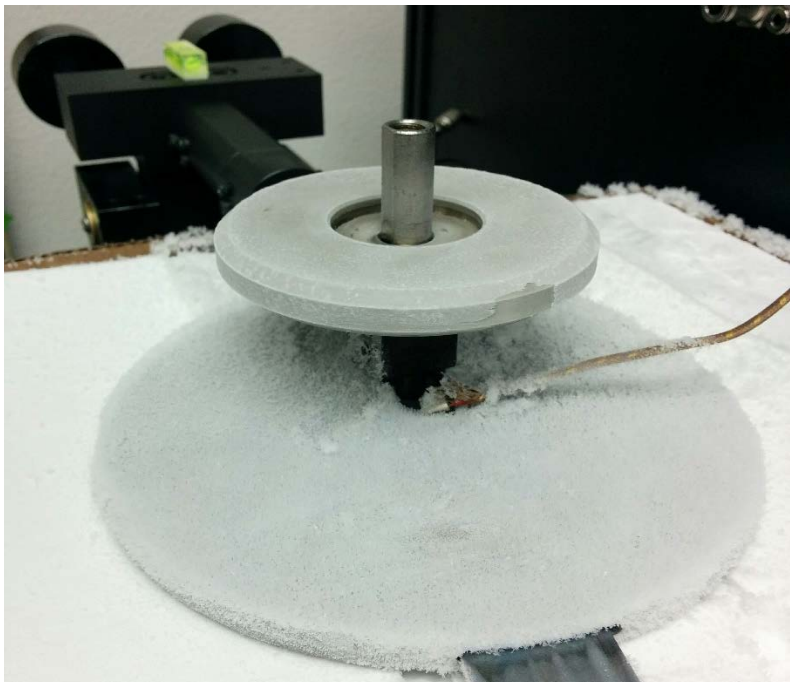
LOW TEMPERATURE TRIBOLOGY OF RUBBER USING TRIBOMETER



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INTRO

Low temperature plays a critical role in the tribomechanical and thermodynamic properties of materials, such as slipping behaviors, resistance to wear or abrasion, and others. For example, viscosity of the crankcase oil in the diesel engine changes during the winter season, which can influence the cold-start abilities of the engines at sub-zero temperatures. The road condition is dramatically different in freezing winter. The cold, rainy and snowy weather creates slippery patch of snow, ice and slush on the road. The significantly reduced traction requires much long distance for a complete stop of the car, making it frightening and dangerous for automobile travel. In addition, summer tires suffer from "glass transition" at low temperatures, as the rubber becomes rock-hard and can provide little traction.

Therefore, a reliable measurement of static and dynamic coefficient of friction, COF, as well as wear behavior at low temperatures is in need in order to better understand the tribological performance of materials for sub-zero temperature applications. It provides a useful tool to correlate the frictional property with the influence of various factors, such as reactions at the interface, interlocking surface features, cohesion of surface films, and even microscopic solid static junctions between surfaces at low temperatures.

MEASUREMENT OBJECTIVE

In this study, we showcase the capacity of Nanovea Tribometer for measuring the static and dynamic COF of a rubber ball against the ice surface at different temperatures from 0 to -50 °C, which makes it an ideal tool for evaluating the material couples for tribological applications at low temperatures.

Fig. 1: Friction measurement of a rubber ball sliding on the ice surface.

TEST PROCEDURE

The rubber ball and ice cup (as shown in Fig. 1) were enclosed in a heat insulated chamber and cooled down to low temperatures from -50 °C to 0 °C. The coefficient of friction, COF, of a rubber ball (6mm in diameter) sliding on ice surface at different temperatures below the ice point was evaluated by Nanovea Tribometer. The speed increased at an exponential rate in a step-less fashion from 0.01 to 10 rpm (see Fig. 2), in order to maintain extremely low speeds for static COF measurement at the beginning of the test while finishing the total experiment in a short time. These two rotational speed values correspond with the 25 mm radius to sliding speeds of 2.625 x 10^{-5} m/s and 2.625 x 10^{-2} 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.

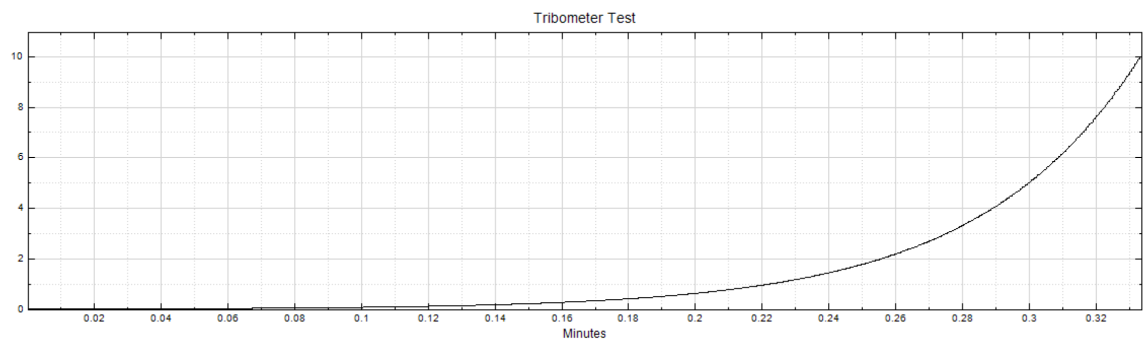

Fig. 2: Rotational speed as a function of time.

Parameter	Value
Temperature	-50, -40, -30, -20, -10, 0 °C
Normal force	2 N
Speed	0.01 to 10 rpm continuous, changed at an exponential rate
Duration of test	0.33 min

Table 1: Test parameters of the COF measurement.

RESULTS AND DISCUSSION

The evolution of COFs of a rubber ball against the ice at different temperatures are shown in Fig. 3, and the static and average dynamic COFs are summerized and compared in Fig. 4. The precise control of the motor at a low speed starting at 0.01 rpm allows us to observe a progressive friction force buildup at the beginning of the tests.

When this friction reaches a certain threshold, the relative motion at the interface of the rubber ball and the ice surface takes place, and the subsequent measured COF decreases. This internal spike of the force at the beginning of the COF test arises from the static friction. 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. Following the static COF measurement, the evolution of the dynamic COF is measured after the macroscopic relative motion between rubber ball and ice surface takes place.

It can be observed that the rubber ball has the lowest static and dynamic COF at the ice point of 0 °C. This is due to the formation of a thin water film layer present between the rubber ball and the ice surface at this temperature, which may result from pressure melting, premelting or heat generated from friction at the interface. This liquid film acts as a lubricant at the sliding interface and substantially decreases the friction. This experiment illustrates the risk of driving in a freezing rain. It generates ice pellets of extremely smooth surface and low friction, which is notorious for causing accidents on roadways.

However, the initial static COF progressively increases as the temperature decreases to -30 °C, as a result of freeze of the surface water film. Moreover, higher COF above 0.3 was observed at higher speeds than 1 rpm during the wear test at -10 °C. However, as the temperature further drops below -40 °C, the static and dynamic COFs decreases to values of ~0.8 and ~0.2, respectively, for the test carried out at -40 and – 50 °C. This may be related to the change in mechanical properties of the rubber ball at this temperature, such as "glass transition".

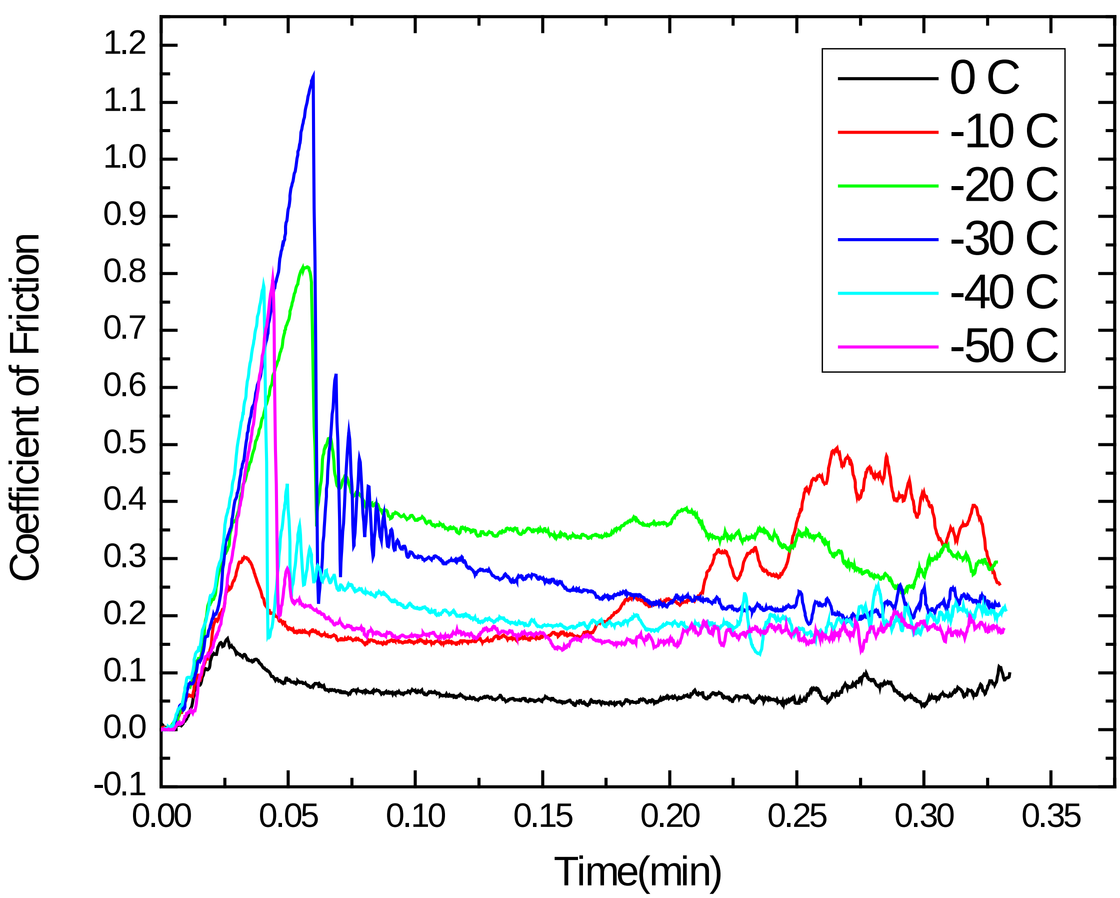

Fig. 3: Evolution of COF of the rubber ball on ice at different temperatures.

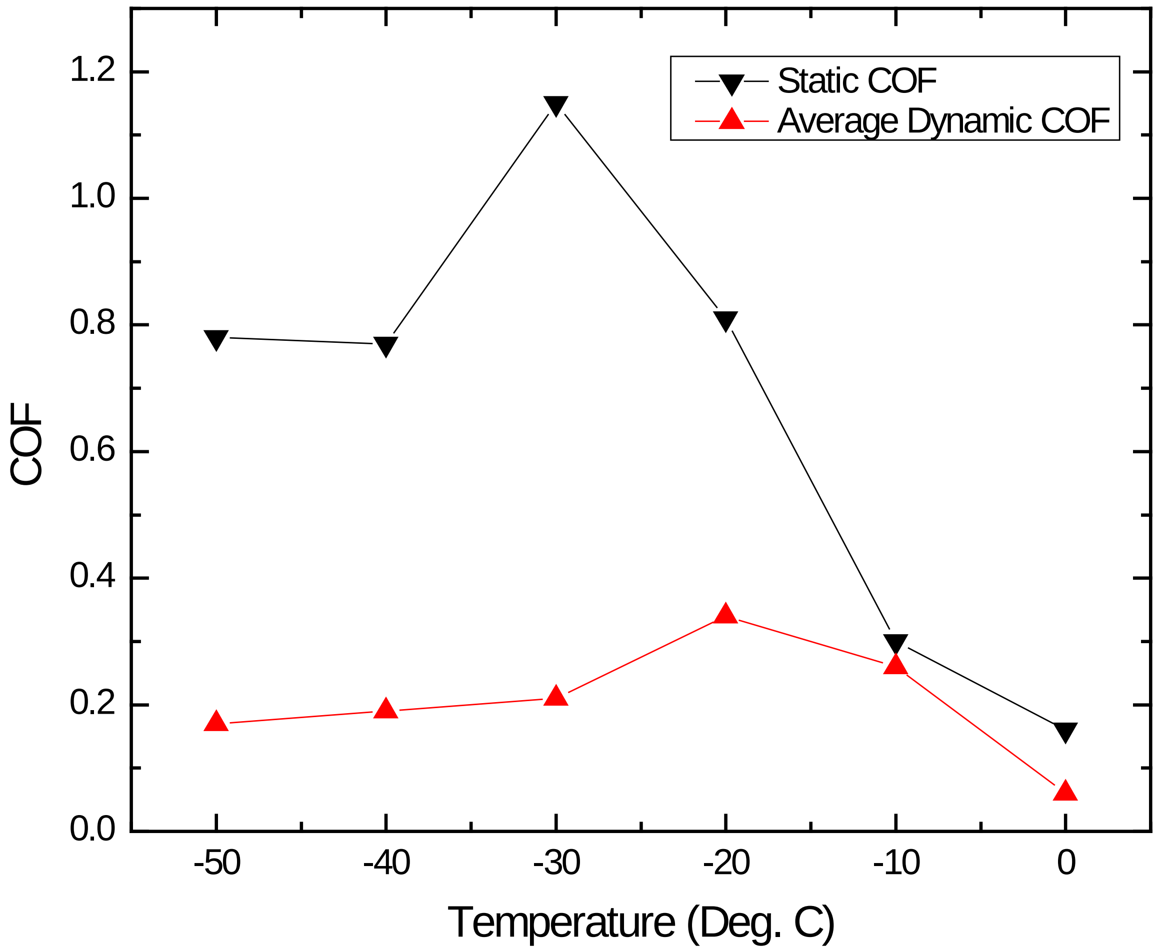

Fig. 4: Static and dynamic COFs of rubber ball on ice at different temperatures.

CONCLUSION

In this study, we show that Nanovea Tribometer measures the static and dynamic coefficient of friction of rubber on ice in a controlled and monitored manner at different temperatures from ice point to -50 °C. COF varies for the rubber/ice sliding couple at different low temperatures. This measurement allows us to better understand the static and dynamic friction mechanism of the materials for low temperature applications 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/low 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

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.

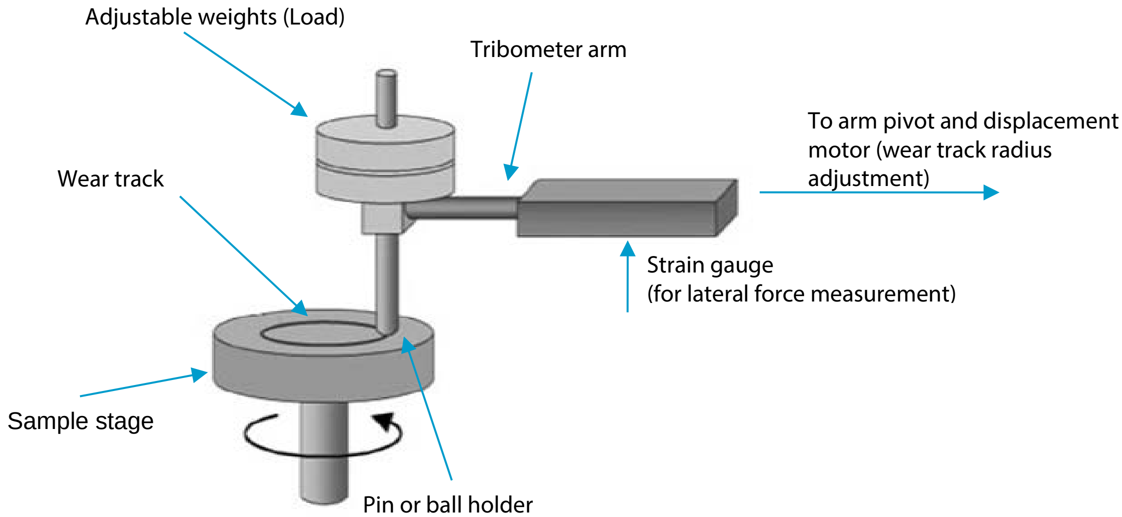

Fig. 5: Schematic of the pin-on-disk test.