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ANALYSIS OF HYDRAULIC PARAMETERS OF CYLINDRICAL VORTEX REGULATORS

On the basis of current knowledge covering a wide range of vortex devices, the methodology of model tests was developed (in pilot-plant scale) for liquid flow in vortex regulators. The paper presents selected investigation results related to the influence of geometric parameters: d_{out}/d_{in}, h_c/d_{in}, D/d_{in}, R_o/d_{in} and constant K, as well as operational parameters, such as an air core diameter (d_a) and a spray cone angle (γ), on liquid flow throttling characteristics for cylindrical vortex flow regulators. The empirical formulae developed allow for a rational selection of geometrical parameters for such regulators that can be used in environmental engineering which was demonstrated in the example.

DENOTATIONS

A_{in} – inlet area, m^2,
A_{out} – outlet area, m^2,
D – vortex chamber diameter, m,
d_{in} – inlet diameter, m,
d_{out} – outlet diameter, m,
d_a – air core diameter, m,
Fr – Froude number,
g – gravitational acceleration , m/s^2,
ΔH – total head loss, m,
h_c – height (axial length) of vortex chamber, m,
K – vortex regulator geometrical constant,
Δp – total pressure loss, Pa,
q_V – volume flow rate, m^3/s,
Re – Reynolds number,
R_o – swirl radius , m,
γ – spray cone angle, ^{o},

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μ – discharge coefficient,
ζ – loss coefficient.

1. INTRODUCTION

Flow regulators are used wherever flow rate control is needed. Traditional throttling devices, such as orifices, reducers or gate valves, allow for a relatively simple regulation of flow rate at the expense of a pipe cross-section reduction, on which they are mounted. As a result, a regulator active cross-section (the so-called free ball passage) may cause its clogging, especially in the case of polluted liquids. In addition, moving mechanical parts may lower the operational reliability of such devices. Hydrodynamic regulators with vortex liquid motion are devoid of such defects. Vortex regulators are more and more commonly applied in environmental protection engineering, among others, as a device for throttling water or wastewater discharge from storage reservoirs, separators or storm overflows [1]. The vortex chamber is also used as a device for swirling liquid jets flowing into pumps, which allows for reducing their power demand [2]. In hydro-engineering, they are used for dissipating energy in bottom sinks [3].

The prototype of vortex devices was the so-called check valve patented by THOMA [4], [5]. When fed by an inlet tangent to a cylindrical vortex chamber, the device generated a considerable hydraulic resistance, whereas when fed by an axial outlet in the cylinder head, the flow was in the opposite direction and flow resistance was little. The device is also known in literature as a vortex diode due to its operation similar to that of a diode. The construction became the subject of investigations in the Ph.D. theses of HEIM [6] and ZOBEL [7]. Their papers were intended to optimize the construction parameters of the device to achieve the highest value of the throttled flow resistance to free flow ratio.

Despite a considerable number of papers – mainly in the field of fluidics and related to check vales [8], [9] and [10] or flow amplifiers (triodes) [11] – literature offers few vortex regulators investigations used in environmental engineering for throttling liquid flows. Furthermore, the device itself is still treated as the so-called black box. Thus far, analytical description of vortex regulator operation breaks down to Torricelli's formula, in which the discharge coefficient (μ) is determined empirically and individually for each regulator [12], [13]. There is a lack of overt hydraulic characteristics specifying the quantitative and qualitative relation of geometric and operational parameters with the throttling effect of the device, measured with such parameters as loss coefficient (ζ) or discharge coefficient (μ). This makes it impossible to assess the operational reliability of such devices, especially of large dimensions.

2. INVESTIGATION GOAL AND SCOPE

In a cylindrical vortex regulator (figure 1), liquid flows into the device through a connector tangent to the cylinder generator. From this, the liquid receives a vortex motion, which is maintained throughout the entire chamber width all the way to an outlet hole on the cylinder head. In the motion, peripheral speed is increased when approaching the cylinder axis. Because of the centrifugal force in the vortex chamber, the pressure decreases towards its axis until it reaches an ambient pressure on the air core surface. The air core being generated has a crucial influence on the throttling efficiency of the device. The atomized liquid in the outflow creates a cone with the angle of flare γ.

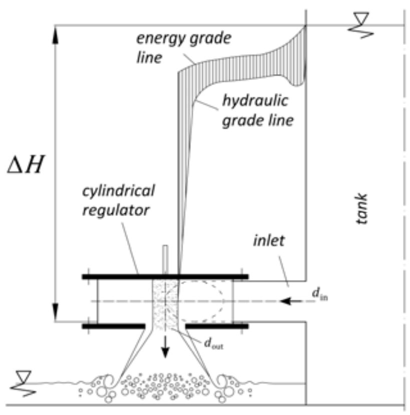

Fig. 1. Schematic diagram of cylindrical vortex regulator operation

This paper tackles model testing of cylindrical vortex regulators in a pilot-plant scale aiming to determine the influence of geometric and operational parameters on throttling efficiency. From the investigations, empirical formulae were developed in which the discharge coefficient (μ) is dependent on device construction dimensions, as well as air core diameter (d_a) and spray cone angle (γ) were established for their rational designing and application.

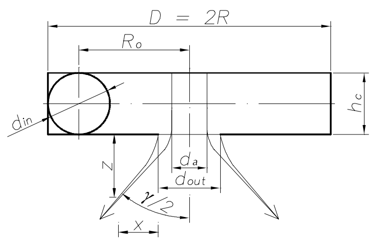

Fig. 2. Geometrical and operational parameters of vortex flow regulator

In 19 runs, devices of vortex chamber heights h_c: 62–312 mm with inlet diameters d_{in} = 30, 50 and 80 mm were tested. At a given diameter d_{in} the outlet diameter d_{out} = 30, 50 and 80 mm was changed. For a total head loss ΔH = 2.5 m H_2O, the minimum vortex valve flow capacity of $d_{in} = d_{out}$ = 30 mm and h_c = 62 mm amounted to q_V = 0.8 dm^3/s, while the maximum for a regulator of $d_{in} = d_{out}$ = 80 mm and h_c = 312 mm reached q_V = 7.9 dm^3/s, a vortex chamber diameter was D = 290 mm.

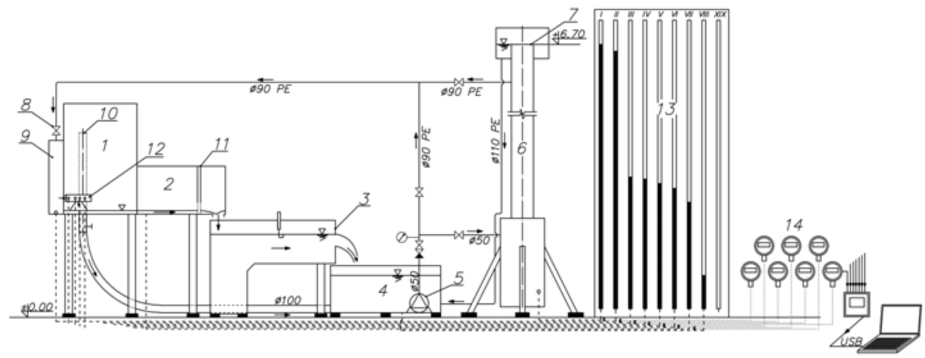

Fig. 3. Scheme of experimental set up (description in the text)

The test stand consisted of two basic systems: testing and supplying (figure 3). The testing system consisted of: an inflow chamber (1), outflow chamber (2) and a measuring weir (3). The supply system consisted of a lower tank (4), circulating pump (5) and upper tank (6) with a surge weir (7). The water inflow to the testing system was controlled by a ball valve (8) located in front of a supply chamber (9), which was connected to an inflow chamber (1). The stand is shown schematically in figure 3 (10 – telescopic weir; 11 – anti-surge baffle; 12 – tested regulator).

The V-notch weir (3) was calibrated by a volumetric method, whereas the digital pressure transmitters (13) were calibrated by means of piezometers. The air core diameter (d_a) and spray cone angle (γ) were measured by a photographic method using a digital camera and Autocad 2004 software.

3. INTERPRETATION OF RESULTS

3.1. THE INFLUENCE OF GEOMETRIC PARAMETERS ON THE COEFFICIENT μ

The total pressure loss Δp in a vortex device depends on the following dimensional variables: liquid density (ρ), dynamic viscosity of water (μ_w), gravitational acceleration (g), volume flow rate (q_V), vortex chamber radius ($R = D/2$), swirl radius at the inlet ($R_o = R - r_{in}$), inlet radius (r_{in}), outlet radius (r_{out}), vortex chamber height (h_c), outlet hole edge thickness (s), and regulator wall roughness (k). From the dimensional analysis (Buckingham's pi-theorem), the pressure loss formula was determined to be in the form of:

$$\Delta p = \zeta \frac{q_V^2 \rho}{2A_{in}^2}, \tag{1}$$

where ζ is the loss coefficient being a function of the following dimensionless similarity numbers and parameters:

$$\zeta = \zeta\left(Re, Fr, \frac{R}{r_{in}}, \frac{R_o}{r_{in}}, \frac{r_{out}}{r_{in}}, \frac{h_c}{r_{in}}, \frac{s}{r_{in}}, \frac{k}{r_{in}} \right), \tag{2}$$

where: Re – Reynolds number: $Re = 2\rho q_V/\pi\mu_w r_{in}$ and Fr – Froude number: $Fr = q_V^2 / 2g\pi^2 r_{in}^5$. Subsequent to expression post- and pre-division (1) by ρg the formula for total head loss (ΔH) was yielded:

$$\Delta H = \zeta \frac{q_V^2}{2gA_{in}^2}. \tag{3}$$

And hence against $1/\sqrt{\zeta} = \mu$

$$q_V = \mu A_{in} \sqrt{2g\Delta H}. \tag{4}$$

The notation (4) is defined in literature as Torricelli's formula, in which μ is the discharge coefficient – a function similar to form (2).

Such an approach up to now is commonly used for quantitative description of vortex regulator operation. The coefficient μ is mainly used for comparing flow throttling effects with traditional devices, e. g., throttling pipe [2], [8], [12] and [13].

The angular momentum on the swirl radius (R_o) is at the entry to the regulator vortex chamber. This generates a swirling motion in which the dominant peripheral speed depends on the inlet area (r_{in}^2). The centrifugal force in the swirling motion, notably, is inversely proportional to the third power of the outlet hole radius (r_{out}^3). The following combination of power products of linear dimensions was introduced to the function (2):

$$K = \frac{R_o r_{in}^2}{r_{out}^3} = \frac{2R_o d_{in}^2}{d_{out}^3} \tag{5}$$

as a geometrical constant (K) of vortex regulators. Then, the coefficient μ function takes the following form:

$$\mu = \mu\left(Re, Fr, K, \frac{R}{d_{\text{in}}}, \frac{R_{\text{o}}}{d_{\text{in}}}, \frac{r_{\text{out}}}{d_{\text{in}}}, \frac{h_{\text{c}}}{d_{\text{in}}}, \frac{s}{d_{\text{in}}}, \frac{k}{d_{\text{in}}} \right). \tag{6}$$

The influence of particular dimensionless parameters and similarity numbers on the coefficient μ was investigated empirically.

Two types of flows can be distinguished for the regulators in question: free flow (irrotational) and vortex flow. The discharge coefficient reaches its maximum value on the boundary of the motions. In particular, it follows from the analysis of the dependence (figure 4) of the discharge coefficient on Reynolds number that its value depends, to a small extent, on *Re* in the lower range of vortex flow ($Re_1 \div Re_2$). The influence of Froude number on μ is similar. Above $Fr > 1$ the value of coefficient μ is practically constant. Because the tests were performed on scaled-down models of real objects, the measurement results obtained for high values of $Re > Re_2$, where μ is practically constant, have practical significance for the assessment of μ value. The mean value of the discharge coefficient computed from the entire vortex flow range (μ_v), that is above the boundary value of number Re_1, was compared with the mean value (μ_c) computed from the range above the boundary value of number Re_2. The mean values differ on average by 1.6% [14], which allows μ_c to be accepted to investigation result interpretation.

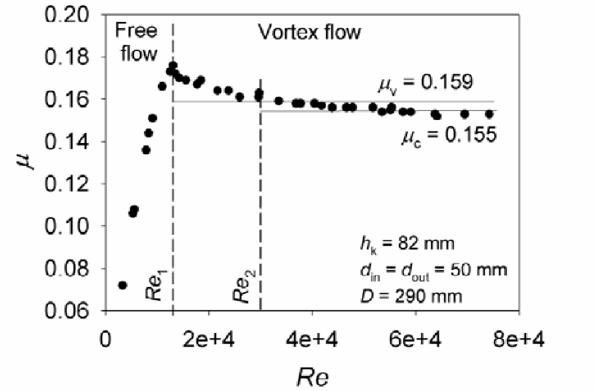

Fig. 4. The interpretation of the discharge coefficient values μ_v and μ_c above the boundary values of Reynolds numbers Re_1 and Re_2 for an example regulator

Apart from the similarity of the numbers *Re* and *Fr*, the influence of construction parameters of cylindrical regulators on the discharge coefficient was analyzed. Dimensionless relations: $d_{\text{out}}/d_{\text{in}}$, h_c/d_{in}, D/d_{in}, R_o/d_{in} and K were subjected to the analysis eliminating a priori k/d_{in} and s/d_{in} from the function. In papers by ELALFY [2] and

ZOBEL [7], it was shown that the roughness of (k) vortex regulator walls has an influence on the discharge coefficient value, and the increase in the roughness reduces flow resistance. This is contradictory to the goals put forward for the devices, that is, the flow throttling maximization. Thus, regulator models were produced in a semi-commercial scale from the smoothest materials (Perspex) of the roughness k closed to the full-scale regulator roughness made of stainless steel.

As far as the outflow hole edge thickness (s) influence is concerned, it was proved in the tests that for a sharp-edge hole of s = 1 mm in comparison to s = 10 mm (the thickness of Perspex used in models) the coefficient μ value shows differences within measurement error limits [14].

Selected dependencies of the discharge coefficient function (6) were shown in the plots (figures 5 and 6).

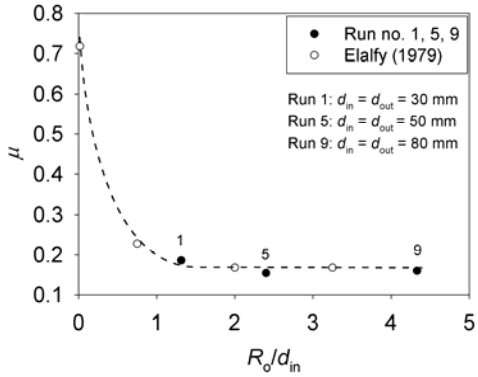

Fig. 5. The dependence of the coefficient μ on the relation R_o/d_{in}

The dependence of the coefficient μ on a relative swirl arm (R_o/d_{in}) was shown in the diagram (figure 5). For a vortex device in the form of a 90° elbow with an inlet d_{in} = 15 mm and outlet $d_{out} = D$ = 15.5 mm, for which R_o/d_{in} = 0.02, ELALFY [2] obtained the value μ = 0.718. For very low values of relative swirl radius (R_o/d_{in}) the discharge coefficient may reach extremely high values. With the increase of R_o/d_{in}, conveying the angular momentum of inflowing liquid, the discharge coefficient initially decreases. This causes the device resistance to increase (figure 5). In the investigated range for R_o/d_{in}, specifically from 1.31 to 4.33, the coefficient μ reaches an approximately constant value, especially if $R_o/d_{in} \geq 1.5$. It should be concluded that increasing the radius R_o further results in a larger vortex chamber diameter D (in relation to the inlet diameter d_{in}). This causes the contact surface of swirling liquid with the walls and motion resistance to increase. Because the momentum increase is compensated for frictional forces, it is therefore unreasonable to design such regulators for the relation $R_o/d_{in} \geq 1.5$ (or respectively $D/d_{in} \geq 4$).

The diagram showing the dependence of the coefficient μ on K is given in figure 6. The regulator constant K groups geometric parameters of vortex regulators such as d_{in}, d_{out} and R_o (formula (5)). It follows from figure 6 that with an increase in K value, μ decreases. Thus, the hydraulic resistance (ζ) generated by the regulator increases (independently of h_c).

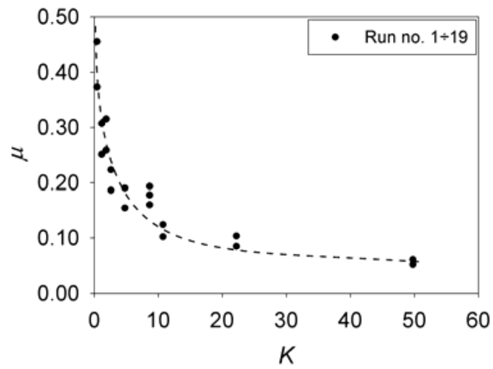

Fig. 6. The dependence of the coefficient μ on the constant K

3.2. THE COEFFICIENT μ DEPENDENCE ON OPERATIONAL PARAMETERS

It should be noticed that in a vortex flow, liquid leaves a device through a discharge ring of an effective jet area A_e, smaller than the outlet hole area A_{out} (of the diameter d_{out}). This is due to an air core having the diameter d_a. Furthermore, jets are deviated from the vertical by a spray cone angle $\gamma/2$, which has not been accounted for in the so far descriptions of vortex regulator operation. Considering measurable operational parameters of vortex regulators, it appears beneficial to account for d_a and γ in the analysis of their influence on μ. The air core diameter is related to the degree of

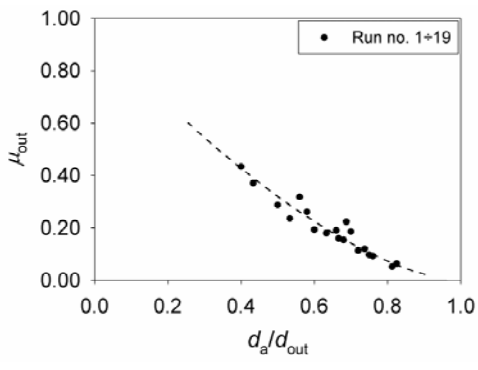

Fig. 7. The dependence of the coefficient $\mu_{out} = \mu\,(d_{in}/d_{out})^2$ on d_a/d_{out} in vortex flow

outlet hole filling by the following dependence: $\delta = 1 - (d_a/d_{out})^2$. This limits the effective area of liquid discharge from a regulator, and δ depends on a dimensionless relation d_a/d_{out}. A spray cone angle is defined by $\tan \gamma/2 = z/(x - r_{out})$, where z – vertical coordinate, x – horizontal coordinate (figure 2). The influence of operational parameters d_a and γ on the discharge coefficient value, related to the outlet diameter d_{out} and defined as $\mu_{out} = 1 - (d_{in}/d_{out})^2$, is presented in figures 7 and 8.

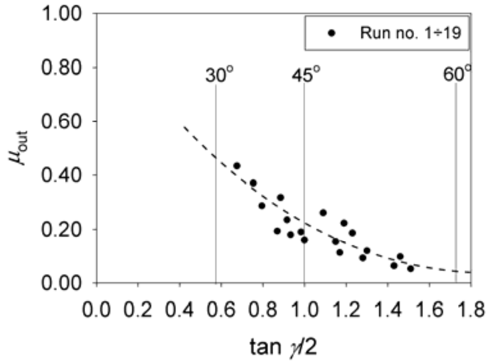

Fig. 8. The dependence of the coefficient $\mu_{out} = \mu\,(d_{in}/d_{out})^2$ on $\tan \gamma/2$ in vortex flow

It follows from the diagrams presented (figures 7 and 8) that with the increase of the relation d_a/d_{out} and the function $\tan \gamma/2$, the coefficient $\mu_{out} = \mu\,(d_{in}/d_{out})^2$ decreases. The increase of relative air core diameter (d_a/d_{out}) is accompanied by the decrease of the outlet δ filling and the increase of spray cone angle ($\gamma/2$). This increases regulator flow capacity measured by the coefficient $\mu(d_{in})$. The increase in regulator flow capacity leads to the decrease in device hydraulic resistance (ζ). This can be explained by the fact that the liquid momentum on the increasing arm (thus, angular momentum) with d_a/d_{out} forces a larger liquid discharge from the outlet and the centrifugal force increases the spray cone angle.

3.3. EMPIRICAL EQUATION

The statistical analysis of measurement results was carried out in order to determine a quantitative influence of geometrical parameters of the regulators investigated on the coefficient μ. The dependencies established (for 19 measurement runs) were obtained based on a multiple non-linear regression by the method of least squares. As a result of the regression analysis, the following empirical equations for d_a/d_{out} and $\tan\gamma/2$ for investigated regulators in the function of their geometrical parameters were developed:

$$\frac{d_a}{d_{out}} = 1.80 - K^{0.084} - 0.050\frac{d_{out}}{d_{in}} - 0.0061\frac{h_c}{d_{in}} + 0.0122\frac{D}{d_{in}} \tag{7}$$

and

$$\frac{\tan\gamma}{2} = 2.38K^{0.561}\left(\frac{d_{out}}{d_{in}}\right)^{2.16}\left(\frac{h_c}{d_{in}}\right)^{-0.080}\left(\frac{D}{d_{in}}\right)^{-0.896}. \tag{8}$$

In the case of formula (7), the coefficient of determination R^2 = 0.993, while RMSPE = 1.51%, whereas formula (8) gave R^2 = 0.975 and RMSPE = 3.69%. The above formulae were subsequently used to expand the description of μ, accounting for both geometric and operational parameters. Statistically, the strongest consistency of measured and approximated data was obtained for the final formula:

$$\mu = K^{-0.189}\left(\frac{d_{out}}{d_{in}}\right)^{0.064} + \left(\frac{h_c}{d_{in}}\right)^{-0.019} + \left(\frac{d_a}{d_{out}}\right)^{-0.040} - 0.551\tan\frac{\gamma}{2} - 2.97. \tag{9}$$

It resulted in R^2 = 0.999 and RMS = 3.5%. The relations derived are valid for the following ranges of dimensionless parameters related to the experiment in question: $0.375 \le d_{out}/d_{in} \le 2.67$; $1.4 \le h_c/d_{in} \le 8.73$; $3.63 \le D/d_{in} \le 9.67$; $0.457 \le K \le 49.78$; $1.31 \le R_o/d_{in} \le 4.33$; $0.40 \le d_a/d_{out} \le 0.825$; $0.675 \le \tan\gamma/2 \le 1.51$ ($68° \le \gamma \le 114°$); $2.7\cdot10^3 \le Re \le 1.4\cdot10^5$; $0.004 \le Fr \le 64.95$.

4. APPLICATION OF INVESTIGATION RESULTS

Geometrical dimensions of a cylindrical vortex regulator should be selected for a throttling flow rate q_V = 0.05 m^3/s at a total head loss ΔH = 3.0 m H_2O – the regulator is intended for the control of sewage discharge from a facility of a storage reservoir of storm overflow type.

The inlet diameter (d_{in}) should be determined by Froude criterion – preservation of vortex flow in regulator: $Fr \ge 1$ (where the value of the coefficient μ is constant), in the following form:

$$\frac{16q_V^2}{\pi^2 g d_{in}^5} \ge 1.$$

The inlet diameter should then satisfy the following relation:

$$d_{\mathrm{in}} \le \sqrt[5]{16 q_{\mathrm{V}}^2 / \pi^2 g}\ ,$$

thus, for a volume flow rate $q_{\mathrm{V}} = 0.05\ \mathrm{m^3/s}$

$$d_{\mathrm{in}} \le [16 \cdot 0.050^2 / (3.14^2 \cdot 9.81)]^{0.2} = 0.210\ \mathrm{m}\ .$$

The inlet diameter $d_{\mathrm{in}} = 0.20$ m was assumed ($Fr = 1.29$).

The formulae (7), (8) and (9) were used for discharge coefficient (μ) value computations. The required value of the discharge coefficient was computed for the assumed parameters q_{V} and ΔH as well as the assumed inlet diameter d_{in}, (after the transformation (4) for μ):

$$\mu = \frac{4 \cdot 0.05}{\pi \cdot 0.20^2 \sqrt{2 \cdot 9.81 \cdot 3.0}} = 0.207\ .$$

It was assumed from the investigations that, due to throttling, the construction of cylindrical regulators should be based on the minimum relation values: $h_{\mathrm{c}}/d_{\mathrm{in}} = 1.4$ and $D/d_{\mathrm{in}} = 3.7$ satisfying the condition of free ball passage in relation to the diameters: $d_{\mathrm{out}}/d_{\mathrm{in}} \in \langle 1;\ 1.5 \rangle$. The design parameter computations were carried out by an iteration method discretely changing its geometrical parameters ($d_{\mathrm{out}}/d_{\mathrm{in}}$), until the required value of consistency μ with the computed one $\mu_{(\mathrm{i})}$ was yielded with the sufficient accuracy:

$$\delta = \frac{\mu - \mu_{(i)}}{\mu} 100\% \le 1\%\ .$$

In the first iteration, for $h_{\mathrm{c}} = 1.4 \cdot 0.20 = 0.28$ m and $D = 3.7 \cdot 0.20 = 0.74$ m, $d_{\mathrm{out}} = d_{\mathrm{in}} = 0.20$ m was assumed and operational parameters $d_{\mathrm{a}}/d_{\mathrm{out}}$ and $\tan\gamma/2$ were computed from formulae (7) and (8):

$$\frac{d_{\mathrm{a}}}{d_{\mathrm{out}}} = 1.80 - 2.7^{0.084} - 0.050\frac{0.200}{0.200} - 0.0061\frac{0.280}{0.200} + 0.0122\frac{0.740}{0.200} = 0.700\ ,$$

$$\frac{\tan\gamma}{2} = 2.38 \cdot 2.7^{0.561}\left(\frac{0.200}{0.200}\right)^{2.16}\left(\frac{0.280}{0.200}\right)^{-0.080}\left(\frac{0.740}{0.200}\right)^{-0.896} = 1.252\ .$$

Subsequently, the value of discharge coefficient was computed from formulae (9):

$$\mu_{(\mathrm{I})} = 2.7^{-0.189} + \left(\frac{0.200}{0.200}\right)^{0.064}\left(\frac{0.280}{0.200}\right)^{-0.019} + (0.700)^{-0.040} - 0.551 \cdot 1.252 - 2.97 = 0.177\ .$$

The relative deviation δ of the computed coefficient value $\mu_{(\mathrm{I})}$ (from the required $\mu = 0.207$) in the first iteration amounted to 14.6%. The outlet diameter d_{out} was increased to 0.230 m ($d_{\mathrm{out}}/d_{\mathrm{in}} = 1.15$) and operational parameters, i.e., $d_{\mathrm{a}}/d_{\mathrm{out}} = 0.730$ and tan $\gamma/2$ = 1.339, were computed in the second iteration. The discharge coefficient $\mu_{(II)}$ = 0.205, while the relative error δ = 0.9% ≤ 1. The actual flow capacity q_V of the regulator for the head loss ΔH = 3.0 m H_2O will amount to 0.0494 m^3/s. (Alternatively, the required value of discharge coefficient can be also obtained at D/d_{in} = 3.7 and $d_{in} = d_{out}$ = 0.20 m, as in the first iteration, but for the vortex chamber height of h_c = 0.62 m).

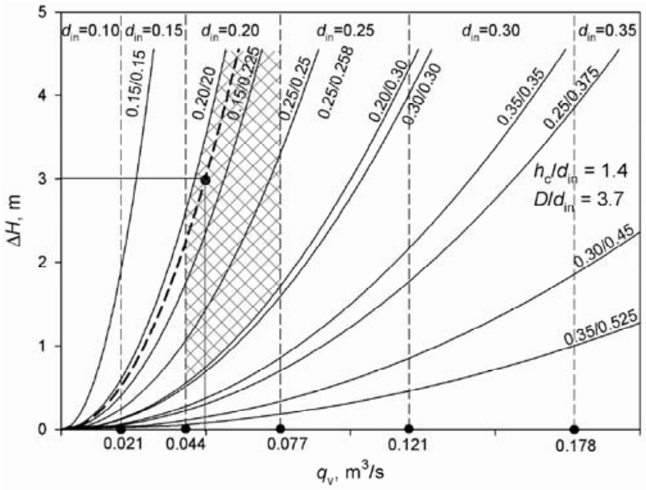

Fig. 9. The nomogram of hydraulic characteristics of cylindrical vortex regulators for the diameter relation d_{in}/d_{out} for h_c/d_{in} = 1.4 and D/d_{in} = 3.7 from range $d_{out}/d_{in} \in$ <1; 1.5> (for computational example)

The diagram of figure 9 presents hydraulic characteristics of an example series of the type of cylindrical vortex valve sizes with the specification of range of their application (for the design parameters established h_c/d_{in} = 1.4 and D/d_{in}=3.7) helpful in the selection of inlet connector and discharge hole diameters (d_{in}/d_{out}).

5. SUMMARY AND CONCLUSIONS

This paper presents selected results of laboratory model study concerning the influence of the construction parameters d_{out}/d_{in}, h_c/d_{in}, D/d_{in}, R_o/d_{in} and constant K on the discharge coefficient. It also shows the influence of operational parameters, such as the air core diameter (d_a) and spray cone angle (γ), of regulators with a cylindrical vortex chamber shape on their flow throttling characteristics (μ). The test results permit us to draw the following conclusions:

1. In a vortex flow, the coefficient μ value is approximately constant above boundary values of the Reynolds and Froude numbers.

2. The increase of both a relative vortex chamber height (D/d_{in}) and relative swirl

radius (R_o/d_{in}) results in the reduction of the value μ, which for $R_o/d_{in} \geq 1.5$ ($D \geq 4$) is already approximately constant.

3. The regulator constant (K) groups the influence of dimensionless parameters d_{out}/d_{in} and R/d_{in} on the coefficient μ, increasing the accuracy of the quantitative description of device operation. With an increase in the value of K, the coefficient μ decreases.

4. The empirical formulae developed in the paper allow for a rational selection and the designing of vortex regulator constructions using the assumed construction parameters and computed operational parameters.

5. The coefficient μ values obtained for investigated vortex regulators range from 0.0521 to 0.455. This corresponds to loss coefficient (ζ) values from 368 to 5, respectively. The smallest possible vortex chamber height determined by an inlet connector diameter and a small outlet hole diameter for the relations of $D/d_{in} \leq 4$ and $R_o/d_{in} \leq 1.5$ are rational for the maximization of the liquid flow throttling efficiency.

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ANALIZA PARAMETRÓW HYDRAULICZNYCH CYLINDRYCZNYCH REGULATORÓW WIROWYCH

Na podstawie analizy dostępnych danych na temat urządzeń o działaniu wirowym opracowano metodologię badań hydrodynamicznych regulatorów przepływu cieczy. Przedstawiono wybrane wyniki badań modelowych w skali półtechnicznej. Dotyczyły one wpływu parametrów geometrycznych: (d_{out}/d_{in}, h_c/d_{in}, D/d_{in}, R_o/d_{in} i stałej K), a także parametrów eksploatacyjnych (takich jak średnica rdzenia gazowego (d_a) oraz kąt rozpylenia cieczy (γ)) na charakterystykę dławienia przepływu cieczy (μ, ζ) regulatorów o cylindrycznym kształcie komory wirowej. Ustalone w pracy wzory empiryczne umożliwiają racjonalny dobór parametrów geometrycznych takich regulatorów do zastosowań w inżynierii i ochronie środowiska, co wykazano na przykładzie obliczeniowym.