Clarification the effects of oxygen to carbon ratio on wear mechanism of diamond-like carbon under pressurized hot water

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ABSTRACT – In this paper, the influence of dissolved oxygen concentration amount by means of sputtering depth profile on the wear rate of a hydrogened Diamond-like Carbon coating (commonly known as DLC) has been studied. The sliding test was performed using a self-developed sliding tester move like pendular, where the DLC coated pins was slid on stainless steel plate (SUS316) at 23˚C,100˚C, 200˚C,and 300˚C in pressurized water environment. The results show that the most crucial factor, affecting the wear rate of DLC coating under sliding in water, devided by two categories. Effect of mechanical wear (graphitization and adhesive wear) was a dominant for low dissolved oxygen concentration. In contrast, above 200℃ in rich O_2 water temperature, the graphitization and oxidation wear of DLC has a dominant role on DLC wear rate where friction enhanced oxidation with temperature.

1. INTRODUCTION

Diamond-like Carbon (DLC) has been used as coatings for other materials due to its properties which have high hardness, chemical inertness,low friction and wear rate. There were many more benefits by using the DLC since it properties can be tailored to suit the desired application. Several tribology studies has been done on DLC in various atmospehere and conditions. The specific wear rate of DLC not influenced by hydrogen content in water and air at atmosphere pressure but wear rate tended to decreases with increasing film hardness [1]. Tribological behavior of DLC in hard water is better than soft water environment when protective tribolayer containing Ca and O formed on steel and brass surfaces at elevated temperature 20˚C,50˚C and 80˚C (0.1MPa) reduces the DLC wear rate and friction [2]. Effects of dissolved oxygen (DO_2) (0.01mg/L,0.1mg/L,7.0mg/L) and water pressure (0.1MPa,1MPa,19MPa) were also examined briefly but no significant effect was observed. Previous report from both group of researchers shows same argument where temperature was the major role of increment of wear rate at 23˚C,100˚C,and 300˚C [2,3]. Effect of pressure was small compared to temperature. However, rich content of DO_2 (35-40mg/L) at 300˚C increased the specific wear rate of DLC in pure water. DO_2 contents play a significance role on wear of DLC in water. They found that high oxygen elements at topmost layer of DLC increased the wear rate of DLC by using AES sputtering methods [3]. It is important to clearly understand the DO_2 effect on DLC wear at room temperature up to high temperature in water environment. Thus,the aim of this research is to determine the effect of oxygen to carbon ratio at 100˚C ,200˚C,250˚C and 300˚C for poor O_2 and rich O_2 content at 10MPa water pressure in order to study the wear mechanism of DLC and its counterparts SUS316 by observing the worn surfaces of DLC and its counterpart.

2. EXPERIMENTAL METHOD

The friction test was conducted by using self developed autoclave tribotester. The autoclave body is made from stainless steel (SUS316). The chamber was filled with pure water up to 3/4 of chamber volume or 380ml of water. Two cases of the experiment were studies. One was poor O_2 and the other was rich O_2 content. For poor O_2, the nitrogen gas (N_2) is bubbled into the chamber up to 5MPa through the inlet pipe valve and then it was released in order to minimize the unwanted gases content in the chamber. The outlet valve was closed and 10 MPa of N_2 gas was pressurized into the chamber.The chamber was driven like a pendular by electric motor with 20rpm around 2700 cycles for 200m of sliding distance. In the chamber the DLC pins was slid in a reciprocating motion. The normal force of pins ,N (load) was 0.056 N.The temperature of the chamber was controlled by heating coils. The test was run at 100˚C ,200˚C,250˚C and 300˚C at 10MPa in water. The procedures were repeated in rich O_2 cases. In rich O_2 cases, the O_2 gases was used as bubbling and pressurizing of water. The wear rate of the DLC film was calculated from the wear diameter measured from the optical microscope by using Archard's formula. In order to evaluate the structure and chemical changes on DLC and SUS316 plate, Raman spectroscopy and EDS SEM analysis were carried out before and after the sliding tests. Auger electron spectroscopy was used in order to examine the tribo layer depth profile for C and O elements at topmost layer of DLC film where Argon gas was for sputtering.

3. RESULTS AND DISCUSSION

The wear rate of DLC under water in rich O_2 and poor O_2 show dependency to temperature as shown in Figure 1. The wear rate was linearly increased with temperature for poor O_2. In contrast, the wear rate with rich O_2 initiated with the same wear rate at 100°C with poor O_2 and sharply increases above 200ºC. Above 200°C with rich O_2 the wear accelerated and reached a maximum of 9.11 x 10^{-7}mm^3/Nm of wear rate at 300˚C which is 2.2 times of the same temperature with poor O_2 water. According to AES sputtering results in Figure 2 and 3, the ratio of oxygen to carbon O/C for poor O_2 was not having much different for inside wear and outside wear area as compared to rich O_2 cases for all the temperatures. The O/C ratio in DLC wear scar for poor O_2 shows no clear depth dependence in various temperature. On the other hand, for rich O_2, the topmost layer of DLC contained a rich O/C ratio above 200ºC water temperature. The maximum O/C ratio for rich O_2 was 0.188 at 300ºC. It was 47 times higher than poor O_2 at the same temperature.

It is believed that graphitization occurred during sliding and hard carbon films change to soft associated with temperature [4]. High temperature made the DLC structure softer due to graphitization that allows C bonds weaken, producing cavities on one surface and depressions on the second surface. Adhesion particles remove and rub against the surface, contributing to wear for poor O_2 and rich O_2 water. In rich O_2, the friction enhanced the oxidation which reactively reacts with water tempearature led to high wear. The oxidation is controlled by diffusion rate of reactants thus increases exponentially dependent on temperature [5].

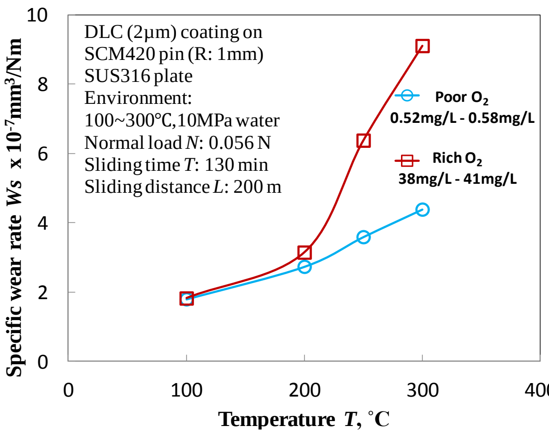

Figure 1 Specific wear rate of DLC in water at various temperature with different oxygen.

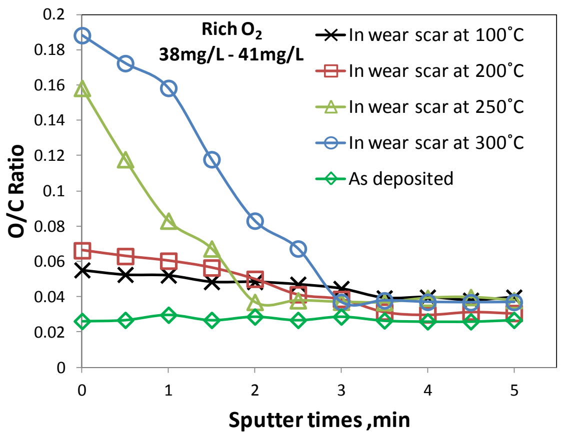

Figure 2 O/C ratio in DLC wear scar for rich dissolved O_2.

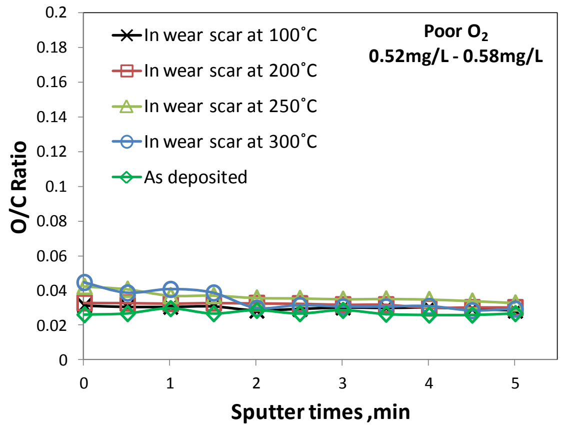

Figure 3 O/C ratio in DLC wear scar for poor dissolved O_2.

4. CONCLUSION

The range of turning parameter obtained from the simulation that can produced dimple structure for A3xx casting Aluminum alloy are cutting speed of 4 – 35 m/min, feed rate of 0.01 – 0.6 mm/rev and depth of cut of 0.01 – 0.05 mm.

5. ACKNOWLEDGEMENT

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6. REFERENCES

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