Swelling Behavior of Irradiated Dual Cooled Annular Fuel Pellet

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1. Introduction

Dual cooled annular fuel has many advantages in terms of fuel temperature and increased thermal margin. Although there are many advantages of dual cooled annular fuel, a 'heat split' is the most important issue which is closely related to the gap width change during irradiation[1].

Among various factors of gap width change, pellet densification and swelling are our major concern. UO_2 pellet densification and swelling are well-known phenomena and various models have been published to predict pellet dimensional change during irradiation. But there are some limitations to applying the proposed models to an annular fuel pellet due to the very low temperature and hollow cylindrical characteristics[2].

At current stage, very high initial density pellet was adopted for dual cooled annular fuel. Therefore, in-reactor densification can be ignored or very small volume change is expected. But, swelling is not controllable factor so we planned irradiation test to confirm swelling behavior of annular pellet.

2. Low Temperature Swelling Behavior

It is generally known that swelling of UO_2 pellet is athermal phenomena. However, there were some studies to confirm a temperature effect on swelling and showed noticeable results.

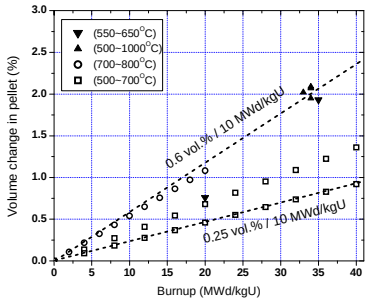

Fig. 1 Low temperature swelling data[3]

Figure 1 shows a measured swelling data which is irradiated at low temperature. Temperature range of showed data is 450~700℃ and measured swelling rate is 0.25~0.6 vol% per 10MWd/kgU. In case of commercial PWR condition, measured swelling rate is about 0.8~1.0 vol% per 10MWd/kgU and it is probable that the different swelling rates might have come from the test temperature.

Especially, from a gaseous swelling point of view, gaseous swelling rate of annular pellet could be lower than that of commercial PWR UO_2 pellet because the contribution of intragranular fission gas bubbles would be smaller due to the reduced number of gas bubbles.

2. Irradiation Test and PIE

Six test rods were irradiated up to a maximum local burnup of about 10.9 MWd/kgU at the research reactor HANARO. Detailed rod design parameters are summarized in Table 1 and power history during test is shown in Fig. 2.

Table 1. Design parameters of test rods

Design parameters	Value
Rod outer diameter	15.9 mm
Rod inner diameter	9 mm
Cladding thickness	0.57mm(in)/0.57mm(out)
Gap width	0.07mm(in)/0.07mm(out)
Stack height	51mm
UO2 pellet density	93/95.5/98 %TD
Enrichment	2.67wt%

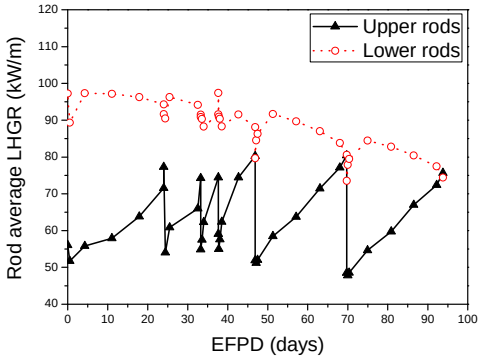

Fig. 2 Power history of the test rods

Pellet temperature during irradiation test was obtained from calculation results of DUOS code[4]. Pellet average temperature was about 500~600℃.

After the irradiation test, the test rods were transferred to PIEF(Post Irradiation Examination Facility) and detailed examinations were performed

The solid swelling rate is obtained by density measurement before and after irradiation test.

Table 2 shows the result of density measurement before and after the irradiation test.

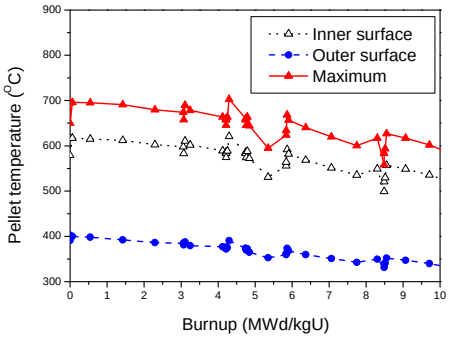

Fig. 3 Temperature of annular pellet during the test

Table 2. Results of density measurement

Specimen	Density [%TD]		Density Change [%TD]
	before	after	
1	98.0	97.61	-0.39
2	97.9	97.53	-0.37
3	98.0	97.60	-0.40
4	98.1	97.62	-0.48

Although, there are a number pellets in six test rods, only four high initial density pellet was considered. Because low initial density of other pellet, swelling rate is diminished by densification and swelling rate can't be decided.

Before the irradiation test, densities of annular pellets are about 98%TD. But, after irradiation, density decreased to about 97.53~97.92%TD. Due to high initial density, densification could be ignored in this test and all density changes were result of swelling. Based on these results, swelling rate of dual cooled annular fuel pellet is decided to 0.41vol% per 10MWd/kgU.

Figure 4 shows the combined swelling rate with other low temperature swelling data. Our test result shows good agreement with other ones.

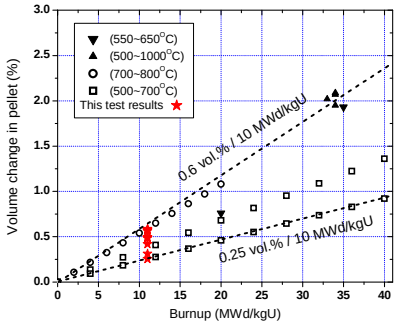

Fig. 4 Low temperature swelling rate

4. Results and Discussion

Irradiation test and PIE were performed of dual cooled annular fuel pellet up to burnup of 10MWd/kgU. Based on density measurement, swelling rate of annular fuel pellet was obtained. Measured swelling rate is 0.41 %TD per 10MWD/kgU and shows good agreement with previous test results which were performed by other researcher's.

However, to decide exact swelling rate of annular pellet under low temperature condition, additional irradiation test is progressing. Target burnup of new test is about 30MWd/kgU and could be confirm an exact swelling rate of dual cooled annular fuel pellet.

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