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Movement of Variable Flow Flux along the Path in a Closed Inclined Pipeline

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Annotation: This article discusses a variable flow rate flow along a path in a closed horizontal pipeline taking into account slope and hydraulic resistance. Formulas are given that take into account the associated water inflow to the drainage pipes, as well as the amount of suspended particles that penetrate together with water through the slots of the drainage pipes.

Keywords: Hydraulics, flow, filtration, irrigation, flow movement, horizontal.

Introduction: Such tasks are observed in the study of filtering in irrigation channels, during water intake from the source, during design and operation, the count of the lecturers and drainage network, with drip irrigation, etc.

The solution is higher than the specified tasks associated with the study of the flow of water flow with unsteadied flow [1 - 3, etc.]. This article discusses the movement of the flow of variable flows along the path in the closed horizontal pipeline, taking into account the slope and hydraulic resistance. The flow in a closed horizontal drainage is moving with an increase in the flow path due to the passing flow of water. As the experience of operating the drainage system (in the Fergana region) shows, the effectiveness of their operation is very low and does not provide the necessary decrease in the level of groundwater (Fig. 1.).

From the point of view of the theory of filtration, the amount of fluid permeable in dretu is proportional to the pressure difference in the ground and in the drainage tube and it reaches

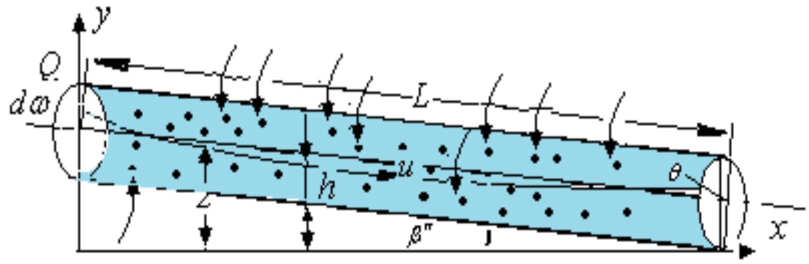

Fig.1.Closed horizontal drainage with variable flow.

The greatest value at the free movement of water in Drene [5]. From the hydraulics of the non-pressure movement, it is known that the largest throughput of the pipeline with the smallest pressure is achieved with the ratio of the depth of the water and the diameter of the pipe H / D = 0.9. The rational use of the drainage pipe is possible when satisfying this ratio.

This can be achieved by changing the diameter of the pipeline and the slope [5].

If the drainage bottom slope is not zero, then, denoting the angle of inclination of the bottom of the pipe to the horizon through α1, we have

$$dz = dh + \sin\alpha_1 dx. \qquad (1)$$

When the flow of consumption along the path is uniform, then the equality takes place:

$$\frac{Q}{Q_k} = \frac{x}{L}, \qquad (2)$$

where L is the length of the pipeline; QK - end flow.

Taking advantage of the equality from (1) and (2), we get

$$dx = \frac{L}{Q_k}(\omega du + u d\omega), \quad dz = dh + \sin\alpha_1 \frac{L}{Q_k}(\omega du + u d\omega).$$

Applying the boundary condition (designations correspond to the designations of work [3])

$$u = u_0, \text{ when } \omega = \omega_0, \qquad (3)$$

find

$$\frac{\alpha u^2}{g} = -\frac{1}{\omega}\int_{\omega_0}^{\omega} \omega dz.$$

Substituting Ω from the equations shown before (3), we have

$$\frac{\alpha u^2}{g} = \frac{1}{\omega}\left[\int_{h}^{h_0} u dh + \sin\alpha_1 \frac{L}{Q_k}\int_{\theta_0}^{\theta} \omega\left(u\frac{d\omega}{d\theta} + \frac{du}{d\theta}\right)d\theta\right]\int_{\omega_0}^{\omega} dz. \qquad (4)$$

The last formula after simple transformations will take the form

$$u^2 + \frac{gL\omega\sin\alpha_1}{2\alpha Q_k} + \frac{g}{\beta\omega}\left[\int_{\theta_0}^{\theta} u\frac{dh}{d\theta}d\theta + \sin\alpha_1 \frac{L}{Q_k}\int_{\theta_0}^{\theta} u\frac{d\omega}{d\theta}d\theta\right] = 0 \qquad (5)$$

from here to find

$$u = -\frac{gL\omega\sin\alpha_1}{2\alpha Q_k} \pm \left[\left(\frac{gL\omega\sin\alpha_1}{2\alpha Q_k}\right)^2 - \frac{g}{\alpha\omega}\int_{\theta_0}^{\theta} u\frac{dh}{d\theta}d\theta - \sin\alpha_1 \frac{g}{\alpha\omega}\frac{L}{Q_k}\int_{\theta_0}^{\theta} u\frac{d\omega}{d\theta}d\theta\right]^{\frac{1}{2}}. \qquad (6)$$

Thus, a nonlinear integrodifferential equation (6) was obtained.

The solution to this equation will allow you to record the nature of the speed change.

The latter equation can be replaced by an ordinary nonlinear equation of type

$$\frac{2\alpha}{g}u\frac{du}{d\theta} - \sin\alpha_1 \frac{L}{Q_k}\frac{r^2}{2}(\theta - \sin\theta)\frac{du}{d\theta} = -\frac{2\alpha}{g}\frac{1-\cos\theta}{\theta - \sin\theta}u^2 + \sin\alpha_1 \frac{L}{Q_k}\frac{r^2}{2}(1-\cos\theta)u - \frac{1}{2}\sin\theta \qquad (7)$$

with boundary condition

$$u = 0 \text{ when } \theta = \theta_0. \qquad (8)$$

We solve the last equation for the case of a small slope, then, according to [7],

$$u = u_0 + u', \qquad (9)$$

where is the solution of the equation of the problem without taking into account the resistance and slope of the drainage; - Small value [6].

Substituting (9) in (7) and neglecting members of the second order of smallness, we get

$$\frac{2\alpha}{g}u_0\frac{du_o}{d\theta}+\frac{2\alpha}{g}\frac{1-\cos\theta}{\theta-\sin\theta}u_0^2+\frac{1}{2}\sin\alpha_1+\left[\frac{2\alpha}{g}u_0-\sin\alpha_1\frac{L}{Q_k}\frac{r^2}{2}(\theta-\sin\theta)\right]\times$$

$$\times\frac{du'}{d\theta}+\left[\frac{2\alpha}{g}\frac{du_0}{d\theta}-\frac{2\alpha}{g}\frac{1-\cos\theta}{\theta-\sin\theta}2u_0+\sin\alpha_1\frac{L}{Q_k}\frac{r^2}{2}(1-\cos\theta)\right]u'=$$

$$=\sin\alpha_1\frac{L}{Q_k}\frac{r^2}{2}(\theta-\sin\theta)\frac{du_0}{d\theta}+\sin\alpha_1\frac{L}{Q_k}\frac{r^2}{2}(1-\cos\theta)u_0. \quad (10)$$

entering the following notation:

$$\varphi_1(\theta)=\frac{2\alpha}{g}u_0-\sin\alpha_1\frac{L}{Q_k}\frac{r^2}{2}(\theta-\sin\theta),$$

$$\varphi_2(\theta)=\frac{2\alpha}{g}\frac{du_o}{d\theta}-(1-cos\theta)\left[\frac{4\alpha u_0}{g(\theta-\sin\theta)}-\frac{L}{2Q_k}\sin\alpha_1\right],$$

$$\varphi_3(\theta)=\frac{Lr^2\sin\alpha_1}{2Q_k}\left[(1-\cos\theta)u_0+(\theta-\sin\theta)\frac{du_0}{d\theta}\right],$$

From (10) we have

$$\frac{du'}{d\theta}+\frac{\varphi_2(\theta)}{\varphi_1(\theta)}u'=\frac{\varphi_3(\theta)}{\varphi_1(\theta)} \quad (11)$$

with a boundary condition at. Here is indicated in contrast to the case of zero slope. The solution of equation (11) has the form

$$u'=e^{-x}\left(\int_{\theta_{00}}^{\theta}\frac{\varphi_3(\theta)}{\varphi_1(\theta)}e^x d\theta+C_1\right) \quad (12)$$

Integral (12) imagine how

Where

$$I_1=\int\frac{\frac{2}{g}\frac{du_0}{d\theta}-\frac{Lr^2\sin\alpha_1}{2Q_k}(1-\cos\theta)}{\frac{2\alpha}{g}u_0-\frac{Lr^2\sin\alpha_1}{2Q_k}(\theta-\sin\theta)}d\theta$$

and

$$I_2 = \int \frac{\left(\frac{2\alpha u_0}{g(\theta - \sin\theta)} - \frac{Lr^2 \sin\alpha_1}{2Q_k}\right)(1-\cos\theta)}{\frac{2\alpha}{g}u_0 - \frac{Lr^2 \sin\alpha_1}{2Q_k}(\theta - \sin\theta)} d\theta.$$

Calculating the integral, we get the following expression: $x = \ln\varphi_1 - 2\ln(\theta - \sin\theta)$,

где $I_2 = \int \frac{\varphi_2}{\varphi_1} d\theta$.

From the boundary condition, we define C1 in the form of: $C_1 = -u_0(\theta_{00})e^{x(\theta_{00})}$. Then out of

we have

$$u' = e^{\left(-\int\frac{\varphi_2}{\varphi_1}d\theta\right)}\left(\int_{\theta_{00}}^{\theta} e^{\left(\int\frac{\varphi_2}{\varphi_1}d\theta\right)} d\theta\right) - e^{\left(-\int\frac{\varphi_2}{\varphi_1}d\theta\right)} u_0(\theta_{00}). \qquad (13)$$

Substituting the last expression in (13), after uncomplicated transformations we find,

$$u' = \frac{(\theta - \sin\theta)^2}{\varphi_1}\int_{\theta_{00}}^{\theta}\frac{\varphi_3}{(\theta - \sin\theta)^2}d\theta - \frac{\varphi_1(\theta_{00})}{\varphi_1(\theta)}\frac{(\theta - \sin\theta)^2}{(\theta_{00} - \sin\theta)}u_0(\theta_{00}).$$

So for having

$$u = u_0 - \frac{\varphi_1(\theta_{00})}{\varphi_1(\theta)(\theta_{00} - \sin\theta_{00})}u_0(\theta_{00}) - \frac{(\theta - \sin\theta)^2}{\varphi_1}\int_{\theta_{00}}^{\theta}\frac{\varphi_3}{(\theta - \sin\theta)^2}d\theta. \qquad (14)$$

Now, defining, i.e. To determine the critical angle, we use a well-known expression for the specific section of the section: $E = h + \frac{\alpha Q^2}{2\omega^2 g}$, при $\frac{\partial E}{\partial h} = 0$ we have $1 - \frac{\alpha Q^2}{2\omega^3 g}\frac{d\omega}{dh} = 0$.

insofar as

$$\frac{d\omega}{dR} = 2r\sin\frac{\theta_{кр}}{2}, \text{ то } 1 - \frac{\alpha Q^2 r \sin\frac{\theta_{кр}}{2}}{g\left[\frac{r^2}{2}(\theta_{кр} - \sin\theta_{кр})\right]^3} = 0.$$

from here we get the equation

$$2\alpha Q^2 \sin\frac{\theta_{кр}}{2} - g\left[\frac{r^2}{2}(\theta_{кр} - \sin\theta_p)\right]^3 = 0. \qquad (15)$$

Defined θ_{00} from the equation (15and substituting it in (14), We obtain the equation to determine θ_{00}

$$u_{кр}=u_0(\theta_{кр})-\frac{\varphi_1(\theta_{00})(\theta_{кр}-\sin\theta_{кр})^2}{\varphi_1(\theta_{кр})(\theta_{00}-\sin\theta_{00})}u_0(\theta_{00})+\frac{(\theta_{кр}-\sin\theta_{кр})^2}{\varphi_1(\theta_{кр})}\int_{\theta_{00}}^{\theta_{кр}}\frac{\varphi_3(\theta)}{(\theta-\sin\theta)^2}d\theta_{00},$$

which we transform the form

$$u_{кр}=u_0(\theta_{кр})-(\theta_{кр}-\sin\theta_{кр})^2\cdot\left\{\left[\frac{2\alpha}{g}u_0(\theta_{00})-\frac{Lr^2\sin\alpha_1}{2Q_k}(\theta_{00}-\sin\theta_{00})\right]\frac{u_0(\theta_{00})}{(\theta_{00}-\sin\theta_{00})^2}+\right.$$

$$\left.+\sin\alpha_1\frac{L}{Q_k}\left[\frac{gr^3}{\alpha g}\int_{\theta_{00}}^{\theta_{кр}}\frac{\sin\frac{\theta}{2}d\theta}{u_0(0)(\theta-\sin\theta)}-\frac{r^2}{4}\int_{\theta_{00}}^{\theta_{кр}}\frac{u_0(0)(1-\cos\theta)}{(\theta-\sin\theta)^2}d\theta\right]\right\}\times$$

$$\times\left[\frac{2\alpha}{g}u_0(\theta_{кр})-\frac{Lr^2\sin\alpha_1}{2Q_k}(\theta_{кр}-\sin\theta_{кр})\right]^{-1}.$$

Equation (4) when registering the pipe resistance to easily lead to mind

$$\frac{\alpha u^2}{g}=+\int\frac{\alpha u^2}{g\omega}d\omega+\sin\alpha_1\frac{L}{Q_k}\int(ud\omega+\omega du)+h+h_e=\text{const},\qquad(16)$$

where h_e - friction losses expressed similarly to the case of a constant flow rate:

$$h_e=\lambda\frac{L}{d}\frac{\alpha u^2}{2g}.$$

where λ — friction losses expressed similarly to the case of a constant flow rate:

$$d\left(\frac{\alpha u^2}{g}\right)+\frac{\alpha u^2}{g}\frac{d\omega}{\omega}+\lambda\frac{L}{d}d\left(\frac{\alpha u^2}{2g}\right)+dh=0$$

or

$$d\left(\frac{\alpha u^2}{g}\right)+\frac{1}{1+\frac{\lambda L}{2d}}\left(\frac{\alpha u^2}{g}\frac{d\omega}{\omega}+dh\right)=0\qquad(17)$$

Solution of this equation using in particular equality zero of the bottom of the bottom, those. $dz=dh$, and considering

$$\left.\begin{aligned} h &= r\left(1-\cos\frac{\theta}{2}\right) \\ \omega &= \frac{r^2}{2}(\theta - \sin\theta) \end{aligned}\right\}, \qquad (18)$$

can be represented as

$$\frac{\alpha u^2}{g} = \frac{ar}{2(\theta - \sin\theta)^a}\int_{\theta}^{\theta_0}(\theta - \sin\theta)^a \sin d\theta, \qquad (19)$$

где h – Depth of pipe filling, $a = \dfrac{1}{1+\dfrac{\lambda L}{2d}}$.

Then to determine the following formula:

$$\frac{4\alpha Q_k^2}{agr}\left(\theta_{кр} - \sin\theta_{кр}\right)^{a-2} - \frac{r}{2}\int_{\theta_{кр}}^{\theta_0}(\theta \;\; - \sin\theta)^a \sin\frac{\theta}{2}\, d\theta = 0. \qquad (20)$$

The resulting equation is solved by a consistent approximation.

Find the function of the slope of the pipe and the diameter d. After some transformations from formula (18) we get

$$\beta'' = 2\alpha Q_k^2 / gr^5,$$

Where we have for pipe diameter expression

$$d = 2\left(2\alpha Q_k^2 / g\beta''\right)^{\frac{1}{5}}.$$

The resulting formulas (18) and (19) for the speed of water movement coincide well with the results of experiments. The results of the calculations are shown in the table.

Results of water flow calculations

D	L	θ_{kp}	β"	d	L	θ_{kp}	β"
0.95	250	2.525	1.937	1.50	750	2.150	0.644
	500	2.060	0.504		1000	1.934	0.304
	750	1.850	0.229	2.00	250	2.900	4.481
	1000	1.633	0.088		500	2.542	2.026
1.00	250	2.542	2.026		1000	2.308	1.054
	500	2.150	0.644				
	750	1.845	0.203	2.50	250	2.150	0.644
	1000	1.640	0.091		500	2.95	5.263
1.165	250	2.606	2.461		750	2.683	2.869
	500	2.255	0.898		1000	2.434	1.513
	750	1.934	0.304	3.00	250	2.266	0.930
	1000	1.845	0.215		500	3.017	6.063
1.50	250	2.700	3.009		750	2.700	3.009

	500	2.384	1.315		1000	2.542	2.026

Thus, the calculations on the resulting formula for the velocity of the water movement in horizontal drains (19) are well coincided with the results of experimental studies [2].

The results of the research confirmed that the throughput capacity of the pipeline with the smallest pressure is achieved with the value of H / D = 0.9 the depth of water to the pipe diameter.

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