Micro-dimple effect on high-cobalt material (2)

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1. Introduction

The texturing of specific patterns on a sliding surface is a known approach to improve the tribological properties. One of the functions of undulations is to trap wear particles [1,2]. Another effect of surface texturing is to act as a reservoir for lubricants, feeding a pumped lubricant directly between two contacting surfaces [3,4]. The endurance life of the surfaces can be prolonged and wear can be minimized by reduced friction.

To enhance endurance life of operating components in a magnetic jack type Control Element Drive Mechanism (CEDM), application of surface texturing on the contact surface was considered, and the results of a preliminary study were presented in a previous paper[5]. In this preliminary study, a photo-lithographic method was applied to form micro-dimples on the disk specimens. The photo-lithographic method can be used to manufacture precise dimples on a cobalt-based disk specimen; however, this method cannot be applied to a curved surface. Major components that bear sliding or impact contacting force in the CEDM are latch pins and latch tips, which have round shapes. As a result, the photo-lithographic method is not applicable to CEDM components, and thus other manufacturing methods have been surveyed. Laser machining and micro-endmilling are potent candidates. In this paper, tribological test results are presented with disk specimens having micro-dimples formed on their surface through laser machining.

2. Methods and Results

In this section, some of the techniques used to manufacture the specimens and the test results using a tribometer are presented.

2.1 Manufacturing of micro-dimple pattern

Mechanically, the weakest points in a CEDM are the latch and latch pin surfaces. These surfaces may be damaged due to fatigue from repeated load, or experience plastic deformation from impacting with a drive shaft. These types of damage may be removed or mitigated by an improvement of material or surface treatment. Generally, a high cobalt alloy, for example, Haynes 25 or Stellite #6, is used as latch and pin material because of its durability, impact resistance, and corrosion resistance. In this research, wear endurance and lubrication characteristics are studied experimentally with respect to surface patterning on a high cobalt alloy.

To produce a micro-dimple pattern on a surface, a CO_2:YAG laser machining method is used. Figure 1 shows the machined surface shape.

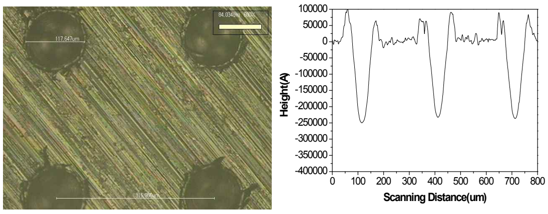


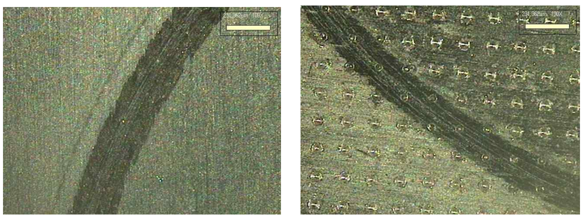
Fig. 1. A typical micro-dimple pattern shape (on Haynes 25) and results of surface roughness measurements.

Through exploration tests, a temporarily optimized pattern was determined as follows:

. Micro-dimple hole diameter: 100 μm
. Distance between micro-dimple holes: 300 μm
. Dimple depth: 30 μm

2.2 Tribometer test results

Tribometer tests were conducted using a temporarily optimized micro-dimple pattern. Figure 2 shows a wear track on the disk specimen after testing.



(a) (b)

Fig. 2.Wear track formed after a tribometer test. (a) shows the wear track on the raw surface, and (b) shows the track on the micro-dimple patterned surface

Tables 1 through 3 show summaries of the frictional characteristics from the tribometer test using disk specimens with and without micro-dimple patterns. Subscript 0 followed by the specimen name indicates a disc specimen with a raw surface, i.e., without a micro-dimple pattern (for example $Haynes_0$), and no subscript indicates a specimen with a micro-dimple pattern. 200m and 800m are the running(sliding) distances loaded with a 500g mass. For Haynes 25, the friction coefficient decreases by about 21%, from 0.46 to 0.36, with micro-dimple patterning compared to the coefficient of a raw surface when the sliding distance is 200m. The friction coefficient decreases 33% for Stellite #6, and 15% for Ultimet. However, a clear decrease in friction and wear volume is not observed for a 800m sliding distance.

Table 1. Friction coefficient and wear volume changes according to whether micro-dimple patterning is used for Haynes 25

Specimen	Friction Coeff.	Wear Vol. of ball ($\times 10^{-15}$ m^3)	Wear Vol. of disk ($\times 10^{-13}$ m^3)
Haynes$_0$ (200m)	0.46 ± 0.09	6.7 ± 4.1	120.6 ± 29.1
Haynes$_0$ (800m)	0.36 ± 0.13	44.0 ± 21.8	263.2 ± 68.5
Haynes (200m)	0.36 ± 0.04	3.5 ± 1.2	118.8 ± 51.1
Haynes (800m)	0.32 ± 0.04	25.0 ± 16.2	294.6± 101.4

Table 2. Friction coefficient and wear volume changes according to whether micro-dimple patterning is used for Stellite #6

Specimen	Friction Coeff.	Wear Vol. of ball ($\times 10^{-15}$ m^3)	Wear Vol. of disk ($\times 10^{-13}$ m^3)
Stellite$_0$ (200m)	0.27 ± 0.15	20.0 ± 11.9	102.8 ± 19.0
Stellite$_0$ (800m)	0.21 ± 0.07	38.6 ± 32.7	225.0 ± 94.6
Stellite (200m)	0.18 ± 0.03	16.9 ± 10.2	89.2 ± 28.4
Stellite (800m)	0.23 ± 0.03	113.5 ± 30.8	155.0 ± 56.5

Table 3. Friction coefficient and wear volume changes according to whether micro-dimple patterning is used for Ultimet

Specimen	Friction Coeff.	Wear Vol. of ball ($\times 10^{-15}$ m^3)	Wear Vol. of disk ($\times 10^{-13}$ m^3)
Ultimet$_0$ (200m)	0.39 ± 0.04	0.30 ± 0.04	111.0 ± 47.8
Ultimet$_0$ (800m)	0.28 ± 0.03	0.78 ± 0.65	282.2 ± 68.0
Ultimet (200m)	0.33 ± 0.03	7.13 ± 3.96	161.0 ± 88.3
Ultimet (800m)	0.31 ± 0.07	21.7 ± 14.7	328.0 ± 144.2

Figure 3 shows a typical variation of friction coefficient used during the test. The friction increased with an increase in sliding distance. However, this is not a usual phenomenon for the frictional behavior of steel. This result shows that micro-dimples affect the frictional enhancement for the initial test stage, but were gradually worn away.

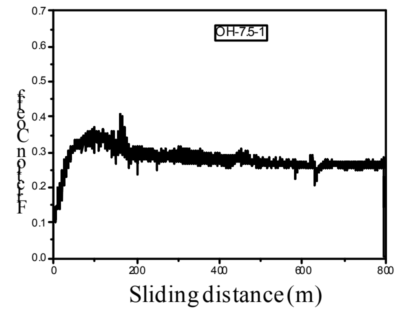


Fig. 3. Variation of friction coefficient during testing. (A typical result)

3. Conclusions

Micro-dimple patterns are machined on high-cobalt materials that are used for the driving parts in CEDM. Also, a tribometer(friction and wear) test was conducted using micro-dimple patterned surface specimens. Micro-dimple patterns affect the frictional characteristics in the early test stage, but the effect vanishes as the sliding proceeds. This means that micro-dimples can decrease the frictional coefficients while they survive. Surficial pressure on the latch pins is much lower than the pressure acted upon the tribometer used in this study. Thus, dimple patterns on latch pins can survive for a long time, and friction and wear can be diminished, increasing their overall lifetime.

The drawback of laser machining is that the produced shapes of the dimples are caved like craters. A proper machining and surface finishing method will be studied in the future work.

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