Verification of RAST-K hexagonal analysis module with SNR and VVER-440 benchmarks

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ABSTRACT

This poster presents verification results of hexagonal geometry analysis module of our in-house nodal diffusion code RAST-K. Hexagonal-geometry based code system has been recently implemented in RAST-K for the purpose of sodium-cooled fast reactor design and analysis. As a nodal solver for hexagonal geometry, a triangle-based polynomial expansion nodal (TPEN) method was used. This method has been previously verified for MOX-3600, CAR-3600, MET-1000 and MOX-1000 fast reactors in steady state condition. In this poster, verification of Liquid Metal-cooled Fast Breeder Reactor (LMFBR) and PWR are performed. VVER is a Russian PWR that is using hexagonal shape fuel assemblies (FA). Currently, there are 128 VVER-type reactors under operation worldwide. In addition, 37 % of all reactors under construction worldwide are VVER reactors. Therefore, development and validation of hexagonal geometry solver is necessary for improving the competitiveness of our in-house nodal code RAST-K. As part of that, this poster performs verification using benchmark problems such as SNR4g and VVER-440.

Code system

- RAST-K is a nodal diffusion code system based on TPEN method for hexagonal geometry analysis [6]
- TPEN solver implemented in RAST-K has been verified with sodium-cooled fast reactor and 33-group cross section data generated by SARAX based on ENDF/B-VII.0 [1]
- RAST-K hexagonal geometry analysis solver had been verified using our in-house Monte-Carlo code MCS for MET-1000 and MOX-3600 fast reactors [2]

[1] Tuan Tran Quoc, Alexey Cherezov, Xianan Du, Jinsu Park, Deokjung Lee, "Development of Hexagonal-Z Geometry Capability in RAST-K for Fast Reactor Analysis", ICENES 2019, Bali, Indonesia, Oct 6-9 (2019)
[2] Tung Dong Cao Nguyen, Hyunsuk Lee, Xianan Du, Vutheam Dos, Tuan Quoc Tran, Deokjung Lee, "Macroscopic Cross Sections Generation by Monte Carlo Code MCS for Fast Reactor Analysis", PHYSOR, Cambridge (UK), (2020)
[6] Jiwon Choe, Sooyoung Choi, Peng Zhang, Jinsu Park, Wonkyeong Kim, Ho Cheol Shin, Hwan Soo Lee, Ji-Eun Jung, Deokjung Lee, "Verification and validation of STREAM/RAST-K for PWR analysis", Nucl. Eng. Tech., 51(2): 356-368, 2019

Specification of benchmark model

● SNR 4-group benchmark
- SNR benchmark is a three-dimensional LMFBR benchmark problem which is a simplified model of MARK-I core design of SNR 300 prototype LMFBR
- 289 fuel assemblies are used to build the core
- Six different types of regions are used in the core
- 181 reflector assemblies are used

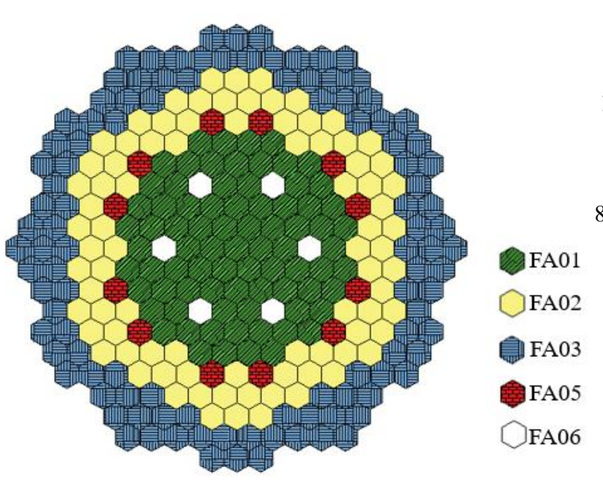

Fig. Radial layout of SNR

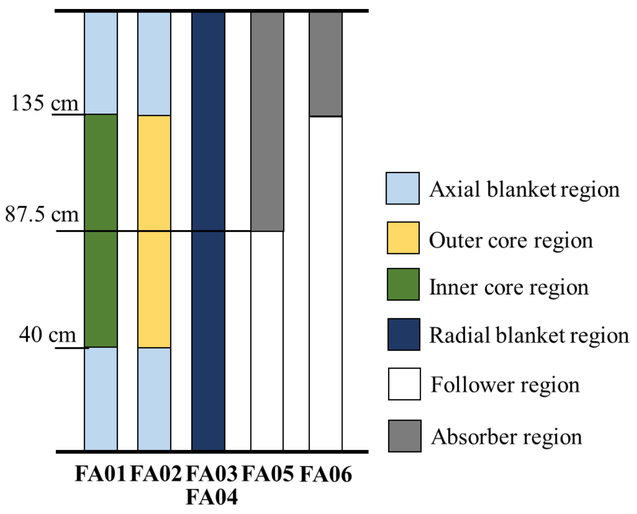

Fig. Axial composition of SNR

● VVER-440 benchmark
- Active height: 250 cm
- 349 fuel assemblies
- 72 radial reflector assemblies
- 12 axial nodes (each of 25 cm) is used for calculation
- Five different types of fuel assemblies are used. FA03 is a reflector assembly.

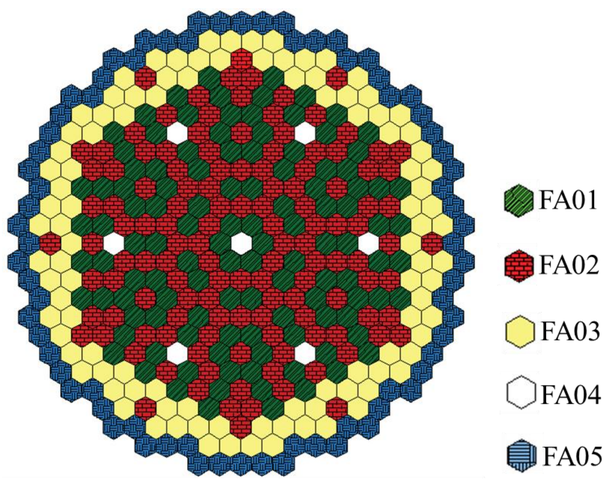

Fig. Radial layout of VVER-440

Table. Specification of CPU

Parameter	Value
Model	Intel(R) Xeon(R) CPU E5-2690 v2 @ 3.00GHz
Processor	2.92 GHz, 20 cores
Memory [GB]	252 GB
Storage	SSD 240 GB x 1ea

Calculation results

■ Calculation results compared with DIF

Table. Multiplication factor of VVER-440

Code system	keff	Difference [pcm]	CPU time [sec]
DIF	1.01132		
RAST-K	1.01136	4	0.880

Table. Multiplication factor of SNR

Code system	keff	Difference [pcm]	CPU time [sec]
DIF	1.00989		
RAST-K	1.00994	5	0.555

■ Relative difference of power distribution
- Y-direction means the FA ID matched with FA ID displayed in FA index figure
- X-direction is calculation node
- Only fuel assembly regions are considered
- 10 calculation nodes are compared for VVER-440 analysis
- Subplot (a) presents a relative power distribution of 37 FAs.
- Subplot (b) contains the comparison data and relative differences.
- Relative differences are within ±2%.

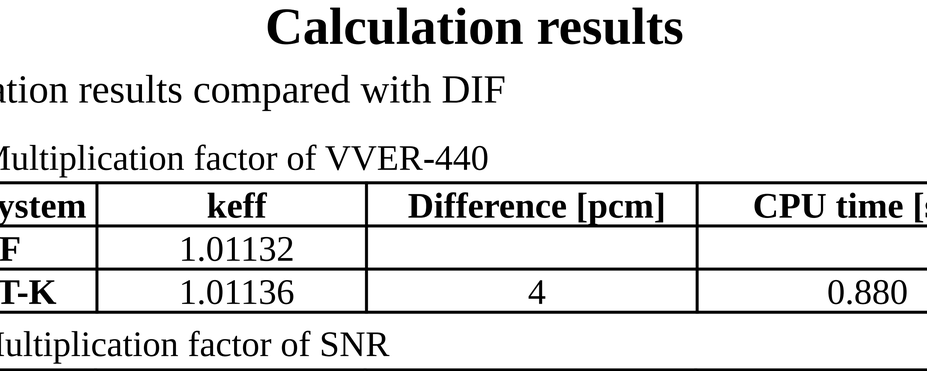

Fig. FA index in VVER-440

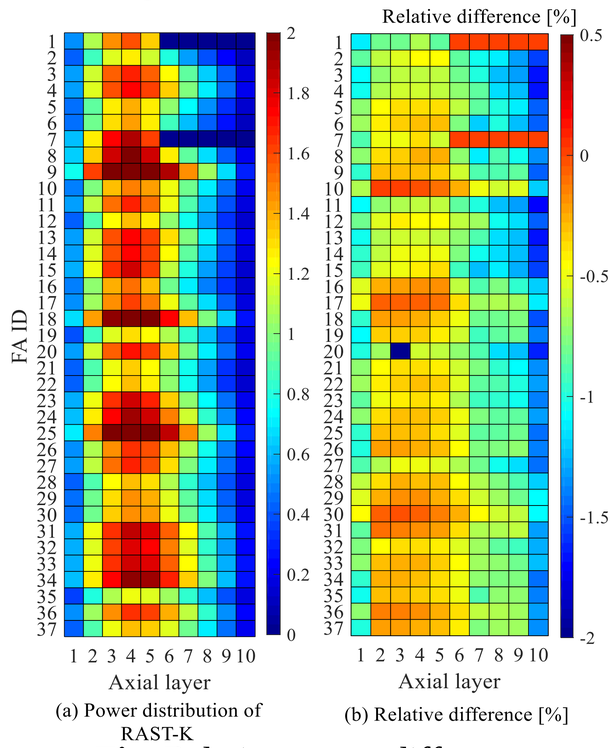

Fig. Relative power difference

DISCUSSION AND SUMMARY

■ In terms of multiplication factor, RAST-K shows a difference within 5 pcm for both VVER-440 and SNR. As for the radial power differences, relative differences are found within ±2%. The reference code system is DIF, and a total of 370 nodes (i.e., 37 FA positions with 10 axial nodes per FA) are compared.

■ These comparisons show that the developed code system can provide reliable results for hexagonal geometry analysis.