EFD studies on liquid metal flows and rotating flows

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EFD (Experimental Fluid Dynamics) studies provide inspirations and rich knowledge for understanding natural phenomena in spite of using highly-simplified laboratory models for the phenomena. Furthermore, recent developments of novel measurement technique and sophistication of measurement tools, e.g. high-speed video cameras, have enabled us to obtain high-dimensional quantitative information of phenomena that can be compared with flow fields estimated by CFD (Computational Fluid Dynamics). Mechanics extracted from the experimental results should be universal and would elucidate skeleton of the phenomena. This talk introduces two recent EFD studies on liquid metal flows and rotating flows.

Particle Imaging Velocimetry (PIV) that provides two-dimensional, two-components of velocity vector fields is one of the typical innovations in EFD. This technique is, however, not applicable for opaque fluids such as liquid metals. Ultrasonic Velocity Profiling (UVP) is an alternative tool of PIV for opaque fluids: Incidence of ultrasonic waves into the fluids allows providing instantaneous velocity profile information of the fluids. Test application of the UVP for a rotating flow of liquid gallium driven by a rotating magnetic field in a cylindrical vessel represented a fluctuated vortex motion in the vessel on the spatio-temporal velocity field. Further the velocity profile measurement of Rayleigh-Benard convection of liquid gallium in a rectangular vessel visualizes organized convection rolls even though point-wise temperature measurements in previous studies told us that the convection rolls of low Prandtl number fluid such as liquid metals collapse into thermal turbulence state even at lower Rayleigh numbers and there is no organized structure in the vessel. The obtained spatio-temporal velocity fields represent periodic oscillations of the rolls and spontaneous transient behaviors of the rolls.

Rotating fluids accompanying with free surface shows variety of phenomena and typical bifurcation process in spite of its simplicity in the configuration (cf. Fig. 1 (A)). Rotating polygons of the free surface of flows in a cylinder driven by a bottom disk rotation is an example of the phenomena. In case of relatively deeper fluid layers, the free surface shows interesting temporal transitions (termed 'temporally irregular surface switching' hereafter). Figure 1 (B) shows typical process of the surface switching that can be divided into symmetry breaking and symmetry recovery. In the symmetry breaking process the free surface having a round cross section changes its shape into an elliptical shape (Fig. 1 (B), (a)-(c)). Then the free surface detaches from the bottom of the cylinder (Fig. 1 (B), (c)-(d)). The detached free surface has humps at the bottom of the surface and repeats vertical oscillation. In the symmetry recovery process the elliptic free surface restores its axi-symmetry and reattaches to the bottom of the cylinder (Fig. 1 (B), (d)-(a)). The processes occur irregularly and thus some disturbances which have a distribution of the intensity may provide the irregularity. Qualitative and quantitative investigations of the flow field have clarified that laminar-turbulent switching (LTS) of the global flow accompanies the surface switching, namely the flow with the round free surface (cf. Fig. 1 (B), (a)) is laminar flow, and the flow with the elliptical free surface (cf. Fig. 1 (B), (d)) is turbulent flow. In the talk we discuss statistics of the global flow transition on time variations of the surface height.

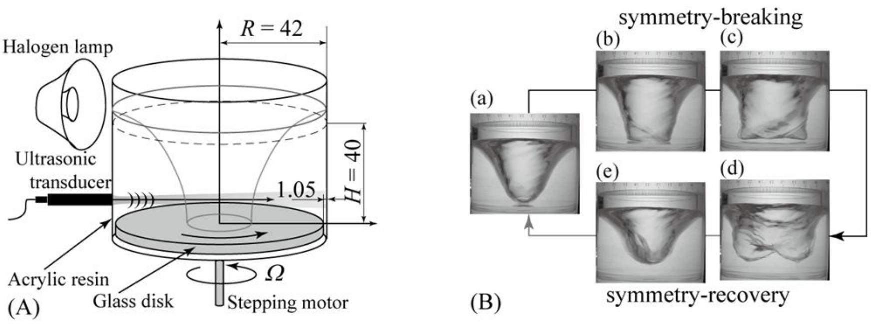

Figure 1 (A) Experimental setup, and (B) typical sequence of the switching process; (a) – (d) symmetry breaking and (d) – (a) symmetry recovery