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Hydrodynamics and flow regime transition study of trickle bed reactor at elevated temperature and pressure

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ABSTRACT

The hydrodynamics in a trickle bed reactor (TBR) in non-ambient conditions are studied for air–water and air–acetone (pure organic liquid of low surface tension) systems. A flow map experiments for air–water and air–acetone systems are performed in a pilot plant reactor of 0.05 m i.d. and 1.25 m height. It has been demonstrated from the experimental results that the pressure drop tends to increase with increasing superficial gas and liquid velocity and reactor pressure, while it tends to decrease with increasing bed temperature. The results also show that the dynamic liquid holdup increases with increasing liquid velocity and decreases with increasing superficial gas velocity, reactor pressure and bed temperature. The dynamic liquid holdup and pressure drop values are obviously higher than those measured for air–water system at the same fluid fluxes, reactor pressure and bed temperature due to the surface tension effects. For higher reactor pressure and temperature, the trickle to pulse transition boundary shifts towered higher superficial velocities of both gas and liquid.

Keywords: Trickle bed reactor; Hydrodynamic; Liquid holdup and pressure drop; Flow regime transition; Trickle flow; Pulsing flow

1. Introduction

Trickle bed reactors (TBRs) are the most widely used type of three phase reactors, in which liquid and gas flow co-currently down through a fixed bed of catalyst particle. It finds a large applicability and importance which arises from their major use in the petroleum industry for hydro-processing of medium heavy and heavy oil fractions, and it is also employed in wastewater treatment and biochemical processing and electrochemical processing. Different flow regime exit in a TBRs; basically, trickle, mist, bubble and pulsing flow regime, depending on the gas and liquid properties, throughputs, operating conditions and packing characteristics. In general, the trickle, pulse and transition regimes between them are of the particular interest in industry (Charpentier and Favier, 1975; Holub et al., 1993; Al-Dahhan and Dudukovic, 1994; Al-Dahhan et al., 1997; Attou et al., 1999). Almost industrial process operates in trickle flow, especially in the process of hydrogenation, while other process operates in pulsing flow (hydrotreating process) due to the energetic interactions between the phases. The processes for heat and mass transfer are greatly intensified where periodic passage of high – rich waves and tends to promote uniform liquid distribution through the packing (Burghardt et al., 2002). This is of crucial important in packed bed reactor in which highly exothermic reactions occur. In TBRs, the flow of gas and liquid over porous catalyst particle is extremely complex. Liquids may or may not wet the surface completely (Al-Dahhan et al., 1997; Dudukovic et al., 2002; Lange et al., 2004; Urseanu et al., 2005; Nigam and Larachi, 2005). Some of the important parameters that affect TBRs performance which interlinked with reaction and selectivity and represent the crucial starting point for reactor design, scale up and scale down are pressure drop, liquid holdup and wetting efficiency are affected by this external surface coverage of the particle and changes from one regime to another. For highly exothermic reactions, the knowledge of these parameters is crucial for both circumventing hot spot and preventing reactor runaway (Charpentier and Favier, 1975; Al-Dahhan and Dudukovic, 1994; Al-Dahhan et al., 1997; Nigam and Larachi, 2005).

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