Transactions of the Korean Nuclear Society Autumn Meeting
Gyeongju, Korea, October 29-30, 2015

Test Methodology of Reproducing Fuel Rod Failure by Debris Fretting Wear

Oh Joon Kwon*, Nam Gyu Park, Jae Ik Kim
KEPCO NF, Daedeok-daero 989 beon-gil, Yuseong-gu, Daejeon
**Corresponding author: ojkwon@knfc.co.kr*

1. Introduction

Debris fretting is one of the most common cause of the nuclear fuel rod failure. Even the most of the nuclear fuels has debris protection system, debris still cause fuel rod failure. From 1994 to 2006, debris fretting failure is around 11% of the total fuel failure [1]. In 2006-2010, the portion of debris rises to over 13% [2]. The total number of fuel rods failure is decreasing, but the portion of the debris fretting wear is growing with time. Therefore reproducing and identifying the mechanism of fuel rod failure by debris fretting wear is needed to improve reliability of the nuclear fuel. To reproduce the fuel rod wear by debris, hydraulic condition for debris fretting is carefully selected. The results show that the fuel rods can be worn out by debris in short time.

2. Methods and Results

Test equipment, specimens and results are described

2.1 Test Equipment

The purpose of this test is to reproduce the debris vibration by hydraulic influence. To observe the movement of debris, the test geometry is needed to be small and the housing should be transparent. Since debris filtering effectiveness test has similar procedure and requirements [3], this debris fretting test was following the general conditions of debris filtering effectiveness test. The test equipment is composed by pump, control inverter, flow meter, housing, flexible pipes, water tank and valves (Fig. 1). The capacity of the pump is about 9.5 kg/s and the cross section size of the housing is 3.9 cm.

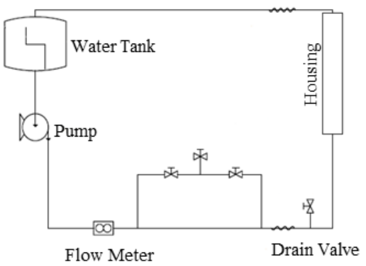
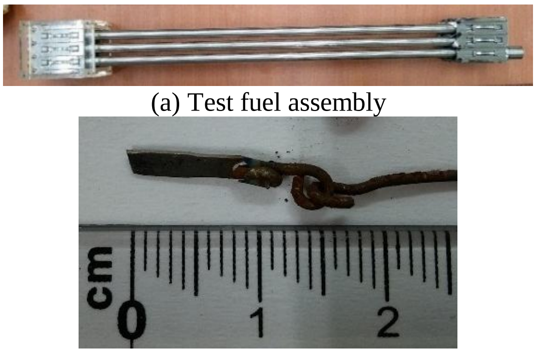


Fig. 1. P&ID of small scale hydraulic test equipment.

2.2 Test Specimens

Since debris is a bluff body, periodic motion of debris can be archived by periodic oscillating flow conditions. Mixing vanes are a common source of swirling flow which can be considered as an oscillating flow [4, 5]. Mid grid was used to generate oscillating flow in this test. The test fuel assembly is 3×3 array with 50 cm length. Fig. 2 (a) shows the shape of test assembly.

Debris specimens were selected to be a part of nuclear fuel component which is a portion of outer strap of protective grid, inner spring of bottom grid and inner spring of mid grid. Protective grid and bottom grid are made of inconel-718, and mid grid is made of zirconium Alloy which is a material of fuel rod cladding. To give degrees of freedom of motion, a simple linkage was installed. Fig. 2(b) shows the shape of debris specimen.



(a) Test fuel assembly

(b) Debris specimens

Fig. 2. Test specimens for debris fretting wear test

2.3 Test Setting

Debris specimens were placed on the center of split vane which is just above a weld nugget. Installation of the debris specimens is shown in Fig. 3. Flow velocity was 4.8 m/s in rod bundle, temperature was 43°C and test duration was 75 hours.

Fig. 3. Installation of debris specimens on mid grid.

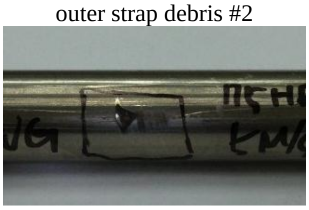
2.4 Test Results

Four fretting wear marks out of twelve possible locations were observed. As shown in Fig. 4, the amount of wear is large enough to be detected by visual inspection without any equipment. The wear volume and depth produced by p-grid debris is greater than that of other debris. Table I shows this tendency clearly. Fig. 4 (a) and (b) is a wear by same debris, but the volume is largely different. On the other hand, depth is similar between these two wear marks. The maximum wear depth is 0.358 mm which is 68% of the fuel rod cladding thickness.

(a) Fretting wear by P-grid outer strap debris #1

(b) Fretting wear by P-grid outer strap debris #2

(c) Fretting wear by bottom grid inner spring debris



(d) Fretting wear by mid grid inner spring debris

Fig. 4. The shape of each debris fretting wear

Table I: Wear Volume and Depth
(scanned by TRIMOS 3D Scanner)

	Wear Volume (mm^3)	Wear Depth (mm)
P-Grid #1	1.705	0.358
P-Grid #2	0.602	0.320
BG spring	0.139	0.079
MG spring	0.136	0.132

3. Conclusions

A test was conducted with simple debris to reproduce debris fretting wear. 68% of fuel rod cladding thickness is worn out by Inconel debris in 75 hours. The test result shows that a simple link system is useful to accommodate debris oscillation, and mid grid mixing vanes could be a source of debris forcing. Additional tests will be conducted with various debris such as wire brush, metal chip, etc which are suspected to generate actual debris fretting wear in future works.

REFERENCES

[1] Review of Fuel Failures in Water Cooled Reactors, IAEA, NF-T-2.1, Vienna, 2010

[2] V. Onufriev, Results of the IAEA Study of Fuel Failures in Water Cooled Reactors in 2006-2010, 2012 IAEA TWGFPT Annual Meeting, Vienna, 2012

[3] Technique Development for Debris Filter Testing Standards, EPRI, Palo Alto, CA: 2015. 300200520.

[4] M.V. Holloway, D.E. Beasley, M.E. Conner, Investigation of Swirling Flow in Rod Bundle Subchannels Using Computational Fluid Dynamics, Proceedings of International Conference on Nuclear Engineering(ICONE14-89068), July 17-20, 2006, Miami, Florida, USA

[5] M.E. Conner, E.E.D-Ontiveros, Y.A. Hassan, Hydraulic Benchmark Data for PWR Mixing Vane Grid, The 14th International Topical Meeting on Nuclear Reactor Thermal Hydraulics (NURETH-14), September 25-29, 2011, Toronto, Canada