Measurement and Evaluation of Fast Neutron Flux for Irradiation Test at HANARO

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1. Introduction

Recently, the need for irradiation testing on materials used in the nuclear industry is increasing because of the following reasons;
(1) Demand of safety improvement for operating and aging nuclear power plants due to the Fukushima accident,
(2) Development and performance verification from in-pile test for future nuclear system and fusion materials,
(3) To produce the design data for small and medium size reactor materials such as research reactor and SMART.

Therefore, it is expected that many irradiation tests will be conducted at HANARO by the material irradiation capsule.

The fast neutron fluence is an important factor because it can affect the integrity of material related to safety. Therefore, a fast neutron fluence for the reactor pressure vessel is periodically evaluated and regulated at commercial nuclear power plants[1]. Also a fast neutron fluence must be accurately evaluated for the irradiation-tested materials at HANARO.

Fast neutron fluence is generally calculated by computer code before an irradiation test to design a material capsule. After the irradiation test, a comparison between the calculated and measured data is conducted to evaluate the exact value and the error. Although many evaluations for the irradiation tests have been conducted, the calculated and measured values are over 20% different. Moreover, the dosimetry method for the fast neutron has yet to be established at HANARO.

In this study, the measurement and evaluation of the fast neutron flux was conducted for a 10M-01K capsule irradiated in a CT irradiation hole. The calculated and measured values were compared. These results will be the basic data to evaluate the neutron dosimetry exactly at HANARO.

2. Methods and Results

2.1 Calculation of neutron flux

During the irradiation test at HANARO, the reactor power is nearly constant. If the neutron flux is directly proportional to reactor power, the neutron fluence can be approximated as follows[2]:

$$\Phi = \left(\frac{\phi}{P}\right)\sum_{i=1}^{n} P_i t_i$$

Where,
ϕ = the neutron flux,
P = the reference power level,
t_i = duration of the i-th operating period,
P_i = reactor power level during that operating period.

Because the neutron fluence is dependent on the irradiation time, it can't be measured directly. Therefore, the neutron flux was calculated from the MCNPX code to compare to the measured value.

Fig. 1 shows the calculated axial neutron flux by MCNPX code for a 10M-01K capsule irradiated in a CT hole depending on the position of control absorber rod (CAR).

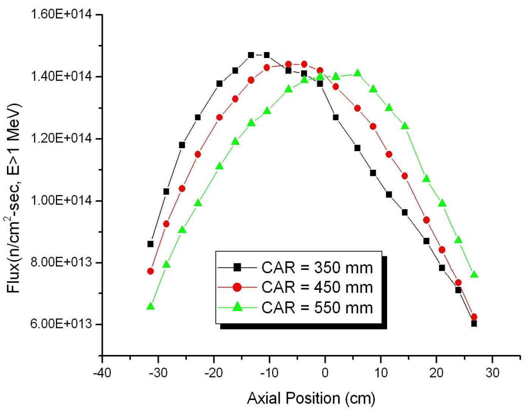

Fig. 1. The calculated axial neutron flux distribution for a 10M-01K capsule irradiated in a CT hole

2.2 Measurement of the neutron flux

To measure the neutron flux, the method for applying the dosimeter activation analysis has been used for the material capsule. It is known as an accurate measuring method, therefore, many countries used this method for the measurement of neutron flux[3].

Pure metal foils and wires were used as the fluence monitor (F/M). In this study, Fe, Ni, and Ti wires were used as the F/M due to an active reaction with fast neutron. These were installed in a capsule at each stage. Before the installation in a capsule, the weights of the F/Ms were measured. After the irradiation test, these F/Ms were disassembled from the capsule and the absolute activities of the F/Ms were measured by HPGe detector. This data was used for computing the measured value.

2.3 Evaluation of fast neutron flux

Before computing the measured data, the CAR operating history must be analyzed because the neutron flux distribution is very different according to the position of the CAR shown in Fig. 1. In the same irradiation cycle of HANARO, CAR is increasingly withdrawn from the core due to the combustion of the fuel. Fig. 2 shows the CAR operation history of the 64th operation cycle of HANARO that was same with the irradiated cycle of a 10M-01K capsule. At the 64th operation cycle of HANARO, a once-in-a-cycle reactor trip occurred. The average position of the CAR was calculated from this history was about 510 mm. The calculated fast neutron flux was linearly considered from the CAR position of 450 to 550 mm.

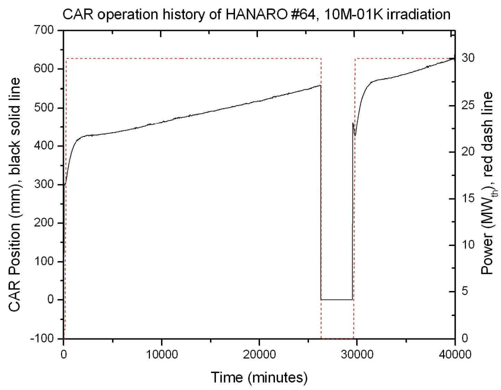

Fig. 2. The CAR operation history of 64th operation cycle of HANARO

To calculate the measured value, many computer codes and methods were used in many countries. SAND-II that is a semi-iterative code to compute the spectrum adjustment was used in this study. Although the neutron reaction cross section was originally provided by the SAND-II code, it was revised by an updated cross section data from ENDF-VII library using an NJOY code. To compute the measured fast neutron flux and the neutron spectrum, the initial spectrum calculated from an MCNPX code and reaction rates of F/Ms were used as input data for the SAND-II code. The SAND-II code adjusted the initial neutron spectrum and computed the fast neutron flux.

Fig. 3 shows the comparison results of the fast neutron flux between the calculated and the measured data of a 10M-01K capsule irradiated in a CT hole. Most of the comparison data showed good agreement within ± 10%. However, at the height of 27.25 cm, the comparison result showed 13.03%. On most of the region of the capsule, the fast neutron flux was linearly increased according to the increase of the CAR position shown in Fig. 1. However, at the upper region over the height of 18 cm, the fast neutron flux was sharply increased from the CAR position of 450 to 550 mm. In this study, the calculation data was considered only with linear increase of flux by the increase of the CAR position. It might affect the difference of the comparison between the calculated and measured value.

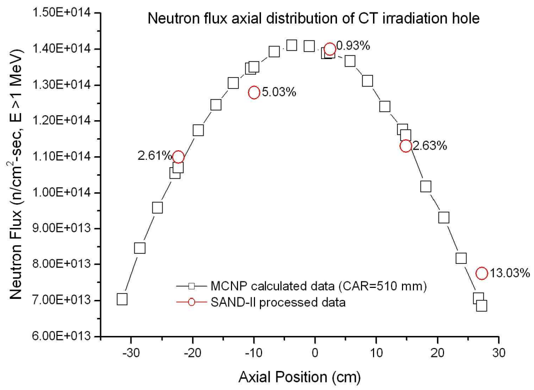

Fig. 3. The comparison fast neutron flux between the calculated and measured value of 10M-01K capsule

3. Conclusions

The measurement and evaluation of a fast neutron flux was conducted for a 10M-01K capsule irradiated in a CT irradiation hole. The fast neutron flux was calculated using MCNPX code. The measured data was used via SAND-II code. A CAR operation history was analyzed for accurate data comparison. Although the maximum difference between the calculated and measured value showed 13.03%, most of the comparison results showed a good agreement within ±10%.

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