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P05

温度差マランゴニ効果に起因するハーフゾーン液柱内粒子集合現象を形成する粒子群の時空間的挙動

Spatio-temporal Behaviors of Particles Constituting Particle Accumulation Structure (PAS) in a Half-Zone Liquid Bridge Induced by Thermocapillary Effect

野口信 [1]，黒瀬築 [2]，上野一郎 [2]，

Shin NOGUCHI[1], Kizuku KUROSE[2] and Ichiro UENO[2]

[1] 東京理科大学大学院，Tokyo University of Science

[2] 東京理科大学，Tokyo University of Science

We investigate experimentally so-called particle accumulation structure (PAS) as discovered by Schwabe et al.[1)] This phenomenon is observed in a half-zone liquid bridge (**Fig. 1.**), and which has a three-dimensional ordered structure formed by the uneven distribution of low-Stokes-number particles in a nonlinear thermal convection field. A liquid bridge is formed by holding a certain amount of liquid between the end of the surface of coaxial circular rods. In our experimental apparatus, the rod placed at the upper part is heated (at T_{H}) while the rod placed at lower part is cooled (at T_{C}) to induce a designated temperature difference ΔT ($\equiv T_{\mathrm{H}} - T_{\mathrm{C}}$) between the end of the surface of the liquid bridge. This temperature difference becomes the driving force for the fluid over the free surface, which is due to the temperature dependence of the surface tension. As ΔT is increased, the convection field within the liquid bridge exhibits a transition from a two-dimensional steady state to a three-dimensional oscillatory state by the hydrothermal wave instability. Such a unique coherent structure manifests in convective flows exhibiting rotational oscillations[2)]. Due to the complexities involved in constructing experimental setups for this system on the ground (normal gravity conditions), prior experimental studies have predominantly focused on oscillatory flow conditions with a low-aspect-ratio cylindrical geometry, where the thermal convection structure exhibits azimuthal wave numbers $2 \le m_{\mathrm{HTW}} \le 5$ [2-5)]. Therefore, research focused on high-aspect-ratio liquid bridge with $m_{\mathrm{HTW}} = 1$ has mainly been conducted by numerical simulations[6,7)]. In recent years, advancements in experimental setups have made it possible to achieve stable observations of PAS of $m_{\mathrm{HTW}} = 1$, which have been demonstrated under both normal and microgravity conditions[8,9)]. However, the detailed three-dimensional structure of particle trajectories and the presence of corresponding ordered flow structures known as the Kolmogorov-Arnold-Moser (KAM) tori[10)] in the high-aspect-ratio liquid bridges remain unexplored.

In the present study, we discovered a PAS which has a distinct spatial structure from the previously reported ones (**Fig. 2.**). Additionally, we achieved accurate quantitative analysis of particle behavior through PTV (**Fig. 3.**) and unveiled the simultaneous existence of two distinct particle trajectories with unique characteristics. Moreover, these structures exhibit similarities with the results of numerical simulations[7)]. Consequently, we managed to identify streamlines with a significant potential to serve as particle attractors. These findings suggest the potential coexist of KAM tori within the convection fields .

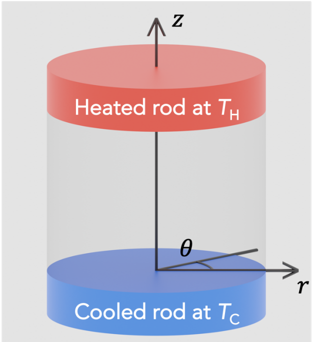

Figure 1. Model of half-zone liquid bridge.

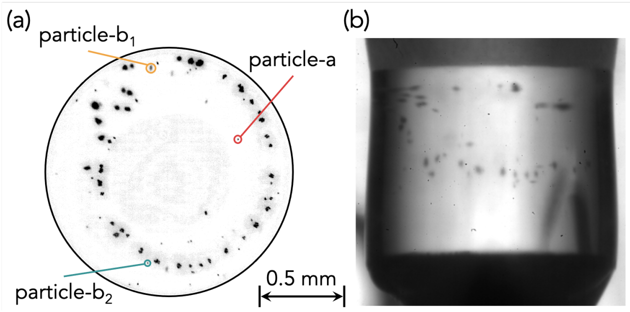

Figure 2. (a) Particle image observed through the upper rod, (b) image monitored through the external shield.

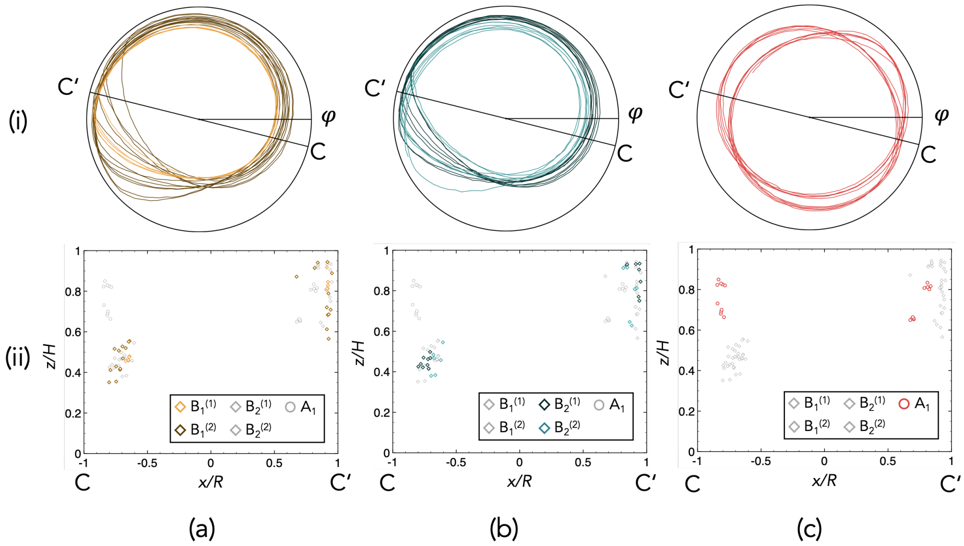

Figure 3. Row (i): top view of coherent structures by (a) particle-b_1 and (b) particle-b_2 and (c) particle-a. Row (ii): Poincaré section at C-C′ cross-section shown . Column (a) and (b) consists of the trajectories (a) ‘$B_1^{(1)}$’ (in orange) and ‘$B_1^{(2)}$’ (in brown) by the particle-b_1 and (b) ‘$B_2^{(1)}$’ (in deep blue) and ‘$B_2^{(2)}$’ (in light blue) by the particle-b_2, and Column (c) consists of the trajectories ‘A_1’ (in red) by particle-a.

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