CHAPTER 6

CONCLUSIONS AND RECOMMENDATIONS

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Conclusions and Recommendations

6-1- Conclusions

In this work some hydrodynamic characteristics of slurry bubble columns, namely gas holdup and mixing in the liquid phase, have been investigated. The experiments were performed in a plexiglass column, 20cm diameter and 120cm height column in presence of tubes of 1.1 cm diameter fixed vertically, using tap water as the liquid phase , air as the gas phase and sand particles (0.5 mm) as the solid phase under batch conditions and at:-

a) Superficial gas velocities 1, 2, ...15 cm/sec.

b) Solid concentration 0- 4% by volume.

c) Number of cooling tubes 0- 57.

The main findings are:

1-the gas holdup increased as the superficial gas velocity was increased in the bubbly flow regime. The transition from bubbly to churn- turbulent flow occurred at superficial air velocity between 5& 6 cm/s.

2-The gas holdup slightly decreased as a result of increasing the number of tubes inside the bed with less pronounced transition point.

3-Solids concentration had negligible effect on gas holdup in both empty bubble columns and in bubble columns containing tubes.

4-Literature correlations for gas holdup were in good agreement with the experimental values.

5-The liquid phase dispersion coefficient generally decreased with increasing the number of tubes and with increasing solids concentration.

6-Literature correlations for liquid phase axial mixing coefficient in empty bubble columns predicted values for D_{axL} very close to the experimental ones. However, for bubble columns containing tubes, the predicted values deviated from the experimentally determined coefficient.

6-2-Reccomendations

1- Using a taller column to increase the height/diameter ratio of the slurry phase.

2 – Measuring tracer response at more than one point inside the column for more accurate calculation of the axial mixing coefficient.

3- Investigate a wider range of solids concentration.

4-Investigate liquids with different physical properties other than water.

5- Investigate gases with different physical properties other than air.

6- Investigate the effect of horizontal cooling tubes as compared to vertical cooling tubes.

References:

- Akita and Yoshida (1973), "Gas Hold Up and Volumetric Mass Transfer Coefficient in Bubble Columns", Ind. Eng. Chem. Process. Des. Dev. 12, 76-80.
- Alexander, B.F., and Shah, Y.T. (1976), "Axial Dispersion Coefficient in Bubble Columns". Chemical Engineering Journal 11, 153-156.
- Aoyama, Y., Ogushi, K., Koide, K., and Kubota, H. (1968), "Liquid Mixing in Concurrent Bubble Columns". J. Chem. Eng. Japan, 1,158.
- Argo, W.B., and Cova, D.R. (1965), Ind. Eng. Chem. Proc. Des. and Dev. 4, 252.
- Badura, R., Deckwer, W.D., Warnecke H.J., and Langemann, H. (1974), "Durchmischung in Blasensaulen", Chem. Eng. Tech. 49, 399.
- Baird, M.H., and Rice, R.G. (1975), "Axial Dispersion in Large Unbaffled Columns". Chem. Eng. J. 9, 171-174.
- Bukur,D.B.,Patel,S.A.and Matho,R.(1983), "Hydrodynamic Studies in Fischer –Tropsch Derived Waxes in a Bubble Column". Chem. Eng., 38, 3, 441.
- Cova, D.R. (1966), 'Catalyst Suspension In Gas-Agitated Tubular Reactors'. Ind. Eng. Chem. Proc. Dev. 5,21.
- Chen, Fan Li, Sujatha Degaleesan, Puneet Gupta, Muthanna H. Al-Dahhan, Milorad P. Dudukovic, and Bernard A. Toseland, (1999), "Fluid Dynamic Parameters in Bubble Columns With Internals". Chem. Eng. Sci., 54, 2187-2197.
- Davidson, J.F. and Harrison D. (1971), "Fluidization", Academic press, London.

- De Bruijm, T.J.W., Chase, J.D., and Dawson, W.H. (1988), "Gas Hold Up in a Two Phase Vertical Tubular Reactor at High Pressure", Can. J. Chem. Eng. 66, 330-333.
- Deckwer, W.D. (1992), "Bubble Column Reactors", Wily and sons, New York.
- Deckwer, W.D., Graeser, V., Langemann, H., and Seprpemen, Y. (1973), "Zones of Different Mixing in The Liquid Phase of Bubble Columns", Chem. Eng. Sci. 28, 1223.
- Deckwer, W.D., Lovisi, Y., Zaid, A., and Ralek, M. (1980), "Hydrodynamic Properties Of The Fischer-Tropsch Slurry Process", Ind. Eng. Process. Des. Dev. 19, 699-708.
- Deckwer, W.D., Serpeman, W.D., Ralek, M., and Schmidt, B. (1981), "On the Relevance of Mass Transfer Limitations in the Fischer-Tropsch Slurry Process", Chem. Eng. Sci. 36, 765-771.
- Deckwer, W.D., Serpemen, Y., Ralek M., and Schmidts, B. (1981), "On the relevance of mass transfer limitations in Fischer-Tropsch Slurry progress', Chem. Eng. Sci. 36,765.
- Deckwer, W.D. and Schumpe .A. (1993), 'Improved Tools For Bubble Column Reactor Design And Scale-Up', Chem. Eng. Sci. 48, 889-911
- Degaleesan, S., Dudukovic, M.P., Toseland, B.A., and Bhatt, B.L. (1997), 'A Two Compartment Convective Diffusion Model For Slurry Bubble Column Reactors'. Ind. Eng. Chem. Res. 36, 4670-4680.
- Degaleesan, S., Roy, S., Kumar, S.B., and Dudukovic, M.P. (1996), 'Liquid mixing based on convention and turbulent dispersion in bubble columns'. Chem. Eng. Sci. 51, 1967-1976.
- Eissa, S.H., and Schugerl, K. (1975), Chem. Eng. Sci. 30, 1251.

- Eissa, S.H., El Halwagi, M.M., and Saleh, M.A. (1977), Ind. Eng. Chem. Proc. Des. Dev. 10, 31.
- El-Temtamy,S. A., Y. O. El-Sharnoubi and M. M. El-Halwagi, (1979 a)," Liquid Dispersion in Gas-Liquid Fluidized Beds, Part 1: Axial Dispersion, The Axially Dispersed Plug Flow Model", Chem. Eng. J. 18, 151
- El-Temtamy,S. A., Y. O. El-Sharnoubi and M. M. El-Halwagi, (1979 b)," Liquid Dispersion in Gas-Liquid Fluidized Beds, Part II: Axial and Radial Dispersion the Dispersed Plug Flow Model". Chem. Eng. J. 18, 160.
- El- Temtamy .S. A., Khalil. S .A., Nour El-Din .A. A., and Gaber .A. (1985), 'Liquid-phase axial mixing in a bubble column bioreactor containing yeast suspensions', Applied Microbiology and Biotechnology', 21, 65-68.
- Forret, A., Jean-Marc Schweitzer, Thierry Gauthier, Rajamani
- Krishna, and Daniel Schweich. (2003), "Liquid Dispersion in Large
- Diameter Bubble Columns, With and Without Internals". The
- Canadian Journal of Chemical Engineering, Vol. 81.
- Hikita and Hikukawa, H. (1974), "Liquid phase mixing in bubble columns: Effect of liquid properties". Chem. Eng. J. 8, 191-197.
- Idogawa, K., Ikeda. K., Fukuda. T., and Morooka. S. (1987), "Effect Of Gas Liquid Properties On The Behaviour Of Bubbles In A Column Under High Pressure", Ind. Chem. Eng. 27, 93-99.
- Kato, Y., and Nishiwaki, A. (1972), "Longitudinal Dispersion Coefficient of a Liquid in a Bubble Column". Ind. Chem. Eng. 12, 182.

- Krishna. R., Ellenberger. J. and Hennephof. D.E. (1993), 'Analogous Description of Gas-solid Fluidized Beds and Bubble Columns', Chem. Eng. J. 53, 89-101
- Konig, B., Buchholz, R., Lucke, J., and Schulgerl, K. (1978), 'Longitudinal mixing of the liquid phase in bubble columns'. Ger. Chem. Eng. 1,199.
- Krishna R. and Sie S.T. (2000), "Selection Design and Scale-Up Aspects Of Fischer –Tropsch Reactors ", Fuel Processing Tech nology.64,73-105
- Krishna, R., Urseanu, M., J.M. Van Baten, and J. Ellenberger (2000), 'Liquid phase dispersion in bubble columns operating on the churn turbulent flow regime'. Chemical Engineering Journal, 7811: 43-51.
- Krishna, R., Wilkinson, P. M., and Dierendonck, L. L. (1991), 'A model for gas hold up in bubble columns incorporating the influence of gas density on flow regime transition', Chem. Eng. Sci. 46, 2491-2496.
- Kunii, D., and LevenSpiel O. (1964), 'Fluidization Engineering' John Wiley and sons and Chapter 11, Chemical Reactors.
- Nicklin, D.J., O. Wilkes and Davinson J.F. (1962), 'Two-Phase flow in vertical tubes', Trans. Inst. Eng. 40, 61-68.
- Nour El-Din. A. A., M. Sc. Thesis, Cairo University (1982).
- Ohki, Y., and Inoue, H. (1970), "Longitudinal Mixing Of The Liquid Phase In Bubble Columns". Chem. Eng. Sci. Vol. 25, pp 1-16.
- Ozturk, S.S., Schumpe A. and. Deckwer W.C. (1987), "Organic Liquids in a Bubble Column, Holdup and Mass Transfer Coefficients". A.I.CH.E. J. 33, 1473-1480.

- Reilly, I. G., Scott D. S., De Bruijm, Jain T. A., and J. Piskorz (1986), 'A correlation for gas hold up in turbulent coalescing bubble columns', Can. J. Chem. Eng. 64, 705-717.
- Reilly, I. G., Scott, D. S., De Bruijm, T., Jaim. A., and Piskorz, J. (1986), 'A correlation for gas holds up in turbulent coalescing bubble columns', Can. J. Chem. Eng. 64, 705-717.
- Reith, T., Renken, S., and Israel, D.A. (1968), 'Gas hold-up and axial mixing in the fluid phase of bubble column'. Ind. Eng. Chem. Proc. Des. Dev. 10, 31.
- Riquarts, H.P. (1981), 'A physical model for axial mixing of the liquid phase for heterogeneous flow regime in bubble columns'. Ger. Chem. Eng. 4, 18-22.
- Shah, Y.T., Kelker, B.G., and Deckwer, W.D. (1982), 'Design parameters estimation for bubble column reactors', A.I.Ch.E. J.28, 353-379.
- Shah, Y.T., Joseph. S., Smith. D. N., and Ruether. J. A. (1985), 'Two-bubble class model for churn-turbulent bubble column reactor'. Ind. Eng. Chem. Proc. Des. Dev. 24, 1096-1104.
- Shah, Y.T., Stiegel, G.J., and Sharma, M.M. (1978), 'Back mixing in gas-liquid reactors'. A.I.Ch.E. J. 24, 369-400.
- Shah. T., Serap Kara and Balmohan (1982), 'Hydrodynamics and Axial Mixing in a Three Phase Bubble Column', Ind. Eng. Chem. Process Des. Dev. 21, 584-594.
- Smith E.L., Fidjett, M., Shaygen J. (1977), 'Liquid phase mixing in bubble column. Second European Conference on Mixing'.
- Stern,D.,Bell.A.T (1985),"Axial Dispersion in Bubble Column",Ind.Eng. Chem.Proc.,Des. & Dev.,24,1213

- Suo, M., (1976), 'Calculation Methods for performance of heat exchangers enhanced with fluidized bed', Letter 1, Heat and mass transfer. 3, 555-564.
- Tarmy, B., Chang, M., Coulaloglou, C., and Ponzi, P. (1984), 'Gas liquid mass transfer in the bubble column with viscoelastic liquid', Can. J. Chem. Eng. 69, 506-512.
- Towell, G.D., and Ackermun, G.H. (1972), 'Axial mixing of liquids and gas in large bubble reactors'. Proceeding of 2nd International Symposium Chem. React. Eng., Amsterdam, P.B 3-1.
- Walter J.F., and Blanch, H.W. (1983), 'Liquid ciculation patterns and their effect on gas hold-up and axial mixing in bubble columns'. Chem. Eng. Commun.19, 243-262.
- Wilkinson M. P., Van Dierendonck L.L. (1992), 'Design parameters estimation for scale up of high pressure bubble column', AICHE J. 38, 544-554.
- Wilkinson, P. M. (1991), 'Physical aspects and scale up of high pressure bubble column PHD thesis', Groningen, The Netherlands.
- Wilkinson, P. M., and Van Dierendonck L. (1990), 'Pressure and gas density effects on bubble break up and gas hold up in bubble columns', Chem. Eng. Sci. 45, 2309-2315.
- Zou, R., Jiang, X., Li. B., and Zhang, L. (1988), 'Studies on gas hold up in a bubble column operated at elevated temperature', Ind. Eng. Chem. Res. 27, 1910-1916.