Mass transport in a two-phase flow of supercritical CO_2 and viscous liquids in static mixers

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In high-pressure processes (>7 MPa) as spray particle formation [1] or physical polymer foaming [2], it becomes necessary to handle two-phase flows of supercritical fluids and liquids. Frequently, static mixers are used in these processes in order to continuously mix the different phases and enhance mass transport. They enable effective dispersive and distributive mixing even for two-phase systems of contrary physical properties as gases and viscous liquids. However, the design and calculation criteria of static mixers for dispersion and mass transport in such high-pressure systems are rare. In order to gain further knowledge on this topic, a high-pressure flow set-up is designed, which allows investigating different sized static mixers (D < 12mm) and a combination of mixers regarding pressure drop, residence time, dispersed phase hold-up, bubble size distribution and mass transport. Therefore, in-situ measurement methods as backlight-imaging, particle image velocimetry and Raman spectroscopy are used and adjusted to the specific need. A transparent mixing section provides optical access to the mixer and the flow pattern.

In this work, two-phase bubbly flows of CO_2 in either glycerol or polyethylene glycol 6000 (PEG6000) are investigated regarding the bubble size and the mass transport at different conditions. This implies the investigation of bubble break-up as well as mass transfer kinetics in these systems. The substances are chosen to observe a system of rather low solubilities (approximately 6 wt-% in the system CO_2-glycerol [3]) and high solubilities in the case of CO_2 in PEG6000 (approx. 25 wt-% [4]). Static mixers of the type SMX-plus from 'Sulzer' are applied with different diameters and lengths. Dispersed phase fractions are varied as well as the continuous volume flow rates at different pressures. The generated dispersion is analyzed with a simple method based on backlight imaging, with that droplet size, specific surface area and the dissolved amount of dispersed phase is measured. A downstream, in-house designed view cell consisting of a flat rectangular channel ensures additional optical access for spectroscopic analysis. Raman spectroscopy is applied and adjusted to be used in two-phase flow in order to proof the dissolution of the dispersed phase at the mixer outlet. Processing the raw data like images and Raman signals, algorithms are developed using Matlab [3] and the open-source add-in PIVlab [4]. Consequently, the effect of residence time, phase ratio, amount of saturation, bubble sizes and specific surface area can be discussed on the background of mass transport.

First results with the SMX4-plus and the system CO_2 in PEG6000 at 10 MPa show that dissolved amounts of CO_2 greater than half of the saturation are reached using a 30 element static mixer in time scales of a few seconds. It can be shown, that mass transport is favored by higher dispersed and continuous phase flow rates up to 60 ml/min. Although residence time decreases in that case, the specific surface area is effectively increased by the static mixer and dominates mass transport.

References

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