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Д.Е. Селезньов, Е.Л. Селезньов

Луцький національний технічний університет

АВТОМАТИЗОВАНИЙ РОЗРАХУНОК ГІДРАВЛІЧНИХ ОПОРІВ ТРУБОПРОВОДУ

В роботі розглядається методика автоматизованого розрахунку опорів трубопроводу.
Ключові слова: *гідравлічний опір, трубопровід, блок-схема, автоматизований розрахунок.*

D.E. Selesnov, E.L. Selesnov

AUTOMATED CALCULATION OF PIPELINE HYDRAULIC RESISTANCES.

The paper considers the method of automated calculation of pipeline resistances.
Keywords: *hydraulic resistance, pipeline, block diagram, automated calculation.*

Introduction

Calculating local and longitudinal hydraulic resistances is quite a cumbersome task. In the article the partial automation of calculation of local and longitudinal hydraulic resistances is carried out. Thanks to the use of a personal computer, it was possible to minimize the time for calculating the resistance in hydraulic systems. A program for calculating these parameters using MathCAD was developed.

Calculation method

For convenience, we introduce the notation of variables:

C − the height of the pipeline at the entrance, *m*; z_1 − the height of the pipeline at the entrance, *m*; z_2 – the height of the pipeline at the outlet, *m*; p_1 − pressure at the inlet of the pipeline, *Pa*; p_2 − pressure at the outlet of the pipeline, *Pa*; Q − fluid consumption, $\frac{m^3}{c}$; ξ − local resistance coefficient; l – the length of the pipeline, *м;* ρ − the density of the working fluid, *kg/m*^{3}*;* v − kinetic viscosity of the working fluid, $\frac{m^2}{c}$; α − kinetic energy coefficient; Δ_e − roughness of the pipeline, *м;* g − free fall acceleration; π − Pythagorean constant; d − diameter of the pipeline, *м;* Re − Reynolds number; λ − Darcy coefficient;

Now we describe the method of calculation:

Write the Bernoulli equation for the section of the pipeline:

$$z_1 + \frac{p_1}{\rho g} = z_2 + \frac{p_2}{\rho g} + \alpha \frac{8Q^2}{\pi^2 d^4 g} + \left(\xi + \lambda \frac{l}{d}\right) \frac{8Q^2}{\pi^2 d^4 g}$$

where z_1 − the height of the pipeline at the entrance, *м*; z_2 – the height of the pipeline at the outlet, *м*;
p_1 − pressure at the inlet of the pipeline, *Pa*; p_2 − pressure at the outlet of the pipeline, *Pa*; Q − fluid consumption, $\frac{m^3}{c}$; ξ − local resistance coefficient; l – the length of the pipeline, *m;* ρ − the density of the working fluid, *kg/m*^{3}*;* α − kinetic energy coefficient; g − free fall acceleration; π − Pythagorean constant; d − diameter of the pipeline, *m;* λ − Darcy coefficient.

After making some transformations we get the equation:

$$\alpha + \left(\xi + \lambda \frac{l}{d}\right) = \left(z_1 + \frac{p_1}{\rho g} - z_2 - \frac{p_2}{\rho g}\right) \cdot \frac{\pi^2 d^4 g}{8Q^2}$$

For preliminary calculations, we assume that $\lambda = 0.01$.

The equation is solved by the iteration method, in which the right and left parts of the equation are approximately the same. So, we get the first approximation to the desired diameter. [1]

Check the mode of movement of the liquid flowing through the pipeline:

$$Re = \frac{4Q}{\pi d v}$$

where, Re − Reynolds number;
d − diameter of the pipeline, *m;*
Q − fluid consumption, $\frac{m^3}{c}$;

v – kinetic viscosity of the working fluid, $\frac{m^2}{c}$;

π – Pythagorean constant.

If, $Re > 10\frac{d}{\Delta_e}$, then we obtain a turbulent mode of fluid motion, in which to calculate the Darcy coefficient, we use the universal Altshul formula:

$$\lambda = 0.11\left(\frac{68}{Re\frac{\Delta_e}{d}}\right)^{0,25}$$

where, Re – Reynolds number;

Δ_e – roughness of the pipeline, *m;*

λ – Darcy coefficient;

d – the diameter of the pipeline in the first approximation, *m*.

Then again by the method of iteration we determine the value of the required diameter of the pipeline, already using the found Darcy coefficient, according to the universal formula of Altshul.

As a result of the calculation, we obtain the desired diameter of the pipeline d, and the Darcy coefficient λ. [2]

Automated calculation program

The block diagram of the calculation program is presented in fig. 1.

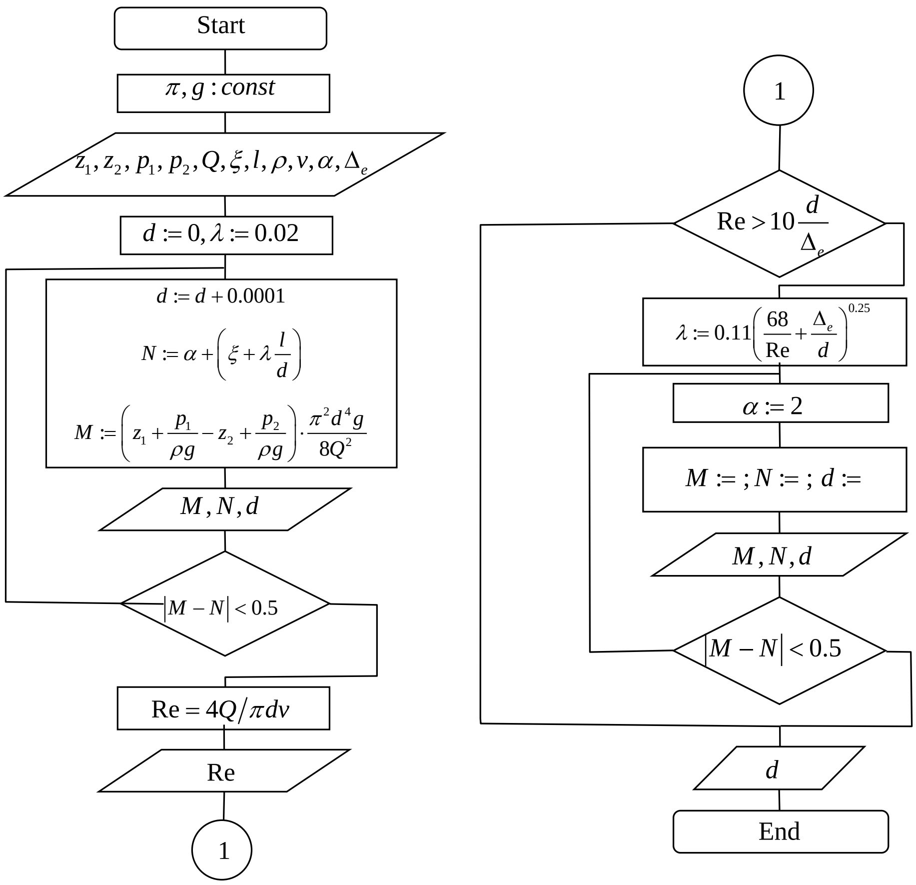

Fig. 1. **Block diagram of the program for calculating the resistance of the pipeline**

For convenience of calculation the initial data in the imaginary pipeline are chosen:

The height of the pipeline above the plane of comparison, $m - z_1 = 2$ ... $z_2 = 1{,}1$

Pressures in the pipeline, $Pa - p_1 = 100000$ ... $p_2 = 98000$

Fluid consumption, $\frac{m^3}{c}$,$- Q = 0{,}001$;

Coefficient of local resistance – $\xi = 3{,}02$;

The length of the pipeline, $m - l = 10$;

Darcy coefficient – $\lambda = 0{,}02$;
The density of the working fluid, *kg/m³* – $\rho = 1000$;
Kinematic viscosity of the working fluid, $\frac{m^2}{c}$ – $\upsilon = 0{,}000001$;
Kinetic energy coefficient – $\alpha = 2$;
The roughness of the pipeline, *m* – $\Delta e = 0{,}00008e$;
Free fall acceleration, *m/c²* – $g = 9{,}81$;
The calculation program developed in the MathCAD environment is presented below [3-4]:

$$F(m) := \left| \begin{array}{l} d \leftarrow 0.0001 \\ \text{while } z_2 - z_1 + \frac{p_2}{\rho \cdot g} - \frac{p_1}{\rho \cdot g} + \alpha \cdot \frac{8 \cdot Q^2}{\pi^2 \cdot d^4 \cdot g} + \left(\zeta + \lambda \cdot \frac{l}{d}\right) \cdot \frac{8 \cdot Q^2}{\pi^2 \cdot d^4 \cdot g} > m \\ \quad \left| \begin{array}{l} d \leftarrow d + 0.0001 \\ m \leftarrow d \end{array} \right. \end{array} \right.$$

$F(0.5) = 0.0304$

$d := F(0.5)$

$$Re := \frac{4 \cdot Q}{\pi \cdot \nu \cdot d}$$

$Re = 4.18829 \times 10^4$

$$\lambda := 0.11 \cdot \left(\frac{68}{Re} + \frac{\Delta e}{d}\right)^{0.25}$$

$\lambda = 0.02809$

$$F(m) := \left| \begin{array}{l} d \leftarrow 0.0001 \\ \text{while } z_2 - z_1 + \frac{p_2}{\rho \cdot g} - \frac{p_1}{\rho \cdot g} + \alpha \cdot \frac{8 \cdot Q^2}{\pi^2 \cdot d^4 \cdot g} + \left(\zeta + \lambda \cdot \frac{l}{d}\right) \cdot \frac{8 \cdot Q^2}{\pi^2 \cdot d^4 \cdot g} > m \\ \quad \left| \begin{array}{l} d \leftarrow d + 0.0001 \\ m \leftarrow d \end{array} \right. \end{array} \right.$$

$F(0.5) = 0.0318$

$k := F(0.5)$

$k = 0.0318$

$$x := \begin{pmatrix} k - 0.0051 \\ k - 0.001 \\ k \\ k + 0.001 \\ k + 0.051 \end{pmatrix}$$

Research results

The dependence of the Reynolds number on the diameter of the pipeline is presented in fig. 2. The dependence of the Darcy coefficient on the Reynolds number is presented in fig. 3.

$$Re(x) := \frac{4 \cdot Q}{\pi \cdot \nu \cdot x}$$

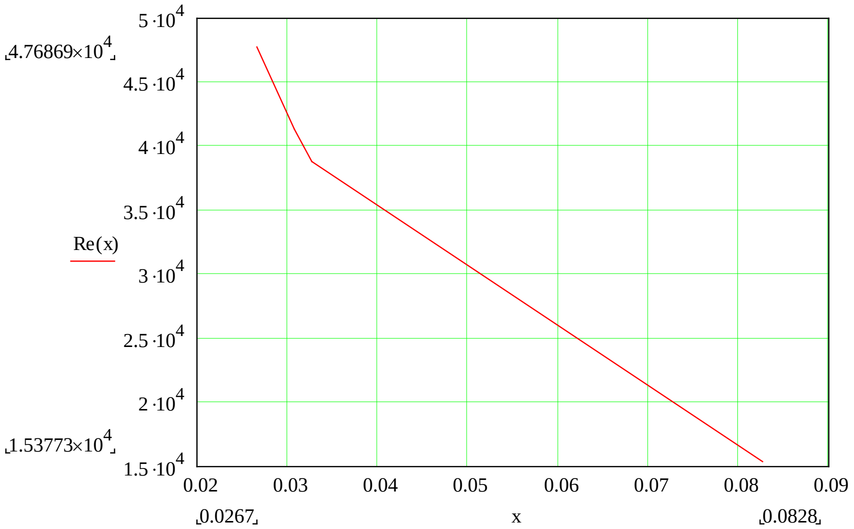

Fig. 2. **Dependence of the Reynolds number on the diameter of the pipeline**

$$\lambda(Re) := 0.11 \cdot \left(\frac{68}{Re(x)} + \frac{\Delta e}{k} \right)^{0.25}$$

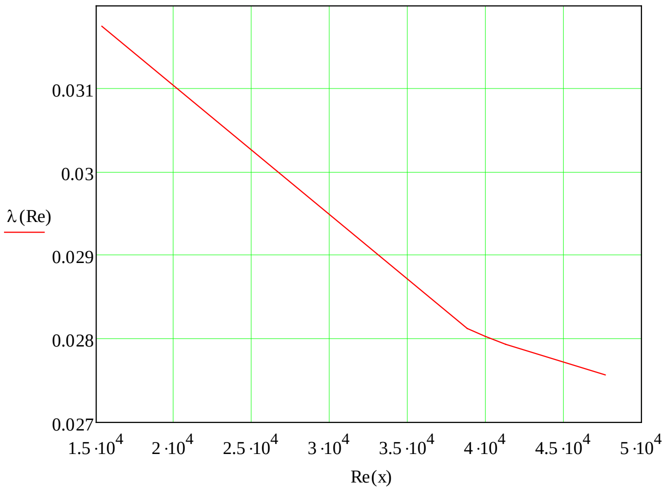

Fig. 3. **Dependence of the Darcy coefficient on the Reynolds number**

Conclusions

As a result of automation of calculations of hydraulic resistances pipeline, time for carrying out difficult mathematical calculations was considerably reduced, there was an opportunity to carry out analytical researches more quickly.

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