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Neutron Absorption Reaction Rates according to Temperature Change of Alloy Specimen

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1. Introduction

In recent years, various designs for Generation-IV reactors and other reactor types have been proposed, leading to a broad spectrum of research and development on various reactor materials. Prior to commercialization, these materials must undergo thorough validation of their integrity and safety.

Neutron irradiation tests using reactors evaluate the capability of various reactor materials, which are currently operational or under design, to withstand extreme environmental conditions. In particular, the pre-reactor nuclear assessment phase constitutes a crucial procedure within the entire irradiation testing process, as it involves determining the suitable test temperatures, the irradiation doses, the exposure periods, and evaluating the test safety.

On the other hand, the research reactors primarily employed for irradiation test are characterized by their short operational periods and relatively frequent cycle replacements, leading to the frequent temperature fluctuations due to changes in reactor power. Therefore, when performing nuclear analysis of irradiated specimens, it is necessary to examine the correlation between the neutron behavior within the material and their subsequent reactions considering the variations in temperature.

In this study, a comparison of the neutron absorption reaction rates for the alloy specimen was made between the Monte Carlo transport calculations that consider and do not consider temperature variations resulting from the reactor core operation.

2. Model Descriptions

This study assumes the neutron irradiations by loading alloy specimens into the irradiation hole located at the central region of the core in the HANARO research reactor. Transport calculations were performed using the MCNP6.1[1] Monte Carlo transport code, based on an equilibrium core with a reactor power of 30 MW, and temperature calculations were performed using the GENGTC[2] one-dimensional code. The alloy specimen has a rectangular shape with dimensions of 1.5×1.0×11.4 cm³, and a total mass of 133.38 g.

Figure 1 represents a schematic diagram of a one-dimensional node divided in the direction passing through the center of the targets from the center of the circular irradiation hole.

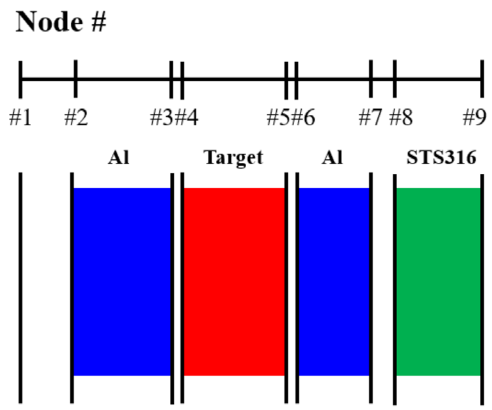

Fig. 1. One-dimensional order of materials arranged from the center of the irradiation hole and the divided node numbers.

The temperature of materials in each node are calculated as follows,

$$T_i = T_0 + \frac{q'''}{4k}\left(R_o^2 - R_i^2\right) + \frac{Q}{2\pi k}\ln\left(\frac{R_o}{R_i}\right) - \frac{q'''}{2k}R_i^2\ln\left(\frac{R_o}{R_i}\right),$$

- R_i : *inner radius*
- R_o : *outer radius*
- q''' : *heat ratio of the ring*
- Q : *heat flow from the inner point*
- k : *heat conductivity coefficient*.

3. Neutron Absorption Reaction Rates

In this study, a comparison was made between the neutron absorption reaction rates obtained from the conventional transport calculations that do not consider temperature effects, and the calculations that incorporate the temperature increase effects.

Figure 2 and Figure 3 show the neutron flux distributions and the neutron absorption reaction rates along with energy for two calculations, respectively. CASE I represents the transport calculations without considering temperature effects, while CASE II takes into account the changed irradiation temperature after the reactor operation.

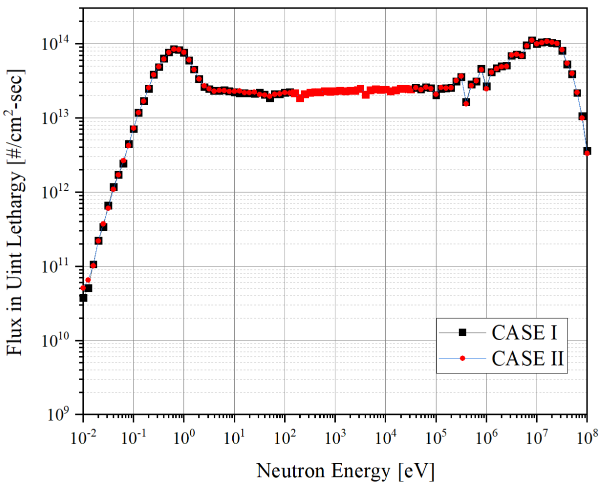

Fig.2. Neutron Flux distributions in unit lethargy along with the neutron energy.

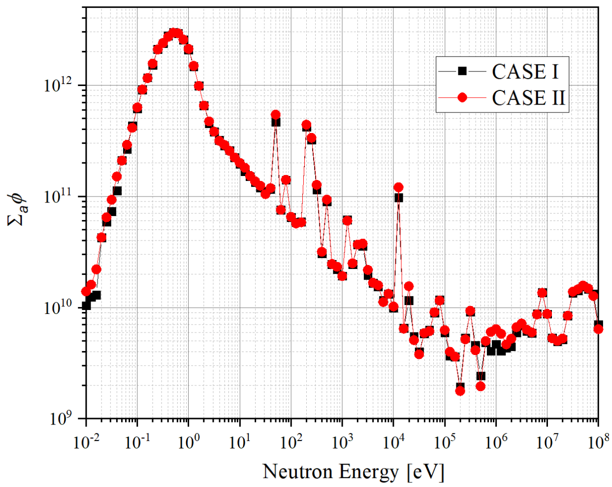

Fig. 3. Neutron absorption reaction rates along with the neutron energy.

Across the entire neutron energy range, the computational errors were found to be less than 5%. The neutron absorption reaction rates showed some differences along with the neutron energy, however, the values were normally higher when temperature effects were taken into account.

Figure 4 shows the relative differences between the CASE I and CASE II. The positive values in the differences indicate that neutron absorption reaction rates are more highly evaluated in the calculations that consider temperature effects, while the negative values indicate the opposite. In most cases, the calculations considering temperature increase showed an increase in the neutron absorption reaction rates within 10%, and in certain energy ranges, the differences exceeding 10% were also observed. As a result, it can be shown that the neutron absorption reaction rate generally increases as the temperature of the specimen material increases. Consequently, by incorporating temperature effects into the transport calculations, it can be verified that the physical phenomena of neutron absorption reactions are more accurately represented.

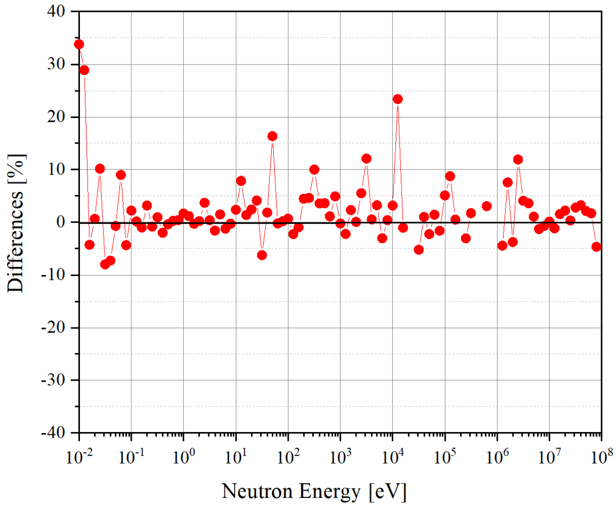

Fig. 4. The relative difference in neutron absorption reaction rates between CASE I and CASE II.

4. Conclusions

This study analyzes the neutron absorption reaction rates for alloy specimen by taking into account the temperature variations associated with changes in reactor power during neutron irradiation tests.

The results indicate the overall increases in the neutron absorption reaction rates when temperature effects are considered. Consequently, this will influence various nuclear parameters derived from the neutron absorption reactions by neutron irradiation.

The results of this study can be used as the fundamental data for various kinds of the nuclear irradiation tests under temperature transient conditions. Furthermore, the additional analysis for various materials will be performed in the further studies.

ACKNOWLEDGEMENT

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