Powder Pointers

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

7010 NW 23rd Way, Suite A Gainesville, FL 32653 Ph: 352-303-9123 E-mail: matflowsol@bellsouth.net

Designing a Successful Handling System for Biomass and Other Fibrous Materials

Biomass is becoming an important energy source in today's world. The technology to convert plant products into energy has been available for decades, but is now being optimized to get the most out of crop and biomass sources.

Three Paths to Energy Conversion from Biomass. (1) Some biomass has sufficient non-cellulous organic material to be converted into energy using anaerobic digestion to create methane or fermentation to create alcohol. Typical anaerobic or fermentation feed stocks are wet cohesive materials that do not feed well. They have irregular particles with sufficient inter-particle forces to be very cohesive. (2) Some biomass is converted into energy through direct combustion of high cellulous materials that are sufficiently dry to permit combustion. These materials, although dry, are very elastic and posses pseudo-strength caused by elastic confinement of material in converging containers. This yield strength has little to do with traditional cohesion effects inherent with powders and most granules. (3) Some cellulous biomass materials are converted to simple sugars using acid hydrolysis, creating a product both elastic and sticky. This material exhibits strength by both elastic confinement of particles and more traditional cohesive problems caused by inter-particle forces which come from the sticky sugars formed on the surface of biomass during or after acid hydrolysis. These cohesive problems are extremely problematic in biomass conversion processes. However, the other characteristic of biomass materials is their light density and highly compressible nature. Most cohesive flow problems (arching and rathole formation) are inversely proportional to the bulk density of the material. Equation 1 shows the relationship between the arching index (AI) and the unconfined yield strength (fc), bulk density (γ), and pressure gradient (dP/dz with z positive downward). A light bulk density and moderate strength result in a large arching tendency. This is not intuitive until one realizes that the forces breaking an arch arise from the unit weight of the bulk material. These must overcome the cohesive forces that support the arch at the walls of the process vessel. Light material cannot easily generate sufficient bulk weight to break an arch or

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

(Continued on Page 2)

In This Issue

Experiencing Product Segregation Issues?

A leading cause of plant down-time: segregation accounts for 1/3 of lost revenue annually. To eliminate segregation, one must understand its source. Segregation generally occurs due to one or more of several mechanisms. To understand segregation that occurs in processes, one must know the operation parameters, process geometry, and relative magnitude of each segregation mechanism. Furthermore, segregation potential measurement should be conducted at conditions that are similar to those found in your process. The ***SPECTester*** measures for up to five (5) typical segregation mechanisms, and analyzes both size distribution and mixture component concentrations of segregating materials in mixtures of six (6) significant components – at process conditions defined to mimic YOUR system. For information, or to evaluate the potential of your materials to segregate in typical process conditions, contact:

Kerry Johanson at 352-303-9123

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Continued from page 1

rathole that would form in process equipment. In addition, the elastic nature of biomass complicates the issue. Compression of bulk material in a hopper results in lateral compressive forces that generate material support along container walls, provided these same forces and the container geometry do not cause flow along the walls. Elastic forces hold the material against the wall in opposition to the force of gravity. Thus, it is possible to generate arching or flow hang-ups in material compresses elastically with no natural attractive forces between particles. If material can flow along container walls, then excessive elastic forces dissipate during flow and prevent arching. Therefore, arching of elastic biomass materials occurs more readily in funnel flow bins than in mass flow bins. An elastic material can arch over 20-foot in diameter in bins that are not steep enough to cause mass flow. This same material can flow easily through 1-foot outlets in a mass flow bin of similar size. In this case, cohesion is caused by elastic wind-up effects, not inter-particle forces. These same elastic properties prevent standard belt, screw, and vibratory feeders from working properly. Special feeder designs are required to relax elastic stresses during flow.

Although equation 1 suggests that a gas pressure gradient acting in the right direction will break arches in bin and hoppers, gas injection systems often do not overcome cohesive flow problems because of the ability to generate insufficient gas pressure gradients at reasonable gas flow rates. It is obvious that the unusual flow properties of biomass materials make them difficult to handle and many of the solutions used with powders and granular materials do not work with biomass materials.

Dry versus Wet Biomass Material. Consider the flow properties of wet and dry straw (Figures 1 through 4). Notice the very light bulk density of dry straw which is between 6 lb/ft^3 and 12 lb/ft^3. The strength is moderate with values between 10 lbf/ft^2 and 20 lbf/ft^2. These low strength values would not normally cause flow problems in typical bins, However, since the density is so light this material will form stable arches over conical outlets that are 3.9-feet in diameter making this a cohesive material. This hang-up tendency is largely due to the elastic properties of the fibrous material and not the sticky nature of the particles.

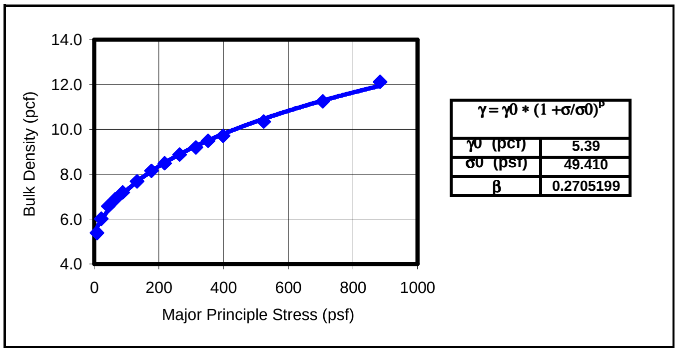

Figure 1. Bulk Density of Dry Straw

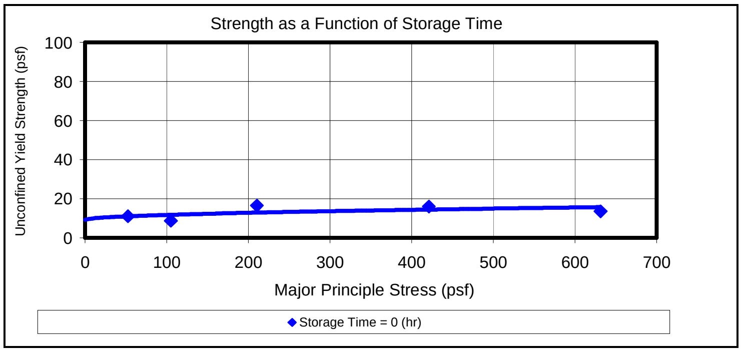

Figure 2. Strength of Dry Straw

Compare this behavior to the same straw with moisture added. In this case the bulk density is between 25 lb/ft^3 and 65 lb/ft^3. As expected, the addition of moisture increases the bulk strength of material to values between 18 lbf/ft^2 and 25 lbf/ft^2. However, the heavy nature of this wet material actually decreases the arching

(Continued on Page 4)

Powder Pointers Preview

Coming Next Quarter – Successful agglomeration

Agglomeration can occur in almost every unit operation or transfer step. In many unit operations agglomeration is unwanted, and the primary goal is to reduce or limit particle growth. Unchecked, particle growth can lead to process plugging caused by lump formation. Sometimes unit operations are specifically designed to achieve agglomeration. However, often the goal of these agglomeration processes is to create a product with a controlled particle size distribution without excessive recycle. In any case, the control of agglomeration is important to the creation of many products. We will approach agglomeration from a mechanistic point of view and provide guidance to limit agglomeration in handling facilities, or enhance and control particle size growth in agglomerators.

Future Topics

To put you at the cutting-edge

- Process simulation and predicting behavior
- PAT implementation
- 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 352-379-8879

Introducing the *SSSpinTester*

SSSpinTester

(patent pending)

- 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 14x16 inch footprint makes the ***SSSpinTester*** easy to accommodate in any testing laboratory.

The ***SSSpinTester*** uses the science of centrifugal force to measure the unconfined yield strength of fine powders using a sample as small as 0.05 gram. Current methods of measuring the strength of a powdered material require at least one liter of sample – usually hard to come by in the pharmaceutical and chemical industries. New technology extends the testing range down to 0.2 KPA, which will allow direct measurement for arching. We no longer must rely on inherently inaccurate extrapolation for answers. If you can generate sufficient sample to run a particle size analysis, you've got a sample of sufficient quantity to measure strength with the ***SSSpinTester.***

The pictured sample is sufficient material to run five (5) strength analyses.

The *SSSpinTester* Will Revolutionize Pharmaceutical and Chemical Industries

Order Yours Today

The ***SSSpinTester*** will arrive at your facility, complete with:

- a pre-programmed laptop
- bonus testing cells
- instruction manual with demonstration video on CD
- one-year limited warranty on parts and labor
- extended service plan available upon request

Material Flow Equipment, LLC

(Sister Company to Material Flow Solutions, Inc)

For more information: Contact Kerry Johanson at 352-303-9123

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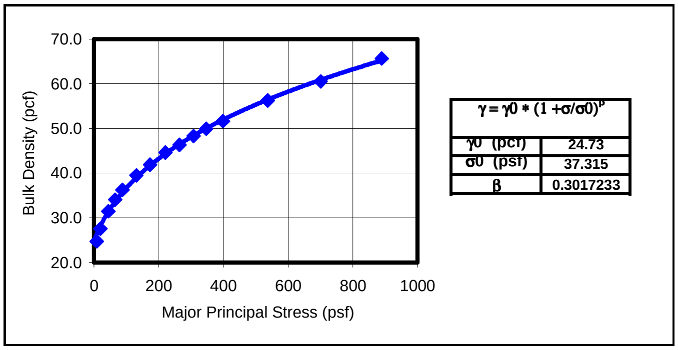
Continued from page 2

tendency, causing stable arches over only 1.1-foot conical outlets. This is an almost four-fold reduction in arching problems between wet and dry material, with wet material being easier to handle. This is counter intuitive since many solids flow practitioners suggest that the addition of moisture increases the stickiness of bulk materials due to addition of capillary forces between particles. In the case of this biomass material, the opposite is true.



γ = γ0 * (1 +σ/σ0)^β	
γ0 (pcf)	24.73
σ0 (psf)	37.315
β	0.3017233

Figure 3. Bulk Density of Wet Straw

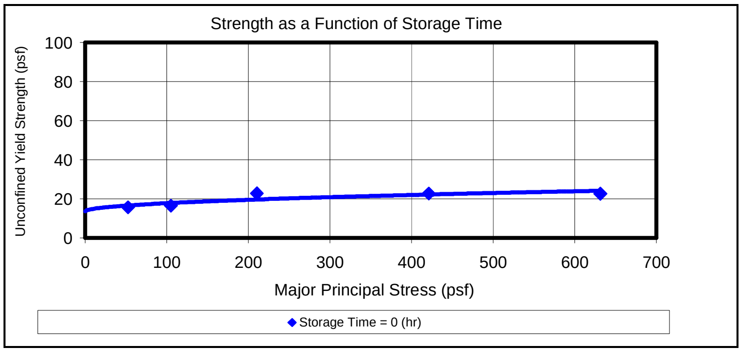


Figure 4. Strength of Wet Straw

To properly design a handling system for biomass one must measure material flow properties at the entire spectrum of conditions expected in the plant. Failure of many energy projects often has more to do with the ability to handle a wide range of biomass flow properties than the efficiency of conversion to energy. When evaluating the biomass flow properties, the size of the test cell must be compatible with the particle size of the biomass material. Standard cells used with powders and granular material will not provide reasonable test data for process design of biomass products. Incidentally, the principles governing flow of biomass materials also apply to non-biomass materials that are fibrous, elastic or extremely light including fibrous minerals, super-sorbent materials, cloth and plastic fibers, large aspect ratio pharmaceutical products, and some metal composite products. We have developed test techniques and testers that can measure flow properties of typical biomass materials. Let us evaluate your materials and provide you recommendations to successfully handle biomass and other difficult-to-handle materials.

Learning the Trade – Drying Parameters

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.

Drying. Materials dry at different rates, depending on the amount of moisture in the sample and where the moisture is bound. Exposing a bulk material to a prescribed relative humidity will cause either drying or moisture pickup, depending on the affinity of the material to absorb moisture. Bulk materials tend toward equilibrium moisture content based on the local relative humidity surrounding the sample. Moisture sorption isotherms describe this behavior. Moisture migration through process equipment depends on thermal gradients, as well as moisture isotherm information. To determine ***drying*** parameters, we measure moisture sorption isotherm data as well as the moisture drying and pickup rates. These data are used, with a mathematical model of process equipment, to determine migration of moisture and predict when the bulk material will wet-out and form cohesive masses in process equipment. We can predict clumping, caking, and other moisture problems in any process equipment subject to prescribed environmental conditions as determined by ***drying*** parameters. Practical applications of understanding ***drying*** parameters include, but are not limited to:

- Prevent wet-out of bulk solid materials
- Predict drying
- Optimize heat tracing
- Prevent hang-ups
- Eliminate clumping and caking
- Evaluate product packaging
- Increase customer acceptance of product
- Product design to limit moisture effects
- Segregation prevention
- Agglomeration studies