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Prediction of the Measured Gold Reaction Rate at OPAL Reactor Using McCARD

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1. Introduction

Reactor physics tests had been conducted at the OPAL research reactor during its commissioning phase. Among them, the gold reaction rates had been measured to have thermal neutron flux distributions in the core region. The gold reaction rates at the same locations are predicted using the Monte Carlo code, McCARD, and compared to the measured ones.

2. Measurement

In this section OPAL reactor and the measurement of gold reaction rates are briefly reproduced [1].

The OPAL reactor is a 20 MW open pool type research reactor. It is composed of a core surrounded by a heavy water reflector. The reactor core contains 16 MTR type fuel assemblies and 5 control plates (CR1~CR5) as shown in Fig. 1.

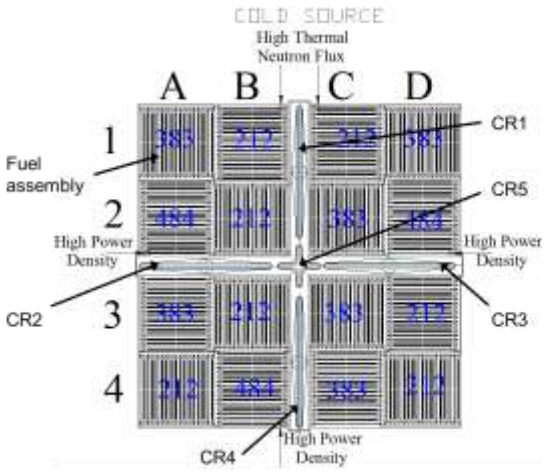

Fig. 1. Core arrangement of OPAL reactor

Gold-aluminium wires were irradiated in the core by inserting an aluminium plate with the wires attached between fuel plates. The reaction rates and thermal neutron flux distributions were obtained from an activation of the irradiated wires. Two irradiations with and without a cadmium cover were performed to determine the absolute thermal neutron flux using cadmium ratio. The wire is 0.508 mm diameter and 0.1124% Au.

Five positions were chosen at which anticipated high thermal neutron flux or high power density. Those are indicated also in Fig. 1.

The control plate affect the thermal neutron flux distribution. During the measurement, CR1 and CR4 were withdrawn 85.7% and 84.8%, respectively, whereas CR2 and CR3 were withdrawn only 36.0% and 35.9%, respectively.

The reactor power during the wire irradiations was reported to 36±6 kW assuming 201.97 MeV/fission for U-235.

3. Calculation

3.1. Modelling

The OPAL reactor is described by McCARD as detail as possible, in which the regions of core and heavy water reflector are included. The MCNP5 model as shown in Fig. 2 is set the same as the McCARD model in order to confirm a correctness of the McCARD model.

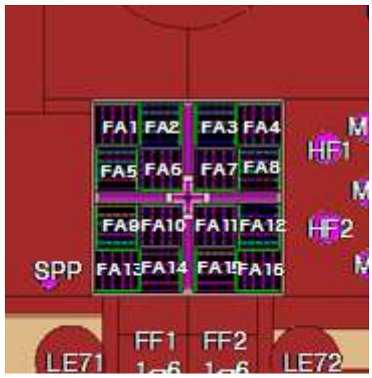

Fig. 2. Plan view of OPAL modelled by MCNP

k_{eff}s are calculated by both MCNP and McCARD for the same core conditions, and the differences in the calculated k_{eff}s are 28~91 pcm for the representative 6 critical states. The standard deviations of the calculated k_{eff}s by MCNP and McCARD were about 0.00013.

3.2. Calculation results

Instead of modelling wire and aluminium plate, the coolant channel between fuel plates are divided into 40 and the axial height are into 21, and gold reaction rates at the wire irradiation positions are calculated using a multiplier card. Since the thermal neutron flux is evaluated using the measured reaction rate, a comparison of reaction rate is better than that of thermal neutron flux.

The calculation is performed using ENDF/B-VII library. The fsds of the calculated gold reaction rates are less than 2%. For a comparison, the McCARD results are normalized to 42 kW power.

The calculated gold reaction rates at five locations in Fig. 1 are shown in Fig. 3.

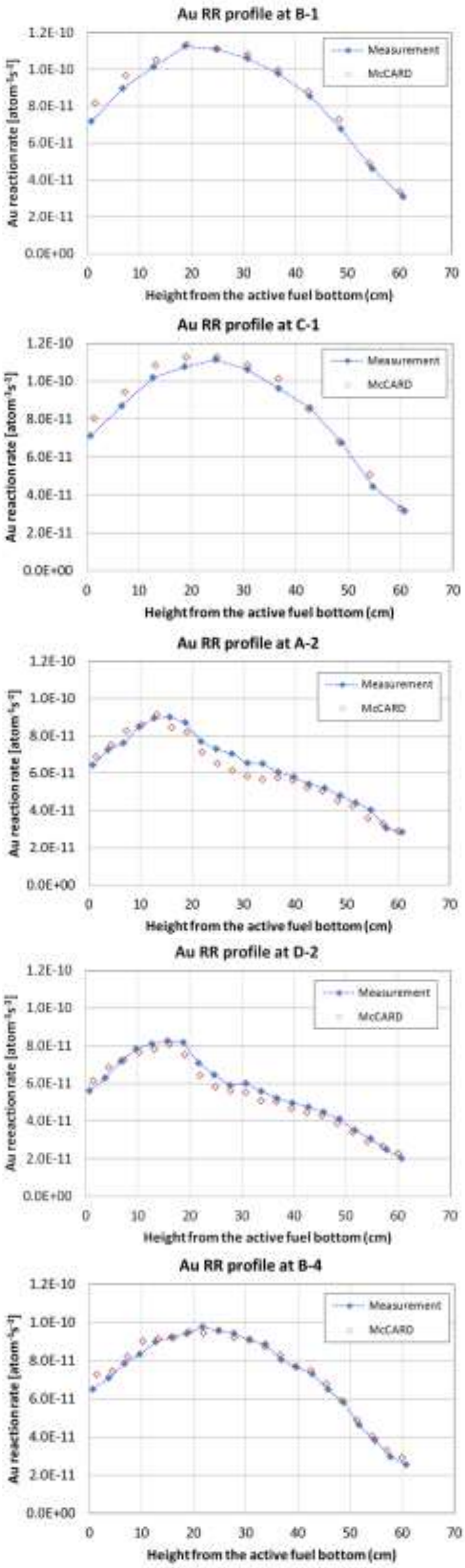

Fig. 3. Calculated and measured gold reaction rate distributions

3.3. Discussions

The McCARD predicts the measured gold reaction rates within 10% error except 12 points among 85 points in total.

The gold reaction rate distributions at B-1, C-1 and B-4 positions show good agreement between the measurement and the calculation, and they are smooth because CR1 or CR4 is almost withdrawn. At the A-2 and D-2 positions, on the other hand, they are skewed to the bottom due to the influence of the CR2 or CR3, the bottom of which is withdrawn to only about 21.5 cm in height from the active fuel bottom. However, they also show a similar shape between the measurement and the calculation despite a large variation near the control rod bottom.

The difference of the gold reaction rates between the measurement and the calculation is inferred to originate from not modelling the wire itself, the uncertainty in the geometric model, tally size, etc.

4. Conclusion

McCARD predicted successfully the gold reaction rates measured at OPAL reactor. The calculated gold reaction rates agree with the measured within 10% at most of positions despite the nearby control rod influence. The McCARD model for OPAL reactor is acceptable for the OPAL analysis, and it can be utilized for the simulation of physics tests of OPAL reactor.

Acknowledgements

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REFERENCES

[1] Research Reactor Benchmarking Database: Facility Specification and Experimental Data, IAEA, 2015.