TEKA Kom. Mot. i Energ. Roln. – OL PAN, 2011, 11A, 107-111

ERROR OF AVERAGE VELOCITY FLOW MEASUREMENT IN VENTILATION SYSTEM CHANNELS

Elizabeth Gusentsova, Alim Kovalenko, Manolis Pilavov

Volodymyr Dahl East-Ukrainian National University, Lugansk, Ukraine

Summary. Influence estimation on exactness of measuring average velocity turbulent flow of radius setting velocity sensor is produced. Analytical dependences, relating the measuring error with the Reynolds number are got. The expressions for determination radiuses of average velocity in ring cylindrical channel are established.

Key words: industrial discharges, velocity, Reynolds number, velocity, flow.

INTRODUCTION

One of the most important problem of ventilation systems parameters control of anthropogenic dangerous objects is determination of harmful discharges total volume. It is set depending of gas flow volume of stream in ventilation pipes, directly carrying out the harmful discharges.

Methods and instrumentation of measuring flow rate are various [1, 2], but aerodynamic method [3] is the most reliable and it obtain the most application. The flow rate is determined by average velocity value, found on difference between total and static pressure,

$$Q = u_0 S \ ,$$

where: u_0 is average velocity; S is cross-sectional area of vent channel.

The velocity sensor is set on the length no less than 20 hydraulic diameters of channel from entrance [3, 4], in order to have the formed velocity profile in control section. The flow measurement accuracy also depends on the place of setting sensor on channel section, as velocity flow is unevenly distributed on channel section. In addition, velocity distribution depends on the Reynolds number [2, 5, 6], i.e. from the average velocity or flow rate. And, if for the round cylindrical channels the recommendation on location of velocity sensors at the developed turbulent flow are present [3], then for the ring channels such information is absent in literature. At the same time, ring cylindrical channels are used frequently as outlet for vent systems, for example, the discharge of the ventilation systems of atomic power units in the emergency-repair mode is carried out through such channels.

Analytical dependences, relating the measuring error of average velocity with the radius of sensor location in round cylindrical pipe and Reynolds's number at the turbulent flow mode are established in the presented work. Also, the expressions for the estimation of zero systematic error radius of average velocity measuring in ring cylindrical channel are determined.

Velocity distribution at turbulent flow in round cylindrical pipe for gas flow at velocities up to 70 m/s and Reynolds numbers Re > 10^4, looks like [5, 6]

$$\frac{u}{u_0} = \frac{(n+1)(n+2)}{2}\left(1-\frac{r}{r_0}\right)^n, \qquad (1)$$

where: u_0 is flow average velocity; n - index of degree, depending on Reynolds number (for example, n=1/7 for Re=10^5); r is radius of arbitrary point, counted out from the pipe axis; r_0 is pipe radius.

Reynolds number:

$$\mathrm{Re} = \frac{u_0 d}{\nu} .$$

Here ν is kinematics viscidity.

Dimensionless deviation of velocity from average value

$$\varepsilon_u = \frac{u-u_0}{u_0} = \frac{u}{u_0} - 1,$$

therefore systematic error of average velocity measuring with a glance of (1), represented in percents, will make

$$\delta_u = \left|\frac{(n+1)(n+2)}{2}\left(1-\frac{r}{r_0}\right)^n - 1\right| \times 100,\% . \qquad (2)$$

Calculations show that at setting the sensor in pipe center the error exceeds 20% for Re=10^5.

The value of average velocity radius can be determined, putting the $u = u_0$ in expression (1),

$$r^* = \frac{d}{2}\left(1-\left(\frac{2}{(n+1)(n+1)}\right)^{\frac{1}{n}}\right). \qquad (3)$$

For determination of average velocity radius at the arbitrary Reynolds numbers we will use the experimental data [6] of values of degree in distributing index (1) of velocity on the pipe section. The n values for the row of Reynolds numbers Re are presented in table.1.

Table 1. **Values of degree index in velocity distributing**

Re	$4 \cdot 10^3$	$2,3 \cdot 10^4$	10^5	$1,1 \cdot 10^6$	$3,2 \cdot 10^6$
n	1/6	1/6,6	1/7	1/8,8	1/10

Tabular data is approximated on least-squares method by the next dependence

$$n = 0{,}252 - 2{,}29 \times 10^{-2} \lg \mathrm{Re} \,. \quad (4)$$

Taking into account approximation dependence (4) it is possible to determine relation between average velocity radius with the Reynolds number for round cylindrical channel. However, as calculations show, the average velocity radius practically does not depend on the Reynolds number and matters ≈0,76r_0 in the range of Re=$10^5 \div 10^6$, which is working band for industrial vent systems.

We will present next algorithmic expression for determining the power dependence for the velocity profile in ring cylindrical channel

$$\frac{u}{u_m} = \begin{cases} \left(\dfrac{r - r_1}{r_m - r_1} \right)^n, r_1 \le r \le r_m; \\ \left(\dfrac{r_2 - r}{r_2 - r_m} \right)^n, r_m \le r \le r_2; \end{cases} \quad (5)$$

where: u_m is maximum velocity; r_1, r_2 are radiuses of internal and external surfaces; r_m is maximum velocity radius.

We use next empiric dependence for the maximum velocity radius [7]

$$\frac{r_m - r_1}{r_2 - r_m} = \left(\frac{r_1}{r_2} \right)^{0{,}343} . \quad (6)$$

Because average velocity

$$u_0 = \frac{Q}{\pi \left(r_2^2 - r_1^2 \right)},$$

and flow rate

$$Q = 2\pi \left(\int_{r_1}^{r_m} urdr + \int_{r_m}^{r_2} urdr \right),$$

in recognition (5) possible to get

$$\frac{u_0}{u_m} = \frac{2}{(n+2)(n+1)} \frac{r_2 + r_1 + nr_m}{r_2 + r_1} . \quad (7)$$

On basis of (7) we will transform dependence (5) to the form

$$\frac{u}{u_0} = \frac{(n+2)(n+1)}{2} \frac{r_2 + r_1}{r_2 + r_1 + nr_m} \times$$

$$\times \begin{cases} \left(\dfrac{r - r_1}{r_m - r_1} \right)^n, r_1 \le r \le r_m; \\ \left(\dfrac{r_2 - r}{r_2 - r_m} \right)^n, r_m \le r \le r_2. \end{cases}$$

Putting equality $u=u_0$ here, we determine expression for two average velocity radiuses

$$r_1^* = r_1 + (r_m - r_1)A^{\frac{1}{n}}, \quad (8)$$

$$r_2^* = r_2 - (r_2 - r_m)A^{\frac{1}{n}}, \quad (9)$$

where:

$$A = \frac{2}{(n+2)(n+1)} \frac{r_2 + r_1 + nr_m}{r_2 + r_1}.$$

Rough estimation of Reynolds's number influence on the radius of zero systematic error of velocity measuring is possible to execute on the basis of approximation dependence (4). However calculations show that, as well as in the case of round cylindrical channel, in the working range of industrial vent systems Reynolds numbers, the value of average velocity radius changes not substantially.

CONCLUSIONS

Thus, the accuracy of average velocity measuring of turbulent stream substantially depends on the radius of sensor location. At the sensor location on the radius of average velocity measuring error practically does not depend on the Reynolds number in the range of Re = $10^5 \div 10^6$. From two radiuses of average velocity in ring cylindrical channel, radiuses of internal and external surfaces determined coming from correlation, in practice it is recommended to use greater, where because of less radial gradient of velocity weaker the error of sensor setting shows up on exactness of average velocity measuring.

REFERENCES

1. Abramovich G.N. 1976.: Prikladnaya gazovaya dinamika. M: Nauka,- 337-369 pp.
2. Boshnyak L.L. 1974.: Izmereniya pri teplotehnicheskih issledovaniyah. L.: Injener. 86-104 pp.
3. Chertyshev YU.F. 1988.: Teoriya i tehnika teplofizicheskogo eksperimenta. L.: Energoatomizdat, 258-296 pp.
4. Deych M.E. 1974.: Tehnicheskaya gazodinamika. M.: Energiya, - 75-96 pp.
5. Emtsev B.T. 1978.:Technicheskaya gydromechanika. M.: Injener. 369-379 pp.
6. Emtsev B.T. 1978.: Tehnicheskaya gidromehanika. - M.: Injener, - 225-247 pp.
7. Gaevskaya V.N., Dashkov U.A. 1984.: Vliyanie otnositelnogo razmera nasadka na pogreshnost' opredeleniya poter' polnogo davleniya. Trudy TSAGI. Vyp. 2219.
8. Golin'ko V.I., Kolesnik V.E. 1999.: Izmerenie skorosti gazovozdushnih potokov pri kontrole promishlennih vibrosov. Ekotekhn. № 1. 39-43 pp.
9. Idel'chik I.E. 1964.: Aerodinamika promishlennih apparatov (podvod, otvod I ravnomernaya razdacha potoka).- M.: Energiya, 132-154 pp.
10. Idel'chik I.E. 1992.: Spravochnik po gidravlicheskim soprotivleniyam.- M.: Injener.

11. Kays W.M., Leung E.J. 1963.: Heat transfer in annular passages - hydrodynamically developed turbulent flow with arbitrarily prescribed heat flux, Int. I. Heat Mass Transfer, vol. 6, 537-557 pp.
12. Khanzhonkov V.I. 1953.: Aerodinamicheskie harakteristiki kollektorov. Promishlennaya aerodinamika. M.: TSAGI, - № 4. - P. 45 – 63pp.
13. Kovalenko A.A., Sokolov V.I., Dymnich A.H., Uvarov P.E. 1998.: Osnovu tehnicheskoy mehaniki zhidkostej i gasov. VUGU. 56-63 pp.
14. Kovalenko A.A., Sokolov V.I., Dymnich A.KH., Uvarov P.E. 1998.: Osnovi tehnicheskoi mehaniki jidkostei i gazov. Lugansk: VUGU. 113- 130 pp.
15. Nedopekin F.V. Kovalenko A.A., Sokolov V.I., Andriychuk N.D., Gusentsova Y.A. 2010.: Osnovi mehaniki sploshnih sred. - Lugansk: Iz-vo VNU im. V. Dalya, – 178-201pp.
16. Petunii A.N., Peshekhonov N.F. 1985.: Metrologicheskie issledovaniya priyomnikov polnogo davleniya s protokom. Trudy TSAGI. Vyp. 277.
17. Petunin A.N. 1996.: Metodi i tehnika izmereniy parametrov gazovogo potoka. M .: Injener, - 336-356 pp.
18. Povkh I.L. 1974.: Aerodynamicheskiy experiment v mashinostroenii. L.: Injener, 120-125 pp.
19. Shlikhting G. 1974.: Teoriya pogranichnogo sloya. - M.: Nauka, - 456-497 pp.
20. Sokolov V.I. 1999.: O raschete nachal’nih uchastkov turbulentnih potokov v tcilindricheskih kanalah. Lugansk: VUGU. 12–15 pp.

ПОГРЕШНОСТЬ ИЗМЕРЕНИЯ СРЕДНЕЙ СКОРОСТИ ПОТОКА В КАНАЛАХ ВЕНТИЛЯЦИОННІХ СИСТЕМ

Елизавета Гусенцова, Алим Коваленко, Манолис Пилавов

Аннотация. Произведена оценка влияния на точность измерения средней скорости турбулентного потока радиуса установки датчика скорости. Получены аналитические зависимости, связывающие погрешность измерения с числом Рейнольдса. Установлены выражения для определения радиусов средней скорости в кольцевом цилиндрическом канале.

Ключевые слова: промышленные выбросы, скорость, число Рейнольдса, расход.