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EXPERIMENTAL STUDY OF THE POLYTROPE COEFFICIENT IN CASE OF HYDRAULIC IMPACT WITH AN AIR-WATER FLOW

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Annotation. The article presents the results of analytical and experimental study of the polytropic coefficient in the process of hydraulic shock with an air-water pressure flow. At the same time, a reliable coincidence of the results of calculating the polytropic coefficient by the proposed method with experimental data is obtained, which also confirms the variability of the polytropic coefficient during hydraulic shock in the air-water flow. The conducted experiments prove that the coefficient of polytropes is strictly polytropic in nature.

Key words: polytropic coefficient, hydraulic shock, air-water pressure flow, pressure system, law of air compression-expansion, velocity of impact wave propagation, isothermal process, adiabatic process.

Annotatsiya. Maqolada politropa koeffisientining gidravlik zarba jarayonida naporli havoli suyuqlik oqimida analitik va eksperimental tadqiqoti natijalari keltirilgan. Bunda taklif etilayotgan usul bo'yicha politropa koeffisientining hisobiy qiymatlari tajriba ma'lumotlari bilan ishonchli mos kelishi olinganki, shuningdek politropa koeffisienti qiymati o'zgaruvchanligi tasdiqlanadi. Utkazilgan tajribalar politropa koeffisientining politropik xarakterga ega ekanligini isbotlaydi.

Tayanch so'zlar: politropa koeffitsiyenti, gidravlik zarba, bosimli havo-suv oqimi, bosim tizimi, havoning siqilish-kengayish qonuni, zarba to'lqinining tarqalish tezligi, izotermik jarayon, adiabatik jarayon.

Аннотация. В статье приведены результаты аналитическое и экспериментальное исследование коэффициента политропы при процессе гидравлическом ударе с воздушно-водяном напорном потоке. При этом получено достоверное совпадение результатов расчетов коэффициента политропы по предлагаемой методике с опытными данными, что также подтверждает изменчивости значение коэффициента политропы при гидравлическом ударе в воздушно-водяном потоке. Проведенные эксперименты доказывают, что коэффициент политропы имеет строго политропического характера.

Ключевые слова: коэффициент политропы, гидравлический удар, воздушно-водяной напорный поток, напорная система, закон сжатия-расширения воздуха, скорости распространения волны удара, изотермический процесс, адиабатический процесс.

Introduction. Currently, there is no single opinion on the choice of the numerical value of the polytropic coefficient n , which takes into account the law of compression-expansion of air in a gas-liquid pressure system.

Literature review. In their works [1,2,3,4,5], the authors recommend considering the compression-expansion process of air in a turbulent gas-liquid flow as adiabatic ($n=1.41$), while other authors [6,7,8,9,10] recommend considering the compression-expansion process of air in the flow as isothermal ($n=1.0$). At the same time, it is stated in [11, 12] that the process of compression and

expansion of air in the system proceeds according to a polytropic law. Therefore, the justification for the correct choice of the numerical value of the polytropic coefficient in the calculations of pressure gas-liquid systems for hydraulic shock, This is very important, since the reliability of determining the propagation velocity of the shock wave, as well as the minimum and maximum pressures in the pressure system, depends on it.

The speed of propagation of the shock wave is the most important parameter in calculating the hydraulic shock. When deriving the dependence, changes in the mass of the gas-liquid pressure stream in an elementary section of the pipeline over time Δt are assumed to determine the propagation velocity of the shock wave. The following assumptions were made:

- 1) the average velocities of the air-water flow components (air and water) are equal to the average velocity of the flow mixture;
- 2) the components of the air - water flow are well mixed with each other;
- 3) the mass transfer equation breaks down into independent mass transfer equations for each component of the air-water flow;
- 4) during the impact, there is no absorption or release of air, t.e. the mass of air in the air-water flow is constant;
- 5) the volume concentration of air is insignificant $\varphi = 0.03$;
- 6) the process of changing the volume of air is considered adiabatic, that is, $n=1.4$.

The research material and method. The dependences obtained in accordance with the described methodology are reduced by equivalent transformations to an equation of the form (1) [3].

We compared the experimental values of the propagation speed of a hydraulic shock wave in an air-water flow C_{exp} with the values C_{cal} calculated using dependence (1) [3]. The results of experiments conducted by D.N. Smirnov, A.G. Dzhvarsheishvili and G.I. Kirmelashvili, V.S. Dikarevsky and A.A. Markin, N.G. Zubkova were used.

Analysis and results. For experimental determination of the numerical value of the polytropic coefficient n Special experiments were performed in the laboratory in a gas-liquid pressure stream, consisting of several series, the methodology of which is described in [3]. The average square deviation of the experimental values C_{exp} the difference from those calculated by formula (1) [3] is 12,7%. Presumably, one of the possible reasons for these discrepancies is that the process of gas compression during hydraulic shock in the air-water flow is not exactly adiabatic. In all likelihood, the values of the polytropic coefficient n are in the range from 1 to 1,4.

To get the value of n , corresponding to the experimental data, we use the least squares method and find the minimum value of the expression:

$$F = \sum_1^i \left(\frac{C_p - C_{on}}{C_{on}} \right)^2,$$

Where $C_p = f_1(P_c, V_p, \varphi, n)$ - are the calculated values of the propagation velocity of the hydraulic shock wave according to the formula (1) [3];

$C_{on} = f_2(P_c, V_0, \varphi, n)$ - the propagation velocity of the hydraulic shock wave according to the experimental data; i is the number of experiments.

We will search for the n – corresponding with the minimum value F c with an accuracy of $\pm 0,5$ % and the expression itself according to the «Minimax plan». The task is to solve a system of difference equations in the range $x' = 1 \leq n \leq x'' = 1,4$ c precision $\eta = \pm 0,5$ %, t.e. must be

$$\eta \leq \frac{mes[x', x'']}{U_n + 2},$$

where $x' = 1$ and $x'' = 1,4$ - the boundaries of the search interval n ; U_{n+2} - the Fibonacci number, defined by the following relation $U_{n+2} = U_{n+1} + U_n$; n - number of steps.

if $\eta \leq \frac{1.4-1.0}{80} \approx 0,5 \%$, to $U_{n+2} \geq \frac{4}{0.005} = 80$.

Find $U_{n+2} \geq 80$. The table of values of Fibonacci numbers will be written as follows:

$$U_0 = 0, U_1 = 1, U_2 = 1, U_3 = 2, U_4 = 3, U_5 = 5, U_6 = 8,$$

$U_7 = 13, U_8 = 21, U_9 = 34, U_{10} = 55, U_{11} = 89, m.e, U_{12} = 144$ and therefore, to determine the value of F_c with precision $\eta = \pm 0,5 \%$ you will need to calculate the expression $\eta = 11 - 2 = 9$ times.

The indicators of the polytropic n , at which the values of F were calculated, and the values of the expression F themselves are shown in Table I.

Table I

The values are polytrope indices n and the expression F

n	1,152	1,163	1,174	1,183	1,192	1,201	1,212
$F^* 10^4$	14859	14690	13958	14504	11197	10905	10256

Thus, the minimum value of the expression $F = 1.0256$ corresponds to n equal to 1,212. This result was obtained by analyzing several series of experimental values of the propagation velocity of a hydraulic shock wave under field and laboratory conditions with an air content of up to 3% by volume at atmospheric pressure. However, the aim of the experiments was not to study the effect of the structure of the air-water flow on the propagation velocity of the hydraulic shock wave.

In conclusion, it can be noted that the research results (Table №. 1) show that the value of the polytropic coefficient n is not constant. The average value of the polytropic coefficient obtained in the experiments is $n=1,182$. In calculations of pressure pipeline systems for hydraulic shock with a gas-liquid flow, take $n=1.20$ with a certain margin, which also proves the reliability of the recommendation D.A.Foksa [12].

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