V. I. Roman, Cand. Sc. (Eng.); F. D. Matiko, Dr. Sc. (Eng.), Professor; V. O. Iliuchok

COMPUTER PROGRAM FOR AUTOMATIC DESIGN OF THE DIAMETRICAL ULTRASONIC FLOWMETERS

Paper highlights another stage of global scientific-practical objective of the authors – development of computer system of automatic design of ultrasonic flowmeters of all available types. For the base of the current stage authors used previously developed computer program for automatic design of multi-channel chord ultrasonic flowmeters Auto Design USM, to which two new functional possibilities are added –calculation of hydrodynamic error of the diametrical single channel single beam ultrasonic flowmeters and calculation of the correction factor on the profile of the flow, which must eliminate this error of flow measuring. To reveal the essence of the added functional possibilities the authors in the given paper theoretically substantiate the emerging of the hydrodynamic error in the diametrical single channel single beam ultrasonic flowmeters (it may achieve more than 30 % for laminar and 8 % for turbulent modes of measured flow motion) and available methods of obtaining the correction factor on the profile of the flow (known empirically obtained analytical dependences or using certain theoretical profile of the flow rate and its numerical integration). As a result of the research carried out the authors of the paper improved the computer program Auto Design USM, this enables the user to apply it in console form for automatic design of the diametrical single channel single beam ultrasonic flowmeters. At the input such program requests the user the value of Reynolds number (indicates the rate of the flow), at the output it allows to obtain the value of Nikuradze number, correction factor on the profile of the flow by four empirical analytical dependences and value of the hydrodynamic error of the diametral ultrasonic flowmeter. The paper formulates the conclusions where further stages of the work on the given subject for achieving the global scientific-practical objective, aimed at the development of the system of automatic design of ultrasonic flowmeters are outlined.

Key words: *diametrical ultrasonic flowmeters, system of automatic design, computer program, hydrodynamic error, correction factor, profile of the flow rate.*

Problem set up

Ultrasonic flowmeters (UFM), in particular those, used for expensive gaseous energy carriers flow measurement, find wide application in various branches of industry, such as, oil and gas industry, chemical industry, power engineering, utility services. For instance, at the beginning of 2022 Ukrainian company" Ukrgasextraction" ordered high accurate UFM for metering units at the sum of approximately 130 mil UAH [1]. Thanks to high accuracy and reliability of measurements ultrasonic flowmeters became very popular all over the world, this is proved by the experts [2]: volume of the global market of UFM in 2021was 690 mil USD and according to forecast, will reach 1 080 mil USD by 2030. However, to provide such economic rate and such metrological characteristics, it is necessary to pay attention to the process of designing new and optimization of the available constructions of UFM, as well as scientific research in the field of ultrasonic flow metering to study problems which have not been solved yet.

Modern level of computer technologies development makes the designers and scientists to be dependent on the software, in particular, in the field of ultrasonic flow metering: for modeling and simulation of fluxes impact to the indices of UFM; analysis of mechanical and acoustic characteristics; optimization of the construction; thermal analysis, etc. The described tools are often realized as separate computer programs (Ansys Fluent, Flow Simulation Solid Works), or have limitations for certain types of UFM. Thus, there appears the need to create single computer system of automatic design, which would reduce the time for the development of new constructions of UFM or optimization (scientific study) of the available. Such system must be flexible and enable the user to work with various types of UFM at different variants of interface realization and be able to develop constantly, adding new functional possibilities (for instance, application of the artificial neural networks for the design of UFM construction on the base of CFD-modeling).

Analysis of the recent research and publications

Idea of developing the computer system of automatic design for UFM is based on the study of the authors Per Lunde, Kjell-Eivind Froysa and Magne Vestrheim [3], where they highlighted the operation of the console program GARUSO (version 1.0). This program was indented for the calculation of the relative expanded uncertainty for four-paths ultrasonic gas flow metering. Further Per Lunde and Kjell-Eivind Froysa within the frame of the work for Norwegian Society of Oil and Gas Measurement, NFOGM created a handbook [4] for calculation of uncertainty of UFM, operating at gas distribution stations of commercial metering (title of the handbook is «Handbook of uncertainty calculations. Ultrasonic fiscal gas metering stations»). On the base of this handbook the authors developed corresponding computer program, which can be downloaded for free as excel-file (the latest version of 2003) from the site of the company, on the link www.nfogm.no.

In the paper [5] we analyzed the state of the software in the field of ultrasonic metering and theoretically substantiated the need in the development of the domestic computer program-calculator for the calculation of structural characteristics of multichannel chordate UFM on the base of classical numerical integration methods (NIM). Further this program underwent two stages of improvement:

– two non-classical NIM are added, they are used for calculation of the structural characteristics 2, 3 4-channel chordate UFM [6];

– received the name Auto Design USM, calculation of the structural characteristics of 5- and 6-кchannel chordate UFM is added and users interface is developed [7].

Problem set up

Papers [5 – 7] present the stages of the development of the domestic console computer program Auto Design USM, which enables the user to obtain the values of the location coordinates and weight coefficients of the acoustic channel (AC) of multichannel chord UFM. Such an approach allowed to automate the process of chordate UFM design reduce the users error to minimum. The objective of the given paper is to continue the improvement of this program, adding to it new functional possibilities, namely, those, regarding the design of diametrical type of UFM:

– calculation of hydrodynamic error (HDE) of diametrical UFM;

– calculation of the correction factor on the profile of the flux rate of diametrical UFM, which is used for the elimination of HDE.

Presentation of basic material

As the research is devoted to the study of diametrical UFM, it would be appropriate to recall briefly the essence of the operation of this type of flow meters. Diametrical UFM, presented for the first time in Japan in 1963, use acoustic vibrations of 16 – 20 kHz (ultrasound) for the determination of the flow rate [8]. Interacting with the flow directly (immersed in the flow, «wet») or indirectly (via the pipeline, «dry»), two electroacoustic converters (EAC) of UFM emit / receive in pairs ultrasonic oscillations (USO). Recording the time of USO passage along certain stable distance L (between the pair of EAC, sometimes it is called AC), the flow rate, which directly influences the speed of USO motion in the flow is determined : at the motion of USO behind the flow (red arrow in Fig. 1), flow rate is added to the speed of USO and vice versa, if USO move against the flow (yellow arrow in Fig. 1), the flow rate is subtracted from the speed of USO. Knowing the time of USO motion behind the flow and against the flow due to their difference the flow rate (U_L) is determined by the formula (1) [8 – 12]:

$$U_L = \frac{L}{2\cos(\varphi)}\left(\frac{1}{t_{ЗА}} - \frac{1}{t_{ПР}}\right), \tag{1}$$

where t_{BF} – is the time of USO following the flow; t_{AF} – time of USO passage against the flow. As USO pass across the center of BT or diameter (Fig. 1), then such UFM are often called diametrical.

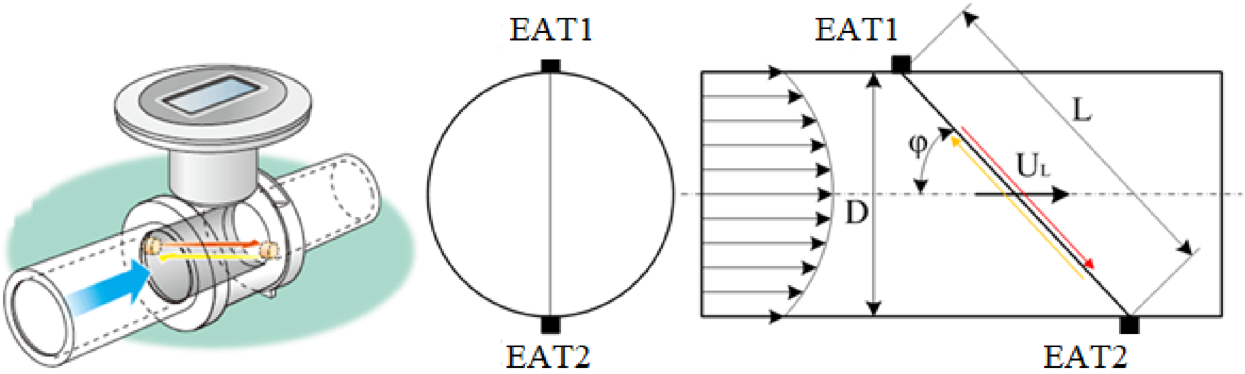


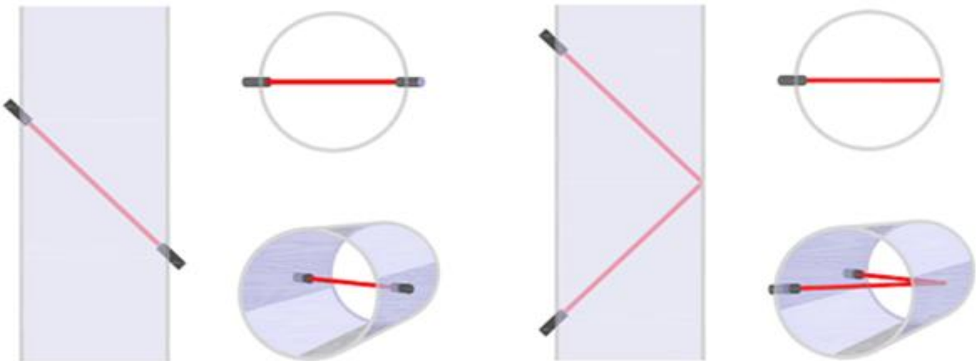
Fig. 1. Principle of flow rate measurement, using USO:
D – diameter of the pipe line; φ – inclination angle of AK relatively the axis of the pipeline

The described principle of flow rate measurement, using USO in scientific and specialized literature is called «transit time» in English-speaking sources [8 – 12]. UFM on the base of this principle is most widely spread on the market. In addition, depending on what path USO moves between the pair of EAC, time-pulse type of UFM may have two ways of realization of a single AC [8 – 12]:

– single beam or Z-like (Fig. 2a);

– multibeam with reflection mode or V- /W-like (Fig. 2b).

For instance, in two-beam single AC (Fig. 2b), USO first move on one straight path (first beam), then reflecting from the inner wall of the pipeline or other device-mirror (reflector), move on the second straight path (second beam).



a) single beam b) two-beam

Fig. 2. Types of diametrical UFM according to the method of AC formation [10]

A number of the external and internal factors influence the metering of the diametrical UFM [8 – 12]. Internal factors depend on UFM itself as a product, manufactured by the manufacturing plant. External factors exist outside UFM, and do not depend on its type: profile of the flow rate (structure of the flow), roughness of the inner wall of the pipeline, parasite noise, generated outside the pipeline or on it temperature and pressure of the measured environment, type of the environment and flow motion mode (Reynolds number, Re) and others [8 – 12].

Taking into account the objective of the given paper it is worth considering in details the last factor – Reynolds number. If $Re < 2000$ the flow is laminar (viscous forces dominates), and if Re is from 2000 to 4000 – transient whereas if $Re > 4000$ – it is turbulent flow (inertia forces dominate). Why is it important for diametrical USO? USO in the conditions of the laminar flow by means of one diametrical AC averages the values on the peak of parabolic profile of the flow. However, for turbulent flow diametrical AC averages far more flatter («square») profile (Fig. 3a). Thus, the results of flow rate measurement will differ. This means, that, for instance, at petrochemical/chemical plant several fluids pass the same pipe, each of these fluids has different viscosity – if the viscosities differ greatly, there may emerge laminar and turbulent flows. That is why, it is natural, that in the process of using single-channel diametrical USO “profile change error”(in English-speaking sources) will emerge [8 – 12]). To eliminate this error of measurement two methods can be used [10]:

1) increase the number of AC (Fig. 3, b, c) located one relatively the other at certain distance (chord scheme) or under other angle (if these are diametrical AC), to monitor more accurately (completely) the total profile of the flow rate;

2) introduction in the formula of volumetric or mass flow of diametrical USO correction factor on the flow profile («meter factor» in English sources [8 – 12]), which is intended for the correction of the measured rate according to the formula:

$$k_v = \frac{U_S}{U_L}, \tag{2}$$

where U_S – is flow rate averaged on the total cross-section. After that the formula for calculation of the volumetric flow of the diametrical USO (q_v) will have the following form:

$$q_v = Ak_v U_L, \tag{3}$$

where A – is cross-sectional area of the pipeline ($A = \pi R^2$, where $R = D/2$ – is a radius of the pipeline).

If diametrical USO has several AC, the formula 3 will have the following form:

$$q_v = Ak_v \frac{\sum_{i=1}^{N} U_L(i)}{N}, \tag{4}$$

where N – is a number of diametrical ACUSO.

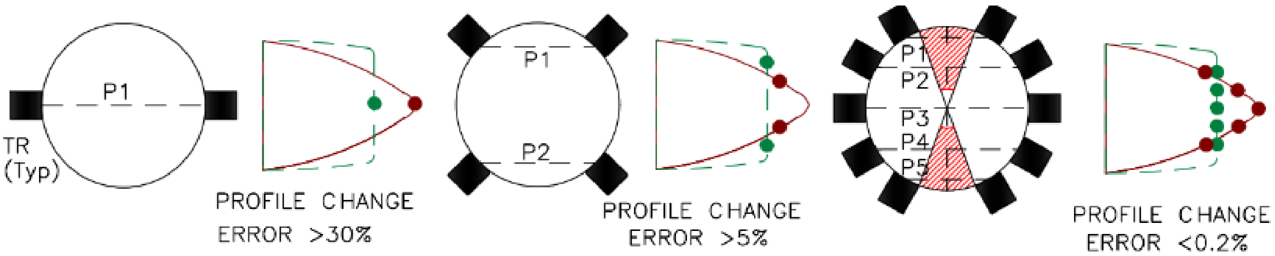


Fig. 3. Profile of the flow rate and performance of USO at different number of AK [8]:
a) one diametrical AK; b) two chordAK; c) five chord AC; P – «path» (AK USO)

Having substituted in (3) formula for calculation rate U_L (1), we obtain the equation of volumetric flow of diametrical single-channel one-beam USO, having the following form [9 – 10]:

$$q_v = \frac{\pi R^2 k_v L}{2\cos(\varphi)} \left(\frac{1}{t_{ЗА}} - \frac{1}{t_{ПР}} \right). \tag{5}$$

As it was noted above, k_v coefficient reduces the measured speed U_L to the needed value for calculation of the volumetric flow of speed U_S. There is a case, when speeds U_L and U_S may be equal in case of the rectangular pipeline and infinitely wide [8]. For the pipelines of the round section it is necessary to introduce the coefficient k_v. In practice, this coefficient for the diametrical USO is replaced by the calibrating coefficient, which is obtained in the process of calibration at special installations [9, 10]. However, calibration is not always obligatory, especially for technical processes with low accuracy of flow metering. These are so called USO of class 3 and 4 for technological processes (maximum admissible error ±1,5… 5 %) and flare gases and discharges (maximum admissible error ±5… 10 %) [9, 10]. For such USO calibration process on special units can be replaced, using analytical dependence to determine k_v coefficient. According to the formula (2) for the determination of k_v coefficient analytical formulas for U_L and U_S determination are to be found. Such analytical formulas are known [11, 12]:

$$U_S = \frac{1}{\pi R^2}\int_0^R U_R 2\pi r dr, \tag{6}$$

$$U_L = \frac{1}{R}\int_0^R U_R dr, \tag{7}$$

where U_R – is the law of flow rate distribution in the pipeline with the internal radius R.

Taking into account the expressions (6) and (7), formula for determination k_v coefficient will have the form:

$$k_v = \frac{\frac{1}{\pi R^2}\int_0^R U_R 2\pi r dr}{\frac{1}{R}\int_0^R U_R dr}. \tag{8}$$

Depending on what the law of flow rate distribution in the pipeline is analytical dependences of k_v coefficient will differ one from another. Greater part of the laws of flow rate distribution are obtained by the results of combining the theory of flow and approximation of the experimental data (such as Nikuradze experiments) [8, 13]: Bazen (1902) suggested the law of distribution, expressed by the quarter ellipse; Khristen (1904) suggested to take the parabola of the 8^{th} order; Krey (1927) proposed to take the logarithmic curve; Karman (1928), Nikuradze (1926), Kirsten (1929), Stanton (1911) proposed the power law of distribution, which in the studies of Darsi, Pannel and Mebius was proved experimentally.

For the application in the computer program Auto Design USM we decided to chose for the determination of the analytical dependence of k_v and coefficient and HDE power law of speed distribution, obtained on the base of processing and integration of the experimental data (curves of speed distribution) obtained by Nikuradze [13]. Formula of the power law of flow rate distribution has the following form [11 – 13]:

$$U_R = u_{\max}\left(\frac{1-r}{R}\right)^{1/n}, \tag{9}$$

where u_{max} – is maximum rate of non-distorted flow (axial rate in the center of the pipeline); r – is the distance from the axis to the point of flow rate determination; n – index of power, that depends on the Reynolds number (number or Nikuradze exponent [10]), and it will be calculated by the equation [14]:

$$n = 11{,}269 - 3{,}019\lg(\mathrm{Re}) + 0{,}432\lg^2(\mathrm{Re}). \tag{10}$$

Having substituted the expressions (9) in the formula (8), we obtain the equation for the determination of k_v coefficient on the base of power law of distribution:

$$k_v = \frac{\frac{1}{\pi R^2}\int_0^R \left(u_{\max}\left(\frac{1-r}{R}\right)^{1/n}\right) 2\pi r dr}{\frac{1}{R}\int_0^R \left(u_{\max}\left(\frac{1-r}{R}\right)^{1/n}\right) dr}. \tag{11}$$

Taking note that u_{max} = 1 and R = 1, the calculation of k_v coefficient for different values of Reynolds number was performed, using the Simpson method of numerical integration (this is the improved variant of the trapezoid method, based on the approximation of the area under the curve by means of parabolic quadratic approximation functions). Simpson`s method is especially useful for computation of complex integrals, where other methods may be not accurate enough. For instance, for the calculation of the area under the curve in physical problems, for the determination of the volume of fluid or analysis of complex economic models [15].

Realization of Simpson method in C# language, used in computer program Auto Design USM, has the following form [16]:

```
privatestaticdouble Simpson(Func<double, double> f, double a, double b, int n){
var h = (b - a) / n;
var sum1 = 0d;
var sum2 = 0d;
for (var k = 1; k <= n; k++){
var xk = a + k * h;
if (k <= n - 1){
    sum1 += f(xk);
  }
var xk_1 = a + (k - 1) * h;
  sum2 += f((xk + xk_1) / 2);
}
var result = h / 3d * (1d / 2d * f(a) + sum1 + 2 * sum2 + 1d / 2d * f(b));
return result;
}
```

where a – is lower limit of the integration; b – is upper limit of integration; n – is the number of subintervals; Func – is delegate that represent the function to be integrated.

The example of the application of Simpson method to find speed U_S, is realized in computer program Auto Design USM:

```
double f1(double y){
return umax * Math.Pow((1 - y) / R, 1 / n) * 2 * Math.PI * y;
}
double uS = Simpson(f1, 0, 1, 1000);
```

The obtained massive of k_v coefficient values turned out to be identical to the values, which can be obtained, using analytical dependence, recommended for diametrical USO by American Gas Association, AZA [11] and European Gas Research Group, GERG [12] in such simplified form (in conditions of the developed turbulent flow):

$$k_v = \frac{2n}{(2n+1)} . \tag{12}$$

There exist other analytical dependences of k_v, coefficient, such as dependences, obtained on the base of the modified power and logarithmic distribution law [11, 12, 14]:

– dependence of Kivilis-Reshetnikov:

$$k_v = \frac{1}{1{,}12 - 0{,}011\lg(\mathrm{Re})} . \tag{13}$$

– dependence of Kritz:

$$k_v = \frac{1}{1 + 0{,}19\,\mathrm{Re}^{-0{,}1}} . \tag{14}$$

– dependence of Birger:

$$k_v = \frac{1}{1 + 0{,}011\sqrt{6{,}25 + 431\,\mathrm{Re}^{-0{,}237}}} . \tag{15}$$

As Simpson method had a drawback, it concerns great expenditures of central processor resources for the calculations, the decision was made not use in the computer program Auto Design USM the calculation of k_v coefficient, using the formulas (11), but suggest the user the results by analytical dependences (12 – 15). User should only choose for which Reynolds number the calculation will be perform and the program will output all four variants of k_v coefficient.

As it is seen from Fig. 4, both analytical dependences of k_v coefficient, developed on the base of power law distribution (AGA-GERG formula (12) and K-R formula (13)) have similar character: with the increase of the flow rate, the value of the coefficient approaches 1. This means that the faster is the flow, the less is the difference between the speeds U_L and U_S.

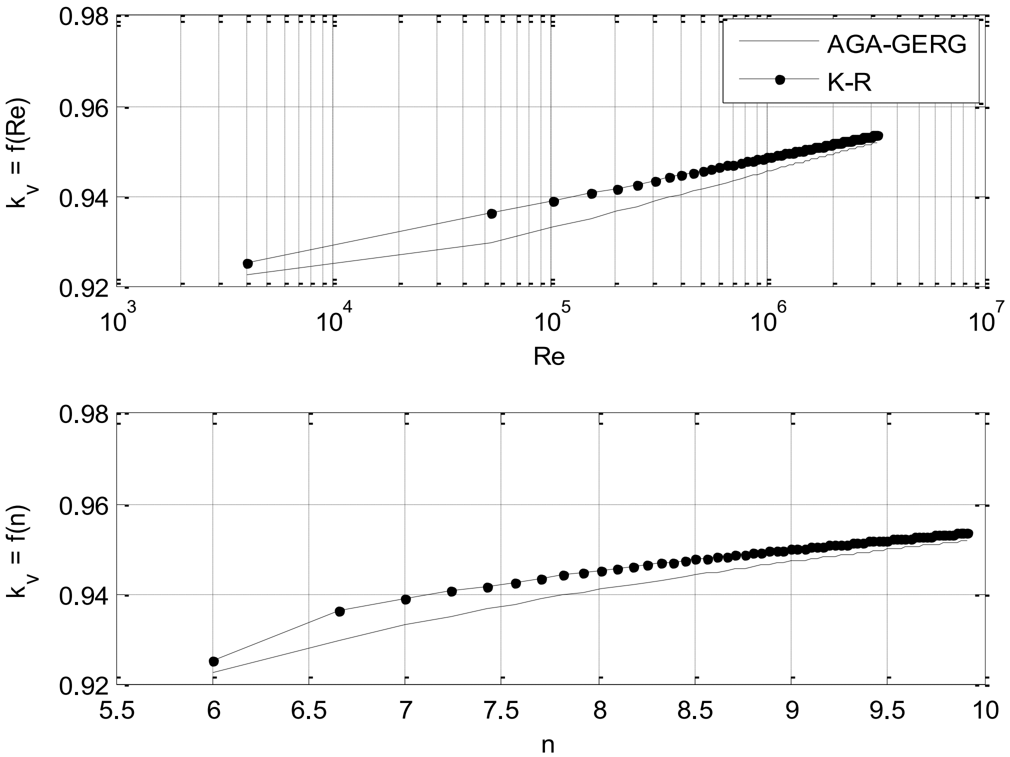


Fig. 4. Dependence of k_v coefficient on Reynolds number (upper part) and Nikuradze number (low part)

Calculation of the MPE for corresponding Reynolds number should be added to computer program Auto Design USM. As the law of flow rate distribution, for the k_v coefficient, power law of distribution was chosen. In general, maximum permissible error MPE may be calculated by the classic formula of relative error of measurement of the type [14]:

$$\delta_{ГДП} = 100\frac{(q_v - q_s)}{q_s}, \quad (16)$$

where q_v – is a volumetric flow of diametral USM; q_s – is a volumetric flow, calculated by averaged flow rate in the cross-section of the pipeline (U_S).

Volumetric flow of diametrical USM by the power law of distribution may be calculated by the formula of the type [11, 12]:

$$q_v = \pi\int_0^1 (1-r)^{1/n} dr. \quad (17)$$

Formula for the calculation of q_s by the power law will have the following form [11, 12]:

$$q_s = \frac{1}{\pi}\int_0^1 2\pi r(1-r)^{1/n} dr. \quad (18)$$

For the realization of the formulas (17) and (18) in the computer program Auto Design USM, we used the described approach, using Sympson method. It is seen from Fig. 5, that with the increase of the flow rate MPE of the diametrical USM decreases. Also, it is seen, that without application of the correction factor on the profile of the flow, the value of MPE exceeds 8 %, this value is an important index and requires special attention.

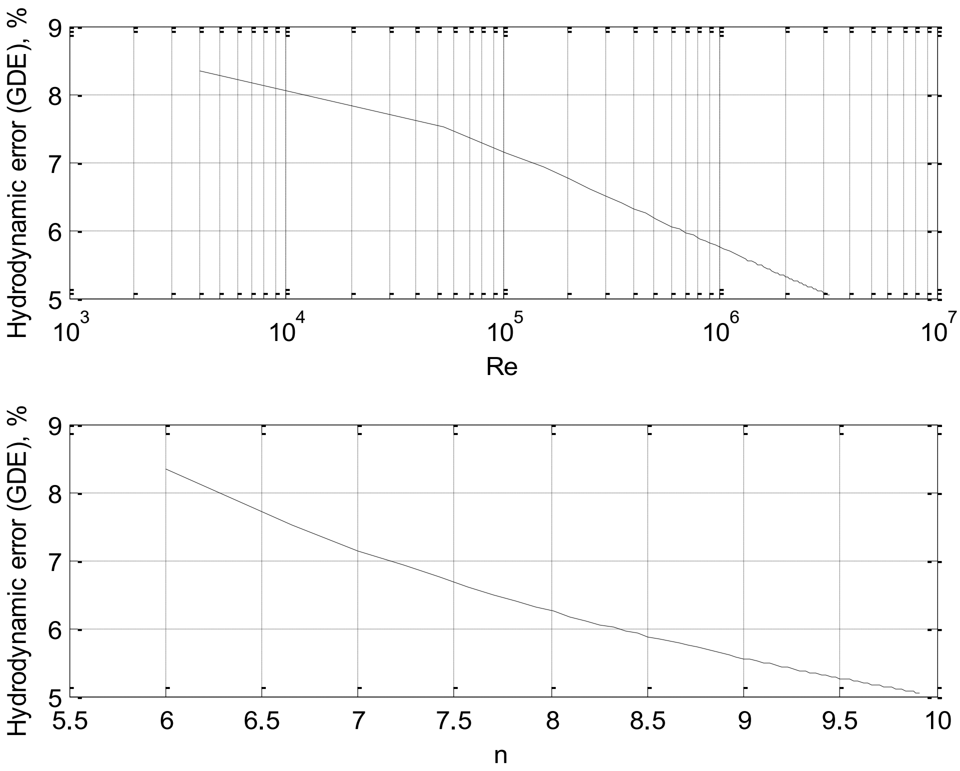


Fig. 5. Dependence of MPE of the diametrical USM on Reynolds number (upper part) and Nikyradze number (low part)

Taking into account the above-mentioned material, we elaborated the algorithm of designing diametrical single-channel single-beam USM, which is integrated into computer program Auto Design USM. These are the steps of the algorithm:

1. Select and introduce the value of Reynolds number from the corresponding range. For instance, Re = 40000…100000. This range is selected so that to cover first of all low boundary of the range of power law of distribution, namely, the area of the turbulent mode start.
2. Calculate Nikuradze number by the formula (10).
3. Calculate k_v coefficient by the formula (12) (in the program it is marked as k_1).
4. Calculate k_v coefficient by the formula (13) (in the program it is marked as k_2).
5. Calculate k_v coefficient by the formula (14) (in the program it is marked as k_3).
6. Calculate k_v coefficient by the formula (15) (in the program it is marked as k_4).
7. Calculate volumetric flow q_s by the formula (18).
8. Calculate volumetric flow q_v by the formula (17).
9. Calculate error δ_{MAE} of diametrical USM by the formula (16).
10. Display n, k_1, k_2, k_3, k_4 and error δ_{MAE}.

Fig. 6 shows the window for the display of computer program Auto Design USM realizing calculation of k_v coefficient and MAE of diametrical single channel USO.

```
Enter Re (Re must be within the range of 40000 to 100000): 40000

                          Calculated values:
                          n = 6,525
                          k1 = 0,929
                          k2 = 0,935
                          k3 = 0,938
                          k4 = 0,940
                          Del = 7,668
```

Fig. 6. Window for the display of the computer program Auto Design USM in the console execution : del – is MAE

Conclusions and prospects of further research

By the results of the research the computer program for automatic design of the diametrical USM was developed, improving the available program Auto Design USM. For this purpose the possibility of calculation of the important for the design of the diametrical USM parameters – error coefficients on the profile of the flow and MAE was added

As the perspective for further research to make the available system of automatic design USM to become more efficient the following steps to be taken are highlighted:

1. Development of graphic interface of the program and the work with the exceptions (errors), when the user introduces the incorrect values of the input parameters unconsciously or unknowingly.
2. Application of other theoretical or empirical laws of flow rate distribution – distorted (improved power distribution law, that better takes into account the wall layer) or distorted (Gredo, Salami).
3. Possibility to display graphs by a program and data arrays (results) storage in the form, convenient for the user.

REFERENCES

1. Ukrgasextraction will buy high accurate meters for the arrangement of gas metering unit for 132 mil hrs [Electronic resource]. – Access mode: https://expro.com.ua/novini/ukrgazvidobuvannya-zakupit-visokotochn-lchilniki-dlya-oblashtuvannya-vuzlv-oblku-gazu-za-132-mln-grn. (Ukr).
2. Ultrasonic flowmeter market [Electronic resource]. – Access mode : https://straitsresearch.com/report/ultrasonic-flowmeter-market.
3. Lunde P. GARUSO Version 1.0. Uncertainty model for multipath ultrasonic transit time gas flow meters (CMR Report no. CMR-97-A10014) / Per Lunde, Kjell-Eivind Froysa, Magne Vestrheim. – Bergen : Christian Michelsen Research AS, 1997. – 242 p.
4. Lunde P. Handbook of uncertainty calculations. Ultrasonic fiscal gas metering stations [Electronic resource] : Handbook / Per Lunde, Kjell-Eivind Froysa. – Norwegian Society of Oil and Gas Measurement (NFOGM) and the Norwegian Petroleum Directorate (NPD), 2001. – 277 p. – Access mode : https://nfogm.no/wp-content/uploads/2014/04/Handbook-USM-fiscal-gas-metering-stations.pdf.
5. Roman V. Software for calculating the location coordinates and weighting coefficients of acoustic paths of ultrasonic flow meters [Electronic resource] / V. Roman, F. Matiko, A. Kutsan // Journal of Energy Engineering and Control Systems. – 2022. – Vol. 8, № 2. – P. 98 – 103. – Access mode : https://doi.org/10.23939/jeecs2022.02.098.
6. Improvement of the computer program for calculation the location coordinates and weighting coefficients of acoustic paths of ultrasonic flow meters [Electronic resource] / V. I. Roman, V. O. Iliuchok // Scientific journal «Computer-integrated technologies: education, science, production». – 2023. – № 50. – P. 157 – 162. – Access mode : https://doi.org/10.36910/6775-2524-0560-2023-50-24. (Ukr).
7. Computer program for design of multipaths ultrasonic flowmeters [Electronic resource] / V. I. Roman, V. O. Iliuchok // Scientific journal «Computer-integrated technologies: education, science, production». – 2023. – № 52. – P. 24 – 31. – Access mode : https://doi.org/10.36910/6775-2524-0560-2023-52-03. (Ukr).
8. Plant Flow Measurement and Control Handbook. Fluid, Solid, Slurry and Multiphase Flow / ed. by Swapan Basu. – Academic Press, 2018. – 1268 p.
9. ISO 17089-1:2019. Measurement of fluid flow in closed conduits – Ultrasonic meters for gas. Part 1: Meters for custody transfer and allocation measurement. – Replaces ISO 17089-1:2010 ; effective from 2019-08-01. – Official edition. – Geneva : International Organization for Standardization, 2019. – 114 p.
10. ISO 17089-2:2012. Measurement of fluid flow in closed conduits – Ultrasonic meters for gas. Part 2: Meters for industrial applications. – Effective from 2012-10-01. Official edition. – Geneva : International Organization for Standardization, 2012. – 38 p.

11. AGA Report No. 9. Measurement of gas by multipath ultrasonic meters. Second edition / edit by AGA Transmission Measurement Committee. – Washington : American Gas Association (AGA), 2003. – 84 p.
12. GERG TM 11. GERG Project on ultrasonic gas flow meters, Phase II/ ed. by P. Lunde, K.-E. Froysa, M. Vestrheim. – Brussels : Groupe Europeen de Recherches Gazieres (GERG), 2000. – 110 p.
13. Kulyk M. S. Mathematical models of constant turbulence / M. S. Kulyk, V. T. Movchan, E. O. Shkvar. – K. : National Aviation University, 2012. – 356 p. (Ukr).
14. The Measurement, instrumentation, and sensors: handbook / ed. by J. G. Webster. – Boca Raton : CRC Press, 1999. – 2630 p.
15. Handbook of mathematical function with formulas, graphs and mathematical tables / ed. by Milton Abramovitz, Irene A. Stegum. – New York : NBS, 1964. – 470 p.
16. Simpson's method [Electronic resource]. – Access mode : https://programm.top/uk/c-sharp/algorithm/numerical-methods/simpsons-rule/. (Ukr).

Editorial office received the paper 23.06.2024.
The paper was reviewed 27.06.2024.

Roman Vitaliy – Cand. Sc. (Eng.), Associate Professor with the Department of Automation and Computer-Integrated Technologies, e-mail: vitalii.i.roman@lpnu.ua.

Matiko Fedir – Dr. Sc. (Eng.), Professor, Head of the Chair of Automation and Computer-Integrated Technologies, e-mail: fedir.d.matiko@lpnu.ua.

Iliuchok Viktor – Student with the Department of Automation and Computer-Integrated Technologies, e-mail: viktor.iliuchok.avm.2020@lpnu.ua.

National University «Lvivska Polytechnica».