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Evaluation of the Measured Nuclear Fuel Center Temperature by using FEMAXI-V

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1. Introduction

The purpose of this paper is to evaluate the measured center temperature of the nuclear fuel by using FEMAXI-V. The measured center temperature of the nuclear fuel was created by using the 03F-05K instrumented capsule for the nuclear fuel irradiation test (hereinafter referred to as the "instrumented fuel capsule"). The irradiation test of the 03F-05K instrumented fuel capsule was carried out at the OR5 vertical experimental hole of HANARO in March 2003 for 59.5 EFPD(Effective Full Power Days) as shown in Table 1. In the 03F-05K instrumented fuel capsule, the instrumentation technologies for measuring the center temperature of the nuclear fuel, the internal pressure of the fuel rod, the elongation of the nuclear fuel and the neutron flux were implemented.[1][2]

This paper presents the specifications of the instrumented fuel rod for measuring the center temperature of the nuclear fuel, the measurement and calculation of the center temperature, and the evaluation results.

Table 1. Irradiation Test of the 03F-05K Instrumented Fuel Capsule

Irradiation Test Subjects	03F-05K
HANARO Power	24 ~ 30 MW
Experimental Vertical Hole	OR5
Maximum Linear Power	50.1 kW/m
Average Linear Power	46.3 kW/m
Average Burn-up	5,556 MWD/MTU
Effective Full Power Days	59.5
Maximum Center Temperature	1,316 ℃
HANARO Operation Cycles	31-2 ~ 33-1
Irradiation Test Period	2004.4.27 ~ 10.1

2. Evaluation of the Measured Center Temperature of Nuclear Fuel

2.1 The Instrumented Fuel Rod for measuring the Center Temperature of Nuclear Fuel

The instrumented fuel rod for measuring the center temperature of the nuclear fuel consists of five fuel pellets, a cladding, a C-type thermocouple, a plenum spring, etc. The characteristics of the pellets and rod are shown in Table 2. Figure 1 shows the schematic diagram of the instrumented fuel rod. The instrumented fuel rod is filled with helium of 1.2 bar pressure.

2.2. Measurement of the Center Temperature

The C-type thermocouple is used to measure the center temperature of the nuclear fuel. The center temperature data was stored in a database every minute. The total counts of the measured temperature are about 117,400 data. The measured maximum center temperature is 1,316 ℃ under the conditions that the HANARO operation cycle is the 32-2 cycle, the HANARO power is 29 MW(Mega Watts), and the control rod position of HANARO is 261 mm.

The trend of the measured center temperature is similar to the trend of the linear power of HANARO during the irradiation test as shown in Figure 2.

Table 2. Characteristics of the nuclear fuel and rod

Characteristic Subjects		Value
Pellet	Type	PWR 17 x 17
	External diameter	8.18 mm
	Length	10.27 mm
	Thermocouple Hole	1.48 mm(ø)
	Depth of Dish	0.13 mm
	Curvature of Dish	12.83 mm
	U-235 Enrichment	2.42 w/o
	Density	10.498 g/cm^3 (95.8%TD)
	Grain Size	9.35 μm
Rod	Material	Zircaloy-4
	External Diameter	9.50 mm
	Thickness	0.57 mm
	Length	132.15 mm
	Gap (between pellet)	167 μm
	Filler Pressure	1.2 bar (Helium)

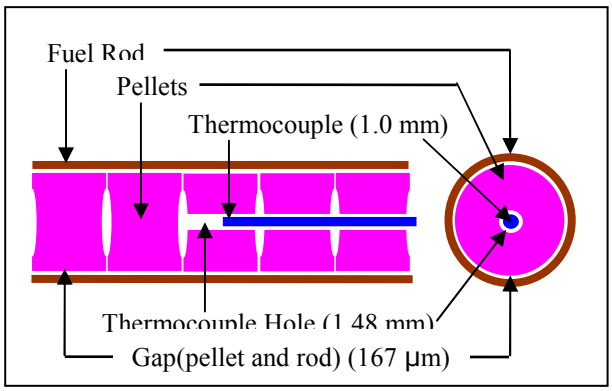

Figure 1. Nuclear Fuel and Thermocouple

2.3 Calculation of the Center Temperature

FEMAXI-V code is used to evaluate the measured center temperature of the nuclear fuel, because the FEMAXI-V code is more efficient than the other codes in calculating the nuclear fuel with a thermocouple hole(hollow type). We considered three options to calculate the center temperature of the nuclear fuel using FEMAXI-V as follows:

- thermal conductivity model option
- gap conductance model option
- fission gas release model option

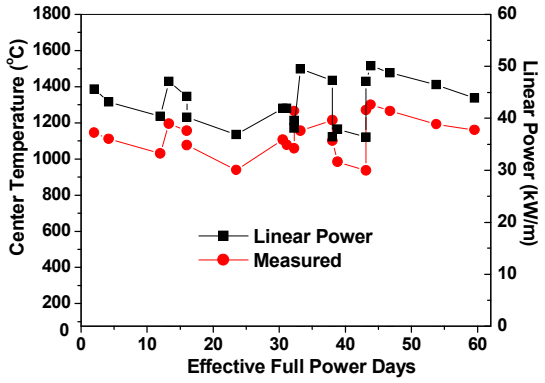

Figure 2. Measured Center Temperature of the Nuclear Fuel and the Linear Power of HANARO

2.4 Evaluation of the Center Temperature

We defined the error rate to compare the measured temperature with the calculated temperature as shown in equation (1).

$$\text{Error Rate} = \sum_{n=1}^{m} (\Delta T_n / M_n) \Big/ m \qquad (1)$$

(ΔT = |calculated temperature-measured temperature|, M = measured temperature)

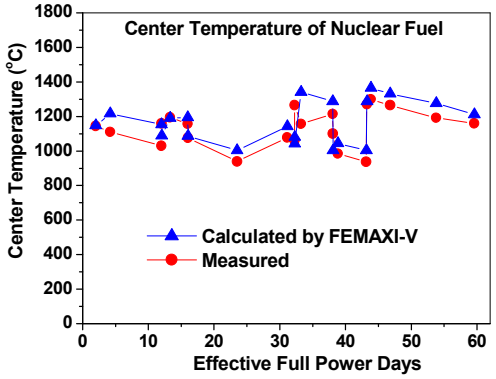

Figure 3. Measured and Calculated the Center Temperature of the Nuclear Fuel

Many calculations using FEMAXI-V were performed with various values of the three options as described before. And we found that the smallest value of the error rate was 0.023, when the MATPRO thermal conductivity model, the Modified Loss & Stoute gap conductance model, and the Morishima fission gas release model were selected. Figure 3 shows the measured center temperature and the calculated temperature using FEMAXI-V(error rate is 0.023 condition). The average difference of the center temperature between the measured temperature and the calculated temperature is 26.3 ℃. To summarize our interpretation of the calculation results, we concluded that the measured temperature of the nuclear fuel is evaluated well.

4. Conclusion

The measured center temperature of the nuclear fuel by using an instrumented fuel capsule agrees well with the calculated temperature using FEMAXI-V. Therefore, the instrumentation technology for measuring the center temperature of nuclear fuel using instrumented fuel capsule is evaluated good quality. This technology will be used continuously for studying the nuclear fuel characteristics by using an instrumented fuel capsule at HANARO.

Acknowledgement

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