Influence of interfacial mobility on bubble motion and collision kinetics at interfaces - experiment and modeling

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Bubble motion and kinetics of its collision at various interfaces is an important problem for mass transfer applications and is of great interest whenever it comes to technological processes involving multiphase flow. The bubble motion in fluids is determined by many factors such as the bubble size, density difference between liquid and gas phases, liquid viscosity and, last but not least, properties of the liquid/gas interface. In pure liquids, the bubble surface is fully mobile (slip hydrodynamic boundary conditions) and the viscous drag is significantly reduced. Therefore, the rising velocity of the bubble is significantly higher than the velocity of a solid sphere (no-slip hydrodynamic boundary conditions) of identical density, diameter and shape. Adsorption of surface-active substances at the bubble surface, and formation of the dynamic adsorption layer (DAL) of characteristic architecture, diminishes fluidity of the liquid/gas interface and leads to lowering the bubble velocity. Depending on the degree of adsorption coverage and the architecture of the DAL formed, the hydrodynamic boundary conditions over the bubble surface are gradually changed from slip to no-slip. Viscous drag exerted by the fluid on the immobilized bubble surface increases and when the bubble surface is completely immobilized then its rising velocity can be by over 50% lower than in distilled water.

Retardation of the bubble surface fluidity (mobility) can affect significantly stability of liquid films formed at various interfaces, affecting timescale of a bubble coalescence or three-phase contact (TPC) formation (bubble attachment to the solid surface). Existing experimental techniques (methods) do not allow a direct observation of the DAL formation and its architecture over surface of the rising bubble. Therefore, different stages of the DAL development can be evaluated and followed only indirectly, using experimental as well as numerical approaches. In the experimental approach, an indirect evaluation of the DAL formation kinetics is usually achieved by analysis of dynamics of bubble motion, i.e. its shape and local velocity variations. Nowadays, monitoring the shape and velocity changes of a rising bubble is presently the most feasible experimental approach for indirect evaluation of the kinetics of DAL development as well as its structure.

The paper presents a review of our recent experimental and theoretical (numerical modeling) results on influence of the interfacial mobility on kinetics of the bubble motion and collision with various interfaces. The review is focused mainly on kinetics of the DAL formation over surface of the rising bubble and presents results showing how important is the DAL formation for stability and kinetics of rupture of the thin liquid films formed at various interfaces by the colliding bubble. We show that the DAL development kinetics can be significantly affected by different degree of initial adsorption coverage over surface of the detaching bubble. In addition, we show, on the basis of comparison between results of experimental and numerical studies, that kinetics of the bubble attachment to solid surface in pure water at hydrophobic solid surface depends on the surface roughness. Thus, it seems that the bubble shape variations can be used as a subtle marker of the different hydrodynamic boundary conditions at the solid/liquid interface.