

Coriolis mass flow meter: High accuracy for high flowrates

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In dry bulk solids flow-control applications, both batch and continuous, many materials such as cement, gypsum, fly ash, corn starch, and others flow at very high rates. Several types of mass flow meters, each with its own advantages and disadvantages, are available to measure these high flowrates. A good choice for a high-flowrate application that demands high accuracy is the Coriolis mass flow meter. After reviewing some mass flow meter basics, this article explains how the Coriolis flow meter works and how it achieves high accuracy.

A mass flow meter measures the flowrate of materials by weight per unit time and is a common component in dry bulk solids applications. Common batch applications for the mass flow meter include truck and rail-car loading, where high flowrates are needed to quickly fill the carrier. A common continuous application is measuring the flow of gypsum to a gypsum-board production line. Of the many available mass flow meters, not every type can provide highly accurate flowrate measurements for a material flowing at a very high rate — that is, faster than 10,000 lb/h and up to as much as 200,000 lb/h. If your operation handles a material at a high flowrate, one solution to improving your flowrate measurement's accuracy is to use a Coriolis mass flow meter. This flow meter's operating principle eliminates some variables that reduce the accuracy of other flow meters in high-capacity applications.

About mass flow meters

Before discussing how the Coriolis flow meter works, let's review some general information about mass flow meters.

The basics. All mass flow meters share common design elements: Each receives the material flow to be measured from an upstream flow generator — typically a feeder — and allows the material to pass through the meter. The flow meter uses the material's flow energy through the meter to create a force, *transduces* (converts) this force into an electrical signal that's proportional to the flowrate, and displays the flowrate. The flow meter itself can't change the flowrate: The flow meter controller sends an electrical signal to the feeder controller, which compares the signal with the feedrate setpoint. If the signal indicates that the flowrate at the flow meter is higher or lower than the feedrate setpoint, the feeder controller changes the feeder's speed to maintain the desired feedrate.

The feeder's importance to flow meter accuracy. Maintaining an accurate feedrate in your operation requires the combination of a reliable flow meter and an accurate feeder. *Accurate*, in this case, means the feeder must be able to control the material flow to ± 1 percent of the preset feedrate by varying the feeder speed with good repeatability and linearity. *Repeatability*, usually expressed as a percentage error, is how well repeated feedrate measurements coincide over short time periods at a given setpoint. *Linearity* is the feeder's ability to deliver the desired material feedrate over the feeder's full operating range, so that the measured feedrate is as close to the setpoint at low feedrates as at high feedrates.

Consider the example of a screw feeder. When the feeder is accurately controlling the material flow, the feeder's screw flights are uniformly filled with material. But if the feeder isn't accurately controlling the flow, the screw flights aren't uniformly filled, and the flow meter's signal to the feeder controller to adjust the screw speed can result in an inaccurate feedrate. How? When a screw flight contains too little material, the flow meter senses the material flowrate is too low and sends a signal to the feeder to increase the screw speed. But if the next screw flight contains more material than the previous flight, the higher screw speed combined with this increased material quantity creates too high a flowrate. In response, the flow meter sends another signal to reduce the screw speed, creating a cycle that alternates between too high and too low a feedrate. To maintain the feedrate within ± 1 percent of the setpoint, the feeder must accurately control the material flow with good repeatability and linearity *and* be used with a reliable flow meter that sends accurate flowrate measurements to the feeder.

How the Coriolis mass flow meter works

Components and operation. A Coriolis mass flow meter, as shown in Figure 1a, has a cylindrical housing with an inlet at the top and an outlet below a conical collection chute. At the housing's top, an AC motor mounted on a turntable-like swivel plate powers a drive shaft extending into the housing. The drive shaft is sealed within a static pipe to protect it from dust. The swivel plate is mounted on flexures that move in one direction in response to force. A bar-like horizontal extension from the swivel plate, called a *force transmission lever*, is connected to a load cell mounted on the housing top to restrict the swivel plate movement, as shown in Figure 1b. At the drive shaft's bottom end is a vaned wheel, called the *measuring wheel*. Fitted inside the housing, above the measuring wheel, is a deflection cone that converges to form an inlet to the measuring wheel. The Coriolis flow meter is totally enclosed, while the motor and load cell are outside the material flow to protect them from the dust generated by the high flowrate. The meter's motor and load cell are linked to a remotely located controller (not shown in the figure), which is linked to the feeder controller. The Coriolis flow meter's configuration makes the unit typically 36 to 50 inches tall — much shorter than high-capacity loss-in-weight feeders, for example, which are often several feet high — and saves headroom in the installation.

The flow meter measures the material's mass flow by measuring the Coriolis force on the motor.

In operation, as the material flows through the inlet into the deflection cone, the drive motor rotates the drive shaft and, in turn, the measuring wheel. The cone funnels the

material into the measuring wheel's inlet, changing the material flow direction from vertical to horizontal, as shown in Figure 1a. The wheel's vanes capture the flow and accelerate the particles to the rotation velocity. Because the drive motor speed is constant, the flowrate of particles exiting the wheel is constant. The exiting particles impact the walls of the conical collection chute and flow downward through the outlet.

Calculating the flowrate. The flow meter measures the material's mass flow by measuring the *Coriolis force* on the motor. This force, which is created when the material mass is accelerated by the measuring wheel's vanes, is a counter-rotating force on the motor that's opposite to the force the motor applies to the rotating drive shaft. If the motor weren't securely mounted, the Coriolis force would tend to cause the motor to rotate in the opposite direction. But because the motor is firmly mounted on the swivel plate, the force created by the material's acceleration causes the motor to counter-rotate only slightly as the flexures bend slightly under the swivel plate. The load cell's connection to the swivel plate's force transmission lever prevents the motor's full counter-rotation, and the load cell measures the Coriolis force on the lever. This force is directly proportional to the mass flow of particles exiting the measuring wheel.

Finally, the flow meter's controller determines the material's mass flowrate by multiplying *velocity* by *mass*. The velocity is the motor's (and measuring wheel's) tangential velocity — the velocity of the particles moving in the circular path created as they exit the wheel — measured in feet per minute. The mass is the motor's counter-rotating force measurement, which is in proportion to the material mass, measured in pounds. The measuring wheel's diameter and rotation speed, as well as other application variables, are factored into this calculation.

How the Coriolis flow meter achieves high accuracy

Two factors — material flow velocity and mass flow measurement — combine to make the Coriolis flow meter highly accurate.

Material flow velocity. With other high-capacity mass flow meters, the material velocity at the meter's inlet is assumed to be constant. However, this velocity can vary due to any number of conditions. Inside these flow meters, the flow velocity is altered by other variables, including the force of gravity and the influence of the meter's measuring component (such as an impact plate, curved plate, slide plate, or combination of these components, depending on the flow meter type). But in the Coriolis flow meter, the material flow velocity is accelerated so that each particle exits the flow meter at the measuring wheel's tangential velocity. In other words, the flow velocity is generated by the flow meter itself, making the flow velocity constant. The measuring wheel's velocity is accurate to within close

tolerances because it's controlled by the motor speed and isn't influenced by gravity or a measuring component.

Mass flow measurement. The energy that the Coriolis flow meter's motor puts into the material flow to accelerate the flow produces a high Coriolis force. Depending on where the load cell contacts the force transmission lever, the load cell can receive from 20 to 250 pounds of Coriolis force. The signal transduced from a small force, such as that received in other flow meters, would have to be amplified for transmission to the controller and would multiply any errors in the signal. As a result of the Coriolis flow

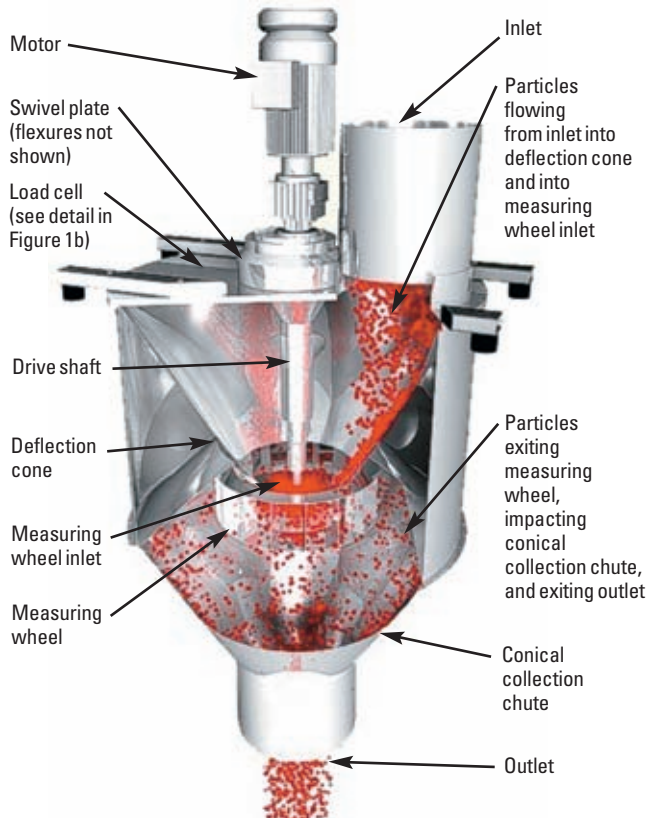
meter's high force, the meter generates a high signal. The high flow velocity generated by the wheel's rotation combined with the high Coriolis force measured by the load cell makes the force (or mass flow) measurement quite stable.

The measuring wheel's high rotation speed keeps the wheel virtually clean of material buildup.

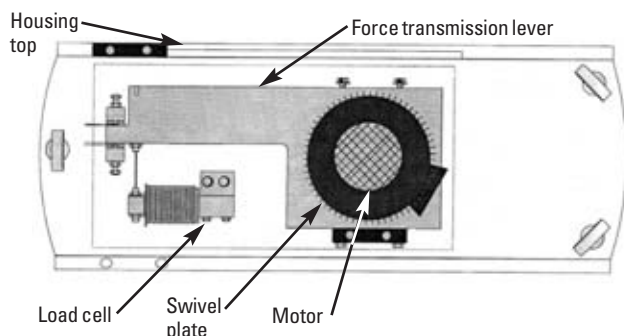
Figure 1

Typical Coriolis mass flow meter

a. Cutaway view



b. Plan view showing load cell and force transmission lever



Eliminating calibration and tare changes

With the Coriolis flow meter, collecting and weighing a timed flow sample is required only to refine the flow meter's calibration. This is because the Coriolis flow



The Coriolis mass flow meter requires little headroom, as shown in this installation below an inclined screw feeder.

meter's flowrate measurement is very close to its *theoretical flow calculation* — that is, the calculation of what measurement the meter will provide at a given flowrate — with a correction factor near unity.

Just as weigh scales must be tared, or zeroed out, when empty, any mass flow meter must be tared (that is, calibrated under no-flow conditions) to eliminate the small signal produced when no material is flowing through the meter. But many mass flow meters are susceptible to tare changes because material adheres to the measurement component, and the meters must be frequently cleaned to eliminate this problem. The Coriolis flow meter has a stable tare that isn't subject to these problems because the tare is calibrated when no material is flowing through the meter but while the measuring wheel is rotating. The empty rotating wheel produces a small counter-rotation force that is tared. The wheel's high rotation speed keeps the wheel virtually clean of material buildup, and small material amounts that may adhere to the wheel don't alter the tare value because the material buildup is *static* (that is, it stays on the wheel) and doesn't influence the *dynamic* force measurement (that is, the material flow measurement). However, the Coriolis flow meter isn't suited for use with highly adhesive materials, such as calcium carbonate, titanium dioxide, or baking mixes with high fat content, because they can build up on the wheel and eventually plug the meter.

A final word

A Coriolis mass flow meter has a capital cost about 50 percent greater than that of other mass flow meters for high-capacity flowrates. But the higher accuracy this flow meter provides can help the unit quickly pay for itself. The Coriolis flow meter also requires little headroom and, unlike other high-capacity mass flow meters, isn't affected by tare change problems. Consult a Coriolis mass flow meter supplier to determine if the device is a good fit for measuring high flowrates in your application. **PBE**

For further reading

Find more information on flow meters, weighing equipment, and feeders in articles listed under "Solids flow," "Weighing and batching," and "Feeders" in *Powder and Bulk Engineering's* comprehensive article index at www.powderbulk.com and in the December 2004 issue.

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