Insights into bubble–particle collisions with gravity from point-particle simulations

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Bubble–particle collisions lie at the heart of flotation processes, which is employed on a vast scale to extract minerals. Such collisions are complex even when gravity is neglected because of the fundamentally different nature of bubble–particle systems compared to particle–particle systems, as highlighted recently[1]. The complexity can be exemplified by the counter-intuitive behaviour that bubbles and particles segregate in turbulence. In reality, gravity plays a non-negligible and non-trivial role by introducing relative settling and anisotropy to the system. To date, a comprehensive picture of the effect of gravity is lacking, partly because systematic studies which go beyond a mere quantification of the collision rate remain limited. We bridge this gap by conducting direct numerical simulations of bubble–particle collisions in homogeneous isotropic turbulence using the point-particle approach[2] over a range of parameters including the Stokes number St, the Froude number Fr (defined as the ratio of the Kolmogorov acceleration to gravity), and the Taylor Reynolds number Re_λ. Curiously, we find that the bubble–particle collision rate for certain parameters is lower in turbulence compared to what is expected for pure relative settling. We quantitatively demonstrate that this is due to a lower effective rise velocity of the bubbles in turbulence, which can be explained in part by the effects of preferential sampling and of the lift force. In addition, we modify existing particle–particle collision models to incorporate the unique behaviour of bubble–particle systems for comparison, and probe the effect of the lift force. We believe that the insights gained from our simulations regarding the effect of gravity will greatly aid modelling efforts of real-life flotation processes.

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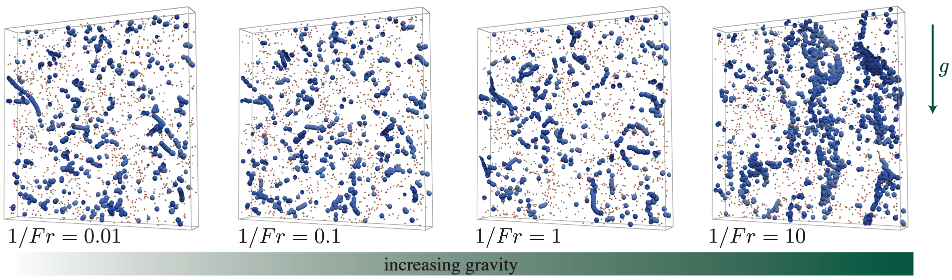

Figure 1: Snapshots of $St = 1$ bubbles (blue) and particles (red) at various $1/Fr$.

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[1] Chan, Ng and Krug, *J. Fluid Mech.* **959**, A6 (2023).

[2] Maxey and Riley, *Phys. Fluids* **26**, 883 (1983).