Putting the Screws To Tough Materials

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Move Difficult-to-Handle Bulk Materials with Flexible Screw Conveyors

Convey tough bulk materials that tend to pack, cake, smear, break apart or fluidize, and prevent separation of blended products

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Flexible screw conveyors are suitable for use with most bulk materials, from sub-micron powders to large pellets, both free-flowing and non-free-flowing. They are capable of conveying bulk materials at any angle, moving over or under obstructions and through small holes in walls or ceilings (Figure 1). These conveyors also have the advantage of simple construction, low space requirements, reliability of operation and favorable economics. Although alternate conveying methods may be preferable depending on the application parameters of a project, this article focuses specifically on flexible screw conveyors for materials that are problematic to convey.

Difficult-to-convey materials
When engineering a flexible screw conveyor for difficult-to-handle materials, it is necessary to establish the materials' physical characteristics, flow properties, temperature, moisture content, inherent hazards and allowable degree of degradation, as well as the material source and destination, conveying rate, distance, cleaning requirements, plant layout and economics. Flexible screw conveyors are appropriate for use with:
- Cohesive materials
- Ultra-fine particles
- Fragile or friable materials
- Abrasive materials

- Materials that fluidize
- Blended products of disparate particle sizes and bulk properties

A caveat for the plant engineer: the flow characteristics of a bulk material being conveyed under unique circumstances cannot always be predicted with sufficient accuracy to ensure successful performance. In these cases, the importance of simulating plant conditions with a full-size conveyor in a test facility is extremely important.

Efficient flow of a bulk material through any bulk-material-handling system is generally a function of the material's physical properties, but it can also be affected by external factors, such as ambient moisture and temperature levels, as well as the design of the equipment in which it is contained. Although certain material parameters, such as the "angle of repose", may be determined by evaluating a material sample in a laboratory.
these controlled-condition tests are not necessarily predictive of flow behavior in full production-scale systems. When dealing with large volumes of materials under varying conditions, a bulk material’s flowability cannot be determined by physical characteristics alone, such as bulk density, particle size and shape, compressibility or cohesive strength.

Therefore, when designing a flexible screw conveyor, the engineer must consider not only the material’s physical properties and flow characteristics, examples of which are illustrated in Figure 3, but also how these characteristics will be affected by actual conditions in the plant and the design of the equipment:

- Is the material free-flowing, semi-free-flowing or non-free-flowing?
- Has the equipment been designed with proper flow-promotion devices and hopper geometry?
- Is it hygroscopic? How much moisture is in the plant environment?
- Does it tend to pack, cake or smear?
- Do the particles interlock or mat?
- Is the product degradable or breakable, such that use or value is impacted?
- Is it abrasive?
- Is it a blend of various types and sizes of particles that should remain homogeneous during conveying?
- Does it bridge or dome in storage vessels, or is it prone to the formation of “rat holes”?
- Does it tend to aerate or fluidize when being handled?

With the answers to these practical questions, as well as testing in a full-scale system if required, the performance of a conveying system for a specific bulk material in a unique plant environment can be predicted.

**Screw geometry**

Geometry of the flexible screw is critical to performance. Screws vary from round wires that produce relatively high radial forces, to flat screws that generate comparatively greater directional force (Figure 2). This difference in the manner in which the forces are distributed within the conveyor allows system performance to be optimized based on the properties of a given material.

For example, due to its greater directional force, a flat design is better suited than a round design for lighter powders that tend to fluidize. Variants of these two basic screw geometries are also available. For example, flat screws with beveled outer edges distribute the forces inside the conveyor in a slightly different manner than a non-beveled design. This variant can allow efficient transfer of materials that may cause problems with other designs. Another variant sometimes employed with high bulk-density materials is a heavy-duty version of one of the basic screw types. Materials of construction and finish levels are specific to application, with screws constructed of spring steel or stainless steel, and tubes of stainless steel or polymer.

**Equipment and systems**

Flexible screw conveyors are frequently integrated into systems with accessories for feeding and discharging bulk materials. These might include: bulk bag dischargers or manual bag-dump stations with dust collection; feed hoppers with or without flow promotion devices, such as pneumatic vibrators or mechanical agitators; weigh batching systems for precise control of feed; discharge equipment, such as bulk-bag fillers; and control systems.

Feed-hopper design is critical when specifying a conveying system for materials with poor flow characteristics, as the throughput capacity of any conveyor is limited to the rate at which...
material will flow down to the pick-up area of the conveyor. The shear stress created by gravitational forces and flow-promotion devices must be high enough to overcome static cohesive forces between the solid particles. If not, some particles in the vessel will remain stationary and the result will be "rat holing" or "bridging" (Figure 4). The resulting restriction of flow may limit downstream processes because of insufficient feed, or cause flooding of the bin if material enters faster than it can exit.

Problems caused by rat holing include loss of effective surge capacity in the feed hopper, reduced system throughput and additional time required for an operator to manually clean the static product out of the hopper, if necessary. The main problem caused by bridging (also known as arching or doming) is that once the bridge forms, material flow essentially ceases, requiring a process shutdown while material is removed.

Feed hoppers for materials that may rat hole or bridge should be designed with proper geometry and sufficiently steep walls to promote flow. They may incorporate devices such as vibrators or air fluidizers to dislodge material from hopper walls, or mechanical agitators to promote flow.

Cohesive materials

Sticking, packing, caking and smearing are the result of particle binding. This can be caused by chemical reactions, partial melting, binder hardening or crystallization of dissolved substances; adhesion/cohesion of particles joined together from mechanical deformation; attractive forces, such as electrostatic or magnetic pull; interlocking forces resulting from irregular particle shapes; and moisture, oil or fat content.

Moisture is particularly problematic for hygroscopic materials, such as magnesium chloride. As water is absorbed from the surrounding atmosphere, relatively free-flowing materials can begin to agglomerate. In extreme cases, large volumes of these types of materials can solidify, creating large masses of material that can impede flow or immobilize moving equipment components. Since flexible screw conveyors are totally enclosed, temperature and moisture levels of the product can be maintained.

Upstream and downstream equipment such as bulk-bag fillers, bulk-bag unloaders, feed hoppers, screeners, blend- ers and discharge vessels, can also have an airtight design.

In addition, materials with high fat content, such as cake mixes, and materials such as zinc oxide and titanium dioxide, which are cohesive and compressible by nature, are generally non-free-flowing, making them good candidates for flexible screw conveyors.

An example from the paint-and-coatings industry demonstrates the design of a mobile conveyor system for cohesive materials. A flexible screw conveyor transports a mixture of five materials, including calcium carbonate, titanium dioxide powder, two semi-free flowing talcs and a free-flowing resin for a producer of aftermarket autobody paints. The materials are particularly difficult to convey because of disparate bulk densities of 16–46 lb/ft³ and flow characteristics ranging from free-flowing to non-free-flowing. The company converted from manual dumping of bags to a 3-m long, 45-deg angle, portable flexible-screw conveyor mounted on a cart with an integral feed hopper and dust collector. The specially engineered screw design allows the system to function across the wide range of materials. The feed hopper has been designed with steep walls and other beneficial geometric features. Flow-promotion devices combined with proper flow angles prevent bridging by directing the material toward the back wall and down into the conveyor. Conveyor interface adapters have vertical walls to keep material flowing. Feed testing on full-size equipment was integral to the success of the design.

Ultra-fine particles

Mechanical conveyors have an advantage over pneumatic conveying for light or dusty materials, because fine particles can make it difficult to keep the filters operational in filter receivers.

Some fine materials tend to fluidize; for example, fumed silica (synthetic amorphous silicon dioxide) is light and feathery with a bulk density of only 2.5–3 lb/ft³ and a very small particle size of 0.2–0.3 μm (Figure 7). It is not
only prone to dusting, but can also fluidize, taking on some characteristics of a liquid, making it a particularly difficult material to convey. A properly designed screw with flat flight surfaces and some modifications will lift particles by restricting the material's ability to fluidize. Bag-dumping stations for such fine materials should be equipped with internal dust collectors, including cartridge filters and pulse-jet filter cleaning.

Many pigments are comprised of particles under 5 μm, and although the bulk densities may range, materials such as titanium dioxide, iron oxide and carbon black all have a tendency to pack. In order to prevent a conveyor from seizing with such materials, the ideal conveyor screw should have a geometry that distributes the forces inside the conveyor to minimize compression. Flexible screw conveyors can reduce fluidization and aeration of light bulk materials by employing proper design elements. For example, diatomaceous earth (DE), a dry, dusty material consisting of irregularly shaped 5–25 μm particles, with a typical bulk density of 10–16 lb/ft³, has a tendency to bridge and rathe in feed hoppers and to fluidize during transport. Flexible screw conveyors for such materials are generally designed to combat aeration with a wide, flat spiral screw to provide a wider carrying surface with positive forward force and minimal radial force.

**Fragile and friable materials**

Testing is particularly important for fragile or friable particles that must be conveyed without breakage. The self-centering action of the rotating flexible screw can maintain ample clearance between the screw and the tube walls to eliminate or minimize product damage.

**Abrasive materials**

Flexible screw conveyors are appropriate for abrasive materials, primarily due to the ease of maintenance resulting from a design that utilizes no internal bearings and only one moving component that contacts material. For example, anhydrous borax is abrasive, yet light and fluffy with a bulk density of 47.6 lb/ft³ and a 74-μm particle size. A flexible screw conveyor with a heavy-duty, flat-wire screw can stand up to the abrasiveness of the product, since the flat conveying surface minimizes the radial force to reduce friction and wear of the conveyor wall. If necessary, the flexible screw can be removed for inspection or replacement with minimal downtime.

**Diverse mixtures**

A properly engineered flexible screw conveyor can prevent separation of blends throughout the length of the conveyor, regardless of differences in flow characteristics, bulk density or particle size, whereas pneumatic conveyors or other types of mechanical conveyors may cause separation of mixtures during transport. For example, a major spice company has over 8,000 different recipes, each consisting of a mixture of 1–25 ingredients, with particle sizes ranging from 150 μm to 6.4 mm. The company tried a pneumatic conveyor, which caused blended products to separate. A bucket conveyor and a rigid auger conveyor both proved difficult to clean. The company found that flexible screw conveyors did not separate blends or damage the fragile spices, and now it operates 15 flexible screw conveyors, all running daily (Figure 8). A removable clean-out cap at the intake of each tube allows reversal of the screw to fully evacuate the tube for ease of cleaning.

In conclusion, flexible screw conveyors are particularly suited for transporting materials that are cohesive, dusty, friable and abrasive, as well as materials that fluidize and blend prone to separate. Conveying such disparate materials efficiently, however, requires engineering of each flexible screw system according to specific application requirements, and running the actual material to be conveyed on full-size test equipment at the rates anticipated during production.

**References**

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