Comparison of LCLS Algorithm and MCNP/CFP Code for Analysis of VHTR Fuel Elements with Randomly Distributed Particles

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1. Introduction

The Monte Carlo method is widely used in particle transport calculations, especially in complex geometry.

Recently, High Temperature Gas Cooled Reactor (HTGR) has rekindled its interest. However, HTGR has several difficulties to analyze. One of these is its randomly distributed particle fuels and the double heterogeneity.

To solve this problem, Limited Chord Length Sampling (LCLS) method [1,2] and the method used in MCNP/CFP code [3-5] were recently developed. Since both of them use probability distributions, they have resemblance, although they use different probability distributions.

Thus, the object of this paper is to compare these two methods.

2. Description of LCLS Method

The concept of LCLS method is based on using probability distribution for stochastic geometry, instead of explicit description of randomly distributed stochastic geometry. To describe randomly distributed stochastic geometry, LCLS method uses two kinds of probability distributions. One of this probability distributions is to sample the chord length [2],

$$P(\lambda)=1-\sqrt{1-\left(\frac{\lambda}{2r}\right)^2}=\xi, \qquad (1)$$

where λ is the chord length within spherical geometry, r is the radius of spherical geometry, and ξ is the random number between 0 and 1. The meaning of chord length is described in Fig. 1.

The other probability distribution is to sample the distance between two spherical geometries, [2]

$$P(\lambda)=1-\exp\left[-\frac{\lambda}{\bar{\lambda}_1}\right]=\xi, \qquad (2)$$

where λ is the chord length between the two spherical geometries, $\bar{\lambda}$ is the mean chord length, and ξ is the random number between 0 and 1. The mean chord length $\bar{\lambda}$ should be obtained by numerical calculation before Monte Carlo calculation.

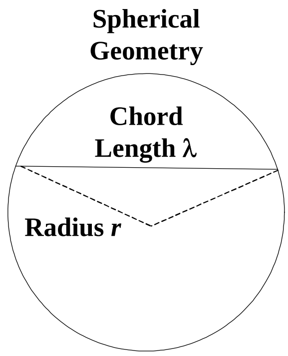

Fig. 1: The meaning of Chord Length within spherical geometry

3. Description of MCNP/CFP Code

The concept of the method used in the MCNP/CFP code is similar with that of the LCLS method. However, the MCNP/CFP code uses different type probability distributions. The probability distributions used in the MCNP/CFP code are four. The first one samples incident angle [3],

$$P(\mu)=\int_0^{\mu}2\mu d\mu=\xi, \qquad (3)$$

where ξ is the random number between 0 and 1. The meaning of incident angle is described in Fig. 2. This probability distribution corresponds to Eq. (1) in the LCLS method.

The other three probability distributions, that correspond to Eq.(2) in the LCLS method, are named as Nearest Neighbor Distribution (NND) [3]. NND1 is a ray-trace starting on the surface of a spherical geometry in the direction sampled from a cosine distribution, NND2 is a ray-trace starting in the matrix (depends on the collision density in the matrix), and NND3 is a ray-trace starting on the boundary surface of the region (except for the direction, NND3 is same as NND2). These NND distributions should also be obtained by numerical calculation before Monte Carlo calculation.

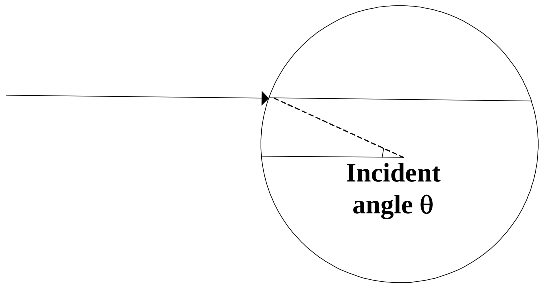

Fig. 2: The meaning of incident angle

4. Comparison of Numerical Results

The sample problem consists of a sphere of radius 25 cm, containing 781 randomly arranged spheres of 1 cm radius [2]. The matrix material is filled with nitrogen and the source is born in the center of matrix material (i.e., the center of a sphere of radius 25 cm).

The results are listed in Table 1.

Density	Tally	MCNP[a]	LCLS[a]	MCNP/CFP[b] (10⁹ histories)
N: 0.001 [g/cc] B : 10.0 [g/cc]	Surface Current [n/source n]	0.347	0.3459	3.53103E
	Matrix Cell Flux [n/cm² /source n]	2.420E-4	2.412E-4	2.43070E
	Stochastic Cell Flux [n/cm²/source n]	8.62E-8	8.64E-8	8.53954E
N: 0. 1 [g/cc] B : 10.0 [g/cc]	Surface Current	0.2042	0.2034	2.06626E
	Matrix Cell Flux	2.472E-4	2.449E-4	2.46787E
	Stochastic Cell Flux	9.05E-8	9.07E-8	9.01211E
N: 1.0 [g/cc] B : 10.0 [g/cc]	Surface Current	7.0E-4	6.2E-4	6.02347E
	Matrix Cell Flux	1.359E-4	1.292E-4	1.29212E
	Stochastic Cell Flux	5.02E-8	5.441E-8	5.44930E

[a] : Library used is not specified in the reference.
[b] : ENDF/B-VI is used.

The MCNP and LCLS results are quoted from reference [2]. The MCNP/CFP results were obtained by our work [6].

For LCLS method, the discrepancy in the high scattering matrix material is already recognized in [2]. It is believed that this discrepancy is due to the assumption of Markovian transport made by the LCLS method [2]. In this work, we find similar discrepancy in the MCNP/CFP results.

5. Conclusions

In this work, we found similar tendency between the LCLS algorithm and the MCNP/CFP code. Although the MCNP/CFP code uses seemingly different probability distributions from those of LCLS algorithm, it exhibits similar discrepancy due to the assumption of Markovian transport in high scattering matrix material.

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REFERENCES

[1] T. J. Donovan, and Y. Danon, "Application of Monte Carlo Chord-Length Sampling Algorithms to transport through a two-dimensional binary stochastic mixture, " *Nucl. Sci. Eng.*, **143**, 226(2003).
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[2] T. J. Donovan, T.M. Sutton, and Y. Danon, "Implementation of chord length sampling for transport through a binary stochastic mixture," *Proc. Int. Conf. Mathematics and Computation, Tennesse, April 6-11,* (2003).

[3] I. Murata, "Studies on Monte Carlo Particle Transport in Irregularly Distributed Fuel Elements for High Temperature Gas-Cooled Reactors," (1999).

[4] I. Murata, T. Mori, and M. Nakagawa, "Continuous Energy Monte Carlo Calculations of Randomly Distributed Spherical Fuels in High-Temperature Gas-Cooled Reactors Based on a Statistical Geometry Model," *Nucl. Sci. Eng.*, **123**, 96 (1996).

[5] I. Murata, T. Mori, and M. Nakagawa, "New Sampling Method in Continuous Energy Monte Carlo Calculations for Pebble Bed Reactors," *J.Nucl. Sci. Technol.*, **34**, 734 (1997).

[6] I. Murata, S. Yun, and N. Z. Cho, "User’s Manual for MCRDF, MCNPCFP, and MCNPBALL," KAIST (2005) 0 (draft).