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Liquid-solid contacting in trickle-bed reactors

by

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Abstract

Several types of reactors are encountered in industry where reagents in a gas and a liquid phase need to be catalysed by a solid catalyst. Common reactors that are used to this end, are trickle-bed reactors, where gas and liquid flow cocurrently down a packed bed of catalyst. Apart from the catalytic process itself, several mass transfer steps can influence the rate and/or selectivity of a solid catalysed gas-liquid reaction. In trickle-bed reactors, flow morphology can have a major effect on these mass transfer steps.

This study investigates the interaction between liquid flow morphology and mass transfer in trickle-bed reactors from three different angles. The primary focus is on liquid-solid mass transfer and internal diffusion as affected by the contacting between the liquid and the catalyst. First, the contacting between the liquid and the solid in trickle-flow, or wetting efficiency, is characterised using colorimetry. Though this investigation is limited to the flow of nitrogen and water over a packed bed at ambient conditions, it provides useful information regarding liquid flow multplicity behaviour and its influence on the distribution of fractional wetting on a particle scale. The colorimetric study also provides descriptions of the geometry of the liquid-solid contacting on partially wetted particles.

These are used in a second investigation, for the numerical simulation of reaction and diffusion in partially wetted catalysts. This second investigation uses numerical simulations to evaluate and develop simple theoretical decriptions of liquid-solid contacting effects on catalyst particle efficiency. Special attention is given to the case where external and intraparticle mass transfer rates of both a volatile and non-volatile reagent affect the overall rate of reaction. Also, since these are not often considered in theoretical studies, some suggestions are made for the evaluation of the particle efficiency of eggshell catalyst.

Finally, liquid-solid contacting is investigated in a high-pressure pilot reactor. Wetting efficiency is measured with a useful technique that does not rely on descriptions of particle kinetics or liquid-solid mass transfer rates. Liquid-solid mass transfer coefficients are also measured and results agree well with the colorimetric investigation, suggesting the existence of different types of flow within in the hydrodynamic multiplicity envelope of trickle-flow.

Since it consists of different investigations of liquid-solid contacting from different angles, the study highlights several aspects of liquid-solid contacting and how it can be expected to influence trickle-bed reactor performance.

KEYWORDS: trickle-bed reactor, trickle flow, wetting efficiency, liquid-solid mass transfer, colorimetry, pellet efficiency factor, finite element method, hydrodynamics, multiplicity

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