MONTE CARLO BENCHMARK CALCULATIONS FOR 400MW$_{TH}$ PBMR CORE

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ABSTRACT

A large interest in high-temperature gas-cooled reactors (HTGR) has been initiated in connection with hydrogen production in recent years. In this study, as a part of work for establishing Monte Carlo computation system for HTGR core analysis, some benchmark calculations for pebble-type HTGR were carried out using MCNP5 code. The core of the 400MW$_{th}$ Pebble-bed Modular Reactor (PBMR) was selected as a benchmark model. Recently, the IAEA CRP5 neutronics and thermal-hydraulics benchmark problem was proposed for the testing of existing methods for HTGRs to analyze the neutronics and thermal-hydraulic behavior for the design and safety evaluations of the PBMR. This study deals with the neutronic benchmark problems, for fresh fuel and cold conditions (Case F-1), and first core loading with given number densities (Case F-2), proposed for PBMR. After the detailed MCNP modeling of the whole facility, benchmark calculations were performed. Spherical fuel region of a fuel pebble is divided into cubic lattice element in order to model a fuel pebble which contains, on average, 15000 CFPs (Coated Fuel Particles). Each element contains one CFP at its center. In this study, the side length of each cubic lattice element to have the same amount of fuel was calculated to be 0.1635cm. The remaining volume of each lattice element was filled with graphite. All of different 5 concentric shells of CFP were modeled. The PBMR annular core consists of approximately 452000 pebbles in the benchmark problems. In Case F-1 where the core was filled with only fresh fuel pebble, a BCC(body-centered-cubic) lattice model was employed in order to achieve the random packing core with the packing fraction of 0.61. The BCC lattice was also employed with the size of the moderator pebble increased in a manner that reproduces the specified F/M ratio of 1:2 while preserving the packing fraction of 0.61 in Case F-2. The calculations were pursued with ENDF/B-VI cross-section library and used sab2002 S(α, β) thermal cross-section library for graphite material. The resulting k_{eff} was calculated to be 1.27949±0.00052 and 1.14014±0.00055 for Case F-1 and F-2, respectively. Comparing with other previous results from MCNP4b code, these results gave an agreement of k_{eff} difference by 141 pcm and 1140 pcm for Case F-1 and F-2, respectively. There results were caused by a different geometry modeled. While 3 bottom cone regions and de-fueling chutes were modeled explicitly in this study, these were assumed to the surfaces flattened in MCNP4b calculations. This study can be contributed and utilized directly in the establishment of benchmark problems to develop deterministic neutronics analysis tools and methods, which lagged behind the state of the art compared to other reactor technologies, to design and analyze PBMR. It is also expected that this study would be utilized in the validation of a deterministic computer code for HTGR core analysis which will be developed in near future in Korea.