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PARAMETRIC SYNTHESYS OF MECHATRONICS MODULE OF DISPENSERING OF LUQUID FOOD PRODUCTS

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Abstract: *The article proposes a methodology for creating new packaging equipment for the distribution of liquid food stuffs, which has a flexible structure and is versatile when changing the dose or packaging material. The authors substantiate the development of a new generation of metering equipment by using the concept of mechatronic design principle. A new design of mechatronic dispensering module based on the use of pneumatic hose closures is proposed and substantiated. A distinctive feature of the hose closures is the cross section, which can be madjusted by changing the air pressure. A mathematical model for calculating the effective cross-sectional area of a pneumatic hose gate as a function of control pressure change is presented. It is established that such dependence is nonlinear and is characterized by a small range of variation of the effective area. This effect significantly affects the method of operation of the mechatronic module with pneumatic hose shutter and the choice of its elements.*

Keywords: *dosage, mechatronic module, effective area, liquid product.*

INTRODUCTION

The development of methods of dispensing liquid food products is directly related to the improvement of production technology, with increasing requirements for metering accuracy, reliability and speed of dispensers. The main requirements for new samples of dispensers are to provide both traditional indicators of productivity, economy (minimum cost), reliability, and technological indicators: stabilization of instant or average costs at a given value; change of cost by a given law (programmatically) depending on the change of process parameters or dosage object.

One of the promising directions of designing new dispensers that meet the above requirements is the use of pneumatic hose closures. A distinctive feature of the hose gate control is the variable cross section, which can be adjusted by changing the air pressure.

EXPOSITION

The purpose of the study is to develop a mathematical model for calculating the change in the effective cross-sectional area of the pneumatic hose gate as a function of control pressure change in the fluid dosing system.

Materials and methods. In the first stage of designing a mechatronic module for dosing liquid foodstuffs, the dependence of the change of the effective cross-sectional area of the hose gate passage from the control pressure was determined. (Fig. 1**).**

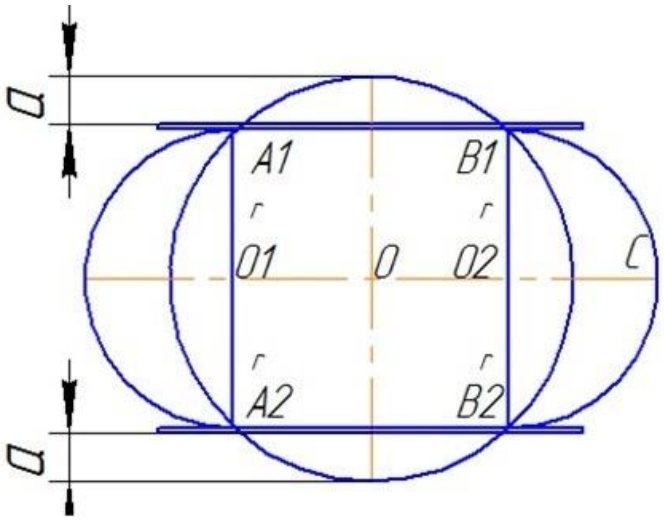

Fig.1. The design scheme of the hose shutter.

If there is no compressed air on the metering gate, then the effective cross-sectional area of the throughlet is determined by the formula:

$$f_0 = \pi \cdot R^2, \quad (1)$$

here, R is the inner radius of the pipe.

When supplying compressed air, the shape of the effective area changes by a value from the starting position. The nozzle takes the form of a rectangle A1A2 B2B1 and two semicircles of radius r.

Given that the perimeter in the middle of the pipe in the intersection plane does not change, we can write the ratio:

$$2\pi R = 2A_1B_1 + 2\pi r \quad (2)$$

From Fig. 4 shows that $r = R - a$ and section $A_1B_1 = \pi a$. (3)

Then, the intersection area of the partially squeezed pipe is determined by the formula:

$$f = 4A_1B_1 r + \pi r^2 \quad (4)$$

Substituting equations (3) and (4) into equation (2), we obtained the magnitude of the change in the effective area as a function of the magnitude of the displacement f as a function of the magnitude of the displacement a:

$$f(a) = \pi\left(R^2 - a^2\right). \quad (5)$$

It is possible to change the gate cross-sectional area by adjusting the pressure in the housing (Fig. 3). In this case, the cross-section f can be established by equation (5). The flow rate of fluid Q (m3 / h) through the intersection of the gate (cm2) f is defined as:

$$Q = 5,04 \cdot f \cdot \zeta^{-0,5}\left(\Delta P / \rho\right)^{1/2} \quad (6)$$

where ζ - dimensionless resistance factor; ΔP - pressure drop in the cross-section f.

To verify the adequacy of the analytical results, an experimental setup was developed (Fig. 2). For the purpose of the experimental studies, a normally open hose shutter of the AKO company was selected and a normally closed hose shutter of FESTO with internal diameters of 15 mm each. The shutter pressure was changed using a VPPX pressure regulator with an analog FESTO output signal.

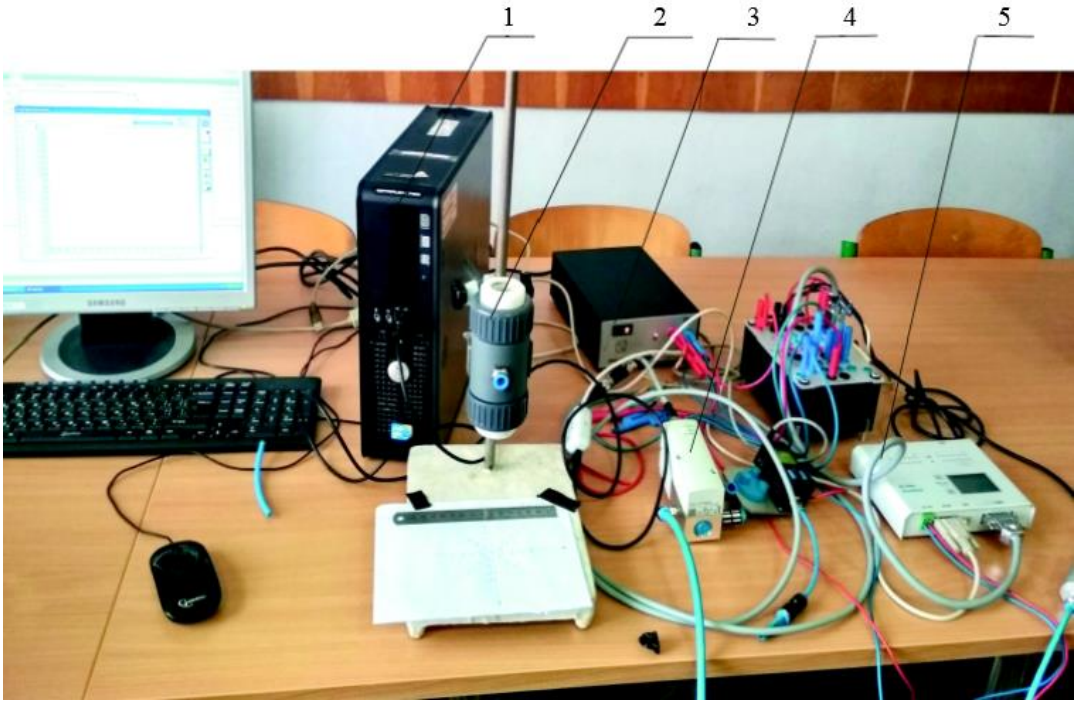

Fig. 2. Experimental set-up for research of hose industries: 1- compensator; 2 - normally open hose gate (a); 2 - normally closed hose shutter (b); 3 - power supply; 4- electronic pressure sensor; 5 - VPPX pressure regulator.

The results of studies of a normally open hose shutter are shown in graphs (Fig. 3).

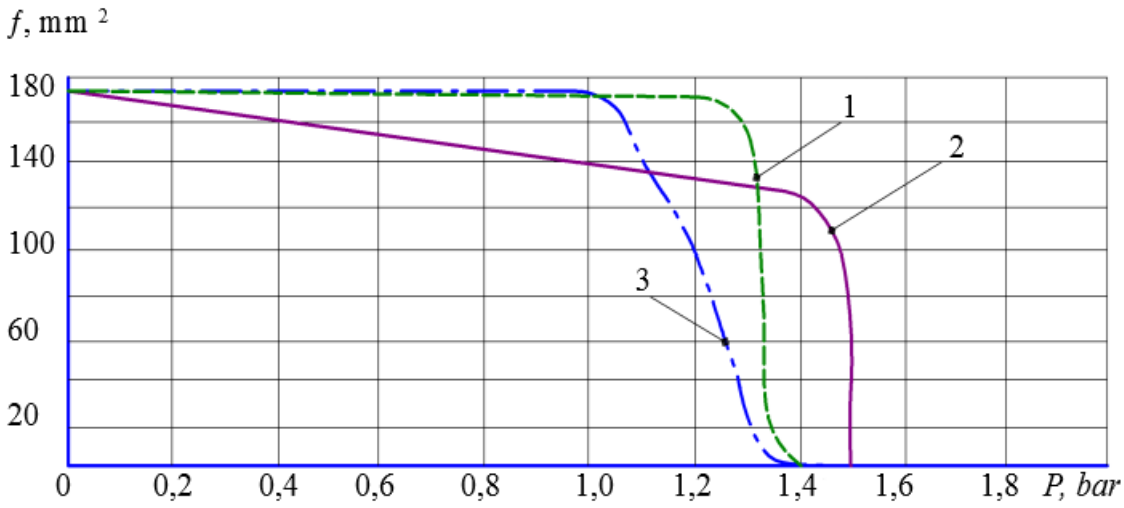

Fig. 3. Graph of change of effective area of normally open hose gate (f) from inlet control pressure (P): 1 - analytical studies; 2 - closing; 3 - opening.

From graph (Fig. 6) it follows that at the stage of closing the hose gate (curve 2) the effective cross-sectional area changes linearly to a pressure value of P = 1,48 bar, after which there is a sharp decrease with a slight change in pressure, the valve closes. At the step of opening the hose gate (curve 3), the effective cross-sectional area does not change to a pressure value of P = 1 bar, after which there is a smooth reduction of the effective cross-sectional area to a pressure of P = 1.36 bar, the valve slowly opens.

The results of the research of a normally closed hose gate are shown in graphs (Fig. 4).

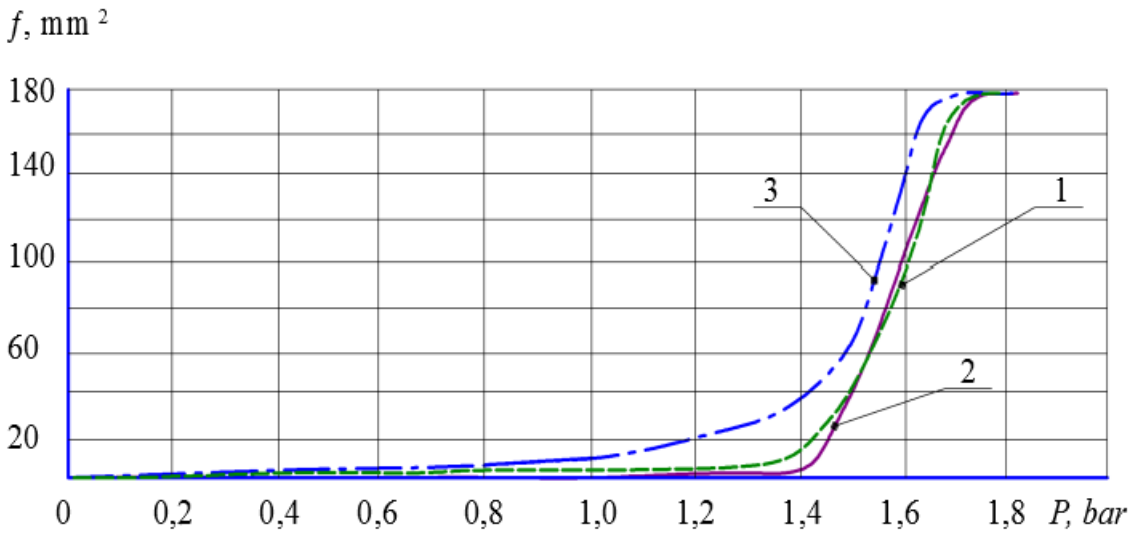

Fig. 4. Graph of change of effective area of normally closed hose gate (f) from inlet control pressure (P): 1 - analytical studies; 2 - opening; 3 - closing.

As a result of processing experimental studies of a normally closed hose shutter (Fig. 4), it was found that the limits of change in the effective area during opening (curve 2) of the shutter are significant. However, at the stage of closing the hose gate (curve 3), the effective cross-sectional area sharply decreases with a slight change in pressure to a pressure value of P = 1.3 bar, after which the closing process goes slow.

On the basis of the analysis of designs of hose closures the structural scheme of mechatronic module for dosing of liquid foodstuffs is offered (Fig.5).

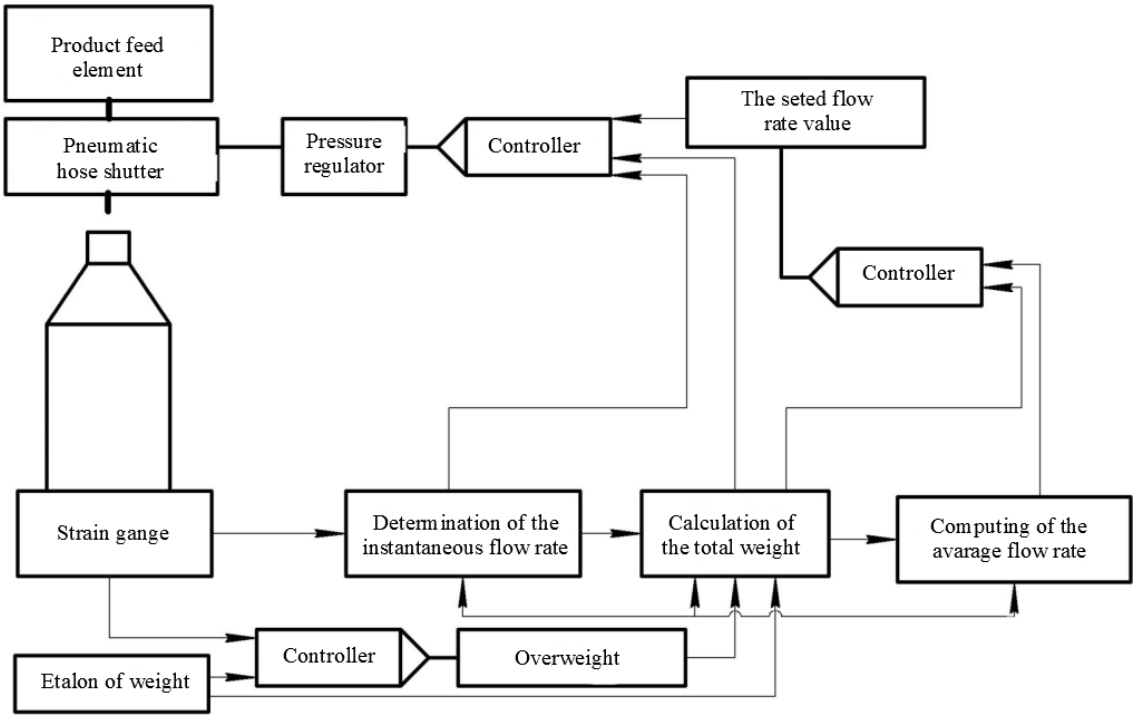

Figure 5. Block diagram of mechatronic module for dispensing liquid products by means of pneumatic hose shutter.

On the basis of the data obtained, the controller controls, by means of a pressure regulator, the cross-sectional area of the pneumatic hose gate, through which the flow of liquid food product is supplied and at the expense of which there is a significant increase in the accuracy of dosing.

CONCLUSION

On the basis of analytical and experimental studies of the normally open and normally closed hose gates, a mathematical model of the calculation of the change of their effective cross-sectional area from the value of the input control pressure was developed and its adequacy was tested by experimental studies. It is established that these dependencies have nonlinear type and are characterized by a small range of change in control pressure, which significantly affects the operation of the dosing system. To change the control pressure in the pneumatic hose shutter, it is recommended to use it in the mechatronic module.

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