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Increasing the accuracy of the ultrasonic gas flow information and measuring system by modifying GFA DN50 ultrasonic gas meters, developed using artificial intelligence tools

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Abstract

The paper presents the results of increasing the accuracy of ultrasonic information and measuring system for gas flow by using a special flow conditioner integrated with a two-channel chord ultrasonic meter. Reducing the asymmetry of the gas flow was achieved by optimizing the flow conditioner parameters using artificial intelligence methods.

The device for an ultrasonic gas meter of DN50 size was developed, which is a complex engineering task with a number of technical problems analysed in detail in the work.

A modified GFA DN50 meter with a special flow conditioner was modelled and manufactured, and experimental studies were conducted, accounting for the influence of local resistances.

It was revealed that the introduction of the flow conditioner provides a significant increase in the accuracy of measurements in inhomogeneous flows. The optimal characteristics of the ultrasonic system were determined by synthesizing the solutions using generative artificial intelligence based on LLM (Large Language Models).

The results obtained confirm the effectiveness of the calculations and demonstrate a significant improvement in metrological characteristics of the modified GFA202 DN50 meter.

The work proves that the use of artificial intelligence in the process of developing and improving gas flow information and measuring systems opens up new prospects for a qualitative transformation of the field of gas flow measurements using ultrasonic methods.

Keywords: metrological characteristics; artificial intelligence; ultrasonic gas meter; information and measuring system; gas flow rate; flow conditioner.

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1. Introduction

Ultrasonic gas flow information and measuring systems have been available for more than 40 years and are continuously being improved. Ultrasonic gas meters, which are the main component of such systems, have undergone significant development over several generations during this time and now differ both in metrological and design features and in features as for their compliance with modern standards [1].

Therefore, these systems are constantly being improved, and the main trend of development is to minimize the impact of real operating conditions (in particular, local resistances) on the measurement error. It is known that calibrating conditions for meters can differ significantly from their operating conditions, therefore, the current standards [2–4] provide an expanded list of tests to confirm the resistance of measurements to the influence of flow distortions.

2. Problem statement

Ultrasonic gas meters, like other industrial gas meters, shall meet certain general requirements, such as, for example, the presence of an output pulse signal for meter verification on available verification installations, as well as the requirements regarding the length of the meter body, which shall be 3DN. In the product line of GFA ultrasonic gas meters, until now, for DN50, the length of the meter body was 250 mm, which is equivalent to 5DN. In this regard, the task of developing a new modification of GFA meters arose, which would meet the requirements for the meter body length of 3DN.

It should be noted that the design of ultrasonic gas meters of DN50 size is a complex engineering task. Most leading manufacturers do not have multi-beam models of this diameter in their lines, producing mainly with DN80–100 at least. This is due to a few technical problems: a limited measurement base, which imposes strict requirements on the accuracy of recording time intervals, as well as a significant impact of flow disturbances on the error at high speeds. In addition, there is a problem of arranging a significant number of ultrasonic transducers (from 4 to 8 units for 2- and 4-channel systems, respectively) with a limited body length (150 mm).

3. Problem solution

A new modification of the GFA DN50 multi-beam ultrasonic gas meter was developed, in which the measuring system was successfully implemented within the standard body length of 150 mm. This allowed combining the compactness of the design with the high accuracy inherent in larger-sized meters (Fig. 1).

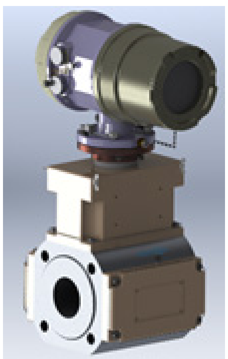

Fig. 1. GFA DN50 ultrasonic gas meter with a body length of 150 mm

To check the influence of local resistances on metrological characteristics of the new meter modification in accordance with the requirements of [2–4], a measuring scheme was implemented (Fig. 2). The experimental setup included the following types of resistances: one bend, two bends in mutually perpendicular planes, and two bends with a segmental diaphragm ("half pipe plate"). Local resistances were installed at a distance of 10DN to the Zanker flow conditioner, after which a calibrated straight section of 20DN (1000 mm) long was mounted directly in front of the meter.

The experimental studies conducted allowed us to determine the errors in flow measurement. The graph (Fig. 3) shows the dependence of the relative error on the flow.

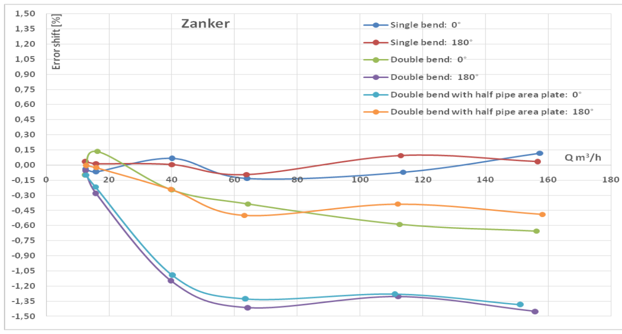

Fig. 3. Results of experimental studies

The results obtained show that the influence of "light" local resistances does not change the measurement accuracy within the permissible value – 1/3 of the basic error (0.33%). At the same time, the influence of two bends and a combination of two bends with a half pipe plate, even in the presence of a long straight section and a Zanker-type flow conditioner, at velocity above 5 m/s significantly increases the measurement errors.

This confirms the premise that the greatest contribution to the increase in the measurement flow errors at small diameters is made by flow disturbances. At the same time, the Zanker-type flow conditioner does not provide sufficient smoothing of the flow asymmetry, which is consistent with the provision of clause 5.2.1 of AGA 9 [2].

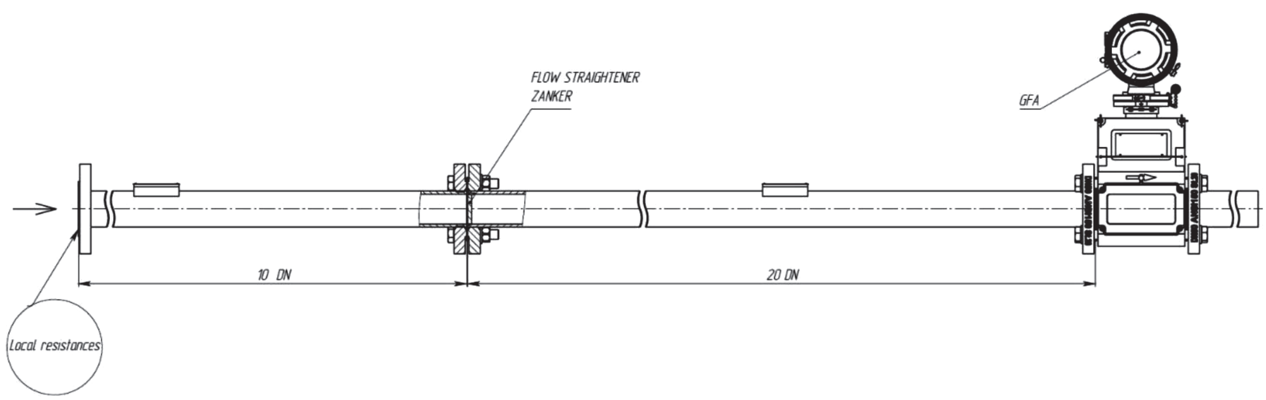

Fig. 2. Scheme of the experimental test setup

Considering the GFA meter as a complex information and measuring system, it was decided to install a honeycomb flow conditioner, similar to the one described in [5], directly at the meter inlet to reduce flow disturbances. The honeycomb flow conditioner has significant advantages over other types: low pressure losses with a high level of flow asymmetry reduction.

Given this, the task of finding the optimal design of a honeycomb flow conditioner was assigned to an artificial intelligence system.

The goal was to determine a structure that provides maximum suppression of flow asymmetry with minimal pressure losses.

According to ISO 3354 [6], the flow asymmetry for two-channel chord ultrasonic gas meters is defined as:

$$A_{USM} = \frac{V_1 - V_1}{(V_1 + V_1)/2},$$

where: V_1, V_1 are axial velocities measured by two ultrasonic paths.

The main task set for artificial intelligence was to determine the optimal geometric parameters of the honeycomb flow conditioner – in particular, the cell size and the thickness of the structure. According to the results presented in [7], it is the combination of these parameters that is crucial for effectively reducing the flow asymmetry. It should be noted that the minimum characteristic cell size cannot be less than 1–2 mm, since a decrease in this indicator leads to an increased risk of cell contamination.

Previously, using AI, the dependence of the flow asymmetry for a simple honeycomb flow conditioner with a diameter of 50 mm, a thickness of 5 mm, and a cell wall thickness of 0.8 mm on the characteristic cell size was obtained (Fig. 4).

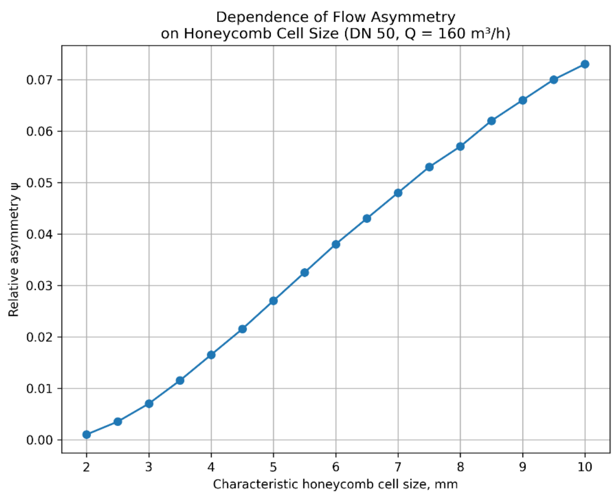

Fig. 4. Results of modelling the dependence of flow asymmetry

Due to the significant limitation of the meter body length of 150 mm, a maximum length of 20 mm was allocated to the flow conditioner. To achieve minimal flow asymmetry, a sequential installation of several honeycomb plates was used, which shall ensure a reduction in flow asymmetry to 0.001–0.002. The requirement for flow asymmetry of no more than 0.001–0.002 (0.1–0.2%) is an order of magnitude better than the asymmetry that occurs at a distance of 20DN from the Zanker flow conditioner and is 0.01–0.03 (1–3%).

An equally important parameter for calculating the flow conditioner is the pressure loss, which shall not exceed 2 kPa at a flow rate of 160 m³/h, a pressure of 1 bar, and an operating medium of air. Together with the Zanker flow conditioner type, the total pressure loss shall remain less than 5 kPa, otherwise it will be impossible to calibrate or verify this meter at any calibration facility in Ukraine.

The design calculated by artificial intelligence had an estimated flow asymmetry suppression of 0.1%, and the pressure loss shall not exceed 0.82 kPa at a flow rate of 160 m³/h.

Based on the calculations obtained, a meter model with an integrated flow conditioner was created, and the modelling in the SolidWorks environment to determine pressure losses under the specified conditions was performed.

According to the results of CFD modelling, the pressure loss was 1.2 kPa at a flow rate of 160 m³/h, a pressure of 1 bar, and an air operating medium, which differs from the calculations obtained by artificial intelligence.

The flow conditioner, which was calculated by artificial intelligence, was manufactured by 3D printing and installed at the inlet of the GFA202 DN50 meter (Fig. 5).

Fig. 5. GFA DN50 ultrasonic gas meter with a meter body length of 150 mm with an integrated flow conditioner

This made it possible to conduct repeated tests, the results of which are shown in Fig. 6.

The results obtained exceeded all expectations: the influence of both "light" and "heavy" local resistances did not exceed ±0.15%. This meets the requirements for ultrasonic meters of accuracy class 0.5, although GFA DN50 meters belong to accuracy class 1. This means that the calculated AI design is really effective and significantly suppresses the flow asymmetry. At the same time, the experimental value of the pressure loss at a flow rate of 160 m³/h was 0.945 kPa, which is in

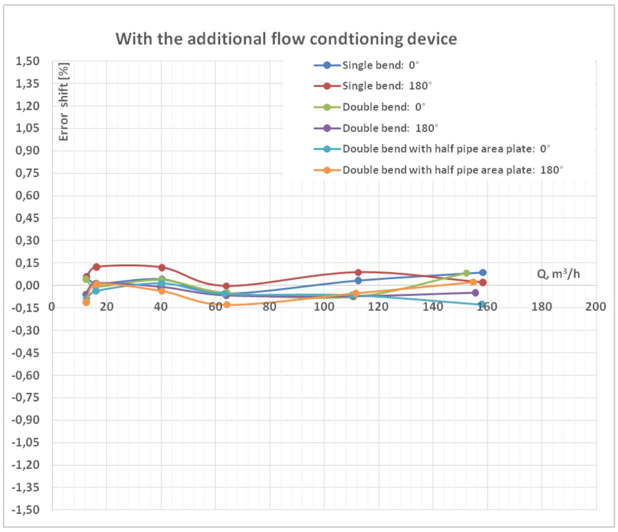

Fig. 6. Test results with an integrated flow conditioner

the middle between the pressure loss value obtained by AI calculations (0.82 kPa) and CFD simulation calculations (1.2 kPa). Thus, the use of AI and CFD simulation makes it possible to determine the limits of such an important parameter for the meter as pressure loss even before the start of the tests.

4. Conclusions

Reducing the influence of local resistances on the error of gas flow information and measuring systems and reducing the length of straight sections for ultrasonic meters is a practically achievable task thanks to the use of artificial intelligence. The flow conditioner built into the meter, calculated using AI, provided a significant reduction in measurement errors with insignificant additional pressure losses.

The use of artificial intelligence opens up prospects for creating a new generation of ultrasonic meters that do not require long straight sections. This will provide effective transition to the mass replacement of mechanical gas meters (rotary and turbine ones) with modern ultrasonic gas flow information and measuring systems.

Підвищення точності ультразвукової інформаційно-вимірювальної системи витрати газу шляхом модифікації ультразвукових лічильників газу GFA Ду50 з використанням засобів штучного інтелекту

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Анотація

Наведено результати підвищення точності ультразвукової інформаційно-вимірювальної системи витрати газу шляхом застосування спеціального випрямляча, інтегрованого з двоканальним хордовим ультразвуковим лічильником. Зниження асиметрії газового потоку досягнуто завдяки оптимізації параметрів випрямляча із використанням методів штучного інтелекту.

Поставлено завдання зменшити довжину корпусу лічильника Ду50 з 5Ду (250 мм) до 3Ду (150 мм). Розробка такого ультразвукового лічильника газу типорозміру Ду50 є складним інженерним завданням із низкою технічних проблем, детально проаналізованих у роботі.

Було розроблено такий лічильник без наявності вбудованого випрямляча потоку, але проведені тести на вплив місцевих опорів на похибку вимірювання лічильника дали незадовільні результати. Завдяки чому було промодельовано та виготовлено модифікований лічильник GFA Ду50 зі спеціальним вбудованим випрямлячем потоку й проведено експериментальні дослідження з урахуванням впливу місцевих опорів.

Встановлено, що впровадження вбудованого випрямляча забезпечує суттєве підвищення точності вимірювань у неоднорідних потоках. Оптимальні характеристики ультразвукової системи визначено шляхом синтезу рішень із використанням генеративного штучного інтелекту на базі LLM (Large Language Models).

Отримані результати підтверджують ефективність проведених розрахунків та демонструють значне покращення метрологічних характеристик модифікованого лічильника GFA202 Ду50.

Робота доводить, що застосування штучного інтелекту в процесі розроблення та вдосконалення інформаційно-вимірювальних систем витрати газу відкриває нові перспективи для якісної трансформації галузі вимірювання витрати газу ультразвуковими методами.

Ключові слова: метрологічні характеристики; штучний інтелект; ультразвуковий лічильник газу; інформаційно-вимірювальна система; витрата газу; вбудований випрямляч потоку.

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