Powder Pointers

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

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Milling: Matching Breakage Mechanism to Milling Action

Milling is the act of creating small particles from larger particles through stress strain events, shear events, particle impact events, and particle fatigue events. Two methods can be used to characterize a milling event. One typical method of classifying a milling process is to compute the specific energy required to create smaller size particles. These energy laws depend on the size of the particles prior to milling and the size of the particles after milling. There are three distinct relationships:

Rittinger's Law $$E = K_1 \cdot \left(\frac{1}{Dp_f} - \frac{1}{Dp_i}\right)$$

Kick's Law $$E = K_2 \cdot ln\left(\frac{Dp_i}{Dp_f}\right)$$

Bond's Law $$E = K_3 \cdot \left(\frac{1}{\sqrt{Dp_f}} - \frac{1}{\sqrt{Dp_p}}\right)$$

Where Dp_f is the final particle size, Dp_i is the initial particle size, E is the specific energy requirement and K_1, K_2, and K_3 are constants. These laws predict the energy needed to create additional surface area within the product during the milling process, generally only a very small part of the energy that a mill may generate during the milling process. Milling is inherently inefficient in terms of energy used to create particle size reduction. Even with that limitation, these laws help in determining the relative energy requirements required to create a given size particle. However, control of particle size distribution for a given mill is still difficult to accomplish. A different analysis is required to characterize how the particles break during a milling process in order to predict the size distribution. This analysis is done using a population balance model approach.

What's the Difference, Anyway? Each mill has a unique combination of mechanisms that result in formation of smaller particles. A jaw crusher decreases the particle size by direct compression stress strain events. A ball mill causes particle size reduction with balls as they tumble in a rotating drum. It stands to reason that any given mill will have a prescribed tendency toward fracture and abrasion resulting in the formation of coarse milled product and very fine powder.

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Material Flow Solutions announces advance of New Segregation Tester

In its final stages of development for market sale, the new SPEC™ (Segregation Potential Evaluation/ Characterization) Tester offers a revolutionary approach to testing of particulate material for segregation tendency. Fully automated, it will provide data concerning: component concentrations, particle size differences, product uniformity, and segregation mechanisms. In as little as ten (10) minutes, the SPEC™ Tester supplies accurate segregation mechanistic-driven potential values. Its user-friendly, touch-pad operation makes the SPEC™ Tester the premier choice for in-house determination of product segregation potential, measuring and reporting ***how much*** as well as ***why*** your material is segregating.

Coming to market, fall of 2008.

For further details, contact:
Kerry Johanson @ 352-303-9123

Milling: Matching Breakage Mechanism to Milling Action

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Since the population balance model is at the heart of understanding milling rates, it would be useful to define some parameters and functions that describe breakage.

- Cumulative density: $R(x, t)$
- Breakage distribution function: $B(x, y)$
- Specific breakage rate function: $S(x)$
- $b(x, y)$ describes the fraction of mass transported from y to x upon breakage of y.

The breakage distribution function (B) is an indication of where (what particle size bin) the particle fragments end up during breakage. It is often described as a matrix of numbers indicating the fractional distribution of transfer to bin sizes smaller than the original. Numbers in this matrix represent the fraction of material transferred to adjacent particle size bins during processing. The B(x,y) function plays the role of a weighting function or stoichiometric constant in a reaction.

The S(x) function represents the probability that a given particle impact will result in particle breakage. It denotes an overall rate of one particle size breaking into any adjacent particle size bin. The S functions are the rate constants for degradation from one particle size to all others. Equations governing the rate of transfer between particle size bins can be written for both the cumulative and mass density distributions.

Equation 1.

$$\frac{d\left(R_i(t)\right)}{dt} = -S_i \cdot R_i(t) + \sum_{j=1}^{i-1} \left(S_{j+1} \cdot B_{i,j+1} - S_j \cdot B_{i,j}\right) \cdot \left(R_j(t)\right)$$

Equation 2.

$$R_i(0) = R_{i0}$$

S-Values are Significant. S-values should correspond to the overall degradation measured from the test method. If the degradation measured from the tester is low, the S-values will also be low. However, S-values give us more precise information since they are specific to a given particle size bin. Generally, the above equations must be solved for the cumulative distribution (R). For the purposes of this work, the rate constants are assumed constant and not as a function of time. This simplifies the analysis. B functions are found simultaneously from the solution of these equations. Since mass cannot be destroyed, the sum of the B functions for any particle size bin must equal one. This solution of the equations above is not a trivial task, but will provide more information concerning the degradation phenomena experienced by the bulk powder material. The solution of the cumulative equations given in equation 1 can be accomplished numerically, but can also be approximated by the following equations if the rate constants are assumed time invariant.

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Powder Pointers Preview

Coming Next Quarter – Dealing with Erratic Flow Rates

Bulk powder flow behavior is a complex phenomenon due to its multi-phase character. Air trapped in interstitial solid voids can cause fluid-like behavior. Conversely, lack of entrained gas can result in a very solid-like behavior. Flow behavior is further complicated by the fact that liquid bridges, or other adhesive forces between particles, modify the interstitial pore structure by creating cohesive stresses in the bulk material that govern local porosity and permeability. The amount of gas carried within the bulk material then controls the flow rate. The ability to lose entrained air, then, is a complex function of compressibility, permeability, cohesion and particle shape. The role of these effects in controlling erratic flow rates and other gas effects will be examined in the next issue of Powder Pointers.

Future Topics

- Product design
- Process design
- PAT implementation
- Successful agglomeration

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.

Milling: Matching Breakage Mechanism to Milling Action

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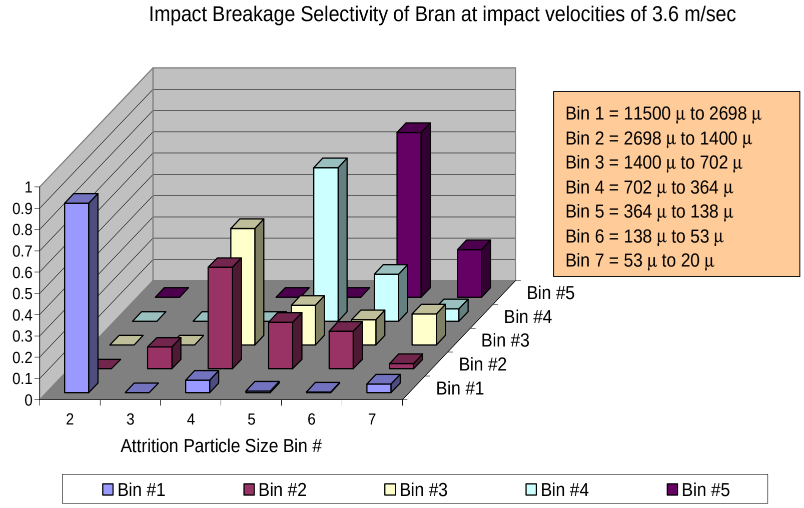
Consider the example of bran being milled in a lab ball impact mill. A population balance model was solved for this case resulting in the generation of the breakage distribution function B(x,y) found in the Figure below. This Figure suggests that most material in bin size #1 (11,000 microns) breaks into material in bin size #2 (2698 microns). However, the material in bin size #2 and size #3 tends to break into material with particles sizes associated with bin size #4 (700 micron). The material that is 700 microns and less tends to break into smaller sizes due to both fracture and abrasion mechanisms. Thus, the bran appears to break into primary particle size of about 700 microns and then is crushed into smaller sized particles through the action of the ball impacting on the particles.



Fracture and Abrasion. Certain materials are sensitive to fracture. Others are sensitive to abrasion. The optimal milling process is one in which the mill produces particle breakage mechanisms that the particular material is most sensitive to, i.e. the mill should be selected to match the materials' breakage characteristics. The population balance model allows engineers to quantify the sensitivity of a particular material to different types of breakage. It provides information that allows choice of the optimal mill for the task at hand. Let us characterize your material and determine the best mill for your product. If you are a mill vendor, then the population balance model study provides a fingerprint of the milling action in your particular mill. Your customers can then use this to decide the best mill for their material.

For information on choosing the correct mill for your process or product: contact Kerry Johanson (352) 303-9123

Customized Seminars – Your Process – Your Personnel – Your Place

Material Flow Solutions offers a set of seminar topics specifically for your process and product engineers to help them design material handling systems, design better products, and successfully select unit operations that are compatible with critical material properties. This proven approach allows your engineers to optimize plant performance and increase your plant and operation productivity. Our seminars are available in one- two- or three-day venues. Customize your seminar by choosing from a wide range of available topics that best meet your company's needs. You may further optimize your seminar by adding a half- or full-day plant visit that will include an on-site review of your current process.

Mix and Match. Our engineers will assist you in designing a seminar program to optimize your time and personnel investment, and assist you in increasing your company bottom line. Simply choose from our shopping list of topics and you are on your way to enhanced company profit and productivity.

We will travel to your facility with a customized presentation that exactly meets your needs and parameters.

Available Seminar Topics

- Successful powder plant design
- Successful powder product design
- Segregation prevention
- Bin and hopper design
- Feeder design
- Optimal blender selection
- Minimizing attrition
- Agglomeration unit operations
- Blender operation
- Mill operations

Schedule your Customized Seminar today: contact Susan Johanson (352) 332-9475

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.

Critical Conical Arching Dimension. The critical conical arching dimension is the smallest span of a conical hopper that will prevent arching of the bulk material. It is a function of the material's unconfined yield strength and storage time in the vessel. A conical hopper must have an outlet at least this big to prevent stable arch formation from occurring in bins and hoppers. Plane flow hoppers can have hopper widths about ½ as wide and still prevent stable arch formation. The critical arching dimension is also a small function of the bin size and, hence, is usually associated with a calculation basis which represents the approximate size of a given bin geometry. Engineers who understand and utilize critical conical arching dimensions in design of their specific system and material are able to avoid costly process downtime caused by hang-up due to arches formed at hopper outlets – getting it right the first time.

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