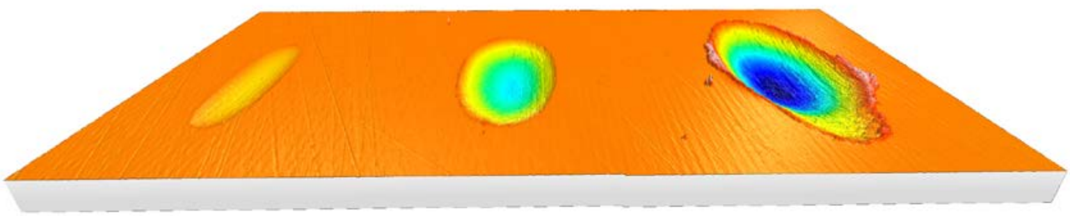
FRETTING WEAR EVALUATION USING TRIBOMETER



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INTRO

Fretting is "A special wear process that occurs at the contact area between two materials under load and subject to minute relative motion by vibration or some other force. [1]" When machines are in operation, vibrations inevitably occur in joints that are bolted or pinned, between components that are not intended to move, and in oscillating couplings and bearings [2]. The amplitude of such relative sliding motion is often in the order from micrometers to millimeters. Such repetitive low-amplitude motion causes serious localized mechanical wear and material transfer at the surface, which may lead to reduced production efficiency, machine performance or even damage to the machine.

IMPORTANCE OF QUANTITATIVE FRETTING WEAR EVALUATION

Fretting wear often involves several complex wear mechanisms taking place at the contact surface, including two-body abrasion, adhesion and/or fretting fatigue wear. In order to understand the fretting wear mechanism and select the best material for fretting wear protection, reliable and quantitative fretting wear evaluation is desirable. The fretting wear behavior is significantly influenced by the work environment, such as displacement amplitude, normal loading, corrosion, temperature, humidity and lubrication. A versatile tribometer that can simulate the different realistic work conditions will be ideal for fretting wear evaluation.

MEASUREMENT OBJECTIVE

In this study, we evaluated the fretting wear behaviors of a stainless steel SS304 sample at different oscillation speeds and temperatures to showcase the capacity of Nanovea Tribometer in simulating the fretting wear process of metal in a well-controlled and monitored manner.

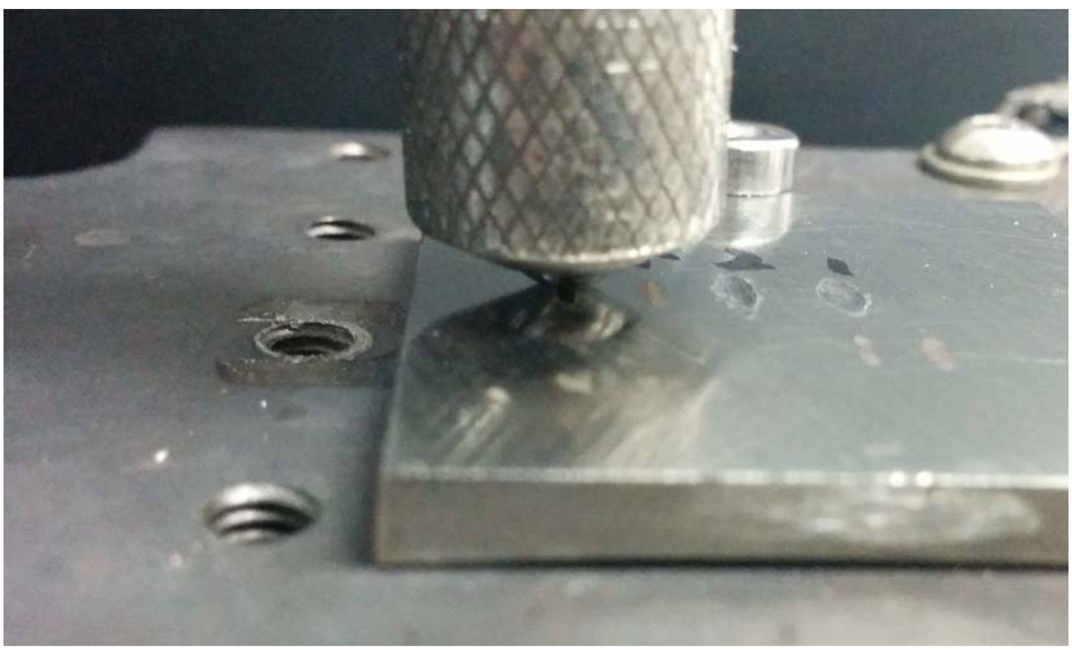


Fig. 1: Fretting wear on a SS304 sample.

TEST PROCEDURE

The fretting wear resistance of a stainless steel SS304 sample was evaluated by Nanovea Tribometer using Linear Reciprocating Wear Module. A WC (6 mm diameter) ball was used as the counter material. The wear track was examined using Nanovea 3D non-contact profilometer. The test parameters are summarized in Table 1. The fretting test was performed at room temperature (RT) and 200 °C to study the effect of high temperature on the fretting wear resistance of the SS304 sample. A heating plate on the sample stage heated up the sample during the fretting test at 200 °C. The wear rate, K, was evaluated using the formula $K=V/(F\times s)$, where V is the worn volume, F is the normal load, s is the sliding distance.

Please note that a WC ball as a counter material was used as an example in this study, any solid material with different shapes and surface finish can be applied using custom fixture to simulate the actual application situation.

Sample description	Polished SS304
Normal force	10 N
Amplitude	2 mm
Speed	100 or 1000 cycles/min
Temperature	Room Temperature (RT) or 200 °C
Duration of test	20000 revolutions

Table 1: Test parameters of the wear measurements.

RESULTS AND DISCUSSION

Fig. 2 shows the wear tracks of the SS304 under the optical microscope after fretting wear tests in different conditions. Fig. 3 compares the 3D wear track profiles to obtain more insight in fundamental understanding of the fretting wear mechanism. The 3D wear track profile allows direct and accurate determination of the wear track volume calculated by Nanovea analysis software as shown in Table 2. The SS304 sample after the reciprocating wear test at a low speed of 100 rpm and room temperature exhibits a small wear track of 0.014 mm^3. In comparison, the fretting wear test carried out at a high speed of 1000 rpm creates a substantially larger wear track with a volume of 0.12 mm^3 (see Fig. 2b). Such an accelerated wear process may be attributed to the high heat and intense vibration generated during the fretting wear test, which promote oxidation of the metallic debris and result in severe three-body abrasion. The fretting wear test at an elevated temperature of 200 °C forms a larger wear track of 0.27 mm^3.

The fretting wear test at 1000 rpm has a wear rate of 1.5×10^{-4} mm^3/N m, which is nearly nine times compared to that in a reciprocating wear test at 100 rpm. The fretting wear test at an elevated temperature further accelerates the wear rate to 3.4×10^{-4} mm^3/N m. Such a significant difference in wear resistance measured at different speeds and temperatures shows the importance of proper simulating fretting wear in the realistic applications.

Wear behavior can change drastically when small changes in testing conditions are introduced into the tribosystem. The versatility of the Nanovea Tribometer allows measuring wear under various conditions, including high temperature, lubrication, tribocorrosion and others. The accurate speed and position control by the advanced motor enables users to perform the wear test at speeds ranging from 0.001 to 2000 rpm, making it an ideal tool for research/testing labs to investigate the fretting wear in different tribological conditions.

(a) 100 rpm, RT: (b) 1000 rpm, RT: (c) 1000 rpm, 200 °C:

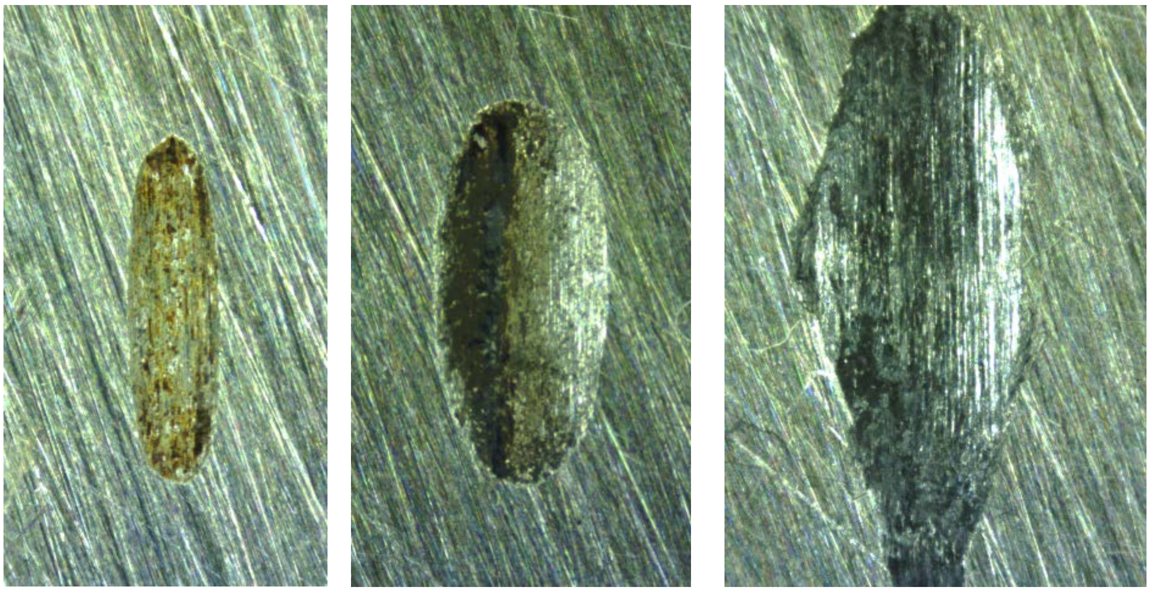
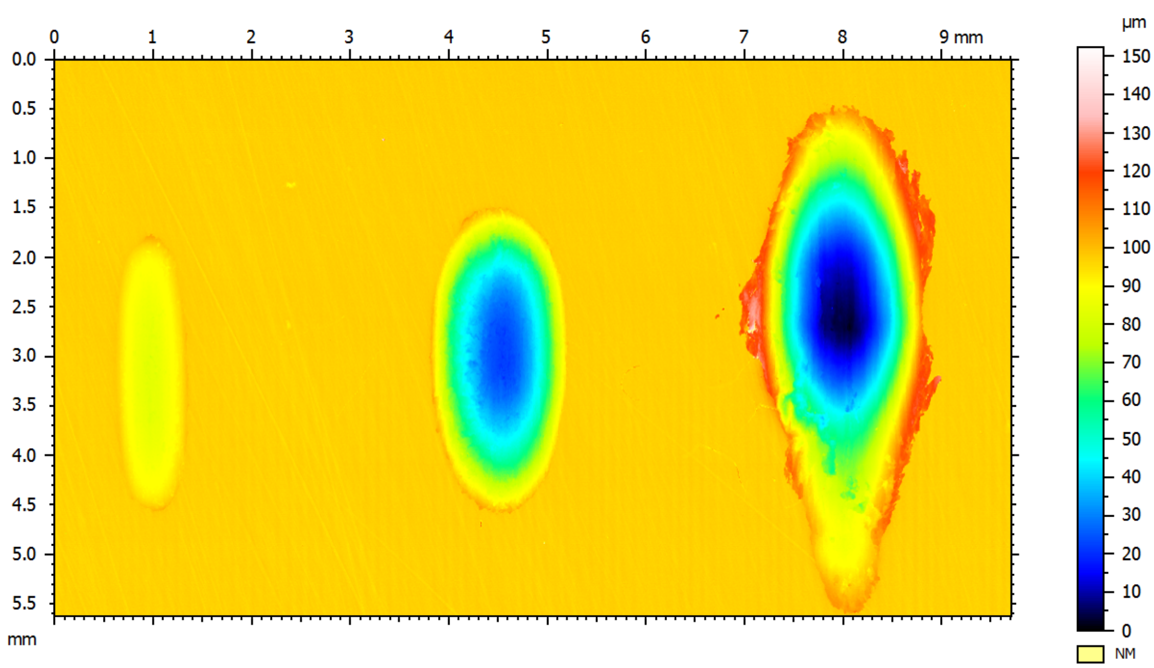


Fig. 2: Fretting wear tracks under the optical microscope.

(a)



(b)

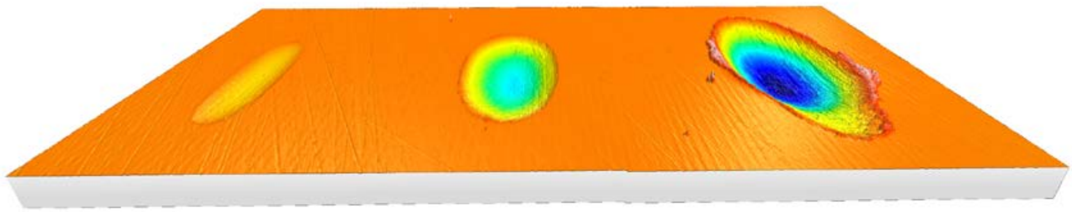


Fig. 3: (a) False color view and (b) 3D view of the wear tracks after the fretting tests.

	Wear Depth µm	Wear Volume mm^3	Wear Rate mm^3/N m
100 rpm, RT	24	0.014	1.7×10^{-5}
1000 rpm, RT	79	0.122	1.5×10^{-4}
1000 rpm, 200 °C	130	0.269	3.4×10^{-4}

Table 2: Result summary of wear tracks measured using different test parameters.

CONCLUSION

In this study, we showcased the capacity of Nanovea Tribometer in evaluating the fretting wear behavior of a stainless steel SS304 sample in a well-controlled and quantitative manner. The test speed and temperature play critical roles in the fretting wear resistance of the materials. The high heat and intense vibration during the fretting result in substantially accelerated wear of the SS304 sample by close to nine times. The elevated temperature of 200 °C further increased the wear rate to 3.4×10^{-4} mm^3/N m. The versatility of the Nanovea Tribometer makes it an ideal tool for measuring fretting wear under various conditions, including high temperature, lubrication, tribocorrosion and others.

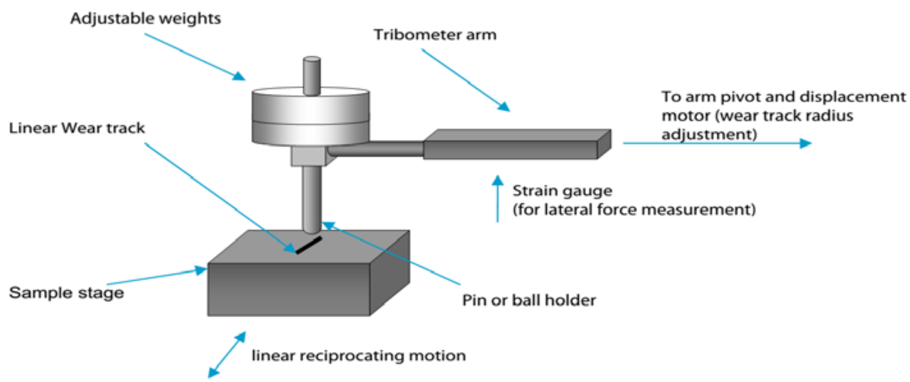
Nanovea Tribometer offers precise and repeatable wear and friction testing using ISO and ASTM compliant rotative and linear modes, with optional high temperature wear, lubrication and tribo-corrosion modules available in one pre-integrated system. Nanovea's unmatched range is an ideal solution for determining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

Learn More about the Nanovea Tribometer, Nanovea Profilometer and Lab Service

APPENDIX: MEASUREMENT PRINCIPLE

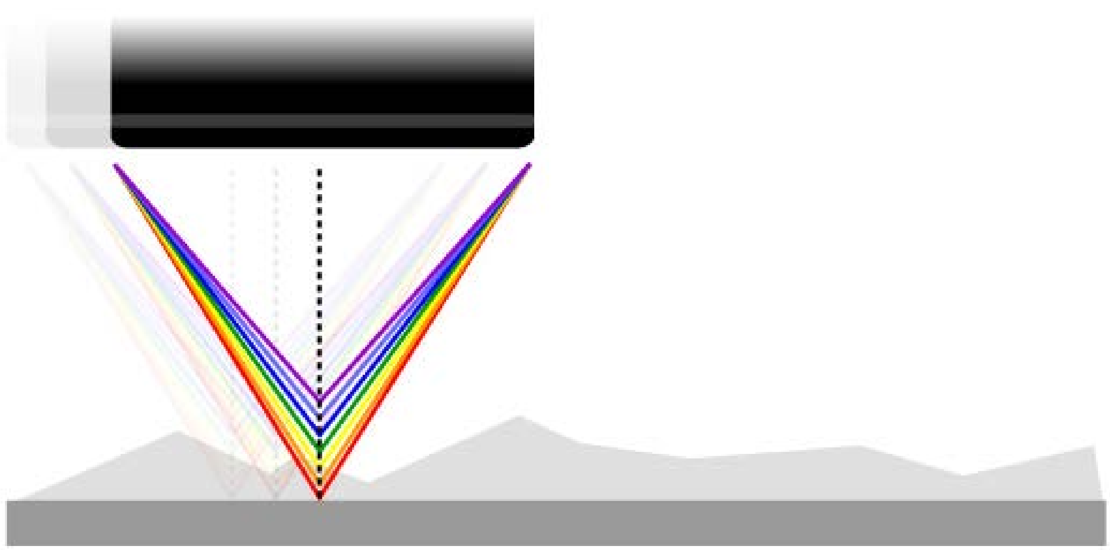
RECIPROCATING WEAR PRINCIPLE

A flat or a sphere shaped indenter is loaded on the test sample with a precisely known force. The indenter (a pin or a ball) is mounted on a stiff lever, designed as a frictionless force transducer. As the plate slides in a linear reciprocating motion, the resulting frictional forces between the pin and the plate are measured using a strain gage sensor on the arm. Wear rate values for both the pin and sample may also be calculated from the volume of material lost during a specific friction run. This simple method facilitates the determination and study of friction and wear behavior of almost every solid state material combination, with varying time, contact pressure, velocity, temperature, humidity, lubrication, etc.



3D NON-CONTACT PROFILOMETER PRINCIPLE

The axial chromatism technique uses a white light source, where light passes through an objective lens with a high degree of chromatic aberration. The refractive index of the objective lens will vary in relation to the wavelength of the light. In effect, each separate wavelength of the incident white light will re-focus at a different distance from the lens (different height). When the measured sample is within the range of possible heights, a single monochromatic point will be focalized to form the image. Due to the confocal configuration of the system, only the focused wavelength will pass through the spatial filter with high efficiency, thus causing all other wavelengths to be out of focus. The spectral analysis is done using a diffraction grating. This technique deviates each wavelength at a different position, intercepting a line of CCD, which in turn indicates the position of the maximum intensity and allows direct correspondence to the Z height position.



Unlike the errors caused by probe contact or the manipulative Interferometry technique, White light Axial Chromatism technology measures height directly from the detection of the wavelength that hits the surface of the sample in focus. It is a direct measurement with no mathematical software manipulation. This provides unmatched accuracy on the surface measured because a data point is either measured accurately without software interpretation or not at all. The software completes the unmeasured point but the user is fully aware of it and can have confidence that there are no hidden artifacts created by software guessing. Nanovea optical pens have zero influence from sample reflectivity or absorption. Variations require no sample preparation and have advanced ability to measure high surface angles. Capable of large Z measurement ranges. Measure any material: transparent/opaque, specular/diffusive or polished/rough.

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[1] Steven R. Lampman, ASM Handbook: Volume 19: Fatigue and Fracture

[2] http://www.machinerylubrication.com/Read/693/fretting-wear