Gravimetric feeders: Advanced control technologies for precise feeding

Achieving precise gravimetric feeding begins with accurate weight measurement and a fast-acting feeder controller. In the world of bulk solids handling where the measurement environment is often far from ideal, the challenge in gravimetric feeding is to obtain legitimate, usable weight measurements without influence from outside environmental forces, and with quick, repeatable results in a set period of time. This article describes how using today’s advanced control technologies with a properly installed feeder will ensure the most reliable, efficient gravimetric feeding control. A sidebar reviews gravimetric feeding basics.

Gravimetric feeders are commonly used to feed bulk solids in the chemical, pharmaceutical, food, and plastics industries. Unlike a volumetric feeder (such as a screw feeder), which feeds material by volume, a gravimetric feeder feeds material by weight. In both batch and continuous operations, the gravimetric feeder uses a load cell measurement to feed material into a process at a constant weight per unit of time. Integrating the load cell measurement with the feeder’s control algorithms is critical to the feeder’s performance.

Today most bulk solids gravimetric feeders are highly automated, and their combination of advanced load cells and control algorithms achieves feeding accuracies as high as ±0.25 percent of the desired feedrate, based on load cell resolutions as high as 1 in 4,000,000. As the following information explains, today’s control technologies allow gravimetric feeders to be customized to deliver high feedrate accuracy even in tough plant environments. [Editor’s note: For a review of how gravimetric feeders work, see the sidebar “Gravimetric feeding basics: LIW and GIW feeder components and operation.”]

Defining gravimetric control

Simply put, a gravimetric feeder controller automates feeding by comparing key measured variables with their required setpoints. These comparisons generate an output signal that the controller uses to adjust a feeder control parameter, such as the feeding device’s motor speed.

The gravimetric feeder measures the actual material discharge rate by taking consecutive weight samples at short time intervals (for example, 1 second, 5 seconds, or 15 seconds) during feeder operation. To control the feedrate, the controller must then compare the actual discharge rate to the feedrate setpoint and calculate and apply any required corrective motor-speed adjustment for the feeding device. The controller also evaluates weight noise (ambient vibration) and adjusts its weight filter (software that filters weight noise from the weight signal) and control parameters accordingly. (Find more information on vibration filtering later in this article.)

This closed-loop control technique requires feedback from various sensors (such as the feeding device motor’s speed pickup sensor) and integrated control elements (such as the load cell and the motor’s speed control). To achieve accurate feeding performance with closed-loop control — especially when the feeder’s required sample duration is measured in seconds rather than minutes — the
resolution and responsiveness of the feeder’s weighing system are critical. These must be sufficient not only to accurately discern the small changes in total system weight that occur during the brief sample period, but to initiate the feeding device’s motor speed changes necessary for maintaining the required discharge rate. Thus, for a process requiring extremely high feeding accuracy over a short timescale, the weighing system’s resolution should be a major factor in evaluating potential feeders and the corresponding design of the feeder’s underlying control system. The weighing system’s high resolution is also essential in a process with a low feedrate, such as 20 g/h, in which the moment-to-moment weight change is extremely small.

**Gravimetric feeding basics:**

**LIW and GIW feeder components and operation**

Two common types of gravimetric feeding systems are loss-in-weight (LIW) feeder systems, which measure the material weight loss during feeding, and gain-in-weight (GIW) feeder systems, which sense the material weight gain during feeding.

**LIW feeder system**

The LIW feeder system, which can provide batch or continuous feeding, basically consists of a feeding device (such as a volumetric screw feeder powered by a variable-speed motor) with a hopper, a weight-sensing device (typically a load cell or set of load cells) that supports or suspends the feeding device and hopper, a refill system above the hopper, and a controller. In operation, the feeding device discharges material from the hopper as the load cell reports the material weight in the hopper to the controller. The controller compares the actual rate of weight loss to the controller’s setpoint and increases or decreases the feeding device’s motor speed to increase or decrease the material weight change in the hopper, matching the feedrate to the setpoint. When the material weight in the hopper reaches a predetermined minimum weight level, the LIW feeder controller briefly interrupts gravimetric control and signals the refill system to refill the hopper.

**GIW feeder system**

The GIW feeder system consists of a feeding device (again, such as a volumetric screw feeder with a variable-speed motor) above a hopper that’s supported by or suspended from a load cell (or set of load cells). The GIW feeder is used only in a batching system, where multiple GIW feeders add ingredients — one per feeder — in sequence to the hopper, as one overall controller monitors all the feeders in the system. In operation, the controller monitors each GIW feeder as its feeding device delivers an ingredient to the hopper, and the load cell reports the weight gain in the hopper to the controller. The controller compares this data to the batch recipe’s weight setpoint for each ingredient and, as appropriate, signals each feeder to increase or reduce speed or stop. Once all ingredients have been fed to the hopper, the batch is discharged to the downstream process.

**Defining terms**

The system weight (that is, the weight sensed by the load cell) in a LIW feeder equals the weight of the feeder assembly (the feeding device with its motor and hopper) plus the material weight in the hopper. In a GIW feeder, the system weight equals the weight of the hopper below the feeder plus the material weight in the hopper. For both LIW and GIW feeders, the weight-sensing device and the controller compose the weighing system (also called control sys-

**How gravimetric control is transferred to the feeding device**

To understand how a gravimetric feeder controller transfers control to the feeding device, it will help to review how a volumetric feeder is controlled.

**Volumetric feeder control.** A volumetric screw feeder, for example, controls the feedrate by adjusting the speed of its variable-speed motor, but it can measure controlled variables in different ways to control feeding:

- It can measure one key controlled variable, such as the feeding device’s motor speed (from the speed pickup sensor), and then send this measurement back to the controller, which compares the measured speed to the required speed setpoint. If the measured speed doesn’t match the setpoint, the controller sends a feedback signal to automatically change the motor speed so this controlled variable is adjusted to match the setpoint.

- A sensor on the variable-speed motor’s shaft can measure the shaft velocity (in revolutions per minute) and send this measurement to the controller, which converts the velocity to a mass flowrate using a formula established when the feeder is calibrated. The controller then
sends a feedback signal that continuously adjusts the motor shaft velocity to match the desired mass flowrate.

For a gravimetric feeder system, how the control is transferred to the feeding device depends on whether it’s a loss-in-weight (LIW) or gain-in-weight (GIW) feeder system.

**LIW feeder control.** In a LIW feeder system, the controller can be used for either continuous or batch operation.

For continuous LIW feeding, such as adding an ingredient or premix to a continuous conversion process (such as blending or extrusion), the motor speed of the feeding device is controlled by measuring weight and motor speed, not just motor speed as with a volumetric feeder. A typical LIW feeder controller adjusts the feeding device’s motor speed to produce a weight-loss rate equal to the desired weight-loss rate, which is based on the controller’s feedrate setpoint. These are the steps in the control process:

1. The feeding cycle begins with the hopper fully loaded with material and at its maximum weight. Once feeding starts, the controller uses the measured weight loss from the weighing system to determine the material’s actual mass flowrate and continually compares this value with the desired feedrate setpoint. Any difference between the actual mass flowrate and setpoint triggers the controller to change the feeding device’s motor speed.

This weight-measuring capability is critical for accurate LIW feeder control. For example, if an abrupt increase in material density causes the LIW feeder to overfeed material, the sensed weight will fall below the weight setpoint, triggering the LIW controller to reduce the feeding device’s motor speed. And because the LIW controller knows the error associated with this overfeed condition, it can further reduce the motor speed to immediately and precisely compensate for the overfeed condition. The LIW controller also does the opposite in an underfeed condition.

**Batch LIW feeding** is used in ingredient batching operations when the accuracy of individual ingredient weights in the completed batch is critical (such as in microingredient batching for high-cost additives and other valuable ingredients) or when the batch cycle time is very short. In such an operation, several high-accuracy LIW feeders, each for one ingredient, operate in batch mode and simultaneously dispense ingredients into one hopper.

Each LIW feeder’s controller adjusts the operation (stop or start) and speed (fast or dribble) of the feeding device’s motor. (In batch feeding, typically 90 percent of an ingredient is fed at a fast speed and the rest at a dribble speed to ensure higher feeding accuracy.) These are the control steps: Once a LIW feeder begins to dispense the ingredient, its controller uses sensed weight loss from the feeder’s load cell to perform a series of tasks, including calculating the actual weight of delivered ingredient, comparing the actual weight to the desired batch weight, switching the feeding device motor from fast to dribble speed, and stopping feeding when the ingredient weight equals the setpoint. Once all the ingredients have been fed by the feeders, the batch is complete and is delivered to the downstream process.

The operation of all the LIW feeders is monitored by an overall controller, often integrated into a plantwide control system. Because all ingredients are fed simultaneously into the hopper, batch LIW feeding shortens the overall batching time and the time required for the overall process. In addition, because each ingredient is fed at the same time and in the exact proportions, the batch may not require an additional blending step.

**GIW feeder control.** GIW feeder systems are also used in batching applications, such as for dispensing ingredients to a batch blender. In this case, one overall GIW controller monitors several feeding devices that sequentially feed ingredients into one hopper mounted on load cells. These are the control steps: Each feeding device delivers about 90 percent of its ingredient’s required weight (the setpoint) at fast speed, then slows down to deliver the last 10 percent...
at dribble speed. The GIW controller monitors each ingredient’s weight based on the increase in the hopper weight below, and, as appropriate, signals each feeding device to start, increase speed, reduce speed, or stop. Once all ingredients have been delivered by each separate feeder, the batch is complete and is discharged into the downstream process. Because this method adds ingredients sequentially, it can take a longer overall time than LIW batching if the batch requires many ingredients. In addition, because the ingredients are actually layered into the collecting hopper, additional mixing is often required.

How the LIW feeder controls feeding during refill
During continuous gravimetric feeding, a feeder’s feed hopper must be periodically refilled to replenish the material being fed. This creates control challenges for a LIW feeder, because its gravimetric operation must be suspended.

The LIW feeder’s refill system can include various equipment (such as a volumetric feeding device or a pneumatic receiver with a butterfly valve at the outlet) along with a separate or combined control device that’s linked to the LIW feeder controller. In the past, a LIW feeder typically handled the refill cycle by stopping gravimetric control and simply holding the feeding device’s motor speed constant, so the feeder would essentially discharge volumetrically for the brief refill cycle (typically 6 to 10 seconds). The discharge rate during this cycle typically corresponded to the setpoint adjustment the feeder used most recently before refill began. Once the hopper’s maximum preset fill level was reached, the controller automatically switched off the refill system and, after a short delay to allow the feeder’s weighing system to stabilize, the controller switched the feeder back to gravimetric operation.

The problem with this refill approach is that it can compromise the feeding process’s overall accuracy, because feeder efficiency is often a function of hopper level. This potentially reduces the product quality or batch recipe’s integrity and reduces the process’s overall yield.

Today, LIW feeder controllers are available with advanced control algorithms that control the feeding device’s motor speed during refill by basing the speed on the most recent feeder performance history. One example is a refill array algorithm, which works by allowing the controller to gradually adjust the feeding device’s motor speed during the refill cycle to precisely counterbalance the effects of increasing material density as the weight in the hopper increases. During feeding, an array of weight indices called feed factors is computed and stored. Each feed factor correlates to a specific motor speed. During the following refill cycle, the feed factor array allows the controller to appropriately adjust the feeding device’s motor speed based on the trended data from the feeding cycle. This eliminates feedrate errors that can occur during refill when the motor speed is constant, preserving the accuracy that true gravimetric feeding provides, even during periodic refill cycles.

How gravimetric feeders can protect the weight signal
In a typical bulk solids plant, external influences such as temperature fluctuations, air drafts, and excessive vibration can affect the gravimetric feeder’s measured weight signal. In an application with fluctuating temperatures, temperature-compensated load cells can be used to protect the weight signal. To prevent air drafts from affecting the feeder’s sensed weight, particularly in a low-feedrate application, the LIW feeder can be equipped with a draft shield that protects or shields the feeding device and load cell (or scale) from air currents.

To prevent ambient vibration from corrupting the precise weight measurements needed for accurate gravimetric feeding control, it’s especially important that the weighing system isolate vibration effects. This means that the controller must suppress and filter out weight noise (ambient vibration) from the feeder’s weight signal in real time, especially over very short timescales. This can be achieved by isolating the feeder using shock mounts and flexible connections between components and by using an advanced load cell (or load cells) and a controller capable of...
real-time signal processing that can distinguish between the load to be measured and the forces induced by vibration. The controller can also be equipped with advanced digital filtering to identify and extract signal components that are characteristic of in-plant vibration; this allows the controller to extract meaningful data from the raw measurement signal, even in a chaotic weighing environment.

The controller can also be equipped with advanced digital filtering to identify and extract signal components that are characteristic of in-plant vibration.

How a gravimetric feeder controller can be integrated into an overall control system

A gravimetric feeder controller is often viewed today as a black-box device with its own control algorithms. Yet to integrate the feeder controller into a plantwide control system, the controller must include the communication protocols typically used in these systems. This can be achieved by equipping the controller with simple communications cards (or modules). These modules provide a powerful, flexible operator interface with a plantwide control system and can be configured for basic start-stop and data-monitoring operations. They can also be configured to handle more complex operations that require monitoring and changing of multiple process variables.

How handheld wireless devices can be used with gravimetric controllers

Handheld wireless devices are another emerging smart technology that can be integrated with today’s gravimetric feeder controllers. Some feeder manufacturers supply wireless devices to allow operators and service personnel to communicate from a distance with the feeder controller, providing them with a direct link to the gravimetric feeder’s actions and operating history. Manufacturers are developing a variety of applications for these handheld devices to provide a more user-friendly interface with the gravimetric feeder controller.

For further reading

Find more information on gravimetric feeding in articles listed under “Feeders” in Powder and Bulk Engineering’s comprehensive article index (later in this issue and at PBE’s website, www.powderbulk.com) and in books available on the website at the PBE Bookstore. You can also purchase copies of past PBE articles at www.powderbulk.com.

Sharon Nowak is business development manager, food and pharmaceuticals, at K-Tron, PO Box 888, Pitman, NJ 08071; 856-256-3119, fax 856-582-7968 (SNowak@ktron.com, www.ktron.com). She holds a BS in chemical engineering from Rutgers University, New Brunswick, N.J., and has 22 years experience in developing process equipment for the food and pharmaceuticals industries.