PERFORMANCE OF MIXING GRANULES SOLID MATERIALS BY FLUIDIZATION

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ABSTRACT

Cohesionless free flowing solid particles of sand (mean particle size 0.642 mm) and salt (mean particle sizes are 0.225,0.433,0.642,0.852,and1.06 mm) with concentration are (5%, 10%, 15%, 20%, and 25%) by weight and similar surface properties were mixed by using a fluidized bed system.The air velocities are (0.85, 0.95, 1.05, 1.15, and1.25) m/s while the mixing time was 1 to 5 minutes.The fluidized column made of standard 3 inch diameter Q. V. F. glass tube, 500mm in height. Each batch was analyzed through a laboratory spinning riffler sampler of eight sample jars.Mixing index was calculated for each experiment, the results were tabulated and treated by using Box-Willson method.

Using Box-Willson method, the experimental data were fitted by, second order polynomial and the coefficients for all controllable variables on mixing index were found.The following response function was obtained:

$$M = -1.4112 + 2.6076X_1 + 0.054X_2 + 1.0416X_3 + 3.4163X_4$$
$$-1.3939X_1^2 - 0.0312X_2^2 - 0.3745X_3^2 - 8.2759X_4^2 + 0.1943X_1X_2$$
$$-0.2359X_1X_3 + 0.0125X_1X_4 - 0.0438X_2X_3 + 010125X_2X_4$$
$$-0.7699X_3X_4$$

The model was tested according to F-test to find the significant of all variable and their interaction on mixing index.The optimum conditions were found by using the model and these variables are:Air velocity = 1.05 m/s, Mixing time = 4 min, Mean particle size of salt = 0.642 mm, and Concentration of salt = 20% by weight.

Mixing index is increased with increasing the air velocity, mixing time, and concentration of trace component until the optimum value. Mixing index is effected by difference of mean particle size of two components and the value of mixing index is depend on magnitude of different in mean particle size.

INTRODUCTION

Mixing of solids materials is widely practiced in industry. It is often required to mix two or more kinds of particulate materials or to homogenize raw or manufactured material. When large quantities of solids are to be mixed and handled, an air mixer is often used {1}.

The mixing of solid systems differs from that liquid system in three respects {2}:

There is no particulate motion equivalent to the molecular diffusion of liquids, therefore there is no relative movement of the particles without an energy input to the mixture.

Although the molecules of a single phase liquid may differ, and may diffuse at different rates, they will ultimately achieve a random distribution, particulate components do not usually have the constant properties of molecular species and differ widely in physical properties, thus a mixing motion which depend on identical particulate properties are unlikely to achieve its objective.

The ultimate element of the material mixture is several degree of magnitude larger than the ultimate molecular element of the liquid mixture.

Particles will change their position only when subjected to movement. Once movement begins, the particles may randomize or segregate depending on both the type of movement imposed on the system and on the physical characteristics of constituents {2}. Mixing of solid particles by fluidization is caused by the passage of a gas through a bed of particles. The industrial utilization of gas fluidized bed has increased markedly, and their application now extends into many diverse fields. The fluidized state provides a convenient means of transporting and mixing particles {2}.

Particles mixing is usually easy to achieve in fluidized bed. The only likely exceptions are when the particles are so fine that they are difficult to fluidize (< 50 μm) or when strong inter particle force (usually of an electrostatic nature) {2}.

The concept of a degree of mixing is necessary to obtain a comparison between mixers and mixture {3}.

Attempts to express accurately the homogeneity or, in other word the degree of homogeneity of any mixture were first made over one hundred years ago, the first expression for the degree of mixing made up of standard deviations was proposed by Lexis in 1877 {4}.Table (1) shows the state of mixture according to standard deviation value.

A measure of the homogenizing effect of the mixer is either the standard deviation of the composition of samples which drawn after the specified homogenizing time or the so called degree of mixing {5}.

The efficiency of the mixer may evaluated from two basis {5}:

a) According to composition of sample on a weight basis.
b) According to composition of sample on number of particles.

Rose {6} was proposed below expression to evaluate the degree of mixing

$$M = 1 - \frac{\delta}{\delta_0} \quad (1)$$

where

$$\delta_\circ = \sqrt{x(1-x)} \quad (2)$$

$$\delta = \sqrt{\frac{(X_i - \overline{X})^2}{n-1}} \quad (3)$$

$$\overline{X} = \frac{1}{n}\sum_1^n X_n \quad (4)$$

Table (2) shows the scale of mixture quality according to Rose equation.

Table (1): The state of mixture according to the Standard deviation value [4]

Value of standard deviation (δ)	*State of mixture*
$\delta = \delta_0$	State of primary segregation
$\delta_0 > \delta > \delta_r$	Incomplete mixture
$\delta = \delta_r$	Random mixture
$\delta_r > \delta > 0$	Order mixture
$\delta = 0$	Perfectly order mixture

Table (2): Proposed scale of mixture quality {4}.

Quality of mixture	Boundary value of M
Bad	0.7
Un satisfactory	0.7-0.8
Fairly Good	0.8-0.9
Good	0.9-0.94
V. Good	0.94-0.96
Excellent	>0.96

Many different type of mixers are used in the various industries but they can be divided into four broad classes:

Type	Example
Rotating shell	Double cone, y-blender
Fixed shell, (horizontal impeller)	Ribbon blender, Z-blade mixer
Fixed shell (vertical impeller)	Nauta mixer, Kenwood mixer
Fluidizing mixer	Air mix.

There are many studies have been dealt with variables that are effected on mixing of solid materials, such as mixing time, mixer speed, mixing element, mixer design, and physical properties of mixture, to evaluate some performance tests for various kinds of mixer.

Most of the early work on solid mixing was carried out with two components systems whose particles were identical in all properties , differing perhaps only in color but in industrial practice there always some difference in the physical properties of the components to be mixed and this may lead to a tendency for the components to unmix or segregate (difference in particle size,difference in density,difference in shape)

The dynamic behavior of solids mixing is complex, Lacey defined three mechanisms of mixing of solid materials particles {8}:

Diffusive mixing, the distribution of particles over a freshly developed surface.

Shear mixing, where slipping planes are formed, and

Convectione mixing, in which groups of particles are moved from one position to another.

In most mixing devices, both connective and diffusive mechanisms are likely to arise {8}.

In any mixer there is an interaction of mixing and demixing and an equilibrium stage is reached, when the rate of mixing is equal to rate of de-mixing. The position of this equilibrium and hence the quality of final mix depends on the mechanisms involved in the mixer for example Table (3).

Table (3) : Role of mechanism, involved various mixers {9}

Mixer	Mechanism		
	Diffusive	Shear	Convectione
Rotocube (with impeller)	Major	Minor	-
Rotocube (without impeller)	Major	Minor	Major
V-mixer	Major	Minor	-
Ribbon blender	-	Minor	Major

EXPERIMENTAL WORK

Experimental design

Generally experimental design used for finding relationship between controllable variables and observed response. The classical approach of experimentation is to study one variable at a time varying is level over a certain range, while holding all other variables constant and observing the effect on the response variable, these observations determine whether there is a quantitative relationship between variables and response, and what the form is linear, quadratic etc. This approach is not very good, however for one reason it is insufficient requiring a separate set of observation; it is also incapable in detecting interaction variables acting alone {10}.

Box Willson, composite rotatable design is common type of statistical experiments, especially applicable to optimization analysis .In this design special series of tests are defined. The experimental results of this test then serve function to represent the relationship between the variable and the response {11}.

Selection of variables for investigation

Many workers have considered that solid mixing in fluidized beds was rapaid and complete . The gas flowrate is an important variable that effect on mixing process , mixing time , particle size for used components , and concentration of trace component.

In order to define the levels of expermentation it was necessary to determine the minimum fluidization velocity, and this was determined experimentally by plot the air velocity verses the pressure drop across the bed.

Application of Box-Wilson design method

Effect of four variables, such as air velocity, mixing time, particle size, and concentration of trace component are investigated and analyzed.

To design the experiments, the operating range of variables are ascribed as follow:

a) Air velocities are 0.85, 0.95 , 1.05 , 1.15, and 1.25 m/s. and designated as X1.

b) Mixing times are 1 ,2 , 3 , 4 ,and 5 minutes, and designated as X2.

1. Particle sizes of trace component are 0.225, 0.433, 0.642, 0.852, and 1.06 mm and designated as X3.
2. Concentrations of trace component are 5% , 10% ,15% , 20% and 25% by weight and designated as X4.

Experimental apparatus

The experimental apparatus are shown schematically diagram in figure (1). The fluidized bed was made from standard, 3 inch diameter Q.V.F glass tube with 500mm height , supported on a conical adapter with air distributor plate 3 inch diameter , and 2 mm thick made from carbon steel . The sample withdrawn from the fluidized bed by sampling thief

Procedure

The materials chosen were sand and salt because the mixture could be analyzed gravimetrically by simply weighting, dissolving salt, drying sand, and reweighting.

Size range employed for salt were between 0.225 mm and 1.06 mm. Various proportion of trace component (salt) of 5%, 10%, 15%, 20%, and 25% by weight were used knowing that the total weight of the charged was 300 g .Air velocities were (0.85, 0.95,1.05, 1.15,and 1.25) m/s and mixing times were (1, 2, 3, 4, and 5) minutes:

1. The materials were weighted according to the desired size and concentration . These materials were loaded to the column carefully to obtain a horizontal interface between two components (the sand at bottom and salt at the top once and vice versa once).
2. The desired air flow was set to allow the bed to fluidize and mixing was achieved.
3. Sample was taken from the bed by means of the sampling thief probe after a given time.
4. The sample was loaded to the spinning riffler sampler where it subdivided it into eight jars.
5. Each jar was weighted.
6. The salt in each jar was dissolved by water.
7. The sand was filtered and dried.
8. The sand was reweighted, the weight of salt was obtained by subtracted sand weight from the total weight.

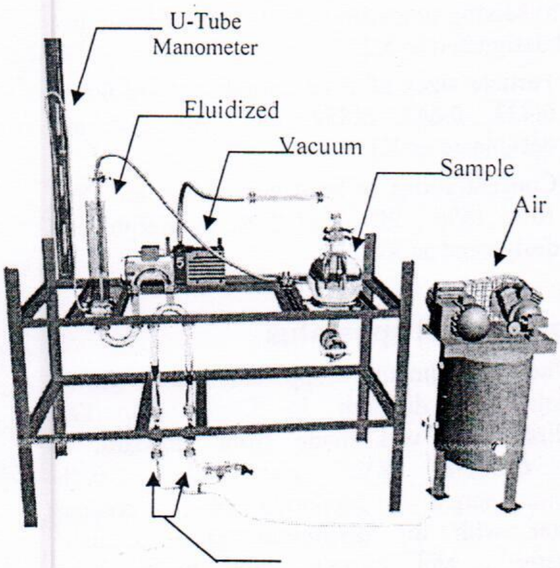

Fig. (1): Schematic diagram of the experimental apparatus

RESULTS AND DISCUSSIONS

Statistical analysis

The statistical analysis was used to calculate mixing index in terms of air velocity, mixing time, mean particle size and concentration of trace component (salt).

To study the influential effects of the studied variables and their interactions the experimental data are fitted by a nonlinear regression analysis and second order polynomial was predicated that reasonably correlates the mixing index in terms of controllable variable furthermore the ensued model and experimental data were analyzed statistically. Eventually the model would give an optimum operating conditions that gave maximum mixed index.

Using experimental data, the coefficients of the second order polynomial are estimated by nonlinear regression analysis using statistic software. The number of iterations was terminated when the proportion of variance accounted was (0.9797) and the correlation factor (R) was equal to (0.98983).

Correlating the four variables with mixing index, The following response function is obtained.

$$M = -1.4112 + 2.6076X_1 + 0.054X_2 + 1.0416X_3 + 3.4163X_4 - 1.3939X_1^2 - 0.0312X_2^2 - 0.3745X_3^2 - 8.2759X_4^2 + 0.1943X_1X_2 - 0.2359X_1.X_3 + 0.0125X_1.X_4 - 0.0438X_2.X_3 + 010125X_2.X_4 - 0.7699X_3.X_4$$

The optimum values of the four variables that correspond to maximum mixing index are found to be equal to

Air velocity = 1.05 m/s ,Mixing time = 4 minutes ,Mean particle size = 0.642 mm , and Concentration of trace component = 20% by weight

Effect of studied variables on the mixing index

To find the effect of each variable on the mixing index, each variable is studied separately from other variables as they kept at constant values (i.e optimum values) these are emphasizing as represented in Figures (2) to (5).

Figure (2) shows the effect of air velocity on the mixing index, with increasing air velocity the mixing index is increased at low values of the used range. The mixing index is decreased with high values of air velocity.

It has already been mentioned that segregation (demixing) is optimized by the presence of small bubbles in the bed by the use of a low gas velocity increase the air velocity leads the bubbles to be as a big size, when the bubble size is increased, the bubble can be transported a more amount of particles from lower layer to upper by its wake . Mixing depends on rate of bubbling but this not necessary increases with increasing air velocity , therefore with any additional increasing in air velocity mixing index may be decreased.

Figure (3) the behavior of mixing index with mixing time is the same to the effect of air velocity, mixing index indrease with increasing time , and with continuation with increase of mixing time the mixing index will decrease.

Figure (4) shows the effect of mean particle size an mixing index. The mean particle size is an important variable on mixing process.The easy mixture was made when the mean particle size for two components is the same. Therefore the demixing between the two components occurred when the difference in particle sizes is found. "Non-easy" mixture were produced whenever differences in particle size occurred between the two mixture components. Only qualitative assessments were made from the experimental data, but these suggest that the extent of demixing occurring was related to the magnitude of difference in particle size {1}

Figure (5) represents the effect of concentration of trace component (salt) on mixing index. Mixing index increase with increasing concentration of trace component because the increasing of distribution of particles of trace component (salt) between sand particles , and according to poole high ratio blends are more easily randomized than low ratio ones, with continuation of mixing process demixing increased and mixing index decrease below the optimum condition.

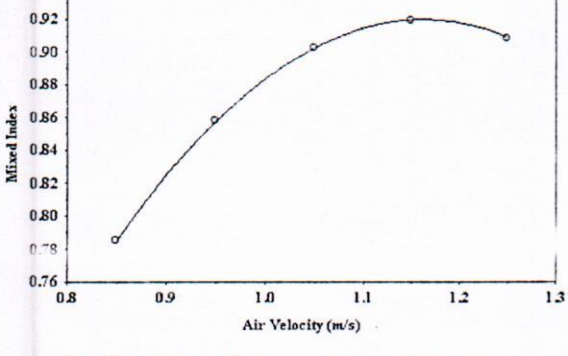

Fig. (2): Effect of air velocity on mixing index

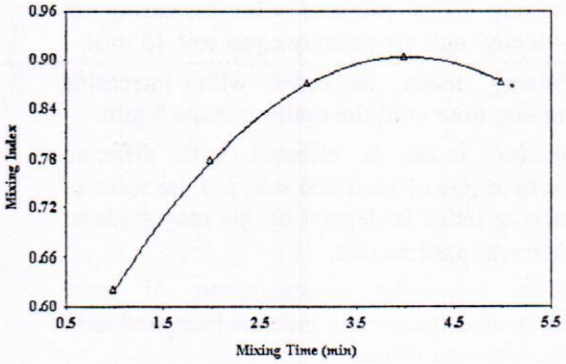

Fig. (3): Effect of mixing time on mixing index

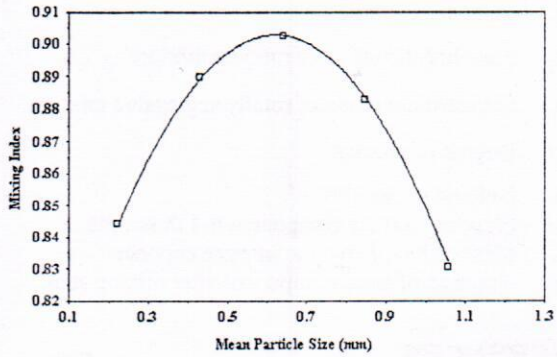

Fig. (4): Effect of mean particle size on mixing index

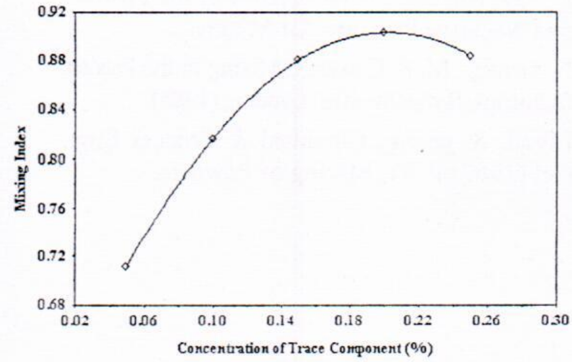

Fig. (5): Effect of concentration of trace component on mixing index

CONCLUSIONS

1. Mixing index is use as a criterion to assess the state of any mixture as well as the mixer performance and is necessary to obtain a good comparison between mixers .
2. Particle size difference which is the main cause of segregation, and according to this fact the mixtures can be classified as an "easy" mixture and "non easy" mixture.

3. Mixing index increase with increasing air velocity until air velocity equal to 1.15 m/s.
4. Mixing index increases with increasing mixing time until the optimum time 4 min.
5. Mixing index is effected with different particle size of sand and salt, and the value of mixing index is depend on the magnitude of different particle size.
6. With increasing concentration of trace compound the mixing index is increased until the optimum value.

SYMBOLS

δ	Standard deviation
δ_r	Standard deviation of random mixture
δ_o	Standard deviation of totally segregated mixture
M	Degree of mixing
n	Number of sample
Xi	Fraction of trace component in I th sample
X	Mean value of fraction of trace coponent
x	Fraction of trace component after mixing start

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