Three ways to improve continuous loss-in-weight feeding accuracy

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The weight accuracy of individual recipe ingredients for a continuous blending, granulation, or extrusion process has a direct effect on product quality and bottom-line savings. This article explains how to optimize continuous loss-in-weight feeder accuracy by separating plant vibration noise from true weight loss, controlling motor speeds during feeder refill, and compensating for process pressure fluctuations.

Too often, companies don't consider the savings an efficient loss-in-weight (LIW) bulk solids feeding system can provide over time and instead consider only the upfront equipment cost. However, buying a more accurate feeding system and optimizing its performance can increase a process's product quality and overall profitability. An efficient LIW feeding system can improve feeding accuracy for even the lowest feedrates or high-value ingredients and reduce your process's overall costs.

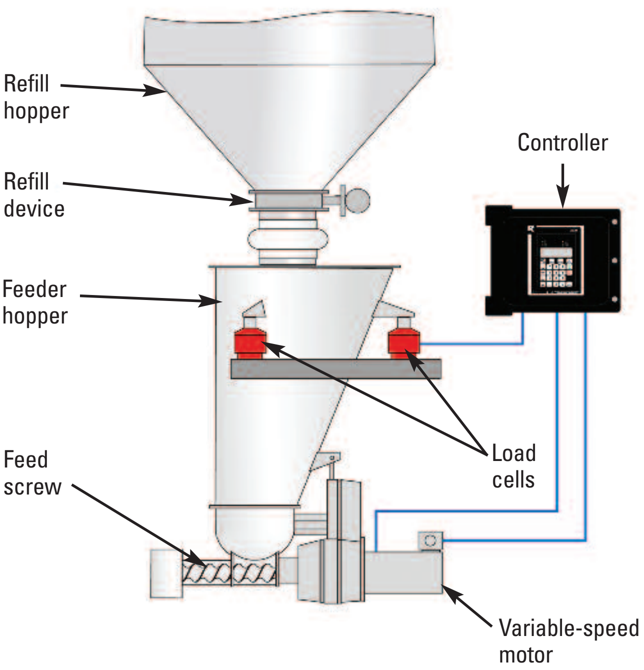
You can also take steps during the system design phase to ensure that your LIW feeder is optimized for accurate, efficient performance. Proper refill algorithms, weighing configurations, feeder controls, and instrumentation can increase feeding accuracy and help you avoid future process problems. Before learning how to improve LIW feeding accuracy, however, it's important to understand how LIW feeding works.

How LIW feeding works

Bulk solids feeders can generally be categorized as volumetric or gravimetric. A volumetric feeder discharges a given volume of material per unit time, while a gravimetric feeder discharges a given weight of material per unit time. A LIW feeder, as shown in Figure 1, is a gravimetric feeder that continuously measures the weight of the material to be fed and adjusts the feeder speed to maintain a predetermined feedrate. LIW feeders are used to dose ingredients into a variety of processes in bulk solids industries such as foods, pharmaceuticals, chemicals, and plastics. A LIW feeding system consists of a hopper, one or more weight-sensing devices (typically either digital or analog load cells), a feed device (typically

Figure 1

Loss-in-weight feeding system



a screw powered by a variable-speed motor), a controller, and a refill hopper and refill device.

In operation, an operator programs the controller to discharge material at a predetermined feedrate (or *setpoint*) measured in weight per unit time (such as pounds per hour). The load cells continuously measure the material weight in the hopper, and the controller regulates the speed of the feed device so the actual rate of weight loss matches the desired rate of weight loss. This allows the system to compensate for nonuniform material flow and variations in bulk density, providing a high degree of feeding accuracy.

How to optimize LIW feeder accuracy

LIW feeding is most accurate when using a high-resolution, fast-response weighing system that's immune to vibrations and temperature fluctuations. You can further optimize LIW feeding accuracy several ways: by separating plant vibration noise from true weight loss, by controlling motor speed during feeder refill, and by compensating for process pressure fluctuations.

1. Separate plant vibration noise from true weight loss.

A LIW feeder's operation depends on accurate measurement of the material weight in the hopper, so the feeder and weight-sensing device must be isolated from external forces and vibration. Position the feeder so that no external forces or friction can influence weighing. Isolate the feeding system by using flexible connections between the feeder and any other part of the system, such as the material or refill inlet and the feeder discharge. Install the feeder so that the weight-sensing device is shielded from vibration effects. Shock and vibration created by other process equipment in the plant can corrupt the load cells' weight measurement, destroying the basis for feedrate control. Ensure that the feeder has a stable mounting, using flexible connections and shock mounts, and eliminate strong air currents near the feeder.

Weight balancing your feeder and filtering the load cell weight readings can help to separate out plant vibration noise from true material weight loss. Modern load cells and control algorithms are able to discriminate between the load to be measured and transient forces imposed by vibration. Sophisticated digital filtering algorithms can be applied to identify and extract frequency components characteristic of in-plant vibration. Such technology, along with proper feeder isolation during installation, can greatly improve feeder accuracy.

2. Control motor speed during feeder refill.

The traditional method of maintaining the material feed while refilling the feeder in a continuous process is to use a constant metering speed throughout the hopper refill phase. The feeder essentially functions volumetrically during refill with the feeder operating speed the same as it was just prior to the refill phase. When the refill phase is complete and the material has settled, the feeder senses the declining system weight and returns to gravimetric operation with the metering speed once again being determined by the LIW.

This method has two problems. First, during refill the feeder can't compensate for fluctuations in material bulk density because the material is being fed volumetrically. Second, when the feeder returns to true LIW control at the end of the refill phase, the feeder speed can change abruptly, sometimes resulting in an extended period of off-spec mass flow until the feeder settles into the new proper speed.

Using a constant feeder speed that ignores bulk density variations during refill can significantly reduce feeder accuracy. An alternative method avoids this problem by storing the feeder's weight-to-speed ratio during gravimetric feeding as the hopper empties and using that data to control the feeder speed during volumetric feeding in the refill phase.

This method is illustrated by the graphs in Figure 2. The top graph plots the net hopper weight during operation versus time. Beginning with a full hopper (where the net hopper weight equals the refill phase stop weight) the feeder operates gravimetrically as previously explained. As the net hopper weight declines, however, the controller also determines and stores an array of up to 100 *feed factors*. A feed factor is a measure of the average bulk density of the material discharged at a given hopper weight. A low feed factor indicates that a higher number of screw revolutions were required to discharge a given weight, implying a reduced material bulk density. A higher feed factor indicates that fewer screw revolutions were required to deliver that same weight, implying a higher material bulk density.

The middle graph in Figure 2 plots the motor speed during operation versus time. As shown in the graph, during the early portion of the gravimetric feeding phase, the motor speed is relatively constant since the material bulk density in the feeder's metering zone doesn't vary substantially. This is because the material in a full hopper has a *head load* that condenses the material in the hopper's lower section to a relatively consistent bulk density. As feeding proceeds and the material level in the hopper declines, the head load above the metering zone decreases, and the material becomes less dense. The controller increases the motor speed to maintain the desired feedrate until the hopper weight reaches the refill request threshold, and the refill phase begins.

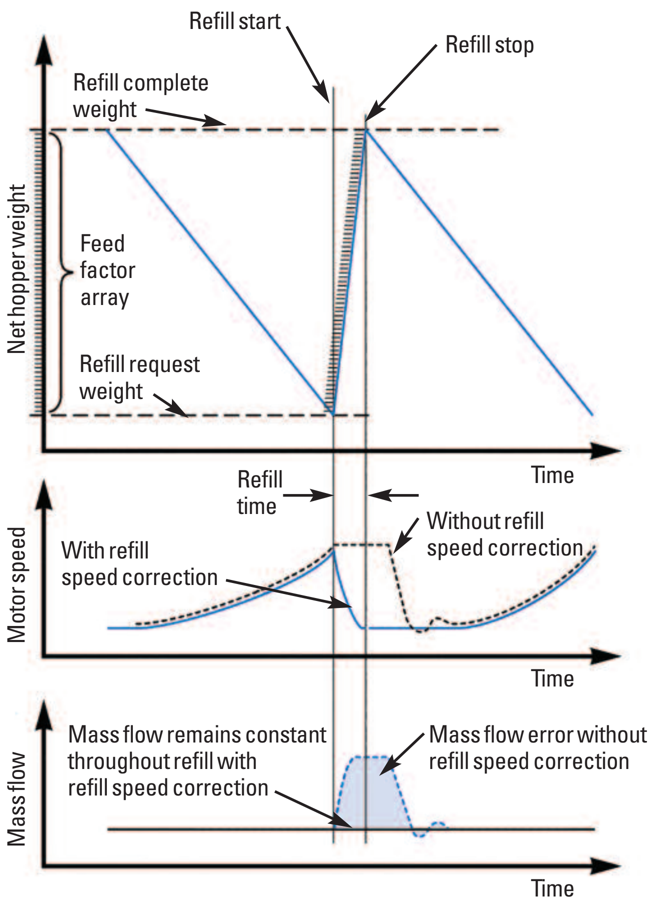
At the beginning of the refill phase, the motor speed is the same as at the refill request threshold, but as the hopper fills, the controller applies the stored feed factors as each corresponding hopper weight is reached and decreases the motor speed accordingly. This more sophisticated approach to hopper refill allows the feeder to smoothly exit the refill phase and return to true gravimetric operation. Additionally, by controlling motor speed based on the most recent performance history, gravimetric accuracy is essentially preserved during refill, as shown in the bottom graph in Figure 2.

3. Compensate for process pressure fluctuations.

If your LIW feeder is discharging material into a variable pressure environment such as a pressure or vacuum pneumatic conveying line, a pulse in the pressure or vacuum can cause a feedrate error. A pressure pulse exerts an upward force, slightly lifting the hopper and affecting the load cells' instantaneous weight measurement. The controller may interpret this effect as too much material having been dispensed and slow the motor speed to compensate, resulting in a lower than desired *actual* feedrate.

Figure 2

Refill speed correction



A consistent positive pressure at the feeder discharge, on the other hand, can cause the controller to underestimate how much material is being fed and speed up the motor, resulting in a higher than desired actual feedrate.

Hopper pressure errors can also be caused by other process factors, such as a clogged vent filter, a dust collection system connected to the hopper vent, or a nitrogen blanket applied to the hopper. In one installation, for example, a gravimetric feeder in a closed system was experiencing bumps in the mass flow signal after every refill. The chart in Figure 3 shows the feeder's pressure curve measurements (converted to grams) during three refill cycles, while the chart in Figure 4 zooms in on the first refill cycle.

In the example, the feeder's setpoint was 150 kg/h, and the post-refill delay time was 5 seconds, which means that the

Figure 3

LIW feeder pressure curve

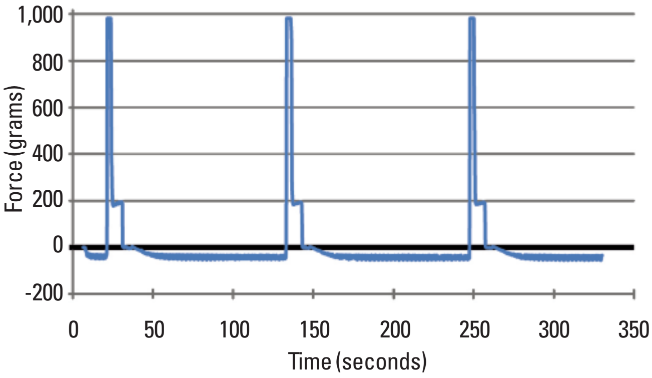
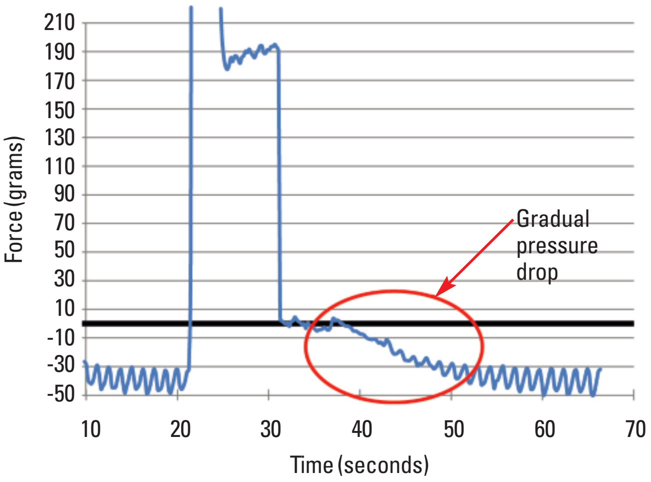


Figure 4

LIW feeder pressure curve

Close-up on refill cycle



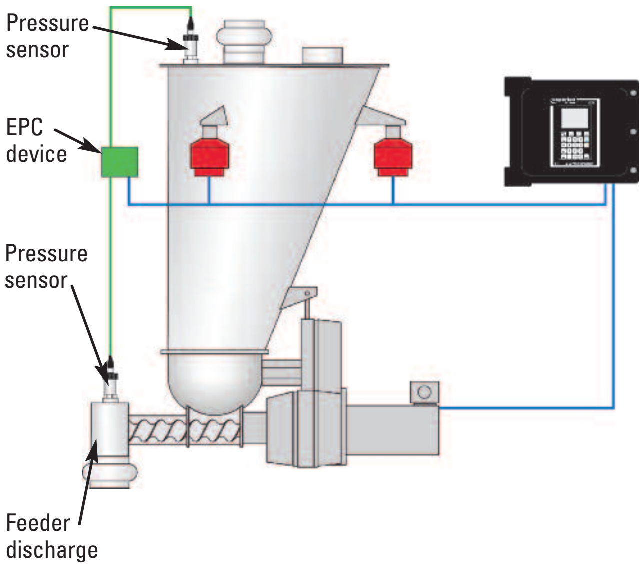
gravimetric feeder controller was set to ignore irregularities during the 5 seconds following the refill phase. The refill device above the feeder was a vacuum receiver with a powered discharge valve. The refill cycle consisted of the valve opening for 10 seconds with aeration pads operating during that time. The aeration pads pumped air into the vacuum receiver to help the material flow out. Material discharge from the receiver into the feeder took approximately 3 seconds (t22 to t25 in Figure 4) and caused a large spike in feeder hopper pressure as air struggled to get out through the hopper's clogged vent filter or back up into the receiver. The aeration pads continued to operate for 7 more seconds (t25 to t32), then the refill valve closed.

After the refill valve had closed, the pressure inside the hopper gradually dropped during the next 20 seconds (t35 to t55) before stabilizing at a slightly negative value. This slight negative pressure is caused by the continuous feeding out of material, which creates a slight vacuum inside the hopper since air can't enter freely to replace the discharged material.

The feeding error occurred during this gradual 20-second pressure drop and ended once the pressure had stabilized. The gradual decrease of the internal hopper pressure caused an apparent decrease in feeder weight, which the controller interpreted as an over-feeding condition. This became manifest in the mass flow display spiking after every refill. More importantly, the apparent overfeeding caused the gravimetric control to react by reducing the motor speed, so while the mass flow display appeared to show the feeder overfeeding after refills, the system was actually underfeeding during that time.

Figure 4

Electronic pressure compensation



Traditionally, feeding systems compensate for these troublesome pressure fluctuations using costly mechanical devices such as flexible bellows. However, factors such as mechanical tolerances and misalignment or aging of flexible bellows can prevent these devices from fully compensating for the forces generated by changing pressures, making this solution deficient. Also, mechanical pressure equalization devices only equalize pressure, they don't measure pressure or indicate what is actually occurring in the feeder.

Alternatively, you can use an electronic pressure compensation device (EPC) along with control algorithms to electronically monitor and compensate for pressure fluctuations, as shown in Figure 5. The EPC device in the figure automatically detects pressure changes in the feeder and adjusts the weight signal to the controller accordingly. The device is connected to pressure sensors on both the feeder's hopper and material discharge to provide a detailed assessment of exactly what's happening in the feeder to alter the feeder output. The control algorithm allows any feeder pressure changes to be identified as such and not misinterpreted as changes in mass flow from the feeder even during and after hopper refills. **PBE**

For further reading

Find more information on feeding methods in articles listed under "Feeders" in *Powder and Bulk Engineering*'s article index in this issue or the Article Archive on *PBE*'s website, www.powderbulk.com. (All articles listed in the archive are available for free download to registered users.)

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