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Ask Joe! Column

Flooding Powders : When Is Permeability Important?

by David Stuart Dick, Solids Handling Technologies, Inc.

The flow of bulk solids includes the flow of air. All bulk solids have air between the particles and when the solid particles move, the air in the voids moves with them. The air will also move relative to the solids particles when there is a pressure gradient. An air pressure gradient may develop when the bulk density of the product changes – decreasing or increasing the volume of the voids.

A pressure gradient may also be due to changing pressures in a process vessel or due to leakage of air past a rotary valve feeding into a pneumatic conveyor etc. There are times when the movement of air (or other gas) can affect, and have an effect on, the movement of the bulk solid.

(Photo: Flooding powder has the properties of a liquid.)

This is especially true when:

1) The solids particles are fine – this implies that the air permeability is low.
2) The air or gas is hot – it is more difficult for the more viscous gas to move through the voids.
3) The solids flow rate is high – air or gas is expected to move quickly relative to the solids as the bulk density changes.
4) Process conditions apply pressure gradients across the moving solids.

The flow of air through the bulk solid is a function of the solid's permeability and the air pressure gradient. Permeability is measured in the laboratory on a sample of the product and is a function of the bulk density. As the product expands and contracts under pressure while it is flowing, its bulk density decreases and increases and the permeability follows.

There are a number of ways that air or gas will influence the flow of solids.

Flooding

Flooding occurs when a fine material with low permeability is handled in a relatively small bin at a high flow rate. It can also occur in a large bin flowing in funnel flow because the flow channel is relatively small in the otherwise stagnant product, effectively making it a small, albeit tall, bin as discussed in the next paragraph.

The mechanism for flooding is that air trapped in the voids travels down with the solid and due to the low permeability of the product is not allowed to dissipate. Near the bottom of the bin, the air in the voids is under high pressure. When the product and trapped air is exposed to atmosphere at the bin outlet, the air expands and removes the bulk solid's ability to form an angle of repose. Without an angle of repose to hold the solids back, the feeder can no longer control the product and it continues to flow past the feeder allowing the product above, which still has air trapped in its voids at high pressure, to escape as well and the product floods uncontrollably.

In a large bin or silo, flooding will occur if the product is flowing in funnel flow. In funnel flow, the product forms a flow channel within otherwise stagnant material. Even a relatively free flowing product will form a steep sided narrow flow channel. The fine product entering the narrow flow channel moves at a high velocity down the channel and the air in the voids is not allowed to dissipate. Again, the high-pressure air at the outlet removes the product's angle of repose and it floods.

It is not unusual to use a rotary valve to prevent product flooding from a hopper. Unfortunately, this deals with the catastrophic symptom of flooding but does not restore reliable, uniform gravity flow. Fine powders flowing in such a bin with a rotary valve will usually come out with widely varying bulk density.

Limited Flow Rate

In a mass flow bin or silo all the product moves whenever any is withdrawn. This means that the solids velocity in the cylinder section is low. As it flows, the solids contact pressures and the bulk density increase and the total volume of the voids decreases, but the air has time to dissipate. Generally, as the solids pressure and bulk density increase in the cylindrical part of the silo, air travels up through the solid and is expelled from the top surface.

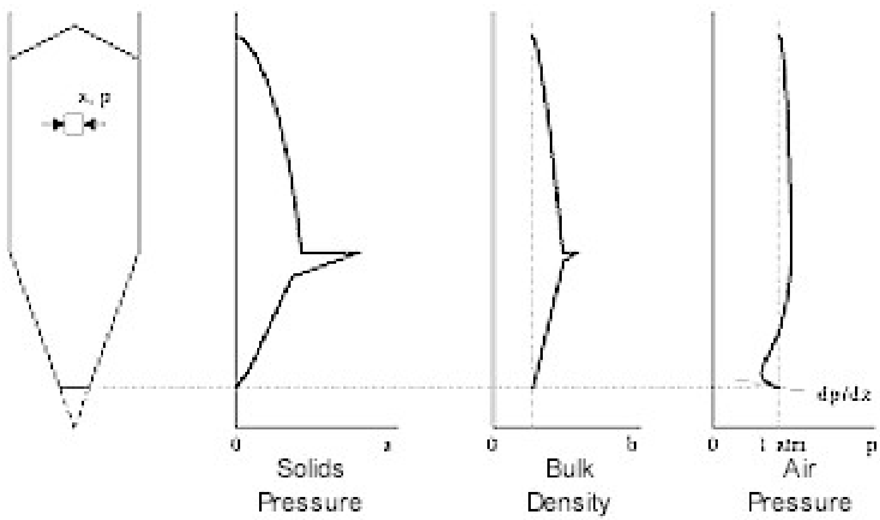

Figure 1: Pressure and Density in an Element during the Flow at a "Limiting Flowrate Condition"

The highest solids pressure in a mass flow bin or silo is at the transition between the cylinder and the hopper. As the bulk solid flows down through the hopper the solids pressure decreases. This allows the bulk solid to dilate as it constantly shears and deforms to flow through the converging hopper section. As it dilates, the voids increase and the air pressure in the voids decreases.

If the flow rate is high enough relative to the bulk solid's permeability, the air pressure in the voids may fall below atmospheric in the lower parts of the hopper. When the powder reaches the outlet, where the air pressure is atmospheric, an upward pressure gradient forms. At a certain flow rate the pressure gradient will be large enough to balance the weight of the flowing product and the limiting flow rate is reached. With fine powders, this limiting flow rate may be a small fraction of the required flow.

The flow rate of the bulk solid can be increased by removing the adverse pressure gradient at the outlet. One way to do this is to increase the size of the outlet. This obviously increases the area through which the solids can flow but also reduces the velocity and accelerations at the critical point where they have the most effect. This also requires a larger feeder.

Another way to increase the solids flow rate is to replace the air in the voids so that negative pressure does not develop in the hopper near the outlet. The amount of air is critical and too much will turn a limited flow rate condition into a flooding condition. The analysis of the two phases (bulk solid and air) flowing together and relative to one another is based on the measured compressibility and permeability properties of the bulk solid. The system design is self-limiting so that it will not induce flooding and will compensate for changes in level of material in the bin. It is often possible to increase the solids flow rate by a factor of ten with an air injection system.

Comments, Suggestions and More!

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About our Author

David Stuart Dick has a BS degree in Civil Engineering from the University of Natal in South Africa. He spent 12 years designing large mining structures and silos as well as developing a solid's flow testing laboratory in South Africa.

In 1982 David joined Jenike & Johanson Inc where he managed their West Coast office and was Vice President and Director of R&D for 10 years. He returned to England in 1997 and started a new consulting firm, working closely with Solids Handling Technologies, Inc during that time. In 2005 he relocated to the USA to add to, and participate in the growth of Solids Handling Technologies.

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Welcome to Ask Joe!, a monthly column by our resident materials handling guru, Joe Marinelli of Solids Handling Technologies. Joe addresses the issues that bug you the most. And Joe knows!! Formerly with Jenike & Johanson, Solids Flow and Peabody TecTank, Joe is an expert on materials handling.

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