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A Study on the Fretting Wear Behavior and the Variation of the Slip Amplitude with Spacer Grid Springs in Room Temperature Air

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1. Introduction

From the results of the previous studies [1-2], the fretting damage of a nuclear fuel rod was mainly controlled by the supporting spring shape even thought the fretting wear mechanism was also influenced by the test condition such as a normal load, slip amplitude, environment, etc. This is because the debris behavior could be frequently affected by the contact shape of the spacer grid spring between the contacting surfaces. If debris is easily removed from the contacting surfaces, fretting wear damage is accelerated with increasing fretting cycles. Otherwise, wear debris layer was formed by the generated wear debris, which acts as a load bearing layer and prohibit further wear damage. During fretting wear, normal load applied by spacer grid spring is gradually decreased due to the wear progress into the depth direction. This means that the shear force and friction coefficient also changed. Finally, relative slip amplitude between the fuel rod and spacer grid spring could be changed with the characteristics of wear debris behavior during the wear testing.

The previous results [1] about the normal load decrease during fretting wear indicated that the concave spring shape condition showed a rapid load drop when compared with a convex spring shape condition. So, it is concluded that the supporting ability of the convex spring shape is superior to that of the concave spring shape. However, it was not examine the effect of the slip amplitude variation during fretting wear testing. So, the objective of this study is to examine the relationship between the wear behavior and the variation of the slip amplitude under a fretting wear condition.

2. Experimental Procedure

2.1 Specimen

In this study, two kinds of spacer grid springs are used and marked as spring A and B. Spring A is designed to have a concave contour with chamfering treatment at both ends. It was intended that this spring could wrap around the tube specimen in a transverse direction to the contact region. While spring B has a convex contour, so this spring has a line contact with the tube specimen in its axial direction.

2.2 Test Condition

All wear tests were carried out up to 10^7 cycles under a normal load of 10 N, a peak-to-valley amplitude of 50, 80 and 100 μm, and at a frequency of 30 Hz in room temperature air. All the measured data (normal and shear load, slip amplitude, etc.) is monitored and recorded on a PC at a real time basis.

2.3 Wear Evaluation

After the wear experiment, the wear volume/depth and worn area of the fuel rod specimen were measured and calculated by using a 2-D surface roughness tester and an optical microscope (OM), respectively.

3. Results and Discussion

3.1 Variation of Specific Wear Volume

Fig. 1 shows the variation of the specific wear volume (wear volume/fretting cycle, Vs) with increasing slip amplitude. The spring B condition has a relatively smaller wear volume (about 50%) when compared with the spring A condition. The Vs in the both spring conditions gradually increased up to the slip amplitude of 80 μm. However, those were considerably increased at the slip amplitude of 100 μm. This result indicated that the wear behavior should be different or changed with increasing slip amplitude and fretting cycles. In order to verify the difference of the wear mechanism, it is necessary to examine the fretting variables such as a normal load, slip amplitude, etc. during fretting wear testing.

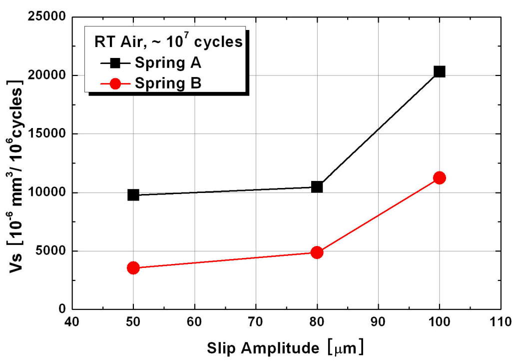

Figure 1. Variation of the specific wear volumes (wear volume/fretting cycles, Vs) with increasing slip amplitude.

Generally, wear damage could be separated to the area expansion and the depth increase. If the area expansion is prohibited by the varying contact condition during fretting cycles, wear damage dominantly progress to the depth direction. Table 1 shows the measurement results of the wear depth (D), worn area size (A) and wear scar length (L). It is found that the wear damage was dominantly progressed by the depth increase in the spring A condition while did by the area expansion in the spring B condition.

Table. 1 The variation of the maximum wear depth (D), the size of the worn area (A) and the wear scar length (L) in room temperature air.

Spring		D [μm]	A [mm^2]	L [mm]
A	50 μm	60.76	5.062	4.251
	80 μm	69.63	7.712	4.344
	100 μm	65.47	7.192	4.344
B	50 μm	24.98	3.425	5.804
	80 μm	33.22	6.075	7.527
	100 μm	55.27	7.521	7.877

3.2 Variation of the Slip Amplitude

Fig. 2 shows the variation of the slip amplitude with increasing fretting cycles at the slip amplitude of 80 and 100 μm. It is apparent that the slip amplitudes of the spring B condition did not changed with increasing fretting cycles even though that was gradually increased at 100 μm. However, in the spring A condition, the slip amplitude were rapidly increased at the beginning of the fretting cycles and then decreased at a specific fretting cycle, which depends on the applied slip amplitude (Fig. 2 (a)). This behavior could explain the relatively high Vs and maximum wear depth in the spring A condition. The spring A has sharp corners with chamfering treatment at both ends to the axial direction of the nuclear fuel rod. With increasing fretting cycles, the wear depth gradually increased and then the slip amplitude also increased. When the increased slip amplitude was prohibited by the contacting surfaces between the nuclear fuel rod and both of the spring ends at a specific depth, the slip amplitude rapidly drop to the initially applied slip amplitude. At this time, wear could be dominantly progress into the depth direction. Consequently, the higher wear volume and maximum wear depth in the spring A condition are due to the localized wear that is induced by the restricted slip amplitude.

4. Conclusion

In order to examine the relationship between the wear behavior and the variation of the slip amplitude, fretting wear tests have been performed using two types of grid springs in room temperature air. The results indicated that the slip amplitude of the spring B is almost constant with increasing fretting cycles while that of the spring A is varied with irregularly. The severe wear of the spring A condition is due to the localized wear that is induced by the restricted slip amplitude.

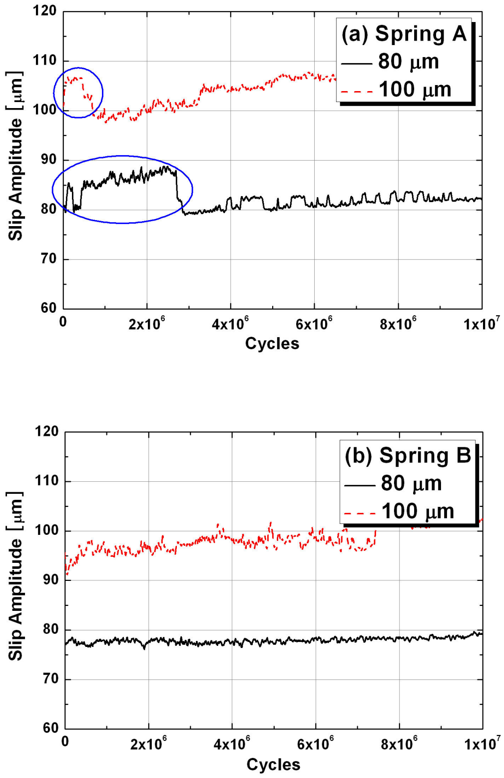

Figure 2. Variation of slip amplitude with increasing fretting cycles; Note that a rapid drop of the applied slip amplitude was occurred in the spring A condition.

ACKNOWLEDGEMENTS

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