Aeration of Bulk Materials in Silos and Storage Tanks

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When handling bulk powder and grain materials in bulk, problems may occur with their discharging, due to doming or sticking to the walls of storage facilities. Stored material can either settle and stick to inclined walls, form a dome or form a central funnel (a “rat hole”).

1. Mechanic and Acoustic Release Systems

Mechanic release systems (vibration bottoms, electric or pneumatic surface vibrators or pneumatic hammers) make use of mechanic energy to produce impacts or vibrations which are transferred from the structure of a storage facility into bulk material. They often have a contrary effect – not only don’t they loosen the material and make its discharge easier, they can even compact it in a discharge hopper and a discharge orifice thus making its discharge completely impossible.

Acoustic release systems are broadband sound resources with low frequency $f$ (usually 60 - 300 Hz) and big acoustic pressure $L_p$ (137 - 147 dB in reference point $r = 1$ m). The sound produced by the resource is transferred to the facility in which the material needs to be loosened. Most energy of acoustic pressure is kept in the area of settled material whereas actuating on air particles causes their vibrating and subsequent loosening of settled dust particles in a given space. On the frequency of the first harmonic component, sound is emitted in the space almost evenly in all directions. This is given by the fact that the orifice of the acoustic line has quite a small diameter and with low frequencies, the condition $d << l$ ($d$ is the diameter of the acoustic line orifice and $l$ is sonic wavelength) is fulfilled. With increasing distance from the acoustic line orifice, the level of acoustic pressure $L_p$ decreases significantly.

2. Pneumatic Release Systems

Pneumatic release elements and systems can be divided into local and surface ones. Local aeration elements include aeration spears, air cannons and pulse nozzles. Surface elements are either fluid bottoms of smaller dimensions or aeration pads assembled to form sets of aeration devices. Surface aeration elements fluidize the material across its surface.

2.1 Local Aeration Systems

Local aeration elements supply pressure air to the aerated material in one point of limited dimensions. Therefore, they cannot fluidize the material across its entire volume even if assembled in respective systems. Therefore, they are suitable especially to facilitate material discharge from feeding hoppers, operating storage tanks and silos of smaller dimensions with fast material turnover and with small top angle of the discharge hopper.

Aeration spears (Fig. 1) and bars provide for spot (the dimensions of the spear are by a degree of magnitude smaller than the dimensions of the storage tank or its discharge) or linear supply of air in bulk material. The air supply is continuous during the entire time of material discharge. Air flow has only limited reach - that is why the aeration spears are installed in the vicinity of output orifices whereas the bars are the most frequently installed in corners of square storage tanks or filter discharges. Aeration spears make use of pressure air with overpressure between 0.05 and 0.6 MPa(g). The limitation of air supply by using an expansion nozzle (Laval nozzle) is recommended.
Air cannons (Fig. 2) supply large volume of gas in the stored material in form of individual impulses. They consist of an air receiver and pulse valve connected with a fluidization body through a hose or pipeline. Air flow spreads through the material spherically and its reach is longer than with aeration spears. The pulse length is adjustable and is in the order from several $10^{-1}$ of second up to $10^{-2}$ of second. Air cannons use pressurized air of between 0.4 and 0.6 MPa(g).

Pulse nozzles (Fig. 3) are quite small devices which supply very short air pulses in the stored material. They are produced with various designs – as a rubber disc, metallic valve or a valve with a rubber membrane. To produce air pulse, a pulse valve installed directly on the nozzle is used. Air discharge is controlled so that the material is fluidized in a radial layer parallel with the wall of a discharge hopper. The reach of the air flow from the nozzles depends on air pressure and the properties of the material and can be up to 1,000 – 1,250 mm from the nozzle.

The length of the pulse is adjustable in the order of tens of milliseconds. Pulse nozzles use pressurized air with of between 0.3 and 0.6 MPa(g) and the air should be dried, especially for outdoor installations, up to dew-point of $-40$ °C. Pressurized air consumption is according to the period of pulsation between $10^{-2}$ and 100 Nm$^3$/h.

### 2.2 Surface Aeration Systems

Surface aeration elements fluidize the material across its surface. The main functioning member of an aeration element is aeration fabric. Its usual thickness varies between 4 and 8 mm, specific resistance between 2,500 and 16,000 Pa at air flow 400 Nm$^3$/m$^2$·h. Aeration fabrics are made of natural or synthetic fibers in accordance to their specific temperature resistance – see the following table:

<table>
<thead>
<tr>
<th>Material</th>
<th>Temperature Resistance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cotton</td>
<td>100 °C</td>
</tr>
<tr>
<td>PES</td>
<td>150 °C</td>
</tr>
<tr>
<td>Para-Aramid</td>
<td>200 °C</td>
</tr>
<tr>
<td>Meta-Aramid</td>
<td>250 - 300 °C</td>
</tr>
</tbody>
</table>

Air flows through the pores in the aeration fabric to the surface and enters the powder material. Hereby, its internal friction is reduced and the material is put in a fluid state thus obtaining properties resembling a liquid.

Especially in sets of multiple units, the aeration elements occupy the entire surface of the bottom of a silo or a storage tank and aerate the material in its entire volume. That is why they are suitable for silos with bigger top angle or flat bottom and for silos with larger diameters – over 3,500 mm. Surface aeration is also suitable where sufficient and stable hydrostatic pressure of material needs to be developed. It is required for uniform discharging or dosing of stored material into linked technological processes or for successive pneumatic transport through a flow feeder.

For surface aeration of the material in storage tanks of smaller dimensions, fluidization bottoms are used. These are either flat or conical with aeration air supplied below an aeration partition in the shape of a circular board or a cone.

A fundamental element of aeration devices is an aeration pad (Fig. 4). The aeration fabric is fixed to its top so that all air leaving the pad passes through the aeration partition. Leakages, if any, may cause limitation or loss of the aeration pad functioning as well as considerable abrasion of the silo bottom. Aeration air supplied should always be distributed through a limiting expansion nozzle. It will help to supply exactly the specified amount of air in the pad regardless of thickness of overlying stored material and the height of the material column above the pad. When using a set of multiple pads, the expansion (divergent) nozzles will provide for functioning of the aeration device also in case one or more pads in the system get damaged.
For the aeration of silos and storage tanks, aeration pads are installed in their bottoms. Radial distribution of the pads is used most frequently (Fig. 5); however, other distributions are also possible depending on the shape and design of the silo bottom (Fig. 6). The angle of the bottom of a silo or a storage tank can differ from a flat bottom (to provide for sufficient discharge, the angle is min. 8° from a horizontal line) to conical bottoms with top angle up to 60°.

To provide for proper functioning of an aeration system and therefore complete discharge of a silo, sufficiently “dense” equipment of the silo bottom with aeration pads is required. Generally, aerated area takes up between 20 and 30% of the total area of a silo bottom in which case silo discharge to more than 97% can be guaranteed. Exact discharge level depends not only on the design of the aeration device but also on the volume and shape of the storage silo. To increase the economy of operation and reduce consumption of aeration air, the aeration devices are divided to sections which regularly and cyclically alter in their operation. In small silos, there are 3-4 sections whereas for silos with the diameter around 20 m 16 to 20 sections are designed.

Roots blowers are often used as the source of aeration air with discharge pressure between 50 and 80 kPa(g). If a compressed-air network is available, pressure air with up to 200 kPa(g) is used in which case its perfect drainage shall be secured and also drying in case of aeration of hygroscopic materials. Using aeration air with higher overpressure is possible, however, with regard to actually achievable pressure of a high fluid layer of a material in silos it is unreasonable and burdens the device with high power consumption. For the extra air through the aeration device of between $10^1$ and $10^2 \text{ Nm}^3/\text{h}$ the capacity of a dust-removing appliance of a silo or a tank needs to be increased.

3. Conclusion

Providing for continuous discharge of materials from silos and tanks by means of properly designed equipment is very important. Continuous flow with required efficiency is needed for concurring technological equipment and properly chosen aeration device will moreover provide for proper emptying of a storage facility and will considerably reduce material residues left in it.

With insufficient material aeration in its entire volume, material doming occurs with higher discharge outputs. Breakdown of the dome may induce a piston effect when a column of the non-aerated material sinks in through the entire height of the silo and causes abrupt decrease of the pressure above the material level. This may lead up to the destruction of the silo (Fig. 6) despite its securing by using a release device which cannot provide for sucking of sufficient amount of air in the silo to equalize the pressures.

Both the local aeration systems (spears and nozzles) and the aeration devices find their utilization in the storage technology. Local systems are suitable for smaller tanks with fast material turnover. Surface aeration devices are suitable for larger storage and dispatching silos and when perfect emptying of a storage facility is required. These have the additional benefit of longer service life and resistance to wearing by the transported material.

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