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Flow instabilities at liquid-liquid interfaces – experimental validation of direct numerical simulations using synthetic shadowgrams

Abstract

Reactive mass transfer of acetic acid across a plane liquid-liquid interface has been investigated experimentally and numerically. A two-layer system of immiscible solvents containing the reactive components is confined in a vertically oriented narrow gap geometry (Hele-Shaw cell) providing nearly two-dimensional flow conditions. Mass transfer and release of heat by an exothermic interfacial neutralization reaction give rise to hydrodynamic instability, which combines plume and fingering convection. It can be shown numerically that the observed fingering structure is a double-diffusive instability. For simulations a two dimensional numerical code has been developed, which solves the coupled equations of mass, heat and momentum. Two systems have been studied in order to compare between reactive and non-reactive mass transfer. In the reactive case a solution of acetic acid in cyclohexane was carefully poured onto an aqueous solution of sodium hydroxide. The respective densities are 0.870 g/cm3 (upper layer) and 1.016 g/cm3 (lower layer, including the base concentration). In the non-reactive case the sodium hydroxide was omitted.

The test cell was equipped with a traditional shadowgraph setup. For comparison between measurements and theory, calculated concentration and density fields were used to generate synthetic shadowgrams applying the Laplacian operator. The resulting two-dimensional plots were directly confronted with the experimental results. Visualizations of the acid distribution are presented for double diffusive instabilities.