Design of an Instrumented Fuel Capsule(09F-08K) for an Irradiation Test of the Double Cladding Fuel Rods at HANARO

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1. Introduction

An instrumented capsule for a nuclear fuel irradiation test (hereinafter referred to as "instrumented fuel capsule"), which is crucial for the verification of a nuclear fuel performance and safety, has been developed to measure the fuel characteristics. Specifically, these areas are the centerline and surface temperatures of the nuclear fuel, the internal pressure of a fuel rod and the elongation of the fuel pellet and the neutron fluxes during an irradiation test at HANARO(High-flux Advanced Neutron Application Reactor). Through the irradiation tests of capsules as shown in Fig. 1, the design specifications and safety of the instrumented fuel capsules had been verified successfully [1]. And the dual instrumented fuel rods, which allow for two characteristics to be measured simultaneously in one fuel rod, have been developed to enhance the efficiency of the irradiation test using the instrumented fuel capsule [2].

In this paper, we designed a double cladding fuel rod for the high temperature of nuclear fuels during an irradiation test at HANARO and an instrumented fuel capsule(09F-08K) for an irradiation test of the double cladding fuel rods.

We had performed the out-pile tests using the double cladding fuel rod mockups to analyze an effect of a gap size(between an outer cladding and an inner cladding) on the temperature and the effect of a mixture ratio of helium gas and neon gas on the temperature. Through the results of the out-pile tests, we have found the effects of a gap size and a gas mixture ratio on the temperature of nuclear fuels [3]. Therefore, these double cladding fuel rods and the 09F-08K instrumented fuel capsule were designed on the basis of the results of the out-pile tests and the design of the 07F-06K instrumented fuel capsule.

Fig. 1. An Instrumented Fuel Capsule

2. Design of a double cladding fuel rod

A double cladding fuel rod contains five UO_2 pellets(17x17 PWR type, 0.71w/o(NU)), an inner cladding, an outer cladding, a thermocouple, two alumina insulators and a plenum spring as shown in Fig. 2. A C-type thermocouple was used to measure the centerline temperature of the nuclear fuels.

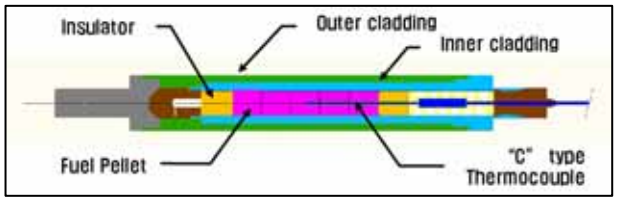

Fig. 2. Design of the Double Cladding Fuel Rod

As shown in Fig. 3, a fuel rod has two gas-gaps between an outer cladding and an inner cladding and between an inner cladding and nuclear fuels. These gas-gaps will be filled with helium gas. The helium gas does not flow through the gas-gaps. Inner cladding, outer cladding and all end plugs were made of STS316L. The dimensions of an inner cladding are 14.36(OD), 8.36(ID), 3.00(T) and 111.15(L). The dimensions of an outer cladding are 18.00(OD), 14.56(ID), 1.72(T) and 109.15(L).

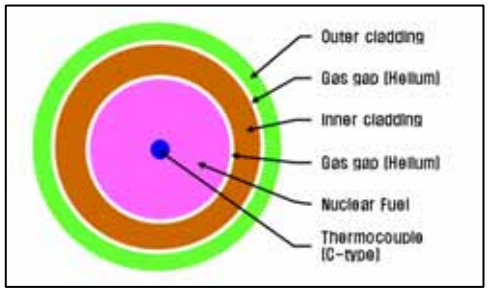

Fig. 3. A Cross Section of Double Cladding Fuel Rod

3. Design of the 09F-08K instrumented fuel capsule

An instrumented fuel capsule(09F-08K) was designed and is being fabricated for a design verification test of a double cladding instrumented fuel rod. Two double cladding instrumented fuel rods and two rhodium type SPNDs(Self-Powered Neutron Detector) will be installed in this capsule as shown Fig. 4. A part of fuel assembly that contains two double cladding fuel rods and a cooling block was newly designed and other parts that contain outer tube, protection tube, bottom guide, etc. were designed same as in the standard instrumented fuel capsule.

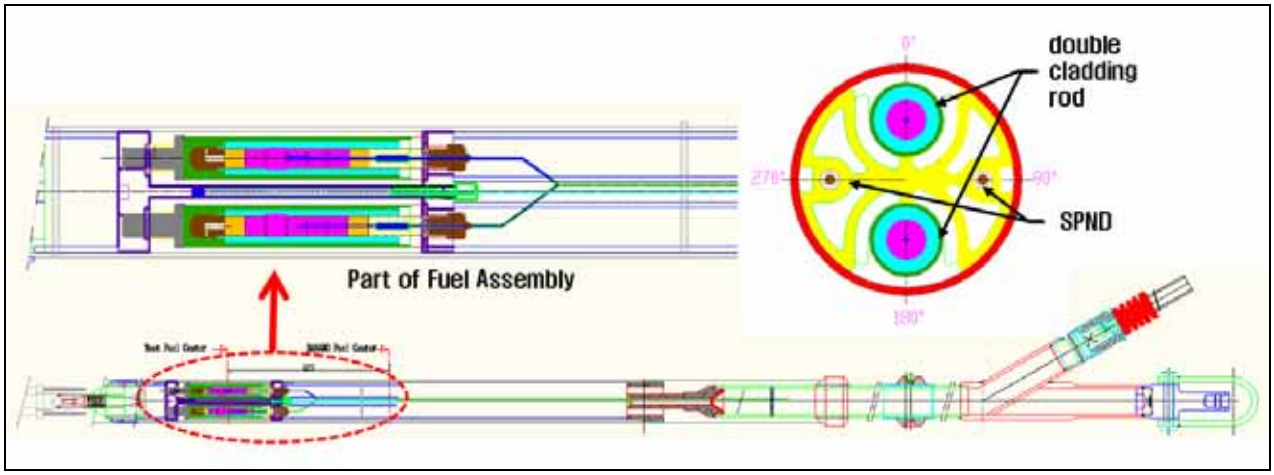

Fig. 5. Drawings of an Instrumented Fuel Capsule(09F-08K) for an Irradiation test of the Double Cladding Instrumented Fuel Rods

The maximum linear power of the nuclear fuels for the 09F-08K instrumented capsule was calculated at 130 W/cm by the MCNP code. The maximum gamma heating of inner claddings and outer claddings were calculated at 21.66 W/cm and 17.22 W/cm, respectively.

Assuming the center of HANARO fuel assembly was 0 mm, the center of the fuel stacks of the double cladding instrumented fuel rods were designed at the relative elevation of -22.5. Two SPNDs will be installed at same elevation of the nuclear fuel stacks. The maximum centerline temperature of nuclear fuels was calculated at 741 ℃ by ANSYS as shown in Table 1. Two rods and two SPNDs will be located at OR5 experimental vertical hole of HANARO as shown in Fig. 6.

Table 1. Calculated temperature of the double cladding nuclear fuel rods (units : ℃)

Rod	Center line of nuclear fuel	Surface of nuclear fuel	Inside of inner cladding	Inside of inner cladding	Inside of inner cladding	Inside of inner cladding
1	741	477	303	248	78	52
2	668	440	275	230	75	51

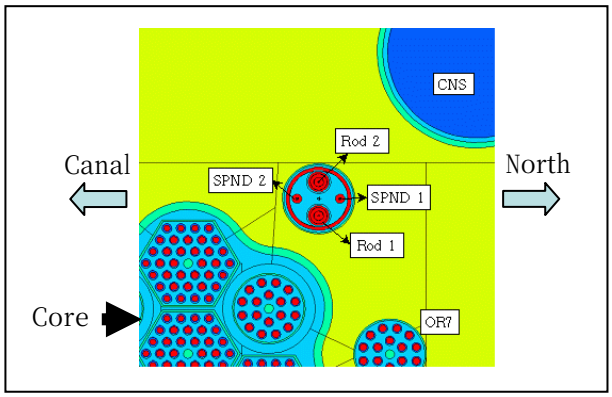

Fig. 6. Direction of double cladding fuel rods and SPNDs at OR5 experimental vertical hole of HANARO

4. Conclusion

The double cladding instrumented fuel rods and 09F-08K instrumented fuel capsule have been successfully designed. The irradiation test of the double cladding fuel rods will be carried out in the OR5 vertical experimental hole of HANARO at the first of next year.

This irradiation test of the double cladding fuel rods that not contains the flow of gases through a gas-gap between an inner cladding and an outer cladding is a basic study to control the high temperature of the nuclear fuels during irradiation test using the flow of mixture gas. The high temperature control technologies of the nuclear fuels using a double cladding fuel rod will be utilized for the development of new types of nuclear fuels.

Acknowledgement

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