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Effect of surface texture on the tribological performance of DLC coating

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ABSTRACT – In the present study, the effect of indirect laser texturing on the tribological performance of diamond like carbon coatings has been investigated. Micro dimples were created before DLC coating was deposited. Dimple diameters were changed while keeping density and depth constant, in order to study the effect of change in dimension on the coating performance. The results indicate that optimum surface texturing parameters reduces the friction and wear at the contact. Dimple diameter of 100 µm increased the wear resistance of DLC by lowering the wear particle induced graphitization.

1. INTRODUCTION

To improve the service life of mechanical components, researchers have been using coatings and surface texturing. Micro surface texturing to improve the tribological performance in mechanical components is a relatively new technique. Majority of the work has been done in the past decade. Micro textured surfaces improves the tribological performance in the case of piston ring/cylinder, mechanical seals [1]. The mechanisms by which textures can improve tribological performance include: lubricant retention ability, wear particle capturing ability and hydrodynamic effect [1]. Few studies [2, 3] suggested that the combination of DLC coating and texturing shows higher improvement in tribological performance compared to coating and texturing alone. Texturing parameters like dimple depth, diameter and density have been found to affect the tribological performance in un-coated steel substrates. However, the effect of texturing parameters have not been investigated thoroughly on hydrogenated DLC coating.

In this study, authors have investigated amorphous hydrogenated DLC coating performance with various dimple diameters by keeping density and depth constant. In this study, diameter of the micro dimples were changed from 50 to 300 µm, as shown in Table 1. The density and depth were kept constant at 20 % and 6 µm respectively.

2. METHODOLOGY

The material used in this study is M2 steel with a hardness of 58 HRC. After polishing of substrates, the roughness was 30 nm. For tribological testing, reciprocating test rig was used. Tribo-testing was conducted at a load, frequency, stroke length and temperature of 50 N, 10 Hz, 2 mm and 28 °C. The duration of each test was two hour. The test was conducted in lubricated conditions. Base oil without additives was used as a lubricant so that the effect of textures can be observed.

2.1 Laser Surface Texturing

An array of micro dimples was created by Pico-second laser with a power of 10 W, wavelength of 1.06-µm and pulse duration of 10.3 Pico second.

2.2 DLC Coating

DLC coating was deposited using Magnetron sputtering by Hybrid PVD machine. Nano indenter (Hysitron, Inc. Model No. TI750 UBI^{TM}) measured coating hardness and was found to be 15.45 GPA.

Table 1 Variation in wear rate with dimple diameter.

Sample	Diameter (µm)	Wear Rate ($\times 10^{-8}$ mm^3 Nm)
A1	50	36.21
A2	100	5.65
A3	150	42.67
A4	200	48.34
A5	300	57.39
A6	Un-textured	53.24

3. RESULTS AND DISCUSSIONS

The friction coefficient (COF) results are shown in Figure 1. It can be seen that the COF is lowest for A2 and highest in the case of A5. Un-textured DLC (A6) showed lower COF compared to all the various textured DLC samples except A5. Table 1 shows the wear rate for various textured and un-textured samples. Sample A2 showed lowest wear and A5 showed the highest. Un-textured sample showed higher wear rate than all samples except A5. The higher wear and lower COF in the case of sample A6 can be due to graphitization. The reduction in COF due to graphitization has been noticed previously [4].

Raman Spectroscopy was utilized to investigate the graphitization phenomenon. Figure 2 shows the Raman spectra for sample A6 and A2. The Raman spectra was deconvulated into D and G peaks for quantitate analysis. The G peak shift and I_D/I_G ratio increase is higher in case of sample A6 than sample A2 (can be seen in Figure 2). The shift in G peak and increase in I_D/I_G ratio indicate an increase in sp^2 fraction or graphite in the DLC film [5]. The graphite formed at

the interface forms a transfer film on the counter ball; this provides easy slip at the interface, thus reducing COF. Due to graphitization, the coating layer becomes soft and the load bearing capacity reduces and wear increases [4]. This can explain higher wear rate of sample A6. Haque et al. [4] found that the wear debris at the wear track could increase the contact pressure, which in turn increases the graphitization transformation. Micro textures can reduce wear particle induced graphitization by capturing the wear debris at the interface. This can explain the lower graphitization of sample A2. These findings show that textures can help in improving the wear resistance of hydrogenated DLC. However, the mechanism of textures by which they improve wear resistance can be obtained only if the texturing parameter are optimum for a particular operating condition.

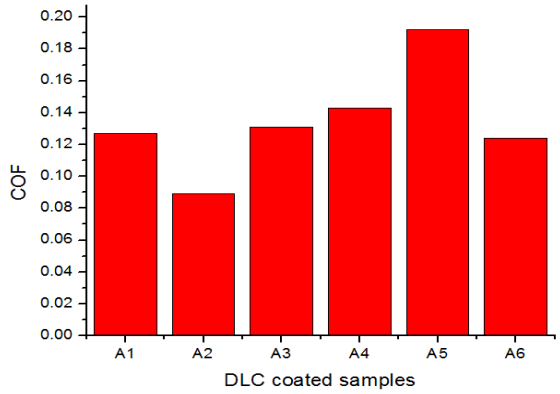
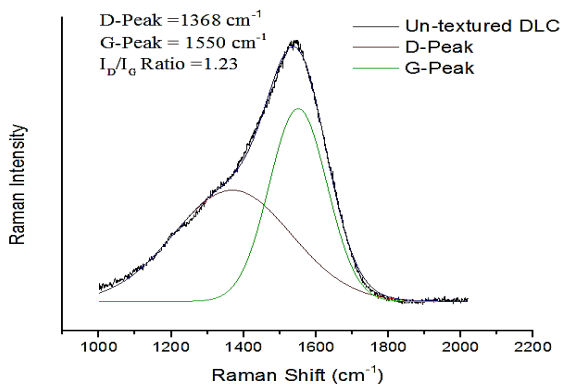


Figure 1 Steady state COF with change in dimple diameter from 50- 300 µm.



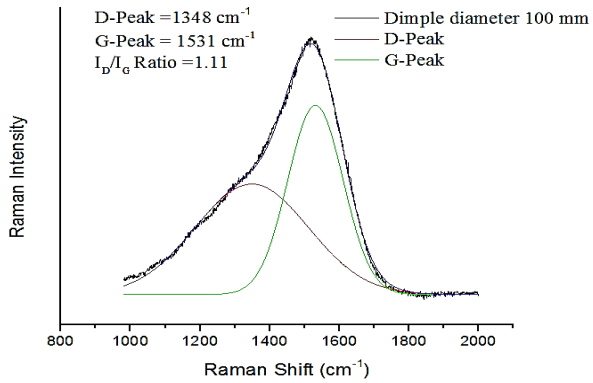


Figure 2 (a) Raman spectra of un-textured DLC, (b) Raman spectra of textured DLC.

4. SUMMARY

a) Micro surface textures can be helpful in improving tribological performance of DLC coating with optimum texture dimensions.

b) Micro dimples can increase the wear resistance of DLC coating by lowering the graphitization transformation. The wear particles created at the contact can be captured by micro dimples, which reduces wear particle induced graphitization.

5. REFERENCES

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