**413c Effect of Elevated Pressure on the Performance of Slurry Bubble Columns**

*Vinit P. Chilekar, John Van der Schaaf, J. Ruud Van Ommen, Ben F. M. Kuster, Johan T. Tinge, and Jaap C. Schouten*

Increasing the operating pressure in slurry bubble columns (SBCs) is often beneficial due to increased gas hold-up and mass transfer coefficients, directly influencing the overall rate of the fast chemical reactions. This is advantageous for numerous oxidation and hydrogenation reactions carried out in the industry under mass transfer limited conditions. To review the effect of pressure on the SBC performance, we present a detailed hydrodynamic study of an air-water system in a slurry bubble column at elevated pressure with two different catalyst particles, namely carbon and silica particles. The study mainly focuses on the influence of the catalyst particles concentration (0 – 5 % v/v) and of the operating pressures (1 – 14 bar) on the main hydrodynamic parameters. The parameters such as fractional gas hold-up, flow regime transition point, average large bubble diameter, and centerline axial liquid velocity were studied using pressure measurements. The experiments were carried out in a 0.15 m inner diameter bubble column operated in a pressure range from 1 bar to 14 bar.

The key hydrodynamic parameter often studied and necessary for the design of a SBC is the fractional gas hold-up. Fractional gas hold-up was calculated using differential pressure measurements. In the homogeneous flow regime i.e. at lower superficial gas velocities ($<0.1$ m $s^{-1}$), the gas hold-up increases almost linearly with the superficial gas velocity. After the flow regime transition to heterogeneous regime, the rate of increase of the gas hold-up is slower than in the homogeneous regime. Increasing the pressure also leads an increasing gas hold-up. This increase in the gas hold-up is significant in the heterogeneous flow regime, but in the homogeneous flow regime the increase is marginal. At higher operating pressures above 10 bar, the setup could only be operated in the homogeneous regime with the maximum superficial gas velocity of 0.11 m $s^{-1}$. In case of slurries, the gas hold-up decreased with increasing slurry concentration irrespective of the type of particles.

The second hydrodynamic parameter studied was the flow regime transition point. The Fourier analysis of the measured pressure-time series determined the flow regime transition from the homogeneous regime to the heterogeneous regime. This method was recently developed by Ruthiya et al. (2005)[1]. Accordingly, the coherent standard deviation of the pressure fluctuations (a measure for the local hydrodynamic phenomena such as bubbles) was calculated at all superficial gas velocities. The trends of the coherent standard deviation with superficial gas velocities obtained at different operating pressures determined the regime transition points at each pressure. The sharp increase in the coherent standard deviation from a nearly zero value indicates the first regime transition point. It was observed that the flow regime transition is delayed by increasing the operating pressure. The homogeneous flow regime prevails for higher superficial gas velocities leading to higher gas hold-ups in the homogeneous regimes. With increase in the slurry concentrations, the flow regime transition point moved to lower superficial gas velocities.

The third hydrodynamic parameter measured was the average large bubble diameter based on the technique developed by Chilekar et al. (2005)[2] for application in bubble columns. Here Fourier analysis is used to separate the local pressure fluctuations generated by the rising bubbles from rest of the pressure fluctuations in the bubble column. The local pressure fluctuations are correlated to the average large bubble size. The same correlation was used to measure the average large bubble diameter in the SBCs at high pressures. It was observed that the average large bubble diameter decreases with increase in the operating pressure. Under pressure, small bubbles are more stable and coalescence decreases, leading to less large bubbles and consequently a lower average bubble size. It is also observed that the liquid circulations increase slightly with the increase in pressure. This indicates that there is a higher break-up rate of the bubbles leading to lower average large bubble size.

The final hydrodynamic parameter studied was the centerline axial liquid velocity in high pressure SBC using a Pitot tube. The tube measured the averaged upward liquid flow in the centre of the column with the help of a differential pressure transducer. The liquid velocity measurements were corrected for the two phase flow and the pressure drop due to the flowing liquid was obtained to calculate the correct axial liquid velocity. It was observed that the average liquid velocity increased slightly with increase in pressure in the heterogeneous regime. This was contradictory to the general notion that with pressure the liquid circulation will decrease leading to higher gas hold-up. However the increase in the liquid velocity is very marginal and can also be considered as constant.

The experimental studies described above, provided the trends of the hydrodynamics in a high pressure SBC. These experimental results are being used in establishing a mathematical model. This is an engineering-type of model, but is based on first principles as much as possible. It can be directly applied in the design of the high-pressure slurry bubble columns.

References: [1] Ruthiya et al., AIChE J., (2005), July issue. [2] Chilekar et al., AIChE J., (2005), July issue.