Experimental study of local flow and concentration fields in Taylor flow by using micro particle image velocimetry and laser-induced fluorescence

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The Taylor flow regime in gas-liquid two-phase flow is characterized by a sequence of elongated gas bubbles, which rise along a capillary channel. These Taylor bubbles, almost filling the channel cross section, are surrounded by a thin liquid film and separated by liquid slugs.

Taylor flow is of great interest for micro process engineering, monolith reactors and for micro-fluidics application due to its capability to enhance transport processes by short diffusion paths, large interfacial area and recirculation within the liquid slugs. Furthermore the well defined conditions offer advantages both the experimental analysis of effects on the microscale and the numerical simulation. Therefore experiments on Taylor flow are well suited for validation of the mathematical models and numerical methods to be developed within the priority program “Transport Processes at Fluidic Interfaces”.

The objective of the present study is the characterization of the dependency of hydrodynamics on mass transfer and especially getting deeper insights into local mass transfer processes at the gas-liquid interface. In addition, the influence of surfactants on mass transfer and hydrodynamics as well as the investigation of the velocity profiles and oxygen concentration within the liquid film are also analyzed.

Taylor flow experiments in a vertical square capillary (hydraulic diameter $d_h = 2\, \text{mm}$) are studied and quantified laser optically. Therefore local velocity fields are measured by Micro-Particle Image Velocimetry and local concentration fields by Confocal Laser Scanning Microscopy with a spatial resolution of $5\, \mu\text{m}$. Fig. 1 and Fig. 2 show the setup schematically with the relevant measurement techniques.

By means of an injection valve the oxygen bubbles are generated creating a mass flow continuously in water/glycerol mixture, which has to be visualised by a Ruthenium-complex as fluorescent dye. The coupling of hydrodynamics and mass transfer at the gas liquid interface are analysed systematically in order to understand the dynamic transport processes on the microscale.

Acknowledgement

The financial support by the German Research Foundation (DFG) within the priority program 1506 “Transport Processes at Fluidic Interfaces” is gratefully acknowledged.