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Natural gas turbine flow meters calibrations in low gas flow pressure sutuations

In the article criteria of possible turbine flow meters calibrations with natural gas parameters fluctuations are determined Article presents experimentation results of natural gas parameters influence on processes that occur in turbine flow meters. In the article criteria of possible turbine flow meters calibrations with natural gas parameters fluctuations are determined. It is known that metrological parameters of the turbine flow meter in operating systems will deter from certificated values. With pressure, temperature or other fluctuations of a flow physical parameters the flow meter's results will occur within of a error space determined by Reynolds number equation for current flow passing through turbine grille. With Reynolds numbers constant aspect ratio the relative error of a flow meter will stay irrelevant of type of the environment. It is suggested to use this value as a criteria that is not affected by thermodynamic parameters and physical characteristics of a environment but of turbine grille model and mechanical state of a flow meter. Turbine flow meter SM-RI-X-KG1000, DN200 was used for experiment with flow volume varies of 80 m3/h to 1600 m3/h and pressure varies of 100 kPa to 700 kPa. Results of theoretical calculations and experimental research data for Reynolds number ratio is shown on a graph of a turbine flow meter speed on pressure dependency. It is determined that flow meter designed for low-pressure environment should be calibrated for actual range of operating environment pressure and temperature values.

Government laws ensure stable and unhindered supply of natural gas to consumers if certain special technical and safety standards are met [1].

In this set up the issue present of providing metrological tools for natural gas volume and usage measurements, especially with in commerce oriented applications. Accuracy of gas usage calculations depends on natural gas turbine flow meter type, its design and gas flow rate fluctuations. It is important to have knowledge about physical processes occurring inside flow meter turbine and their influence on result of measurements.

Gas flow meter turbine processes are described in works [2-4]. Although result of these works are, usually, based on research of processes present within turbine before turbine grille. Metrological parameters of the turbine flow meter in operating systems will deter from certificated values when changing operating environment as it is shown in work [5].

With pressure, temperature or other fluctuations of a flow physical parameters the flow meter's results will occur within of a error space determined by Reynolds number equation for current flow passing through turbine grille.

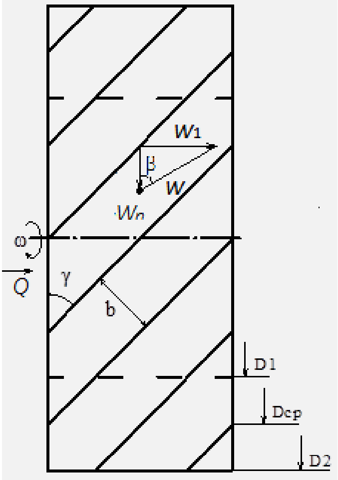
In case of constant Reynolds number the relative error of a meter will remain constant regardless of working conditions [5, 6]. So the issue is to determine influence of natural gas parameters on physical processes occurring in turbine meter grill dynamic and possibility of turbine gas meter calibration depending on gas parameters in current working conditions.

Active turbine with degree of reaction of zero is a working element of turbine flow meter. Relative velocity of gas flow at rotor entrance to relative velocity at rotor exit is a constant and pressure on working surface of rotor blades is applied by gas flow change of direction of flow.

Relative velocity of gas flow W consists of swirl velocity W_n that ensures rotation of a turbine and axial velocity W_i that transfers the gas through the turbine grille of gas meter. Swirl velocity to axial velocity ratio for turbine grille has a constant value and one of concepts of similitude [7].

$$k = W_n / W_i \,. \tag{1}$$

Due to kinematic similarity this ratio (1) is not affected by outside parameters or natural gas parameters but is affected by geometrical parameters of turbine meter grill and current state of a meter (bearing friction coefficient, dirt in filter, etc). Schematic view of gas turbine grille SM-RI-X-KG1000, DN200 is shown on pic.1



Pic. 1. Technical Data for SM-RI-X-KG1000, DN200 gas meter

Markings for technical data pic1. are: l – blade height; t – number of blades; $D_{cp}=(D_1+D_2)/2$ – diameter of turbine grille; l/D_{cp} – relative height of blades; b – blade distance; t/b – blade step; γ – blade angle in turbine grille. Dimensions of gas meter turbine grill are: $D_1 = 205$ мм, $D_2 = 154$ мм, $D_{\text{ср}} = 179{,}5$ мм, $b = 5$ мм, γ =450, $в = 610$, $h = 25{,}5$ мм.

To determine actual values of swirl velocity W_n, axial velocity W_i and relative velocity W, similarity ration k and we used calibration stand with Honeywell Elster SM-RI-X-KG1000 turbine gas meter with atmospheric air as working gas.

Measuring range of experiment was $Q_{\min} = 80$ m^3/h to $Q_{\max} = 1600$ m^3/h with pressure range from $p_{\min} = 100$ kPa to $p_{\max} = 700$ kPa.

Experimental research results are presented in Tab1.

Таблиця 1

Experimental research results

	Q, m³/h	p, barg	T, ˚C	δ, %	β	W_i, м/с	W_n, м/с	W, м/с	W_n/W_i
1 barg	77,26436	1,029031	14,60656	-1,93537	61,05316	1,78853	0,98923	2,34556	0,5531
	1515,63	1,02137	14,63613	-0,34094	61,05316	35,0840	19,4049	46,0109	0,5531
1,5 barg	83,24398	1,565633	14,71132	-0,51889	61,05316	1,92694	1,06579	2,52709	0,5531
	1143,814	1,536033	14,98275	-0,08638	61,05316	26,4772	14,6445	34,7234	0,5531
1,7 barg	79,36739	1,706152	14,37008	-1,50816	61,05316	1,83721	1,01615	2,40940	0,5531
	1292,979	1,675377	14,47381	-0,22703	61,05316	29,9301	16,5542	39,2517	0,5531
2 barg	85,3376	2,083882	20,62826	-0,50564	61,05316	1,89582	1,04857	2,59064	0,5531
	1266,985	2,04508	20,9764	-0,22182	61,05316	28,0782	15,5300	38,4626	0,5531
2,5 barg	131,5926	2,544862	29,6673	-0,21673	61,05316	3,04613	1,68480	3,99483	0,5531
	1192,768	2,45112	29,92996	-0,27662	61,05316	27,6104	15,2712	36,2095	0,5531
3 barg	82,22063	3,02918	15,28748	-0,93252	61,05316	1,90326	1,05269	2,49602	0,5531
	1094,522	3,079774	15,10496	-0,10889	61,05316	25,3362	14,0133	33,2271	0,5531
4 barg	80,22753	4,125961	21,19302	-0,09281	61,05316	1,85712	1,02717	2,43551	0,5531
	1033,377	4,056986	21,63516	-0,10322	61,05316	23,9208	13,2305	31,3708	0,5531
5 barg	83,0656	5,111237	20,61264	-0,25276	61,05316	1,92282	1,06350	2,52167	0,5531
	948,0284	4,97733	21,03734	-0,07187	61,05316	21,9451	12,1378	28,7799	0,5531
6 barg	85,89529	6,142233	20,46773	-0,29916	61,05316	1,98832	1,09973	2,60757	0,5531
	909,4109	6,027679	20,92208	-0,064	61,05316	21,0512	11,6433	27,6075	0,5531
7 barg	82,385	6,794484	20,11842	-0,11862	61,05316	1,90706	1,05479	2,50101	0,5531
	837,6646	6,626538	20,60357	-0,08935	61,05316	19,3904	10,7248	25,4295	0,5531

During manipulations with values of swirl velocity W_n from 0.98m/s to 19.4m/s, axial velocity W_i from 1.7m/s to 35.1m/s, and relative velocity W 2.3 m/s to 46m/s the similarity ratio remained constant at $k = 0{,}553$.

Turbine meter rotor rotate velocity ω depends on Reynolds number Re of gas that flows thought turbine grille.

So equation (1) can be presented as:

$$k = \text{ш}D_{\text{ср}} / 2W_i \,, \qquad (2)$$

and Reynolds number Re as:

$$\mathrm{Re} = \frac{4R_g}{\text{м}}\,\text{c}W_i = \frac{4R_g}{\text{м}}\frac{p}{zRT}W_i \,, \qquad (3)$$

де R_g — hydraulic radius of turbine grille; ρ — density; μ — dynamic viscosity of the gas; p — pressure; R — gas constant; z— compression ratio; T — temperature.

Getting W_i from equation (2) and using it with equation (3) we can get formula of rotate velocity (therefore number of rotations) dependency from physical properties of working flow and Reynolds number for current flow:

$$\text{щ}=\frac{k}{4\pi R_g D_{\text{ср}}}\frac{\mathrm{Re}\,RzT\text{м}}{p}=A\frac{\mathrm{Re}\,RzT\text{м}}{p}\,, \qquad (4)$$

Equation (4) shows that rotate velocity depends directly from dynamic viscosity and inversely from flow rate. Attempts to apply results for use with natural gas flow were described in [5].

Results of experiments for rotation speed values are presented on Pic.2 with a set of hyperbolic curves for different Reynolds number values.

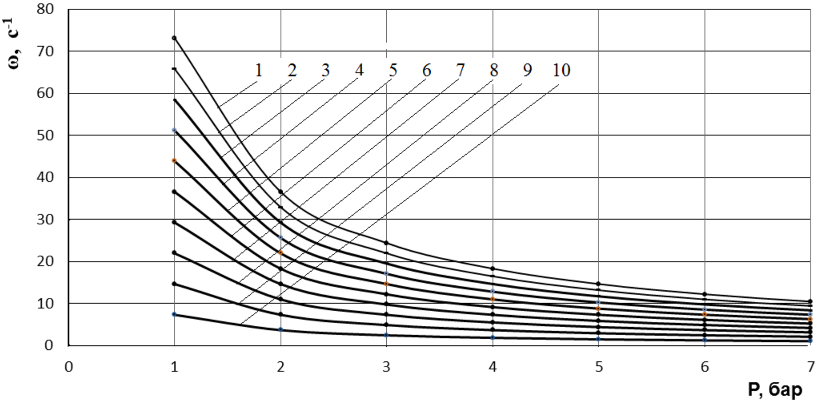


Рис. 2. . Diagram of rotation speed of turbine gas flow meter according to gas pressure dependencies with different Reynolds numbers: 1 — Re = 10^5; 2 — Re = $9{\cdot}10^4$; 3 — Re = $8{\cdot}10^4$; 4 — Re = $7{\cdot}10^4$; 5 — Re = $6{\cdot}10^4$; 6 — Re = $5{\cdot}10^4$; 7 — Re = $4{\cdot}10^4$; 8 — Re = $3{\cdot}10^4$; 9 — Re = $2{\cdot}10^4$; 10 — Re = 10^4

It is clear that for pressure environment lower 5 barg there is a heavy influence of gas pressure over gas meter rotating speed. Further increase of environment gas pressure lowers that influence. Variations in rotating speed of turbine gas flow meter is sensitive to environmental pressure fluctuations especially with high Reynolds number present. With Reynolds number over 40000 the relative error in gas turbine meter will be minimal [6,7].

Thus selection of gas flow meter that is calibrated for pressure range of than 5bar should be re-calibrated when used in lower actual gas pressure environment with actual pressure and temperature values. And statements of [8] what allows calibrations of natural gas meters in open air environment for range of working environment lower 5 barg should be corrected.

Summary

Toe ensure quality and precision of gas flow measurement, calibration of gas flow meters, designed for 5barg of absolute gas pressure, should be performed in an actual working environment keeping in mind range of realistic pressure and temperature fluctuations. Calibrations of gas flow meters that designed for gas pressure environment exceeding 5barg could be performed with environment that keeps defined Reynolds numbers ratio constant [6].

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