Micro-dimple effect on high-cobalt material

Jae-Seon Lee [a*], Chul-Hwa Song [a], Jong-Joo Rha [b], Young-Ho Jang [c]
[a]*Korea Atomic Energy Research Institute, 1045 Daedeok Street, Yuseong-gu, Daejeon*
[b]*Korea Institute of Materials Science, Changwondaero, Changwon, Kyungnam*
[c]*Nuclear Engineering & Technology Institute, 25-1 Jang-dong, Yuseong-gu, Daejeon*
[*]*Corresponding author: leejs@kaeri.re.kr*

1. Introduction

The magnetic jack type Control Element Drive Mechanism (CEDM) consists of the motor assembly, the pressure housing assembly, the extension shaft assembly and the magnetic assembly. To operate the CEDM under load-following strategy, it needs a longer endurance lifetime, actually of the motor housing assembly. The assembly consists of latches and linking mechanisms. The latches contact with the drive shaft and the latch pins slide along the pin holes, so wear occurs at the points and surfaces. Because wear leads to mechanism failure, it is necessary to reduce wear between the moving parts.

To enlarge the endurance lifetime of the driving mechanism of the CEDM, micro-dimple surface patterns are textured on the high cobalt materials to enhance lubrication and lessen wear. Samples are manufactured using photo -lithographic method and tested with a tribometer. Test results are presented here.

2. Methods and Results

In this section some of the techniques used to manufacture the test samples and test the effect using a tribometer are duscussed.

2.1 Purpose and application

The Korean APR+ nuclear reactor has been developing with increased thermal and electric capacity and enhanced safety. As for the CEDM, the magnetic jack type CEDM will be installed to control reactivity of the core. A longer endurance lifetime is required to apply the load-following strategy because the travel length of the CEDM would be increased. Surfaces of the latch and the latch pin are the weakest points. Impact forces between the latch and the drive shaft contact points are applied and macro and micro slip occurs, so wear occurs.

To reduce wear on the surface, many surface treatment methods have been proposed. One successful method is surface patterning. Micro-scale dimples are patterned on the surface, and the dimples function as traps for wear particles [1, 2]. Another function of the surface dimple is to act as reservoirs for lubricants [3, 4]. And many researches have been performed to different materials and patterns [5, 6].

Surface texturing method with micro-dimple pattern could be applied to the CEDM driving elements to reduce friction and wear, eventually to enlarge the endurance lifetime. It is not applied to the high-cobalt materials yet, so a new trial is performed in this analysis.

2.2 Micro-dimple patterning

Photo-lithographic processes are used to manufacture micro-dimples on test specimens made of Haynes 25. Haynes 25 is used as the latch material and it consists of more than 50% cobalt. Figure 1 shows the micro-dimple pattern on the test specimen. Two different cobalt base materials are used to compare research (M1, M2 in Figure 3 and 4).

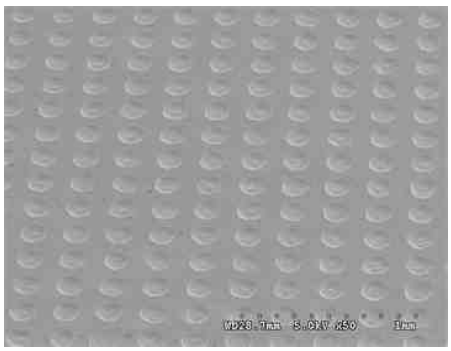

Fig. 1. Micro-dimple surface after photo-lithographic process on the Haynes 25 test specimen. (Mean diameter of the circular patterns: 120㎛, mean depth: 20㎛, center distance between patterns: 250㎛)

2.3 Test Results

A rotational tribometer is used for friction and wear measurement. The specimens are 20mm diameter, and rotate 100 rpm forming about 5mm contacting radius with a stainless steel ball. 1kg of pressing load is applied on the ball.

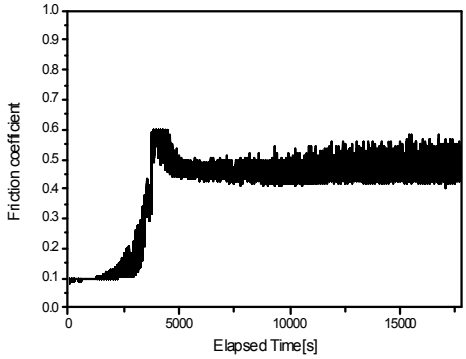

Fig. 2. Raw data for measured friction coefficient.

Frictional coefficient is varying as wear increased as shown in Figure 2. The total characteristics of surface texturing are compared with wear volume.

Figure 3 shows wear volume comparison in case of dry friction. H25, M1 and M2 represent Haynes 25, cobalt base material #1 for comparison and cobalt base material #2 for comparison without any surface texturing, respectively. And suffix '-M' means the specimens after surface texturing. For Haynes 25 specimen, wear volume decreases to about 1/10 for surface texturing specimen compared to non-textured specimen.

Figure 4 shows wear volume comparison in case of water lubrication. It says that wear volume decrease about 1/20 in case of surface texturing.

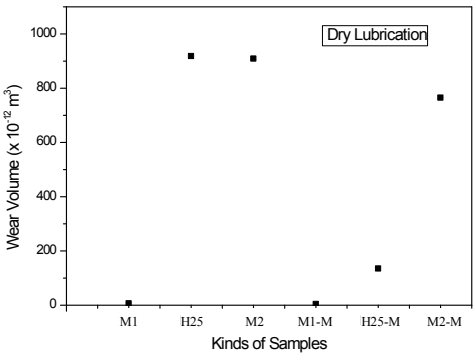

Fig. 3. Wear volume reduction on the patterned surface in case of dry contact.

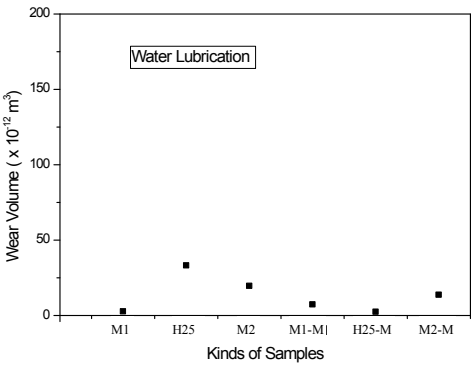

Fig. 4 Wear volume change on the patterned surface in case of water lubrication.

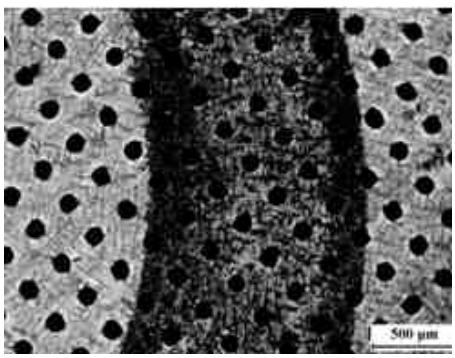

Fig. 5 Wear trace on the test specimen.

Figure 5 shows wear trace on the test specimen. After 30,000 revolutions, wear width increased to about 1mm and micro-dimples disappear gradually from the wear center.

3. Conclusions

Lubrication characteristics of high-cobalt material, especially on friction coefficient and wear volume, are researched with surface-textured high-cobalt material by micro-dimples.

Wear resistance increases more than 10 times in any lubrication conditions. So, it can be found that surface texturing with micro-dimples might be applied to the parts of the CEDM latch assembly to enlarge its lifetime. The latch pin and latch surfaces are the target points of this research. However the loading pattern is different on each surface. Slip on the surface contact would be dominant for the latch pin case, and impact and micro slip for the latch. So it is required that the optimum shape of the micro-dimples be selected.

Photo-lithographic method can be applied to flat surface at present because only flat masking can be made. Further research will search for micro-dimple manufacturing methods and optimizing the effect with machine manufacturing methods for curved surfaces.

REFERENCES

[1] Suh NP, Mosleh M, Howard PS., Control of Friction, Wear Vol. 175, 1994

[2] Suh NP, Saka N, Surface engineering, Annals of the CRIP, Vol. 36 1987

[3] Tian H, Saka N, Suh NP, Boundary lubrication studies on undulated titanium surfaces, STLE Tribology Transactions, Vol. 32 1989

[4] Saka N, Tian H, Suh NP, Boundary lubrication of undulated metal surfaces at elevated temperature, STLE Tribology Transactions, Vol 32, 1989

[5] Ulrika Patterson, Staffan Jacobson, Influence of surface texture on boundary lubricated sliding contacts, Tribology International, Vol. 36, p.857-864, 2003

[6] Younghun Chae, Seoksam Kim, Friction Characteristics of Micro-scale Dimple Pattern under mixed and Hydrodynamic Lubrication Condition, Journal of the Korean Society of Precision Engineering, Vol. 22, No. 2, 2005

Acknowledgement

This work had been performed under the nuclear research & development program sponsored by Ministry of Knowledge and Economy of Republic of Korea.