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Studies on segregation of binary mixture of solids in continuous fast fluidized bed Part II. Effect of particle size

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Abstract

Experimental investigations on the continuous fast fluidized bed were extended for size segregation of binary mixture of solids in the column with air as the separation medium [1]. The feed is either jetsam-rich or flotsam-rich binary mixture of particles of different size, but same density. The variables tested were superficial gas velocity, solids feed rate and feed characteristics. At steady state, there exists physical equilibrium between the evolved flotsam and the residual jetsam when the granular solids are in fluid-like state as in the case of density segregation of solids [1]. Using the analogy of the binary liquid mixtures separation by distillation, the phase diagram was constructed from the experimental observations. The effect of solids feed rate, feed composition, particle size ratio and particle size on equilibrium distribution of the flotsam and jetsam were presented.
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Keywords: Fast fluidization; Size segregation; Equilibrium; Phase diagram; Binary solids mixture; Bed pressure drop

1. Introduction

Fluidized beds can be operated in a number of contacting modes ranging from dense bubbling fluidization to dilute pneumatic conveying. From an engineering point of view, two hydrodynamic states of a given bed should always be considered for segregation: the onset of fluidization that occurs at the minimum fluidization velocity and the beginning of entrainment of solids that is more or less close to the terminal (free fall) velocity of the bed particles [2]. Segregation of equal density or different density binary mixtures in gas–solids fluidized bed has been widely investigated over the past two decades at gas velocities between the two minimum fluidization velocities of the binary mixture of particles. A substantial number of papers have been published covering various aspects such as the segregation mechanisms, possible inconsistencies and patterns, feasibility analysis, applications and other accompanying aspects [3–13]. Hydrodynamics and segregation studies in conical spouted beds with binary and ternary mixtures of spherical particles of varying size are clearly recognized [14,15]. The solids segregation in batch circulating fast fluidized bed has been defined by few investigators during the last decade [16–18].

Industrial classification process is most likely to be a continuous one, with continuous removal of lighter/fine particles from top portion of the bed and removal of heavier/coarse particles from bottom portion of the bed. Few investigators have studied the segregation of solids in continuous operating mode using bench scale columns by two methods. The first method is based on the separation of lighter/fine particles by fluidizing the mixture to be separated without allowing any lighter/fine particles to return to the column. There is then no reflux [19–22]. The second method is based on the return of part of the lighter/fine particles into the column [23,24]. Both these existing studies do not provide clear information about the fluidization regimes.

The prediction of the segregation of solids using continuous fast fluidization is still difficult. Fast fluidized bed classifiers operated at higher gas velocities are especially useful for recovering lighter/fine particles from heavier/coarse particles, with minimum or no loss of the heavier/coarse fraction, using high-velocity classifying air. Continuous separation of lean phase binary mixture of particles of varying size using continuous fast fluidization technique has not been investigated clearly to the best of our knowledge. The present study focuses on the separa-

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Nomenclature

B	flow rate of bottom particles (kg/h)
C_1	critical point at which segregation begins
C_2	critical point at which segregation ends
d_c	diameter of coarse particle (μm)
d_f	diameter of fine particle (μm)
D	flow rate of overhead particles (kg/h)
F	flow rate of the feed particles (kg/h)
U_F	lower bound of fast fluidization regime (m/s)
U_P	upper bound of fast fluidization regime (m/s)
U_T	velocity corresponds to beginning of turbulent fluidization (m/s)
U_{TF}	velocity corresponds to transition to fast (m/s)
U_0	superficial gas velocity (m/s)
X_c	weight fraction of coarse particles in bottom flow
X_f	weight fraction of fine particles in bottom flow
Y_c	weight fraction of coarse particles in top flow
Y_f	weight fraction of fine particles in top flow
Z_c	weight fraction of coarse particles in feed
Z_f	weight fraction of fine particles in feed

Greek letter

α	particle size ratio

tion of solids of varying size and same density using continuous fast fluidization. This paper provides apparent information about the fluidization behavior and the distribution of fine and coarse particles in a novel way. The analogy with distillation has been used to describe the solids distribution. The distribution of fine and coarse particles is investigated for various superficial gas velocities, solids feed rate, feed composition and particle size ratio.

The density segregation studies in the continuous fast fluidized bed are described in first part of this communication [1] and the present part corresponds to the size segregation. The additional feature in this part is the chosen particle size and selected particle size ratio. The intention is to look initially at near ideal systems in an attempt to understand the simple case first. Close density particles will be rarely of practical interest. So by looking at materials used in Part I [1], it is concluded that those materials are more representative of real industrial situations. The wide operating range and the chosen particle size ratio of the present study gives a better understanding of the segregation possibilities and limitations of the operation of continuous fast fluidized beds.

Table 2
Details of the size ratios selected in the present study

Type	Size ratio, α	Value
III	[a]/[e]	2.38
IV	[b]/[e]	2.00
V	[a]/[d]	1.68
VI	[c]/[e]	1.68

Table 3
Range of the operating variables used in the present study

Variable	Range
U_0 (m/s)	2.01–5.42
F (kg/h)	32–82
Z_c (%)	3, 5, 10, 90, 95, 97

2. Experimental

The experimental set-up used and the experimental procedure employed in the present study are described in first part of this communication [1]. Table 1 reports the properties of solids used in the present study. Feed mixture consists of colored glass beads (jetsam)–colorless glass beads (flotsam). All the particles were of density of 2500 kg/m^3 and of sphericity one. The size ratio selected is given in the Table 2.

All the selected particles fall in the Geldart group B class. Reasonably close sized granular particles were obtained for each kind of solids by taking a single screen cut using the ‘JAYANT’ standard ‘A’ class test sieves. The range of operating variables used in the present study is given in Table 3.

3. Results and discussion

3.1. Fluidization behavior

The existence of different flow regimes in a gas–solid fluidized bed has been known for a long time. From the experimental evidence available in the literature so far, there are at least five different fluidization regimes observed in the order of increasing the gas velocity [2]. It is believed that continuous fast fluidization may exhibit various flow structures due to the continuous entrainment and discharge of solids. The fluidiza-

Table 1
Properties of solids used in the present study

Solids	Screen size (μm)	Average particle diameter (μm)	Terminal velocity[a] (m/s)	Minimum fluidization velocity[b] (m/s)	Kind
[a]	−850 + 710	780	5.92	0.38	Jetsam (colored)
[b]	−710 + 600	655	5.22	0.29	Jetsam (colored)
[c]	−600 + 500	550	4.56	0.21	Jetsam (colored)
[d]	−500 + 425	462.5	3.94	0.15	Flotsam
[e]	−425 + 300	326.5	2.82	0.08	Flotsam

[a] Value calculated according to Haider and Levenspiel [25].
[b] Value calculated according to Wen and Yu [26].

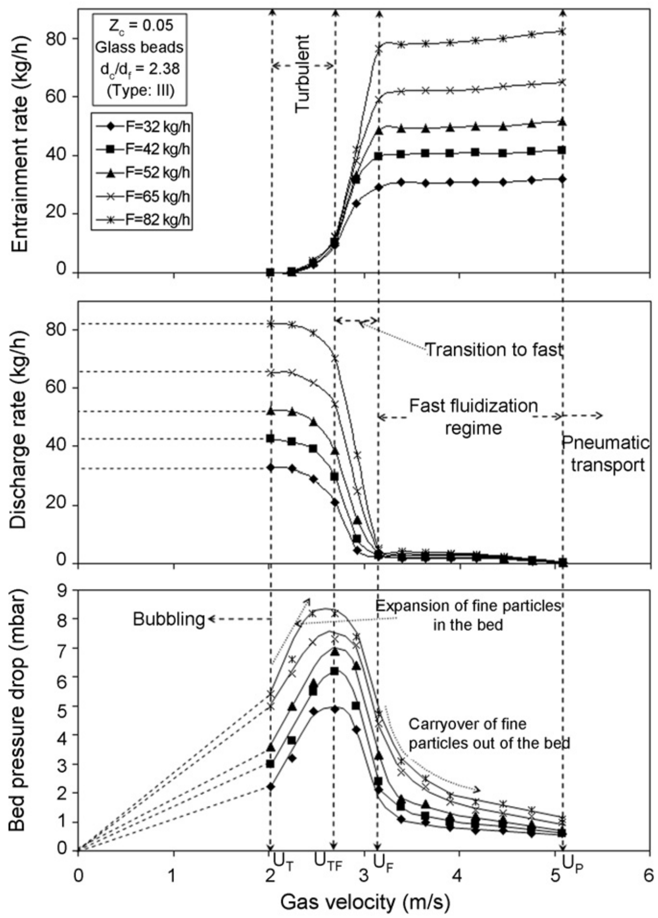

Fig. 1. Fluidization behavior of flotsam-rich feed mixture.

tion behavior of the binary mixture of solids of varying size mainly depends on the flow rate of fluid through it and also a number of effects such as the solids feed rate, feed composition, feed characteristics and column design. In the present study, the fluidization behavior of the flotsam-rich and jetsam-rich mixtures is studied for various solids feed rate and gas velocity. A variety of flow structures for the bed consisting of a binary mixture of particles of different size is identified from the measured bed pressure drop, entrainment rate and discharge rate of solids.

3.1.1. Flotsam-rich feed mixture

Fig. 1, typically, shows the fluidization behavior of the flotsam-rich binary mixture of type III for various gas velocity and solids feed rate. It is obvious from the figure that with increase in gas velocity, the entrainment rate increases and the discharge rate decreases for various solids feed rate. The bed pressure drop reach a maximum, decline, and then gradually level off. When the operating gas velocity is less than U_T, the fluidized bed behaves like a bubbling column. The solids are ejected by the bubbles in the freeboard. The ejected solids from the dense bed by the bubbles do not attain sufficient velocity to entrain out and falls back towards the distributor into the bed. Hence there is no entrainment of solids and only discharge of solids. At gas velocity U_T, the entrainment of solids begins. The bubble motion becomes increasingly vigorous as the gas velocity increases. The bubbles coalesce above the distributor. Internal circulation becomes well established, with bubbles primarily moving through the core region while the solids tumble down along the annular region. The operating regime is believed to be turbulent where the competition between the large bubble formation process and breakup process is continuously present. The rate of entrainment and the rate of discharge of solids balance with the solids feed rate and the operation is steady. The transition of the turbulent regime to fast fluidization regime is said to occur over a relatively small gas velocity range of U_{TF} to U_F defined by an increase in solids carryover from the bed with further increase in gas velocity. The flow structure becomes homogeneous compared to turbulent fluidization due to disappearance of bubbles when the gas velocity crosses U_F. A sharp change in the pressure gradient is recorded. The fast fluidization is characterized by the presence of two zones: a lower dense-phase zone with high-pressure gradient and an upper lean-phase zone [27–29]. A sharp drop in the discharge rate of solids and raise in the entrainment rate of solids are noted. The transition velocity remains unaltered with the range of solids feed rate selected. The solids volume fraction in bottom dense region in the fast fluidized bed is found to be comparable to the solids volume fraction of the turbulent bed. Most of the ejected particles into the free board are entrained out of the bed. The dense phase of the bed is rich in the particles and the dilute phase of the bed is rich in the fluid. Further increase in the gas velocity decreases the bottom dense phase zone. The hold up of the solids in the bed reduces. Decrease in particle-particle friction and volume fraction of solids in the bed results in minimum bed pressure drop. At the final stage, the bottom dense zone completely disappears. When the velocity crosses U_P, the bed is transformed into a pneumatic transport line. When the gas velocity is increased beyond U_P, the holdup of solids is minimum and the bed pressure drop remains unaltered. At fixed solids feed rate U_F is the lower bound and U_P is the upper bound for the existence of the fast fluidization with binary mixture of solids.

The choking of solids is not observed in the size segregation of solids because the volume fraction of solids is lesser for size segregation of solids compared to that of the density segregation of solids and density of the solids selected for the study possibly an additional reason [30].

3.1.2. Jetsam-rich feed mixture

Figs. 2 and 3 show the fluidization behavior of the jetsam-rich binary mixture of type VI for various gas velocity and solids feed rate. As described earlier, with increase in gas velocity, the entrainment rate increases and the discharge rate reduces for any feed composition due to increase in the drag force acting on the solids. When the operating gas velocity is below U_T, the entrainment of solids from the bed is zero and the discharge rate is highest. The observed regime is bubbling. The entrainment of solids begins when the operating gas velocity is U_T. Further increase in gas velocity, the bottom densely filled bed begins to expand and the inter-particle friction greatly reduces. The voidage of the bed increases. The entrainment

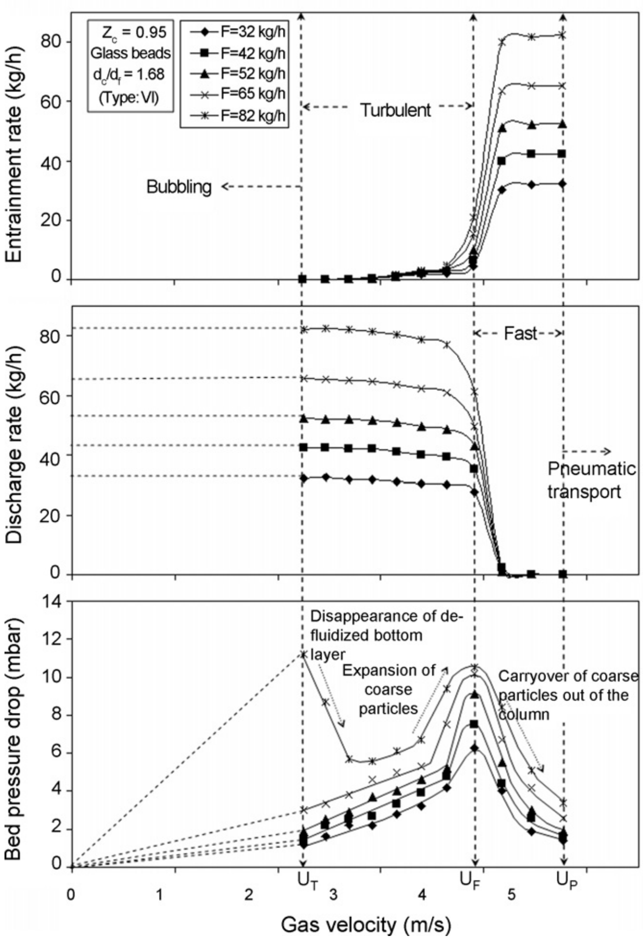

Fig. 2. Fluidization behavior of jetsam-rich feed mixture.

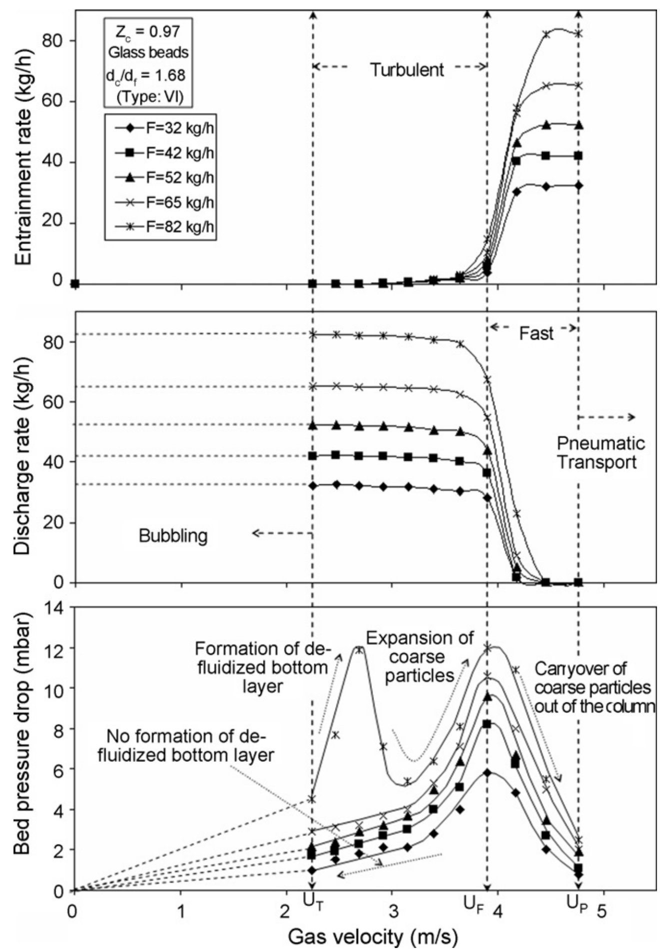

Fig. 3. Fluidization behavior of jetsam-rich feed mixture.

rate of solids increases and the discharge rate of solids start dropping.

The coarse particles settles down for higher solids feed rate and lower gas velocity which results in the formation of de-fluidized bottom layer. A growth of the de-fluidized bottom layer is identified for the higher solids feed rate of 82 kg/h. Lesser composition of the fine particles in the jetsam-rich feed mixture increases the viscosity of the bed markedly and activates in the formation of the de-fluidized bottom layer. The effect of adding a relatively large amount of coarse particles to a bed of flotsam-rich particles has little effect on its viscosity. Generally, the effect of increasing the fine particles concentration in the bed tends to prevent the interlocking of coarse particles in the bed and hence reduce its viscosity. Increasing the amount of fine particles in the jetsam-rich mixture will serve as the lubricant to reduce the friction between the coarse particles and thereby the bed viscosity decreases. Presence of additional fine particles than necessary to keep the coarse particles from interlocking has a minor effect on the bed viscosity [31].

Comparing Figs. 2 and 3, it is understandable that a mixture with more amounts of fine particles lubricates the coarse particles and releases the fine particles which form a fluidized bed. A mixture with less than minimum amount of fine particles, however, cannot release the fine particles because of their interlocking with coarse particles forms the de-fluidized layer. Higher velocity is therefore required to fluidize the mixture and to separate the fine particles. Increase in gas velocity, increases the entrainment of solids and the concentration of coarse particles in the dilute phase and ends in disappearance of de-fluidized bottom layer. The operating regime is found to be turbulent when the operating gas velocity is between U_T and U_F.

When the operating gas velocity is U_F, the entrainment increases sharply and the discharge rate drops since the coarse particles begins to entrain out of the column. The voidage of the bed increases further because of decrease in the holdup of solids in the bed. The downward flow of the solids towards the distributor greatly reduces. Most of the particles entering the freeboard are entrained out of the column. The operating regime is found to be fast when the operating gas velocity is between U_F and U_P. The recorded peak in the bed pressure drop corresponds to the expansion of coarse particles and the carryover of coarser solids out of the bed. The coarse particles attains sufficient velocity to entrain out at the bed pressure drop corresponds to the head of the peak. When the velocity is above U_P, the bed behaves as the pneumatic transport of solids. It is noticed that the dense region in a fast bed contain more solids similar to those in the turbulent fluidized beds while the dilute region contain less solids similar to those in the pneumatic transport lines.

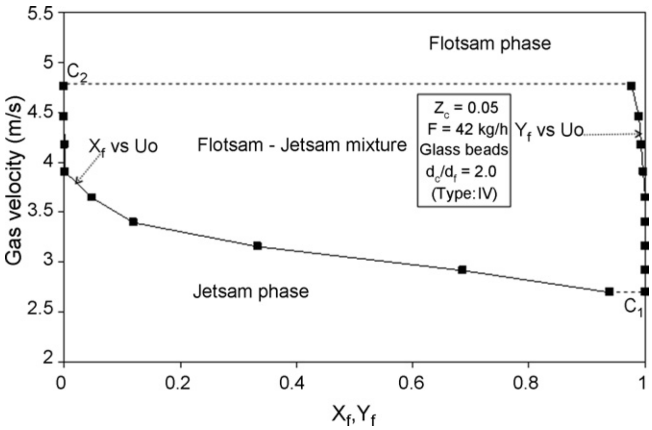

Fig. 4. Velocity concentration phase diagram.

3.2. Velocity–concentration phase diagram

Fig. 4, typically, shows the velocity–concentration phase diagram of the type IV flotsam-rich mixture. The U_0–Y_f–X_f diagram shows how the equilibrium compositions of fine and coarse particles in the binary solids mixture vary with gas velocity. The entire diagram can be divided into three different regions, viz., jetsam phase, jetsam–flotsam mixture and flotsam phase as performed in density segregation study [1].

The upper curve provides the velocity–flotsam composition (U_0–Y_f) relationship that is the carryover of solids. The lower curve provides the velocity–jetsam composition (U_0–X_f) that is the settling of solids. When the fluidized bed is operated below the point C_1, the separation of the particles does not exist. The fine particles fed into the column would not attain sufficient velocity to entrain out. The expanding fine particles from the bed slow down in the freeboard and fall back into the bed. There is only discharge and no entrainment of solids. All the solids behave like jetsam. The holdup of solids in the fluidized bed depends on the solids feed rate. The fluidization regime is bubbling. The material flow from the bed is steady. The concentration of solids in the bottom flow is equivalent to the feed composition. When the fluidized bed is operated above the point C_2, all the solids of the binary mixture behave like flotsam. The discharge rate is zero. The segregation of particles does not exist. The holdup of solids in the fluidized bed is less. The concentration of solids in the top flow is equivalent to the feed composition. The column acts like a pneumatic transport of the solids.

Segregation of the binary mixture begins at point C_1 when the gas velocity is sufficiently enough to fluidize the entire height of the column. The entrainment of solids from the fluidized bed at this point is lower while the discharge of solids is higher. The top flow is pure flotsam ($Y_f = 1$) since only fine particles are entrained. The holdup of solids in the fluidized bed is more. The segregation of solids ends at the point C_2. At this point the entrainment of solids from the fluidized bed is highest while the discharge of solids is least. The bottom flow is pure jetsam ($X_f = 0$). The points C_1 and C_2 are therefore critical points. For separating any binary system the points C_1 and C_2 must be known.

In designing an equilibrium segregation process it is necessary that conditions be selected such that both flotsam and jetsam phases co-exist. The condition of the two-phase region lies between the points C_1 and C_2. Mixture of coarse and fine particles is found in both top as well as bottom flows. This region is found to be the operating regime for segregation of binary mixtures in the continuous fast fluidized bed. As the gas flow rate increases, segregation occurs over a range of velocity. At any velocity, the line U_0–Y_f gives the concentration of the top flow and the line U_0–X_f gives the concentration of the bottom flow.

When the bed is operated in-between the points C_1 and C_2 there is distribution of the fine and coarse particles in the top and bottom flows. The fractional entrainment is fixed by the mass fraction of the fine or coarse particles in the top and the bottom flows.

3.3. Effect of solids feed rate

The influence of solids feed rate on the phase diagram is investigated for different gas velocities and feed composition. The different sets of the data obtained for the flotsam-rich and jetsam-rich mixtures shows identical behavior as presented, typically, in Figs. 5 and 6. The area of the flotsam–jetsam coexistence curves shrink with increase in the solids feed rate both for the flotsam-

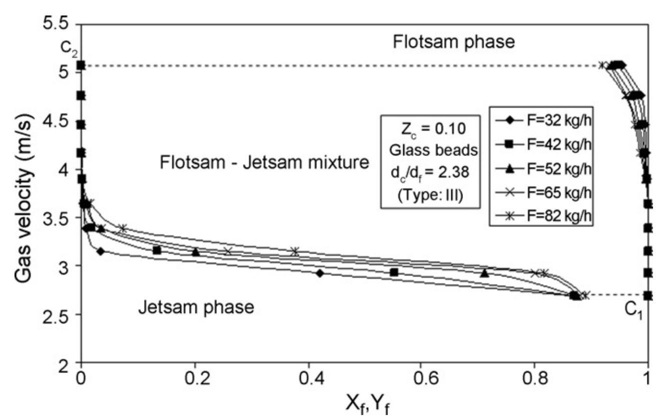

Fig. 5. Effect of solids feed rate on the phase diagram for flotsam-rich feed mixture.

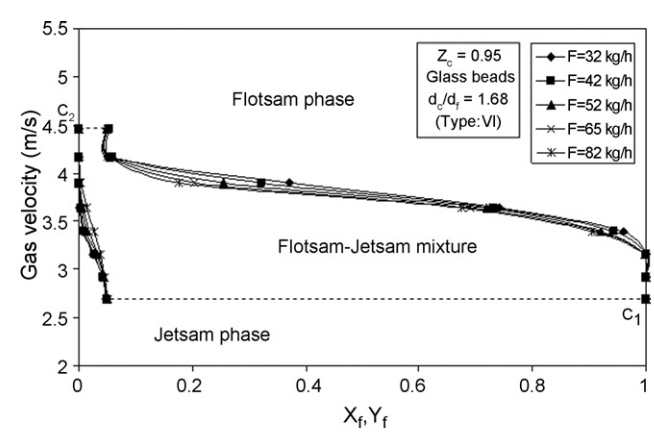

Fig. 6. Effect of solids feed rate on the phase diagram for jetsam-rich feed mixture.

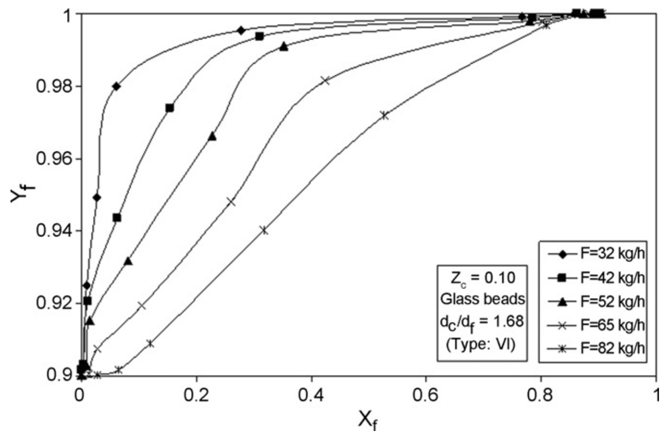

Fig. 7. Effect of solids feed rate on the equilibrium diagram for flotsam-rich feed mixture.

rich and jetsam-rich feed mixtures. The critical points C_1 and C_2 remain constant for any feed rate of solids. The created equilibrium curves for different solids feed rate for the flotsam-rich and jetsam-rich mixtures is presented, typically, in Figs. 7 and 8. For higher solids feed rate the equilibrium lines approach the diagonal. This confirms that the better separation of solids is not possible with increase in solids feed rate to the fluidized bed. The obtained result is regular when comparing with the density segregation of solids [1].

At higher solids feed rate the volume fraction of particles in the fluidized bed column is more. Particle–particles interactions increase. Due to this, the mobility of single particle is affected by the neighboring particles. The differential settling of the particles decreases as the outcome. The period of residence of the particles inside the column is believed to be more. The concentration of fine particles in the top flow and the concentration of coarse particles in the bottom flow reduce because of this effect with increase in the solids feed rate. This effect is dominating when the operating gas velocity is lower. At higher gas velocities, the entrainment of solids is more. So the concentration of fine particles in top flow further reduces due to increase in the carryover of coarse particles along with the fine particles to the top flow. In summary, it can be said that the increase in the solids feed rate reduces the concentration of fine particles in top flow and concentration of coarse particles in the bottom flow due to decrease in the differential settling of solids.

Comparing the obtained results of jetsam-rich and flotsam-rich mixtures, the effect of solids feed rate on the concentration distribution of jetsam-rich mixture is found to be little. This proves that the amount of fine particles reporting to bottom flow and amount of coarse particles reporting to top flow is found to be lesser for jetsam-rich mixture for higher solids feed rate. This is believed to happen because of decrease in formation of particles clusters and increase in settling of coarse particles for higher solids feed rate and higher feed composition of coarse particles.

When there is no differential settling, no separation is achievable. This happens at very high solids feed rate and very low operating gas velocity. If it is required to obtain the top flow with only fine particle species, then one has to operate at a lower solids feed rate and lower gas velocity approximately the critical velocity. If one operates the fluidized bed at higher feed rates, it will not be possible to avoid contamination with the coarse particle species even at lower gas velocity [21,24].

3.4. Effect of feed composition

The particles fluidization behavior as well as the composition of the top flow and bottom flow is affected by changes in the concentration at which the initial mixture is supplied to the column. Figs. 9 and 10, typically, illustrate the effect of feed composition on the phase diagram for the flotsam-rich and jetsam-rich feed mixtures. The shape of the curves alters due to the change in

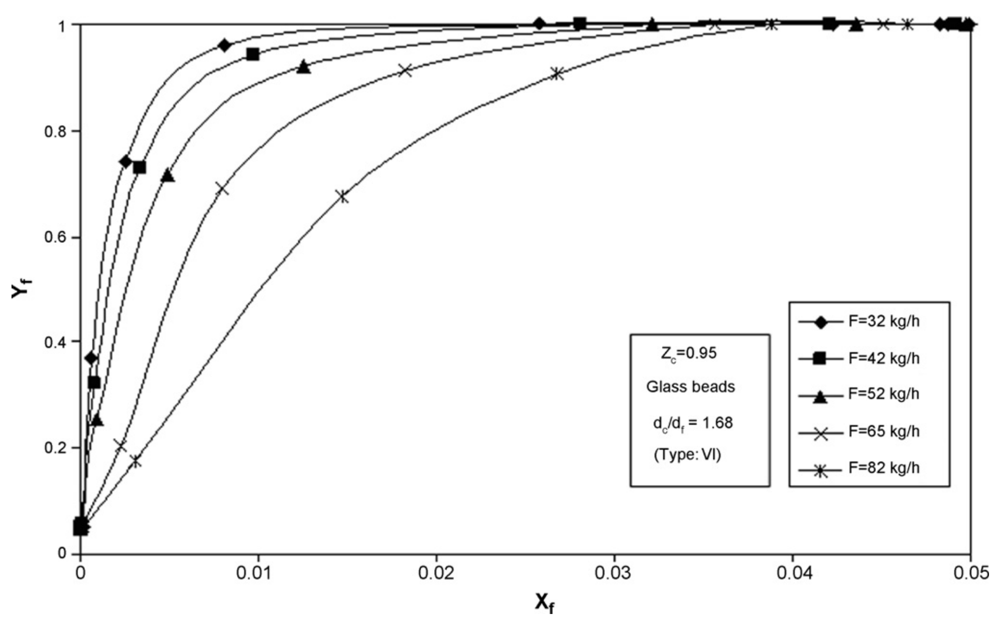

Fig. 8. Effect of solids feed rate on the equilibrium diagram for jetsam-rich feed mixture.

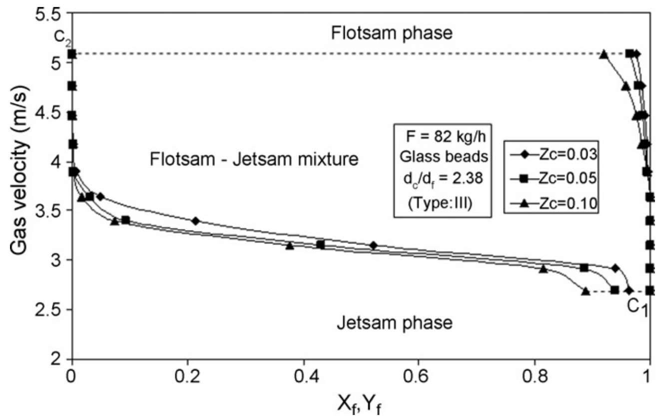

Fig. 9. Effect of feed composition on the phase diagram for flotsam-rich feed mixture.

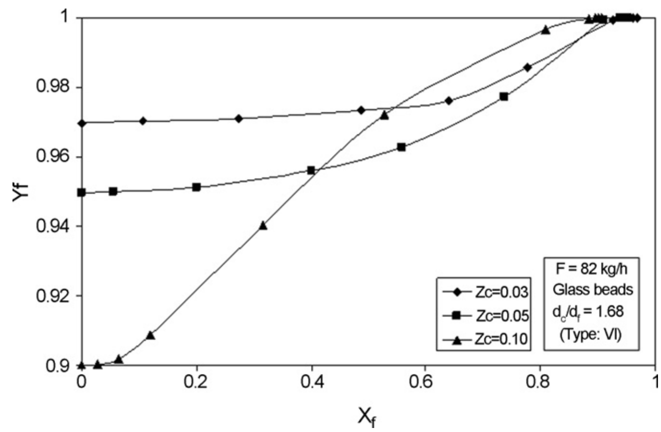

Fig. 11. Effect of feed composition on the equilibrium diagram for flotsam-rich feed mixture.

the concentration of particles in top and bottom flows for the flotsam-rich and jetsam-rich feed mixtures.

The settling of coarse particles is found to be more for higher feed composition of coarse particles. So the composition of coarse particles in the bottom flow increases. Decrease in voidage due to increase in coarse particles concentration in the bottom dense phase reduces the settling velocity due to hindered settling of solids. It is understood that clusters are created in the freeboard due to non-uniformity in the return flow of the fluid due to the settling of solids. The created clusters capture few coarse particles in the freeboard along with the fine particles to the top flow. So, the composition of fine particles is found to be lower in the top flow. This effect mostly disappears at higher gas flow rates. It is well known that the entrainment of solids increases with increase in the fine particles concentration in the feed mixture. The carryover of coarse particles along with the fine particles increases with the increase in the entrainment. The concentration of the bottom flow attains maximum and the concentration of top flow drops further at higher gas velocities.

The area of the curve remains unaltered since the concentration of coarse particles in the bottom flow increasing and the concentration of fine particles in the top flow decreasing with increase in the feed composition of coarse particles. The critical points C_1 and C_2 remain constant for any feed composition of the solids. The effect of feed composition of size segregation study is found to be identical to the effect studied in the density segregation of solids [1].

The effect of feed composition on the binary system equilibrium is presented for type VI system, typically, in Figs. 11 and 12 for flotsam-rich and jetsam-rich feed mixtures, respectively. For higher feed composition of the coarse particles, settling of coarse particles is more and the concentration of the coarse particles in the bottom flow increases. Fine particles concentration in the top flow is higher since only fine particles are entrained at lower gas velocity. But at higher gas velocities the concentration of fine particles in the top flow decreases due to the carryover of the coarse particles along with the fine particles. The equilibrium curves are reproducing the observed result. The observed trend depends on the type of the system and fluidization behavior of the mixtures. Generally, higher the composition of coarse particles in feed ends in poorer separation.

3.5. Effect of particle size ratio

The particle size ratio is defined as, $\alpha = d_c/d_f$. It is well known that the separation of components from a solid mixture via fluidization depends principally on the differences in density or

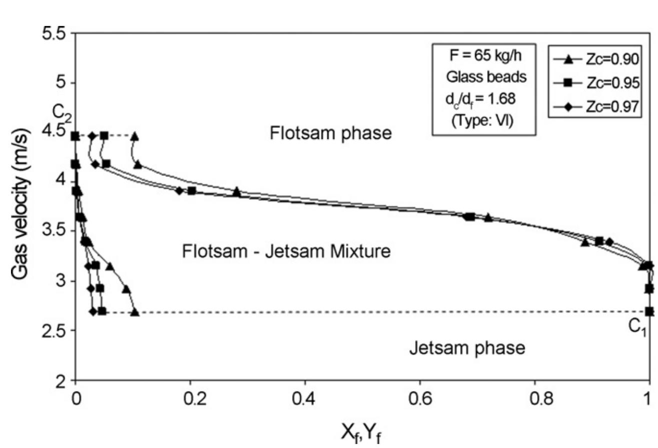

Fig. 10. Effect of feed composition on the phase diagram for jetsam-rich feed mixture.

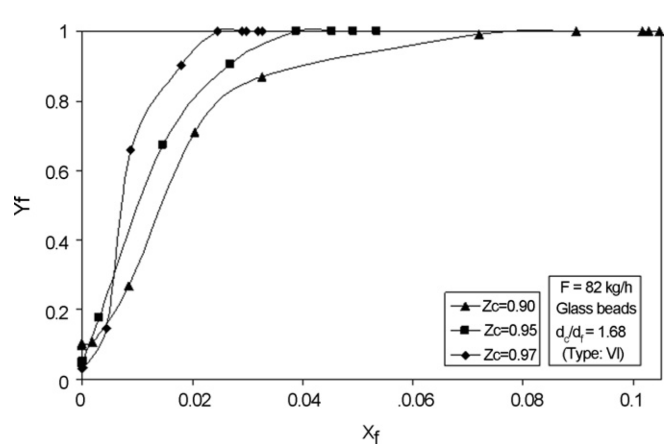

Fig. 12. Effect of feed composition on the equilibrium diagram for jetsam-rich feed mixture.

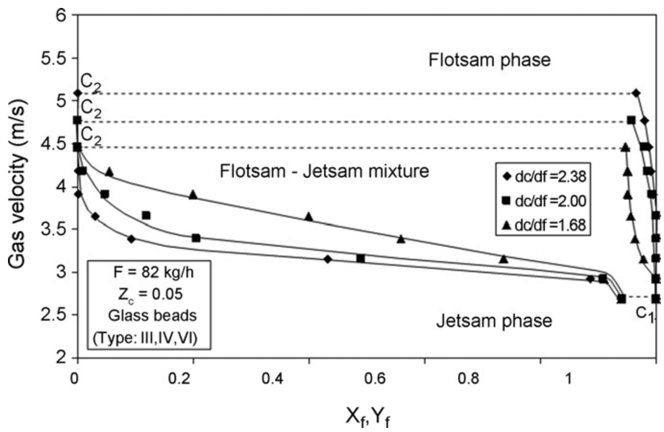

Fig. 13. Effect of particle size ratio on the phase diagram.

size of the individual components. The effect of particle size ratio on the separation of particles is examined in the present study. Three different size ratios of 2.3, 2 and 1.6 of mixtures types III, IV and VI were tested in the present work. The selected size ratio used in the experiments is listed in Table 2. The fine particles used in the mentioned three types of binary mixture is same. The coarse particles size is diminished for getting the required particle size ratio.

The shape and the position of the phase diagram curves depends on the ratio of the densities or the dimensions of solids particles in the binary mixture. The effect of particle size ratio on the phase diagram is presented, typically, in Fig. 13. When α is closer to unity, the area of the phase diagram is very less. There will be a discontinuity in the curves when α is very high. Generally with increase in α, there is an increase in the area between the curves of the beginning of entrainment and the ending of settling. Therefore the range of existence of the mixture of two components in the top and bottom flows increases and the separation becomes sharper. Else the separation becomes poorer while the size or density ratio of the particles is lesser.

The critical points C_1 and C_2 depend on the density or the size ratio of the particles to be separated. From the Fig. 13, it is obvious that the critical point C_2 varies with increase in the particle size ratio in the feed mixture. Fig. 14, typically, shows the effect of particle size ratio on the existing physical equilibrium between the flotsam and jetsam phase. It is understandable from the figure that for the minimum particle size ratio, the equilibrium lines approaches the diagonal. This clearly bears out that decreasing the particle size ratio ends in poorer separation. It is also noticed in the figure for size ratio less than 2 there is a rapid fall in the concentration of both top and bottom flows. The fine particles and the coarse particles move hither and thither inside the fluidized bed at intermediate gas velocities due to the reduction of particle size ratio. The carryover of coarse particles as well as the settling of fine particles occurs in such case.

The particle size or density ratio is believed to be comparable with the relative volatility ratio of separation of liquid mixtures in the distillation column. The co-existence of the flotsam–jetsam phases decreases with decrease in the particle size or density ratio. This occurs because of the convergence of the terminal settling velocities of the components. It is impossible to separate the mixture sharply into components by fluidization, when the terminal settling velocities of the components are close to one another. This is analogous to the reduction of the relative volatility of a liquid mixture as the boiling points of the components converge [24]. Continuous, stable and complete separation is achievable when the density or size ratio is greater than 2.4.

3.6. Effect of particle size

Fig. 15, typically, shows the effect of particle size on the velocity–concentration phase diagram for types V and VI mixtures. Type V mixture is made of 780 μm size particles as coarse and 462.5 μm size particles as fine and type VI mixture is made of 550 μm particles as coarse and 326.5 μm particles as fine. Both the types has same particle size ratio of 1.68 but the position of the *U–XY* curves varies for both the mixtures. Fig. 16, typically, shows the effect of particles sizes on the equilibrium lines. These figures indicate that the granular mixture of larger diameter particles provides a better separation compared to that of the smaller size particles. This outcome believed to occur because of the increase in the formation of the particles clusters due to the reduction in the diameter of particles. But the energy requirement for the separation of fine particles mixture is less compared to the coarse particles mixture.

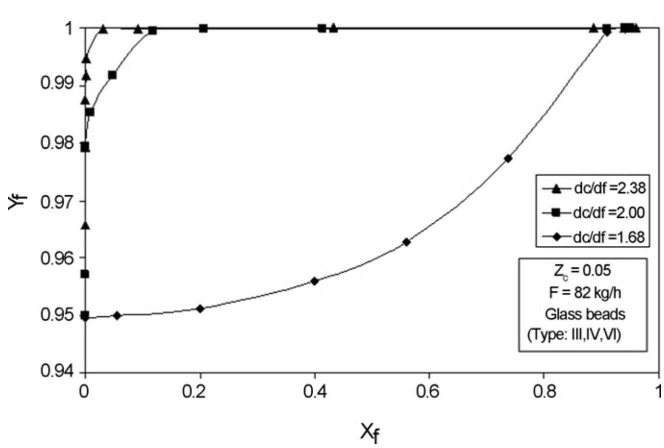

Fig. 14. Effect of particle size ratio on the equilibrium diagram.

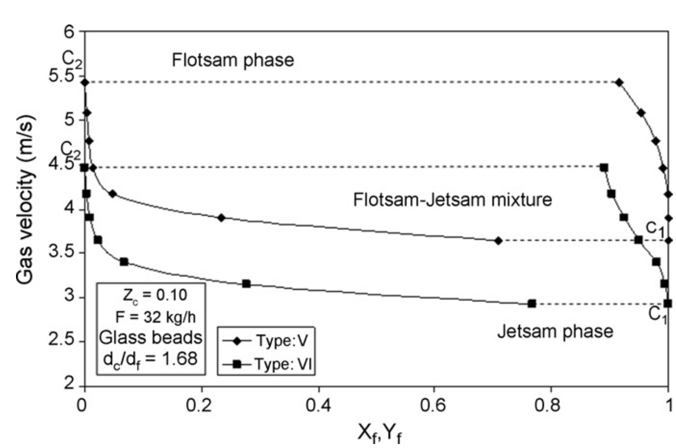

Fig. 15. Effect of particle size on the phase diagram.

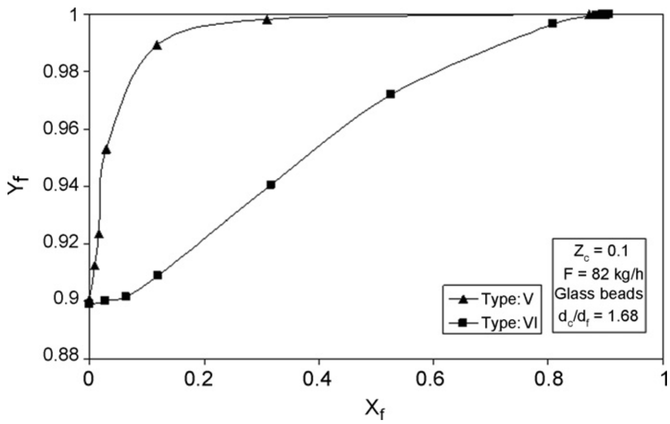

Fig. 16. Effect of particle size on the equilibrium diagram.

The critical point C_1, decreases with reduction in the particle diameter or density of the lighter/fine particles. The critical point C_2, increases when the particle diameter or density of the heavier/coarse particles is higher in the system selected for separation. The area of the coexisting flotsam and jetsam phase seems to vary marginally comparing both the cases. Fig. 15 clearly brings out the statement that the position of the co-existence of the jetsam and flotsam phases in the phase diagram and critical points C_1 and C_2 depends on the individual particles sizes.

4. Conclusions

The segregation of a binary mixture differing in particle size with the same density was experimentally studied for flotsam-rich and jetsam-rich feed mixture. The column pressure drop, entrainment and discharge rates, mass fraction distributions of fine and coarse particles in the top flow and bottom flow were determined for each experiment. Fluidization behavior of the flotsam-rich and the jetsam-rich feed mixture was presented. Analysis of the obtained data confirmed the dependency of the particle segregation on the solids feed rate, feed composition, particle size ratio and particles size. The results are presented as phase diagrams and equilibrium diagrams in agreement with the analogy of distillation. Some contradictory observations noted in case of the size segregation of solids compared with the density segregation [1] are highlighted.

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