



# Standard Test Method for Shear and Bending Fatigue Testing of Calcium Phosphate and Metallic Medical and Composite Calcium Phosphate/Metallic Coatings<sup>1</sup>

This standard is issued under the fixed designation F1160; 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 ( $\epsilon$ ) indicates an editorial change since the last revision or reapproval.

## 1. Scope

1.1 This test method covers the procedure for determining the shear and bending fatigue performance of calcium phosphate coatings and of porous and nonporous metallic coatings and for determining the bending fatigue performance of metallic coatings over sprayed with calcium phosphate. This test method has been established based on plasma-sprayed titanium and plasma-sprayed hydroxylapatite coatings. The efficacy of this test method for other coatings has not been established. In the shear fatigue mode, this test method evaluates the adhesive and cohesive properties of the coating on a metallic substrate. In the bending fatigue mode, this test method evaluates both the adhesion of the coating as well as the effects that the coating may have on the substrate material. These methods are limited to testing in air at ambient temperature. These test methods are not intended for application in fatigue tests of components or devices; however, the test method which most closely replicates the actual loading configuration is preferred.

1.2 The values stated in either SI units or inch-pound units are to be regarded separately as standard. The values stated in each system may not be exact equivalents; therefore, each system shall be used independently of the other. Combining values from the two systems may result in non-conformance with the standard.

1.3 *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.*

<sup>1</sup> This test method is under the jurisdiction of ASTM Committee F04 on Medical and Surgical Materials and Devices and is the direct responsibility of Subcommittee F04.15 on Material Test Methods.

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## 2. Referenced Documents

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

- E6 Terminology Relating to Methods of Mechanical Testing
- 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
- E1832 Practice for Describing and Specifying a Direct Current Plasma Atomic Emission Spectrometer

## 3. Terminology

3.1 The definitions of terms relating to shear and fatigue testing appearing in Terminology E6 shall be considered as applying to the terms used in this test method.

3.2 *loading points, n*—objects in contact with the test beam or bar used to apply force to the beam or bar, usually radiused to concentrate the force to a point or a line.

## 4. Summary of Test Method

### 4.1 Shear Fatigue Testing:

4.1.1 The intent of the shear fatigue test is to determine the adhesive or cohesive strength, or both, of the coating.

4.1.2 This test method is designed to allow the coating to fail at either the coating/substrate interface, within the coating, or at the interface between the coating and the adhesive bonding agent used to transmit the force to the coating.

### 4.2 Bending Fatigue Testing:

<sup>2</sup> 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.

4.2.1 The primary intent of the bending fatigue test is to quantify the effect that the coating has on the substrate it is applied to. Secondly, it may be used to provide a subjective evaluation of coating adhesion, (that is, spalling resistance, cracking resistance, and so forth).

4.2.2 This test method is designed to first provide a substrate fatigue strength to serve as a baseline to assess the effects of the coating on the resulting fatigue strength of the system.

**5. Significance and Use**

5.1 The shear and bending fatigue tests are used to determine the effect of variations in material, geometry, surface condition, stress, and so forth, on the fatigue resistance of coated metallic materials subjected to direct stress for up to 10<sup>7</sup> cycles. These tests may be used as a relative guide to the selection of coated materials for service under condition of repeated stress.

5.2 In order that such basic fatigue data be comparable, reproducible, and can be correlated among laboratories, it is essential that uniform fatigue practices be established.

5.3 The results of the fatigue test may be used for basic material property design. Actual components should not be tested using these test methods.

**6. Equipment Characteristics**

6.1 Equipment characteristics shall be in accordance with Practice E466, Section 7. See also Practices E467 and E1012 and Terminology E1832.

**6.2 Shear Fatigue Test Grips:**

6.2.1 *General*—Various types of grips may be used to transmit the load to the specimens by the testing machine. To ensure axial shear stress, it is important that the specimen axis coincide with the centerline of the heads of the testing machine and that the coating test plane be parallel to the axial force. Any departure from this requirement (that is, any eccentric loading) will introduce bending stresses that are not included in the usual stress calculation (force/cross-sectional area).

6.2.2 A drawing of a typical gripping device for the test assembly is shown in Fig. 1.

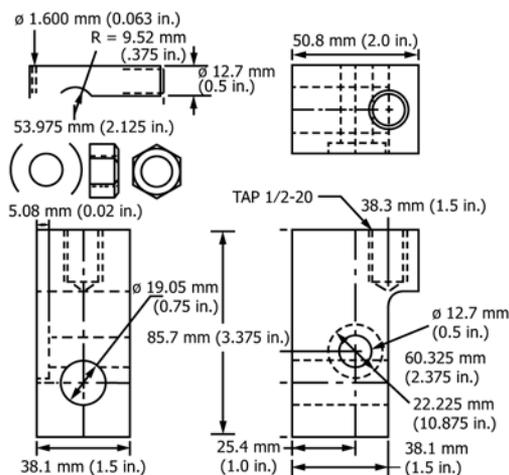


FIG. 1 Gripping Device for Shear Testing

6.2.3 Fig. 2 shows a drawing of the adaptor to mate the shear fixture to the tensile machine

6.2.4 Figs. 3 and 4 show schematics of the test setup.

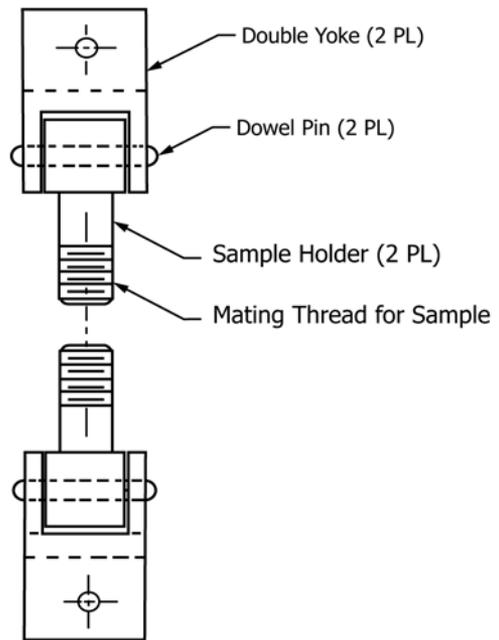
6.3 *Bending Fatigue Test Grips*—There are a variety of testing machines that may be employed for this test (that is, rotating beam fatigue machines and axial fatigue machines). The gripping method for each type of equipment shall be determined by either the manufacturer of that equipment or the user.

**7. Adhesive Bonding Materials**

7.1 *Adhesive Bonding Agent*—A polymeric adhesive bonding agent in film form, or viscous adhesive cement, shall be identified and shall meet the following requirements.

7.1.1 The bonding agent shall be capable of bonding the coating on the test specimen components with an adhesive shear strength that is at least 34.5 MPa [5000 psi] or as great as the minimum required adhesion or cohesion strength of the coating, whichever is greater. The 34.5 MPa bonding strength is the static strength of the adhesive. The fatigue strength of the adhesive is usually less than that value. In fatigue the coating under test is often stronger than the adhesive causing the fracture to occur at the adhesive interface. If it is desirable to continue a fatigue test after fracture through the adhesive, the test sample may be rebonded and testing.

7.1.2 In instances where coating porosity extends to the coating/substrate interface, the bonding agent shall be sufficiently viscous and application to the coating sufficiently detailed, to ensure that it will not penetrate through the coating



NOTE 1—(2 PL) indicates the top and bottom adapters are identical.  
 FIG. 2 Adaptor to Mate the Gripping Device to the Tensile Machine

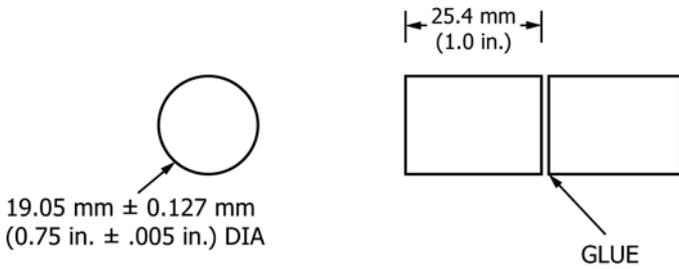


FIG. 3 Schematic of the Shear Test Setup

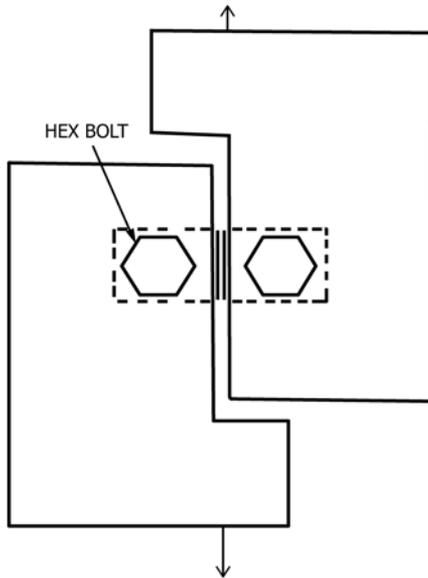


FIG. 4 Drawing of the Recommended Shear Test Specimen Assembly

to the substrate. The FM 1000 Adhesive Film<sup>3</sup> with a thickness of 0.25 mm [0.01 in.] has proven satisfactory for this test method.

7.1.3 If a material other than FM 1000 is used, or the condition of the FM 1000 is unknown, it must be tested to establish its equivalence to fresh FM 1000. Testing should be performed without the presence of the coating to establish the performance of the adhesive. Two alternative adhesives that have been used successfully are HYSOL 9514 and 3M 2214 non-metallic filled. Validation data on Hysol 9514 from Indolab GmbH is presented in Appendix X1. These adhesives may not be suitable for HA coatings because they could penetrate the HA.

## 8. Test Specimen

### 8.1 Shear Fatigue Specimen for Calcium Phosphate and Metallic Coatings Only:

<sup>3</sup> The sole source of supply of the apparatus known to the committee at this time is Cytec Engineered Materials, Inc., 1300 Revolution St., Havre de Grace, MD 21078. If you are aware of alternative suppliers, please provide this information to ASTM International Headquarters. Your comments will receive careful consideration at a meeting of the responsible technical committee,<sup>1</sup> which you may attend.

8.1.1 The recommended shear test specimen and setup is illustrated in Figs. 3 and 4, respectively. A complete assembled test assembly consists of two solid pieces, one with a coated surface and the other with an uncoated surface. The uncoated surface may be roughened to aid in the adhesion of the adhesive bonding agent.

8.1.2 The cross-sectional area of the substrate upon which the coating is applied shall be a nominal 2.85 cm<sup>2</sup> [0.44 in.<sup>2</sup>]. When specimens of another cross-sectional area are used, the data must be demonstrated to be equivalent to the results produced using the 2.85-cm<sup>2</sup> standard cross-sectional area and the specimen size should be reported.

### 8.2 Bending Fatigue Specimen for Calcium Phosphate, Metallic, and Calcium Phosphate-Metallic Composite Coatings:

8.2.1 The type of specimen used will depend upon the objective of the test program, the type of equipment, the equipment capacity, and the form in which the material is available. The *R* ratio for bending fatigue tests shall be 0.1 or less excluding rotating beam samples. For rotating beam samples the *R* ratio shall be -1.0. However, the design shall meet certain general criteria as follows:

8.2.1.1 The design of the specimen shall be such that if specimen failure should occur, it should occur in the test section (reduced area as shown in Figs. 5-8).

8.2.1.2 Specimens using a flat tapered beam configuration should be designed such that a tapered gauge section with a constant surface stress exists when the specimen is constrained at one end and force applied through loading points perpendicular to and centered on the beam axis at the other end (that is, cantilever loading, usually a tapered cantilever beam as shown in Fig. 10).

8.2.1.3 Four-point bend specimens consisting of straight bars of constant, usually rectangular, cross section loaded in four-point bending also produce a region of constant surface stress in the center span between the two center loading points. The distance between the two external loading points shall always be identical (see Fig. 9).

8.2.1.4 Rotating beam specimens may have unique dimensions, depending upon the type of machine used. Appropriate manufacturers' specifications for these specimens should be used.

8.2.1.5 The tensile surface edges of the flat tapered cantilever beam specimen and the four point bend specimen may be broken to a small non zero radius to avoid stress concentrations at the edge.

### 8.3 Specimen Coating Preparation:

8.3.1 Coatings may be applied by any one of a number of techniques. All test specimens for coating characterization

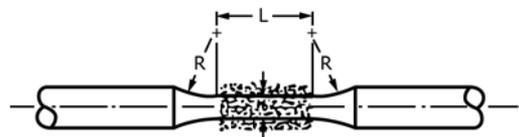


FIG. 5 Bending Fatigue Specimen With Tangentially Blending Fillets Between the Test Section and the Ends for Rotating Beam or Axial Loading