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MATHEMATICAL MODELING OF THE DETERMINATION OF LOCAL RESISTANCE IN THE WATER SUPPLY SYSTEM AND PRESSURE LOSS IN PIPES BY TRANSITION AREAS

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Abstract

In this article, calculation work was carried out through a novel mathematical model of calculation using the formulas Nikuradze, Stokes, Blazius, Altshunya, Ciphrinsonva, Darcy-Veysbach and related developments in practical application of the local resistance generated in the water supply system in flowing streams in water pipes. In this case, it is possible to determine the Reynolds number, hydraulic resistance coefficient and pressure loss, calculated according to the fluid flow in the pipe.

Keywords: Local resistance, sharp expansion, sharp narrowing, flat narrowing, hydraulic resistance, equivalent roughness, Reynolds number, piezometric slope, laminar motion, turbulent motion, critical velocity.

Introduction

Although the fluid flow is extremely complex, it is divided into 2 types. From the results of scientific research, it turned out that G. Hagen and D. I. Mendeleev studied fluid motion, but the English physicist O. Reynolds studied the order of fluid motion in the conditions of labaratory and obtained results in perfect accuracy. [4,5] The first type of motion is the laminar motion, and at small velocities some tubes of the fluid in the flow travel parallel to each other and are said to flow on the axis of this type of movement of the fluid. The second order action is the turbulent, distinguished by the disorganization of its movement, and observed at large velocities. Despite the fact that turbulent movement is its complexity, even in this stream, movement is based on certain laws. When switching to other types of first-order motion type, fluid velocities change, and the rate of this change may vary. [2,1] The velocity of a fluid's order of motion within the boundary of the interchange is called the critical velocity.

Main Body:

O. Reynolds was determined based on the results obtained in the experiment that the critical value of velocities at transition points from motion to turbulence in the laminar order would not be stationary, so he introduced a dimensionless parameter as a description of fluid motion and called it Reynolds criterion or Number Re:

$$Re=\upsilon\rho d/\mu=\upsilon d/\nu, \qquad (1)$$

there are $\upsilon = \mu/p$ – kinematic roughness coefficient. German scientist Schiller, based on studies, found that the smallest value of the Reynolds number in the transition from a flow of laminar order to a flow of turbulent order is 2320, and took it as a critical number. $Re_{kr}=2320$ in it, the critical velocity value is written as below based on the above equation:

$$\upsilon_{kr}= Re_{kr}\, v/d=2320\, v/d, \qquad (2)$$

2320 not a strictly fixed number. Its value can vary over a very large range and can be attributed to other types of effects, namely the roughness of the pipe, the vibration of the pipe, the sudden change in speed, etc.k. related. Delay the transition from the movement of the liquid in the laminar comb to the turbulent if the value of the effects is approximated to zero and Re_{kr} the value of 11,000-13,000 can be reached. Hence, there is a very large range between the lower and higher values, the fluid in this area can be in a laminar or turbulent type of motion, depending on the conditions. Without Laminar order motion being stationary in this range, it can quickly move to turbulent order motion. The same is called the transition area. Practical hydraulic calculations typically use the only critical value of the Reynolds number and $Re_{kr} <2320$ when fluid motion is laminar, Re_{kr} >2320 will be turbulent. It is found not only for pipes with a rounded cross-section, but also for those with different geometric shapes. During the movement of the liquid along the pipe, its pressure drops, and the decrease in the pressure of the liquid will depend on the movement of the flow.[5,6] The main reasons for this are due to friction against its wall along the length of the pipe and the energy consumption to overcome local resistances (sharp turns of the pipe, expansion, narrowing, sliding cap mounted on the pipe, valve, etc.). For example, the inner wall of the liquid is moving in a smooth pipe and local resistance h_m =0 and h_w=h while, in that case, Writing Bernoulli's equation for sections of the flow lying at some distance:

$$h + p_1/pg +\alpha_1\, \upsilon_1/2g = h_2 + p_2/pg +\alpha_2\, \upsilon_2/2g + h_w, \quad (3)$$

we write the formula below, having determined the indicated height of the piezometers with respect to the axis of the current quoted:

$$H_1 – H_2 = P_1\text{-}P_2 / pg = p_{ish}/pg, \qquad (4)$$

there are $H_1=p_1$; $H_2=p_2/pg$; $h_1=h_2$; $\upsilon_1 =\upsilon_2$ is taken to be equal, and the piezometric slope is formed if the piezometers are in the fixed range:

$$(H_1 – H_2)/l = h_w/l =tga, \qquad (5)$$

there are h_w pressure height. The pipe is carried out through the results determined by Nikuradze of internal roughness. From the above formula, it can be seen that many results are obtained in the conditions of labaratory, and now digitization of these formulas and modern solutions are being presented. It is known that the hydraulic resistance coefficient, allowance, depends not only on the Reynolds number, but also on the absolute roughness of the pipe. [2,3] Equivalent roughness (Δ_e) – this is the average value of protrusions and irregularities of different heights located inside the pipe. Relative roughness ($\varepsilon= \Delta_e/d$) this absolute roughness is the size equal to the ratio of the pipe size. If the Reynolds number increases, the laminar layer of the flow becomes thinner, and the surface becomes hydraulic rough. Conversely, when the Reynolds number becomes smaller, the turbulent flow increases and the surface becomes hydraulically smooth. Hydraulic resistance roughness to describe the effect relative roughness Δ_e/d we use the concept of, which is inverted on it d/

Δ_e is taken to be the relative smoothness of the surface. Hence the hydraulic resistance coefficient for turbulent flow λ Reynolds number and relative smoothness of the surface the function of d/Δ_e is $\lambda = f/(Re_d, d/\Delta_e)$ in appearance. [1,7]

Equivalent roughness values for the pipe [3]

1- table

№	Pipe type	Pipe position	Δ_e, mm
1	Steel pipe laid in its entirety	New, unused	0.02-0.1
		Waxed	to 0.04
		Used, plumbing	1.2-1.5
		Used for many years, cleaned	0.04
2	Monolithic soldered	In good condition, new or old	0.04-0.1
3	Steel pipe	Fresh, waxed	0.05
		Uniform rust layer	0.15
4	Cast iron	New pipe	0.25-1.0
		The top is covered with asphalt	0.12-0.3
		Used plumbing	1.4
5	Concrete	Can be used in the middle position	2.5
6	Asbestos-cement	New pipe	0.05-0.1
7	ceramics	Glazed	1.4

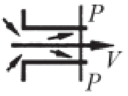
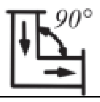
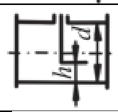
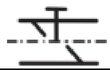
Equivalent curvature is determined differently in different materials (Table 1), and J. Poiseuille studied the laminar movement of liquid in pipes with a round cross-section, and we use the following formula to determine the pressure drop:

$$h_w = 32\upsilon v l / g d^2, \quad (6)$$

there are, $\upsilon = \mu/p$ – kinematic viscosity coefficient; *l and d are the pipe length and diameter*; v – is the speed of fluid movement.

Local resistance coefficients in pipes with different materials and local resistance

2-table

Types of local resistance	Sketches of fashion parts	Local resistance coefficient
To the pipe inlet: The tip is sharp The tip is curved		 0.5 0.05-0.2
Elbow: When R>2d When R(3-7)d		 0.5 0.3
Angular 90^0		1.1
A round cap installed on the pipe: Fully open ¾ open to the part		0.07 0.26 2.06
Medium open valve		1-3

Darcy-Weisbach studied laminar and turbulent flows and derived a formula for calculating fluid pressure drop through Reynolds number and hydraulic resistance coefficient.

$$h_w=64lv/Re_d2gd = \lambda lv/2gd, \qquad (7)$$

there are, $\lambda=64/Re_d$ – is the dimensionless hydraulic resistance coefficient, It is a function of the Reynolds number and is directly proportional to the fluid velocity. To create the Darcy-Veysbach formula for pipes with a non-round cross-section and open channels, we add the diameter in the above formula to the hydraulic radius (d=4R):

$$h_w=64lv/Re_d8Rg= \lambda lv/8Rg, \qquad (8)$$

after some substitutions, the above formula is written as below through consumption module and amount:

$$h_w=Q^2l/K^2=li=8\ \mu v/pgr^2=\lambda 32v\upsilon/gd^2\ , \quad (9)$$

The formulas given above are widely used in hydraulic calculations. Currently, the development of this field is entering a new stage. Numerical processing and modeling of these types of issues is becoming increasingly popular. Using modern programming languages, the above formulas are calculated in a couple of minutes using computer programs. Relevant developments in the implementation of calculations and practical applications through a new mathematical model for calculating the local resistance in the water supply system in the water supply system using the Blasius, Poiseuille, Darcy-Veysbach formulas. can be shown to achieve effective results. In this case, it is possible to determine the Reynolds number, the coefficient of hydraulic resistance and the pressure loss by calculating the fluid flow in the pipe, and with this type of modeling, the door of additional possibilities can be opened. The results obtained by the program can be expressed in the form of diagrams in the "EXCEL" program, and this helps to reproduce the calculations of Nikuradze and Murin and other well-known scientists in a very close condition. This, in turn, will help you manage your time and work efficiently. In turn, the obtained results are calculated separately for each transition area, and the transition areas are calculated by the type of pipe and the Reynolds number. The Stokes formula is used for the laminar region, the transition region, the Blazius formula for the first turbulent transition region I, and the Altshulya and Shifrinson formulas for the second turbulent transition region II. The Prandtl formula is used for all turbulent motion. Based on the obtained results, it is possible to choose the diameter of the pipe, the type of pipe material, nozzles for turns and bends, valves and valves of the required diameter. The calculated dependencies can be included in the equation in polar coordinates to apply the results and determine the pressure loss per meter. Changing the equations is carried out in each case, taking into account the calculated calculation scheme of the plots. This software product is written in Pascal ABC, using a graphical mode. It can be used to determine the diameter and type of material of its pipes. Comparing the results we can see the diagram below. Seeing the Nikuradze diagram:

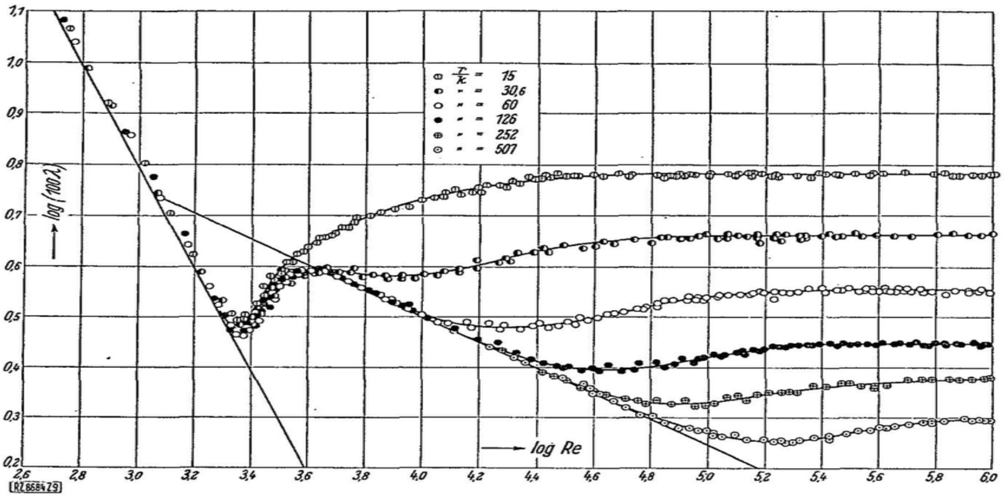


Diagram 1. Fluid movement determined by roughness in pipes.[1]

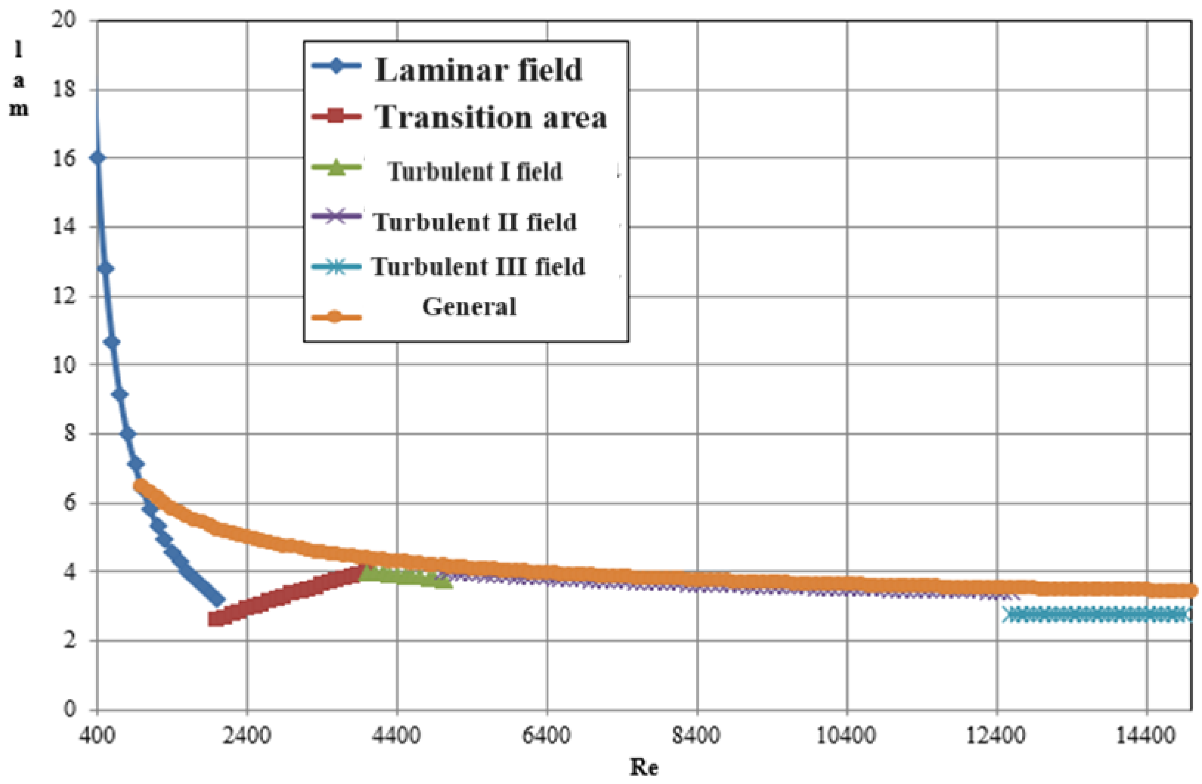


Diagram 2 results obtained through the Pascal programming language.

In this case, Equivalent roughness (Δ_e)=252 received and we can reverse this through the Nikuradze diagram above to see the other states of curvature. Looking at these results, we can see the following table:

Results considering Reynolds number and friction coefficient for Laminar motion and transition domain.

3-table

	Re	lam		Re	lam
laminar	100	64	O'tish	2000	2.587237
	200	32		2100	2.667347
	300	21.33333		2200	2.746039
	400	16		2300	2.8234
	500	12.8		2400	2.899509
	600	10.66667		2500	2.974438
	700	9.142857		2600	3.048252
	800	8		2700	3.121008
	900	7.111111		2800	3.19276
	1000	6.4		2900	3.263557
	1100	5.818182		3000	3.333445
	1200	5.333333		3100	3.402464
	1300	4.923077		3200	3.470653
	1400	4.571429		3300	3.538048
	1500	4.266667		3400	3.604681
	1600	4		3500	3.670583
	1700	3.764706		3600	3.735782
	1800	3.555556		3700	3.800306
	1900	3.368421		3800	3.864179
	2000	3.2		3900	3.927425
				4000	3.990065

Results obtained for Turbulent area I and II.

4-table

	Re	lam		Re	lam
tur1	4000	3.978519	tur2	5000	4.004745
	4100	3.954035		5100	3.989461
	4200	3.930286		5200	3.974597
	4300	3.907233		5300	3.960135
	4400	3.884842		5400	3.946057
	4500	3.863077		5500	3.932347
	4600	3.841908		5600	3.918989
	4700	3.821308		5700	3.905969
	4800	3.801248		5800	3.893274
	4900	3.781703		5900	3.88089
	5000	3.762651		6000	3.868805

Results obtained for Turbulent area III.

5-table

	Re	*lam*
Tur3	*12600*	*2.760848*
	12700	*2.760848*
	12800	*2.760848*
	12900	*2.760848*
	13000	*2.760848*
	13100	*2.760848*
	13200	*2.760848*
	13300	*2.760848*
	13400	*2.760848*
	13500	*2.760848*
	13600	*2.760848*
	13700	*2.760848*
	13800	*2.760848*
	13900	*2.760848*
	14000	*2.760848*
	14100	*2.760848*
	14200	*2.760848*
	14300	*2.760848*
	14400	*2.760848*

Fluid motions only work for fluids in turbulent flow, and of course the programming we used could still be improved upon. Reynolds number and friction coefficient in the above tables λ many scientists, such as Bazius, Prandtl, Karman, Konakov, etc., tested the relationship and issued empirical formulas. Based on the experiments of his and other authors, Kolburk proposed a formula common to all zones of turbulent order for the calculation of technical pipes, and we did programming work through the same formula.

$$\frac{1}{\sqrt{\lambda}}=2\lg\left(\frac{2.5}{Re}\frac{1}{\sqrt{\lambda}}+\frac{\varepsilon}{3.7}\right), \qquad (10)$$

Substituting this formula for the quadratic resistivity domain of rough tubes, we proceed to Prandtl formula for rough tubes:

$$\lambda=\frac{0.25}{(lg\frac{\varepsilon}{3.7})2}, \qquad (11)$$

In this way, a program was created using the formulas of other scientists, and research is being conducted on it.[3]

In turn, the results obtained for fluid movements in the general state.

6-table

umum	
Re	*lam*
1000	*6.48914*
1100	*6.302437*
1200	*6.127079*
1300	*5.97246*
1400	*5.835148*
1500	*5.712157*
1600	*5.601163*
1700	*5.500339*
1800	*5.408228*
1900	*5.323646*
2000	*5.230216*
2100	*5.161807*
2200	*5.095182*
2300	*5.033471*
2400	*4.975619*
2500	*4.921323*
2600	*4.870225*
2700	*4.822029*
2800	*4.776471*

Conclusion

As can be seen from the obtained results and the diagram, the general fluid motions only work for fluids in turbulent flow, and of course the programming we used can be improved by working on it. In this way, a program was created using the formulas of other scientists, and research is being conducted on it. Currently, I am working on a dissertation to improve this direction. DGU No. 27933 and No. 28134 all received for this program.

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