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INCREASING EFFICIENCY OF OPERATION OF SHUT-OFF VALVES IN PIPELINES

E.F. Akhundov [1], V.M. Fataliyev [1], E.A. Aslanov [1], E.Q. Hashimov[1]

R.A. Quluyev [2], I.A. Ismayil [1]

1. Mechanics Department, Azerbaijan Technical University, Baku, Azerbaijan,

2. Taghiyev Operating Company, Baku, Azerbaijan

The design of pipelines of different purposes and scales is not possible without the use of special equipment - different types of shut-off valves that allow to control the direction and amount of flow, as well as to close the environment flow. Currently, several types of connecting fittings are widely used in pipelines: valves, taps, slide-valves and others. Quantitatively, shut-off valves cover for more than 70% of the total number of pipeline fittings in used.

The constant improvement of the design and the use of new structural materials lead to the expansion of the scope of application connecting fittings and of the solution of problems in this direction.

The principle of operation of valves equipped with these drive systems is the same - by taking the pressure of the working agent (liquid or gas) on the drives piston, the spring force and the pressure of the environment acting on the rod immediately close (pushing) the valve.

Figure 1. a), b), c) some types of modern connecting fittings and their elements, which are often used by the oil and gas industry, are indicated.

Figure1. a) The main types of shut-off valves, the most common and widely used in the oil and gas industry

Figure1. b) Full-coated connection fittings (flaps)

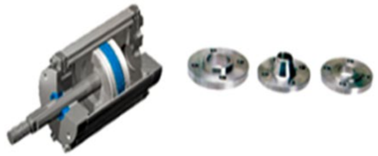

Figure1. c) The main element of the hydraulic drive is a hydraulic cylinder and connecting flanges

The results of the research in this direction allow us to conclude that if the valve is closed immediately, there is a sharp rise in pressure (pressure increase ΔP) in the connecting pipelines, that is, hydraulic shock occurs. During a hydraulic shock, the pressure in the pipeline may rise above the allowable limit, which in turn can lead to a violation of the tightness of its connections and the valve itself. On the other hand, in emergencies, if the shut-off valve closes too slowly, there may be a loss of portable or working environment, and then there is the difficulty (impossibility) of overcoming the consequences that will adversely affect the environment. The processes described earlier also apply to technological pipelines.

The value of $(h\rho g f_{pis} + F_2)$ must be less than the total value of the force pushing the rod and the spring force, i.e. it is necessary to fulfill the inequality:

$$h\rho g f_{pis} + F_2 < F_s + F_1 \qquad (1)$$

It follows from here, that the value of "C" in the final formula (basic formula for $\tau = t_{finite}$) must be a minus value. It is known that with a sharp change in the velocity of fluid movement in the pipeline, the pressure increment (at $\tau > T = 2l / c$ is determined by the formula

$$\Delta P = \rho \upsilon c \frac{T}{\tau} \qquad (2)$$

Where, ρ and v are, respectively, the density and velocity of the liquid; c is the velocity of propagation of the shock wave, determined by the formula of I.V. Zhukovsky; T Hydraulic shock phase; l The length of the pipeline to the gate valve; τ The closing time of the gate valve.

It is known that the speed of valve control depends on the characteristics of the valves themselves, their drives and hydraulic control systems. When calculating the closing time of the valve, pressure losses in the tubes, local hydraulic resistances in the elements of the hydraulic system, the density and viscosity of the liquid, as well as the operating pressure of the liquid in the valve actuator are taken into account. In order to derive a calculation formula for determining the closing time of the gate valve, we use the well-known equation, which allows us to determine the optimal closing time of the gate valve from the rod coordinate.

$$\left(\frac{dz}{d\tau}\right)^2 + A\frac{dz}{d\tau} - Bz + C = 0 \qquad (3)$$

Two approaches can be used to solve equation (3) in time τ :

- in the first approach, it is possible to solve equation (3) in terms of time τ and obtain an analytical expression between τ and z , varying it by the variable z . The resulting expression can be used according to the current system mode.

- in the second approach, it is possible to solve equation (3), which are applied in this paper within the given boundary conditions as follows and obtain numerical results.

Therefore, at the design stage of pneumo-hydraulic control systems, it is necessary to set the closing time of the shut-off valve for slide valves and adjust it if necessary. As an example, the calculation formula for determining the execution speed (time) of shut-off valves equipped with one-way hydraulic drive is given below (determined based on the results of the research of the shut-off time of the shutter):
Solving equation (3) under boundary conditions when
$\tau = 0,\ z = z_0$ and $\tau = t_{finite},\ ,z = 0$ we get:

$$\tau = \frac{\sqrt{A^2 - 4C + 4Bz_0} - \sqrt{A^2 - 4C}}{B} + \frac{A}{B}\ln\frac{\sqrt{A^2 - 4C + 4Bz_0} - A}{\sqrt{A^2 - 4C} - A} \qquad (4)$$

Here,

$$A = \frac{120 f_0 \mu^2 \nu l}{f_{pis} d^2 \left(1 + \sum \xi \mu^2\right)}; \qquad B = \frac{2\left(F_b - F_s\right) f_0^2 \mu^2}{f_{pis}^3 \rho z_0 \left(1 + \sum \xi \mu^2\right)}; \qquad C = \frac{2 f_0^2 \mu^2 \left(h \rho g f_{pis} - F_s - F_1 + F_2\right)}{f_{pis}^3 \rho \left(1 + \sum \xi \mu^2\right)}$$

Also, allow us to draw up the dependence –for different values of the diameter of the hydraulic drive tube and thereby determine the distance from the control station to the valve for a given diameter of the control tube and the optimal closing time of the valve.

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Formula (1) allows you to determine the closing time of the valve (knowing the characteristics of the drive, slide-valve and hydraulic control system), however, by setting the graph dependence $\tau = f\ (f_0)$, you can choose another number for f_0 that ΔP increase to an acceptable level;

By setting the measurement parameters for f_0, it is possible to adjust the closing speed of the valve on the shut-off valves (slide-valves).

The resulting calculation formula for determining the closing time of the gate valve with a single-acting hydraulic drive, considering the design parameters of the valve and hydraulic resistance in the control system, makes it possible to develop a method for controlling the process of closing the gate valve to avoid hydraulic shock, which consists in adjusting the moment of throttling the working fluid coming out of the drive hydraulic cylinder.

Completed work and the formula calculated based on its results makes it possible to determine the approach methods for solving the range of issues under consideration to determine the optimal closing time of the gate valve for other designs of shutoff valves and their drives. Obtained results create the prerequisites for further experiments on full-scale samples of gate valves of the indicated designs, comparing experimental data with data based on theoretical calculations.