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PRACTICAL ASPECTS OF MODELING HYDRODYNAMIC CHARACTERISTICS IN THE SYSTEM OF PIPELINE VALVES

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Abstract: *Proper operation of control valves allows you to maintain the parameters of technological processes and increase the effect of juice purification and sugar yield, reduce the sugar content in molasses, reduce fuel consumption and milk of lime. Search for rational parameters. The technology of the control valve selection is offered in the work, on the basis of the analysis of the static characteristic of the working object. It is shown that when choosing the standard size of the valve according to the equations of flow and throughput characteristics, the operation of the valve is considered separately from the operation of the control system of flowing of modern sugar production. The technology of the control valve selection is offered in the work, on the basis of the analysis of the static characteristic of the working object.*

Empirical methods have been used to calculate the cost characteristics for evaluating the operation of control valves and shut-off elements. Models of the object of regulation on the experimental stand are investigated. The study of the transient process when emptying the working chambers proved the following - the time of the transient process depends on the initial pressure in the chamber, the volume and type of muffler installed on the exhaust of the regulator (creates additional resistance to working air during discharge). At an initial pressure of 5 bar, for V = 4 l at step change of a control signal, time of transient process at use of the muffler on an exhaust to 1,8s is accurately fixed. When reproducing the operation of the regulator without a muffler - the transient time is twice less.

Keywords: *c*ontrol valves, parameters, technological processes, sugar yield.

INTRODUCTION

Industrial control systems of shut-off valves, on the one hand, are participants in the digital exchange of data on the process, and on the other - themselves carry out the industrial process. The pressure drop in the valve is a necessary condition for the implementation of its control function and manifests itself as a loss of energy in the energy balance of the production process. (Jeong-Hyoun Sung,2000) Proper operation of control valves allows to maintain the parameters of technological processes and increase the effect of juice purification and sugar yield, reduce the sugar content in molasses, reduce fuel consumption and milk of lime. The search for rational parameters of shut-off and control valves is an urgent issue for the creation of modern sugar production. To study the synthesis of industrial control valves at the defecosaturation station of the sugar enterprise, an experimental laboratory installation was developed. (Vrabie, D., 2009).

The sugar contained in beets is removed by extraction (diffusion). According to Fick's law, the mass transfer rate is proportional to the contact surface of the phases and inversely proportional to the path (chip thickness). (Bianchi, S., 2003) To speed up the process of sugar extraction, the contact surface of the extractant (water) and beets is increased and the chip thickness is reduced during beet root grinding. (Peresada, S., 1999)

EXPOSITION

Subject, methods and experimental studies of optimal modes of operation of foam-regulating devices

To study and control the water supply regimes, a technique related to the operation of shut-off and control devices is proposed. It is possible to change the laws of motion of the output link (disk, layer, valve), which allows you to set and track the kinematic and dynamic parameters of the shut-off and control device in terms of variable performance of the process site (Fig. 1).

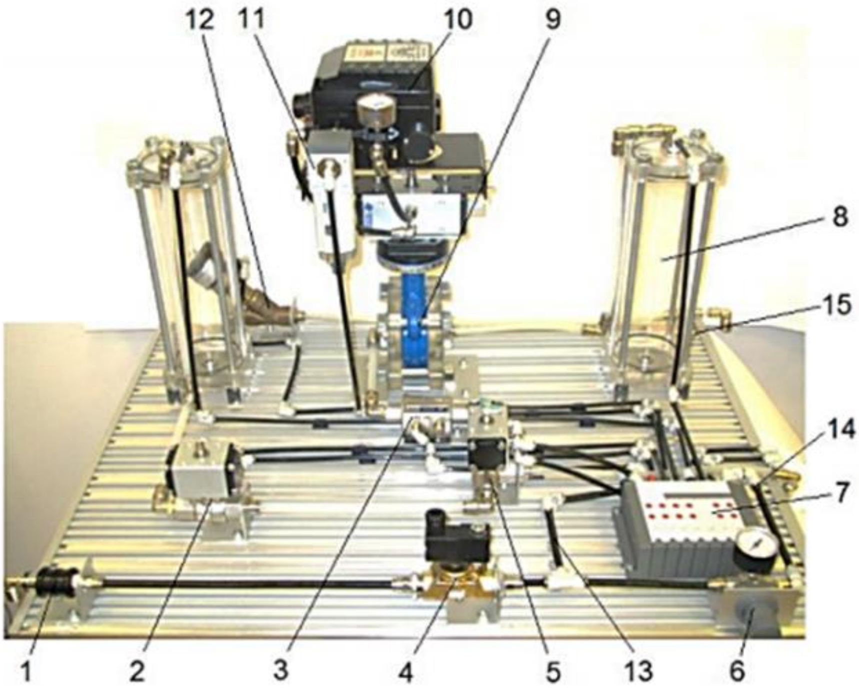

Fig.1 Experimental installation for research of kinematic and dynamic parameters of shut-off and regulating devices in the conditions of variable productivity: a) the general type of installation (1-valve VMS-114-1 / 4 of supply of compressed air; coaxial valve VNC10003; 4 - solenoid valve; 5 - three-way ball valve L-port; 6 - pressure regulator; 7 - pneumatic island; 8 - fluid collection receiver, 10 l; 9 - disc interflange latch D376; 10 - electropneumatic positioner (4..20 mA); 11 - koalis-centric filter; 12 - seat valve NZ; 13 - high pressure line; 14 - low pressure line; 15 - check valve

The main elements of the experimental stand in Fig.1. operate in a two-circuit network: high pressure zone - compressed air 6 bar (temperature 20°C), positions 1,3,6,7,10,11,13,14 ,; low pressure zone - water 0.2 - 1 bar (temperature 20 - 70 °C), all other positions. During the experiments, the operation of shut-off and control devices 2,5,9,10,12,21 was investigated. With the help of a digital flow meter, pressure sensors, force and acceleration sensors, the main kinematic and dynamic parameters of the shut-off and control devices were recorded. Pressure losses in the sections of air ducts and water supply pipeline were determined, pressures at the nodal points of the stand were coordinated by adjusting the signals of the electropneumatic positioner, which provides the optimal law of motion of the disc flanged valve.

The method of research of influence of elastic dissipative properties of links and friction in contact pairs of shut-off and regulating elements on work of the electro-pneumatic drive of the equipment is developed.

Practical aspects and methods of synthesis of the layout of the locking and regulating elements and the drive

The purpose of mathematical modeling of pneumatic automation in the elements of shut-off valves is to obtain a system of equations describing the work of structurally similar elements of the valve, further study of which on a computer allows to solve problems of analysis and synthesis of dynamic parameters of automatic control. Figure 3 shows a functional diagram of the electropneumatic control subsystem in the pipeline with a liquid product. It includes an electronic error signal amplifier (EPS), an electrical mismatch signal meter (Σ), an electromechanical converter (EMF), a pneumatic amplifier (PP), an executive pneumatic cylinder (PC), a pressure sensor in the pipeline (DT). feedback on the movement of the piston of the pneumatic cylinder (remote control) and the object of regulation - the shut-off plunger of the control valve (OP).

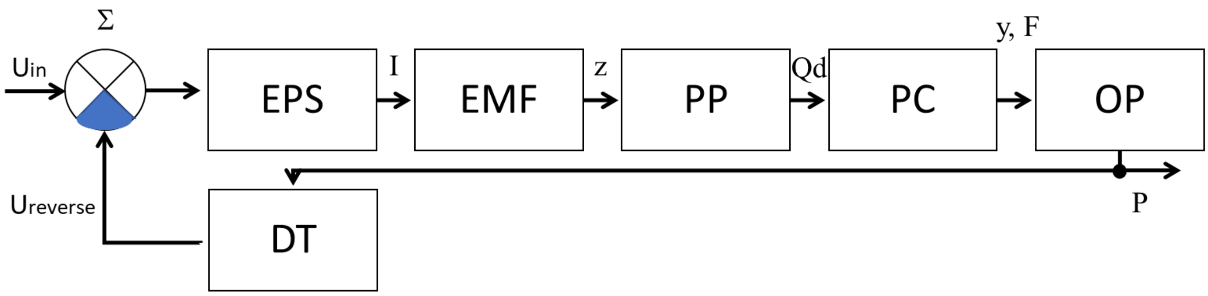

Fig.2 Block diagram of the object of regulation.

The mathematical model of the subsystem of pressure regulation in the pipeline consists of differential mathematical equations that describe the transient processes. To close the system of equations it is necessary to introduce a function that describes the change in the area of the critical cross section of the hole from the movement of the Central body of the locking plunger, F* = f (y).

To model the transients of Fig.2, Fig.3 in electropneumatic

a number of assumptions were made to the control subsystem of the shut-off plunger of the control valve: a double-acting pneumatic cylinder was used as a power element of the drive; the coefficients of flow and recovery of pressure in the pneumatic amplifier, supply pressure and drain are constant values; the temperature and viscosity of the working fluid (product) in the pipeline during the considered dynamic process do not change; the volume losses in the supply pneumolines of the pneumatic cylinder are small and can be neglected. Based on the accepted assumptions, the mathematical model has the following form.

The equation of the electrical circuit of an electromechanical converter.

$$\left(U_{dr} - k_{\text{oc}} \cdot Q_K(t)\right) \cdot K_y = R_{dr} \cdot i_{dr}(t) + L_{dr} \cdot \frac{di_{dr}}{dt} + K_{\text{Kп ers}} \cdot \frac{dh(t)}{dt}, \tag{1}$$

where Udr is the voltage in the control winding of the electromagnet, V; Rdr - active resistance of the control winding of the electromagnet, Om; idr (t) - the dependence of the current in the control winding on time, A; Ldr - inductive resistance of the control winding of the electromagnet, H(henry), Kp ers - coefficient of anti-EMF of the electrical circuit of the electromechanical converter, V·s/m; h (t) is the dependence of the movement of the throttle control valve on time, m.

Equation of motion of the control valve of the shut-off valve.

$$m_{\text{dr}} \cdot \frac{d^2 h(t)}{dt^2} = K_{fid} \cdot i_{\text{dr}}(t) - b_{vdd} \cdot \frac{dh(t)}{dt} - c_{\text{dr}} \cdot h(t), \tag{2}$$

where m_{dr} is the mass of the throttle control valve, kg; K_{fid} - current ratio in the electrical circuit of the electromechanical converter, N/A; b_{vdr} - coefficient of viscous friction in the throttle, N·s/ m; C_{dr} - spring stiffness coefficient in the throttle, N /m

The equation of motion of the spool valve constant pressure drop.

$$m_K \cdot \frac{d^2 x_K(t)}{dt^2} = A_1 \cdot \left(p_2(t) - p_3\right) - b_{VK} \cdot \frac{dx_K(t)}{dt} - c_K \cdot x_K(t), \tag{3}$$

where mk is the mass of the spool valve constant pressure drop, kg; xk (t) - the dependence of the movement of the valve spool constant pressure difference on time, m; A1 - area of the end surface of the valve of constant pressure drop, m^2; p_3 is the dependence of the pressure at the outlet of the throttle on time, Pa;bvк - coefficient of viscous friction of the spool in the valve of constant pressure drop,

N·s/m; Ck is the coefficient of spring stiffness in the valve of constant pressure drop, N /m.

Equation of cost balance through the cost regulator:

$$\mu_K \cdot b_K \cdot x_K(t) \cdot \sqrt{\frac{2 \cdot (p_1(t) - p_2(t))}{\rho_0}} - \mu_{\partial p} \cdot b_{\partial p} \cdot h(t) \cdot \sqrt{\frac{2 \cdot (p_2(t) - p_3(t))}{\rho_0}} = \frac{V_{K1}}{2 \cdot E} \cdot \frac{dp_2(t)}{dt} + A_1 \cdot \frac{dx_K(t)}{dt} \quad (4)$$

where N is the number of channels; μ_k - flow rate of the throttle gap of the valve constant pressure drop; bk - the width of the slot of the spool valve constant pressure drop, m; Vk_1 - volume of the upper cavity of the valve constant pressure drop, m^3; E is the reduced modulus of volumetric elasticity of the working fluid, Pa. μdr - throttle flow factors; b_{dr} - width of the throttle gap, m, Vk_2 - the volume of the lower cavity of the valve constant pressure drop, m^3.

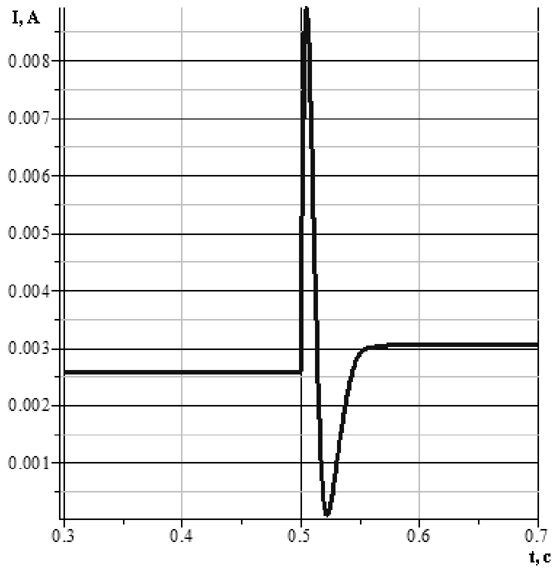

Fig.4. The control signal is given by shifting the damper of the flow controller

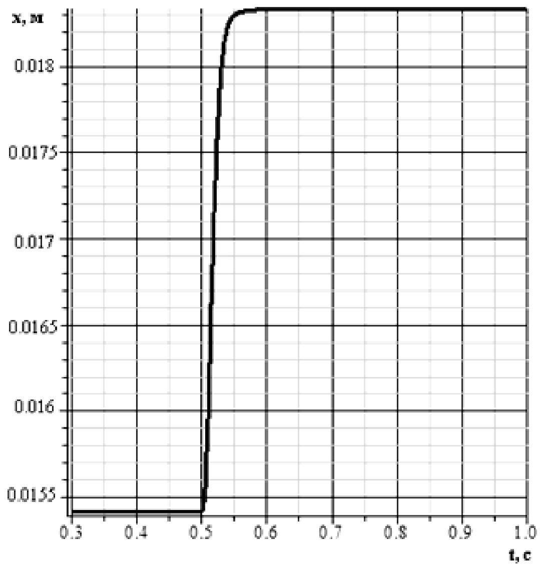

Fig.3 Coordinate of the valve

The objectives of the research were: to improve the transients in the drive, reduce the transient time and the maximum dynamic error.

The error of the performance of the moving part of the drive, at steady state, is largely determined by the accuracy of the pressure regulator.

CONCLUSION

1. Based on the analysis of known methods and techniques of mathematical, physical modeling of the shut-off and control system, as well as structural synthesis and parametric optimization of functional modules of packaging machines - a number of technical solutions are proposed.

2. The operational properties of actuators (control valves) are substantially largely determined by the main characteristics: hydraulic, power and design for the drive as a whole. Given the characteristics of the actuators, such as: bandwidth (determined by the volumetric flow rate of the medium in (m^3/h)), the short-circuit density (gradually changed by the regulator when the pressure drop across the drive in 0.1 MPa - can be calculated the current value of the capacity at a given value of the stroke of the working link (pneumatic cylinder rod) in percent.

3. In real conditions of operation of pipeline systems the pressure difference on the regulating valve which does not remain constant, and changes depending on hydraulic characteristics of pump installation, constituent elements of pipeline system, expenses of environment, properties of working environment, its viscosity, hydraulic mode is defined. movement, ability to boil due to lowering pressure and other factors.

REFERENCES

Vrabie, D. (2009) Neural network approache to coutinuous-time direct adaptive optimal control for partially unknow nonlinear systems. *Neural Networks.* V.22. №3. P. 237-246.

Jeong-Hyoun Sung,(2000) A new approach to vector control for a linear induction motor considering end effects.. *Department of electrical engineering, Postech University*. Hyoja San-31, Pohang, Republic of Korea. pp. 2284 – 2289. doi:10.1109/ias.1999.799162

Bianchi, S. (2003) Tubular linear permanent magnet motors: an overall comparison. *IEEE Transactions on Industry Applications.*. Volume 39, Issue 2. p. 466 – 475.

doi: 10.1109/tia.2003.809444

Peresada, S. High-performance robust speed-flux tracking controller for induction motor. *International Journal of Adaptive Control and Signal Processing*. № 14. – pp. 177–200.

Saravanakumar, D. (2017) A review on recent research trends in servo pneumatic positioning systems. Precis. Eng. J. Int. № 2. – pp. 117–224.

Shilin, A. A. (2014) The Reduction of the Multidimensional Model of the Nonlinear Heat Exchange System with Delay. Springer International Publishing Switzerland. CCIS 487, pp. 387–396.

Milam, M. B. (2003) Real-Time Optimal Trajectory Generation forConstrained Dynamical Systems: diss of Dr. Ph / Mark B. Milam. – California Institute of TechnologyPasadena, California, 179 p. 219.

Mirkin, B. (2009) Continuous Model Reference Adaptive Control with Sliding Mode for a Class of Nonlinear Plants with Unknown State Delay. Proc. of American Control Conference. – St. Louis, MO, pp. 574– 579.

Mohammad-Hoseinia, S. (2008) Robust adaptive control of uncertain non-linear systems using neural networks. International Journal of Control, № 81(8). pp. 1319–1330.

Paidoussis, M.P. (1999) Pipes conveying fluid: a model dynamical problem. Journal of Fluids and Structure. Vol. 7. P. 137–204.

Wang, L.(2006) A note on the stability and chaotic motions of a restrained pipe conveying fluid. Journal of Sound and Vibration. Vol. 296. P. 1079–1083.

Paidoussis, M. P.(2000) Fluid–Structure Interactions: Slender Structures and Axial Flow. Vol. 1. London: Elsevier Academic Press. 573 p.

Czerwiński, A. & Łuczko, J. (2012) Vibrations of steel pipes and flexible hoses induced by periodically variable fluid flow. Mechanics and Control. Vol. 31 (No.2). P. 63–71.