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MODELLING OF FLOW CHARACTERISTICS OF SHUT-OFF AND CONTROL VALVES

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Introductions. In modern mechatronic systems for controlling fluid and gas flows, it is extremely important to take into account the flow characteristics of control elements, in particular globe valves. The efficiency of shut-off and control systems directly affects the stability of the technological process, energy conservation and the accuracy of compliance with technological regulations. Modelling the flow characteristics of globe valves, taking into account design parameters, drive type and operating modes, allows for more accurate design of automatic control systems in industries where hydraulic stability is critical. Innovative solutions include adaptive control algorithms that take into account the actual flow characteristics of valves, the use of digital twins for preliminary flow dynamics prediction, the use of self-tuning electric drives, and the introduction of intelligent sensor systems for continuous parameter monitoring. Such approaches ensure the flexibility, stability, and efficiency of automated systems in the complex hydraulic conditions of modern production.

Keywords: Seat valves, flow characteristics, modelling, mechatronics, automatic control, hydraulic stability, boundary conditions.

Aim. When calculating a modern system for regulating the flow of working media in power or technological installations, it is important to consider the influence of the design features of valves and types of actuators on the stability and accuracy of regulation. An urgent task is to study the influence of different types of electro-pneumatic actuators on the flow characteristics of valves, in particular seat valves, under variable load and dynamic operating conditions [1, p. 45]. In order to simplify the mathematical description of the flow control process, it is often assumed that the flow passing through the valve is ideal. [2, p. 56], [4, p. 87]. CFD modelling of the flow through control valves was carried out, taking into account the complex geometry of the valve and unstable operating modes. One way to overcome these difficulties is to develop hybrid models that combine experimental data with simulation [3, p. 111], [5, p. 34]. Current issues include the development of adaptive control algorithms that change control parameters depending on changes in the environment and operating modes. For this purpose, the results of numerical modelling and data from physical bench tests are effectively used [6, p. 96], [13, p. 390]. For example, in pneumatic systems with electro-pneumatic actuators, the flow rate depends on the non-linear deformation of the valve and the compressibility of the air [14, p. 47].

Analysis of calculations, as well as experimental and practical data, has revealed the shortcomings of known models that ignore the nonlinearity of valve characteristics when transitioning from one mode to another. [7, p. 75], [8, p. 17]. Some models provide only a static flow calculation without taking into account transient processes that significantly affect the accuracy of the control system [10, p. 22]. The use of mechatronic systems based on proportional control with feedback allows compensating for controllability losses at low flow rates. Such solutions require precise adjustment of throttle elements and consideration of hydraulic losses in pipelines. [9, p. 63]. Particular attention is paid to determining the flow characteristics in dynamics. Studies conducted using physical modelling have established that even a slight change in the geometry of the flow channel leads to significant fluctuations in flow, especially in cases of proportional control [11, p. 32], [12, p. 15].

In conclusion, the results of the study show that effective modelling of the flow characteristics of saddle valves should be based on a comprehensive approach that takes into account the physical properties of the medium, the valve design, the type of drive and the external authority of the system. In the future, it is planned to improve the models by using neural networks and machine learning methods to increase the accuracy of real-time flow prediction [13, p. 32], [14, p. 74].

Materials and methods. The experimental and theoretical studies conducted are based on the fundamental principles of hydraulics, the theory of fluid flow control, modelling of flow characteristics, and the use of numerical methods within the framework of engineering analysis (Fig. 1).

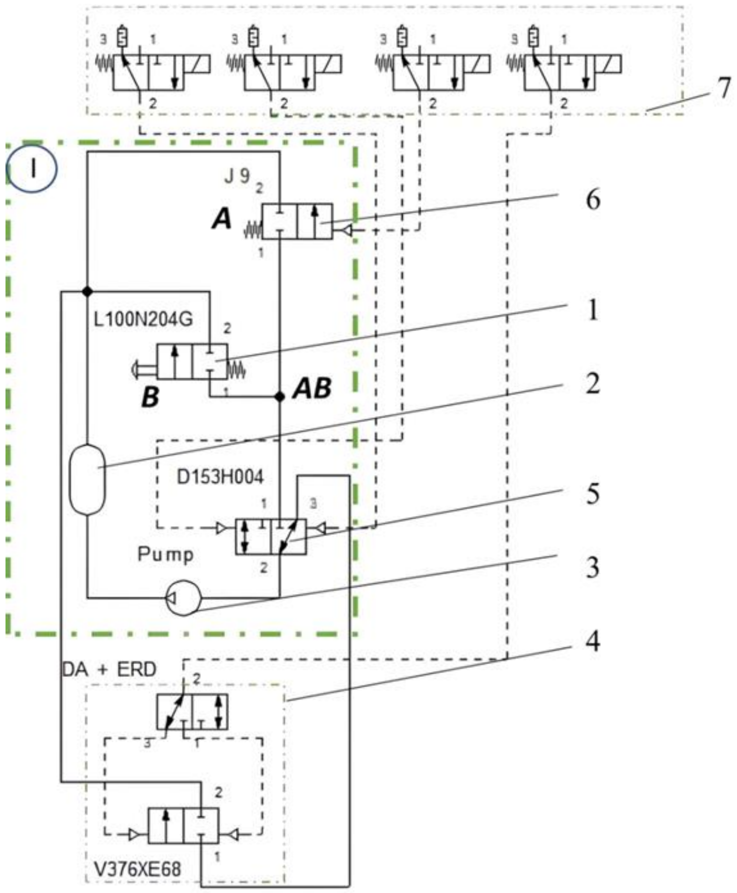

Fig. 1. Calculation diagram for testing two J9 check valves in circuit 1 (item 6)

The symbols in Fig. 1 correspond to the following description: 1 – ball valve, 2 – test fluid supply receiver; 3 – pump, 4 – D376 disc gate valve; 5 – L-port three-way ball valve; 6 – NZ seat valve; 7 – pneumatic island. When calculating a modern hydraulic flow control system, the relationship between the flow rate of the medium and the degree of opening of the control element is taken into account, which is described by the dependencies between h/h100 and V/V100. To study the flow characteristics, a setup with a J9 two-way valve (Fig. 1) was modelled within the experiment, where the circuit diagram takes into account the dynamics of fluid movement through the valve. The flow (consumption) characteristic of the valve is defined as the dependence of the relative flow rate on the relative stroke of the valve (Fig. 2). Fig. 2 shows graphs of flow characteristics for different geometric profiles: linear, logarithmic, parabolic and mixed types. It can be seen that the linear characteristic has the smallest deviation in the working area, while the logarithmic characteristic provides better control at low flow rates.

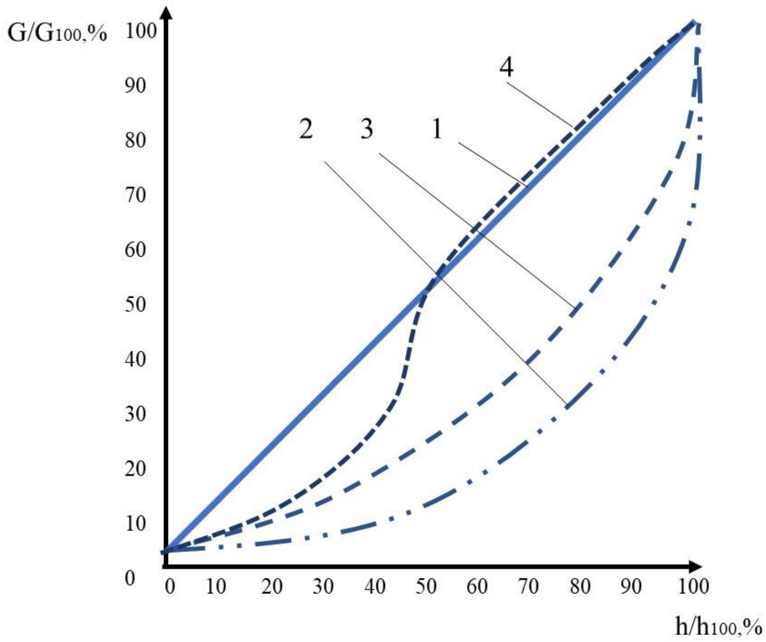

Fig. 2. Ideal flow characteristics of control valves: 1 linear; 2 logarithmic (equal percentage); 3 parabolic; 4 logarithmic-linear

Conclusions. In the system under study, it was determined that the flow characteristics of valves depend on both the type of drive and the hydraulic authority of the controlled section. The results of numerical modelling make it possible to reduce errors in the design of control systems and to select the optimal type of flow characteristic for a given mode. The use of a logarithmic-linear model allows for the smallest deviation (up to 2%) with a significant reduction in pressure losses. The developed model can be integrated into automated process control systems to ensure stable operation of equipment in variable performance modes. The relevance of the study is due to the need to improve the efficiency and reliability of shut-off and control valves (SCCV) in complex technological conditions, in particular in sugar production systems. Physical modelling of various types of valves revealed a significant influence of design features, drive type and operating modes on the dynamic characteristics of VRV, in particular flow properties, control stability and pressure losses. Improving the methods of calculating and adjusting valves, taking into account real flow characteristics and control authority, allows for improved process control accuracy, minimised energy consumption and increased valve service life.

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APPLICATION OF MODERN INFORMATION TECHNOLOGIES IN HIGHER EDUCATION

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Introduction. In today's world, information technologies (IT) have become an integral part of the educational process, especially in institutions of higher education. The challenges of the digital era require universities and educators to implement modern tools and approaches to enhance learning efficiency, ensure access to educational resources, and foster students' competencies.

Information and communication technologies (ICT) offer broad opportunities for modernizing education, developing electronic learning courses, interactive content, virtual laboratories, and distance learning. They enable flexible learning, personalized educational experiences, and the development of skills necessary for students' future professional activities.

The development and implementation of modern information technologies in higher education is a highly relevant topic of research, as it determines the competitiveness of graduates in the labor market, their adaptation to contemporary demands of industry and science, and also promotes the integration of Ukrainian education into the global educational space.

Today, information technologies are not only tools for accessing knowledge but also the foundation for updating the content, forms, and methods of learning. Their active implementation in higher education meets the needs of the digital transformation of society, the growing demands for digital competence among professionals, and the necessity to adapt the educational environment to the challenges of the 21st century. Therefore, the study of modern IT as a factor of innovative development in higher education is extremely relevant and practically significant.