MATHEMATICAL MODELING OF MULTIPLE BUBBLE INTERACTIONS IN HYDRODYNAMIC UNSTABLE MIXING

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ABSTRACT

Fluid mixing occurs frequently in basic science and engineering applications. When a heavy fluid is supported by a lighter fluid in a gravitational field, the interface between the fluids is unstable under small perturbations. This phenomenon is known as the Rayleigh-Taylor instability [1]. The Rayleigh-Taylor instability plays important roles in many fields ranging from astrophysics to inertial confinement fusion. Since Rayleigh first considered this problem, it has received attentions in a wide range of contexts, but many aspects of dynamics of the instability are still uncertain.

Small perturbations at the interface grow into nonlinear structures in the form of bubbles and spikes. When the interface has random initial perturbations, different frequencies excite nonlinear interactions and the flow eventually develops into a turbulent mixing. At the random perturbations, bubbles of different radii propagate with different velocities and the leading bubbles grow in size at the expense of their neighboring bubbles. This phenomenon is known as a *bubble interaction* or *bubble merger* process [1,2].

A central issue in the turbulent mixing by the RT instability is a scaling law for the growth of mixing zone. It has been known that the bubble front in the RT mixing grows as

$$h = \alpha A g t^2, \tag{1}$$

and the coefficient α is insensitive to the density ratio [1,2], where $A = (\rho_1 - \rho_2)/(\rho_1 + \rho_2)$ is the Atwood number and g is a gravitation acceleration. Previous theoretical models for multiple bubble interactions to estimate the growth coefficient α, are based on statistical or phenomenological equations, which usually include unknown parameters. A number of numerical simulations also have been performed to study the scaling law (1), but it is difficult to draw a unified conclusion from numerical simulations.

In this talk, we present the mathematical model for the evolution of multiple bubbles in Rayleigh-Taylor mixing for the system of arbitrary density ratio [3]. The model is the extension of the potential source-flow model for single-mode bubble [4]. We investigate dynamics of the evolution of multiple bubbles for finite density contrast and demonstrate bubble interaction process from the model. We also discuss the prediction from the model for the scaling law (1) of bubble fronts, comparing with experimental and numerical results.

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