EXPERIMENTAL RESEARCH ON MAGNETOHYDRODYNAMIC (MHD) FLOWS IN LIQUID METAL COOLING SYSTEMS FOR FUSION REACTORS

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Several projects for thermonuclear installations and hybrid facilities (thermonuclear neutron sources) consider liquid lithium or lead-lithium eutectic usage as a coolant and a tritium production source. Liquid metals and salt melts are significantly electrically conductive media. In the case of thermonuclear devices with magnetic and magnetically inertial plasma confinement, the operation of these media will occur in the presence of strong magnetic fields, which requires the study of thermal hydraulics in configurations as close in geometry as possible to realistic devices.

JIHT RAS and MPEI conducts research by studying the characteristics of basic geometries – forced flow in rectangular and round pipes, jet behaviour, flow around obstacle, flows in combined channel systems and free convection under the combined influence of both strong magnetic fields and high heat fluxes.

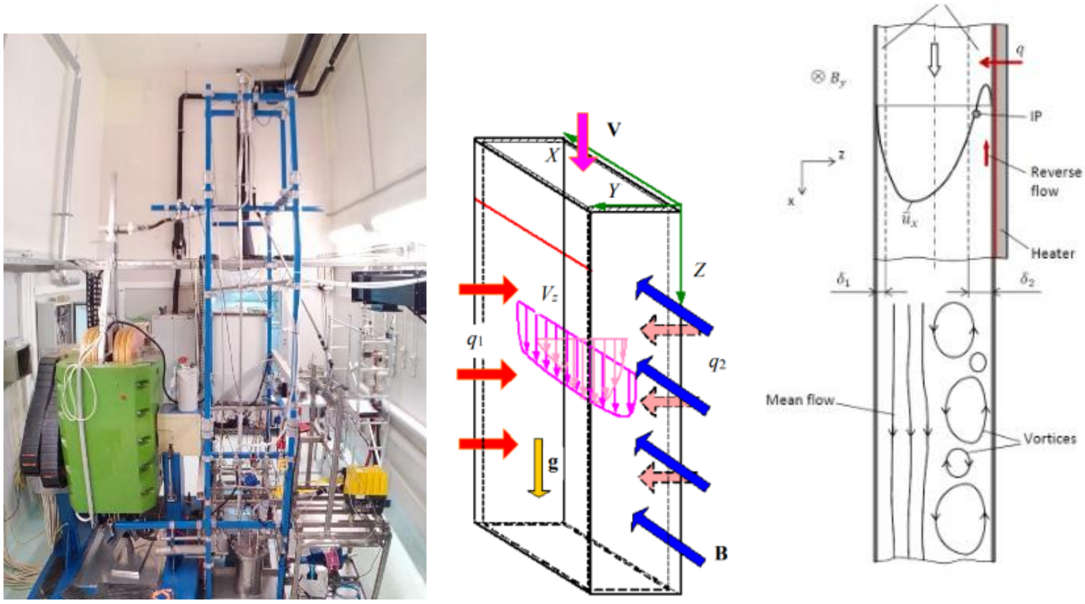
The research team has at its disposal magnets capable of creating stationary magnetic fields of up to 2.7 T. Usage of mercury gives the highest value of Grashof number (one or two orders of magnitude higher than with other metals). Mercury, therefore, allows us to perform heat transfer experiments at the lowest heat fluxes and liquid metal volumes. Studies of the flow structure are carried out by scanning submersible probes, which make it possible to reconstruct three-dimensional fields of average and fluctuating temperature and fields of average longitudinal velocity.

Fluctuations of flow and temperature that develop naturally under the influence of a magnetic field and a strong thermal load [1]. As a criterion, it is proposed to use the intensity of the resulting fluctuations of velocity or temperature in the form of a standard deviation. Strong temperature fluctuations in the reactor heat exchange path are highly undesirable, as they can create local overheating points, lead to thermal cycling loads, provoke corrosion and shorten the service life of the equipment.

The control complexes of dimensionless parameters are defined, which make it possible to formulate the laws of the existence of magneto-convective fluctuations, to describe the changes under the influence of a magnetic field. It is shown that it is necessary to analyse not just the dimensionless criteria Ha, Re, Gr, but such dimensionless complexes as Gr/Re^2, Ha/Re [1,2].

The available experimental data made it possible to localize the existence of magnetically convective fluctuations in the parameter space for the flow of liquid metal in pipes and channels under the influence of a transverse magnetic field [1].

Experimental studies have shown that using geometrically simple devices embedded at the entrance to the channel under study, effective control of the MHD flow of liquid metal is possible [3]. The use of such devices in the practice of model experiments does not cause difficulties related to the constructive part, which looks optimistic for their use in real installations.



HELM experimental facility, problem formulation and resulting flow mechanism [4]

Currently, research is also aimed at studying the hydrodynamics of liquid metal under the influence of magnetic field and electric current pulses that occur during possible plasma disruptions. Short and intense pulses of electric current and magnetic field can have a significant effect on liquid metal media used as working fluids or coolants. Despite the short duration of exposure, it is expected that the consequences of such effects will be significant, since the amount of energy involved in the exchange between the two media is comparable to the energy stored in plasma in stationary operation.

The experimental study is enhanced through validated direct numerical simulations [5], conducted under conditions that align with the experimental program. By employing direct numerical methods, the research extends beyond the limitations of physical experiments, as not all possible combinations of operational parameters can be feasibly tested in a laboratory setting. This approach provides a more comprehensive understanding of the systems under investigation.

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