DEVELOPMENT OF TRAINING MONTE-CARLO CODE FOR 2D AXISYMMETRIC SIMULATION OF NEUTRON TRANSPORT

A. V. Sokolov, A. A. Pikhulya, M. A. Polozkova

FSUE «RFNC – VNIITF named after Academ. E. I. Zababakhin», Snezhinsk, Russia

The application of Monte-Carlo software packages allows for rapid and accurate simulation of particle transport. These packages are used to predict the performance of nuclear reactor core, protection against ionizing radiation, medical and research facilities with sources of radiation. Computer simulation significantly reduces development and test costs for the designs subjected to ionizing radiation.

For many years, the Monte-Carlo codes have been developed and improved in Russia. Among them are the PRIZMA code developed at RFNC – VNIITF [1], the C-007 code developed at RFNC – VNIIEF [2], the MCU code developed at NRC "Kurchatov Institute" [3].

Scientific and research efforts of the students attending higher educational establishments and specializing in the related fields of science need to focus on mathematical methods, algorithms, and tools for computer codes development. One of the best ways for a student to learn how to do this within the framework of these efforts is to personally develop a code or code modules that extend capabilities of the existing code. In this case, it is better to develop a small code that implements a simplified model while describing the principal laws of a physical process rather than generalized computer codes that have more complex architecture.

A training Monte-Carlo code for 2D axisymmetric simulation of neutron transport was developed and tested by the authors with the assistance of supervisors from RFNC – VNIITF. The code allows for adding of new code modules, for example, in order to change the geometry or the simulation methods and add new types of particles under consideration.

Based on this code, a training code for students who study fast neutron physics, mathematical methods, and programming can be developed.

The code capabilities make it possible to:

- apply a system of spectral constants (SC);
- simulate the interaction of neutrons with the substance of the system with due regard for the SC data;
- use the input language to set the simulated system geometry and its properties;
- compute the neutron density distribution on a rectangular mesh using two methods, namely, collision-based estimation and path-based estimation [4];
- count the number of region boundary crossings as well as the number of particles that escaped from the system;
- estimate statistical error of the results;
- perform parallel computations with OpenMP [5].

Nuclear data used in computations are represented in the form of the model SC created based on the ENDF/B-V SC [6]. It includes nuclear data that correspond to approximations used in computations. The data structure in the model constants files is similar to the SC files used in PRIZMA that are described with the help of D-diagrams [7]. This approach to data organization allows for adding of extra information into the file. At that, there is no need to bring about radical changes to the code module responsible for interactions modeling and to rewrite the code to account for a new data format.

Collision-based estimation is rather easy to implement but its efficiency impairs greatly when the cells of the resultant mesh decrease in size. In such a case, path-based estimation can improve the computational efficiency. Besides, some other methods to reduce the results variance with the help of non-analog simulation are realized in the code. They include statistical weight of survival, weight windows method, as well as Russian roulette and splitting methods [4]. These methods can increase the number of collisions in the states that are valuable for the final result, while leaving the mathematical expectation of the result unchanged.

In order to speed up the computations on multicore processors, the OpenMP paralleling of particle transport simulation is implemented in the code.

The code testing involved consideration of several problems, including those that have analytical solution, for example, the sphere made of absorbing substance with a point isotopic source of neutrons in its center. More complex multiplying systems computed in PRIZMA were also considered.

References

1. **Vakhonina, T. V.** PRIZMA Status [Text] / T. V. Vakhonina, N. A. Voronina, O. V. Zatsepin et al. // Joint International Conference on Supercomputing in Nuclear Applications and Monte Carlo. – Paris, 2013. – P. 9.
2. **Zhitnik, A. K.** C-007 technique using Monte-Carlo method of coupled linear equations of neutron, gamma-quantum, electron and positron transfer [Text] / A. K. Zhitnik et al. // Voprosy Atomnoy Nauki i Tekhniki [Problems of Atomic Science and Technology]. Ser. "Mathematical modeling of physical processes". – 2011. – Iss. 1. – P. 17–24 (in Russian).
3. **Gurevich, M. I.** Neutron transport computation based on Monte-Carlo method using the MCU code [Text] : Training manual / M. I. Gurevich, D. A. Shkarovsky. – M. : National Research Nuclear University MEPhI Publ., 2012. – 156 p. (in Russian).
4. **Panin, M. P.** Radiation transport simulation [Text] : Training manual. – M. : MEPhI Publ., 2008 (in Russian).
5. **Antonov, A. S.** Parallel programming using OpenMP [Text] : Training manual. – M. : Moscow State University Publ., 2009 (in Russian).
6. IAEA. IAEA Nuclear Data Centre [dig. resource]. http://www-nds.iaea.org.
7. **Ogibin, V. N.** D-diagrams: a graphic means for data description [Text] / V. N. Ogibin, V. M. Shmakov // Voprosy Atomnoy Nauki i Tekhniki [Problems of Atomic Science and Technology]. Ser. "Mathematical modeling of physical processes". – 1989. – Iss. 1. – P. 3 (in Russian).