

PAPER • OPEN ACCESS

Hydrotransport of river sediments in hydroelelators

To cite this article: Aybek Arifjanov *et al* 2020 *IOP Conf. Ser.: Mater. Sci. Eng.* **869** 072003

View the [article online](#) for updates and enhancements.

Hydrotransport of river sediments in hydroelevator

Aybek Arifjanov¹, Kudrat Rakhimov¹, Dilbar Abduraimova¹, Askar Babaev²
and Sarvar Melikuziyev¹

¹Tashkent Institute of Irrigation and Agricultural Mechanization Engineers, Hydraulic Department, 100000 M.Ulugbek str. Tashkent, Uzbekistan

²Tashkent Railway Engineering Institute, Transportation Department, 100000 8-Mart str. Tashkent, Uzbekistan

E-mail: obi-life@mail.ru, s.melikuziyev@tiame.uz

Abstract. The article considers the hydrotransport of river sediment in a cylindrical pipeline. To describe the nature of hydraulic phenomena, experiments were carried out for single-phase and two-phase flows. Based on the results of the experiments, the main hydraulic parameters of the suction pipeline of the hydraulic elevator were determined during hydrotransport of river sediment. Based on the processing of available data, as well as data from specially designed experiments, the dependences of the flow coefficient at the expiration of the slurry flow from the hydraulic elevator pipeline on the Reynolds number are valid, which are valid for certain limits of the change in Reynolds numbers. The design parameters of the hydraulic elevator are substantiated, calculation formulas are given for determining the characteristics of a hydraulic mixture consisting of a solid particle and a carrier fluid. The methodology for calculating the concentration distribution and the method for determining the bottom concentration are given. A calculation formula is proposed for determining the flow rate and flow rate of a hydraulic elevator slurry. As a result of the analysis of these experiments, the dependences of the concentration of solid particles on the relative pressure in the hydraulic elevator are established.

1. Introduction

The flow of a two-phase mixture (slurry), consisting of solid particles and a continuous medium transporting them, is widespread in nature and technology. Pipeline transport occupies an important place in the transport system of industrialized countries. In a number of countries, trunk hydrotransport systems have been built and are successfully operating to move tens of hundreds of kilometers of coal, iron and copper ore concentrates and other minerals through pipelines. Pipeline transport is widely used in gas and oil technology, chemical technology, biomechanics, irrigation, land reclamation, and other industries [1,2, 3,4,7, etc.].

The theoretical foundations of the movement of hydraulic mixtures in pipelines are described in [1,2, 3,4, etc.]. The main mode of motion of a mixture of liquid and solid particles is turbulent. Therefore, the kinematic structure of such flows is closely related to turbulence and, especially, to physical phenomena occurring in flows of a homogeneous fluid with developed turbulence. The presence of solid particles in a homogeneous fluid flow can significantly affect its turbulent characteristics. Typically, river sediments have a higher density than the density of the liquid, which causes an



asymmetry in the distribution of averaged velocities and concentration over the flow cross section [2, 3,4,5,6,7,12,13 and others].

In this paper, we consider the movement of a two-phase mixture (liquid and river sediments) in a horizontal cylindrical pipe with an uneven distributed concentration. In this case, special attention is paid to the study of the throughput of pipelines, where taking into account the distribution of sediment concentration over the cross section of the pipeline is of great importance in describing the nature of the two-phase flow.

With the effective cleaning of sediments of the upper pools of hydraulic structures, sedimentation tanks for various purposes, reservoirs, tank chambers of pumping stations, various hydraulic elevators are used. For the rational operation of hydraulic elevators, a determination of the throughput and hydraulic parameters of the installation is required.

2. Methodology

One of the main factors affecting the efficiency of hydraulic elevators is the nature of the movement of a solid particle in cylindrical pipelines. Theoretical and experimental work shows that the concentration distribution over the vertical diameter of a horizontal pipeline is clearly uneven. To determine the plot of the distribution of the concentration of the second phase over the cross section, the following formula was proposed [9,10,12,13]:

$$s_i = s_0 \cdot \exp \left[\left[-\frac{3 \cdot (\rho_i - \rho) \cdot g}{\rho_i \cdot u_2^2} + \frac{3}{2} \cdot \rho C_0 \cdot \frac{S_r \cdot w_r^2}{m_r \cdot u_2^2} \right] (R + r \sin \varphi) \right] \quad (1)$$

there: s_{i0} - concentration of i -ith fraction of the particle at the bottom; ρ_i , ρ - bulk density of particles and liquids; u_2 - is the longitudinal velocity of the i -th fraction; S_r - is the particle cross-sectional area; C_0 - resistance coefficient; W_r - is the relative velocity of the particle.

From the analysis of the proposed formula (1), it follows that the uneven distribution of the concentration of the second phase is obtained by this formula. By the sticking condition, on the wall $u_2=0$, according to formula (1), we have $s_0=0$.

For the convenience of calculating the concentration distribution according to the proposed formula, the variable speed of the second phase over the flow cross section in formula (1) is replaced by the average speed of the second phase.

$$u_{cp} = \frac{\int_0^R \int_0^{2\pi} u dr d\varphi}{\pi R^2} \quad (2)$$

which can be considered constant over the flow cross section.

In addition, there are difficulties in using formula (1) related to the determination of the bottom concentration value s_0 . Currently, there are a number of empirical formulas [14,15,16,17] for determining s_0 . However, their application in practical calculations requires additional research. In many works [10, 12, etc.] s_0 is determined through the average concentration of the second phase. Given these works, s_0 is determined by the following formula:

$$s_0 = \frac{s_{cp} \cdot \pi R^2}{\int_0^R \int_0^{2\pi} \exp \left\{ -3g(\rho_i - \rho)(R + r \sin \varphi) \left(\frac{di}{do} \right)^3 / \rho_i u_{2cp}^2 \right\} dr d\varphi} \quad (3)$$

Here, the average concentration of the second phase s_{av} can be determined by measurement.

Based on the proposed formula (3), calculations were performed to evaluate the effect of the pressure drop on the concentration distribution over the depth of the stream. With an increase in the pressure drop, an increase in the steepness of the concentration distribution curves is observed due to

the redistribution of solid particles along the depth of the flow, caused by an increase in weighing forces. The bulk of the second phase, located in the lower part of the pipeline, is transported at speeds lower than the average flow rate. It is in this region that the deformation of the velocity diagram is detected. If we trace the concentration distribution diagrams for different values of the pressure drop, it will be noticeable that all the curves intersect at approximately the same point.

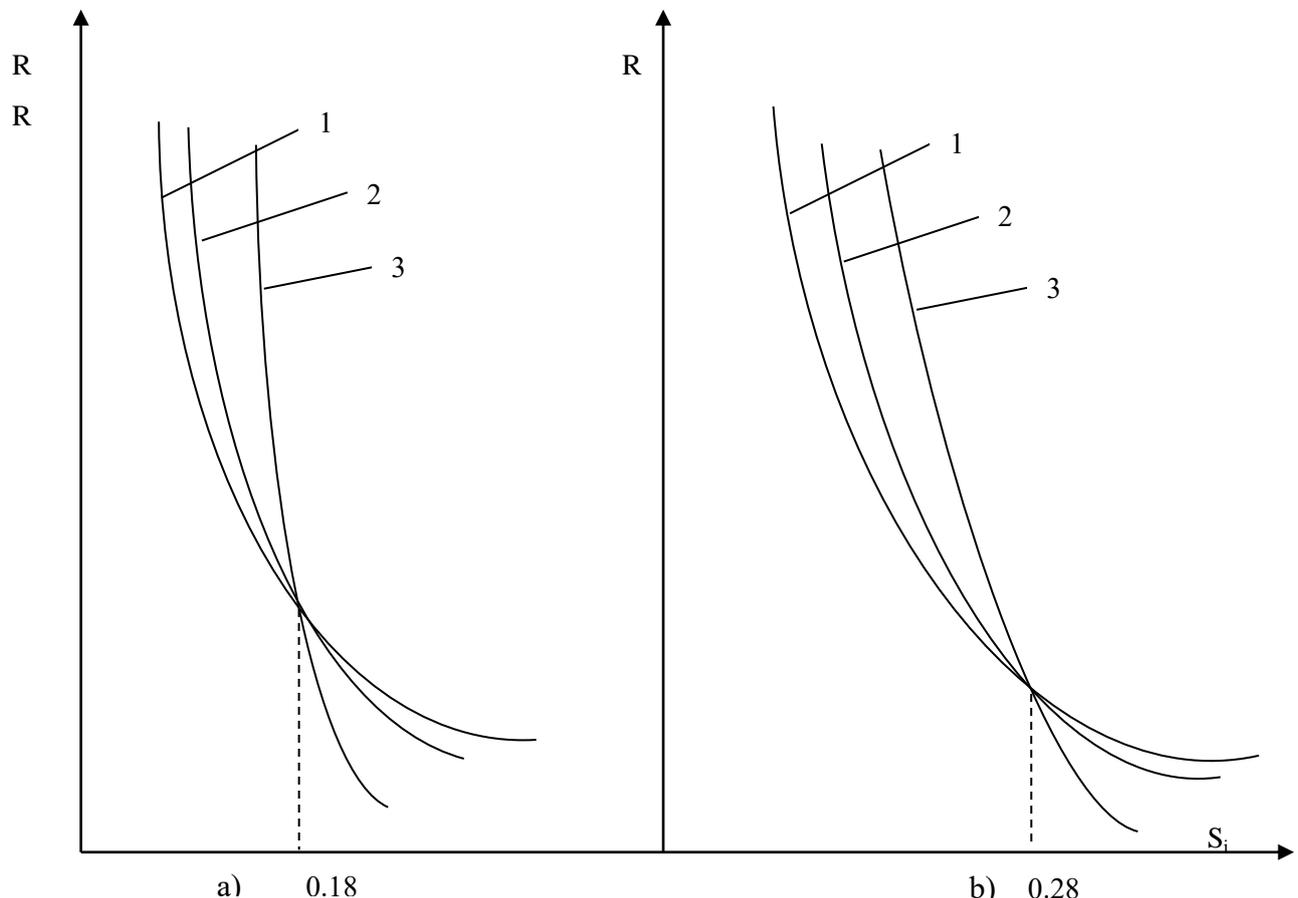


Figure 1. The distribution of the concentration of the second phase in the depth of flow depending on the pressure drop at different values of the average concentration, a) $s_i = 0.18$; b) $s_i = 0.28$.

From the diagram of the concentration distribution it is seen (Fig. 1.) that the intersection point does not depend on the pressure drop and the intersection point corresponds to the average concentration of the second phase.

To assess the hydraulic parameters of a hydraulic elevator for transport of river sediment, experimental studies were conducted. Fig. 2. The experimental setup is shown. Transport of river sediments is carried out using a hydraulic elevator operating on the principle of the jet apparatus, which is widely used in practice [10,13,14,16].

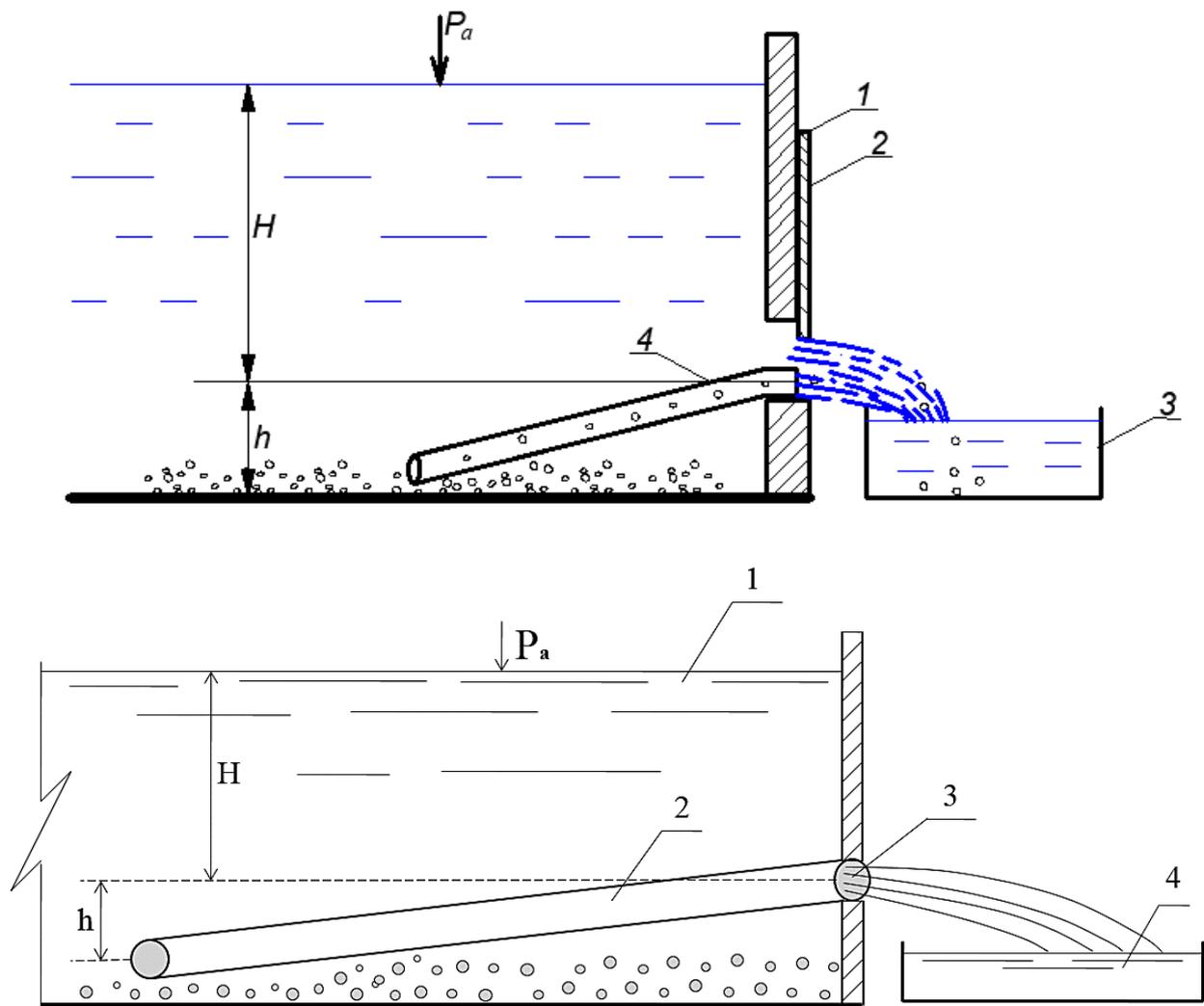


Figure 2. The experimental setup.

1 - reservoir; 2 - inlet pipe; 3 - valve; 4 - discharge pipe; 5 - holes; 6 - disk; 7 - suction pipe; 8 - drain tank; 9 - piezometer; 10 - measured tank; 11- valve; H is the flow head; h-suction height.

3. Results

As a result of special experiments, the dependences of the resistance coefficients on the Reynolds number were established for some practically important cases, when the net flow and hydraulic mixture from the hydraulic elevator pipeline expire, the changes in the Reynolds numbers are valid within certain limits.

To describe the nature of hydraulic phenomena, experiments were carried out for a single-phase and two-phase flow. According to the results of the experiments, the main hydraulic parameters of the proposed hydraulic elevator [12,13] during hydrotransport of river sediments were determined.

Discussions For the intermediate region of Reynolds numbers, in which inertia forces and viscosity forces are simultaneously manifested, by processing experimental data and also special experimental studies, the dependences of the local resistance coefficients for fluid motion in pipes on the fluid

viscosity (Reynolds numbers), which are valid over a wide range, were established Reynolds numbers, and calculation formulas are proposed.

Based on the processing of experimental data, was obtained the dependence of the flow coefficient on the μ Reynolds number.

The calculation formula obtained on the basis of experimental data processing for the hydraulic elevator flow coefficient (the correlation coefficient is $r = 0.87$) for a two-phase flow has the form:

$$\Delta\mu_2 = 0,58 - \frac{4,22}{\sqrt[4]{Re_H}}. \quad (4)$$

The flow rate coming out of the hydraulic elevator pipeline and openings is determined by the formula:

$$Q = Q_1 + Q_2 \quad (5)$$

there: Q_1 - the discharge of the working stream, determined when closing the suction pipe of the hydraulic elevator, where the flow is single-phase;

Q_2 - discharge of the slurry in the suction pipe of the hydraulic elevator:

$$Q_2 = Q - Q_1 \quad (6)$$

Finally, the formula for the flow rate of the suction pipe of the elevator has the form:

$$Q_2 = \Delta\mu_2 \omega \sqrt{2gH} \quad (7)$$

Thus, a calculated dependence is proposed for determining the flow rate of the hydraulic mixture in the suction pipe of the hydraulic elevator.

Based on experimental studies, the influence of relative pressure $\left(\frac{h}{H}\right)$ on the conveying ability of the jet apparatus is analyzed.

As a result of processing the experimental data, the dependence of the turbidity of the flow on the relative pressure in the form is obtained:

$$S = A_1 \cdot \rho_t \left(0,75 - \frac{h}{H}\right)^{0,5} \quad (8)$$

there: ρ_t - is the density of suspended particles, kg/m^3 ;

A_1 - coefficient, determined on the basis of experimental data;

h - is the suction height, m ; H - pressure of flow, m ;

Moving from the turbidity of the flow to the average concentration S , it will be possible to describe the nature of the distribution of concentration (6) of the slurry over the cross section of the pipeline.

4. Conclusions

1. It was revealed that the non-uniform distribution of the S_i concentration over the depth of the flow is characterized by a large accumulation of solid particles in its lower part, which tends to move near the bottom of the flow, which causes great resistance to the movement of the lower layers of the liquid. It has been quantitatively established that there is a close relationship between the distribution of the S_i concentration and the longitudinal velocities along the depth of the stream.

2. On the basis of processing the available data, as well as the data of specially designed experiments, the dependences of the flow coefficients at the expiration of the slurry flow from the hydraulic

elevator pipeline on the Reynolds number are valid, valid for certain limits of the change in Reynolds numbers.

3. The design parameters of the hydraulic elevator for cleaning water bodies from river sediments are substantiated, design formulas are proposed for determining the throughput and hydraulic parameters of the proposed hydraulic elevator.

References

- [1] Asaulenko I.A. et al. Theory and applied aspects of hydrotransport of solid materials. –Kiev: Naukova Dumka, 1981-365 p.
- [2] Karasik V.M., Asaulenko I.A. Pressure hydrotransport of sand materials. -Kiev: Science. Dumka, 1965.-107 p.
- [3] Arefiev N.N. The theoretical rationale for the introduction of a hydraulic monitor soil receiver with forced soil supply: Hydrotechnical construction 2010 №6. S. 36-39
- [4] Arifjanov A.M., Fathullaev A.M. Dynamics of a weighted flow in channels. Tashkent: Fan, 2014. –180 p.
- [5] Matousek, V. (1996). “Solid Transportation in Long Pipeline Connected with a Dredge”, Terra et Aqua, Vol. 121, No.1, 72-76.
- [6] Matousek, V. (1996). “Solid Transportation in Long Pipeline Connected with a Dredge”, Terra et Aqua, Vol. 121, No.1, 72-76.
- [7] Wicks, M. (1968). “Transportation of solids at Low Concentrations in Horizontal Pipes” Amer. Soc. of Civil Eng. Symposium on Solid-Liquid Flow in Pipes, Univ. of Pennsylvania, March 1968.
- [8] Krill S.I. Pressure-bearing flow. - Kiev., 1990. -158 p.
- [9] Rakhimov K.T., Abduraimova D.A., Duskulova N.A. Critical speed of hydraulic flow in cylindrical pipes // Tashkent, Tashkent State University News, 1-2 pp. 2012. 60-63 pp.
- [10] Smoldyrev A.E. Calculation of the distribution of concentration and flow rate of hydraulic mixtures in pipes // Hydrotechnical construction. 2002.-N7.-C.26-29.
- [11] Razumov I.M. Pneumatic and hydraulic transport in the chemical industry. -M: Chemistry, 1979.- 248 p
- [12] Shtin S.M. Lake sarpopels and their integrated development. - M .: MGGU, 2005.-116s.
- [13] Latipov K.Sh., Arifzhanov A.M. Issues of the movement of a weighted stream in open channels. T. 1994 -110s.
- [14] Arifzhanov AM, Fathullaev AM, Rakhimov K.T., Nizamutdinov D. Inkjet apparatus for cleaning water bodies // Republican scientific-practical conference "Development of water management and land reclamation of the Republic of Uzbekistan during the transition to a market economy" Tashkent, 2006. 41-42.
- [15] Rakhimov K., Khamraev S., Rasulov R. Turbulent flow flow // Agro Ilm - Toshkent, 2010.-№3. –P.41-45.
- [16] Bryansk Yu.V., Markova I.M., Ostyakova A.V. Hydraulics of water and suspension flows in rigid and deformable boundaries. Moscow. 2009 - 263 p.
- [17] Arifzhanov A.M., Fathulloev A.M. A program for calculating the dynamic parameters of a turbulent weighted flow. Copyright certification for computers No. DGU 04730. Agency for Intellectual Property of the Republic of Uzbekistan. - Tashkent, 06/02/2017.
- [18] Karashev A.V. Theory and methods of calculating river sediment. - L .: Gidrometeoizdat, 1977.-270 p.