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Standard Guide for Determination of Static Coefficient of Friction of Test Couples Using an Inclined Plane Testing Device[1]

This standard is issued under the fixed designation G219; 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 is intended to standardize the use of an inclined plane testing device to measure the breakaway friction (static) coefficient of mating couples that are of such size and shape that they can be made into a rider (one member of the sliding couple) on a flat surface (the second member of the sliding couple) that can be inclined at an angle to produce motion of the rider. The tangent of the angle at which breakaway motion of the rider occurs on the angled plane is the breakaway or static coefficient of friction for that sliding couple.

1.2 *Units*—The values stated in SI units are to be regarded as the standard. No other units of measurement are included in this 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, health, and environmental practices and determine the applicability of regulatory limitations prior to use.*

1.4 *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

3. Terminology

3.1 *Definitions:*

3.1.1 *friction force, n*—resisting force tangential to the interface between two bodies, when under action of an external force, one body moves or tends to move relative to the other.

3.1.2 *static coefficient of friction, n*—coefficient of friction corresponding to the maximum friction force that shall be overcome to initiate macroscopic motion between two bodies.

3.1.2.1 *Discussion*—Breakaway friction coefficient is synonymous with static coefficient of friction.

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *inclined plane device, n*—mechanism with a flat horizontal surface to be made of or covered with a material of interest on which a second member made of a material of interest can be placed and the mechanism is then actuated such that the horizontal plane is increasingly angled with respect to its original horizontal position until motion is produced on the member placed on the raising plane.

3.2.1.1 *Discussion*—The device allows for the continuous measurement of the angle of inclination and the angle at which motion of the rider commences.

3.2.2 *rider, n*—body to be placed on the inclined plane.

4. Summary of Guide

4.1 The technique of placing an object on a flat and horizontal "plane" such as a piece of sheet metal and raising one end of the sheet until the body placed on the sheet starts to slide has been used for centuries to compare the ease with which different objects or materials slide on each other. Quantitative comparison of various couples can be made by measuring the angle at which the body placed on the plane starts to slide. The angle at which motion commences is the test metric. The test couple is the plane surface and the surface that contacts the plane. For example, if a shoe is placed on a flooring sample on the inclined plane, the test couple is the shoe sole versus the type of flooring. Different shoe bottoms can be compared for their ability to slip on particular flooring. The materials of construction as well as the nature of the contacting surfaces determine the breakaway angle. When ranking, for example, different shoe soles on particular flooring, the shoes are weighted so that they are all the same weight when compared for ease of sliding on the flooring of interest.

[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.

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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.

4.2 The tangent of the breakaway angle becomes the final test metric. This converts the breakaway angle to a dimensionless number: the static coefficient of friction.

5. Significance and Use

5.1 Guide G115 lists a number of ASTM International standards that use the inclined plane test rig to measure the static coefficient of specific tribosystems. This guide applies to any couple that can be made into test specimens that can be made into a rider on a plane that can be angled to produce motion of the body on the plane. Footwear on walkway surfaces is an example of a very important application. Flooring surfaces that are slippery to various types of footwear can produce accidents and testing should be done on candidate flooring surfaces and candidate shoe soles and heels to quantify their relative slip resistance. This guide shows how an inclined plane can be used to make such a comparison.

5.2 The inclined plane method is also very useful in machine design in which parts of components shall slide unassisted down chutes and the like. An inclined plane test can be used to determine the chute angle that is needed to allow motion on all parts that are placed on the chute. The applications are numerous.

6. Apparatus

6.1 Appendix X1 shows a typical inclined plane device being used to compare shoe soles on prefinished oak flooring (see Fig. X1.1).

6.2 Any apparatus can be used for this test if it can progressively tilt the plane to produce motion of the rider. The device in Fig. X1.1 is an electronic protractor that automatically measures the angle of one leg of the protractor.

6.3 The simplest mechanism for performing this test is to use a hinge as the pivot for the raising plane and a protractor can be used to measure that angle that the hinged plane makes with the horizontal inclined plane surface.

6.4 The plane to be inclined could be elevated with a servo motor and a rotary encoder could monitor the angle with the horizontal. Whatever the mechanism, the required features shall be:

6.4.1 A flat plane large enough to hold the rider of interest with free space all around;

6.4.2 A way to put a surface of interest on the flat plane;

6.4.3 A mechanism to raise the plane progressively on an angle of inclination with the horizontal;

6.4.4 A way to measure the angle of inclination of the plane continuously; and

6.4.5 A way to apply weights to riders when necessary, for example, in the shoe study shown in Fig. X1.1, the shoes were made by different manufacturers and were of different styles so they had different weights. When they were friction tested against the same counterface, weights were added to the shoes so that they had the same mass. In this way, weight differences were eliminated as factors in measuring friction versus counterface differences.

6.5 If a specific environment is part of a study (wet, controlled humidity, with particles, etc.), a means will be necessary to guarantee the same testing environment for each friction test.

7. Sample Preparation

7.1 Test specimens can be any shape that fit the test rig requirements, but most inclined plane test rigs consist of a flat rectangle as the plane that will be angled to initiate motion and the other member is an object/surface of interest: a shoe bottom, a plastic part, a package, a part, a donut, a loaf of bread, and so forth.

7.2 The plane should have the surface features of interest (coating, topography, surface finish, machine lay, and so forth) of the material of interest. The example test rig in Appendix X1 shows a counterface of prefinished oak flooring with a "rider" that is a shoe bottom.

7.3 The contacting surface should be free of all films and dirt that are not part of the study. The contacting surfaces should be in the condition that they will be in the tribosystem of interest. In the shoe/flooring example, the shoes had different tread designs and they were cleaned with a damp microfiber cloth to remove particulates and allowed to dry. The flooring counterface was used as-manufactured.

8. Procedure

8.1 Place the rider on the plane near the edge that will be raised with the desired contact surface on the inclined plane counterface.

8.2 Increase the inclination of the plane from the horizontal at a slow steady rate (from 5 to 10°/s) until motion of the rider commences. If a motor is used to raise the plane, it should not produce vibrations of the sliding contacts.

8.3 Record the incline plane angle at the point of rider breakaway (±1°).

8.4 Repeat 8.1 – 8.3 enough times to produce the desired degree of statistical significance. No less than three replicates should be tested. Fresh specimens should be used for each test if they are available or if that represents the system under study. Otherwise, retests can be done immediately after testing with the same surfaces as long as they are not handled during or after testing. If they are contaminated in any way, they should be recleaned before retesting.

8.5 Take the tangent of the breakaway angles. This number is the metric for each test. It is the static coefficient of friction for that tribosystem.

9. Report

9.1 State the sliding couple, the test conditions, and the static coefficient of friction for each test. Report the average static friction coefficient for the test couple along with the standard deviation. Test conditions are very important in friction testing and should be described in sufficient detail that would allow others to reproduce the test. Test parameters that are commonly needed to be stated are sample geometry, loading, cleaning procedures, temperature, relative humidity,