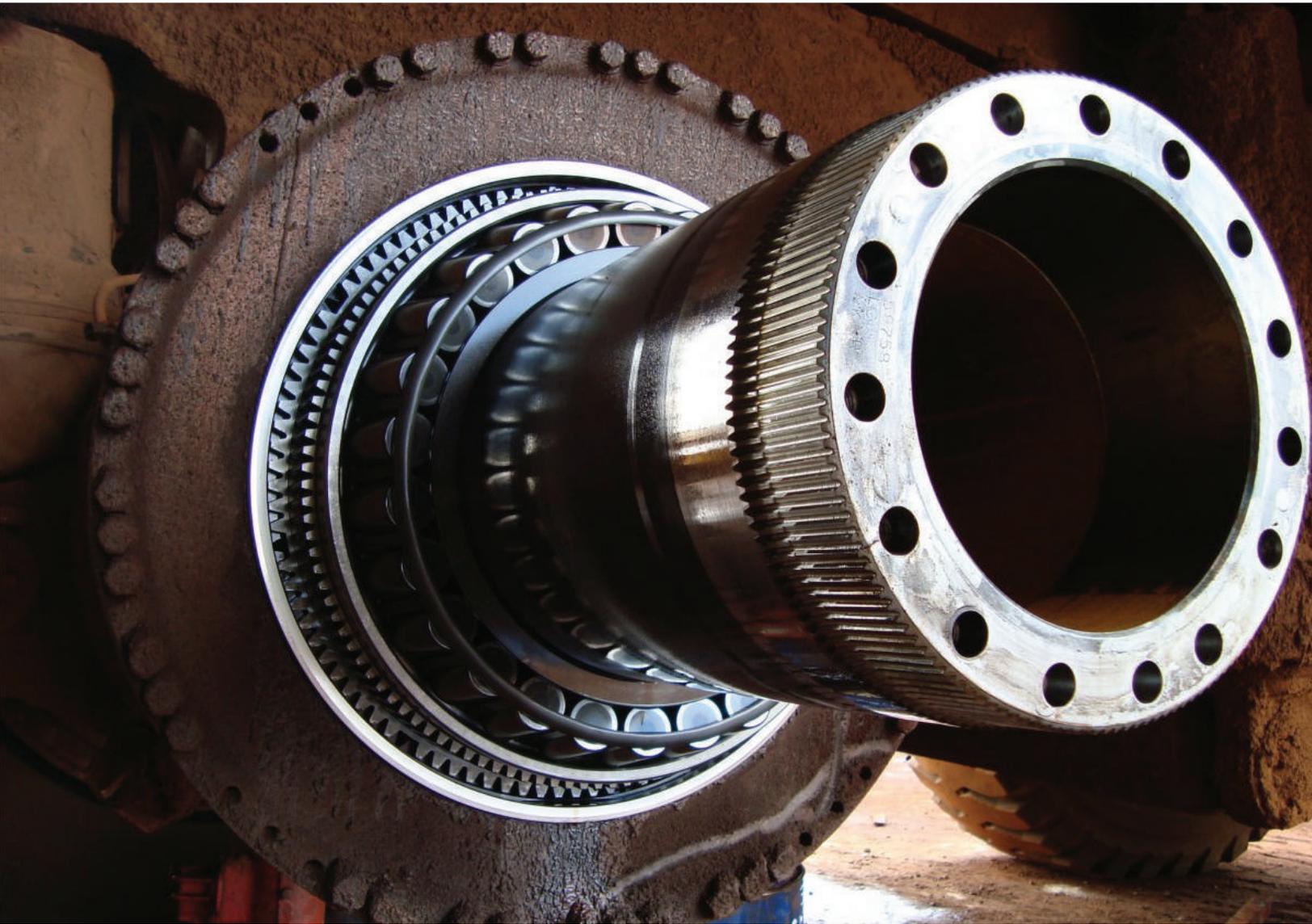


## *BLOCK-ON-RING*

### *SLIDING WEAR EVALUATION*



Prepared by  
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## Introduction

Sliding wear is the progressive loss of material that results from two materials sliding against each other at the contact area under load. It occurs inevitably in a wide variety of industries where machines and engines are in operation, including automotive, aerospace, oil & gas and many others. Such sliding motion causes serious mechanical wear and material transfer at the surface, which may lead to reduced production efficiency, machine performance or even damage to the machine.

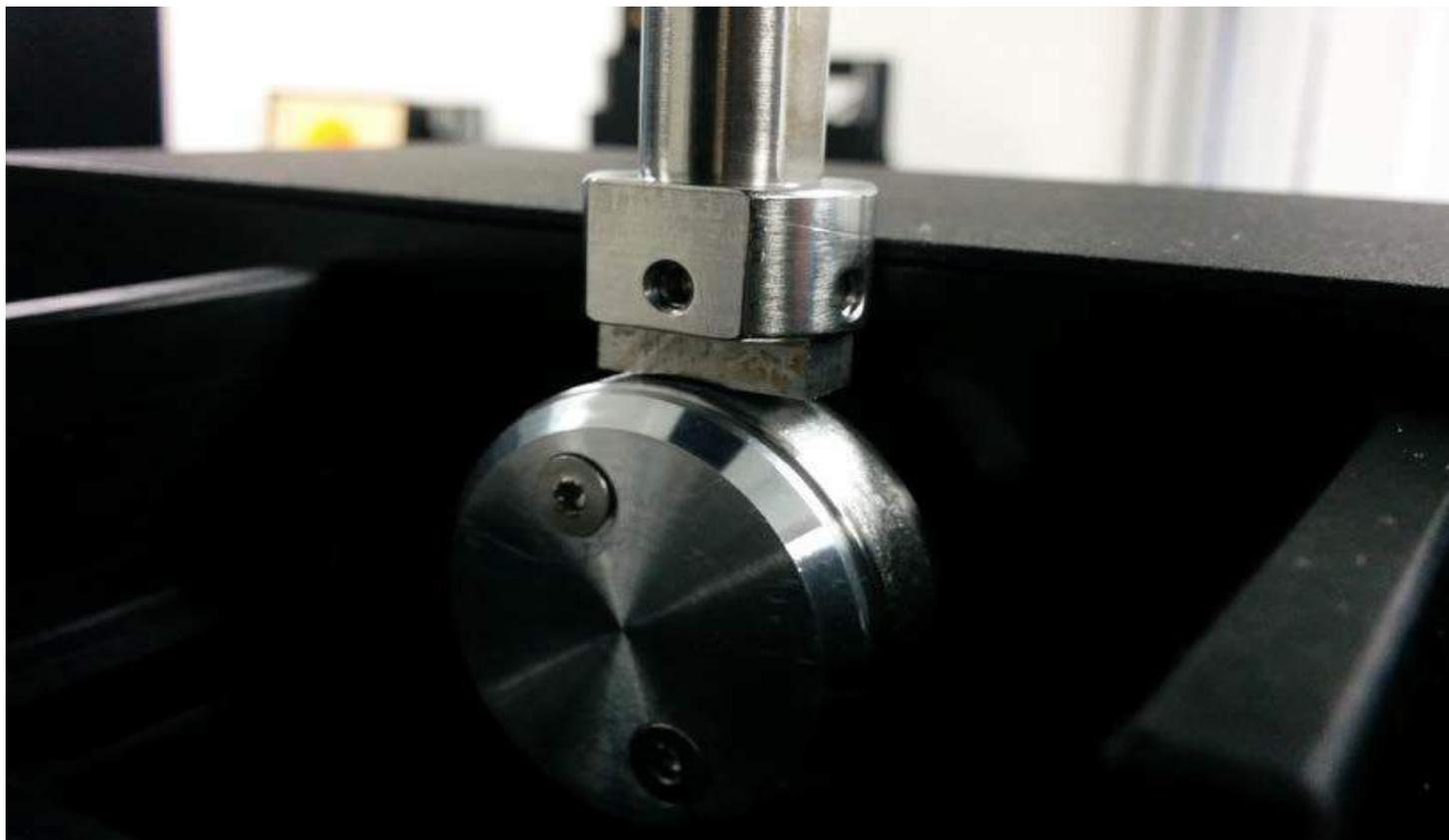
## Importance of Block-On-Ring Wear Evaluation

Sliding wear often involves complex wear mechanisms taking place at the contact surface, such as adhesion wear, two-body abrasion, three-body abrasion and fatigue wear. The wear behavior of materials is significantly influenced by the work environment, such as normal loading, speed, corrosion and lubrication. A versatile tribometer that can simulate the different realistic work conditions will be ideal for wear evaluation.

Block-on-Ring (ASTM G77) test is a widely used technique that evaluates the sliding wear behaviors of materials in different simulated conditions, allows reliable ranking of material couples for specific tribological applications.



In this study we evaluate the sliding wear behaviors of an H-30 block on an S-10 ring in dry and lubricated environments. Nanovea's Block-on-Ring module showcases controlled and repeatable sliding wear simulation of metal couples.



**Figure 1: Block-on-Ring wear test setup.**

The sliding wear behavior of an H-30 block on an S-10 ring was evaluated by Nanovea's tribometer using the Block-on-Ring module. The H-30 block is made of 01 tool steel of 30HRC hardness, while the S-10 ring is steel type 4620 of surface hardness 58 to 63 HRC and ring diameter of ~34.98 mm. Block-on-Ring tests were performed in dry and lubricated environments to investigate the effect on wear behavior. Lubrication tests were performed in USP heavy mineral oil. The wear track was examined using Nanovea's 3D non-contact profilometer. Test parameters are summarized in Table 1. 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.

|                           |   |
|---------------------------|---|
| <b>Sample description</b> | H-30 block vs. S-10 ring                      |
| <b>Normal Load</b>        | 134 N   |
| <b>Revolutions</b>        | 200 for dry wear; 500,000 for lubricated wear |
| <b>Speed (rpm)</b>        | 72 for dry wear; 197 for lubricated wear      |
| <b>Temperature</b>        | Room Temperature (RT)                         |



Figure 2 compares the coefficient of friction (COF) of the Block-on-Ring tests in dry and lubricated environments. The block has significantly more friction in a dry environment than a lubricated environment. COF fluctuates during the run-in period in the first 50-revolution and reaches a constant COF of  $\sim 0.8$  for the rest of the 200-revolution wear test. In comparison, the Block-on-Ring test performed in the USP heavy mineral oil lubrication exhibits constant low COF of 0.09 throughout the 500,000-revolution wear test. The lubricant significantly reduces the COF between the surfaces by  $\sim 90$  times.

Figures 3 and 4 show the optical images and cross-section 2D profiles of the wear scars on the blocks after dry and lubricated wear tests. The wear track volumes and wear rates are listed in Table 2. The steel block after the dry wear test at a lower rotational speed of 72 rpm for 200 revolutions exhibits a large wear scar volume of  $9.45 \text{ mm}^3$ . In comparison, the wear test carried out at a higher speed of 197 rpm for 500,000 revolutions in the mineral oil lubricant creates a substantially smaller wear track volume of  $0.03 \text{ mm}^3$ .

The images in figure 3 show severe wear takes place during tests in the dry conditions compared to the mild wear from the lubricated wear test. High heat and intense vibrations generated during the dry wear test promotes oxidation of metallic debris resulting in severe three-body abrasion. In the lubricated test the mineral oil reduces friction and cools the contact face as well as transporting abrasive debris created during wear away. This leads to significant reduction of wear rate by a factor of  $\sim 8 \times 10^5$ . Such a substantial difference in wear resistance in different environments shows the importance of proper sliding wear simulation in realistic service conditions.

Wear behavior can change drastically when small changes in test conditions are introduced. The versatility of Nanovea's tribometer allows wear measurement in high temperature, lubrication, and tribocorrosion conditions. The accurate speed and position control by the advanced motor enables wear tests to be performed at speeds ranging from 0.001 to 5000 rpm, making it an ideal tool for research/testing labs to investigate the wear in different tribological conditions.

The surface condition of the samples was examined by Nanovea's non-contact optical profilometer. Figure 5 shows the surface morphology of the rings after the wear tests. The cylinder form is removed to better present the surface morphology and roughness created by the sliding wear process. Significant surface roughening took place due to the three-body abrasion process during the dry wear test of 200 revolutions. The block and ring after the dry wear test exhibit a roughness Ra of 14.1 and  $18.1 \mu\text{m}$ , respectively, compared to 5.7 and  $9.1 \mu\text{m}$  for the long-term 500,000 - revolution lubricated wear test at a higher speed. This test demonstrates the importance of proper lubrication of piston ring-cylinder contact. Severe wear quickly damages the contact surface without lubrication and leads to irreversible deterioration of the service quality and even breakage of the engine.

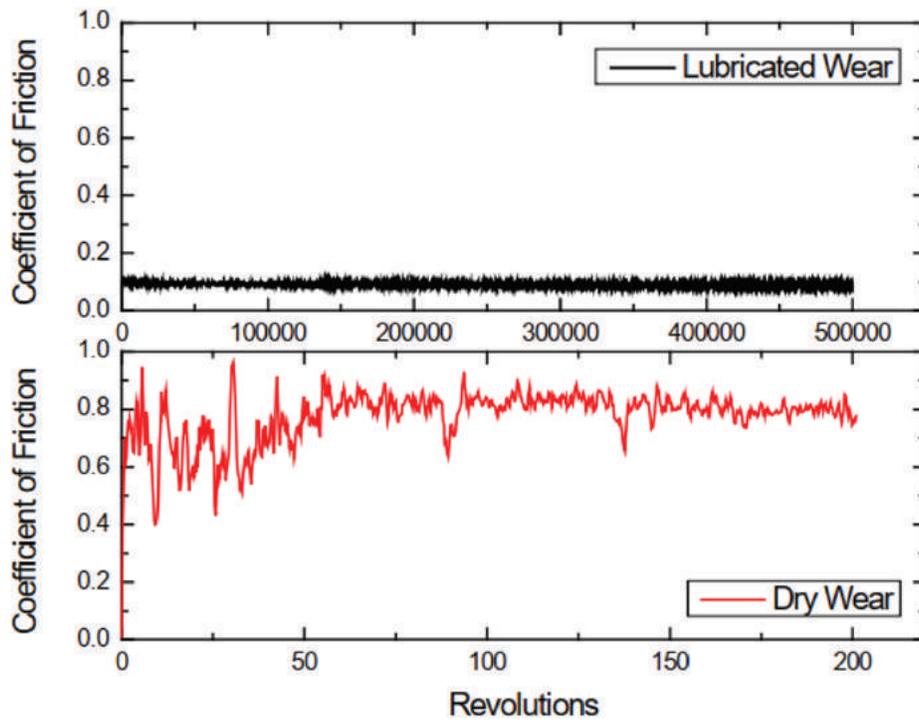


Figure 2: Coefficient of friction of the Block-on-Ring tests in dry and lubricated environments.

(a) After Dry Wear Test

(b) After Lubricated Wear Test

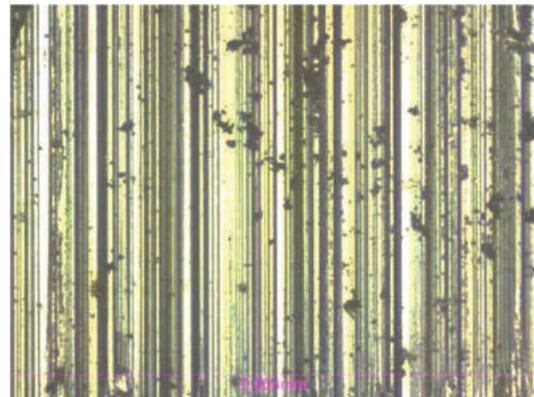
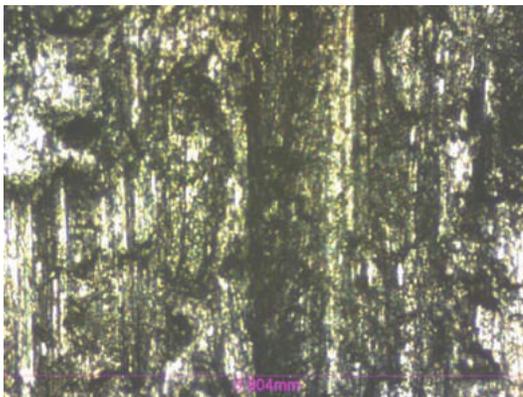


Figure 3: Wear scars of the blocks after (a) dry and (b) lubricated wear tests.

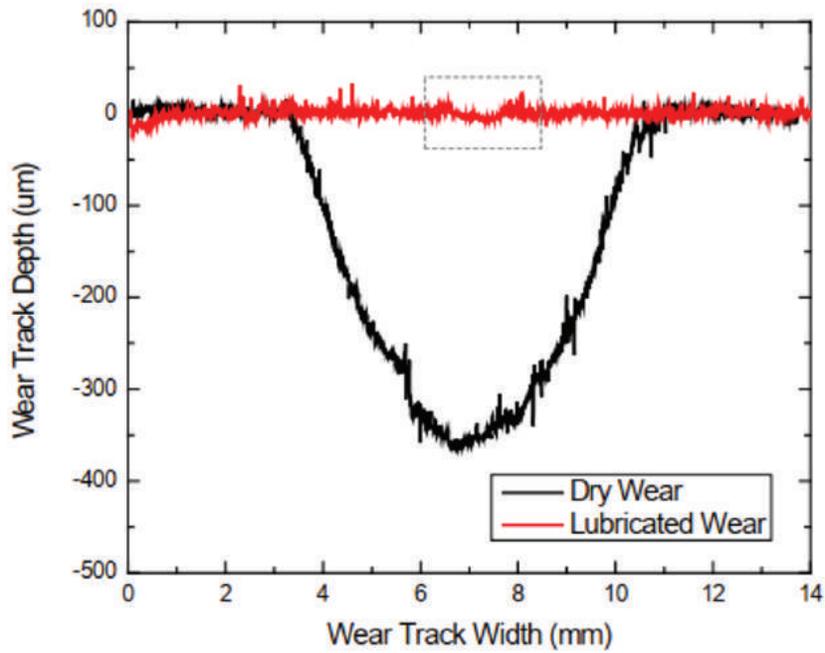
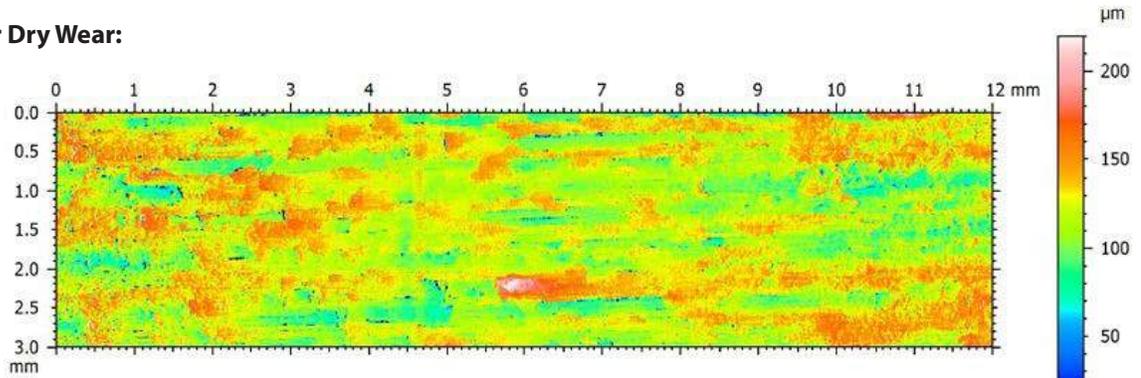


Figure 4: Wear scar profiles on the block after the dry and lubricated wear tests.

(a) After Dry Wear:



(b) After Lubricated Wear:

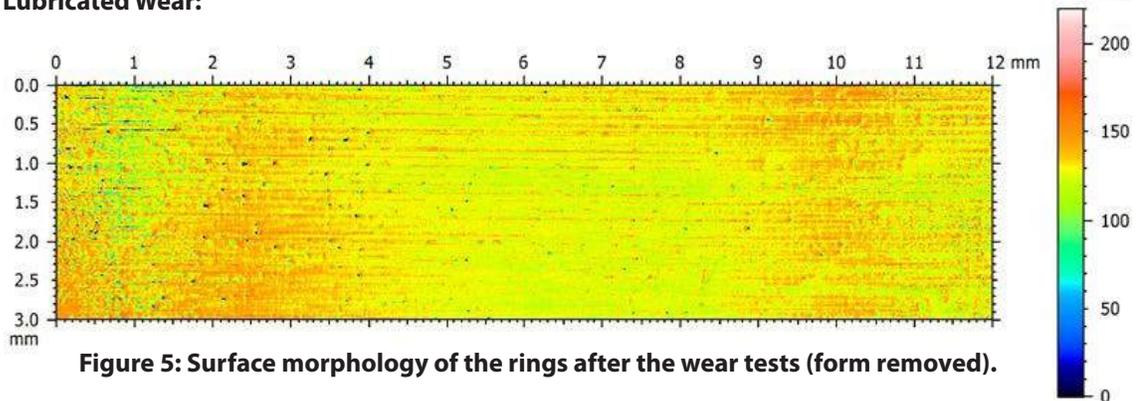
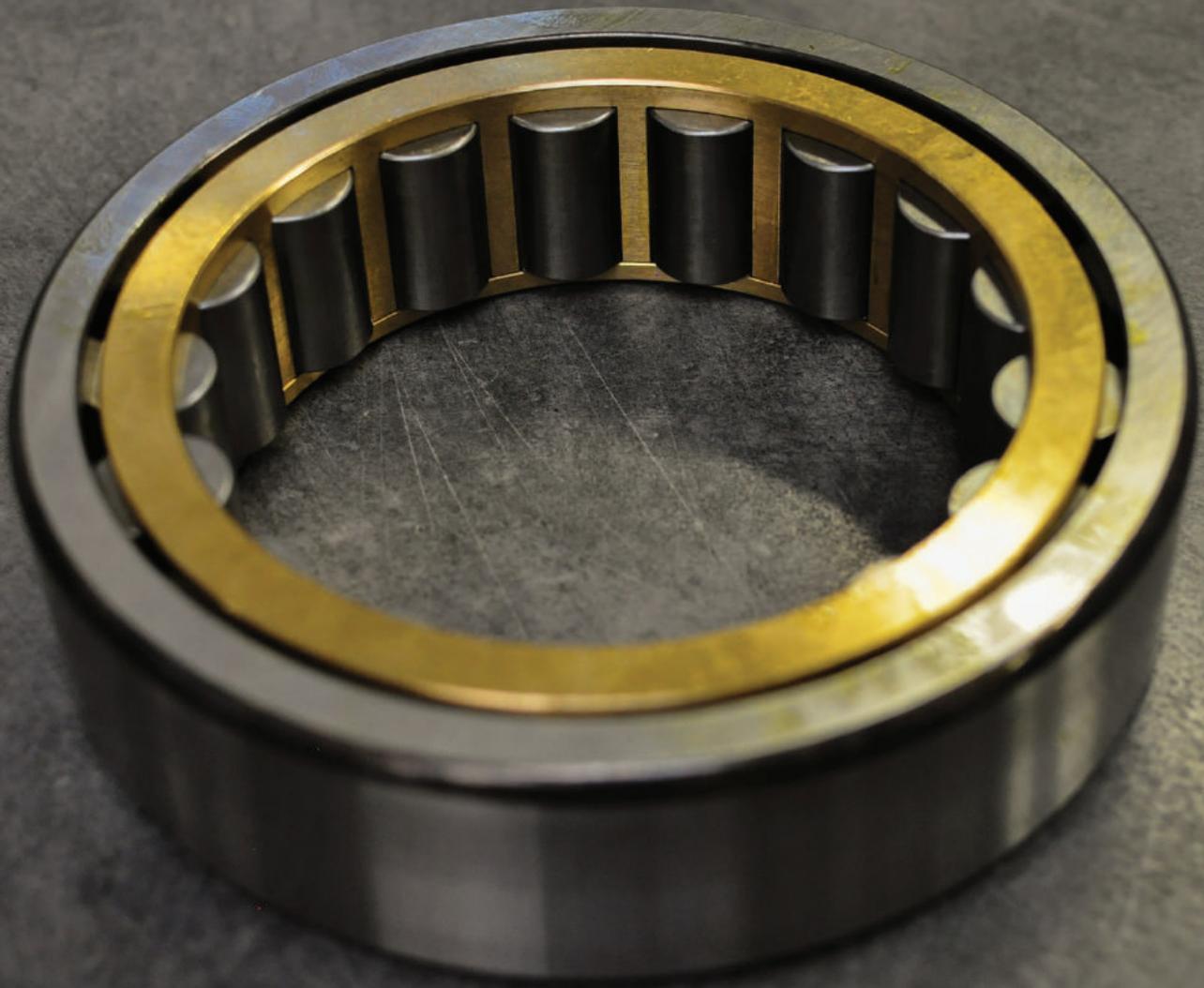


Figure 5: Surface morphology of the rings after the wear tests (form removed).

|                 | Wear Track Width<br>[mm] | Wear Volume<br>[mm <sup>3</sup> ] | Wear Rate<br>[mm <sup>3</sup> /N m] |
|-----------------|--------------------------|-----------------------------------|-------------------------------------|
| Dry Test        | 6.8 ± 0.2                | 9.45                              | 3.2 × 10 <sup>-3</sup>              |
| Lubricated Test | 1.0 ± 0.1                | 0.03                              | 4.1 × 10 <sup>-9</sup>              |

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



## Conclusion

In this study we showcase how Nanovea's Tribometer is used to evaluate the sliding wear behavior of a steel metal couple using the Block-on-Ring module following the ASTM G77 Standard. The lubricant plays a critical role in the wear properties of the material couple. The mineral oil reduces the wear rate of the H-30 block by a factor of  $\sim 8 \times 10^5$  and the COF by  $\sim 90$  times. The versatility of Nanovea's Tribometer makes it an ideal tool for measuring wear behavior under various lubrication, high temperature, and tribocorrosion conditions.

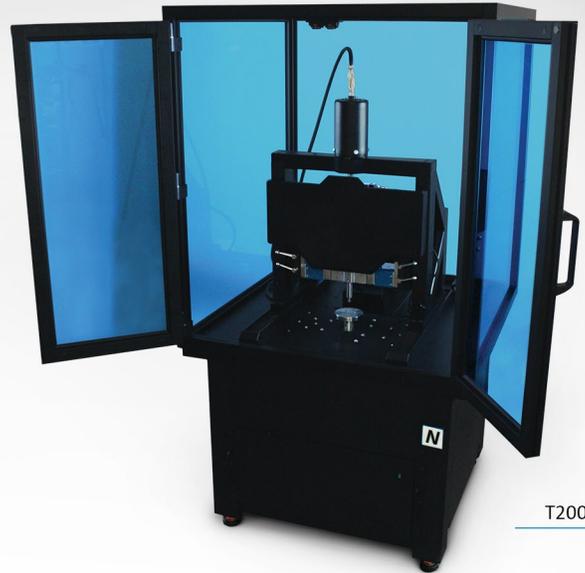
Nanovea's Tribometer offers precise and repeatable wear and friction testing using ISO and ASTM compliant rotative and linear modes, with optional high temperature wear, lubrication, and tribo-corrosion modules available in one pre-integrated system. Nanovea's unmatched range is an ideal solution for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

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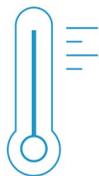


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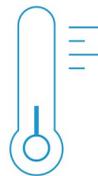
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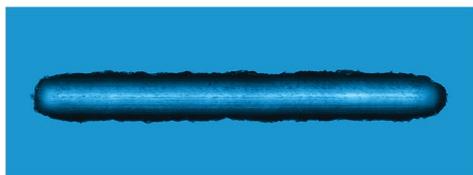
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