Experimental Simulation of Flow-Induced Vibration for Developing a Grid-to-Rod Fretting Model

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1. Introduction

A grid-to-rod fretting (GTRF) is the predominant fuel failure mechanism in U.S. pressurized water reactors, accounting for more than 70% of failures since 2000, or about 40 failed assemblies per year [1]. The Consortium for Advanced Simulation of LWR (CASL) was launched to develop advanced modeling and simulation capabilities for LWRs and one of the challenge problems is to predict the GTRF because improved understanding of GTRF can help to reduce capital and operating costs per unit energy by allowing power uprates and increased cycle length, and to reduce the volume of generated waste by allowing higher fuel burn-up [2]. However, it is noted that wear cannot be analytically predicted at this time [3]. This is because in reactor GTRF will depend on various parameters, including the cross flows signature, which is plant dependant and difficult to quantity.

However, the results of full core analysis and efforts to increase fretting margin cannot be considered as proven solutions because the applicability of these results are limited to a specific plants. For example, GTRF margin was calculated based on the fuel reliabilities program of operating power plants. But they have not accumulated sufficient experience under challenging operating conditions to be considered proven solutions. In addition, GTRF behaviors were significantly differed according to the plant types, operating condition and fuel types. So, analytical methods to resolve GTRF degradations are considered as difficult procedures for actual application. One of the most important problems is that it is difficult to evaluate the GTRF resistance of new spacer grid under operating power plant condition. Up to now, as a consequence, compliance with the fretting wear limit (typically 10% of the cladding thickness) is checked a posteriori, through post-irradiation examination [3]. Therefore, in this study, rod simulation method for determining GTRF resistance of new spacer grid was proposed with a specially designed wear tester. This simulator enables us to examine the spacer grid shape effect under relatively short development period. In addition, for developing GTRF model, flow-induced vibration (FIV) was measured with different major variables such as GTR clearance, flow rate, etc.

2. Methods and Results

2.1 Tester and Experimental Conditions

A FIV-wear simulator has been specially designed to examine GTRF by FIV, and a schematic view is provided in Fig. 1. A fuel rod is randomly vibrated by a fluid flow from bottom to top, which simulates the primary coolant in a nuclear reactor core. Also, a GTR clearance is adjustable from 0 to 1 mm for considering the spring relaxation of a spacer grid by both thermal relaxation and neutron radiation damages. In this study, GTRF simulations at room temperature have been performed with flow rates of 3, 5, and 7 m/s and GTR clearance of 0.1 and 0.25mm up to a testing time of 1, 3, and 5 hours. During the tests, rod trajectories at the upper region of the spacer grid specimen was monitored and stored on a real-time basis using LabVIEW®.

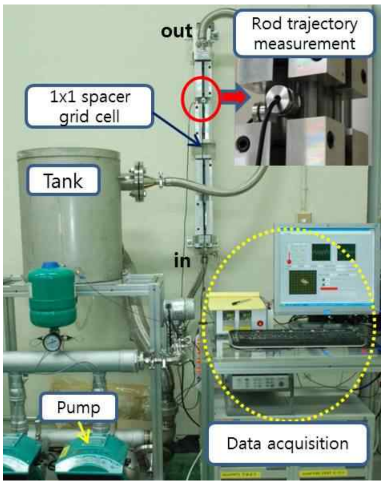

Fig. 1. Schematic view of FIV-wear simulator used in this study.

2.2 FIV Simulation Results

Fig. 2 shows a measured size of in the rod trajectory with increasing flow rate in a GTR gap of 0.1 mm in a 1x1 grid cell. It is apparent that the overlapped rod trajectories show a circular shape, and their dimensions are proportional to the applied flow rate condition. Up to a 3 m/s flow rate, however, severe rod vibrations are not detected at any significant amount. Thus, negligible wear scar at a flow rate of 3 m/s is due to sparse contact possibilities during the fretting wear tests. So, only scratch on fuel rod specimen was detected after the FIV wear experiments. Above a 4 m/s flow rate, however, the extent of the rod trajectory is rapidly increased and irregular peak values of rod displacement are initiated at each spring and dimple position. When considering a grid to rod gap of 0.1 mm, these irregular values are expected to generate from the random behavior of a fuel rod after the contacts between the rod and grid spring and/or dimple.

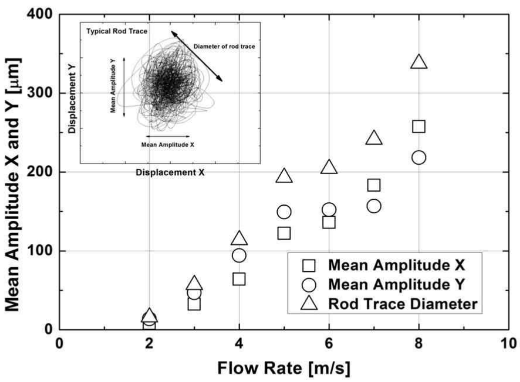

Fig. 2. Variation of rod trajectory size with increasing flow rate.

3. Conclusions and Further Study

Fretting wear tests of nuclear fuel rods (i.e. grid-to-rod fretting) have been performed to examine the flow rate effect by using a specially designed test section with a simulated primary coolant. Based on above results, developed FIV-wear simulator could be effective to examine the spacer grid shape effect with short development period. Further study will be discussed on the GTR clearance effect with various spacer grid shapes.

ACKNOWLEDGEMENT

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