IOSR Journal of Mechanical and Civil Engineering (IOSR-JMCE)
e-ISSN: 2278-1684,p-ISSN: 2320-334X
PP. 39-43
www.iosrjournals.org

Design And Analysis of Powder Mixing Ribbon Blender - A review

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Abstract : *Performances of Dry solid powder mixing with in a twin Ribbon blade blender have been performed in this work in order to characterize mixing behavior in such a mixer of binary mixtures with different cohesionless materials. The effects of fill height and blade rotation speed on mixing homogeneity have been studied. Design considerations had been studied during Analytical Calculations .Analysis of varience is used to determine significance of main effects and their interactions. The residence time is significant by both rotational rate and mixing angle.*
Keywords – *Powder mixing, ribbon mixer, cohesion ,continuous mixing homogeniety*

I. INTRODUCTION

Powder mixing is an important operation that concern many industrial fields. It is an important step since it allows combining properties of different powders into single product that has to meet specifications and standards based on homogeneity of mixers. Successful manufacturing of a variety of products is heavily dependent on the efficiency of this process, because the final product quality is inherently dependent on the quality of the obtained mixture. The mixing performance, which is usually characterized by the degree of mixing, is of paramount importance to the quality of products in industrial processes. Some research investigated the effects of the operating conditions on the particles mixing in cylindrical vertical mixers with bladed impeller, including the fill level, rotational speed and number of impeller blades.[14]

The impeller speed of the mixer is one operational parameter that can affect both the mixing performance and stresses on particles being mixed. For example, it is reported that the mixing quality decreased with an increase in the blade speed in a continuous ribbon mixer. [10]

In this experimental work, the mixing vessel was open at the top, and thus the particles were free to move vertically upwards. However, when the particle motion is constrained at the vessel top, circumferential motion of particles becomes dominant as the shaft speed increases, and the curves of mixing index versus shaft revolutions may be affected by the shaft speed, as observed previously in the case of a vertically-shafted cylindrical mixer. Although the use of a low blade speed can reduce stresses on particles and hence particle fractures, it may result in a poor homogeneity when mixing cohesive particles because of the reduction of shear stresses, which are responsible for the diffusing of particles in the mixing . [10]

In recent years, with increased interest in continuous pharmaceutical solid oral dose manufacturing, continuous powder mixing has begun to receive a significantly higher level of attention. Research thus far has focused on the effect of process parameters and material properties on process performance. Attention also has been given to understanding the residence time distribution of the material in continuous mixers. Additionally, Government and others have examined powder behavior inside the continuous blender on a micro-scale using **Discrete Element Method** simulations. [17]

II. DISCRETE ELEMENT METHOD (DEM)

Discrete element method (DEM) is a numerical technique used to simulate the movement of particles interacting with each other through collision. In fact, DEM simulates the dynamics of each particle individually and numerically integrates their accelerations, which depend on the sum of all contact forces acting on spherical particles and gravitational forces. Particle positions are recorded and their interactions are evaluated in every time-step. Then, all forces acting on each particle are calculated and Newton's second law is applied to determine the accelerations. Afterwards, the accelerations are integrated with time to find the velocity and position of each particle in the new state. This process is repeated until the end of the simulation.

In the mixing of solid particles, the motion of each individual particle is modeled by solving Newton's second law of motion. Forces applying on a particle are the sum of the contact force (*fc*) and gravitational force (*fg*). Basically, the contact force is composed of a normal (f^n) and a tangential force (f^t) i.e. $Fc=f^n + f^n$. [12,13]

III. CONTINUOUS MIXING

Continuous mixing occur when separate streams of ingredients are combined in some device, mixed, and the mixture removed continuously. The device may be a ribbon or paddle mixer in which the feed enters at one end and is withdrawn at the far end or it may be a rotating tube with baffles or V-turns. In any case, the accuracy and reliability of the feeders is the key to success. Some feeders are volumetric while others rely on scales or load cells to continuously weigh a flowing stream. Weigh belt feeders need some positive control over the flow of solids. Some try to control flow by changing the speed of a belt conveyor, but for many solids the range of control by this method is limited. It is better to use the weight belt as a measurement while running at constant speed and to adjust flow with the speed of a star wheel or screw feeder. Volumetric feeders can be sufficiently accurate alone when the bulk density of a material is constant, but the bulk density of many solids changes with aeration, compaction, and moisture adsorption. Vibratory feeders are trays fed by slide gates, which control the flow of solids by changing the amplitude and frequency of vibration. Other solids feeders rely on using the angle of repose at rest to stop flow and initiating flow by inducing motion. These rely on the angle of repose being constant, which rarely is true for real materials. An important consideration for solids feeders is the range of their operation, the ease of cleaning if they are used on more than one material, and their durability in service. [17]

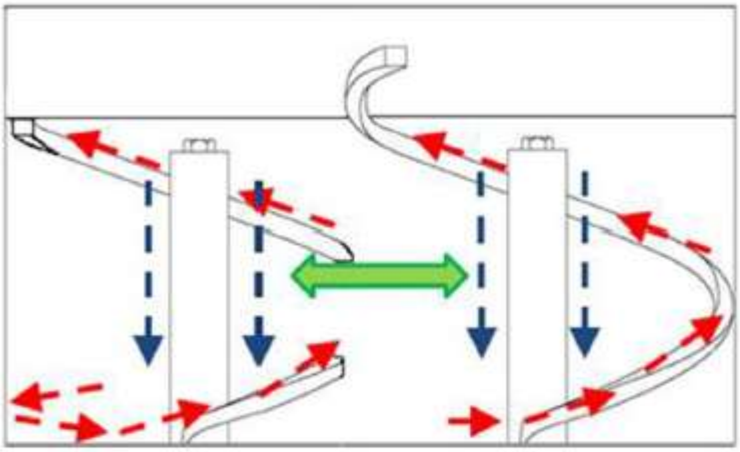

Fig (1): Schematic view showing material flow during continuous mixing

IV. TYPES WHICH USED FOR POWDER MIXING

Two main technologies are employed to mix powders: **Convective Mixers** for which the vessel is fixed and an impeller allows the motion of the bulk; **Tumbling Mixers** for which the vessel itself is put into motion. Powder mixing in tumbling blenders has been studied, for both free-flowing and cohesive powders. These mixers are less adapted than convective ones for cohesive powder blending, because the avalanching movement located mainly at the powder bed surface can induce powder agglomeration. Convective blenders seem more suited to mix cohesive powders, as long as the impeller can be rotated at a sufficiently high speed to break these agglomerates.[14]

V. MATERIALS AND METHODS

Two powders are used in this study: a free-flowing one (semolina) and a cohesive one (fine lactose).$d50$ being the median diameter measured by LASER diffraction (Mastersizer3000,Malvern) under an air pressure of 3.5 bar. The particle density ρp has been measured thanks to an Accumulator Pyc 1330 (Micromeritics) with the 10 cm3 cell. The bulk and tapped densities, ρb and ρt, have been measured with a tap and bulk density measuring device (Erweka SVM 22) with 110 g of powder, the tapped density being measured after 1000 taps. The important Carr Index (CI) of the fine lactose, greater than 22 %, means that this powder is effectively cohesive. The Carr Index of semolina, smaller than 15 %, suggests to classify this powder as free-flowing. [14]

VI. EXPERIMENTAL PROCEDURE

A typical experiment of powder stirring consists in filling the blender with a powder and its corresponding tracer, agitating the powder bed at a given rotational speed ω for a duration t, and then sampling the whole powder bed according to the six cells defined previously. For each of the two powders studied, two agitation speeds and several stirring times are chosen.

The fluctuating values of the mass are mainly due to the different state of compaction of the powder, depending on its position in the vessel. The angle of repose of the powder near the blades and near the walls has an impact on the mass sampled too. For semolina, the mass do not vary a lot from zone to zone, nevertheless it can be seen that the mean values are greater for zones 1 and 4 that are closer from the free-surface. Concerning lactose, the cells 1 and 4 contain also more powder, as well as zone 3 for which powders may be compacted at the bottom of the blender.

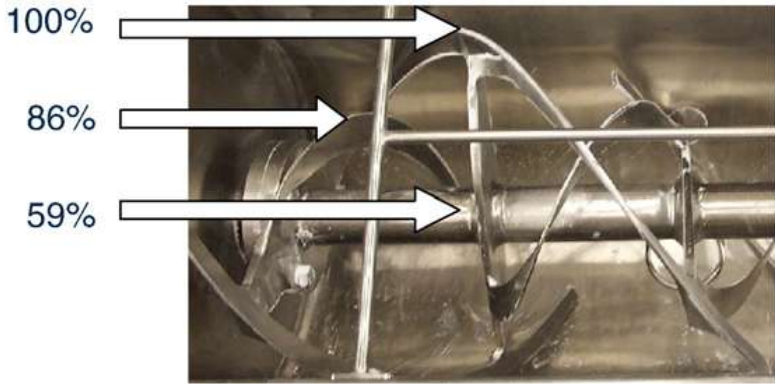

Fig (2). mass distribution as per zone

VII. Physical Properties Of The Materials

Physical Properties	Value
Material (particle/impeller/tank)	Glass/Steel/PMMA
Particle diameter/mm (*d*A/*d*B)	2.0-3.0/4.5-5.5
Number of particles (*N*A/*N*B)	60000, 125000, 200000/210000
Density *ρ*/kg·m-3 (particle A/particle B/impeller/tank)	2460/2500/7800/1150
Poisson's ratio *ν* (glass/steel/PMMA)	0.25/0.3/0.3
Young's modulus *E*/Pa (glass/steel/PMMA)	1×106/1.31×1011/1.56×107
Coefficient of restitution *e*	0.695, 0.768 and 0.955 (for particle A-glass, particle A-steel and particle A-PMMA) 0.415, 0.615 and 0.803 (for particle B-glass, particle B-steel and particle B-PMMA)
Static friction coefficient □ s	0.5, 0.4 and 0.7 (for glass-glass, glass-steel and glass-PMMA)
Rolling friction coefficient □ R	0.005, 0.001 and 0.01 (for glass-glass, glass-steel and glass-PMMA)

VIII. OBSERVATIONAL RESEARCH

Flow and mixing performance of ribbon blender

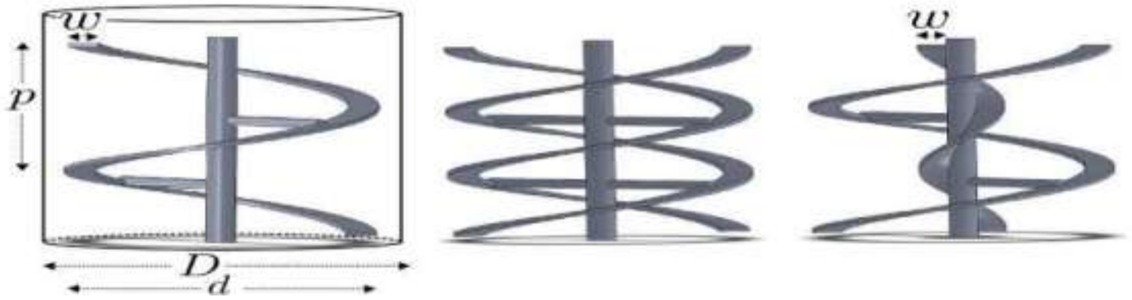

Figure (3): The three helical ribbon impellers used in this study. From left to right: The Single Helical Ribbon (SHR), the Double Helical Ribbon (DHR) and the SHR with a Central Screw (CSR). The SHR also shows the geometry of the outer tank.

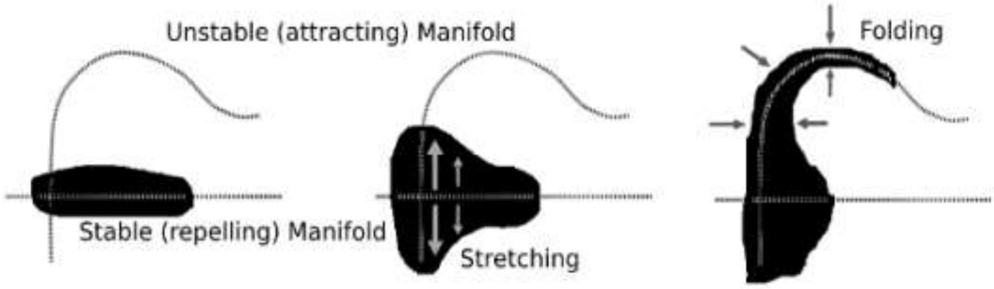

Figure (4): Diagram showing the stretching and folding of free flowing powder surrounding to cohesive repelling and attracting manifolds.

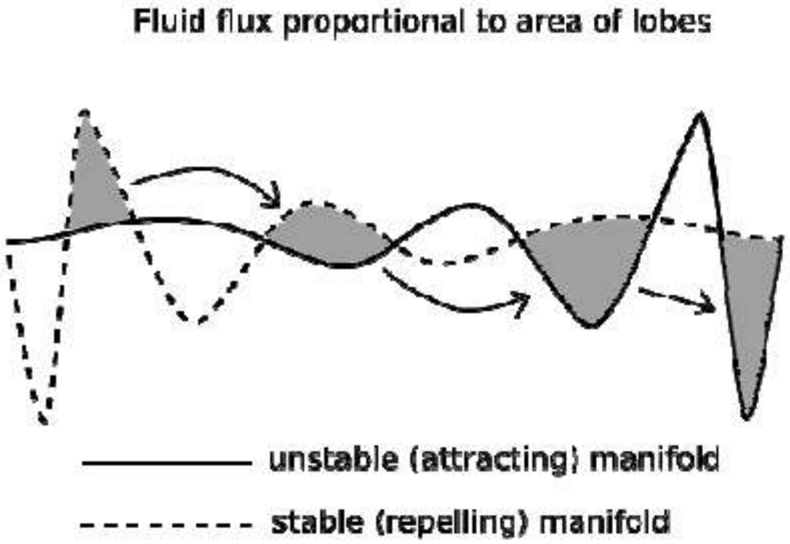

Figure (5): Diagram showing the transport of a single lobe of fluid (coloured grey) across a tangle of manifolds in a periodic flow. After each period the manifolds have returned to their original position, and the grey areas show the position of the same lobe of fluid at subsequent periods.

IX. RESULTS AND DISCUSSIONS

Mixing happens in both axial and radial directions of the ribbon blenders. The axial direction is defined as parallel to the axis of rotation and the radial direction is perpendicular to the rotation axis plane. The governing mixing mechanism in the axial direction is diffusion and a combination of convection and diffusion in the radial direction.

Three main transport mechanisms are identified during powder mixing operations: convection, diffusion and shearing. Convection can be described as the movement of adjacent groups of particles. Diffusion is a movement of the powder at a scale closer to that of the particle's size. Shearing is characterized by the slipping of planes within the mixture.

A. Low-speed stirring of free-flowing powders

The focus is made here on experiments performed with semolina, the rotational speed of the blades being 20 rpm. Under these operating conditions, the flow regime that takes place is rolling, which is characterized by a movement of avalanching of the powder carried by the blades, since gravity is greater than centrifugal force.

B. Low-speed stirring of cohesive powders

This part focuses on the stirring experiments performed with lactose and its tracer at a rotational speed of 20 rpm, which corresponds to the rolling flow regime. Similar experiments as for semolina are performed. However, since three stirring times are investigated, the kinetic data is less accurate. The RSD obtained will be directly compared to that of semolina experiments presented in the last part, in order to evaluate the main differences between free-flowing and cohesive powders.

C. High-speed stirring of free-flowing powders

For rotational speeds greater than 86 rpm, the flow regime is contracting. Contracting is characterized by a movement of projection of the powder carried by the blades, since centrifugal force is greater than gravity.

D. High-speed stirring of cohesive powders

As in the previous section, the cataracting mechanism, which is enhanced by a higher speed, improves the distribution of the powder over the different zones of the blender.

X. CONCLUSION

This paper analyzes the impact of operating conditions and characteristics of a industrial-scale ribbon blender on the blend homogeneity and the mixing rates of commercial dry powder stearate. The loading methods explored are the layering and the off-center spot injection; the benefits of this method is the greater homogeneity of the blends, and the reduction of mixing time.

It is also observed that the ratio of the product of median particle size and the bulk density of one ingredient to the other in a binary mixture bears a quadratic correlation to their segregation index.

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