Powder Pointers

Winter 2007 Volume 1 No D

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

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A New Particle Size Degradation Analysis

The use of nano-particles in bulk solid materials has led to enhanced ability of these materials. There is a movement in industry to create large size particles (agglomerates) with a high degree of porosity and large surface areas where nano-particles on the surface perform various functions. Herein lies the dilemma.

The Dilemma. Large particles are preferred due to the lack of cohesive flow problems. However, large particles have low surface area and, hence, limited chemical functionality. One solution to this particle design process quandary is to use an agglomeration process that creates a large porous particle from a series of small nano-particles. Unfortunately, these engineered materials are generally both highly porous and friable, resulting in significant degradation during use. Whatever the reason, particle size degradation of particles is a problem in today's production facilities. Degradation produces fines that limit the life of catalysis in fluid bed operations. It causes fines production in pharmaceutical products that subsequently segregate, resulting in quality issues. Particle size degradation causes consumer acceptance issues with many products from food to bath products. Degradation issues also lead to dust generation problems and environmental discharge concerns. Thus, measuring and understanding degradation is critical to help engineers and materials scientists design processes and products that minimize these effects.

Key Issues. There are several key issues to developing a robust method to mitigate size degradation effects. Degradation is caused by different external influences. Placing material in a condition where it is exposed to large stresses and high strains can cause a reduction in particle size due to particle breakage under the stress/strain behavior. Impact can also result in particle breakage.

Quantifying. Particle size degradation can be quantified by observing the shift in particles size after subjecting particles to a controlled impact condition or a controlled strain condition. For example, Figure 1 shows a typical shift in the cumulative particle size as bran buds are subjected to repeated impact conditions. Note that this shift is not equal for all particle sizes. The maximum shift likely occurs at particle sizes around 2000 microns. If the particular process of interest operated at material impact velocities of 11.8 ft/sec, then this figure could be used to estimate the amount of fines generated during plant operation. However, real plants operate within a range of impact velocities, and also a range of stress and strain conditions.

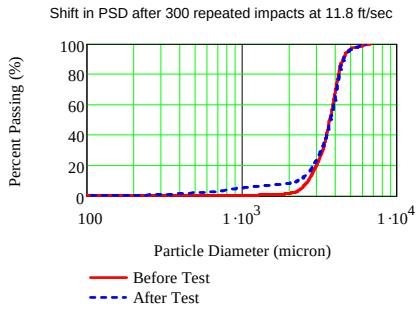

Figure 1. Shift in particle size of bran buds when subjected to 300 impacts at 11.8 ft/sec impact velocity.

Degradation should be measured at various conditions and used with process models to compute the integrated effect of particle size degradation based on the

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range of impact velocities and stresses in the prescribed equipment. Figure 2 shows the increase in bran particle size for 100 repeated impacts at various process impact velocities. This figure shows the cumulative increase in particle size for a given maximum particle size limit at various impact velocities between 0 ft/sec and 14 ft/sec.

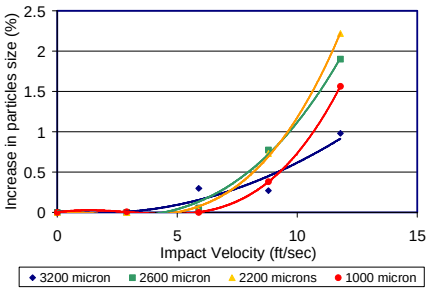

Figure 2. Shift in particle size of bran buds when subjected to 100 impacts at 11.8 ft/sec impact velocity.

These types of impact velocities may exist in mixing, blending, and drying equipment in typical handling facilities. Notice that the 3200 micron material shows less size degradation than the 2200 micron material. This suggests that the 3200 particles are breaking faster than they are being generated by the breakage of larger particles. The particle size degradation of 1000 micron particles is also less than the 2200 micron material. In this case, the rate of production of 1000 micron particles is slower than the rate of production of 2200 micron particles. We routinely compute the stress and strain levels and impact conditions in typical process equipment. Suppose that the primary process of interest was principally an impact process, such as drying in a rotary drum. This is degradation analysis combined with calculations of impact velocities allows us to estimate the overall process degradation. If the drum is two foot in diameter, has lifter bars and operates at 20 RPM with a fill rate of 7%, then the expected impact velocities are around 8.6 ft/sec. However, multiple impacts occur after the initial drop onto the pile from the lifter blades. In addition, not all the material drops the full distance. Taking all this into account and assuming about 150 impact events before material exits, the drum leads to an estimated increase in 1000 micron material of about 0.52%. It is important to note that many processes depend on both impact and stress and strain effects and will require doing degradation tests as a function of impact velocity as well as stress/strain effects. This type of analysis helps with process issues, but does not address the rudimentary cause of particle breakage. Therefore, it is difficult to apply to particle design. However, modifying the degradation test method allows us to determine the mechanisms involved in size reduction. In this case, the test is run at a controlled constant impact or stress/strain condition for various times. This generates a series of particle size distribution curves as a function of the time applied.

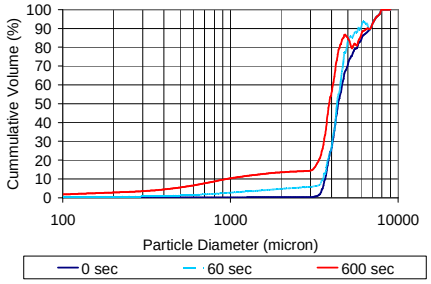

Figure 3. Shift in particle size of bran buds when subjected to repeated impacts at 17.8 ft/sec.

This technique is called population balance modeling. *continued →*

Powder Pointers Preview

Coming Next Quarter – Optimal Blender Choices

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, blender selection is typically a trial and error process. Scale-up of blending operations also requires knowledge of how material flow properties, blender geometry, and blender operation parameters influence blending quality. Since segregation is the opposite of blending, selection of the proper blender often depends on the type of segregation (a key material flow property) occurring in the material during blender operation. We will discuss the effect of flow properties on blender design and operation, and consider how selecting optimal blending apparatuses can overcome segregation in industrial processes, resulting in optimal plant output.

Future Topics

- Milling issues
- Erratic flow rates
- Successful agglomeration
- Product 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.

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Population Balance Modeling. Particle size distribution is broken into individual particle size bins and equations describing the rate of transfer between particle size distribution bins. This series of equations can be solved for both the rate of breakage and the breakage mode. Figure 4 shows the type of breakage that occurs. When a given particle size breaks, a series of particles result. If fracture is an important effect, then a large fraction of particles end up in an adjacent particle size bin. If abrasion is occurring, then the fraction transferred directly to fine particles is large. This figure shows the fraction of bin size #1 (6258 micron) that ends up in bin size #2 is only 45%. The remaining material of this size distributes between bin sizes #3 and #4 with trace amount of finer particles. This suggests that both abrasion and fracture are occurring during impact of (6258 micron) bran buds at this velocity. However, fracture appears to the dominate cause of breakage. Likewise, 76% of material in bin size #3 (1723 microns) ends up in bin Size #4 (904 microns) indicating a dominate fracture mechanism. Conversely, the behavior of bin #4 and bin #5 suggest that abrasion is the predominant degradation mechanism of particles less than 904 microns. Examining the structure of these bran buds can lead to what may be causing these mechanistic degradation effects. Careful examination of a bran bud indicates that buds are made of a collection of flakes or particles that are about 900 microns. These primary particles are liberated from the bud particle matrix by an initial breakage event followed by abrasion of 900 micron primary particles to finer material. Strengthening the binding action between these original particles will help reduce particle size degradation of bran buds. Thus, a population balance degradation study provides a powerful analysis to determine the modifications to the structure of the particles that will lead to a reduction in attrition.

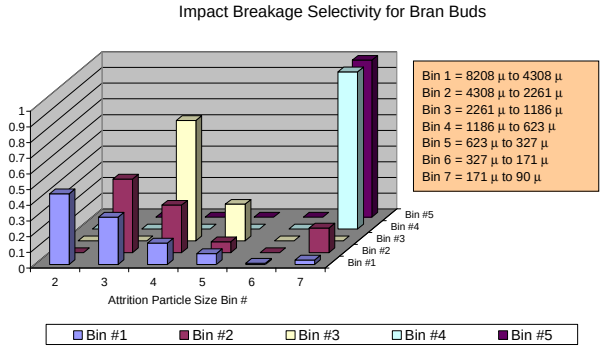

Figure 4. Results of population balance modeling for bran buds after impact at 17.8 ft/sec.

May we assist you? At Material Flow Solutions Inc., we can provide you with a degradation analysis for your process and/or a population balance model analysis of your product to aid with your product design. For more information contact Dr. Kerry Johanson: 352-303-9123.

Experiencing Product Segregation Issues?

One of the issues with predicting segregation is that segregation occurs because of different mechanisms which are dependant on process geometry and operational parameters. Thus, to understand the segregation that occurs in processes one must know the operation parameters, process geometry and have some idea of the relative magnitude of each segregation mechanism. This requires measurement of segregation due to various mechanisms at conditions that are similar to those found in your process. We have developed a new tester that measures the segregation potential of up to five typical segregation mechanisms and analyzes both size distribution and mixture component concentrations of segregated materials. Segregation can be measured with as little as 600 ml of powder mixture. For further information or to evaluate the potential of your materials to segregate in typical process conditions, contact Kerry Johanson at **352-303-9123**.

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.

Fine Powder Limiting Flow Rate:

Fine materials consolidate as they flow through process equipment. If this consolidation occurs slowly, then entrained gas in the interstitial voids of the bulk material leaves through the top surface. As this deaerated material approaches the outlet it must expand to flow, resulting in negative gas pressure formation near the outlet. Gas rushes in to equalize this negative pressure. With low permeability material, this process takes time resulting in partial support of bulk flowing from the outlet and creating a slow flow rate through the equipment cross-sectional area (A_{out}). To compute this limiting flow rate (Qs_{limit}), it is critical to know the bulk density at high $\gamma(\sigma_{max})$ and low $\gamma(\sigma_{out})$ stress levels to determine gas storage capacity of the bulk material . The permeability $(K(\sigma_{out}))$ is required to determine the gas rate leaving the bulk material. The equation below provides an estimate for limiting flow rates of fine materials. It applies to conditions where low permeability controls flow. Better estimates for larger permeability materials will not be presented here.

$$Qs_{limit} = \cdot \left(\frac{\gamma(\sigma_{out}) \cdot A_{out} \cdot K(\sigma_{out})}{1 - \frac{\gamma(\sigma_{out})}{\gamma(\sigma_{max})}} \right)$$

Contact us for further details and particular applications.

Please contact us with any comments, suggestions or inquiries you may have regarding our services. We also encourage and welcome your suggestions for powder flow topics which you would like to see included in future editions of Powder Pointers.

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