Comparison of Transport Calculation Between 2D/1D synthesis and RAPTOR-M3G at Core Barrel of Korea Standard Nuclear Plant(KSNP), OPR-1000

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1. Introduction

2D/1D synthesis method[1] using DORT code[2] and BUGLE-96 library[3] based on ENDF/B-VI has been widely used to calculate fast neutron (E>1.0MeV) fluence exposure to the beltline region of reactor pressure vessel(RPV). Recently, RAPTOR-M3G (RApid Parallel Transport Of Radiation-Multiple 3dimension Geometries) using 3D parallel discrete ordinate calculation was jointly developed by Korea Reactor Integrity Surveillance Technology (KRIST) and Westinghouse to satisfy the requirement of regulatory agencies (USNRC and KINS) for 3D calculations [4]. The DORT code for 2D/1D synthesis has been actively applied to calculate the fast neutron (E>1.0MeV) fluence exposure of RPV. RAPTOR-M3G code is also applied for the comparison of 2D/1D synthesis, and it was found that 2D/1D synthesis method generally provided more conservative results than RAPTOR-M3G at both RPV and surveillance capsule locations. As a result, definitely RAPTOR-M3G for 3D calculation must apply for accurate evaluation of the integrity and ageing of RPV and internal structures. Therefore, the purpose of this paper is to compare the differences in terms of geometric aspect of KSNP model between 2D/1D synthesis and RAPTOR-M3G at core barrel area.

2. Methods and Results

1) Comparison of R-Z model between 2D/1D synthesis and RAPTOR-M3G

The distances between the end of rectangular-shaped baffle plate and cylindrical-shaped core barrel (bypass water region) change, and thus the big difference between 2D/1D model and 3D model is R-Z geometry model. As shown in Fig.1, 2D/1D synthesis method has only one R-Z model representing R-Z plane.

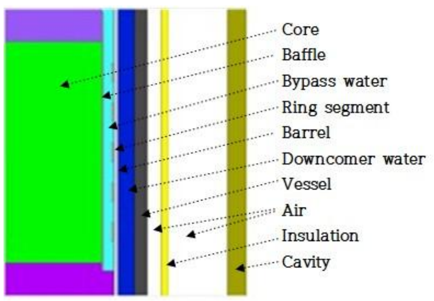
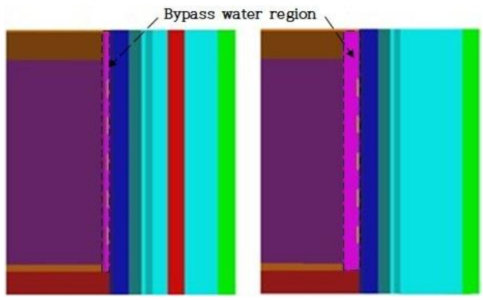


Figure 1 - ***R-Z geometry model of 2D/1D synthesis method.***

However, RAPTOR-M3G model can be imitated realistically by using BOT3P [5] and has various R-Z model along with azimuthal angle. Fig.2 shows R-Z vertical cross section view of RAPTOR-M3G using Tecplot [6] to check the geometry of model. The pink area indicated in arrow shows the bypass water region in Fig. 2, which is that 56 degree and 68 degree have the narrowest and widest bypass water regions respectively.



(a) (b)

Figure 2 - ***R-Z vertical cross-section view of RAPTOR-M3G at (a) 56 degree and (b) 68 degree.***

Therefore, core barrel located in the nearest to the baffle will be strongly affected by fast neutron fluence due to shorter distance of bypass water. Also, It can be expected that the neutron flux of 3D calculation at 56 degree is relatively higher than that of 2D/1D, because the distance of bypass water region in 3D R-Z model is shorter than that of 2D R-Z model.

Fig. 3 shows comparison of axial neutron flux profile between 3D and 2D/1D analysis. Both 2D/1D and 3D at 56 degree having relatively shorter bypass water distance is higher than 68 degree. But unlike the expectation, 2D/1D synthesis results are still higher than RAPTOR-M3G. RAPTOR-M3G has realistic model and more closer to real value. Thus, 2D/1D synthesis method is excessively conservative, when calculating neutron (E>1.0MeV) flux.

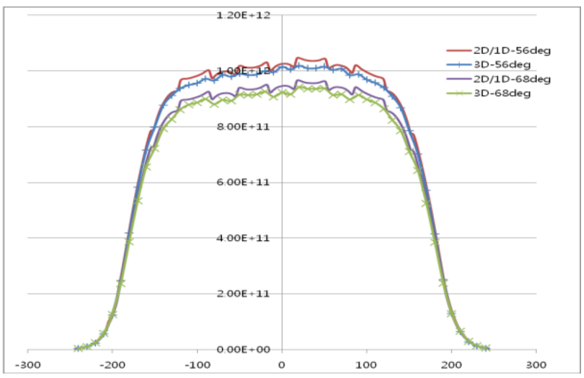


Figure 3 - ***Axial neutron flux (E>1.0Mev) comparison between 2D/1D synthesis and RAPTOR-M3G at core barrel, 56 degree and 68 degree***

Four half-rectangular-shapes of each graph in Fig.3 are caused by ring segment made of steel, which is one of the reactor internal structures located between baffle and barrel discontinuously and thus has lower moderation ability than water. This phenomenon has also been observed. [7]

2) Comparison of R-θ model between 2D/1D synthesis and RAPTOR-M3G

In order to find out azimuthal angle where 3D is higher than 2D/1D, azimuthal neutron flux profiles are required. 2D/1D synthesis method has also only one R-θ model representing core mid-plane (z=0). There is no significant distinction between 2D/1D and 3D in R-θ model. However, fuel loading pattern can affect azimuthal neutron flux profile and maximum neutron flux location in R-θ model. For this reason, constant enrichment, burn-up and axial relative power are applied to compare each R-θ model. The result is shown in Fig. 4.

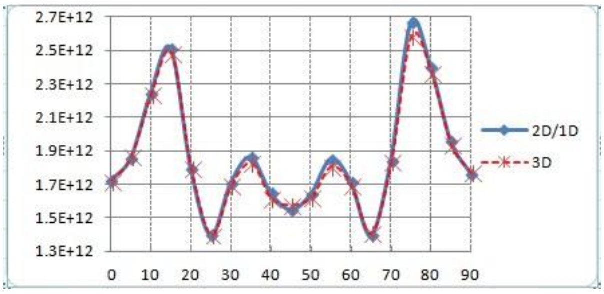


Figure 4 - ***Azimuthal neutron (E>1.0MeV) flux comparison between 2D/1D synthesis and RAPTOR-M3G at core barrel mid-plane.***

The content achieved in Fig. 4 is that upward peaks are produced around baffle corner (Fig. 5) location, but 45 degree which is also baffle corner shows downward peak. The angle (56 degree) having the shortest distance of bypass water region shows also that 2D/1D synthesis result is still higher than RAPTOR-M3G result excluding the impact of fuel loading patterns.

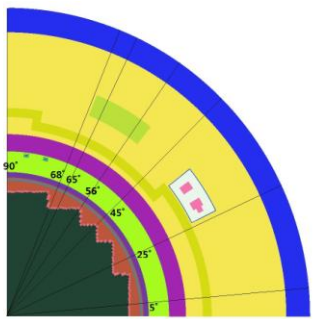


Figure 5 - ***R-θ horizontal cross-section view of RAPTOR-M3G at core mid-plane***

To confirm the detail, relative values [(2D-3D)/3D] between 2D/1D synthesis and RAPTOR-M3G is displayed in Table 1. In the Table 1, the angles that RAPTOR-M3G results are higher than 2D/1D synthesis are appeared at 5, 25, 45, 65 and 90 degrees and do not indicate shorter distance of bypass water region except 45 degree (Fig. 5).

Table 1 – ***Relative values, [(2D-3D)/3D]*(%,) of neutron flux (E>1.0MeV) results between 2D/1D synthesis and RAPTOR-M3G***

Angle	Relative value (%)	Angle	Relative value (%)
0	0.1800 %	50	1.2263 %
5	-0.5831 %	55	2.3871 %
10	0.2811 %	60	1.1618 %
15	0.8997 %	65	-0.6247 %
20	0.0111 %	70	0.4138 %
25	-0.1643 %	75	2.9383 %
30	0.9203 %	80	1.1385 %
35	1.8413 %	85	1.0424 %
40	1.8848 %	90	-0.4344 %
45	-1.9222 %		

* 2D denotes 2D/1D synthesis result
3D denotes RAPTOR-M3G result

3. Conclusions

1) 2D/1D synthesis method shows still higher results at the shortest distance of bypass water region. The reason is that 2D/1D synthesis method has excessive conservatism because of having just one model of R-θ and R-Z separately.

2) Angles (5, 25, 45, 65 and 90 degrees) that RAPTOR-M3G results are higher than 2D/1D synthesis results seem to have almost regular interval. The reason can be that neutron flux to reach to barrel is affected by the nearest core definitely and all of near core areas including bypass water.

3) RAPTOR-M3G performing 3D calculation can be applied to various reactor structures, because the code can simulate the model realistically and reasonably in geometric view points.

4) Understanding the phenomenon that 45 degree shows downward peak, in spite of baffle corner location, remains.

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