Technology Developments in Bulk Bag Discharging

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As the use of FIBCs (Flexible Intermediate Bulk Containers) or bulk bags in the transportation and processing of bulk materials continues to grow, so does the research and study of how to improve their use. Improvements in the discharging of bulk bags are of particular interest to bulk material users as process requirements, operator interfaces and material processing costs are analyzed. This articlewill review recent developments in the discharging of bulk bags based on laboratory testing and process observations including:

- Bulk Bag agitation requirements for efficient material flow.
- Agitation designs and the effect on discharging, compaction and material flow.
- Process controls with respect to agitation.

A bulk bag is a large woven bag designed to carry bulk materials. Bulk bags range in size from 36"x36"x12" to 51"x51"x71" (filled dimensions) and may contain up to 4000 lbs. of material. They differ from RIBCs (Rigid Intermediate Bulk Containers) by having flexible walls rather than rigid walls and tend to be for dry bulk solids. However recent developments in bag liners and bag manufacturing have allowed the bulk bag to be used in other applications as well.

The growth in bulk bag usage has been fairly constant over the last 10 years. Approximately 11 to 13 million bags are used annually with an average annual growth rate of around 15% per year.[1] This growth is projected to continue.

The growth is undoubtedly due to the many advantages bulk bags provide over other containers like paper bags, fiber, plastic and metal drums, and rigid IBCs.

Several key advantages were identified in our research with purchasers and users of bulk bags. These advantages include:

- Improved safety
- Cost savings
- Economical packaging.

Improved Safety

Although estimates vary, government studies, union reports and insurance statistics indicate that:

- The annual cost of medical treatment and lost productivity due to back injuries is estimated to exceed $30 billion.
- Over 1.25 million back injuries due to lifting occur in the workplace each year.
- Eighty percent of back injuries in the workplace occur to the lower back and are associated with manual material handling.[2]

The manual material handling of bulk material in bags and drums and the dumping into process equipment can expose workers to lifting injuries. Bulk bags require less manual movement since they require a mechanical means (fork truck, pallet jack or hoist) to move the container and introduce it into the process (bulk bag discharging frame).

Cost Savings

The labor cost per container is typically reduced when bulk bags are used. The lifting, opening, dumping and disposal of forty, 50-lb. paper bags is in most cases greater than positioning and opening one 2,000-lb. bulk bag.

Economical Packaging

Shipping cost is another area where bulk bags can produce savings. As bag capacity increases, tare weight as a percentage of material weight decreases. This means more material can be shipped with less packaging for the same cost. Properly sized bulk bags can also be positioned and stacked more efficiently to heights exceeding that of smaller bags, maximizing shipping container usage and storage facility space. Container "heels" or residual material left in the container after it is emptied is generally reduced as well.

When determining if the product or process is suitable for bulk bag use, it is important that the bulk material supplier, bulk bag supplier, discharging equipment supplier and material feeding or metering equipment supplier review the application so that the proper bulk bag, discharging frame and feeding equipment can be identified. Eighty percent of all complaints to bulk bag and machinery manufacturers are due to improper bag sizing or styles.[3]

Filling vs. Discharging

The two major points in the bulk bag life cycle are:

- Filling of the bag at a material suppli-

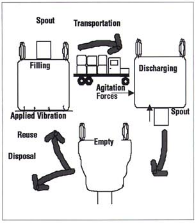

Figure 1: Bulk Bag Life Cycle

er or somewhere else in the process.

- Discharging of the bag at the location of material usage.

These two processes produce material and flow characteristics that are sometimes at odds with each other. See Figure 1.

Filling

The purpose of bag filling stations is to fill the bag efficiently, quickly and to the desired amount. Typically, material becomes aerated as it is deposited into the bag. This makes it difficult to fill the bag to capacity. To overcome this, the bag is manipulated during filling (usually with applied vibration) to de-aerate and compact the material. This procedure produces a full bag that rests more securely on a pallet, stacks better, and utilizes storage space more efficiently.

Discharging

The purpose of discharging stations is to empty the bag by means of a spout or opening at the bottom of the bag. For consistent and trouble free discharging, material that is free flowing, loose and fluid is desired. These characteristics are actually the opposite of the characteristics of the material when it left the filling station. After the bag is filled, it is usually stacked, packed, transported (applying more compacting vibration) and stored, all of which compounds the effect and makes free flow even less probable.

Impeded material flow due to compaction or clumping may require operator manipulation of the bag after opening the spout to start or continue material evacuation. The manipulation may take many forms including hitting the bag bottom with appendages, rods or boards. These remedial practices can easily outweigh the safety and cost savings advantages of bulk bags.

Manufacturers of bulk bag discharging stations offer a multitude of agitation methods to improve material flow. Some of these methods include a variety of moving paddles, pads or rods, and applied vibration. These will be reviewed later in the text.

Through the course of discharging a variety of materials from bulk bags, including titanium dioxide, calcium carbonate, calcium sterate, rubber regrind and various plastic resins, a definite pattern was observed in agitation requirements in bag discharging. This pattern can best be described as two distinct areas that, when influenced by agitation forces at different times during a discharge cycle, produce optimal discharge performance: spout and side agitation forces.

Spout Agitation

Spout agitation is defined as an agitation force applied very near the discharge spout at the bottom of the bag. See Figure 2. This force was observed to be extremely effective at the beginning of the discharge cycle to break the material bridge that typically forms over the spout. The bottom of the bag typically is very compacted due to bag filling and transportation compaction described previously.

A characteristic of the spout agitation force that produced optimal results was a concentrated lifting force, applied perpendicularly to the bag bottom, near the spout. This force lifts the bag near the bridge, thus breaking the bridge and restoring flow.

Another characteristic exhibited was when the force was applied during a bag discharging cycle. In the initial stages of discharging, particularly when the bag is first opened, the spout agitation force is extremely effective. As the bag discharges, the less compacted material from the top portion of the bag has replaced the compacted material at the bottom of the bag and as head pressures from material load are reduced, this force becomes less effective.

Side Agitation

Side agitation is defined as an agitation force applied to the sides of the bag, typically the lower half. See Figure 3.

As the bag discharges, a tension line is produced from the top straps to the spout area. See Figure 4. This effect is due to bag shape.

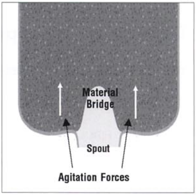

Figure 2: Spout Agitation

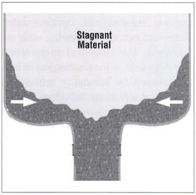

Figure 3: Side Agitation

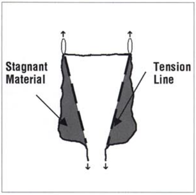

Figure 4: FIBC Loop to Spout Tensile Lines

Most bags are designed with square corners for greater capacity and increased stability when stacked. The bag corners become very slack as the tensile line develops from the bag hanging loops to the spout. This corner slack provides pockets where bulk material can accumulate out of the main material flow. As the bag continues to empty, this stagnant corner material (sometimes up to 100 lbs. or more) may remain in the bag creating a large "heel" (unusable material left in the container after emptying). This "heel" may then flow from the bag as it is removed from the discharging frame, creating cleanup and safety issues, or requiring operations personnel to poke or prod the bag at the end of the discharge cycle.

Increasing bag tension by raising it may reduce the corner slack somewhat, but most of the force just increases the hanging loop to spout tensile force.

A side agitation force applied to the lower portions of the bag sidewalls, very close to the corners, was observed to have a much greater impact on complete bag evacuation. A characteristic of the side force is low force applied over a large area. The purpose of this force is to move the stagnant corner material from its resting place in the corner pockets into the main material flow.

A low force is most effective since it reduces the likelihood of compacting the material once it is moved to the main material flow path. The force must be applied over a large area because a concentrated force would merely move the material in a localized area and not evacuate the entire pocket of stagnant material.

The side agitation force also is most effective when applied at the correct time in the agitation cycle. During laboratory tests, the side agitation was observed to have the greatest effect on material discharging when the bag had approximately 25% of its capacity remaining. This effect was material-dependant and changed slightly with various materials tested.[4]

Figure 5 demonstrates the influence of bottom and side agitation on the discharging cycle of a bulk bag. As described earlier, spout agitation is most effective at the beginning of the cycle with side agitation increasing in importance and becoming dominant when about 25% of the material remains to be discharged. To maximize the influence on bag discharging, the bottom agitation force should be applied until the point depicted on the graph (Figure 5) where the bottom agitation line intersects the side agitation line. Side agitation should then be applied until the bag is empty.

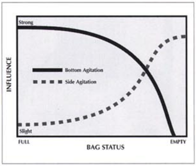

Figure 5: Influence of Agitation on Bag Discharging.

Agitation applied at the wrong place and at the wrong time can produce counterproductive results. Compaction or impedance of the bulk material flow can occur when agitation forces are greater than required or if applied at the wrong time in the discharge cycle.

If side agitation is applied at the beginning of the discharge cycle when spout agitation would be more effective, compaction can occur as the side agitation forces attempt to break the material bridge over the spout. These side forces must be transmitted through the bulk material from the side of the bag to the spout area before it can affect the spout bridge. This is very difficult since bulk material in bags does not transmit forces very efficiently. The result is that the side forces must be great because so much of the force is diffused by the bulk solid. This high force pushing against the material at the side of the bag may cause localized compaction. This effect is evident by observing that the corner of the bag does not move when the side force is removed. See Figure 6.

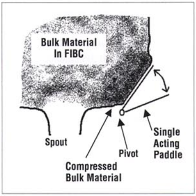

Figure 6: Bulk Bag Corner Compression

Likewise, spout agitation force, applied near the end of the discharge cycle when side agitation is required, may result in impeding the stagnant material in the corner of the bag from reentering the material flow path. The result is a "starvation" condition with no material in the material flow path.

It should be clear that both types of agitation forces - spout and side - are extremely effective when applied properly, but there are also advantages to applying them in a reduced form at the same time. At the beginning of the discharge cycle, alternating application of side agitation and spout agitation forces can further reduce potential compaction. Single axis force applications, as discussed earlier, can produce localized compaction. If alternating forces are applied at perpendicular axes, this is greatly reduced.

For example, imagine trying to knead a lump of bread dough by pushing your fist into the dough in only one direction. The dough will compress and, with further application of the force from your fist, flatten out and compact in the localized area under your fist. Now alternate the direction of the force with your fist at a perpendicular axis. The dough will flatten under the first force and, as perpendicular force is applied, distort in the direction of the first force. The result will be reduced compaction and fluid material movement.

This example is also true when applying alternating spout and side agitation forces. These forces are applied perpendicularly to each other and when applied in alternating fashion, create a very fluid material condition in the bottom of the bag thus improving material flow without the risk of compaction.

TYPES OF AGITATION

A variety of agitation means exists to improve material flow. These include:

- Paddles
- Pads and Rods
- Vibration

Paddles

A paddle is defined as a pivoting or linear-moving plate with a large contact surface, typically actuated by pneumatic cylinders or mechanical means. The paddle was observed to be the most effective agitation means when properly applied and sequenced. Advantages also include good bag support and contouring for improved material flow, large surface area for effective side agitation and mechanical advantages available with lever ratios on pivoting designs. Disadvantages include localized compaction with single acting forces and large bearing points to support large bag capacities.

Pads and Rods

Pads or Rods are defined as pivoting or linear moving plates with a contact surface area significantly less than a paddle, typically actuated by pneumatic cylinders or mechanical means. Characteristics include high-localized forces. This type of agitation is effective for bottom agitation when applied near the bag discharge spout. Disadvantages include a small area of influence and poor force transmission as material moves out of the path of the concentrated force. Therefore, these devices are not effective at applying side agitation force.

Applied Vibration

Vibration is an effective means of compacting and de-aerating, particularly high frequency, low amplitude vibration. For dislodging compacted material though, this type of vibration is not very effective. High amplitude low frequency vibration is better suited for initially restoring material flow from a bulk bag, however limitations of vibratory equipment to provide amplitudes great enough and frequencies low enough in a cost effective manner makes this type of vibration difficult to achieve. Vibration is ineffective in removing material from the corners of bulk bags in the low-tension zones at the end of discharging cycles.

It is important that agitation devices improve material flow characteristics and not manipulate the bag to the point where the device may cause compaction and impede material flow. This risk is present when applied vibration is used or when agitation pads or paddles repeatedly apply single axis forces to a localized area.

Process Controls for Optimizing Agitation

As described earlier in this article, matching agitation application to the agitation requirements of the bulk bag during discharge was observed to be a major factor in realizing advantages of processing material in bulk bags. Negative results of not matching the agitation to bag discharge requirements include:

- Increased labor to break material bridges over the spout
- Increased labor to empty bag corners or clean up after this material spills during bag removal
- Larger material "heels"
- Material flow interruptions due to compaction or starvation.

A process control that matches the flow requirements can produce positive results. As stated earlier, laboratory and field observations support a defined point in the bag discharging cycle when agitation requirements change. This transformation can be determined for a given material by observing the discharge through several discharging cycles. By using timers, load cells, or other devices, a process may be defined that would change the force application of the agitation devices. However, this could be quite time consuming and costly, and the discharge characteristics are dependent on material properties and feed rates.

For example, if a simple timer is used to operate one set of pneumatic cylinders for bottom agitation and another for side agitation at an interval determined through observation, any change in feed rate, bag capacity, or material flow properties could significantly vary from initial observations. The result is a less than optimal match between requirements and application. Similar problems could arise with any rigid program using load cells or level indicators. Worse yet, a purely manual operation requiring continuous operator observation and intervention to maintain material flow could significantly reduce labor savings in bulk bag usage.

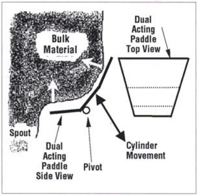

Figure 7: Dual Paddle Movement

A better solution in bulk bag discharging is an adaptive process that determines the status of the bag discharging cycle and makes the appropriate change in the agitation application. One adaptive design that was tested uses two dual-pivoting trapezoid-shaped paddles actuated by pneumatic cylinders. See Figure 7. This design used proximity sensors on the cylinders to provide a feedback loop to the bulk bag discharging frame process control. This feedback loop provides the determina-

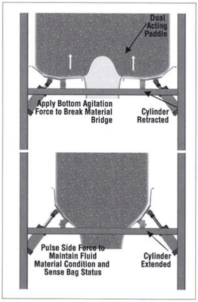

Figure 8

tion point when the bag discharging requirements have changed by monitoring the position of the pneumatic cylinder piston.

When the bulk bag is full of material, the process control opens a valve to allow the cylinder to retract, moving the small side of the paddle upward into the material bridge and restores flow. The short lever arm and the small surface of the trapezoid paddle results in a large concentrated force upwards.

As the process control opens the valve to the other end of the cylinder and allows it to extend, the large side of the paddle moves up against the side of the bag near the corners. The long lever arm and large surface area result in a low, evenly applied force. The cylinder extension is activated for a preset time. When the bag is full, the material resistance force is greater than the cylinder force applied through the paddle, and thus stops the cylinder's extension. The process control then returns to the retraction stroke of the cylinder applying force to the bottom of the bag. This cycle is continued as the bag empties. See Figure 8.

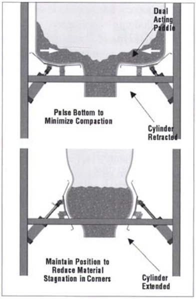

Figure 9: Dual Paddle Movement with Near Empty Bag

Figure 8: Dual Paddle Movement with Full Bag

When sufficient material in the bag has been discharged, the material force resisting paddle movement (side agitation force) is reduced. This circumstance allows the cylinder to extend further in the timeframe of the open valve. This results in the cylinder extending further, pushing the piston past a proximity sensor. This action provides the process control with an indication of bag status and the agitation mode can then be changed to extend the cylinders for longer duration, thus emptying the corners of the bag. See Figure 9.

As the empty bag is unloaded and a full bag is reinstalled, this adaptive system is reset to bottom agitation and the cycle begins again.

An enhanced feature to the adaptive agitation system is the ability of the operator to manually activate the system via a "jog" button. This allows the operator to agitate the bag through a cylinder extension and retraction cycle. This is generally desired when the bag is first opened to break the spout bridge and initiate material flow. The process control is then switched to automatically continue through the adaptive cycle.

Summary

The use of bulk bags (FIBCs) is expected to continue due to the advantages of improved safety, labor cost savings and economical packaging. Through extensive testing of a variety of materials, two distinct types of agitation, bottom and side, were identified to maximize material flow. Also observed was the importance of timing in the application of the forces during the bag discharging cycle.

Adaptive agitation systems, those systems that change the application and timing of the agitation forces, were identified to produce the best material flow patterns, while minimizing compaction of the bulk solid and completely emptying the bag.

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