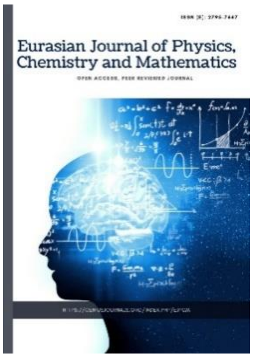

Determination of the Low Pressure Zone of the Water Conducting Tract of Reservoirs

Negmatulloyev Zafardjon Turdibeko vich[1]
[1]Associate Professor of the Department of Applied mathematics and Information Technologies, Doctor of Philosophy (PhD) in Technical Sciences, Gulistan State University
E-mail: nztnoyabr11@gmail.com

Ganisher Abdurashidovich Nafasov[2]
[2]Associate Professor of the Department of Mathematics, Doctor of Philosophy (PhD) in Pedagogical Sciences, Gulistan State University
E-mail: gnafasov87@gmail.com

Saitmuratov Ulmasbek Nurullo ugli[3]
[3]Gulistan state university, department of Mathematics, Gulistan, Uzbekistan
saitmuratovolmas@gmail.com

ABSTRACT

In this article, it is obtained an exact solution to the problem of the flow of a dispersed mixtin e in a cylindrical pipe, and given the concentration distribution in the case of deposition of earned particles on the lower inner surface of the cylinder. The performed hydraulic calculations provided material for assessing the hydraulic operating conditions of the bends of the end section of the outlet, the nature of the occurrence of dynamic conditions in the flow and their effect on the flow structure. Based on the analysis of the operating conditions and the interaction of the flow with structural elements, the main sources and causes of vibration of the cone gates were identified.

Keywords: aeration process, cavitation, low pressure zones, pulsation, velocity pressure, hydrostatic pressure.

Introduction. With a change in the inclination of the water supply tract, the flow rate increases, which can lead to the emergence of a zone of low pressure, which will cause the water flow to become saturated with air, i.e., an aeration process occurs. The reasons for the occurrence of an aeration zone are various, such as destruction of the free surface, turbulent disturbance, loss of wave stability on the free surface, loss of jet continuity, and the occurrence of cavitation.

The mechanism of air capture can be explained by the excess of the kinetic energy of an ejected drop of water from the flow more than the forces of surface tension and gravity, as well as the collapse of caverns, the destruction of surface waves, and others [2]. Typically, the aerated flow is a complex, interacting link between layers. At the bottom of the stream there is a layer of water that does not contain air. Above it is a layer of water-air mixture, where the volumetric concentration of water is greater than the volumetric concentration of air bubbles. Further above the above mentioned layers there is a layer of air-droplet mixture, where the volumetric concentration air is greater than the volumetric concentration of a drop of water [3]. Studies of these layers are complex; mass exchange between the layers and particles of water and air is complex, where zones of low pressure may arise [4]. In areas of low pressure, the likelihood of pulsation velocities occurring is high. To study the nature of the pulsation, it seems to us that it is necessary to divide the length of the water supply tract into several parts and conduct research in each part in accordance with the configuration and hydraulic parameters. In this work we will try to build a universal formula, i.e. a recurrent formula showing characteristic zones along the entire length of the water supply tract under study, including changes in pressure in these parts. Using a recurrent formula, we create a calculation algorithm for the entire length of the water supply tract. We divide the length of the water supply tract into several parts; the condition for division will be the places where local resistances change.

Research methods. For the first part of the water supply tract, we write the Bernoulli equation [5] in the following form:

$$\frac{1}{2g}\left(\frac{dH(t)}{dt}\right)^2 + H(t) + \frac{p_0}{\gamma} = \frac{p_1}{\gamma} + \frac{\upsilon_1^2}{2g}\left(1 + \frac{l_1}{d_1} + \xi_m\right) + z_1 \qquad (1)$$

To find the change in pressure, we find the pressure difference and energy in the inner part of each section of the water supply tract. For this purpose, we transform the Bernoulli equation (1) and write it in Poiseuille form:

$$\frac{p_1}{\gamma} = \frac{p_0}{\gamma} + \left(H(t) - z_1\right) - \left(1 + \frac{l_1}{d_1} + \xi_m\right)\frac{Q_1^{\ 2}}{\omega_1 2g} + \frac{1}{2g}\left(\frac{dH(t)}{dt}\right)^2 \qquad (2)$$

Let's write this equation in terms of velocity pressure:

$$\begin{aligned} p_1 &= p_0 + \frac{\rho}{2}\left(\frac{dH(t)}{dt}\right)^2 - \frac{\rho\upsilon_1^2}{2}\left(1 + \frac{l_1}{d_1} + \xi_m\right)_1 + \gamma\left(H(t) - z_1\right) = \\ &= p_0 - \frac{\rho\vartheta_1^2}{2}\left(\frac{l_1}{d_1} + \xi_{m_1}\right) + \gamma\left(H(t) - z_1\right) \end{aligned} \qquad (3)$$

Thus, we can write a calculation algorithm for the second part of the water supply tract. For the second part of the water supply pipeline we have the following Bernoulli equation [5]:

$$\frac{p_2}{\gamma} + \frac{\vartheta_2^2}{2g}\left(1 + \frac{l_2}{d_2} + \xi_{m_2}\right) + z_2 = \frac{p_1}{\gamma} + \frac{\vartheta_1^2}{2g} + z_1$$

From here we find the expression for the velocity pressure:

$$\frac{p_2}{\gamma} = \left(z_1 - z_2\right) + \frac{\vartheta_1^2}{2g} - \frac{\vartheta_2^2}{2g}\left(1 + \frac{l_1}{d_1} + \xi_m\right) - \frac{p_1}{\gamma}$$

Using formulas (1) we have:

$$\frac{p_2}{\gamma} = \frac{\vartheta_1^2}{2g} - \frac{\vartheta_2^2}{2g}\left(1 + \frac{l_2}{d_2} + \xi_{m_2}\right) - \left[\frac{p_0}{\gamma} + (H(t) - z_1) - \left(1 + \frac{l_1}{d_1} + \xi_{m_1}\right)\frac{\vartheta_1^2}{2g}\right]$$

After opening the brackets and contracting, we have an equation for the pressure in the second zone of the water outlet section:

$$p_2 = p_0 + \frac{\rho}{2}\left\{\vartheta_1^2\left(\frac{l_1}{d_1} + \xi_{m_1}\right) - \vartheta_2^2\left(\frac{l_2}{d_2} + \xi_{m_2}\right) - \vartheta_2^2 + 2g\left[H(t) - z_1\right]\right\} \qquad (4)$$

The calculation algorithm for the third part of the water supply tract is compiled in the above form. For the third part of the pipeline we have the following form of the Bernoulli equation [5]:

$$p_3 = p_0 + \frac{\rho \vartheta_1^2}{2}\left(\frac{l_1}{d_1} + \xi_{m_1}\right) - \frac{\rho \vartheta_2^2}{2}\left(\frac{l_2}{d_2} + \xi_{m_2}\right) -$$
$$- \frac{\rho \vartheta_3^2}{2}\left(1 + \frac{l_3}{d_3} + \xi_{m_3}\right) + \gamma\left(H(t) - z_1\right)$$

To find pressures in an arbitrary part of the pipeline we have the following recurrent formula:

$$p_i = p_0 + \frac{\rho}{2}\left\{\vartheta_1^2\left(\frac{l_1}{d_1} + \xi_{m_1}\right) - \sum_{i=2}^{n} \vartheta_i^2\left(\frac{l_i}{d_i} + \xi_{m_i}\right) + \vartheta_n^2 + 2g\left[H(t) - z_1\right]\right\} \qquad (5)$$

Where

$i = 1,2 \ldots n$.

From here we can write a recurrent formula for the entire part of the water outlet, in the following form:

$$\sum_{i=1}^{n} p_i = p_0 + \frac{\rho}{2}\left\{\vartheta_1^2\left(\frac{l_1}{d_1} + \xi_{m_1}\right) - \sum_{i=2}^{n} \vartheta_i^2\left(\frac{l_i}{d_i} + \xi_{m_i}\right) + \vartheta_n^2 + 2g\left[H(t) - z_1\right]\right\} \qquad (6)$$

Thus, you can use this formula to find the pressure of the water mixture in the water supply tract in an arbitrary part along its entire length.

Cavitation can occur in the zone of vortices that form in places of increased shear and low pressure. Vortex cavitation is often observed at the leading edge of hydrofoils, at the leading edges of blades, and behind the propeller hub. It is possible that different types of cavitation may occur simultaneously. It is known that cavitation occurs when the flow reaches its limiting speed $\vartheta = \vartheta s$ when the pressure in the flow becomes equal to the pressure of vaporization (saturated vapor). This speed corresponds to the limit value of the cavitation criterion. Depending on the value of X, four types of flows can be distinguished: before cavitation - a continuous (single-phase) flow at X>1, cavitation - (two-phase) flow at X~1, film - with a stable separation of the cavitation cavity from the rest of the continuous flow (film cavitation) at X<1, supercavitation - at X<<1.

The level of cavitation is measured (usually in relative units) using instruments called cavitometers [4]. Typically, the pressure that a liquid exerts on the surfaces surrounding it depends on temperature. This pressure is called vapor pressure and is a unique characteristic of any liquid that increases with temperature. When the vapor pressure of a liquid reaches ambient pressure, the liquid begins to evaporate or boil. The temperature at which this evaporation occurs will decrease as the ambient pressure decreases.

When a liquid evaporates, it increases in volume significantly. One cubic foot of water at room temperature turns into 1,700 cubic feet of steam (evaporation) at the same temperature. To find pressures in an arbitrary n-part of the pipeline we have the following recurrent formula:

$$\frac{p_n}{\gamma} = \frac{p_0}{\gamma} + \frac{1}{2g}\left\{\vartheta_1^2\left(\frac{l_1}{d_1} + \xi_{m_1}\right) - \sum_{i=2}^{n} \vartheta_i^2\left(\frac{l_i}{d_i} + \xi_{m_i}\right) + \vartheta_n^2 + 2g\left[H(t) - z_1\right]\right\} \qquad (7)$$

Results. Transferring similar terms of equation (7) to the left side, equating the right side to zero and taking out the general factor of the change in pressure over time, bringing it into the general factor relative to $\gamma = \rho g$ and bearing in mind the slope $z = z_1 \cos \theta_1$ of the water supply tract, we can write:

$$\rho\left(\frac{dH(t)}{dt}\right)^2\left(1-(\alpha\varphi)^2(1+\xi_m+\frac{l_1}{d_1})\right)-2H(t)\gamma-2(p_1-p_0)-2\gamma z_1\sin\theta_1=0 \quad (8)$$

For the convenience of carrying out computational calculations, we introduce some notations for hydraulic parameters:

$$a=\rho\left(1-(\alpha\varphi)^2(1+\xi_m+\frac{l_1}{d_1})\right), b=2(p_1-p_0), C^*=2\gamma z_1\sin\theta_1 \quad (9)$$

Then we arrive at a first-order, second-degree differential equation:

$$a\cdot\left(\frac{dH(t)}{dt}\right)^2-2H(t)\gamma-(b+C^*)=0 \quad (10)$$

To solve the differential equation (10), we divide by and transfer some terms of this equality to the right side, we have:

$$\frac{\partial\rho_n}{\partial t}+div\left(\rho_n\vec{V}_n\right)=J_0\,,\rho_n=\rho_{ni}f_n$$

$$\left(\frac{dH(t)}{dt}\right)^2=\frac{2}{a}\left(H(t)\gamma+\frac{b+C^*}{a}\frac{a}{2}\right)=\frac{2}{a}\left(H(t)\gamma+\frac{b+C^*}{2}\right)$$

Для удобства решения и сохранения физического смысла, правую часть этого уравнения обозначим через функцию напора- $h(t)$:

$$h(t)=\left(H(t)\gamma+\frac{b+C^*}{2}\right) \quad (11)$$

Conclusion. The application of the proposed hydrodynamic model contributes to the development of technology for the influence of flow on the conical part of the water supply tract by mixture particles and the exposure time, taking into account the interaction of phases and external influences, which will lead to a significant reduction in cavitation of the conical valve. Application of the proposed hydrodynamic model contributes to development of technology for the influence of flow on the conical part of the water supply tract by mixture particles and exposure time, taking into account the interaction of phases and external influences, which will lead to a significant reduction in cavitation of the conical valve. In determining the hydrodynamic parameters of suspension-carrying flows, the interaction of the carrier particles of the carrier medium with the carrier suspended particles has a significant influence.

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