Hydrodynamic Flow Measurement Error of Ultrasonic Flowmeters

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Annotation – In this work the essence of hydrodynamic flow measurement error of ultrasonic flowmeter (USM). The methods of eliminating this error are analyzed. One of these methods is considered in detail – optimization of the location schemes of chordal acoustic paths (APs) of USM. The optimization is performed on the basis of the analytical-empirical power law of the distribution of the velocity of the undistorted flow. As a result of the work, the authors calculated the optimal location of the APs chordal USM allows to reduce the hydrodynamic flow measurement error to a value of 0.05 % (for USM with two chordal APs) and 0.1 % (for USM with three chordal APs). The developed approach is convenient when designing multipath USM and their research in laboratory conditions.

Keywords – ultrasonic flowmeter; hydrodynamic flow measurement error; power law; acoustic paths; location scheme.

I. Problem and purpose of research

The emergence of the hydrodynamic flow measurement error of the USM (δGD) is due to the fact that the flow velocity, calculated by the value of the passage of sound δ error of the USM (Research in laboratory conditions approach is convenient when designing multipath USM and their measurement error to a value of 0.05 % (for USM with two chordal APs) and 0.1 % (for USM with three chordal APs). The developed approach is convenient when designing multipath USM and their research in laboratory conditions.

The volume flow rate of USM in conditions of undistorted and distorted flows.

q = 2π \int_0^1 (ru)dr.,

\[ q = 2\pi \int_0^1 (ru)dr. \tag{3} \]

Applying the distribution law (1) and the geometric characteristics of location schemes of the APs (see Fig. 2), we obtain the equation of the volume flow rate of multipath chordal USM [4]:

\[ d_{USM} = \pi R^2 \sum_{i=1}^{N} u_L(i) \]

\[ = \left[ \sqrt{R^2-x(i)^2} \right] \left[ \int_0^1 u \left( \alpha + \arctg \frac{L_{x(i)}}{x(i)} \right) dL + \int_0^1 u \left( \alpha - \arctg \frac{L_{x(i)}}{x(i)} \right) dL \right] \]

\[ = \pi R^2 \sum_{i=1}^{N} T(i) \]

where: \( \alpha \) - the angle of rotation and the width of the plane in which the i-th chordal AP USM passes relative to the horizontal plane; \( L \) - length of i-th AP; \( x(i) = 0...1 \) - coordinate of the location of the plane in which the i-th chordal AP USM passes; \( N \) - number of chordal AP USM. In this work, the case of standard horizontal installation of an USM is used, therefore the angle \( \alpha = 0^\circ \).
The calculation of the error $\delta_{GD}$ occurs according to the formula [1]:

$$
\delta_{GD} = \frac{q_{USM} - q}{q} \times 100.
$$

(5)

### III. Research results

The optimization of the location schemes of chordal APs using the power law of distribution is to determine the coordinate $x(i)$ of the AP location in which the error $\delta_{GD}$ will be equal to or close to zero.

Analyzing the results of work, which are partly presented in Fig.2, it can be argued that:

1. Using of the analytical-empirical power law of the distribution of the velocity of undistorted flow is a convenient way to conduct research on the location scheme of APs chordal USM.

2. Using of optimized location scheme of APs chordal USM allows to reduce the hydrodynamic flow measurement error of the cost:
   - to the value $\delta_{GD} < 0.05\%$ for two-path chordal USM at $x_{1,2} = \pm 0.53R$;
   - to the value $\delta_{GD} < 0.1\%$ for three-path chordal USM at $x_{1,3} = \pm (0.64... 0.65)R, x_{2} = 0$.

3. The obtained results can be applied during the design of multipath USMs and their research in laboratory conditions.

**References**


