To Weigh, or Not to Weigh

Michael Purcell, Director of Marketing and Product Development, Venture Measurement, USA, presents the benefits of using a weighing system for inventory measurement.

Introduction

In the cement manufacturing process, accurate measurement of material inventories is critical in controlling the flow of materials through the process, as well as accounting for them. Consequently, most vessels are equipped with some type of inventory measurement system. Although level measurement techniques are often used, it is important to understand the advantages and options associated with weighing systems.

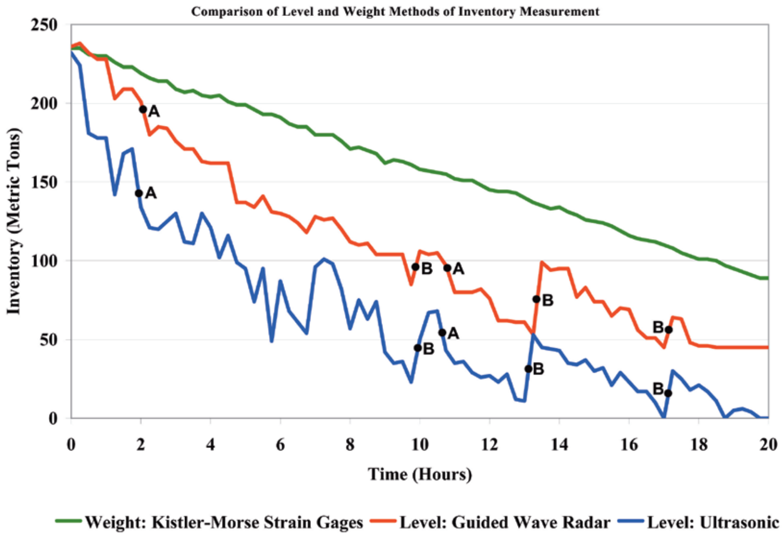

Figure 1. The different approaches to inventory measurement.

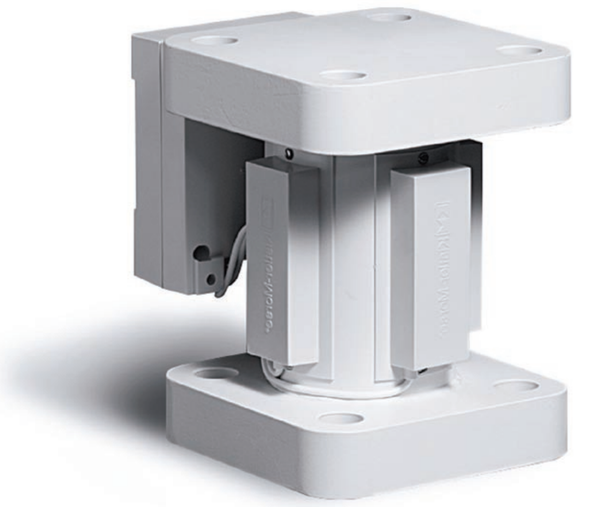

Figure 2. A load stand from the Kistler-Morse Load Stand II™ range.

Options for inventory measurement

Throughout the cement manufacturing process, material inventories are generally accounted for and expressed in units of weight. Major bulk solids storage and surge vessels in the plant are typically equipped with some form of instrumentation to provide a continuous inventory reading. There are generally two approaches to continuously monitoring the inventory of material in a bulk solids vessel:

- Directly weighing the material using a sensor attached to, or placed under, the vessel supports.
- Locating the top surface of the material with a level measurement device and converting it into a calculated weight.

All weighing devices utilise a sensor to take a physical measurement, such as strain or capacitance, and then convert it directly into a weight value. The most common weighing devices are either direct load bearing devices installed under the vessel supports (load cells or load stands) or strain gauges mounted onto the vessel supports.

Among the most common continuous level techniques used to measure inventory levels are ultrasonics, pulsed radar, and guided wave radar devices. Each operate by measuring the time required for a transmitted signal to reach the top surface of the material and return to the sensor, after which the elapsed time is then converted to a distance. Plumb bob monitors measure the distance to the top of the material by dropping a weight on a cable to the material surface and pulling it back up, counting the rotations of the cable feeding mechanism, and converting it to a distance. For all these devices, arriving at a weight value is accomplished by converting the distance reading to a volume, and then to an approximate weight using the estimated bulk density of the material.

The case for weight

For producers who require a consistent and accurate measure of physical inventory at key points throughout the process, a weighing approach is considered to be the most reliable solution. Although continuous level measurement techniques can be instrumental in monitoring the space inside a vessel, they can present several challenges when obtaining accurate and consistent physical inventory measurements.

More specifically, level measurement as a method of determining the weight of bulk solids poses two main sources of error: the level measurement itself, and the conversion of that level to a weight value.

All level measuring systems for bulk solids function by locating a specific point on the surface of the material, which is taken to be the level of the material for the entire vessel. In practice, bulk solids do not distribute in a flat and horizontal manner across the vessel; instead, they tend to have an angle of repose, which is produced when the material enters into or empties from the vessel. The method of filling a vessel can produce a wide variety of shapes to the material surface. Off-centre fill points and angled or multiple fill pipes all produce multiple cones and peaks.

In addition, bulk solids are subject to funnel flow patterns in which the column of material above the discharge point flows preferentially out of the silo, leaving a vertical layer of material against the sidewall. Periodically, this material at the edge will become unstable, resulting in a sudden slide. This "ratholing" behaviour can produce level measurements that are both erroneous and erratic. It is important to note, however, that the proper selection and configuration of continuous level devices can help to minimise the impact of these inaccuracies.

The uncertainty in the level measurement is further compounded in the conversion to weight. The level system must first make a conversion to volume, using the vessel height and cross-section dimensions, followed by a conversion to weight, using the estimated bulk density of the material. The values chosen for bulk density can be of particular concern here since published bulk densities are typically an average value and can vary by as much as 50% from the actual values. Additionally, the bulk density value can vary over time with process and environmental conditions. Pneumatic conveying aerates the materials such that its bulk density will change as it compacts with time. Moisture can also have a significant impact on bulk density.

Figure 1 shows data from a test performed by a customer to compare the two approaches of weight and continuous level in the task of inventory measurement. In this case, bolt-on strain gauge weight sensors were compared with both guided wave radar and ultrasonic level devices. The figure shows readings taken over an emptying operation during which no material was added to the silo. Although the readings were in close agreement with a full silo prior to emptying, a significant deviation emerged as the vessel was emptied. As shown in Figure 1, the weight measurement shows a steady and even decline in the inventory consistent with the flow rate out of the silo, while the readings based on level consistently underestimated the inventory and showed an erratic pattern as a result of abrupt changes in material distribution. At several points either (A), an apparent rapid loss of inventory occurred due to funnel flow or ratholing, or at other times (B), the inventory appeared to rapidly increase when material cascaded into a void created by funnel flow.

Because weighing systems are not subject to the errors introduced by the material distribution and bulk density variations, they can provide a more precise and consistent reading on inventory throughout filling, storage, and emptying cycles.

Methods of weight measurement

In terms of weighing systems, various options are available to designers, constructors, and operators of cement plants. Among them, direct support weighing systems are ideal for new plant installations. In these systems, the force transducers are built into a structural element that is then installed as part of the vessel's support system during construction. Compression (or "pancake") load cells have long been used in such installations. Another approach, which has seen considerable success recently in cement plant installations, is the "load stand". A load stand is a direct vessel-to-foundation structural member designed to deliver dependable and accurate continuous inventory monitoring. The rugged monolithic design results in a simplified and less costly installation compared to typical load cells, since no external vessel tie downs are needed and because blank ("dummy") load cells are not required during silo placement to prevent damage to sensor elements. The load stand becomes a permanent part of the vessel support structure because it never needs to be removed for repair or maintenance. The sensing elements are accessible on the outside of the device and can be serviced without taking the vessel out of service. As an example, Figure 2 shows a load stand from the Kistler-Morse Load Stand II™ range, which is available for vessels with loads of 25 000 to 1 million lb (111 000 to 453 000 kg) per support point.

Figure 3. A Kistler-Morse Microcell®.

For operators of existing cement plants who desire the benefits of the weighing approach, but without the expense of a costly retrofit, bolt-on strain gauges represent an economical and reliable solution. These sensors are simply bolted on to the support structure of the vessel and measure the strain experienced in the structure due to the load imposed by the product in the vessel. Bolt-on sensors are suitable for any vessel with leg-supports, horizontal beam supports, or skirts, and can be quickly and easily installed while the vessel is in productive use. Typically, four sensors per silo are used to measure the strain in the four legs; the readings are summed in a signal processor and then transmitted to a display or to the plant control system. As an example of a bolt-on strain gauge, Figure 3 shows a Kistler-Morse Microcell®.

Suitable vessels for weighing systems include any silo, bin or hopper with a steel support structure. Examples include coal silos and bins, limestone silos, raw meal additive silos, cement additive silos, and reject bins. The major exceptions are slipform or jump-form concrete silos, often used for storage of raw meal, clinker, and cement product. For these cases, continuous level devices remain the only feasible option.

Conclusion

A weighing systems approach can provide clear advantages in the accurate and consistent measurement of physical inventory in many vessels throughout the cement manufacturing process. Since inventory is typically accounted for in units of weight, this approach enables a more straightforward determination of that value. Finally, because weighing systems are subject to less error associated with material, vessel and process conditions, they can provide more reliable inventory information than continuous level systems.

Note

Venture Measurement is the brand owner for the Kistler-Morse weighing system and Bindicator level measurement product line.