Consulting & Engineering

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Design of Surge Bins / Wet Solids Concentrator Vessels

Introduction

Wet solids concentrator vessels, also called surge bins or constant density cones are vital components for the minerals processing industries around the world. In the Australian mineral sands industry, surge bins have been used for many years in an attempt to maintain feed to the separation equipment, should feed from the mine be interrupted. These vessels are also used to homogenise the slurry fed into the Wet Concentrator Plant and promote conditions for optimum mineral separating efficiency. Combining the above functionalities should result in the stable operation of the downstream mineral separation equipment.

Figure 1: Surge bin in service

Importance of a correct design

Conventional thinking tended to treat bins containing a water sand slurry mixture as a viscous liquid storage system. However, because the solids settle and consolidate in the vessel, which causes water to rise towards the bin overflow, those mixtures are better considered as a bulk solid under saturated conditions. This was confirmed by recent research results proving that the flow behaviour in mineral surge bins is analogous to the flow of a bulk material [1-2].

Unfortunately, many surge bins designed and built before this change in the approach regularly show material flow problems including material hang-ups, slumping and rat-holing. These issues cause the feed rate and slurry density to the separation equipment to vary considerably, resulting in reduced concentrate grades and reduced mineral recoveries in the concentrator plants. Correct operation often relies on the injection of water to improve solids discharge.

Design approach

Step 1: Conceptual bin design

Goal: Ensure reliable and consistent material discharge

The primary objective in the design of wet solids storage vessels is to ensure that the contents will mass flow at a consistent rate without flow obstructions occurring (Fig. 2). This requires determination of design parameters including wall angle and outlet opening size using the principles of Jenike [3] to describe the stress fields in a surge bin during initial filling and discharge.

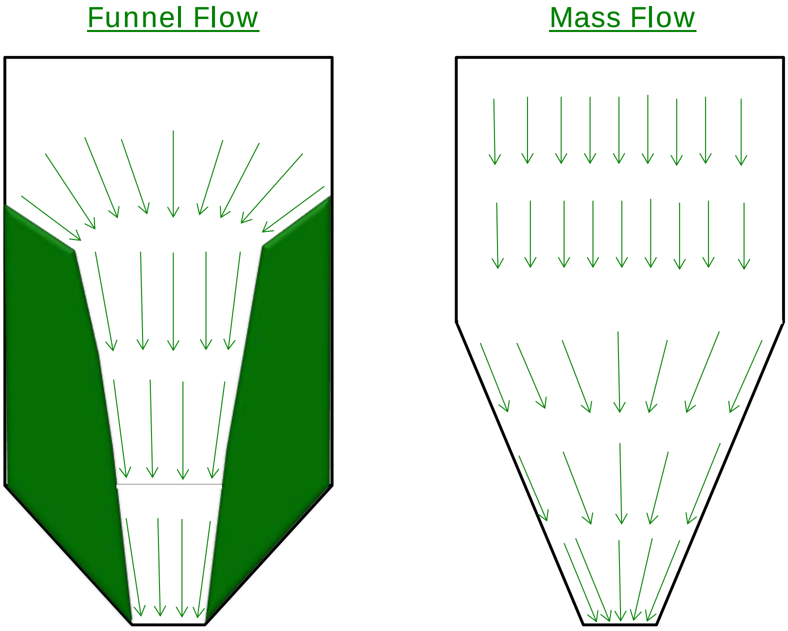

Figure 2: Funnel flow in contrast to mass flow

The determination of the maximum hopper half angle to allow mass flow and minimum outlet opening size is based on the knowledge of the material flow properties. To simulate the actual conditions in the wet solids concentrator vessels and improve design reliability, the design should consider the material flow properties determined in submerged conditions in contrast to dry conditions. This includes consolidation behavior, flow function, wall friction, and inter-particle friction coefficients. Failure to determine the material flow properties will result in either wet solids concentrator vessels with flow issues or vessels that have steeper wall angle than required, so as to ensure that mass flow and therefore reliable discharge will occur. As a consequence, those vessels will be taller than necessary, resulting in greater manufacturing costs.

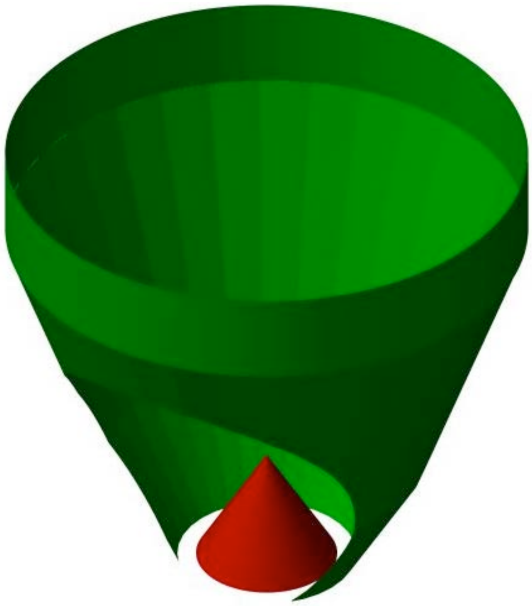

Figure 3: Addition of a conical insert to create a plane-flow annulus

To summarize, the first design step consists of determining:

1. Whether the hopper will be **conical or plane-flow**
2. The **maximum hopper half-angle** that allows mass flow
3. The **minimum outlet dimension** to avoid material arching

Further, the conceptual design phase will consist of:

4. Determining whether adding a **conical insert** will be beneficial to either reduce the overall bin size by creating a plane flow annulus (allowing about 10˚ less steep angle than for a conical hopper) and/or improve material flow (Fig.3)
5. Calculating the **wall loads**[1] in
   - Initial condition (after initial filling)
   - Flow condition

[1] based on AS 3774-1996

Step 2: Design of fluidization and extraction systems

Goal: Ensure reliable solids extraction

The wet solids are usually extracted from the bottom of a bin by a suction pump. To allow extraction, the consolidated material is **fluidised with water injected through a plenum** (Fig. 4). This assists in moving the solids towards the outlet and reduces the solids concentration to a more dilute and pumpable slurry.

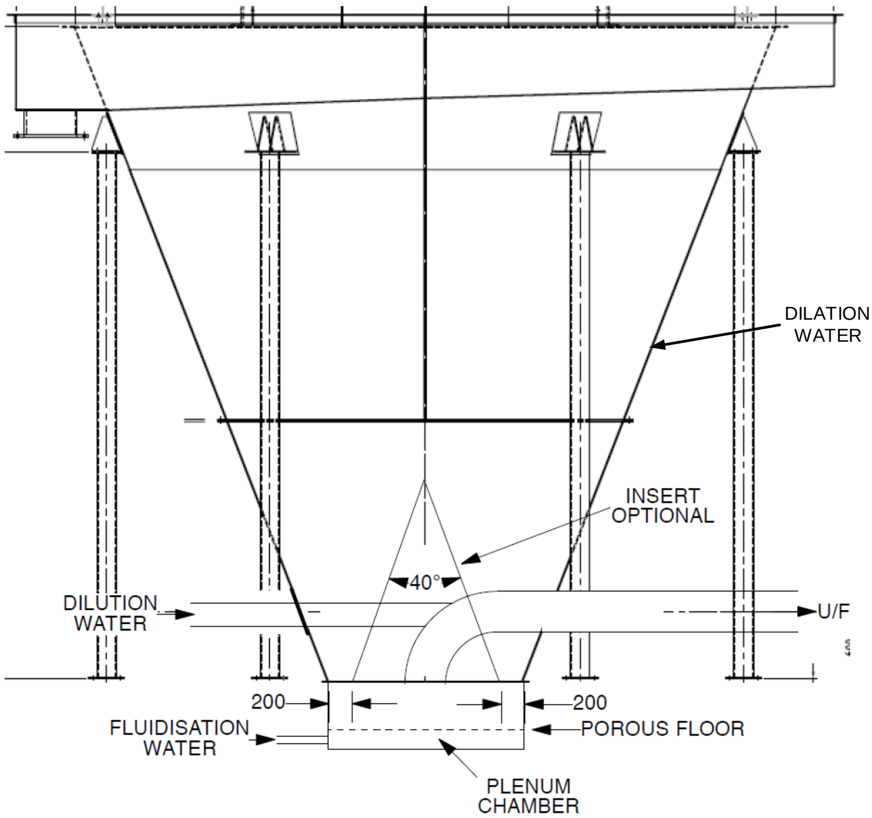

Figure 4: Schematic of a wet solids concentrator vessel showing fluidisation, dilution and dilation water

Step 3: Addition of dilation water

Goal: Avoid material hang-up

Another important material property required for design is the **wet permeability** of the material. In fact, during discharge, the pressure decreases down the hopper due to the formation of an arch stress field analogous to the principle of the roman arch. As a result, as the material moves down the hopper, it will **dilate** as the bulk density is decreasing due to the decrease in consolidation pressure. The spaces created between the solids particles must then be filled by water. If the material is very permeable, the water is available from some other parts of the bin. If the material is poorly permeable, material hang-up will occur. To improve material discharge and ensure that dilation water is available, water can be injected at one or several locations along the hopper walls (Fig. 4). Addition of dilation water will help avoiding material hang-up, in particular if the material has low to moderate permeability, such as a material containing clay. The **amount** of dilation water to be added and the **optimal locations of the injection points** can be determined based on the knowledge of consolidation pressure down the hopper and material compressibility.

In an industrial size surge bin, the dilation water for a low compressible material usually represents an additional volume flow rate of water of only a few m^3/h. However, in the case of a compressible material, the amount of dilation water required to fill the gaps is no longer negligible.

Step 4: Supply of dilution water

Goal: Achieve desired slurry concentration at outlet

If the addition of fluidisation and dilation water is not sufficient to achieve the desired solids to fluid ratio for optimal downstream process, **dilution water** can be added to the slurry extracted, as indicated in Fig. 4.

References

[1] I. Lecreps-Prigge and S. Wiche, Design Principles for Wet Solids Concentrator Vessels. In proceedings of the "11th International Conference on Bulk Materials Storage, Handling and Transportation – ICBMH 2013", Newcastle, Australia, July 2-4, 2013

[2] S. Wiche and I. Lecreps-Prigge, Applicability of Jenike mass flow design principles to wet solids vessel design. In proceeding of the Conference "PARTEC 2013", Nürnberg, Germany, April 23-25, 2013

[3] Jenike, A.W., Storage and Flow of Solids. Bulletin 123 Utah Engineering Experiment Station, University of Utah, Utah,1964