Extension Of Tubular Water Discharge Limitations With Water Flow Extinguishers

Ergash Kazakov, Uktam Jovliev, Gulomzhon Yakubov

Abstract: This article presents the results of theoretical and experimental studies on optimizing the parameters of a tubular spillway with energy absorbers for a water flow. The results show that the energy quenching obtained on average does not exceed the corresponding indicator for diffusers of other designs. The advantage of the installation of the type described is that, firstly, it provides sufficient damping of the flow energy, and secondly, the proposed solution for optimizing a diffuser with a small angle of attack can ensure flow continuity on its surface. Due to this, the level of turbulence of the flow after passing through the diffuser is lower than that of diffusers of other structures installed in spillway structures.

Index Terms: confuser, dampers, diffuser, flow energy, tubular, spillways, water.

1. INTRODUCTION

Spillways of high dams are carried out in the form of spillways, deep or bottom holes (in the form of channels of closed section, tubular spillways). The greater the pressure, the greater the flow rate that affects the elements of the structure, the more difficult the flow control and the greater excess kinetic specific energy of the water must be extinguished in the downstream of the spillway. The flow within the spillway structures of high-pressure waterworks is called high-speed. However, a number of features attributed to the high-speed flow also appear at relatively low speeds. At pressures of 35-45 m, which correspond to speeds of 25-28 m / s, special measures have to be taken to ensure the normal operation of culverts. In particular, when designing high-pressure spillways, it is necessary to take into account the constructive solution for installing various types of damper [1]. Studies show that when water moves in spillway structures with various devices for damping flow energy, the velocity fields continuously deform, resulting in almost always uneven velocity fields in the cross sections of the corresponding channels. In addition, in complex constructions of spillways, where it is practically impossible to maintain an uninterrupted flow in the aquatic environment, the velocity fields turn out to be unsteady, respectively, and the pressure fields turn out to be unsteady. In [2], amplitudes of pressure pulsations reaching 10% of the absolute pressure in front of the shutter were obtained in front of the segmented gates. As a result, unacceptably large dynamic loads occur, acting on all elements of various devices and spillway walls.

2 METHODS OF RESEARCH

At the same time, the swirls of the flow sharply increase or axisymmetric and asymmetric deformations of the velocity diagram leads to the occurrence of cavitation processes. Accordingly, to eliminate this problem, it is necessary either to provide a long linear spillway section behind the disturbance source, or to install a damper of the diffuser and confuser type between the disturbance source in order to reduce the length of the indicated section of the pipeline and ensure uniform distribution of velocity over the cross section [3,4,5,6,7,8,9,1]. In view of the foregoing, it is difficult to overestimate the relevance of suppressing the unevenness and non-stationarity of velocity fields generated in various devices and corresponding pipelines. In solving the indicated problem, two ways of suppressing the non-uniformity and non-stationarity of velocity fields are possible [7,8,9,10]. The first way is reduced to purely constructive changes in the flow parts of the corresponding devices in order to eliminate the causes of the unsteady flow with large vortex formations. The second way involves damping the unsteady flows that have already arisen with a sharply expressed unevenness of the velocity fields in the cross sections of the water supply path. In practical terms, it is much more often necessary to quench an already unsteady flow with a very complex velocity field in the cross sections of the water supply path, where the vector velocity field can contain areas with the return movement of the working media. In this case, any method of suppressing the non-uniformity of velocity fields is accompanied in most cases by an increase in hydraulic resistance due to the introduction of an additional device — a non-uniformity damper (diffuser, confuser, etc.) into the flow. But do not forget that cavitation is of a general nature, i.e. to develop in sections of the conduit with reduced pressure, regardless of the state of the solid boundaries and local, when even with excessive pressure in this section there is a local decrease in pressure on the flow energy absorbers (like a diffuser and confuser). Based on theoretical and experimental studies, the question of optimizing the shape of the diffuser was studied. The diffuser effect is explained by the fact that it slows down the incoming flow, creating excessive pressure in the inlet section and a vacuum in the outlet. The experimental results show that the velocity in the outlet section is one and a half times greater than the velocity of the incident flow, which is a consequence of the resulting difference in total pressures. Indexes 1 and 2 correspond to the input and output sections of the diffuser by planes orthogonal to its axis, index 0 corresponds to sections of an imaginary cylindrical volume coaxial with the diffuser, the velocity on the side surface of which will be considered parallel to its generatrix (Fig. 1). In this approximate model, the shape of the longitudinal section of the diffuser is not taken into account, therefore, we make an assumption about the constancy of speed in sections 0, 1, 2 and its orthogonality to the planes of these sections [2]. Since the density is assumed to be constant, the integral equation for the conservation of mass in a volume bounded by a closed surface S has the form $\int_{s} V_n \, ds = 0$.

- *Ergash Kazakov, Researcher at Research Institute of Irrigation and Water Problems, Tashkent, Uzbekistan.*
- *Uktam Jovliev, Researcher at Research Institute of Irrigation and Water Problems, Tashkent, Uzbekistan.*
- *Gulomzhon Yakubov, PhD doctorate at Research Institute of Irrigation and Water Problems, Tashkent, Uzbekistan.*

Here V_n is the component of the flow velocity V along the vector n of the external unit normal to S.

Between sections S_1 and S_2 S_1 of the diffuser this equation takes the form $V_1 S_1 = V_2 S_2$, for the volume between sections S_0 and S_1 - $V_0 S_0 = V_1 S_1 + (S_0 - S_1)v$,, in the confuser - $(S_0 - S_1)v = (S_0 - S_2)V$.

Here v, V are the velocities in sections S_1 and S_2 of the confuser.

The integral equation of conservation of momentum for an ideal fluid in the absence of external forces acting on the flow

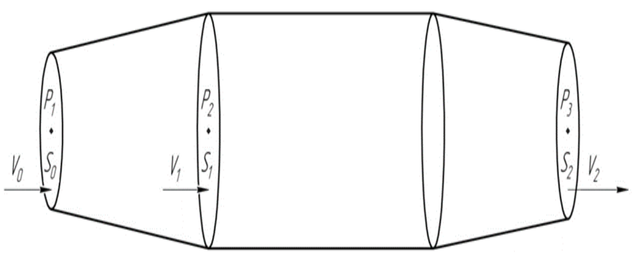

***Fig. 1**. Flow pattern for diffuser and confuser*

in the volume bounded by a closed surface S, has the form [2]:

$$\int_S (\rho V V_n + nP)\,ds = 0$$

where P is the pressure.

For the volume between sections S_0 and S_1 , this equation takes the form

$$(\rho V_0^2 + P_0)S_0 = (\rho V_1^2 + P_1)S_1 + (\rho v^2 + P_0)(S_0 - S_1)\,,$$

for volume between sections S_1 and S_2 —

$$(\rho V_1^2 + P_1)S_1 + (\rho v^2 + P_0)(S_0 - S_1) =$$

$$= (\rho V_2^2 + P_2)S_2 + (\rho V^2 + P_0)(S_0 - S_1)\,.$$

Energy conservation equation

$$\int_S \left(\frac{\rho V^2}{2} + P\right) V_n ds + \frac{dE}{dt} = 0$$

for the entire imaginary cylindrical volume is described by the formula

$$\frac{dE}{dt} = \left(\frac{\rho V_1^2}{2} + P_1\right) V_1 S_1 - \left(\frac{\rho V_2^2}{2} + P_2\right) V_2 S_2$$

From the equations of conservation of mass and momentum we find the expressions for the pressure of the flow at the input and output of the confuser:

$$P_1 = P_0 + \rho V_0^2 \frac{S_0}{S_1} - \rho \frac{(V_0 S_0 - V_2 S_2)^2}{(S_0 - S_1)S_1} - \rho \left(V_2 \frac{S_2}{S_1}\right)^2,$$

$$P_2 = P_0 + \rho V_0^2 \frac{S_0}{S_2} - \rho \frac{(V_0 S_0 V_2 S_2)^2}{(S_0 - S_2)S_2} - \rho V_2^2\,.$$

Substituting these values in the energy conservation equation, we obtain the equality

$$\frac{dE}{dt} = \rho V_2 S_2 \left\{ \frac{V_2^2}{2}\left(1 - \left(\frac{S_2}{S_1}\right)^2\right) - V_0^2 S_0 \frac{S_1 - S_2}{S_1 S_2} + (V_0 S_0 - V_2 S_2)^2 (S_1 - S_2)\, x \right.$$

$$\left. x \frac{S_0 - S_1 - S_2}{(S_0 - S_1)(S_0 - S_2)S_1 S_2} \right\} = \alpha_\omega(z) \rho V_2^3 S_2\,.$$

$$\alpha_\omega(z) = \alpha_0 - arctg \frac{\omega z}{V}\,.$$

here $\alpha_\omega(z)$ is the angle of attack of the flow on the diffuser surface. Where: V is the velocity of the flow incident on the diffuser, ω is the angular velocity of the swirling flow, z is the coordinate of the center of the minimum profile, α_0 is the angle of the minimum cross section of the diffuser, i.e. angle between the x axis and the axis of rotation.

3 RESULTS

Introducing the dimensionless $\sigma = \frac{S_1}{S_2}$, $\sigma_0 = \frac{S_0}{S_2}$, $v = \frac{V_2}{V_0}$, we rewrite the last equality in the form

$$\frac{v^2}{2}\left(1 - \frac{1}{\sigma^2}\right) - \sigma_0\left(1 - \frac{1}{\sigma}\right) + (\sigma_0 - v)^2(\sigma - 1)\frac{\sigma_0 - \sigma - 1}{(\sigma_0 - \sigma)(\sigma_0 - 1)\sigma} = \alpha_\omega(z) v^2$$

Denoting by v the positive root of this equation, we construct the dependence v (σ) for fixed values $\alpha_\omega(z)$, σ_0. Moreover, σ_0 has the meaning of the square of the relative relative width of the water supply path.

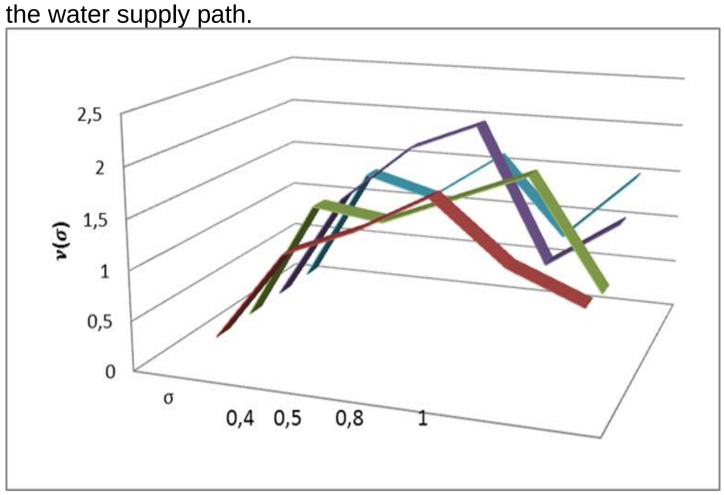

***Figure 2**. Dependences v (σ) for the values*

Figure 2 shows the dependences v (σ) for the values of $\sigma_0 = 6,\ldots,10$ with a unit step (with increasing σ_0, the curve shifts downward). It can be seen that the maximum is $\nu \approx 1{,}5$, i.e. a 1.5-fold change in speed in the output section corresponds to σ≈0.81, which corresponds to a 10% narrowing along the diameter of the diffuser.

4 CONCLUSION

Consequently, choosing the values of water density ρ = 1000 kg / m^3, cross-sectional area S_2 = 0.15 m, flow velocity V_0 = 3.3 m / s, the following optimal values of the diffuser work were obtained, the eddy velocity at the end of the diffuser was $\omega z_1 \approx 0{,}99$ m / s, which corresponds to a 20% energy loss with respect to the kinetic energy of the incident flow passing through the area S_2 of the maximum cross-section of the diffuser while maintaining the $\alpha_{\omega}(z)$ angle of attack of the flow on the diffuser surface.

REFERENCES

[1] Goes. Calculation of the maximum pressure recovery in plane diffusers / Goes, Kline // Tr. America total engineer-fur. Ser .: Theoretical foundations of engineering calculations. - 1978. - T. 100, No. 4. - p 130-138. (1);

[2] Deutsch M.E. Aerodynamics of diffusers and exhaust pipes of turbomachines / M.E. Deutsch, A.E. Zaryankin. - Ph .: Energy, 1970 .– 384 p. (7)

[3] Stron. The method of calculating plane and axisymmetric diffusers, based on determining the margin by separation / Stron, Kline // Tr. America total engineer-fur.: Theoretical foundations of engineering calculations. - 1983. - T. 105, No. 1. - 115-121 p.

[4] Boyko A.V. Aerodynamics of the flow part of steam and gas turbines: calculations, research, optimization, design: monograph. / A.V. Boyko, A.V. Garkusha. - X . : KHGPU, 1999 .- - 360 p.

[5] Grushevsky M.S. "Unsteady movement of water in rivers and canals." L .: Gidrometeoizdat, 1982, 288 p.

[6] I. Makhmudov "Hydraulic processes in water facilities." Monograph, Tashkent, 2018, 236 p.

[7] Kokorin Y.V., Laksberg A.I., Troitsky V.P. Hydraulic calculation of non-deformable (in the absence of soil exchange) channels in disconnected soils // Land reclamation and water management. 2006. No. 5. 2-4 p.

[8] Pakhomov A.A., Kolobanova N.A., Skvortsov V.F. Calculation of transients in channels with automatic regulation of water supply // Izv. / Lower Vol. agricultural university. complex: science and higher professional. education. 2010. Issue 4 (20). S. 176-181.

[9] Kazakov E.A. "Modeling of unsteady water movement in the lower Biof of the Uchkurgan hydroelectric station". Architecture, Construction, Design. Scientific-practical journal. Tashkent 2018 No. 3-4 178 p.

[10] Kazakov E. A. Natural Researches on Condition of Reliability and Efficiency of Major Canals of the Tashkent Area. IJARSET.com 2019 , No. 6 p-9824-9828