General Geometry Capability in the Transport Lattice Code LIBERTE

Kang-Seog Kim, Chung Chan Lee, Sung Quun Zee
Korea Atomic Energy Research Institute P.O. Box 105, Yuseong, Daejon, 305-333 Korea, kimks@kaeri.re.kr

1. Introduction

The transport lattice code LIBERTE (Linear Boltzmann Transport Equation Solver for Reactor Physics and Engineering) [1] developed at KAERI was only for the rectangular domain problems including the structured square mesh pins with an intra structure. The characteristics method for the spatial discretization which the LIBERTE code adopts is advantageous for a complicated geometrical structure. Since the geometry treatment module in LIBERTE includes only a rectangular geometry with square mesh cells, its application has been limited to the conventional PWRs. Therefore, we developed the general geometry handling module for the characteristics method and restructured the LIBERTE code to treat the general geometrical problems. The geometry handling module is based on any type of polygon with an intra structure and their couplings at the rectangular, triangular and hexagonal domain boundaries. We also developed the visualizing program called LIBGRAF to help the users to construct the complicated geometrical structures.

The basic concept for the general geometry treatment in LIBERTE is introduced, and several sample calculations were performed and the results were compared to those of the MCNP [2].

2. Methods and Results

2.1 LIBERTE Methods

LIBERTE adopts the characteristics method [3] for the spatial discretization which includes the merits of the integral transport method and S_N method. The former is advantageous for a complicated geometrical structure and the latter for a highly anisotropic scattering and large problems. Since the characteristics method does not solve the huge matrix, this can be easily extended to the whole-core transport calculations. The subgroup method [4,5] has been implemented to treat the resonance, where the resonance integrals are approximated by quadratures. To obtain the equivalence cross sections, the transport calculation using the characteristics method is performed at the resonance energy ranges. The criticality spectrum can be obtained by the B_1 approximation [5] to consider the neutron leakage effect in the core with a buckling adjustment. This criticality spectrum is used to obtain the one-group cross sections for the depletion calculation. The exponential matrix method [6] is implemented to perform the depletion calculation for the change of the compositions. Currently the HELIOS library is used in transport calculation and the ORIGEN-2 [6] libraries are used for the depletion calculation.

2.2 General Geometry Module

The general geometry module consists of four main parts which include the domain boundary treatment, basic polygon cell construction, coupling of the constituent cells and the visualization of the geometrical structure.

Domain boundaries of a square, a regular triangle and a regular hexagon are possible, and the ray tracking method has been generalized for those domain boundaries.

The problem domain consists of various types of basic polygon cells with intra subcells. These polygon cells can be constructed with a lesser effort by the user or with the full descriptions to construct the basic cell. Figure 1 shows some of the basic polygon cells which include the circular subcells or not. The center of the circular subcell can be located on the inside, edge and corner nodes and the other subregions can be automatically divided into the subcells by connecting the edge node with the center of the cell.

The neighboring polygon cells can be easily combined together by coupling one of the edge nodes in each cell. This procedure is repeated in rows and columns. The input deck is simple and easy to construct a complicated geometrical structure with the least input descriptions.

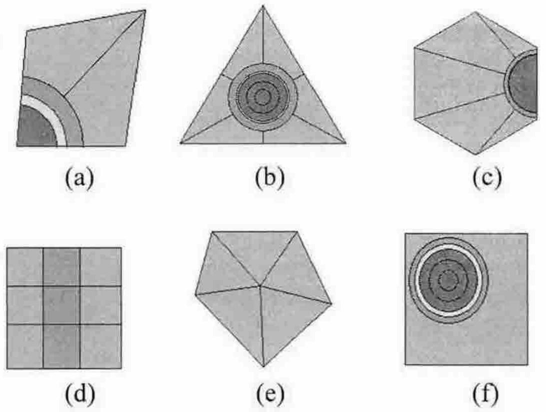
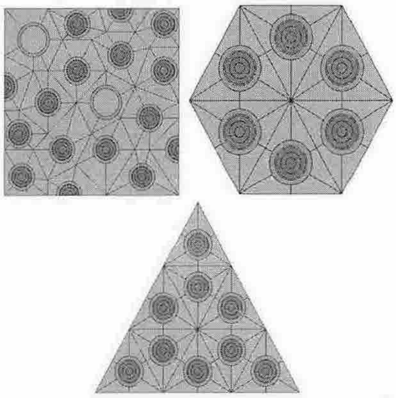


Figure 1. Basic polygon cells



(a) (b) (c)

Figure 2. Geometrical structures of the sample problems

We also developed the visualizing software called LIBGRAF using QWIN in FORTRAN to help the users to construct the complicated geometrical structures. LIBGRAF can draw the basic polygon cells separately as well as a whole geometrical structure. Figures 1 and 2 show some examples of the basic polygon cells and the whole structure drawn by LIBGRAF. LIBERTE code independently verifies the correctness of the geometrical construction from calculating the domain volume and the summation of the constituent cells.

2.3 Sample Calculation

Three types of geometries with triangular, rectangular and hexagonal domain boundaries were constructed as shown in Figure 2. The fuel pins are located randomly in the moderator for case (a) and regularly for cases (b) and (c). We performed the transport calculations using these geometrical structures, and compared the results with those of the MCNP calculations. Multiplication factors and pin power distributions were compared as shown in Table 1. The multiplication factors agree well within the differences of 50 pcm for the triangular and hexagonal boundaries and 150 pcm for the rectangular boundary. The maximum difference of the pin power distributions is 3.2 %. The results show that the LIBERTE code with the capability of a general geometry treatment works reasonably well.

Table 1. Comparison of the multiplication factors and the pin powers

Domain	Multiplication Factor		Pin Power
	MCNP*	LIBERTE	Max. Diff (%)
Triangular	1.44649	1.44692	0.0
Rectangular	1.44407	1.44548	3.2
Hexagonal	1.44649	1.44692	0.0

*Standard deviation : < 0.00050

3. Conclusion

We developed a general geometry treatment module and implemented it into the transport lattice code LIBERTE. It is capable of modeling any complex geometry with a domain boundary of triangular, rectangular and hexagonal geometries. The comparison of the results with the MCNP shows that the LIBERTE code woks well for the complex geometries. This capability enables LIBERTE to be applied to various types of reactor cores and fuels without any limitations.

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