Measured Parameters of Nuclear Fuel during Irradiation Testing at the HANARO

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1. Introduction

Various irradiation devices, capsules for irradiation testing of nuclear fuels and materials and Fuel Test Loop (FTL) for irradiation testing of nuclear fuels under the conditions of commercial nuclear power plants (CANDU; Canadian deuterium and PWR; Pressurized water reactor), have been developed at HANARO. Among the irradiation devices, a capsule is the most efficient device to cope with the various test requirements at HANARO. The capsule has been developed for irradiation tests of nuclear fuel and materials in the core region of the HANARO [1,2]. In this paper, not only certain measured data from fuel irradiation testing at the HANARO but also efforts to detect more accurate and reliable data from thermocouples, Linear Variable Differential Transformer (LVDT) and Self-Powered Neutron Detector (SPND) are described.

2. Irradiation Devices

Fig. 1 shows the HANARO reactor core having the FTL and the capsule in the test holes during its operation. The equipment for the irradiation tests of nuclear fuels and materials in HANARO are classified into two categories: a capsule and an FTL.

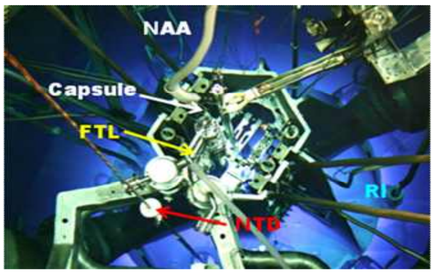
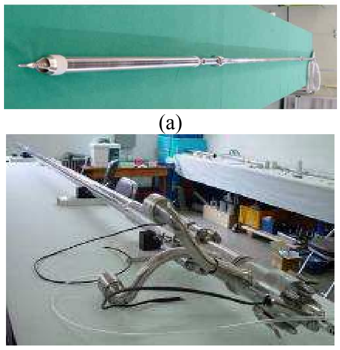


Fig. 1. HANARO reactor core during an irradiation test.

Capsules for the irradiation tests of nuclear fuels and materials in the HANARO have been developed; extensive efforts have been made to establish the design, manufacturing and irradiation technologies for irradiating nuclear fuels and materials by using capsules and their control systems, which should be compatible with HANARO's characteristics [3]. Fig. 2 shows an instrumented capsule for nuclear fuel irradiation testing at the HANARO and an in-pile section of FTL for nuclear fuel irradiation testing under the condition of commercial power reactor condition at the HANARO. The irradiation plans related to developing the Generation-IV reactor systems, such as sodium-cooled fast reactors and very high temperature reactors, give more emphasis on developing capsules and instrumentation focusing on irradiation tests of materials or fuels for Generation-IV reactor systems in Korea.

The FTL is one of the irradiation devices that can conduct an irradiation test for a nuclear fuel in HANARO under the operating conditions of commercial nuclear power plants (PWR and CANDU). It can simultaneously contain up to three instrumented PWR or CANDU test fuel rods. The installation of the FTL was completed in March 2007, and the commissioning test was finished in September 2009. This was first used to perform an irradiation test of an advanced nuclear fuel for PWRs.



(a)

(b)

Fig. 2. (a) Instrumented capsule for nuclear fuel irradiation testing and (b) In-pile section of fuel test loop.

3. Measured Parameters

Fig. 3 shows measured central fuel temperature of fuel pellets during irradiation testing at the HANARO, respectively. The average LHGR is determined by MCNP calculations. Type C thermocouple has been installed to monitor temperature in the center hole (ø 1.5 mm) of fuel pellet at its midplane and Type K thermocouple to monitor temperature on the groove (width 1.2mm, depth 1.2mm) at the surface fuel pellets surface. Maximum central temperature was indicated to 1370℃ at 53 KW/m of the LHGR, and surface temperature to 380℃ at 46 KW/m of the LHGR. A good correlation between the temperatures data and the average LHGR (linear heat generation rate) is shown in this figure. A comparison of the measured central fuel temperatures of fuel pellets during the irradiation test in the OR5 hole of HANARO with the calculated average central temperature of fuel pellets by INFRA-HANARO modified from INFRA code [4,5] was performed. Taking the recommended correlation for the thermocouple decalibration by Vitanza and Stien [6] into consideration, this calculated temperature is overestimated. Fig. 4 shows variation of data from LVDTs during the irradiation test in the OR5 hole of HANARO. A good correlation between data from LVDTs and the average LHGR is shown in this figure. Fig. 5 shows variation of data from SPNDs during the irradiation test in the OR5 hole of HANARO. SNPDs were placed at regular intervals in the vicinity of the test fuel rods. Although one of SPNDs lost its function during each irradiation, they were successfully used to follow the fuel power evolution, that is, a good agreement between the thermal neutron flux data from the SPNDs and the average LHGR is shown in this figure. A major cause of the loss of SPND's function is presumed the damage on SPND MI (mineral insulated) cable during assembling devices. But, the cause of its failure must be investigated more thoroughly.

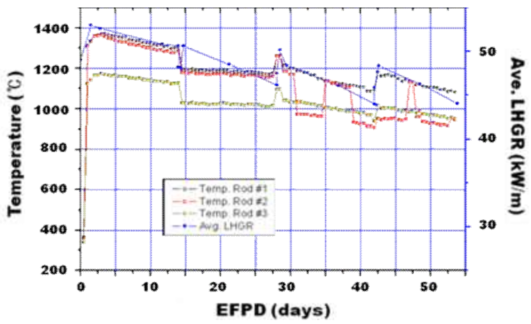


Fig. 3. Central temperature of nuclear fuels during the irradiation tests.

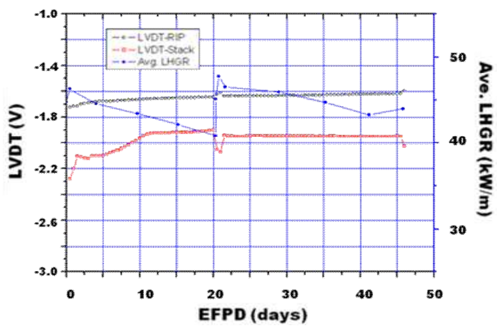


Fig. 4. Variation of data from LVDTs during the irradiation test in the OR5 hole of HANARO.

4. Conclusions

Various irradiation devices, capsules for irradiation testing of nuclear fuels and materials and Fuel Test Loop for irradiation testing of nuclear fuels under the conditions of commercial nuclear power plants (CANDU and PWR), have been developed at HANARO. Non-instrumented and instrumented fuel irradiation tests have been conducted at HANARO during the past years and are scheduled for the near

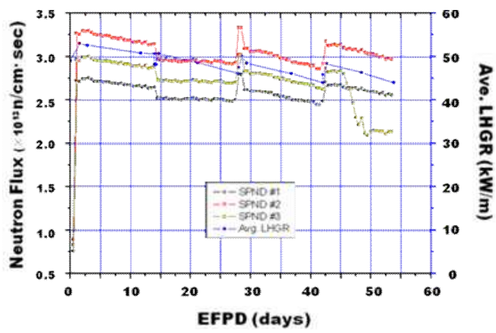


Fig. 5. Neutron flux during the irradiation test in the OR5 hole of HANARO.

future. Irradiation test parameters such as temperatures, internal pressure change of test rod, length change of fuel pellets, and neutron flux are successfully measured by using instrumented capsules during irradiation tests. And, a comparison between the measured data and the calculations is under way. In order to improve the monitoring of the irradiation conditions and the accuracy reliability of measured data, capsule design has to be modified and more instruments have to be equipped on irradiation device as far as possible.

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