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SYNTESIS OF MECHATRONIC FUNCTION MODULES DRIVES OF FLOW TECHNOLOGICAL LINES IN FOOD PRODUCTION

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Abstract: *The tasks were considered, which are related to the working bodies for the artificial food products movement according to the specified movement law and their positioning in the intermediate positions of the kinematic cycle. The actuators dynamics characteristics and control system of power part of positional electro-pneumatic actuators were researched. The methods of mathematical and computer modeling, and methods of solving ordinary differential equations and partial differential equations and method of correlation analysis were used. In the obtained results of modeling the kinematic load and the pressure of the working position pneumatic actuator, clearly observed that the inertial component increases in 4 stages (braking), during the narrowing the exhaust section of the working cylinder of the positional pneumatic actuator. The results of mathematical modeling for positional pneumatic actuators with the condition of changing the section of the exhaust hole allowed to track all the kinematic characteristics of the actuator. The obtained results allow to assign to the working body the law of motion, approximated to the optimal on the speed of action, not exceeding at the same time the maximum permissible dynamic influences for a moving artificial product.*

Keywords: *functional, module, packing, electro-pneumatic actuator, accuracy.*

INTRODUCTION

In recent years, a rather complicated process of optimal control of actuators of technological equipment for food production has been studied by many authors (Krivts I., Krejnin G., 2006). The authors took the various assumptions in order to simplify the mathematical description of the work of tracking and positional actuators (Janiszowski K., Kuczyński M. 2007). For a long time, this approach was justified, but over time, the productivity of mechatronic functional modules as part of technological equipment has increased significantly. In this connection, many control models of positional actuators with rational kinematic and dynamic parameters have become unacceptable for practical use (Virvalo T., 2016). Therefore, modulation of the moving process of artificial products by pusher on the basis of a position pneumatic actuator taking into account the real boundary conditions, as well as dynamic processes in the pneumocylinder, is relevant.

The main ways of packing artificial products in polymer films are revealed: the placement of the product in a pre-made package and fastening it with clips; the placement of the product in the sleeve, which is formed from roll packaging material; the placement of the product between two films and the formation of a package with four seams; the wrapping of the product with a polymeric film (Gavva O., 2017).

The analysis of the existing equipment for the packaging of artificial and small artificial foods, showed the priority of using polymeric packaging materials for a number of economic, environmental and protective parameters (Richard E., Hurmuzlu Y., 2015). There are modules with linear displacement actuators in the composition of the collision mechanisms in the studied packaging machines (PMs), the most common mechatronic functional modules (MFMs) feeding the food product to the packaging area. The main ways of packing artificial products in polymer films are: placing the product in a pre-made package and fastening it with clips; placement of the product in the sleeve, formed from roll packaging material; placement of the product between two films and the formation of a package with four seams; wrapping the product with a polymeric film (Kinyckyi Y., 2008).

The tasks of the study

The tasks of the following studies are:

- the modeling of piston movement law of the pneumocylinder with an initial difference in air pressure, approximating to the optimal speed. In this case, the loads movement on the fixed flat is considered a collision mechanism with a positional pneumatic actuator.

- using the mathematical modeling to study the cases of smoothing the acceleration function at the moment of disengagement of the driving force, which allows to change smoothly the working parameters of the positional pneumatic actuator.

- the creation of the simulation model of the positional actuator, with taking into account the cases of functions smoothing of the of the analogue of speed and analogue of acceleration.

- the description of the method of choosing the initial movement stage (in the coordinate x), with taking into account the possible reduction of the actuating mechanism productivity.

EXPOSITION

Materials

The materials were chosen the positional actuators of packaging machines. The aim of the study was chosen the dynamics of electro-pneumatic positional actuators. The analysis of the working bodies motion laws of the initial kinematic link of the collision mechanisms was carried out for the technological schemes of the MFM movement of artificial products and the group (layer) of artificial products into the formed sleeve of the packaging material.

MFM formation characteristics of artificial products packaging

The operations of forming the artificial products packaging are connected to the work of the MFM elements according to the laws of motion, which determine the required productivity of the packaging machine. As an researched positional actuator, for the given layout of Fig. 1, MFM was chosen on the basis on pneumo actuator of positional type.

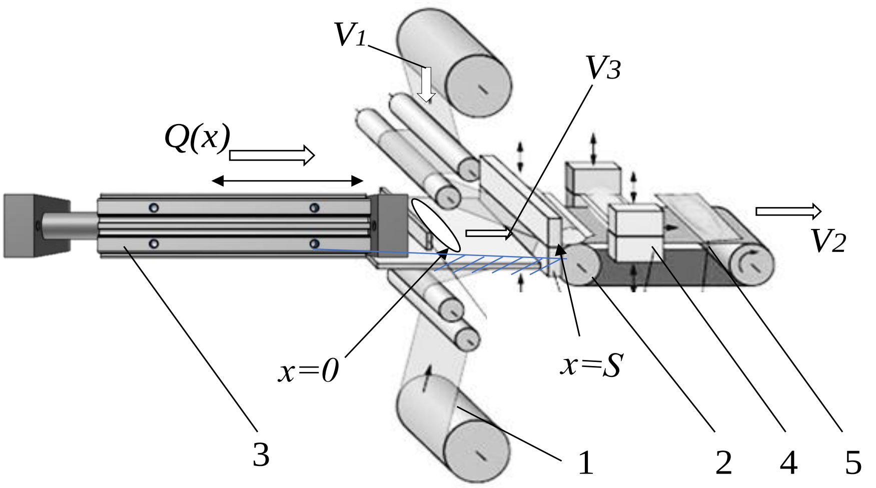

Fig. 1. General scheme of the technological module for the packaging of food products:

1—functional mechatronic module (FMM) supply of packaging material; 2 - functional device for formation of transverse joints and cutting off finished packages; 3 - FMM movement of products into the sleeve; 4 - FMM forming a longitudinal seam; 5 - FMM withdrawal of finished packages; x - coordinate of movement of a piston (m); V - speed of movement of a piston (m / s); Q(x) - acceleration of movement of the piston; P_1 - pressure in the piston chamber of the pneumocylinder (Pa); P_2 - pressure in the ventricular chamber of the pneumocylinder (Pa); t -time movement (sec).

Methods of mathematical and computer modeling, methods of solving ordinary differential equations and differential equations in partial derivatives were used to study the dynamics of compressed air in the cavities of the pneumocylinder. In the study of the layout of MFM packaging machines, the theory of automated control of electropneumatic position drives is used.

Thus the resultant of all resistance forces at I, II and III stages of the kinematic links movement:

$$P(x) = P_{pak} + \left(m_{pak} + m_n\right)\ddot{x} + m_{pak} gf + p_a\left(F_1 - F_2\right) \qquad (1)$$

The resultant of all resistance forces at stage IV:

$$P(x) = P_{pak} + m_n\ddot{x} + p_a\left(F_1 - F_2\right) \qquad (2)$$

m_{pak} - is the mass of the product; m_{pak} =0.5 kg; P_1, P_2 - is pressure of the piston and stomach cavity(Pa), $F_{1,2}$ - is square of the piston pneumocycline (m^2); f = 0.3 coefficient of friction; pa - atmospheric pressure; P_{pak} - is the dynamic load of the pneumocylinder(N); g=9.81 (m/sec^2) - free fall acceleration; m_n - is the mass of the piston.

Consider the law of movement of the leading link as a part of the mechatronic FD. It requires:

-to find the time T (on) of load movement in the optimal speed of the two-stage mode to set the required value of x (lk) of load movement at the first stage I in a four-stage mode;

-to determine the equations on the basis of the obtained value x(Ik), describing the kinematic parameters of the moving load at first stage in the four-stage mode, and also the final conditions for this stage;

-to consider the load movement as a three-stage and to determine the shutdown time of the driving force and the total time of movement. In this case, the final coordinates for the stages I and III of the three-stage mode of motion coincide with the final coordinates for stages I and IV of the four-stage mode of movement;

-to determine the equations describing the load movement at II and IV stages, and then at III stage for a four-stage mode of motion.

This sequence of tasks is connected with determining the initial and final coordinates of the load movement for each stage and with the searching for integration constants.

The time T_{on} of the load movement at optimal speed in two-step mode is determined by the method.

$$T_{on} = \sqrt{\frac{2S}{gf\left(1-\left(m_{pak} g\, f / Q\right)\right)}} \qquad (3)$$

where S is value of load movement (piston stroke); *f* is the coefficient of friction between the bearing surface of the load and the displacement flat.

Fig. 2 shows the graphs of the dependence of kinematic parameters from the time of movement of an artificial product in the implemented mode and the pressure change in the working cavities of the pneumocylinder (the power part of the position actuator).

a) b)

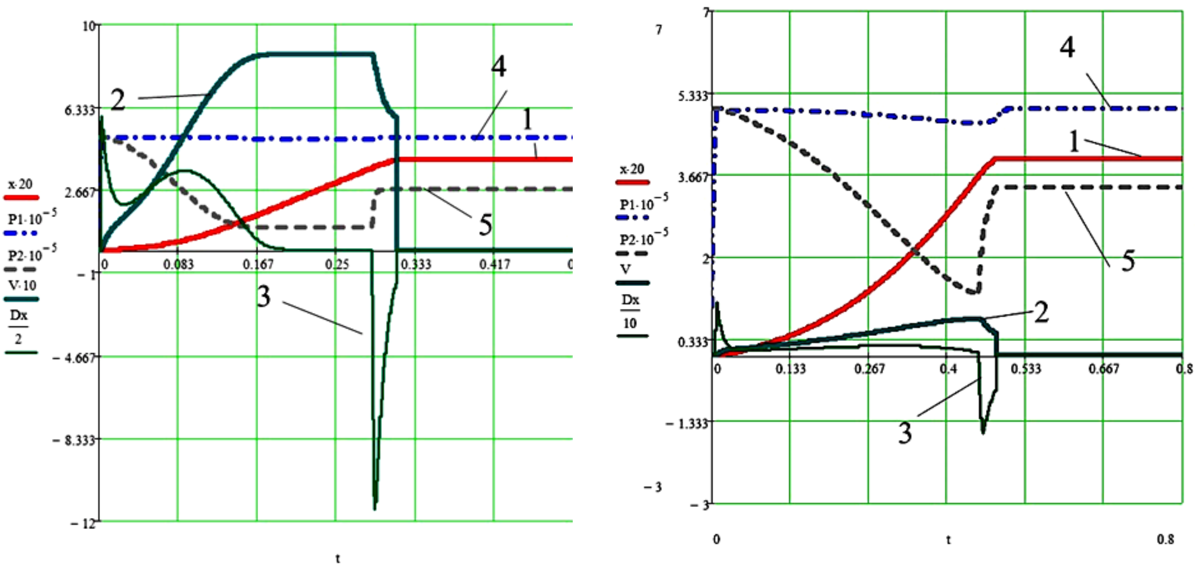

Fig. 2. Results of simulation of the kinematic load and pressure of the working position pneumatic drive with the power part: 1 - change of coordinate of movement; 2 - change of speed; 3 - change of acceleration; 4 - change in pressure in the piston chamber; 5 - change in pressure in the vent chamber of the pneumocylinder; diameter of the piston 25 mm; rod diameter 12 mm;

a) pipeline diameter 10 mm; effective cross-sectional area $f^e{}_1$ =7.854×10-5 m^2 ;

b) pipeline diameter 6 mm; effective cross-sectional area $f^e{}_1$ =2.827×10-5 m^2 ;

CONCLUSION

The output link movement of the experimental MFM, the pneumo-cylinder rod of the electro-pneumatic positional actuator are implemented and mathematically described. The conditions of the initial difference of air pressure are taken into account. The mathematical description of the rod movement law, which is optimal for the speed of action, is obtained. In the obtained results, it is clearly observed that when the exhaust section of the working cylinder of the positional pneumatic actuator is narrowed, the value of the inertial component at stage 4 (deceleration) increases. In addition, given the complexity of the working environment, - compressed air - it is necessary to apply the additional parameters: viscous friction coefficients of the working kinematic pair of piston-rod, resistance coefficients in the exhaust section in the implementation of the fourth stage of motion.

The movement of products on a fixed reference flat by a mechanism of collision with an electro-pneumatic positional pneumatic actuator with consideration of the control system is researched.

The proposed analytical dependences allow:

- to set the working body the law of translational motion, approximating to the optimal speed, without exceeding the maximum permissible dynamic load for the moving load;

- to move the artificial product from the initial position to the final in the shortest possible time for the pneumatic actuator;

- to analyze the existing structures of operating actuators with pneumatic actuators.

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