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Standard Guide for Fretting Fatigue Testing[1]

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1. Scope

1.1 This guide defines terminology and covers general requirements for conducting fretting fatigue tests and reporting the results. It describes the general types of fretting fatigue tests and provides some suggestions on developing and conducting fretting fatigue test programs.

1.2 Fretting fatigue tests are designed to determine the effects of mechanical and environmental parameters on the fretting fatigue behavior of metallic materials. This guide is not intended to establish preference of one apparatus or specimen design over others, but will establish guidelines for adherence in the design, calibration, and use of fretting fatigue apparatus and recommend the means to collect, record, and reporting of the data.

1.3 The number of cycles to form a fretting fatigue crack is dependent on both the material of the fatigue specimen and fretting pad, the geometry of contact between the two, and the method by which the loading and displacement are imposed. Similar to wear behavior of materials, it is important to consider fretting fatigue as a system response, instead of a material response. Because of this dependency on the configuration of the system, quantifiable comparisons of various material combinations should be based on tests using similar fretting fatigue configurations and material couples.

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]

E3 Guide for Preparation of Metallographic Specimens
E4 Practices for Force Calibration and Verification of Testing Machines
E466 Practice for Conducting Force Controlled Constant Amplitude Axial Fatigue Tests of Metallic Materials
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
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
E1942 Guide for Evaluating Data Acquisition Systems Used in Cyclic Fatigue and Fracture Mechanics Testing
G15 Terminology Relating to Corrosion and Corrosion Testing (Withdrawn 2010)[3]
G40 Terminology Relating to Wear and Erosion
G190 Guide for Developing and Selecting Wear Tests (Withdrawn 2021)[3]

3. Terminology

3.1 Definitions and symbols used in this guide are in accordance with Terminology E1823. Relevant definitions from Terminology G15 or G40 are provided in 3.2. Additional definitions specific to this guide are provided in 3.3.

3.2 *Definitions:*

3.2.1 Terms from Terminologies G15 and G40.

3.2.2 *coefficient of friction (COF)*—The dimensionless ratio of the tangential force, Q, between two bodies to the normal force, P, pressing these bodies together when the two bodies are slipping with respect to each other, $\mu=Q/P$.

3.2.2.1 *Discussion*—Under partial slip conditions, the ratio of the tangential force to the normal force is less than the COF. In addition, when COF is defined as the ratio of Q to P, the

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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.

measured COF is an average along the interface. In reality, the COF can vary along the interface. Hence, a local definition is often used, given by $\mu(x,y)=q(x,y)/p(x,y)$ where $q(x,y)$ is the shear traction distribution along the interface and $p(x,y)$ is the normal pressure distribution. The COF is often greater in the slip regions of a partial slip interface compared to the stick regions due to the disruptions in the surface caused by fretting. **G40**

3.2.3 *fretting*—Small amplitude oscillatory motion, usually tangential, between two solid surfaces in contact.

3.2.3.1 *Discussion*—The term fretting refers only to the nature of the motion without reference to the wear, corrosion, fatigue, or other damage that may occur. It is discouraged to use the term fretting to denote fretting corrosion or other forms of fretting wear due to the ambiguity that may arise. As the amplitude of fretting increases, the condition eventually becomes reciprocating sliding and the interaction should no longer be referred to as fretting.

3.2.4 *fretting corrosion*—The deterioration at the interface between contacting surfaces as the result of corrosion and slight oscillatory slip between the two surfaces. **G15**

3.2.5 *fretting wear*—Wear that occurs as the result of fretting action. **G40**

3.3 *Definitions of Terms Specific to This Standard:*

3.3.1 *displacement amplitude*—The peak-to-peak relative displacement divided by two or total cycle displacement divided by four.

3.3.1.1 *Discussion*—The displacement amplitude is typically based on a remote reference location. Note that the definition of displacement amplitude in the context of fretting wear and tribosystems testing sometimes refers to the full peak-to-peak relative displacement, rather than the definition given here, which is consistent with the use of the term amplitude in Terminology E1823. Hence, whenever the term displacement amplitude is used, it should be clearly defined or a reference made to this guide.

3.3.2 *fretting damage*—The pits, scarring, disruptions and material transfer on the surface due to fretting.

3.3.2.1 *Discussion*—Cracks may be associated with the fretting damage, though in many cases they may not be present or be sufficiently small, such that the fatigue life is not significantly degraded. Hence, the disturbed appearance and level of roughness of the fretting damage cannot be reliably used to determine whether the fatigue life is reduced. In some cases the directionality of roughness, also called the surface texture, can be determined via profilometry methods. This texture may be correlated to the directionality of fretting and in some cases the characteristics of the texture can provide a useful screening metric for fretting damage.

3.3.3 *fretting fatigue*—The process of crack formation at a fretting damage site, progressive crack growth, possibly culminating in complete fracture, occurring in a material subjected to concomitantly fretting and fluctuating stresses and strains.

3.3.3.1 *Discussion—Fretting fatigue* is generally characterized by a sharp decrease in the fatigue life at the same stress level of a standard specimen, attributed to the shortened time to form a crack and the acceleration of the crack growth under the coupling of the fretting and bulk cyclic stresses and strains.

3.3.4 *fretting fatigue knockdown factor*—The reduction in fatigue strength due to the presence of fretting, defined as the difference in the fatigue limit and fretting fatigue limit divided by the fatigue limit.

3.3.4.1 *Discussion*—This knockdown factor may also be based on the fretting fatigue strength defined either as the stress level (maximum stress or stress amplitude for a given mean stress or stress ratio) for failure at a certain number of cycles or the stress level at which a percentage of the population would survive a certain number of cycles.

3.3.5 *fretting fatigue limit*—The limiting value of the median fatigue strength when fretting is present as the fatigue life becomes very large.

3.3.5.1 *Discussion*—The fretting fatigue limit strongly depends on the fretting conditions.

3.3.6 *fretting fatigue reduction factor*—The reduction in fatigue strength due to the presence of fretting, defined as the ratio of the fretting fatigue limit and fatigue limit.

3.3.6.1 *Discussion*—This reduction factor may also be based on the fretting fatigue strength defined either as the stress level (maximum stress or stress amplitude for a given mean stress or stress ratio) for failure at a certain number of cycles or the stress level at which a percentage of the population would survive a certain number of cycles.

3.3.7 *fretting fatigue damage threshold*—The combination of fretting fatigue loading conditions and number of fretting cycles that can be sustained before degradation of fatigue life is observed.

3.3.7.1 *Discussion*—The fretting fatigue loading conditions may include combinations of the normal force, the displacement amplitude, the tangential force amplitude, and the bulk fatigue loading. The concept of a fretting fatigue damage threshold is related to the development of an initial crack characterized with a maximum and range in stress intensity that exceeds the threshold value for crack growth. Generally, after the fretting fatigue damage threshold has been reached, removing the source of fretting, while maintaining the fatigue loading, in configurations where they can be separated, has minimal effect on the remaining life.

3.3.8 *gross slip*—The condition for which all points in contact experience relative slip over a complete cycle, as illustrated in Fig. 1.

3.3.9 *normal force*—Force normal to the contact interface.

3.3.9.1 *Discussion*—Due to the accumulation of debris within the contact or wear in the slip regions, this force may not remain constant but change during the test.

3.3.10 *normal pressure*—Resultant of the normal force divided by the contact area.

3.3.10.1 *Discussion*—To be considered an average only. The true distribution of pressure within the contact area depends on the exact profile and roughness of the contacting surfaces. Analytical or computational methods may be used to determine