Hydraulic Friction Coefficient at Hydraulic Mixing Movement in Pressure Pipelines

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Abstract--- In production, we often encounter the movement of hydraulic mixtures in pressure pipelines. Determination of the coefficient of hydraulic friction is important in the hydraulic calculation of pressure systems. When a homogeneous fluid moves to determine this coefficient, there are several formulas that have a theoretical basis and have experimental evidence. In a single-phase flow, the coefficient of hydraulic friction depends on the nature of the movement and the relative roughness of the pipe wall. The determination of this coefficient is much more complicated when solid particles move in the pipeline along with water. When moving slurries through pipes, gravity plays a significant role. Under the influence of excess mass, transported solid particles in the general case are unevenly distributed along the depth of the stream and their bulk moves at the bottom of the pipe. This circumstance determines the axial asymmetry of the velocity field, expressed in the upward displacement of the kinematic axis of the flow relative to the geometric axis of the pipe, corresponding to the location of the maximum averaged velocity and in the lower highly concentrated layers of the flow. As for the specific hydraulic resistances, in a pressure-bearing flow, they are always greater than the specific hydraulic resistances in the corresponding flow of a homogeneous liquid. The article discusses the issue of experimental determination of the coefficient of hydraulic friction during the movement of hydraulic mixtures in pressure systems. The calculated dependences for the coefficient of hydraulic friction obtained based on the processing of experimental data by the methods of mathematical statistics are proposed and are reliable over a wide range of changes in the conditions of hydro transportation, and, therefore, they can be recommended for practical use.

Keywords--- Hydraulic Friction Coefficient, Two-phase Flow, Hydraulic Mixture, Reynolds Number, Pipelines, Pressure System.

I. Introduction

Determination of the coefficient of hydraulic friction is one of the important tasks in the calculation of pressure pipelines. For single-phase flows, there are several classical formulas where the coefficient of hydraulic friction depends on the Reynolds number and the relative roughness of the pipeline wall[1–3].

$$\lambda = f\left(Re; \overline{\Delta}\right) \quad (1)$$

where: λ – coefficient of hydraulic friction;

Re – Reynolds number;

$\overline{\Delta}$ - relative roughness of pipe wall.

For cylindrical pipelines, the Reynolds number is determined by the formula $\mathrm{Re} = \frac{\vartheta \cdot d}{\nu}$ in which average velocity of flow takes into accountϑ, geometric dimensions of the pipeline d,and kinematic coefficient of viscosity ν.

Relative roughness of pipe wall $\overline{\Delta} = \frac{\Delta}{d}$, with taking into account absolute roughness of pipe wallΔ and diameterd.

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At an insignificant Reynolds numberRe < $Re_{кр}$the flow moves in laminar mode in this case, the coefficient of hydraulic friction for single-phase flows depends on the Reynolds number and does not depend on the relative roughness of the wall

$$\lambda = \frac{64}{\mathrm{Re}} \qquad (2)$$

With an increase in the Reynolds number, the flow gradually switches from laminar to turbulent mode. In hydraulic smooth pipelines and pre-quadratic resistance regions, the coefficient of hydraulic friction depends on the Reynolds number and on the relative roughness of the wall

$$\lambda = 0{,}11\left(\bar{\Delta} + \frac{68}{\mathrm{Re}}\right)^{\frac{1}{4}} \qquad (3)$$

For higher Reynolds numbers, the flow switches to a self-similar mode where the coefficient of hydraulic friction depends only on the relative roughness of the pipe wall and does not depend on the Reynolds number.

$$\lambda = 0{,}11\bar{\Delta}^{\frac{1}{4}} \qquad (4)$$

The above and other similar formulas are widely used to calculate the coefficient of hydraulic friction during the movement of a single-phase flow. But when the hydraulic processes occurring in the pipeline are much more complicated when the solids move together with water and the solids in the pressure systems, the determination of hydraulic parameters including the hydraulic friction coefficient will differ from the movement of a single-phase flow [4–6]. In industrial practice, in some cases, in the hydraulic calculation of pressure systems for the supply of hydraulic mixtures, formulas are used that do not take into account solid particles in the water stream. As a result, gross errors are happen. The movement of suspended solids in a water stream is closely related to the turbulent mode of motion[7–9]. An analytical determination of the internal stress of which forms the theoretical basis for the coefficient of hydraulic friction during the movement of a hydraulic mixing in pressure systems is practically impossible. Therefore, most of the formulas that are used for the coefficient of hydraulic friction during the movement of hydraulic mixtures in pressure systems are empirical. Many scientists[10–15] have studied the coefficient of hydraulic friction during the movement of a hydraulic fluid in pressure systems.

II. Methods and Materials

For an experimental study of the coefficient of hydraulic friction at the laboratory of the Department of Hydraulics and Hydroinformatics of the Tashkent Institute of Irrigation and Mechanization of Agriculture, an inkjet apparatus was created for cleaning water bodies from river sediments. As a pressure pipeline in which the hydraulic mixture is transported, a suction pipe of the jet apparatus is considered. As a result of laboratory studies, the dependences of the coefficient of hydraulic friction of the suction pipe of the jet apparatus with large changes in the Reynolds number[16].

For hydraulic calculations, the density and average velocity of the slurry are determined taking into account the concentration of solid particles [17,18].

$$\rho = (1-s)\rho_1 + s\rho_2 \qquad (5)$$

$$\vartheta = \frac{(1-s)\rho_1\vartheta_1 + s\rho_2\vartheta_2}{(1-s)\rho_1 + s\rho_2} \qquad (6)$$

where: $\rho_1\vartheta_1$ - density and average speed of water;

$\rho_2\vartheta_2$ - density and average velocity of solid particles.

Changing the water pressure in front of the water outlet, the flow rate of the slurry Qcm is determined by the volumetric method and dividing by the cross-sectional area ω we find the average speed of the slurry.

Having taken the coefficient of hydraulic friction in pressure pipelines equal to unity ε = 1, the value of the flow coefficient of the suction pipe of the jet apparatus is the same as the speed coefficient φ .

$$\mu = \varphi \qquad (7)$$

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Knowing the ideal fluid flow rate $u = \sqrt{2gH}$ laboratory flow rate determination as follows:

$$\mu = \varphi = \sqrt{\frac{\vartheta}{2gH}} \qquad (8)$$

By changing the suction and pressure head in front of the water outlet, we determine the concentration of solid particles and the flow coefficient of the suction pipe. Based on the results of experimental studies, we construct dependency graphs$\mu = f(Re)$fig.1.

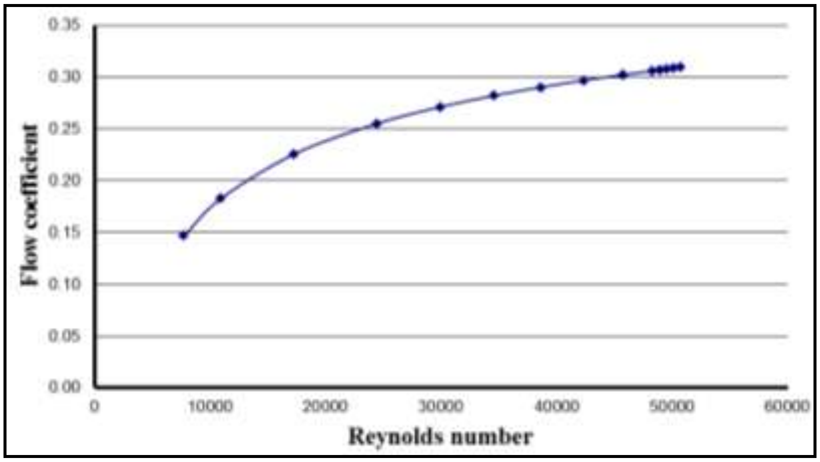

Figure 1: The Graph of the Dependence of the Flow Coefficient of the Suction Pipe of the Jet Apparatus from the Reynolds Number

Based on experimental studies, we obtain the following empirical formula for the dependence of the coefficient of flow of the suction pipe and the concentration of solid particles:

$$\mu = \mu_1 \left(\frac{\gamma}{\gamma_1} \right) \Big/ (1 - S)^2 \qquad (9)$$

where: γ – specific water weight;

γ_1 – specific weight of hydraulic mixing;

S – the concentration of solid particles.

The concentration of solid particles mainly depends on the suction height and the pressure of the water in front of the water outlet $S = f\left(\frac{h}{H}\right)$fig.2.

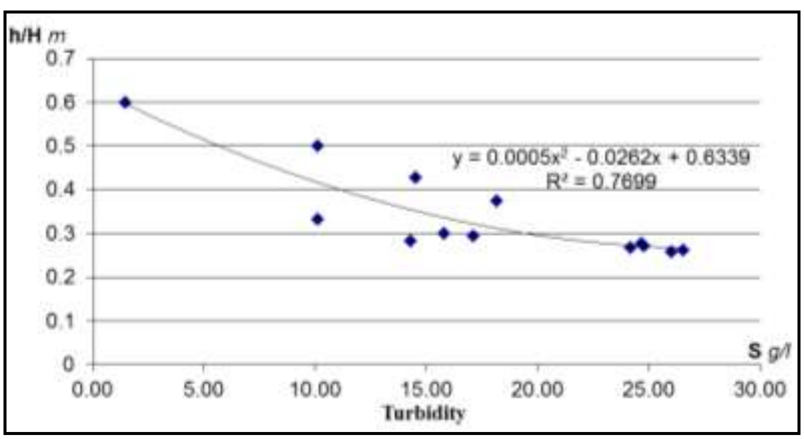

Figure 2: The Graph of the Dependence of the Turbidity of the Flow Relative Pressure

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Further research was aimed at determining the coefficient of hydraulic friction during movement of the hydraulic mixture. Having accepted the suction pipe refers to short pipelines for determining the coefficient of hydraulic friction during movement of the hydraulic mixture based on the following expression:

$$\mu = \frac{1}{\sqrt{\frac{\lambda l}{d} + \xi}} \qquad (10)$$

From here for the coefficient of hydraulic friction during the movement of the hydraulic mixture we derive the following formula:

$$\lambda_{см} = \frac{D}{l}\left(\frac{1}{\mu^2} - \xi\right) \qquad (11)$$

To apply the obtained experimental results in nature, we use the theory of hydrodynamic similarity [1,19,20]. The basis of hydrodynamic similarity is the geometric and kinematic similarity [5].

If the ratio of the length of the corresponding dimensions of the model and nature does not change, then the model is called geometric similar to nature:

$$\frac{l_1}{l_1^/} = \frac{l_2}{l_2^/} = \frac{l_3}{l_3^/} = ... = \frac{l_n}{l_n^/} = const$$

where: l_1, l_2, l_3 … l_n – the length of size of model;

$l_1^/, \ l_2^/, \ l_3^/ ... l_n^/$ - the length of respected size in the nature.

If the ratio of the average flow rates in the corresponding sections of the model and nature does not change, then the model is called kinematic similar to nature:

$$\frac{\vartheta_1}{\vartheta_1^/} = \frac{\vartheta_2}{\vartheta_2^/} = \frac{\vartheta_3}{\vartheta_3^/} = ... = \frac{\vartheta_n}{\vartheta_n^/} = const\ .$$

If the ratio of the corresponding forces of the model and nature does not change, then the model is called hydrodynamic similar to nature:

$$\frac{F_1}{F_1^/} = \frac{F_2}{F_2^/} = \frac{F_3}{F_3^/} = ... = \frac{F_n}{F_n^/} = const\ .$$

There are several criteria for hydrodynamic similarities in hydrodynamics: Ne - Newton, Sh - Struhal, Re - Reynolds, Eu - Euler, Fr - Frud.

Above the process under consideration, we use the Reynolds criterion because in this process one of the main forces is the friction force.

III. Conclusion

The determination of the coefficient of hydraulic friction during the movement of hydraulic mixtures in pressure systems is one of the important tasks. There are several theoretical and empirical formulas for the coefficient of hydraulic friction for a single-phase flow. However, the use of these formulas when moving the slurry is practically impossible. As a result of experimental studies, the dependence of the coefficient of hydraulic friction during the movement of hydraulic mixtures in pressure systems on the flow rate of the pipeline with large changes in the Reynolds number is determined. The following formula is proposed for the coefficient of hydraulic friction during the movement of hydraulic mixtures in pressure systems:

$$\lambda_{см} = \frac{D}{l}\left(\frac{1}{\mu^2} - \xi\right) \qquad (12)$$

The relationship between the coefficients of flow rates of clean water and hydraulic mixtures is determined.

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$$\mu = \mu_1 \left(\frac{\gamma}{\gamma_1} \right) \Big/ (1 - S)^2 \tag{13}$$

The use of the theory of hydrodynamic similarity for the application of the obtained experimental results in kind is substantiated. In the process under consideration, we use the Reynolds criterion because in this process one of the active forces is the friction force.

References

[1] Altunin V S 1977 Hydraulics - N.N. Kremenetskii, D.V. Shterenlikht, V.M. Alyshev, and L.V. Yakovleva *Hydrotechnical Constr.*11 333–4

[2] Brandt MJ, Johnson KM, Elphinston AJ, Ratnayaka DD, Brandt MJ, Johnson KM, Elphinston AJ and Ratnayaka D D 2017 Hydraulics *Twort's Water Supply* 581–619

[3] FUJITA H and FUJITA H 1962 Two-Component Systems *Math. Theory Sediment. Anal.* 46–143

[4] Wang J, Yang T, Wei T, Chen R and Yuan S 2020 Experimental determination of local head loss of non-coaxial emitters in thin-wall lay-flat polyethylene pipes *Biosyst. Eng.*190 71–86

[5] Kim JH, Kwon SH, Yoon KS, Lee DH and Chung G 2016 Hydraulic Experiment for Friction Loss Coefficient in Non-circular Pipe *Procedia Eng.*154 773–8

[6] Lu C, Kong R, Qiao S, Larimer J, Kim S, Bajorek S, Tien K and Hoxie C 2018 Frictional pressure drop analysis for horizontal and vertical air-water two-phase flows in different pipe sizes *Nucl. Eng. Des.*332 147–61

[7] Sorgun M, Aydin I and Ozbayoglu ME 2011 Friction factors for hydraulic calculations considering presence of cuttings and pipe rotation in horizontal/highly-inclined wellbores *J. Pet. Sci. Eng.*78 407–14

[8] Sundstrom LRJ, Saemi S, Raisee M and Cervantes M J 2019 Improved frictional modeling for the pressure-time method *Flow Meas. Instrum.*69 101604

[9] Wang X, Sui X, Zhang S, Yan M, Yang J, Hao J and Liu W 2019 Effect of deposition pressures on uniformity, mechanical and tribological properties of thick DLC coatings inside of a long pipe prepared by PECVD method *Surf. Coatings Technol.*375 150–7

[10] Ferràs D, Manso PA, Schleiss A J and Covas D I C 2016 Experimental distinction of damping mechanisms during hydraulic transients in pipe flow *J. Fluids Struct.*66 424–46

[11] Hu Q, Wang S, Qu T, Xu T, Huang S and Wang H 2020 Effect of hydraulic gradient on the permeability characteristics of foam-conditioned sand for mechanized tunnelling *Tunn. Undergr. Sp. Technol.*99 103377

[12] Li Y, Wu S and Jin T 2018 Experimental investigation on pressure drop and friction factor of slush nitrogen turbulent flow in helically corrugated pipes *Cryogenics (Guildf).*94 56–61

[13] Matoušek V 2009 Predictive model for frictional pressure drop in settling-slurry pipe with stationary deposit *Powder Technol.*192 367–74

[14] Nazari-Giglou A, Jabbari-Sahebari A, Shakibaeinia A and Borghei SM 2016 1. Nazari-Giglou, A., Jabbari-Sahebari, A., Shakibaeinia, A. & Borghei, S.M. An experimental study of sediment transport in channel confluences. Int. J. Sediment Res. 31, 87–96 (2016). An experimental study of sediment transport in channel confluences *Int. J. Sediment Res.*31 87–96

[15] Arifjanov A, Samiev L, Apakhodjaeva T and Akmalov S 2019 Distribution of river sediment in channels *IOP Conference Series: Earth and Environmental Science* vol 403

[16] Arifjanov A, Rakhimov K, Abduraimova D and Akmalov S 2019 Transportation of river sediments in cylindrical pipeline *IOP Conference Series: Earth and Environmental Science* vol 403

[17] Arifjanov A and Fatxullaev A 2020 Natural Studies for Forming Stable Channel Sections *Journal of Physics: Conference Series* vol 1425

[18] Engelund F and Fredsøe J 1982 Hydraulic Theory of Alluvial Rivers *Adv. Hydrosci.*13 187–215

[19] Alghamdi Y, Peng Z, Zanganeh J, Moghtaderi B and Doroodchi E 2019 Hydrodynamics similarities in cold flow model of chemical looping combustors: An experimental study *Powder Technol.*343 542–50

[20] Natarajan P, Velraj R and Seeniraj R V 2014 Hydrodynamic similarity in liquid–solid circulating fluidized bed risers *Powder Technol.*264 166–76.

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