Two Step Procedure using a 1-D Slab Spectral Geometry in a Pebble Bed Reactor Core Analysis

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1. Introduction

A strong spectral interaction between the core and the reflector has been one of the main concerns in the analysis of pebble bed reactor cores. To resolve this problem, VSOP adopted iteration between the spectrum calculation in a spectral zone and the global core calculation [1]. In VSOP, the whole problem domain is divided into many spectral zones in which the fine group spectrum is calculated using bucklings for fast groups and albedos for thermal groups from the global core calculation. The resulting spectrum in each spectral zone is used to generate broad group cross sections of the spectral zone for the global core calculation.

In this paper, we demonstrate a two step procedure in a pebble bed reactor core analysis. In the first step, we generate equivalent cross sections from a 1-D slab spectral geometry model with the help of the equivalence theory [2]. The equivalent cross sections generated in this way include the effect of the spectral interaction between the core and the reflector. In the second step, we perform a diffusion calculation using the equivalent cross sections generated in the first step. A simple benchmark problem derived from the PMBR-400 Reactor was introduced to verify this approach. We compared the two step solutions with the Monte Carlo (MC) solutions for the problem.

2. Methods and Results

2.1 Benchmark Problem and the Reference Solution

A simple benchmark problem derived from the PMBR-400 Reactor was introduced. Figure 1 shows the geometry and the dimensions of the problem. We assumed that the core and reflector region are homogeneous for a simplicity. The temperature was assumed to be 300K everywhere. The nuclide number densities in each region of the problem are listed in Table 1. The reference solution was obtained from the MC calculation using the MC-CARD code.

2.2 1-D Spectral Geometry and Cross Section Generation

Figure 2 shows the 1-D slab spectral geometry model. Though the original problem is defined as a cylindrical reactor, the 1-D spectral geometry was modeled as a slab for a simplicity. We preserved the distances to the core-reflector interfaces from the center of the reactor. We used the HELIOS code to generate 8-group cross sections for each region. From the 8-group cross-sections and the fluxes and the net currents at the core-reflector interface, we obtained 8-group equivalent cross sections by applying the simplified equivalence theory. However, we ignored the discontinuity factor at the right boundary of the 1-D slab spectral problem for a simplicity. A large number (=100.0) was used as the diffusion coefficients of the void region.

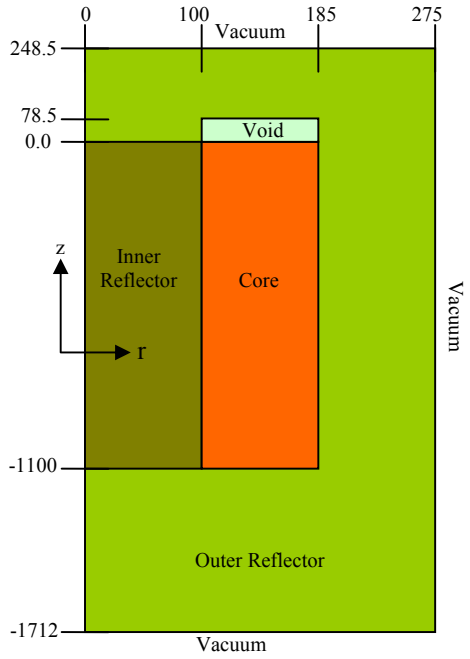

Figure 1. Geometry and dimensions of the problem

Table 1. Nuclide Number Densities in each region

Region	Nuclide	Number Density (#/barn-cm)
Core	U234	6.22417E-08
	U235	7.08600E-06
	U238	1.15700E-04
	O16	2.45700E-04
	Si	2.77203E-04
	C	5.26260E-02
Inner Reflector	C	9.00000E-02
Outer Reflector	C	9.00000E-02
Void	-	-

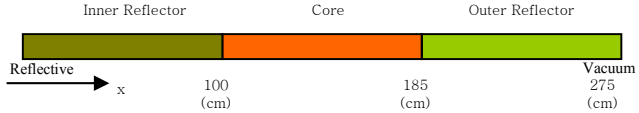

Figure 2. 1-D Slab Spectral Geometry Model

According to the equivalent theory, we can reproduce the HELIOS solution by solving the diffusion equation with the

equivalent cross sections. The second low of Table 2 and the solid lines in Fig.3 compare the diffusion FDM solutions obtained from the equivalent cross sections, the HELIOS solutions, and the MC solutions to the 1-D slab problem shown in Fig. 2. FDM solution agrees well with HELIOS solution and its difference from the MC solution is acceptable. The small k_{eff} difference between HELIOS and FDM is ascribed to the fact that we ignored the discontinuity factor at the right boundary of the problem. The third row of Table 2 and the dotted lines in Fig. 3 compare the diffusion FDM solutions obtained from the equivalent cross sections, the HELIOS solutions, and the MC solutions to the 1-D cylinder problem shown in Fig. 4. FDM solution agrees well with HELIOS solution and its difference from the MC solution is also acceptable, which justifies the use of the equivalent cross sections generated from the 1-D slab spectral geometry to problems defined in a cylindrical geometry.

Table 2. Comparison of k_{eff} of the 1-D problems

	HELIOS (H)	FDM (F)	F-H (pcm)	MC (M)	F-M (pcm)
Slab	1.21563	1.21574	+11	1.21198±10pcm	+376
Cyl.	1.22203	1.22172	-31	1.21793±10pcm	+379

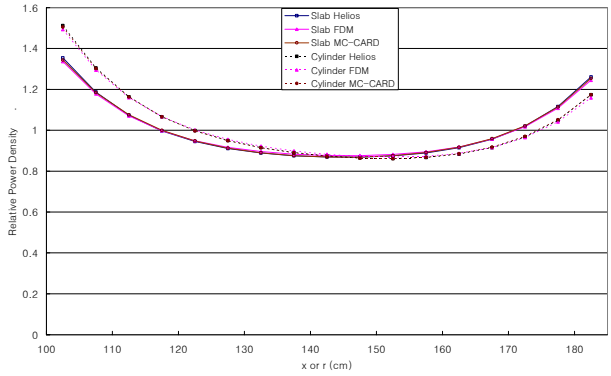

Figure 3. Power distributions of the 1-D problems

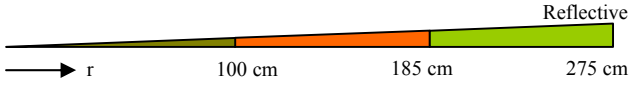

Figure 4. 1-D Cylinder Problem

2.3 Two Step Solution to the Benchmark Problem

Table 2, Figure 5, and Figure 6 compare the diffusion FDM solutions and MC solutions to the benchmark problem shown in Fig 1. The equivalent cross sections generated from the 1-D slab spectral geometry were used in the diffusion FDM calculation. The diffusion FDM solutions predict the MC solutions well and the errors are acceptable.

Table 2. Comparison of k_{eff} of the benchmark problem

FDM (F)	MC (M)	F-M (pcm)
1.21342	1.20928±3pcm	+414

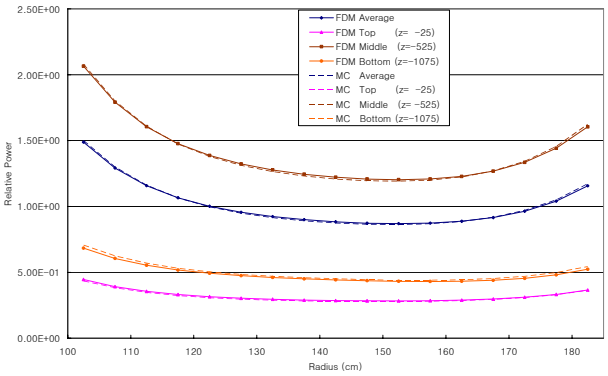

Figure 5. Comparison of radial power distributions

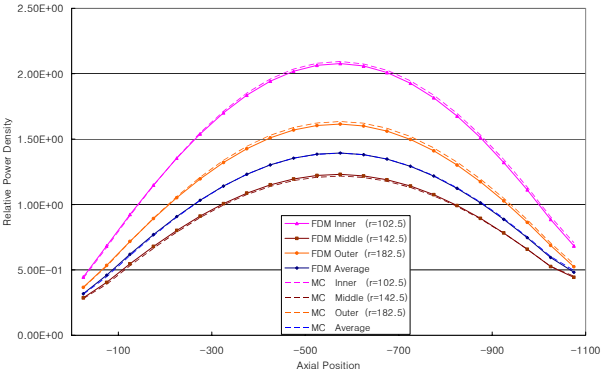

Figure 6. Comparison of axial power distributions

3. Conclusion

In this paper, we demonstrated a two step procedure in a pebble bed reactor core analysis. In the first step, we generated equivalent cross sections from a 1-D slab spectral geometry model with the help of the equivalence theory. In the second step, we performed a diffusion calculation using the equivalent cross sections generated in the first step. We showed that the effective multiplication factor and the power distributions of the benchmark problem can be predicted accurately by the two step approach.

REFERENCES

1. E. Teuchert et al. "V.S.O.P.('94) Computer Code System for Reactor Physics and Fuel Cycle Simulation – Input Manual and Comments," Institute für Sicherheitsforschung und Reaktortechnik, April 1994.
2. K. S. SMITH, "Spatial Homogenization Methods for Light Water Reactor Analysis," PhD Thesis, Massachusetts Institute of Technology (1980).