Planar coflowing air-water sheets: experiments and linear stability analysis

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The dynamics of a plane air sheet surrounded by a coflowing water sheet, both discharging into stagnant air, is investigated by means of experiments and theory. For a fixed liquid-to-gas thickness ratio, $a = h_w/h_a = 10.21$, two different flow regimes are experimentally observed depending on the values of two control parameters (Fig. 1b), namely, the Weber number, defined as $We = \rho_w u_w^2 h_a/\sigma$, and the velocity ratio, $\Lambda = u_w/u_a$, where u_w and u_a are the velocities of the water and air streams respectively, ρ_w is the water density and h_a is the half-thickness of the air sheet at the exit slit. The study focuses on the near field of the sheets, where instabilities are observed to grow, leading to the periodic breakup of the air sheet into bubbles for low enough values of Λ. High-speed imaging has been used to measure several relevant parameters, such as the bubbling frequency and the size of the bubbles formed (Fig. 1a). In addition, air pressure variations close to the exit slit have been measured using a microphone. Finally, with the aim at explaining the transitions experimentally observed, an analytical study based on linear, local, spatiotemporal stability theory, has also been performed based on different models for the basic flow, contemplating, in particular, the influence of the control parameters We and Λ, as well as the liquid-to-gas thickness ratio, a.

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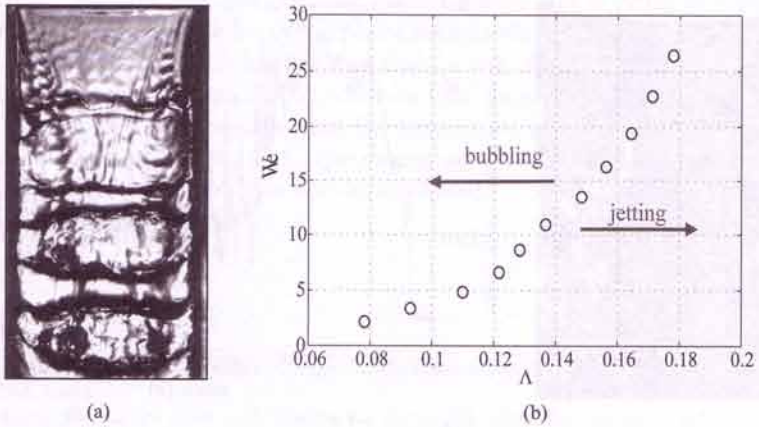

(a) (b)

Figure 1: (a) Snapshot showing the front view of the planar coflowing sheets in the bubbling regime. (b) Experimental transition curve in the $We - \Lambda$ plane.