CHAPTER I

INTRODUCTION

The three-phase (gas-liquid-solid) fluidized bed is a device in which the gas phase moves in the form of bubbles relative to the liquid phase, and eventually reactive solid (catalyst) is fluidized in the liquid phase. The commercial applications of three-phase fluidization systems are in heavy oil, resid hydroprocessing, synthetic crude processing, coal liquefaction in the presence of catalyst, biological waste water treatment and fermentation (Fan, 1989).

The hydrodynamic behavior of gas-liquid-solid fluidized bed is a complex subject and one of the most important for basic understanding of certain refinery and petrochemical industrial applications. Overall three-phase fluidized bed behavior, bubble motion and breakage have been experimentally studied by a number of researchers (Fan, 1989; Kim et al., 1975; Henrickson and Ostergaard, 1974). Also, considerable fundamental work has been successfully demonstrated for petroleum resid processing at Kuwait Shuaiba, Texaco Convent, and Amoco Texas City Refineries. However, recent reviews by Fan (1989), Tarmy and Coulaloglou (1992) show that there exist no hydrodynamic models for three-phase fluidized beds in the literature.

The Illinois Institute of Technology (IIT) three-phase fluidized bed is a two-dimensional rectangular vertical column. The solids (leaded glass beads) are present inside the bed, the gas (air) enters at the bottom through a distributor and liquid (water) is also fed to the bed through another distributer which is located at the bottom of the

bed. In this study, the overall hydrodynamics of the three-phase fluidized bed are investigated. The details of experiments and multiphase computer simulations are described in the following chapters.

In Chapter II, the three-phase fluidized bed experimental setup, x-ray and γ-ray radiation densitometer assembly, and procedures for concentrations (volume fraction) measurements using radiation (x-ray and γ-ray) absorption techniques are described. The visual observations of bubble coalescence and break-up in three phase fluidized bed and their comparison with observations in literature are also narrated.

Chapter III describes the principle of interpretation, calibration for concentration measurements using x-ray and γ-ray absorption techniques, experiments relating to time averaged concentrations, and instantaneous porosity oscillations measurements for gas, liquid and solids phases. A discussion is also included on the bubble sizes and coalesced bubble flow regime used in the experiments of the three phase fluidized bed.

In Chapter IV, the porosity fluctuation signals detected by using a γ-ray absorption technique are reported. The frequencies of porosity oscillations at various locations inside the bed have been analyzed by means of the fast Fourier transform power spectrum method for both two phase and three phase fluidized beds. The experimental porosity fluctuations and bubble frequencies are compared with those obtained using computer simulations of the beds.

Chapter V describes the high resolution micro-imaging / measuring system apparatus for particles velocity measurements; experimental setup for fluidized beds with uniform distributor, and central jet; and experimental procedure. The instantaneous and

time averaged particle velocity measurements using CCD video camera are also recounted.

In Chapter VI, the experimental setup and the measurement of bed viscosity of the three-phase fluidized bed using a Brookfield viscometer are reported. The computed particle fluctuating velocities based on measured bed viscosities are compared with those measured directly using a CCD video camera.

Chapter VII describes the predictive hydrodynamic model including the numerical scheme, initial and boundary conditions and computer simulations of three-phase fluidized bed in symmetric and asymmetric modes. The comparison between experiments and simulation results is also given.

The future work in fluidized beds related to volume fractions, solids velocity and bed viscosity measurements, and hydrodynamic simulations are summarized in Chapter VIII.

Appendix A includes the raw experimental data for measured bed intensities using x-ray and γ-ray densitometers, and corresponding gas, liquid and solids instantaneous volume fractions at different locations inside a three phase fluidized bed.

Appendix B consists of the raw experimental data for instantaneous particles velocity measurements using a CCD video camera at many locations, under different operating conditions inside three phase fluidized beds with a uniform distributor and central jet. The statistical analysis, such as mean, median and variance values of the raw data, is also included.

Appendix C contains raw experimental data for bed viscosity using a Brookfield viscometer at different operating conditions inside two phase and three phase fluidized beds.

Appendix D describes the predictive multiphase hydrodynamic computer model used in the computer simulations, including continuity and momentum equations. The fluctuating energy equations for kinetic theory of granular solids are also included.