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A Feasibility Study on the Worn Area Estimation by Measuring a Contact Resistance (I)

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1. Introduction

In order to improve the fretting wear resistance of the nuclear fuel rod with considering the effect of the contacting spring shape, it is necessary to examine the formation procedure of the worn area during the fretting wear experiments with including its shape, size and the debris removal path. This is because the wear volume and the maximum wear depth are dominantly affected by the worn area [1] and the wear resistance of the nuclear fuel rod was dominantly affected by the spring shape rather than the test environment and the contact mode (i.e. impact, sliding, rubbing, etc.). Unfortunately, it is almost impossible to archive the size and shape of the worn area on real-time basis because the contact surfaces are always hidden. If we could measure the worn area properties during fretting wear tests, it enables us to promptly estimate the wear resistance or behavior with various contacting spring shapes.

Generally, fretting wear degradation is generated by the localized plastic deformation, fracture and finally detachment of wear debris. Generally, wear debris easily oxidized by frictional heat, test environment, etc. From the previous studies [2], most of the wear debris was detached from the worn surface in the distilled water condition while the wear debris in the dry condition remained on or adhered to the worn surface. At this time, it is reasonable that the accumulated wear debris on the worn surface is existed in the form of oxide. If small amount of electric current was applied between the contacting surfaces, wear debris could be an obstacle to flow the electric current. This means that the variation of the contact resistance under constant electric current during the fretting wear tests has much information on the formation of the worn area even though the applying current could accelerate the oxidation of the generated wear debris. So, in this study, fretting wear tests have been performed with applying an electric current in room temperature air in order to examine the variation of contact resistance with increasing slip amplitude and fretting cycles. The objective is to verify the relationship between the variation of contact resistance and the worn area characteristics.

2. Experimental Procedure

The spacer grid spring with concave shape are used in this study. A fuel rod specimen was prepared with 50 mm in length by using a commercial Zirconium alloy. All the fretting wear tests were carried out with a normal load of 10 N, a peak-to-valley amplitude of 100, 135 and 170 μm, applying current of 20 mA, fretting cycles of 10^4 ~ $5x10^5$ and at a frequency of 30 Hz in room temperature air. All the measured data (normal and shear load, electric resistance, slip amplitude, etc.) is monitored and recorded on a PC on a real time basis. After the wear experiment, the worn area of the fuel rod specimens was measured an optical microscope (OM).

3. Results and Discussion

3.1 Worn Area Variation

Fig. 1 shows the analysis result of a worn area measurement with increasing fretting cycles that was tested in room temperature air. The measurement procedure of the worn area size was introduced in the previous study in detail [3]. With increasing fretting cycles, the size of worn area also increased. However, it is expected that the size of worn area could be saturated to a certain value due to the limited contact area of the supporting spring. This behavior is quite different when compared with the same experiments except the applying electric current [4]. At this time, the size of the worn area was saturated about $3x10^5$ cycles. So, it is expected that the applying electric current accelerated and weakened the oxidation rate and the agglomeration behavior of the detached wear debris, respectively.

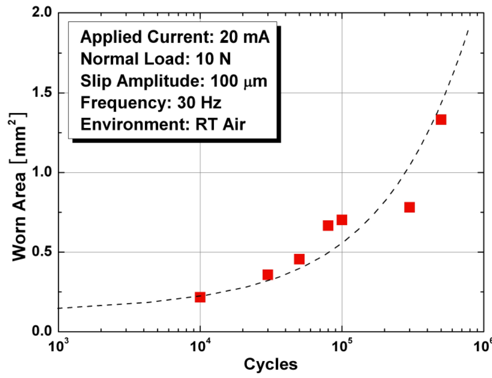

Figure 1. The variation of the worn area size with increasing fretting cycles.

3.2 Contact Resistance

Fig. 2 shows the variation of the contact resistance at the slip amplitude of 100, 135 and 170 μm. It is apparent that the hump cycle (N_h) that could be defined as the rapid increase of the contact resistance at initial stage increased with increasing slip amplitude. This result seems that the large slip amplitude creates the severe plastic deformation on the worn surface and then delays the detachment of the wear debris. However, final wear damages could be accelerated by the large slip amplitude after the generation of wear debris was initiated. As shown in Fig. 2, the initial contact resistance is almost zero and this means the metal-to-metal contact is dominant. Therefore, the stable contact resistance (100 μm) indicates the well developed wear debris layer on the worn surfaces while the fluctuation of the contact resistance indicates the repeated formation and break-out of the wear debris layer.

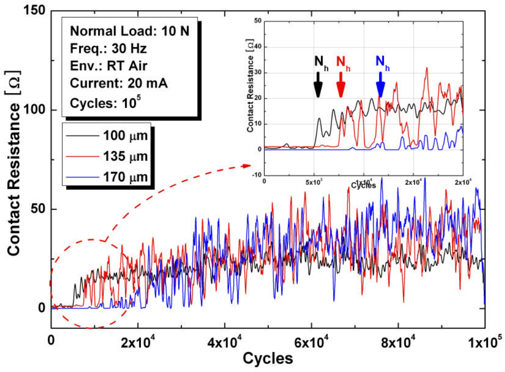

Figure 2. Effect of slip amplitude on the variation of the contact resistance.

3.3 Relationship between Contact Resistance and Worn Area

Fig. 3 shows the relationship between the final contact resistance and the measured worn area size. It is apparent that the contact resistance gradually increased with increasing worn area. It is thought that some deviated data from an estimated curve were originated from the amount of the remained wear debris and which was affected by the alignment between fuel rod and spring specimens. Consequently, it is possible to estimate the worn area by measuring the contact resistance during the fretting wear tests.

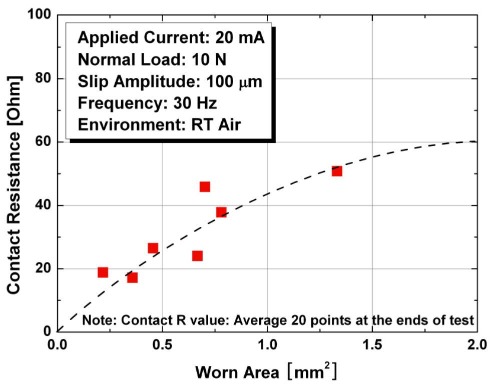

Figure 3. Relationship between the contact resistance and the measured worn area size.

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4. Conclusion

Fretting wear tests have been performed with applying an electric current in room temperature air in order to examine the variation of contact resistance with increasing slip amplitude and fretting cycles. From these experimental results, the following conclusions are drawn.

(1) The applying electric current accelerated the oxidation rate of the detached wear debris.

(2) The stable contact resistance during the fretting wear tests indicates the well developed wear debris layer on the worn surfaces.

(3) From the above results, it is possible to estimate the worn area by measuring the contact resistance during the fretting wear tests.

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