Designation: G204 – 15

Standard Test Method for Damage to Contacting Solid Surfaces under Fretting Conditions[1]

This standard is issued under the fixed designation G204; 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.

INTRODUCTION

Fretting is small amplitude oscillating motion usually in the range of 10 to 300 µm. Contacting solid surfaces subjected to this type of motion can develop significant damage in the form of mass loss, pitting, debris generation, etc. Frequently, pitting damage caused by fretting creates stress concentrations that contribute to mechanical failures. Most material couples are susceptible to fretting damage and this test method is intended to assess a tribocouple's relative susceptibility to damage under fretting conditions.

When tribocouples experience oscillating relative motion less than about 10 µm, gross slip (all points in a contact experience relative slip over a complete cycle) may not occur. The elastic behavior of the real contacts may accommodate this motion and fretting damage may not occur.

When metal couples are subjected to fretting motion, there is a potential for chemical reaction with the ambient environment to be a component of the damage. In metals rubbing in air, oxidation of freshly fractured surfaces can occur. When chemical reaction is conjoint with the mechanical damage produced by fretting, it is called fretting corrosion. When most plastic couples are damaged by fretting motion, the fractured surfaces may not react with the environment and fretting wear occurs as opposed to fretting corrosion.

1. Scope

1.1 This test method covers the studying or ranking the susceptibility of candidate materials to fretting corrosion or fretting wear for the purposes of material selection for applications where fretting corrosion or fretting wear can limit serviceability.

1.2 This test method uses a tribological bench test apparatus with a mechanism or device that will produce the necessary relative motion between a contacting hemispherical rider and a flat counterface. The rider is pressed against the flat counterface with a loading mass. The test method is intended for use in room temperature air, but future editions could include fretting in the presence of lubricants or other environments.

1.3 The purpose of this test method is to rub two solid surfaces together under controlled fretting conditions and to quantify the damage to both surfaces in units of volume loss for the test method.

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

1.5 *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]

E177 Practice for Use of the Terms Precision and Bias in ASTM Test Methods

E691 Practice for Conducting an Interlaboratory Study to Determine the Precision of a Test Method

G40 Terminology Relating to Wear and Erosion

G99 Test Method for Wear Testing with a Pin-on-Disk Apparatus

G117 Guide for Calculating and Reporting Measures of

[1] This test method is under the jurisdiction of ASTM Committee G02 on Wear and Erosion and is the direct responsibility of Subcommittee G02.40 on Non-Abrasive Wear.

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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.

Precision Using Data from Interlaboratory Wear or Erosion Tests

G133 Test Method for Linearly Reciprocating Ball-on-Flat Sliding Wear

3. Terminology

3.1 *Definitions:*

3.1.1 *fretting, n—in tribology*, small amplitude oscillating motion usually tangential between two solid surfaces in contact. **G40**

3.1.2 *fretting corrosion, n*—form of fretting wear in which corrosion plays a significant role. **G40**

3.1.3 *fretting wear, n*—wear arising as a result of fretting. **G40**

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *coefficient of variation (COV), n*—test standard deviation divided by the test mean.

3.2.2 *counterface, n*—flat surface that the rider rubs on in this test.

3.2.3 *crater, n*—counterface damage in a fretting test from a hemispherical or spherical rider characterized by loss of material in the form of a surface depression.

3.2.4 *fretting amplitude, n*—sliding distance between direction reversals (for example, if a dial indicator is used to measure stroke, the amplitude is the indicator movement on the dial).

3.2.5 *rider, n*—ball or hemisphere that oscillates on another surface to produce fretting damage.

3.2.6 *scar, n*—damage to either rider or counterface in a fretting test.

4. Summary of Test Method

4.1 This test method rubs a spherical or hemispherical solid rider on a solid flat under prescribed conditions to produce fretting damage on one or both surfaces. If damage occurs, it is quantified as a wear volume on each member and as system wear, the sum of the rider and counterface wear.

4.2 Friction forces can be measured during the fretting test, but these measurements, as well as reporting these data, is optional.

5. Significance and Use

5.1 Fretting wear and corrosion are potential serviceability factors in many machines. They have always been factors in shipping finished goods by truck or rail. Packing materials rubbing on a product in transit can make the product unsalable. Beverage cans and food cans can lose their trade dress and consumers often equate container damage to content damage.

5.2 Clamping surfaces on injection molds are damaged by fretting motions on clamping. This damage is a significant cause for mold replacement.

5.3 Machines in shipment are subject to fretting damage in the real area of contact of the bearings on the machines.

5.4 Operating vibration and movement of mechanically clamped components, like screwed assemblies, can produce damage on the clamped faces and other faces that affects machine function or use. Many times fretting damage appears in the form of pits, which are stress concentrators that can lead to mechanical fractures.

5.5 Electrical contacts in any device that is subject to vibration are susceptible to failure (open circuit) due to fretting damage at real areas of contact.

5.6 This test method is intended to be used to identify mating couples that may be less prone to fretting damage than others. This information in turn is used to select materials of construction or surface treatments that are less prone to fretting damage for applications where fretting conditions are known or perceived to exist.

6. Apparatus

6.1 Fig. 1 is a schematic of the test apparatus showing necessary features. The schematic shows the counterface moving laterally with respect to the rider. The rider could reciprocate with respect to the counterface as long as it still can move in the downward direction to accommodate wear.

6.2 The rider or counterface holder can be instrumented to sense friction force, but the device cannot interfere with achieving the required relative motion between the rider and counterface. Test rigs need instrumentation or a system to verify that the amplitude of oscillation is the test value of 50 ± 2 µm at test frequency.

6.3 The test specimens must be affixed to the test rig in such a manner that their movement in specimen clamps is less than 1 µm during testing.

6.4 Wear in the specified test can be such that vertical motion of the rider as wear occurs can be hundreds of micrometers. Thus, the test rig should be designed such that the rider can move into the counterface at least 500 ± 20 µm.

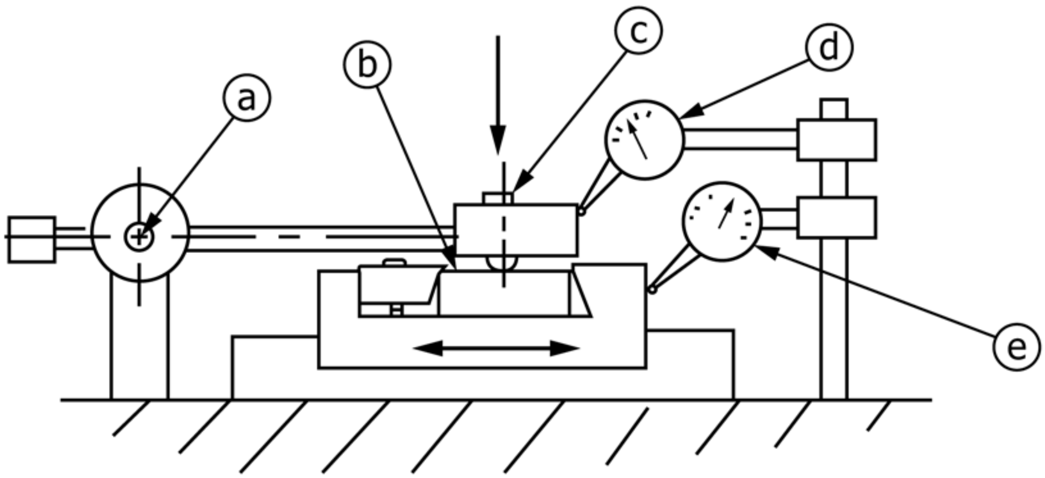
6.5 The test specimens should be protected from environmental contamination during testing and testing should be done in an atmosphere that stays consistent in nature throughout the test. The standard test is performed in ordinary laboratory air at 20°C, 50 to 70% RH.

6.6 The test rig shall be capable of an oscillating frequency of 13 ± 0.8 Hz (see Note 1). Most test rigs have variable frequency capability, and it is not usual to design a rig for a wide frequency range. Mechanical actuators are usually adequate for frequencies in the range of 1 to 50 Hz. Higher test frequencies usually require piezocrystals or the like as a source of oscillation. The standard test was developed using mechanical activation (electric motor driven crank).

NOTE 1—This frequency was chosen for convenience. It produces 10^6 cycles in about 21.4 h. Users can do a test a day.

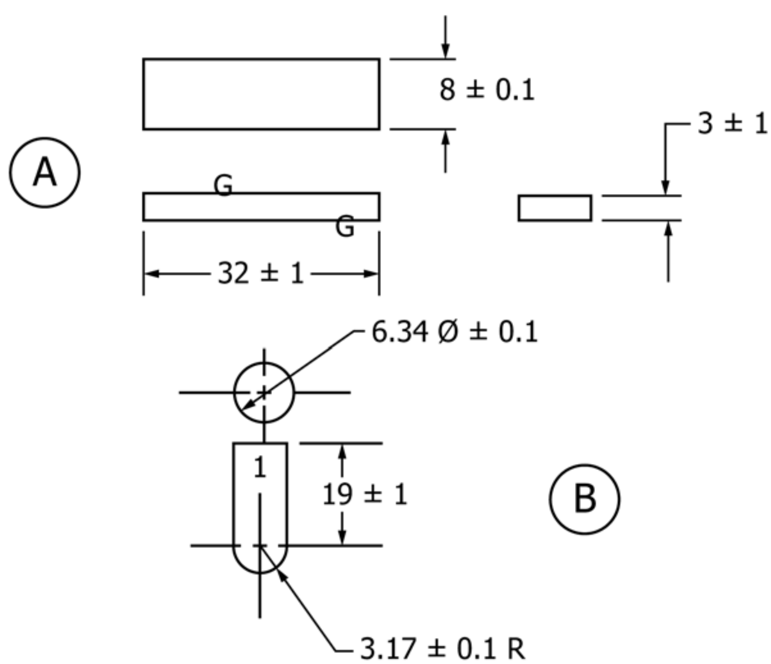
7. Test Specimens

7.1 The test specimens used in this test method can vary in shape as long as the rider has a 3.17 mm radius at the point of contact and the counterface is flat within 1 µm per cm at the point of contact. The test specimens used in the development of this test method are shown in Fig. 2.



a = loading arm pivot
b = counterface test specimen
c = rider test specimen
d = device to measure rider movement
e = device to measure counterface movement

FIG. 1 Schematic of a Suitable Fretting Testing Rig



A = counterface
B = rider (a ball may be adhered to a pin to make the rider)
Surface roughness of both specimens = < 0.1 µm Ra

FIG. 2 Fretting Test Specimens

7.2 Measuring wear scars with surface analysis instruments can be very challenging. The standard test was developed with surface roughnesses on both rider and counterface of less than 0.1 µm Ra. Surface finish can play a role in susceptibility to fretting damage. Polished surfaces produce the most succinct wear scars. Very rough surfaces (> 1 µm Ra) may produce hard-to-measure scars. Sometimes, only the rider wears; sometimes only the counterface wears; sometimes both members wear. Test Method G99 and G133 describe wear scar measurement in detail.

7.3 Some surfaces of interest, like thermal spray deposits, are often incapable of being ground and lapped to this roughness. They can be tested, but the users need to establish the effect of excessive roughness on repeatability. The COV may be high for these test couples.

7.4 The surface lay of the test specimens can affect results and care should be taken to produce non-directional lay in the counterface and accurate curvature (no centerline protuberance greater than 1 µm on the rider). If test surfaces have a distinct lay, the relationship of the rubbing to the lay (parallel or perpendicular) should be kept the same for each test couple.

7.5 Grain direction can be a factor in both counterface and rider in crystalline materials. It is acceptable to ignore grain orientation in ground balls, but the grain orientation in the counterface should simulate the application. The test was developed with counterfaces produced as flat-rolled steel and testing was performed on the flat surfaces as opposed to end grain.

8. Procedure

8.1 Clean test specimens of all films and particles. Ultrasonic degreasing for 1 min in 100 mL of fresh acetone for each specimen has been determined to be adequate for metals. Clean plastics and ceramics with techniques that do not contaminate or attack the test surface.

8.2 Assemble specimens into the test rig after cleaning using procedures that do not contaminate the testing surfaces. Affix the rider to the rider arm and the counterface to the counterface holder. Gently lower the rider onto the counterface so there is no damage from this initial contact. Do not drop the rider on the flat.

8.3 Load the rider on the flat with a normal force of 10 N. Cycle the test rig in "jog mode" for up to 100 cycles or similar such that the relative movement between the rider and counterface can be measured. Adjust the machine so that this relative motion is 50 ± 2 µm.

8.4 When the required amplitude is achieved, commence testing at 13 Hz (780 cycles/minute) and continue until reciprocating 10^6 cycles are completed (21.36 h) Use ultrasonics or other processes to clean the debris from the fretting damaged surfaces (for example, inhibited acid etch).

8.5 Measure the wear volumes on both members. If a flat is worn on the spherical-shaped rider, the flat diameter can be used to calculate a wear volume using the formulas in the G99 procedure for pin-on-disk testing. Counterface wear can usually be measured by profilometer traces through the wear crater; establish the cross-section area of the crater and calculate the volume swept by revolution of this area or by suitable other calculations. It is possible that one member of the test couple will not wear. It is also possible that one member will adhere to the other such that the wear volume is really a mass increase. Most often, both members wear.

8.6 Use mass change to calculate specimen wear and converted to volume using material densities, but the mass changes are usually so small that this technique may lead to a high COV, which is the test standard deviation divided by the test mean. Volume calculation from scar dimensions is the preferred technique.

8.7 Calculate system friction coefficients for the test. They will likely vary during the test and the friction coefficient averaging technique should be stated. The total friction energy dissipated in the test (in joules) may be useful, but it is an optional test metric. This standard was developed without friction measurement, since force measurement devices usually deflect to in order to sense force. Thus, this deflection must be considered in its effect on fretting amplitude. Three test replicates are a minimum for each test couple.

9. Report

9.1 See Fig. 3 for a sample test report. Be sure to include the wear volume of each member and the system wear volume.

10. Precision and Bias (Provisional)[3]

10.1 The precision of this test method is based on an interlaboratory study of G204, Standard Test Method for Damage to Contacting Solid Surfaces under Fretting Conditions, conducted in 2013. Four laboratories participated in this study. Each of the labs reported three replicate test results for a single test couple in light mineral oil. Every "test result" reported represents an individual determination. Except for the use of only four laboratories, Practice E691 and Guide G117 were followed for the design and analysis of the data; the details are given in ASTM Research Report No. RR:G02-1015.

10.1.1 *Repeatability (r)*—The difference between repetitive results obtained by the same operator in a given laboratory applying the same test method with the same apparatus under constant operating conditions on identical test material within short intervals of time would in the long run, in the normal and correct operation of the test method, exceed the following values only in one case in 20.

[3] Supporting data have been filed at ASTM International Headquarters and may be obtained by requesting Research Report RR:G02-1015. Contact ASTM Customer Service at service@astm.org.

	Test No.
	Descriptions
1. Test Couple:	
Rider	
Counterface	
2. Surface Condition (Ra)	
Rider	
Counterface	
3. Test Force	10 N
4. Test Amplitude	50 µm
5. Test Frequency	13
6. Test Environment	20°C, 50% RH
7. Test Duration	10^6 cycles
8. Rider Wear Volume	
9. Counterface Wear Volume	
10. System Wear Volume	
11. Friction and Other Comments	

FIG. 3 Sample Test Report

10.1.1.1 Repeatability can be interpreted as the maximum difference between two results, obtained under repeatability conditions, that is accepted as plausible due to random causes under normal and correct operation of the test method.

10.1.1.2 Repeatability limits are listed in Table 1 below.

10.1.2 *Reproducibility (R)*—The difference between two single and independent results obtained by different operators applying the same test method in different laboratories using different apparatus on identical test material would, in the long run, in the normal and correct operation of the test method, exceed the following values only in one case in 20.

10.1.2.1 Reproducibility can be interpreted as the maximum difference between two results, obtained under reproducibility conditions, that is accepted as plausible due to random causes under normal and correct operation of the test method.

10.1.2.2 Reproducibility limits are listed in Table 1 below.

10.1.3 The above terms (repeatability limit and reproducibility limit) are used as specified in Practice E177.

10.1.4 Any judgment in accordance with 10.1.1 and 10.1.2 would normally have an approximate 95 % probability of being correct; however, the precision statistics obtained in this ILS must not be treated as exact mathematical quantities which are applicable to all circumstances and uses. The limited number of materials tested and laboratories reporting results guarantees that there will be times when differences greater than predicted by the ILS results will arise, sometimes with considerably greater or smaller frequency than the 95 % probability limit would imply. The repeatability limit and the reproducibility limit should be considered as general guides, and the associated probability of 95 % as only a rough indicator of what can be expected.

10.2 *Bias*—At the time of the study, there was no accepted reference material suitable for determining the bias for this test method; therefore, no statement on bias is being made.

10.3 The precision statement was determined through statistical examination of twelve results, from four laboratories, on a single material. Additional laboratories are sought to expand the study to six or more total.

11. Keywords

11.1 fretting; fretting corrosion; fretting wear

TABLE 1 Average Rider Scar Diameter (µm) (Provisional)

	Average[A] $\bar{x}$	Repeatability Standard Deviation s_r	Repeatability Limit r	Repeatability COV %	Reproducibility Standard Deviation s_R	Reproducibility Limit R	Reproducibility COV %
Test Couple[B] in light mineral oil	198.8	13.1	36.7	6.59	28.3	79.2	14.24

[A] The average of the laboratories' calculated averages.

[B] Test Couple: the hemispherical rider (3.2 mm radius) was type 52100 steel at 60 HRC; the counterface was type A2 tool steel at 60 HRC; the mineral oil was pharmaceutical grade obtained independently by each participant.