Designing New Process Equipment – Get it Right the First Time

Material Flow Solutions, Inc.

Sometimes the best decision to alleviate flow problems in process vessels is to install a new bin design. This approach has the flexibility of being able to freely create an optimal design without the significant limitation that might be present in a retrofit situation. However, the new design must be undertaken with basic solid's flow principals in mind. Let's consider some of those principles.

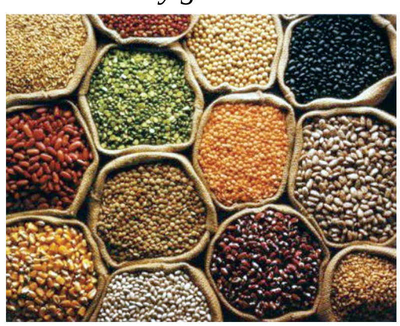
The process will handle one or many products. The flow properties of these materials, along with the particular equipment geometry, will dictate the expected behavior in the process. Thus, the first principle of successful process design is to design the process with a set of materials in mind (Figure 1). Inexperienced engineers frequently leave decisions involving the material flow in the process as the last design step, assuming all powders and granular material are the same. However, successful process design must be achieved with knowledge of the key flow properties.

Fine pigment powder

Clay granules

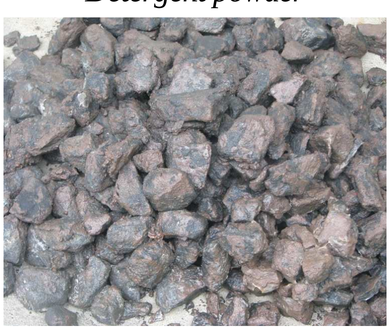
Fibrous biomass feedstock

Detergent powder



Granular foods

Plastic resin pellets



Iron ore

Pharmaceutical powder

Fiberglass shreds

Figure 1. Know your material and its key flowability properties

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When initiating process design it is important to determine which criteria is critical for successful operation of the process. Unscheduled flow stoppages are always bad and can become catastrophic, so one primary consideration should be to avoid hang-ups in process equipment (Figure 2). Another consideration may be the need for a desired flow rate with prescribed variances off that desired rate, so another consideration may be a process that can control the flow of material to some downstream process vessel.

Figure 2. Material hang-up (rathole and arching) of material in a system causes process down-time

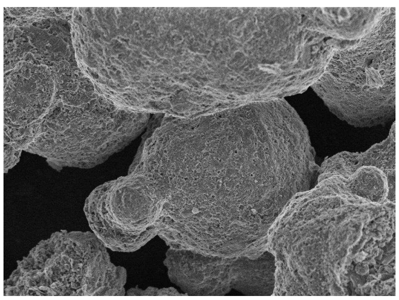
Some materials may be a mixture of key ingredients that must remain in a well-mixed condition through the process. In such cases, a key consideration may be to create a process that is free from segregation of key properties. Sometimes the process requirement is to create a product with uniform density or mass to be injected into a prescribed package. In this case, even if the material is not a mixture, the goal of the process is to prevent segregation of differently sized particles to assure consistent density (Figure 3).

Figure 3. Segregation patterns formed during pile formation in a process

Alternately, density variations during packing may be due to temporary aeration of fine powders (Figure 4). In this case the goal of the process should be to control the aeration of the material during handling.

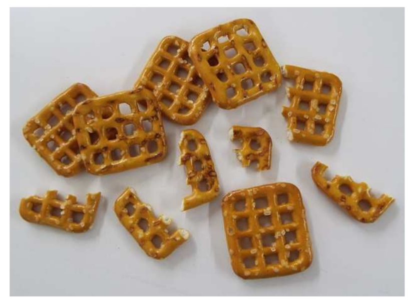
Figure 4. Examples of density variation in packaged food products

In still other cases, successful process operation requires that a friable material remain unbroken during handling and storage, making control of particle breakage critical to the process design (Figure 5).



FCC catalyst

Recycled glass



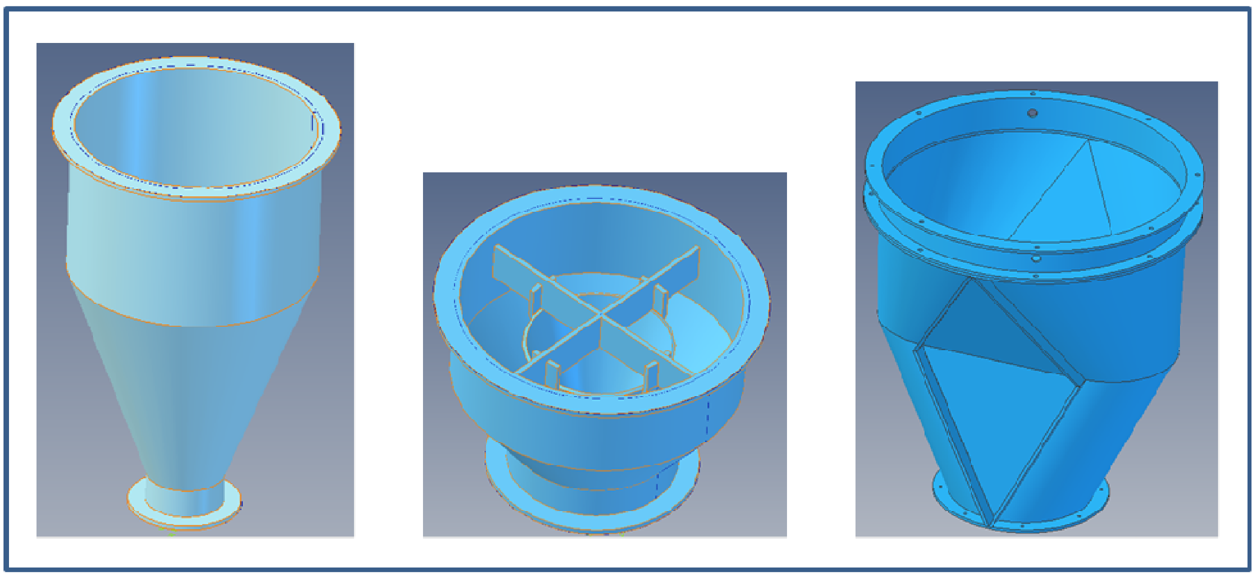
Pretzel squares

Figure 5. Examples of particle breakage

When considering a new design, the first step is to acquire sufficient flow property testing data to assure that all material in the process will behave well relative to the set of criteria that determines successful operation in the handling process. If a critical process criterion is to minimize component segregation of a mixture, then segregation testing of a representative number of mixtures should be done. If a successful process criteria is to avoid hang-ups, then the cohesive flow properties of a representative number of materials is required. If flow control is a process consideration, then measurement of bulk density, permeability and perhaps segregation due to particle size may be required. Often flow properties and process flow behavior depend on the stress levels in the process equipment. These stress levels and flow regimes are usually a function of the key flow properties such as unconfined yield strength, bulk density, permeability, wall friction angle and adhesion. It is not generally necessary to measure every mixture and/or product going thru the process, but the savvy design engineer would measure enough materials to determine a representative collection of key flow properties.

It is also important to measure key flow properties at conditions that mimic process behavior (temperature, relative humidity, temperature cycle, time at rest, static charge, etc). In some cases the material may be undergoing changes (crystallization, aging, particle breakage, or chemical reactions) that will change one or more of the key flow properties during handling. Therefore, a testing regiment must be selected that isolates conditions that would include these changes. Where possible, the key flow properties should be measured prior to the changes, during these changes (to act as base-case information) and again after these changes (for comparison, to reduce the number of process variables which affect the material performance). In some cases, the material may have some viscous behavior that can cause key flow properties to be a function of strain rate. The testing protocol should include these effects as well. Fibrous material may require special testing protocols.

Next, with the key flow properties in mind, a successful new handling process design can be created. Often there are many process designs that can work for a set of materials subject to a set of process criteria. It will be necessary to address the critical constraints on the new vessel which may make some of these process design recommendations more, or less, desirable (Figure 6). For example, the flow properties may suggest that typical conical process vessels must be very steep to assure reliable operation. But, additional constraints on the new process vessel may require designs be limited to a smaller headroom. In this case, process vessels of different shapes can be utilized to achieve design recommendation that will fit in limited headroom. Sometimes the flow properties suggest that outlets must be overly large to avoid arching and hang-ups in process vessels requiring very large feeders to accommodate the material. However, alternate process designs can reduce the outlet size to reasonable parameters. Certain process vessels are better at preventing segregation than other vessels, so the selection of the optimal vessel design may be driven by segregation prevention requirements.



Conical hopper *Cone-in-cone hopper* *Diamondback® hopper*

Figure 6. Some examples of mass flow hopper configurations

Finally, process operation practices can sometimes change the flow behavior in s system, so these effects must be included in the design of the new handling system. Consider, for example, a fine powder in a process vessel exposed to very fast and frequent filling/emptying sequences. In this case, the gas entrained with the bulk material may change the key flow properties and, therefore, the expected flow behavior. It may increase or decrease the hang-up potential depending on the situation. It could modify the segregation potential as well. If these operational conditions are known at the time of design, then the effect of these conditions can be incorporated in the process design, including a set of operation parameters to assure reliable operation. At Material Flow Solutions, we can help you find the optimal solution for your new process design – getting it right the first time.