Sloshing instability induced by a bubble flow

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Several industrial processes rely on the injection of gaseous bubbles into a liquid bath, as seen in bubble column reactors, where a sparger immersed in a water tank injects air vertically at a constant flow rate. The primary goal is often to enhance mass or heat transfer between the phases during chemical reactions. In certain conditions, sloshing has been observed, characterized by large-scale oscillations of the water surface [1]. These oscillations arise from the interaction of lateral jet oscillations and the free surface. The phenomenon referred to as self-induced sloshing, where the oscillations are self-sustained without any external input.

The setup comprises a rectangular water tank with adjustable width L_1 and depth L_2 (Fig. 1.a.), ensuring primarily two-dimensional flow by maintaining $L_2 < L_1$. An upward air jet is issued from a sparger at an effective depth h_e, possibly differing from the free-surface height h_0. We measure the critical air flow rate by varying the aspect ratio h_0/L_1 and h_e. The flow rate Q is controlled, and shadowgraphy captures jet location, interface shapes, and emerging frequencies, thanks to backlighting from an LED panel.

The unstable behaviour (cf Fig. 1.b.) only occurs above a critical air flow rate Q_c, which varies non-monotonously with the tank's geometry . In this study, we aim to explain how the tank geometry affects this critical threshold. We also that the instability threshold is minimized when the natural frequencies of the bubble jet and the free surface match, consistent with experimental observations.

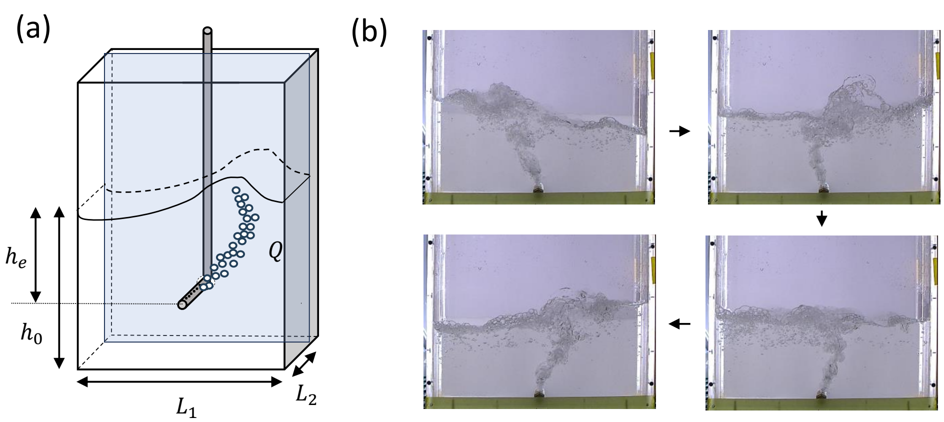

Figure 1. (a) Experimental setup : static water level h_0, width L_1 and depth L_2. (b) Snapshot of the oscillations in the tank ($h_0 = h_e = 130$ mm, $L_1 = 400$ mm, $L_2 = 100$ mm, $Q = 2.5$ m^3(n).h^{-1}).

References

1. AOKI ET AL., Experimental Study and Prediction by Computational Fluid Dynamics on Self-induced Sloshing Due to Bubble Flow in a Rectangular Vessel *Journal of Chemical Engineering of Japan*, **54**,51–57 (2021).