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METHODS OF CORRECTING ERRORS DURING THE OPERATION OF THE DRIVE OF VALVES

Abstract. To ensure reliable operation of the valves it is necessary to lay the conditions for management at the stage of selecting and designing. Control system electric pneumatic (EPC) ensure smooth and reliable operation of mechanisms in many areas of technology today. Functional capabilities of modern EPP are determined by the characteristics of the applied management systems in many ways, as well as the parameters of the power part.

Keywords: servo pressure regulator, modeling, actuator

Formulas: 20, fig.: 4, tabl.: 0, bibl.: 9

Introduction. You must take into account the change of engine parameters, to reduce the number of failures of control system components EPP (shut-off pipeline armature) given the environmental changes. This will ensure the required quality of regulation.

To solve the set tasks were used: the theory of electric pneumatic actuator and electrical machinery, automatic control theory, mathematical modeling. Management system EPP properties belong to systems with delay. Such systems close to systems with distributed parameters. An example of one-dimensional pressure-regulation system with distributed parameters shown in Fig. 1 [Tarasov 2007].

To regulate the pressure in the pipeline with the liquid, use the measuring device P. The measurement results is perceived by the control device and is compared with the setting (set point pressure). If rejected the measurement results from the set value, the control device acts on the valve actuator and changes its flow area so as to eliminate the deviation. Feedback will be received by the control device only after the pressure waves will propagate through the pipeline before the measuring device. The system inherent delay, which in this

case is caused by the distribution of properties of fluid flow in the pipeline (along the x coordinate).

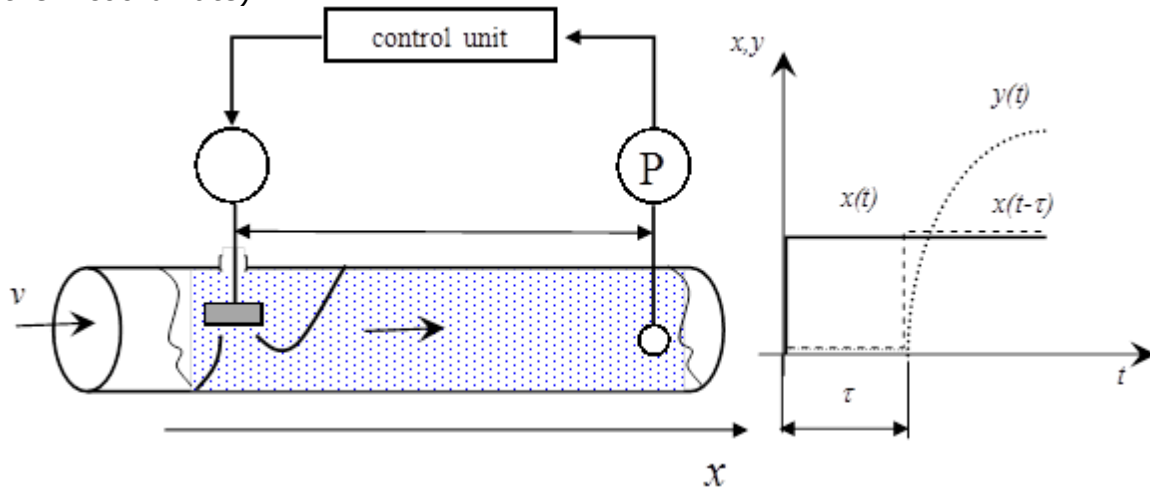


Figure 1 - System with distributed parameters, the schedule delay of the transition process

Source: authors' own development

Literature review and the problem statement.

There are many scientific papers of famous scientist, including Johansen O. (2003), Pavlidis T. (1995), Fannelop T. K. (1994) [Johansen 2003; Pavlidis 1995; Fannelop 1994] - which are devoted theoretical and methodological foundations and practical aspects of pulse-frequency modulated feedback systems.

The system in (fig. 1) is applied at research of electric - pneumatic flow valve with a Series IRV electric - pneumatic actuator 2024 - DIN F-TYPE, connector connection, sealing, compression or release of pressure from the actuator, control action input 4...20mA, supply pressure max. 6 bar, - safe position: valve CLOSED or valve OPEN, optionally equipped with end-limit sensor [Fannelop 1980]. The movement of a liquid in a long pipeline can be described by differential equations in partial derivatives:

$$\begin{cases} \frac{\partial v}{\partial t} = g \frac{\partial h}{\partial x}, \\ \frac{\partial h}{\partial t} = \frac{a^2}{g} \cdot \frac{\partial v}{\partial x}; \end{cases} \quad (1)$$

where: v - the fluid velocity at the point with x - coordinate along the pipeline, h - the pressure of the fluid at this point, a - the speed of sound in the fluid, g - acceleration of free fall.

The process was simulated for the system of regulating the gas pressure in the pipeline, if connected to the end consumers, taking into account the gas flow from consumers (changes randomly in time). The controls object is described by differential equation in partial derivatives:

$$F\left(\frac{\partial h}{\partial t}, \frac{\partial v}{\partial t}, \frac{\partial h}{\partial x}, \frac{\partial v}{\partial x}\right) = 0. \quad (2)$$

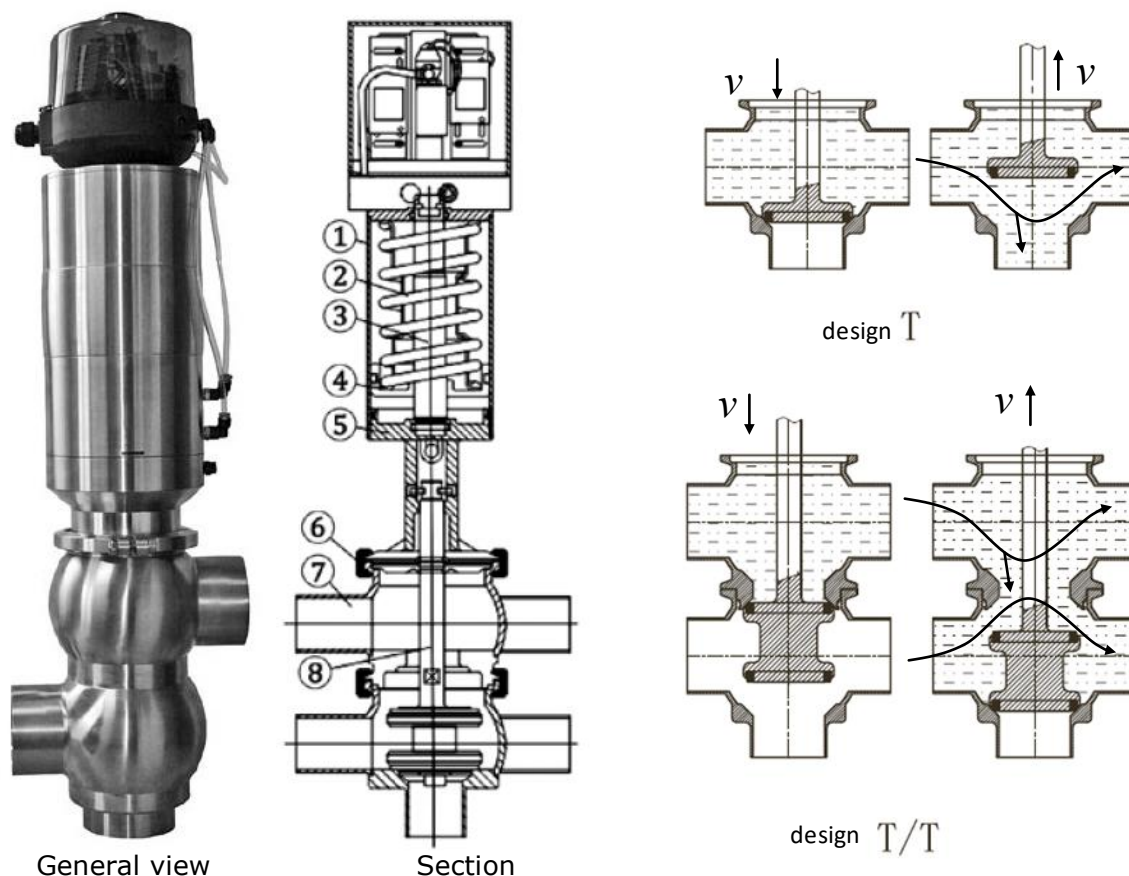


Figure 1 - General view of the actuator design, the design of the shut off valve with IRV electro-pneumatic control: 1 - cylinder, 2 - spring, 3 - piston, 4 - piston, 5 - bracket, 6 - clamp connection, 7 - casing, 8 - the plunger

Source: CAMOZZI. - General product catalog

This equation is deduced based on the patterns of flow of a compressible gas. Taking into account the compressible of the gas, its movement in the pipeline as described:

$$\left\{ \begin{array}{l} \frac{\partial \omega}{\partial t} + \omega \frac{\partial \omega}{\partial l} = -\frac{1}{\rho} \cdot \frac{\partial p}{\partial t}, \\ \frac{\partial p}{\partial t} + \rho \frac{\partial \omega}{\partial l} + \omega \frac{\partial \rho}{\partial l} = 0, \\ \left(\frac{\rho}{\rho_0} \right)^k = \frac{p}{p_0}; \end{array} \right. \quad (3)$$

ω , p , ρ – velocity, pressure and density of gas,
 k - is the adiabatic index,
 l - is the coordinate along the length of the pipeline.
 If you go to the relative value:

$$\varphi = \frac{\Delta p}{p_0}, \quad \lambda = \frac{l}{L}, \quad \psi = k \cdot \frac{\Delta \omega}{\omega_0};$$

L – the total length of the pipeline, the pipeline equation.

$$\left\{ \begin{array}{l} \gamma^2 T_0 \frac{\partial \psi}{\partial t} = -\frac{\partial \varphi}{\partial \lambda}, \\ T_0 \cdot \frac{\partial \varphi}{\partial t} = -\frac{\partial \psi}{\partial \lambda}; \\ T_0 = \frac{L}{\omega_0}, \quad \gamma = \frac{\omega_0}{a}. \end{array} \right. \quad (4)$$

Solution of partial differential equations for the system [Pavlidis 1995]:

$$\left\{ \begin{array}{l} \varphi = \phi'(t - \gamma T_0 \lambda) + \phi''(t + \gamma T_0 \lambda), \\ \psi = \frac{1}{\gamma} [\phi'(t - \gamma T_0 \lambda) - \phi''(t + \gamma T_0 \lambda)], \end{array} \right. \quad (5)$$

ϕ' , ϕ'' functions defined by properties of the control system and boundary conditions. The resulting equation contains the delay argument for functions ϕ' , ϕ'' . Its structure is similar to the description of the system with delay. Thus, the properties of systems with distributed parameters are similar to the properties of systems with delay. Both types of systems have the same type of description. The dead time is determined by the properties of the system. For this parameter, this value is determined when $l = L$, $\lambda = 1$, $\tau = 2\gamma T_0 = 2\frac{L}{a}$. In the system with

time delay and distributed parameter deviations occur controlled variable. They affect the input of the control device with delay. This determines the delay of the transition process in the system is relatively perturbation which causes this process. A feature of the transition process shown in Fig.1. Input action $x(t)$ formed at time zero. But the response of the system to this effect will be observed only after a delay τ . The output of the system will occur the transition process $y(t)$. Its appearance will depend on the type of the input and dynamic properties of the system [Johansen 2003]. Therefore, the system response can be described transient, caused by an input action $x(t)$, given the time lag T . As input action to consider $x(t-T)$. The differential equation of the system taking into account the lag takes the form:

$$Q(p)y(t) = R(p)x(t - \tau), \quad (6)$$

$Q(p)$, $R(p)$ – operator expressions left and right parts of differential equations that describes the dynamics of the system without delay. The last equation can be represented in the form of a system of equations:

$$\left\{ \begin{array}{l} Q(p)y(t) = R(p)x^*(t), \\ x^*(t) = x(t - \tau). \end{array} \right. \quad (7)$$

Research results. In accordance with the mathematical description of a system with delay can be represented as connections of ordinary linear parts and link with delay. Link of the lag carries out the shift of the input signal $x(t)$ with dead time τ . The output signal is delayed by $x^*(t)$. It is input to the system described without taking into account hysteresis transfer function $W_o(p)$ [Koh 2006].

$$W_o(p) = \frac{R(p)}{Q(p)}. \quad (8)$$

In the image area of the Laplace process in the system are described as follows

$$Y(p) = X^*(p) \cdot W_o(p). \quad (9)$$

The image of the delayed input signal, subjecting the function of this signal to the Laplace transform and using the shift property of the argument image

$$X^*(p) = L\{x^*(t)\} = L\{x(t - \tau)\} = e^{-\tau p}. \quad (10)$$

The resulting expression can be considered as the transfer function of the link delay

$$W_3(p) = e^{-\tau p}, \quad (11)$$

τ - the dead time.

The block diagram of the closed-loop system with delay can be represented in the form depicted in Fig.3. Transfer function open-loop system with delay will be determined through known transfer functions:

$$W(p) = W_3(p) \cdot W_o(p) = e^{-\tau p} \cdot W_o(p). \quad (12)$$

Transfer function open-loop system with delay will be determined through known transfer functions:

$$W(p) = W_3(p) \cdot W_o(p) = e^{-\tau p} \cdot W_o(p). \quad (13)$$

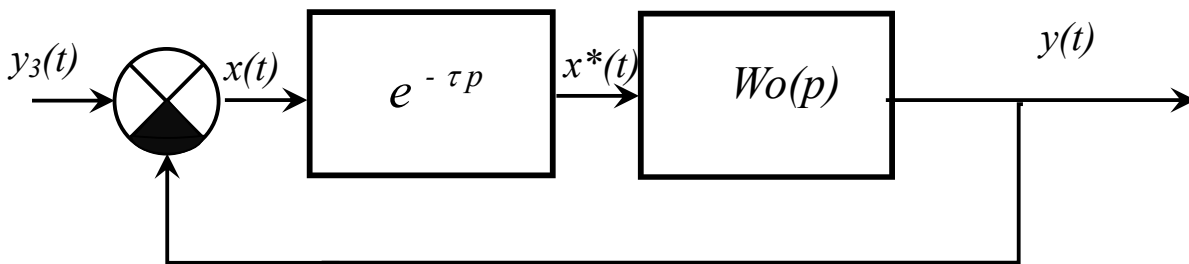


Figure 3 - The structure of the system with delay

Source: authors' own development

Transfer function open-loop system with delay:

$$W(p) = e^{-\tau p} \cdot W_o(p) = e^{-\tau p} \frac{A(p)}{B(p)}, \quad (14)$$

$W_o(p) = \frac{A(p)}{B(p)}$ – the transfer function of the system without delay.

The delay does not affect the stability of the open-loop system with delay as its characteristic polynomial $B(p)$ does not depend on lags. For the closed-loop system with time-delay transfer function of the closed system:

$$\Phi(p) = \frac{e^{-\tau p} \cdot A(p)}{B(p) + e^{-\tau p} \cdot A(p)} \quad (15)$$

In this case, the characteristic polynomial of the closed-loop system: $C(p) = B(p) + e^{-\tau p} \cdot A(p)$ depends on the size of delay. Consequently, the delay affects the stability of the closed-loop system. Investigation of stability of delay systems it is convenient to perform using the stability criterion of Nyquist. Transfer function open-loop system with delay

$$W(p) = e^{-\tau p} \cdot W_o(p)$$

The frequency transfer function of the system with delay:

$$W(j\omega) = W_o(j\omega) \cdot e^{-j\tau\omega} = A_o(\omega) \cdot e^{-j[\theta_o(\omega) + \tau\omega]} \quad (16)$$

To construct the amplitude-phase frequency response of system with delay, sliding the point of the amplitude-phase frequency characteristics of the system without delay, on the frequency ω , at an angle of $\tau\omega$. A characteristic difference of amplitude-phase characteristics of the system with delay is that the feature becomes a spiral. When $\omega \rightarrow \infty$, the circumferential asymptotically to the origin. You can see that the stability margin of the system decreases with increasing delay, the system may become unstable. For the system there exists a critical value of time delay at which resistant no lag the system becomes unstable

$$\tau_{kp} = \frac{\varphi_3}{\omega_c}, \quad (17)$$

φ_3, ω_c – stability margin from phase and cut-off frequency of the system.

Thus, the delay in the system affects its stability and should be considered in the analysis of systems with delay.

A series connection of inertial links:

$$W(p) = \frac{k_1}{T_1 p + 1} \cdot \frac{k_2}{T_2 p + 1} \cdot \frac{k_3}{T_3 p + 1} \dots \quad (18)$$

transient response of this compound takes the form presented in fig. 4.

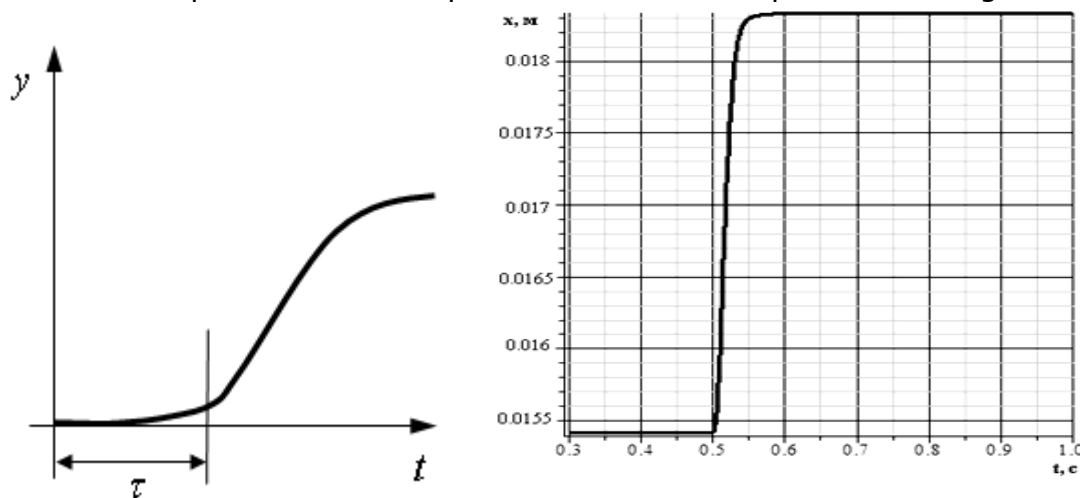


Figure 4 - Transient response

Source: authors' own development

The presence of the initial phase with a small amount of change in the

output value is the feature of this transient response. This initial section can be interpreted as the delay τ . Then the transfer function of the serial connection of the inertial units can be represented by the transfer function of the system with delay [Rodionov 2000]:

$$W(p) = e^{-\tau p} \frac{k_m}{T_m p + 1}, \quad (19)$$

m – the index of the element having the largest time constant, T_m is the largest time constant among the time constants of parts of the connection.

Considered approach allows reducing the order of the differential equation system and simplifying its description. In General, if the system has a number of inertial units with small time constant (relative to the largest time constant of one of the links). Then these links can be replaced by one equivalent element with delay:

$$\tau = \sum T_i. \quad (20)$$

Conclusions. System with delay can be described by an ordinary differential function without the trailing argument, but of a higher degree. The possibility of description of the system must be chosen depending on specific conditions, taking into account the systems with delay amplitude–phase characteristics specified.

The study also identifies the performance criterion of EPP (shut-off pipeline armature), which include requirements for various options of the electric pneumatic actuator and reliability of the EPP type control system.

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Data przesłania artykułu do Redakcji: 24.03.2016
Data akceptacji artykułu przez Redakcję: 07.04.2016