , must be equal to or greater than  $2.5 (K/\sigma_{YS})^2$ .

**E399**

**crack-tip plane stress**—a stress-strain field (near the crack tip) that is not in plane strain.

DISCUSSION—

In such situations, a significant degree of plane strain may be present.

**E1823**

**creep crack growth (CCG) rate,  $da/dt$  or  $\Delta a/\Delta t$  [L/t]**—the rate of crack extension caused by creep damage and expressed in terms of average crack extension per unit time.

**E1457**

**creep zone boundary**—the locus of points ahead of the crack front where the equivalent strain caused by the creep deformation equals 0.002 (0.2%).

DISCUSSION—

Under small-scale creep conditions, the creep zone expansion with time occurs in a self-similar manner for planar bodies, thus, the creep zone size,  $r_c$ , can be defined as the distance to the creep zone boundary from the crack tip at a fixed angle,  $\theta$ , with respect to the crack plane. The rate of expansion of the creep zone size is designated as  $r'_c(\theta)$ .

**E1457, E2760**

**criterion of failure**—complete separation, or the presence of a crack of specified length visible at a specified magnification. Other criteria may be used but should be clearly defined.

**E468**

**crystallographic cleavage**—the separation of a crystal along a plane of fixed orientation relative to the three-dimensional crystal structure within which the separation process occurs, with the separation process causing the newly formed surfaces to move away from one another in directions containing major components of motion perpendicular to the fixed plane.

**E1823**

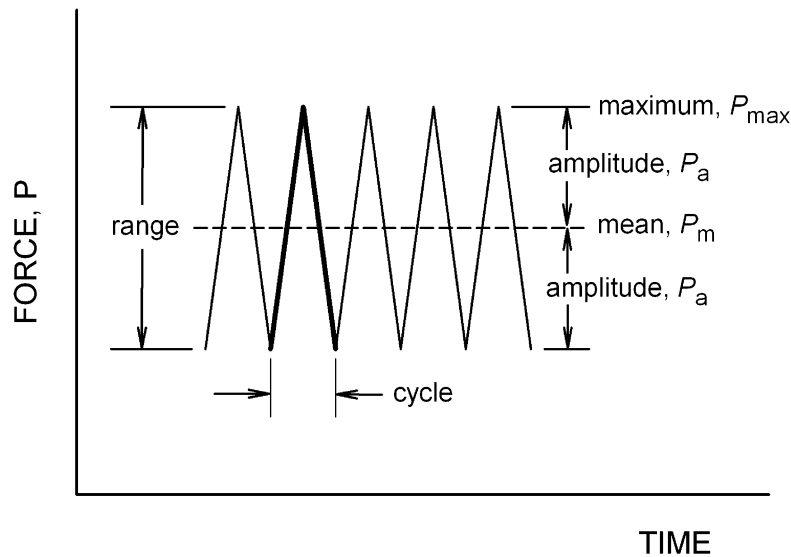
*cumulative frequency spectrum*—See **exceedances spectrum**.

*cumulative occurrences spectrum*—See **exceedances spectrum**.

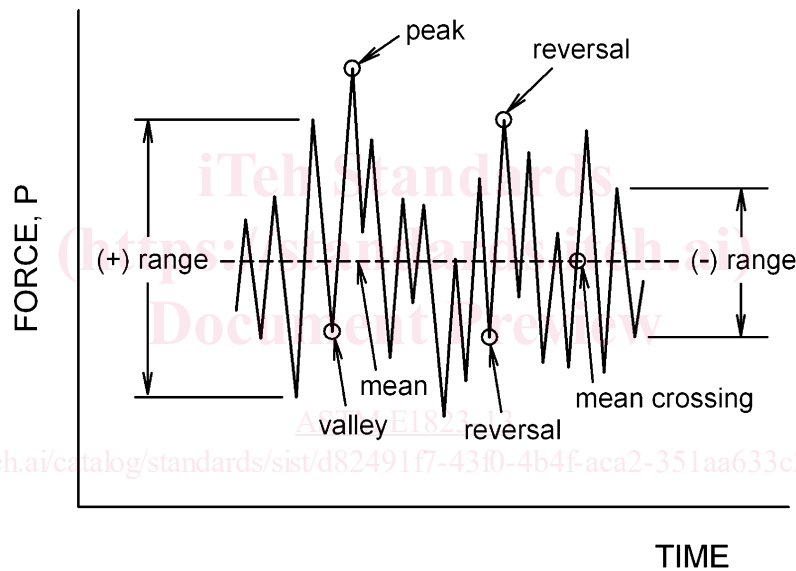
**cycle**—*in fatigue*, one complete sequence of values of force (strain) that is repeated under constant amplitude loading (straining). (See **Fig. 4.**) The symbol  $N$  (see definition of **fatigue life**) is used to indicate the number of cycles.

DISCUSSION—





(a) Constant Amplitude Loading



(b) Spectrum Loading

FIG. 4 Fatigue Loading Basic Terms

In *spectrum loading*, definition of cycle varies with the counting method.

E1823

**cycle ratio,  $D$** — the ratio of cycles endured,  $n$ , to the estimated fatigue life,  $N_f$ , obtained from the stress versus fatigue life ( $S-N$ ) or the strain versus fatigue life ( $\epsilon-N$ ) diagram for cycles of the same character, that is,  $D = n/N_f$ .

E1823

**cycles endured,  $n$** —in *fatigue*, the number of cycles of specified character (that produce fluctuating force) which a specimen has endured at any time in its force history.

E1823

*cyclic loading*—See **fatigue loading**.

**deaeration**—in *environmentally affected fatigue testing*, the process of removal of air from the liquid environment before and during a test.

E1823

**derived data**—data obtained through processing of the raw data.

E1942, E2208, E2443

**dynamometer**—an elastic calibration device used to verify the indicated forces applied by a fatigue testing system. It shall consist of an instrumented member having mass, stiffness, and end displacements such that the inertial effects of the specimen and its attachments to the testing machine for which the verification of forces is desired are duplicated within 5 %. The instrumentation shall permit an accurate determination of the magnitude of the average strain in a region of the uniform transverse cross section

when the dynamometer is subjected to a tensile or compressive force along its longitudinal axis, within 1 % of the true strains. A strain gaged specimen is often used as a dynamometer. **E467**

**dynamometer dynamic forces [F]**—the maximum and minimum forces (or the mean force and the force amplitude) that correspond to the readings obtained from the dynamometer output according to an existing static calibration. Such forces are considered true specimen dynamic forces for the purpose of this terminology. **E467**

**dynamometer range [F]**—the range of forces for which the dynamometer may be used for verification purposes. A dynamometer for use in tension and in compression will have two dynamometer ranges, one in tension and one in compression. **E467**

**effective crack size,  $a_e$  [L]**—the physical crack size augmented to account for crack-tip plastic deformation.

DISCUSSION—

Sometimes the effective crack size,  $a_e$ , is calculated from a measured value of a physical crack size,  $a_p$ , plus a calculated value of a plastic-zone adjustment,  $r_y$ . Another method for calculation of  $a_e$  involves comparing the compliance from the secant of a force-deflection trace with the elastic compliance from a calibration for the given specimen design. **E561**

**effective modulus,  $E_{\text{eff}}$  [FL<sup>-2</sup>]**—an elastic modulus that allows a theoretical (modulus normalized) compliance to match an experimentally measured compliance for an actual initial crack size,  $a_0$ . **E561, E1450, E1921**

**effective thickness  $B_e$  [L]**—for compliance-based extension measurements: **E1823, E1820**

$$B_e = B - (B - B_N)^2 / B \quad (2)$$

DISCUSSION—

for Test Method **E1820**, for side-grooved specimens this is used for elastic unloading compliance measurement of crack size.

**effective yield strength,  $\sigma_y$  [FL<sup>-2</sup>]**—an assumed value of uniaxial yield strength, that represents the influences of plastic yielding upon fracture test parameters. **E1820, E1921**

DISCUSSION—

1 It is calculated as the average of the 0.2 % offset yield strength,  $\sigma_{ys}$ , and the ultimate tensile strength,  $\sigma_{TS}$ , as follows:

$$\sigma_y = (\sigma_{ys} + \sigma_{TS}) / 2 \quad (3)$$

DISCUSSION—

2 In estimating  $\sigma_y$ , influences of testing conditions, such as loading rate and temperature, should be considered.

**elastic constraint modulus,  $E'$  [FL<sup>-2</sup>]**—a linear-elastic factor relating stress to strain, the value of which is dependent on the degree of constraint. For plane stress,  $E' = E$  is used, and for plane strain,  $E / (1 - \nu^2)$  is used, with  $\nu$  being Poisson's ratio. **E399, E647, E1457, E1681, E1921**

*elastic modulus*—see **modulus of elasticity**.

**environment**—*in fatigue testing*, the aggregate of chemical species and energy that surrounds a test specimen. **E1823**

**environment chamber**—*in fatigue testing*, the container of the bulk volume surrounding a test specimen. **E1823**

**environment chamber volume [L<sup>3</sup>]**—*in fatigue testing*, that bulk volume surrounding a test specimen. **E1823**

**environment composition [ML<sup>-3</sup>]**—*in corrosion fatigue testing*, the concentration of the chemical components in the fluid environment surrounding a test specimen. **E1823**

**environment hydrogen content [ML<sup>-3</sup>]**—*in corrosion fatigue testing*, the hydrogen gas concentration of the fluid environment surrounding a test specimen. **E1823**

**environment monitoring**—*in fatigue testing*, the periodic or continuous measurement of fluid concentrations of the environment. **E1823**

**environment oxygen content [ML<sup>-3</sup>]**—*in corrosion fatigue testing*, the oxygen concentration of the fluid environment surrounding a test specimen. **E1823**

**environment pressure [FL<sup>-2</sup>]**—*in fatigue testing*, the pressure of the bulk volume surrounding a test specimen. **E1823**

**environment temperature**— *in fatigue testing*, the temperature of the bulk volume surrounding a test specimen. **E1823**

**environment volume [L<sup>3</sup>]**—*in fatigue testing*, the total volume immediately surrounding a test specimen plus that contained in a circulating reservoir if applicable. **E1823**

**estimate**—*in statistical analysis*, the particular value or values of a parameter computed by an estimation procedure for a given sample. **E1823**

**estimated crack extension,  $\Delta a$ [L]**—an increase in estimated crack size ( $\Delta a = a - a_{oq}$ ). **E1737**

**estimated crack size  $a$ [L]**—the distance from a reference plane to the observed crack front developed from measurements of elastic compliance or other methods. The reference plane depends on the specimen form, and it is normally taken to be either the boundary, or a plane containing either the force line or the centerline of a specimen or plate. The reference plane is defined prior to specimen deformation. **E1737**

**estimation**—*in statistical analysis*, a procedure for making a statistical inference about the numerical values of one or more unknown population parameters from the observed values in a sample. **E1823**

**exceedances spectrum**— *in fatigue loading*, representation of spectrum loading contents by the number of times specified values of a particular loading parameter (peak, range, and so forth) are equaled or exceeded (also known as *cumulative occurrences* or *cumulative frequency spectrum*). **E1823**

**fatigue**—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.

DISCUSSION—

- 1 In ceramic technology, static tests of considerable duration are called “static fatigue” tests, a type of test referred to as stress-rupture in metal testing.

DISCUSSION—

- 2 Fluctuations may occur both in force and with time (frequency) as in the case of “random vibration.” **E1823**

**fatigue-crack-growth rate,  $da/dN$ , [L/cycle]**—the rate of crack extension under fatigue loading, expressed in terms of crack extension per cycle. **E1823, E399, E647**

**fatigue-crack-growth threshold,  $\Delta K_{th}$  [FL<sup>-3/2</sup>]**—that asymptotic value of  $\Delta K$  at which  $da/dN$  approaches zero. For most materials an *operational*, though arbitrary, definition of  $\Delta K_{th}$  is given as that  $\Delta K$  which corresponds to a fatigue crack growth rate of  $10^{-10}$  m/cycle.

DISCUSSION—

The intent of this Definition is not to define a true threshold, but rather to provide a practical means of characterizing a material’s fatigue crack growth resistance in the near-threshold regime. Caution is required in extending this concept to design. **E647**

*fatigue cycle*—See **cycle**.

**fatigue ductility coefficient,  $\epsilon'f$** —the ability of a material to deform plastically before fracturing, determined from constant strain-amplitude, low-cycle fatigue tests. Intercept of the log-log plot of plastic strain amplitude and the fatigue life in reversals (1 cycle = 2 reversals). **E1823, E606, E2207**

DISCUSSION—

The fatigue ductility coefficient corresponds to the fracture ductility, the true tensile strain at fracture. Elongation and reduction in area represent the engineering tensile strain after fracture.

**fatigue ductility exponent,  $c$** —the slope of the log-log plot of plastic strain amplitude and the fatigue life in reversals (1 cycle = 2 reversals). Determined from constant strain amplitude, low-cycle fatigue tests. **E1823, E606, E2207**

DISCUSSION—

The fatigue ductility exponent varies between -0.5 and -0.7 for many metallic alloys.