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Hydraulic structures, hydraulic shock, aerated flow, internal volume, lower slope aerated flow in the Rezaksay reservoir

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Abstract: This article theoretically studies the occurrence of cavitation in water discharge pipes during hydraulic shock, the mechanisms of its development, and the physical processes associated with the transition of the flow to an aerated state. According to the results of the study, significant excessive hydrodynamic loads appear in pipes, valves, and other hydraulic structures under the influence of hydraulic shock, which leads to rapid failure of structural elements. It is also shown that cavitation and aeration processes have a significant impact on the internal structure of the flow, causing the formation of gas bubbles in the water flow, sharp fluctuations in pressure, and a complication of energy exchange processes. Based on the results obtained, the laws of distribution of the aerated flow over the internal volume under hydraulic shock conditions are expressed using mathematical models and their physical content is analyzed. During the experimental and theoretical analyses, the physical and mechanical properties of the flow, the time variation of pressure pulses, and the processes of energy dissipation were determined, and their impact on the stability of hydraulic structures was assessed. The results show that changes in the flow structure under hydraulic shock conditions increase abrasive erosion processes in structural elements, which significantly reduces their service life. The scientific results obtained in the article serve as an important theoretical basis for correctly determining safety margins in the design of hydraulic structures, reducing accidents during operation, and increasing energy efficiency.

Keywords: ydraulic structures, hydraulic shock, aerated flow, internal volume, lower slope. Aerated flow in the Rezaksay reservoir

Gidrotexnika inshootlarida gidravlik zarba tufayli aeratsiyali oqimning ichki xajmi bo‘yicha tarqalishining nazariy yechimlari

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Annotatsiya: Ushbu maqolada gidravlik zarba jarayonida suv chiqarish quvurlarida kavitatsiya hodisasining yuzaga kelishi, uning rivojlanish mexanizmlari hamda oqimning aeratsiyalangan holatga o‘tishi bilan bog‘liq fizik jarayonlar nazariy jihatdan o‘rganilgan. Tadqiqot natijalariga ko‘ra, gidravlik zarba ta’sirida quvurlarda, klapanlarda va boshqa gidrotexnika inshootlarida sezilarli darajada ortiqcha gidrodinamik yuklanishlar paydo bo‘lib, bu esa konstruktiv elementlarning tez ishdan chiqishi aniqlangan. Shuningdek, kavitatsiya va aeratsiya jarayonlari oqimning ichki tuzilishiga sezilarli ta’sir ko‘rsatib, suv oqimida gaz pufakchalari hosil bo‘lishi, bosimning keskin tebranishi hamda energiya almashinuvi jarayonlarining murakkablashishiga sabab bo‘lishi ko‘rsatilgan. Olingan natijalar asosida gidravlik zarba sharoitida aeratsiyalangan oqimning ichki hajmi bo‘yicha tarqalish qonuniyatlari matematik modellar yordamida ifodalangan va ularning fizik mazmuni tahlil qilingan. Tajriba va nazariy tahlillar davomida oqimning fizik-mexanik xususiyatlari, bosim impulslarining vaqt bo‘yicha o‘zgarishi hamda energiya so‘nish jarayonlari aniqlanib, ularning gidrotexnika inshootlari barqarorligiga ta’siri baholangan. Natijalar shuni ko‘rsatadiki, gidravlik zarba sharoitida oqim strukturasining o‘zgarishi inshoot elementlarida abraziv yemirilish jarayonlarini kuchaytiradi va bu holat ularning xizmat muddatini sezilarli darajada qisqartiradi. Maqolada olingan ilmiy natijalar gidrotexnika inshootlarini loyihalashda xavfsizlik zaxiralarini to‘g‘ri belgilash, ekspluatatsiya jarayonida avariya holatlarini kamaytirish hamda energiya samaradorligini oshirish uchun muhim nazariy asos bo‘lib xizmat qiladi.

Kalit so‘zlar: gidrotexnika inshootlari, gidravlik zarba, aeratsiyali oqim, ichki hajmi, pastki nishblik. Rezaksoy suv omborida aeratsiyali oqim

1. Kirish

Jahonning ilg‘or mamlakatlarida so‘nggi yillarda gidravlikaga xos bo‘lmagan jarayonlarni tadqiq qilish va aeratsiyaga ega quvurlardagi oqimlarining barqaror holatini shakllantirishda matematik modellashtirish jarayonlariga katta e’tibor berilmoqda, ayniqsa, bu jarayonlar Rossiya, Xitoy, AQSH, Yaponiya kabi ilg‘or davlatlarda intensiv

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rivojlanib kelinmoqda. Ma’lumki, gidravlik zarba tufayli oqimdagi aeratsiyaning shakllanish mexanizmi statsionar bo‘lmagan buzilishlarning paydo bo‘lishiga olib kelishi bilan birgalikda, suv omborlarida yuqori yuklanishlarning yuzaga kelishi orqali deformatsiyalanishning paydo bo‘lishiga olib keladi. Natijada suv chiqarish quvurlarini ishlamay qolishi, quvurlarning yaxlitligi va ishonchliligining yo‘qolishi kabi gidravlikaga xos bo‘lmagan jarayonlar yuzaga kelishini e’tiborga olish dolzarb vazifalardan hisoblanadi. Zamonaviy gidrotexnika inshootlarini loyihalash va ulardan samarali foydalanish jarayonida oqimlarning murakkab xatti-harakatlarini chuqur o‘rganish muhim vazifalardan biri hisoblanadi. Ayniqsa, gidravlik zarba hodisasi suv uzatish tizimlarida tez-tez uchrab, quvurlar, kanallar va boshqa inshoot elementlariga sezilarli dinamik yuklama beradi. Bunday sharoitda oqimning aeratsiyalanishi, ya’ni suv tarkibiga havo aralashishi jarayoni oqim parametrlarini sezilarli darajada o‘zgartiradi.Aeratsiyali oqimlar oddiy bir fazali oqimlarga nisbatan ancha murakkab bo‘lib, ularning ichki tuzilishi, zichligi, bosim taqsimoti va energiya yo‘qotishlari o‘ziga xos xususiyatlarga ega. Gidravlik zarba paytida esa bu jarayonlar yanada murakkablashadi, chunki bosimning keskin o‘zgarishi oqim ichidagi havo pufakchalari harakati va taqsimlanishiga bevosita ta’sir ko‘rsatadi.

Shu sababli, aeratsiyali oqimning ichki hajm bo‘yicha taqsimlanishini nazariy jihatdan o‘rganish nafaqat ilmiy, balki amaliy ahamiyatga ham ega. Bu orqali gidrotexnika inshootlarida yuzaga kelishi mumkin bo‘lgan avariyaviy holatlarning oldini olish, konstruktiv yechimlarni takomillashtirish va tizimlarning ishonchliligini oshirish mumkin. Olingan nazariy natijalar asosida aeratsiyali oqimning ichki hajmiy strukturasini prognoz qilish imkonini beruvchi matematik model taklif etiladi. Ushbu model yordamida gidrotexnika inshootlarida bosimning xavfli oshib ketish holatlarini oldindan aniqlash, kavitatsiya va zarba ta’sirlarini kamaytirish bo‘yicha muhim tavsiyalar ishlab chiqiladi.

Natijalar shuni ko‘rsatadiki, aeratsiyalangan oqim gidravlik zarba energiyasini qisman yutish xususiyatiga ega bo‘lib, bu holat inshootlarning mustahkamligi va uzoq muddatli ishlashiga ijobiy ta’sir ko‘rsatadi. Shu bilan birga, aeratsiya darajasining ortishi oqim parametrlarining barqarorligiga turlicha ta’sir ko‘rsatishi mumkinligi aniqlangan.

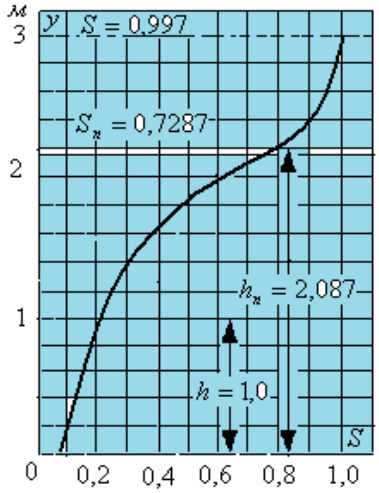
2. Tadqiqot metodologiyasi

Ushbu tadqiqotda gidrotexnika inshootlarida gidravlik zarba tufayli aeratsiyali oqimning o‘zgarishi bosqichma-bosqich o‘rganilgan.Birinchi navbarda, gidrotexnika inshootlarida gidravlik zarba tufayli oqim suv va havodan iborat aralashma sifatida qaraldi hamda uning asosiy ko‘rsatkichlari — tezlik, bosim va havo miqdori aniqlab olindi.Keyingi bosqichda aynan gidravlik zarba tufayli, ya’ni bosimning keskin o‘zgarishi va uning oqimga ta’siri nazariy jihatdan aniqlangan. Shu bois oqim ichidagi havoning taqsimlanishi matematik tenglamalar orqali ifodalandi.

Tadqiqotlar asosida suv ombori to‘g‘onining suv chiqarish joytidagi quvur uzunligi bo‘ylab tarqaladigan vibratsiya to‘lqinining hosil bo‘lish jarayonlarini aniqlangan.

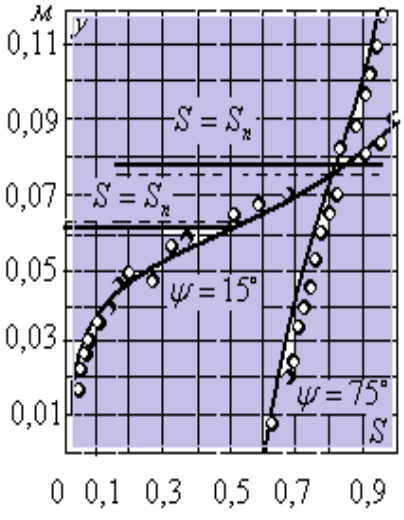
Bosimli quvurlarda quvurning ichidagi bosim, quvur uzunligi, quvur diametri va mahalliy qarshiliklarni bog‘lovchi Bernulli tenglamasi asosida vibratsiyali kavitatsiya vaqtida paydo bo‘ladigan shiddatli bosimni aniqlash ifodasi ishlab chiqilgan.Suv omborining ishlash rejimiga bog‘liq holda suv chiqarish traktlarida vujudga keladigan kavitatsiya jarayonlarini boshlanish chegaralarini aniqlash mezoni ishlab chiqilgan.

Bundan ko‘rinadiki tadqiqotlar jarayonida suv omborlaridagi suv chiqarish quvurlarida havosiz bo‘shliqning(vakuum) paydo bo‘lishi tufayli yuzaga keladigan gidravlik zarbalar, tufayli kavitatsiya yuzaga kelish, suv chiqarish quvurining deformatsiyanish oqibatida hisoblashning nazariy uslublaridan, matematik modellashtirish hamda “**ANSYS” workbench** zamonaviy dasturiy ta’minoti asosida chekli elementlar hisoblash usullaridan foydalanib, suv ombori suv o‘tkazish quvuridagi kuchlanganlik-deformatsiya holatlari aniqlahsdan iborat.



A)

1-rasm. Mahalliy konsentratsiyaning oqim chuqurligi bo‘yicha o‘zgarish grafii



B)

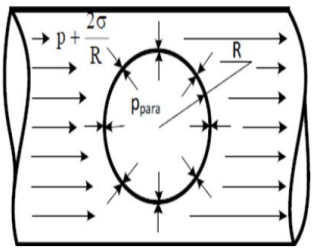
2-rasm. Gidrotexnika inshootalrning oqim chuqurligi bo‘yicha mahalliy havo konsentratsiyasi tarqalishining eksperimetlar qiymatlarini solishtirish:

bu yerda,

——— nazariy sirt sathi;

ooooo - tajribadan olingan sirt sathi.

Gidrotexnik inshootalrda gidravlik zarba tufayli suv chiqarish quvurlarda bo‘ladigan tebranishlar kuchli bo‘lib, bunda kavitatsiya jarayonlar tez fursatda ro‘y beradi. Ushbu sinovlarni bajarish Namangan viloyati joylashgan rezaksoy suv omborida olib boriladi.



3-rasm. Statik muvozanatda bug‘li pufakcha sirtiga ta’sir etuvchi kuchlar. Bu yerda $R_0 \approx 10^{-9}$ga teng bo‘ladi.

3. Natija va muhokamalar

Gidravlik zarba tufayli suv ombordagi pastki nishabligningkengligi b=8.0 m bo‘lgan Rezaksoy suv omborida aeratsiyali oqimning chuqurligi bo‘yicha konsentratsiya taqsimotini aniqlangan.

$$i = sin\psi = sin\,4\,0^\circ = 0{,}643 \qquad (1)$$

O‘rganilayotgan bo‘limdagi o‘rtacha tezlik $\vartheta = 40\frac{м}{с}$, aeratsiyasiz chuqurlik $h = 1{,}0м$, ekvivalent pastki g‘adir-budurlik $\Delta_э \approx 0{,}003м$. Suv harorati 15°S

$$\bar{\delta}_R = \frac{3{,}3R}{Re_{*R}} + \Delta_э = \frac{3{,}3 \cdot 0{,}8}{1{,}576 \cdot 10^6} + 0{,}003 = 0{,}0030016$$

tanlash orqali biz $\xi = 0{,}187$ni aniqlaymiz va $\bar{h} = 0{,}187 \cdot 5{,}45 = 1{,}019м \approx 1м$ ni hisoblaymiz.

Shunday qilib, $\bar{h} \approx h$, shuning uchun $\bar{П} = П$, ya’ni $\bar{П}$ kompleksi tomonidan h chuqurlikda hisoblanadi va Frud soni quyidagi formula orqali yoziladi:

$$\bar{F}r_{R,\psi} = \frac{\bar{\vartheta}^2}{g\bar{R}\,cos\,\psi} = \frac{40^2}{9{,}81 \cdot 0{,}8 \cdot cos\,4\,0^\circ} = 266{,}1$$

$$\nu = 1{,}14 \cdot 10^{-6}\frac{м^2}{с} \qquad (2)$$

Chuqurlik bo‘yicha konsentratsiya taqsimoti (1) va (2) formulalar bilan aniqlanadi. Bu formulalarga kiritilgan qiymatlar (1-jadval) o‘lchamsiz murakkab $\bar{П}$-kompleks (2) formulaga bog‘liq. O‘lchovsiz kompleksning ta’rifi (2).

$$\bar{П} = \left(\frac{\bar{R}}{\bar{h}}\right)^{1,2}\left(\frac{\bar{\delta}_R}{\bar{R}}\right)^{0,25}\bar{F}r_{R,\psi} \qquad (3)$$

Bu yerda:

$$\bar{F}r_{R,\psi} = \frac{\bar{\vartheta}^2}{g\bar{R}\,cos\,\psi}, \bar{\delta}_R = \frac{3{,}3\bar{R}}{Re_{*R}} + \Delta_э \qquad (4)$$

$$\bar{h} = \xi h_{кр}, h_{кр} = \sqrt[3]{\frac{q^3}{g}}.$$

ξ koeffitsienti (2) formuladan hisoblanadi:

$$6{,}45\left(1 + 2\frac{h}{b}\right)^{-1}\frac{h^3}{\delta_R^{0,125}h_{кр}^{2,875}} = \xi^{1,375}\left(1 + 2\frac{h_{кр}}{b}\xi\right)^{-0,975} 6{,}45\left(1 + 2\frac{1}{8}\right)^{-1}\frac{1^3}{0{,}0030016^{0,125} \cdot 5{,}45^{2,875}} = \xi^{1,375}\left(1 + 2\frac{5{,}45}{8}\xi\right)^{-0,975}$$

$$0{,}0814 = \xi^{1,375}(1 + 1{,}3625\xi)^{-0,975}$$

1-jadval

Gidravlik zarba tufayli suv chiqarish quvurining aeratsion asosiy ko’rsatgichlari.

Kuchsiz va o‘rtacha aeratsiyalangan oqim	Sezilarli darajada aeratsiyalangan oqim	
	$71 \le \bar{П} \le 280$	$\bar{П} \succ 280$
$l\bar{g}\,S = 0{,}6\,l\bar{g}\,П - 1{,}33$		
$\bar{S}_n = \bar{S}^2$		
$k = 390\bar{П}^{-1{,}332}$	$\bar{S} = 0{,}295\bar{П}^{0{,}167}$	$l\bar{g}\,S = 0{,}5\,l\bar{g}\,П - 0{,}250$
$\bar{П} \le 32$da	$\bar{S}_n = 0{,}0922\bar{П}^{0{,}333}$	$l\bar{g}\,S_n = 0{,}10\,l\bar{g}\,П - 0{,}460$
$\bar{S}_n = 0{,}5, R/\bar{R}_n \approx 1$	$k = 10{,}35\bar{П}^{-0{,}5}$	$k = 4{,}03\bar{П}^{-0{,}333}$
$h/\bar{h}_n \approx 1$; $h/h_n \approx 1$;	$\bar{S}_n = 1 - 1{,}62\bar{П}^{-0{,}333}$	$S_n = 1 - 1{,}01\bar{П}^{-0{,}25}$
$\sigma \approx 0{,}0087\bar{h}\bar{П}$	$lg\,R/\bar{R}_n = 0{,}2\,l\bar{g}\,П - 0{,}295$	$tg\,R/\bar{R}_n = 0{,}10tg\bar{П} - 0{,}050$
$32 \prec \bar{П} \prec 71$da	$lg\,\sigma/\bar{h} = 0{,}45\,l\bar{g}\,П - 1{,}2$	$lg\,\sigma/\bar{h} = 0{,}30\,l\bar{g}\,П - 0{,}833$
$\bar{S}_n = 1 - 1{,}62\bar{П}^{-0{,}333}$		
$tg\,R/\bar{R}_n = 0{,}2\,l\bar{g}\,П - 0{,}295$		

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$lg\,\sigma/\bar{h} = 0{,}45\,lg\,\bar{\Pi} - 1{,}2$		
$\bar{R}_n = \frac{b\bar{h}_n}{b+2\bar{h}_n} h_n = \frac{\bar{h}_n}{1-\bar{S}_n}$		

2-jadval

Chuqurlik bo‘yicha konsentratsiya taqsimoti egri chizig‘ini qurish

$y, м$	**0**	**0,3**	**0,5**	**0,7**	**1,0**	**1,5**	**2,0**
S	0,0889	0,120	0,147	0,180	0,243	0,403	0,66

3-jadval

Chuqurlik bo‘yicha konsentratsiya taqsimoti egri chizig‘ini qurish

$y, м$	y^*	$t = \frac{y^*}{\sigma}$	$F(t)$	$\frac{1-S}{2(1-S_{\Pi})}$	S
2,2	0,1131	0,307	0,1215	0,3785	0,7947
2,5	0,4131	1,122	0,3685	0,1315	0,9290
2,7	0,6131	1,666	0,4520	0,0480	0,9730
3,0	0,9131	2,481	0,4935	0,0065	0,9970

Ushbu jadvallardan foydanilgan holatda masalani yechish shartlari berilgan. Bunda o‘tish sirtidan yuqorida, ya’ni $y \prec h_{\Pi}$ joylashgan mahalliy (suv-havo aralashmasi) konsentratsiyani (2) formula orqali hisoblanadi.

O‘tish sirtidan yuqorida, ya’ni $y \prec h_{\Pi}$ joylashgan mahalliy (suv-havo aralashmasi) konsentratsiyaning (2) formula, ya’ni:

$\frac{1-S}{2(1-S_{\Pi})S_{б.л}} = \frac{1}{\sigma\sqrt{2\pi}} \int_{y^*}^{\infty} e^{-\frac{1}{2}\left(\frac{y^*}{\sigma}\right)^2} dy^*$ orqali hisoblangan qiymatlari 3- jadvalda keltirilgan. Quyidagi formulalar orqali suvchiqarish quvurining gidravlik zarba tufayli qanday kavitatsion jarayonlar bo‘lishini aniqlanadi.

$\frac{1-S}{2(1-S_{\Pi})S_{б.л}} = \frac{1}{\sqrt{2\pi}}\left(\int_0^{\infty} e^{-\frac{1}{2}t^2} dt - \int_0^{t} e^{-\frac{1}{2}t^2} dt\right);\ \frac{1-S}{2(1-S_{\Pi})} = 0{,}5 - F(t);$

4. Xulosa

1. Mamlakatimiz hududidagi barcha suv omborlaridagi idravlik zarbaga qarshi ishlab chiqilgan algoritm va uning asosida qurilgan model yuqori bosimli suv tashlash va suv chiqarish quvurlaridagi oqim dinamikasi va bostirilgan oqim xarakatidagi energiya sarfini hisoblash usullari Rezaksoy suv omboriga qo‘llashishi mumkin.

2. Natijada suv tashlash quvuri bosh qismi konstruksiyasi optimal parametrlari takomillashtirildi. Quvur bosh qismidagi oqim tezligi topilib, pulsatsiyalanuvchi oqimning pulsatsiyasini tashkil etuvchi tezliklarini topish, quvurning tekis bo‘lmagan qismidagi bosim kattaligini ifodalovchi parametrlar topilib, ogolovkaning optimal chuqurligi, geometriyasi kattaliklari olindi.

3. Ishlab chiqilgan algoritm va uning asosida qurilgan model yuqori bosimli suv tashlash va suv chiqarish quvurlaridagi oqim dinamikasi va bostirilgan oqim xarakatidagi energiya sarfini hisoblash usullari Rezaksoy suv omboriga qo‘llashishi mumkin.

4. Bosimli quvurlardagi gidrodinamik bosim, quvur uzunligi, quvur diametri va mahalliy qarshiliklarni bog‘lovchi Bernulli tenglamasi asosida vibratsiyali kavitatsiya vaqtida paydo bo‘ladigan shiddatli bosimni aniqlash ifodasi keltirib chiqarildi.

5. Rezaksoy suv ombori suv chiqarish inshootidagi turbulent oqimining burilish qismidagi vibratsiyalarni baholash algoritmi tuzilib dasturi va grafiklari olindi.

6. Natijada suv o‘tkazish quvurlarini ishonchli ekspluatatsiya qilish va ekspluatatsiya davrini 18% ga uzaytirishga erishish mumkinligi ko‘rsatildi.

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