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Interfacial Instability and Mixing Behavior between Two Liquid Layers Bounded in Finite Volumes

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Abstract : The mixing process of two liquid layers in a cylindrical container includes the upper liquid with higher density rushing into the lower liquid with lighter density, the lower liquid rising into the upper liquid, meanwhile the two liquid layers having interactions with each other, forming vortices, spreading or dispersing in others, entraining or mixing with others. It is a complex process constituted of flow instability, turbulent mixing and other multiscale physical phenomena and having a fast evolution velocity. In order to explore the mechanism of the process and make further investigations, some experiments about the interfacial instability and mixing behavior between two liquid layers bounded in different volumes are carried out, applying the planar laser induced fluorescence (PLIF) and the high speed camera (HSC) techniques. According to the results, the evolution of interfacial instability between immiscible liquid develops faster than theoretical rate given by the Rayleigh-Taylor Instability (RTI) theory. It is reasonable to conjecture that some mechanisms except the RTI play key roles in the mixture process of two liquid layers. From the results, it is shown that the invading velocity of the upper liquid into the lower liquid does not depend on the upper liquid's volume (height). Comparing to the cases that the upper and lower containers are of identical diameter, in the case that the lower liquid volume increases to larger geometric space, the upper liquid spreads and expands into the lower liquid more quickly during the evolution of interfacial instability, indicating that the container wall has important influence on the mixing process. In the experiments of miscible liquid layers' mixing, the diffusion time and pattern of the liquid interfacial mixing also does not depend on the upper liquid's volumes, and when the lower liquid volume increases to larger geometric space, the action of the bounded wall on the liquid falling and rising flow will decrease, and the liquid interfacial mixing effects will also attenuate. Therefore, it is also concluded that the volume weight of upper heavier liquid is not the reason of the fast interfacial instability evolution between the two liquid layers and the bounded wall action is limited to the unstable and mixing flow. The numerical simulations of the immiscible liquid layers' interfacial instability flow using the VOF method show the typical flow pattern agree with the experiments. However the calculated instability development is much slower than the experimental measurement. The numerical simulation of the miscible liquids' mixing, which applying Fick's diffusion law to the components' transport equation, shows a much faster mixing rate than the experiments on the liquids' interface at the initial stage. It can be presumed that the interfacial tension plays an important role in the interfacial instability between the two liquid layers bounded in finite volume.

Keywords : interfacial instability and mixing, two liquid layers, Planar Laser Induced Fluorescence (PLIF), High Speed Camera (HSC), interfacial energy and tension, Cahn-Hilliard Navier-Stokes (CHNS) equations
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