Powder Pointers

Fall 2013 Volume 7 No C

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

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Blending Powders for Optimal Performance

Background. Blending is an important unit operation in many industries. However, a systematic method of selecting the proper blending system for the mixing task at hand is not common knowledge. Thus, the selection of a blender is typically a trial and error process. In addition, scale up of blending operations requires knowledge of how material flow properties, blender geometry, and blender operation parameters influence blending quality. Segregation is the opposite of blending and occurs due to a variety of mechanisms.

The fines may sift through a coarse matrix resulting in size separation of particles. The fines may also be carried by air currents and deposit in process vessels where entrainment velocities decrease below some minimum value. Sometimes the blending velocity profiles in a particular blender also cause segregation. The selection of the proper blender then depends on the type of segregation occurring in the material during blender operation. There are dozens of possible reasons why material mixtures separate, or de-mix, during processing and handling. In this Newsletter we will address those which most often occur with powders: sifting, angle of repose, and air entrainment.

Angle of repose segregation. Consider the case where two or more components segregate due to angle of repose differences as the mixture forms a pile. Differences in frictional properties of particle surfaces result in variation in repose angles and velocities down piles and chutes, causing separation of particles during pile formation. Some blenders mix by continually forming and reforming a pile. When blending action also causes segregation, the efficiency or usefulness of that blender depends on whether the velocity profiles in the blender are sufficient to overcome segregation that also occurs.

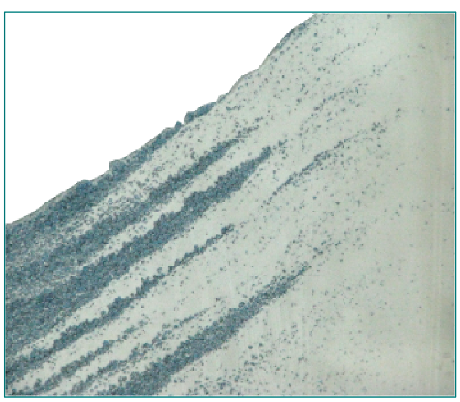

Figure 1. Angle of repose segregation results when gas causes finer, lighter particles to float out of the material stream during system fill

Sifting Segregation. In a mixture of multiple components, fines may sift through a matrix of coarse particles during handling. Sifting segregation

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In This Issue

Upcoming Conferences

13AIChE Annual Meeting, San Francisco, CA

Dr. Johanson will be presenting 3 Papers

Monday, Nov 4, 2013 – 1:06 PM
Golden Gate 6 (Hilton) Session: 120C
"Relating Gas Pressure Gradient to Flow Profiles in Process Equipment"

Tuesday, Nov 5, 2013 – 4:21 PM
Golden Gate 7 (Hilton) Session: 362D
"Developing a Cohesive Model to Describe Channeling in Fluidized Behavior"

Wednesday, Nov 6, 2013 – 4:55 PM
Golden Gate 6 (Hilton) Session: 553F
"Product Design Methodology to Overcome Segregation"

2013 AAPS Annual Meeting and Exposition November 10-14, 2013

Dr. Johanson will be presenting 2 Posters

Tuesday, Nov 12, 2013 – 1 :30 to 4:30 PM

"Product Design to Prevent Segregation of Bulk Drug Mixtures"

"New Test Technique to Measure Bulk Powder Strength at Low Consolidation Pressures"

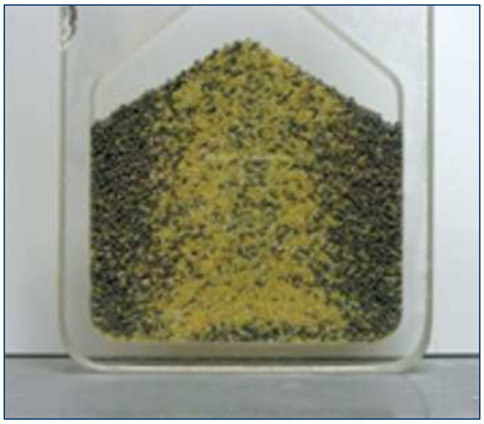

Figure 2. This mixture segregates due to sifting caused by significant variation in the particle size of the individual components

that void space between adjacent particles may be large enough to permit fine particles to pass through (a particle size difference of about 3:1). Inter-particle motion is required to provide a means of exposing empty void spaces to fine particles and fines must be free flowing enough to prevent arching between adjacent particles. In general, this sifting segregation produces a radial pattern as material forms a pile in process equipment. Fines accumulate near the pile charge point and decrease in concentration toward the pile edge. Components separate due to differences in particle scale properties. Blending must induce inter-particle motion. Conversely, inter-particle must be present for sifting to occur. Sifting segregation will always occur in the direction of gravity, the key to selecting a blender that works with material sensitive to sifting is to ensure that the mixing inter-particle motion opposes the direction of gravity. In this case, sufficient blending energy can be imparted such that blending velocities win the battle against segregation. The worst possible case would be if the blending action was positioned 90 degrees from the sifting action. Thus, pile formation in a blender with a material sensitive to sifting segregation is always troublesome since the blending action is down the pile and the sifting action is downward through the pile.

Figure 3. As gas currents diminish, fine particles are deposited, resulting in air entrainment

Air entrainment segregation. In many systems, fine particles are carried by air currents and deposited in the bin wherever the air currents reduce sufficiently for fine particles to drop out of the flow stream. When the falling stream impacts the material level, the entrained air is pushed out of the interstitial pores and carries the fine particles in the resulting dust cloud. This segregation typically causes a radial pattern during pile formation, but the fines are at the bottom of the pile and not the top. However, when dealing with mixtures that segregate due to angle of repose differences between components, a blender that works by pile formation is not a good choice. Even though fines separate in a radial pattern, the reason for the separation is critical to successful blender selection. If a blender forms piles during operation with a material sensitive to air entrainment segregation, it may not cause a problem since the air entrainment mechanism requires an air stream (generally caused by free-fall) to separate the particles. Thus, a blender that operates through repeated pile formation without free-fall may be a good choice with this type of material. In other words, to achieve a proper fine powder material blend, one must eliminate all segregation issues. Selection of the proper blender then depends on the type of segregation occurring in the material during blender operation: one must match the blender choice to the material properties.

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Powder Pointers Preview

Coming Next Quarter – Robust product design

Today's design engineers have decades of experience (their own, or that of others) designing processes to handle the bad-acting products we are forced to create as a result of traditional, outdated unit operations. Unfortunately, the concept of product design if far less understood. The rules required to design a robust product that will not segregate, possesses the appropriate cohesive properties, and will not flow erratically require more experience than the typical design engineer has. Our next Powder Pointers Newsletter will address this issue of designing a robust product to prevent these handling issues in the first place. As always, our goal is to help you "Get it Right the First Time."

Future Topics

To put you at the cutting-edge

- Making the process work for you – optimize your design
- Managing agglomeration
- Controlling particle breakage
- Preventing caking

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*.

Contact: Susan at 352-379-8879

Blending for Optimal Performance

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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.

Figure 4. A rotary blender – best considered to reduce segregation resulting from air entrainment.

Blending and segregation. As discussed above, 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.

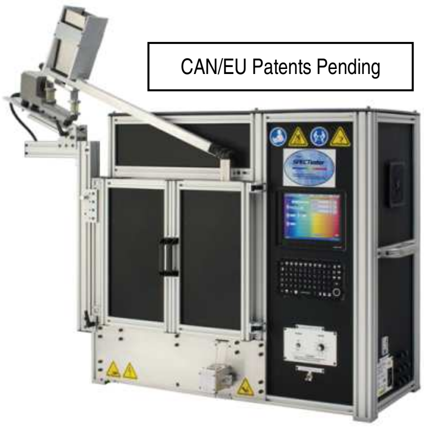
Table 1: The Blender for Optimal Performance

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

Blender selection. 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. 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 trap air in the mixture, 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.

It is obvious that selection of an optimal blender depends on the type of segregation that occurs in a blender. If we consider only these three types of segregation (sifting, air entrainment, and angle of repose) and limit our analysis to general blender types, we can produce a ranking of blender effectiveness based on segregation mechanism. The blender ranking presented in Table 1 is the result of analysis where 1 is a poor blender and 10 is perfect blending. Measurement of key segregation tendencies is required to effectively evaluate a blender for optimal performance.

Innovative SPECTester granted US patent



Material Flow Solutions is pleased to announce the granting of:

US patent 8,467,066

MIXTURE SEGREGATION TESTING DEVICES AND METHODS

Abstract: "Methods and devices are provided to measure segregation in solid particulate mixtures. Light energy is projected through a transparent barrier and reflected off a surface of a mixture volume. The constituent fraction in the mixture is determined by analyzing the mixture reflected light spectral contents and intensities. This is accomplished at multiple surface locations to provide constituent fraction data over the mixture volume surface."

The SPECTester's ability to analyze mixture samples of multiple ingredients is significant because it can be used not only during the formulation process, but actually on the production line as a quality control measure. It supplies information not only about WHAT a mixture is doing in the processing system, but WHY it is behaving this way. This is important because, in order to design an optimal production system and/or product, engineers and formulators MUST understand how a mixture of ingredients will interact with the process to form the desired final product. To gain this understanding, tests must be performed that quantify some basic characteristics of the powder or granulate components of the product.

- ***YESTERDAY***: Industry waited two, four, or more **weeks**, outsourcing testing to busy laboratories, for answers concerning the how and why of product segregation issues.
- ***TODAY***: In just 15 to 30 minutes, the SPECTester, a revolutionary technological testing breakthrough, answers the quality control questions – what, where, when, how, and why products segregate in the process system – On-site and in real time.

Learning the Trade – Mechanisms of Segregation

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.

Segregation occurs through several mechanisms. Identification of the segregation cause and pattern produced through handling is critical to prevent de-mixing during handling and packaging. Any property difference between materials can cause separation of critical material components, although there are five common causes of segregation problems in typical handling systems. In this Newsletter, we will discuss two additional causes of segregation, as well as best practices to eliminate or mitigate the condition. Subsequent issues will discuss other mechanisms and their prevention.

Impact fluidization. If the mixture is fine enough, then air trapped in the interstitial voids can cause material to fluidize. As a large particle drops into this fluidized layer, momentum causes the large particles to penetrate this fluid layer, resulting in a top-to-bottom segregation of fine and coarse particles. This mechanism requires a source of air and the ability of the bulk material to hang onto entrained air for a moderate amount of time and large, heavy particles.

Percolation. A fluidized layer of material can lose its entrained air as it sits stationary in a container that was just filled. Percolation forces air up through the bulk material. Generally, this process forms fissures in the bulk material where the gas escapes. The local velocity in these fissures is relatively high and can entrain fine particles in the process, causing top-to-bottom segregation.

It is critical to identify the cause of segregation to avoid processing that will induce the problem. We also need to know the pattern of segregation to provide a means of re-mixing material, if required. Understanding the segregation mechanism will also help us determine what must be done to the material to create a product that is less likely to segregate. Both of the mechanisms require sufficient air and/or agitation to create a semi-fluidized mass. Reducing the quantity of entrained air during transport can sometimes limit the segregation.