Technical Paper

Electronic Pressure Compensation EPC

Electronic Pressure Compensation for gravimetric feeders offers a reliable and cost-effective alternative to traditional mechanical compensation

Introduction

Where gravimetric feeders operate in a closed system, changes in pressure within the feeder hopper or the outlet tube can lead to incorrect weight signals, causing erroneous mass flow and poor feeding accuracy. Traditionally, these troublesome pressure fluctuations have been compensated for by mechanical means, as shown in fig. 1. Factors such as mechanical tolerances, the alignment and age of the flexible bellows, etc. can impact the mechanical pressure compensation and prevent it from fully compensating for the forces generated by changing pressures, making this costly solution deficient.

Coperion K-Tron has addressed these issues with the development of the effective but simple electronic pressure compensation, EPC. This solution has shown to significantly improve feeding accuracy of gravimetric feeders in closed systems and can be less expensive than traditional solutions. In addition, EPC is more effective and reliable, maintenance free, and easy to retrofit on existing systems.

This paper discusses the need for pressure compensation in gravimetric feeders, lays out the functional principle of the EPC system and verifies its effectiveness using an application example and actual data from the field.

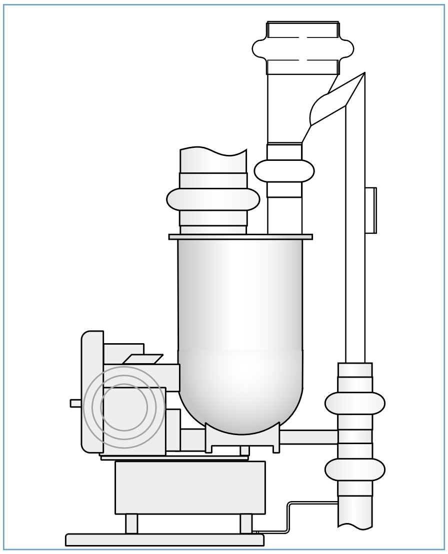

Figure 1 - Feeder with traditional mechanical pressure compensation on both hopper and discharge

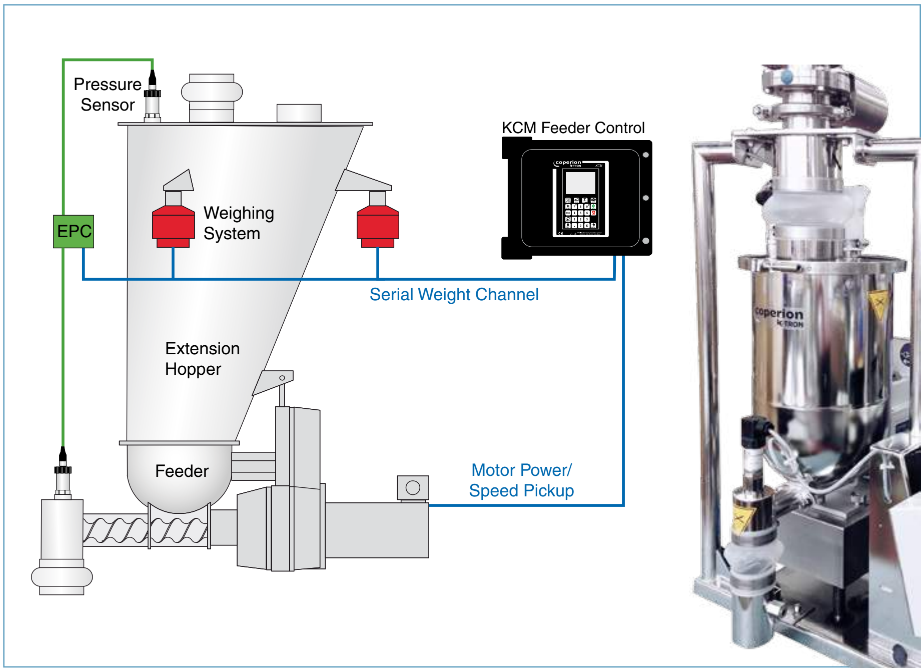

Figure 2 - Electronic Pressure Compensation EPC

Why Pressure Compensation is Required

In a sealed pressure vessel the pressure forces balance perfectly in all directions and the measured weight is unaffected. However, the feeder hopper has an inlet in the lid for refills and is isolated from the rigidly mounted refill valve with a flexible bellows.

Pressure Fluctuations in the Hopper

A feeder's refill cycle increases air pressure in the hopper due to the sudden inflow of material. Any positive air pressure acts equally towards all sides and so also pushes up on the hopper lid and the refill valve. Because the force in the inlet area is not applied to the hopper lid but to the refill valve above, pressure forces inside the hopper are not balanced. Due to the inlet opening, forces acting up on the lid are lower than those acting down oppositely on the floor of the hopper. The higher forces acting down result in an increase in the weight signal. The loss-in-weight controller would interpret the increased weight signal to mean that mass flow is slowing and react by erroneously increasing the feeder output creating a mass flow error.

Hopper pressure issues can also have other causes such as a clogged vent filter, a dust collection system connected to the hopper vent, or a nitrogen blanket applied to the hopper. Sometimes the dust collection systems or nitrogen blankets are connected across many feeders and when any of the feeders refill, the others see pressure disturbances.

Pressure Fluctuations at the Feeder Discharge

A pressure fluctuation at the feeder discharge also distorts the feeder's weight signal if the outlet is sealed with a cap. Pressure increases in the discharge tube push up on the cap, which, if it is connected to the feeder, pushes up on the feeder and reduces the measured weight. To mitigate pressure fluctuations on the outlet, the cap may be isolated from the feeder by a flexible bellows rigidly mounted to an outside structure. This is how mechanical pressure compensation works on the discharge.

Discharge pressure problems may be caused by extruder back pressure, extruder screw pulsations, a nitrogen blanket, etc.

Calculation Example

Consider a feeder with a six inch [15.24 cm] diameter refill hole in the lid that is decoupled by means of a flexible bellows. Say the pressure inside the hopper increases by 0.1 PSI (lb/in²) [0.007 bar]. This pressure change makes the feeder's weight increase by more than 2.8 pounds [1.28 kg].

Formulas:
$A = \pi \times R^2$ (Area of circle = π x Radius squared)
$F = p \times A$ (Force = Pressure x Area)

Imperial units:
F = 0.1 PSI x 3.14 x 3 in x 3 in
F = 2.83 lb

Metric units:
F= 0.007 bar x 3.14 x 7.62 cm x 7.62 cm
F = 1.28 kg

This simple example ignores the vent hole in the lid, but shows how even small pressure fluctuations can greatly affect the feeder's measured weight.

The Technology behind EPC

Pressure compensation may be required for the feeder hopper, the discharge tube, or even both. Coperion K-Tron's Electronic Pressure Compensation solution is based on a high-precision pressure sensor which is mounted on the hopper lid and/or the outlet tube and constantly measures the pressure. The signal from the sensor is transmitted via EPC sensor board to the KCM feeder control system where it is used to dynamically compensate for the pressure fluctuations and thus prevent weighing errors.

The EPC sensor measures gauge pressure (relative to atmosphere). Using very sensitive pressure sensors, the EPC will measure and correct for pressure fluctuations inside of a hopper in the range of ±0.05 bar. If the pressure is outside of this range an alarm will be generated.

The EPC sensor can be installed on the feeder hopper or the outlet or both. It is also possible to use EPC for the hopper while utilizing traditional mechanical pressure compensation on the discharge. However, EPC and mechanical pressure compensation cannot be used simultaneously on the same discharge.

EPC vs. Traditional Solutions

Electronic Pressure Compensation (EPC) can be used to automatically detect changes in pressure within a feeder and adjust the weight signal accordingly. When it comes to handling air pressure issues in loss-in-weight feeders, especially for pressure issues in the feeder's material hopper, EPC offers distinct advantages over traditional mechanical pressure compensation systems such as:

- simple, cost-effective design
- fewer parts, easy to install and clean
- more effective and reliable
- maintenance free
- easy to retrofit on existing systems
- pressure data available electronically
- alarms on over-/under-pressure

EPC on the Hopper

Traditional mechanical pressure compensation on a hopper is quite complex and must be installed correctly. Any deviations, e.g. a misalignment of inlet tube and hopper inlet, adversely affects the result. In comparison, EPC is easy to install, self-optimizing and significantly less expensive.

EPC on the Feeder Outlet

Pressure changes at the feeder outlet, when sealed and connected to the downstream process with a bellows, also create a weight error which can be corrected with a separate pressure sensor connected to the same EPC junction box.

Traditional mechanical pressure compensation on a feeder outlet is often relatively simple and effective and therefore often a good solution. However, even a relatively simple mechanical pressure compensation system requires on-going maintenance including periodically readjusting or replacing flexible bellows. Therefore the EPC may still be the better choice, even compared to a simple mechanical discharge solution.

An Application Example

This example from the field illustrates how a clogged air filter can cause real-world problems and it represents a typical situation where EPC can relieve a troublesome situation.

A gravimetric feeder in a closed system was experiencing bumps in the massflow signal after every refill. The refill device above the feeder was a vacuum receiver with a powered dump valve.

In order to collect tangible data for diagnosis, a Coperion K-Tron EPC Field Evaluation Kit was used to measure and record pressures during feeder runtime. (Features and usage of the field evaluation kit are detailed at the end of this paper.)

The chart in Fig. 4 shows the pressure curve created with the measurements collected by the evaluation kit during three refill cycles. The chart in fig. 5 zooms in on the first refill cycle.

The pressure was converted to grams before charting. The feeder's setpoint was 150 kg/h and the post refill delay time was 5 seconds so that the gravimetric feeder controller would ignore irregularities during this period of time.

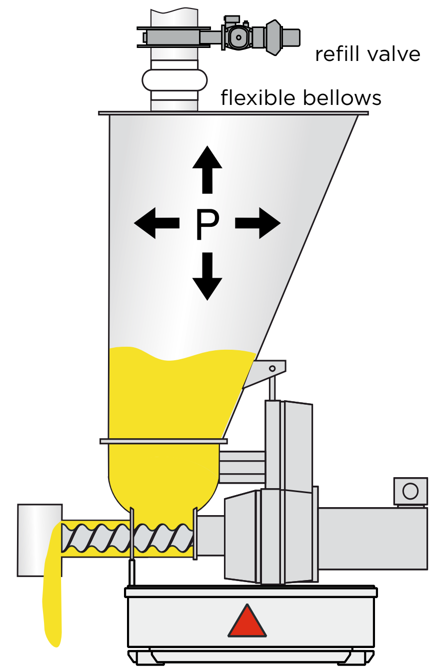

Figure 3 - Pressure acting on all sides of the feeder hopper

The refill cycle consisted of the valve opening for 10 seconds and aeration pads operating during this time. The aeration pads pumped air into the receiver to help the powder flow out. Powder dumping out of the receiver and into the feeder took approximately three seconds (t22-t25) and caused a large spike in feeder hopper pressure as air struggled to get out through the clogged vent filter or back up into the receiver. The aeration pads continued to operate for seven more seconds (t25-t32), then the refill valve closed. After the refill valve had closed, the pressure inside the hopper continuously dropped during the next 20 seconds (t35-t55) before stabilizing at a slightly negative value – the continuous feeding out of material pulls a slight vacuum inside the hopper since the air cannot enter freely to replace the fed-out powder.

Assessment

The feeding error occurred during the next twenty seconds while the pressure gradually reduced, until it reached steady state. The gradual decrease of the internal hopper pressure for 20 seconds led to a decrease in feeder weight and an apparent over-feeding condition. This became manifest in the massflow display spiking after every refill. But more importantly, it caused the gravimetric control to react to this apparent overfeeding by reducing motor speed. So, while the massflow display made it look like the feeder was overfeeding after refills, in fact the opposite was happening. The massflow chart shows a filtered mass-

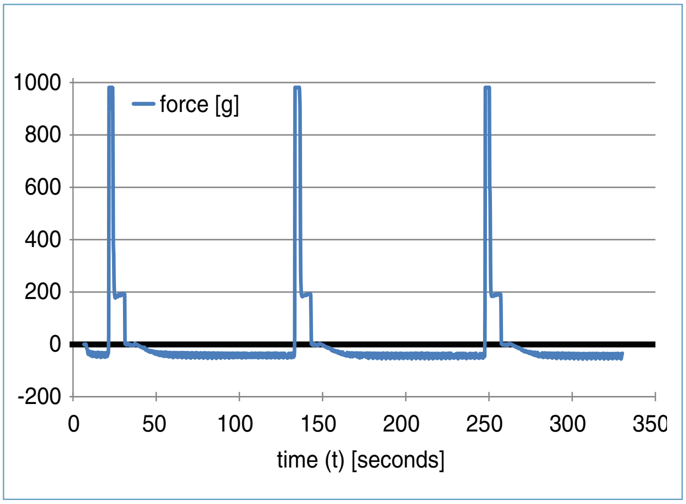

Figure 4 - Pressure curve based on the values measured by the Field Evaluation Kit

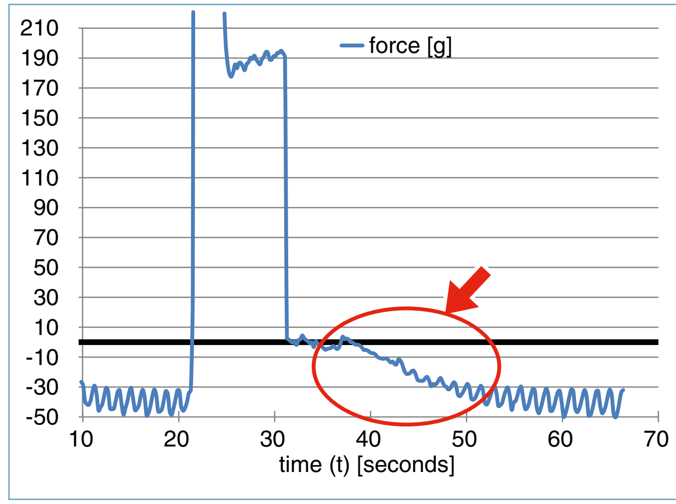

Figure 5 - 60 seconds detail of pressure curve

flow with a 60-second exponential filter with 40 grams of error accumulated over 20 seconds of feeding.

The detail chart revealed another interesting aspect of this feeder's pressure data: steady pressure pulsations occurring every second. A close look at the data from this feeder showed that the oscillating pressure curve correlated with the screw speed. The feeder is a single screw feeder which tends to feed out the powder in pulses rather than smoothly like a twin screw feeder does. The very sensitive pressure sensor was clearly able to show how even small pressure fluctuations can affect the feeder's weight.

Conclusion

This is a typical application for Coperion K-Tron's Electronic Pressure Compensation system. Based on actual pressure measurement inside the feeder hopper or discharge by the EPC sensor, changes in pressure will be identified as such and will no longer be misinterpreted as changes in bulk material weight. The data transmitted via the EPC sensor board will enable the gravimetric feeder control to regulate the massflow correctly and thus the required highly accurate feeding rate can be obtained even during and after hopper refills.

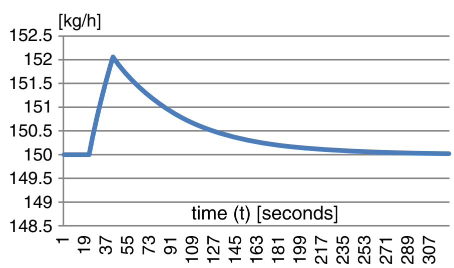

Figure 6 - Massflow chart spikes after every hopper refill

Field Evaluation Kit

The Field Evaluation Kit is a handy tool for measuring and logging pressure changes inside a hopper. It serves to collect tangible data for evaluating the current pressure situation and evaluating the extent of pressure-related feeding errors.

The kit consists of a pressure sensor with USB interface, a USB cable to connect to a PC or laptop, a silicon mounting adapter with tubing, and data collection software. The silicon adapter protects the Tyvek air pressure tube from being crushed and it allows the band clamp and bellows to reseal again.

A PC/laptop with the pressure measurement software installed (download via internet) and with USB support is required on site and must be connected to the kit when measuring. A preconfigured Excel sheet is provided for evaluation of the measurement data.

This kit can help guide the decision on whether to invest in eliminating possible pressure problems.

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