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Pressure reduction study in a trickle bed using polyacrylamide

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Abstract
Trickle bed operation is energy intensive and to reduce energy consumption in a trickle bed, pressure reducing agents are added to the liquid. In the present work pressure drop at various operating conditions were measured and the effect of polyacrylamide as a pressure reducing agent on pressure drop reduction were investigated. The experimental result shows a increase in percentage pressure reduction with increase in the concentration of polyacrylamide up to a concentration of 8 ppm. Beyond 8 ppm significant foam formation was observed along with an increase in pressure drop. A maximum of 60% pressure reduction is achieved using polyacrylamide (8 ppm) as pressure reducing agent.

Keywords: Trickle bed, pressure drop, pressure reduction, polyacrylamide

1. Introduction

Trickle beds are widely used three-phase (gas-liquid-solid) systems in chemical process industries mainly in hydrotreating and hydrodesulfurization applications in the refining industry, and hydrogenation, oxidation and hydrodenitrogenation applications in the chemical and biochemical industries (Eftaxias *et al*. 2003; Ferdous *et al*. 2005; Liu *et al*. 2006; Gaur *et al*. 2007; Sigurdson *et al*. 2011; Tan *et al*. 2012) [1-6]. Pressure drop is an important parameter as it decides the energy requirements and hence the operating cost (Bansal *et al*. 2008) [7]. The pressure drop in the bed is more for liquid of high surface tension and high solid–liquid interaction. Blockage in void space due to high liquid holdup increase the gas–liquid interfacial friction, hence the pressure also. The pressure in trickle bed can be reduced by elevating operating temperature, improving porosity of bed by effective packing or by using pressure reducing agents like surfactant and polymer. By reducing pressure drop the mechanical energy losses can be reduced, which will reduce the overall operating costs (Regupathi *et al*. 2010) [8].

Literature survey indicates that very limited work has been reported on the pressure reduction of a gas-liquid-solid trickle bed (Aydin and Larachi 2008; Regupathi *et al*. 2010; Patel and Majumder 2011; Giri and Majumder 2014) [8-11]. Pressure drop reduction behavior of polyacrylamide in packed bed systems has not yet evaluated. Polyacrylamide is a very efficient pressure reducing agent and at lower concentrations results measurable pressure drop (Oliver and Bakhtiyarov 1983) [12]. A polymer is a large molecule, or macromolecule, composed of many repeated subunits. The polymers help with pressure reduction by stabilizing the turbulent boundary layer, leading to less turbulent energy generation and hence less dissipation (Khadom and Abdul-Hadi 2014) [13]. The present study aims at evaluating the effect of polyacrylamide and finds its concentration that produces maximum pressure reduction in a trickle bed.

2. Experimental

Experiments were carried out on a 10 cm diameter cylindrical Plexiglas column, packed with raschig rings of 9.86 mm up to a height of 128 cm. Schematic representation of the experimental setup is shows in Fig. 1. Entry for gas and liquid phases were from the top of the column. The packing in the column was supported on a stainless steel mesh. For an even distribution of liquid, a perforated plate distributor was provided at the top of the column with 127 holes of 3 mm size. Firstly air was injected into the column at a desired flow rate using air rotameter and then the liquid was pumped at a desired flow rate using water rotameter. The flow pattern across the Plexiglas column was visually observed. For each run the gas flow was kept constant and the liquid flow rate was gradually increased in steps. For the measurement of pressure drop in the bed, pressure ports were provided at the top and bottom of the column and connected to manometer filled with water as the manometric fluid. Water and polyacrylamide solutions of various concentrations in water were used as the liquid phase. The pressure drop reduction in percentage (% PDR) can be calculated from the following formula (Mowla and Naderi 2006) [14].

$$\%\mathrm{PDR} = \left(\frac{\Delta P_{\text{without PRA}} - \Delta P_{\text{with PRA}}}{\Delta P_{\text{without PRA}}}\right) * 100 \qquad (1)$$

where,
% PDR = Percentage pressure drop reduction
ΔP = Bed pressure drop (Pa)
PRA = Pressure reducing agent

3. Results and discussion

Experiments were conducted at different gas and liquid velocities in the range of 0-0.128 m/s and 0.003-0.038 m/s respectively. To ensure steady state in operation at least ten minutes were allowed, after which the readings for bed pressure drop were noted down. The results obtained from the experiment are presented graphically.

Fig. 2 shows the variation of pressure drop with superficial liquid velocity at various constant superficial gas velocities for air-water system. The bed pressure drop found to increase with both the liquid and the gas velocities. The rise in pressure drop is due to the increase in interfacial shear stress with both the gas and liquid velocities. As the liquid velocity increases, liquid saturation of the bed increases, which creates less void space for the gas to flow. This leads to more gas–liquid interfacial shear stress and increase in pressure drop.

Fig. 3 shows the variation of bed pressure drop with superficial liquid velocity for different concentration of polyacrylamide at constant gas velocity. The pressure drop decreases as the concentration of polyacrylamide increases. This happens may be due to the fact, when polymer solutions are added to a liquid; they go to the liquid surface and act to reduce the surface tension. Above the critical micelle concentration, additional surfactant molecules no longer migrate to the surface and they begin to form micelle structures within the liquid (Wilkens and Thomas 2007) [15]. The bed pressure drop increase at 10 ppm polyacrylamide solution may also be because of the change of non-foaming flow to a foaming flow.

The percentage reduction in pressure drop with variation of liquid velocity at various constant gas velocities for air-8 ppm polyacrylamide solution system is shown in Fig. 4. From the figure, it is observed that as the superficial liquid velocity increases the degree of the pressure reduction first increases reaches a maximum at some velocity and then decreases gradually with a further increase in liquid velocity. But with increase in gas velocity the pressure reduction always decreases.

Fig. 5 shows the variation of percentage pressure reduction with superficial liquid velocity at different concentration of polyacrylamide solution. It is observed that percentage of pressure reduction increases with an increase in the concentration of pressure reducing agent. Polyacrylamide as a pressure reducing agent is effective up to a concentration of 8 ppm in the trickle bed under study. In the present work, a maximum 60% pressure reduction is achieved using polyacrylamide (8 ppm) as pressure reducing agent, higher concentration of polyacrylamide results in increase the bed pressure drop in the system which is undesirable.

4. Conclusion

Polyacrylamide is an effective pressure reducing agent as observed from the present trickle bed experiment. The bed pressure drop is found to increase with both the liquid and the gas velocities and decreases with the concentration of polyacrylamide. The percentage pressure reduction is found to increase with an increase in the concentration of polyacrylamideup to a maximum pressure reduction at a concentration of 8 ppm. Above this concentration an increase in pressure drop observed and a maximum of 60% pressure reduction is achieved with polyacrylamide of concentration, 8 ppm.

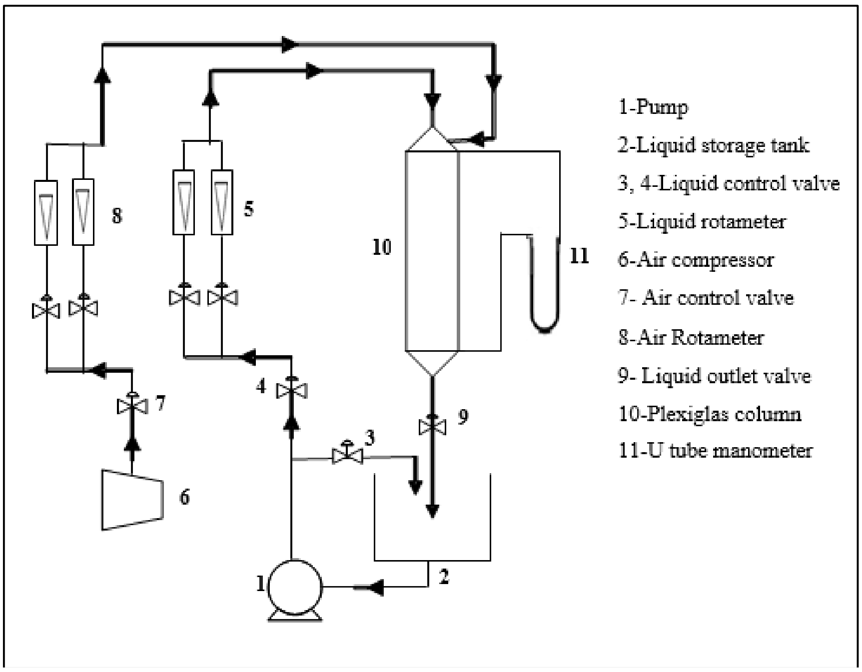

Fig 1: Schematic representation of the experimental setup

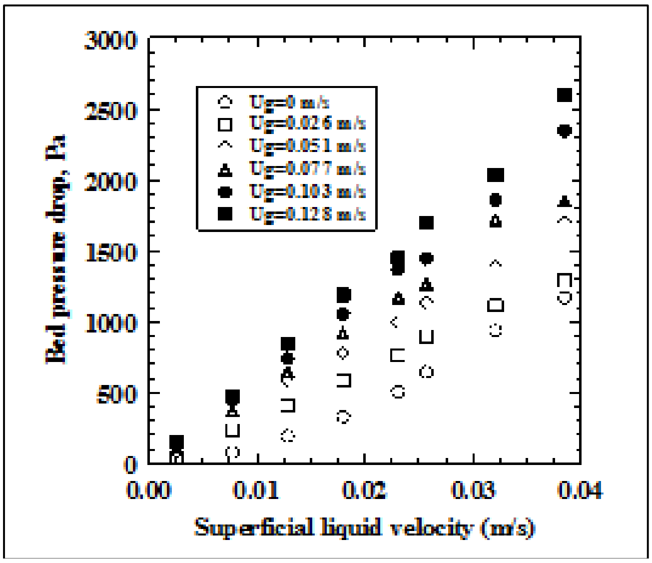

Fig 2: Variation of bed pressure drop with superficial liquid velocity for different values of superficial gas velocity (air-water)

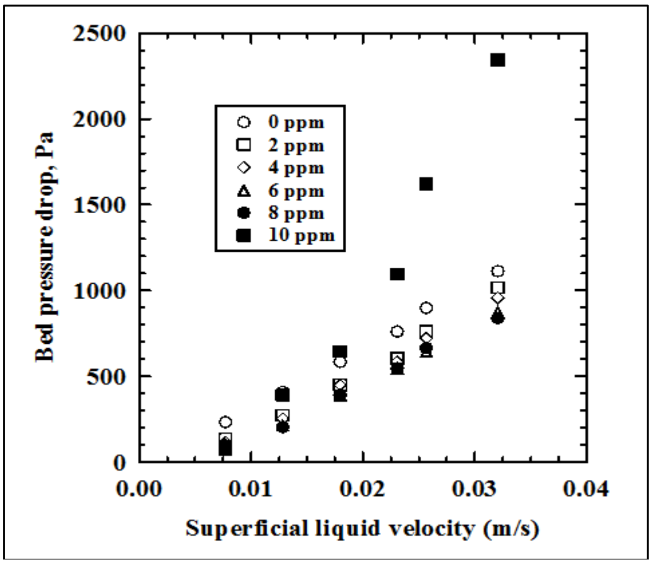

Fig 3: Variation of bed pressure drop with superficial liquid velocity for different concentration of polyacrylamide at constant gas velocity of 0.026 m/s

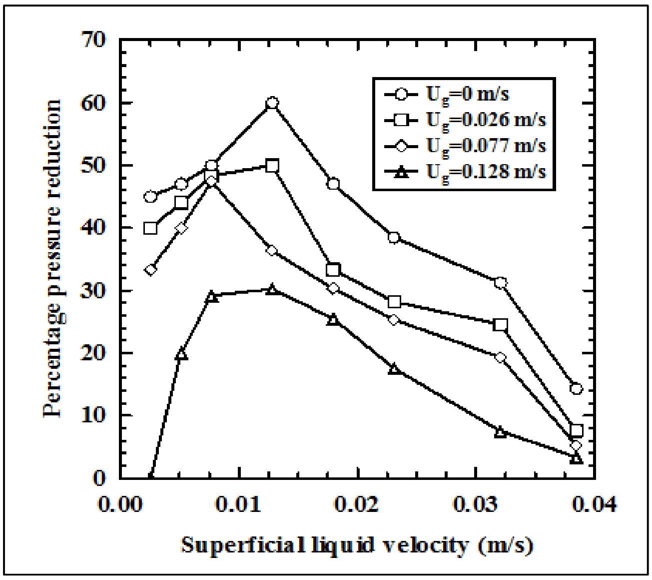

Fig 4: Variation of percentage pressure reduction with superficial liquid velocity for different values of superficial gas velocity (air-8 ppm polyacrylamide solution)

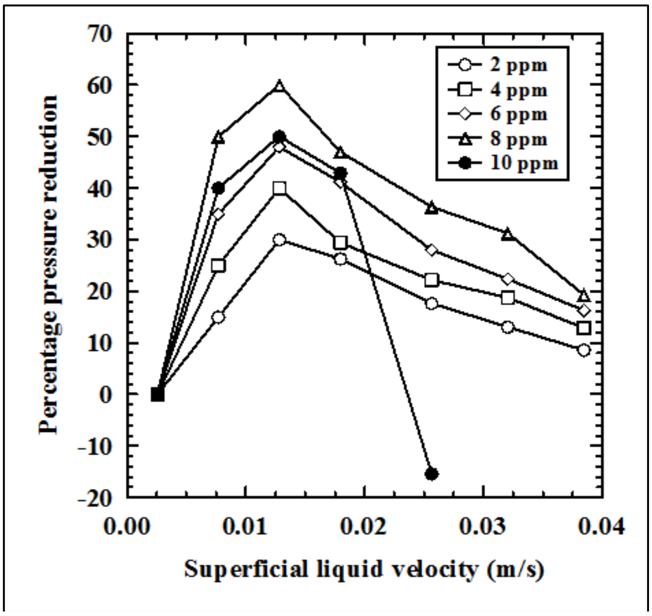

Fig 5: Variation of percentage pressure reduction with superficial liquid velocity for 9.86 mm raschig ring particles in aqueous solutions of polyacrylamide of varying concentration at superficial gas velocity=0 m/s

5. References

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