Evaluation of the Centerline Temperature for the Sixth Irradiation Test of the DUPIC Fuel

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1. Introduction

The DUPIC fuel is fabricated by using spent PWR fuel with the OREOX process[1] in which most of the fission products remain without some volatile elements. Thus, the DUPIC fuel provides a strong proliferation resistance and has an efficiency of a fuel utilization and waste treatment by reusing the spent PWR fuel. To evaluate the fuel performance of the DUPIC fuel, six irradiation tests have been performed in the HANARO reactor. Recently, the sixth irradiation test was successfully done for a total of three cycles (about 69 effective full power days) from March 2006 to July 2006. The most important characteristics of the sixth irradiation test of the DUPIC fuel are the remote-instrumented test of the pellet centerline temperature by extending the technology of the fifth irradiation test. This paper reports on some results of the analysis results for the fuel centerline temperature by using the results of the sixth irradiation test of the DUPIC fuel.

2. Methods and Results

For the analysis of the pellet centerline temperature, two codes were considered, FRAPCON[2] and KAOS[3]. The KAOS code system is being developed for the DUPIC fuel performance by considering the models of the DUPIC fuel and the experimental results based on the previous code systems. The summary of the sixth irradiation test for the fuel performance is given in Table I.

There are several errors which should be considered. The linear power of the fuel rod comes from the analysis code system of the HANARO core because the linear power was not measured during the test. For the linear power, about a 10% variation is assumed including the axial distribution. Fig. 1 shows the linear power change during the sixth irradiation test of the DUPIC fuel. It was found that there were abrupt power changes during a short time and it was expected that the robustness of the pellet was affected by the steep power variation. For a simplicity, the linear power changes are broadly assumed to be constant.

Fig. 2 shows the results of the fuel performance analysis based on the given linear power change. The maximum temperature was measured at about 1400 ^{o}C at the end of the first cycle. Therefore, the pellet centerline temperature without a hole is estimated to be over 1600 ^{o}C. This high temperature is strongly dependent on the linear power rate in the HARAO irradiation hole. However, the estimated pellet centerline temperature exhibits a slightly higher results than the measured temperatures after the first irradiation period. This behavior is also found in the previous fifth irradiation test.[4]. To modify this overestimation in the fuel performance code, a correction of the gap conductance is suggested in the previous study. The main reason for this correction is the pellet relocation and crack due to abrupt power changes. Some cracks in the pellet were found in the optical microscopy of the fifth irradiation fuel. With these assumptions, the gap conductance(h_g) is modified with the following correction as:

$$h_{gc} = h_g \times \exp(\alpha \cdot Bu) \ , \qquad (1)$$

where α is chosen as 1.5 for this study and Bu is a burnup (GWd/tHM).

From Fig. 3, the corrected results for the pellet centerline temperature become lower than the uncorrected results, but there are still discrepancies when compared to the measured data at the end of the second cycle. At the end of the second cycle, the measured temperature is 924 ^{o}C, while the calculated temperatures are 1582 ^{o}C, 1442 ^{o}C, for the uncorrected and corrected results, respectively. This significant difference may result from another mechanical problem including a radiation damage of the connection part of the thermocouple. A detailed investigation will be presented later about this issue. And the post-irradiation test of the sixth irradiation test is being processed. To provide a more reliable correction model for the above difference, more tests and data should be studied from the previous tests data and literatures. If necessary, more additional irradiation and post-irradiation tests should be followed to obtain more convincing results.

TABLE I. Summary Data for the Sixth Irradiation Test of the DUPIC Fuel

Parameter	Value
Coolant temperature	313 K
Coolant pressure	0.4 MPa
Fast flux spectrum	2.40 E13 #/cm^2-sec

Diametral gap	0.314 mm
Stack height	5.8 cm
Cladding outside diameter	1.212 cm
Cladding inside diameter	1.080 cm
Clad thickness	0.660 mm
Hole diameter	0.13 cm
Pellet diameter	1.048 cm
Pellet length	1.160 cm
Grain size	10.0 μm
Initial gas pressure	0.1 Ma

3. Conclusion

The sixth irradiation test of the DUPIC fuel was performed successfully by achieving the remote instrumentation technology necessary extend the fifth irradiation HANARO test. The measured temperature of the pellet center was analyzed by using fuel performance code systems (FRAPCON and KAOS). We found a similar behavior for the estimated pellet centerline temperature to the fifth irradiation test. A correct model was implemented such as a modification of the gap conductance accommodating a pellet crack and relocation due to an abrupt power changes. In the near future, it is expected that more reliable models for a DUPIC fuel will be developed based on the irradiation and post-irradiation data.

Acknowledgements

This work has been carried out under the Nuclear Research and Development program of the Korea Ministry of Science and Technology.

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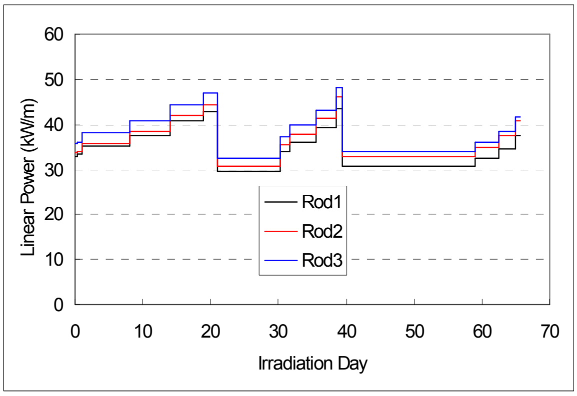

Figure 1. Linear power change during the fifth irradiation test of the dry process fuel.

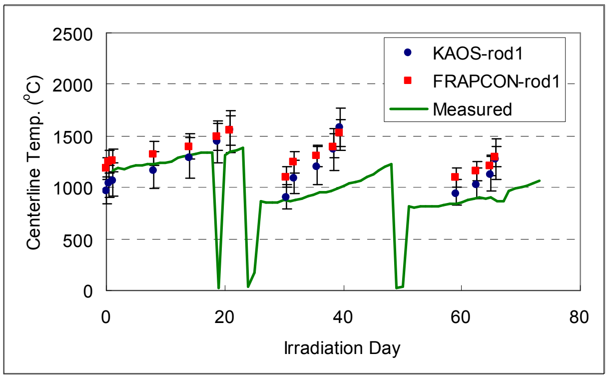

Figure 2. Centerline temperature distribution for the sixth irradiation test of the DUPIC fuel.

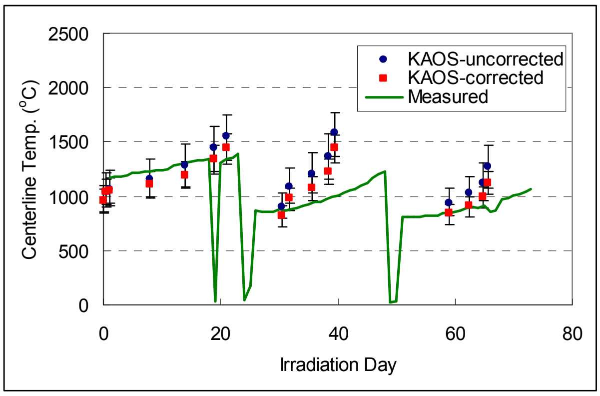

Figure 3. Centerline temperature distribution of uncorrected and corrected results for the sixth irradiation test of the DUPIC fuel.