TITLE: NOVEL TECHNIQUES FOR SLURRY BUBBLE COLUMN HYDRODYNAMICS **DATE:** April, 1998

PI: Dr. M.P. Dudukovic', Dr. L.S. Fan

Co-Investigators: P. Gupta, Dr. Y. Yiang, Dr. Yu Pan, Dr. M. Al-Dahhan
(Graduate Students, Research Associates-Washington University)
D.J. Lee, J. Reese, Dr. P. Jiang, Dr. R.F. Mudde
(Graduate Students; Research Associates-Ohio State University)
Dr. M. Chang (Exxon Research and Engineering)

INSTITUTIONS: Washington University, Chemical Engineering Department
Campus Box 1198, St. Louis, MO 63130-4899
(314) 935-6021;
Ohio State University, Department of Chemical Engineering
140 West 19th Avenue, Columbus, OH 43210
(614) 292-7907;
Exxon Research and Engineering
PO Box 101, Florham Park, NJ 07932-0101
(201) 765-6109

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I. ABSTRACT

OBJECTIVE: The overall objective of this collaborative project between Washington University, Ohio State University and Exxon Research and Engineering is to improve the basis for scale-up and operation of slurry bubble column reactors (SBCRs) by an increased reliance on experimentally verified computational fluid dynamic (CFD) codes. The emphasis is on development of novel experimental techniques.

WORK DONE AND CONCLUSIONS: The past twelve months were dedicated to studying bubble rise velocities at high temperature and pressure, comparison of fluid dynamic simulations for liquid velocity and gas holdup profiles with experimental data and development of a high pressure 6" diameter bubble column facility for studies of scale-up effects.

At Washington University (WU) a high pressure 6" diameter column and associated facilities were constructed. The system was designed to accommodate Computer Automated Radioactive Particle Tracking (CARPT) and Computed Tomography (CT) which are the only techniques capable of providing column -wide information on liquid velocity and gas holdup profiles. Experiments are planned for the May/June 1998 period at elevated pressure (100 psig) and at high gas velocities for comparison with previously taken data at atmospheric pressure. The accuracy of the CARPT technique was established by comparison with Particle Image Velocimetry (PIV) data. Extensive work on computational fluid dynamics (CFD) resulted in good comparison of CFD velocity predictions and data for 2 dimensional (2D) bubble columns. It was shown that a 2D CFD code, based on the two fluid model using a bubble induced turbulence closure scheme, is successful in predicting the observed velocity profiles. These results, as well as CARPT-PIVcomparison, will be illustrated at the poster session.

At Ohio State University (OSU) the emphasis was on identifying the effects of high pressure and temperature on the micro structure of gas liquid flows. A 2" and 4" diameter columns were constructed with planar quartz windows to accommodate the laser sheet for the PIV system. PIV was then used to investigate the bubble rise velocity and bubble size distribution at high pressure and temperature. It was found that for a given bubble size, the rise velocity decreases with increased pressure. It was observed that when bubble interactions are weak the initial bubble size as well as the number density of dispersed bubbles determines the rise velocity and residence times of bubbles. For highly interactive systems with high coalescence/redispersion the dominant factors are those that control the dynamic bubble size variation. A correlation for bubble rise velocity and data on the effect of pressure on bubble size distribution will be presented.

Exxon Research and Engineering contributed significantly to the design and construction of the high pressure facility at WU. Exxon personnel also provided key inputs and advice for CFD modeling and were instrumental in making the modeling effort a success.

SIGNIFICANCE TO FOSSIL ENERGY PROGRAM: The work executed in this project represents a complementary effort to the DOE program on hydrodynamics of slurry bubble columns in conjunction with the operation of the advanced fuels development unit (AFDU) in LaPorte, Texas, operated by Air Products.

PLANS FOR THE COMING YEAR: This project comes to a close on June 30, 1998. The plans are to prepare a thorough final technical report.

HIGHLIGHT OF ACCOMPLISHMENTS: (4/1/97-3/31/98)

- Observing pressure effects on bubble size distribution and bubble rise velocity.
- Successful comparison of PIV and CARPT.
- Successful CFD modeling of 2D bubble column and favorable comparison with data.
- Construction of high pressure 6" diameter column.

III. ARTICLES AND PRESENTATIONS (1997-98 only)

1. Kumar, S.B., Dudukoviç, M.P. and Toseland, B.A., "Measurement Techniques for Local and Global Fluid Dynamic Quantities in Two and Three Phase Systems", *Non-Invasive Monitoring of Multiphase Flows,* Elsevier, (Chaouki, J.l, Larachi, F. and Dudukoviç, M.P., eds.), Chapter 1, 1-45 (1997).
2. Kumar, S.B. and Dudukoviç, M.P., "Computer-Assisted Gamma and X-Ray Tomography: Application to Multiphase Flow Systems", *Non-InvasiveMonitoring of Multiphase Flows,* Elsevier, (Chaouki, J., Larachi, F and Dudukoviç, M.P., eds.), Chapter 11, 335-406 (1997).
3. Larachi, F., Chaouki, J., Kennedy, G. and Dudukoviç, "Radioactive Particle Tracking in Multiphase Reactors: Principles and Applications", *Non-Invasive Monitoring of Multiphase Flows,* Elsevier, (Chaouki, J., Larachi, F. and Dudukoviç, eds.), Chapter 11, 335-406 (1997).
4. Dudukoviç, M.P., Degaleesan, S., Gupta, P. and Kumar, S.B., "Fluid Dynamics in Churn- Turbulent Bubble Columns: Measurements and Modeling", 1997 ASME Fluids Engineering Summer Meeting, FEDSM 97-3517.
5. Pan, Y., Dudukoviç, M.P. and Chang, M., "Numerical simulation of gas-liquid flow in bubble column reactors with two-fluid model", ISCRE15, Newport Beach, CA., Sept., 1998 (accepted).
6. Lin, T.-J., K. Tsuchiya, and L.-S. Fan, "Bubble Flow Characteristics in Bubble Columns at Elevated Pressure and Temperature", *AIChE J* ., 44, 545, 1998.
7. Luo, X.G. Yang,D.J. Lee, and L.-S. Fan, "Single Bubble Formation in High Pressure Liquid - Solid Suspensions", Powder Technology, in review, 1998.
8. Lee, D.J., X. Luo, and L.-S. Fan, "Dynamic Gas Disengagement in High Pressure Slurry Bubble Columns", will be presented at ISCRE 15, Newport Beach, CA., September 1998.
9. Lee, D.J. and L.-S. Fan, "Coherent Structures in a Three-Dimensional Bubble Column", will be presented at AIChE Annual meeting, Miami, FL., Nov., 1998.
10. Luo, X.G., Yang, Q. Chen, J. Zhang, Y. Li and L.-S. Fan, "Flow Visualization of High Pressure Three-Phase Fludization (part 1); and Computational Flow Visualization of Gas-Liquid-Solid Fluidized Systems using the Combined CFD-DPM-VOF Method (part II)" presented at International Conference of Fluidization IX, Durango, CO, May 1998.
11. Luo, X.G., Yang, Q. Chen, and L.-S. Fan, "Heat Transfer of High Pressure Slurry Bubble Column", will be presented at AIChE Annual Meeting, Miami, FL., 1998.
12. Zhang, J., Y. Li and L.-S. Fan, "Numerical Simulation of Gas-Liquid-Solid Fluidized Systems Using the Combined CFD-DPM-VOF Method", will be presented at AIChE Annual meeting, Miami, FL., Nov., 1998.