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DeCART Solutions for C5G7 Hexagonal Variation Problems

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1. Introduction

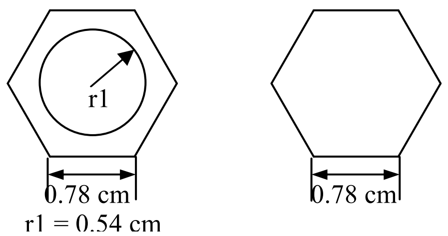
Recently, a 3-D capability for a hexagonal core has been equipped to the DeCART hexagonal kernel.[1] The equipped axial kernel solves the diffusion equation or the SP_N equations [2] by a nodal method as the NEM or SANM. This paper first establishes a C5G7 hexagonal variation problem to examine the implemented hexagonal kernel and then compares the solutions of the DeCART code to the Monte Carlo solutions which are obtained by using the McCARD code.

2. C5G7 Hexagonal Variation Problems

C5G7MOX benchmark problems are established for a rectangular geometry to benchmark the current deterministic code without a spatial homogenization. In this Section, these problems are modified for the hexagonal problems for an examination of the DeCART hexagonal modules.

2.1. Pin Cell Configuration

In determining the pin cell geometry, the same outer radius of 0.54 cm as the rectangular problem is used, and the pin pitch is modified to conserve the pin volume. The finally determined pin pitch which is defined as the side length is 0.78 cm. The material compositions for the fuel rods, fission chamber, control rod and guide-tube are not changed. Also, the reflector material is same as in the rectangular problem. Fig. 1 shows the pin cell configurations according to the cell types.



(a) Fuel, F/C, G/T and CR Cells (b) Reflector Cells

Fig.1 Pin-Cell Configurations for C5G7 Hexagonal Benchmark

2.2. Assembly Configuration

Fig. 2 shows the assembly configurations for the UO_2 and MOX assemblies. Fuel assembly consists of 198 fuel and 19 non-fuel cells, which entails 9 rings of pin cells. The fission chamber is inserted into the center of the assembly as for the rectangular problems, and the control rods are inserted into the other 18 non-fuel cells for the rodded problems. The assembly pitch which is defined as the side length is 11.9 cm, and about 0.17 cm of a coolant gap spacing exists.

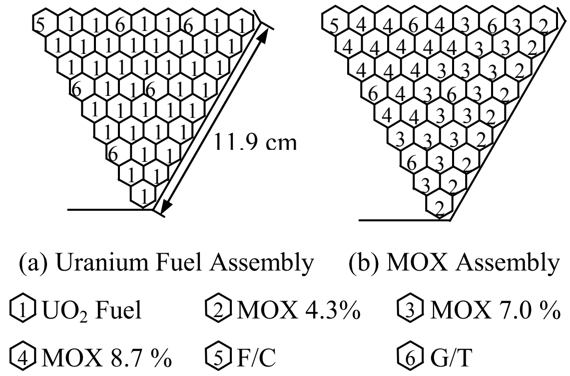


Fig. 2 Fuel Assemblies for C5G7 Hexagonal Benchmark

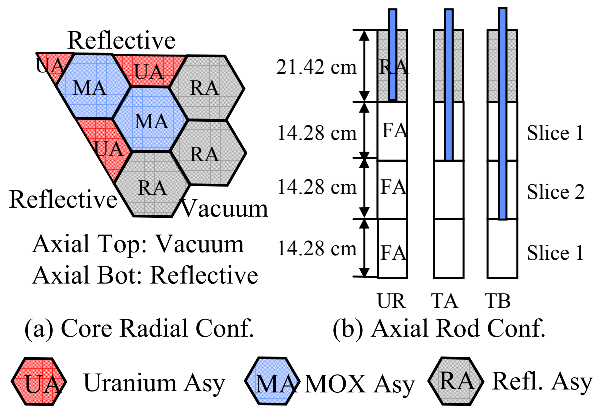


Fig.3 Core Configurations for C5G7 Hexagonal Benchmark

2.3. Core Configuration

Fig. 3 shows the radial and axial core configurations for the established problem. In the radial direction, this problem contains a total of 19 fuel assemblies and 18 reflector assemblies, and imposes a 30° reflective symmetry. In a real calculation, a 60° reflective symmetry condition is used because of a limitation of the developed code. In the axial direction, this problem contains 3 fuel planes and one reflector plane as for the rectangular core. Vacuum and reflective boundary conditions are imposed at the top and bottom surfaces.

The established problem consists of three configurations: (1) unrodded, (2) slightly rodded A and (3) heavily rodded B configurations. In the unrodded configuration, the control rods are inserted into the axial reflector plane for all the fuel assemblies. In the rodded A configuration, the control rods at the center UA assembly are inserted into the slice 3 fuel plane. In the rodded B configuration, the control rods at the center UA assembly and at the other UA assemblies are inserted into the slice 2 and slice 3 fuel planes, respectively.

3. Benchmark Calculation

The DeCART solutions for the proposed C5G7 hexagonal variation problems are compared to the McCARD solution. In the DeCART calculation, the fuel cell is divided into five fuel rings and three coolant rings for the uniform cross section regions which are again divided into the six azimuthal regions for the flat source regions. Therefore, a total of 48 flat source regions exist in a fuel cell. The reflector cell is divided into 150 flat source regions with the same volumes. For the axial calculation, the NEM-SP_3 option which solves the SP_3 equations by using the NEM approximation is applied. For this calculation, the axial domain is first divided into four planes for the radial MOC calculation and next it is divided into total 12 sub-planes for the NEM-SP_3 calculation.

Table 1 summarizes the eigenvalue and local pin power differences for the 2-D unrodded problem. DeCART shows about 10 pcm of an eigenvalue and about 1.8 % of a maximum, 0.38 % of a average and 0.50 % of a RMS pin power differences from the McCART solutions. Table 2 summarizes the eigenvalue and local pin power differences. DeCART shows less than 60 pcm of eigenvalue differences for all the problems. In the local pin power comparison, DeCART shows less than 2.0 % of maximum differences, less than 0.5 % of average differences and less than 0.6 % of RMS differences at slice 1 for all the problems. In the axially integrated pin power comparison, DeCART shows less than 1.7 % of a maximum difference, less than 0.4 % of an average difference and less than 0.6 % of a RMS difference. The pin power differences of the 3-D problems are similar to that of the 2-D problem.

Table 1. Eigenvalue and Power Difference for 2-D problem

keff[1)] Difference, pcm		-9.6
Pin Power[2)] Difference, %	Maximum	1.83
	Average	0.38
	RMS	0.50

1) keff = 1.16244, $\sigma = 0.00009$
2) $\sigma < 0.5$ %

Fig. 4 shows the assembly power difference between the solutions of the DeCART and McCARD codes. The assembly power of the DeCART code agrees very well to that of the McCARD code. Therefore, it can be concluded that the hexagonal kernel of the DeCART code works well and produces reasonable solutions.

Table 2. Eigenvalue and Power Difference between DeCART and McCARD

		Unrodded	Rodded A	Rodded B
keff Diff., pcm		-52.4[1)]	-52.7[2)]	-61.7[3)]
Slice 1 Power[4)] Diff., %	Max.	1.87	1.84	1.92
	Avg.	0.35	0.42	0.43
	RMS	0.54	0.58	0.60
Slice 2 Power Diff., %	Max.	1.77	1.88	1.92
	Avg.	0.35	0.42	0.43
	RMS	0.54	0.59	0.59
Slice 3 Power Diff., %	Max.	0.90	0.78	1.17
	Avg.	0.38	0.48	0.53
	RMS	0.45	0.53	0.59
Axially Integrated Power	Max.	1.59	1.64	1.62
	Avg.	0.31	0.37	0.39
	RMS	0.48	0.51	0.53

1) keff = 1.12273, $\sigma = 0.00001$
2) keff = 1.11890, $\sigma = 0.00001$
3) keff = 1.10262, $\sigma = 0.00001$
4) $\sigma < 0.2$ %

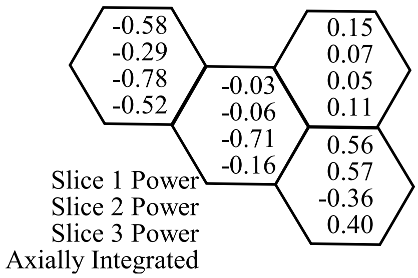


Fig.4 Planar Assembly Power Difference for C5G7 Hexagonal Benchmark

4. Conclusion

In this paper, C5G7 hexagonal variation problems were established to examine the 3-D hexagonal kernel implemented in the DeCART code. The benchmark calculation showed that the hexagonal kernel of the DeCART code worked well and produced reasonable solutions.

REFERENCES

[1] J. Y. Cho, et al., "CMFD Formulation for Hexagonal MOC Transport Calculation," 2006 KNS Autumn Mtg, Kyungju, Nov. 2-3, 2006
[2] J. Y. Cho, et al., "Error Reduction of the Axial Kernel of the DeCART code," 2007 KNS Spring Mtg, Jeju, May. 10-1, 2007