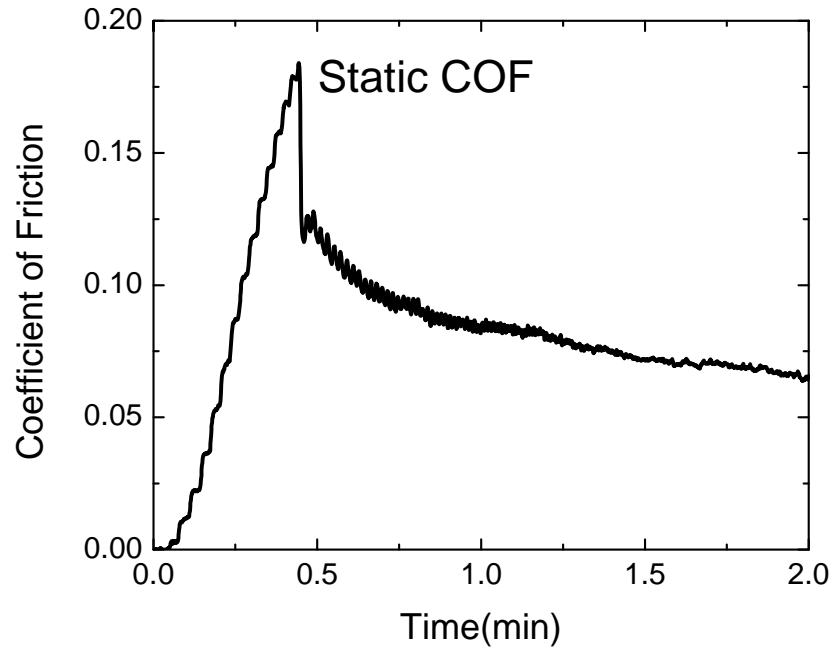


**STATIC COEFFICIENT OF FRICTION MEASUREMENT
USING TRIBOMETER**



Prepared by
Duanjie Li, PhD

INTRO

The measurement of friction force and the calculation of the coefficient of friction, COF, are critical for many industrial applications, e.g. brakes, valves, clutches, and similar power- and motion-control mechanisms. High friction during machine operation not only generates frictional heating that might cause failure of a machine part, but also consume a large amount of energy. It is estimated that one-third to one-half of the world's energy production is wasted through friction [1].

The static COF is defined as the "COF corresponding to the maximum force that must be overcome to initiate macroscopic motion between two bodies." [2] To simulate different application conditions, a variety of ASTM compliant experimental setups have been developed to evaluate the static COF, such as ASTM D 1894, D 2047 and D 3247, etc. However, a reliable measurement of static COF remains challenging due to the influence of numerous factors, such as reactions between surfaces, interlocking surface features, or other more subtle phenomena such as van der Waals forces, cohesion of surface films, and even microscopic solid static junctions between surfaces.

MEASUREMENT OBJECTIVE

In this study, we would like to showcase the capacity of Nanovea Tribometer for measuring the static COF. The COF of an aluminum block against Glass and Teflon samples was measured and analyzed as examples.

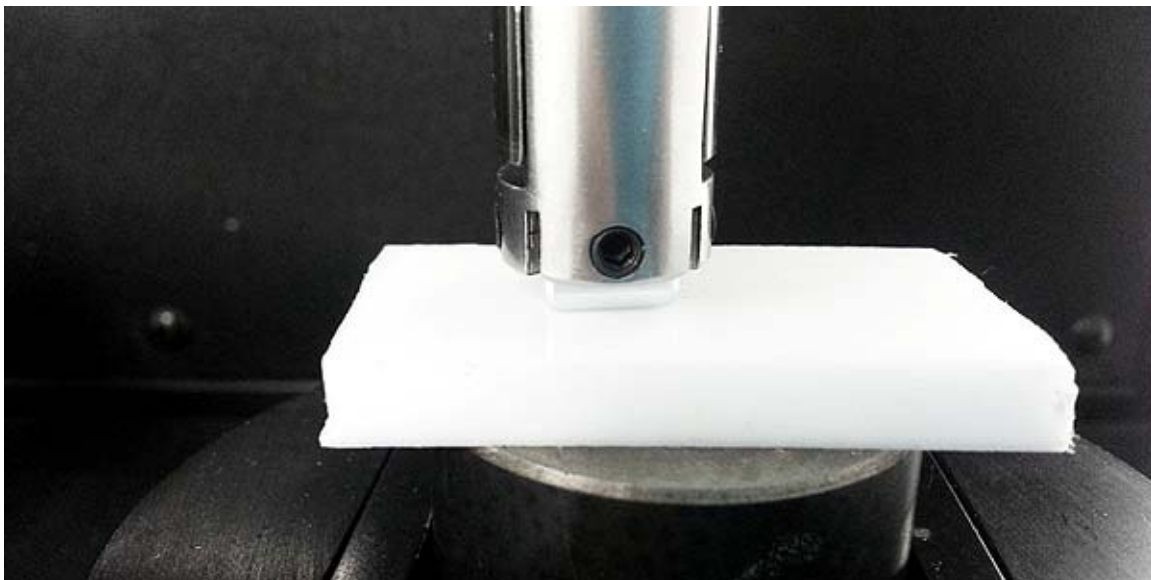


Fig. 1: Pin-on-disc test setup for static COF evaluation.

MEASUREMENT PRINCIPLE

TRIBOMETER PRINCIPLE

The sample is mounted on a rotating stage, while a known force is applied on a pin, or ball, in contact with the sample surface to create the wear. The pin-on-disk test is generally used as a comparative test to study the tribological properties of the materials. The coefficient of friction, COF, is recorded in situ. The volume lost allows calculating the wear rate of the material. Since the action performed on all samples is identical, the wear rate can be used as a quantitative comparative value for wear resistance.

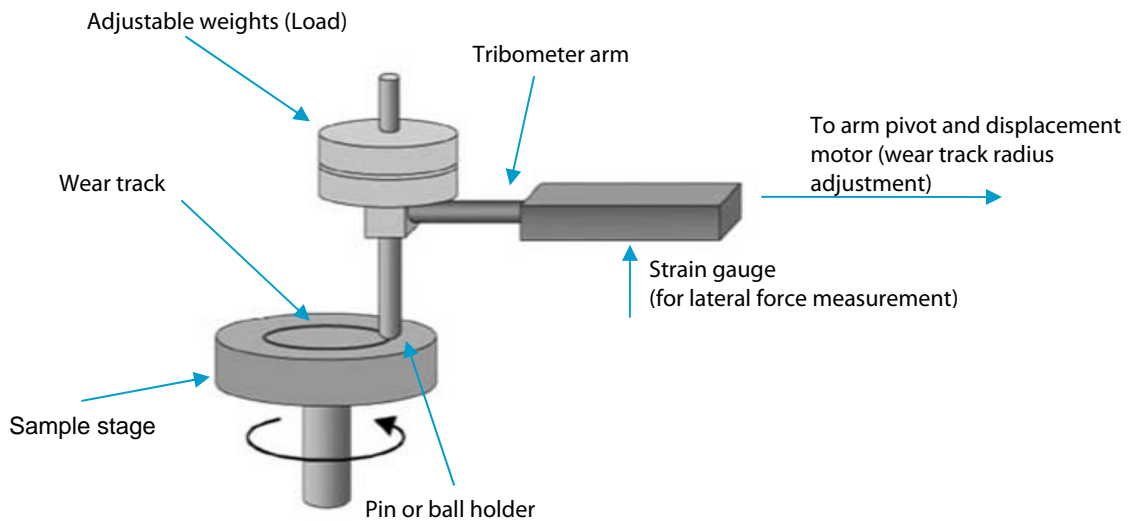


Fig. 2: Schematic of the pin-on-disk test.

TEST PROCEDURE

The coefficient of friction, COF, of an aluminum block on Glass and Teflon surfaces was evaluated by Nanovea Tribometer. The speed increased at an exponential rate in a step-less fashion from 0.001 to 0.6 rpm (see Fig. 3), in order to maintain extremely low speeds for static COF measurement at the beginning of the test while finishing the total experiment in a reasonably short time. These two rotational speed values correspond with the 10 mm radius to sliding speeds of 1.05×10^{-6} m/s and 6.3×10^{-4} m/s, respectively. The COF was recorded in situ with a time interval of 0.1 s. The test parameters are summarized in Table 1.

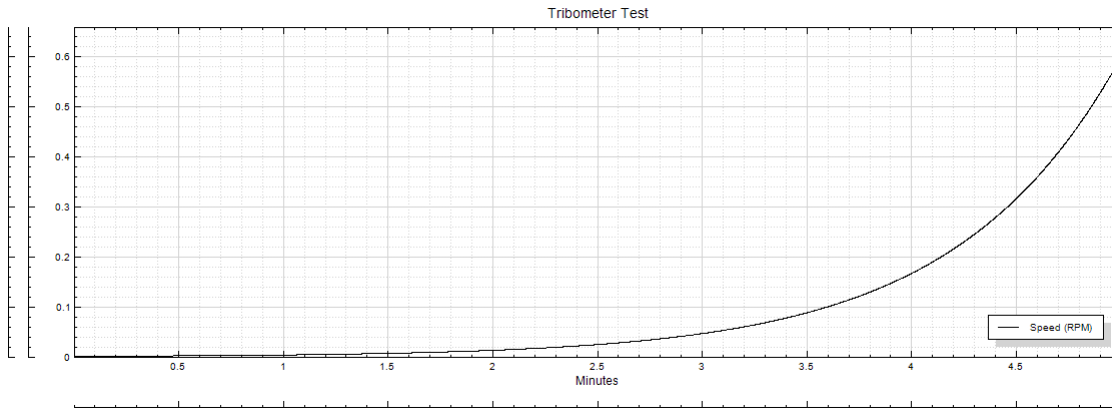


Fig. 3: Rotational speed as a function of time.

Sample	Glass	Teflon
Normal force	50 N	5 N
Speed	0.001 to 0.6 rpm continuous, changed at an exponential rate	0.001 to 0.6 rpm continuous, changed at an exponential rate
Duration of test	5 min	5 min

Table 1: Test parameters of the COF measurement.

RESULTS AND DISCUSSION

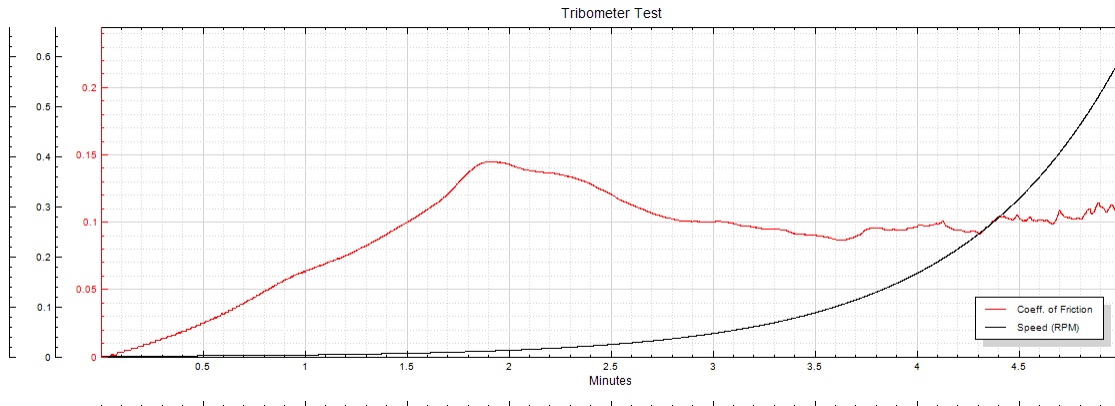
The evolution of COFs of Al block against Glass and Teflon samples are shown in Fig. 4, and the static and average dynamic COFs are summarized and compared in Table 2. The precise control of the motor at extremely low speed starting at 0.001 rpm allows us to observe a progressive friction force buildup at the beginning of the tests for both the Glass and Teflon samples.

When this friction reaches a certain threshold, the relative motion at the interface of the tested sample and the Al block takes place, and the subsequent measured COF decreases. This internal spike of the force at the beginning of the COF test arise from the static friction, which is defined as the "COF corresponding to the maximum force that must be overcome to initiate macroscopic motion between two bodies." It may result from several sources, such as reactions between surfaces, interlocking surface features, or other more subtle phenomena such as van der Waals forces, cohesion of surface films, and even microscopic solid static junctions between surfaces. Due to the complication of the above factors, variations of the measured static COF are observed in this study. Several precautions should be taken to ensure a repeatable measurement [2-4]:

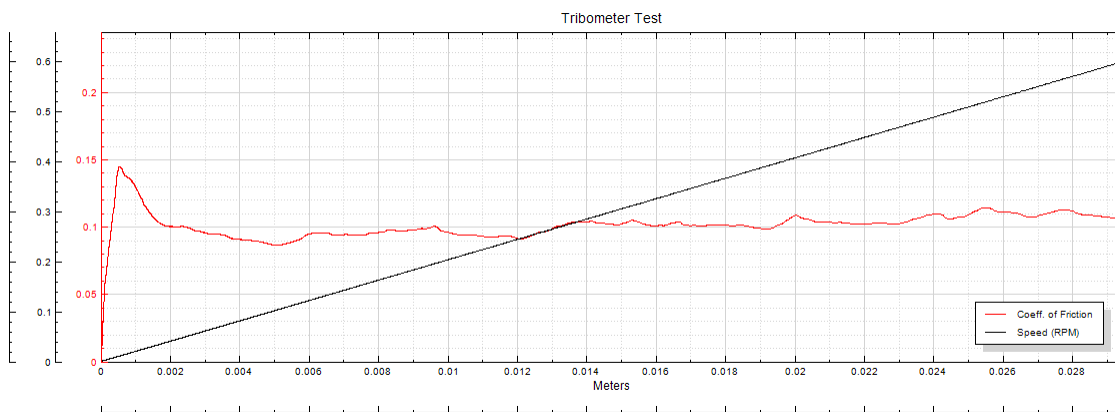
- 1) Surface Finish is critical — the surface roughness has a significant impact on the COF measurement, including directional machine marks, inhomogeneous asperities, etc.
- 2) Properly clean and dry the specimens immediately prior to testing.
- 3) Carefully adhere to the specified procedure by the instrument operator.
- 4) Ensure that the tested sample surface is horizontal.
- 5) Sliding velocity and normal force may affect the frictional characteristics of many material couples. To verify systems for sensitivity to these factors is recommended.

Following the static COF measurement, the evolution of the dynamic COF is measured after the macroscopic relative motion between the Al block and tested sample surface takes place.

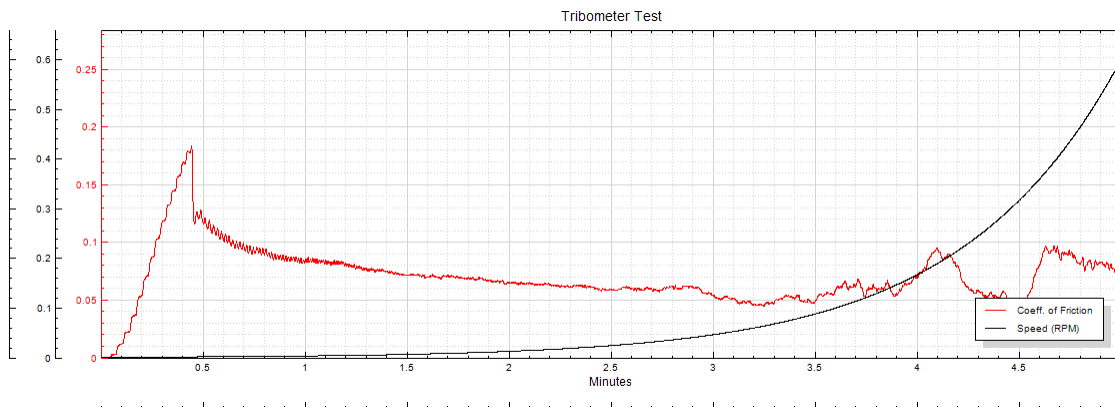
(a) COF vs. Time for Glass sample:



(b) COF vs. Distance for Glass sample:



(c) COF vs. Time for Teflon sample:



(d) COF vs. Distance for Teflon sample:

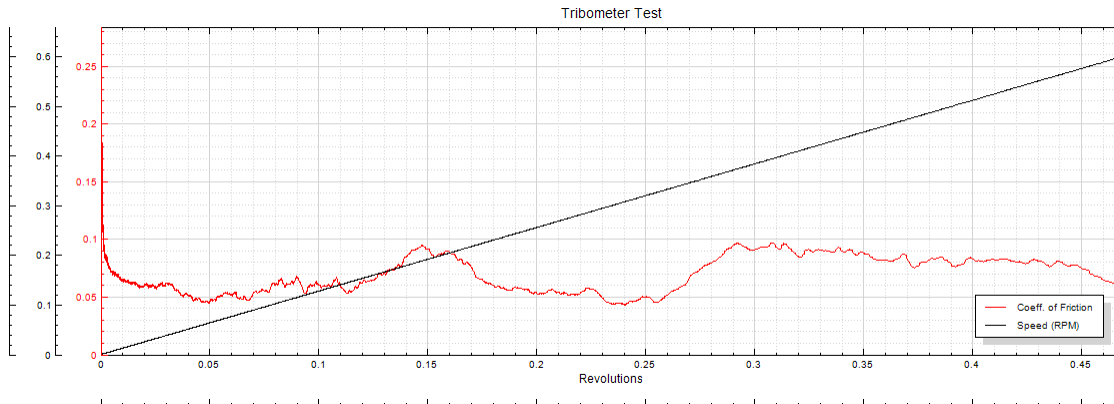


Fig. 4: Evolution of COF and Rotational speed of Al block on Glass and Teflon samples.

Sample	Static COF	Dynamic COF
Glass	0.145	0.097
Teflon	0.182	0.064

Table 2: Static and dynamic COFs of Al block against Glass and Teflon.

CONCLUSION

In this study, we show that Nanovea Tribometer measures the static coefficient of friction of different material couples in a controlled and monitored manner, due to its high-precision speed control motor that is capable of moving the rotational stage at extremely low speeds down to 0.001 rpm. This static friction measurement allows users to improve fundamental understanding of the static friction mechanism of the materials and select the best material couple for intended tribological applications.

Nanovea Tribometer offers precise and repeatable wear and friction testing using ISO and ASTM compliant rotative and linear modes, with optional high temperature wear, lubrication and tribo-corrosion modules available in one pre-integrated system. Nanovea's unmatched range is an ideal solution for determining the full range of tribological properties of thin or thick, soft or hard coatings, films and substrates.

Learn More about the [Nanovea Tribometer](#) and [Lab Service](#)

REFERENCES

1. Szeri, A.Z. Tribology: Friction, Lubrication and Wear. Hemisphere Publishing.
2. Mang, T., K. Bobzin, and T. Bartels, *Industrial tribology : tribosystems, friction, wear and surface engineering, lubrication*. 2011, Weinheim: Wiley-VCH. xxvii, 644 p.
3. Malhotra, R.C. and J.P. Sharma, *Proceedings of the first World Conference in Industrial Tribology, New Delhi, 1972*. 1973, s.l.: s.n. ca. 1050 p.
4. *Standard Test Method for Linearly Reciprocating Ball on Flat Sliding Wear*, in *ASTM G 133*.