УДК 621.646:664.1

Development and research of a pneumatic actuator for shut-off valves for food processing equipment

Volodin S., PhD, Engineering, **Myronchuk V.** Doctor of Engineering, Prof.
Gavva O., postgraduate student, **Yemelianov D.**
National University of Food Technologies (NUFT), Kyiv, Ukraine

Introduction. The use of the latest process control and management systems is a topical area of development in the food industry. Replacing labour-intensive process circuits of pipeline valves with programmable positioning devices using a 4-20 mA control signal makes it possible to reduce energy and process losses in food production.

Materials and methods. The research was carried out on the pneumatic pipeline valve experimental bench developed by the authors, designed to study changes in the pneumatic control signal of the first control circuit (low-pressure line of 0.2-1 bar for barometric fluid movement) with feedback from the current signal of the positioning actuator. The energy and flow characteristics were calculated using iterative methods to evaluate the operation of control valves and shut-off elements.

Results and discussion. The models of the control object on the experimental stand are investigated: Type 1 - has a constant volume, the flow rate of the working medium is directed to the receiver and is determined by the pressure drop; Type 2 - has a variable volume, and the process of flowing of the working medium is determined by hydrodynamic laws. The method is implemented by the nth number of iterations.

$$\Delta Q = Q_i - Q_{i-1}$$

The criterion for stopping the iterative process is the value of ΔQ (volumetric flow rate corresponding to the measured level of receiver filling), which is defined as the difference in flow rates obtained at successive iterations [1].The numerical value of ΔQ is set depending on the operating conditions of the measuring system and the normalised values of metrological characteristics required for the experimental systems. According to the analysis of the layout of pipeline valves actuators [2,3], the block diagram of the positioning actuator consists of the following main elements (Fig. 1): a signal setting device that generates a control signal proportional to the required movement of the actuator (sensors that respond to changes in operating conditions or process parameters); a comparative device or a mismatch sensor that establishes the correspondence of the reproduction signal coming from the actuator to the control signal; an amplifier that amplifies the power of the control signal due to an external energy source; a locking device drive that moves the control object and reproduces the control signal.

Feedback is a characteristic element of both position and tracking drives. The value $x = f(t)$ (displacement, velocity, or other parameter) reported by the signal conditioning device for comparison is called the "input", and $y = \varphi(t)$ (displacement, velocity) reproduced by the actuator is called the "output". The difference $(x - y) = \varepsilon$ is called the observation error or system inconsistency. It was found that the actuator, when the rod crosses the boundary of the insensitivity zone, will always react in such a way as to keep the misalignment within the permissible deviation value. Therefore, the specified accuracy of positioning the actuator of the aperture control valve in the required position is maintained.

In [2, 3], it is described that the parameters of the drive of a shut-off control valve, such as the movement speed and positioning accuracy, are always calculated with the exclusion of the possibility of self-oscillations.

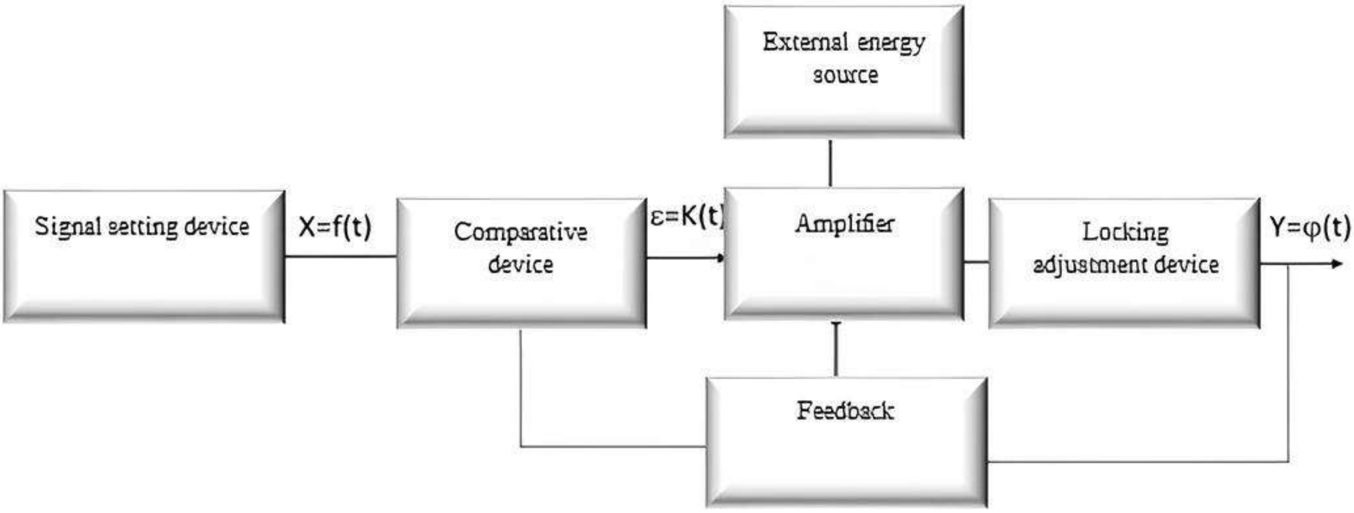

Figure 1 – Block diagram of a positioning actuator for pipeline valves

The principle of operation of the positioning actuator is to change the operating conditions of the PSC or process parameters by moving the signal setting device, which creates a mismatch in the system. The mismatch signal affects the amplifier and, through it, the shut-off device.[4] The movement of the actuator caused by this signal through feedback eliminates the mismatch and brings the entire system back to its original position. Fig. (2) shows the graphs of the characteristics of the positioning drive of the shut-off control valve (SOV). The graph of the dependence x = x (t) shows that the movement of the input (distributor spool) along the path x_1 from the neutral position (corresponding to the time t_1 from the start of the input movement) is not accompanied by the movement of the output (rod, shaft). This path characterises the system's insensitivity zone. During the further movement of the input, the output is set in motion, but its speed is established only after the input has travelled a certain distance x_2 during time t_2. Accordingly, the movement of the output at the end of the working stroke will stop only after some time after the input stops, which is characterised by the segment t_3.

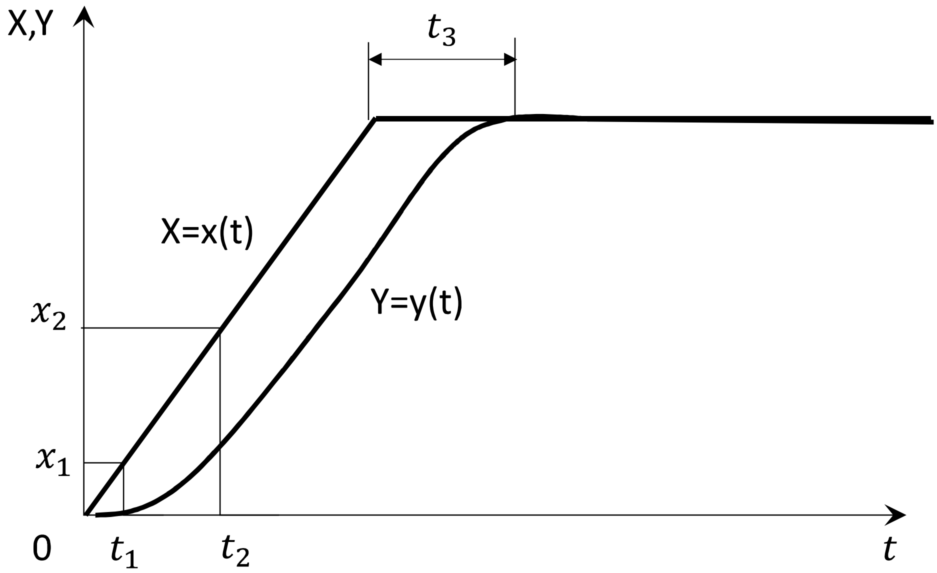

Figure 2 - Time-dependent displacement of the inlet and outlet of the positioning actuator of a gate valve

This inconsistency in the movements of the input and output (displacement error) is defined as the tracking error. The tracking error is caused by a number of factors, including the feedback coefficient, which characterises the gear ratio of the kinematic feedback loop. [5]. In addition, the tracking error is affected by the tightness of the system, backlash in its mechanical components, loads and output speeds, and a number of other factors.

Conclusions

The iterative method allows us to determine the refined coefficients included in the flow equation, namely the flow and velocity coefficients, as well as the boundary layer thickness, which is a function of the Reynolds number. The study of processes for an actuator based on a cylinder with a piston diameter of 100 mm and a stroke of 220 mm revealed the following characteristics during the mode of testing step actions (70, 200, 130, 50mm) in order to adjust the flow characteristics for the pipeline. For the mode of working out a sinusoidal control signal: with an action frequency of 0.7 rad/s; an initial coordinate of 160 mm and an action amplitude of 100 mm.

Based on the analysis, we note that the operational properties of the executive links of the gearboxes significantly affect the main characteristics of the technological equipment: power and structural, hydraulic for the drive as a whole. Therefore, there is a need for further research on the characteristics of shut-off control valves, such as: throughput, which is determined by the volume flow rate of the medium in m^3/h; tightness of the closure, which gradually changes of the shut-off control valve during a pressure drop of 0.1 MPa on the actuator. It is also necessary to calculate the current value for the flow capacity of the shut-off control valve at a given value of the stroke of the actuator's working link.

At present, measures to eliminate cavitation are successfully implemented in the development of shut-off control valves, so this study does not investigate damage caused by cavitation processes. Due to the fact that the vibration caused by hydrodynamic processes has a high intensity compared to vibration from mechanical sources, as well as the assumption of the absence of resonance and self-oscillatory processes due to the sufficient rigidity of the elements of pipeline systems and the shut-off valves themselves, the

References

1. Zhang, H., Liu, M. (2012). Densegas–particle flow in vertical channel by multi–lattice trajectory model. «Science in China» Series E: Technological Sciences, vol. 55, no. 2, 542–554. DOI: https://doi.org/10.1007/s11431–011–4578–7.
2. Kryvoplias-Volodina, L., Gavva, O., Sukhenko, V., Myronchuk, V., Tokarchuk, S., & Volodin, O. (2022). Synthesis of the control system for the positioning pneumatic drive of shut-off fittings according to the criteria of technological efficiency. Eastern-European Journal of Enterprise Technologies, 4(2(118), 79–91. DOI: https://doi.org/10.15587/1729-4061.2022.263622
3. Gavva, O., Kryvoplias-Volodina, L.,Marynin, A. (2023) Architecture of hybrid mechatronic dosing and packing module of packaging machine based on qualitative analysis. Eastern-European Journal of Enterprise Technologies, 4(2(124)), pp. 70–79. DOI: https://doi.org/10.15587/1729-4061.2023.286615
4. Volodin, S. Myronchuk, V. Dynamic optimization of pipeline transport systems in sugar factories. 8-th Central European Congress on Food 2016, Food Science for Well-being, 23-26 May,2016 – Kyiv – p.251.
5. Tanaka, M. Numerical investigation on large scale eddy structure in unsteady pipe elbow flow at high Reynolds number conditions with large eddy simulation approach / M. Tanaka, H. Ohshima // Journal of Power and Energy Systems. – 2012. – Vol. 6. – Issue 2. – pp.210-228