Monte Carlo Assessment of Neutronic Impact of Pressure Tube Creep in a CANDU Lattice

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1. Introduction

In the CANDU reactor, the coolant channel diameter increases due to the pressure tube creep resulting from neutron irradiation damage. It is well known that a crept pressure tube leads to a non-uniform coolant flow causing a concern in the fuel cooling. In the previous work [1], it has shown that the impact of the pressure tube creep on the physics parameters is significant. In particular, the difference of the void reactivity by the other work [2] was greatly different from that by our work shown in Reference 1. In this study, in order to see the neutronic impact of the pressure tube creep more accurately, the Monte Carlo depletion calculations are performed using the McCARD code [3]. Impact of the crept pressure tube is evaluated in terms of the lattice reactivity and void reactivity.

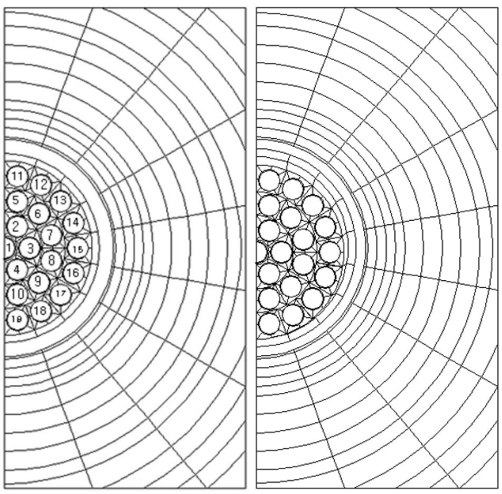

Fig. 1. Nominal and perturbed lattice models

2. CANDU Lattice Models and Analysis Methods

In this work, the standard 37-pin CANDU lattice is used and two values of diametric creep (2.5% and 5% of nominal) are considered. Fig. 1 shows HELIOS-1.8 [4] models for the reference and 5% creep case. Natural uranium is used as the fuel and, in normal operating condition, temperatures of fuel, coolant, and moderator are 960 K, 561 K and 342 K, respectively.

The HELIOS calculations are done with a 190-group adjusted cross section library. In the reference case, reflective boundary conditions are imposed on all the boundaries, while a periodic boundary condition is used on the top and bottom surfaces due to the asymmetry of the perturbed lattice. Regarding the mesh coupling in the HELIOS calculations, the exact coupling option is used in both nominal and perturbed models.

In parallel with HELIOS, the crept problems are also analyzed with McCARD code for comparison. McCARD is a Monte Carlo neutron transport code and basically designed for the depletion analysis for the nuclear power reactors. In the McCARD calculations, the continuous energy nuclear data cross section libraries based on ENDF/B-VII are used.

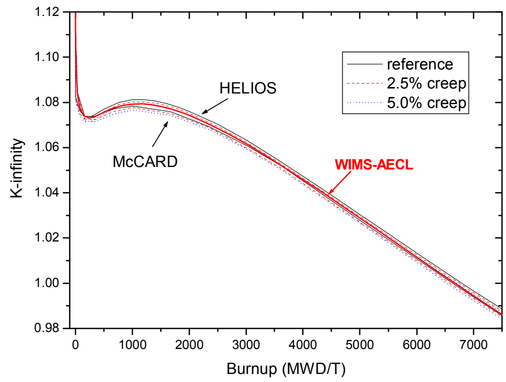

Fig. 2. Comparison of the lattice reactivity on burnup

3. Analysis Results

In Fig. 2, the lattice reactivity of the perturbed geometries is compared with that of the reference model. For the reference model, the result of WIMS-AECL calculation is added for comparison. Compared to the results of McCARD, the HELIOS and WIMS-AECL codes underestimate by 4.2 mk and 2.4 mk, respectively, at the fresh fuel state and overestimate by 0.3 mk and 0.1 mk, respectively, when the fuel burnup is above 1000 MWd/tU.

Fig.3 shows that the lattice reactivity is decreased noticeably in case of the pressure tube creep. The reactivity reduction ranges from -2 mk to -3 mk for the 2.5% creep and from -4 mk to -5.5 mk for the 5% creep. It is expected that the discharge burnup will be reduced by a few percents in the crept case. Generally the result of

McCARD calculation agrees well to that of HELIOS calculation. The reduced reactivity is mainly ascribed to the increased coolant volume in the perturbed case.

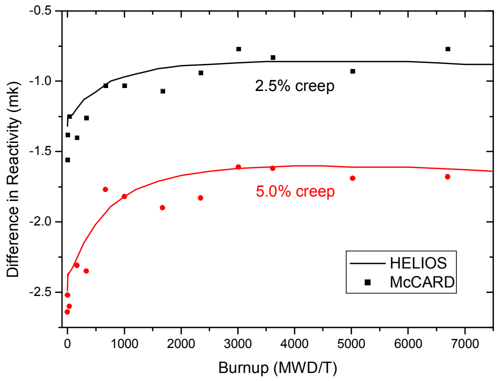

Fig. 3. Difference in the lattice reactivity

The coolant void reactivity was evaluated for the three lattice models and the results are shown in Fig. 4. The result indicates that the void reactivity increases with the creep. Compared to the result of McCARD, HELIOS underestimates at low burnup, and overestimates at high burnup inversely. The maximum difference between two codes is ~0.9 mk. Fig. 5 shows the difference in void reactivity between reference and crept lattices. Fig. 5 also compares the current results with a previous work [2] for the 5% creep case. The result indicates that the void reactivity increases with the creep and the difference is rather significant (~2 mk at zero burnup for 5% creep) at low burnup and decreases with the fuel burnup. At mid-burnup, the differences are ~0.4 mk and ~1 mk for 2.5% and 5% creep, respectively. However, a big difference is observed between the current and previous works. In the previous result, which was also obtained with HELIOS-1.7, the void reactivity difference is rather big over the whole burnup range. The reason for the difference is not identified at the moment and it is under investigation.

5. Conclusions

In the standard CANDU lattice, the impact of the pressure tube creep on the physics parameters is significant. In particular, the coolant void reactivity increases noticeably with the crept geometry. Therefore, the irradiation damage of the pressure tube should be duly considered in the nuclear design and safety analysis of a CANDU core. The pressure tube creep would result in a slightly reduced fuel burnup and a slightly higher power peaking in a fuel bundle.

ACKNOWLEDGEMENT

This work was supported by Nuclear Research & Development Program of Korea Science and Engineering Foundation (KOSEF) grant funded by the Korean government (MEST). (grant code : M20702040005-08M0204-00510)

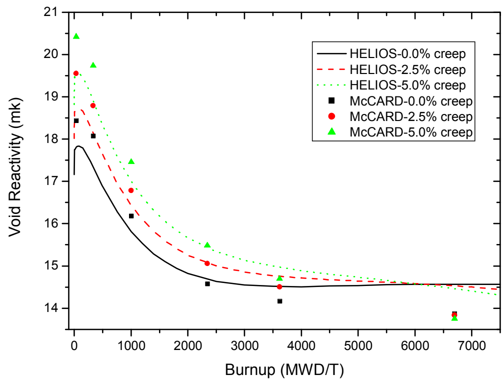

Fig. 4. Impact on the coolant void reactivity.

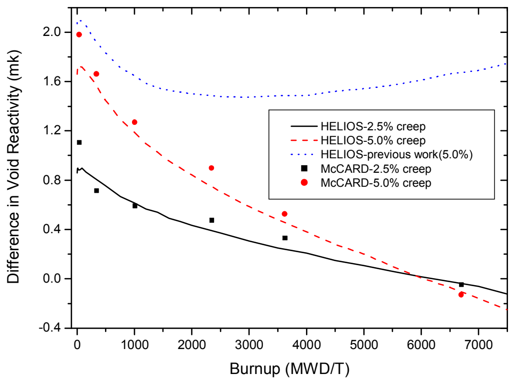

Fig. 5. Difference in coolant void reactivity

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