Transactions of the Korean Nuclear Society Spring Meeting
Jeju, Korea, May 10-11, 2007

A Feasibility Study of a Wear Depth Estimation by using a Wear Scar Analysis (II)

Young-Ho Lee[†] , Hyung-Kyu Kim
Korea Atomic Energy Research Institute, 1045 Daedeokdaero, Yuseong, Daejeon, 305-353, Korea

1. Introduction

From previous study [1], it is possible to evaluate and estimate the wear depth by using a wear scar analysis. To summarize, the wear depth distribution was dominantly affected by the spring shape rather than the test environment and the contacting mode (i.e. impact, sliding, rubbing, etc.). This result indicates that a wear volume and a wear depth distribution could be estimated by analyzing the wear scar of each springs' shape. Generally, a governing factor for determining a wear-resistant spring shape is only concerned about a wear depth behavior regardless of a high wear volume and a wear scar size. This is because the wall opening of the fuel rod during a PWR plant operation is directly related to a release of a radioactive fission gas.

When considering the development of a long-term operation and a high burn-up fuel, the wear-resistance of each developed springs' shape should be evaluated even though a fuel rod was not perforated during a PWR operating period. In other words, it is difficult to decide that a developed spring has a wear-resistance even though severe wear damage is not appeared during the PWR operation. In order to verify the wear resistance of an improved commercial grid spring/dimple, it is reasonable to evaluate the wear scars in the spent fuel rod. Due to a high level radiation and an enormous expense, however, there are very few methods to confirm whether the wear-resistance is improved in the PWR operating conditions. In this study, fretting wear tests have been performed in room temperature air and water to develop an applicable method for estimating a wear depth by using an external surface photograph of the spent fuel rod. The objective of this study is to examine the relationship between the wear scar characteristics and the wear depth distributions with three kinds of springs.

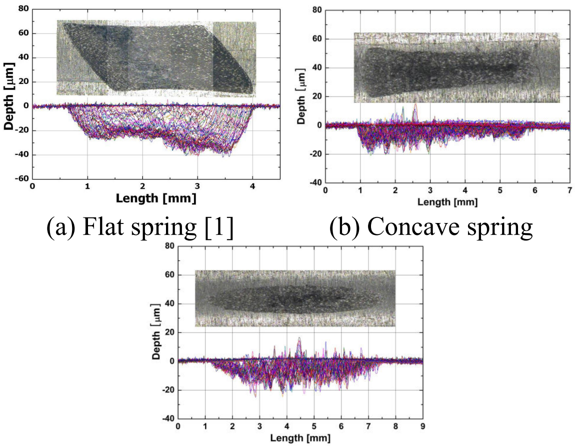
2. Experimental Procedure

Three specific spacer grid springs with flat, concave and convex 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 up to 10^5 cycles under a normal load of 10 N, a peak-to-valley amplitude of 10, 30, 50, 80 and 100 μm, and at a frequency of 30 Hz in room temperature air and water. All the measured data (normal and shear load, slip amplitude, etc.) is monitored and recorded on a PC on a real time basis. After the wear experiment, the wear volume/depth and worn area of the fuel rod specimens were measured and calculated by using a 2-D surface profilometer and an optical microscope (OM), respectively.

3. Results and Discussion

3.1 Wear Scar and Depth Profile

Fig. 1 shows a typical result of the wear scar that was tested in room temperature air by using a surface profilometer and an OM. Generally, it is difficult to obtain linear or parabolic relationship between a maximum wear depth and wear scar characteristics (i.e. wear scar size, shape, etc.). This is due to a localized wear that was frequently appeared in the early stage of the fretting wear tests. However, it is apparent that a maximum wear depth under the worn surface is comparable with an average wear depth (i.e. wear volume / wear scar size). In other words, three spring shapes in this study did not show a localized wear with increasing slip amplitude and fretting cycles. It enables to estimate the maximum wear depth by analyzing the relationship between a maximum wear depth and a wear scar size.



(a) Flat spring [1] (b) Concave spring

(c) Convex spring

Figure 1. The typical results of the wear scar at each spring shape.

3.2 Wear Scar Size

Generally, the wear scar size (A_t) could be divided into a worn area (A_w) and a protruded area (A_p) [1-3]. For a procedure of a volume measurement by using a surface profilometer, a wear volume could be defined as an amount of the removed materials under a fuel rods' surface. Therefore, A_w could be calculated easily by a summation of the unit area in which a surface profile has a negative value. It was found in the previous study

[1] that the ratio of A_w to A_t of the flat spring has a nearly constant regardless of the size of the A_t if a wear scar size reaches above 3 mm^2. Fig. 2 shows the variation of the worn are size (A_w) with increasing the wear scar size (A_t) at the concave and convex spring shapes. This result is exactly the same as the result of the flat spring experiment.

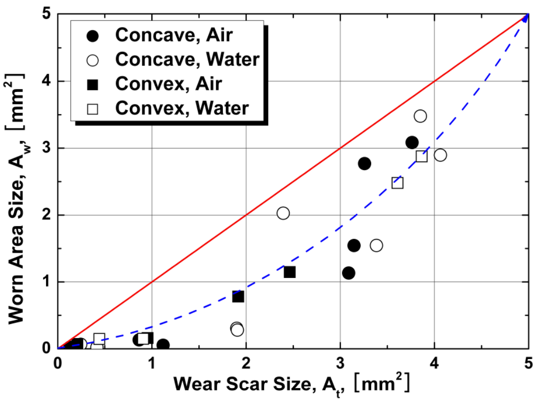


Figure 2. Variation of the worn area size (A_w) with increasing the wear scar size (A_t).

3.3 Data Base for Wear Depth Estimation

Fig. 3 shows the relationship between the maximum wear depth and the A_w in the two spring shape (i.e. concave and convex springs). It is apparent that the variation of the maximum wear depth could be estimated by a variation of the A_w. Consequently, this study gives evidence for the possibility of the wear depth estimation by analyzing the wear scar of various springs' shapes. Further study on the wear scar observation of the spent fuel rod is now in progress.

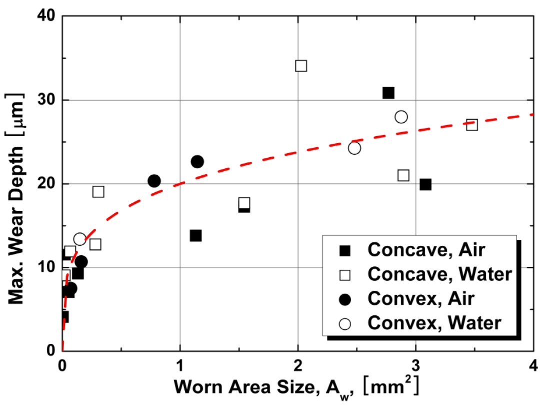


Figure 3. Variation of the maximum wear depth with increasing the worn area size (A_w).

4. Conclusion

From the above results, three spring shapes in this study did not show a localized wear with increasing slip amplitude and fretting cycles. Also, the variation of the maximum wear depth could be estimated by a variation of the A_w even though they did not have a linear relation contrary to our expectations. This study gives evidence for the possibility of the wear depth estimation by analyzing the wear scar of various springs' shapes.

ACKNOWLEDGEMENTS

This study has been carried out under the Nuclear R&D Program by Ministry of Science and Technology in Korea.

REFERENCES

[1] Y.-H. Lee, H.-K. Kim, A Feasibility Study of a Wear Depth Estimation by using a Wear Scar Analysis (I), *Proceedings of KNS Autumn Meeting* (2006).

[2] Y.-H. Lee, H.-K. Kim, Comparison of a Supporting Ability of Spacer Grid Springs under Fretting Wear Condition in Room Temperature Air, *Proceedings of KNS Autumn Meeting* (2005).

[3] H.-K. Kim, Y.-H. Lee, Influence of contact shape and supporting condition on tube fretting wear, *Wear* 255 (2003) 1183-1197.