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Dynamics of Hydraulic Size and Constraint Coefficient of Flow of High Turbidity

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Abstract:

The article presents the main patterns in the dynamics of hydraulic size and the flow restriction coefficient of increased turbidity. The results of the analysis and research of the authors showed that when water is saturated with sediment, different curves are obtained for different sediment diameters. With increasing heterogeneity of sediment composition, the exponent increases. It has been proven that the change in the constraint coefficient with depth is insignificant compared to the hydraulic coarseness of the sediment. The highest values of the constraint coefficient are observed at the surface of the flow and towards the bottom this value decreases.

Keywords: *flow, turbidity, speed, flow restrictions, density, turbulence, dynamics.*

INTRODUCTION

The hydraulic flow size characterizes the rate of sediment deposition in the flow and is the determining factor in determining the siltation of a riverbed or reservoir. Although, the change in the constraint coefficient with depth is insignificant compared to the hydraulic size of the sediment and the highest values of the constraint coefficient are observed at the surface of the stream and towards the bottom this value decreases. Therefore, the above-mentioned flow parameters determine the nature of the process of sediment deposition to the bottom of a channel or reservoir, which is the basis for the relevance of studying them in channel hydraulics. The object of study of this process is stream reservoirs with saturated turbidity. The main characteristic that determines the movement of solid particles in a flow of increased turbidity is the speed of their fall under the influence of gravity in standing water, called hydraulic size. The fall of particles with a small content in the volume of liquid is called free fall, and the fall with a large content of particles is constrained. The first theoretical solution to the problem of determining hydraulic size belongs to [1], who, based on the law of laminar flow, derived a formula for determining the resistance of a ball when it falls out in water.

Many researchers [2-4] studied the degree of influence of particle shape on their hydraulic size and found that it depends on the parameter that determines the turbulence of the flow. The formulas they obtained were used only for the movement of large sediment particles. The most detailed studies of the hydraulic fineness of sediments were carried out abroad [5-10]. Studies have been carried out to establish the hydraulic size under constrained falling of particles.

To determine the hydraulic fineness of sediment during a constrained fall of particles, the traditional formula is usually used, where the hydraulic fineness of the flow is determined by the product of the falling velocity of a sediment particle with a coefficient that takes into account the decrease in hydraulic fineness with a large amount of particles in the volume of liquid, due to an increase in the viscosity of the density of the mixture.

To establish the above coefficient, there are numerous formulas [11-13]. These formulas are mainly obtained in relation to granular soils and take into account only the influence. The value of the hydraulic sediment coarseness is the density of the mixture. Meanwhile, as noted above, in water masses saturated with sediment, the hydraulic size of sediment particles, in addition to density, is also seriously influenced by changes in the viscosity of the medium. Taking this into account, empirical dependencies were obtained based on formulas [11,12] to determine the values of the correction factor for the hydraulic particle size in a liquid increased by fine-grained wear. Separately for the region of the laminar deposition regime, for the region of the transition regime and for the region of the turbulent deposition regime. As follows from these formulas, they differ from the formulas proposed [11] in that they take into account the influence of changes in the viscosity of the medium caused by the presence of small particles in the form of the ratio of the kinematic viscosity coefficients of pure water and the mixture.

Despite numerous studies to establish the dynamics of hydraulic size and flow constraint coefficient, the dynamics of the above-mentioned flow parameters for a saturated turbidity flow has not been studied at a sufficient level, so it was chosen as the main goal of this work. Based on the chosen goal, the research objectives were determined:

- establishing the values of the ratio of the coefficient of kinematic viscosity of pure water and a mixture with sediment depending on the saturation of the flow;

Establishment of stream saturation with sediment;

- determination of the values of the ratio of the coefficient of kinematic viscosity of pure water and the mixture;

- the determination of sediment size is distributed differently in depth, depending on the flow speed and the degree of sediment heterogeneity;
- analysis of distribution curves of hydraulic sediment size vertically;
- establishing the exponent depends on the flow velocity and the degree of sediment heterogeneity;
- determination of the change in the constraint coefficient in depth is insignificant compared to the hydraulic size of the sediment.

RESEARCH METHOD

The study of field research data, processing of experimental data and establishing the basic patterns of the dynamics of the speed of falling solid particles to the bottom of the bed of a stream of high turbidity is a research method.

RESEARCH RESULTS AND DISCUSSION

To establish the values of the ratio of the coefficient of kinematic viscosity of pure water and a mixture with sediment, depending on saturation, data were used to determine the viscosity of the mixture on a viscometer using the results of research [14-18] calculated using the formula [19, 20]. These data made it possible to construct graphs of the dependence $\frac{\nu_w}{\nu_{m.s.}} = f(S)$.

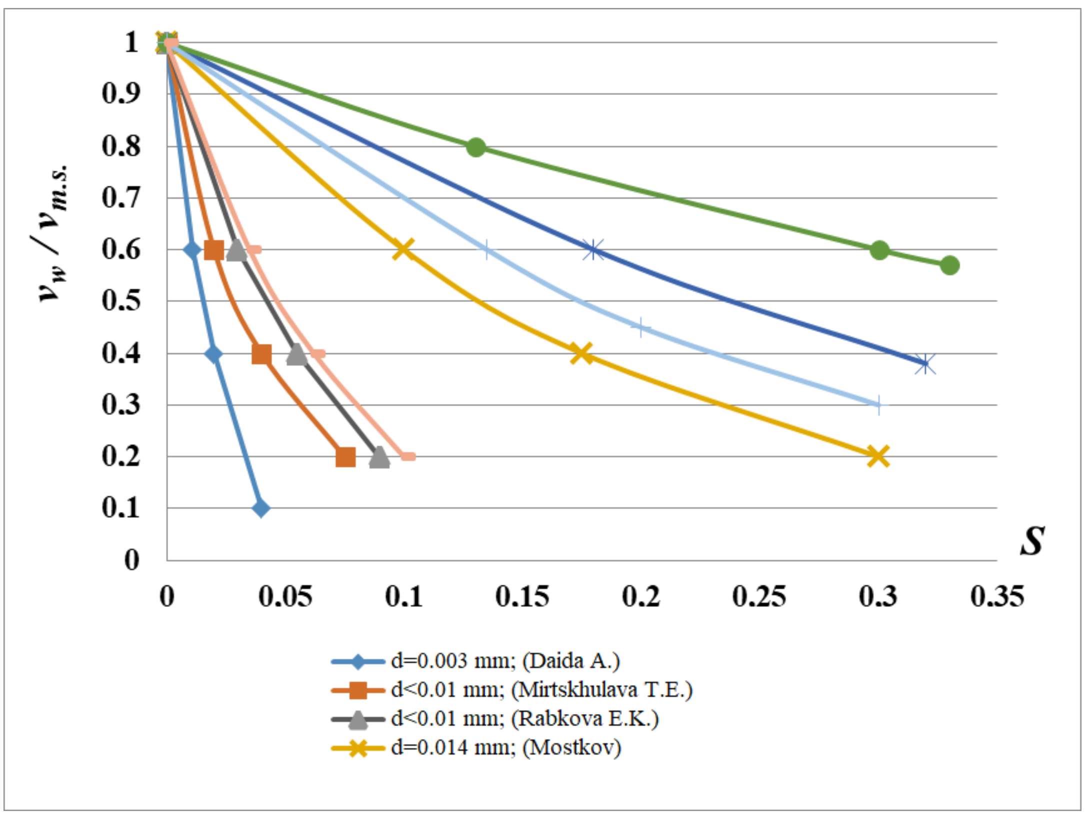

Figure 1. Graphs of dependence $\frac{\nu_w}{\nu_{m.s.}} = f(S)$.

When water is saturated with sediment, different curves are obtained for different sediment diameters. The smaller the sediment size at the same saturation, the greater the effect on the viscosity of the mixture.

Based on the curves (Fig. 1.) the following formula was obtained

$$\frac{\nu_w}{\nu_{m.s.}} = 1 - \frac{0,035}{d_{sus.}} S^{0,85} \quad (1)$$

The coefficient $\frac{0.035}{d_{sus}}$ in this formula takes into account the increase in the viscosity of the mixture with a decrease in the diameter of sediment particles. Moreover, its numerator 0.035 has a dimension of a millimeter and characterizes the maximum size of sediment particles that affect the viscosity of the mixture.

Formula 1 should be rewritten as follows:

For the laminar deposition region;

$$\omega_c = \omega(1 - \frac{0{,}035}{d_{sus}} S^{0{,}85}) \cdot \frac{\rho(\rho_T - \rho_c)}{\rho_c(\rho_T - \rho)} \quad (2)$$

For the region of transitional deposition regime;

$$\omega_c = \omega \left(1 - \frac{0{,}035}{d_{sus}} S^{0{,}85}\right)^{1/3} \cdot \left[\frac{\rho(\rho_{s.p.} - \rho_m)}{\rho_m(\rho_{s.p.} - \rho)}\right]^{2/3} \quad (3)$$

For the region of turbulent deposition regime;

$$\omega_c = \omega \sqrt{\frac{\rho(\rho_{s.p.} - \rho_m)}{\rho_m(\rho_{s.p.} - \rho)}} \quad (4)$$

where $\rho,\ \rho_T, \rho_c$ – density of water, solid particle and mixture.

In figure 2 diagrams of the distribution of hydraulic particle size of sediment particles in depth are presented, constructed according to the data of experimental experiments carried out on the riverbed site of the National Research University "TIIAME". As follows from these diagrams and other data, the sediment size is distributed differently in depth, depending on the flow velocity and the degree of sediment heterogeneity. At high velocities and small, relatively homogeneous sediments, the particle size varies little with depth. With an increase in the heterogeneity of sediment composition, small fractions mainly saturate the upper layers of the flow, while larger particles are concentrated in the lower layers.

[11] explains the physical reason for this distribution of the size of solid particles over the cross section of the flow as follows: "Since the velocity gradient at the bottom of the flow is greatest and decreases towards the surface of the flow, then, naturally, the largest particles are kept in suspension at the bottom, and the higher from, the smaller the size of the transferred particles. Small particles are in the area of predominance of large particles, as if they are washed out into the upper layers due to the resulting circulation flow of liquid around large particles."

Analysis of the vertical distribution curves of hydraulic sediment size showed (Fig. 2.) that these curves can be described by the equation

$$\omega_y = \omega_g[1 - (y/H)^{z_1}] \quad (5)$$

where ω_g hydraulic sediment size near the stream bottom; z_1- exponent varying from 0 to 1.

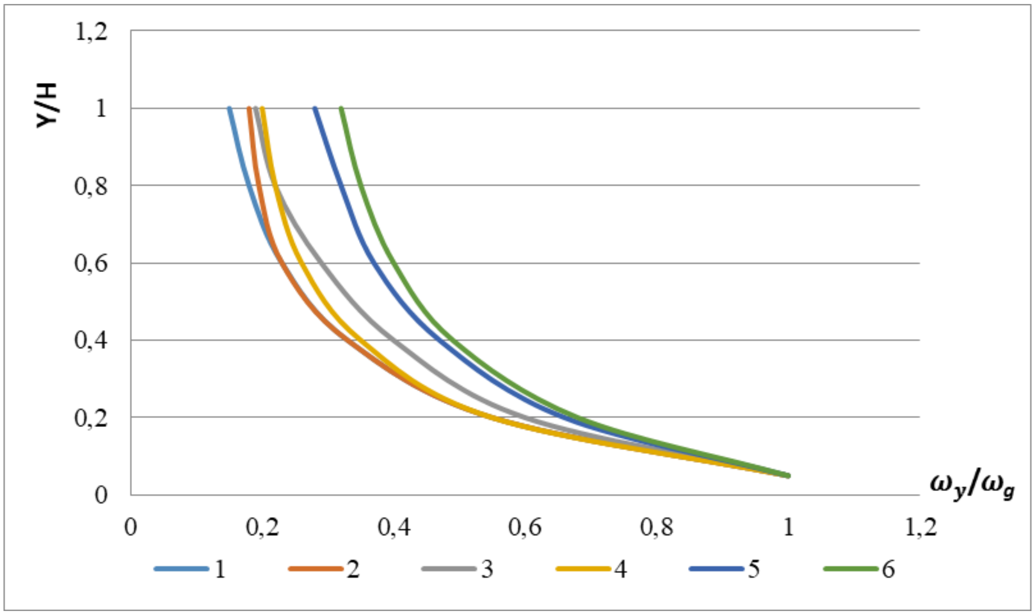

Figure 2. Graph of distribution curves of hydraulic sediment size vertically in experiments: 1) $\frac{\vartheta}{\omega} = 186$; 2) $\frac{\vartheta}{\omega} = 240$; 3) $\frac{\vartheta}{\omega} = 500$; 4) $\frac{\vartheta}{\omega} = 900$; 6) $\frac{\vartheta}{\omega} = 1600$

The exponent depends on the flow velocity and the degree of sediment heterogeneity. At high velocities and small, relatively homogeneous sediments, the exponent has the lowest values. With increasing heterogeneity of sediment composition, the exponent should increase. Analysis of the sediment size distribution curves (Fig. 2) gives the value $z_1 = 0,5$.

The constraint coefficient (β) in depth also changes (Fig. 3.).

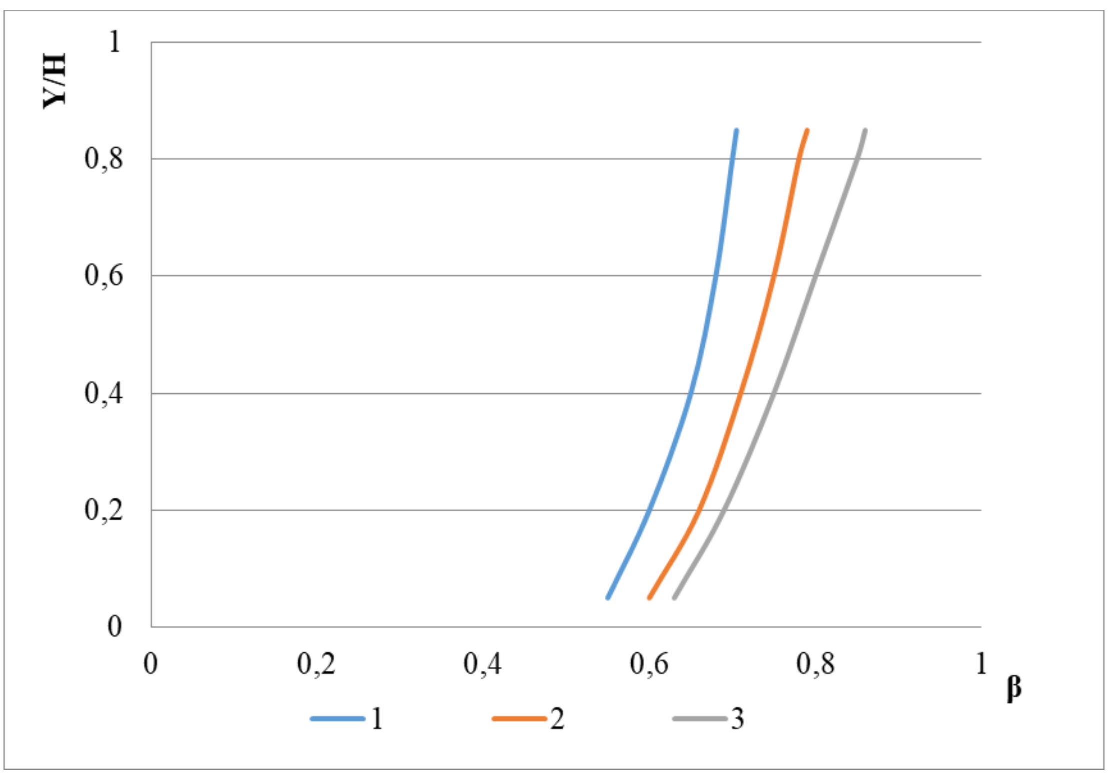

Figure 3. Graph of changes in β by depth

$$1)\ \frac{\vartheta}{\omega} = 50;\ 2)\ \frac{\vartheta}{\omega} = 800;\ 3)\ \frac{\vartheta}{\omega} = 1700$$

The change in the constraint coefficient with depth is insignificant compared to the hydraulic coarseness of the sediment. The highest values of the constraint coefficient are observed at the surface of the flow and towards the bottom this value decreases.

The change in the constraint coefficient in depth can be described by the formula

$$\beta_y = \beta_d[1 + 0{,}3(y/H)^{1{,}6}] \quad (6)$$

where β_d – constraint coefficient near the bottom of the flow; y/H – relative depth of a point on the vertical; H is the depth of the flow on the considered vertical; the y is the coordinate is measured from the flow surface..

CONCLUSION

Analysis of the research results of the authors of this work and other researchers gave grounds to draw the following conclusions:

- When water is saturated with sediment, different curves are obtained for different sediment diameters. The smaller the sediment size (at the same saturation, the greater the effect on the viscosity of the mixture);
- The values of the ratio of the coefficient of kinematic viscosity of pure water and a mixture with sediment depends on the saturation of the flow and characterizes the maximum size of sediment particles affecting the viscosity of the mixture;
- Sediment coarseness is distributed differently in depth, depending on the flow velocity and the degree of sediment heterogeneity. At high velocities and small, relatively homogeneous sediments, the particle size varies little with depth. With an increase in the heterogeneity of sediment composition, small fractions mainly saturate the upper layers of the flow, while larger particles are concentrated in the lower layers;
- Analysis of the vertical distribution curves of hydraulic sediment size showed (Fig. 2) that these curves can be described with a power equation;
- It has been established that the exponent depends on the flow velocity and the degree of sediment heterogeneity. At high velocities and small, relatively homogeneous sediments, the exponent has the lowest values. With increasing heterogeneity of sediment composition, the exponent increases;
- The change in constraint coefficient with depth is insignificant compared to the hydraulic fineness of sediment. The highest values of the constraint coefficient are observed at the surface of the flow and towards the bottom this value decreases.

REFERENCES

1. Барышников Н. Б., Исаев Д. И. Русловые процессы. 2014.
2. De Vries, M. Scale models in hydraulic engineering. IHE Delft. 1982.
3. Ashworth P. J., Best J. L., Leddy J. O., Geehan G. W. The physical modelling of braided rivers and deposition of fine-grained sediment. In Process models and theoretical geomorphology, pp. 115-139. John Wiley & Sons, Ltd. 1994.
4. Chang H. H. Fluvial processes in river engineering. 1992.
5. Демидов В. Н. Численное моделирование процессов формирования дождевого стока. М.: ИВП РАН. 2007.
6. Клавен А. Б., Копалиани З. Д. Экспериментальные исследования и гидравлическое моделирование речных потоков и руслового процесса. 2011.

7. Bazarov D., Umarov S., Oymatov R., Uljaev F., Rayimov K., Raimova I. Hydraulic parameters in the area of the main dam intake structure of the river. In E3S Web of Conferences, Vol. 264, 2021.
8. Мухамедов А. М. Эксплуатация низконапорных гидроузлов на реках, транспортирующих наносы. Ташкент: Фан, стр.59-85. 1976.
9. Hancock P. E., Bradshaw P. The effect of free-stream turbulence on turbulent boundary layers. 1983.
10. Мирцхулава Ц. Е. О некоторых возможностях предсказания характеристик катастрофических паводков. Метеорология и гидрология, (1), стр.89-101. 2002.
11. Мирцхулава Ц. Е. Размыв русел и методика оценки их устойчивости. М.: Колос, стр. 170. 1967.
12. Караушев, А. В. Теория и методы расчета речных наносов, № 444, Гидрометеоиздат. 1977.
13. Мельникова О. Н. Динамика руслового потока. М.: Макс Пресс. 2006.
14. Рабкова Е.К. О движении селевых потоков, Гидротехническое строительство, № 12, 1955.
15. Магомедова, М. Р. Расчетная модель движения твердых частиц в природных турбулентных потоках. Вестник Дагестанского государственного технического университета. Технические науки, № 46(2), 98-107. 2019.
16. Мостков М.А. Очерк теории руслового процесса. М.,Из-во АН СССР,1959,с.216.;
17. Dafto Incipient moyyon end bed load of sediment in steep chennel. p.293-296(Japen).
18. Петров А. Г., Петров П. Г. Перенос взвешенных частиц турбулентным потоком над размываемым дном. ПМТФ., (4), 61. 1992.
19. Nagata N., Hosoda T., Muramoto Y. Numerical analysis of river channel processes with bank erosion. Journal of Hydraulic Engineering, 126(4), 243-252. 2000.
20. Bazarov D. R., Mavlyanova D. A. Numerical studies of long-wave processes in the reaches of hydrosystems and reservoirs. Magazine of Civil Engineering, (3 (87)), pp.123-135. 2019.