Effect of Variation in Size of Solids on Fluctuation Ratio of the Fluidized Bed During Stationary Liquid Fluidization

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Abstract

Fluctuation ratio of the fluidized bed is a 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 andfew 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 the 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*

1. 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 the stationary liquid is almost neglected. After competition of Gabor et al. (1981) work, in the recent years, Campos et al. (2003) presented a model for axial solid distribution in a 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 is 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 the 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).

2. 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 (1974) worked on three phase semi-fluidization and reported that for finer sized solids the minimum fluidizing velocity will be more.Geldart (1972) mentioned in his famous investigation regarding the classification of particles that coarser sized particles tend to earlier slugging and greater pressure fluctuation. Jong and 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.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 Li, 2002). Baker (2003) reported that gas holdup of the fluidized bed increases with increasing size of the solids.Kantarci 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.

3. Experimental Set-Up and Procedure

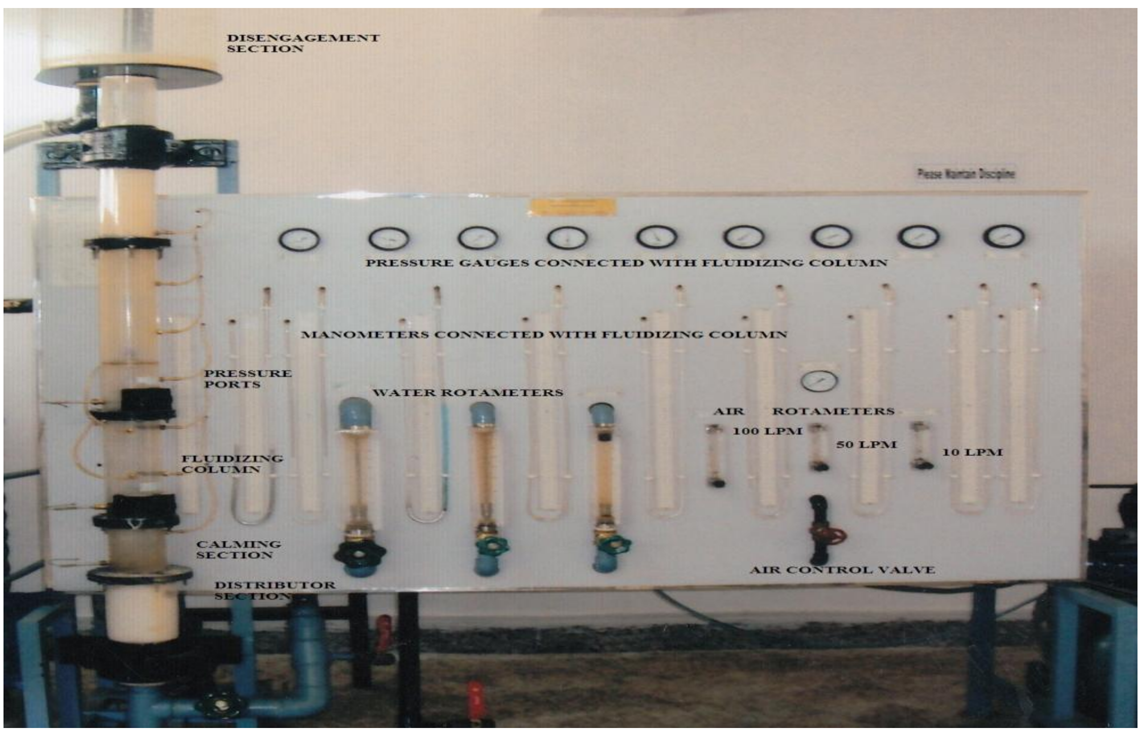

Figure 1: Photograph of experimental set-up

Experimentations have been carried out in a fluidizing column. The internal diameter of the fluidized was 90 mm and outer diameter was 100 mm. The height of the fluidized was 1800 mm. The entire fluidizing column has four different parts. Those are conical section, calming section, fluidizing zone and disengagement section. The distributor section consists of air sparger. The experimental procedure has been standardized using gauge repeatability and reproducibility theory. There are nine different pressure gauges for measuring pressure in the fluidizing column at different locations.

Three different liquids are selected for experimentations are water, kerosene and turpentine. Similarly, three different solids are stone, peanut and coal. The three different sizes of the solids which are taken in experimental work are 2 mm, 4 mm and 6 mm. The range of static solid bed heights are 10, 20, 30 cm and height of liquid taken in the column are 40 cm, 50 cm and 60 cm. The air flow rate during experimentation are 0 ,7.5lpm, 15 lpm, 30 lpm and 45 lpm. The experimental set-up consists of three different range rotameters (0-10 lpm, 0-50 lpm, 0-100 lpm).

4. Results and Discussions

Fluctuation ratio has been calculated using maximum expanded bed height and minimum expanded bed height during fluidization for the different flow rates. During the height measurement, proper precautions have been taken. It has been observed that expansion in the fluidized bed tend to form a particular oscillation pattern after a certain time interval. So, minimm and maximum bed heigh measurement have been taken only after oscilattion pattern establishes in the fluidized zone.

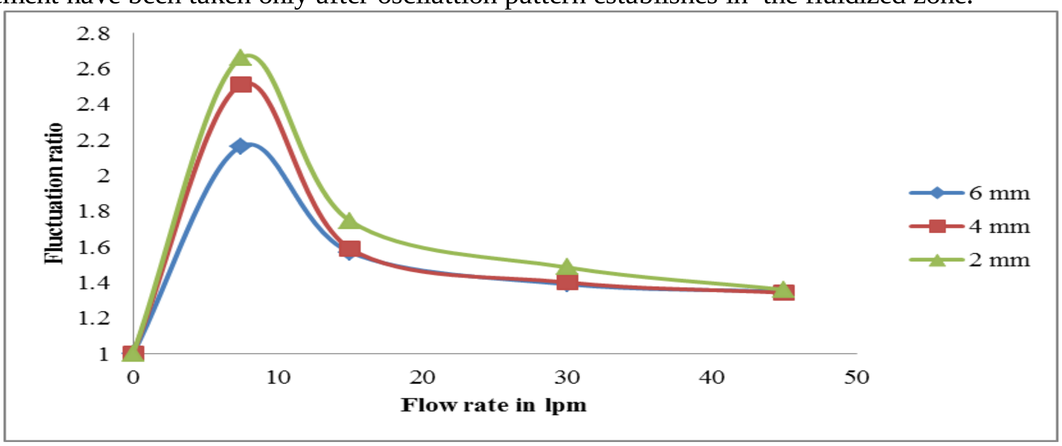

Figure 2: Variation of fluctuation ratio with air flow rate for different material sizes [solid - stone, liquid - kerosene, hs = 0.1 m, hl = 0.4 m]

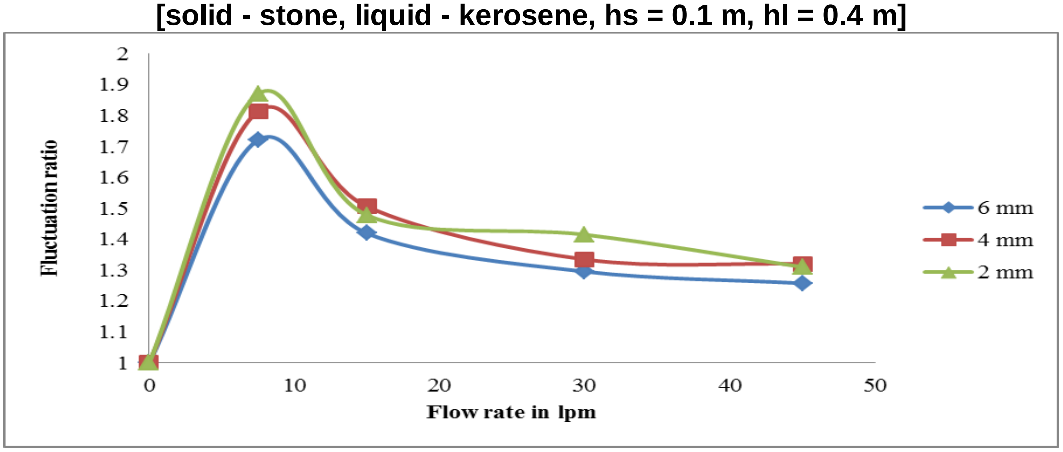

Figure 3: Variation of fluctuation ratio with air flow rate for different material sizes [solid - stone, liquid turpentine, hs = 0.1 m, hl = 0.5 m]

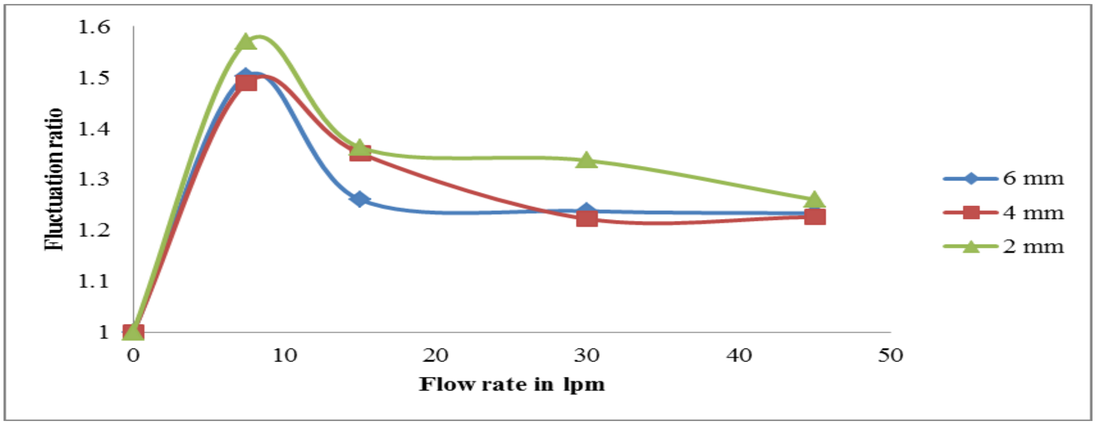

Figure 4: Variation of fluctuation ratio with air flow rate for different material sizes [solid - stone, liquid - water, hs = 0.1 m, hl = 0.6 m]

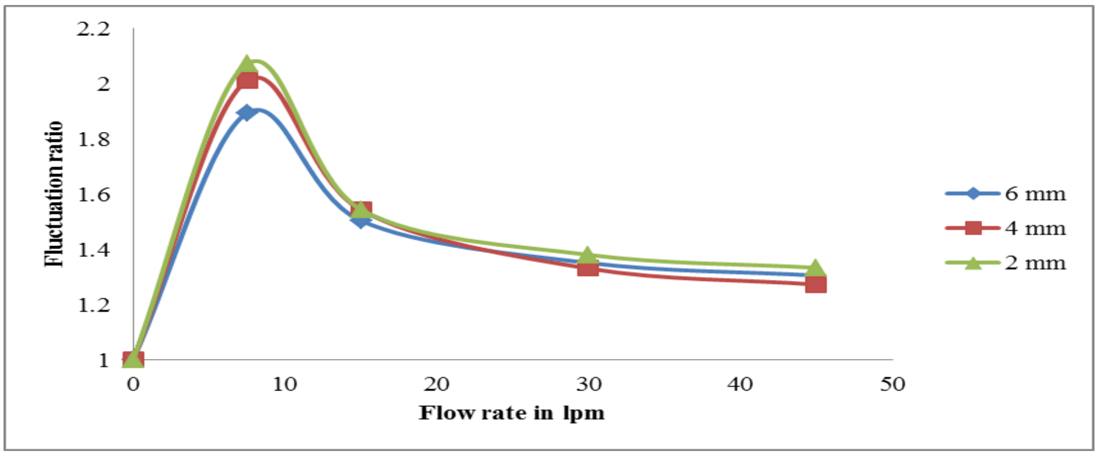

Figure 5: Variation of fluctuation ratio with air flow rate for different material sizes [solid - peanut, liquid - water, hs = 0.2 m, hl = 0.4 m]

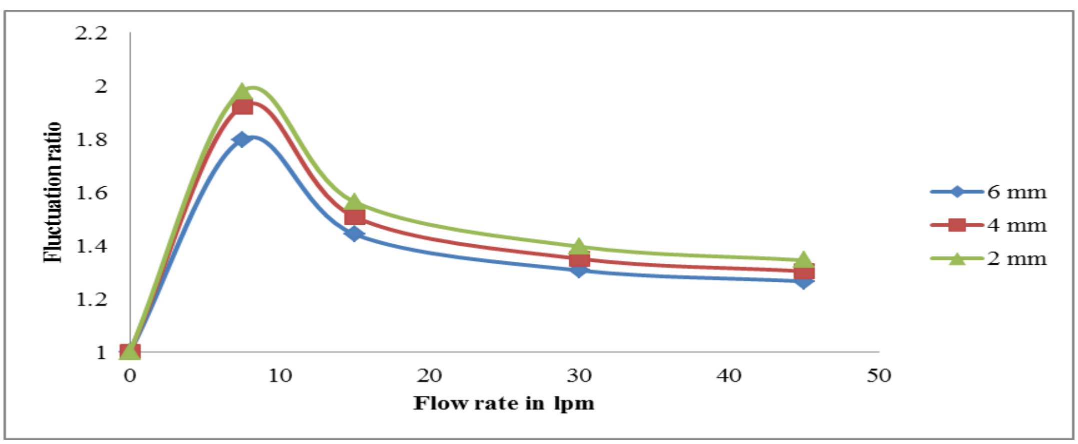

Figure 6: Variation of fluctuation ratio with air flow rate for different material sizes [solid - peanut, liquid - turpentine, hs = 0.3 m, hl = 0.4 m]

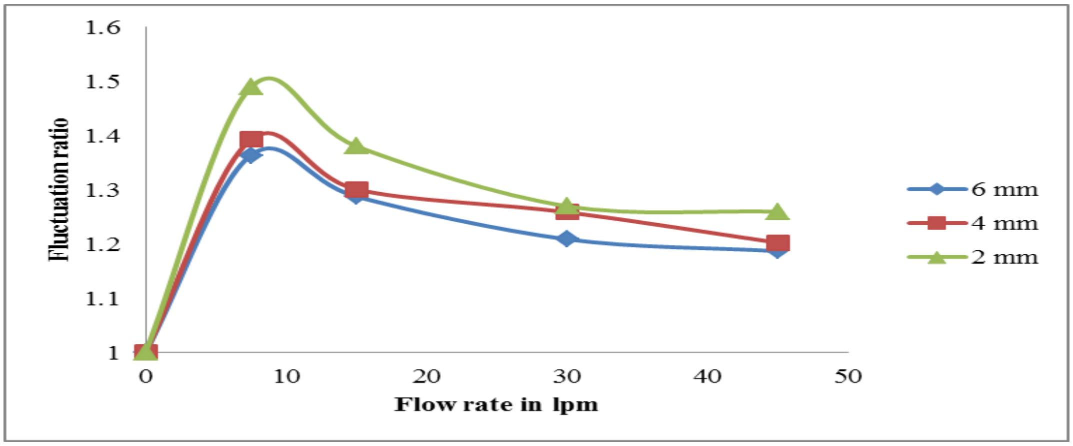

Figure 7: Variation of fluctuation ratio with air flow rate for different material sizes [solid - peanut, liquid - water, hs = 0.3 m, hl = 0.6 m]

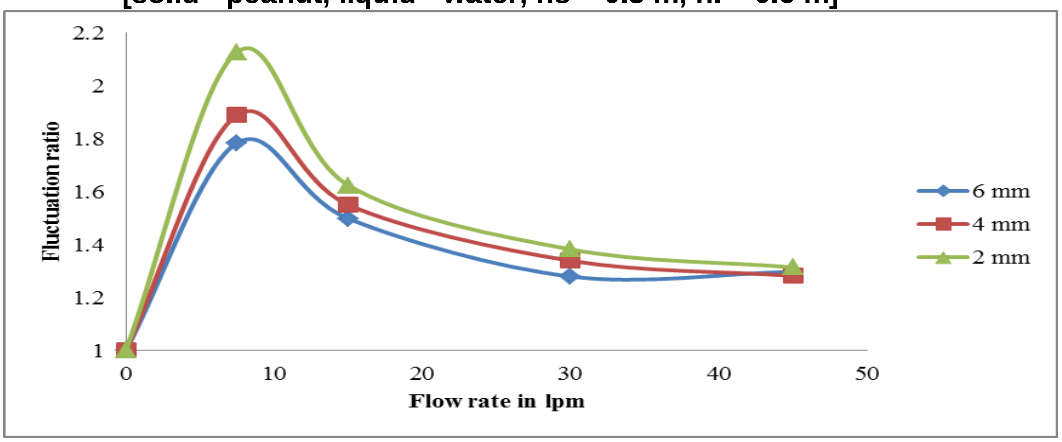

Figure 8: Variation of fluctuation ratio with air flow rate for different material sizes [solid - coal, liquid - turpentine, hs = 0.1 m, hl = 0.4 m]

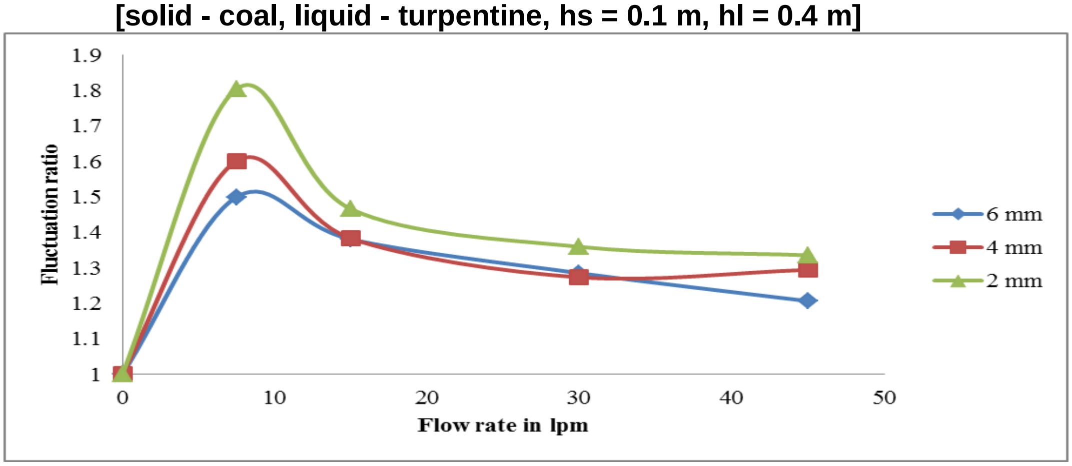

Figure 9: Variation of fluctuation ratio with air flow rate for different material sizes [solid - coal, liquid - kerosene, hs = 0.1 m, hl = 0.5 m]

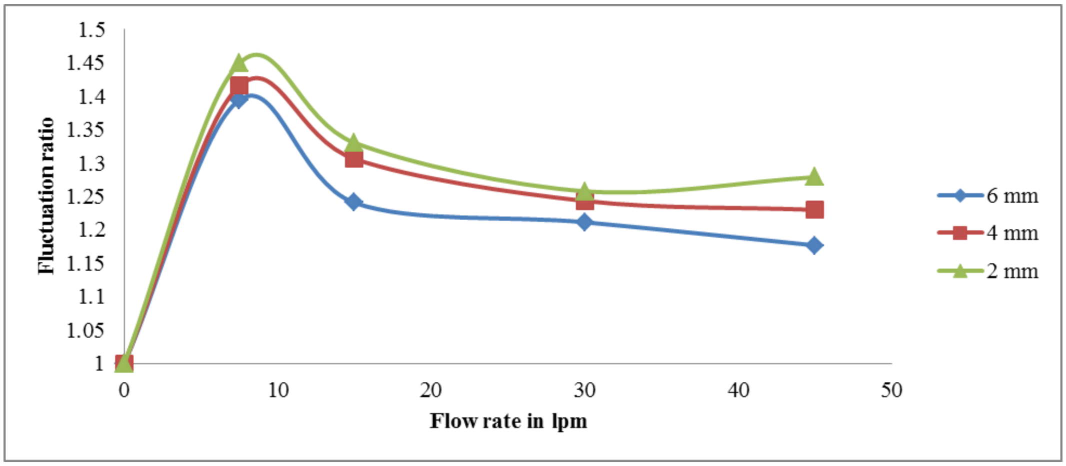

Figure 10: Variation of fluctuation ratio with air flow rate for different material sizes [solid - coal, liquid - water, hs = 0.1 m, hl = 0.6 m]

Rigorous experimentations have been conducted for performance analysis on fluctuation ratio. The general observation is that fluctuation ratio is decreasing with increasing air velocity. However, in three phase gas-liquid-solid fluidization, fluctuation ratio increases with increasing gas velocity (Padhi et al., 2016). Although, the expanded bed height for increasing flow rate is increasing however, the fluctuation ratio is decreasing.

The effect of particle size on the fluctuation ratio is found as decreasing for all the sizes. However for increasing size of the particles the fluctuation ratio is decreasing particularly for lower flow rates. However, for higher flow rates seldom it has been observed that curves are intersecting to each other. The reason behind decreasing fluctuation ratio with increasing size of solids is that the 2 mm size material has less mass in comparison to 6 mm solid so 2 mm particle imparts less resistive inertial force (against liquid and gas)than 6 mm solid for rise. Secondly the finer sized solids tend to form clusters or groups of many solids. These clustersfluctuate more with liquid fluctuation. Kang et al. (1999) predicted these cluster fluctuation ratio in three phase fluidization using Shanon entropy and reported that fluctuation of smaller size particles are more than coarser size solids.

5. Conclusion

The research work has been undertaken with an objective to find out the effect of fluctuation ratio on differently sized solids present in stationary liquid for different solid heights. It has been found that for increasing gas flow rates corresponding fluctuation ratiosare decreasing. Further, conclusion has been made that coarser sized solids fluctuate less than the finer sized solids during gas fluidization of solids in a stationary liquid.

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