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Minimum Fluidization Velocity studies by using Pressure Drop in Inverse Fluidization

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Abstract *Hydrodynamic characteristics of two phase fluidized bed reactor termed as liquid-solid inverse fluidized bed reactor in which low density particles are fluidized with downward flow of liquid are studied in the present investigation. Experiments were conducted using 2-4.26 mm diameter spherical particles of high density polyethylene (HDPE), low density polyethylene (LDPE) and polypropylene (PP) with water. It was found that the Minimum fluidization (U_{mf}), Depends upon the Pressure drop(**Δp**).*

1. Introduction

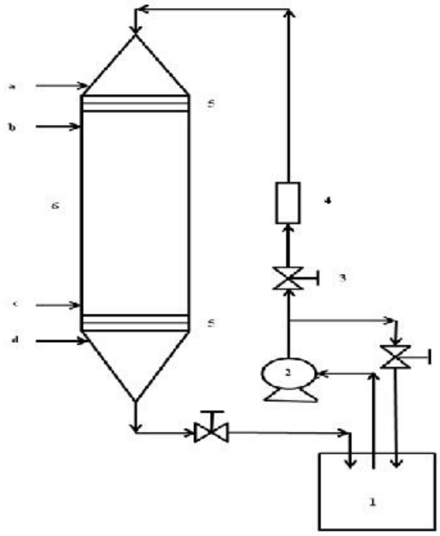
When the density of the particles is smaller than that of the liquid, fluidization can be achieved with downward flow of the liquid counter to the net upward buoyancy force on the particles. In this type of process the gas flow is upward, counter to the liquid flow. This type of fluidization is termed inverse fluidization. Inverse Fluidized Beds can be operated as two-(liquid-solid)or three- (gas-liquid-solid) phase systems. Under the fluidized state, gravitational pull force on solid particles is offset by the fluid drag force. In fluidized condition particles remain in a semi-suspended condition. Liquid fluidization technologies have received large attention because of the development of newer application fields, mainly biochemical processing and waste-water treatment. Liquid–solid fluidization generally operates with an upward flow of liquid using particles of higher density than the liquid. Inverse fluidization is a phenomenon where the particles, which have a density lower than that of the liquid, are fluidized by a down-flow of the liquid. The inverse fluidization system has gained significant importance during the last decade in the field of environmental, biochemical engineering, and oil–water separation. The inverse fuidizedbed reactor (IFBR) is a very efficient system for the biological treatment of waste water system when compared to an up flow fluidized bed reactor because in an inverse fluidized bed reactor, the control of biofilm thickness is achieved within a very narrow range. The inverse fluidized bed reactor was also used in ferrous iron oxidation by Thiobacillus ferrooxidans and for the hydrolysis of milk protein as the solids can be fluidized at low liquid velocity, the energy expenditure is low and also the solids attrition is minimum.The other advantages are the high mass transfer rates, minimum carryover of coated microorganisms due to less solids attrition than normal fluidization and ease of re-fluidization in case of power failure. Mass transfer studies in liquid-solid inverse fluidized bed reactor have been reported by Nikov and Karamanev, 1991. They found that the mass transfer rate is independent of superficial velocity and particle and strongly depends on the density of the particles.Ulaganathan and Krishnaiah(1996).They presented empirical equations to predict the pressure drop in different regimes of fluidization[9]. From the available literature it is observed that only limited studies were reported in two phase inverse fluidized bed reactor with reference to bed expansion and pressure drop studies. It is also found that very little information is available where the fluid phase is non-Newtonian. The objective of the present investigation is to study the bed expansion characteristics and pressure drop across the column using particles having density closer to that of liquid phase using water and different concentrations of non-Newtonian fluids (glycerin) as a liquid phase.

2 .Experimental set-up and methods

2.1

Experimental set-up

The schematic diagram of the experimental set-up is shown in Fig. 1. The column was made of



1.(liquid)Storage tank,2.centrifugal pump,3.control valves,4.liquid rotameter,5.liquid distributor,6. Perspex transparent glass column

Fig 1: Schematic diagram of experimental setup

Perspex and the system consists of the column is transparent and made up of glass material with a diameter of 50 mm and the height of the column is 70cm, with an inlet at the top and an outlet at the bottom. The flow of the fluid (water) through this opening was controlled by use of valves. Water and glycerin pumped through a pipe which connected with a U tube manometer which is filled with mercury by 0.5HP motor pump to the top of the column. The pressure tapings were mounted on the top of the column and bottom of the column and were connected to U tube manometers which are filled with carbon tetra chloride as a manometer liquid. Fine stainless steel mesh was used at both openings of the column to stop the escape of particles with liquid and its acts as a distributor. A motor driven reciprocating Pump is used to pump the water at the top of column. A known quantity of one of above mentioned solid particles are loaded into the glass column. The pump was started and the column was filled with liquid. Prior to each experimental run the particles were fully fluidized, subsequently the flow rate of liquid was gradually reduced until the solids are rise up slowly to form a packed bed i.e initial bed height. Then the flow rate was gradually increased and variations of bed height and pressure drop were observed. This procedure was repeated for various liquid flow rates. The flow rate was controlled by adjusting the control valves at the bottom of the column and the by-pass line.

2.2Materials and methods

Pressure drop was measured using a U-tube manometer and observed visually using a scale attached on the manometers which are connected to pressure tapings on the fluidized bed. Prior to each experimental run the solid particles was fully fluidized, subsequently the flow rate of liquid was gradually reduced until the solids rise up slowly to form a fixed bed i.e initial bed height. This procedure is essential for obtaining reproducible results. The loading of particles for each experimental run determined by the height of the initial bed height obtained by repeating the procedure, the pressure of the different bed heights was varied.

$$\Delta p = pgh \quad (1)$$

Where Δp=Pressure drop

g=gravitational force

h=Height of the difference between the manometer

p=Density of the CCL_4 there in the manometers

The minimum fluidization velocity of the fluidized bed particles at different flow conditions was determined using the following equations:

From the Wen&Yu(1966) proposed correlation the minimum fluidization velocity Eqn(2)as

$$U_{mf} = \frac{(\mu)}{(\rho_s \times d_p)}\left(\sqrt{(33.7)^2 - (0.0408 \times Ar)} - 33.7\right) (2)$$

The minimum fluidization velocity, U_{mf} is an important parameter in determining the operating range of a reactor. It is estimated from the correlation obtained from the experimental data relating to the minimum fluidization velocity, U_{mf}, Archimedes number, Ar and density difference.

$$U_{mf} = a[Ar]^b \left[\frac{(\rho_l - \rho_s)}{\rho_l}\right]^c (3)$$

From experimental data

$$a = 8.464 \times 10^{-3}$$

$$b = 0.459, \quad c = 0.301$$

$$U_{mf} = 8.464 \times 10^{-3} [Ar]^{0.459} \left[\frac{(\rho_l - \rho_s)}{\rho_l}\right]^{0.301} (4)$$

$$Ar = d_p^3\, p(p_l - p)\frac{gl}{\mu^2}$$ Where Ar is the Archimedes' number

$$10^4 < Ar < 8 \times 10^4$$

3 Results and discussion

3.1 Pressure drop studies

The determination of pressure drop in fluidized bed is a very important parameter for the efficient and economical operation of the reactor, since it facilitates us to determine friction factor i.e. energy loss and conditions of stable flow regimes and minimum fluidization velocity of inverse fluidized bed reactor for the given operation. The variation of pressure drop with liquid flow rate for different initial bed height for different systems water- 0.28 mm,0.33mmand 0.42mm diameter of particles (HDPE,PPand LDPE) are shown in Figs 1-9. As in classical fluidization the pressure drop increases with increase in liquid flow rate till the condition of onset of fluidization is reached which represents packed bed. On further increase the pressure drop remains almost constant as the resistance for the liquid decreases significantly. It is observed from the (1-9)Figs that pressure drop increases with increase in particle diameter,decrease in particle density and the minimum fluidization velocity independent on th intial bed heights. The calculated values of U_{mf} using pressure drop data is also presented in **Table 1.**

Table1. Values of minimum fluidization velocity

System	Particle diameter Dp(cm)	U_{mf} (cm/sec) From wen&yu equation(3)	U_{mf} (cm/sec) From Correlated equation(4)	U_{mf} (cm/sec) from pressure drop graph
Water-LDPE	0.28	0.63	0.66	0.7
	0.33	0.66	0.69	0.8
	0.42	0.7	0.78	0.9
Water-HDPE	0.28	0.32	0.34	0.5
	0.33	0.36	0.39	0.58
	0.42	0.47	0.5	0.8
Water-PP	0.28	0.48	0.5	0.58
	0.33	0.5	0.56	0.95
	0.42	0.62	0.65	1.2

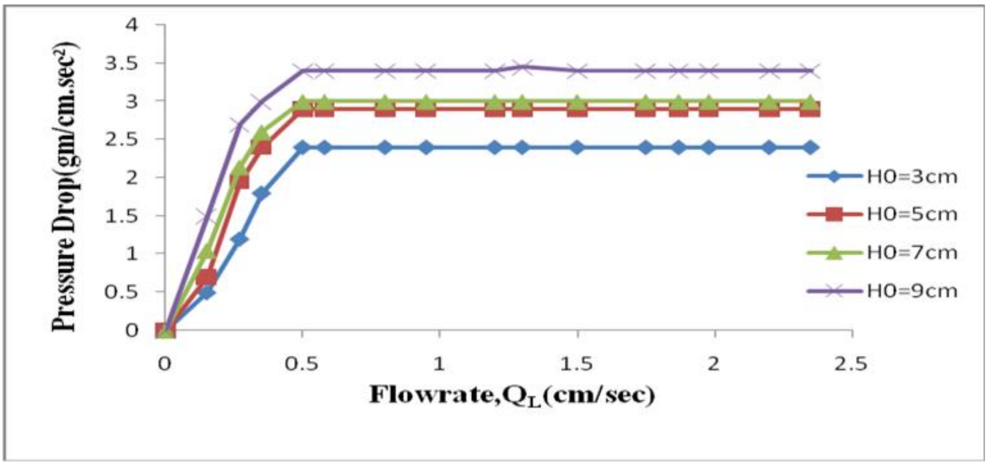


Fig. 1. Variation of Pressure drop with liquid flow rate for the system Water—0.28 cm HDPE

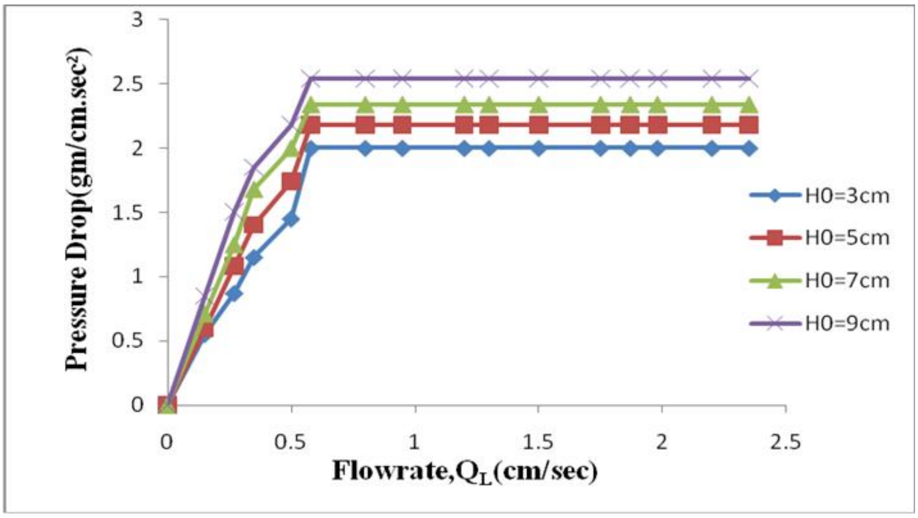


Fig. 2. Variation of Pressure drop with liquid flow rate for the system Water—0.33 cm HDPE

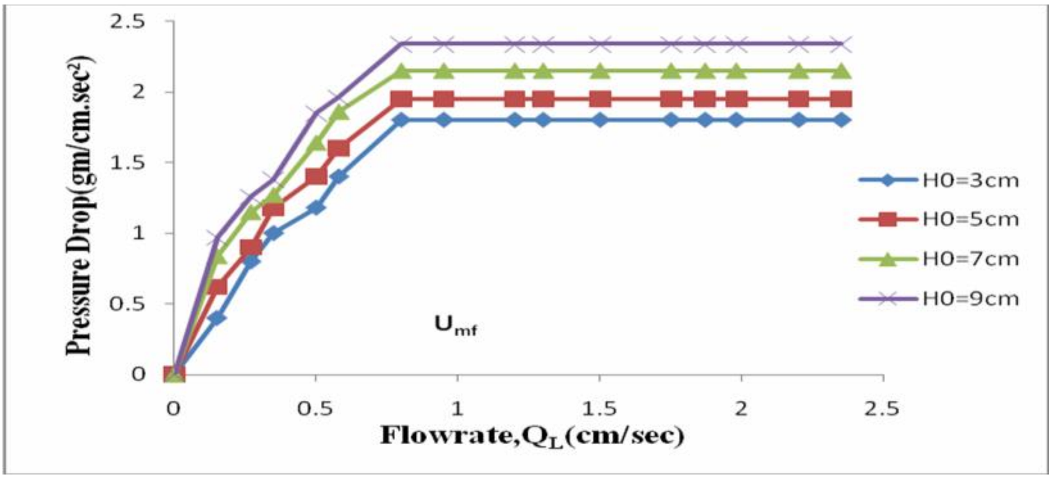


Fig. 3. Variation of Pressure drop with liquid flow rate for the system Water—0.42cm HDPE

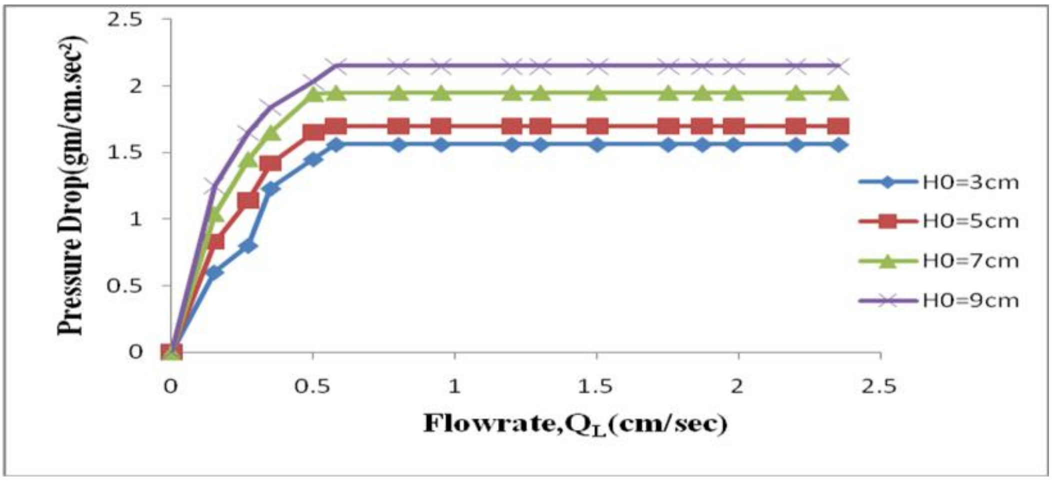


Fig. 4. Variation of Pressure drop with liquid flow rate for the system Water—0.28cm PP

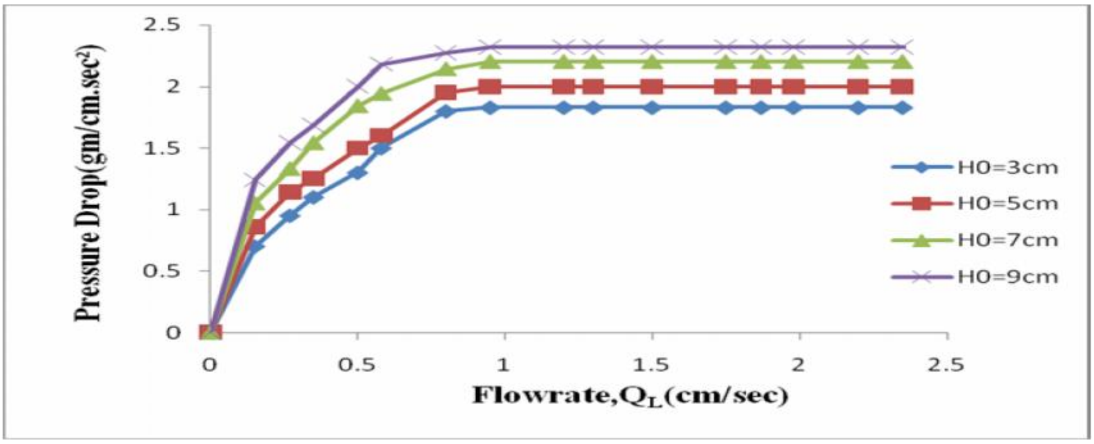


Fig. 5. Variation of Pressure drop with liquid flow rate for the system Water—0.33cm PP

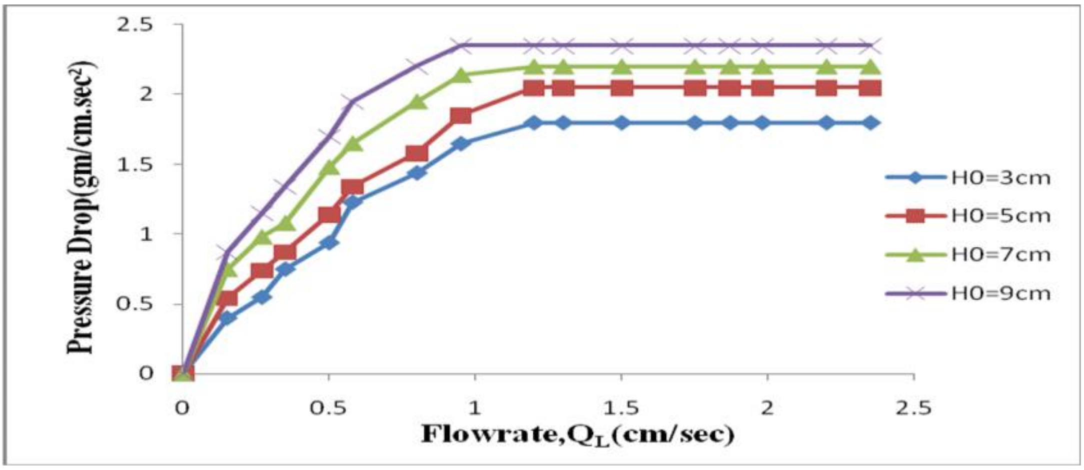


Fig. 6. Variation of Pressure drop with liquid flow rate for the system Water—0.42cm PP

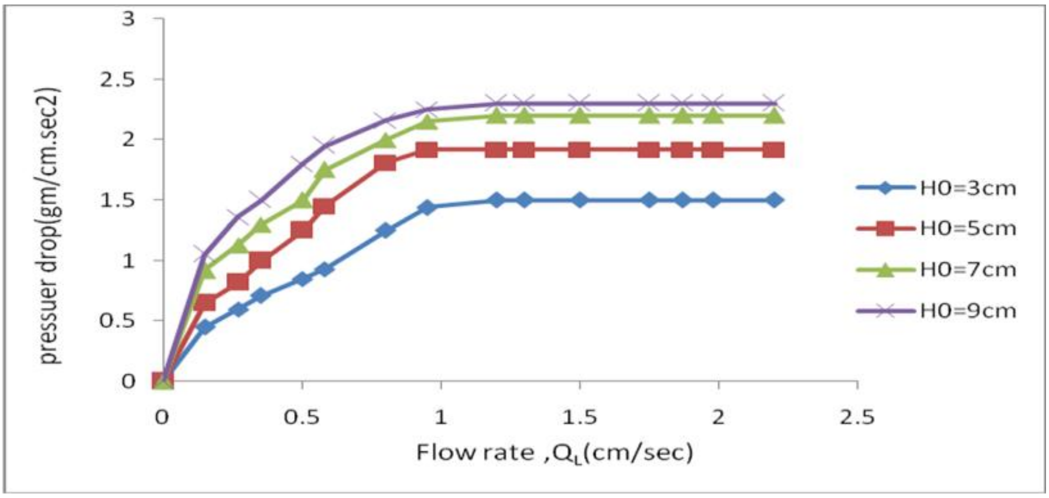


Fig 7. Variation of Pressure drop with liquid flow rate for the system Water—0.28cm LDPE

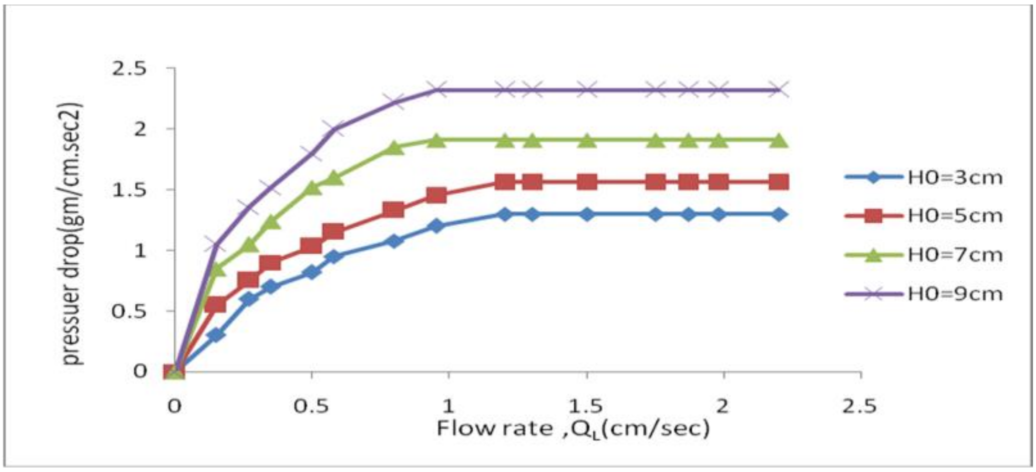


Fig 8. Variation of Pressure drop with liquid flow rate for the system Water—0.33cm LDPE

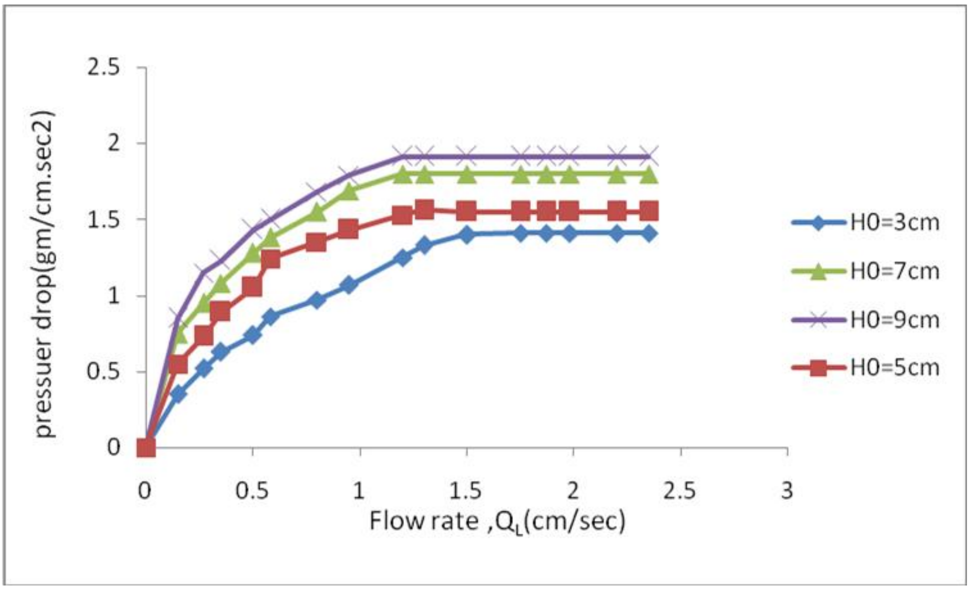


Fig 9 Variation of Pressure drop with liquid flow rate for the system Water—0.42cm LDPE

4. Conclusions

The minimum fluidization velocity characteristic of inverse fluidization is similar to that of classical fluidization.Minimum fluidization velocity is found to decrease with increase in particle density and increase in Particle diameter. The pressure drop increased with increase liquid flow rate up to minimum fluidization velocity was reached and the minimum fluidization velocity independent of the initial bed height

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