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Optimization of Design Parameters in Circulating Fluidized Bed for Food Materials using Response Surface Methodology

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Abstract: The objective of the study was to analyze the effect of pressure drop with axial co-ordinate for different gas mass flux and solid circulation rate in a circulating fluidized bed with poppy seeds. The optimum conditions to study the hydrodynamics characteristics were performed using a two-factor and five-level central composite design under response surface methodology. The data obtained from the experiments shows that the pressure drop increases with the gas flow rate and solid circulation rate, but decreases along the length of the riser. It has been observed that to reduce the homogeneity of solids concentration horizontal perforated plates can be placed along the length of the riser. It was found that the pressure will be optimum with a gas flow rate of 6.84 kg/m^2s and solid circulation rate of 4.77 kg/m^2s.The experimental values were nearer to the predicted values.
Keywords- circulating fluidized bed, food grains, gas flow rate, pressure drop, solid circulation rate, response surface methodology, optimization.

Introduction:

Circulating fluidized beds finds applications in Calcination of aluminium hydroxide to high grade alumina, coal combustion and catalytic process such as fluid catalytic cracking and Fischer-Tropsch synthesis. Circulating fluidized beds are being considered as substitutes for conventional fluidized bed because of their apparent intrinsic advantages, including short and controllable residence time for the gas and solids, high turn do and controllable residence time for the gas and solids, high turn down ratios, flexibility, good heat and mass transfer and uniform temperature distribution. The behaviour of CFB differs from a conventional fluidized bed, because of absence of bubbles and entrained flow of solids.

The circulating fludized bed reactor can also be used for drying of food materials and the dried food materials nutrition content was determined by spectroradiometer[4].The downcomer bed height or solids inventory, and the operational status of the solids flow control valve, including its opening and aeration, have to be specified in addition to U_g and G_s when analyzing the gas–solid flows in CFB risers. This provides the general steps necessary to compute the axialvoidage profiles of such riser[3]. The effect of the operating parameters on the system hydrodynamics and mixing inside two circulating fluidized bed reactor risers with different ring baffle configurations were investigated using computational fluid dynamics simulations. It was found that the low variability of the solid particle distribution and the high solid particle concentration will be suitable for chemical reactions[1].

The hydrodynamics and scale-up of liquid-solid circulating fluidized beds were investigated and that developing flow structures in liquid-solid circulating fluidized beds are strongly influenced by some parameters such as turbulent kinetic energy at the inlet so that the proposed similitude method may not always be applicable[8]. Here the hydrodynamics behaviours of the constructed liquid-solid circulating fluidized beds are simulated by a validated CFD model[2] and compared in terms of the axial and radial flow structures characterized by the solids fraction, particle and liquid velocities and solids mass flux.

Experimental :

Hydrodynamics in a 500 mm i.d., 1600mm high circulating fluidized bed (CFB) riser were studied for superficial gas velocities ranging from 3 to 5 m/s.A gas-solid separator and a bag filter were provided at the top of the riser for separating solids and gas. For the co-current upward movement of the solids, air is introduced at the bottom of the column. Air enters through distributor plate of 0.8mm diameter holes from the bottom of the riser. Air for fluidization is supplied through air compressor of 8 HP. Six Pressure tapings are located at the riser column of 500mm, 700mm, 900mm, 1100mm, 1300mm and 1500mm from the riser bottom respectively. The pressure measurements are made using inclined manometer range from 0-50mm water. Ball valves were provided at the solids feed point and at the column to facilitate the measurement of solid circulation rate in the riser[6].The food material used for study was millet with mean diameter 1.40mm and density 845.35 Kg/m^3.

Results and Discussions:

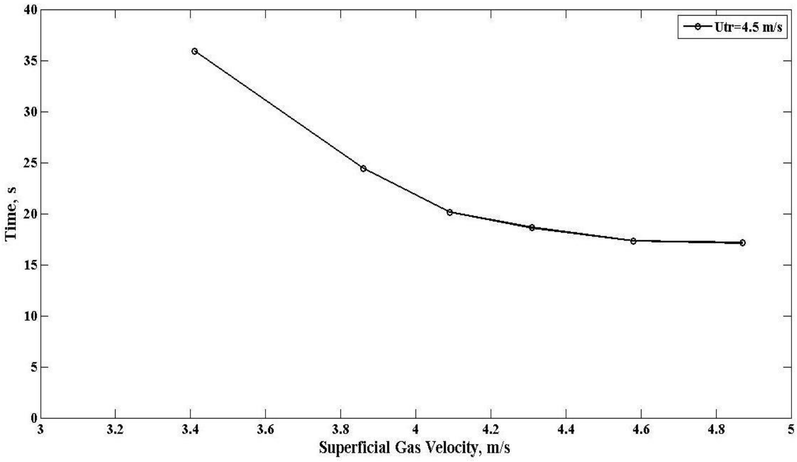

Fig 1.1 : Determination of Transport Velocity

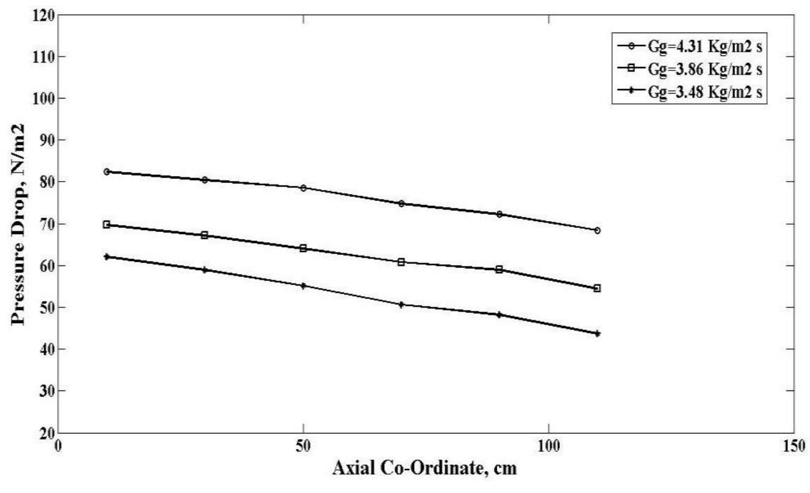

Fig 1.2 : Variation of Pressure drop with gas flow rate

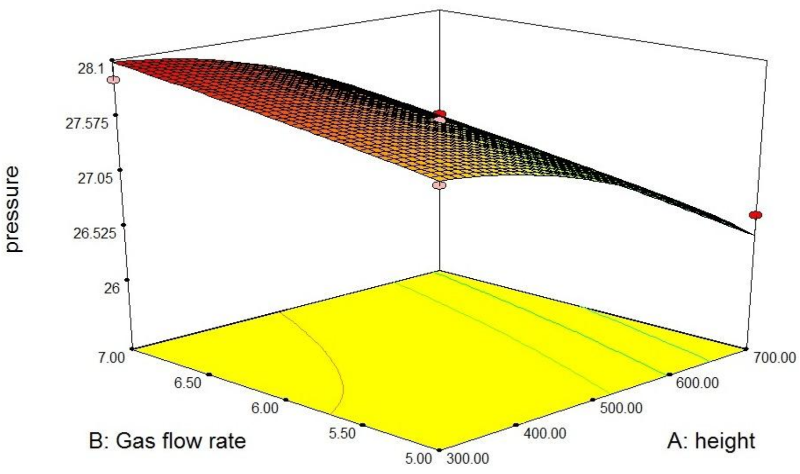

Fig 1.3 : Variation of pressure drop with gas flow rate, optimization using response surface methodology

Gas velocity U_g and solids circulation rate G_s are still being commonly treated as the only parameters determining the hydrodynamics of circulating fluidized bed (CFB) risers. The transport velocity is determined by emptying time techniques and shown in fig 1.1. It has been observed that the time required for emptying of solid particles decreases with increase in velocity. As the velocity increases the bed could be emptied in a short period of time due to sharp increase of particle carryover in the absence of solid recycle The axial variation of pressure drop with gas flowrates 3.48Kg/m^{2}s, 3.86Kg/m^{2}sand4.31Kg/m^{2}s for millet were studied. The variations were shown in fig. 1.2. It was observed that the pressure drop decreases along the length of the riser. The pressure drop is more at the bottom of the riser and decreases towards the top of the riser. When the gas flow rate is increased the pressure drop also increases. The same behaviour was observed in the hydrodynamics of poppy seeds[5]. The results were optimized using response surface methodology and they are shown in fig 1.3.

The non-uniformity of solid particle distribution in a circulating fluidized bed riser is an significant problem, since it leads to a poor system mixing and low chemical reaction conversion. So a ring baffle configuration may be used which can improve the system mixing and eliminated the backflow near the wall with improved heat and mass transfers[7].The axial variation of pressure dropwith different solid circulation rates 6.299 Kg/m^{2}s,7.514Kg/m^2 and 7.891Kg/m^{2}s were studied. The lower part of the riser have higher solids concentration and it is the region of higher hold up, while the upper part of the riser is the region of lower hold up. Fig 1.4 indicates the axial variation of pressure drop at different solid circulation rates, fig. 1.5 show the optimization of the above parameters using response surface methodology. It was observed that the pressure drop and solids concentration decreases along the length of the riser.

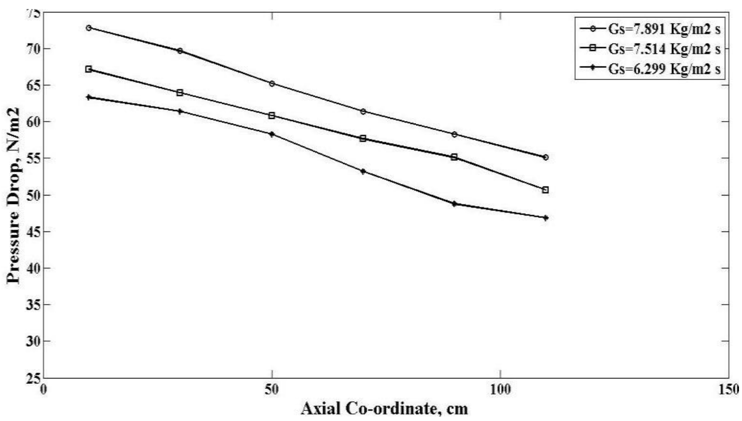

Fig 1.4 : Variation of pressure drop with solid circulation rate

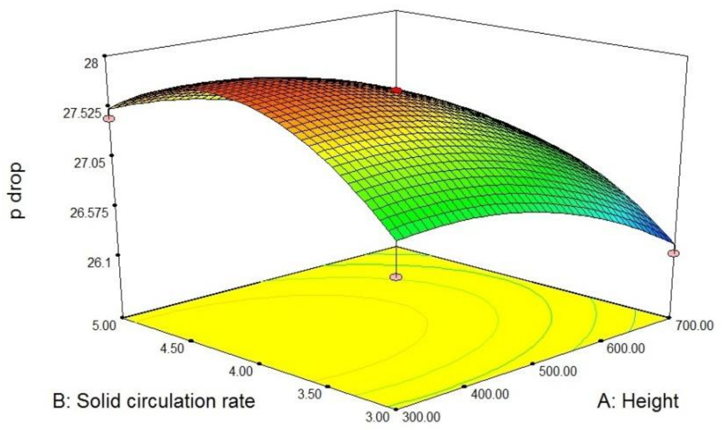

Fig 1.5 : Variation of pressure drop with solid circulation rate, optimization using response surface Methodology

Fig : 1.6 represents the variation of both the solid circulation rate and gas flow rate. At low solids rate, the pressure drop increases slowly, corresponding to pneumatic transport, and at high solids rate, it approaches an asymptotic value corresponding to conventional fluidization. Also, the pressure drop decreases with increase in gas velocity for a given solids rate. It has been observed that the pressure drop increases with solid circulation rate and gas flow rate but decreases with gas velocity. The effect of power on pressure drop for different food materials is shown in Fig 1.7. It has been observed that the power requirement increases with increase in pressure drop.

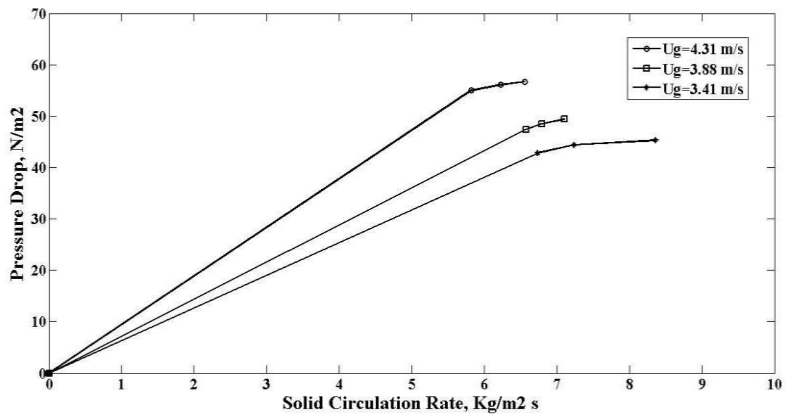

Fig 1.6 : Variation of pressure drop with gas flow rate and solid circulation rate

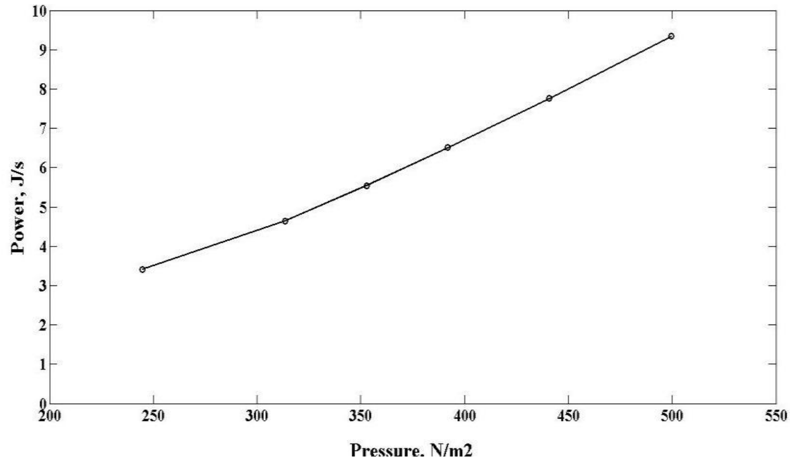

Fig 1.7 :Effect of power on pressure drop

Conclusion:

An extensive investigation has been carried out to study the effect of pressure drop with axial co-ordinate for different gas mass flux and solid circulation ratein a circulating fluidized bed with mustard. It was observed that the pressure drop increases with the gas flow rate and solid circulation rate, but decreases along the length of the riser. The lower part of the riser have higher solids concentration and it is the region of higher hold up, while the upper part of the riser is the region of lower hold up. Using the response surface methodology it was found that the pressure will be optimum with a gas flow rate of 6.84 kg/m^2s and solid circulation rate of 4.77 kg/m^2s.The experimental values were found closer to the predicted values.

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