Loss-in-weight feeding success: As easy as 1, 2, 3

Steve Musser Merrick Industries

Proper material handling, weighing, and control: Getting these three basics right will help your loss-in-weight feeder satisfy your process performance requirements. Before explaining how these basics affect your feeder's design, this article describes loss-in-weight feeder operation and discusses factors for evaluating your feeder's performance.

Moving and metering your material, weighing it correctly, and controlling the material's flowrate are equally important elements in getting top performance from your continuous loss-in-weight (LIW) feeder. If one element isn't up to par, your feeder's performance will suffer.

Understanding the LIW feeder's complex operation can be easier if we make an analogy to explain the elements affecting feeder performance. Picture these elements-- material handling, weighing, and control -- as the three legs of a stool, as shown in Figure 1. The stool's top is perfectly flat and supports three balls. The balls represent three factors for evaluating LIW feeder performance: repeatability (how consistently the feeder delivers a desired feedrate), accuracy (how close the feeder's feedrate is to your desired feedrate), and uptime (the time the feeder is performing as required).

If any of the stool's legs is unstable or poorly designed, the stool will tilt. This will cause the balls to move and even roll off the stool. Likewise, if any of the feeder's material handling, weighing, or control elements is poorly designed, the feeder's repeatability, accuracy, or uptime will drop.

How a LIW feeder works

A continuous LIW feeder meters powders, pellets, granules, or solids-liquids mixtures into a downstream process at a desired feedrate. The feeder, shown in Figure 2, consists of an integral hopper, discharge device (such as a screw feeder or vibratory pan feeder), weight-sensing device (either digital or analog), and controller. The feeder operator or a supervisory controller at a remote location sets the feeder's desired feedrate, called the *setpoint*, by sending the information to the controller.

In operation, the discharge device draws material from the hopper and meters it into the downstream process. The weight-sensing device continuously reports the weight of the material in the hopper to the controller. The controller compares this weight loss to the setpoint and increases or decreases the discharge device's speed to accelerate or slow the change in weight (that is, the loss in weight) of material in the hopper so the feedrate will match the setpoint.

While this operation may seem simple enough, your LIW feeder may not perform at the level your process requires unless every component in the feeder is carefully designed and operates as it should. You can measure the feeder's performance by evaluating its repeatability, accuracy, and up-time -- the three balls resting on the stool. To correct performance problems, you need to consider each of the stool's legs -- material handling, weighing, and control -- and whether they're properly designed for your application.

Evaluating repeatability

Repeatability is a percentage that statistically predicts how consistent your LIW feeder's feedrate will be. This value is usually calculated by collecting 30 consecutive samples of the material as it's discharged from the feeder. Each

Figure 1

Elements affecting feeder performance

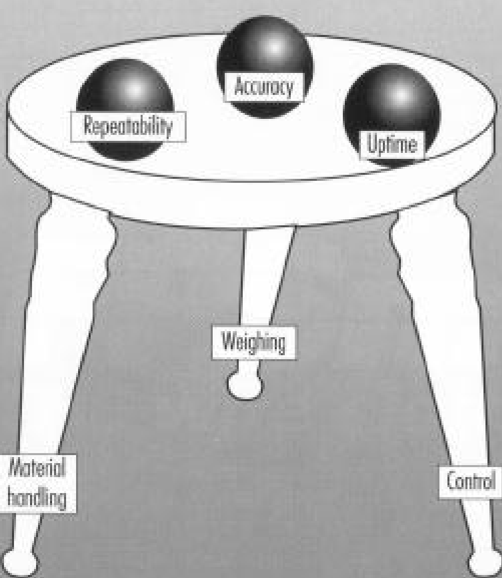
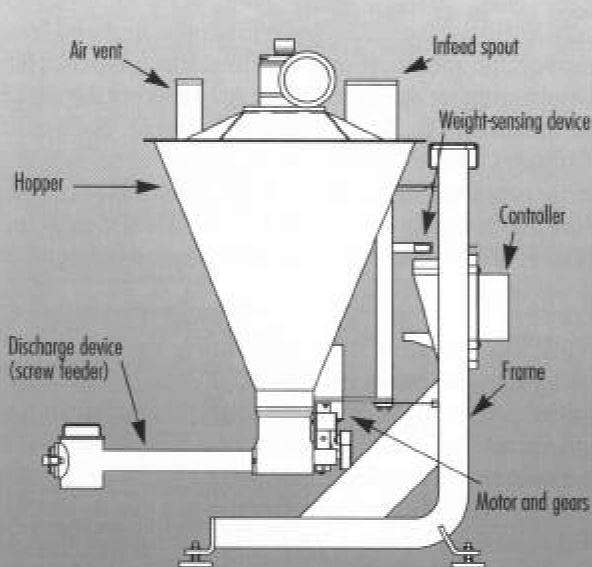


Figure 2

Loss-in-weight feeder



sample is collected over a 1-minute period. The samples are weighed, and the sample weights are compared to each other. To meet the industry standard of 2 sigma (that is, 2 standard deviations), 95 percent of all the sample weights must fall within plus or minus the average sample weight's repeatability percentage.[1]

The repeatability formula is:

$$\text{Repeatability} = \frac{\text{2 X standard deviation}}{\text{Mean}} \text{ X } 100$$

In the formula, the value you calculate is doubled because the range is plus or minus (above or below) the average of the samples.

The more repeatable your LIW feeder's performance is, the more consistent the feedrate will be, regardless of when you take the samples. The lower the repeatability percentage, the better the feeder performance. If your LIW feeder's electrical and mechanical components are performing as designed, you can usually attribute poor repeatability to the controller's control algorithm computations. In such a case, you can sometimes tune the algorithm to provide better feeding performance (discussed in the later section, "Control").

Evaluating accuracy

Your LIW feeder's accuracy is the deviation of a set of feedrate samples' weight average from your setpoint and is given as a percentage. For evaluating accuracy, timed samples of the material are typically collected from the feeder discharge. While the same samples used for a repeatability test can be used to measure feeder accuracy, you don't need 30 1-minute samples to measure accuracy. In fact, the longer the sampling time, the fewer timing errors are likely to be made and the more correct your test results will be.

Assuming your LIW feeder's setpoint is in weight-per-minute units, calculate the feeder's accuracy for 30 1-minute samples using this formula:

$$\text{Accuracy} = \frac{\text{Sample mean - setpoint}}{\text{setpoint}} \text{ X } 100$$

For one 30-minute sample, use the formula:

$$\text{Accuracy} = \frac{\frac{\text{Sample}}{30} - \text{setpoint}}{\text{setpoint}} \text{ X } 100$$

As you can see, evaluating 30 consecutive 1-minute samples will result in the same accuracy value as one 30-minute sample. The latter will provide better results, however, because it minimizes timing errors during sampling and provides higher resolution.

The lower the resulting accuracy percentage, the more accurate the feeder. Poor accuracy is typically caused by weighing or calibration errors. To improve poor accuracy, check the operation of the LIW feeder's weight-sensing device and recalibrate the feeder.[2]

Combining LIW feeder repeatability and accuracy for:

The elusive hole-in-one

Your LIW feeder requires both good repeatability and good accuracy. Let's use a golf analogy to explore why.

Assume that a hole on a golf course represents your feedrate setpoint. You hit three balls toward the hole, but all miss by the same distance, as shown at the top of Figure A. You're dismayed at how far the balls are from the hole, but you did hit all the balls in the same direction with equal success. Thus, your performance showed very poor repeatability even though you hit the balls with good accuracy. You're not happy.

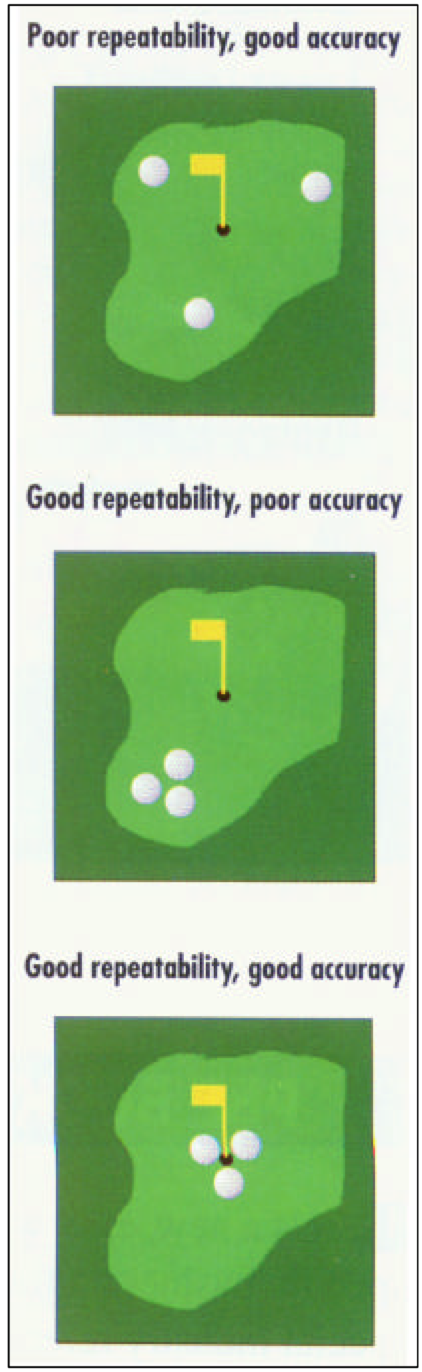
Next, you hit three more balls at the same hole. The balls land within a few inches of each other but are very far from the hole, as shown at the middle of Figure A. This time, you've hit the balls with ability but poor accuracy. You're still not pleased.

Finally, you hit three more balls that all land within inches of the hole, as shown at the bottom of Figure A. You've now achieved good repeatability *and* good accuracy, and you're happy with your performance.

Both good repeatability and good accuracy will make you happy with your LIW feeder's performance, too. If all your feedrate samples are close in weight and their average weight is also close to your setpoint, you can be confident your feeder is performing well.

Of course, if your golf performance was perfectly repeatable *and* perfectly accurate, you would have had three consecutive holes-in-one. In the same way, if your LIW feeder performance was perfectly repeatable and perfectly accurate, the feedrate would exactly match your setpoint all the time. Unfortunately, this sort of perfection is as difficult to achieve in LIW feeding as it is in golf. However, using the tips outlined in the accompanying article should improve your LIW feeding performance. Improving your golf game is, of course, another story.

--S. Musser.



To understand how repeatability and accuracy are both important for your LIW feeder, see the related article, "Combining LIW feeder repeatability and accuracy for the elusive hole-in-one."

Evaluating uptime

Evaluating a LIW feeder's uptime can be somewhat subjective. But typically, to determine whether your feeder is up and running as much as your process requires, you need to consider the unit's cleaning and maintenance ease, parts availability and cost, design simplicity, operating simplicity, and overall reliability.

Even if your feeder provides good repeatability and accuracy, it won't satisfy your performance requirements without adequate uptime. Each moment that the feeder isn't in operation can cost your company money. For instance, if your feeder requires regular cleaning and its mechanical design makes this a time-consuming process, your feeder's uptime will drop. If some of the feeder's components require periodic maintenance or can fail, you need to design the feeder to minimize downtime for service. Delayed parts orders, lengthy operator training periods, and feeder stoppages because of failing mechanical or electrical parts can all reduce your feeder's uptime.

Now that you understand the tools for evaluating your LIW feeder's performance, let's consider how to design the feeder to maximize performance. The basic elements in LIW feeder design -- the three legs of the stool -- are material handling, weighing, and control.

Material handling

Several material handling factors can affect your LIW feeder's performance. They include the material's entry into the hopper, the hopper design, flow aids, and the discharge device design.

***Material's entry into the hopper*.** Your material must be consistently available to fill your LIW feeder's hopper. The direction of material flow before it enters the hopper can influence this availability. For instance, if prior to entering your feeder the material flows in a vertical direction, such as down through a bin outlet, and then tums to flow in a horizontal direction, such as through a screw conveyor, the flow into the hopper can be inconsistent or even become blocked. Flow can also be inconsistent if the material moves from a large containment area into a smaller one, such as from a bin's cone section to the outlet or through a pipe with decreasing diameter. To prevent these problems, select material handling equipment that will provide consistent flow to the hopper.

The lower the resulting accuracy percentage, the more accurate the feeder.

An aerated or compressed material can also flow inconsistently into the hopper. Select material handling equipment that prevents aeration or compression or can provide smooth flow of an aerated or compressed material to your hopper.

Hopper design. Design your hopper so material can enter it at a rate 10 times faster than the feeder's maximum discharge rate. Make sure that the hopper's *infeed spout,* the opening through which material flows into the hopper, is large enough to avoid becoming blocked by material.

To move material from the hopper into the downstream process, design the hopper to allow material to flow into the discharge device at the rate demanded by the device. Material that forms a bridge or rathole in a poorly designed hopper can starve the discharge device. Material that moves in *a funnel-flow* pattern, in which material at the center flows faster than that at the sides, can segregate by particle size, changing the material's flow characteristics and slowing or stopping flow.

Instead, material should move through your hopper in a first-in first-out, or *mass-flow* pattern, in which the material at the center flows at the same rate as that at the sides. Designing your hopper for mass flow will provide a steady flow of material with consistent density to and through the discharge device. This increases the feedrate stability and can improve your feeder's performance.

Flow aids. If your material has flow characteristics that prevent it from flowing freely in any hopper design, you need to choose a flow aid for the hopper that will promote material flow to the discharge device. Several flow aids are available, including aeration pads, vibrators, hoppers with flexible walls, vertical and horizontal rotating vanes, and others. Research the available types and consult the LIW feeder manufacturer before choosing one for your material and hopper.3

Discharge device design. Whether the discharge device you select is a single- or twin-screw feeder, vibratory pan, or other type, it should consistently meter the material to the downstream process to achieve your desired feedrate. It should also handle your minimum and maximum feedrates.

Research the options to choose a discharge device that can handle your material without problems such as material buildup, flooding, or pulsing flow. For instance, combat material buildup by selecting a discharge device with a surface coating that prevents material from sticking to it. A twin-screw feeder has intermeshing screws that also prevent buildup. This device will discourage flooding and pulsing flow, as well. Avoid using a single-screw feeder or vibratory pan feeder for a material that tends to flood. Select a vibratory pan feeder for a material such as soft pellets or cereal, which can degrade in a screw feeder.

The discharge device should consistently meter the material to the downstream process to achieve your desired feedrate.

Poor flow from the discharge device can also create LIW feeder problems. If material below the discharge device backs up into the device rather than flows away from it, the result can be a weighing error. A weighing error can also occur if the material bounces back from the downstream process into the discharge device. To prevent these problems, you can install a level probe in downstream equipment to detect material backup. The probe can signal an electronic interlock to stop the feeder before the backup affects the feeder's performance.

Weighing

Without a weight-sensing device, your LIW feeder would simply be a volumetric feeder. But using a weight-sensing device allows the LIW feeder to adjust to changes in your material's characteristics and compensate for feedrate fluctuations. This requires the feeder's controller to monitor the weight signal from the weight-sensing device and make intelligent decisions on how to command the discharge device to adjust the feedrate. Without the correct weight information, the controller can make incorrect decisions that impair the feeder's performance.

More about the weight-sensing device. The weight-sensing device transmits a weight value or signal that represents weight to the controller. The device is available in two basic types: digital and analog. A digital unit sends a digital weight value through a serial communications link to the controller, which typically contains circuitry to receive and store the value. An analog unit sends an analog signal (a voltage that represents the weight) through a wire to the controller. The analog unit uses circuitry at either the device or the controller to transform this analog signal into a digital weight value. The most common analog weight-sensing device is a strain gauge load cell. Consult the LIW feeder manufacturer for help selecting a weight-sensing device for your application.

Installing the weight-sensing device. How you install the weight-sensing device also affects your feeder's performance. A common method is to suspend the device from a frame and then suspend the feeder from the device, as shown in Figure 3a. Another common method is to place the feeder on a platform that rests on the weight-sensing device (called a *platform scale),* as shown in Figure 3b. You can also use variations of these methods in which a counterbalancing mechanism removes part of the device's *dead load*-- that is, any sensed weight that isn't associated with the material being fed (also called *tare weight).*

Problems can result from using the platform scale method. When your feeder is placed on a platform scale, the feeder's center of gravity is above the weight-sensing device, which can sometimes result in an unstable installation that produces weighing errors. This is more likely to occur when the ratio of platform width to feeder height is greater than 1:2. In this sort of unstable installation, any force or disturbance at the feeder's top can be amplified down the feeder's length to the weight-sensing device.

For best results, install the weight-sensing device as high as possible in relation to the feeder-- that is, by suspending the feeder from the weight-sensing device. This will produce a lower center of gravity and a weighing system that's inherently more stable. Stabilizing the weighing system can help it resist vibration and disturbances that would affect a feeder mounted on a platform scale. If your feeder is equipped with a flow aid that creates vibration or other movement, suspending the feeder from the weight-sensing device will also help stabilize the feeder.

How much dead load the weight-sensing device measures can also affect your LIW feeder's performance. The hopper

Figure 3

Installation Methods

a. Feeder suspended from weight-sensing device

b. Feeder mounted on platform scale

and discharge device are examples of components that contribute dead load to the weight the feeder must measure. The *live load* is the weight sensed from the material being fed.

By reducing the amount of dead load your feeder senses, you can improve the feeder's weighing resolution for the material being fed. If you use an analog weight-sensing device, the device can electronically remove the dead load before the signal reaches the controller. In turn, this allows you to eliminate some of the feeder's mechanical counter-balancing devices such as pivots and beatings that can distort the weight signal from the weight-sensing device.

Control

No matter how well your LIW feeder's material handling and weighing work, the feeder needs a good control algorithm to perform well. The control algorithm is the formula the controller uses to direct and regulate the LIW feeder's operation.

What the control algorithm does. The control algorithm must make sense of several input signals and react appropriately. The primary input to the controller is the weight- sensing device's signal. Other inputs can also contribute to the controller's decision-making process. For instance, an encoder can send a pulse signal that the controller uses to check for the discharge device motor's rotation. The controller can also use the pulse signal to check system synchronization, which involves synchronizing the weight-sensing device's weight readings with a screw discharge device's motor rotation to filter vibration and mechanical noise. The pulse signal can be used to set the screw discharge device's discharge rate, as well. You can also use a vibration detector to send a signal from a vibratory pan discharge device to the controller to indicate whether the device is vibrating and, if so, the vibration's amplitude or frequency.

Several proprietary control algorithms have been developed to provide intelligent control for LIW feeders.

In its crudest and most basic form, a LIW feeder control algorithm calculates the change in weight between two samples. The controller uses this change in weight and the time between samples to calculate the feedrate. Then the controller compares this feedrate to the setpoint and changes its signal to the discharge device in direct proportion to the error between the feedrate and setpoint. For instance, if the feedrate is 10 percent lower than the setpoint, the controller increases the signal to the discharge device by 10 percent.

But such a simple algorithm is usually not intelligent enough for LIW feeding applications. Why? Moving and weighing a bulk material while external forces such as vibration affect the feeder present some formidable obstacles to the controller. Determining which signal represents vibration or electronic noise and which represents a true weight change requires complex mathematical and electronic processes. As a result, several proprietary control algorithms have been developed to provide intelligent control for LIW feeders.

Tuning your control algorithm. In some cases, a control algorithm is flexible because its parameters can be modified. This allows the LIW feeder operator or an instrument technician in your plant to adjust the algorithm to suit your application, which is called *tuning the algorithm*. The operator or technician can use any of several mathematical formulas developed for tuning industry-standard algorithms. However, a LIW feeder algorithm is often so specialized that the person tuning it must have extensive experience in this task.

This problem can be avoided by using a LIW feeder with a self-tuning control algorithm. In this feeder, the algorithm learns your process and adjusts the algorithm's parameters based on historical information about the process. This eliminates the need for an experienced operator, removing this potential source of errors from the factors affecting your feeder's performance. PBE

Endnotes

1. More details on calculating sigma for your test results are provided in "How to test your gravimetric feeder's performance" by Norman R. Johnson, *Powder and Bulk Engineering,* December 1993, pages 43- 48.

2. Find more information on improving LIW feeder performance in the author's article, "How to fix mechanical problems with your loss-in-weight feeder," Part I (December 1998, pages 71-77) and Part II (January 1999, pages 17-24).

3. For help selecting a flow aid, see articles listed under "Solids flow" in *Powder and Bulk Engineering's* comprehensive "Index to articles" (later in this issue and on *PBE's* Web site, www. powderbulk.com).

For further reading

Find more information on loss-in-weight and other feeder types in articles listed under "Feeders" in *Powder and Bulk Engineering's* comprehensive "Index to articles" (later in this issue and on *PBE's* Web site, www. powderbulk.com).

Steve Musser *is manager of the Process Industries division of Merrick Industries, 10 Arthur Drive, Lynn Haven, FL 32444; 850/265-3611, fax 850/265-9768, (steve@merrick-inc. com). He holds a BS in computer science from Cameron University in Lawton, Okla.*