Fretting Wear Behavior of Cr-coated Fuel Rod for Accident-Tolerant Fuel in Flowing Fluid

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1. Introduction

Accident-Tolerant Fuel (ATF) could be defined as new fuel/cladding system with enhanced accident tolerant to loss of active cooling in the core for a considerably longer time period under severe accidents while maintaining or improving the fuel performance during normal operations [1-3]. Recently, new fuel cladding candidates by using surface modification techniques with corrosion-resistant alloying elements are under developing in KAERI. In this study, the fretting wear behaviors of one of these candidates were experimentally investigated in a flowing fluid condition. This is because the grid-to-rod fretting (GTRF) is attributed to flow-induced vibration (FIV) and is one of the main degradation mechanisms of PWR fuel assemblies. This experimental result is described focusing the reliability of Cr-coated layer on Zr-based fuel cladding in fretting wear condition under flowing fluid with 5 m/s of flow rate.

2. Methods and Results

A GTRF simulator under FIV condition in room temperature (i.e., FivWearRT) has been developed in previous study as shown in Fig.1 [4]. This facility consists of a water pump, a rectangular housing with a 1x1 grid cell, six displacement transducers for measuring rod vibration and displacement, etc. In this test, Cr-coated fuel rod is installed in rectangular flow channel and a spacer grid spring that was developed in KAERI also installed with 1x1 cell. At this time, grid-to-rod gap between fuel rod and spacer grid was set to 0.1~0.25 mm. Flow rate was fixed to 5 m/s in order to compare the effect of clearance on the fuel rod vibration and fretting wear behavior of the Cr-coated cladding candidate.

2.1 Rod Vibration Behavior

Fig. 2 shows typical results of rod traces during the GRTF tests in both 0.1 and 0.25 mm clearances under the condition of 5 m/s of flow rate. It is apparent that center point of rod trace was gradually moved to a specific direction, which results in a localized wear scar of fuel rod. . Also, the shape and center deflection of the overlapped rod trajectories gradually changed to distorted circular and continuously shifted to certain directions, respectively.

Fig. 1. Schematic view of FivWearRT used in this study. (Grid-to-rod fretting simulator for RT)

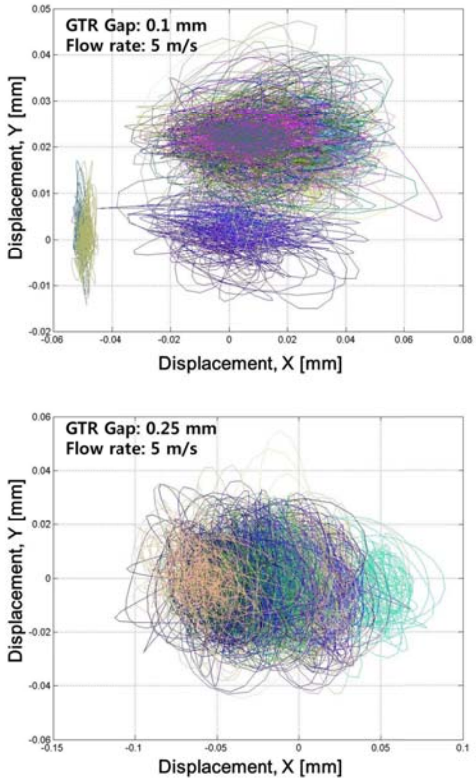

Fig. 2. Typical rod traces of 5 m/s of flow rate with variation of GTR gap.

2.2 Wear Measurement Results

Fig. 3 shows the measurement results of the wear volume with the variation GTR gap. As expected, rod wear volume at each grid spring and dimple (i.e. total wear volume) is dramatically increased with GTR gap even though each wear scar is not evenly distributed within a 1x1 grid cell. When considered a random vibration of fuel rod within a 1x1 grid cell, a rapid increase at dimple specimen is expected due to both its high stiffness when compared to that of spring and severe localized wear, which corresponding to rod trace results. From the results of OM and SEM, Cr-coated layers on Zr-based alloy show relatively small wear scar because Cr particles adhered to fuel rod surface could accommodate random impacting force during FIV environment without any significant wear degradation.

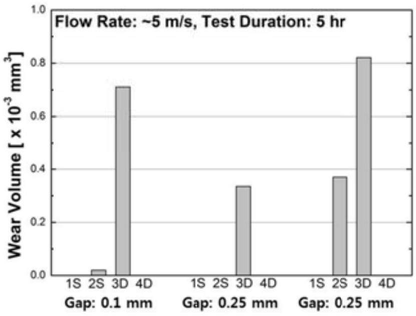

Fig. 3. Wear measurement results with GTR gap.

3. Summary

Fretting wear tests of the Cr-coated fuel cladding candidate have been performed in the flowing fluid condition in order to verify the reliability of Cr-coated layer on Zirconium-based fuel cladding. From these experimental results, Cr-coated layers on Zr-based alloy show relatively small wear scar because Cr particles could accommodate impact force during the random vibration without any significant wear degradation.

REFERENCES

[1] S.J. Zinkle, K.A. Terrani, J.C. Gehin, L.J. Ott, L.L. Snead, Accident Tolerant Fuels for LWRs: A Perspective, Journal of Nuclear Materials, Vol.448, p. 374, 2014.
[2] L.J. Ott, K.R. Robb, D. Wang, Preliminary Assessment of Accident-Tolerant Fuels on LWR Performance During Normal Operation and Under DB and BDB accident Conditions, Journal of Nuclear Materials, Vol.448, p.520, 2014.
[3] J. Carmack, F. Goldner, S.M. Bragg-Sittona, L.L. Snead, in: Proceedings of LWR Fuel Performance Meetings, ANS, Charlotte, NC, 2013, Paper 8547.
[4] Y.-H. Lee, H.-K. Kim, Fretting wear behavior of a nuclear fuel rod under a simulated primary coolant condition, Wear, Vol. 301, p. 569, 2013.