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Liquid metal natural convection research heat transfer in the presence of a transverse magnetic field

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In the fusion reactor, there are large heat loads in the first wall of facing high temperature plasma to be large temperature differences in the cladding walls to form natural convection and there is a magnetic field to damp out or to stabilize the fluid flow of the liquid metal. Natural convection under a magnetic field is different from the general fluid and in-depth study has important engineering values for the design and safe operation of the fusion reactor.

The MHD buoyant driven convection in a horizontal enclosure of square cross-section has been studied experimentally. In the experiment, we focus on the case where the magnetic field is perpendicular to the applied temperature gradient, and we measure simultaneously the temperature on the plate wall and the fluid velocity by using UDV located on the bottom of the enclosure successfully.

The present paper is focused on the influence on the liquid metal heat transfer Nusselt number in the liquid metal with an external, transverse magnetic field. When there is a magnetic field, the velocity and Nusselt number would be strongly influenced. The natural convection flow is from three dimensionality flow to quasi-two-dimensionality flow in the presence of an external magnetic field. The Lorentz force caused by the magnetic field influences the vertical component velocity observably. When the magnetic field is small, the buoyancy force produces the three dimensionality flow including the mainstream clockwise flow and the minor flow in the other plane. If we continue to increase the magnetic field, the electromagnetic force of fluid inhibits the three dimensionality flow. The quasi-two-dimensionality flow would show a biggest velocity in such a case. When there is a strong magnetic field environment, liquid metal natural convection mainstream clockwise flow is inhibited too.

Two different modes are found in different magnetic field strength when there is a magnetic field exerted effects on the liquid metal natural convection. First, when the Stuart number is less than 4, the fluid flow is described as three-dimensional buoyant flow. The convection in the enclosure includes two contributions of inertia, buoyancy and Lorentz force on a quasi-steady flow. Second, when the Stuart number is greater than 4, the fluid flow is the transition from three-dimensional to quasi-two-dimensional. The inertia can be negligible, and the velocity components of the flow perpendicular to the magnetic field become uniform in the core and exhibit the classical exponential distribution in the Hartmann layers.

The ability of the fitting equation to predict the Nusselt number of the liquid metal natural convection in a strong magnetic field is meaningful in an electromagnetic forces dominated regimes. Two multiple linear regression models of the Nusselt number are summarized which imply that the mechanism of induced current's restraining influence determines the natural convection heat transfer of viscous electric liquids in a strong magnetic field. Research proves that the striking consistency of the magnetic field strong influence on the natural convection heat transfer in different liquid metal and different aspect ratio.

Eligible for student paper award?

No

Authors: Prof. Z H, Wang; Prof. M J, Ni; Mr X, Meng

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