Modern Electronics Meet Turbine Flowmeters

Measurements & Control, April 1995
Author: Ron Madison

High accuracy, exceptional turndown, repeatability and speed of response have made turbine flowmeters the meter of choice for obtaining precise flow measurements in liquids and gases. But unlike the outdated notion that many users have of a mechanical meter, modern turbine flowmeters are utilizing state-of-the-art electronics to enhance the advantages they have traditionally enjoyed in industrial, aerospace, automotive, and pharmaceutical markets. This article explores the recent advances made by turbine flowmeter manufacturers, and describes the reasons why turbine meters have remained among the most popular flowmeter designs.

The turbine flowmeter was originally developed in the early 1960s as a solution to critical flow measurement applications in the aerospace industry. Many of the first turbine flowmeters were used to measure fuel flow for rocket engines at the White Sands missile range. The turbine flowmeters also helped determine the performance characteristics of both jet and piston engines.

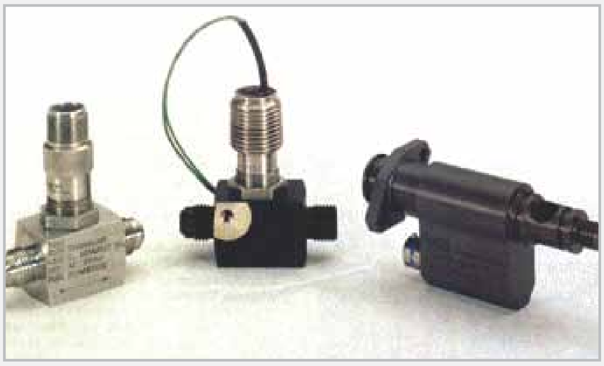

Figure 1. Turbine flowmeters can be manufactured to meet stringent size, weight and mounting requirements for aerospace applications

More recently, with their ability to withstand high g forces, turbine flowmeters have played a key role in the development of sophisticated fighter and surveillance airplanes, helicopters, cruise missiles and drones (Figure 1). Various military and government departments, as well as major aerospace manufacturers, utilize turbine flowmeters as an integral component in their equipment test stands.

Turbine flowmeters have gained acceptance among industrial users who require accurate, repeatable readings of flow conditions that affect their automated manufacturing processes. Likewise, turbine flowmeters are replacing DP orifice plates and other traditional industrial flow sensing devices in custody transfer applications involving both liquid and gas.

Volumetric Measuring Technique

A turbine flowmeter, due to the simplicity of its design, is a dependable volumetric transducer which provides a direct physical measurement of flow that can be converted into digital pulse outputs. With the addition of modern electronics, however, turbine flowmeters become sophisticated flow sensors with greatly enhanced accuracy and turndown capabilities. All turbine flowmeters, including those with axially-mounted rotors, tangentially mounted "paddle-wheel" rotors, and insertion-type probes, incorporate a freely suspended rotor that is rotated by the flow of fluid (liquid or gas) through the meter body. An external pickoff senses the passing of each rotor blade, generating a frequency output. The frequency is directly proportional to the velocity of the fluid, and because the flow passage is fixed, the turbine's rotational speed is a true representation of the volumetric rate of fluid flowing through the flowmeter (Figure 2).

Either a magnetic or modulated carrier (RF) pickoff can be used to sense the rotation of the turbine rotor and provide an electrical output that is proportional to the flow rate. The RF pickoff extends the low flow range of the meter by eliminating magnetic drag on the rotor. This is particularly useful on very low flow-range meters where magnetic drag has a significant influence on linearity.

In many applications, the meter's frequency output is processed by electronics, ranging from basic amplifiers, indicators and totalizers, to more complex flow computers which compensate for all measurable parameters and provide optimum volumetric or mass flow measurement accuracy.

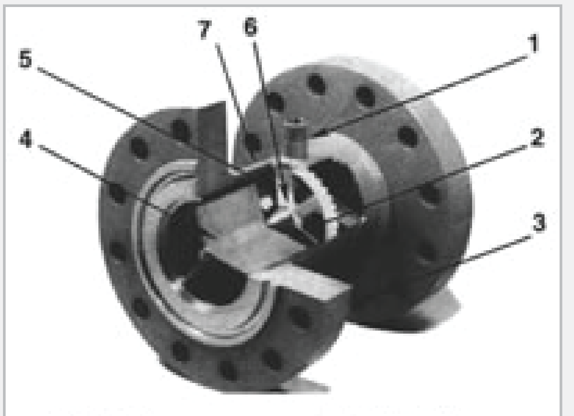

Figure 2. Cutaway view of a typical, axially-mounted turbine flowmeter

Reasons for Selecting A Turbine Meter

The turbine flowmeter has remained a popular flowmeter design because of its direct measurement technique, fast speed of response, lightweight package, compact size, rugged construction, inherently digital electronic output, cost advantages, and accuracy. These features have led to the use of turbine flowmeters in a cross section of industries. From measuring the flow of molten lead for car batteries, to metering a trickle flow of purge air from water-level sight glasses at nuclear power plants, to dispensing water to test animals in space, to metering flow in hydraulic lines at the bottom of the North Sea, turbine flowmeters offer exceptional versatility.

Turbine Meters for Direct Measurement

Unlike many other flowmeter designs, turbine meters have the advantage of being a direct measurement instrument. For example, a differential pressure transmitter with an orifice plate requires a pressure differential to be created by an obstruction in the pipe. The DP transmitter measures the differential pressure and determines the pressure drop across the orifice plate. The pressure drop is then converted to a 4-20 mA analog signal. The square root of the signal is proportional to the flow rate. The accuracy, therefore, is no better than the ability of an orifice to create a repeatable differential which is then measured and converted back to flow. In contrast, a turbine flowmeter is a volumetric measurement device which provides an output directly proportional to the flow rate, and hence is a direct measurement method of greater accuracy.

The accuracy of a turbine meter in a clean, known fluid cannot be achieved as easily with other flowmetering techniques. For this reason, it is the meter of choice for such critical applications as product custody transfer, aircraft fuel flow measurement, and diagnostic engine test stands.

Turbine Meters Fast Response Time

The rugged construction of the turbine flowmeter is another key feature – meters often remain in service for over 20 years with just a change of bearings and minor reconditioning.

A variety of construction materials can be used for the turbine's housing, rotor, bearings, and shaft. Stainless steel ensures utmost strength and corrosion resistance, but many other materials (e.g., Hastelloy C, aluminum, PVC, and Teflon) are frequently required. Some turbine flowmeter manufacturers now use ceramic journal bearings for added bearing life and resistance to galvanic reaction in deionized water and conductive chemicals. Tungsten carbide bearings may be selected for use in heat transfer fluids in R&D applications due to their hardness (wear resistance) and high temperature capability.

Figure 3. An injection-molded turbine flowmeter constructed of lightweight, corrosion-resistant materials

The turbine's compact size enables it to be installed in areas where larger, heavier turbine flowmeters would not be feasible. These applications include use on aircraft where cramped engine compartments limit the available space for external sensors, and in test stands that contain a wide array of electronic equipment, fluid pumps, valves, and piping.

Modern injection molding techniques have made it possible to produce less costly turbine flowmeters that are suited for high volume OEM applications (Figure 3). Other new materials and manufacturing techniques will continue to complement bearing designs to meet specific, demanding applications.

Turbine Meters and Modern Electronics

As inherently digital devices, turbine flowmeters can easily be paired with powerful microprocessors to offer a host of cost/performance advantages over other flowmeter designs. These electronic packages are similar to those used and accepted in magnetic, differential pressure and ultrasonic flowmeters. But unlike these meters, which are dependent upon electronics in order to function, the turbine meter is able to utilize electronics as an enhancement to its performance.

The use of a digital transducer such as a turbine flowmeter eliminates temperature sensitive analog circuits and produces a stable digital output. Moreover, there are subsequent cost advantages in reducing the amount of electronics to condition the output, not to mention MTBF (mean time between failure) and accuracy.

Recently, turbine flowmeter manufacturers have introduced "smart" turbine meters which incorporate an integrally-mounted electronic pickoff that performs all temperature compensation, linearization and signal conditioning internally, and thus can correct for temperature effects on fluid viscosity and density (Figure 4).

Whereas standard turbine flowmeters are viscosity sensitive, which can cause K-factor (the number of output pulses produced per volume throughput) shifts as temperature affects viscosity, smart turbine meters are able to compensate for viscosity effects. An integral temperature sensor inputs to the microprocessor, which calculates flow frequency divided by viscosity (f/μ) to establish the actual K-factor of a known fluid.

A unique feature of the smart turbine flowmeter is its ability, by linearizing within ±0.1%, to operate across the entire usable flow range. By extending the turndown range to 100:1, the smart turbine flowmeter also eliminates the need for multiple flow-metering devices. Repeatability of .05% with accuracies better than .25% can be achieved without the need for additional external temperature sensors, signal conditioners and linearizers.

Figure 4. New smart turbine flowmeters incorporate an integrally-mounted electronics package that performs all temperature compensation internally

Another advantage of the smart turbine flowmeter is that its scalable pulse outputs allow any number of meters to have the same output per unit of volume. This allows for complete interchangeability of units and prevents the common problem of scaling associated electronics incorrectly. The meter's pulse outputs can be amplified for maximum signal strength for transmission to distributed control systems, PLCs or a personal computer.

Furthermore, smart turbine flowmeters can be field programmed to change pulse output, unit of volume, flow range, and to provide a calibration history while maintaining the same pulses per unit of measured output.

Conclusion

Although they have been in service for more than 30 years, turbine flowmeters are far from being outdated. With their direct measurement technique and inherently digital operation, turbine meters can be paired with today's most advanced electronic circuitry to achieve a host of cost-effective benefits, including high accuracy, fast response, improved viscosity compensation, increased rangeability, and material flexibility. Most importantly, the turbine meter is based on a reliable, robust technology that has proven itself over many years in the most demanding environments.

FTI Flow Technology Inc.
8930 South Beck Ave
Suite #107
Tempe, AZ 85284

Telephone: +1 480 240 3400
Fax: +1 480 240 3401
E-mail: ftimarket@ftimeters.com •
www.ftimeters.com