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Analysis of the Internal Pressure of the Nuclear Fuel Rod Irradiated by an Instrumented Fuel Capsule at HANARO

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1. Introduction

The purpose of this paper is to analyze the internal pressure of the nuclear fuel rod. The internal pressure was measured 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 nuclear 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 internal pressure of the nuclear fuel, the measurement method of the pressure, and the results of the analysis of the measured internal pressure.

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

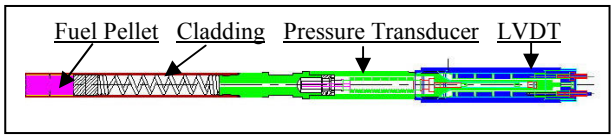
2. Analysis of the Measured Internal Pressure of the Nuclear Fuel Rod

2.1 The Instrumented Fuel Rod for Measuring the Internal Pressure of the Nuclear Fuel Rod

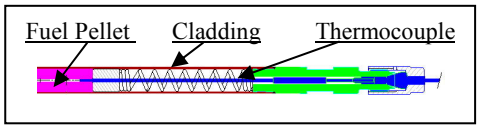
The instrumented fuel rod for measuring the internal pressure of the nuclear fuel rod consists of five fuel pellets, a cladding, a pressure transducer and LVDT(Linear Variable Differential Transducer), a plenum spring, etc. The characteristics of the pellets and fuel rod are shown in Table 2. Figure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



(b) to measure the center temperature of nuclear fuel

Figure 1. Instrumented Fuel Rods

2.2. Measurement of the Internal Pressure

A pressure transducer and a LVDT were used to measure the pressure. The sensitivity of the LVDT is 10.92 mV/bar(at 240 ℃), the pressure range is 15 bar and the temperature sensitivity(from 240 ℃) is -0.41 %/℃. The operation temperature of LVDT was

about 40 ℃ during the irradiation test at HANARO. The LVDT output signals for measuring the pressure were measured through the amplifier and stored in a database every minute. The total counts of the pressure data were about 117,400 records. The center temperature and elongation data of the nuclear fuel were also measured and stored.

In the 31-2 HANARO operation cycle, the initial pressure of the nuclear fuel rod was 1.196 bar and the maximum pressure was 1.371 bar. Therefore the variation of the pressure was 0.175 bar. 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 Internal Pressure

Figure 2 shows the trend of the measured internal pressure and the linear power of HANARO. The trend of the internal pressure is similar to the trend of the linear power during irradiation test.

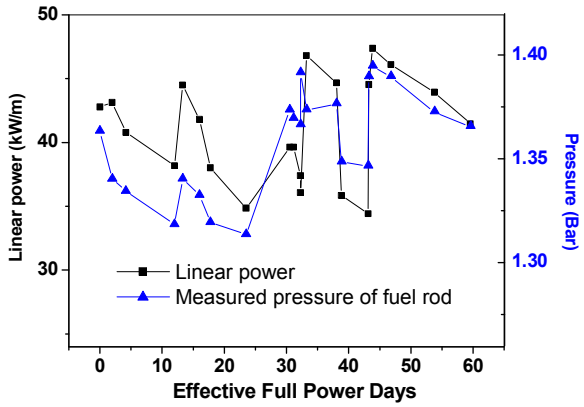


Figure 2. Measured Internal Pressure of the Nuclear Fuel Rod and the Linear Power of HANARO

The internal pressure of the nuclear fuel rod is affected by the nuclear fuel temperature and the released fission gas. But, in this case, only a little fission gas was created because the burn up of the nuclear fuel was low level. Therefore the pressure was only affected by the nuclear fuel temperature. The trend of the measured pressure is similar to the trend of the center temperature of the nuclear fuel and the linear power of HANARO during the irradiation test as shown in Figure 3. The measured center temperature of the nuclear fuel by using an instrumented fuel capsule has already been evaluated as a good agreement with the calculated temperature using FEMAXI-V.[3]

4. Conclusion

The instrumentation technology for measuring the internal pressure of a nuclear fuel rod by using an instrumented fuel capsule is very appropriate and the result of the analysis for the internal pressure 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 at HANARO.

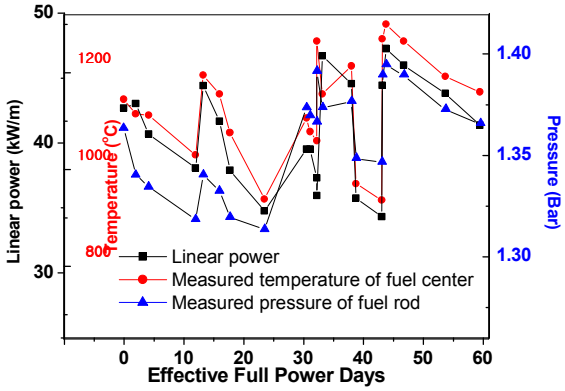


Figure 3. Measured Internal Pressure of the Fuel Rod, Measured Center Temperature of the Nuclear Fuel, and Linear Power of HANARO

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