Results of modeling of thermal-hydraulic processes in the sodium cooled experimental assembly in approach of an anisotropic porous body

M V Bayaskhalanov, M N Vlasov, A S Korsun, I G Merinov and V V Silvestrov
National Research Nuclear University MEPhI (Moscow Engineering Physics Institute), Kashirskoe shosse 31, Moscow, Russia

E-mail: mr.bayashalanov@mail.ru

Abstract. Results on the second stage of the program APMod module testing are presented. As well as at the first stage of testing good high-quality and quantitative coincidence of hydrodynamic characteristics of the sodium coolant in the area behind blockage has been received. At the same time the noticeable divergence of settlement and experimental fields of temperature remained. The analysis of the possible reasons of a results divergence of calculation with experimental data is carried out.

1. Introduction
Modeling of thermal-hydraulic processes in the core of the modern fast reactors made from the jacketless fuel assemblies and cooled by the liquid metal coolant demands use of three-dimensional mathematical models. Use of an anisotropic porous media approach [1-3] allows to solve an objective with rather low expenses of the computer resources (in comparison with CFD codes).

The purpose of this work was testing of the program APMod module developed for the modeling of heat and mass transfer processes in perspective nuclear reactors cores and heat exchange equipment in approach of an anisotropic porous media. Testing was carried out during the simulation of the sodium coolant flow in experimental fuel assembly with partial blockage of the flow section.

2. Experimental installation
The results received on the experimental KNS-Test [4] installation (Figure 1) used for a research of processes of a heat and mass transfer in a core of the SNR-300 reactor were used as an experimental data. Assembly contained 169 smooth cylindrical rods, some of which was heated by electric current. Sodium coolant flow simulation in assembly was carried out for a case of partial flow section blockage at 21% overlapping of an angular part of cross section of assembly (Figure 1). Blocking settled down in 40 mm from the beginning of a zone of energy release. As boundary conditions were set coolant velocity on an entrance to assembly – 4 m/s, his temperature – 668°C and pressure at the exit (it was accepted equal atmospheric).

The first stage of testing has been described in work [5]. The results of the first stage showed operability of the APMod module and both good quantitative and high-quality coincidence of settlement and experimental characteristics for the sodium coolant flow. However, the divergence of the coolant temperature fields was observed. Therefore the main attention was paid to establishment of
the reasons of a results divergence of calculation and an experiment in definition of the field of temperature behind blockage and optimization of the used settlement grid.

![Figure 1. Experimental KNS-Test installation](image1)

3. Calculation results
Optimization of a settlement grid has allowed to reduce number of elements of splitting from 106470 to 3888 elements (Figure 2) that has sharply reduced time of calculation performance at preservation of accuracy of the received results.

![Figure 2. Settlement grid used for computer simulation: 1 – region with blockage and heat release, 2 – region with heat release, 3 – region without flow blockage and heat release](image2)
The resulting calculated coolant velocity distribution in longitudinal section of assembly is shown on Figure 3 with the characteristic points noted. Received distribution is qualitatively coinciding with the experimental results. In the coolant flow behind of blockage a sector of a toroidal vortex was watched. For the analysis of the reasons leading to a divergence of settlement and experimental data there was a carried-out series of calculations, with various coefficients of blockage resistance. Results of comparison of hydrodynamic characteristics of these calculations with experimental are given in Table 1.

![Figure 3. Velocity distribution in longitudinal section of assembly](image)

| Parameter                      | Experiment | Calculation (blockage resistance 4500, l/s) | Calculation (blockage resistance 6000, l/s) | Calculation (blockage resistance 9000, l/s) |
|--------------------------------|------------|---------------------------------------------|---------------------------------------------|---------------------------------------------|
| Height of the stagnant zone, mm| 105        | 87                                          | 97                                          | 120                                         |
| Vortex center position, mm     | 45         | 46                                          | 46                                          | 45                                          |
| Relative velocity of reverse flow | 0.17      | 0.08                                        | 0.14                                        | 0.18                                        |

As well as at the first stage of testing good high-quality and quantitative coincidence of hydrodynamic characteristics of a sodium coolant flow in the area behind blockage has been received. It is even observed at less detailed grid.

For comparison of settlement fields of temperatures with experimental, the received values of temperature were normalized by the technique used in work [4]. The short description of this technique is provided in work [5]. In the Figure 4 results of comparison of radial fields of temperatures in the area behind blockage at various coefficients of blockage resistance are shown.

As it follows from figure 4, calculation results more consistent with experimental data at increasing of resistance in flow blockage region. The remaining noticeable deviation of settlement dependences on experimental curves in the area over the blockage adjacent to an assembly jacket (at big x) at long distances behind the blockage can be explained by heat exchange between assembly and environment in the experiment that wasn't considered in calculations.
Figure 4. Radial temperature distributions at different distances from the blockage (a – 10 mm, b – 30 mm, c – 50 mm, d – 70 mm): 1 – experimental data [4], 2 – calculation (blockage resistance 4500, 1/s), 3 – calculation (blockage resistance 6000, 1/s), 4 – calculation (blockage resistance 9000, 1/s)

4. Conclusion
The optimization of a settlement grid which has allowed to increase significantly the speed of calculations without loss of accuracy has been made. The executed calculations have shown that the main reason for a divergence of settlement and experimental fields of temperatures is the description of blockage in the program module by a high hydraulic blockage resistance. The blockage remains partially permeable, unlike impenetrable blockage in an experiment. Justice of this conclusion is confirmed by the fact that increase in blockage resistance leads to improvement of coincidence of results of calculation to an experiment. In general the conducted calculations confirm operability of the program APMod module.

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