Chapter V

DISCUSSION

As far as this work was concerned, the main intention was to find out an expression of mass transfer with chemical reaction in fluidized bed in the dense phase region using a perforated plate distributor.

5.1 Some Technical Details in Equipment Design and Operating Technique

The experimental apparatus was designed and constructed such that it would be possible to check the hydrodynamic condition with the previous works. This would then enable the comparision to be made. The fluidization column was made of Plexiglass which was transparent, so that the fluidized bed level could be observed. The diameter of the column was 94 mm and the height was 650 mm. These dimensions were so selected on the basis of available pumps and for the purpose of eliminating the end effect of fluidization, respectively.

The homogenisation section was essential to keep the flat velocity profile in the fluidized bed and thereby to elminate channelling effect. The flat velocity profile was checked by measuring the pressure drop around the column at the position just above the distributor. The perforated plate distributor was used instead of a sintered plate distributor. It is known that a perforated plate distributor gives higher mass transfer rate than that of a sintered plate distributor. This is due to the flow of the liquid through the plate which is in the form of jets in the lower part of the bed [8]. The perforated plate distributor is mornally selected for its lower pressure drop and the ease of cleaning.

The orifice meter was used to indicate the volumetric flow-rate of liquid in terms of liquid height in a manometer. The meter gives more accurate reading than other meters such as a rotameter and a disc meter.

In liquid-solid system an increase in flow-rate above minimum fluidization usually results in a smooth,progressive expansion of the bed. Gross flow instabilities are damped and remain small, and large-scale bubbling or heterogeneity is not observed under normal conditions. A bed such as this is called a particulately fluidized bed or a homogeneously fluidized bed. There are two regions of the particulately fluidized bed: A dense phase region as long as there is a clearly defined upper limit or surface to the bed. And a lean phase region, at a sufficiently high fluid flow-rate the terminal velocity of the solid is exceeded, the upper surface of the bed disappears, entrainment becomes appreciable [9]. In the experimental work, the dense phase region was selected, because the operation was easily controlled and the flow-rate of liquid was low and could be varied in a wide range. The results of mass transfer compare well with previous works. The voidage range was varied from 0.513 to 0.787.

Experimental data were obtained from dissolution of benzoic acid particles of uniform diameter in dilute NaOH solutions.

The large amount of benzoic acid particles used in this work had a modified ball shape. The number of particles for each run was 3,500. Their average density was 1,275 Kg/m^3. The maximum particle diameter of 5.874 mm was smaller than ten times of column diameter, which was required for fluidized bed reactor [10].

The evaluation of the mass transfer coefficient was carried out by calculating the amount of solid dissolved during fluidization over a period of time. The period of fluidization used in this work was 15 minutes for each run. This time was long enough for the determination of the mass dissolution. The particles after each run were dried in a dryer until a constant weight was obtained. Hot air was blown from an electric heat source to the solid particles which were spreaded over a stainless steel sieve plate. The temperature was carefully kept below 40°C in order to avoid the sublimation of benzoic acid.

The experiments were performed at room temperature of about 30°C. Due to a very small value of heat of reaction between benzoic acid and NaOH solution, the bed temperature was constant at all times.

5.2 Testing of Experimental Apparatus

The experimental apparatus was first operated using the same system and operating conditions as that of the previous works to see if it functioned properly. The benzoic acid-water system was used. The mass transfer coefficient was evaluated from the amount of benzoic acid dissolved during fluidization over a period of time by using Eq.(2.2) and Eq.(2.3). The inlet stream was pure water (C_1=0). The concentration of benzoic acid in the bed was calculated from weight loss of the solid during the run, the flow-rate of water, and the period of dissolution. From experimental results the correlation of ϵ and Re were plotted on a log-log scale and found to be represented by straight line of slope 2.39 which agreed well with that of Richardson and Zaki [5]. And the variations of Sh $\epsilon^{1.25} Sc^{-1/3}$ against Re could be conveniently represented by straight line on a log-log scale plot. The average exponent of Re was 0.584 and the constant value K_1 was 0.686. The results from this experiment showed that the mass transfer correlations agree well with that of the previous work as represented in Eq.(2.14). Hence, it was confirmed that the experimental apparatus was suitable for further study.

5.3 The Results of Mass Transfer with Chemical Reaction

5.3.1 Effect of NaOH Concentration on the Correlation between ϵ and Re

The Reynolds number was calculated from the volumetric flow-rate and the physical properties of NaOH solutions in various concentrations. The volumetric flow-rate of liquid did not change so much within the range of concentration concerned. Therefore, the values in various concentrations were assumed to be the same as that of pure water. From Fig.4.1, it was shown that plots of ϵ vs. Re on a log-log scale for various particle diameters and initial NaOH concentrations resulted in a set of parallel straight lines having the slope as that of benzoic acid-water system. Furthermore, both system had the same correlation at the same particle diameters.

This indicated that the concentration of NaOH solution had no effect on the correlation.

5.3.2 Effect of Mass Transfer with Chemical Reaction

The diffusivity of benzoic acid-water system was used in the calculation of Sh and Sc in all runs. The approximation was made due to lack of data for benzoic acid-NaOH system and the very dilute concentration of the NaOH solution. As a matter of fact, the value of effective diffusivity for the system containing both the reactants and products should be used. This approximation was previously used by reference (1).

As has been earlier shown in Fig.4.2, plots of $Sh\,\epsilon^{1.25}Sc^{-1/3}$ vs. Re with initial NaOH concentration as a parameter gave a set of parallel straight lines having the same slope as that of benzoic acid-water system. The value of mass transfer as represented by the group $Sh\,\epsilon^{1.25}Sc^{-1/3}$ increased as the initial NaOH concentration was raised. This is of course due to the effect of chemical reaction, as could be seen from Eq.(4.1)

$$Sh\,\epsilon^{1.25}Sc^{-1/3} = 0.686\ Re^{0.584} + 1.871\ Cr^{1.369}$$

The second term on the right-hand side was due to chemical reaction. This equation would be reduced to benzoic acid-water system if the second term dropped out. The new correlation should be useful in the prediction of the mass transfer rate in the range of the variables studied. One could expect a similar correlation as Eq.(4.1) for other systems of different chemical reactions. The magnitude of the second term would directly depend on the particular rate of chemical reaction and the concentration of the reactants.