Computation Methods and Techniques for Solution of Coupled Multiphysics Problems in Precision Calculations of VVER Type Reactors

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ABSTRACT

Coupled problems are typical in calculations for nuclear power engineering. Nuclear power is important source of energy along with thermal and hydraulic power stations. Nuclear power plants require precision calculation techniques for all stages of development, design, construction, and operation due to the high level of technology and high safety requirements. Nuclear power plants are the field of engineering, in which problems relating to different fields of physics and technology such as nuclear physics, neutron physics, heat engineering, radiochemistry should be solved consistently because the processes from different fields of physics and chemistry influence to each other. In this paper, one such problem is discussed, combining neutron-physical and heat engineering problems arising in simulation of the isotopic composition of nuclear fuel during operation of nuclear reactors.

For modeling the isotopic composition of fuel, and maximum temperatures at different moments of time, one can use different algorithms and codes. In connection with the development of new types of fuel assemblies and progress in computer technology, the task makes important to increase accuracy in modeling of the above characteristics of fuel assemblies during the operation. Calculations of neutron-physical characteristics of fuel rods are mainly based on models using averaged temperature, thermal conductivity factors, and heat power density. In this paper, coupled approach is presented, based on modern algorithms, methods and codes to solve tasks of thermal conductivity, neutron transport, and nuclide transformation kinetics, which influences to each other. So, neutron-physical and thermal-physical calculation of the reactor gives detailed temperature distribution, with account of temperature-depending thermal conductivity and other characteristics. It was applied to studies of fuel cell of the VVER-1000 reactor. When developing new algorithms and programs, which should improve the accuracy of modeling the isotopic composition and maximum temperature in the fuel rod, it is necessary to have a set of test tasks for verification. The proposed approach can be used for development of such verification base for testing calculation of fuel rods of VVER type reactors.

Simplified models of calculation are often used in traditional approach to modeling neutron-physical characteristics of fuel rods and isotopic composition in process of nuclear fuel burning. For instance, in many cases neutron-physical characteristics of fuel depending on temperature are determined by use of average temperature of fuel rod, while the existing dependencies of the neutron cross sections on temperature are neglected. In thermal-physical calculations of the radial distribution of fuel temperature, constant average value of thermal conductivity factor is often used. However this factor depends really both on the temperature and on fuel burnup, which change with radius of fuel rod.

In this paper, mathematical models of coupled neutron-physical and thermal-physical calculation are presented. This approach was applied to calculation investigation of fuel element of the power reactor of VVER-1000 type. Short description of benchmarks for verification of obtained results is given. It is demonstrated how the account of dependence of the thermal conductivity factor on temperature affects on the value of temperature in the center of fuel rod for the VVER type reactor.