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Development of CAD Based Geometric Module for Monte Carlo Calculations

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1. Introduction

Conventional Monte Carlo (MC) codes use the text based geometry input system. However, two difficulties can be found as the result of adopting text based geometry input system. One is a user's burden for writing a complex geometric data in the text file, and the other is the limited capability of modeling the geometry due to the usage of predefined types of surfaces in the MC codes.

To lessen the burden for users to write geometric input files, and to utilize the convenience of CAD software in modeling 3D shapes, interfacing codes [1-5] which converts CAD file into MCNP input file have been developed. However this approach still shows limitation of geometric capability because the CAD model is converted into combinations of the predefined types of surfaces. Different from the converting approach, well-developed CAD kernels can be embedded in the MC codes for raising the geometric capability of MC codes. In ITER TBM program, Mengkuo [6] applied CGM as the geometric engine of MCNP [7] to use CAD data directly.

As like the second approach, this work is to augment the geometric capability of McCARD [8] using OpenCASCADE 6.3 [9], an open source of CAD kernel. By the aid of C++ libraries and development tools supplied in the OpenCASCADE package, the CAD based geometric module for McCARD has been developed. In this paper, we describe technical works for implementing the CAD based geometric module and optimization approaches to accelerate the CAD based MC calculations.

2. Algorithms and Implementation

2.1 Algorithm for CAD based Monte Carlo calculation

For the spatial consideration for neutron behavior, it is essential to calculate a minimum distance to surface (DTS) under given particle position and direction. Beside of the DTS calculating, in the case a particle migrates to another cell, the destination cell should be clearly defined. For retrieving geometric information from the CAD file, DTS and next cell specification are to be clearly obtained.

The module for calculating DTS is implemented by using the functions and tools provided by OpenCASCADE. After importing a CAD file, DTS and connectivity information are able to be obtained by calling functions of the CAD kernel.

2.2 Optimization of CAD based geometry module

Repeated calling of CAD kernel functions takes enormous time unless any optimization processing is applied. In the MC calculation, the optimization for accelerating the calculation is crucial.

To make the geometric module perform the essential work efficiently, procedures which do not need to be repeated should be separated from the module. Separated parts of the module are gathered into a preprocessing module.

After the optimization, the CAD based DTS module shows similar performance with conventional module in McCARD as shown in Table I.

Table I: Performance of DTS calculation module after optimization

Type of Surface	McCARD	McCARD/CAD
Plane	0.104	0.104
Quadratic surface	0.528	0.483

*Elapsed time [sec] for 10,000,000 repeated calculations in a Linux system.

As to the next-cell-finding module, a similar approach is tried. Before starting the calculations, the connectivity information of the entire cells is preprocessed. By utilizing the connectivity information, the only essential calculations can be performed in the code.

3. Application Results

2.1 C5G7 benchmark problem

To demonstrate the geometrical capability of McCARD/CAD, eigenvalue calculations of the C5G7 benchmark problem are performed..

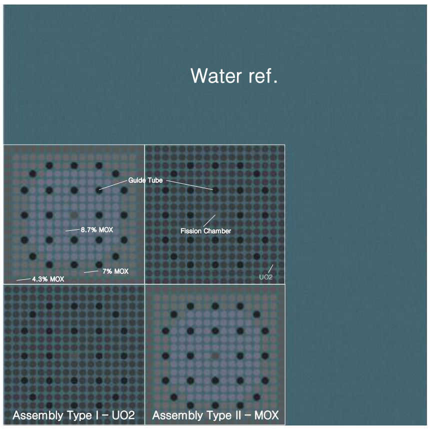


Fig. 2 Core configuration of C5G7 in a CAD file format.

By using a commercial CAD software of SolidWorks2009, the geometrical data of the quarter core is saved as the STEP file format. Fig 2 shows core configuration of C5G7 problem generated from SolidWorks2009. 100,000 histories per a cycle were simulated in 400 total cycles including 200 inactive cycles.

Table II shows the comparisons of k_{eff}'s estimated by the original McCARD, McCARD/CAD, and MCNP. From Table II, we can see that the k_{eff} calculated by McCARD/CAD agrees well with the results from other codes within the 95% confidence intervals.

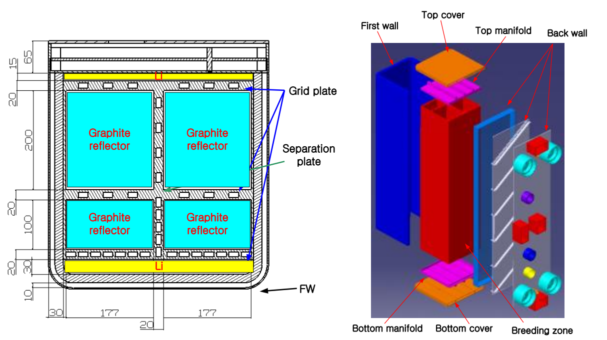
Table II: Calculation result of the C5G7 benchmark problem.

	McCARD	McCARD/CAD	MCNP*
k_{eff} (SD)	1.18671 (14)	1.18641 (15)	1.18655 (4)
Elapsed Time [sec]	4840.9	5941.8	-

* Chung, Jong Sung, Status of Neutron Multi-group Module in McCARD, 2006

2.2 Korean HCML TBM

Neutronics calculations is conducted for the Korean Helium Cooled Molten Lithium (HCML) Test Blanket Module (TBM). Regional neutron fluxes and neutron heating powers are estimated by McCARD/CAD and the original McCARD. Its 2D configuration, dimensions and material compositions of the TBM is listed in the following pictures.



(a) (b)

Fig. 1 (a) 2D configuration and dimensions (b) 3D contour and components of the Korean HCML TBM

Its simplified geometrical data is saved as the STEP file format. Total 105 cells in the TBM model are represented in box shape. Continuous cross section libraries from FENDL-2.1(ENDF/B-VI) were used in the calculations.

The calculation result from McCARD/CAD is identical with that from the original McCARD. The additional calculation time for introducing the CAD engine is estimated as the range from 40% to 80% comparing with the original calculation.

Table II: The elapsed time for calculating the TBM.

# of sources	Elapsed Time [sec]	
	McCARD	CAD/McCARD
10,000	25.7	36.4
100,000	119.2	222.1

3. Conclusions and Future Works

By implementing the CAD based geometric module in McCARD, it has a capability of using CAD data directly for the system geometry input. Optimizations for the CAD engine were also performed for the speedup of the geometrical calculations. Calculation results from McCARD/CAD for the TBM problem and C5G7 problem show that it produces statistically the same tally outputs with a moderate calculation performance. Additional calculation times for adopting the CAD engine were estimated about 20~80% of the total calculation time

Currently the CAD based geometric module has implemented for the plane and cylindrical surfaces. Further works for improving geometric capabilities of McCARD/CAD is desired.

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