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FLOW PRESSURE ON THE ROTATION OF THE PRESSURE WATER DISCHARGE OF THE KARKIDON RESERVOIR AND VELOCITY DISTRIBUTION ALONG SECTION

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ANNOTATION

The article discusses the change in pressure at the turn of the pressure spillway of the Karkidon reservoir and the laws of distribution of velocities over the cross-section of the pipeline. The flow in the pressure pipeline is investigated and where vibration is expected in the pressure pipeline. To find the beginning of vibration, we will use the Euler motion equation. The coefficient of kinetic pressure is found by the method of L. Prandtl. The main causes of vibration are inconsistencies between pressure and velocity. Basically, the discrepancy occurs at the turn of the pressure spillway.

To eliminate the vibration of the pressure pipeline, initial and boundary conditions are introduced and calculations are carried out according to the method of L. Prandtl. Calculations of the velocity's and pressures at the turn based on the initial and boundary conditions of the pressure spillway of the Karkidon reservoir can be divided into three groups. The article discusses the second group of calculations, which combines engineering solutions that allow them to be used in practice without performing complex mathematical operations or a large amount of calculations, in addition, the group presents experimental work in the form of graphs of empirical formulas.

For this purpose, the kinetic component is found due to the presence of normal accelerations in the section at the turn. Through the coefficient of kinetic pressure, the fluid pressure arising due to normal accelerations is expressed in fractions of the velocity pressure calculated from the average velocity.

KEYWORDS: *flow pressures, speed distribution, cross section, interaction, Prandtl method, hydrodynamic method, pressure change, flow rate, flow equations, kinetic energy coefficient*

DISCUSSION

In many reservoirs, different vibrations occur at the turn of the pressure spillway, which are the main causes of destruction of the entire system of hydraulic structures. The basis of these vibrations is the discrepancy between the pressure and speed at the turn of the pressure spillway. To eliminate the vibration of the pressure pipeline, we perform calculations using the method of Prandtl. Calculations of speeds and pressures at the turn of the pressure spillway of the Karkidon reservoir can be divided into three groups.

The solutions of the first group can be performed using hydro-mechanical methods. Being mathematically complex, they are mostly not brought to an engineering solution or require a lot of computational work that is not justified by the achieved accuracy of calculation.

The second group combines engineering solutions that allow them to be used in practice without performing complex mathematical operations or a large amount of calculations. The group presents experimental work in the form of graphs of empirical formulas.

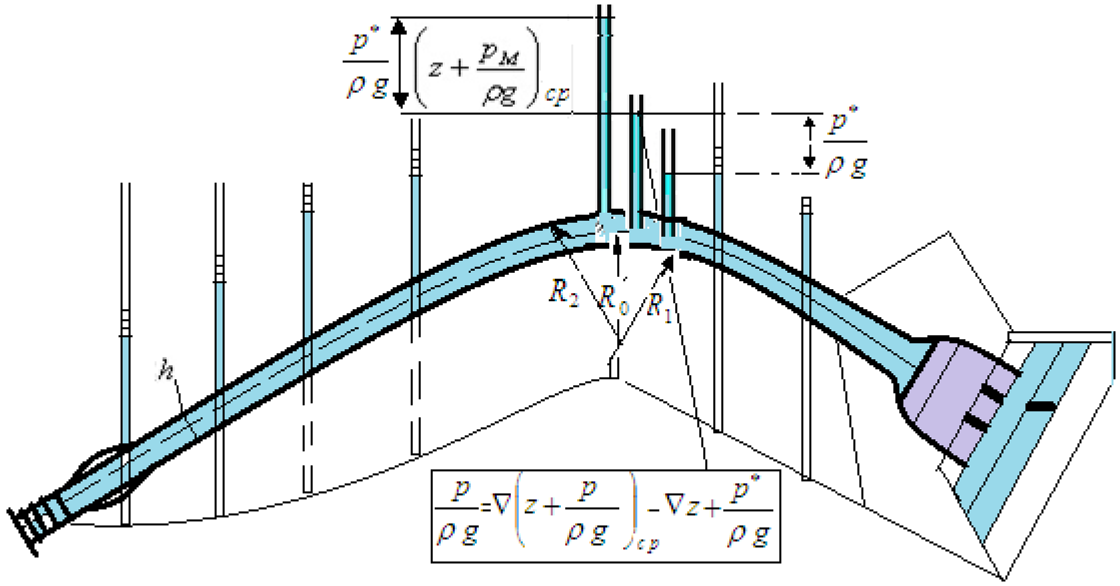

Fig. 1. Influence of the kinetic component of pressure on the distribution of excess pressure at the corner.

A curved water conduit, due to the kinetic component, the excess pressure increases on the outer wall and decreases on the inner:

Following Prandtl [1,4], we decompose the pressure into two terms p_{cm} and p^*, of which p_{cm} is the component corresponding to the hydrostatic law of pressure distribution (weight pressure), and p^* is the kinetic component due to the presence of normal accelerations in the cross section at the turn: According to the Fig. 1, $p = p_{cm} + p^*$

$$\frac{p}{\rho g} = \nabla\left(z + \frac{p}{\rho g}\right)_{cp} - \nabla z + \frac{p^*}{\rho g}$$

In order to determine the p^*, we use the Euler equation in polar coordinates for a plane-parallel flow:

$$\frac{\partial u_r}{\partial r}u_r + \frac{1}{r}\frac{\partial u_r}{\partial \theta}u_\theta + \frac{\partial u_r}{\partial t} - \frac{1}{r}u_\theta^2 = g_r - \frac{1}{\rho}\frac{\partial p}{\partial r}$$

Taking the flow steady ($\frac{\partial u_r}{\partial t} = 0$), the liquid is weightless, i.e., excluding the weight pressure ($g_r = 0$) from consideration, we obtain for the scheme Fig. 1, c at $u_r = 0$

$$\frac{1}{\rho}\frac{\partial p^*}{\partial r} = \frac{u_\theta^2}{r} \tag{1}$$

and after integration:

$$p^* = \rho\int \frac{u_\theta^2}{r} dr \tag{2}$$

Thus, the p^*-kinetic pressure is really caused only by the movement of the liquid. Pressure and velocity distribution with concentric arrangement of the walls. Fig. 2.

Fig. 2 Pressure and velocity distribution with concentric arrangement of walls

We use equation (1) to determine p^*. Since we consider an ideal liquid, we have:

$$\frac{p}{\rho g} + \frac{u_\theta^2}{2g} = const$$

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$$-\frac{1}{\rho}\frac{\partial p^*}{\partial r} = u_\theta \frac{\partial u_\theta}{\partial r}$$

From this expression and (1) we obtain the differential equation:

$$\frac{dr}{r} = \frac{du_\theta}{u_\theta} \tag{3}$$

integration of which gives:

$$\ln r + \ln u_\theta = \ln C ;$$

$$ur = const \, .$$

Since on the axis, i.e. for $r = R_0$, $u_\theta = u_0$, we get $u_0 R_0 = u_\theta r$. $u_\theta = \frac{u_0 R_0}{r}$ substituting the found value and in (2) and integrating:

$$p^* = \rho \int \frac{u_\theta^2}{r} dr = \rho u_0^2 R_0^2 \int \frac{dr}{r^2}$$

we get

$$p^* = -\frac{\rho u_0^2 R_0^2}{2r^2} + C$$

At $r = R_0$ the pressure is $p^* = 0$, whence $C = \frac{u_0^2 \rho}{2}$. As a result

$$\frac{p^*}{\rho g} = \frac{u_0^2}{2g}\left[1 - \left(\frac{R_0}{r}\right)^2\right] u_\theta \frac{\partial u_\theta}{\partial r} \tag{4}$$

On the inner wall $r = R_0 - \frac{h}{2}$, on the outside $r = R_0 + \frac{h}{2}$ where h is the distance between the walls. The velocity on the axis of the conduit is found from the continuity equation:

$$Q = b\int_{R_1}^{R_2} u dr = b u_0 r_0 \int_{R_1}^{R_2} \frac{dr}{r} = b u_0 R_0 \ln\left(\frac{R_2}{R_1}\right)$$

$$u_0 = \frac{Q}{bR_0 \ln\left(\frac{R_2}{R_1}\right)} = \frac{\vartheta h}{R_0 \ln\left(\frac{R_2}{R_1}\right)} \tag{5}$$

Knowing the speed u_0 on the axis and using the equality $u(R_0 + y) = u_0 R_0$,: the average speed of u at any point of the section at a distance y from the axis of the conduit is determined by the formula:

$$u = \frac{u_0 R_0}{R_0 + y} C^B \tag{6}$$

Where the C^B multiplier is an empirical correction to reduce the speed to zero when approaching a hard boundary:

$$C = 1 - \left(\frac{y}{\frac{h}{2}}\right)^3$$

$$B = 0{,}125 - 0{,}0833\left(\frac{h}{R_0}\right)^{0{,}113}$$

The values of C and B can be taken from table. 1.

Table 1. Values of coefficients A and B, C.

h/R_0	0,00	0,025	0,050	0,075	0,100	0,200	0,300	0,400	0,500	0,000	0,700	0,800	0,900	1 ,000
A	1,125	1,100	1,0835	1,0715	1,032	1,042	1,031	1,025	1,021	1,018	1,016	1,014	1,012	1,011
B	1,125	0,0702	0,0358	0,0329	0,050	0,05)	0,052	0,050	0,048	0,046	0,045	0,044	0,043	0,042
$\frac{u}{h/2}$	0,999	0,998	0,997	0,993	'0,995	0,994	0,993	0.992	0,991	0,99 Э	0,985	O.C80	0.975	0,970
C	0,0020	),0040	),0030	),0080	),0100	),0120	),0140	),0159	),0179	0,019	),0228	),0396	),0494	),0591
$\frac{y}{h/2}$	0,935	0, 950	0,955	0,953	0,945	0,940	0,935	0,930	0,925	0,920	0,915	0,910	0,905	0,900
C	0,0688	0,0784	0,0880	0,0975	0,1070	0,1164	0,1258	0,1351	0,1444	0, 153	0,1628	0,1719	0,1810	0,191

The coefficient of kinetic energy in the cross section at a turn with a concentric arrangement of the walls, corresponding to the velocity distribution according to expression (12) at $C^B = 1$, is determined by the formula: [2, p. 376]

$$\alpha = \frac{\left(\frac{1}{R_1^2} - \frac{1}{R_2^2}\right)(R_1 - R_2)^2}{2\left[\ln\left(\frac{R_2}{R_1}\right)\right]^3}. \qquad (7)$$

The $\frac{p^*}{\rho g}$ can be calculated by the dependency:

$$\frac{p^*}{\rho g} = C_p^* \frac{\vartheta^2}{2g} \qquad (8)$$

Where C_p^* - the kinetic pressure coefficient. The C_p^* coefficient expresses the fluid pressure arising from normal accelerations in fractions of the velocity head calculated from the average velocity. Substituting (5) into formula (4), we find the expression for the C_p^* coefficient:

$$C_p^* = \frac{h^2\left[1-\left(\frac{R_0}{r}\right)^2\right]}{R_0^2\left[\ln\left(\frac{R_2}{R_1}\right)\right]} \qquad (9)$$

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