6 - 10 Fabrication of Neutron-photon Coupling Multi-group Cross-section Library Based on Monte Carlo Method for Discrete Ordinates Transport Code

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Radiation shielding calculation plays a critical role in ensuring the safety of nuclear reactors. In the field of nuclear reactor shielding calculations, deterministic computing codes are commonly used due to their computational efficiency and capability to solve deep penetration problems. However, the accuracy of deterministic codes heavily relies on the precision of the multi-group cross section library[1]. To enhance the computational accuracy of deterministic codes, the Monte Carlo method has been used to make the multi-group cross section library. Leveraging the open-source Monte Carlo code OpenMC, improvements have been made to the fabrication method of the multi-group cross section library, allowing for the creation of a neutron-photon coupling multi-group cross section library. The OpenMC code has been enhanced to include the counting of photon production cross sections resulting from neutron reactions. Additionally, the functionality to account for the scattering and merging of photon sources generated by atomic relaxation, bremsstrahlung, positron-electron annihilation has been added. The process of making the neutron-photon coupling multi-group library based on OpenMC is shown in Fig. 1.

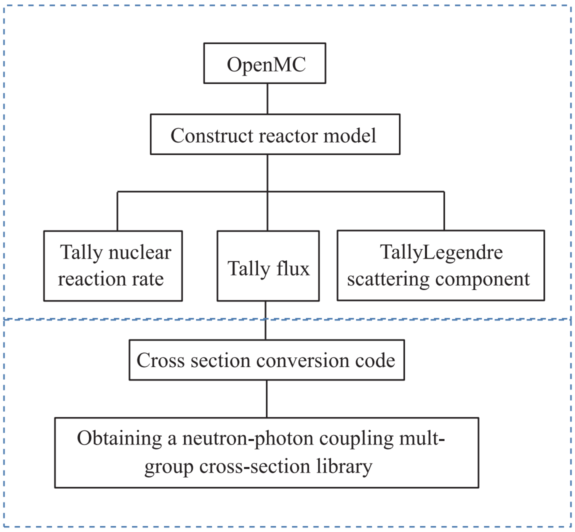

Fig. 1 (color online) Process of making neutron photon coupling multi group cross section library based on OpenMC.

In order to verify the applicability of this method, the OECD/NEA fast reactor benchmark and Savannah thermal reactor benchmark were used to make the neutron-photon coupling multigroup cross sections. These multigroup cross section libraries were provided to the deterministic code DORT for calculations. The calculated results are shown in Figs. 2 and 3. The results show that the neutron-photon coupling multi group cross section libraries produced by this method have high accuracy.

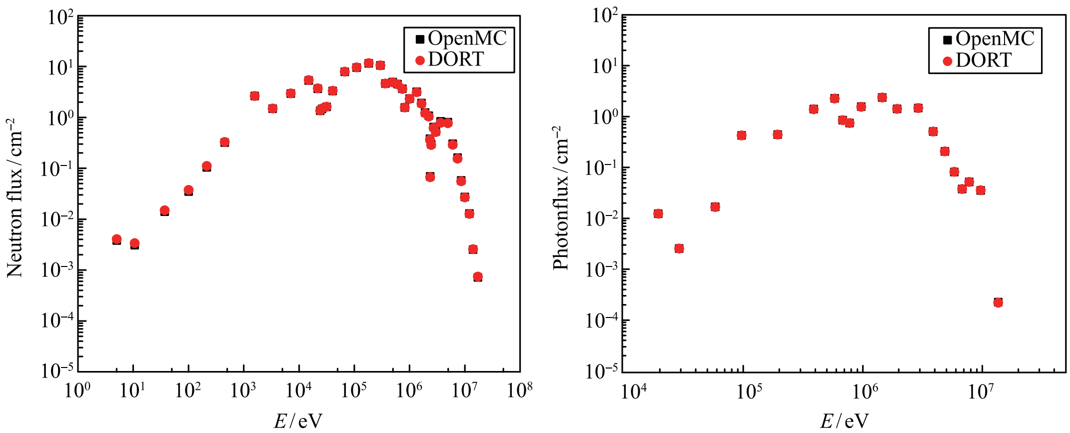

Fig. 2 (color online) Neutron and photon flux distribution in the fuel region of the OECD/NEA fast reactor.

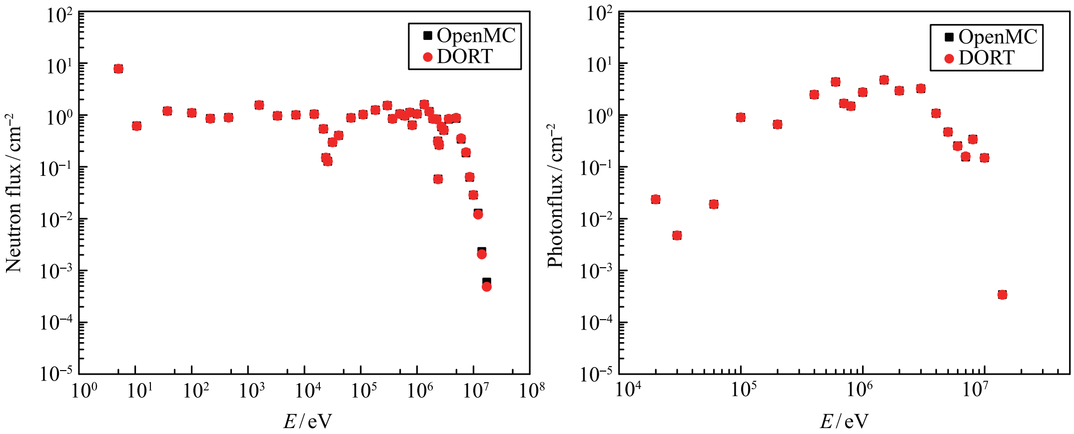

Fig. 3 (color online) Neutron and photon flux distribution in the core of the Savannah reactor.

Reference

[1] S. Hong, Y. Yang, L. Zhang, et al., Nuclear Techniques, 40, 4(2017)4. (in Chinese).

6 - 11 R&D Progress of CiADS Reactor Main Equipment Prototypes and LFR Non-nuclear Integrated Verification Device

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Due to the excellent neutron physical properties and thermal safety performance, the lead-based fast reactor is adopted as subcritical reactor in the CiADS project. In order to overcome the technical difficulties in the design and manufacture of the main equipments, test the operating characteristics of the main equipments, and study the thermal-hydraulic and safety characteristics of the reactor, the reactor group carried out the research and development of CiADS liquid lead-bismuth cooled fast reactor main equipment prototypes and LFR non-nuclear integrated verification device in 2022.

At present, the scheme design and detailed design of reactor main vessel, reactor internals, main heat exchanger, lead bismuth pump, lead bismuth melting tank and storage tank have been completed. In the design, the special technical problems caused by lead bismuth medium such as seismic design, thermal hydraulic analysis and instrument layout have been solved. The design scheme of the equipment prototypes have passed the expert review. The layout of the LFR non-nuclear integrated verification device and the design of the auxiliary system have also been completed.

The manufacturers cooperated with IMP completed the preparation of the equipment prototype processing technology and started the equipment manufacturing. The lead bismuth pump pilot small prototype has been completed in 2022. Reactor main vessel, reactor internals, lead bismuth melting tank and storage will be completed in July 2023, as shown in Figs. 1 and 2. Main heat exchanger pilot small prototype will be completed in October 2023. Main heat exchanger and lead bismuth pump will be completed in Spring 2024.

Based on the lead bismuth pump pilot small prototype, we carried out the water medium experiments as shown in Fig. 3, measured the hydraulic characteristic curve of the pump, and verified the rationality of the pump hydraulic design method. At the same time, we also obtained the pressure pulsation characteristics of the pump and the liquid level fluctuation characteristics of the pump chamber, which are important for the design of experimental loops and operation scheme.