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Analysis of the Elongation of Nuclear Fuels Irradiated by an Instrumented Fuel Capsule at HANARO

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1. Introduction

The purpose of this paper is to measure and analyze the elongation of nuclear fuels. The elongation of nuclear fuels was measured by using the 03F-05K instrumented capsule for 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 nuclear fuel rod, the elongation of nuclear fuels and the neutron flux were implemented.[1,2]

This paper presents the specifications of the instrumented fuel rod for measuring the elongation of nuclear fuels, the measurement method of the elongation, and the results of the analysis of the measured elongation.

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

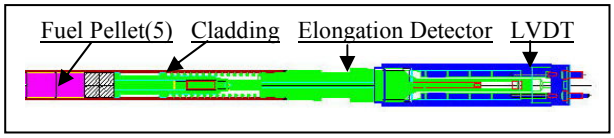
2. Analysis of the Measured Elongation of Nuclear Fuels

2.1 The Instrumented Fuel Rod for Measuring the Elongation of Nuclear Fuels

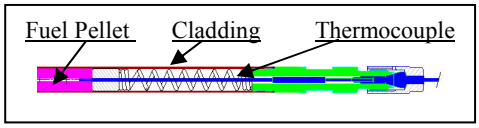
The instrumented fuel rod for measuring the elongation of nuclear fuels consists of five fuel pellets, a cladding, a plenum spring, an elongation detector and a LVDT(Linear Variable Differential Transducer), etc. The characteristics of the pellet and fuel rod are shown in Table 2. Figure 1(a) shows the schematic diagram of the instrumented fuel rod to measure the elongation of nuclear fuels, Figure 1(b) shows the instrumented fuel rod to measure the center temperature of the nuclear fuel and Figure 1(c) shows the instrumented fuel rod to measure the internal pressure of the fuel rod. The instrumented fuel rods were filled with helium of a 1.2 bar pressure.

Table 2. Characteristics of the Nuclear Fuel and Rod

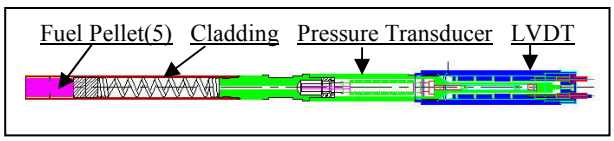
Characteristic Subjects		Value
Pellet	Type	PWR 17 x 17
	External diameter	8.18 mm
	Length	10.27 mm
	Thermocouple Hole	1.48 mm(ø)
	Depth of Dish	0.13 mm
	Curvature of Dish	12.83 mm
	U-235 Enrichment	2.42 w/o
	Density	10.498 g/cm^3 (95.8%TD)
	Grain Size	9.35 μm
Fuel Rod	Material	Zircaloy-4
	External Diameter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



(a) to measure the elongation of nuclear fuels



(b) to measure the center temperature of the nuclear fuel



(c) to measure the internal pressure of the nuclear fuel rod

Figure 1. Schematic Diagram of the Instrumented Fuel Rods

2.2. Measurement of the Elongation

An elongation detector and a LVDT were used to measure the elongation of nuclear fuels. The sensitivity of the LVDT is 62.19 mV/mm(at 240 ℃), the detection range is ±2.5 mm and the temperature sensitivity(from 240 ℃) is -0.013 %/℃. The operation temperature of the LVDT was about 40 ℃ during the irradiation test at HANARO. The LVDT output signals for measuring the elongation were measured through an amplifier and stored in a database every minute. The total counts of the elongation data were about 117,400 records. The center temperature and internal pressure of fuel rod of the nuclear fuel were also measured and stored.

In the 31-2 HANARO operation cycle, the measured maximum elongation level of the nuclear fuels was 0.069 x 10^{-6} meter and the minimum level was -0.8 x 10^{-6} meter. Therefore the variation of the elongation was 0.869 x 10^{-6} meter. The 31-2 operation cycle was operated during 16.01 EFPD under the conditions that the HANARO power was 24-28 MW(Mega Watts) and the average linear power was 41.9 kW/m.

2.3 Analysis of the Measured Elongation

Figure 2 shows the trend of the measured elongation and center temperature of the nuclear fuels, and the linear power of HANARO.

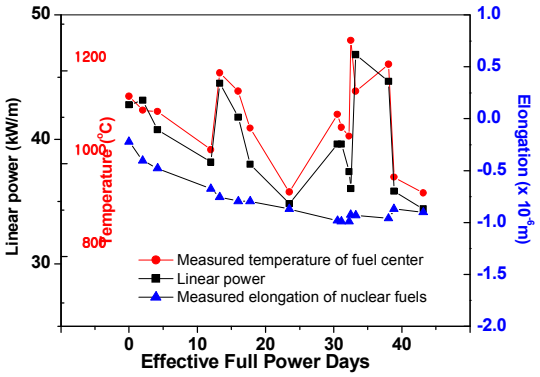


Figure 2. The Measured Elongation of Nuclear Fuels with the Center Temperature of the Nuclear Fuel and the Linear Power of HANARO

The trend of the measured elongation shows a gentle rate of decrease. The elongation of nuclear fuels is affected by the burn up and temperature of a nuclear fuel. But, in this case, only a little densification of the nuclear fuels was measured because the burn up of the nuclear fuels was a low level. Further analysis of the elongation will be made with a burn up rate analysis in the future. The trend of the measured pressure and center temperature are similar to the trend of the linear power of HANARO during the irradiation test as shown in Figure 3. The measured center temperature of the nuclear fuel and measured internal pressure of the fuel rod by using an instrumented fuel capsule have already been evaluated as having a good agreement with the calculated temperature using FEMAXI-V.[3, 4]

4. Conclusion

The instrumentation technology for measuring the elongation of nuclear fuels by using an instrumented fuel capsule is very appropriate and the result of the analysis for the elongation shows a good agreement when compared with the linear power and the nuclear fuel center temperature. This technology will be used continuously for studying nuclear fuel characteristics by using an instrumented fuel capsule and 3-pin FTL(Fuel Test Loop) at HANARO.

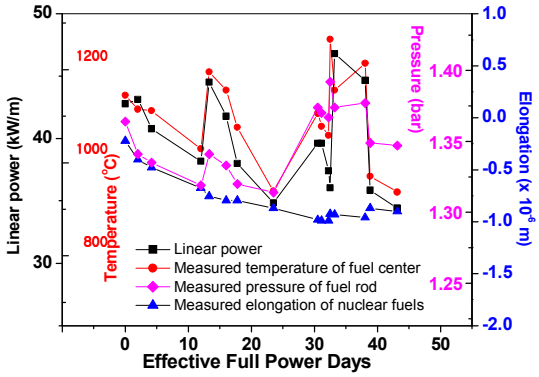


Figure 3. A Trend of the Measured Elongation of Nuclear Fuels and Internal Pressure of the Fuel Rod with Measured Center Temperature of the Nuclear Fuel and Linear Power of HANARO

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