Intermittent convection regimes in magnetic suspensions

Alexandra A. Bozhko*, Gennady F. Putin

Department of General Physics, Perm State University
15 Bukirev Street , Perm, Russia, 614990
e-mail: bozhko@psu.ru, putin@psu.ru

Interest towards studying convective motion in magnetic suspensions is two-fold. On one hand, this is an investigation of magneto-convection arising in artificial non-conducting magnetic fluids whose magnetization in externally applied magnetic fields is many orders of magnitude higher than that in natural fluids [1]. On the other hand, it is important to determine the influence of such factors as sedimentation and thermodiffusion on thermal and mass fluxes occuring in various nano-fluids [2].

Experiments have been performed using a polietilsiloksan colloid with magnetite phase stabilized by oleic acid. The average magnetite particle size was 10 nm. The density of colloid was $0.46 \cdot 10^3$ kg/m^3, and its dynamic viscosity coefficient was 0.365 kg/(m·s). A spherical cavity of the diameter 16.0 ± 0.06 mm was cut inside two Plexiglas blocks. The flow structure was monitored using a set of four mutually orthogonal copper-constantan thermo-couples located in the equatorial plane of the cavity. The temperature difference detected between the poles of the sphere and the thermal exchangers was used to determine the heat flux through the fluid filling the cavity.

When a sphere is heated from below convection arises subcritically and the transition reveals hysteresis. The depth of hysteresis depends on the history of experiment and can be more than 100% of the critical temperature difference corresponding to the cessations of convection when the temperature difference is gradually reduced.

During lengthy (up to one month) experiments an unsteady convection was observed near the convection threshold. It was characterized by an irregular change of flow regimes at fixed temperature differences between the poles: oscillations were intermittently replaced by quasi-steady flows with nearly constant amplitude. The oscillations were linked to the rotation of the axis of a convection roll around the center of a sphere in the equatorial plane or to its precession around some fixed direction.

The change of flow regimes occurred after the spontaneous rotations of the axis of the convection roll. Three main types of convective motion were observed: 1) quasi-steady flows with weakly modulated thermal signature; 2) large-amplitude quasi-harmonic oscillations with a gradually increasing period that were replaced with non-harmonic oscillations over the time interval of about one day; 3) less often yet prominent regime of the spontaneous decay and subsequent self-excitation of convection occurring without any external influence.

Such oscillations and transitions between them occur in nano-suspensions due to the presence of the density gradients caused by thermal expansion and thermodiffusion. These mechanisms were found to play a destabilizing role. In contrast, density variations due to gravitational sedimentation of particles were found to stabilize the flows.

REFERENCES

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