ORIGINAL ARTICLE

INTERNATIONAL JOURNAL OF ARTIFICIAL INTELLIGENCE

ISSN: 2692-5206, Impact Factor: 12,23
American Academic publishers, volume 05, issue 11,2025

Journal: https://www.academicpublishers.org/journals/index.php/ijai

UDK 532.595.2:532.529

CALCULATION OF A POSITIVE WATER HAMMER ABSORBER

prof. **A.M.Arifjanov,**
prof. **A.M.Fatkhulloev** ("TIIAME" NRU),
B.U.Jonkobilov,
ass. prof. **U.M.Rajabov,**
ass. prof. **S.U.Jonkobilov (**KSTU)

Annotation: The article is devoted to the calculation of a hydraulic shock absorber with a diaphragm installed at the end of a pressure pipeline. Theoretical solutions of hyperbolic type wave equations for a polytropic process (n=1.20) are proposed.
To dampen the intensity of hydraulic shock from increasing pressure in pressure-hydraulic systems, an effective design of a hydraulic shock absorber with a diaphragm is proposed.
The article presents the results of analytical and experimental studies of water hammer in the presence of a damper. The results of the proposed method for calculating the water hammer are in good agreement with the experimental data. This confirms the reliability of the proposed analytical method for calculating the water hammer.
Key words: hydraulic shock, pressure pipeline, hydraulic shock absorber, pressure-hydraulic system, damper with a diaphragm, positive hydraulic shock.
Аннотация: Статья посвящена для расчета гасителя гидроудара с диафрагмой, установленным в конце напорного трубопровода. Предложены теоретических решений волновых уравнений гиперболического типа для политропного процесса (n = 1,20).
Для гашения силы положительного гидроудара в напорных системах предложена эффективная конструкция гасителя гидроудара с диафрагмой.
В статье приведены результаты теоретических и экспериментальных исследований гидроудара при наличии гасителя. Результаты предлагаемой методики расчета гасителя гидроудара хорошо согласуется с опытными данными. Это подтверждает о достоверности предлагаемой теоретической методики расчета гидроудара.
Ключевые слова: гидроудар, напорный трубопровод, гаситель гидроудара, напорная система, гаситель с диафрагмой, положительный гидроудар.

Introduction. To protect pressure pipeline systems from the effects of hydraulic shock (HSH), various dampers are used [1,2,3,4,5,6,7,8], in particular, air-hydraulic caps (AHC) [9,10,11,12,13,14].
In [1], N.E. Zhukovsky proposed a method for calculating the WH in the presence of a AHC installed on a pipeline. The author proposes an approximate formula for determining the volume of air in the AHC and adopts the adiabatic law of compression and expansion of air in the AHC, since, according to the author, the WH process is rapid [1].
I.A. Charny [2] uses linearized WH equations to calculate the AHC. In this case, the author adopts an isothermal law (n=1.0) for the compression and expansion of air in the AHC.
In practice, the most widely used calculation method was the one proposed by G. Evangelisti [3]. This method is based on the use of special graphs compiled by G. Evangelisti as a result approximate integration of wave differential equations of hydraulic shock using the finite difference method [3].

ORIGINAL ARTICLE
INTERNATIONAL JOURNAL OF ARTIFICIAL INTELLIGENCE
ISSN: 2692-5206, Impact Factor: 12,23
American Academic publishers, volume 05, issue 11,2025
Journal: https://www.academicpublishers.org/journals/index.php/ijai

The disadvantage of these graphs is the limited range of variation of the initial parameters and therefore in many cases the Evangelisti method is not applicable.
In the work [4] V.S.Dikarevsky, trying to eliminate the shortcoming of the method of G. Evangelisti, constructed diagrams $\overline{Z}_{\max} = f\left(\sigma, \overline{h}_{mp0}\right)$ for $\overline{Z}_{\min} = f\left(\sigma, \overline{h}_{mp0}\right)$ the isothermal law (n=1.0) in a wide range of changes in the parameters σ and $\overline{h}_{mp0}$. However, the author [4] allows for inaccuracies in solving the basic equations.
F.M. Darson and A.A. Kaliske [5] present an analytical method for determining the dimensions of a cap located at the end of a pressure pipeline in front of a valve. In this case, the author [5] adopts an isothermal law (n=1.0) for the change in gas volume in the pressure vessel and does not take into account the effect of pressure losses on friction in the pressure pipeline. This method for calculating the cap is also approximate.
In the work [6] B.F. Lyamaev developed a method for calculating the AHC on a computer. The proposed method is based on the combined solution of the WH equations, the continuity at the connection point of the cap to the pipeline and the state of the gas in the AHC. The calculation is performed by the author using the iteration method [6].
In the work [7] D.A. Fox presents a numerical method for calculating the AHC. The author applies the method of characteristics with a regular rectangular grid with constant steps Δx and Δt . The author solves the equations of continuity, the equations of the air (gas) state, and the equations of relationships on the characteristics simultaneously. The calculations are implemented on a computer. The author [7] proposes to take the polytropic coefficient equal to n=1.20 in the calculations and takes into account the pressure losses along the length according to the quasi-stationarity hypothesis.
To conduct the experiments, an experimental setup was designed and built, which is intended to study the WH with increasing pressure in the presence of a damper with a diaphragm installed at the end of the pressure pipeline [8].
Experiments conducted to determine the value n confirm that when calculating the WH in a gas-liquid flow n=1.20 is very practical and effective, relative to isothermal and polytropic processes, and the experimental data are in good agreement with the calculated data [8,15]. Therefore, in this work, all studies and calculations were carried out at n=1.20.
To dampen the shock wave that occurs in pressure pipelines, along with other shock absorbers, a diaphragm air-hydraulic cap (DAHC) is used - a damper with a diaphragm (Fig. 1), the dimensions of the damper are determined by the conditions for starting and stopping the pumps [2,3,4,6,7,8].

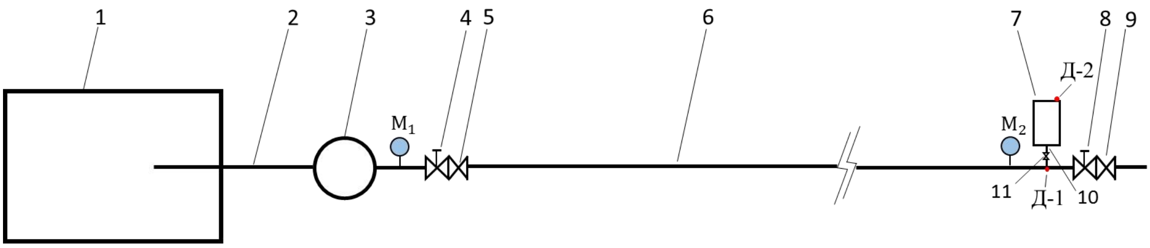

Fig. 1. Pumping unit diagram: 1-tank; 2-suction pipeline; 3-pump brand 3K-6; 4.8-valves; 5,9-quick-acting plug valves; 6-pressure pipeline; 7-water hammer absorber; 10-connecting pipeline; 11-diaphragm; D $_1$, D $_2$ - pressure sensors; M $_1$, M $_2$ - pressure gauges.
In this work and in Fig. 1 we will use the notations that we described earlier in detail in [8,15].

Methods and materials. This paper presents an analytical method for calculating the DAHC installed at the end of a pressure pipeline [8,15] (Fig. 1).

ORIGINAL ARTICLE

INTERNATIONAL JOURNAL OF ARTIFICIAL INTELLIGENCE

ISSN: 2692-5206, Impact Factor: 12,23
American Academic publishers, volume 05, issue 11,2025

Journal: https://www.academicpublishers.org/journals/index.php/ijai

When developing the methodology in [8,15], it was assumed that the closing time of the fast-acting plug valve 9 is equal to zero.
To calculate the hydraulic shock absorber with pressure increase, installed at the end of the pipeline, the following system of equations is used [4,8] :

$$\frac{d\bar{\vartheta}}{d\bar{t}} = \frac{2\pi}{\sqrt{2\pi\ \sigma}}\left[1 - h - \left(\bar{h}_{mp} + \bar{h}_{\partial}\right)\ \bar{\vartheta}\left|\bar{\vartheta}\right|\right]$$
$$\frac{dh}{dt} = 2\ n\ h^{\frac{1+n}{n}}\ \pi\sqrt{\frac{2\ \sigma}{n}}\ \bar{\vartheta} \qquad (1)$$

The system of equations (1) is solved under the following initial conditions [4,8] :

$$\bar{\vartheta} = \bar{\vartheta}_0 = 1; \quad h_0 = 1 - \bar{h}_{mp0}, \text{ at } \bar{t} = 0 . \qquad (2)$$

Results. To determine $H_{a\ min}$ and $H_{a\ max}$ in a pressure system with a DAHC as a result of a theoretical solution of the system of equations (1) the following dependencies were obtained.
To determine h_{max}
1. When $\chi \neq 1$

$$e^{-\xi_0}(1 - \sigma) + \chi\left[\frac{\xi_0^{1-\chi}}{1-\chi} - \frac{\xi_0^{2-\chi}}{(2-\chi)1!} + \frac{\xi_0^{3-\chi}}{(3-\chi)2!} - \frac{\xi_0^{4-\chi}}{(4-\chi)3!} + \ldots + \frac{\xi_0^{n+1-\chi}}{(n+1-\chi)n!} - \ldots\right] =$$
$$= e^{-\xi_m} + \chi\left[\frac{\xi_m^{1-\chi}}{1-\chi} - \frac{\xi_m^{2-\chi}}{(2-\chi)1!} + \frac{\xi_m^{3-\chi}}{(3-\chi)2!} - \frac{\xi_m^{4-\chi}}{(4-\chi)3!} + \ldots + \frac{\xi_m^{n+1-\chi}}{(n+1-\chi)n!} - \ldots\right] . \qquad (3)$$

2. When $\chi = 1$

$$e^{-\xi_0}(1 - \sigma) + \ln\left|\xi_0\right| - \frac{\xi_0}{1\ 1!} + \frac{\xi_0^2}{2\ 2!} - \frac{\xi_0^3}{3\ 3!} + \ldots + \frac{\xi_0^n}{n\ n!} - \ldots =$$
$$= e^{-\xi_m} + \ln\left|\xi_m\right| - \frac{\xi_m}{1\ 1!} + \frac{\xi_m^2}{2\ 2!} - \frac{\xi_m^3}{3\ 3!} + \ldots + \frac{\xi_m^n}{n\ n!} - \ldots , \qquad (4)$$

where ξ_0 and $\varkappa$ are found by the formula $\xi_0 = \frac{}{h_0^{\frac{1}{\chi}}}$; $= \frac{\bar{h}_{mp0} + \bar{h}_{\partial 0}}{\sigma}$, and ξ_m – by the formula

$$\xi_m = \frac{}{h_{max}^{\frac{1}{\chi}}} .$$

To determine h_{min}
1. When $\chi \neq 1$

$$\chi\left[\frac{\xi_m^{1-\chi}}{1-\chi} + \frac{\xi_m^{2-\chi}}{(2-\chi)1!} + \frac{\xi_m^{3-\chi}}{(3-\chi)2!} + \frac{\xi_m^{4-\chi}}{(4-\chi)3!} + \ldots + \frac{\xi_m^{n+1-\chi}}{(n+1-\chi)n!} + \ldots\right] - e^{\xi_m} =$$
$$= \chi\left[\frac{\xi_{max}^{1-\chi}}{1-\chi} + \frac{\xi_{max}^{2-\chi}}{(2-\chi)1!} + \frac{\xi_{max}^{3-\chi}}{(3-\chi)2!} + \frac{\xi_{max}^{4-\chi}}{(4-\chi)3!} + \ldots + \frac{\xi_{max}^{n+1-\chi}}{(n+1-\chi)n!} + \ldots\right] - e^{\xi_{max}} . \qquad (5)$$

2. When $\chi = 1$

INTERNATIONAL JOURNAL OF ARTIFICIAL INTELLIGENCE

ISSN: 2692-5206, Impact Factor: 12,23
American Academic publishers, volume 05, issue 11,2025

Journal: https://www.academicpublishers.org/journals/index.php/ijai

$$\ln|\xi_m| + \frac{\xi_m}{1\ \ 1!} + \frac{\xi_m^2}{2\ \ 2!} + \frac{\xi_m^3}{3\ \ 3!} + \ldots + \frac{\xi_m^n}{n\ \ n!} + \ldots - e^{\xi_m} =$$

$$= \ln|\xi_{\max}| + \frac{\xi_{\max}}{1\ \ 1!} + \frac{\xi_{\max}^2}{2\ \ 2!} + \frac{\xi_{\max}^3}{3\ \ 3!} + \ldots + \frac{\xi_{\max}^n}{n\ \ n!} + \ldots - e^{\xi_{\max}} , \qquad (6)$$

where $\xi_{\max}$ is found by $\xi_{\max} = \frac{\;}{\frac{1}{h_{\min}^{\chi}}}$.

From equation (3) or (4), with known ϰ, σ, χ and ξ_0, one can determine the value of ξ_m using the method of successive approximations, and then calculate h_{max} and H_{amax} using the formulas

$$h_{\max} = \frac{m_2}{\xi_{\max}}^{\,n} \text{ And } H_{a\max} = h_{\max} H_{га} \qquad (7)$$

From equation (5) or (6), with known ϰ, σ, χ and ξ_m (h_{max}), one can determine the value of ξ_{max} using the method of successive approximations, and then calculate h_{min} and H_{amin} using the formulas

$$h_{\min} = \left(\frac{m_1}{\zeta_m}\right)^n \text{ And } H_{a\min} = h_{\min} H_{га} \qquad (8)$$

The problem of determining h_{min} and h_{max} using equations (3) - (6) is implemented on a computer.

It should be noted that the use of approximate formulas (3), (4), (5) and (6) allows us to determine the dimensions of the DAHC with a margin of 0÷14.5% [8].

To verify the reliability of the above-proposed analytical dependencies for calculating the DAHC, experimental studies were conducted. The results of comparing the calculated data using formulas (3) and (5) and the experimental data [8] for studying the DAHC at n=1.20 are shown in Fig. 2 and Fig. 3.

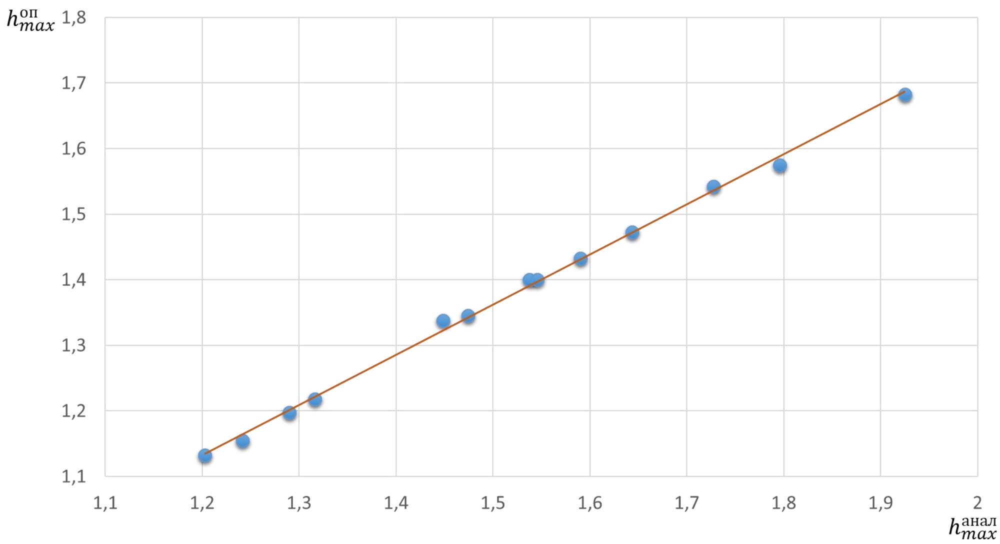

Fig. 2 Comparison of the results of analytical calculations of the WH in the presence of a DAHC according to formula (3) with experimental data [8] .

ISSN: 2692-5206, Impact Factor: 12,23
American Academic publishers, volume 05, issue 11,2025
Journal: https://www.academicpublishers.org/journals/index.php/ijai

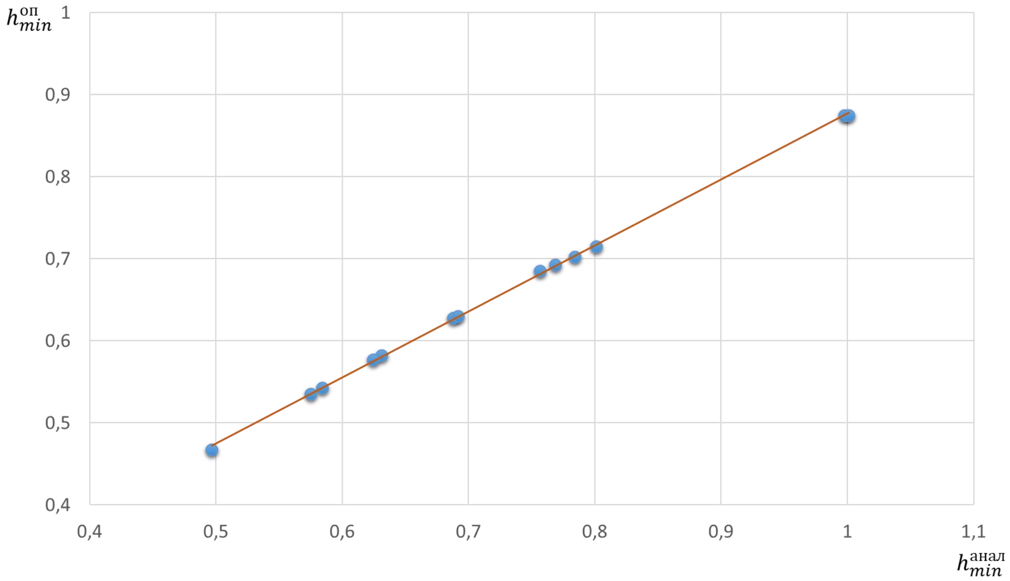

Fig. 3 Comparison of the results of analytical calculations of the WH in the presence of a DAHC according to formula (5) with experimental data [8].

Discussion. A literature review shows that a positive pressure drop in a long pressure pipeline leads to a non-stationary process. To prevent this, it is crucial to develop a new methodology for calculating the pressure drop in the presence of a pressure regulator installed at the end of the pressure pipeline.

To effectively dampen the intensity of WH shocks in pressurized systems, it is crucial to consider changes in local resistance in the diaphragm of the connecting pipe and the law of air expansion and compression in the proposed cap design. These factors must also be considered when integrating the wave differential equations of WH shocks using the finite difference method to determine the optimal dimensions of the proposed damper design.

Conclusion. Thus, as a result of the analytical solution of the wave differential equations of the WH with increasing pressure in the presence of a damper, dependencies for calculating the maximum and minimum pressures of the WH are proposed.

The reliability of the proposed formulas (3) and (5) is proven by comparing the calculated values maximum and minimum pressures of the gas turbine unit with their experimental values [8].

References

1. 1. Zhukovsky N.E. On Hydraulic Hammer in Water Pipes. Moscow, Gostekhizdat, 1949. 104 p.
2. 2. Charny I.A. Unsteady Motion of Real Fluid in Pipes. Moscow, Nedra, 1975. 296 p.
3. 3. Evangelisti G. Il colpo d'aviete nelle condotte munite di camera d'avia elevator. L'Energia, Elektrica. Milano, 1938, no. 9, pp. 600-615.
4. 4. Dikarevsky V.S. Water Pipes. Monograph. Proceedings of the Russian Academy of Architecture and Construction Sciences. Construction Sciences. Vol. 3 – Moscow: RAASN, 1997. 200 p.
5. 5. Darson F.M., Kalinske A.A. Methods of calculating water-hammer pressures. – Journal of the AWWA, 1939, v.31, no. 11, pp.1835-1864.
6. 6. Lyamaev B.F., Nelyubov G.P., Nebolsin V.A. Stationary and transient processes in complex hydraulic systems. – Leningrad: Mashinostroenie, 1978. – 192 p.

ISSN: 2692-5206, Impact Factor: 12,23
American Academic publishers, volume 05, issue 11,2025
Journal: https://www.academicpublishers.org/journals/index.php/ijai

7. 7. Fox D.A. Hydraulic analysis of unsteady state in pipelines. – Moscow: Energoizdat, 1981. – 247 p.
8. 8. Arifzhonov A.M., Zhonkobilov U.U., L.N. Samiev, L.N., Ibragimova Z.I., Apakhuzhaeva T.U. Methodology for calculating an air-hydraulic cap with a diaphragm. Collection of articles of the IX International Scientific and Practical Conference "Innovative Technologies in Science and Education" - Penza, October 20, 2018. - pp. 29-32.
9. 9. Jonkobilov U., Jonkobilov S., Rajabov U., Bekjonov R., Norchayev, A. Shock wave velocity in two-phase pressure flow. IOP Conference Series: Materials Science and Engineering. 2021. 1030. Pp. 012129. DOI: 10.1088/1757-899X/1030/1/012129.
10. 10. Arifjanov A., Jonqobilov U., Jonqobilov S., Khushiev Sh., and Xusanova J. The influence of hydraulic friction on the maximum pressure of water hammer. IOP Conf. Series: Earth and Environmental Science. 2020. 614. Pp. 012092. DOI:10.1088/1755-1315/614/1/012092.
11. 11.Al-Khomairi A.M., Plastic water hammer damper, Aust. J. Civ. Eng. 8 (1) (2010) 73–81.
12. 12.Kim S.G., Lee K.B., Kim K.Y., Water hammer in the pump-rising pipeline system with an air chamber, J. Hydrodyn. Ser. B 26 (6) (2015) 960–964.
13. 13.Moghaddas S., The steady-transient optimization of water transmission pipelines with consideration of water-hammer control devices: a case study, J. Water Supply Res. Technol. - Aqua 67 (6) (2018) 556–565.
14. 14. Kim S. Impulse response method for pipeline systems equipped with water hammer protection devices [J]. Journal of Hydraulic Engineering, ASCE, 2008, 134(7): 961–969.
15. 15. Zhonkobilov U. U., Zhonkobilov S. U., Razhabov U. M., Khushiev Sh. P. Accounting for the influence of the polytropic coefficient on hydraulic hammer with a two-component flow// Innovatsion tekhnologilar zhurnal makhsus son, Karshi 2021, pp. 43–47.