Influence of the Magnetic Field on Thermal Convection in a Magnetic Fluid

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Abstract. Regulation and control of heat and mass transfer processes in liquid media is of significant fundamental and applied importance. Such regulation can be carried out by means of external electric and magnetic fields if the liquid is sensitive to these fields. In addition to direct interest, the study of the influence of an external field on heat transfer in a liquid on a laboratory scale can be considered as a model problem for phenomena and processes on other scales. The results of such studies can be useful for understanding, in particular, the exchange processes in cosmic plasma.

Keywords: magnetic fields; convection

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In the present study, a magnetic nanocolloid (magnetic liquid) was used as a medium that actively interacts with the magnetic field. The medium was a stable dispersion of magnetic nanoparticles (10 nm) in the carrier fluid. To study convective heat transfer, a liquid in the form of a layer 1 cm high and 9 cm wide was placed between aluminum plates that act as a heater (lower plate) and a cooler (upper plate). The entire system was placed in a uniform magnetic field between the poles of the electromagnet. The generated heat flow was directed vertically. The magnetic field was oriented horizontally along the liquid layer. The thermal regime of the liquid was monitored and measured using a thermal imaging camera. Additionally, the temperatures of the aluminum plates were controlled using thermocouples.

The dependences of the fluid flow geometry and the heat transfer intensity on the magnitude of the applied external magnetic field for various temperature difference values and properties of the magnetic nanocolloid are studied. It was found that heating the lower aluminum plate leads to the development of a system of convective cells in the liquid layer. The action of an external magnetic field suppresses the development of convection (Fig. 1). Measurements have shown that the heating of the lower aluminum plate is faster under the

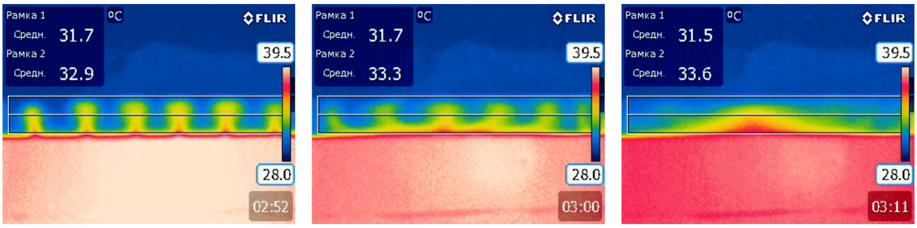

Fig. 1. Visualization of thermal convection in a magnetic fluid layer and its sequential suppression in a magnetic field. The magnetic field increases from left to right.

influence of a magnetic field. This is due to a decrease in the heat flow in the cell with the magnetic fluid. The decrease in the heat flow in the magnetic field is also seen in the dynamics of cooling of the heated lower plate after the heating is turned off. In this case, the heat flow decreases with increasing the field strength (Fig. 2).

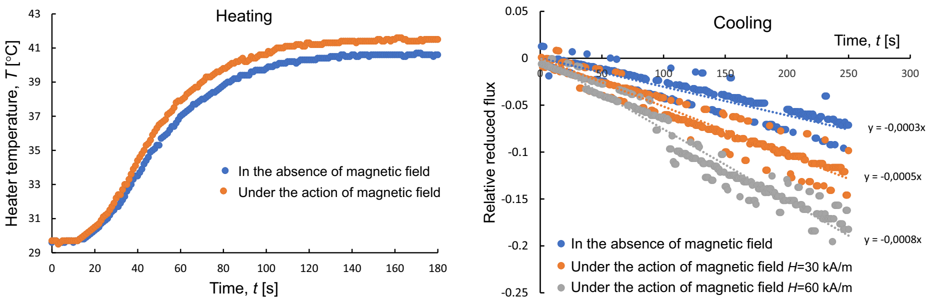

Fig. 2. Dependences of the heater temperature (left) during heating and the heat flow in the cell (right) during cooling on time in a magnetic field.

The studied phenomena were simulated based on the numerical solution of the ferrohydrodynamic equations (Rosensweig 2014) in the approximation of a continuous magnetizing medium. The simulation was performed using the finite volume method. As a result, the fact of suppression of convection and reduction of heat flow in the magnetic field was confirmed.

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Bibliography

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