MOVING DIFFICULT-TO-HANDLE BULK MATERIALS WITH FLEXIBLE SCREW CONVEYORS

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Flexible screw conveyor systems can be engineered to transport bulk materials that tend to pack, cake, smear, break apart or fluidise, and can prevent the separation of blended products. This article looks at the how flexible screw conveyors can be designed to convey such problematic materials.

Flexible screw conveyors are suitable for most bulk materials, from submicron powders to large pellets, both free-flowing and non-free-flowing. They are capable of conveying bulk materials at any angle - over or under obstructions and through small holes in walls or ceilings. They have the advantage of simple construction, low space requirements, reliability of operation and favourable economics.

Engineering for difficult-to-convey materials

When engineering a flexible screw conveyor for a difficult-to-handle material, it is necessary to establish the material's 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. Experience establishes flexible screw conveyors to be appropriate for:

- Cohesive materials
- Ultrafine particles
- Fragile or friable materials
- Abrasive materials
- Materials that fluidise
- 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 be always predicted with sufficient accuracy to ensure successful performance; in these cases, the importance of simulating plant conditions in a full-size conveyor in a test facility using the actual material cannot be overemphasised.

Efficient flow of a bulk material through any bulk material handling system is generally a function of the material's physical properties, but can also be affected by external factors such as ambient moisture and temperature levels, and the design of the equipment in which it is contained.

Therefore, when designing a flexible screw conveyor, the engineer must consider not only the material's physical properties and flow characteristics, 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 and how much moisture is likely to be 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 formation of 'rat holes'?
- Does it tend to aerate or fluidise when being handled?

With the answers to these practical questions, plus testing in a full-scale system if required, 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. This difference in the manner that the forces are distributed within the conveyor allows the system performance to be optimised based on the properties of a given material. For example, due to the greater directional force, a flat design is better suited than a round design for lighter powders that tend to fluidise. Variants of these two basic screw geometries are also available. For example, flat screws with bevelled outer edges, available in a variety of custom and proprietary designs, distribute the forces inside the conveyor in a slightly different manner than a non-bevelled 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 the application, with screws 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 of bulk materials. These might include bulk bag dischargers or manual bag dump stations with pneumatic 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 poorly flowing products 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 sufficient 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 3). 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.

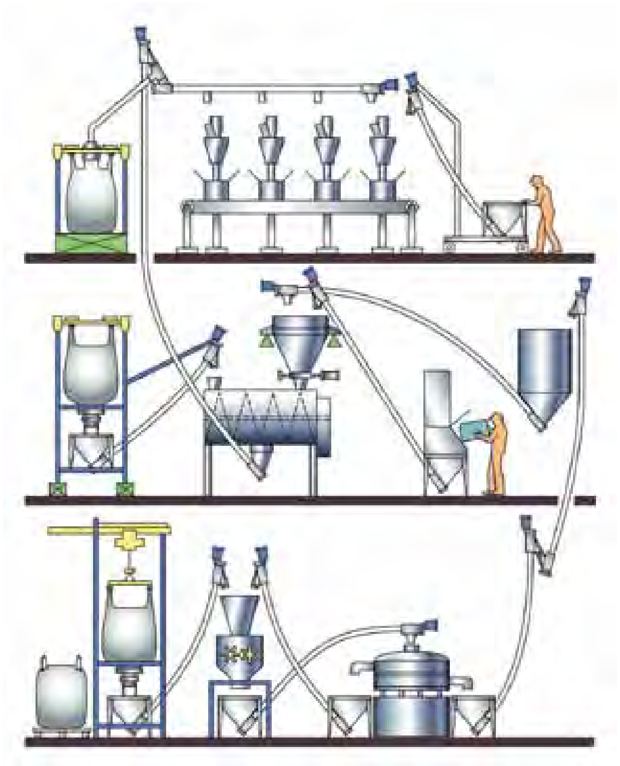

Figure 1: *Properly engineered flexible screw conveyor systems can transport free-flowing and non-free-flowing bulk materials at any angle, through small holes in walls or ceilings. The screws and tubes of certain designs can be curved under, over or around obstructions, eliminating the need for exact conveyor routing.*

Figure 2: *The geometry of flexible screws can be engineered to optimise efficiency for free-flowing as well as non-free-flowing bulk materials, including blends comprising ingredients that tend to separate.*

Problems caused by rat-holing include loss of effective surge capacity in the feed hopper, reduced system throughput and additional time required by an operator if the static product needs to be manually cleaned out of the hopper. 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, and may incorporate devices such as vibrators or air fluidisers 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, which may be caused by: chemical reactions, partial melting, binder hardening or crystallisation 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; or moisture, oil, or fat content.

Moisture is particularly problematic in 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 immobilise 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, blenders and discharge vessels can also be designed to be airtight.

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

Ultrafine 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 fluidise; for example, fumed silica (synthetic amorphous silicon dioxide) is light and feathery, with a bulk density of only 40-50 kg/m^3, and a very small particle size of 0.2 to 0.3 microns. It is not only prone to dusting, but can fluidise, 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 other modifications will lift particles by restricting the material's ability to fluidise. Bag dumping stations for such fine materials should be equipped with internal dust collectors, including cartridge filters and pulse-jet filter cleaning.

Many pigments comprise particles below 5 microns, and although the bulk densities may range, materials such as titanium dioxide, iron oxide and carbon black all share a tendency to pack. In order to prevent a conveyor from seizing with such a material, the ideal conveyor screw would have a geometry that distributes the forces inside the conveyor to minimise compression.

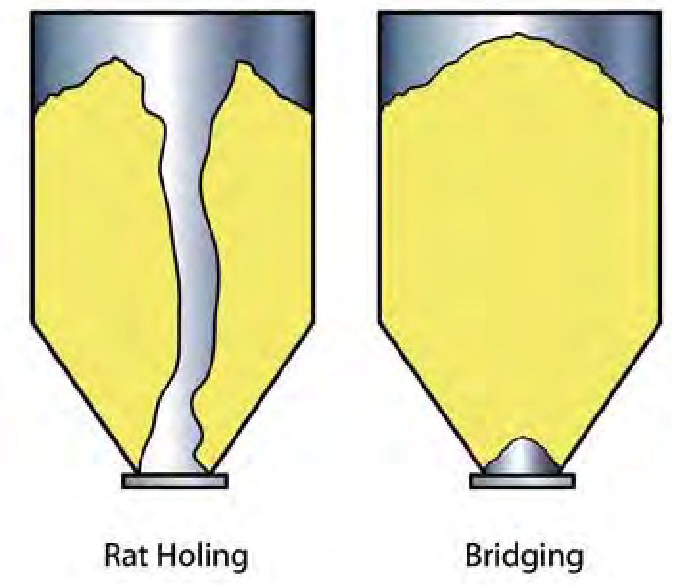

Figure 3: *'Rat-holing' (left) describes a ragged, tunnel-shaped void through stagnant material in the vessel. 'Bridging' (right), also known as doming or arching, describes a void area at the vessel outlet. Both rat-holing and bridging completely prevent the flow of material.*

Figure 4: *Electron micrograph of fumed silica at 100,000x magnification - with a bulk density of 40-50 kg/cm^3, fumed silica is an ultra-light powder, its chain-like particle morphology contributing to the characteristics that make it difficult to handle.*

Flexible screw conveyors can reduce fluidisation 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 micron particles, with a typical bulk density of 164-260 kg/m^3, has a tendency to bridge and rat-hole in feed hoppers and to fluidise 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 a positive forward force and minimal radial force.

Fragile and friable materials

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

Abrasive materials

Flexible screw conveyors are appropriate for abrasive materials primarily due to ease of maintenance resulting from design that utilises no internal bearings and only one moving component that contacts the material. For example, anhydrous borax is abrasive, but light and fluffy, with a bulk density of 760 kg/m^3 and a 74-micron particle size. It can be conveyed using a flexible screw conveyor with a heavy-duty, flat-wire screw to stand up to the abrasiveness of the product. The flat conveying surface minimises the radial force to reduce friction and wearing 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 8000 different recipes, each consisting of a mixture of 1-25 ingredients, with particle sizes ranging from 150 microns to 6.4 mm. The company tried a pneumatic conveyor, which caused blended products to separate, and a bucket conveyor and a rigid auger conveyor, both of which proved difficult to clean. The company found that flexible screw conveyors did not separate blends or damage the spices, many of which are fragile, and now operates 15 flexible screw conveyors, all running daily. A removable clean-out cap at the intake of each tube allows reversing of the screw to fully evacuate the tube for ease of cleaning.

Conclusion

Flexible screw conveyors are particularly suitable for transporting of materials that are cohesive, dusty, friable and abrasive, as well as materials that fluidise and blends prone to separating. 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.

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