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PROBLEMS OF EXPERIMENTAL STUDY OF ACCUMULATED AIR RELEASE

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The paper studies accumulated in a pipeline air emission into the atmosphere. The analysis of the differential equation of a fluid column motion has shown that flow rate at the outlet section tends to infinity.

Since the blowout rate is finite then it is commonly accepted that blowout of air-mixed mass occurs not at the outlet section but at the section located at some Xx distance from the outlet section. This assumption is proven by the experiment carried out at the damaged force pipeline of the Saralanj pump station.

A formula has been derived to determine the blowout rate. To evaluate the Xx distance a laboratory experimental studies have been carried out. The measured magnitude of range obtained by the experiments enables to quantify the Xx value.

An analytic calculation method for energy loss in a straight hydraulically smooth pipe of uniform cross-section through which a viscous fluid flows in steady-state conditions has been suggested. This method enables to determine hydraulic friction losses based on a unified approach, i.e. without binding it to the fluid flow regime. Satisfactory convergence of calculated and known in literature values of friction resistance coefficients has been shown.

Key words: *fluid, viscosity, velocity, energy, loss, pressure.*

Introduction

Complex and effective use of water resources requires combination of environmental, socio-economic and technical issues. In irrigation and drinking water systems of the Republic of Armenia hundreds of pump stations, gravity water pipelines are in operation of which the total length of the water main measures three thousand km. [3]. Physiographic characteristics, rough landscapes of mountainous countries cause serious difficulties for implementation and effective operation of engineering infrastructures and especially water supply systems.

In highlands pressure lines of irrigation, drinking water gravity cannels and pump stations have many siphon sections in the vertical plane where air accumulations occur which sometimes are called air cushions [1, 2, 7, 8, 10]. The main reason of air accumulations development in high locations of gravity pipelines is an aerated water entry developed in head works. rising and descending branches of high location pipelines in many cases are of large inclination due to which air accumulations developed in the siphon sections in conditions of operation hydraulic mode are not entrained by the fluid flow. As a consequence of all this the value of discharge flow through the pipeline is diminished. Not frequently, particularly, in small diameter siphon pipes the bubbles can occupy the entire section of the siphon pipes and make the siphon flow stop [4, 9, 12].

Many research workers carried our theoretical and experimental study of air accumulation development reasons in siphon sections of a pipeline and impact of the accumulations on the hydraulic mode. Release from the pipe end of the accumulated air entrained by fluid flow is less studied and known as “Air Shot”. This phenomenon occurs almost in all pipelines functioning in pressure mode mainly when hydraulic mode undergoes a drastic change [5].

At the moment you open your kitchen water tap after a long interruption of the water supply service when the pipeline became full of air a sudden release of water mixed with accumulated air will occurs with a specific noise reminding that of sneezing. This stream of the water and air mixture strongly hits the washbasin. This phenomenon is far more dangerous in gravity water lines, pressure pipelines of pump stations. There it causes destruction and rupture of the pipe in head works (Mkfchian pump station first step, Saralanj pump station, Hermon-Elpin gravity canal [4]).

Waterlines of turbine installations of small hydropower stations built in the last decade in Armenia are located higher than the head works of the gravity waterline. It makes operation of the station complications [7, 11].In case the small hydropower stations taken out of service in the head works of the waterline due to water discharge abrupt decrease a difference occurs between the given and demanded discharges and as a consequence on some part of the waterline adjacent to the head works non-pressure flow is developed.

When on derivation length at the river section the discharge is recovered, in the head works the water level rise takes place, but the waterline no longer can receive additional discharge, till the entrapped in the pipeline air is not removed by an air release valves.

Currently a number of gravity waterlines are under design and construction in the country. Most of problems we are after is related to the design, effective operation, raising of safety, and maintenance.

Release of accumulated air was also observed in non-pressure tunnel of Tatev hydropower stations. As a result of a discharge more than water discharge, the tunnel cross-section was locked and when the entrapped air was released from the entrance section, the metal structures of the tunnel portal were destroyed.

Conflict settings

The problem of theoretical analysis of the water and air mixture stream release from the pipe end is reduced to determination of two physical magnitudes: ***release velocity*** and ***a force that stream hits on the motionless obstacle***.

Theoretically, determination of these two physical magnitudes, particularly, impact of the released mass on an motionless obstacle, is impossible, because releasing aerated two-phase mass concentration is unknown. For this reason investigation of this phenomenon should be carried out experimentally.

Researchresults. We planned to design, build, and install an experimental setup (Fig.1) in the hydraulic research laboratory of the Institute of Water Problems and Hydro-engineering after Academician Yeghiazarov.

The experimental setup consists of a D=25mm diameter glass tube (1), plug valve (2), check valve (3), valve of discharging unit (4), air release valve (5), flexible unit of connection (6), slope changing device (7). The experimental setup is fed from a large basin, which is installed at H=7m height from the entrance valve.

Sequence of experiments performance and obtained results

The experiment is performed in the following way: the glass tube is installed at $i_0 = \sin\alpha$ angle and by full opening the entrance valve the discharge Q and long-term L_0 are measured (Fig.1).

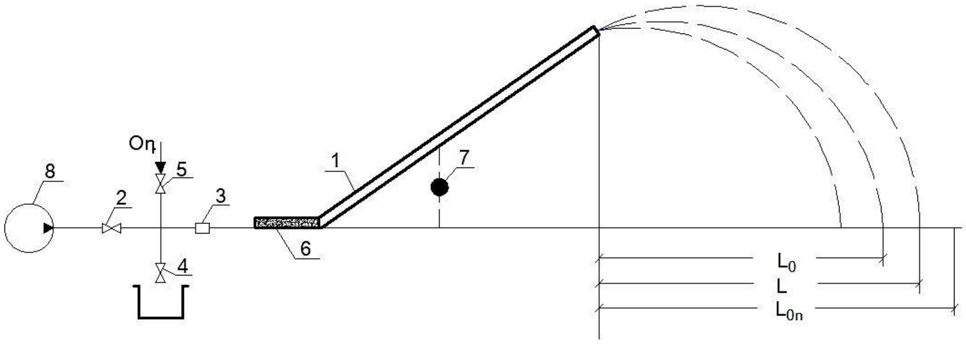

Figure 1. Experimental setup for release phenomenon observation

Trajectory equation of the stream's central particle can be expressed as

$$y = \frac{g\,x^2}{2V^2\cos^2\alpha} - x\,tg\alpha \tag{1}$$

Taking into account that when $y = h,\ \ x = L$, we have

$$L = \frac{V}{g}\cos\alpha\left(V\sin\alpha + \sqrt{V^2\sin^2\alpha + 2gh}\right): \tag{2}$$

It is evident that $L_0 / L = k$ quantity will characterize atmospheric air influence on the range of the stream.

A.Ya.Margaryan [5, 7] differential equation of the fluid column situated in front of air accumulation (in the line of flow) presents as

$$\frac{dV}{dt} = \frac{g\,i_0}{A}\,\frac{p_0\,W_0}{x\left[p_0 + \rho\,g\,x\left(i_0 + \frac{Q^2}{K^2}\right)\right]}, \tag{3}$$

where p_0 and W_0 are initial absolute pressure and volume of air accumulation, respectively, K is pipeline transmission capacity, x is the length of the fluid column between the outlet cross-section and air accumulation.

From Eq.(3) it follows that when $x \to 0,\ \ dV/dt \to \infty$ hence $V \to \infty$, that is from the pipe's end air accumulation is released by infinite high velocity.

The below table shows relative release ranges

Table 1

Relative release ranges

α 0	h cm	Q cm^3/s	V cm/s	L_{0d} cm	L_0 cm	L cm	L_{od} / L_0 -	$k = L_0 / L$ -

Actually the release velocity is final. This means that air mixed fluid flight starts from a section located at some x_* distance from the pipe end (Fig. 2).

Let us determine $V(x)$function in the [x_0, x_*] interval. As far as $dx = -Vdt$, then Eq.(3) takes the following expression of a differential equation with detachable variables

$$VdV = -\frac{b}{c}\frac{dx}{\left(x+\frac{p_0}{2c}\right)^2 - \left(\frac{p_0}{2c}\right)^2}, \tag{4}$$

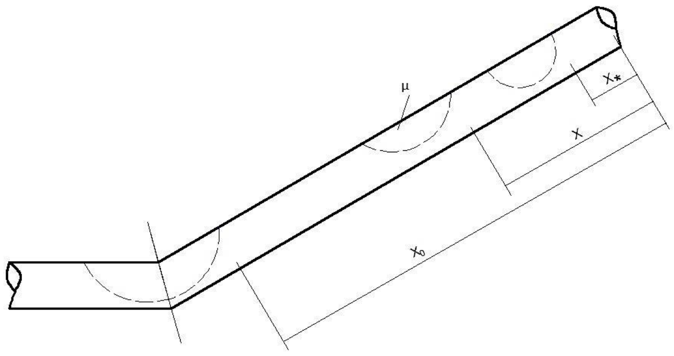

Figure 2. Time-dependent positions of air accumulation

where $b = p_0 W_0 \frac{i_0\, g}{A}$, $c = \rho\, g\left(i_0 + \frac{Q^2}{K^2}\right)$: (5)

Substituting the variable, we have

$x + \frac{p_0}{2c} = u$ and denoting $\frac{p_0}{2c} = a$: (6)

Eq.(4) takes the following expression

$$VdV = -\frac{b}{c}\frac{du}{u^2 - a^2}: \tag{7}$$

Integrating Eq.(8) for boundary conditions

$$u = u_0,\ V = 0, \tag{8}$$

we get

$$V^2 = \frac{b}{ca}\ln\left|\frac{(u_0 - a)(u + a)}{(u_0 + a)(u - a)}\right|: \tag{9}$$

Substituting constants of Eqs.(5) and (6), we have

$$V=\sqrt{\frac{2g\,i_0W_0}{A}}\sqrt{\ln\frac{x_0\left(x+\dfrac{p_0}{\rho\,g\left(i_0+Q^2/K^2\right)}\right)}{x\left(x_0+\dfrac{p_0}{\rho\,g\left(i_0+Q^2/K^2\right)}\right)}}: \tag{10}$$

First root of Eq.(10) has a dimension of velocity

$$\sqrt{\frac{2g\,i_0W_0}{A}}=V_0 : \tag{11}$$

Hence

$$V=V_0\sqrt{\ln\frac{x_0\left(x+m\right)}{x\left(x_0+m\right)}}, \tag{12}$$

$$\left(m=\frac{p_0}{\rho\,g\left(i_0+Q^2/K^2\right)}\right) \tag{13}$$

According to the above assumption and substituting $x=x_*$ in Eq.(12), we get the release velocity

$$V_*=V_0\sqrt{\ln\frac{x_0\left(x_*+m\right)}{x_*\left(x_0+m\right)}}: \tag{14}$$

Conlusion

Experimental studies will enable to clear up a number of problems which play a decisive role in design and operation processes, including the following:

1. findings obtained by experimental study on air accumulations displacement nature in gravity waterlines,
2. analysis of results obtained by theoretical and experimental study on critical velocity value of air accumulation entrainment by fluid flow,
3. theoretical and experimental study on air accumulation development reasons in the pressure pipeline and impact mechanism of water and air mixture stream released from the end outlet of the pipeline.

The work has been performed within the framework of 15T-2K263 theme.

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ԽՈՂՈՎԱԿԱՇԱՐԻՑ ՕԴԱՅԻՆ ԿՈՒՏԱԿՄԱՆ ԱՐՏԱՆԵՏՄԱՆ ՓՈՐՁԱՐԱՐԱԿԱՆ ՀԵՏԱԶՈՏՈՒԹՅՈՒՆՆԵՐԻ ԽՆԴԻՐՆԵՐԸ

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Քննարկվում է խողովակում առկա օդային կուտակման՝ մթնոլորտ արտանետման երևույթը: Օդային կուտակման առջևում գտնվող հեղուկի սյան շարժման դիֆերենցիալ հավասարման վերլուծությամբ պարզվել է, որ ելքի կտրվածքում հոսանքի արագությունը ձգտում է անվերջության:

Քանի որ արտանետման արագությունը պետք է լինի վերջավոր, ապա ընդունված է, որ օդախառը զանգվածի արտանետումը կատարվում է ոչ թե խողովակի ելքի կտրվածքից, այլ դրա ծայրից որոշ Xx հեռավորության վրա գտնվող կտրվածքից:

Այս պնդումը հաստատվել է Սարալանջի պոմպակայանի վթարված մղման խողովակաշարի վրա կատարված փորձերով:

Ստացվել է արտանետման արագության որոշման բանաձև: Որպեսզի գնահատվի Xx-ի մեծությունը, կատարվել են լաբորատոր փորձնական հետազոտություններ: Դրանց արդյունքում որոշված հեռահարության չափված մեծության միջոցով գնահատվել է Xx- ի մեծությունը:

Բանալի բառեր. հեղուկ, մածուցիկություն, արագություն, էներգիա, կորուստ, ճնշում:

ЭКСПЕРИМЕНТАЛЬНОЕ ИССЛЕДОВАНИЕ ПРОБЛЕМЫ ВЫБРОСА СКОПИВШЕГОСЯ ВОЗДУХА

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В статье рассматривается проблема выброса воздуха в атмосферу,скопившегося в трубопроводе.Анализ дифференциациального уравнения движения жидкости в трубе показывает,что скорость потока на выходе из секции,как правило,бесконечна.

Поскольку дебет фонтанирующей скважины ограничен,то обычно считается,что дебет смешанных воздушных масс происходит не на выходе выпускной секции,а на участке,расположенном в некотором Хх расстоянии от секционной розетки.Это предположение подтверждается экспериментом,проведеннм трубопроводом насосной станциии Сараландж.

Ключевые слова: жидкость, вязкость, скорость, энергия, потеря, давление.

$$u=\left(\frac{2a}{\upsilon^2}\right)^{1/2}\upsilon l_0^{1/2} f'=U_0 f'$$

The local shear stress is determined by the below equation

$$\tau_0(z)=\mu\frac{\partial u}{\partial r}\bigg|_{r=0}=\frac{1}{\sqrt{2}}f_0''U_0\mu\left(\frac{2a}{\upsilon^2}\right)^{1/4}\frac{1}{z^{1/4}}$$

The average value of shearing stresses is determined by the below formula

$$\tau_w=\frac{4}{3\sqrt{2}}f_0''U_0\mu\left(\frac{2a}{\upsilon^2}\right)^{1/4}\frac{1}{l^{1/4}}$$

Pressure loss in the l long section of under consideration will be

$$\Delta p_2=\frac{16}{3\sqrt{2}}f_0''U_0\mu\left(\frac{2a}{\upsilon^2}\right)^{1/4}\frac{l^{1/4}}{d}$$

Making some simple transformations of the above equation, we have

$$\Delta p_2=45.5\cdot\frac{1}{\mathrm{Re}^{3/4}}\cdot\left(\frac{l}{d}\right)^{3/4}\cdot\frac{\rho\langle u\rangle^2}{2}$$

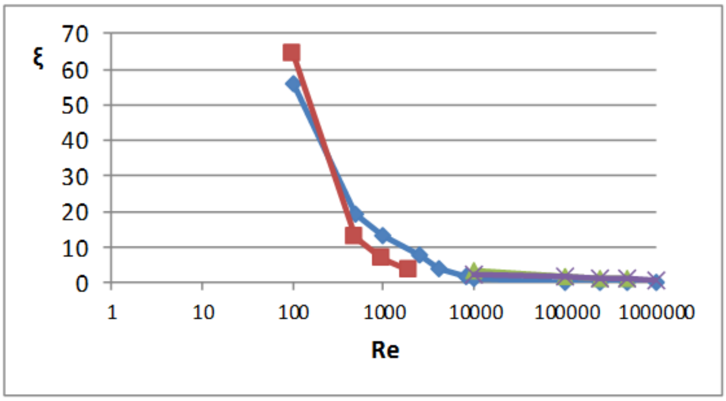

Figure 1. Comparison of friction resistance coefficients for $l/d=100$

1- theoretical curve plotted by Eq. (20) $\zeta=\left[\frac{45.5}{\mathrm{Re}^{3/4}}\cdot\left(\frac{l}{d}\right)^{3/4}+2.42\right]$, 2- plotted by $\zeta=\frac{64}{\mathrm{Re}}\cdot\frac{l}{d}$ [1],

3- plotted by $\zeta=\frac{0.316}{\mathrm{Re}^{0.25}}\cdot\frac{l}{d}$ [1], 4- plotted by $\zeta=\left(0.0032+\frac{0.221}{\mathrm{Re}^{0.237}}\right)\cdot\frac{l}{d}$ [4].

Pressure general loss in the pipe is summed up from losses at the initial section where velocity profile is stabilized and in the section of stabilized flow

$$\Delta p=\Delta p_2+\Delta p_0=\left[45.5\cdot\frac{1}{\mathrm{Re}^{3/4}}\cdot\left(\frac{l}{d}\right)^{3/4}+2.42\right]\frac{\rho\langle u\rangle^2}{2} \qquad (20)$$

Comparison of calculated values of the friction resistance coefficient with experimental data available in the literature (see the Figure)

Discrepancy between the two Averaged 8 per cent.