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Ask Joe! Column

Does Your Silo Honk and Thump?

by David S. Dick, Solids Handling Technologies, Inc.

The problems of thumping and vibration in silos are relatively common in some bulk solids handling industries. There are many reasons for these problems, some better understood than others. They vary from relatively high frequency to very low frequency and from being a minor nuisance to a serious structural concern.

High frequency vibrations will often be a nuisance to neighbors and plant personnel and may require operators to wear ear protectors. Low frequency vibrations and sporadic thumping can be much more serious. Significant energy may be released with each thump, which at least can be disconcerting and at worst may cause catastrophic structural failure in the silo itself and in adjacent buildings.

Dynamic loads in funnel flow

Dynamic loads in funnel flow silos have created structural problems for as long as products have been stored in silos. When a flow channel empties out it is called a rathole. A rathole may be very stable and require a flow aid to restore flow or it may collapse spontaneously. The amount of product that falls depends on when and how the sides of the rathole will give way.

There are many examples of collapsing ratholes creating a vacuum and sucking in the roof and top part of a silo and/or very high pressure blowing off the hopper or causing damage to the support structure and foundation. We have had experience with loads large enough to tear a hole in a 0.5" (12.7 mm) thick stainless steel plate and enough to move a 2000 ton silo by shearing its foundation bolts. (See photo)

The solution to these problems will usually involve either retrofitting the silo to convert it to mass flow or expanded flow. Expanded flow is a short mass flow hopper that expands the flow channel up to a diameter that will always be unstable. This prevents the flow channel from emptying out and therefore prevents dynamic loads while ensuring complete cleanout of the silo. Sometimes the solution is to correct the design details of the feeder to restore mass flow in a silo. Even a hopper steep enough for mass flow will flow in funnel flow if the hopper and feeder combination is not working properly.

Vibrations in mass flow

There are a number of mechanisms that can cause vibrations in a mass flow silo. High frequency vibrations are almost always due to a slip-stick phenomenon as the particles slide on the silo walls. ‘Honking’, or ‘singing’ silos can create noise with sound pressure levels in excess of 110dB.

Depending on the frequency, the sound has been described as honking like a train horn or singing. (Click on the image to hear recordings of actual silo sounds)

The phenomenon is seen in aluminum and stainless steel silos. It only occurs at a certain level of contact pressure between the particles and the silo wall. One method of dealing with the problem is to convert the silo to funnel flow. This may be done with an internal tube or tubes either in the center of the silo or attached to the walls to force a first-in-last-out flow sequence. With a free-flowing, non-degrading product this may be acceptable. If it is necessary to maintain mass flow, a number of other remedies are available. One is to reduce the loads.

Experience has shown that if the silo is allowed to empty, the honking stops at some point when the level of product reaches a certain point. Laboratory tests confirm that the slip-stick phenomenon is a function of wall contact pressure and it disappears when the pressure is reduced. It is possible to build relatively simple internal structures in the silo to prevent the solids contact pressure reaching levels where slip-stick and honking would start. The internal structures shed the loads due to the weight of the product into the silo walls higher up in the silo rather than allowing the loads in the cylinder section to build up to a level where honking would start.

Vibrations at an intermediate frequency (or pulsing) are often due to a high-pressure region in the flowing mass near a region of low pressure. Elastic potential energy builds up in the highly stressed region which, when released into the low-pressure region allows a mass of solid to move suddenly. A large amount of solid is usually involved but since the frequency is relatively high, the amount of movement is small.

Pulsing may also be due to slip-stick but instead of occurring at the interface between the product and the silo wall, it occurs as the product shears on itself. This will often occur if the solid is relatively compressible and springy.

Low frequency vibrations in mass flow also may be due to a number of mechanisms. Plate-like products such as wood chips, chopped plastic bottles, chopped plastic film etc are not homogeneous and can transfer stresses in unusual ways when stored in a silo. It is not uncommon for fairly large voids to open up in the lower portion of the silo when this type of product is discharged. The voids are not necessarily like ratholes and have been described as ‘caverns’ in the hopper. When the voids collapse, the material above falls and the results are similar to a collapsing rathole in a funnel flow silo. (See photo)

There is another low frequency vibration mechanism that occurs in mass flow that has been more difficult to pin down. This mechanism usually occurs with relatively free-flowing, relatively incompressible products like plastic pellets, dry sand, hard granules etc. These vibrations have a relatively fixed period and are what is often referred to as ‘thumping’. The reason it has been difficult to pin down the actual cause is that thumping is due to a number of properties of the bulk solid.

When certain values of compressibility, internal friction and angle of sliding friction on the hopper wall combine, portions of the stored volume cannot move unless other parts move first. This creates an intermittent movement pattern in the bulk of the stored product and while it appears that there is mass flow, the flow is in fact switching between funnel flow where only some of the material is in motion and mass flow where all of the silo contents are in motion.

Thumping can be a nuisance, a discomfort or a dangerous condition causing structural damage. The magnitude of the thumps is a function of the period. The longer the period between thumps the higher the magnitude. Since the flow of product at the outlet is constant, the longer the period between thumps the more potential energy of the stored product will be converted to kinetic energy when it starts to move. Structural distress can range from dents in the silo wall to catastrophic failure of the weakest element in the structure – the wall, the hopper or the foundation. Thumping can also pose a risk to nearby, and possibly connected, buildings.

It is possible to identify combinations of compressibility, angle of internal friction of the product, angle of sliding friction between the product and the hopper wall and the angle of the hopper wall that are likely to cause thumping. When the conditions have been identified the critical combination may be designed out of the system. If an existing silo is found to be thumping, making relatively simple modifications to change one of the parameters so that the combination falls outside the critical values will stop the thumps.

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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Guest articles for the **Ask Joe!** Column are always welcome, for more information please contact Joe Marinelli directly at his email address: joe@solidshandlingtech.com.

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