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Computational Studies of Advantages of Lead-Cooled Fast Reactor Core

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Concept of the BREST reactor with lead coolant and dense heat-conductive nitride fuel envisages the development of an equilibrium core with complete breeding of fissionable nuclides in the core (core breeding ratio of ~ 1) without a blanket compensating for reactivity reduction due to fuel burn-up and fission product build-up. This makes it possible to operate the reactor in the period between two regular refuelings with a low reactivity margin (< βeff). At the same time, efficient utilization of uranium is ensured by means of conversion of U-238 to Pu-239 in the fast reactor spectrum and a possibility of transmutation of the produced minor actinides during the reactor operation in the closed nuclear fuel cycle.

To carry out computational studies of the BREST reactor core, a design code system is used, which includes the FACT-BR diffusion software system, the MCU-BR software tool based on the Monte-Carlo method, and the IVIS-BR thermophysical module. Analytical models of the MCU-BR code provide the most precise description of geometry and composition of the core, reflectors and other components affecting the neutronic characteristics of the reactor. In calculations, a neutronic cross-section library based on the ENDF/B-VII.1, JENDL-4.0, ROSFOND actual authenticated data files was used. FACT-BR and MCU-BR have been certified for calculations of the BREST-OD-300 reactor with lead coolant and nitride fuel. Experimental results obtained with the BN-350, BN-600 reactors and BFS test facility with lead were used for validation.

During the computational studies, impact of manufacturing tolerances on Keff and reactivity margin was evaluated. Maximum deviation of each manufacturing parameter was conservatively considered, including the most significant ones: plutonium mass fraction, mass of fuel, nitrogen content. The estimated overall technological error was 1.17, and the total error for Keff and reactivity margin was 1.36 % δk/k. Feasibility of low reactivity margin during rated reactor operation (~ 0.54 βeff) was demonstrated even for the initial period of operation given the compensation of the methodical, constant and manufacturing uncertainties by technical measures taken at the first criticality stage. Calculations of fuel and absorber burn-up, power distribution in the core, worth of control and safety rods, reactivity effects and other core characteristics were carried out.

The developed and validated design code system, the results obtained in computational studies can be used to support design concepts for the BREST-OD-300 reactor and commercial lead-cooled fast reactors.

Country/Int. organization

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