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Load Cells Versus Coriolis Mass Flowmeters In Batch Applications

Executive summary

This paper includes a brief overview of load cell weighing systems and Coriolis mass flow technologies, as well as a discussion of special considerations and benefits that each technology provides. Load cell-based weigh scales have been used by a variety of industries for many years in custody transfer and batching applications. They are generally accepted and most industries are familiar with the technology and its limitations.

In 1977, the first industrial Coriolis mass flowmeter was introduced. Coriolis mass flowmeters measure the mass flow directly of liquids, slurries, and gases. Since being introduced, Coriolis mass flowmeters have steadily gained acceptance for many applications as an alternative to load cell-based weigh systems. End users will gravitate to one technology or the other, depending on the specific needs of the application and their knowledge and comfort with each technology.

Load cells are generally well suited for measuring dry materials. They are also well suited for applications in which the customer must know precisely how much material has been transferred into a vessel (specifically industries such as pharmaceutical or biotech).

Coriolis mass flowmeters are well suited for simultaneous batching applications and where precise measurement over a broad range of flow conditions is needed. Simultaneous batching (adding multiple ingredients at the same time) can significantly reduce total batch time compared to the sequential batching that is required for load cell systems. Simultaneous batching will increase the effective capacity of the batch or blend unit operation.

In addition to technical requirements, customers must also consider the costs associated with engineering and installing the load cell weighing system versus Coriolis meters. In most cases, where precise measurement is required, engineering and installation costs can be significantly higher for load cell systems than for Coriolis meter installations.

Load cell technology: Introduction

The majority of weigh scales consist of one or more strain gauge load cells, which sense force coupled with scale electronics that convert this signal to weight (pounds force). The load cells are mounted to a platform in truck or railcar custody transfer systems.

In batch or blending systems, the load cells are mounted to a mix tank or vessel. In either case, the load cells measure the combined weight of the product and the platform, tank or other attached mechanical devices. The weight of the product (net weight) is calculated by subtracting the empty weight of the mechanical system (tare) from the full weight (gross weight).

The force measured at the load cell includes both vessel weight and raw material weight. Consequently, the product being weighed is a fraction of the overall weight measured. To achieve the best accuracy possible, the measurement range is determined from the anticipated process fluid weight in a full vessel. While this range can be many thousands of pounds, electronic resolution at steady-state conditions is typically to tenths of a pound.

Load cell systems require that the mechanical system reach a stable condition in order for accurate measurements to be made. Circumstances that can negatively impact accuracy include fluid instability (splashing or agitation), poor mechanical isolation from other devices (pumps, blowers, conveyors), simultaneous flows into a batch vessel (leaky valves, bad sequencing), and physical changes (materials interfering with the scale movement, material build-up on the exterior).

Making a weight measurement is difficult when “noise” is present: agitation or splashing of liquids being added to a vessel. In some cases, vessel charging systems include dribble feed control algorithms to help stabilize conditions near the endpoint for the vessel addition. After reaching the desired endpoint (and the system comes to rest) the load cell allows noise-free precision in verifying the overall raw material quantity that was transferred.

Sometimes, procedures are developed to transfer raw material at a controlled flow rate. A weight signal must be differentiated with respect to time to produce a rate signal (weight per time). Differentiation amplifies any noise that is affecting the weight measurement. Newer load cell electronic packages provide enhanced filtering and noise rejection algorithms to help minimize these influences.

In many applications, weight (pounds force) and mass (pounds mass) are generally accepted as interchangeable measurements. This assumption can become an issue if the weigh scale values (weight or pounds force) are being compared to the mass measurement from Coriolis meters.

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In these cases, a correction factor (for fluid buoyancy) is necessary to accurately correlate load cell weight to true mass. The buoyancy correction helps the end user compensate for the difference in conditions that occur between load cell calibration and actual process fluid weighing.

The weighing system is calibrated with a set of reference weights that usually take up a much smaller volume than the process fluid being measured. The buoyancy correction compensates for the difference in volume of air that is displaced during calibration versus that displaced during a process fluid weighing operation.

The error between the weight and mass measurements is usually insignificant. In specific applications such as custody transfer and mass balance, however, the end user may achieve greater accuracy by incorporating the buoyancy correction.

Load cell technology: Benefits

Load cells have been used for many years in the process industries. Load cells are often chosen because the end user is familiar with the technology and understands how to maintain and troubleshoot the technology. Often times, the end user also has an inventory of weigh scale spare parts, easing concerns related to maintenance.

Load cells are especially well suited when the end user has a need to feed dry materials into a vessel. This technology is also used when multiple dry and liquid raw materials are being added to a vessel. Load cells can be well suited for situations where large quantities of material are added to a large vessel over a relatively short period of time.

Finally, load cells are used in situations where the end user must account for the exact amount of process fluid, down to the last drop, that is being transferred into a vessel. There are specific situations in regulated industries, such as pharmaceutical or biotech, where this is the case.

Calibration is well understood for load cells. A known weight is suspended from the vessel and compared against the load cell read-out. Calibrated weights, traceable to NIST via a Weights and Measures organization, are often selected as a reference standard. Care must be exercised in maintaining these reference weights to ensure their traceability is not compromised. If there is a discrepancy between the reference standard and the load cell output, the system must be inspected and adjusted to ensure agreement between the reference weight and load cell. Calibration can be time consuming, because multiple heavy reference weights must be hoisted into place and removed, sometimes multiple times.

Load cell technology: Special considerations

Load cells are usually mounted to the floor (or foundation) of a structure or to the super-structure of a building. To ensure optimal performance, end users must ensure that the load cell system is isolated from environmental influences. Typical environmental influences include the rigidity of the supporting structure; external vibration from other processing equipment or road traffic; internal vibration and sloshing from mixers; binding between the load system and the supporting structure and/or process piping; ambient temperature variations; and distribution of the load within the vessel (for dry materials).

Ensuring that the load cell is isolated from its environment is often accomplished by adding structural steel, which increases project costs. These installation costs can vary widely depending on the specific location of the load cell system as well as the desired performance of the weighing system.

To eliminate or reduce the impact of environmental influences on the load cell system, engineers must exercise care when designing and constructing an installation. Often times, a multi-disciplinary team, including structural, mechanical, and process engineers is needed to design a quality load cell installation. Coordinating the efforts of this team can add significant time and cost to the effort.

Load cells measure the weight change as raw materials are added to a vessel. To properly control a batch or recipe, these raw materials must be added sequentially to the vessel, resulting in longer ingredient addition time and potentially increasing stratification of the ingredients in the vessel.

To maintain good performance in a load cell weighing system, care must be taken to reduce the amount of frictional forces being introduced into the system. Sources of friction include binding between the load system and the supporting structure and/or process piping (discussed earlier), and accumulated liquid spillage and/or dry materials. Friction due to binding can be eliminated via flexible hose connections in the piping system. Routine system cleaning is also needed to eliminate friction in load cell systems.

The stiffness of process piping and the vessel shell will increase with increases in operating pressure. This changes the installation conditions under which the weighing system was calibrated. When significant, these changes can introduce a shift from calibration, which can correspond to measurement errors.

Coriolis mass flow metering technology: Introduction

Coriolis meters directly measure the mass flow rate of liquids, slurries, and gases. The mass flow rate is unaffected by changes in fluid composition or density, because it is a direct measurement. Coriolis meters also provide direct density and temperature measurements. These meters have no wearing parts that can cause drift in performance over time. Flow measurement accuracy as well as usable flow range make Coriolis meters the best performing and most accommodating flow measurement technology on the market today.

Coriolis mass flow metering technology: Benefits

Coriolis meters measure the mass flow rate. This rate can be totalized to determine the specific amount of process fluid being added to a vessel during a batch. There are several benefits that end users can realize with totalized mass flow rate. First, raw materials can be added simultaneously to the vessel, significantly reducing the time needed to perform numerous sequential additional steps. Coriolis meters are immune to the effects of agitation and splashing, so the batch can be continuously mixed, reducing total batch time. Further, the customer has flexibility regarding where this totalizing is performed. A Coriolis meter's transmitter has an internal totalizer that can then be used to trigger the closure of a valve. Moving the totalizer closer to the batch can improve speed of response for the overall system. The end user can also perform this function in their control system where batch or recipe management is often performed.

Engineering and installation costs are significantly reduced when a Coriolis metering system is used. Multi-disciplinary engineering teams are usually not required to design a Coriolis metering system. Standard good piping practices—providing adequate support for the piping and the meter and limiting induced stress or torque—will result in a stable, accurate system.

Coriolis meters also maintain their accuracy over a broad flow range. This provides versatility for using the technology when batching requirements include multiple recipes and multiple process fluids and quantities.

Because Coriolis meters have no wearing parts, maintenance and calibration costs can be dramatically lower when compared to load cell systems. Once properly installed and operational, Coriolis meters rarely fail. The transmitters on Coriolis meters also have internal diagnostics that help to monitor the performance of the meter. If there is no change in the flow tube's characteristics—from erosion, corrosion, or product build-up over time—there is no change in performance from the initial factory calibration.

It is recognized that routine calibration is mandated as part of validation protocols for regulated industries, including pharmaceutical and biotech facilities. However, the period between routine calibrations can be extended due to the reliability of Coriolis meters.

Coriolis master meters are used as calibration standards in process facilities for other flowmeters and for pumps and load cell systems. The meters can provide volumetric flow rate information and totalized mass and volumetric values. Usually, the master meters are returned to a certified factory calibration site, on an annual basis, for verification.

Advances in Coriolis meter designs have virtually eliminated the impact of environmental influences on the meters. Significant improvements have been made in designing meters that are immune to external vibration, piping stresses, and changes in ambient temperature.

Coriolis mass flow metering technology: Special considerations

Compared to load cell systems, Coriolis meters are a relatively new process automation technology. Some end users are not familiar with the specifics of the technology. Consequently, end users may not be as comfortable or confident with it. Verifying Coriolis meters in the field can be relatively straightforward. Some Coriolis meters are capable of performing in-situ meter verification by using programming imbedded in the transmitter to compare the stiffness of the meter's tubes to a factory baseline. Since tube stiffness is directly related to the meter's flow calibration factor, this verification technique confirms that the meter is accurately measuring flow. Deviations from the factory baseline indicate potential problems with meter accuracy and alarms/ notifications are delivered to alert users to this situation.

Coriolis meter performance can be impacted by two-phase flow (gas and liquid) in the process. This phenomenon is sometimes referred to as “slug flow.” The drive energy delivered to Coriolis meters is limited by intrinsic safety requirements. The gas/liquid fluid combination causes damping to the drive energy within the flow tubes. The meter compensates for this damping by requesting additional drive energy. At some point, the amount of entrained gas in a liquid (or liquid in the gas stream) will cause the meter to reach its intrinsic safety drive energy limit. When this drive energy maximum is reached, the meter will stop functioning. During “slug flow,” the meter's accuracy is impacted—higher levels of entrainment degrade meter performance. There is usually no long-term meter damage when this condition occurs. Once the two-phase flow condition is eliminated, the meter will again function properly.

Coriolis sensors are constructed of thin-walled metal tubing. Corrosion can occur when the sensor's tubing material is incompatible with the end user's process fluid. Because Coriolis sensors are vibrating elements, fatigue corrosion failure can occur very quickly in these circumstances. Fatigue corrosion most often takes place at a pit or other occlusion in the tubing material. Special consideration should be given to ensure that process fluids are compatible with the Coriolis flow tube's material of construction. General piping corrosion tolerances must not be used to select the materials of construction for a Coriolis sensor. Rather, end users should consult with the meter manufacturer to determine the recommended flow tube material for the end user's process situation. Extensive research and testing has been performed to determine the compatibility between meter tube material and numerous process fluids.

Coriolis flowmeters also provide a direct temperature measurement. One must keep in mind, however, that the precision of the RTD measuring temperature is ±0.5 °C. This temperature measurement is primarily used to compensate for the elasticity of the flow tube material. As process fluid temperature changes, the stiffness of the Coriolis flow tubing changes. The Coriolis meter electronics utilizes the temperature measurement to compensate for changing stiffness in the tubing material. This stiffness compensation is part of what allows Coriolis meters to provide their remarkable accuracy over a broad flow range.

When properly installed, Coriolis meters can provide extremely good accounting for the amount of process fluid being transferred into a vessel. However, the end user should ensure that on/off valves are placed near the meter and that the entire valve/meter assembly is positioned as close to the inlet of the vessel as possible. It should be noted that Coriolis meters have received agency approval and are used for the fiscal transfer of numerous process fluids throughout the world. In any case, the end user must evaluate the needs for precise accounting of material being transferred versus installation costs and regulatory requirements.

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