Powder Pointers

Spring 2008 Volume 2 No A

Brought to you by: **Material Flow Solutions, Inc.**

3536 NW 97th Blvd. Gainesville, FL 32606 Phone: 352-303-9123 E-mail: matflowsol@bellsouth.net

In This Issue

Optimal Blender Choices

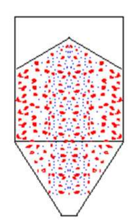
Selecting the right blender is often considered an art rather than a science. However, knowledge of basic material flow properties and segregation tendencies provides guidance in selecting the right blender for the task. Two issues affect blending quality and effectiveness. First, a blender must produce residence time distribution functions that involve all material in the blender. Stagnant zones or regions result in poor blending and blender velocity profiles must be steep enough to achieve a wide range of transport velocities. Second, segregation occurring during blending operation will undo the mixing created by blending. Therefore, blending action must be compared with actions that result in segregation. Any blender that enhances any segregation mechanism is a poor choice.

Blending Action. Blending of bulk solids occurs because of velocities and velocity gradients in a given blender. Normally we think of diffusion and convection as the active mixing means where convection causes large scale mixing and diffusion provides mixing on a smaller scale. This is true in liquid systems, but not in solids systems. Mixing of solids on the small scale also occurs by convective velocity gradients. This process is called dispersion and means that all material in a blender must be subject to velocities and velocity gradients to mix. At Material Flow Solutions we can rank a specific blender based on its ability to generate velocity profiles that lead to intimate mixing of bulk materials. The key variables are blender geometry, cohesive flow properties, wall friction angles, and mode of operation.

Blending and Segregation. Blending is the act of bringing distinct bulk material particles into intimate contact so as to produce a mixture of consistent quality at a prescribed scale of scrutiny. Each blender mixes by a particular set of actions (i.e. formation of a pile, paddle movement). Segregation undoes blending by inducing the separation of distinct particles. If material segregates due to a particular blending action, then any blender causing that specific action is a poor choice for the material mixture in question. Thus, we rank blending effectiveness based on the type of segregation which may occur with the mixture. Let's review some segregation mechanisms and discuss how they relate to blending and blender selection. Any difference in bulk or particle scale property can cause separation of material during handling and blending. There are at least 14 distinct segregation mechanisms for bulk mixtures.

In this article, we will address three – sifting, angle of repose, and air entrainment segregations – and discuss how they relate to blending and blender selection.

Sifting. Sifting is caused when fine particles pass through the inter-particle pore structure of the material during shear or vibration. The rate at which this happens depends on the size of the voids relative to the size of the fine particles, the degree to which the pore structure is already filled, the amount of cohesion of the fines, the degree of exposure to new pore structures during movement, rate of shear, and induced external forces. If the entire void structure of a bulk material is filled with fines, there will be no sifting. As shown here, sifting segregation



produces a radial pattern or a directional segregation down the pile with the fines at the top and the coarse material at the bottom of the pile.

(Continued on page 3)

New approach for predicting attrition and comminution

The following outlines an approach to generate a process specific prediction of the attrition or comminution in your processes. This approach combines experimental and multistage modeling steps.

- Conduct a population balance model study of your process or a representative attrition/comminution process. A population balance model quantifies the causes of particle scale attrition/comminution (fracture, abrasion, and fatigue). Obviously, the best method is to conduct this study on your process. It requires the ability to generate time sequence particle size data. If your process is not conducive to generating time sequence data, then a suitable independent attrition/comminution process can be selected to generate reasonable time sequence particle size data. This data is used to identify critical causes of particle attrition/comminution (both magnitude and type).

- Conduct a SEM or optical analysis of the structure of your particles. What we are looking for here is a description of the grain size, grain size distribution, size of contact zones, and contact fabric structure. This data will be fed into a model describing the breakage of particles.

- Conduct a finite element analysis (FEM) of key aspects of your process and generate the expected impact velocities distribution, and impact angle distributions in the proposed process.

- Use the structure information found from SEM work to generate a statistical representation of a single agglomerate consisting of the grain structure observed in SEM using discrete element modeling (DEM). Next, impact this agglomerate on wall surfaces at various angles comparable to those computed from the FEM model. The size and amount of sub-particles produced will be compared to the population balance model to validate the approach.

Once these steps are completed, a model describing breakage of your specific material in your particular system will be ready for use. This model can then be used for a parametric study to analyze the effect of change in grain size, grain size distribution, inter-grain bond strength, or grain structure. Change of processes can also be accommodated. The beauty of this approach is that it de-convolutes the elements that result in attrition/comminution and allows independent control of each.

If such an analysis and model generation interests you: contact Kerry Johanson (352) 303-9123

Powder Pointers Preview

Coming Next Quarter – Milling Issues

Milling is an important operation in many processing plants. Optimization of a milling operation is typically approached from an energy conservation (cost reduction) perspective. This is fine if we wish to minimize the energy that goes into milling. However, the trouble with this approach is that very little of the energy consumed by the mill actually translates into change in particle size. Hence, true optimization of milling operation from an energy perspective must focus on the mechanical attributes of the mill – friction in the bearings and energy to move material.

Sometimes we wish to optimize selection or production of the type of fines exiting our mill. In this case, it is useful to understand the type of particles a mill produces. This particle size selectivity will be the discussion of our next newsletter.

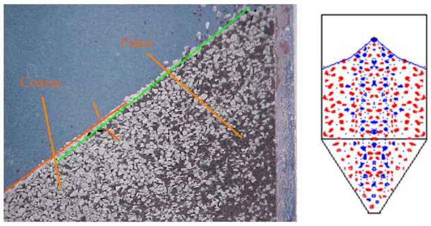
Future Topics

- Erratic flow rates
- Successful agglomeration
- Product design
- Process design

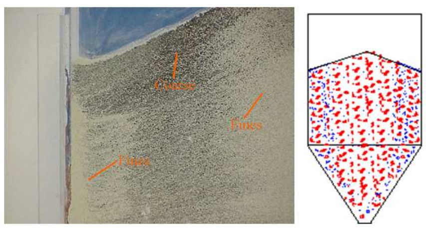
We encourage and welcome your suggestions and special requests for powder flow topics which you would like to see included in future editions of Powder Pointers.

Optimal Blender Choices

Continued from page 1



Angle of Repose. Angle of repose segregation occurs when two (or more) components of the material mixture have different frictional characteristics. As the bulk material mixture flows down a pile, the component with the flattest repose angle accumulates at the bottom while the steeper repose angle particles accumulate at the top of the pile. A two degree difference in repose angle between mixture components is enough to cause significant segregation. The particle shape also affects segregation. Rounder particles accumulate at the bottom of the pile. Piles must form in the equipment for this type of segregation to take place. Cohesion also affects the separation of materials. Cohesive materials tend to form agglomerates. Thus, a round particle coated with angular particles tends to have similar repose angles as separate angular particles and reduce segregation tendencies.



Air Entrainment. Air entrainment segregation occurs as the mixture impacts on a surface. Air carried with the bulk material transports fines to other points in the process equipment. There must be a difference in particle size for this mechanism to be a problem. Fines must be sufficient in size to be carried by air currents. The bulk material must be compressible and fine enough to store air during the impact. The pattern is also a radial pattern with the fines at the bottom of the pile and the coarse at the top.

If we consider the blending action in a given blender, we find that some blenders rely on pile formation to mix. Rotary shell blenders (V-blenders, twin cone, and tumble blenders) all induce shear with tumbling action. Mixing occurs in a thin layer along the top as material slides down a continually forming pile. Rotary shell blenders are a poor choice for materials that segregate via angle of repose. Alternatively, the blending action in vertical shaft blenders (day paddle mixer, plow mixer, Forberg® mixer) occurs as paddles transport material to different areas in the blender. The paddles or plows rotate at speeds that prevent pile formation. Material sensitive to angle of repose segregation will blend effectively in these style blenders. However, the paddles can induce entrained air in the mixture and resulting in air entrainment segregation during operation. Thus, the vertical shaft blender is a poor choice for use with material sensitive to air entrainment segregation.

Blender Type	Segregation Mechanism	Ranking 1 = poor : 10 = perfect
Rotary Shell	Angle of repose	3
	Sifting	3
	Air entrainment	8
Plow / Paddle	Angle of repose	8
	Sifting	7
	Air entrainment	5
Tube	Angle of repose	5
	Sifting	5
	Air entrainment	7
Nauta	Angle of repose	4
	Sifting	4
	Air entrainment	7
Ribbon	Angle of repose	4
	Sifting	4
	Air entrainment	8
Cone-in-Cone	Angle of repose	7
	Sifting	8
	Air entrainment	8

It is obvious that the selection of an optimal blender depends on the type of segregation that happens in a blender. If we consider only these three types of segregation mechanisms and limit our analysis to general blender types we can produce a ranking of blender effectiveness based on segregation mechanism. The ranking in the table below is the result of this analysis where 1 is a poor blender and 10 is perfect blending. Obviously, a measurement of the key segregation tendencies is required to evaluate a blender performance. We routinely evaluate the five most common segregation mechanisms and provide blender evaluation and selection recommendations.

Learning the Trade

Knowing and understanding key material properties is power to characterize bulk material flow behavior. We will empower you quarterly as we discuss one of these fundamental flow properties and its industrial application.

Permeability (air flow rate). Permeability is the superficial velocity of gas or fluid passing through the bulk material when the pressure drop across the material equals the weight density of the bulk solid. It can be thought of as an incipient fluidization velocity, except it is measured as a function of the stress applied to the bulk material. However, the value of the permeability extrapolated to zero stress is identically equal to the incipient fluidization velocity. Permeability data is used to determine the pressure drops in packed bed operation. It is also used to determine the limiting flow rates where the resistance to gas flow is the key limiting factor to solids flow. With an understanding of permeability, the engineer can calculate the necessary de-aeration time and/or installation of air-flow-aid devices in the equipment to achieve required process flow rate and/or break bridges and ratholes that are negatively affecting the system. It is a useful tool when designing or retrofitting a new or existing solids flow processing system when the primary goal is to "get it right the first time."

Material Flow Solutions, Inc.
3536 NW 97th Blvd.
Gainesville, FL 32606