Good Vibrations

Applications in Direct Mass Flow Measurement

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MICRO MOTION MASS FLOWMETERS OFFER SUPERIOR FUEL METERING IN STATE-OF-THE-ART AUTOMOTIVE ENGINE TESTING

Benefits Summary

- Density-independent mass flow measurement eliminates need for separate in-line densimeter and volumetric flow rate correction
- Highly accurate measurement at flow rates down to 0.5 kg/h, turndown in excess of 2000:1
- Less than 0.5 psi pressure drop in continuous flow measurement during transient testing
- Non-intrusive flow-through design resists damage by solids in the process stream
- Capital savings and reduction in annual maintenance costs

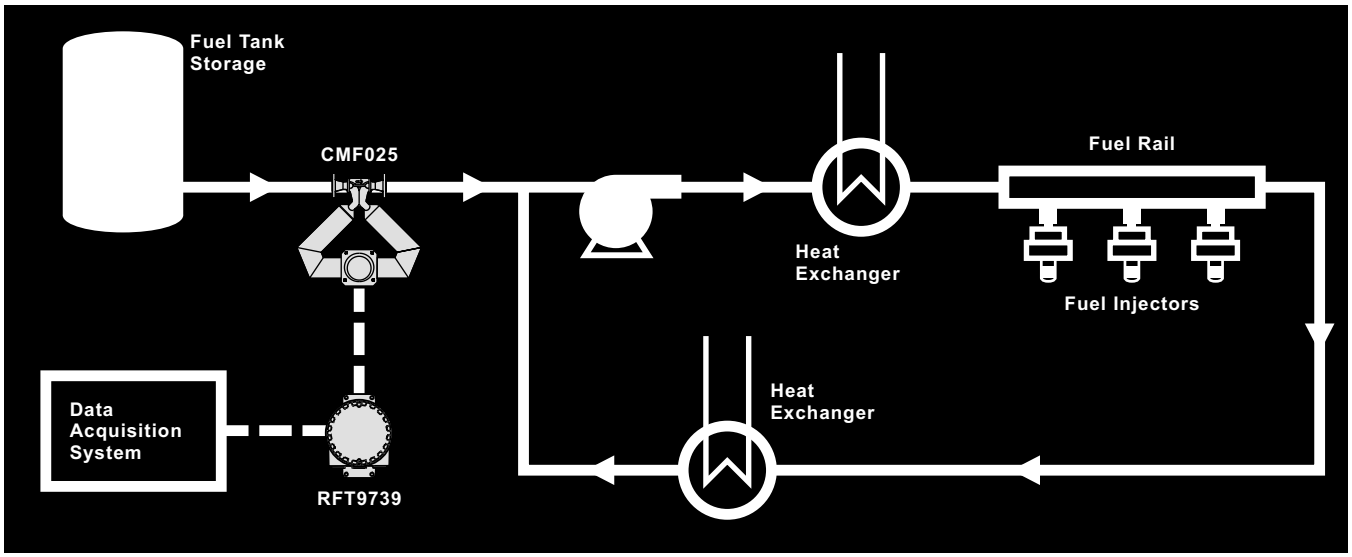

Figure 1: Engine Test Fuel Metering System

In the ongoing quest to design better, more efficient engines for motor vehicles, researchers are finding Micro Motion Coriolis mass flowmeters to be powerful tools. These meters, which feature high accuracy and exceptional reliability in a wide variety of applications, are changing the way design engineers measure fuel flow during engine testing.

Background

Engine testing requires an elaborate test stand. Engines are put through a complete range of potential operations, from idle to full throttle, under light and heavy loads. In order to evaluate engine efficiency, it is crucial to obtain a highly accurate measure of fuel consumption. This application is beyond the capabilities of most metering devices, since a suitable meter must maintain its accuracy over an extensive flow range as an engine is put through its paces.

Traditionally, researchers have used a number of different technologies to measure fuel flow. Most recently, precision gear meters have been preferred, because they are very accurate and have a wide operating range. However, they are problematic devices in several respects. First, since they measure flow volumetrically, temperature and pressure variations must be corrected for, or prevented. Second, gear meters must also be corrected or recalibrated if the fuel density varies, or if different types of fuel are tested (e.g., methanol, gasoline, and diesel). Because fuel density is usually not constant, in-line densimeters are often installed so that a constant density correction factor can be calculated. These in-line analyzers come with their own set of accuracy and reliability problems. Finally, because gear meters are positive displacement devices that contain finely machined moving parts, they are susceptible to damage by particulates in the fluid stream. Extensive upstream filtering is required to protect these meters.

Micro Motion mass flowmeters offer distinct advantages over precision gear meters in this application. Using Coriolis technology, Micro Motion meters measure mass flow directly. Therefore, the need for pressure and density correction is eliminated. Micro Motion meters also determine fluid density independently from the mass flow measurement. The density reading allows changes in fuel properties to be monitored and volumetric flow rates to be calculated easily. In addition, these meters accurately measure the flow of different fuels (even compressed gases) without recalibration. Finally, maintenance concerns are alleviated because Micro Motion sensors, unlike other types of devices, are resistant to damage by solids in the process stream. The flow-through design includes no internal moving parts.

The Application

To ensure its position as one of the world's leading automobile manufacturers, Ford Motor Company focuses a continuous effort on engine development. At its research facility in Michigan, several dozen test stands are maintained for use in engine testing. When Ford decided to expand its testing facilities, it chose AVL North America, Inc., to assist. AVL's parent company, located in Graz, Austria, has been an industry leader in design and construction of engine test stands for more than 40 years. It was AVL's expertise in systems integration and emission systems on which Ford sought to capitalize.

Ford's engine "test stands" are actually room-sized laboratories that feature extensive engine control, instrumentation, and data recording devices. Ford asked AVL to design a test facility expansion, integrating a number of next-generation improvements, including climatic and dynamic testing capabilities.

Various flow metering techniques were considered. Mass flow measurement was desirable, since it does not require correction for process conditions or fluid characteristics. Ford had experienced positive results with Micro Motion

mass flowmeters in another application, and was interested in using Micro Motion meters in the new test facility. As an alternative, AVL proposed using a gravimetric meter. This meter directly determines fuel consumption by measuring instantaneous weight changes in a fuel vessel. In conjunction with AVL, Micro Motion and Ford conducted a series of tests on the two mass flow metering methods and the volumetric precision gear meter.

Meter Testing

The Micro Motion ELITE® Model CMF025 sensor, which has a nominal operating range of 0 to 1090 kg/h (0 to 2400 lb/h), combined with an ELITE Model RFT9739 transmitter, was proposed as a good fit for Ford's application. To prove the sensor's suitability at high turndowns, it was tested for accuracy at the low end of a gasoline engine's operating range, at rates down to 0.5 kg/h (1.1 lb/h) —a turndown greater than 2000:l. Sensor performance was well above the calculated accuracy, based on zero stability, that Micro Motion generally uses to predict meter performance (see Figure 2). Typical error was less than 1% across the test range; less than 0.3% when flow was 2 kg/h (4.41 lb/h). The CMF025 sensor's high-turndown performance excited Ford engineers.

Thorough engine development requires a combination of steady-state (static) and dynamic testing. Static tests, conducted in an engine laboratory, are vital during the initial phases of engine development and calibration. In the final phase of development, however, engine performance must be tested and adjusted during acceleration and under changing loads. Traditionally, dynamic tests are carried out on roads and test tracks after fitting the engine into a prototype vehicle. This final phase of development and calibration is time consuming, expensive, and full of variables—weather, track conditions, and drivers all influence test results. In a desire to decrease the time between vehicle concept and final product, reduce seasonal dependency, and lessen variable influences, Ford wanted to move at least a portion of the track-testing capability to the controlled environment of its new dyno test facility.

Because of quickly and constantly changing fuel flow rates, dynamic testing requires a flowmeter with good transient functionality. Figure 3 shows the results of a dynamic test on the Micro Motion CMF025 sensor and the precision gear meter. During this test, a step change in fuel flow was made in 0.1 second. The fuel flow measured by the two devices is shown.

The Coriolis meter closely tracked the fuel increase. However, the gear meter attempted to maintain zero pressure drop and severely overshot. In Ford's normal operating range (engine fuel flow range), the Micro Motion meter presented less than 0.5 psi pressure drop across the flowmeter—in effect, a zero-loss system. To Ford, this was one of the CMF025 sensor's most attractive features.

The variation in measurement characteristics is indicative of the instruments' design differences. In the gear meter, rotation of the gears must be adjusted by an external motor in response to the changing fuel flow to bring pressure drop back to zero. While the gear meter's response is 0.2 to 0.3 seconds faster, inertial and control loop effects can result in overshoot and line-out problems. The Micro Motion sensor has a flow-through design that measures the rate of mass flow directly, based on tube vibration. Therefore, the Coriolis meter tracks variable flow very closely.

Based on Fords specifications and the positive results of the accuracy and dynamic tests, the Ford/AVL team chose Micro Motion Model CMF025 sensors for the test facility expansion. In addition to being highly accurate, the Coriolis sensors are also less expensive to own and operate than precision gear meters—in-line densimeters are not necessary, and maintenance is substantially reduced.

The lower cost also allowed Ford to install two flowmeters in series. In this application, a redundant meter ensures test data quality and minimizes system uncertainty. The two flowmeters serve as checks for one another, thereby increasing confidence in fuel flow data. The high cost of precision gear meters would have made this type of installation prohibitive.

Because of the positive performance Ford and AVL saw from Micro Motion flowmeters, AVL has expressed interest in using Coriolis flowmeters in future applications.

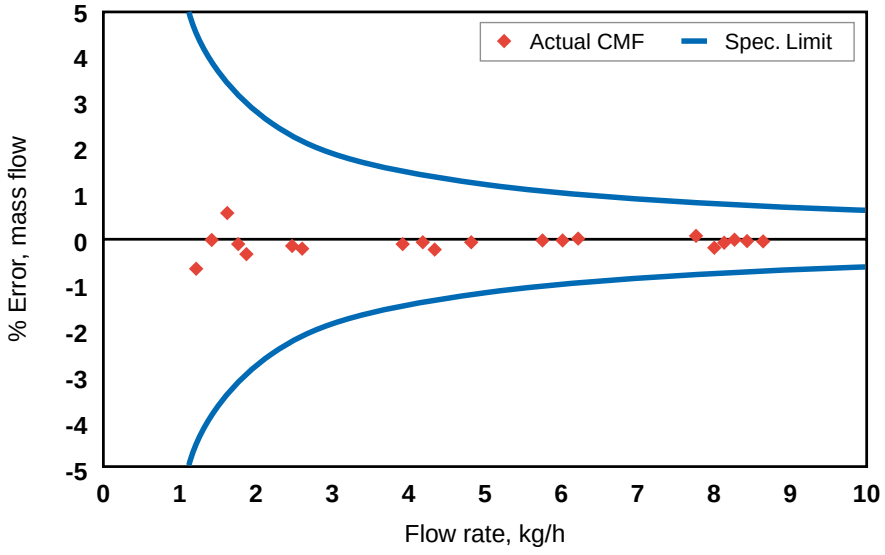

Figure 2: Typical CMF025 Error at High Turndown

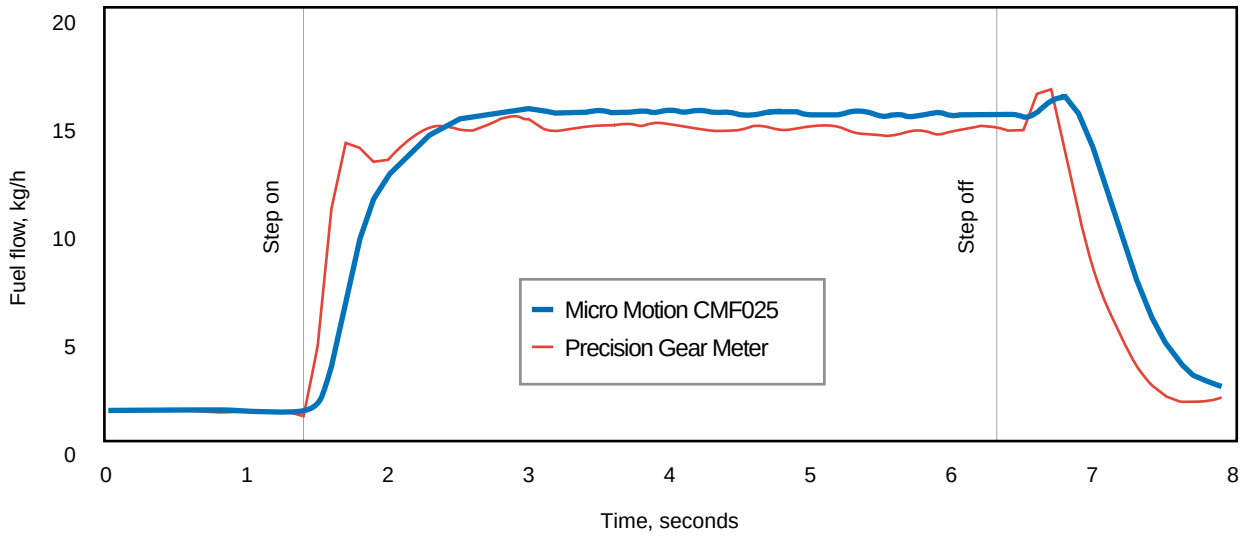

Figure 3: Dynamic Engine Test

Upcoming Developments

As part of Micro Motion's ongoing effort to improve its products as new applications and customer needs are determined, its engineers are working on ways to enhance the performance of Coriolis flowmeters at very high turndowns. For example, even at a turndown of 2000:1, error from the CMF025 was less than 1%. This offset is due to electronic noise from the transmitter. As part of Micro Motion's commitment to continuous improvement of its products, Micro Motion is currently developing methods to eliminate the effects of this noise on flow measurement.

"Micro Motion has really been impressive in wanting to fully understand the application and then making their meter work to meet our needs."

- Ford Engineering Technologist

Micro Motion is eager to work with your test group to develop an accurate and reliable fuel metering system. Whether it's engine testing or another precision application, let Micro Motion show you how Coriolis mass flowmeters can become an indispensable part of your research team.

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