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Experimental Investigations on Variation in Static Bed Height and Particle Size on Pressure Drop and Bed Expansion Ratio in Three Phase Fluidized Bed

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Abstract: ***Fluidized beds have got a great application in the industries. Fluidization depends on the effective contact between the phases. So it is very important to understand aspects like type of distributor, particle shape and size, type of fluid etc. for the proper functioning of the fluidized beds. In the present work, hydrodynamics of the fluidized bed with irregular particles was studied. The hydrodynamic behaviour like pressure drop, minimum fluidization velocity and bed expansion ratio of a co-current three-phase fluidized bed have been studied. Experiment was carried out using raschig rings as solid particles, water as liquid and compressed air as gas .Variation of pressure drop and bed expansion ratio with liquid velocity at constant gas velocity and minimum liquid fluidization velocities with gas velocity were investigated. It has been observed that the minimum liquid fluidization velocity, pressure drop decreases with the increase in superficial gas velocity but increases with particle size. Bed expansion ratio increases with increase in the values of both liquid and gas velocities but decreases with diameter of particles and initial static bed height. The results obtained have been compared with other correlations and have been found to agree well.***

Keywords: Fluidization, Hydrodynamics, Raschig Rings, Pressure drop, Minimum Fluidization, Bed Expansion Ratio

1. Introduction

The process in which a bed of solid particles is converted from static solid-like state to dynamic fluid-like state when a fluid (liquid or gas or both) is passed up through the solid particles is termed as fluidization. If a fluid is passed through a bed of fine particles at a low flow rate, the fluid just percolates through the void spaces between the stationary solid particles. This condition is called the fixed bed. With increased flow rate, particles move away from each other and a few vibrate and move in restricted regions. This condition is called the expanded bed. At a still higher velocity, a point is reached where all the particles are just suspended by the upward flowing fluid. At this point, the frictional force between solids and fluid just counterbalances the weight of the particles, the vertical component of the compressive force between adjacent particles disappears, and the pressure drop through any section of the bed about equals the weight of fluid and particles in that section. The bed is considered to be just fluidized and is referred to as minimum or incipient fluidization (Chidambaram, 2011). At this stage, the bed is said to be fluidized and will exhibit fluidic behaviour. Under fluidized state, a bed of solid particles will behave as a fluid, like a liquid or gas.

Due to its at most importance, hydrodynamic properties of three-phase fluidized beds are important for analyzing its performance. Hydrodynamic behaviour of the bed such as bed pressure drop, minimum fluidization velocity, phase holdup, bubble properties, mixing characteristics and bed expansion have to be investigated to provide the basic information required for the design of such fluidized bed (Fan,1989; Lee et al.,2001).

2. Experimental Studies

2.1 Experimental setup

The experimental setup assembled in three parts Test column assembly, liquid flow system and air flow system .

The test column comprises the following components. The copper material is used for construction except test section. Test section is made of Perspex material. Entering section is 40cms long and provided with two inlet fluid openings. One for liquid flow and another for air flow. Liquid enters at height of 10cms from the bottom of the column and air enters at height of 5cms from the bottom.

Calming section is 30cm long and filled with 1cm diameter marbles. This arrangement provides for uniform distribution of liquid and air flows. The tube has an inlet diameter of 2.54cms and outlet diameter of 5.08cms. Liquid and gas, both enters the calming section and flow through a strenuous path and enters into test section.

Test section is 70cms long. This is the main soul of the experiment and made up with Perspex material. The tube has an inner diameter of 5.08cms and 3mm thick. Pressure taps are providing at the top and bottom of the column. These taps helps to measure the differential pressure by a manometer where Carbon tetrachloride is used as manometer fluid. For every flow rate of liquid and air, we note the manometer reading and calculate the pressure drops.

Fluid dis-engaging section is above the test section and made up with copper material. At the end of the column 1-inch pipe is connected and handle the outgoing fluids into a circulation tank.

2.2 Experimental Procedure

The three-phase system Solid- Liquid - Gas is irregular size raschig ring particles, tap water and oil free Compressed air respectively. The air-water flow was Co-Current and upwards. Accurately weighed amount of material was fed into the column and adjusted for a specified initial static bed height. Two calibrated rotameters with different ranges one for water as well as one for air have been used for the accurately record of the flow rates.

The experiment was carried out using Raschig rings as solid particles, water as liquid and compressed air as gas. Initially the column is filled with water keeping constant gas flow rate, variation of pressure drop and bed height is taken for different liquid flow rates at steady state condition. The temperature of the water was at normal room condition. The procedure was repeated for different liquid and gas flow rates, particles of different sizes and varying initial static bed heights.

3. Results and Discussions

3.1 Effect of Pressure Drop

Figure 1- 6.shows that ,as the superficial liquid velocity increases the pressure drop also increases and become constant for further increase in the superficial liquid velocity which indicates that the liquid as reached the minimum liquid fluidization velocity for all the different gas velocities. Since, at minimum fluidization condition drag on the particles counter balance the weight of the particles. It is interesting to note that with increase in gas velocity the bed pressure drop decreases, this may be due to the increased gas holdup in the bed.

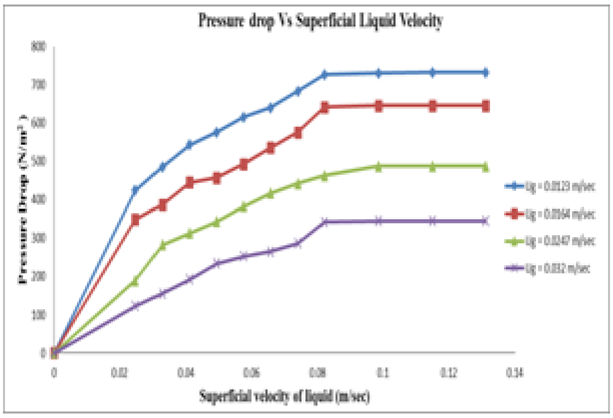

Figure 1: Variation of Pressure drop with Superficial Liquid Velocity for different Gas Velocities at Hs = 30.4cm, dp = 5.9mm.

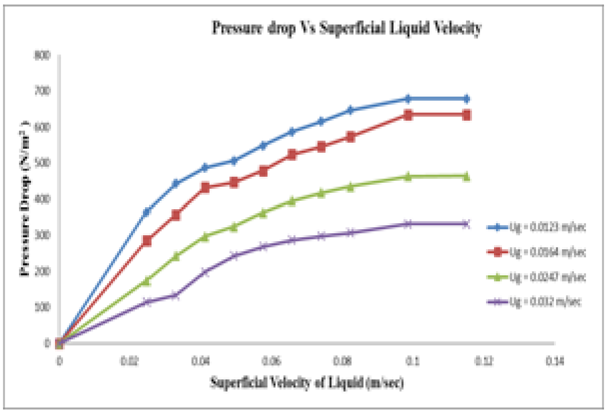

Figure 2: Variation of Pressure drop with Superficial Liquid Velocity for different Gas Velocities at Hs = 30.4cm, dp = 3.3mm

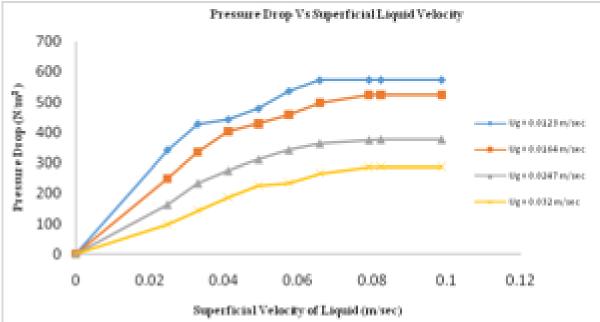

Figure 3: Variation of Pressure drop with Superficial Liquid Velocity for different Gas Velocities at Hs = 30.4cm, dp = 2.1mm

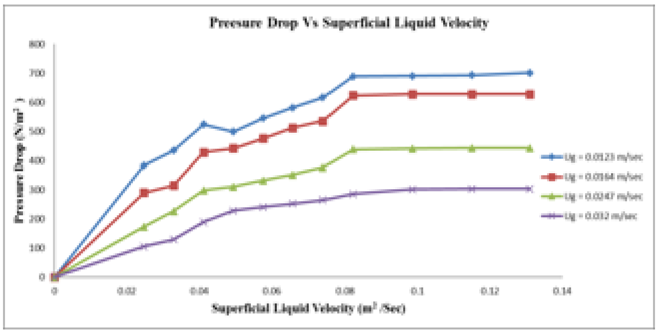

Figure 4: Variation of Pressure drop with Superficial Liquid Velocity for different Gas Velocities at Hs = 20.4cm, dp = 5.9mm

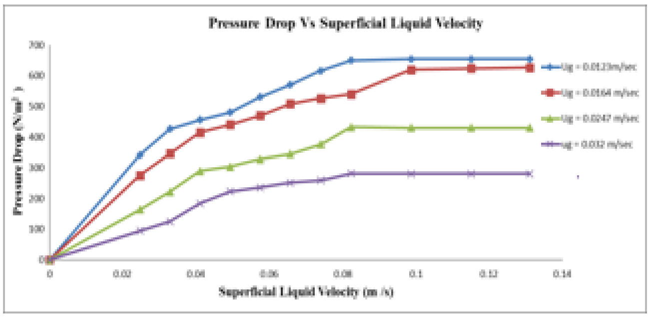

Figure 5: Variation of Pressure drop with Superficial Liquid Velocity for different Gas Velocities at Hs = 20.4 cm, dp = 3.3mm

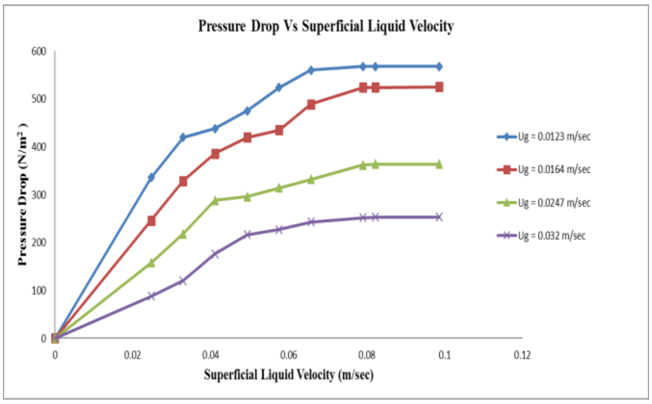

Figure 6: Variation of Pressure drop with Superficial Liquid Velocity for different Gas Velocities at Hs = 20.4cm, dp = 2.1mm

3.2 Comparison of Pressure Drop for Different Bed Heights

Figures 7, 8 and 9 shows that, as the superficial liquid velocity increases the pressure drop also increases and becomes constant as it reaches minimum liquid fluidization velocity with increase in static bed height due to increase in the bed mass for all different particle sizes.

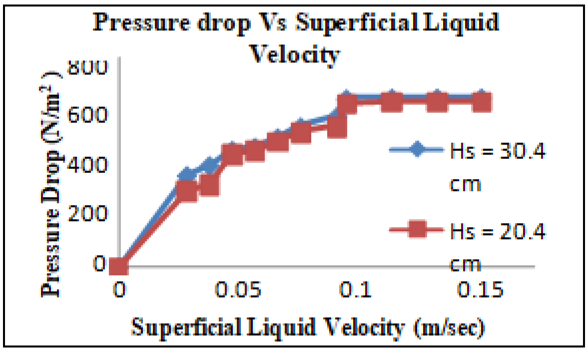

Figure 7: Variation of Pressure Drop with Superficial Liquid Velocity at different Static Bed Heights for dp = 5.9 mm and Ug = 0.0164 m/sec

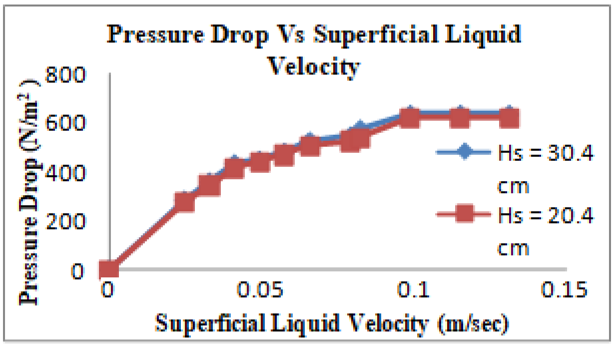

Figure 8: Variation of Pressure Drop with Superficial Liquid Velocity at different Static Bed Heights for dp = 3.3 mm and Ug = 0.0164 m/sec

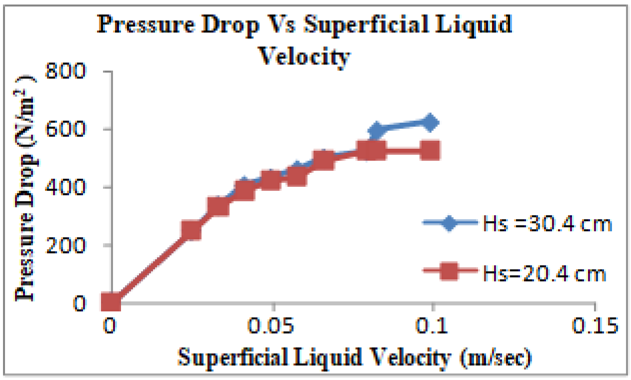

Figure 9: Variation of Pressure Drop with Superficial Liquid Velocity at different Static Bed Heights for dp = 2.1 mm and Ug = 0.0164 m/sec

3.2 Comparison of Pressure Drop for Different Particle Sizes

Figures 10 and 11 respectively. It was found that as the superficial liquid velocity increases the pressure drop also increases and becomes constant as it reaches minimum liquid fluidization velocity with increase in particle size due to increase in the drag force and the larger size particles require much pressure force for fluidization for both static bed heights.

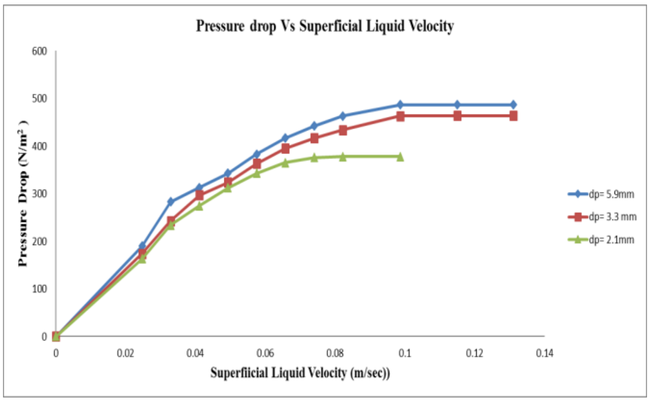

Figure 10: Variation of Pressure Drop with Superficial Liquid Velocity for different Particle Sizes at Hs = 30.4 cm and Ug = 0.0164 m/sec

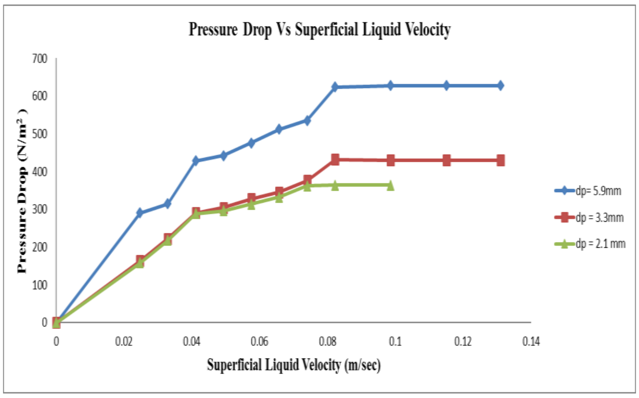

Figure 11: Variation of Pressure Drop with Superficial Liquid Velocity for different Particle Sizes at Hs = 20.4 cm and Ug = 0.0164 m/sec

3.3 Comparison of Minimum Fluidization Velocity for Different Particle Sizes

Figure 12.It was found that as the superficial gas velocity increases the minimum fluidization velocity decreases with decrease in particle size due to increase in the drag force and the larger size particles require much pressure force for fluidization.

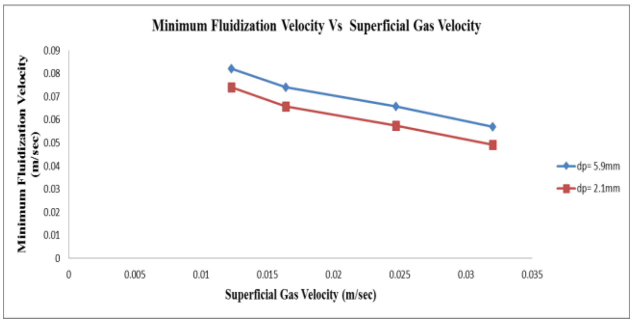

Figure 12: Comparison of Minimum Fluidization Velocity with Gas Velocity for Different Sizes

3.4 Variation of Bed Expansion Ratio with Superficial Liquid Velocity

Figure 13- 18. Shows that as the superficial liquid velocity increases the bed expansion ratio also increases for all the different gas velocities. This is due to the increased gas holdup in the column which accounts for further bed expansion. It is interesting to note that with increase in gas velocity the bed expansion ratio also increases, this may be due to the increased gas holdup in the bed and it rises above the column so there may be chances of particle loss.

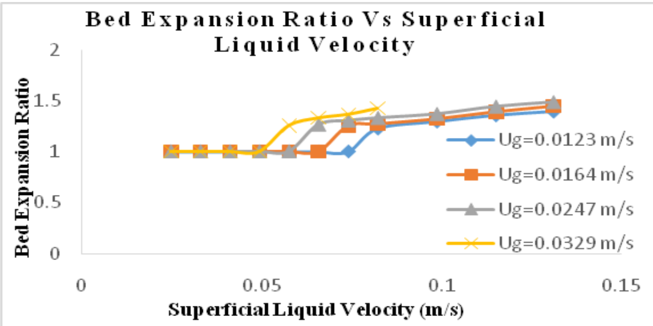

Figure 13: Variation of Bed Expansion Ratio with Superficial Liquid Velocity at different Gas Velocities at Hs = 30.4 cm and dp = 5.9 mm

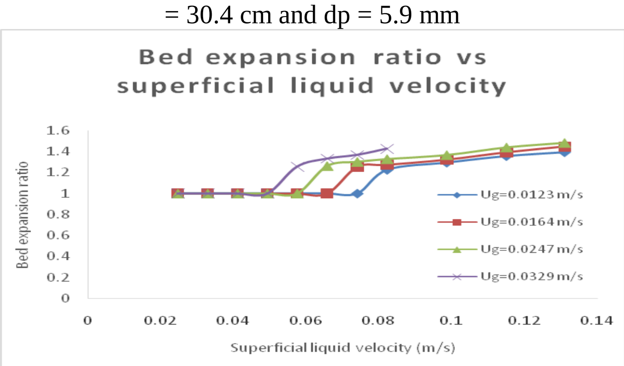

Figure 14: Variation of Bed Expansion Ratio with Superficial Liquid Velocity at different Gas Velocities at Hs = 30.4 cm and dp = 3.3 mm

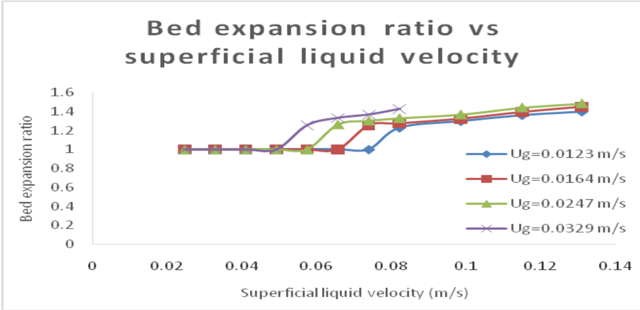

Figure 15 Variation of Bed Expansion Ratio with Superficial Liquid Velocity at different Gas Velocities at Hs = 30.4 cm and dp = 2.1 mm

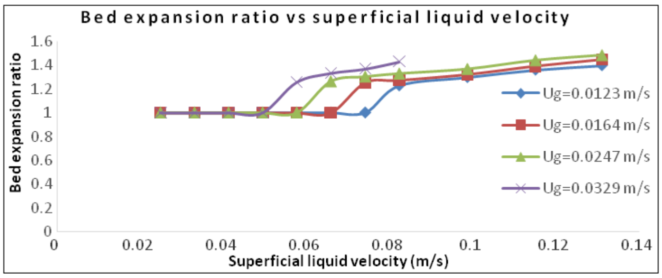

Figure 16: Variation of Bed Expansion Ratio with Superficial Liquid Velocity at different Gas Velocities at Hs = 20.4 cm and dp = 5.9 mm

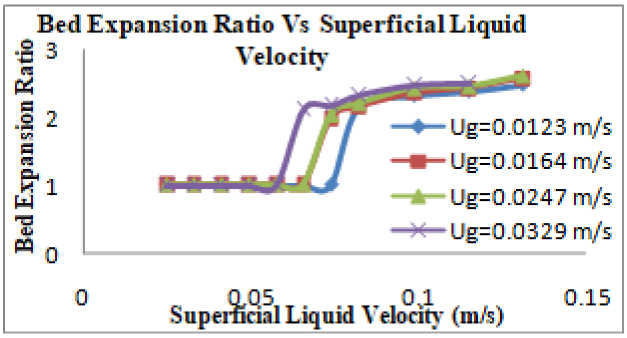

Figure 17: Variation of Bed Expansion Ratio with Superficial Liquid Velocity at different Gas Velocities at Hs = 20.4 cm and dp = 3.3 mm

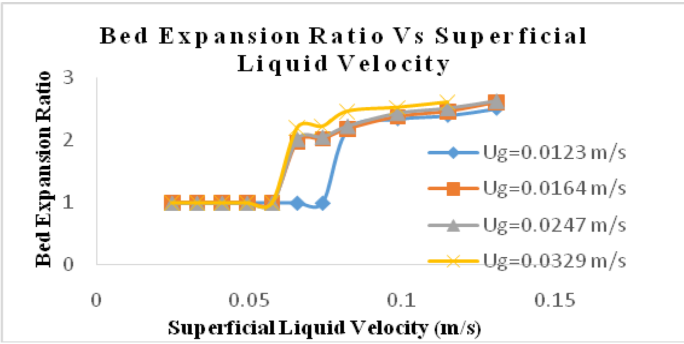

Figure 18 Variation of Bed Expansion Ratio with Superficial Liquid Velocity at different Gas Velocities at Hs = 20.4 cm and dp = 2.1 mm

3.5 Comparison of Bed Expansion Ratio for Different Bed Heights

Figures 19, 20 and 21 shows that, as the superficial liquid velocity increases the bed expansion ratio also increases with decrease in static bed height due to increase in the bed mass for all different particle sizes. It was found that the bed expansion ratio is more for static bed height of 20.4 cm than the static bed height of 30.4 cm for all superficial liquid velocities and different particle sizes.

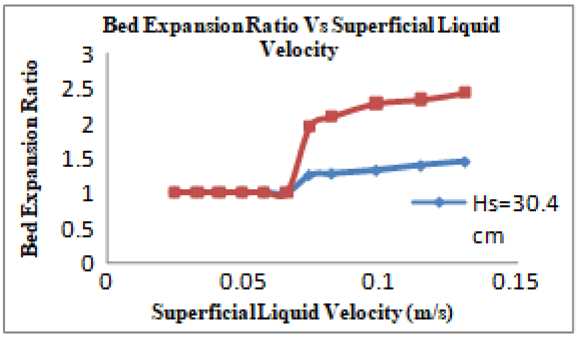

Figure 19: Variation of Bed Expansion Ratio with Liquid Velocities at $U_g = 0.0164$ m/s, dp = 5.9 mm for different bed heights

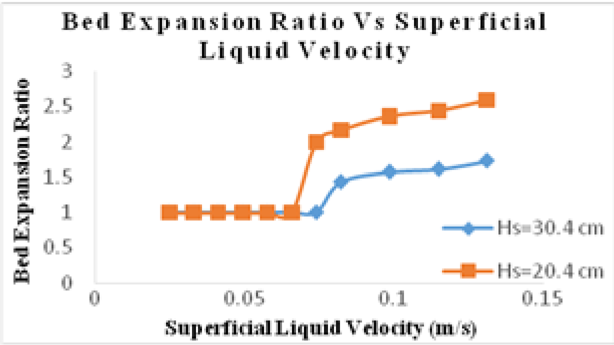

Figure 20: Variation of Bed Expansion Ratio with Liquid Velocities at $U_g = 0.0164$ m/s, dp = 3.3 mm for different bed heights

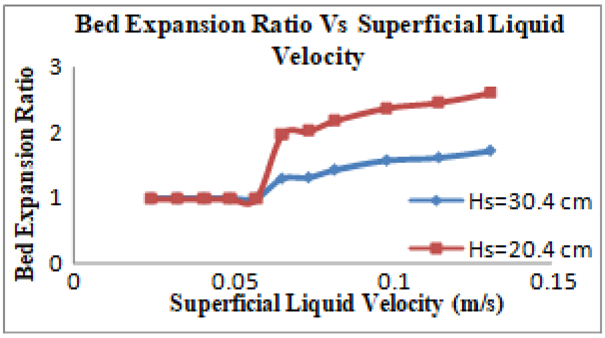

Figure 21: Variation of Bed Expansion Ratio with Liquid Velocities at $U_g = 0.0164$ m/s, dp = 2.1 mm for different bed heights

3.6 Comparison of Bed Expansion Ratio for Different Particle Sizes

Figures 22 and 23 shows that as the superficial liquid velocity increases the bed expansion ratio also increases with decrease in particle size due to increase in the drag force and the larger size particles require much pressure force for fluidization for both static bed heights. It was found that the bed expansion ratio is more for particle size of 2.1 mm than the particle sizes of 5.9 mm and 3.3 mm for all superficial liquid velocities and both static bed heights due to its less particle weight.

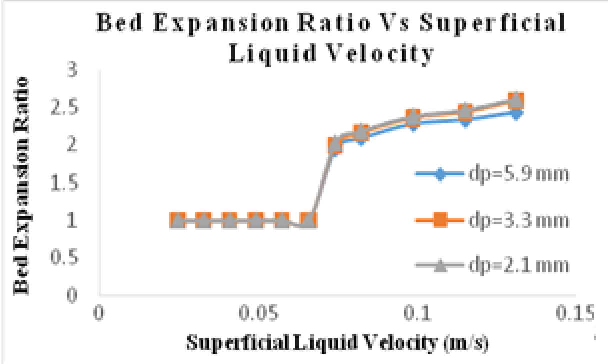

Figure 22: Variation of Bed Expansion Ratio with Liquid Velocity at $U_g = 0.0164$ m/s and Hs = 20.4 cm for different Particle Sizes

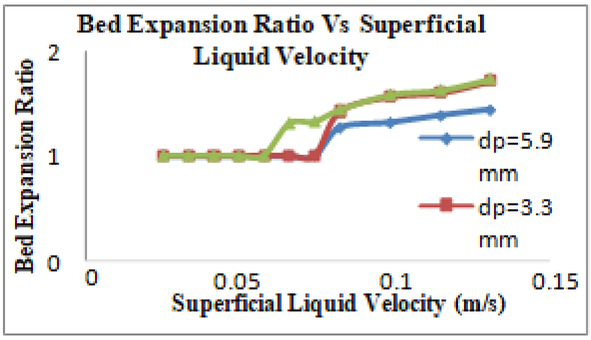

Figure 23: Variation of Bed Expansion Ratio with Liquid Velocity at $U_g = 0.0164$ m/s and Hs = 30.4 cm for different Particle Sizes

4. Conclusions

The hydrodynamic study of the three- phase fluidized bed has been determined and following conclusions are drawn. The bed pressure drop decreases with the increase in gas velocity, bed mass and particle size. The minimum liquid fluidization velocity decreases with the increase in gas velocity, increases with the increase in particle size and is independent of initial static bed height. Bed expansion ratio increases with the increase in gas and liquid velocity and with decrease in initial static bed height.

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