Coefficient of hydraulic friction of plastic pipes

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Abstract. Pressure systems are widely used in almost all areas of the public economy related to liquids. For example, at present, in the supply of drinking water to populated areas in the world, in heating systems, in agriculture, in cleaning water basins from muddy flows, in the mining industry, in construction, in the raising of muddy flows, in the chemical industry, in the process of moving muddy flows at the same speed, in pipeline systems of viscous muddy flows efficient systems are being used for transportation and many other purposes. Recently, plastic pipes have been widely used in production. Such pipes are cheap, light, and resistant to various decays, and their installation is relatively easy. One of the main problems in the hydraulic calculation of pressure systems is the determination of the coefficient of hydraulic friction. Recently, many scientists working in the field have been improving the hydraulic calculations of such pipelines. Yet, there is still a lot of theoretical and experimental research to be done. The article presents a method for determining the coefficient of hydraulic friction in plastic pipes in laboratory conditions.

1 Introduction

Numerous foreign and local scientists have made significant contributions to the hydraulic calculations of pressure systems and continue to do so with advancements in technology. Notable foreign researchers such as N.A. Silin, Yu.K.Vitoshkin [14], E.V.Semenenko [10], and A.E. Smoldriev [8], as well as local scientists including K.Sh.Latipov [5], A.I.Umarov [3], A.I.Shakirov [7], A.M.Arifjanov, and Kh.Ilkhamov [5] have researched determining the coefficient of hydraulic friction in pipes. This body of work can be seen as an extension of the original theory proposed in 1956 and has been further developed by A.M.Arifjonov and K.T. Rakhimov [1], who have presented laboratory-based determination and theoretical justification of hydraulic parameters for reverse slope pipes. In their experiments, they consider the suction pipe of the jet apparatus as a pressure pipe with a reverse slope and derive relationships between the flow coefficient and the direction of movement for both clear and turbid waters.

$$h_0 = \frac{\lambda_{см} l}{D} \cdot \frac{\vartheta_{кр}^2}{2g} \quad (1)$$

In his doctoral dissertation, A.R. Babayev has conducted research to enhance the methodology for calculating flow parameters in hydrotransport processes within pressure systems. One of the key findings of this study is that the longitudinal pressure within a pipe during steady-state flow can be determined based on the stress exerted by the liquid. Babayev has also proposed a formula for calculating the coefficient of hydraulic friction in this context [13]:

$$\frac{\tau_0}{\rho} = u^2 = \frac{L}{gR} h_{dl} = \frac{gR}{gRL} \frac{L}{4R} \frac{\vartheta^2}{2g} \lambda = \frac{\vartheta^2}{8} \lambda; \quad \text{or} \quad \lambda = \frac{u^2}{\vartheta^2} 8; \quad (2)$$

MNA Mikhaylev conducted a scholarly investigation into the hydraulic calculation of pressure pipes, utilizing advanced modeling methods. The findings of this research revealed that the coefficient of hydraulic friction exhibits a notable dependency on variations in the Reynolds number, which is a crucial parameter in fluid dynamics analysis [10]:

$$\lambda = f(Re; \frac{\Delta}{R}; K); \ \frac{1}{\sqrt{\lambda_0}} = 2.01\, lg(Re\sqrt{\lambda_0}) + 0.4 \quad (3)$$

It has been determined that the coefficient (denoted as K) in the hydraulic calculation of pressure pipes is influenced by the material properties of the pipe. Through experimental observation, it has been noted that errors in the calculated values tend to exhibit a negative bias at lower Reynolds numbers (Re).

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As a result, the authors have formulated their equation accordingly, taking into account these findings [11]:

$$\lambda = \frac{0.2479 - 0.0000947(7 - log_{10} Re)^4}{(log_{10}(\frac{\varepsilon}{3.615D} + \frac{7.366}{Re^{0.9142}}))^2} \quad (4)$$

This article presents methods for determining the coefficient of hydraulic resistance of plastic pipes, which are widely used in production in laboratory conditions.

Article Yıldırım G. and all considers the issue of determining the coefficient of hydraulic friction in irrigation polyethylene pipelines. Article 18 defines the Hazen-Williams head loss for polyethylene pipelines in which the flow is distributed along the length. Irrigation pipelines. [18,19]

In article Romeo E. and all, the authors present a new approach to determining the coefficient of hydraulic friction, considering the pipeline wall's roughness.[20,21]

2 Materials and Methods

In the realm of pressure pipe systems, the coefficient of hydraulic friction is commonly ascertained through two distinct approaches: theoretical and empirical formulas. Theoretical methods involve employing established formulas, such as the Darcy-Weisbach equation, to calculate the pressure loss along the length of the pipes:

$$h_l = \frac{\lambda l}{d} \frac{\vartheta^2}{2g} \quad (5)$$

λ is coefficient of hydraulic friction ;
l is the distance between the given sections [m]
$d$is pipe diameter [m]
$\vartheta$is speed between sections [m/s]
Because the coefficient of hydraulic friction in the turbulent movement zone is impossible to determine theoretically, it is determined by empirical formulas such as Blazius, Altschul, Shifronson.

The Darcy-Weisbach equation serves as the primary tool for determining the coefficient of hydraulic friction in pressure systems, as evident from the provided formulas. Laboratory-based investigations have been conducted to measure and calculate relevant parameters, excluding the coefficient of hydraulic friction, to deduce its value based on the obtained data. In pursuit of this research objective, a specialized apparatus was developed in the laboratory setting for accurately determining the coefficient of hydraulic friction in plastic pipes (Fig.1). In this device, the experimental process takes place as follows: a container (1) is filled with water and a pump (2) is lowered into this water, the liquid is transferred to a plastic pipe (3), and in this case, to change and control the consumption given by the pump, (4) is added the tap is connected and it is possible to change the consumption generated by the pump by opening or closing the tap, two sections are marked in the pipe and the distance between these sections is 5m, and the pressure in these sections is manometers installed on the device is determined by (5), the consumption water passing through the pipe is measured by the measuring device (6), and the water moved from the pipe falls into the water receiving tank (7), and in order to keep this process for a long time, the containers It is connected through an additional pipe (8), and taps (9) installed in this pipe were used to control the work process.

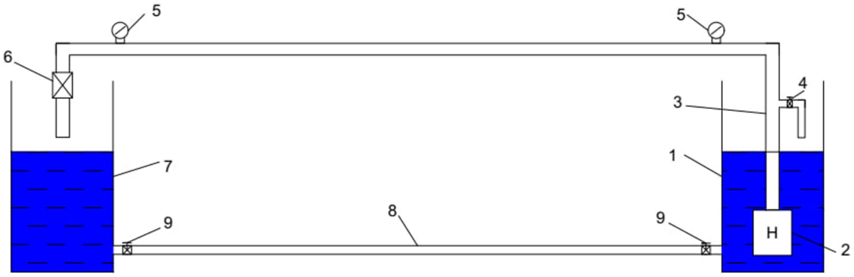

Figure 1. Diagram of laboratory device

Working equipment installed on the device:
Containers: 2 with a volume of 250 l;
A pump that creates pressure in the pipe:
Model QDX 1.5-17
$Q_{max} = 100l/min$
$H_{max} = 20m$
N/W=6.5kg
D=32mm plastic pipe;
Manometers: p =1.6 kg/sm^2 designed pressure gauge;
SGV-20 water meter;

Water consumption is measured using a water meter installed in the system, and the average speed of the flow is determined as follows:

$$\vartheta = \frac{Q}{\omega} = \frac{4Q_{o\prime l}}{\pi d^2} \tag{6}$$

The energy expended between the sections, i.e., the lost effort, is found by the difference between the two manometers as follows:

$$h_l = \frac{P_1}{\gamma} - \frac{P_2}{\gamma} \tag{7}$$

From Darcy Weissbach's formula, the hydraulic friction coefficient (λ) was derived as follows:

$$\lambda = \frac{h_l}{l}\frac{d2g}{\vartheta^2} = \frac{(h_l = \frac{P_1}{\gamma} - \frac{P_2}{\gamma})d2g}{l\vartheta^2} \tag{8}$$

Reynolds number:

$$Re = \frac{\vartheta d}{\nu} \tag{9}$$

here υ is coefficient of kinematic viscosity;

3 Results and Discussion

The experiments were carried out through multiple repetitions, and variations in other hydraulic parameters were observed at significant changes in the Reynolds number, as illustrated in Figure 2. The results of these experiments revealed that for water flow in plastic pipes, Reynolds numbers ranging from 20,000 to 25,000 were associated with the coefficient of hydraulic friction values between 0.15 and 0.08. When Reynolds numbers were in the range of 25,000 to 40,000, the coefficient of hydraulic friction was observed to be between 0.08 and 0.04. Subsequently, as the Reynolds number increased beyond 45,000 to 50,000, the coefficient of hydraulic friction decreased to 0.04.

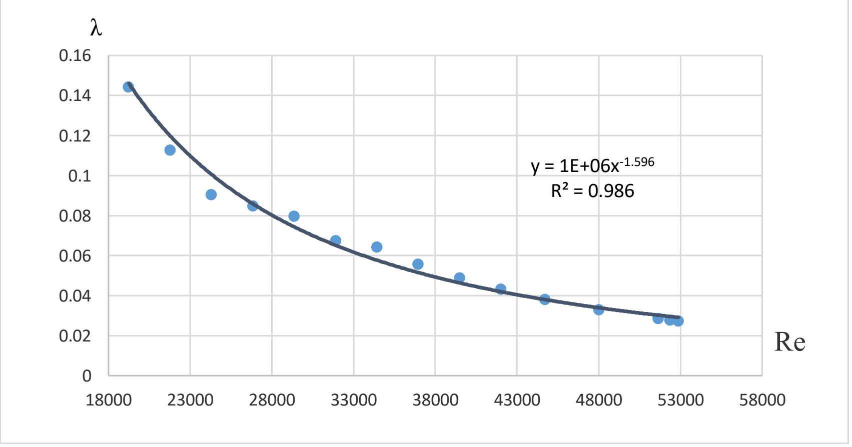

Figure 2. Graph of hydraulic friction coefficient G as function of Reynolds number

The literature analysis above shows that the coefficient of hydraulic friction is one of the main parameters in determining the pressure loss in pressure systems. During the transfer of coal and various ore products through pipelines [5], [8], the values of hydraulic friction coefficient in metal pipes in different turbulence zones have been determined, but what changes will occur if these pipes are replaced with plastic. [1] talks about the hydraulic processes in the polyethylene pipe used in hydromechanization works. The experimental studies carried out in O'hPlasimassa pipes made it possible to determine how the coefficient of hydraulic friction in such pipes can change with large changes in the Reynolds number. It is determined at what values of the Reynolds number the movement can occur in square resistance fields.

4 Conclusion

As a result of the conducted laboratory experiments, the values of the hydraulic friction coefficient of water supply plastic pipes were determined depending on the Reynolds number change over a wide range.

Furthermore, the results show that at values of Reinschlds number around 40,000-50,000, the flow begins to occur in the field of square resistance, and the coefficient of hydraulic friction takes values close to 0.04.

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