Tribological Behavior of Oil-Lubricated Laser Textured Surfaces in Conformal Flat and Point Contacts

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ABSTRACT
The effects of laser surface texturing (LST), which involves the creation of an array of microdimples on the surface with laser, on friction and wear behavior of oil-lubricated steel surfaces were evaluated. Tests were conducted in unidirectional sliding in both the conformal and non-conformal contact configurations with a pin-on-disc test rig using fully formulated synthetic oil lubricant. In conformal contact, LST expanded the operating conditions for mixed and hydrodynamic lubrication regimes to higher loads and slower speeds i.e. the Strubeck curve was shifted to the left. LST was also observed to reduce the magnitude of friction coefficients in the boundary regime. For the non-conformal contact configuration, LST produced more wear on the rubbing counterface compared to untreated surfaces. This also accelerated the run-in process in the tests with LST treated surfaces.

INTRODUCTION
Surface texturing has emerged in the last decade as a viable option of surface engineering resulting in significant improvement in load capacity, wear resistance, friction coefficient etc. of tribological mechanical component. Techniques as vibrorolling, undulated surfaces, reactive ion etching, abrasive jet machining, lithography, anisotropic etching and others can be employed for surface texturing but Laser Surface Texturing (LST) is probably the most used for tribological components so far. This is because the laser is extremely fast, environmentally clean and provides excellent control of the shape and size of the micro-dimples, which allows designs optimization. LST involves creation of numerous micro-dimples with periodic arrangement on a surface by ablation with a controlled pulsating laser beam. The dimples serve as micro-hydrodynamic bearings generating hydrodynamic pressure between oil and water-lubricated sliding surfaces. LST was shown both analytically and experimentally to enhance hydrodynamic and hydrostatic lubrication of mechanical seals. With the excellent results in seal applications, LST technology is now being considered and evaluated for other tribological applications, especially those that involve conformal contacts. The impact of LST on friction and wear behavior of steel surfaces under oil lubrication was investigated in this study.

TEST DETAILS
Tribological experiments were conducted with a pin-on-disk apparatus at sliding speeds in the range of 0.015 - 0.75 m/s and nominal contact pressures that ranged from 0.16 to 1.6 MPa. For the conformal flat configuration, a flat contact area was created on the ball sample by first sliding the ball against a flat sample that contained a series of SiC abrasive papers, ending with very fine, 4000-grit paper. The final flat area created on the ball has a diameter of 4.7 mm and surface roughness of 0.01 µm Rₐ. Disc samples with three different surface preparation and finishes, namely polished, ground...
LST and lapped were tested. Two oils with different viscosities (54.8 and 124.7 cSt at 40°C) were used as lubricants. In addition to the friction coefficient, the electrical resistance between the pin and disk was measured during tribological experiments and also used to establish the operating lubrication regime. For the non-conformal configuration, tests were conducted with a 9.55 mm diameter steel balls.

RESULTS AND DISCUSSION

The test results showed that laser texturing expanded the contact parameters in terms of load and speed for mixed and hydrodynamic lubrication with reduced friction coefficient, as indicated by friction transitions on the Stribeck curve (Figure 1). LST expands the relatively benign hydrodynamic lubrication regime, in which wear and surface damage are not expected. The beneficial effects of laser surface texturing are more pronounced at higher speeds and loads and with higher viscosity oil. The results of the present study have major technological implications. Oil-lubricated tribological components that operate under the low-efficiency, high-friction boundary lubrication regime can be made more efficient by simply applying LST to the lubricated surfaces. This will enable such components to operate in the lower-friction hydrodynamic lubrication regime.

However, under non-conformal concentrated contact, the dimpled surface produced more wear on the ball counterface as shown in Figure 2. After running-in, the transition of the lubrication regime from boundary to mixed took place as the contact area increased due to wear. This transition occurs sooner in LST disc, resulting in rapid reduction in friction coefficient. Between the two types of lubricants, the ball wear rate is higher in all tests with lower viscosity oil, regardless of the disc surface condition, as expected. The lower lubricant film thickness in the lower viscosity oil is responsible.

![Figure 1: Effect of LST on friction behavior in conformal contact](image1.png)

![Figure 2: Wear in the ball counterface rubbed against disc with different surface preparation](image2.png)