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Nonlinear interaction of two interfaces in the multi-component Richtmyer-Meshkov instability

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The motion of unstable interfaces in multi-layer flow is important in various areas such as internal gravity waves, geophysical fluid dynamics, and plasma physics. These multi-layer interfaces often occur in the fluids with density stratification, and they interact with each other when the interfaces are located close together. The Rayleigh-Taylor instability (RTI) and the Richtmyer-Meshkov instability (RMI) are the examples of such density stratification instabilities. RMI is a shock-induced interfacial instability that occurs at a corrugated interface separating two fluids with density jump [1-2]. This instability plays an important role in various fields such as astrophysical supernova explosion, supersonic combustion, inertial confinement fusion (ICF), and fundamental plasma physics [3].

In real laboratory experiments, the density jump in RMI between an interface is often composed of multi-layer interfaces with density stratifications [4-6]. In the current study, we propose the theoretical model for solving the nonlinear interaction of double-layer interfaces in three-component RMI and investigate the long-time behavior of that using the vortex sheet model (VSM) [7-11].

We present various interfacial motions (Figure 1) together with the growth velocities of bubbles and spikes by varying those Atwood numbers and initial conditions including the distance between the two interfaces. We show that the two interfaces gradually approach each other for all cases due to the incompressibility. When the initial distance between the two interfaces is sufficiently small (less than or equal to the half of the wavelength of the initial perturbation), the two interfaces merge and behave like one vortex sheet at the last computed stage, although they do not coincide exactly to maintain the initial area between them. Here, we select incompressible RMI as a physical example of multi-layer systems; however, the model and analysis developed here are applicable to general unstable multi-layer interfacial motions, such as the Kelvin-Helmholtz instability (KHI), RTI, and internal gravity waves.

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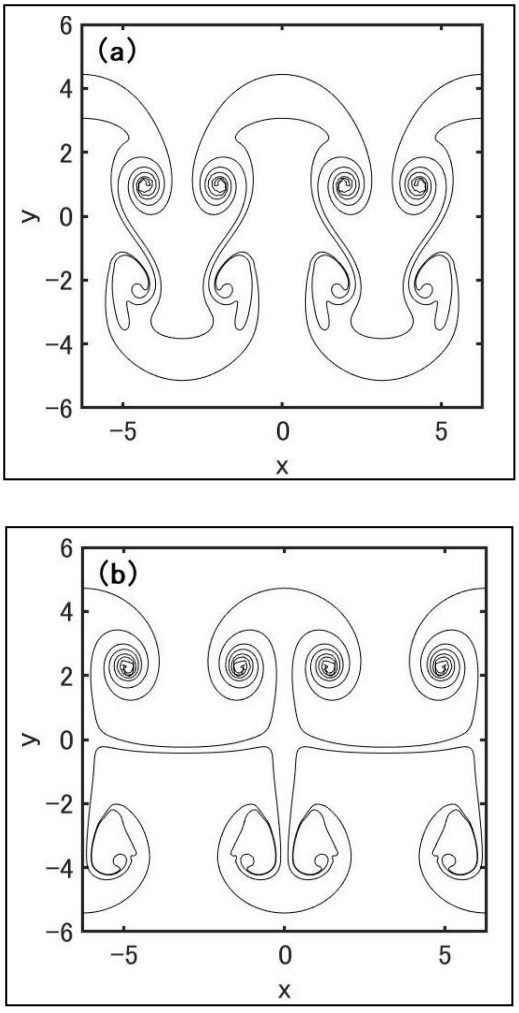

Figure 1: Examples of multi-layer interfacial structures in RMI with (a) in phase and (b) out of phase initial conditions.