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HYDRAULIC RESISTANCE OF UNLIMITED DERIVATIVE AND MACHINE CHANNELS IN LARGE HYDRO-POWER ENGINEERING CONSTRUCTIONS

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Abstract: Theoretical studies of the dependence of hydraulic resistances for non-pressure derivational and machine channels of trapezoidal and other cross-sectional shapes are presented, taking into account the influence of channel shape and roughness.

Keywords: hydraulic resistance, hydropower facilities, turbulence, machine channels.

Currently, many authors have studied the uniform axisymmetric pressure head laminar and turbulent movement of water in hydraulic smooth and rough (with uniform roughness) pipes of circular cross-section. The results obtained in the study of a plane-parallel turbulent flow in pressure channels allow here only to outline the structure of the corresponding dependencies and to clarify the simplest case of unpressurized fluid movement, when this movement can also be reduced to plane-parallel or, in other words, to movement in channel of infinitely large width with a flat bottom. In all other cases, the only way to solve the problem is experiment. But the possibilities of the experiment are limited, as are limited, and in a number of cases debatable, and the information accumulated to date on the uniform free-flow motion of fluid in channels of various cross-sectional shapes.

The paper provides theoretical studies of the dependence of hydraulic resistance for free-flow diversion and machine channels of trapezoidal and other cross-sectional shapes, taking into account the influence of the channel shape and roughness.

The question of studying resistance to fluid movement under turbulent conditions has a history of more than a century, but continues to remain relevant to the present day. Widespread construction of numerous free-flow watercourses, diversion and machine canals of hydropower structures requires scientifically based calculation methods. To correctly establish calculation methods, a sufficiently deep study of the physical essence of the phenomena occurring in free-flow flows is necessary. As is known, when fluid moves in non-pressure diversion and machine channels of hydropower structures, a number of factors are added that are usually not encountered during pressure fluid flow in pipelines (where their entire live section is filled with liquid), the presence of a free surface, the existence of suspended materials in the flow, the difference in the shape of the transverse cross-sections of channels from a circular cross-section, the existence of two different flow states depending on the slope of the channel, the presence of a wider range of roughness in free-flow channels and machine channels, etc. If the average velocity in a channel with a different correct cross-section is calculated by the usual average velocity equation and in this case will have almost the same form, then you can find that the expressions for the average velocity in this case will have almost the same form as the expressions obtained for average speed in the channel for a trapezoidal section (equations (1) and (2)):

$$\nu/\nu_* = a_{гл} - b + b\ln(R\nu_*/\nu) + b\Phi - \overline{\kappa}\nu/\nu_* \quad (1)$$

$$\nu/\nu_* = a_{ш} - b + b\ln(R/\Delta) + b\Phi - \overline{\kappa}\nu/\nu_* \quad (2)$$

only Φ and $\overline{\kappa}$depending on the geometry of the cross section of the channel will vary (from section to section). In view of the above, equations (1) and (2) we have the right to consider as rational equations for determining the average flow velocity in channels with a constant cross-section and slope.

If these general equations are compared with the corresponding equation for a channel of infinite width, then one can see that they differ in the presence of terms in bф and $\overline{\kappa}\overline{u}/\overline{u}_*$. These terms can be interpreted as reflecting the joint influence on pressure loss of the presence of a free surface and the non-uniform distribution of tangential stresses on the bottom and walls of the channel. On the other hand, the indicated general equations (1) and (2) make it possible to find the magnitude of the error in determining the pressure loss that would occur if the terms bf and $\overline{\kappa}\nu/\nu$ were odd. The term "bф" can be calculated for any given cross-sectional shape of the channel, since it is determined only by its geometry. Calculation according to Keleghan [1], and according to our method, shows that in channels of triangular cross-section the value of Φ does not depend on the water depth, and in this case Φ = 0,19. For channels of rectangular cross-section, the expression for Φ takes the form:

$$\phi = \ell n\left(1 + 2h/B_0\right) - h/B_0 \quad (3)$$

For channels with a semicircular crosssection:

$$\phi = \int_0^h \left[\ln\left(\frac{y}{R}\right)\right]\frac{B_0}{R}\frac{dy}{\chi} + 1{,}0 \quad (4)$$

To find the value $\overline{K}$, it will probably be necessary to introduce some parameter expressing the ratio of the transverse size of the free surface of the flow in the channel to the wetted perimeter. It is quite possible that the best way $\overline{K}$ can be found from experiments. However, as follows from equations (1) and (2), before carrying out these experiments, the characteristics of the bottom and walls of the channel must be determined in advance (also from experiments - preferably with very wide channels of rectangular cross-section).

According to our method and according to the method of G. Kelegan, the hydraulic resistance formulas for trapezoidal channels and other forms of regular cross-section can be represented as:

$$\frac{1}{\sqrt{\lambda}}=\frac{1}{\bar{\chi}\sqrt{2}}\left(\ln\frac{\eta_\Lambda R}{\delta_\Lambda}-1+\ln\frac{h}{\eta_\Lambda R}-\frac{\xi h^2}{4\omega}\right) \qquad (5)$$

The same ratio is obtained by V.T.Chou [2] for channels of a curved transverse profile. In the ratio (5) it is accepted: $\bar{\chi}$ - Karman constant [3]; $\bar{\chi}$= 0,4 η_Λ - Reynolds number.

For a viscous sublayer, $\eta_\Lambda = \delta_\Lambda v_* / \nu$; δ_Λ - thickness of the viscous sublayer; h – channel filling; ξ – the function of the channel shape in the ratio *b(y)=χ- ξy*; χ – wetted perimeter; ω – the area of the live section of the channel.

Formula (5) is valid both for fluid motion in smooth (η_Λ =1/9) and rough channels (η_Λ=1/30, with $\eta_\Lambda=\delta_\Lambda$/Δэ). The third and last terms in this formula take into account the influence of the shape of the living section of the channel on its hydraulic resistance. However, formula (5) does not fully take into account the influence of the free surface on the distribution of velocities and pressure losses. Bearing this in mind and some other assumptions made in the derivation of formula (5), it should be assumed that formula (5) only allows us to outline the general form of the terms determining the dependence of the hydraulic resistance of the channel on the shape of its living section [3,4]. The specific type of the corresponding dependence can be established only from consideration of the corresponding experimental data for non-pressurized machine channels with turbulent fluid motion.

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