УДК 621.039.517.5

SIMULATION OF THERMOPHYSICAL PROCESSES OF THE FUEL ASSEMBLY OF THE IRT-T REACTOR AT A POWER OF 10 MW

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МОДЕЛИРОВАНИЕ ТЕПЛОФИЗИЧЕСКИХ ПРОЦЕССОВ ТОПЛИВНОЙ СБОРКИ РЕАКТОРА ИРТ-Т НА МОЩНОСТИ 10 МВТ

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Аннотация. *В работе рассматривается поведение материалов активной зоны исследовательского реактора ИРТ-Т при повышении его тепловой мощности с 6 до 10 МВт. Исследованы параметры ядерного топлива и его оболочки с точки зрения изменения нейтронных и тепловых полей. Работа включает в себя компьютерное моделирование с использованием программ для симуляции потока теплоносителя (САПР Solidworks) и симуляции нейтронной физики реактора ИРТ-Т (MCU-PTR).*

Introduction. Research nuclear reactors are most often installations that have been modernized several times over their rather long existence. This situation has developed due to the uniqueness of the objects, their properties and capabilities. However, despite the accumulated experience in improving research nuclear reactors, there is a problem of the applicability of existing methods for separately selected facilities. In particular, it is planned to modernize the IRT-T reactor in terms of thermal power from 6 to 10 MW. Such large projects should be checked from a variety of viewpoints, including operability in the new planned conditions of existing control and safety systems.

Research methods. Recently, industrial simulation methods have been actively used to check thermal parameters. One of the most suitable software environments for the purposes of the work was Solidworks CAD. In this software package, a model of the IRT-3M side fuel assembly (FA) with simulators was created and subsequently verified by the coolant velocities in each of the gaps between the fuel elements and the pressure drop across the entire FA according to the article [1]. Since it was not possible to take into account the complex flows and stagnant areas, as well as correct turbulence, the virtual assembly was verified in a combined way: in terms of velocities and total pressure drop. This approach implies the assembly simulation in a differential form and in an integral form.

Differential calculus includes splitting the water flow in the assembly separately for each gap so that it is possible, by changing the boundary conditions (the pressure drop), to adjust the flow rate corresponding to the actual one from [1]. The total pressure drop was also calculated separately for each gap. For simplicity, the upper and lower limit switches are disabled in the model. Integral calculus implies the standard setting of the boundary conditions for the entire assembly as a whole with the addition of similar [1] imitators to the model for a more correct simulation of the coolant outflow in the extreme gaps.

The MCU-PTR software was used to determine the maximum power release. The standard model of the IRT-T reactor in the MCU consists of 1479 materials and 4014 zones, out of which 120 materials define the fuel matrix of all fuel assemblies, 1018 materials define the biological protection, 50 materials define the area of the HEC-1 and HEC-4 channels, 259 materials define the central and side beryllium reflectors, and the rest are responsible for the control rods, as well as for the aluminum shells and the remaining experimental channels. The fuel matrix of each fuel assembly in the model was divided into 6 layers to allow tracking the altitude component of the flow. The calculation was carried out for 50 series of 50 independent generations with 3000 neutrons in each one, which according to [2] gives a fairly accurate result for a research reactor.

Results. The thermal correspondence of the model to the real fuel assemblies was established according to the data from the reactor plant, namely, the coolant heating. In the real case, the heating was 7.27 °C, in the model with an average energy release - 6.16 °C, which indicates the influence of neighboring assemblies on the water temperature. Nevertheless, the obtained results are sufficient for conducting a study at an increased power of IRT-T.

The calculation showed that for a 10 MW reactor for IRT-3M with an average energy release of 500 kW, the heating of the coolant was 11.87 °C, and for a maximum of 659.69 kW – 15.41 °C. The maximum water temperature did not exceed 88.92 °C. Figure 1 shows the calculation results for the assembly with the maximum energy release. These data indicate a significant excess of the established conditions for the operation of emergency protection – 10 °C. To eliminate this problem, the following three actions are proposed: changing the settings for emergency operation; an increase in coolant consumption; and reduction of the reactor power to the requirements of emergency safety.

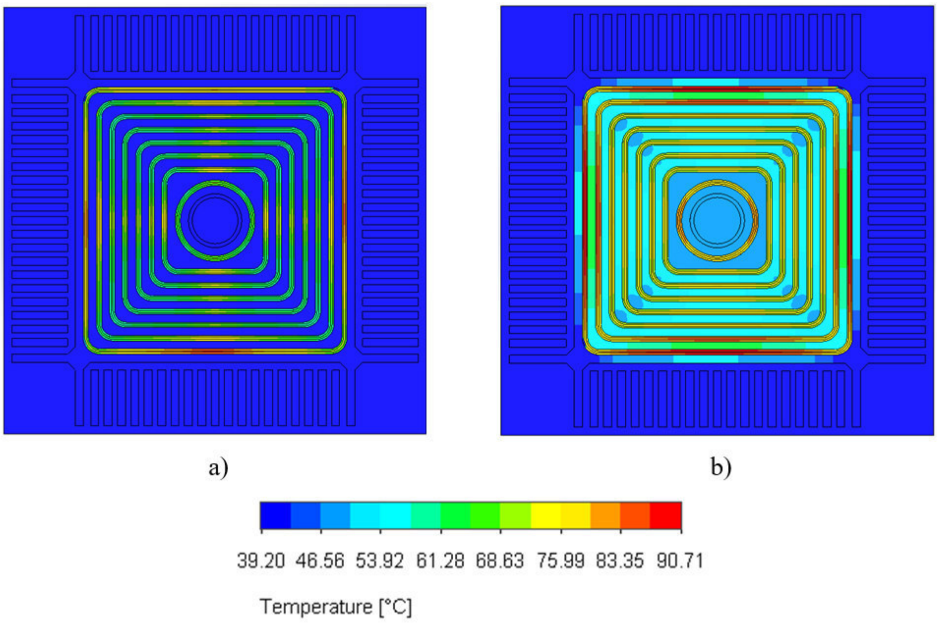

Fig. 1. Temperature distribution in IRT-3M for power generation of 659.69 kW:
a) – at inlet of the FA; b) – at outlet of the FA

Figure 2 shows the distribution of maximum temperatures for the most heated segment of the maximum loaded FA in the radial direction (from the center to the edge). In accordance with [2], an increased energy density is observed in the central and outer fuel elements, which is the main factor of the increase in temperatures in the gaps of the center and edge of the fuel assembly. A relative increase in the maximum heating of the coolant in the most stressed areas is noted.

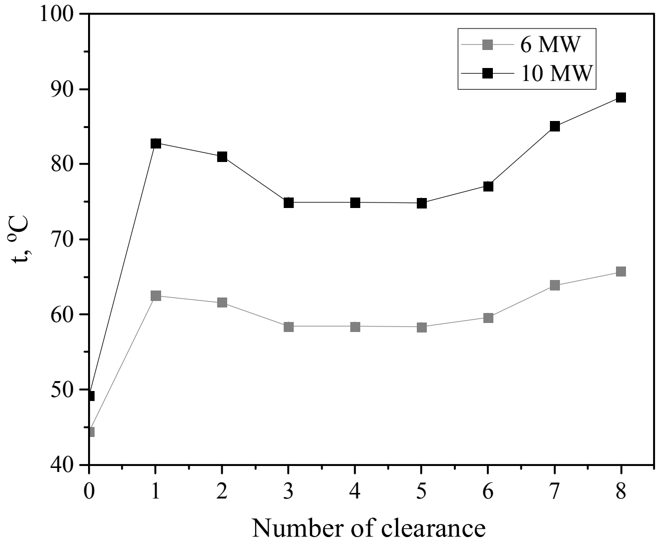

Fig. 2. Maximal temperature of the coolant for FA with maximal heat releases for 6 and 10 MW reactor by the radius of the FA

Conclusion. The calculation of the FA thermal parameters showed that an increase in the IRT-T power from 6 to 10 MW with the current reactor configuration can lead to an excess of the existing trip set point for the coolant heating at its maximum, more than 54%. In this regard, several options have been proposed to solve this problem. If the reduction of the reactor power to the requirements of emergency safety option is chosen, the reactor will be able to be powered up to a maximum of 8 MW, it will not be necessary to upgrade any of the existing systems, however, the neutron fluxes will be lower than the fluxes at a power of 10 MW. Also, this calculation shows that the reactor has a significant margin to maintain thermal power in the event of a large-scale contamination in the cooling system, including heat exchangers.

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