PVD-BASED MICROSTRUCTURING SURFACE TECHNIQUES FOR TRIBOLOGICAL APPLICATIONS

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ABSTRACT

Combined techniques of Physical Vapour Deposition (PVD), laser ablation and UV-Photolithography have been set up to produce well defined surface textures able to increase the seizure resistance of high loaded lubricated systems. Using these new techniques, different predefined surface textures, following rectangular grid and zigzag stripped patterns have been generated. The microstructured surfaces developed have been characterised with confocal microscopy, optical and scanning electron microscopy. Ball-on-disc tribological tests under progressively increased load have been carried out using mineral oil as lubricant to determine the influence of surface microtextures on seizure resistance. The influence of shape and size of texture patterns on the tribological performance of the surface have been also studied.

Keywords: Surface texturing, Physical Vapor Deposition (PVD), Ultraviolet Photolithography, Laser technology; Friction, Wear, Lubrication.

INTRODUCTION

It is well known that tribological performance of materials is highly dependent on many parameters being surface topography one aspect of crucial importance [1-3]. Microstructures on surfaces can act as lubricant pockets retaining the oil in the contact even under high pressures. These pockets can also accommodate wear particles generated during movement, “removing” them from the contact point. These processes can lead to lower friction and less wear prolonging the life in service of components.

EXPERIMENTAL DETAILS

Test samples were mirror polished AISI M2 high speed steel discs, Ø 24 mm x 8 mm, hardened at 62 ± 2 HRC. 850-900 nm thick chromium coatings were deposited on these specimens using a PVD system MIDAS 450 from Millennium Coatings. Coating depositions were done in an Argon atmosphere at 1 Pa of pressure. Arc discharge intensity was kept constant at 100 A for the whole process. Hardness and Young modulus measurements were performed using a Ficheroscope H100 tester, the Vickers equivalent hardness of the chromium coating was found to be 900 Kgf/mm$^2$ and the Young modulus 400 GPa.

Surface texturing was first performed by Ultraviolet Photolithography wet etching. The chromium coated surfaces were covered by MA-P1275 photo-resin, which was cured at 100°C for 30 minutes. Then specimens were exposed to ultraviolet radiation (wavelength 250-450 nm and power density 14 mW/cm$^2$) trough different masks. A negative replica of the mask drawing was obtained on the surface by wet etching with a MA231D revealing solution and further rinsing in deionized water and drying in air. The etching depth was varied between 290 and 620 nm. Mask patterns were rectangular grids and zigzag strips, which line width was varied from 40 to 200 µm with an interline size also varying from 20
to 200 µm. Fig. 1 shows a 3D confocal microscopy reproduction of their surface topography.

A Q-switched Nd:YAG laser was applied to steel samples in order to produce similar texture patterns to those produced by photolithography. The etching depth was 1 µm, the pulse frequency 39 KHz, and the track offset was 10 µm under a laser beam displacement speed of 400 mm/s.

The tribological performance of the microtextured surfaces was evaluated with a reciprocating Optimol SRV Friction and Wear Test Machine, using a ball-on-disc configuration. The counterbody were standard 100Cr6 steel balls, Ø 10 mm. The tribotest conditions were: stroke 1 mm, frequency 50 Hz; load was progressively increased from 50 N, steps of 100 N each 2 minutes up to the seizure of the system. The lubricant was a commercially available SAE 90 mineral oil. The failure criterion was friction coefficient up to 0.35 or 10% reduction of stroke.

RESULTS AND DISCUSSION

Fig. 2 compares the evolution of friction coefficient during the SRV tests for an untextured specimen and two different surface patterns. While for the untextured surface the friction coefficient increases dramatically at 300 N of load, samples textured as 100 x 100 µm rectangular grid failed at 700 N. For those specimens textured following a 20/40 µm width zigzag stripped pattern seizure only occurred at 1200 N. The effect of the texture depth is showed by figure 3.

CONCLUSIONS

A combined technique consisting of the application of chromium coating by cathodic arc deposition and further ultraviolet photolithography with selective wet etching has been developed to impose a predefined texture and topography on steel specimens. Similar surface textures were generated by Q-switched Nd-YAG laser ablate on of steel surfaces and further PVD chromium coating. Using SRV reciprocating ball-on-disc tribotests at progressively increasing load, it has been demonstrated that these deterministic textures allow improving the tribological performance of surfaces, increasing their seizure resistance up to x 4 factor.

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REFERENCES

