**Pressure drop and Pressure reduction in trickle bed using polyethylene oxide**

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**Abstract**

Pressure drop is a significant parameter in the design and energy requirements of the trickle bed system. Pressure reduction is the best significant procedures for reducing energy utilization in a trickle bed. The present work involves an experimental investigation on pressure drop and its reduction using polyethylene oxide as pressure reducing agent. Pressure reduction was quantified from the bed pressure drop data. Based on the present observations, it was found that the percentage pressure reduction increases with an increase in the concentration of pressure reducing agent and it is only effective in the range of 10 ppm to 40 ppm. A maximum 77% pressure reduction is accomplished utilizing polyethylene oxide (30 ppm) as pressure reducing agent.

**Key words**: Trickle bed, Pressure drop, Pressure reduction, polyethylene oxide

1. **Introduction**

The three phase trickle-bed system is packed bed in which, the liquid and gas phase flow downward and on both directions upward as well as downward, respectively. These types of reactors have significant applications in water treatment process which were primarily used in 19th century. The prominent chemical industries such as petrochemical, refinery and effluent treatment plants have tremendous use of trickle bed reactor. The refinery, chemical and biochemical industries were limited to use only for applications of hydrotreating, hydrodesulfurization, hydrogenation, and oxidation and hydrodenitrogenation process until the unveiling of trickle bed systems (Eftaxias et al., 2003; Ferdous et al., 2005; Liu et al., 2006; Gaur et al., 2007; Sigurdson et al., 2011; Tan et al., 2012).

Bed pressure drop in trickle bed structure is the effective parameter from designing point of view as it deals with the energy needed to move the liquids by means of the bed. It is ordinarily utilized as a relating parameter for calculating other required parameters, for example, gas-liquid mass transfer coefficient, liquid-solid mass transfer coefficient, wetting proficiency and heat transfer coefficient. The energy is basic alongside the gas-liquid flow resistance in porous media. The resistance to flow in trickle system is generally a result of shear and capillary forces. Bed pressure drop along the length of the column is a component of segment equipment, for example, particle size and shape and operating parameters, operating boundaries like gas-liquid flow rates and liquid properties, for example, viscosity and density of flowing liquid surface tension and surface attributes. Operating pressure and temperature optionally move the pressure drop through liquid properties (Bansal et al., 2008; Lali, 2017; Omar, 2018; Omar et al. 2019).

. Pressure reduction is the best significant procedures for reducing energy utilization in a trickle bed. The bed pressure drop is extra because of high liquid surface tension and high liquid-solid collaboration. Additionally bed pressure enhances because of blocking of void space by a more liquid holdup that prompts high gas–liquid interfacial contact. The bed pressure drop in trickle bed system can be decreased by moving of working temperature, improving porosity of bed by prevailing packing or by utilizing pressure reducing agents such as surfactant and polymer. Pressure reduction focuses on trickle bed are really valuable to reduce the mechanical energy loss, which reduces the cost related with transport of liquids such as pumping, thus reduces the general working expenses.

Giri and Majumder, 2014 studied the flow system map in trickle bed system with air-Newtonian and air-non-Newtonian liquid systems, the impact of dynamic factors with Newtonian and non-Newtonian liquid systems on bed pressure drop, and analysed the behaviour of bed pressure drop by proposing the suitable model for understanding the level of pressure reduction in a trickle bed system.

Patel and Majumder, 2011 concluded an exploratory analysis of pressure reduction in a packed bed system. They considered the pressure reduction in particle Reynolds number in the scope of 10-250 and found to be dependent on the concentration of PRA and liquid velocity. The highest pressure reduction was observed 38% for single stage non-Newtonian liquid.

Based on earlier research work, the hydrodynamics of Newtonian liquids is studied for trickle bed system in large scale during current years; however researchers have not so much attempted the performance of trickle bed system with non-Newtonian liquids. So that, there is good scope from industrial point of view to study the hydrodynamics of non-Newtonian liquid and pressure reduction in trickle bed system. Pressure reduction is valuable for designing the reactor which ultimately results as high effectiveness and low cost.

In light of the literature survey, it was discovered that very minute information is available in research papers (Giri and Majumder, 2014) which is motivated on the impact of polyethylene oxide as pressing reducing agent in co-current air-water downstream through a trickle bed structure. The polymers help in the system with pressure reduction by diminishing turbulence in the oil lines. This grants for oil to be pumped at lower pressures. The present work depicts the impact of polymer (polyethylene oxide), pointed toward finding the most minimal concentration of polymer which creates the highest pressure reduction.

1. **Experimental**

Experiments were carried out on a 10 cm diameter cylindrical Plexiglas column, packed with glass beads of 4mm with a height of 128 cm. Schematic representation of the experimental setup is shows in Figure 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. Initially, 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 rate was kept constant and the liquid flow rate was gradually increased in steps.

For the measurement of pressure drop in the bed, the pressure ports have been provided at the top and bottom of the column and fitted to the manometer filled with mercury as the manometric fluid. Water and various polyethylene oxide solutions in water (10 ppm, 20 ppm, 30 ppm and 40 ppm) are utilized as the liquid stage. Polyethylene oxide is utilized as a pressure reducing agent at various concentrations under this study.

In multiphase flow, percent pressure drop reduction (% PDR) is defined as the ratio of reduction in the frictional pressure drop when the flow rates are held constant to the frictional pressure drop without pressure reducing agent (PRA), multiplied by 100.

 The percentage pressure drop reduction (% PDR) can be calculated from the following formula (Mowla and Naderi, 2006).

$\%PDR=\left(\frac{∆P\_{without PRA }-∆P\_{with PRA  }}{∆P\_{without PRA  }}\right)\*100$ (1)

**1**

**4**

**5**

**6**

**8**

**2**

**3**

**9**

**10**

**7**

**11**

1-Pump, 2-Liquid storage tank, 3,4-Liquid control valve, 5-Liquid rotameter, 6-Air compressor 7- Air control valve, 8-Air Rotameter, 9- Liquid outlet valve, 10-Plexiglas column, 11-U tube manometer

**Figure 1** Schematic representation of the experimental setup

1. **Results and discussion**

The velocities for gas and liquid are operated during the experiment in the range of 0-0.128 m/s and 0.003-0.038 m/s, respectively. There is minimum requirement of ten minutes time to achieve the steady state condition for noting the bed pressure drop readings. The results are presented as graphically from conducting the experiments.

For air-water system, the bed pressure drop variation with liquid velocity at different constant gas velocities is shown in Figure 2. It is observed that the enhancement of bed pressure drop occurs with increasing both gas and liquid velocities which is due to increase in interfacial shear stress. Dynamic liquid saturation of the column increases with increasing the liquid velocity in which gas velocity creates less void space. This prompts more liquid-gas interfacial shear stress and expansion in bed pressure drop.

For air-10 ppm polyethylene oxide solution, the bed pressure drop variation with liquid velocity considering different gas velocities is shown in Figure 3. It is clear from the figure that enhancement of bed pressure drop occurs with increasing both gas and liquid velocities which have similar trend as for the air-water system.

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| **Figure 2** For, air-water system, the bed pressure drop variation with liquid velocity considering different gas velocities | **Figure 3** For air-10 ppm polyethylene oxide solution, the bed pressure drop variation with liquid velocity considering different gas velocities |

Figure 4 shows the bed pressure drop variation with liquid speed for various concentration of polyethylene oxide solution at stable gas speed. It is observed that as the concentration of polyethylene oxide solution increases, initially the bed pressure drop decreases till the minimal point at certain optimum concentration, then gradually increases with further enhancement in the concentrations of polyethylene oxide solution. This is due to the addition of polymer solutions in the liquid which in turn reduces the surface tension.

Figure 5 shows the variation of percentage pressure reduction with liquid speed at various concentrations of polyethylene oxide solution. It is clear from figure that the enhancement of percentage pressure reduction occurs with increasing the concentration of pressure reducing agent. Polyethylene oxide as pressure reducing agent is efficacious for the trickle bed structure in the concentration range of 10 ppm to 40 ppm. In the present work, 77% pressure reduction is accomplished utilizing polyethylene oxide (30 ppm) as pressure reducing agent; higher concentration of polyethylene oxide brings about reverse effect in the system which is not desirable.

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| **Figure 4** The bed pressure drop variation with liquid velocity considering different concentrations of polyethylene oxide solution at gas velocity of 0 m/s | **Figure 5** The percentage pressure reduction variation with liquid velocity for 4 mm glass beads particles in aqueous solutions of polyethylene oxide of varying concentration at gas velocity of 0 m/s |

**4. Conclusion**

In this study, the bed pressure drop enhances with increasing both gas and liquid velocities. As the concentration increases, initially there is reduction in the bed pressure drop and it reaches the minimum point at certain optimum condition; thereafter as the concentration increases further, the value of bed pressure drop gradually increases. The enhancement of percentage pressure reduction occurs with increasing the concentration of pressure reducing agent. Polyethylene oxide as pressure reducing agent is valuable for the trickle bed system in the concentration range of 10 ppm to 40 ppm. A maximum 77% pressure reduction is accomplished utilizing polyethylene oxide (30 ppm) as pressure reducing agent.

**References**

Bansal, A., Wanchoo, R. K., Sharma, S. K., 2008. Two-phase pressure drop in a trickle bed reactor involving newtonian/non-newtonian liquid phase. Chem. Eng. Comm. 195, 1085-1106.

Eftaxias, A., Larachi, F., Stuber, F., 2003.Modelling of trickle bed reactor for the catalytic wet air oxidation of phenol. Can. J. Chem. Eng. 81, 784-794.

Ferdous, D., Dalai, A. K., Adjaye, J., 2005.Hydrodenitrogenation and hydrodesulphurization of heavy gas oil using NiMo/Al2O3 catalyst containing phosphorus: experimental and kinetic studies. Can. J. Chem. Eng. 83, 855-864.

Gaur, V., Sharma, A., Verma, N., 2007. Removal of SO2 by activated carbon fibre impregnated with transition metals. Can. J. Chem. Eng. 85, 188-198.

Giri, A. K., Majumder, S. K., 2014. Pressure drop and its reduction of gas–non Newtonian liquid flow in down flow trickle bed reactor (DTBR).Chem. Eng. Res. Des. 92, 34-42.

Lali, F., 2017. A hydrodynamic study of cylindrical metal foam packings: Residence time distribution and two phase pressure drop. Chem. Eng. Processing: Process Intensification, 115, 1–10.

Liu, G., Mi, Z., Wang, L., Zhang, X., Zhang, S., 2006. Hydrogenation of dicyclopentadiene into endo-tetrahydrodicyclopentadiene in trickle-bed reactor: experiments and modelling. Ind. Eng. Chem. Res. 45, 8807-8814.

Mowla, D.; Naderi, A. (2006). Experimental study of pressure reduction by a polymeric additive in slug two-phase flow of crude oil and air in horizontal pipes. Chem. Eng. Sci. 61, 1549-1554.

Omar, R., 2018. Hydrodynamics of Hollow Cylindrical Particle in a Trickle Bed for Non-Newtonian Liquid and Foaming Liquid. Int. J. Eng. Res. Adv. Develop. 4, 11-23.

Omar, R., Mishra, D., Nigam, R.S., 2019. Experimental and CFD Simulation Study of a Trickle Bed with Foaming Liquid at Different Concentrations. Int. J. Eng. Res. Tech. 8, 501-505.

Patel, S.K., Majumder, S.K., 2011. Reduction of pressure in non-Newtonian flow through packed bed. J. Eng. Appl. Sci. 6,147–151.

Sigurdson, S., Dalai, A. K., Adjaye, J., 2011. Hydrotreating of light gas oil using carbon nanotube supported NiMoS catalysts: kinetic modelling. Can. J. Chem. Eng. 89, 562 -575.

Tan, J., Zhang, J. S., Lu, Y. C., Xu, J. H., Luo, G. S., 2012. Process intensification of catalytic hydrogenation of ethylanthraquinone with gas-liquid microdispersion.AIChE J. 58, 1326-1335.