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ON THE LOAD DEPENDENCE OF THE FRICTION COEFFICIENT

TRACK OR CATEGORY

Tribotesting

AUTHORS AND INSTITUTIONS

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INTRODUCTION

In 2016 The ASTM Committee on Wear and Erosion initiated an effort to develop a test method or guide using the slope of a friction force versus normal force plot from any tribotester as the coefficient of friction for that tribosystem.   By definition the coefficient of friction is the ratio of the friction force and normal force [1]: coefficient of friction (COF) = friction force/normal force.

This relationship dates to the work of Amontons centuries ago [2] and it suggests a direct proportionality of friction force to normal force. Thus, conceptually the slope of a plot as shown in Figure 1 should be the value used as the friction coefficient for a particular tribosystem.

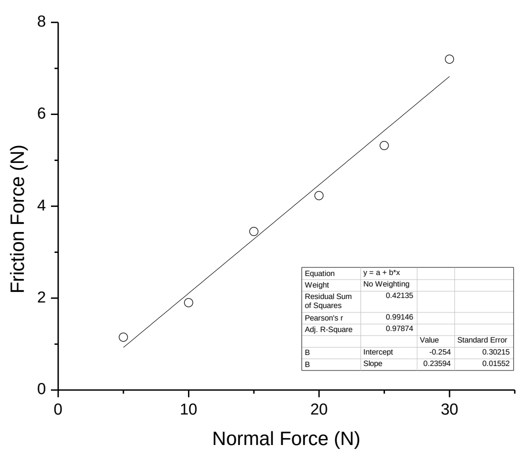

Figure 1 Use of slope methodology to determine COF

However, when the proposed methodology was balloted for approval as a standard, a significant number of issues were identified by those reviewing the standard. One of the most significant issues was identification of the force range that should be used to in testing for the COF of a tribosystem. Examples can be found in the literature of the use of this methodology with force ranges of several orders of magnitude [3]. However industrial data on unlubricated metals where the test force varied over three orders of magnitude indicated that the friction force versus normal force plots were indeed not linear over that range and the COF calculates with the slope methodology did not correlate with COF's determined at the decade force level (1, 10 , 100N). These findings prompted new laboratory testing.

It is the purpose of this paper to discuss work associated with standardization of COF testing using varying normal forces and to present results on laboratory tests aimed at resolving the issue of allowable load range for friction force versus normal force plots. The objective of this work is to establish the feasibility of standardizing the slope methodology for determining friction coefficient. The format of this paper is to review the proposed test standard, to describe tests used to try to resolve the allowable force issue, and finally to draw conclusions on the role of load (force) on the COF of a tribosystem.

Elements of the proposed guide

The rationale for a standard methodology for COF testing was that there are many tests, and many purposes for measuring COF [4], but varying the force in a standard way may produce the most representative results. Undoubtedly force (load) variations exist in all real tribosystems. It is unrealistic to perform a COF test at a single force and deem that this single force is typical for the system. All forces have some variability. Using the slope methodology should address possible force variations.

All ASTM standards contain required elements such as: test material, test specimen configuration, test procedure, reporting results, etc. One of the first requirements in a standard is "scope". The scope of the proposed slope methodology guide was:

> This guide specifies how to use friction force measurements in a tribosystem to develop a coefficient of friction for a sliding couple in a particular tribosystem. It requires the use of various normal forces in testing as opposed to a single normal force. This guide applies to all mating couples and to test rigs or devices that allow variation of the force used to press the sliding members against each other under sliding conditions,

The procedure stated:

> Plot the friction force (Ff) required at various normal forces (Fn)and apply a mathematical treatment (least squares etc.) to develop a straight line plot of Ff versus Fn and use the slope of the resultant line to be the coefficient of friction of that sliding couple in that tribosystem.

In order for an ASTM test or guide to be approved it needs a certain percentage of affirmative ballots in committee and society balloting. If a member votes negative on a proposal, the issue must be resolved for the initiative to proceed further. This proposed guide received a number of negative votes including: the allowable range of normal force variation must be specified. This negative could not be resolved from information in the literature so it was decided to perform lab tests to answer the allowable-force question.

LABORATORY TESTS

Coefficients of friction were conducted on three test rigs: inclined plane (ASTM G 115)[5], sled (ASTM D 1894 [6], and pin-on-disk ASTM G 99[7]. The test couple for the first two tests was: prefinished oak flooring (50 x 380 mm test surface) for the counterface and a chromium-plated flat (6 x 60 x 60 mm) rider. The test couple for the pin-on-disk test was hard 52100 steel ball rider (60 HRC, 4mm diameter,) versus a 1020 steel disk (20 mm diameter. 0.005 m/s) with a ground surface. Test forces varied from 0.5 to 5N

TEST RESULTS

The sled and inclined plane test produced linear plots and the slope method could be used to determine the COF. However, their COF's varied: 0.18 for the incline plane test and 0.21 for the sled test. The pin-on-disk test produced a result that was linear except for the highest testing force. It appeared to lie on another slope line.

DISCUSSION

The different COF's in the sled and inclined plane test were anticipated. Different COF results for the same couple on different test rigs have been observed by others [7]. Fiction is a system output and these were two significantly different tribosystems. The slope discontinuity in the pin-on disk results was explained by optical microscope examination of the sliding tracks and contacts on the balls and disks. The 1020 steel started to plastically deform at forces above two N and at 5 N, the rider was wearing the counterface; a "new" tribosystem was produced.

CONCLUSIONS

1. The slope methodology applies to COF determination as long as the tribosystem does not significantly change in nature in the measuring process.
2. System wear can create a different tribosytem from one that is not wearing.
3. Different test rigs can produce different COF's for the same couple under the same testing conditions.
4. Varying the normal force in testing by more than a factor of 10 is likely to change the tribosystem

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KEYWORDS
friction, coefficient of friction, friction testing