feeders

Using trending capabilities to troubleshoot continuous feeder performance problems

Sharon Nowak
Coperion K-Tron

This article describes how to use a loss-in-weight feeder's trending capabilities to help determine the cause of feeder performance problems.

The pharmaceutical industry is undergoing a paradigm shift from batch to continuous processes, including direct compression, blending, wet and dry granulation, coating, and hot-melt extrusion. At the heart of these processes is the loss-in-weight (LIW) feeder, which delivers excipients, active pharmaceutical ingredients (APIs), and lubricants directly to the continuous process. The pharmaceutical industry is slowly coming to understand the basic rules of operation for LIW feeders and how to optimize their performance, but operators are often unfamiliar with how to use a feeder's trending capabilities to understand and even predict feeder performance.

Current LIW feeders display many parameters associated with feeding performance and machine status, ranging from feedrates and motor-drive commands to span settings and alarm limits. While these parameters allow you to monitor and manage the feeder's operation, analyzing the trends for some of these parameters can also help to identify conditions external to the feeder that may be limiting its performance. Sharpening your ability to find external process causes affecting feeder performance can reduce unplanned downtime, improve process efficiency, and, most important, improve the output of the process.

Working from the feeder

To use a feeder's trending capabilities to identify an external cause of a feeding problem, you must first understand the feeder's operating principle. As the feeder discharges material, the combined weight of the feeder and material decreases. Load cells monitor this weight decrease, and the feeder's control system constantly adjusts the operating speed to produce the desired gravimetric feedrate—equivalent to the rate of the system's weight loss, as shown in Figure 1. A typical LIW feeding technology for continuous pharmaceutical processes is a

twin-screw feeder, due to its ability to handle relatively cohesive and sticky materials.

As a direct result of its operating principle, a LIW feeder requires: 1) a periodic refill to recharge its supply hopper and 2) isolation from the process environment to permit accurate and continuous weighing. This means that, as part of the larger process environment, the LIW feeder must perform a balancing act of sorts. On the one hand, it must connect to and interact with the process to receive and discharge material; on the other hand, it must be isolated from the process to ensure maximum weighing accuracy.

In operation, an LIW feeder continually circles the simplified control loop pictured on the left in Figure 2, constantly attempting to drive mass-flow error to zero. The time it takes to complete one loop represents the interval during which the feeder measures weight loss and determines any required adjustment to its speed. Using the simplified control loop as a template to organize the typical locations and causes of feeding problems, the right side of Figure 2 separates feeding problems originating in the feeder from problems originating in the external process.

Since a feeder's main mission is to control flowrate, the trend for measured mass flow can indicate a performance problem. However, the trend for weight measurement is most helpful for narrowing the diagnostic possibilities. After you have checked the feeder and eliminated it as a problem's cause, you must then turn your attention to the surrounding process environment.

The first alert to a feeding problem will likely be an alarm from the feeder's control system. Properly used, alarms are your first tool for detecting and diagnosing a problem, whether inside or outside the feeder. When an event such as crossing a limit triggers an alarm, the alarm's cause may be a condition that lingers long enough for diagnosis or it may be an isolated, momentary condition that passes before you can identify it. By analyzing trends through time, you can often correlate events and conditions inside the feeder with events and conditions in the external process environment, even in the absence of a triggered alarm.

Analyzing trends

While analyzing the trends can reveal much about problems inside the feeder, the most useful parameter for locating causes outside the feeder is measured weight. Most equipment manufacturers design modern LIW feeding systems to combat performance-eroding influences faced in typical process environments. But given the need to discern exceedingly small weight changes reliably in hostile process surroundings, these design measures sometimes prove insufficient. Trend analysis can reveal process influences that make it past a feeder's defenses, allowing you to identify and solve a problem.

FIGURE 1

LIW feeder operating principle

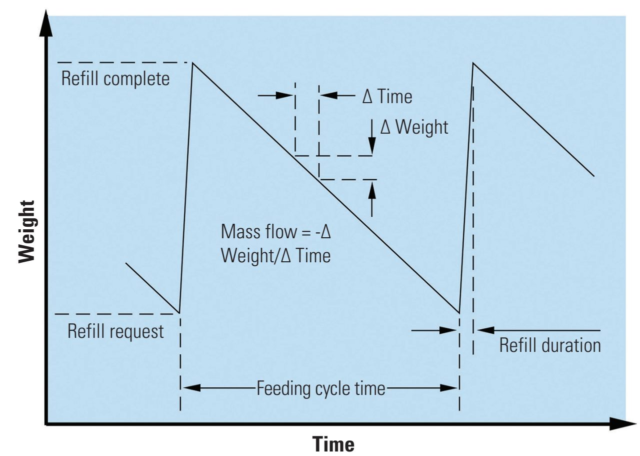
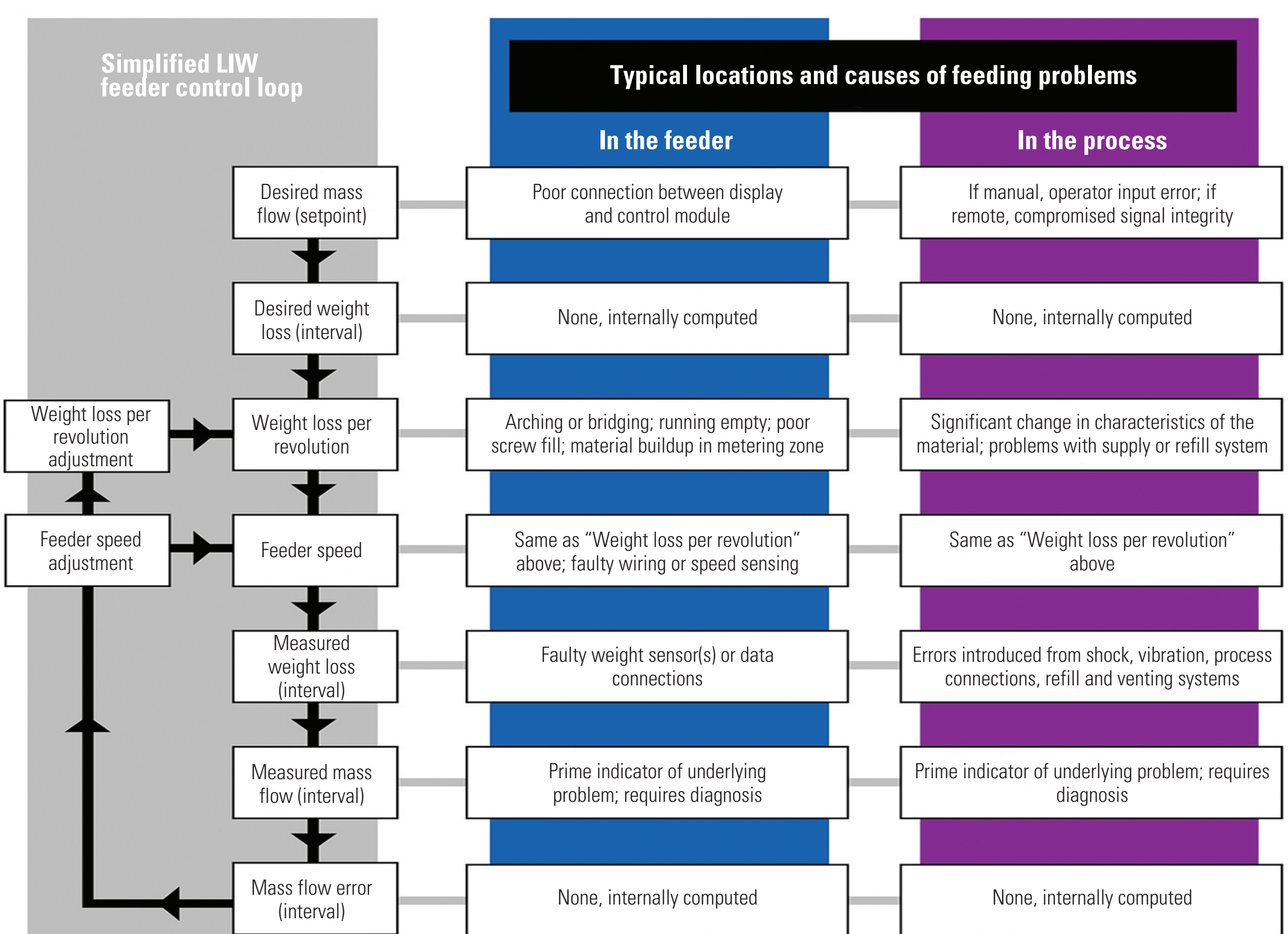


FIGURE 2

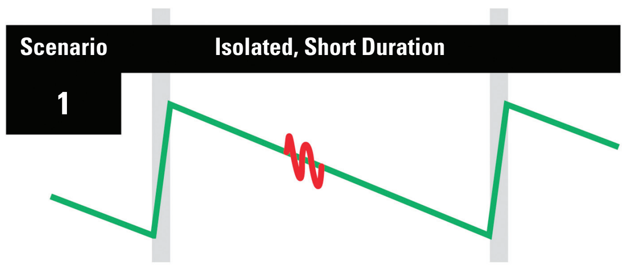
Locations and causes of feeding problems



Scenario 1: An isolated, short duration weight disturbance. A passing plant worker bumping the feeder, or some other form of momentary incident, can cause an isolated, short-duration weight disturbance, as shown in Figure 3. Most LIW feeders can recognize a brief disturbance and quickly determine whether to ignore it or compensate for any resulting excess or shortfall in discharge depending on the disturbance's duration and severity. While a disturbance of any kind will tend to reduce a feeder's overall measured accuracy, the harm inflicted by isolated, infrequent disturbances is typically not significant.

FIGURE 3

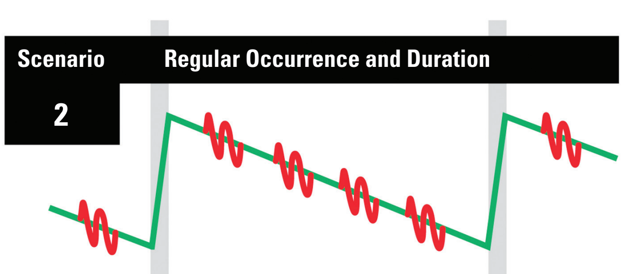
Isolated, short duration weight disturbance



Scenario 2: Disturbances of regular occurrence and duration. When you require the feeder to perform in a more disturbance-prone process environment, the cumulative effect of ongoing disturbances can degrade the feeder's overall performance, as shown in Figure 4. If your feeder's weight trending displays such a disturbance pattern, the likely cause is shock or vibration transmitted to the feeder from some nearby piece of equipment, such as a continuous mixer or the support platform itself. If multiple sources of regular disturbance are at play, the disturbance's pattern may appear random, as in the next scenario, but closer inspection should reveal the pattern's composite character. The frequency and duration of regular disturbances can direct you to the offending equipment, but the particular remedy depends on the situation.

FIGURE 4

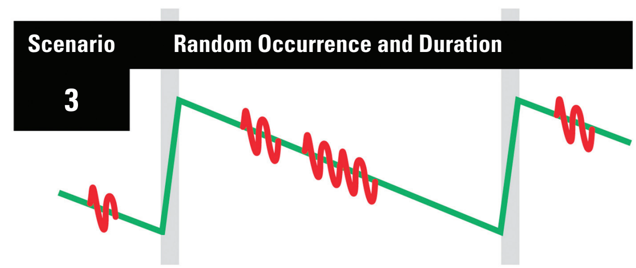
Disturbances of regular occurrence and duration



Scenario 3: Disturbances of random occurrence and duration. If you find, upon analysis, that disturbances are truly random in their occurrence and/or duration, as shown in Figure 5, you must use a divide-and-conquer strategy of methodically eliminating all potential causes. Is the feeder being buffeted by rogue air currents, which can occur in a high-laminar-flow room or when the air pressure changes constantly within an isolator? Do the disturbances occur when the rest of the process is shut down? Is something odd going on inside the feeder, such as random changes in material characteristics causing occasional ratholes? Are the feeder's process connections secure and not causing additional stress on the feeder and scale? One by one, you must nominate, assess, and eliminate possible causes until you identify the culprit or culprits.

FIGURE 5

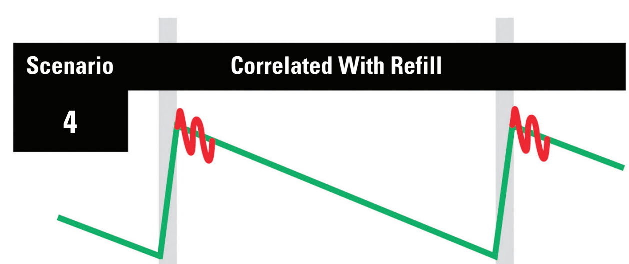
Disturbances of random occurrence and duration



Scenario 4: Disturbances correlated with refill. An often-underappreciated requirement of LIW feeding is the need to return to acceptable weighing conditions as soon as possible after completing a refill, allowing the feeder to resume gravimetric operation. A refill is a major disturbance to the feeder's weight and requires a settling time after the refill to allow the feeder's scale system to stabilize and begin to collect the correct weight-loss data, as shown in Figure 6.

FIGURE 6

Disturbances correlated with refill



Several external process factors can contribute to disturbances following feeder refill. Although a required element in a fully automated LIW feeding system, the refill system itself is not weighed and is considered to be part of the process environment. Any unintended post-refill leakage from the refill device, such as less-than-complete shutoff, can corrupt the feeder's weight measurement until the leakage has ceased. In one unusual case where the refill device had been positioned some distance from the hopper because of limited headroom, an analysis found the post-refill weight disturbance to be caused by the protracted trailing off of flow resulting from the transit length. To fix such a condition, check your refill device for proper operation and confirm positive shut-off.

Venting of the feeder's hopper is another potential cause of post-refill weight disturbance. Proper venting permits the air displaced from the hopper by incoming material to escape and facilitates material de-aeration and settling. Venting can be an internal feeder issue or an external process issue, depending on whether the venting is passive or active.

With passive venting, the displaced air exits the hopper of its own accord, impeded only by the size of the aperture and the resistance that any sock or filter presents. An improperly sized vent or a clogged filter can delay complete venting, temporarily pressurizing the hopper and inducing stress on flexible connections. At worst, this can pressurize the feeder's hopper enough to force material out through the discharge. These conditions can produce a perceived weight disturbance, a feedrate error, and/or an abnormal motor-speed trendline. The fix is simply to clean or replace the filter and if needed, increase the vent size.

Alternatively, active venting and dust collection uses a vacuum to encourage the air to exit from the hopper, which involves pressure forces that can compromise weighing. If active venting is too aggressive, the low pressure in the feeder's hopper can induce stresses on flexible connections that directly register as weight disturbances and provide a path for the transmission of vibrations from the process environment to the feeder. In such a case, check the inlet, vent, and discharge connections for full flexibility during active venting and correct as necessary.

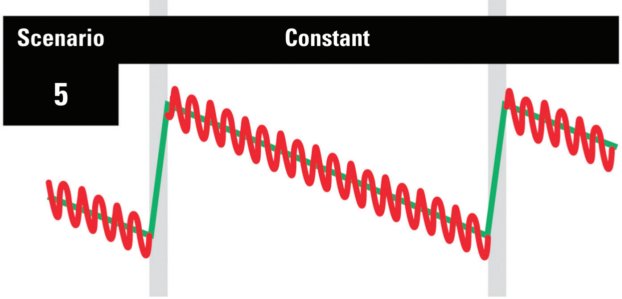
New electronic, pressure-compensation devices are available to detect pressure fluctuations and correct for their effects. This control addition uses pressure transmitters on the feeder's hopper and discharge to detect pressure fluctuations and then filters them out from the weight signal to avoid a change in the mass flow.

Scenario 5: Constant disturbances. The final scenario depicts weight measurement swamped with constant contamination, as shown in Figure 7. This most visually intimidating category of weight disturbance is also the most performance damaging. After you have eliminated possible internal causes—electronic noise, static, or binding of scale flexures—you can see clearly that the process must have found some direct route, some point of least resistance, to manifest its contaminating influence on the feeder's weighing environment.

Constant disturbances are commonly caused by poor mounting practices. For example, the company may have installed the feeder without adequately considering the transmission of shock or vibration through the feeder's base or other supports, or the installation may have resulted in stiff or stressed flexible inlet, venting, or discharge connections or electrical wiring and cabling.

FIGURE 7

Constant disturbances



Material factors

The material being fed is the only part of the external process invited to cross the LIW feeder's defensive line. Unfortunately, the flow properties of most pharmaceutical excipients and active ingredients are not ideal. Familiar difficulties include bridging, arching, and other problems related to the material's flow through the feeder, such as caking, clumping, or buildup on the feed screw or tube or on the agitator, if used.

You can best anticipate, address, and resolve these problems during feeder selection and testing, or at worst, in the pre-operation shakedown. However, actual process conditions can and do change, and the character of the material can vary as well. Such changes can cause old flow problems to return or new ones to emerge. While such problems will almost certainly cause one or more alarm conditions, monitoring a feeder's performance variables through trends can identify and diagnose emerging concerns.

Figure 8 shows a trendline pattern typical of material suddenly becoming hung up due to arching, bridging, or some other form of blockage in the hopper. After the feeder empties the material below the blockage, the feedrate quickly falls to zero; the hopper's net weight remains constant; the feeder's speed maxes out in its futile attempt to dose material that is no longer available; and weight loss per revolution drops to nil.

Figure 9 shows a trendline pattern typical of material buildup on the feed screw. In this case, the weight loss per screw revolution declines more than expected over time as material builds up on the metering element(s). In response, the feeder's speed increases to compensate for the reduction in the screw's efficiency. If buildup stabilizes and is not severe, feedrate and hopper weight remain on track. However, too much buildup will eventually trigger an alarm related to the feeder's speed or a violation of the limits for weight loss per revolution.

Figure 10 shows a trace pattern signaling an abrupt change in the material's density or handling characteristics. This condition could arise from any of several causes, ranging from a different material supplier to changes in storage or transport practices that mistakenly introduce the wrong material. The figure shows the con-

FIGURE 8

Material blockage

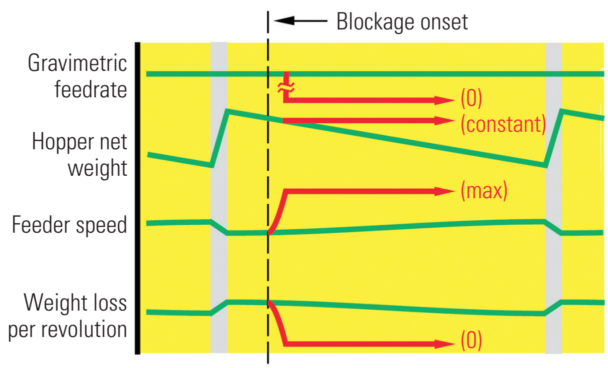


FIGURE 9

Buildup on feed screw and/or screw tube

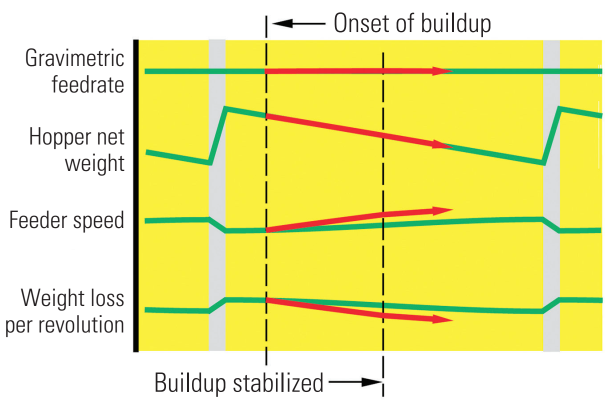
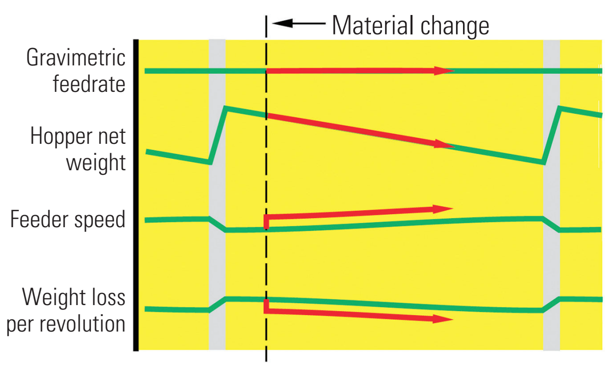


FIGURE 10

Material-property variation



dition where the density of the material abruptly falls to a slightly lower-than-expected value. The feeder's speed increases in a step-like fashion to adjust for the sensed reduction in weight loss per revolution. To compensate for an increase in material density, the opposite would occur. The figure shows that the feedrate and hopper weight remain on target, but if the change in material properties or handling characteristics is too great, the feeder may not be able to accommodate it, and an alarm will sound.

Summary

Proper refill algorithms, the ideal weighing configurations, and the proper choice of feeder controls and instrumentation can help to avoid many feeding problems, but feeder performance problems may still occur. Using the trending capabilities that your feeder displays can provide valuable clues to some of the more elusive causes of feedrate disturbances, allowing you to keep your process running smoothly. T&C

Sharon Nowak is the global business development manager for the food and pharmaceutical industries at Coperion K-Tron (856 256 3119, www.coperionktron.com). She holds a BS in chemical engineering from Rutgers University, New Brunswick, NJ, and has more than 25 years of experience in developing process equipment for the pharmaceutical and other process industries. *This article originally appeared in* T&C's Solid Dose Digest *on February 26, 2018.*