DE-FC22-95PC95051--17

Engineering Development of Slurry Bubble Column Reactor (SBCR) Technology

Quarterly Report
April 1 - June 39, 1996

By:
Bernard A. Toseland

Work Performed Under Contract No.: DE-FC22-95PC95051

For
U.S. Department of Energy
Office of Fossil Energy
Federal Energy Technology Center
P.O. Box 880
Morgantown, West Virginia 26507-0880

By
Air Products and Chemicals, Inc.
7201 Hamilton Boulevard
Allentown, Pennsylvania 18195-1501

Disclaimer

DISCLAIMER

ENGINEERING DEVELOPMENT OF SLURRY BUBBLE COLUMN REACTOR (SBCR) TECHOLOGY

Quarterly Technical Progress Report No. 5 for the Period 1 April - 30 June 1996

Contract Objectives

The major technical objectives of this program are threefold: 1) to develop the design tools and a fundamental understanding of the fluid dynamics of a slurry bubble column reactor to maximize reactor productivity, 2) to develop the mathematical reactor design models and gain an understanding of the hydrodynamic fundamentals under industrially relevant process conditions, and 3) to develop an understanding of the hydrodynamics and their interaction with the chemistries occurring in the bubble column reactor. Successful completion of these objectives will permit more efficient usage of the reactor column and tighter design criteria, increase overall reactor efficiency, and ensure a design that leads to stable reactor behavior when scaling up to large diameter reactors.

Summary of Progress

- *State of the Art*

  Assessment of tomography and densitometry has been completed, and a report is under review. A "poor man's tomograph" suitable for installation at LaPorte has been designed, details will be published in a topical report, which is under second revision.

  (Washington University in St. Louis)
  (Air Products and Chemicals, Inc.)

  A search of the literature on spargers provided insight into what parameters should be considered in sparger design. However, insufficient information is available for sparger design for industrial systems at high gas flow rates and elevated pressures. Good design methods exist for understanding the generation of bubbles, but design methods for spargers in columns do not exist. Additional experimental work is needed to begin to understand the importance of various sparger parameters on column performance.

  (Air Products and Chemicals, Inc.)

Task 2 - Technique Development

Understanding physical phenomena requires an understanding of the physical properties of the system under study. Because the effect of high temperature and pressure on viscosity is very difficult to predict, measurements are needed. A falling ball viscometer was devised for the high-pressure/high-temperature column, and its operation was validated at low pressure. Viscosity of liquids at high temperature and pressure was measured. The complicated effect of temperature at high pressure was demonstrated; as pressure increased from 0.1 to 21 MPa, the viscosity increased by 65% at 20^{o}C and by only 10% at 100^{o}C.

(The Ohio State University)

Task 3 - Model Development

A new phenomenological model was developed for the liquid and gas phase in a bubble column reactor. It employs the same concept--recirculating cell with interchange coefficients--as the liquid phase model described in previous reports. The gas phase is described by a two-bubble class model. The large bubbles rise with high velocity in plug flow in the core region of the bubble column, while the small bubbles move more slowly in both upflow in the core and downflow, carried by the liquid, in the wall region. Interchange is allowed between bubble classes so that coalescence and breakup of the bubbles can be described.

(Washington University in St. Louis)

Task 4 - SBCR Experimental Program

Transient flow fields in a 2D air-water bubble column were measured using the PIV technique. Velocity profiles and Reynolds stresses were obtained. Since the Reynolds shear stress is proportional to the averaged vertical velocity gradient, these data verify the Boussinesqu hypothesis. However, the Reynold's normal stresses are much greater than the shear stresses. This finding challenges the usual symmetry of stress assumptions made in CFD calculations.

(The Ohio State University)

Time series analysis of the 2D column data shows the presence of vortices in the flow field. Several characteristic frequencies are revealed by the power spectrum analysis, but high-frequency signals are low, indicating that the vortex structure is the main feature of the flow, and other "purely turbulent" energy contributions are rather low.

(The Ohio State University)

The effect of pressure on gas holdup was measured for gas flow rates up to 8 cm/sec. Gas holdup increases with increasing pressure up to about 10 MPa. Because the average bubble size was insensitive to pressure, the increase in holdup must be due a larger number of bubbles at high pressure.

(The Ohio State University)

Task 6 - Data Processing

The liquid recirculation with crossflow and dispersion model (RCFD) matched, at least semi-quantitatively, the tracer test results obtained during the last test at the AFDU in LaPorte. Since this model had no adjustable parameters (model parameters were estimated from laboratory data), the agreement is noteworthy.

(Washington University in St. Louis)

The Ohio State University Research

The following report from Ohio State University for the period April - June 1996 contains the following brief chapters:

1. Measurement of liquid viscosity (Task 2-5)
2. Bubble effects on the transient flow pattern in bubble columns (Task 3)
3. Gas holdup in high-pressure and -temperature bubble column (Task 4)
4. Work to be performed next quarter (Task 7)
5. References