Mass Transfer and Reaction in Rotating Foam Reactors

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Introduction

The production of fine chemicals and pharmaceuticals is commonly performed in batch reactors, using slurry catalysts, due to their high flexibility. However, the catalyst particles need to be filtered from the slurry when the reaction is finished, which is a costly and time consuming operation. The objective of this work is, therefore, to develop new three-phase reactor configurations based on the application of solid packings, such as open cell solid foams. These materials show a good mechanical stability, a high porosity, and a high specific surface area, which offers great potential for their use as catalyst packings. The foam surface area can be further increased by deposition of a catalyst wash coat or by the growth of nanofibers [1,2]. The catalyst is fixated on the solid foam surface, which enhances the mechanical stability of the catalytic material. Rotation of the foam structures leads to a high mixing of the phases and smaller gas bubbles. The rotation also increases the mass transfer rates due to the expected improved refreshment of the liquid layer on the wetted solid foam surface. Additionally, the reaction mixture can be drained off easily, without the need to filter the catalyst particles.

Materials and Methods

Two solid foam stirrer configurations, as shown in Figure 1, are compared with a Rushton turbine. The gas-liquid mass transfer is measured by desorption of oxygen from water into nitrogen gas. The liquid oxygen concentration was measured using an optical fiber based oxygen probe. The liquid-solid mass transfer is studied with the fast oxidation of formic acid on Pt/Al_2O_3. The liquid-solid mass transfer is determined from the measured oxygen concentration in the liquid and the reaction rate. The catalyst is prepared by applying an alumina wash coat on the solid foams similar to the method of Nijhuis et al. [3]. The stability of the wash coat is increased with an alumina sub layer, grown by anodization. Palladium is deposited by deposition precipitation.

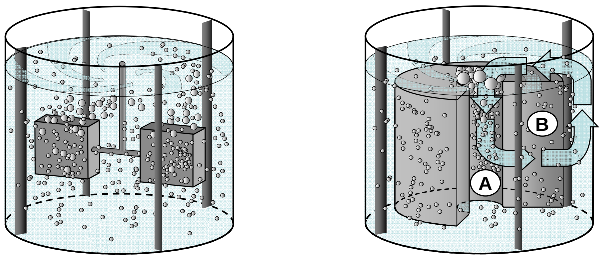

Figure 1. Schematic drawing of the rotating foam designs. The blade stirrer design(left) induces bubbles through the hollow shaft. Rotation of the foam block(right) leads to fast circulation of small bubbles.

Results and Discussion

Using the foam blade design, gas bubbles are created by turbulence at the gas-liquid interface and by gas induction through the stirrer. These bubbles are broken by the collisions with the foam struts. Rotation of the foam block leads to a high liquid circulation (Figure 1). In the center section (A) fine bubbles are formed, which circulate with the liquid through the foam structure (B). Figure 2 shows the gas-liquid mass transfer as a function of stirrer speed and power input. Both foam designs work at much lower stirring speed. For similar power input, comparable values of $k_{GL}a_{GL}$ are obtained. The liquid circulation can be further improved by the baffle design. The liquid solid mass transfer is expected to be increased due to the high velocity of the liquid on the catalyst surface. In slurry reactors the catalyst particles are moving with the liquid and the catalyst surface is hardly refreshed. Experimental data on liquid-solid mass transfer will be presented.

Highly stable alumina coatings on aluminum foams were prepared by a combination of anodization and wash coating. The coating thickness could be varied between 5 and 50 µm resulting in a specific surface area of up to 24 m^2/g_{foam}. The interparticle pores in the micrometer range provide the space for a high mass transfer of reactants to the catalytically active sites.

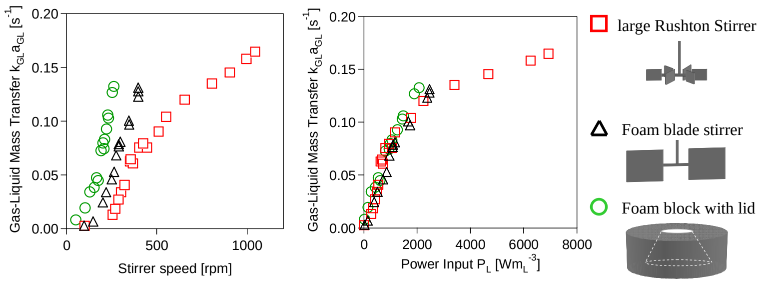

Figure 2. Gas-liquid mass transfer coefficients of the foam blade and foam block stirrers compared to the Rushton stirrer, measured by oxygen desorption from water at 20 ºC, gas and liquid in batch mode.

Significance

With this convenient reactor concept the catalyst can be re-used, but also replaced easily by exchanging the foam stirrer. Using the foam block, the reactor volume is used efficiently. The rotating foam stirrers show good mass transfer characteristics and they can be easily implemented in existing reactors.

References

1. Wenmakers, P.W.A.M., van der Schaaf, J., Kuster, B.F.M., Schouten, J.C. *J. Mater. Chem.* 18, 2426 (2008).
2. Chinthaginjala, J.K., Seshan, K., Lefferts, L. *Ind. Eng. Chem. Res.* 46, 3968 (2007).
3. Nijhuis, T.A., Beers, A.E.W., Vergunst, T., Hoek, I., Kapteijn, F., Moulijn, J.A. *Catal. Rev.* 43, 345 (2001).