On-Line Temperature Measurement of Dry Process Fuel at HANARO

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1. Introduction

The 5th irradiation test of dry process fuel that is fabricated without any separation of isotopes except volatile material from spent PWR fuel has been performed on February 2004. For this test, the instrumentation rig for measuring the centerline temperature of a pellet was manufactured.[1-4] Post irradiation examination (PIE) was performed at the end of 2004. This paper described the analysis results of the measured data and PIE of this irradiation test.

2. Irradiation Test at HANARO

2.1. Development of Instrumentation Rig

Fig.1 shows the design of the instrumentation rig. The total length of the rig is 1,060mm and 6 sensors are established in the rig: The 3 C-type thermocouples for measuring the pellet center temperature, the 2 K-type thermocouples for measuring the coolant temperatures at the inlet and outlet of the rig, and the 1 SPND for measuring the thermal neutron flux**.** Those 6 sensors are connected to the extension cable by the remote connector at the HANARO pool.

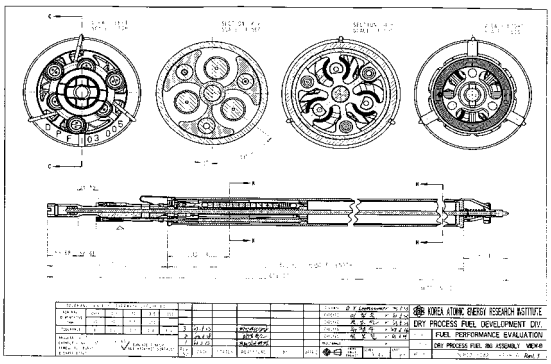

Figure 1. Design of the instrumentation rig

2.2. Design of Instrumented Mini-Element

Fig.2 shows the design of the instrumented mini-element. The thermocouple for measuring the pellet centerline temperature is equipped at the center hole of the 3rd pellet. The upper 3 pellets were drilled to ϕ1.3mm using the remote drilling machine in the hot cell. The ϕ1.2mm C-type thermocouple was inserted into the drilled pellets as depicted in Fig.3.

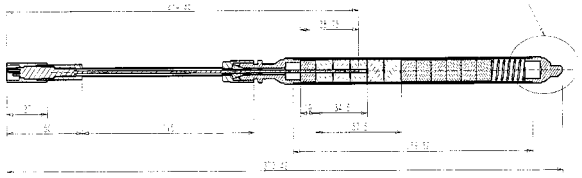

Figure 2. Design of the instrumented mini-element

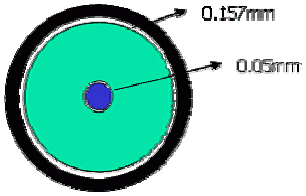

Figure 3. Sectional schematic of the instrumented mini-element

2.3. Data Measurement

Fig.3 shows the measured center temperatures of Rod-1 and Rod-2 during the irradiation period acquired by the DAS. The irradiation test was carried out for 75 days from Feb. 2004 to April 2004, and the average burn-up was estimated to be about 2,100 MWd/tHM.

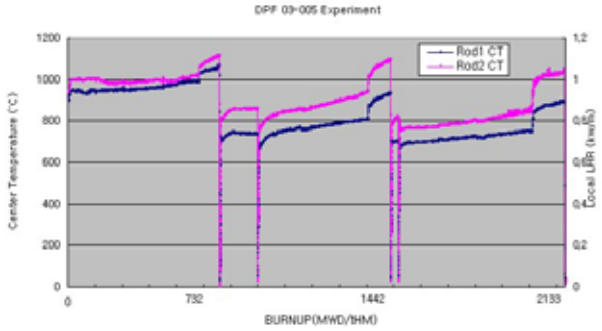

Figure 4. Pellet centerline temperatures acquired by DAS

For the irradiation period, the normal operation of 18 days and shutdown of 10 days were maintained at HANARO. During the 3 operating cycles (30-1 cycle, 30-2 cycle, 31-1 cycle), the normal operating power of the first operating cycle was 24MW. The operating power

was gradually increased by 1MW for each operating cycle, and finally reached to 26MW for the 31-1 cycle. The maximal centerline temperatures of Rod-1 and Rod-2 were measured to be about 1,050℃ and 1,100℃ at the 30-1 cycle, respectively. Meanwhile, at the 30-2 cycle and 31-1 cycle, the averaged pellet centerline temperature was decreased by about 200℃ compared to that of 30-1 cycle.

3. Post Irradiation Examination

3.1. Optical Microscopy

For the PIE analysis, the third pellet of Rod-2 that was equipped with a thermocouple was examined. The fifth pellet that was not equipped with a thermocouple was also observed for comparative analysis. Fig.5 shows the sectional view of the third pellet. The thermocouple was seen at the center region. Fig.6 shows the sectional view of the fifth pellet of Rod-2 without a thermocouple.

3.2. Analysis of Post irradiation Examination Result

As shown in Fig.5, larger radial cracks were observed in the instrumented pellet. A pellet center hole was drilled elliptically due to the up- and down-directional drilling for a pellet. This may cause much stress onto the inner boundary of the drilled pellet, and consequently larger radial cracks on the pellet during the irradiation. Also, the tantalum sheath was placed coincidently into an elliptical center. The thermocouple might be expanded radially due to swelling. Although the cracks of the tantalum sheath do not cause any effect for measuring the center temperature, the expansion of the tantalum sheath can contribute to the pellet cracking. From this observation, the gap between the pellet hole and thermocouple should be designed to be bigger in the next irradiation test for more accurate measurement of the centerline temperature.

Fig. 6 shows more cracks than Fig. 5. According to the performance code calculation, the centerline temperature of fifth pellet (Fig. 6) is estimated to be about 300°C - 400°C higher than that of the third pellet (Fig. 5). This can cause more thermal stresses to the pellet during irradiation, and more cracks in the fifth pellet.

4. Conclusion

Two centerline temperature sensors were installed in each mini-element. Maximum temperatures of Rod-1 and Rod-2 were estimated to be 1,060°C and 1,110°C, respectively. The center temperature difference between 30-2 cycle and 31-1 cycle was measured by 120°C. It may be caused by sudden power change and creaks happened for radius direction according to results of post irradiation examination. Method on the one through pellet drilling and center temperature measurement of dry process fuel & UO_2 fuel will be gone in next research.

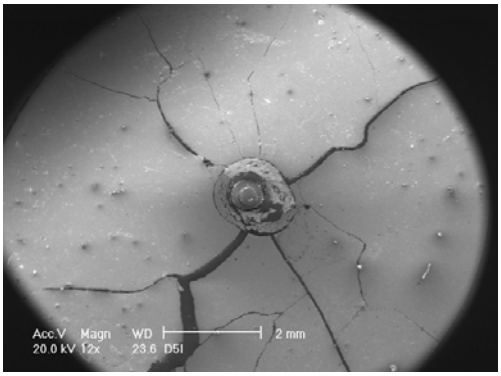

Figure 5. Sectional view of the third pellet of Rod-2

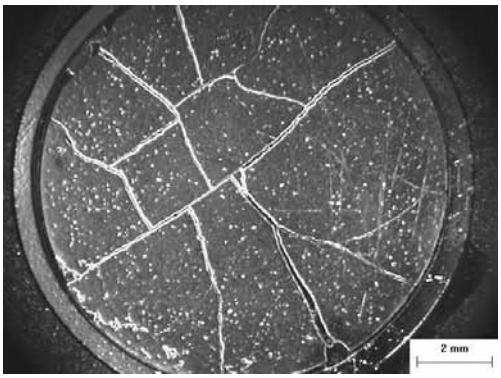

Figure 6. Sectional view of the fifth pellet of Rod-2

Acknowledgement

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