Innovative flow measurement used in the field of process engineering

The ultrasonic flow meter DU manufactured by the G. KROMSCHRÖDER AG represents a good alternative to traditional industrial metrology tools. The dominating technical features have a positive effect on the metrological and economic results. The large measuring range of more than 1:100 ideally meets the requirements of an ever changing industrial environment without losing any of the high degree of accuracy required by today's applications. The integrated analogue and digital interfaces allow fast and easy adjustment to existing automation systems. Since the ultrasonic gas meters log even the smallest amounts of creeping or leaking gas, measurements are accurate and transparent – not to mention the improved operational safety and reliability. This also supports the reproducibility of the measurements. Since pressure losses are almost nonexistent, pressure increases or equalisations required when using the differential pressure method are no longer necessary, thus resulting in energy savings. Calibration, maintenance and work tasks are minimised due to the system's insensitivity to pulsating flows, moisture-saturated and slightly contaminated gases, as well as the lack of moving parts. This means the ultrasonic meter used as a flow meter is able to measure accurately and reliably under operating conditions. This system proves to be superior even when compared with measuring instruments subject to mandatory calibration due to its clear advantage of short response times during intermittent or alternating operation.

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Introduction

To be able to "peek" into a pipeline and to learn something about the flow characteristics without affecting the flow characteristic of the glass column – this is the desire of a great many process engineers. Now, this is possible with the contact less sensor system, the ultrasonic flow meter (DU) manufactured by the G. KROMSCHRÖDER AG (**Fig. 1**). This system is suitable for measuring natural gas, compressed air, nitrogen or oxygen (up to 10 bar) as well as argon gas.

Reaching goals successfully

Volume logging of gases in pipelines can be carried out with various methods, with more or less accurate results depending on the technical effort involved. In addition to the traditional turbine meter for gas, the anemometer, the orifice method, the mass flow meter for gases and the eddy current vortex measurement instrument are used as well. All methods share the fact that they quickly reach the limits of accuracy when used in practical applications. Error sources are, for example, contamination, moist gas or heavy fluctuations in the delivery or flow volumes. The inadequate measuring range dynamics of the measurement sensors then lead to inaccurate results – flawed or incorrect values may be transmitted especially in case of small flow volumes. Conventional metrology does not permit any clear findings about leakage rates, i.e. experience has shown that 'creep volumes' of 5% or more are common. Mass flow meters usually transmit incorrect gas volumes in the case of wet and/or contaminated gases. Longer sensor exposure times result in an unnoticeable drift and falsify the measured gas volumes. Orifice measuring instruments also have the disadvantage that the measurement is determined on the basis of the differential pressure – the energy required for building the pressure is at the expense of the consumer.

Fig. 1: The new DU series

G. Kromschröder AG has been distributing the ultrasonic meter for gas DU since 1998. This generation of instruments has proved its worth without exhibiting any of the described disadvantages and error sources. The company's mission is to design new flow processes to measure gases in pipelines that do not affect the pipe flow and that are as accurate as possible without moving mechanical parts. Measuring flows with ultrasonic technology is considered the way of the future in the field of process engineering.

Working principle

Ultrasound is defined as sound vibrations with frequencies undetectable by the human ear (beyond 20 kHz). The actual measuring principle of the ultrasonic flow meter for gas is based on measuring signal running times along a measuring path (measured displacement). Two ultrasonic converters (transmitter/receiver) A and B are usually attached to the measuring tube diagonally facing one another. Converters A and B are alternated as receiver and transmitter (**Fig. 2**).

This makes it possible to use one pair for reversing the signal direction (A->B or B->A). The time required by sound to travel the distance L between the two converters is called the sound running time. If it is measured in the direction of the gas flow (t_{AB}), this time will be shorter due to the carry effect. However,

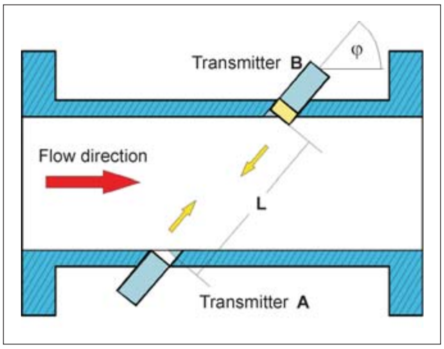

Fig. 2: Sound path

if measured in the opposite direction (t_{BA}), this time will be longer. The average speed v_m of the gas flow is calculated by subtracting the reciprocal values of the sound running time and considering the reception angle and length L.

The running time is thus a measure of the flow speed. The derived measuring principle is designated as “running time difference method” based on its functional connection. Multiplying the average speed with the pipe cross-section yields the operating flow rate Q_b of the installation. The operating volume V_b is the result of integrating the operating flow rate with the specified time. A special feature of this measuring method is that the speed of sound c is not used in calculating the flow rate and thus is not determined. Running time differences to be resolved within two nanoseconds occur with the typical nominal diameters, the usual flow speeds, required measuring accuracy and measuring ranges. One nanosecond corresponds to one billionth of a second. This is the time needed by light to travel a distance of approx. 30 cm.

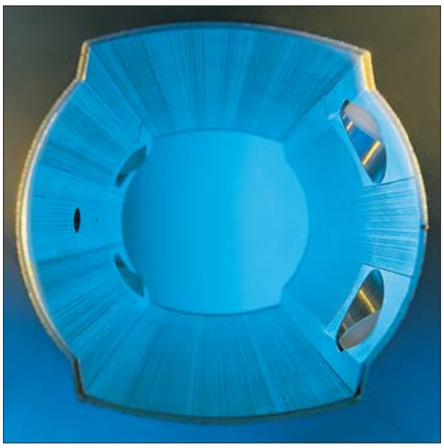

Fig. 3: Measuring area

The measuring area cross-section shows distinctly shaped reflection areas instead of the usual circular shape (**Fig. 3**). These areas are sections of ellipses containing the ultrasonic converters in their centres. They focus the transmitted ultrasonic cone on the converters, which has several advantages. For one, the transmitted energy is used more efficiently. This makes it possible to measure even highly evaporative gases such as natural gas at atmospheric pressure. Another advantage of the ultrasonic cone focussing is the almost complete capture of the cross-section area. This ensures a very low degree of sensitivity towards an asymmetric flow profile. The overall high level of insensitivity towards prior interferences has already been confirmed with different experimental setups and is expressed in the short required inlet section. The elliptical reflection areas also help to ensure that the measuring behaviour be independent of the type of gas. The angle of the “V” formed by the reflected ray is determined on the basis of the entire focussed ultrasonic cone in such a way that the measuring behaviour is independent of the Reynolds number.

Model Series

The DU Series is currently offered in four nominal sizes (DN 50, 80, 100 and 150). Using the ultrasonic measuring instrument, it is possible to cover a measuring range of 8 to 1600 m^3/h with a high degree of measuring accuracy (± 1–2 %) in spite of a short inlet section. The measuring instrument is able to log the operating volume V_b (m^3) as well as the operating flow rate Q_b (m^3/h); either one can be viewed with a toggle key below the display. The instrument also features two standard signal outputs. The 4…20 mA interface supplies a flow-proportional signal that is also suitable for control and regulating purposes due to its short response times, as well as a low-frequency impulse signal (1 pulse/m^3) that serves to display the accumulated total volumes. Since the ultrasonic gas meters log even the smallest amounts of creeping or leaking gas, measurements are transparent and provide operational safety and reliability. This also supports the reproducibility of the measurements. Since pressure losses are almost nonexistent, pressure increases or equalisations required when using the differential pressure method are no longer necessary, thus resulting in energy savings as well. Calibration, maintenance and work tasks are minimised due to the system’s insensitivity to pulsating flows, moisture-saturated and slightly contaminated gases as well as the lack of moving parts. This means the ultrasonic meter used as a flow meter is able to measure accurately and reliably under operating conditions. This system proves to be superior even when compared with measuring instruments subject to mandatory calibration due to its clear advantage of short response times during intermittent or alternating operation. The ultrasonic meter is thus a good alternative to traditional industrial metrology methods.

An RS232 interface together with a parameterisation, analysis and diagnostic software (WinPADS) are used to configure the instrument. The functionality of the data interface covers device configuration and calibration by the manufacturer, as well as the possibility for measurement data analyses and customising of the measuring dynamics to meet the demands of the respective customer application. The signal-to-noise ratio (SNR) is improved by routing test bench operating load values as digital signal information serially to the control system. The ultrasonic meter DU does not feature any moving or flow-disrupting parts within the measuring tube. This means the meter is overload-protected, low-wear and maintenance-free, and works without pressure loss. Its peripheral interfaces allow for an easy integration into an energy data management system and thereby reduce the setup costs during installation.

Installation advantage

The compact intermediate flange design allows the system to be installed into the pipeline easily, very quickly and cost-efficiently without taking up a lot of space. Compared with conventional measuring methods, extended inlet and outlet sections (DIN 1952), measurements exclusively in turbulent flow and high noise development are a thing of the past. The DU can be installed in any position. The system has to be installed vertically for gases loaded with condensation. Additional safety measures are not necessary.

Process heat and test bench technology: Practical experiences

Customers have been able to collect plenty of practical experience in the past six years since the market launch of the

DU Series. An aluminium producer in Switzerland uses regenerative burner systems of Messrs. Bloom to meltdown aluminium scrap in smelting furnaces. A decisive quality property of industrial furnaces is the economic energy management in addition to proper process management. At least one gas measurement point has to be in place in order to be able determine the exact gas consumption of the furnace (**Fig. 4**).

Existing orifice measurements in the inlet section of the furnace were replaced with ultrasonic gas meters (DN 100 nominal size) to meet the demand for an exact, long-term stable and cost-effective measurement. Temperatures of up to 70 °C are standard at the measurement points. This means the equipment used has to be reliable and effective under such extreme conditions. The operating conditions are also influenced by ambient factors such as dust, dirt and continuously changing ambient temperatures. The ultrasonic meters are installed in a gas inlet section in close proximity to the furnace and supply the regenerative burners with gas. Approx. 350 m^3/h of gas flow through the meter during the heating-up phase. After the heating-up phase, the electronic controls of the furnaces switch to pulsed burner operating mode. Solenoid valves subsequently activate or deactivate zone burners in a one-minute cycle. The interval duration and the gas flow rate depend, among other things, on the desired process temperature and the uniform temperature distribution within the furnace. Under the previously mentioned operating conditions, the associated flow rates are designated as alternating (changing). The higher the load jumps and the faster activation/deactivation are carried out, the more difficult it is to measure a correct consumption value. The gas consumption is also used by internal cost centres for accounting purposes. This means that the total gas consumption of all furnaces is calculated and compared with the total volume delivered by the supplier. Only small measuring deviations were detected compared with the ultrasonic gas meter when verifying the individual measurements with a calibrated rotary displacement gas meter installed for a trial.

Fig. 4: Gas measurement point

Modern engine test bench requirements

The quality and effectiveness of engine test benches depend on the utilised measuring technology. Relevant laws require certain basic accuracy levels of the used measuring technology as defined, among others, by the EC Directive 97/68/EC ("Measures against the Emission of Gaseous and Particulate Pollutants from Internal Combustion Engines to Be Installed in Non-Road Mobile Machinery"). Among other things, this directive specifies that the accuracy of the calibration of all measuring instruments has to be based on national (international) standards and that the permissible error limits for the measuring instruments for engine data have to be in the range of ± 2 % of the read value or, if greater, ± 1 % of the max. value of the engine [1]. Since legislators plan to limit emission values further in the forthcoming years, the demand for higher degrees of precision in metrology will be greater.

Engine test benches are to cover the entire engine range of a manufacturer, ensure maximum measuring accuracy and meet future demands of national and international laws in the long run. Today, automation of the standard measuring tasks is for the most part already an established practice in the production processes of system operators and thus offers test repeatability. Regarding inlet air control, the utilised measuring technology has to satisfy especially demanding requirements. A broad measuring range according to the output ranges of the engines and a high level of reproducibility of the measurement are absolutely mandatory. A few simple maintenance tasks and subsequent calibration is all that it takes to ensure the availability of each measuring system. Quick response time of the measuring signal for dynamic measuring cycles is a matter of course. This is exactly where the ultrasonic gas meter is superior to other measuring systems. The potential afforded by this measuring technology yields good reproducibility as well as accuracy in the range of measuring instruments subject to mandatory calibration. Government emission guidelines for pollutant emission of combustion engines force system operators to invest in higher-quality measuring systems. The use of ultrasonic metrology with first test benches has shown that this type of flow detection meets and even exceeds the most stringent requirements – today and in the future.

References

[1] EC Directive 97/68/EC: Measures against the Emission of Gaseous and Particulate Pollutants from Internal Combustion Engines to Be Installed in Non-Road Mobile Machinery, 1997.