Fluidic Flowmeters

Oscillatory Flowmeters: An Effective Solution for Flow Measurement

Roger C. Hunt
Consulting Engineer
MycroSENSOR Technologies
Phoenix, AZ 85028

Flowmeters based on oscillation principles can provide a cost-effective solution for many flow measurement applications.

Flip open any industry product directory to the section on flowmeters, and you'll find yourself in a situation very similar to the one faced by customers in a Baskin-Robbins ice cream store. There are at least as many types of flowmeters as there are flavors of Baskin-Robbins ice cream — differential pressure (DP) flowmeters, magnetic flowmeters, Coriolis flowmeters, turbine meters, ultrasonic meters, and the list goes on.

Actually, you'll be able to narrow down the field fairly quickly, since most types of meters excel in some situations and are lacking in others. For example, a meter that's ideal for measuring flow velocity in a wastewater application might not be appropriate for a volumetric measurement in a chemical plant.

One flow technology, based on oscillation flow principles, has been largely overlooked in recent years, yet can be used in numerous applications. Meters based on these principles have been around since the early '70s and provide simple, effective flow measurement (Figure 1).

There are three primary types of oscillation flowmeters: vortice-shedding meters, fluidic flowmeters, and swirl meters (also known as vortex precession meters). While each operates differently, oscillatory flowmeters share a number of characteristics:

- They are relatively simple devices and generally have no moving parts;
- They are all fairly stable, minimizing the need for calibration;
- They all shape the fluids flowing through them to generate regular oscillations in fluid pressure that can be sensed and used to compute flow rate;
- All but one function only in turbulent flows.

Vortice-shedding Flowmeters

Vortice-shedding meters are available from a number of major vendors and are the most commonly used devices within the oscillation flowmeter family. They are based on a principal discovered by famed aeronautical engineer Tódor von Kármán. While a young boy, von Kármán fished in the mountain streams of the Transylvanian Alps. During one fishing trip, he noticed that, when the flow of the stream hit a rock, the water would separate from the rock's downstream sides, first on one side of the rock, and then on the other. As the water on each side curled back on itself, it would form vortices. He also noticed that the distance between shed vortices was constant and dependent only on the size of the object creating the vortices (i.e., the vortex shedder).

It was later determined that, as long as a stream has low viscosity (with Reynolds numbers between 20,000 and 7 million) the ratio between the shedder width and vortex interval is 0.17. Therefore, if you know the vortex shedder width, and can detect the vortices and determine their frequency, you can measure the velocity of flow. Thus, the stage was set for the introduction of the vortice-shedding meter.

In vortice-shedding meters, an obstruction, known as a bluff body, is placed inside the pipe. Typically, the width of the obstruction is one-quarter the diameter of the pipe. As liquids or gases with suitably low viscosity flow through the meter body, a vortex is shed on one side of the obstruction. In the formation of the vortex, fluid velocity increases while pressure drops. On the opposite side of the bluff, the effect is reversed (i.e., higher pressure, lower velocity), leading to the subsequent creation of a vortex on that side. The pattern repeats continuously.

Sensors used to measure the pressure changes are located on the face of the bluff, its sides, its rear, or downstream. Among the sensors typically used for this are thermistor elements, spherical magnetic shuttles, or pressure detectors of various types. Additionally, piezoelectric crystals can be used to detect the shedding forces on the bluff body.

Vortice-shedding meters provide not only a linear digital output, but also good accuracy over a wide flow range, good long-term stability and repeatability, and no moving components. In addition, installation cost is low compared with orifice plates or DP transmitters.

On the downside, bluff bodies are subject to long-term degradation, and can be a source of inaccurate measurement if they become coated or eroded. However, they're easy to replace in many units. Also, fluid viscosity must be low enough to insure the flow is turbulent.

Fluidic Flowmeters

While not as well known as vortex-shedding flowmeters, fluidic flowmeters offer many of the same advantages and, in the case of one style, are suited for the measurement of laminar (nonturbulent) flows. Moore Products (now part of Siemens Energy and Automation) invented fluidic flowmeters in the 1970s. The devices now are being developed and manufactured by MycroSENSOR Technologies.

Two styles of s of fluidic flowmeters are available. One uses a physical phenomenon known as the Coanda effect; the other is based on the fluid phenomenon of Momentum Exchange.

The Coanda effect is named after Rumanian aerodynamicist Henri-Marie Coanda, who discovered that, as a free jet emerges from a nozzle or conduit, it will tend to follow a nearby surface and will attach to it. (Unfortunately, his first exposure to this phenomenon occurred when jet engine exhaust gases attached themselves to the fuselage of his primitive aircraft.)

The geometric shape of the Coanda flowmeter creates a continuous, self-induced oscillation. Fluid passing through the meter body bends toward, and attaches itself to one of the meter's sidewalls. A portion of the flow is diverted through a feedback passage and travels back to the control port. This feedback stream breaks the main stream's attachment to the near sidewall and pushes it toward the opposite sidewall, to which the main stream then becomes attached. A portion of the flow is diverted to the far-side feedback passage and the entire process repeats (Figure 2). This oscillation is self-sustaining.

A sensor, which is located in one of the feedback passages, detects the presence and absence of flow. The frequency of these pulses is linear with volumetric flow rate. The sensors used to detect the flow pulses are either thermal or strain gauge devices.

Coanda-style fluidic flowmeters can be used in most liquid flow streams. Like the vortex-shedding flowmeter, they provide good accuracy over a wide flow range, offer excellent long-term stability and repeatability, and are less susceptible to calibration shifts due to erosion. The sensor can be replaced without any effect on the meter calibration. Like the vortex shedder, the wall attachment phenomenon requires that the flow be turbulent.

The Momentum Exchange (MX) flowmeter also is a feedback oscillator similar in design to the Coanda meter, but it differs in the mechanism used to create oscillations. The shape of the MX meter body creates a main flow that passes through the nozzle and is directed toward one side of the meter body or the other. The force of the jet creates a flow pulse in a feedback passage, which exerts a force on the main jet and deflects it in such a way that it exerts a force on the fluid in the opposite feedback passage (Figure 3). This pattern repeats continuously, creating a self-sustaining oscillation. Like the Coanda meter, a sensor in one of the feedback passages detects the fluid pulses.

While the Coanda meter requires turbulent flow to function, the MX meter does not, making it an ideal device for measuring higher-viscosity fluids. The MX meter was designed for, and has found widespread acceptance in, burner management applications involving the flow measurement and control of No. 2 and No. 6 fuel oil. It offers the same high stability, turndown, and low installed cost as its partners, with the additional ability to operate in both laminar and turbulent flow regimes. This ability to operate at low Reynolds numbers allows high turndown on moderate viscosity fluids such as ethylene glycol or carbolic acid.

Swirl Meters

Swirl meters were the predecessors to vortice-shedding meters. In this device, fluid entering the meter body passes through vanes or blades that put the fluid in a swirl condition. After the swirl blades, flow is contracted, then suddenly expanded. The geometry of the meter body moves the vortex off of the meter's centerline, creating a helical path (or precession) as the fluid flows through the body. A sensor placed downstream from the swirl blades measures the frequency of the precessions. As is the case in all of the meters discussed so far, there is a linear relationship between the oscillation frequency and the flow rate.

Swirl meters work best with relatively clean flow streams and are well suited for liquids, gases, and steam. They can be used in tight piping applications and are available in sizes as large as 16 inches. Compared to vortex meters, they have higher head loss and higher initial cost. Like vortex meters, they are susceptible measurement errors due to material build up on the swirl blades.

Which Flowmeter Is Best?

Vortice-shedding meter? Coanda meter? MX meter? Swirl meter? Which is the right choice? The answer (as always) is "It depends."

To varying degrees, all oscillating flowmeters offer the same advantages — relatively inexpensive to purchase, install, and maintain; no moving parts; and stability. Beyond that, however, there are differences that help limit the choice. For example, if your application has a laminar flow, the only appropriate member of the oscillating flowmeter family is the MX meter. The fluidic flowmeters have the least obstruction in the flow path.

Fluidic flowmeters are limited to pipes of a 4-inch diameter or less, since use of larger pipes would create an unacceptably low number of pulses per gallon, and a resulting loss of resolution as well as a large casting. Larger line sizes can be handled using bypass techniques, but that adds an additional element. Vortex-shedding meters, on the other hand, oscillate faster for a given flow rate, so they can more easily be adapted for larger pipe diameters. Generally, they are also more compact.

As mentioned previously, inaccuracies in vortice-shedding flowmeters can occur if the bluff body becomes worn or coated by fluids flowing through it. In addition, the signal from both types of fluidic flowmeters generally is stronger than that of vortice shedders, and is easier to sense and condition.

As for choice of models, there are numerous vortice-shedding flowmeters available from multiple manufacturers, while the selection of fluidic flowmeters and swirl meters is more limited.

About the Author

Roger C. Hunt is a consulting engineer with MycroSENSOR Technologies. From 1963 until 2000, he served in a variety of positions as a supervisor and product development engineer for Moore Products, (Spring House, PA). He holds a bachelor's in engineering from Lafayette College and a master's in engineering from Penn State University.

Figure 1: Flowmeters based on oscillation flow principles are relatively simple devices with generally no moving parts. Shown is MycroSENSOR Technologies' Fluidic Flowmeter Model 140 that is based on the momentum exchange (MX) principle.

Figure 2: Coanda Effect Flowmeter

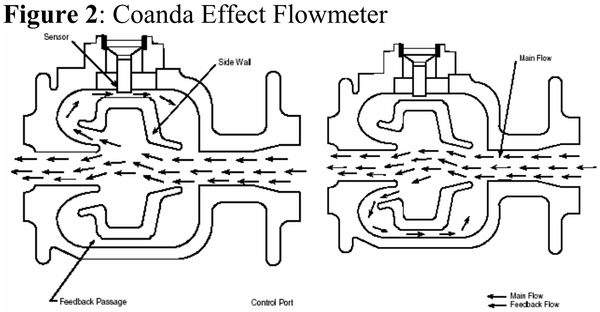

Figure 3: Momentum Exchange Flowmeter