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Experimental RTD Studies In Circulating Fluidized Bed

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ABSTRACT
In the present study the tracer experiments were carried out in a 0.0762m ID and 3m height specially designed laboratory scale liquid – Solid circulating fluidized bed apparatus by using plastic beads act as solid media and Water as fluidizing media. Dispersion Coefficients were calculated, effect of bed height, liquid velocity and solids flux on the Dispersion Coefficient was thoroughly studied.
KEY WORDS: Residence time, liquid solid circulating fluidized bed, Dispersion number.

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I INTRODUCTION

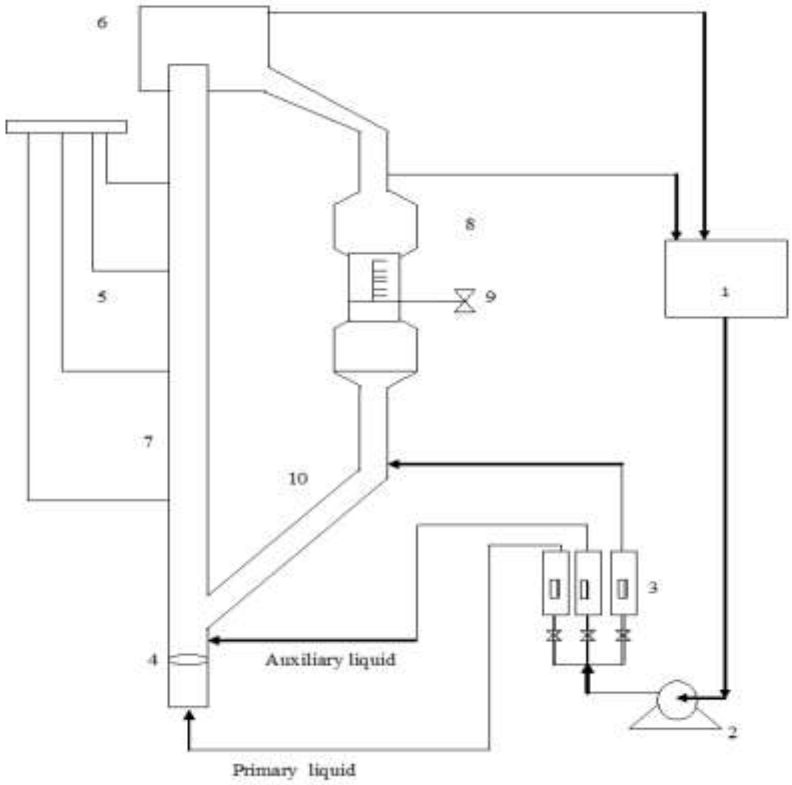
In the past few years, there have been some limited studies on the hydrodynamics in the riser of the LSCFBs and its overall operation [1-5].when the liquid velocity is low, the riser is operated in the extensively studied conventional fluidization regime, which is considered to be a homogeneous where particles are uniformly spreader in both axial and radial directions in the dense phase [6]. When the liquid velocity is increased beyond the particle terminal velocity, the liquid fluidized bed in the riser transfers into the high velocity circulating fluidized regime [7-8]. LSCFB is an excellent candidate for the continuous recovery of protein from unpurified whole broth where the adsorption and desorption of proteins can be carried out separately in the down comer and the riser in a continuous mode with the ion exchange particles adulating between the two columns, where it requires longer residence times to use the riser for desorption and the down comer for adsorption. A superlative candidate for enzymatic reactions and regeneration of biocatalyst can be carryout concurrently and independently in the LSCFB system. The continuous enzymatic polymerization was carried out in the riser part and in the down-comer regeneration of the coated immobilized enzyme particles of LSCFB [9], while there are many reports on the gas – solid circulating fluidized systems comparatively liquid – solid systems. However, extending the current knowledge on the gas-solid systems to liquid-solid fluidized systems may lead to open new horizons for potential applications of circulating fluidized bed technology, especially for the field of Chemical, Biochemical, Food processing, Petrochemicals and Metallurgical processing, etc. For analysis, design and evaluating the performance of continuous fluidized beds, the measurement of the residence time distribution (RTD) has become a prominent tool. Residence time theory deals with how particles enter flow through and leave the system. It seems natural to expect that not all the particles will have the same residence time, so still it needed the thrusting research area.

In this present work, RTD experiments were carried out in liquid solid circulating fluidized bed (LSCFB) in order to understand the effect of liquid velocity, solids flow rate and bed height on axial distribution.

II MATERIALS AND METHODS

Experimental set-up of the LSCFB

The experiment has been conducted to determine the average resident times and the resident time distributions of particles in the riser of a circulating fluidized bed. Present work, LSCFB referred as the riser-down comer type LSCFB and it shown schematically in fig.1. The system consists of a Plexiglas riser with an I.D. of 0.076m and a height of 3m and the down comer of 121mm in ID and 2.5m in height. The riser was connected to the down comer on the upper part through the liquid - solid separator, the top washing section and the top solids return pipe. The liquid-solid separator is a cone based cylindrical vessel made of glass and of 11.016cm in diameter. The solids rate measuring device is Perspex and of 0.0889m in Dia., it consists of a butterfly valve, used to measure the height of the solids accumulated over a given time period. The solids feed pipe is 0.0350m in diameter and is made of glass; it connects the solids rate measuring device and the base of the riser, and is inclined at an angle of 50^0 to the vertical. At the bottom, the riser and the down comer were connected to each other through the bottom washing section and the bottom solids return pipe. A riser having series of rubber septum's are at equal distances and these are helpful for taking samples.



1. Liquid Reservoir 2. Pump 3. Flow meters 4. Distributer Section 5. Manometers 6. Liquid Solid Separator 7. Riser 8. Solids rate measuring device 9. Valve and 10. Solids feed pipe.

Fig.1: Schematic of Liquid-Solid Circulating Fluidized Bed.

Experimental Procedure

When steady state is reached, a liquid tracer (NaOH) was injected at the bottom of the riser, clearly 100mm above the distributor plugs and preference given to a base tracer to avoid the reactive nature with glass column, many other factors also influenced us to prefer it to acidic tracer and it taken fresh samples for every set of experiments. The samples were collected from four different sections of the bed, such as 0.5m, 1.2m, 1.9m, and 2.8m at equal intervals of time, at their different auxiliary liquid rates and it repeated for different solids flow rates. The concentrations of the samples were measured through obtained calibration readings of the pH. The experiments are repeated to get results as accurate as possible. The holdup was measured by suddenly stopping the liquid flow during steady state operation. A large number of measurements taken at irregular intervals are necessary to prevent measuring the holdup always at the same interval in the oscillation. The solid and liquid media Characteristics were listed in Table.1.

Table1: Characteristics of fluidizing medium considered for present study

Medium	Dp(mm)	ρ_p(kg/m^3)
Plastic Beads	5.0	1080
Water	-	1000

III RESULTS AND DISCUSSIONS

Several methods have been proposed for the determination of the axial dispersion coefficient. In our case, the measurement of RTD curves and exit age distribution functions $C(t)$ and $E(t)$[10] opted and to evaluate axial dispersion coefficient(D_a) by using equations (1) to (4), where C is concentration, C_0 is initial concentration, M is Amount of tracer, t is time and V_0 is volumetric flow rate, D_a is Axial Dispersion coefficient and U_l is Liquid Velocity.

$$C_0 = \frac{M}{V_0} \quad (1)$$

$$E(t) = \frac{C(t)}{C_0} \quad (2)$$

$$\sigma^2 = \frac{\sum C(t)t^2}{\sum C(t)} - (\bar{t})^2 \quad (3)$$

$$\frac{D_a}{U_l(L)} = \Delta\sigma^2 \quad (4)$$

The mean residence time($\bar{t}$) taken from graph $E(t)$, for Plastic beads shown in fig. 2. Even though the dispersion number is a function of variance (σ) and mean residence time($\bar{t}$), effect of the following varibles have been investigated: (i) Influence of liquid velocity (ii) Influence of solids flow rate (iii) Influence of the bed height.

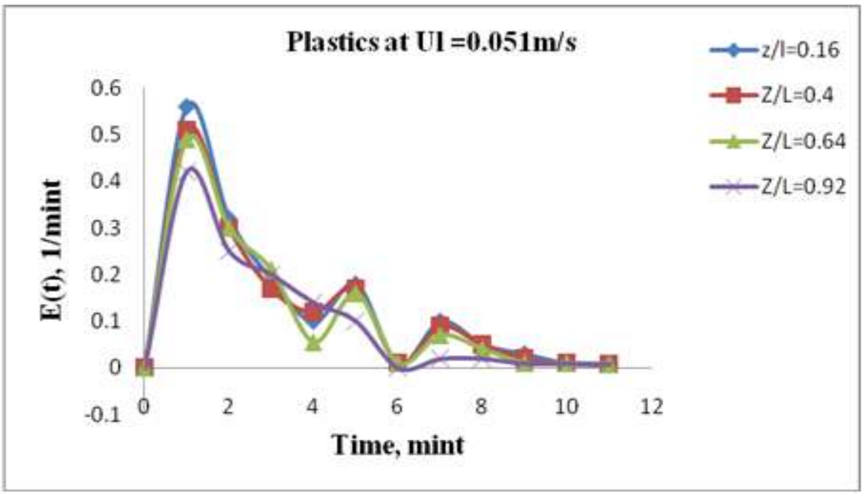


Fig.2: E- Curve for Plastic beads at U_l=0.051 m/s & Gs= 15.12 kg/m^2-s

Influence of liquid velocity

The solids flux is kept constant, the liquid velocity is varied and it has a large influence on the residence time as well as the spread in residence time. With increasing liquid velocity the residence time decreases shown in the fig. 3 and it reveal that effect of liquid velocity on dispersion of plastic beads at different axial heights (Z/L), It was observed that the successive increment on liquid velocity causes a lower hold-up of the solid particles are more able to give corresponding high dispersion values.

Influence of solids flow rate

In this section the liquid velocity kept constant and the solid flow rate is varied and at fixed axial heights. It was found that while increment of solids flow rate, the hold-up constant by applying the same liquid velocity in every experiment, leads to the spread became smaller and particle residence time increases. The effect of Plastic Particles flow rate (Gs) on Dispersion at fixed heights and liquid velocities was shown in fig.4; the dispersion coefficient values are decreases while increases the solids flux.

By comparing the two effects, the mixing mechanism is influenced more by a change in the liquid velocity than by changing the solids flux. These two adjustable parameters in the system can cause reverse effects in the spread of residence time.

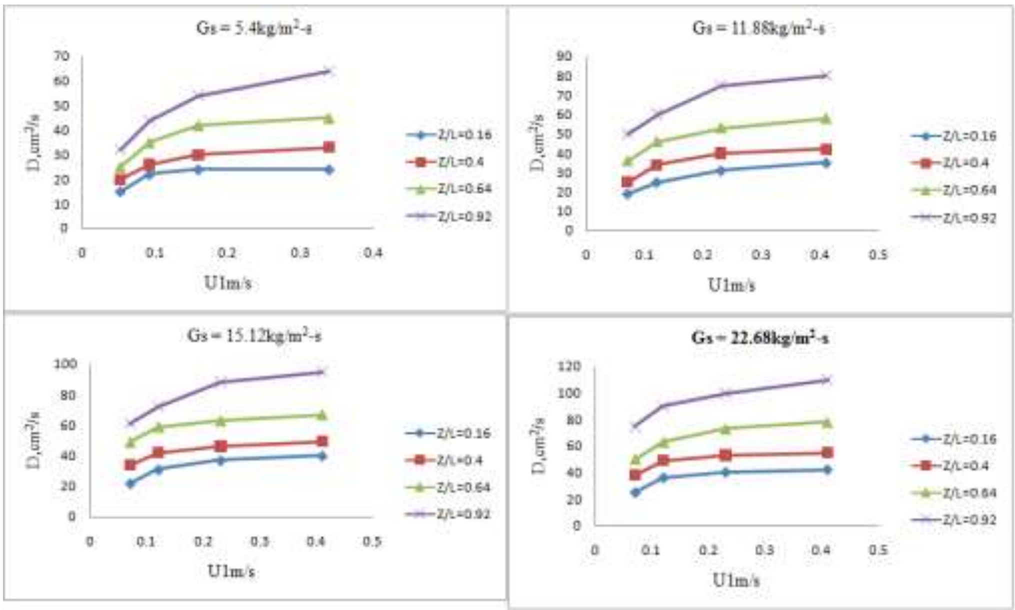


Fig.3: D_a x 10^{-4}cm^2/s vs. U_l for plastics at a fixed solid flow rate for different

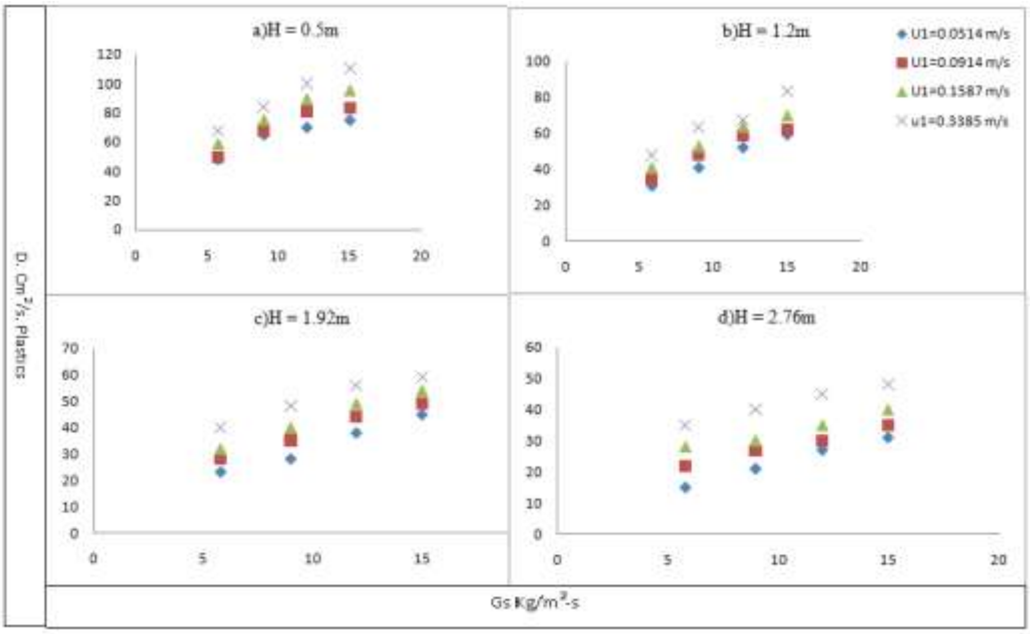


Fig.4: D_a x 10^{-4}cm^2/s vs. Gs for Plastics at a fixed Height for different U_l

Influence of the bed height

The influence of the bed height is studied based on two parameters one is at fixing the solids flux where the liquid flow rate varying, another case maintaining at constant liquid flow rate and different solids flow rate. The effect of Dimensionless fraction of the bed height (Z/L) on axial dispersion at constant Gs of Plastic beads is plotted, it shown in fig.5. The effect of axial dispersion on dimensionless fraction of the bed height (Z/L) at constant U_l and different Gs for Plastic beads shown in fig.6.

By observing both cases, it could be that the axial mixing is high at lower bed heights further the parameters such that liquid velocity (U_l) and solids flux (Gs) contrary in nature with respect dispersion.

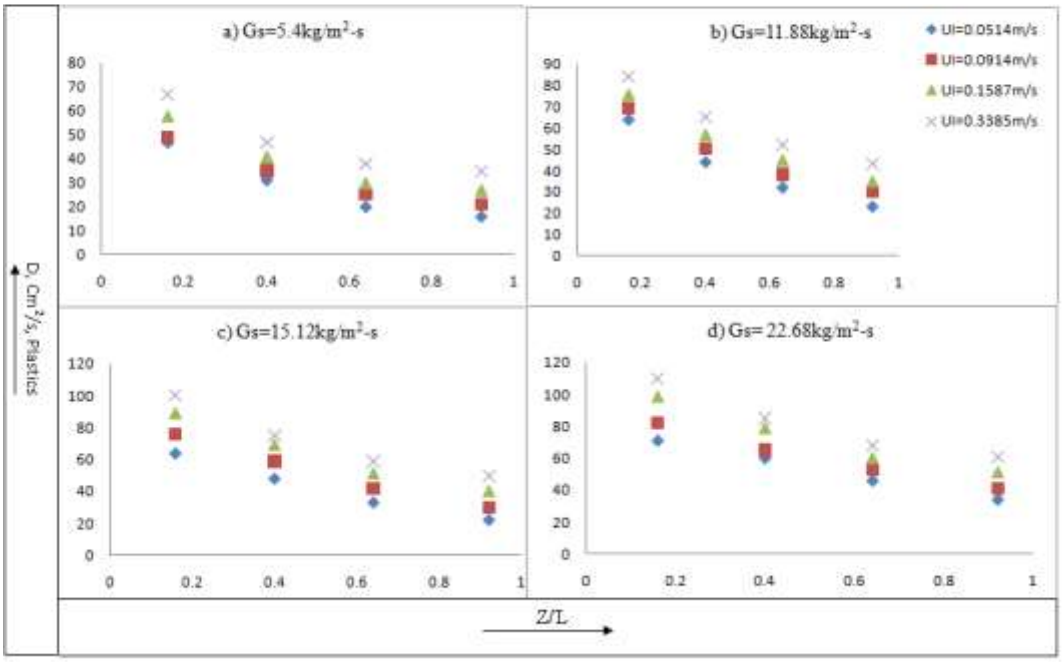


Fig.5: D_a x 10^{-4}cm^2/s vs. Bed Height at fixed Gs for different U_l for Plastic beads.

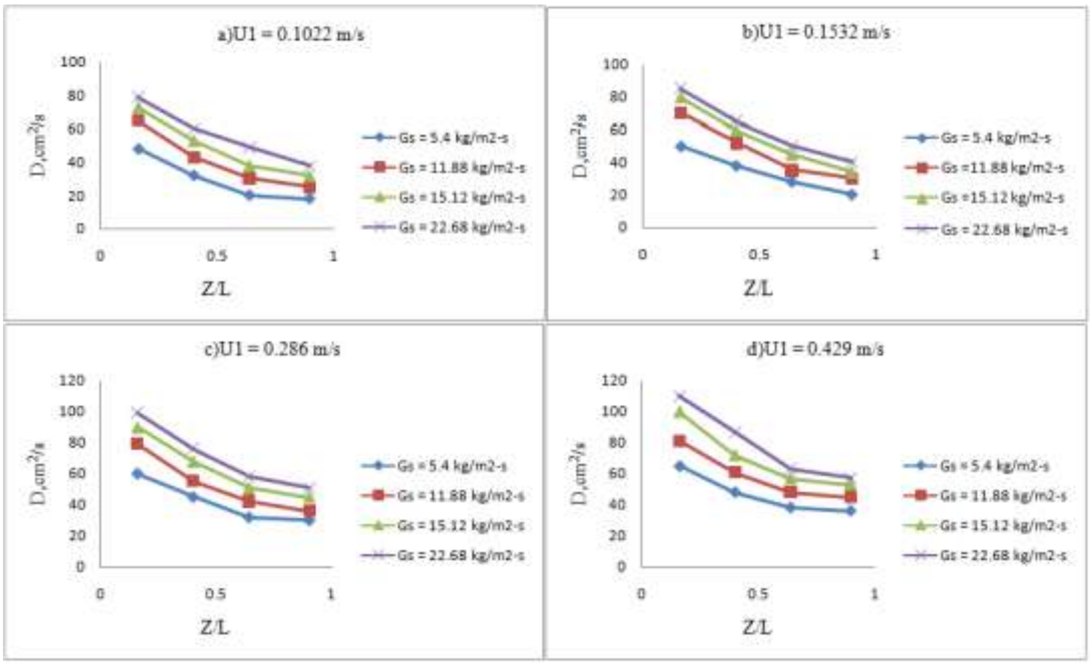


Fig.6: D_a x 10^{-4}cm^2/s vs. Bed Height at fixed U_l for different Gs for Plastics

IV CONCLUSIONS

Experiments were carried out to determine the axial dispersion coefficients by residence time distribution of particles in a circulating fluidized bed operated under high velocity fluidization regime in the riser, and summarizing the results presented in this work, it may be concluded that mixing effects play a major role in fluidization, they tend to give a more mixed flow like behavior with a broad particle size distribution.

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