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Thermal convection and heat transfer in rotating horizontal annulus

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Extended Abstract

Thermal convection and heat transfer in a rotating horizontal annulus, with different constant temperatures set at the boundaries [1], are investigated theoretically and experimentally. Consideration is carried out from the standpoint of thermal vibrational convection – convection caused by the average lift force generated as a result of oscillations of nonisothermal fluid with respect to the cavity. The tidal oscillations of nonisothermal liquid in the cavity frame with the frequency of rotation are induced by the gravity field. The linear stability of mechanical quasi-equilibrium with respect to monotonic 2D perturbations, which are, as shown experimentally, the most dangerous, is studied. The numerical simulation of 2D convection in overcritical domain is performed using the equations of thermal vibrational convection [2]. The action of the centrifugal force field is also taken into account. The threshold of convection excitation, convective flows structure and heat transfer are investigated for cylindrical layers of various relative thickness in the plane of control parameters, the centrifugal and vibrational Rayleigh numbers.

The cases of the layer heated from inside and outside, at positive and negative values of centrifugal Rayleigh number, are considered. It is demonstrated that due the thermal-vibrational mechanism the convection appears in case of cylindrical layer heated from inside, i.e. in stably stratified liquid at negative centrifugal Rayleigh number. In the case of rapid rotation the monotonic mode in the form of two-dimensional rolls extended along the axis of rotation is the most dangerous. The thermal convection is determined by the action of the centrifugal and thermal vibrational mechanisms. A good agreement of the threshold of excitation of two-dimensional convective structures obtained experimentally and on the basis of the linear theory for the layers of various relative thickness is found in the plane of the control parameters, namely, the centrifugal and vibrational Rayleigh numbers. The Nusselt number versus these governing parameters in overcritical domain agrees in experiment and numerical simulation in case of high dimensionless rotation frequency.

The experiments showed that in the subcritical domain the flows in the form of toroidal vortices manifest themselfs. These flows appear in the not-threshold manner, have a relatively low intensity, and are generated by inertial waves propagating in the layer.

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References

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