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Studies and Investigations on Bubble Column Rectors: An Insight

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ABSTRACT

A multiphase reactor involves two or more phases. Most of these reactions involve gas and liquid in contact with solid. In these reactors the reaction takes place on the surface of solid catalyst. In slurry reactor, gaseous reactant is bubbled through a solution containing solid catalyst particles. The contacting equipments for gas liquid reactor includes trickle bed(packed bed), packed bubble column, agitated slurry reactors, slurry bubble column reactor and fluidized bed reactors. Current review summarizes research and investigations on bubble column reactors.

Key words: Hydrodynamics, mass transfer coefficient, pressure, temperature, modeling, gas holdup.

INTRODUCTION

A heterogeneous reaction involves substance which exists in different phases and reaction usually takes place at an interface between the phases or in one of the phases. A multiphase reactor involves two or more phases. Most of these reactions involve gas and liquid in contact with solid. In these reactors the reaction takes place on the surface of solid catalyst. [1] In slurry reactor, gaseous reactant is bubbled through a solution containing solid catalyst particles. The contacting equipments for gas liquid reactor includes trickle bed (packed bed), packed bubble column, agitated slurry reactors, slurry bubble column reactor and fluidized bed reactors. Various investigators have carried out investigation on bubble column reactors for studying performance, affecting parameters and modeling. Current review summarizes research and investigations on bubble column reactors.

RESEARCH AND STUDIES ON BUBBLE COLUMN RECTORS

Wang et.al. carried out review on slurry reactors. [2] According to them, slurry reactor has the advantages of simple construction, excellent heat transfer performance, online catalyst addition and withdrawal. In case of slurry reactor operations, they discussed the influences of the superficial gas velocity, operating pressure and temperature, solid concentration, column dimensions, and gas distributor. The bubble column reactor is one of the slurry reactors. Slurry bubble column is the simplest in construction. According to Palma et.al., the important design and scale up parameters for a bubble column includes volumetric gas hold up, flow pattern, average gas bubble size, average interfacial area, RTD (residence time distribution), dispersion coefficient, Peclet number. [3] According to their studies, gas hold up along the reactor increased without internal trays inside the column.

Chen explained absorption of carbon dioxide in a bubble-column scrubber. [4] He illustrated absorption of CO_2 in a continuous bubble-column scrubber. Heused a two-film model with fast reaction case to determine the absorption rate and overall mass-transfer coefficient. In his studies, he discussed the effects of process variables on the individual mass-transfer coefficients. He found that bubble columns have a higher scrubbing capacity than packed beds. The material balance model proposed by him indicated that the size of bubble column scrubber could be evaluated when the individual mass-transfer coefficients are available.

Wei-rong et.al. used Danckwert's method to determine the specific interfacial area and the individual mass transfer coefficient. [5] They carried out experiments on absorption of CO_2 in a bubble column with an anionic surfactant in the carbonate-bicarbonate buffer solution and $NaAsO_2$ as catalyst. They observed that with increasing superficial gas velocity, the specific interfacial area and the individual mass transfer coefficient increased. They also found that, with increasing temperature, specific interfacial area decreased and the individual mass transfer coefficient increased. They observed 10% deviation in the calculated results and the actual experimental results. Bai carried out experimental and numerical investigations on bubble column reactors. [6] According to him, bubble column reactors have advantages of ease of operation, low operating and maintenance costs. High catalyst durability and excellent heat and mass transfer characteristics makes them more sought after choice. He introduced some experimental techniques and numerical methods used in multiphase flows.

Blazej et.al. carried out work on gas-liquid simulation of airlift bubble column reactor. [7] They used commercial fluent software in their studies. They compared simulation data with the experimental data. They compared vertical velocity and gas hold-up for series of experiments. Kim et.al. investigated heat transfer and bubble phenomena in a viscous slurry bubble column reactor (SBCR). [8] In their investigation, they examined the effects of superficial gas velocity, solid concentration and liquid viscosity on the gas holdup and heat transfer characteristics. They observed that the gas holdup increased with increasing superficial gas velocity. It decreased with increasing solid concentration and slurry viscosity. Also they observed decrease in the local heat transfer coefficient (h) between the immersed heater and the bed with liquid viscosity and solid concentration.

Chaumat et.al. investigated effects of organic medium, gas and liquid flowrates and column design on mass transfer in bubble column. [9] Their work provided new data more relevant for industrial conditions. They used IR spectrometry for quantification of steady state mass transfer of CO_2 in an absorption-desorption loop. They found that the volumetric mass transfer coefficient was unaffected by the partition plates introduction and the liquid medium. Superficial gas velocity had influence on it. Ghani et.al. carried out an investigation on volumetric mass transfer coefficients in slurry bubble column reactor. [10] Their studies were concentrated on gas holdup, volumetric mass transfer and local mass transfer coefficients in a slurry bubble column. They used Iraqi paraffin oil as a liquid phase, alumina and silica particles as a solid phase and oxygen as gas phase. They found that the gas holdup increases linearly with superficial gas velocity at both homogeneous and heterogeneous regimes. Also it was observed that, with increasing solid loading, the gas holdup and volumetric mass transfer coefficient decreased.

According to Krishna, there are considerable reactor design and scale-up problems associated with the Fischer-Tropsch bubble column slurry reactor. [11] They investigated the hydrodynamics in columns of different diameters. They found that column diameter, elevated system pressures, concentration of the slurry affected hydrodynamics of the column. Raimundo investigated hydrodynamics in bubble columns. [12] They carried out experiments over extended ranges in terms of column diameter and superficial gas velocities. They ensured a fairly constant mean bubble size as well as spatially homogeneous injection.

Bartrand et.al. presented results of experimental and numerical investigations into the hydrodynamics of a bench scale bubble column reactor. [13] They used computational fluid dynamics computer code to model bubble column flow. They also performed numerical studies to refine and validate the CFD model. They compared a gas flow rate within the ideal bubbly flow regime at which large-scale hydrodynamics and phase distribution with those encountered at lower gas flow rates. The results, they obtained were significantly different. Schweitzer and Viguie investigated a slurry bubble column for Fischer-Tropsch synthesis. [14] They developed a complete reactor model for a slurry bubble column. They considered the hydrodynamic features of the three phases (syn-gas, liquid mixture of linear paraffins and solid catalyst).They concluded that model was able to take into account the gas recycle after condensation steps. Shah et.al. carried out review on design parameter estimation of bubble column reactors. [15] Their review provided an insight into present state of the art for the estimation of nonadjustable parameters in bubble column reactors. They also pointed out the inadequacies of the data in some areas of practical importance. They reiterated advantages of bubble column reactors like simplicity of operation, low operating costs, and ease with which liquid residence time can be varied. They found that the estimations of non-adjustable parameters are not much focused study area. According to them, bubble dynamics and flow regimes had indirect influence on the scale up and design of bubble column reactors. Shaikh and Binous investigated high-pressure bubble column reactors. [16] They carried out research on the effect of pressure on the possible existence of multiple steady states in bubble column reactors. To describe the performance of non-isobaric, non-isothermal reactors, they used a mathematical model involving fast pseudo first-order kinetics. According to their investigation, the existence of multiplicity is sensitive to pressure variation.

Shaikh carried out an investigation on mixing, flow regime transition and scale up of bubble and slurry bubble column reactors. [17] He studied effect of liquid phase physical properties and solids loading on the flow structure of slurry bubble column reactors. He found that the neural network correlation yielded better correlation than those obtained for the selected literature correlations. Khan worked on fluid dynamic modeling of bubble column reactor. [18] His work was aimed at identification of proper simulation parameters for a given system. He simulated numerical simulations of rectangular shape bubble column reactors. He carried out transient, three dimensional simulations with FLUENT software. He emphasized need for enough fine mesh grids and appropriate closure of interfacial forces.

Mandal carried out experiments on the gas holdup, bubble sizes and their distribution, mass transfer area and mass transfer coefficient. [19] For experimentation, he chose bubbly flow regime. His analysis pointed out unambiguous relationship between gas holdup, bubble size, bubble size distribution and interfacial area. He observed that gas holdup and interfacial area was a strong function of slip velocity. He concluded that gas holdup obtained in the present system is significantly higher compared to other reported gas liquid systems. Mousavi et.al. investigated ferrous bio-oxidation in a bubble column bioreactor. [20] They used a commercially available computational fluid dynamics package (FLUENT). They also simulated thebio-oxidation rate in the column. They used an Eulerian model for modeling of gas-liquid interactions. They also investigated the effects of inlet air velocity and initial substrate concentration on the velocity field, air volume fraction and bio-oxidation rate of ferrous iron in the column. In their investigation they observed that the initial ferrous concentration and the inlet air velocity had a pronounced effect on the ferrous bio-oxidation rate.

CONCLUSION

A heterogeneous reaction involves substance which exists in different phases and reaction usually takes place at an interface between the phases or in one of the phases. A multiphase reactor involves two or more phases. Most of these reactions involve gas and liquid in contact with solid. In these reactors the reaction takes place on the surface of solid catalyst. Current review summarizes research and investigations on bubble column reactors.

The studies reveal that slurry reactor has the advantages of simple construction, excellent heat transfer performance, online catalyst addition and withdrawal. Slurry bubble column is the simplest in construction. Investigations also revealed that bubble columns have a higher scrubbing capacity than packed beds. Also the gas holdup increases with increasing superficial gas velocity. Commercially available computational fluid dynamics package (FLUENT) can be used for the simulation of bubble column reactors.

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