RESULTS OF CALCULATION OF THE COEFFICIENT OF HYDRAULIC FRICTION

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Abstract. *According to the results of theoretical studies, according to the given conditions, with an increase in water pressure at the beginning of the line, the total pressure and pressure at the beginning and end of the pipeline also increase.*

Keywords: *local resistances, hydraulic losses, head losses, roughness, coefficient of friction, laminar and turbulent regime.*

Introduction.

When a real fluid moves in a pipe, all hydraulic losses are made up of friction losses along the length and losses in local resistances. For hydraulic head loss $\sum \Delta h_w$ we have:

– pressure loss along the length of the pipeline due to the presence of friction (losses for friction along the length) $\sum \Delta h_l$;

– pressure loss in local resistances (for example, sudden narrowing or expansion of the flow, cock (valve), bends, etc.) $\sum \Delta h_m$. those.

$$\sum \Delta h_w = \sum \Delta h_l + \sum \Delta h_m \text{ m.}$$

Loss of pressure due to friction along the length in the i-th section is determined from the Darcy-Weisbach formula

$$\Delta h_{l_i} = \lambda_i \frac{l_i}{d_i} \frac{\upsilon_i^2}{2g}, \text{ m}$$

where λ_i is the coefficient of hydraulic resistance; l_i – section length, m; d_i – pipe diameter, m; υ_i - average speed of liquid particles, m/s.

Head loss in local resistances is determined from the Weisbach formula

$$\Delta h_{m_i} = \zeta \frac{\upsilon_i^2}{2g}. \text{ m}$$

where ζ – is the coefficient of local resistance (selected from the reference literature for a specific type of hydraulic resistance).[1,2]

Materials and methods.

The study used the existing methods of theoretical calculations for determining the pressure loss in local and linear resistances, in addition, the coefficient of friction in 5-zones is determined.

The greatest difficulty in determining Δh_{li} is caused by the coefficient λ_i. If during the experiment the pressure drop and the average velocity in the pipeline are measured, then the coefficient of hydraulic friction λ can be found using the Darcy-Weisbach formula. For the first time such experiments were carried out and generalized for hydraulically smooth and rough pipes by Ivan Ilyich Nikuradze at Goetingen University in 1933 under the direction of L. Prandtl. The experiments were carried out for pipes with artificially created uniformly granular roughness, that is, the roughness tubercles had approximately the same size and shape. The results of I. Nikuradze's experiments are presented in the diagram, Fig.1. As a geometric similarity parameter in processing the results of experiments, the ratio is taken k_s / d, where the index "s" marks the uniform-grained roughness. There are five zones on the diagram.[2]

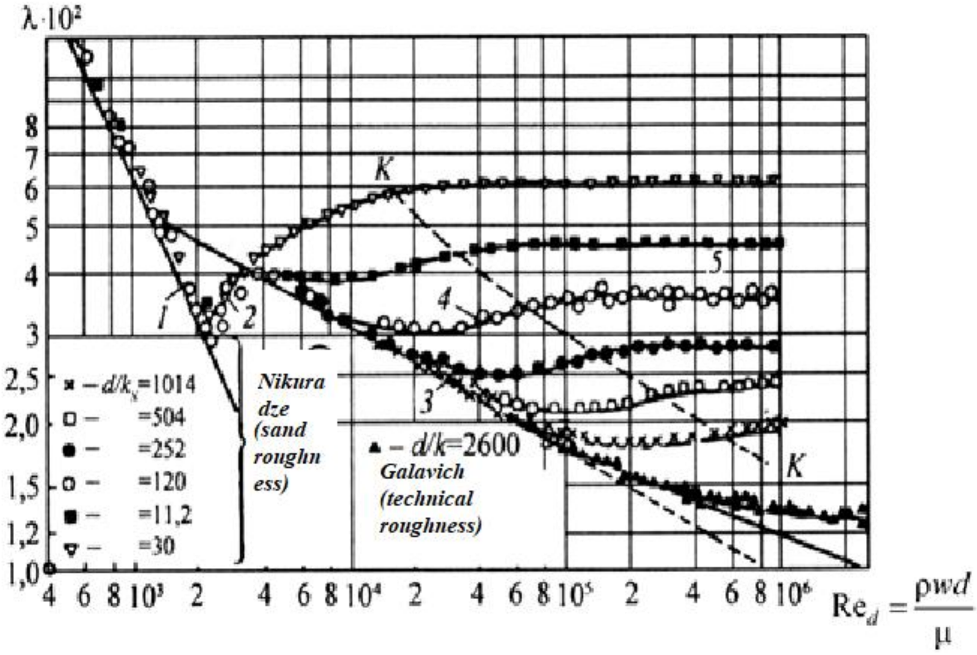

Fig. 1. Diagram by I. Nikuradze of the dependence of the friction coefficient for pipes with uniformly granular roughness

1 – laminar regime zone ($Re_d < 2300$). Within this zone, λ does not depend on the roughness (curve 1) and obeys the Poiseuille formula

$$\lambda = \frac{64}{\mathrm{Re}_d}. \tag{1}$$

Here and below, Re_d – is the Reynolds number determined by the diameter of the pipeline, i.e. .

$$\mathrm{Re}_d = \rho w d / \mu$$

2 – the transition zone from laminar to turbulent flow corresponds to the Reynolds numbers $2300 < \mathrm{Re}_d < 4000$ (curve 2). Vanishing centers of turbulence are observed in the flow. The friction coefficient is determined by the Frenkel formula [1,2]

$$\lambda = \frac{2,7}{\mathrm{Re}_d^{0,53}}. \tag{2}$$

3 – the zone of turbulent motion in hydraulically smooth pipes (curve 3 in Fig. 1.) corresponds to the Reynolds numbers $4000 < \mathrm{Re}_d < 20\frac{d}{k_s}$ and the height of the roughness tubercles $\delta_л = 68,4 r_0 \mathrm{Re}_d^{0,875} > k_s$. The coefficient of friction can be determined from the Blasius formula

$$\lambda = \frac{0,316}{\mathrm{Re}_d^{0,25}}. \tag{3}$$

4 – the pre-square resistance zone is limited by curve 3 and the dashed line K-K (mode of partially rough pipes) corresponds to Reynolds numbers $20d/k_s < \mathrm{Re}_d < 500d/k_s$. The coefficient of friction can be determined by the Altshul formula

$$\lambda = 0{,}11\left(\frac{k_s}{d} + \frac{68}{\mathrm{Re}_d}\right)^{0{,}25} \tag{4}$$

5 – the zone of quadratic resistance is formed by horizontal sections of the curves (the mode of developed roughness) corresponds to the Reynolds numbers $\mathrm{Re}_d > 500d/k_s$. Nikuradze's formula works here

$$\lambda = 1{,}74 + \lg\left(\frac{d}{k_s}\right) \tag{5}$$

or Shifrinson's formula

$$\lambda = 0{,}11\left(\frac{k}{d_s}\right)^{0{,}25}. \tag{6}$$

For this flow regime, the thickness of the viscous sublayer is small and the turbulent flow directly interacts with the roughness ridges. This zone is called the self-similar zone, since λ does not depend on Re_d.

Note that the Altshul formula is universal, since at $k_s = 0$ it goes over to the Blasius formula, and at $\mathrm{Re}_d \to \infty$ it goes into the Shifrinson formula.[2,6]

Results and discussion.

For the purposes of water supply, water is supplied to consumers in the amount of $V=200$ $m^3/hour$ at a temperature of $t=70^0C$. Pipeline length $l=1000$ m, inner diameter $d_w=259$ mm, water pressure at the beginning of the line $p_1=5$ kgf/cm^2. The elevation of the axis of the pipeline at the end point is *2 m* higher than the start point. Determine the total head and pressure at the beginning and end of the pipeline, if the roughness of the pipes is $k = 5 \cdot 10^{-4}$ m, and the pressure loss in local resistances is equal to 10% of the linear losses.

The total head at the starting point is determined by the Bernoulli equation

$$H_1 = z_1 + \frac{p_1}{\rho g} + \frac{v_1^2}{2g}$$

Pressure at the end of the pipeline

$$H_2 = H_1 - h_l$$

The head loss is determined by the equation

$$h_l - h_n + h_м = 1{,}1h_l = 1{,}1\lambda_{tr}\frac{l}{d}\frac{v^2}{2}\rho$$

Determine the nature of the movement of fluid in the pipeline

$$\upsilon_{prev} = 568\frac{\nu}{k}$$

At t=70^{0}C coefficient of kinematic viscosity $\nu = 0{,}416 \cdot 10^{-6}\ m^2/s$;

$$\upsilon_{prev} = 568\frac{0{,}416 \cdot 10^{-6}}{5 \cdot 10^{-4}} = 0{,}472\, m/s$$

Water velocity in the pipeline

$$\upsilon = \frac{V}{S} = \frac{4V}{\pi d_b^2} = \frac{4 \cdot 200}{3600 \cdot 3{,}14 \cdot 0{,}259^2} = 1{,}055\, m/s$$

Since $\upsilon > \upsilon_{prev}$, then λ_{tr} should be determined by the Shifrinson formula

$$\lambda_{tr} = 0{,}11\left(\frac{k}{d}\right)^{0{,}25} = 0{,}11\left(\frac{0{,}0005}{0{,}259}\right)^{0{,}25} = 0{,}024$$

Finally, we find the head loss according to the formula $h_l = \lambda_{\text{тр}}\frac{l}{d}\frac{\upsilon^2}{2}\rho$ under the condition t=70^{0}C. ($\rho_{\text{в}} = 977{,}81\ kg/\text{м}^3$) taking into account local losses, which, according to the condition, are 0.1 linear

$$h_l = 1{,}1 \cdot 0{,}024\frac{1000}{0{,}259} \cdot \frac{1{,}055^2}{2}977{,}81 = 64534{,}8\, Pa$$

If we take z_1=0 as the origin, then

$$H_1 = 0 + \frac{5 \cdot 9{,}81 \cdot 10^4}{977{,}81 \cdot 9{,}81} + \frac{1{,}055^2}{2 \cdot 9{,}81} = 51{,}186\, m$$

$$H_2 = 51{,}185 - 6{,}45 = 44{,}645\, m$$

Pressure at the end of the pipeline

$$p_2 = p_1 - h_l - (z_2 - z_1)\rho g = 5 \cdot 98066{,}5 -$$

$$64534{,}8 - (2 - 0)977{,}81 \cdot 9{,}81 = 406210\, Pa$$

$$p_2 = 408210 \cdot 1{,}01972 \cdot 10^{-5} = 4{,}16\, kgf/sm^2$$

Conclusions.

According to the results of theoretical studies, according to the given conditions, with an increase in water pressure at the beginning of the line, the total pressure and pressure at the beginning and end of the pipeline also increase.

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