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The Post-irradiation Test of the Large Grain UO_2 Pellets

Dae Ho Kim, Jae Geon Bang, Yong Sik Yang, Sun Ki Kim, Yong Bum Chun, Kun Woo Song
P. O. Box 150, Yuseong, Daejeon, Korea, 305-600, Korea Atomic Energy Research Institute
kdh@kaeri.re.kr

1. Introduction

The 1st irradiation test of a large grain UO_2 pellet was completed in July of 2005[1,2] The purpose of irradiation test was to confirm the in-pile performance of a large grain UO_2 pellet which has been developed for a high burnup PWR fuel. The large grain pellets were inserted into the non-instrumented test rig and loaded into the OR-4 hole at HANARO.

As can be seen in figure 1, the test rig has two clusters(upper and lower) and each cluster is composed of three test rods. The three rods of upper and lower clusters contains different grain size pellet, 8 ㎛, 15 ㎛ and 23 ㎛ respectively and five pellets were inserted per rod. The target burnup of irradiation test was planned up to 70MWd/kgU but, the 1st test was completed at 35MWd/kgU. Three rods of the upper cluster were withdrawn from the test rig and transported to PIEF for post irradiation examination. Three new rods, which are identical to the removed rods, were inserted into the upper cluster and the test rig was re-assembled. In February of 2006, the test rig was reloaded into the HANARO and the irradiation test will be continued until the target burnup.

A calculated average burnup of the upper and lower cluster rods are 33.6 and 37.4MWd/kgU respectively and the cumulative effective full power days was determined as 601.02 days.

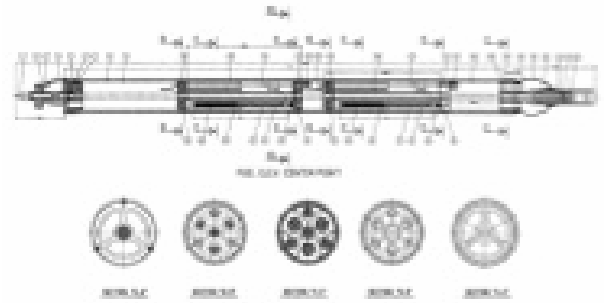

Fig 1. Schematic drawing of the test rig[3,4]

2. Test rods and PIE results

2.1 Characteristics of test rods and irradiation history

The three rods which were transported to PIEF have and identical characteristics and dimensions except for pellet grain size. Detailed pellet fabrication and rod manufacturing information is summarized in reference[2] and Table 1 shows the characteristics of the test rod.

Table 1. Characterization of the upper test fuel rods

Parameter	Description	Grain size	Amounts(Pellet)
Test rod 1	STD Commercial Pellet	8 ㎛	5ea
Test rod 2	Large Grain Pellet	15 ㎛	"
Test rod 3	Annealed Pellet	23 ㎛	"

The average LHGR and EFPD of the three rods were estimated at about 315.5W/cm and 601.02 respectively. The maximum LHGR was reached up to 400W/cm at the beginning of the test and the test power decreased gradually.(Fig. 2)

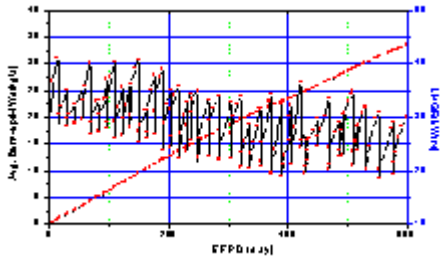

Fig 2. Average burnup and LHGR for test rod

2.2 PIE results

For the large grain UO2 pellet performance evaluation, a post irradiation examination has been performed at PIEF. In the non-destructive test, an axial gamma scanning and ECT were performed for a measurement of the axial burnup profile and oxide thickness. After the NDT, a fission gas release measurement and detailed destructive test were performed.

2.2.1 Gamma Scanning

In figure 3, the axial gamma scanning results are shown and a relatively flat axial burnup distribution can be found.

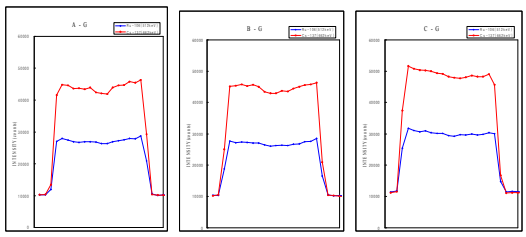

Fig 3. Cs & Ru Gamma scanning of radial section

2.2.2 Density

The as-fabricated pellet densities are 10.5, 10.52 and 10.51 for rods 1, 2 and 3 respectively. After the sample preparation, the density changes were measured by the immersion method. The density data shows that the pellet density decreases by about 1.57%, 0.49% and 2.5% for rods 1, 2 and 3 respectively.

2.2.2 Oxide layer

Figure 4 shows an oxide thickness profile of rod 3. The oxide thickness of test rods 1, 2 and 3 is below 15 microns which is a very thin oxide thickness when compared with a commercial reactor. These low oxidation is concluded to be a relatively low coolant temperature during a irradiation.

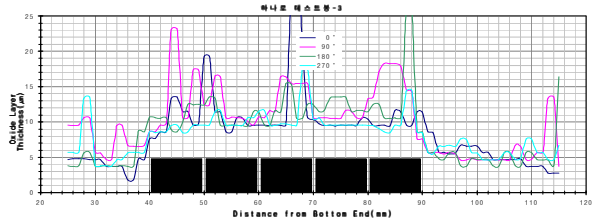

Fig 4. Oxide layer thickness of the test rod 3

2.2.4 Fission Gas Release

The released fission gases were collected by a rod puncturing and a chemical analysis was performed for the component analysis. In table 2, the chemical analysis results are summarized. Detailed analysis for a fission gas release behavior such as the amount of generated and released gases will be performed soon.

Table 2. Chemical analysis of collected fission gas

Parameter	FGPressure (mbar)	Volume%				
		Kr	Xe	O_2	Ar	He
Test rod 1	180	0.96	6.35	1.18	0.09	88.10
Test rod 2	184	0.73	4.67	1.05	0.04	90.36
Test rod 3	189	0.32	1.74	1.08	0.06	89.23

2.2.5 Others

To investigate the microstructural change of a large grain UO_2 pellet such as a grain size change and pore distribution, optical microscopy examinations were performed. Figure 5 shows the optical microscopy results. Very fine and small bubbles were found at the outer region of a pellet but its density differed with the grain size.

As mentioned above, the coolant temperature of each rod is relatively very low(~40℃). So, it seems that the fuel surface temperature was very low during irradiation. This average pellet burnup of test rods is too low to show a rim microstructure formation. But a very low fuel temperature can lead to a rim microstructure formation at very limited local position. The SEM and WDS analyses will be required for a precise conclusion.

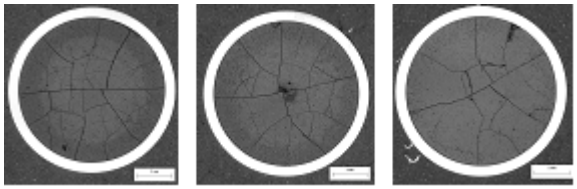

Fig 4. Macro image of the irradiated pellet cross section

3. Summary

The 1st irradiation test of a large grain UO2 pellet was completed. After the three rods were changed, the test rig was re-assembled and an additional irradiation test has been started for a target burnup of 70MWd/kgU. Removed three rods which have a similar burnup (~35MWd/kgU) were transported to PIEF for post irradiation examinations. After the NDT such as a axial gamma scanning and oxide thickness measurement, detailed DT tests have been started such as a fission gas collection and optical microscopy examination. Further tests, SEM and WDS analyses, will be started to investigate and confirm the performance of a large grain UO_2 pellet.

REFERENCES

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