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Portfolio Paper

Visualizations of Instabilities in Free Convection Plumes

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Fig. 1 : Mushroom-like vortex above a heated horizontal cylinder

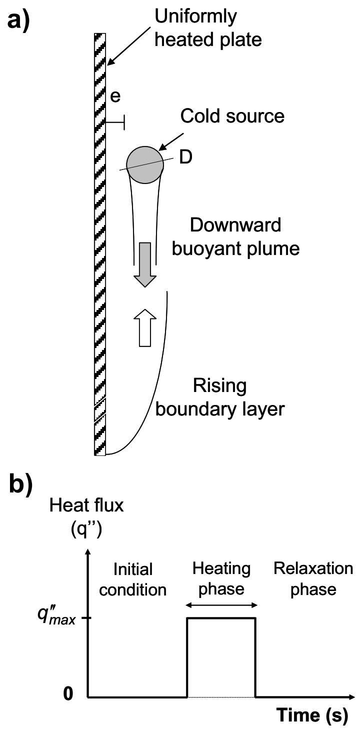

Fig. 2 : Opposite buoyancy-induced flows : (a) Flow configuration, (b) Heating cycle

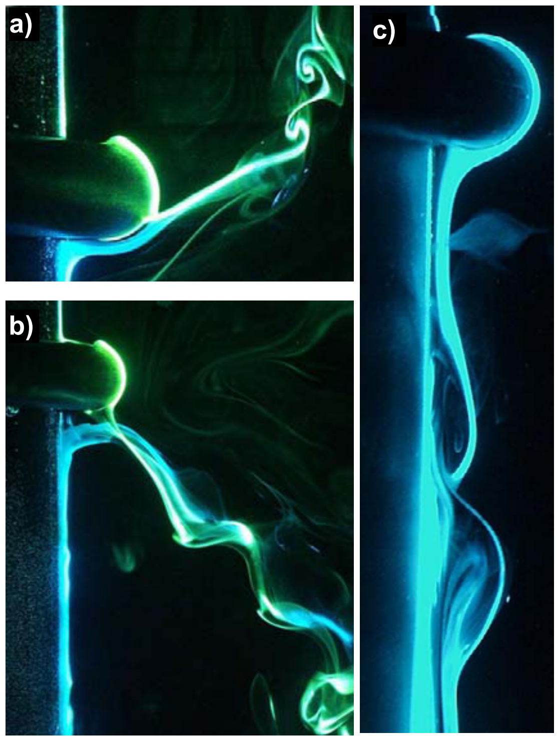

Fig. 3. Flow instabilities : (a) Kelvin-Helmholtz type, (b) 3D Spiral motion, (c) Counter-rotating vortex system

Flow visualization techniques[1,2,3] were employed to investigate vortex instabilities in free convection plumes (Fig. 1) as well as in the interaction of opposite buoyancy-induced flows (Figs 2,3). Visualizations were carried out by means of laser tomography combined with the electrolytic precipitation method[2] (Figs 1,3) and the dye fluorescent technique[4] (Figs 3(a,b)). The opposite flows consist in an ascending boundary layer developing along a uniformly and periodically heated vertical plate and a descending plume generated by a constantly cooled horizontal cylinder placed near the wall[4] (Fig. 2). The electrolytic method and the dye technique were used simultaneously for part of the investigation of the opposite buoyancy-induced flows (Figs 3(a,b)) in order to distinguish the boundary-layer development (electrolytic method) from that of the plume (dye technique).

Figure 1 highlights the usual development of a mushroom-like vortex above a heated horizontal cylinder while Figure 3 shows some singular structures developing at the plume/boundary layer interface during the interaction of the opposite flows. The wall heating results in the formation of a mushroom-type vortex (not shown here), that is transported along an axis oblique with respect to the wall. Then, the wall thermal relaxation phase leads to an interfacial instability in the form of a Kelvin-Helmholtz instability (Fig. 3a). This instability becomes the source of three-dimensional small-scale structures resulting in a large three-dimensional spiral motion (Fig. 3b). Finally, the flow is reattaching at the wall in the form of multiple counter-rotating vortices (Fig. 3c) originating from the opposition of the descending plume and the ascending boundary layer.

References : (1) Nakayama Y., Aoki K., Journal of Visualization, 4 (2001), 9-18. (2) Taneda S. et al. Proc. Int. Symp. on Flow Visualization, Tokyo, (1977) 133-138. (3) Polidori G. et al., Journal of Visualization, 11 (2008), 184. (4) Fohanno S. et al., Heat Mass Transfer, 43 (2007), 997-1002.