Transport calculation for plate-type nuclear reactor with the direct transport code SHARK

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1. Introduction

Direct whole-core transport method has been developed with high-fidelity requirement in reactor physics calculation and the booming of computer industry. Researches of the direct transport method have made great progress for pin-cell geometry pressurized water reactor (PWR). As for the other type of nuclear reactor, the direct transport method is applied in the MAGNOX gas-cooled reactor with MPACT [1-3]. The application extension to the other type of reactors is still inadequate and further research of the direct transport method needs to be conducted.

Simulation-based High-fidelity Advanced Reactor physic Kit (SHARK) [4-5] has been developed for further research of the direct transport method and application expansion in reactor physics simulations. In the conceptual design of SHARK, the importance of high-fidelity geometry modeling and direct transport method without geometry restrict has been raised. Considering that, the CSG method, subgroup resonance method and the MOC transport method are applied in SHARK for a broader range of application in cases with complicated geometry. One of the most important goals in the design of SHARK is the capability to simulate pin-cell geometry and the other complex geometry simultaneously. In this paper, the plate-type JRR-3M benchmark is adopted for the verification of SHARK

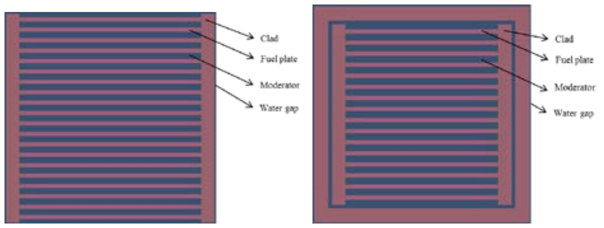
2. Model of the JRR-3M plate-type reactor with SHARK

2.1 Standard fuel

Geometry model of the standard fuel lattice is shown in Fig.1. Dimension of the plate-type fuel assembly is 7.72cm*7.72cm. 20 Fuel plates are arranged in an array in y-axis direction. The thickness and length of each fuel plate are 0.038cm and 6.16cm separately. Clad and water moderators are located outside of fuel plates. A 0.05cm-thick water gap lies outside of the fuel assembly.

2.2 Follow fuel

Geometry of the follow fuel lattice is shown in Fig.1. Dimension of the follow fuel lattice is 7.72cm*7.72cm, which is totally same as the standard fuel. The number of fuel plates is decreased from 20 to 16 in the follow fuel and the length of fuel plate is 4.9cm.

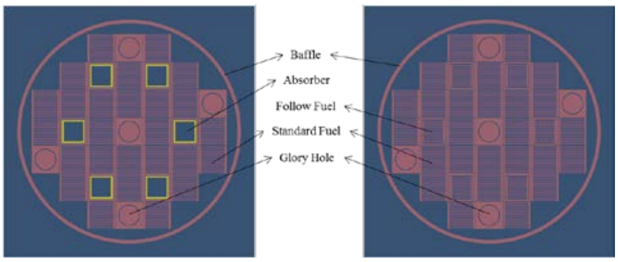


(a)Stardard fuel *(b) Follow fuel*

Fig. 1. Stardard fuel and follow fuel assembly model with SHARK

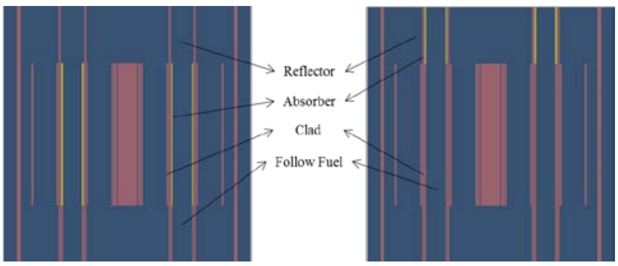
2.3 Whole core

The radial and axial cuts of the JRR-3M reactor whole-core model are shown in Fig.2~Fig.3. All absorber in (AAI) and all absorber out (AAO) cases are modeled. The whole-core consists of 26 standard fuel assemblies, 6 absorber/follow fuel assemblies and 5 glory hole assemblies. The baffle outside of the reactor is modeled explicitly. Thickness of the baffle is 1cm and the inner radius is 30.0cm. Height of the axial reflector region is 30cm on the top and bottom of the reactor.



(a)AAI *(b) AAO*

Fig. 2. Radial cut of the JRR-3M reactor whole-core model.



(a)AAI *(b) AAO*

Fig. 3. Axial cut of the JRR-3M reactor whole-core model.

3. Numerical Results

3.1 Results of 2D whole-core cases

Two-dimensional whole-core cases of all absorber out (AAO) and all absorber in (AAI) cases were applied in the validation. Calculation condition in SHARK was 0.02 cm ray spacing, 128 azimuthal and 6 polar angles, which was according to the fuel lattice sensitivity analyses. Eigenvalue and fission rates results were shown in Tab.1. The eigenvalue differences were 40 and 51 pcm and the maximum plate fission rates differences were 1.39% and 1.37%. All these results show good accuracy of SHARK in plate-type reactor calculation. The detailed flux distribution results of these two cases were shown in Fig.4-5.

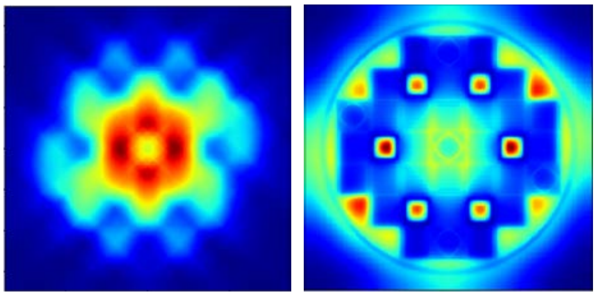


Fig. 4. Flux distribution results of on the 1st and 7th energy group for the 2D whole-core AAI case

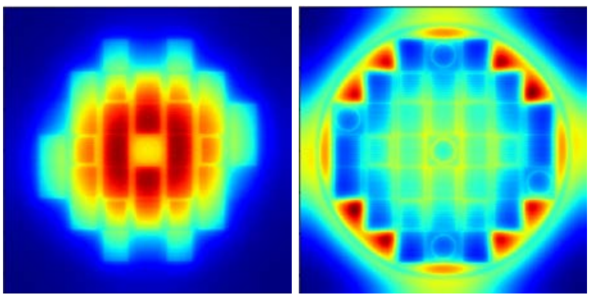


Fig. 5. Flux distribution results of on the 1st and 7th energy group for the 2D whole-core AAO case

Table I: Results of 2D whole-core cases in SHARK

	AAO	AAI
RMC(Ref.)	1.14237±1pcm	0.92213±1pcm
SHARK	1.14277	0.92162
Diff	40pcm	-51pcm
Plate Max	1.39%	1.37%
Plate RMS	0.25%	0.36%

3.2 Results of 3D whole-core cases

The JRR-3M macro 3D whole-core cases were calculated with RMC and SHARK. In calculation with SHARK, traditional 2D/1D transport method was applied. In each assembly, 6*6 pin cells were separated artificially for axial homogenization calculation and CMFD acceleration. Eigenvalue and fission rate results were shown in Tab.2 and axial homogenized results are shown in Fig.6. The eigenvalue differences for these two cases are 102 and 74 pcm and the maximum plate fission rate differences are 1.68% and 2.10%. All these results show the good accuracy of SHARK in plate-type JRR-3M reactor macro benchmark.

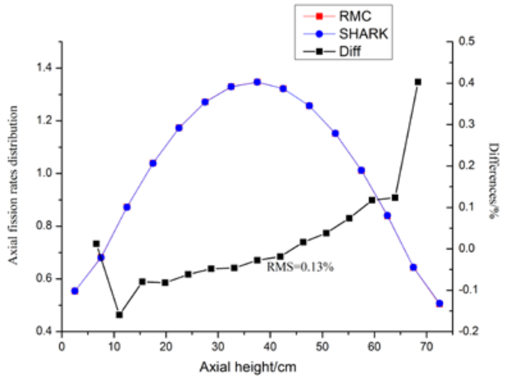


Fig. 6. Flux distribution results of on the 1st and 7th energy group for the 2D whole-core AAO case

Table II: Results of 3D whole-core cases in SHARK

	AAO	AAI
RMC(Ref.)	1.08964±1pcm	0.88223±1pcm
SHARK	1.08890	0.88121
Diff	-74pcm	-102pcm
Plate Max	2.10%	1.68%
Plate RMS	0.30%	0.35%

4. Conclusions

In this paper, the macro JRR-3M benchmark is calculated with the Monte-Carlo code RMC and the deterministic direct transport code SHARK. The geometry models of the standard fuel, follow fuel and 3D whole-core are introduced. Numerical results of eigenvalue and plate fission rate are compared. In 3D whole-core AAI and AAO cases, eigenvalue difference is 102 and 74 pcm and the maximum differences of 3D plate fission rate are 1.68% and 2.10% separately. These results show the good accuracy of SHARK in the JRR-3M macro benchmark. The transport calculation ability for the plate-type reactor is primarily validated in SHARK.

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