



Conference Paper

Visualization and Finding Ways to Intensify the Processes of Non-isothermal Mixing Flows

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Abstract

Simulation of mixing flows of different temperature, density structure has important implications for the assessment of thermal reliability of reactor plants, thermo-cyclic pulsations, and safety analysis. To study the mixing model was used for the mixing, which was visualized by using imaging methods. The injection of cold water into the hot volume was examined, which simulates the flow of the coolant in the pressurized-water reactor. The obtained results have given the basis for further analysis of non-isothermal mixing flows. However, the model is still far from the real geometry of the reactor plant. The construction of a reactor reduced model with a simulation of one loop of a coolant flow with low settings has been developed for a more detailed study of the processes of non-isothermal mixing flows has planned. In the future, these data will be used in the programs of computational fluid dynamics (CFD).

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1. Introduction

Modeling of the mechanisms of mixing fluids of different temperatures, viscosity, chemical composition is important for understanding the processes of heat and mass transfer. These processes have a significant impact on the working conditions of the reactor, its neutron physics, hydraulics, safety, strength. For example, one such important issues that have a significant impact on the housing material, is the definition of thermo-cyclic pulsations. Their determination is necessary for evaluating the strength and reliability of elements of the reactor plant. Especially important is the welding of the main pipes and welded seams of shells of the reactor design, of a steam generator, a pressurizer, and other important parts of the equipment. Pulsations of the temperatures lead to an uneven heat load on metal products, leading to fatigue damage, cracks and the equipment elements failure [1].

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Investigation of flow mixing for the reactor plant is needed for evaluation of its thermal properties. The results of the analysis of flow mixing mechanisms are required to optimize the reactor, to reduce its mass-dimensional characteristics, to transfer a conservative approach (with large safety factors) to a more loyal, one without losses associated with security. In addition, the intensification of the mixing process plays an important role in the cooldown of the reactor plant (especially emergency), in the heat removal from the fuel assemblies (main and decay heat). In VVER reactors (water-water energetic reactor) liquid boron is used to control its reactivity.

Incomplete mixing of the boron solution and the establishment of the water (without boron) tubes can create the conditions for the occurrence of local critical masses and the crisis of heat transfer in such areas. Also, this problem is particularly acute in transient modes of the reactor plant. This issue [2] the parameters of the active zone are analyzed a tube of pure water during a stop of a shutdown reactor under pressure of approximately 25 bar with natural circulation.

The formation of the representative for description the non-isothermal and isothermal flows, has become thanks to the advent of accurate systems of measurement which can determine field parameters (laser methods for field measurement of temperatures and speeds, methods, PIV, PLIF, LDV, thermographic measurement techniques of the temperature field, grid sensors for measuring field concentrations, conductivity probes).

Currently, it has become possible to study processes of heat and mass transfer with the use of modern computer systems and programs. You can also conduct field experiments using modern accurate equipment (thermal imaging cameras, conductometric sensors). However, the similarity and the possibility of transfer of the results from models to nature is one of the main issues that arise when conducting experimental studies on water reduced models. All experimental studies on the stands of water provide a good opportunity to analyze the main features of thermohydraulic processes in the reactor.

The aim of this work is the construction of an experimental model for studies of flow mixing with a supply from below, which simulates the main flow of the coolant in a modern pressurized water reactor plants. In addition, an important task is to discover possibilities intensification of this confusion, and visualization of these models in complex computational fluid dynamics (CFD).

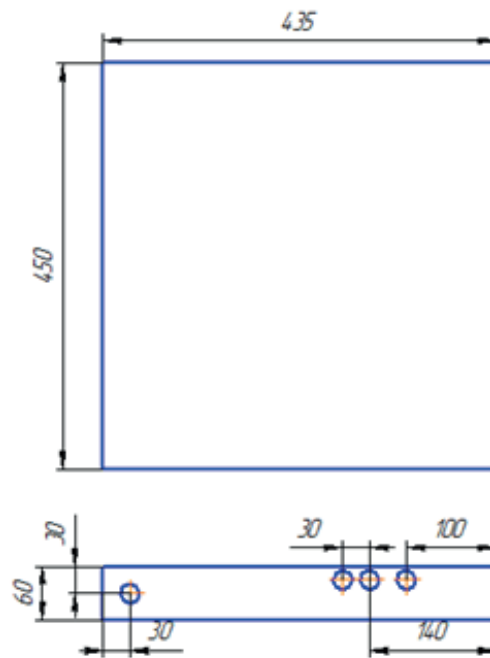


Figure 1: Overall dimensions of the adopted model.

2. Materials and methods

The main method of the research was the thermal imaging method of research. It envisages the use of thermal imaging and measuring instruments (thermal) – opto-electronic devices for non-contact (remote) observation, measurement and registration of spatial/spatio-temporal distribution of radiation temperature of objects within a field of view of the instrument, by forming a time sequence of thermograms and determining of the temperature [3] of the object surface of known emissivity and shooting parameters (ambient temperature, atmospheric transmission, observation distance, etc.) [4].

For research we have proposed a simple model to study the non-isothermal mixing of streams. It is a cuvette. The material of the two walls (rear and side) is a transparent Plexiglas with a thickness of 12 mm with a linear scale. Other wall (front and side) is made of sheet steel (Steel 3) covered with black Matt paint. It is necessary to eliminate the influence of reflection from the surface radiation. It is also known that the spectrum of radiation of absolutely black body is determined by its temperature. Parameters and dimensions are shown in Figure 1. Diagram of the major components and organization of the supply of water is shown in Figure 2.

In the present issue, at the above stand, was studied temperature field of the model with a supply jet from the bottom in volume. This is a simulation of the injection of the

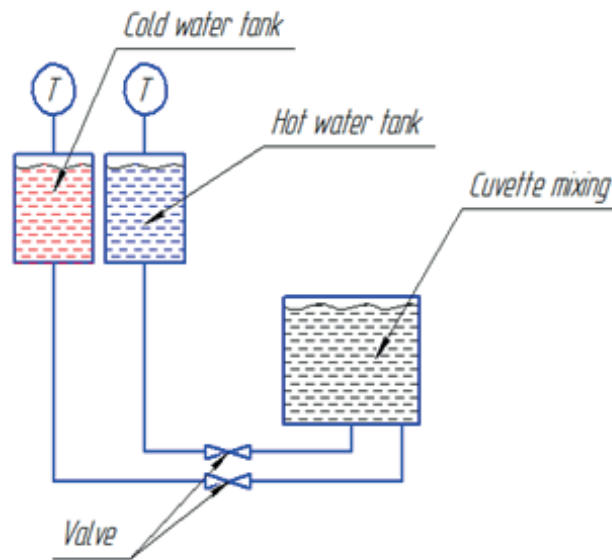


Figure 2: Scheme of arranging flows to the model.

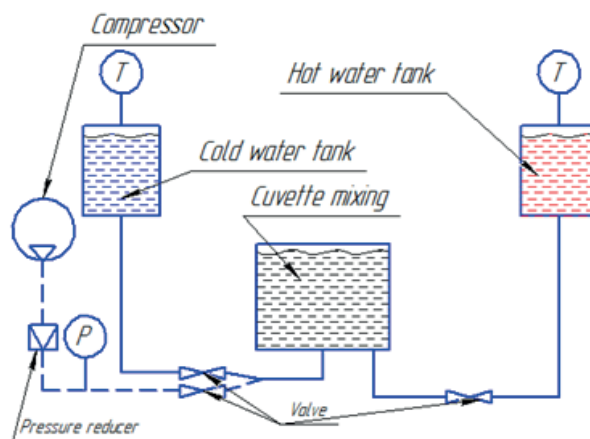


Figure 3: Scheme of flow supply organization for investigation of mixture intensification.

coolant into the hot volume of the active zone of the reactor. While measuring were the thermograms of the temperature fields on the surface of the cell obtained. For intensification of mixing the model of mixing of two-component flow (water+gas (air)) was proposed. To do this the scheme included a three-way device (tee with angles of 60° , a given t-device the least distorts the geometry of the flow) and a compressor with micro regulation pressure (for controlling the additive gas flow). Installation diagram is shown in Figure 3. In the experiment the survey was carried out with two cameras, a front wall (steel sheet) was visualized with a thermographic camera, and the rear (transparent) with a video camera. Then, the resulting frames were processed and synchronized.

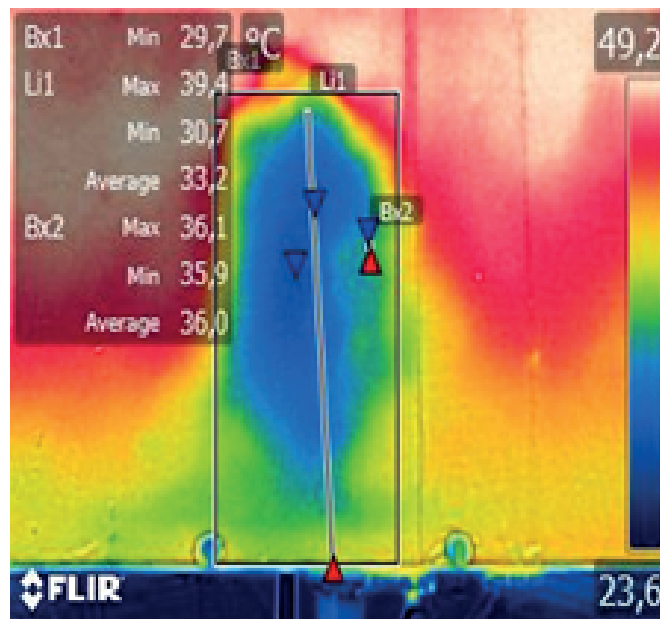


Figure 4: Single-component flow injection thermogram.

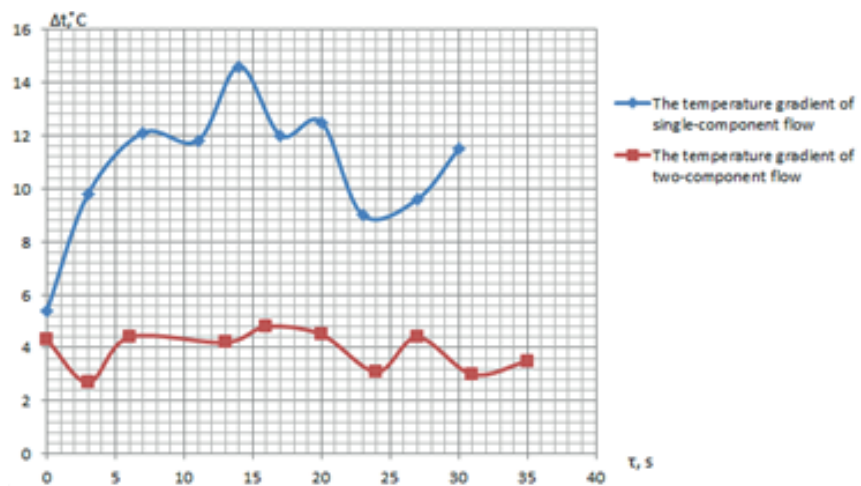


Figure 5: Graph for comparison of temperature gradient versus time for one-component and two-component flows.

The obtained data (in first approximation) we use not only as boundary conditions but also for comparison with computer simulation of mixing of non-isothermal flow in other models. Computer simulation methods (computational fluid dynamics) are based on certain models. In General these models are described by the equation of motion in the form of Navier-Stokes and the continuity equation is unsolvable in an analytical form. One of the approaches to the modeling of turbulent exchange is based on direct numerical solution of the system differential equations of motion and continuity and it is recorded for the instantaneous (actual) values of the parameters of a turbulent flow. The system of equations is closed, since there are 4 equations for determining the 4 desired quantities u, v, w, p . However, the mathematical formulation of the problem in

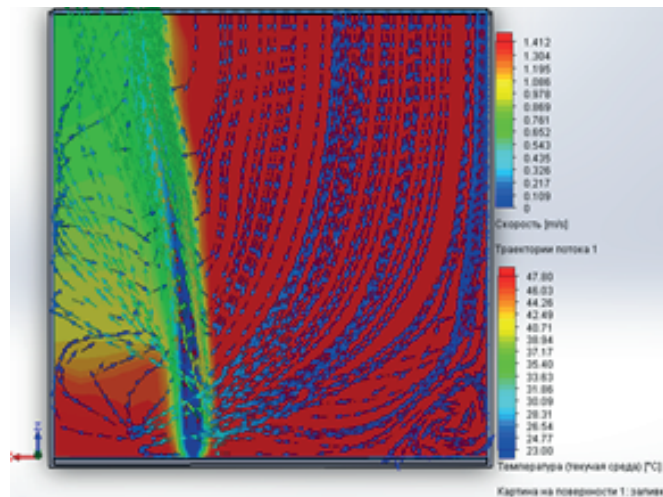


Figure 6: Visualization of mixing of non-isothermal flows, performed in Solid Works Flowsimulation.

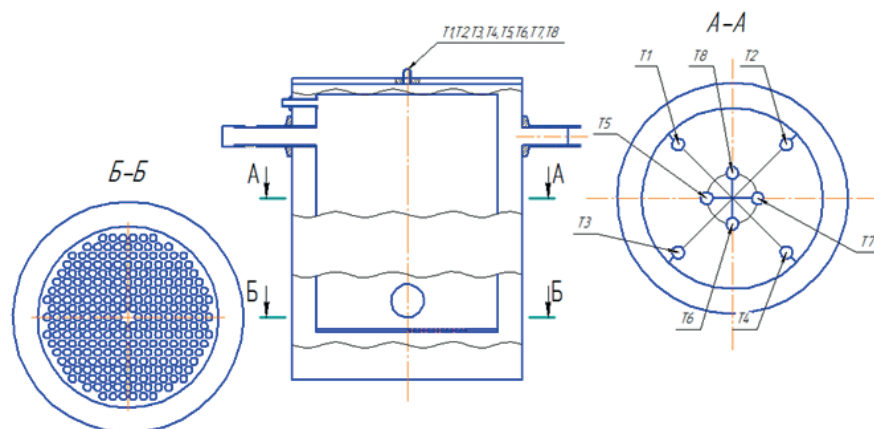


Figure 7: One loop model for simulation of mixing processes.

General remains open because of the uncertainty in initial and boundary conditions of uniqueness [5].

3. Results

During the processing of thermograms (Figure 4 shows one of the frames of the mixing of non-isothermal flows) the maximum, minimum and average temperature in the area of mixing flows and on the line passing through the centre of the flow core was studied. The boundaries of the mixing (the coordinates along the axes x and y of the stream) were also defined. The corresponding charts depending on the time of mixing. They can observe the maximums (peaks) that are likely associated with instability of the flow. Therefore, the goal for future research will be to reduce this volatility and reduce gradients on the computational domain mixing. For this purpose, was used to supply the two-component medium (water+gas) in the cuvette for mixing. It is possible to

reduce temperature gradients along the region of mixing in an average of 2 times. These measurements can be seen in Figure 5.

At present software tools developed in Russia and abroad describe the flow processes that need verification. Because of high cost and complexity of full-scale experiments, the most of the phenomena occurring in the equipment of reactor facilities can be investigated on models that run on water under the pressure close to atmospheric.

Obtained in the experiments, boundary and initial conditions of full-scale models were used for visualization in the software package Solid Works Flowsimulation. Complex Solid Works Simulation is a CAE-module based on finite element method is intended for conducting different types of analysis. Supported modules of the engineering analysis include: the configuration management of the computational grid, the simulation of the flow of liquid and gas, the use of different physical models with the flow of liquid and gas, thermal calculation, hydro/gas dynamic and thermal models of technical devices, stationary and non-stationary calculations.

Finite element method is one of numerical methods used for solving differential equations, and integral-differential equations for the problems of applied physics. The investigated area is broken by chosen grid into some (finite) s . In each element equation is selected to find the approximating function and then the numerical values of the functions at the boundaries of these grid elements are calculated. The resulting pattern is mainly identical to the picture of the experiment. It is shown in Figure 6.

4. Discussion

The investigated geometry is quite far from the real nuclear power plant. However, this is one step for understanding the principles of complex calculation of the mixing of non-isothermal flows. The creation of a reduced model of the reactor installation with a simulation of one loop of coolant flow with low settings is planned for a more detailed study of the processes of mixing of non-isothermal flows. Figure 7 shows the model geometry, input and output connections. The active zone is modeled by perforated sheet. Its geometry is performed on a smaller scale, which is the part of ciemnego unit. The main method of research is the study of the fields of temperature distribution in the mixing area by constructing a layered (tiered) of the pattern of the temperature distribution read from the temperature sensors located in the path of flow mixing. A special fast-acting program has been created to poll multiple sensors (first modification of the 8 sensors). Circulation in the model is created by centrifugal pump, with the ability to change the number of revolutions of the motor with the help of

frequency control. Consumption is measured automatically at the outlet port of the pump, and at the injection of non-isothermal flow. In addition to the main circulation loops it is also possible to study the flow top (simulated emergency spilling and steam mode), the flow bottom (the study of the flow distribution areas) and combined modes.

Additionally the model is equipped with a transparent viewing window (Plexiglas). It is necessary to visualize the model using the camcorder, as well as the use of PIV (Particle Image Velocimetry) for measuring the instantaneous velocity field of a flow in a given cross-section with moving particles of impurities in the section plane for a certain period of time. To the fluid flow the particles of small size are added (tracer). The measuring area of the flow is considered to be a plane "cut" a light beam (laser knife). Images of these particles are recorded with a digital camera. Subsequent image processing allows to calculate the particle displacement during the time between flashes of the light source and to construct a two component velocity field [6].

On the basis of the received data the spatial temperature distribution will be built, the boundaries of the flow mixture are defined as well as the characteristic sizes of mixing areas (the length of path of confusion). This information will also be verified in the complexes of computational fluid dynamics.

5. Conclusion

As a result a large amount of experimental data (more than 350 thermograms) of the different blend modes have been obtained. For intensification of mixing gas was added in the flow, which led to reducing of the temperature gradients on average up to 2 times! The reactor plant model presenting one reactor loop is being developed to study the processes of mixing. In addition to the study of intensification of mixing of the additive gas to the flow. It is also planned the new experiments on the flow side, mutual influence flows on each other when approaching from below the tangential swirling flow, a study of various devices for intensification of mixing and (the next stage) using CFD modeling to predict the behavior of such flows.

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