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Movement of water in narrowing channels, taking into account vortex and cavitation zones

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ABSTRACT: A jet calculation scheme is proposed in a plane formulation of the problem of fluid motion in a tapering channel. Analytical solutions to the problem in a channel are given, taking into account vortex and cavitation zones.

KEYWORDS: effects of cavitation, vortex zones, unsteady cavitation fluid, Predictive Analysis, Social Networking Spam, Spam detection.

I. INTRODUCTION

Cavitation and vortex zones are constantly encountered in hydraulic structures. Examples include the entrance sections of canals, bends of canals, tunnels, etc. [1,2,3]
Operational experience shows that these zones formed in channels make it difficult to control flows, cause erosion of the channel wall material, vibration of the installation and hydraulic machines, and a decrease in power supply and efficiency of the vane pump. Therefore, the effects of cavitation and vortex zones must be given serious attention when designing and operating hydraulic structures. The question of obtaining quantitative ideas about these phenomena and describing their nature at various stages depending on the flow parameters comes down to solving the two- dimensional problem of cavitation flow of an ideal fluid in channels. [4, 5, 6].

II. METHODOLOGY:

Let us consider models of stationary and unsteady cavitation fluid flow in a tapering channel and in a channel with a kink. Area of change of complex potential ω_0 is a strip with a semi-infinite cut the top of the cut D corresponds to the bifurcation point of the flow.
The conformal mapping of the region of change ω_0 onto the upper half-plane is given by the formula;

$$u = \xi + i\eta ; \quad (1)$$

$$\omega_0\,(u) \;=\; \frac{n(Q-q_E)}{(d-1)\pi}\left[(a+d)\,ln\frac{u-a}{a+d} - (-1)\,ln\frac{u+1}{d-1} - 1(a+1)\pi\right] + iq_E \quad (2)$$

Where Q - flow discharge; q_A and q_E - flow rates in cross-section AA and EE respectively

Taking this condition into account, from (2) we obtain the relation

$$\frac{q_E}{Q} = \frac{a+1}{a+d} \; . \quad (3)$$

From (3) we also find

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$$\frac{dW_0}{du} = \frac{1}{\pi}\left[\frac{Q - q_E}{d - 1}\right]\left[\frac{a+1}{u-a}\right]\left[\frac{u+d}{u+1}\right]$$

$$\frac{dz}{du} = \frac{Q}{\pi V_k}\left[\frac{a+1}{a+d}\right]\frac{(u+d)EXP\left[\pi\frac{(1+a)}{F(-1)}F(u) - ia)\right]}{(u-a)(u+1)}$$

or

$$\frac{dW_0}{du} = \frac{Q}{\pi}\left[\frac{a+1}{u-a}\right]\left[\frac{u+d}{(u-a)(u+1)}\right]. \qquad (4)$$

The derivative of the complex potential $\frac{dW_0}{du}$ can also be easily constructed using the method of singular points. [7, 8]

Formulas (2) and (4) give a solution in the form, since

$$\frac{dz}{du} = \frac{Q}{\pi V_k}\left[\frac{a+1}{a+d}\right]\frac{(u+d)EXP\left[\pi\frac{(1+a)}{F(-1)}F(u) - ia)\right]}{(u-a)(u+1)}.$$

When moving from MA to AE a jump Z it is equal to $-iH$. That's why

$$-iH = -i\pi \underbrace{RES}_{u=a}\left[\frac{dz}{du}\right] \qquad (5)$$

those.

$$H = \frac{Q}{V_k} l^{\pi\left[\frac{(1+\alpha)}{F(-1)}(I_{1n} - I_{ma})\right]}$$

Similarly, when passing DC to CB we get

$$i\delta_c = -i\pi \underbrace{RES}_{u=-1}\left[\frac{dz}{du}\right]$$

(δ_c- thickness of the stream), i.e.

$$\frac{\delta_c}{H} = \frac{U}{V_k}\left[\frac{d-1}{d+a}\right]; \qquad \frac{q_c}{Q} = \frac{d-1}{d+a}. \qquad (6)$$

To calculate the ordinate of a point, $M - h_m$we integrate (1) along the path in the upper half-plane from $u = 1$ to $u = m$:

$$\frac{h_m}{H} = \frac{1}{H} I_m \int_1^m \frac{dz}{du} du = \frac{U}{V_k}\left[\frac{a+1}{a+d}\right] \cdot \frac{1}{\pi} I_m \int_1^m \frac{(u+d)}{(u-d)(u+d)} l^{\pi\left[\frac{(1+\alpha)}{F(-1)}F(u) - i\alpha\right]} du$$

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On the other side

$$\frac{1}{H} I_m \int_1^m \frac{dz}{du} du = 1 - \frac{h}{H} \quad (7)$$

Further, from Fig. 1 it is easy to see that

$$\frac{q_E}{Q} = \frac{h}{H}\frac{V_E}{U} \quad (8)$$

$$\frac{q_c}{Q} = \frac{Q - q_E}{Q} = \frac{\delta_c}{H}\frac{V_k}{U} \quad (9)$$

where q_c is the flow rate of the stream.

Since the flow rate through the sections AA is equal to the sum of flow rates q_c and q_E, where

$$Q = q_c + q_E \quad (10)$$

If $\frac{U}{V_k}$ and are known $\frac{h}{H}$, then the unknown parameters can be determined d, m, n, a from the system of equations (3), (11). Integrating (9) in a segment $[m, n]$ of the real axis u, we find the shape of the whirlpool zone MN:

$$x(u) = x_n Re \int_n^u \frac{dz}{du} du$$
$$n \leq u \leq m \quad (11)$$
$$y(u) = h_n + I_m \int_n^u \frac{dz}{du} du$$

Here

$$x_n = Re \int_1^n \frac{dz}{du} du, \qquad h_n = I_m \int_1^n \frac{dz}{du} du$$

Integrating from $u = 1$ to in a similar way $u = -d$, we find the abscissa of the point D:

$$x_d = \int_1^{-d} \frac{dz}{du} du \quad (12)$$

The region of change of the function W is a pentagon with a cut, on which there is a display of the point at infinite point A. When passing through points G and D the value ϴ changes abruptly. Mapping the pentagon $ADCBG$ onto the upper half-plane using the Christoffel-Schwartz formula and determining the unknown constants, we obtain [2,3,4]

$$w(u) \frac{(1+\alpha)\pi}{F_1(-1)} \int_1^u \frac{(\xi - a) d\xi}{\sqrt{1-\xi^2 (\xi - g)(\xi - d)}} - i\alpha\pi \quad (13)$$

Where

$$F_1(-1) = \int_1^1 \frac{(a - \xi) d\xi}{\sqrt{1 - \xi^2 (g - \xi)(\xi + d)}} - i\alpha\pi$$
$$C_1 \frac{a+d}{\sqrt{d^2 - 1 (d+g)}} = -1$$

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$$C_1\frac{g-a}{\sqrt{g^2-1}(g+d)}=\alpha\pi$$

From these relations we obtain

$$\frac{a-g}{a+d}\sqrt{\frac{d^2-1}{g^2-1}}=\alpha \tag{14}$$

The conjugate flow velocity is determined from formula (13);

$$\frac{dw_0}{dz}=\frac{V_K(d+u)(u-g)^{\alpha}}{\left[1+du+\sqrt{(d^2-1)(u^2-1)}\right]\left[gu-1+\sqrt{(g^2-1)(u^2-1)}\right]^{\alpha}} \tag{15}$$

Using (15), I obtained a formula for the $\frac{U}{V_K}$speed ratio:

$$\frac{U}{V_K}=\frac{(d+a)(a-g)^{\alpha}}{\left[1+da+\sqrt{(d^2-1)(a^2-1)}\right]\left[ga-1+\sqrt{(g^2-1)(a^2-1)}\right]^{\alpha}} \tag{16}$$

From (2) and (15) we have

$$\frac{dz}{du}=\frac{Q}{XV_k}\left[\frac{a+1}{a+d}\right]\frac{\left[1+du+\sqrt{(d^2-1)(u^2-1)}\right]\left[gu-1+\sqrt{(g^2-1)(u^2-1)}\right]^{\alpha}}{(u-a)(1+u)^{\alpha}} \tag{17}$$

Therefore, replacing in formulas (4), (6) and (12) $N$and M with G, we get

$$H=\frac{Q}{V_k}\frac{\left[1+ad+\sqrt{(d^2-1)(a^2-1)}\right]\left[ag-1+\sqrt{(g^2-1)(a^2-1)}\right]^{\alpha}}{(a+d)(a-g)^{\alpha}} \tag{18}$$

$$\frac{h}{H}=1-\frac{U}{XV_k}\left[\frac{a+1}{a+d}\right]\sin\alpha\pi\int_1^g\frac{\left(1+du+\sqrt{(d^2-1)(u^2-1)}\right)\left(gu-1+\sqrt{(g^2-1)(u^2-1)}\right)^{\alpha}}{(a-u)(u+1)(g-u)^{\alpha}}du \tag{19}$$

$$\frac{x_D}{H}=\frac{U}{XV_k}\left[\frac{a+1}{a+d}\right]\mathrm{Re}\int_{-d}^1\frac{\left(1+du+\sqrt{(d^2-1)(u^2-1)}\right)\left(gu-1+\sqrt{(g^2-1)(u^2-1)}\right)^{\alpha}}{(a-u)(u+1)(u-g)^{\alpha}}du \tag{20}$$

III. RESULTS AND DISCUSSIONS

The resulting formulas (14), (16), and (19) constitute a system of equations for finding the unknown parameters of the problem: d, g, a.

This system is solved with Newton's numerical method on a computer at certain values $\alpha, \frac{U}{V_k}, \frac{h}{H}$.

From formula (15) it follows that the point on the real half plane U_0 at which the tangent to the cavity boundary is horizontal is determined from the equation:

$$\mathrm{arctg}\frac{\sqrt{(d^2-1)(1-u_0^2)}}{1+du_0}+\mathrm{arctg}\frac{\sqrt{(g^2-1)(1-u^2)}}{gu-1}+\alpha\pi=0 \tag{21}$$

We will determine the cavity width from equation (17) in which the value of the unknown limit in the integral is found from the equation:[6,7,8]

$$\frac{B}{H}=I_m\frac{1}{H}\int_1^{u_0}\frac{dz}{du}du=\frac{U}{\pi V_k}\left[\frac{a+1}{a+d}\right]x\int_{u_0}^1\frac{(d+u)\sin(arctg\beta_1+\alpha arctg\beta_2+\alpha\pi)}{(a-u)(u+1)}du \tag{22}$$

$$\beta_1 = \frac{\sqrt{(d^2-1)(1-u^2)}}{1+du}$$

$$\beta_2 = \frac{\sqrt{(g^2-1)(1-u^2)}}{gu-1}$$

In the special case of this problem, $\alpha = {}^1/_2$ equation (20) is simplified:

$$u_0 = \frac{-B_0+\sqrt{B_0^2-4A_0C_0}}{2A_0} \quad (23)$$

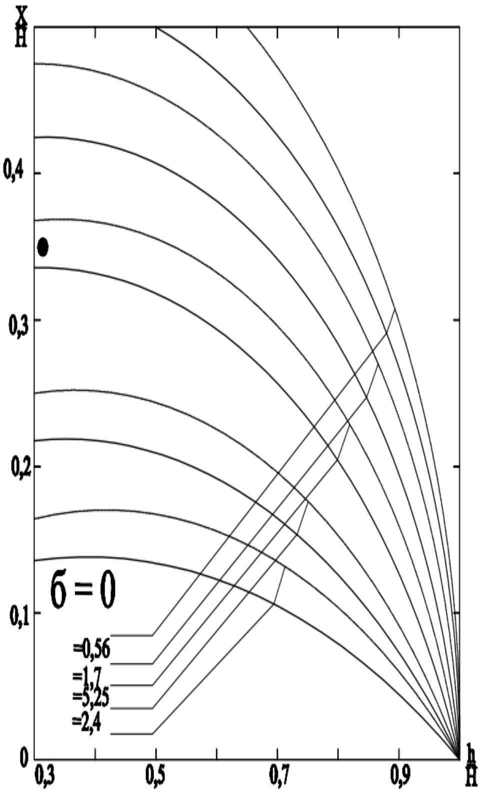

Figure 1. Experimental measurements of the axial velocity of the liquid

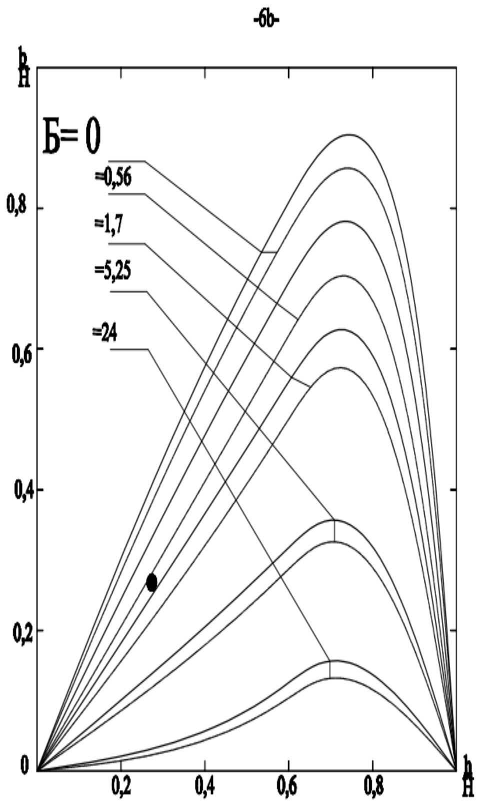

Figure 2. Experimental measurements of the axial velocity of the liquid

where

$$A_0 = 2\beta gd + 2d^2 - 1,$$

$$B_0 = 2(\beta(g-d)+d)$$

$$A_0 = 2(1-\beta) - d^2,$$

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$$\beta = \sqrt{\frac{d^2-1}{g^2-1}}.$$

For hydraulic applications, the abscissa of the flow bifurcation point is of interest D. Figure 1 shows the dependencies $\frac{x_D}{H} = f(\frac{h}{H}, \frac{U}{V_k})$. They make it possible to evaluate the pattern of changes in the relative distance $\frac{x_D}{H}$ as it increases. $\frac{h}{H}$ as can be seen in Fig. 1, with values of $\frac{h}{H} \leq 0{,}5$. This relationship is directly linear, and then the ratio $\frac{x_D}{H}$ quickly approaches zero at and $\frac{h}{H} \to 1$.Here the solid curves are obtained at $\alpha = {}^{1}/_{2}$, and the dashed curves at $\alpha = {}^{1}/_{3}$.

Figure 2 shows the dependence of the change in cavity width $\frac{b}{H}$ on the relative width $\frac{h}{H}$for various values $\frac{U}{V_k}$ and at α: 1/2 and 1/3 (mistaken curves were obtained at $\alpha = {}^{1}/_{2}$dashed curves at $\alpha = {}^{1}/_{3}$). Calculations show that maximum values are observed at a distance $\frac{h}{H} \approx$ 0.7 0.8. As the relative speed increases $\frac{U}{V_k}$ at a constant value, $\frac{h}{H}$ the relative width $\frac{b}{H}$ increases.

CONCLUSION

The results of the theoretical and experimental determination of the dependence of the axial velocity on the relative distance $\frac{x}{H}$ are shown in Fig. 2. Experimental measurements of the axial velocity of the liquid were carried out by employees of the Central Asian Research Institute of Irrigation.

The graph shows that as the distance increases, the axial velocity first increases and approaches $\frac{x}{H} = 0.1 \div 0.3$ its maximum value. Then it decreases and at some distance $\frac{x}{H}$ acquires constant values, as evidenced by experimental data.

Note that this flow structure is built by dark threads fixed in cords. The continuous boundary of the cavern was obtained by theoretical calculation.

The results of theoretical calculations for the distribution of axial velocity and flow structure in the water intake are in fairly satisfactory agreement with the results of experimental data from SANIIR employees at $\frac{h}{H} = 0.6$.

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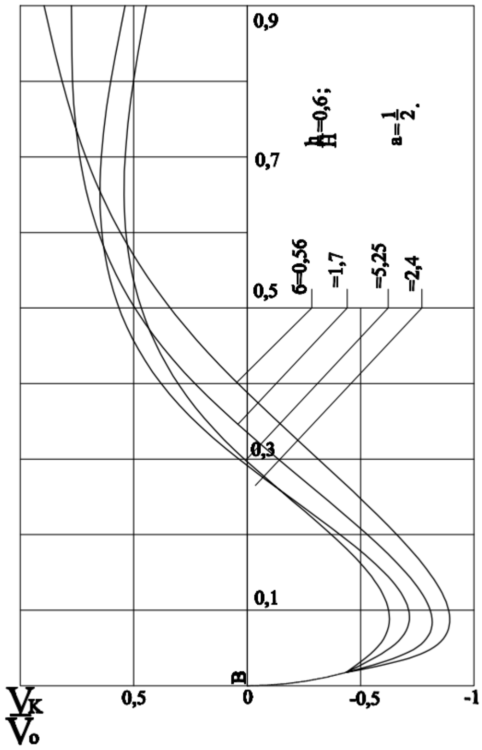

Figure 3. Velocity distributions along the wall BD

The velocity distributions along the wall $BD$are shown in Fig. 3 at $\frac{h}{H} = 0.3$, $\alpha = {}^{1}/_{2}$ and at different values of cavitation numbers. It is interesting to note that the abscissa of the point $D$where the fluid velocity is zero in Fig. 1 and 3 coincide with the same values $\frac{U}{V_k}$.

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