Effect of Variation in Size of Solids on Fluctuation Ratioof the Flidized Bed during Stationary LiquidFluidization

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Abstract –

Fluctuation ratio of the fluidized bed is very sensitive parameter and it is very important for defining the quality of the fluidization. Previous investigations for evaluating fluctuation ratio are mostly attempted in two phase gas-solid fluidized beds. Few works are available for three phase concurrent fluidization. The present research work is carried out to investigate the effect of increasing size of the fluidizing solids on the fluctuation ratio during gas fluidization of solids in stationary liquid. It has been found that for increasing size of solids the fluctuation ratio decreases.

Keywords-Fluctuation ratio, fluidization, stationary liquid, size of solids, bed expansion

I.INTRODUCTION

Epstien (1981) suggested the classification of three phase fluidization as concurrent, countercurrent and stationary liquid fluidization. Numbers of research works have been reported for defining the fluidization hydrodynamics in concurrent mode of three phase fluidization and relatively lesser work have been in the field of countercurrent mode of three phase gas-liquid-solid fluidization. However, for fluidization in stationary liquid is almost neglected. After Gabor et al. (1981) work, in the recent years, Campos et al. (2003) presented a model for axial solid distribution in batch liquid column in which they found that upward movement of solids particles increases with increasing bed height , gas flow rate and decreasing particle diameter. Varas (2011) reported that air crosses the large grain sizes particles immersed in liquid easily and produced multiple simultaneous bubbles at the top surface of bed and this bubble formation is time dependent for large particle sizes and small particle size. However, the intermediate sized particles, bubble formation is independent of the time. Vidal et al. (2015) worked on the mobility of the solids in the liquid saturated grains. The authors introduced new parameter flow density to quantify the motion of grains in the fluidizing zone and reported that fluidization zone grows initially then stabilizes after a particular time and maximum expansion in the fluidization zone in found at the center of the bed for increasing grain sizes. Kumar et al. (2015) carried out to investigate the effect of size of solids on the pressure drop of the fluidized bed and the pressure distribution in the fluidized zone during gas fluidization of solids in stationary liquid (2017a). The same authors also reported that for increasing static bed height of solids in stationary liquid fluidization decreases the fluctuation ratio (Kumar et al. 2017b).

II.RELATED WORK

Leva (1956) defined the fluctuation ratio as the ratio between maximum possible fluidized height to the minimum bed height attained by the top layer of the fluidized bed. Mathematically it is given in the following form.

$$r = \frac{h_{max}}{h_{min}}$$

Roy et al. (1964) related the effect of solid size on the critical solid hold-up and suggested that critical solid holdup decreases with increasing particle size. Macfarlane et al. (1968) investigated and reported that the average particle velocity during fluidization is a complex function of the particle size, density of solids, liquid properties and fluid velocity. Roy (1971) worked on three phase semi-fluidization and reported that for finer sized solids the minimum fluidizing velocity will be more.Geldart (1971) mentioned in his famous investigation regarding the classification of particles that coarser sized particles tend to earlier slugging and greater pressure fluctuation. Jong and Nomden (1974) defined that fluid velocity range for homogenous fluidization depends mainly upon average particle size. They also stated that beyond the limiting size of the solids only heterogeneous fluidization is possible. Fan (1985) mentioned in his review work of gas-liquid-solid fluidization that during three phase fluidization of fine particles, some investigators have been reported that solid bed contracts instead of expansion for initial flow rates of gas. For increasing gas flow rate, solid bed further contracts.Pandit and Joshi (1986) concluded that particle size and particle settling velocity are most prominent parameters for deciding the suspension of particles the three phase processes.Clift and Grace (1995) related the viscosity of fluidized beds with the particle size and mentioned that viscosity of the fluidized bed increases slightly with increasing size of solids in bed.Kim et al. (1990) stated that in three phase gas-liquid-solid fluidization, bed porosity decreases with increasing particle size. Yates and Simons (1994) reported that bubble rise velocity increases with increasing solid size. Zhang (1996) reported that at low liquid velocity, minimum gas fluidizing velocity increases with particle size and density in three phase gas-liquid-solid fluidization. Hepbasli (1998) reported that bed expansion decreases with increasing size of solids.Hoffman (1995) expressed that transition gas velocity responsible for changing the homogenous flow regime to turbulent flow regime decreases with increase in the particle size. In the upper side of the bed, solid concentration increases significantly for lower sized solids (Zhang and Lin, 2002). Baker (2003) reported that gas holdup of the fluidized bed increases with increasing size of the solids.Ulgen et al. (2005) reviewed the work in the field of bubble column reactor and mentioned that it has been reported by many researchers for fixed gas velocity, solid concentration in the liquid, with increasing the solid diameter gas holdup decreases.Shaikh and Muthanna (2007) emphasized on the systematic experimental study to find out the effect of solid bed height, particle size and sparger dimension to study the transition flow regime

Several research work has been reported to quantify fluctuation ration in the fluidized beds. Kawabata et al. (1981) investigated the effect of pressurisation on the fluctuation ratio. They found that courser sized particles are more sensitive in comparision to fner size particles as well as fluctuation ratio is concerned. Fluctuation ration in the conical type of fluidizing column has been calculated by Biswal et al. (1982). Singh and Roy (2006) carried out the study to find the effect of the shape of particle size on the fluctuation ratio. Mohanty et al. (2008) related the fluctuation ratio with the height of the fluidizing column. Dora et al. (2016) studied the fluctuation ratio in three phase co-curret type fluidized beds. They found that fluctuation ratio decreases wih increase in the solid bed heights.

III.EXPERIMENTAL SET-UP AND PROCEDURE

Experimental set-up consists on fluidizing column of 90 mm internal diameter and of 1800 mm height. The bottom of the fluidizer in connected with the calming section and at the top of the fluidizer there is disengagement section. Distributor section having air sparger is fitted just below the calming section. The fluidizing section has three different parts of 450 mm, 600 mm and 60mm height which are connected by flanges. Nine different pressure ports are given at different heights of the fluidizing column. Complete experimental set-up and its procedure are standardized using measurement system analysis. Kumar et al., 2015 conducted similar study for standardizing the experimental set-up and procedure during gas fluidization of solids in stationary liquid for 50 mm diameter fluidizer.

Different liquids (water, kerosene, turpentine) are filled into the column up-to different heights (40 cm, 50 cm, 60 cm). Then different solids (coal, peanut, stone) are added into the column for different heights (10 cm, 20 cm, 30 cm). Peanut has been selected to extend the studies in the field of fluidization of food particles as conducted by Kumar et al. (2011). The solids are initially crushed and then sieved to segregate into 2 mm, 4 mm and 6 mm sizes. Now, air from the compressor is allowed to flow through the fluidizer at different flow rates (0, 7.5, 15, 30 and 45 lpm). The solids and liquid expanded and starts fluctuating inside the fluidizer. The top layer of the solids within the liquid boundary is carefully observed and it’s oscillating heights have been measured from the distributor plate.

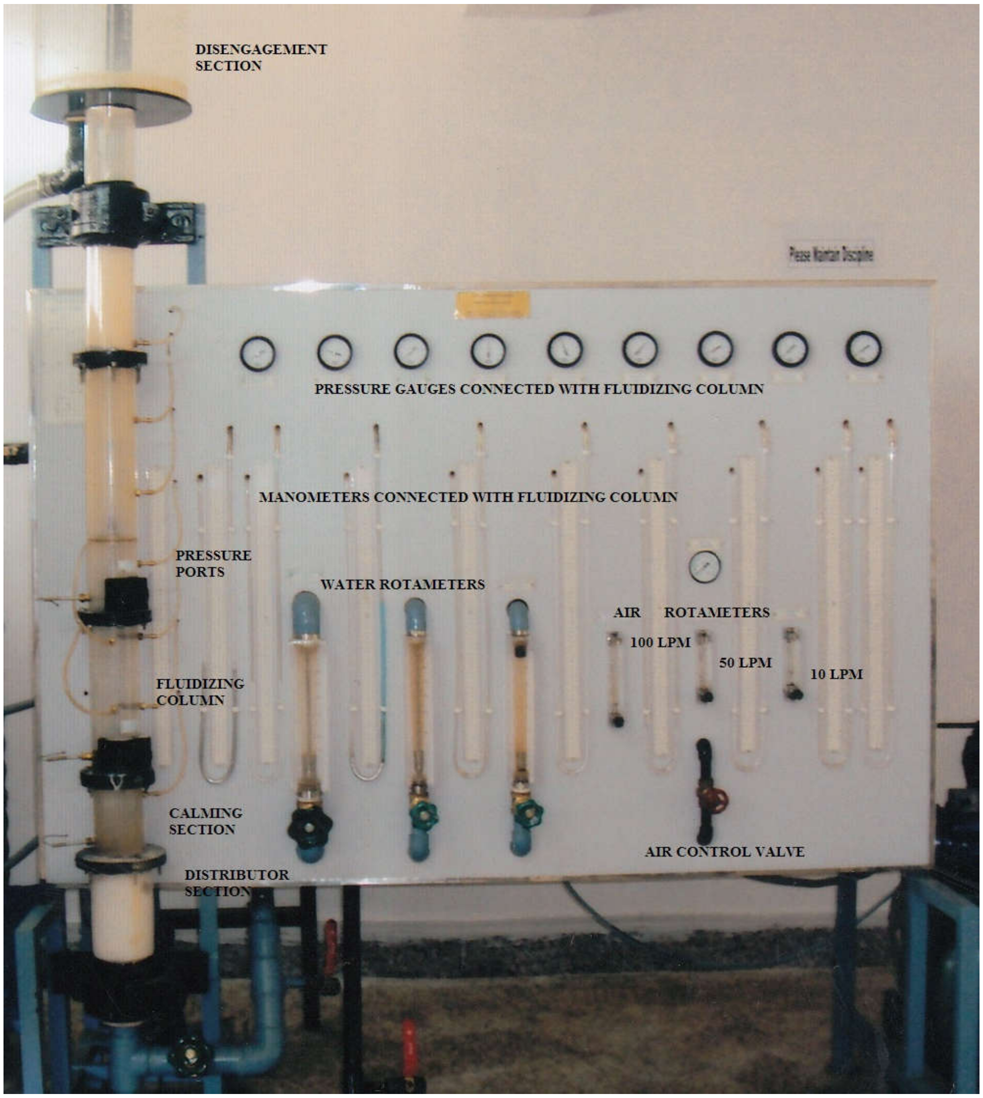

Fig. 1 Photograph of the experimental setup

IV.RESULTS AND DISCUSSIONS

The description of parameters selected for the investigation and their rang has been presented in table 1.

Table 1 Experimental Range of Parameters

Sr.	Parameter	Range	Level
01	Flowrate, Q	0-45 lpm	0, 7.5, 15, 30, 45 lpm
02	Solid bed height, *h*	10-30 cm	10, 20, 30 cm
03	Liquid height,	40-60 cm	40, 50, 60 cm
04	Size of material,	3	2, 4, 6 mm
05	Solid	3	Coal, Peanut, Stone
06	Liquid	3	Water, Kerosene, Turpentine

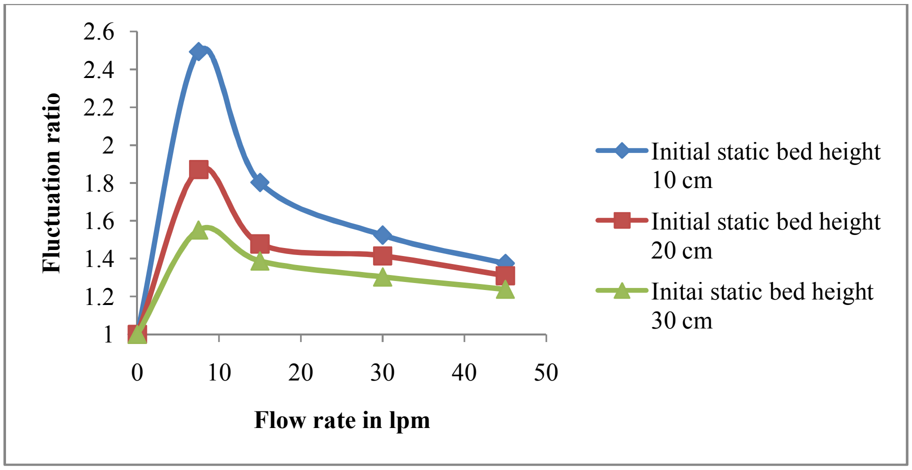

Fig. 2 Variation of fluctuation ratio with air flow rate for different solid bed heights [solid - stone, liquid - turpentine, d_p= 2 mm, h_l= 0.4 m]

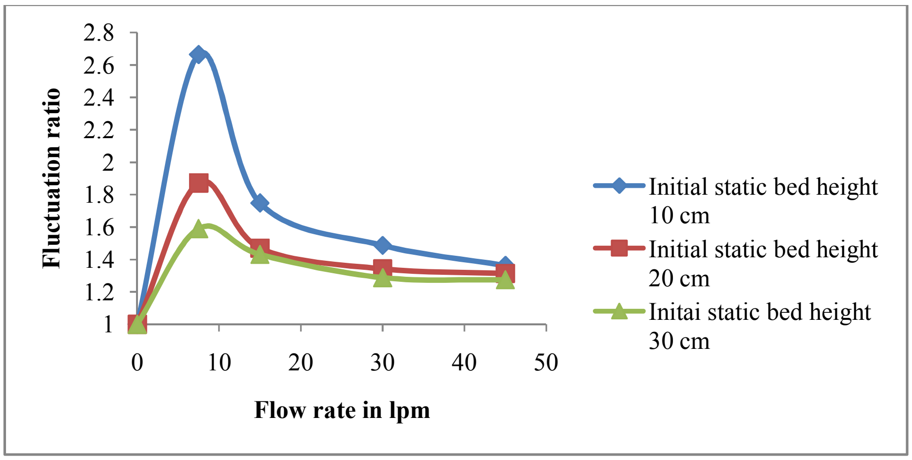

Fig. 3 Variation of fluctuation ratio with air flow rate for different solid bed heights [solid - stone, liquid - kerosene, d_p= 2 mm, h_l= 0.4 m]

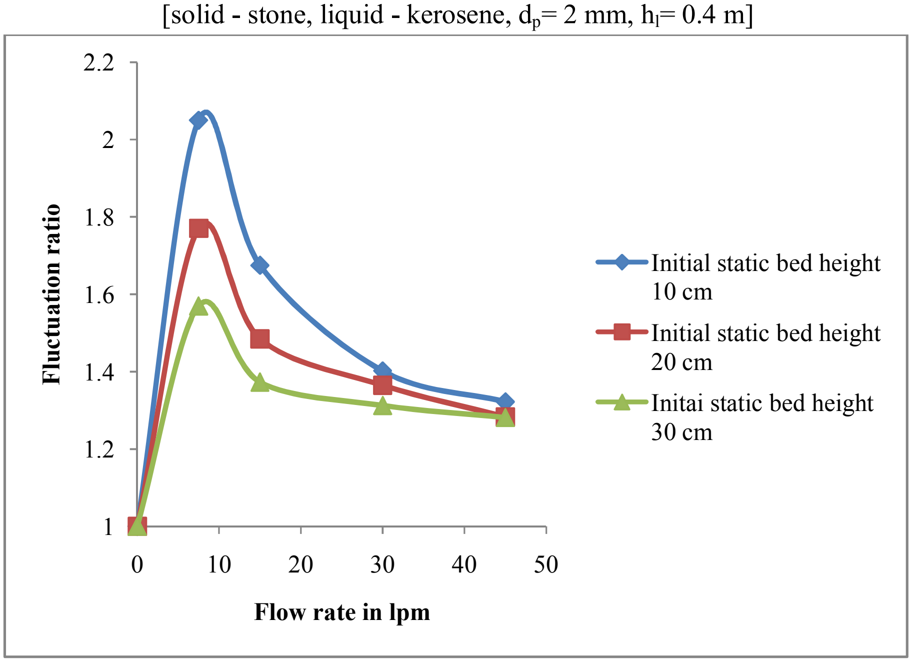

Fig. 4 Variation of fluctuation ratio with air flow rate for different solid bed heights

[solid - stone, liquid - water, d_p= 2 mm, h_l= 0.5 m]

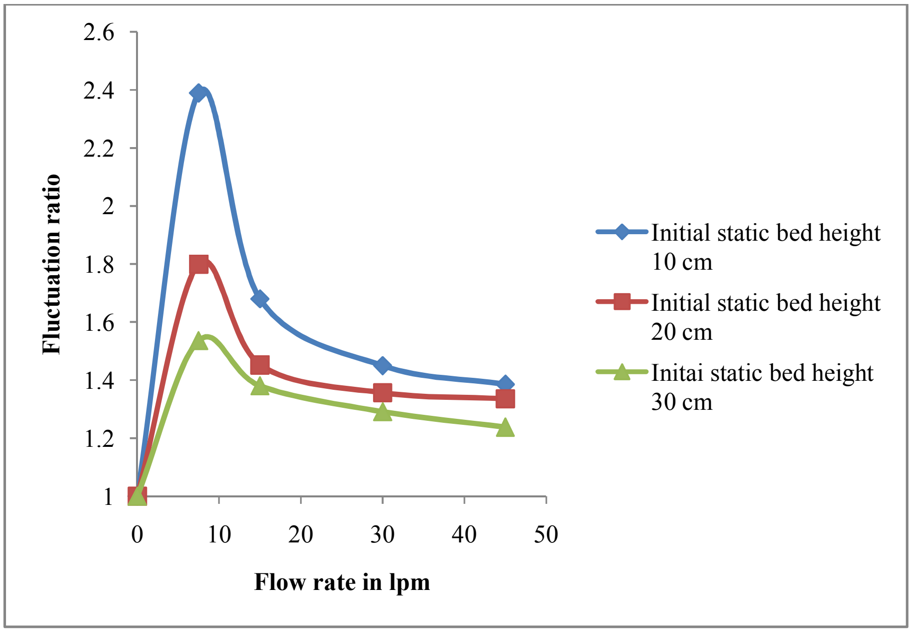

Fig. 5 Variation of fluctuation ratio with air flow rate for different solid bed heights
[solid - peanut, liquid - turpentine, d_p= 2 mm, h_l= 0.4 m]

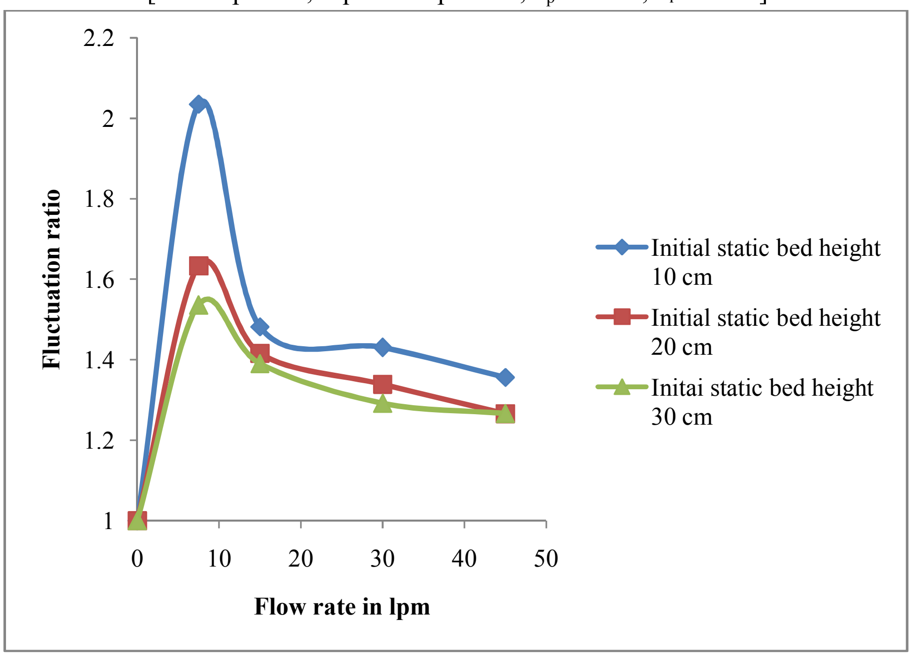

Fig. 6 Variation of fluctuation ratio with air flow rate for different solid bed heights
[solid - coal, liquid - kerosene, d_p= 2 mm, h_l= 0.5 m]

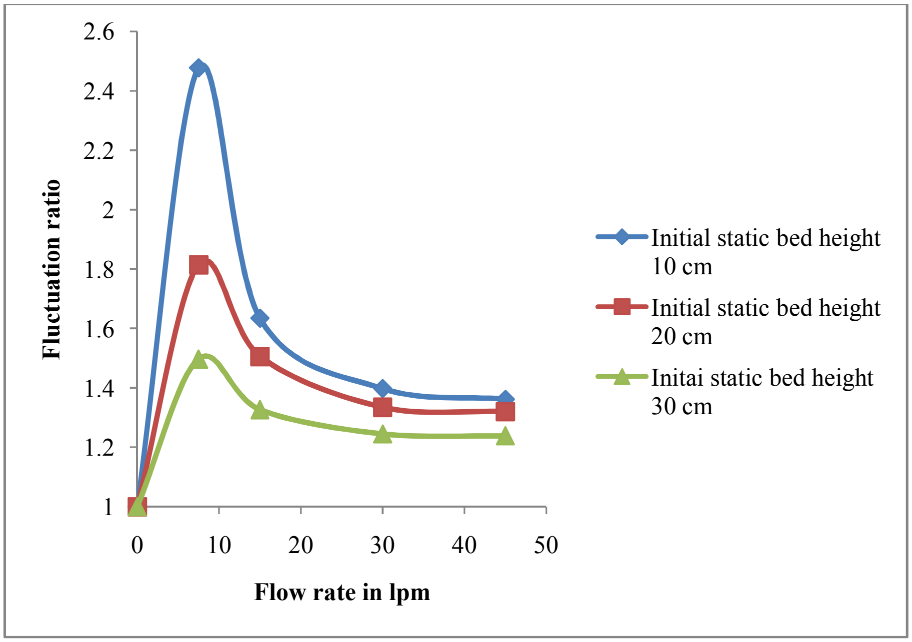

Fig. 7 Variation of fluctuation ratio with air flow rate for different solid bed heights [solid - stone, liquid - turpentine, d_p= 4 mm, h_l= 0.4 m]

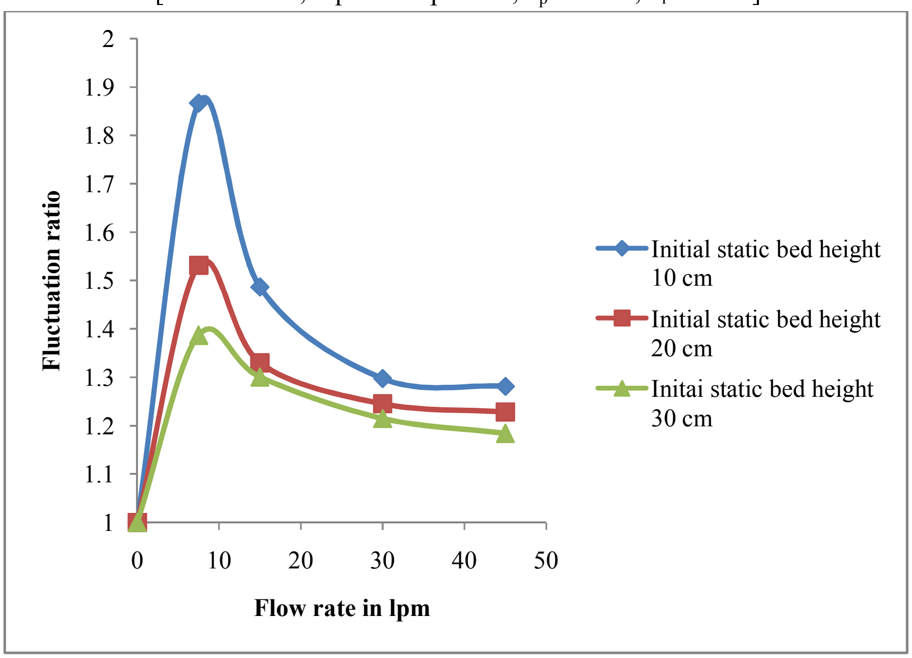

Fig. 8 Variation of fluctuation ratio with air flow rate for different solid bed heights [solid - coal, liquid - turpentine, d_p= 4 mm, h_l= 0.6 m]

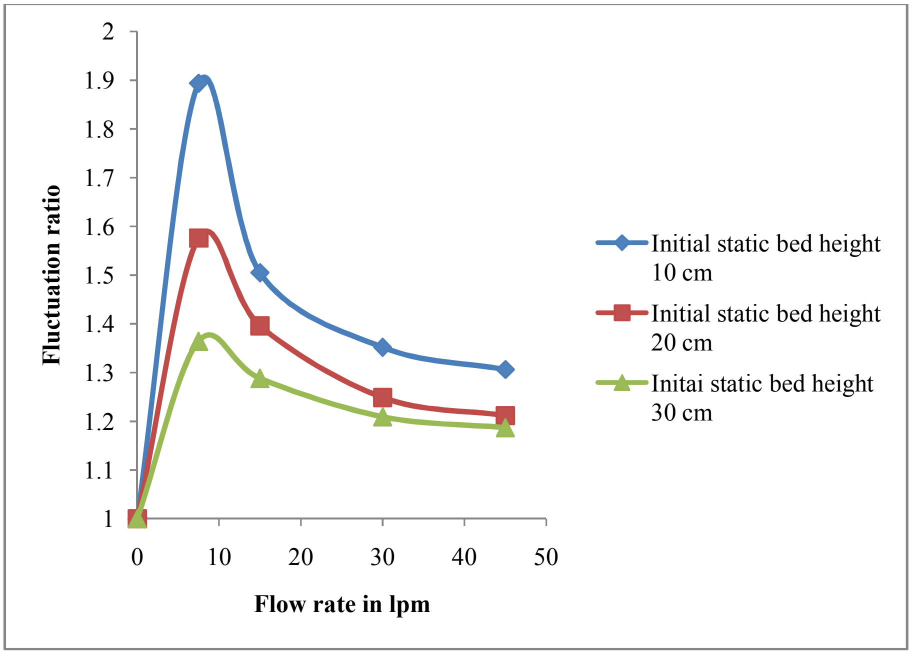

Fig. 9 Variation of fluctuation ratio with air flow rate for different solid bed heights [solid - peanut, liquid - water, d_p= 6 mm, h_l= 0.5 m]

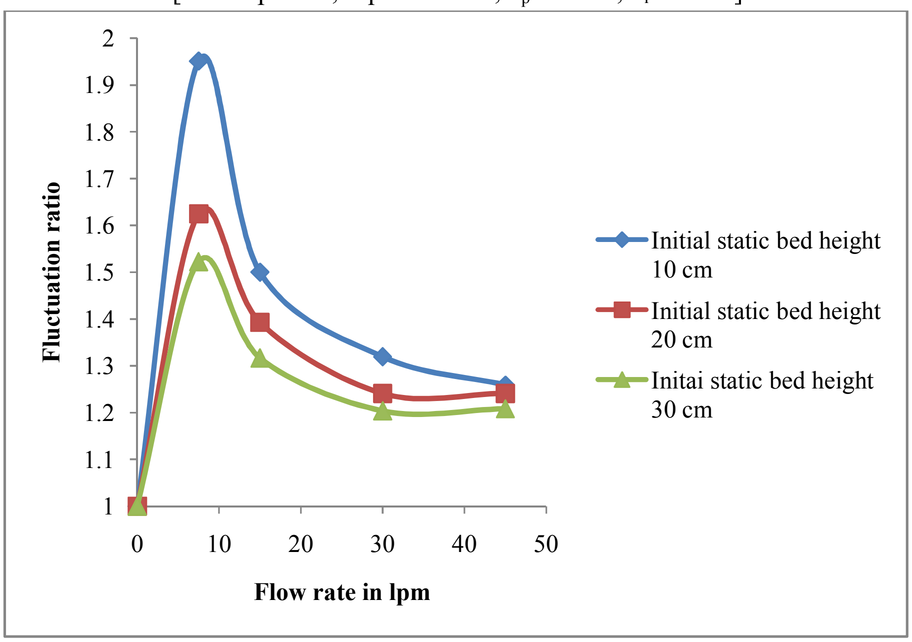

Fig. 10 Variation of fluctuation ratio with air flow rate for different solid bed heights [solid - stone, liquid - kerosene, d_p= 6 mm, h_l= 0.5 m]

Extensive experimentations have been performed for analyzing the effect of solid bed height on the fluctuation ratio. It is quite clear from the analysis that for increasing solid bed height fluctuation ratio decreases. Further, fluctuation ratio is found maximum at a lower flow rate and then decreases sharply for increasing flow rates. Padhi et al. (2016) also reported similar findings that for increasing solid bed height fluctuation ratio decrease. However they reported that for increasing flow rates fluctuation ratio also increases. In the present investigation,conflicting results are found. Although fluctuation ratio is decreasing with increasing flow rates but maximum and minimum oscillating height of the expanded fluidized bed are found increasing with increasing flow rate. However, the ratio between maximum to minimum expanded bed height is decreasing this also shows the fluctuation is decreasing. The reason behind this finding is that the presence of liquid in stationary state.Abraham et al. (1992) reported that in three phase batch type slurry column above the critical gas velocity i.e. minimum velocity to suspend the solids, the liquid starts recirculation behaving within the column. During recirculation behavior liquid with gas moves up then after reaching certain height it starts moving downward. Subsequently, entire liquid mass starts behaving in the same manner. Due to this liquid recirculation state and momentum took from the liquid, solids also move upward then moves downward and form a continuous cyclic motion within the fluidizing zone. This condition of recirculation is possible at higher flow rates only. However, excessive amount of flow rate breaks this recirculation flow pattern and again fluctuation may start increasing.

V.CONCLUSION

Present work has been undertaken to examine the effect of increasing solid bed height on the fluctuation ratio. In fluidizing bed, fluctuation of bed is most undesirable situation. In certain cases, solids move out from the fluidizer also. Further, fluctuation also reduces the heat and mass transfer operations in the bed. For the selected range of experimentations, it is now possible to take control on the fluctuation. It has also been suggested that fluctuation of fluidized beds particularly during higher flow rates of gas can be controlled by using stationary liquid fluidizer.

RFERENCE

[1] The Expanded Bed. (1959). In Fluidization (pp. 104-105). McGraw-Hill Book Company.

[2] Epstein, N. (1981). Three-phase fluidization: Some knowledge gaps. The Canadian Journal of Chemical Engineering, 59(6), 649-657. doi:10.1002/cjce.5450590601

[3] Kawabata, J. I., Yumiyama, M., Tazaki, Y., Honma, S., Chiba, T., Sumiya, T., & Endo, K. (1981). Characteristics of Gas-Fluidised Beds Under Pressure. Journal of Chemical Engineering of Japan, 14(2), 85-89. doi:https://doi.org/10.1252/jcej.14.85

[4] Biswal, K., Sahu, S., & Roy, G. (1982). Prediction of the fluctuation ratio for gas—solid fluidization of regular particles in a conical vessel. The Chemical Engineering Journal, 23(1), 97-99. doi:10.1016/0300-9467(82)85011-9

[5] Gabor, J. D., Cassulo, J. C., Fountain, D., &Bingle, J. D. (1984). AIChE annual meeting. Retrieved from https://inis.iaea.org/search/search.aspx?orig_q=RN:16030991

[6] Abraham, M., Khare, A. S., Sawant, S. B., & Joshi, J. B. (1992). Critical gas velocity for suspension of solid particles in three-phase bubble columns. Industrial & Engineering Chemistry Research, 31(4), 1136-1147. doi:10.1021/ie00004a024

[7] Singh, R., K.,& Roy, G., K., (2006).Prediction of Bed Fluctuation Ratio for Gas-solidFluidization in Cylindrical and Non-cylindrical Beds.Indian Journal of Chemical Technology, 13, 139-143.

[8] Sau, D., Mohanty, S., &Biswal, K. (2008). Correlations for critical fluidization velocity and maximum bed pressure drop for heterogeneous binary mixture of irregular particles in gas–solid tapered fluidized beds. Chemical Engineering and Processing: Process Intensification,47(12), 2386-2390. doi:10.1016/j.cep.2007.11.003

[9] Kumar, S., Arora, A., & Chandra, H. (2011). Experimental investigation of gas-solid fluidization of spherical food material. CSVTU Research Journal, 4(1), 113-116.

[10] Dora, D., Panda, S., Mohanty, Y., & Roy, G. (2013). Hydrodynamics of gas–solid fluidization of a homogeneous ternary mixture in a conical bed: Prediction of bed expansion and bed fluctuation ratios. Particuology, 11(6), 681-688. doi:10.1016/j.partic.2013.02.009

[11] Kumar, S., Arora, A., & Chandra, H. (2015). Standardization of Measurement Process during Gas Fluidization of Solids in Stationary Liquid Using Gauge Repeatability and Reproducible

Methodology. . . Global Journal of Multidisciplinary Studies, 4(6), 156-163. Retrieved from http://www.gjms.co.in/index.php/gjms2016/article/view/895

[12] Kumar, S., Arora, A., & Chandra, H. (2015). Experimental investigations on variation in particle size on pressure drop during gas fluidization of solids in stationary liquid. International Research Journal of Engineering and Technology (IRJET), 2(5), 883-886. Retrieved from https://www.irjet.net/archives/V2/i5/IRJET-V2I5150.pdf.

[13] Padhi, R., Dora, D., Mohanty, Y., Roy, G., &Sarangi, B. (2016). Prediction of bed pressure drop, fluctuation and expansion ratios for three-phase fluidization of ternary mixtures of dolomite in a conical conduit. Cogent Engineering, 3(1). doi:10.1080/23311916.2016.1181821

[14] Kumar, S., Arora, A., & Chandra, H. (2017). Effect of variation in solid bed height on the pressure distribution during gas fluidization of solids. , Research Journal of Engineering Sciences, 6(7), 7-13. Retrieved from http://www.isca.in/IJES/Archive/v6/i7/2.ISCA-RJEngS-2017-143.pdf