VERA Solution for 2D HZP BOC Quarter Core by DeCART2D/MASTER

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1. Introduction

The VERA Core Physics Benchmark Progression Problems provide a method for developing and demonstrating increasing capabilities for reactor physics methods and software. Design is based on Watts Bar Nuclear 1 (WBN1); Westinghouse designed 17x17 PWR the common vintage built in the U.S. in the 1980's and 1990's. In VERA Core Physics Benchmark, Monte Carlo methods (KENO-VI) with ENDF/B-VII.0 cross sections had been used [1]. However, in this study usage of DeCART2D/MASTER [2][3] codes with the same design specification and boundary conditions, which are 2D quarter, core hot zero power at beginning of cycle (initial load). Then a comparison would be on the eigenvalue, pin power distribution, and control rod worth.

2. Methods and results

In this section some of the techniques used to simulate the quarter core for VERA. The fuel pin, assemblies and core loading pattern.

2.1 Fuel pin

Table I Fuel Rod Specification [1]

Input	Value
Pellet Radius	0.4096 cm
Inner Clad Radius	0.4180 cm
Outer Clad Radius	0.4750 cm
Pellet Material	UO_2
Fill Gas Material	Helium

In Table I, the specification of fuel rod has been used for simulation in VERA benchmark problem.

2.2 Fuel assembly

The fuel assembly is 17x17 lattice with assembly pitch of 21.50 cm. There are three different enrichments of 3.10, 2.619 and 2.11 w/o. Some of the fuel assemblies have Pyrex rods consist of borosilicate glass that inserted in the guide tubes, helping the reactivity control during operation. See Table II.

2.3 Moderator

The moderator is borated light water, the boron have two natural isotopes of B-10 and B-11 with nat. abundance of 19.8% and 80.2%, respectively.

Table II Fuel Assembly Specification [1]

Assembly Type	No. of Assemblies	Fuel Enrichment	No of Fuel Rods per Assembly	No. of Pyrex	Pyrex Type
A0	32	3.1	264	0	B2O3-SiO2 with 12.5wt% B2O3
A2	8		256	8	
A3	4		252	12	
A4	8		248	16	
A6	8		240	24	
B0	4	2.619	264	0	
B4	8		248	16	
B5	40		244	20	
B6	16		240	24	
C0	65	2.11	264	0	

2.4 Loading pattern

Since the octant core will be applied for reflector cross section generation; octant core will be used in DeCARD2D, Fig. 1 is illustrating the loading pattern.

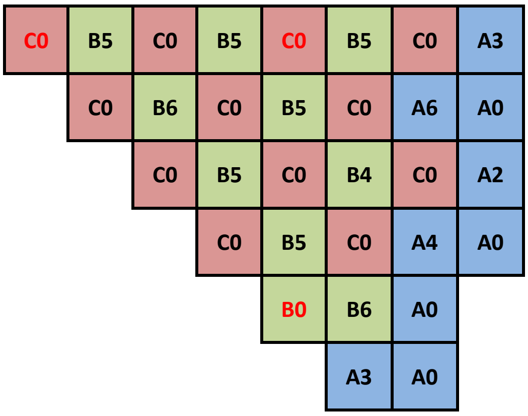

Fig. 1. Octant Core for VERA Benchmark [1]

2.5 Control rods

The control rods are consisting of two types of absorber materials. First, AIC is Ag-In-Cd with 80/15/5% in the lower part of the absorber rod. Second, the B_4C is in the upper part of the absorber rod. Since 2D would be simulated, calculations of control rod will be divided into two calculations. Control rods are inserted in the assemblies that have no Pyrex rods. In Fig. 1, the position of CR is colored by red.

2.6 Results

First, DeCARD2D has to be applied for homogenizing the cross section (See Fig. 2). Then using PROLOG and PROMARX.

PROLOG is used for generating cross section library for each fuel type. PROMARX is used for generating cross section library for each reflector.

Then, these libraries will be used in MASTER.

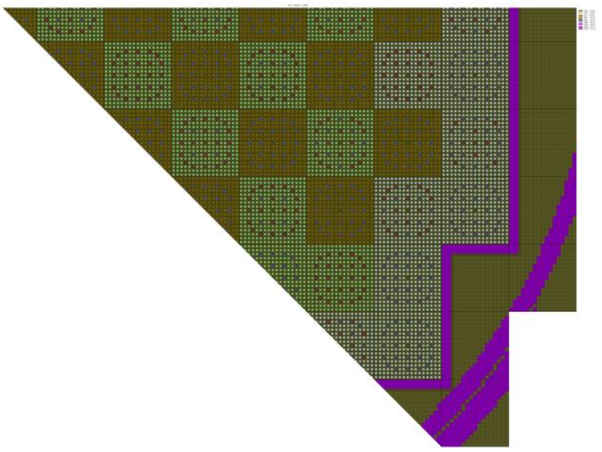

Fig. 2. DeCART2D for Octant Core to Generate the Reflector Cross Section, where the pryex absorbers appears in red dot. [2]

Table III shows the eigenvalue and control rod worth for each DeCARD2D/MASTER results and reference results.

Table III Results for Eigenvalue and Control Rod Worth Using DeCART2D/MASTER

Problem 5	KENO-VI		DeCART2D/MASTER		Difference	
	k-eff.	RW (pcm)	k-eff.	RW (pcm)	Δk x1e-5	%
5A-2D	1.004085	-	1.002909	-	-117.6	-
5B-2D	0.991496	1265	0.990644	1233	-85.2	-2.38
5C-2D	0.990227	1394	0.989316	1368	-91.1	-1.71

MASTER is capable to generate each power for the pins in the core. Usage of coloring for comparing the power distribution with DeCART2D/MASTER analysis and VERA (KENO-VI) structure. (See Fig. 3 and Fig. 4)

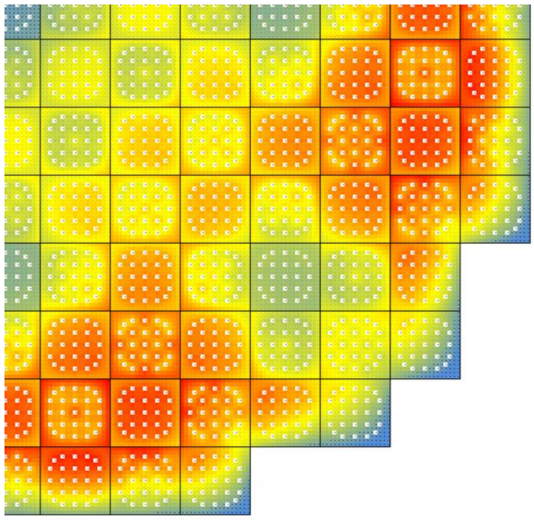

Fig. 2. DeCART2D/MASTER's Power Distribution for Insertion of AIC

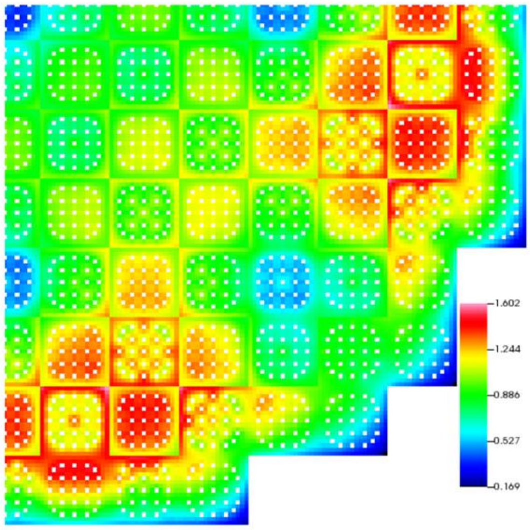

Fig. 3. VERA'S Power Distribution for Insertion of AIC [1]

3. Conclusions

From the results section, it can be noticeable that the differences are around 98 pcm, which is considered not large but also not small. The reason is that DeCART2D use methods of characteristics, while MASTER uses nodalization methods with diffusion equation. For the pin power distribution, DeCARD2D/MASTER shows an excellent structure.

In VERA benchmark problem, Monte Carlo methods (KENO-VI) had been used. Moreover, both of these codes use the same libraries cross section (ENDF/B-VII.0).

In conclusion, this study shows the capabilities of DeCART2D/MASTER for generating data to analyze reactor core physics.

REFERENCES

[1] A.T. Godfrey, VERA Core Physics Benchmark Progression Problem Specifications, Rev. 4, Oak Ridge National Laboratory, Oak Ridge (TN), 2014. CASL-U-2012- 0131-004.

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[3] J. Y. Cho, et al., "MASTER-4.0: Multi-purpose Analyzer for Static and Transient Effects of Reactor," KAERI/TR-6947/2017, 2017.