Designation: G203 − 10 (Reapproved 2020)

Standard Guide for Determining Friction Energy Dissipation in Reciprocating Tribosystems[1]

This standard is issued under the fixed designation G203; 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 guide covers and is intended for use in interpreting the friction forces recorded in reciprocating tribosystems. The guide applies to any reciprocating tribosystem, whether it is a wear or fretting test or an actual machine or device.

1.2 The energy dissipation guide was developed in analyzing friction results in the Test Method G133 reciprocating ball-on-flat test, but it applies to other ASTM or ISO reciprocating tests. This technique is frequently used to record the friction response in fretting tribosystems.

1.3 Specimen material may play some role in the results if the materials under test display viscoelastic behavior. This guide as written is for metals, plastics, and ceramics that do not display viscoelastic behavior. It also applies to lubricated and non-lubricated contacts.

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, health, and environmental practices and determine the applicability of regulatory limitations prior to use.*

1.6 *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]

G40 Terminology Relating to Wear and Erosion

G115 Guide for Measuring and Reporting Friction Coefficients

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

G163 Guide for Digital Data Acquisition in Wear and Friction Measurements (Withdrawn 2016)[3]

3. Terminology

3.1 *Definitions:*

3.1.1 *coefficient of friction, n—in tribology*, the dimensionless ratio of the friction force (F) between two bodies to the normal force (N) pressing these bodies together. **G40**

3.1.2 *fretting*—small amplitude oscillatory motion, usually tangential between two solid surfaces in contact. **G40**

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *friction envelope*—when making friction energy loss measurements, the graphic representation of the cyclic friction force versus time history of a tribosystem in which the boundaries surrounding these variations in time produces a shape with a measurable area.

3.2.2 *reciprocating tribosystem*—sliding system where the direction of motion of the moving member periodically reverses (for example, piston in a cylinder).

3.3 *Acronyms:*

3.3.1 *DAS, n*—data acquisition system.

3.3.2 *FED, n*—friction energy dissipated. The work required to overcome the resistance to motion encountered in sliding one solid on another expressed in energy units (joules).

3.3.3 *RFED, n*—relative friction energy dissipated. The work required to overcome the resistance to motion encountered in sliding one solid on another solid expressed in arbitrary units for comparison studies on candidate tribocouples.

4. Summary of Guide

4.1 Frictional effects can be a concern in many tribosystems so it is common to monitor friction force in laboratory tests and even field evaluations of machines. There are many ways of

[1] This guide is under the jurisdiction of ASTM Committee G02 on Wear and Erosion and is the direct responsibility of Subcommittee G02.50 on Friction.

Current edition approved Nov. 1, 2020. Published November 2020. Originally approved in 2010. Last previous edition approved in 2016 as G203 – 10 (2016). DOI:10.1520/G0203-10R20.

[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.

reporting the recorded friction forces: friction force (see Guide G115), average friction force for a test, average coefficient of friction, static and kinetic coefficient of friction, coefficient of friction at periodic time intervals, etc. This guide presents a methodology to convert friction forces monitored throughout a test cycle into a test metric called *friction energy dissipated* (FED). For within-lab tests the metric is *relative friction energy dissipated* (RFED). Both of these terms represent an integration of the area within the force/tangential displacement output of the force measurement system.

4.2 The FED parameter will have energy units; the RFED parameter can have arbitrary units because it is used to compare various candidates in the same test in the same laboratory using the same test equipment.

5. Significance and Use

5.1 Many sliding systems exhibit intermittent high friction force excursions compared to competing tribosystems. However, where friction forces or friction coefficients are averaged, the test data may show that the two systems have the same friction characteristics, when in fact they were not the same; there was a friction "problem" in the one with the periodic aberrations. The FED takes into account all friction forces that occur in the test increment. It is all of the friction energy that the couple dissipated in the designated test duration. It captures the friction profile of a system in a single number that can be used to screen candidate couples for friction characteristics.

5.2 If the friction energy used in a reciprocating tribosystem is of concern this metric along with the friction recording, average coefficient of friction, and standard deviation of the force readings, produces the most meaningful data. It is a metric of the energy loss in a tribosystem.

6. Apparatus

6.1 This guide can be used with any reciprocating wear test or device that is instrumented to produce a friction force recording for the entire test interval with a force recording at intervals that allow characterization of each reciprocating (forward and back) cycle. A chart recorder produces adaptable force information and any data logging system that allows integration of the area of a force/distance recording for a test can be used (see Guide G163). Fig. 1[4] is an example of suitable experimental data from a single back and forth cycle. The figure shows force as the vertical axis and sliding distance as the horizontal axis in a fretting test. Fig. 2 is the force/distance recording from Test Method G133 sphere-on-flat test modified to produce four hours of rubbing using Option B (see 8.1.2). The ability to record friction forces depends on the sampling rate of the DAS. Thus, when using friction energy dissipation as a test metric, all tests used in ranking tribosystems should use the same force measurement system, force sampling rate, DAS and energy analysis technique.

[4] Mohrbacher, H., et al, "The Influence of Humidity on the Behavior of PVD TiN Coatings," *Wear*, Vol 180, 1995, pp. 43-52.

7. Test Specimen Configuration

7.1 This friction assessment methodology has been used on reciprocating sphere-on-flat, block-on-ring, and flat-on-flat specimens.

8. Procedure

8.1 Two options are described, depending on the type of friction-measuring and recording system available for use. In Option A, discrete friction loop capture, the features of individual cycles are recorded by a high-speed DAS (for example, see Fig. 1). In Option B, details of individual cycles are not clearly observable, but rather, the general trend of the cyclic friction force variation, called a friction envelope, is obtained.

8.1.1 *Option A, Cumulative Friction Loop Method*—The DAS shall have sufficiently high recording rate and friction force resolution to enable the details of friction versus time plots for individual forward and back cycles, called friction loops, to be captured. It is the responsibility of the user to ensure the proper calibration of the force and displacement sensors. The area enclosed by each loop, in force-time space, is a measure of the frictional energy dissipated during that loop. Cumulative summation of the areas of all loops generated during a given test represents the total FED. A variation of the friction loop method is when time, rather than displacement is measured during reciprocating motion. An example is shown in Fig. 2. In that case, the time axis is converted to sliding distance, using the known velocity characteristics of the tribosystem, and the areas enclosed by the friction force trace and the horizontal axis are summed to provide the FED.

8.1.2 *Option B, Friction Envelope Method*—This method provides a relative measure of the frictional energy dissipated and is useful for within-laboratory comparisons. It can utilize lower speed DAS or chart recorders where the details of individual loops cannot be resolved. In that case, the shape produced by the friction force versus sliding distance or time record is enclosed and measured (see Fig. 3). These enclosing shapes can be called friction envelopes. If the velocity characteristics of the tribosystem do not change during the test, then the time can be used as one axis of the friction envelope plot. Comparing the areas enclosed by friction envelopes, plotted using the same axes scales, provides a measure of the RFED.

NOTE 1—*Option A versus Option B*—Fig. 4 represents the friction envelope produced by enclosing the detailed friction force versus elapsed time trace shown in Fig. 2. It is clear that by enclosing the plot, the frictional energy of the spaces between loops included in the tally. Therefore, the use of Option B should not be assumed to provide an accurate measure of the frictional energy dissipated by individual reciprocating cycles, but rather it can be used as a convenient way of comparing the frictional behavior of various material combinations under similar test conditions.

9. Report

9.1 Information on the FED may be included as a supplement to the report that describes the testing parameters, specimen preparation, cleaning methods, materials, and other aspects associated with selected friction test method to which these data apply. Examples of supplementary information on FED, reported in the form of Option B, are given in Fig. 5.

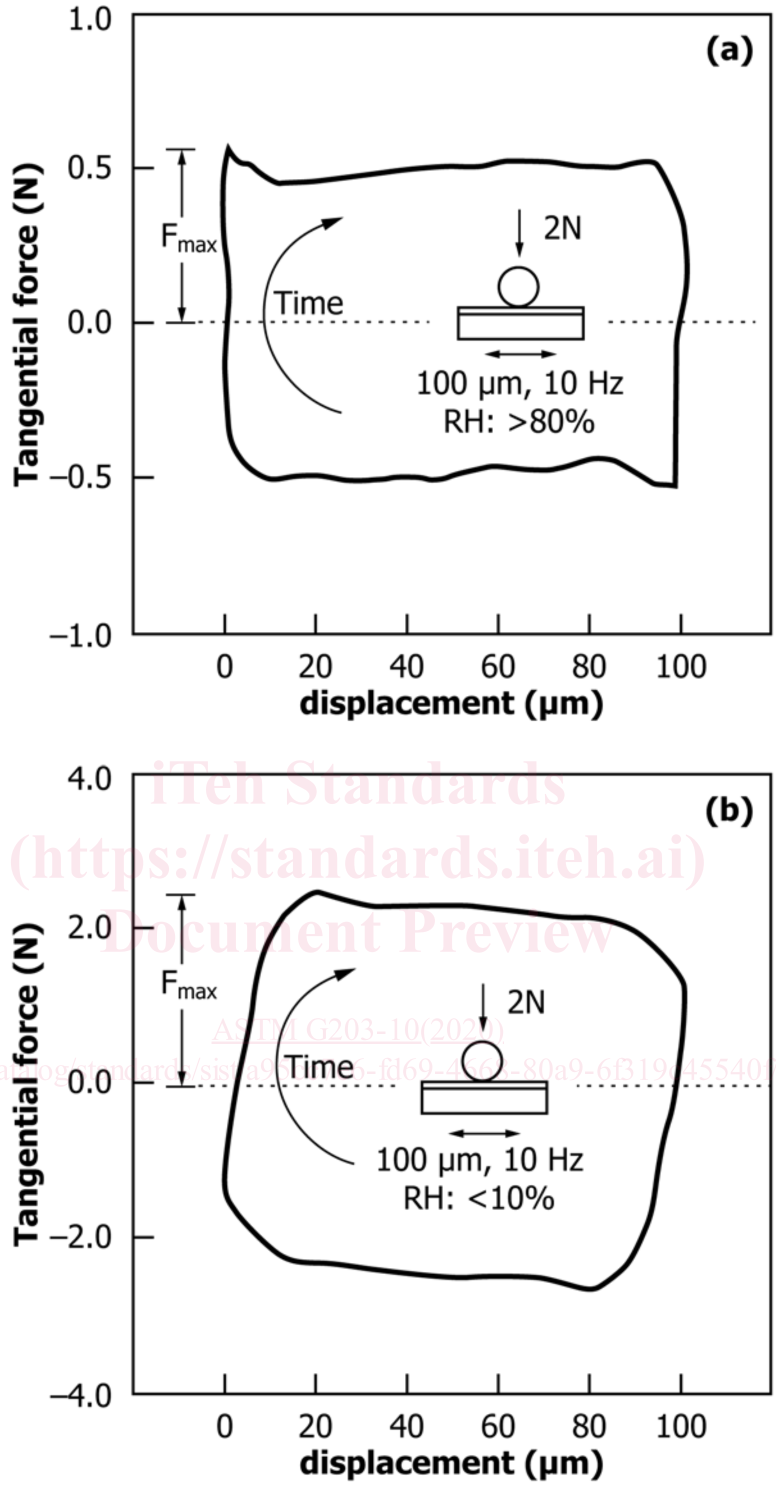


FIG. 1 Tangential Force-Displacement Hysteresis Loops between Measured during Fretting between TiN (Sample B) and Corundum in (a) Moist (RH > 10 %) Air

10. Keywords

10.1 friction; friction coefficient; friction energy

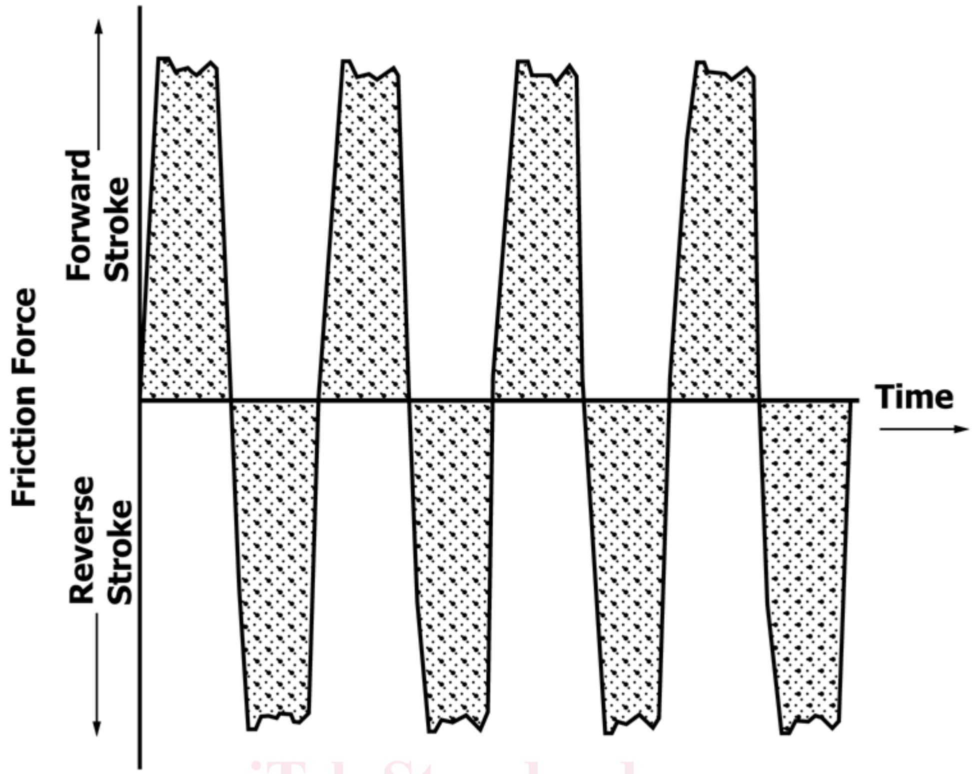
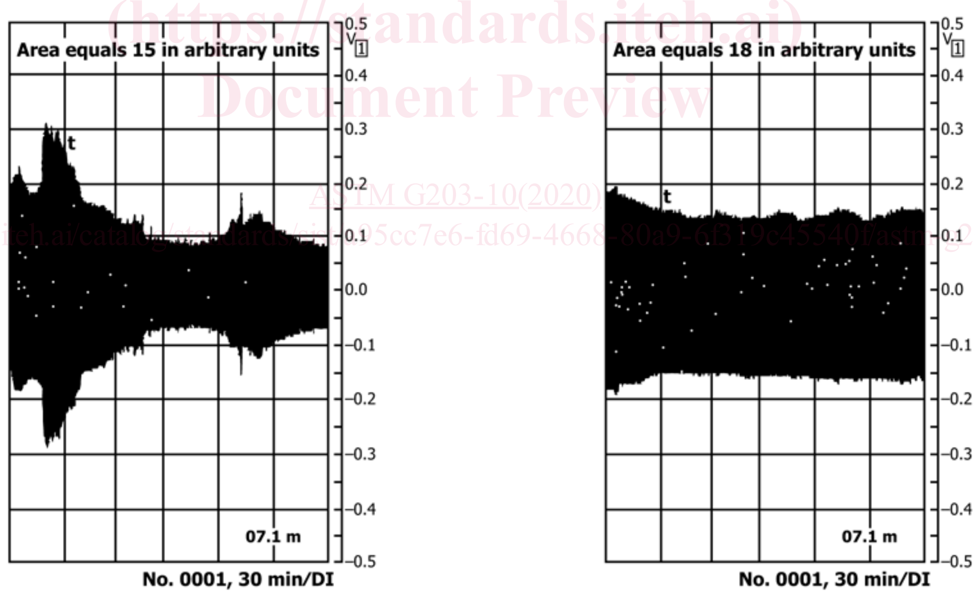


FIG. 2 Areas Under the Traces of Individual Strokes



NOTE 1—Area can be measured by counting squares, inputting the shapes into a CAD analysis program, etc.

FIG. 3 Strip Chart Recordings from Test Method G133 Used in RFED Determination

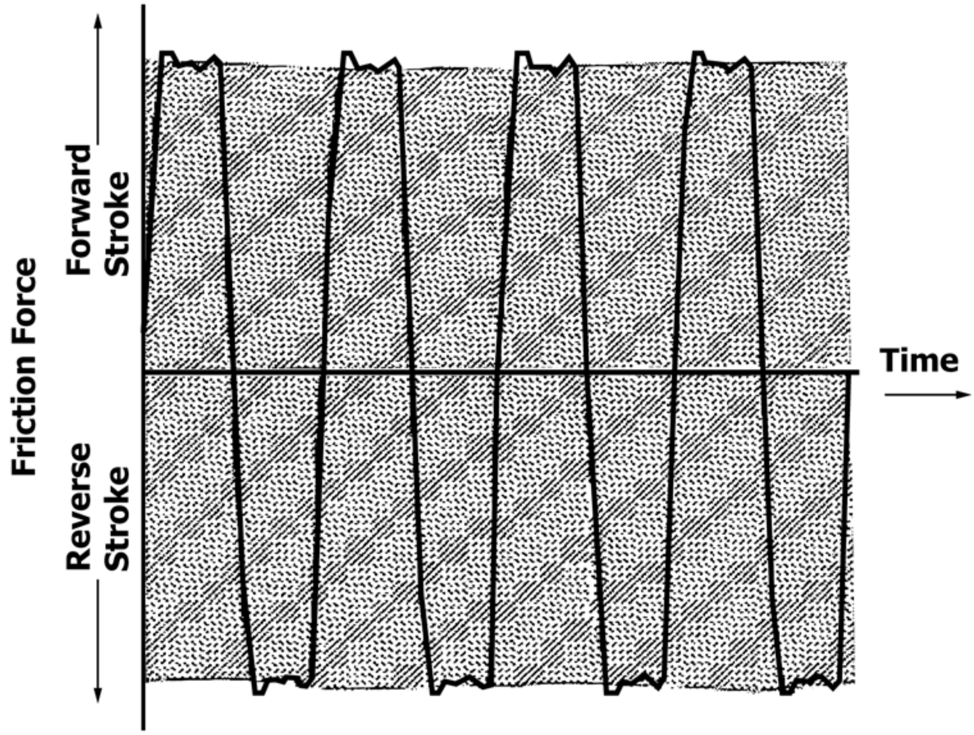


FIG. 4 Area Enclosed by the Total Friction Envelope