Problems with the Design of Short Drop-Height Soft Flow Chutes

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Abstract

Transfer chutes are an indispensable part of bulk material handling systems where they are used for loading and unloading conveyors. Although seemingly simple, if a comparatively blasé approach is followed in the design of a chute, there is a high risk that, just as with other – more complex – equipment in a given plant, the chute could become a bottle neck by not efficiently passing material from one system to the next. Chute bottlenecks can manifest as repeated shutdowns to repair damaged conveyors or to manually clear a blockage from the chute for example.

A common design issue with new chutes in new handling plants is the relative locations of the discharge conveyor and the receiving conveyor below. Usually, the design position for the receiving and discharge conveyors will be too close vertically – in an effort to reduce plant construction costs by reducing the overall height for instance – and in many cases, a chute will be intended to handle material from a discharge conveyor to a receiving conveyor on the next floor down with conveyor-to-conveyor drop heights of as little as two or three metres. These problems will likely be brought to light by the engineers tasked with the chute design and, by this time, the plant's structural design and layout will be advanced to the point where only small, potentially insignificant, adjustments to the chute's constraints are possible.

In the following, some chute performance problems that result from insufficient drop heights will be investigated with reference to soft-flow chute designs though the issues that will be discussed can be applicable to other chute types.

1. Soft Flow Chutes

Soft flow transfer chutes are a comparatively recent development in the materials handling industry with their theory and design maturing throughout the past three or four decades and their acceptance by industry occurring within that time. Prior to the uptake of soft flow chutes, chute designs were characterized by having only flat surfaces and a minimum of steel work, using simple shapes, to direct material from one conveyor to the next. Soft flow chutes, as depicted in Figure 1, are characterized by curved surfaces that catch and redirect the flow of material. A soft-flow chute will typically consist of two curved sections called a hood and a spoon with the hood taking the place of a traditional flat impact plate, or curtain, and being engineered to catch the bulk material stream with minimal impact and redirect it downwards to the spoon and the spoon which is positioned to catch the material stream from the hood with minimal impact and direct it onto the receiving conveyor. The two curved surfaces are specially engineered to gently control the material flow and their radii, relative positions, entry and exit angles, and rate of convergence are carefully calculated. For obvious reasons soft-flow chutes are commonly referred to as hood and spoon chutes.

Soft-flow chutes offer many advantages, including: reduced material degradation; a reduction of receiving conveyor belt wear; and the potential to reduce the generation of dust. These advantages have been enough to overcome the need to engineer the chute design and the more difficult manufacturing process required to construct them and they are now routinely specified, wherever possible, in new plant designs and chute replacement projects. Unfortunately, the design of a soft flow chute is sensitive to the drop height from the discharge conveyor to the receiving conveyor and the chute's performance can be greatly affected by poor placement of these items.

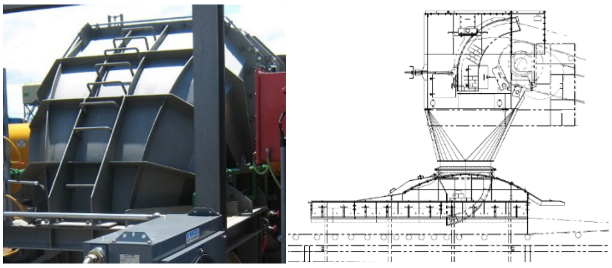
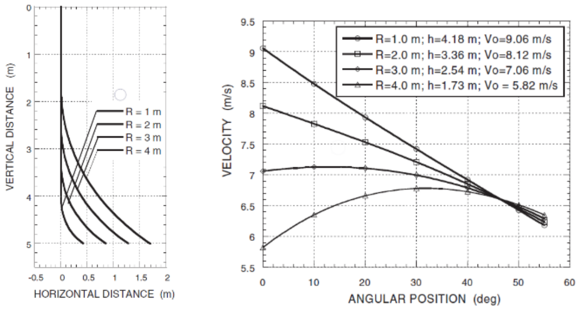

(a) (b)

Figure 1 (a) Conveyor transfer chute hood. (b) Diagram of a hood and spoon chute from a stacker.

2. Chute Exit Velocities

One of the design goals of soft flow chutes is to accelerate the material such that the component of its exit velocity acting in the direction of the receiving conveyor is, as much as possible, matched to the belt speed of the receiving conveyor; since, rubber is typically poor at withstanding the rubbing wear generated by accelerating the bulk solid up to the conveyor belt speed. The goal of velocity matching is at odds with the use of curved surfaces, which are gentler on the bulk material, but also keep the bulk material in contact with friction generating walls for longer than in traditional chute designs. The way that this conflict is mitigated is by designing the chute with enough drop height to allow gravity to accelerate the material to a sufficient speed before it is caught by the spoon and passed on the receiving conveyor at a matched velocity. Obviously, the lack of a suitable drop height in a soft flow chute will reduce the exit velocity accordingly and expose the receiving conveyor to higher wear rates; critically, velocity matching of the bulk material stream and the receiving conveyor is even more important for the typically short conveyors used in handling plants where each section of conveyor belt is exposed to the chute flow more often. An apparently obvious way to increase a deficient drop height by using a smaller spoon radius will not only increase the wear on the chute's lining through higher normal pressures but, as shown by Roberts [1] in Figure 1, will also fail to increase the exit velocity by any appreciable amount due to the increased resistance developed by the higher normal pressures.



(a) (b)

Figure 2 (a) Layouts of chutes with different radii [1]. (b) Material velocities for chutes with different radii [1]; note the small spread of exit velocities despite the wide range of entry velocities.

3. Dealing with Scraper Fines

Poor drop heights between discharge and receiving conveyors are also a problem when dealing with scraper fines. A well-designed chute will have two sets of scrappers installed to clean the conveyor belt: there will be a set of primary scrapers that contact the belt on the head pulley and a second set, called secondary scrapers, contacting the conveyor belt a short distance after it has left the head pulley. The primary scrapers are designed to remove the majority of the material not thrown from the belt – termed the *carry-back* – and because of their location on the head pulley the carry-back they collect simply falls down the chute and becomes entrained into the main material stream. Handling of the carry-back that is collected by the secondary scrapers is more difficult as the small amounts that are collected can only generate low normal wall pressures and therefore high wall friction angles when compared to the main stream as shown by Roberts [2] in Figure 2. The result of higher wall friction is that the angle of the surfaces catching the carry-back must be steep and this is a problem when trying to collect them from behind the discharge pulley and moving them forward into the main stream, within the length of a short drop height.

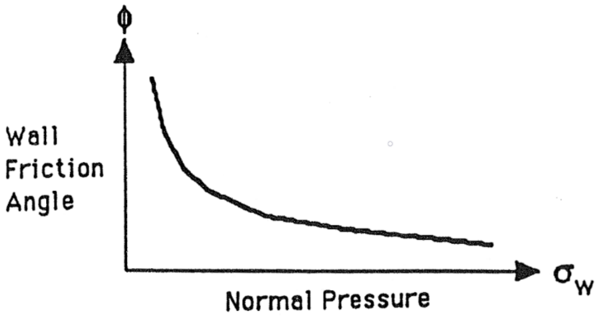


Figure 3 The relationship between wall friction angle and normal pressure [2].

The best compromise for the problem of moving the ultra-fine material is to envelope the secondary scrapers in the main chute and to rely on induced vibrations and stray lumps of bulk solid to dislodge any build-up. An alternative to enveloping the secondary scrapers within the chute is to provide a secondary – *dribble* – chute that, with its steep sides, collects the ultra-fine material and deposits it onto the receiving conveyor up-stream of the main flow. This solution can be effective but is only really practical when the discharge and receiving conveyors are in line or nearly in line. A further, though unrecommended, alternative is to collect the ultra-fines in a small hopper which is connected to a pipe that links to the receiving conveyor. This option is tempting if the structure hasn't been designed with a suitably sized hole to accommodate the secondary scraper location as it only requires the boring of a 200 to 300 millimetre hole under the conveyor to pass the pipe through; however the hopper walls and pipe still need to be steeply inclined which is a problem if the hopper has to fit in the space between the return strand of a conveyor and the floor beneath as shown in Figure 4, and now there is a small diameter pipe in the system which can block easily and is almost impossible to inspect internally. The main problem that can be caused by a blocked fines chute is that the build-up can reach the underside of the conveyor belt and then lift the belt off the secondary scrapers and, in the worst case, pinch the conveyor belt against the conveyor structure hard enough to retard the motion of the belt and cause a fire risk or other belt damage.

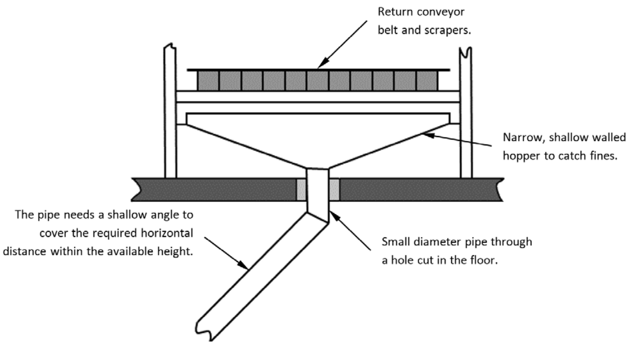


Figure 4 An example of an inappropriate fines chute that would need flow aids to work effectively.

4. Central Loading of the Receiving Conveyor

Insufficient drop height can also be partly responsible for poor loading of receiving conveyors and central loading of any belt conveyor is critical as it is the primary means by which the belt's tracking is maintained. Central loading of a conveyor is best achieved by incorporating a long, and thus high, spoon section that provides sufficient transit times for gravity to pull the material stream to the centre of the chute before depositing the material centrally on the receiving conveyor as shown in Figure 5. Problems with central loading occur when vertical material flow exiting the hood is not directly in line with the receiving conveyor and must therefore be deflected sideways to meet the conveyor as is common in splitter, or trouser leg, chutes. In these types of chutes, a large part of the drop height is used to shift the bulk solid stream sideways, with respect to the receiving conveyor, and unless the drop height is significant there won't be enough height left for the spoon to collect and centralize the flow before it reaches the receiving conveyor represented by the dashed outline in Figure 5.

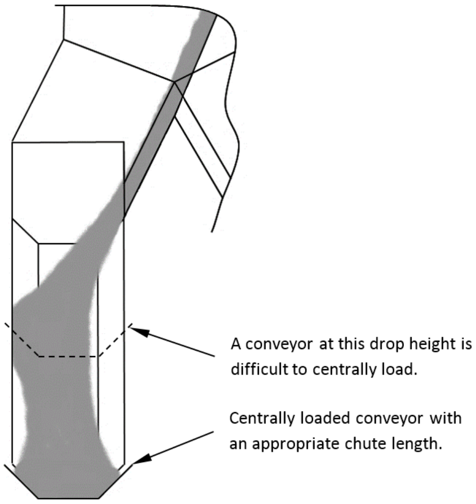


Figure 5 A splitter chute with enough length to centralize the material flow.

5. Conclusion

This paper has demonstrated a number of ways in which the poor planning of transfer chutes can lead to problems with their ability to function efficiently. The problems of incorrect exit velocities, handling of carry-back and the centralized loading of receiving conveyors that can be caused by low drop heights in combination with soft flow chutes have been discussed. It is recommended that a chute designer be consulted during the layout phase of a material handling plant so that potential problems can be discussed and reasonable compromises can be made that reduce the chances of problems occurring a plant's soft flow chutes.

6. References

[1] Roberts, Alan W., Chute Performance and Design for Rapid Flow Conditions, Chemical Engineering Technology, Volume 26, Issue 2, 2003.

[2] Roberts, Alan W., Friction Adhesion and Wear in Bulk Materials Handling, Basic Principles of Bulk Solids Storage, Flow and Handling, Chapter 21, The Institute for Bulk Materials Handling Research, 1993

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