Powder Pointers

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

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In This Issue

Knowing Your Material: Achieving Successful Process Design

The Issue. Currently, many processes that handle bulk solids are not operating efficiently. Some are subject to occasional, or even frequent, hang-ups. Others experience erratic flow rate problems due to rathole collapse, aerated material, poor gas injection, or lack of mass flow. Still others are tasked with combining dissimilar products and maintaining this mixture in uniform condition during handling and packaging. Hang-ups, erratic flow rates, and segregation appear to be major causes of handling systems problems. Due to the length of this newsletter format, we will only consider the case where hang-ups are present in the process. Let's identify some general guidelines to avoid these situations.

The Cause. Hang-ups are caused by the cohesive (or adhesive) nature of the bulk material. The material property responsible for this behavior is the unconfined yield strength of the bulk material. Strength is the major principle stress that is required to cause the bulk material to fail or shear after storage. Most engineers experience the effect of this property when material arches over the outlet of a process vessel. They may experience the influence of this property when attempting to empty a process vessel and notice stagnant regions where material is clinging to the walls. Bulk strength is sometimes responsible for poor blending. The cohesive nature of the material will also control the weight variations in tablet dies and small packages. The solution to the arching problem is to make the outlet large enough to prevent the arch from forming. Obviously it is critical to measure the unconfined yield strength of the bulk material. However, the forces acting to break the arch depend on the bulk density. So, another critical material property to measure is the bulk density. The type of flow channel surrounding the outlet also

Arch across hopper opening

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The *SSSpinTester*

(patent pending)

Will Revolutionize the Pharmaceutical and Chemical Industries

In its final stages of development, the new ***SSSpinTester*** measures the strength of fine powders using a sample as small as 0.05 gram. Current methods of measuring the unconfined yield strength of a powdered material require at least one liter of sample – usually hard to come by in the pharmaceutical and chemical industries.

Able to quantify the strength of fine powders in as little as 15 minutes, this novel tester takes its user to the cutting-edge of productivity. Its 16x20 inch footprint makes it easy to accommodate in any testing laboratory.

The ***SSSpinTester*** will arrive at your facility, complete with bonus testing cells, a preprogrammed laptop, and instruction manual with demonstration video on CD.

Plan ahead to start your New Year right – coming in early 2010. For additional information:

Contact: Susan at 352-332-9476

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has a significant impact on the material's propensity to arch. A flow channel which converges in all directions simultaneously has twice the propensity to arch as a flow channel that directs flow in one direction (plane flow). At first glance, solving the arching problem should be a straightforward task. One would simply measure the key flow properties (strength and density) and use these to compute the critical arching dimension and assure the process outlet is greater than this dimension. However, storage conditions and the amount of entrained air or local gas pressure gradients in the material play a significant role in inducing hang-ups due to external forces.

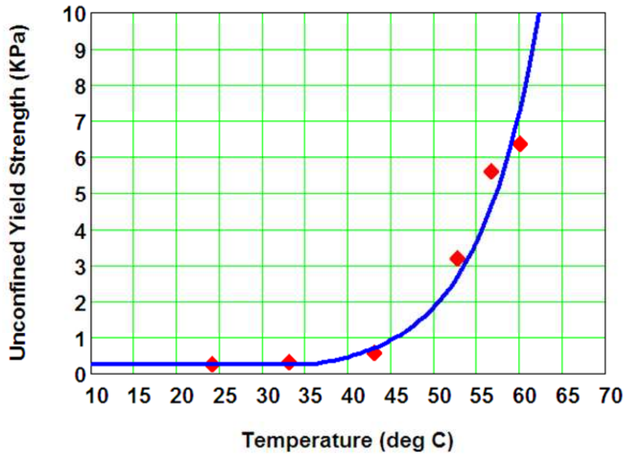

Figure 1. Strength of Erucamide as a function of temperature

The Example. Consider erucamide pellets stored at elevated temperatures. Plastic creep occurs between these pellets, cementing particles together and resulting in a substantial gain in strength and arching propensity. In this case, the difference between the operation temperature and the glass transition temperature plays a major role in the strength of the bulk material. Quite often strength increases exponentially at temperatures above the glass transition, or softening, temperatures. Notice the increase in strength as a function of temperature (see Figure 1). A temperature of 36^{o}C appears to be the critical temperature that initiates significant strength increase. Arching behavior is directly proportional to the bulk yield strength and, as a result, is a function of the process temperature, process temperature swings, storage time, environ-mental conditions (humid or not), aeration condition, and surface chemistry. A similar relationship can describe rathole behavior. Conversely, external forces or gas pressures applied to the material can change the forces acting to break the arch. Thus, gas pressure gradients can be instru-mental in increasing or decreasing arching or rathole problems, depending on the direction they act. If the gas pressure gradient acts in a direction opposite to flow, then the gas pressure increases arching problems. If the gas pressure gradient acts in a direction compatible to flow, then the arch dimension decreases. Equation 1 summarizes this behavior. Although it is more complex, the critical rathole dimension is also modified by local gas pressure gradients or other external forces. It is obvious from equation 1 that knowledge of the gas pressure gradient near the hopper outlet, or other places in

$$AI = \frac{H_\theta \cdot fc}{\gamma \cdot g - \dfrac{dP}{dz}} \qquad (1)$$

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Powder Pointers Preview

Coming Next Quarter – Preventing Segregation

Segregation is a primary cause of process failure. Understanding segregation can lead to the ability to greatly increase product quality, reduce product loss, and increase customer acceptance. We have been able to provide segregation solutions that reduce the amount of poor quality product produced from 30% down to 0.3% making statistical control possible. Understanding segregation of just two components is relatively easy. However, real materials are often a mixture of many more than two components. The interaction of all the components leads to complex segregation behavior that is not intuitively obvious, nor explained by popular academic bimodal segregation theories. Our next newsletter will address how to characterize multi-component segregation and how to design for multi-component and multi-mechanism segregation issues.

Future Topics

To put you at the cutting-edge

- PAT implementation
- Successful agglomeration
- Process simulation and Predicting Behavior
- Milling – new techniques

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 352-332-9476

Achieving Successful Process Design

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the hopper, is critical to understanding arch formation in the process equipment. This is best seen in Figure 2. Bad placement of gas injection causes gas pressure gradients that result in arching within the upper hopper. A similar analysis could be done for rathole problems in aerated systems. These pressure profiles can be computed for any process equipment once the density, permeability, strength, and friction angles are known. This analysis allows optimal placement of air injection to prevent hang-up conditions. Likewise, changing gas pressure gradients will also change critical mass flow hopper angles. Thus, gas injection in the right location can help mass flow. Gas injection in the wrong location can hurt mass flow.

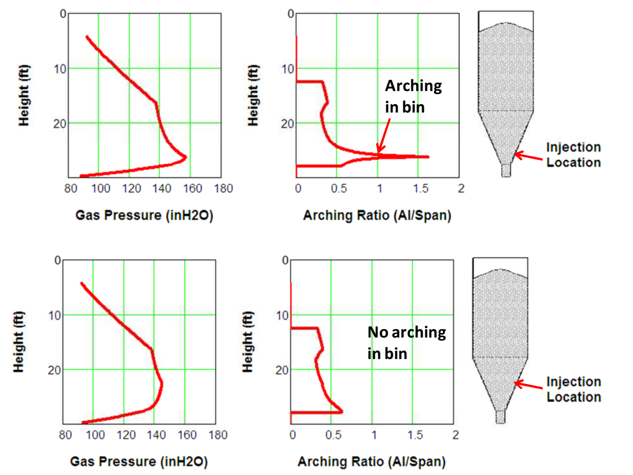

Figure 2. Arching in hopper due to bad placement of gas injection

The Guidelines. The solution of cohesive flow problems requires:

- Measure key flow properties at conditions similar to real process conditions. Knowledge of particle surface changes as a function of environment, system temperature, and surface chemistry will help identify the proper test conditions to measure these flow properties. We can aid you in selecting the right conditions for your process.
- Identify storage conditions, storage times, and any temperature swings that will aid in proper material flow property analysis. Your process will naturally be subject to typical day-night cycles or heating-cooling cycles. We can review your process and help you determine the magnitude of these changing process conditions. If the change is critical, we can also simulate these day-night temperature excursion using finite element software.
- Calculate the influence of external forces to determine if they will hurt or help cohesive hang-up conditions. This requires an analysis of your specific process and can be accomplished once key material flow properties are known.

It is clear that process hang-ups are a convoluted combination of process flow properties, environmental conditions, process geometry, and operation conditions. The solution for arching and/or rathole problems can often be found in controlling or changing one or more process variables. Our testing and modeling methods allow us to predict process behavior **in your process** so we can optimize process design based on key flow properties as well as typical thermodynamic properties of the bulk solid that are easily measured. Let us help you understand how to relate simple flow properties to critical process behavior. ***Contact: Kerry Johanson 352- 303-9123***

The *SPECTester* Measures Segregation in a Four-Salt Mixture

Four salts in a hopper

Generally, segregation studies are done only for bimodal combinations because analysis of multi-component materials is difficult and time-consuming. The interaction of two materials is fairly simple and follows one or both of two predictable rules: fines fill the voids, and/or fines collect near the hopper walls. However, the majority of real process mixtures contain more than two components, and the segregation pattern of a multi-modal mixture is more complex due to interaction of multiple particle sets. Therefore, predictable patterns do not always hold true. The segregation pattern of a bulk mixture can be measured by observing the concentration of various components along a pile. One way to gain access to the cross section of a pile is to fill a slice model with material and observe the segregation pattern through the side of the slice model using optical techniques. The

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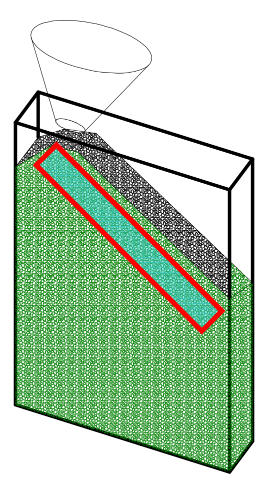

Schematic of a hopper slice

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.

Recommended Mass Flow Angle. The friction angle discussed last quarter is used to compute the recommended mass flow angle for conical bins. This mass flow angle represents the slope angle of the conical hopper measured from the vertical that will produce flow along the walls. Conical hoppers must be steeper than this to cause flow along the walls. It is important to point out that the recommended mass flow angles are a function of the shape of the bin. Plane flow hoppers converge in one direction at a time and also have a recommended mass flow angle that will produce flow along bin and hopper walls. However, plane flow mass flow angles generally require about 10 to 12 degrees flatter than corresponding conical angles to achieve mass flow. Please note that mass flow does not mean plug flow. Substantial velocity gradients can exist in mass flow bins. The recommended mass flow angle also depends on the solids contact stress in the bin. The stress level in a given bin depends on the position in the bin. At Material Flow Solutions, Inc. we compute the range of pressure expected in a given bin configuration and then use the worse case friction angle in this stress level range to compute the recommended mass flow angle. It is important to note that the recommended mass flow angles are for flow in a conical hopper.

The *SPECTester* Measures Segregation in a Four-Salt Mixture

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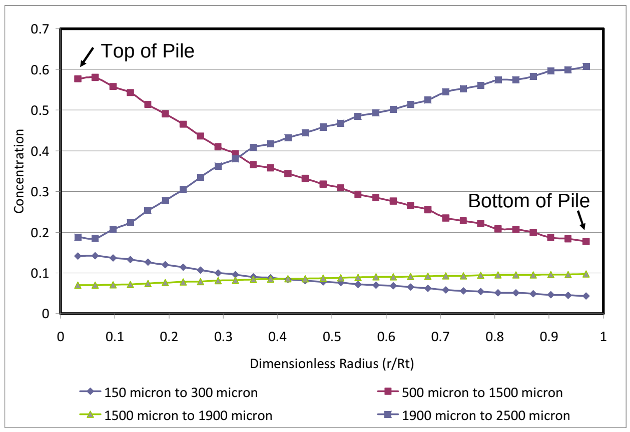
ability to measure segregation patterns of a multi-component mixture is critical to understanding segregation behavior of that mixture.

Variation in color intensity is often very subtle. However, reflectance spectroscopic methods can be employed to measure these subtle differences. Using photospectral technology, the revolutionary ***SPECTester*** is able to identify segregation in this sample of four distinct table salts based on particle size due to differences in the spectral hue of the differently sized particles. The finer particles scatter more light and manifest as brighter than coarse particles. In this instance, the data is used to quantify the segregation pattern due to particle size differences. The profile to the right indicates that the coarsest particles (1900 to 2500µm) accumulate near the bin wall while the finer particles (500 to 1500µm) accumulate near the center of the pile. Very fine particles (150 to 300µm) and mid-size particles (1500 to 1900µm) show a minimal tendency to segregate.



Segregation profile of a four-salt mixture

Particle size segregation, while common, is but one of the segregation mechanisms measured by the ***SPECTester***. The tester also measures segregation by:

- Air entrainment
- Angle of repose
- Chemical component
- Fluidization
- Sifting

Should a material be subject to multiple segregation mechanisms, the ***SPECTester*** can determine both the primary and secondary mechanism. All segregation data is collected and stored in both numerical and graphical form and is downloadable via USB thumb-drive in Excel-ready format.

For additional information contact: Kerry Johanson 352-303-9123