RESEARCH OF DYNAMIC PROCESS IN THE PNEUMATIC CYLINDER SYSTEM OF DOUBLE ACTION AT THE STABLE MOVEMENT

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Abstract: *In the article we will consider basic principles of functioning of the system automat of loading of pneumatic drive formed on a base. Experimental the stages of stabilizing of pressure in the working cavities of cylinder of two-sided action that was used as a drive of oscillation tray - metering device. A receipt the results of mathematical model give possibility to describe the kinematics and dynamic parameters of drive taking into account expense character and give to recommendation on the use of these systems.*

Key words: kinematic parameters, packaged cargoes, compound downhill, movement

I. Introduction

The analysis of basic principles of functioning of the system of the automatic loading allowed to define a task on the choice of optimal parameters of work of the loading systems of blister machines without losses on the productivity. Research was based on the analysis of a few arrangements centrifugal the loading devices made a home producer for self-feeding in a packing machine for close-settled sugar or close-settled of salt (Figure 1).

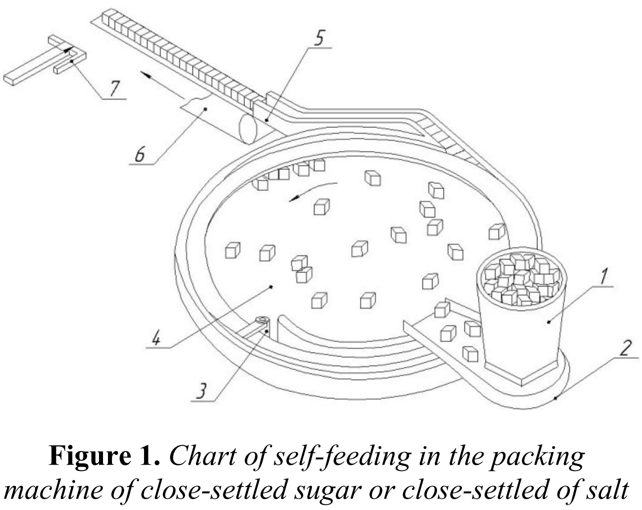

Figure 1. *Chart of self-feeding in the packing machine of close-settled sugar or close-settled of salt of centrifugal loading devices:*

1 is a loading bunker, 2 is an oscillation metering tray-device, 3 is an active directing roller, 4 - a drawing plane is a centrifugal loading device, 5 is a directing tray, 6 is a band conveyer-store, 7 is feed-in.

II. Materials and methods

By the problem area of presented on(Fig.1)there is a transition of wares from an oscillation metering tray-device on a drawing plane. The drive was examine pneumatic drive of linear type, loaded with permanent on a size force of useful resistance, that provides recurrently is reciproating motion of oscillation tray - metering device in machines automats.The task of calculation is set forth usually in a next kind: to move horizontally some mass of M to the size of S for this time of t with permanent speed. Force of useful resistance of N is set.

The calculation chart of pneumatic cylinder is presented on Figure 2.

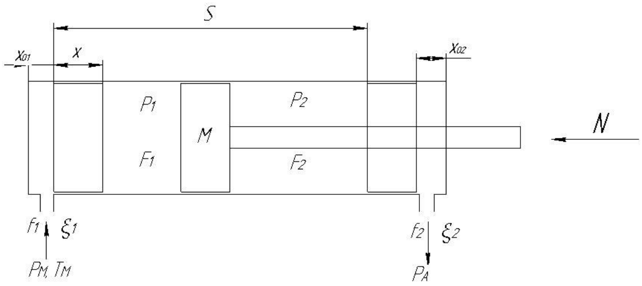

Figure 2. *Calculation chart of pneumatic cylinder double action*

A mathematical model of pneumatic drive is the system of differential equalizations, describing rod movement of pneumatic cylinder and pressure changes in rod and piston chamber [1].

$$M\frac{d^2x}{dt^2} = P_1F_1 - P_2F_2 - P_A(F_1 - F_2) - N,$$

$$\frac{dP_1}{dt} = \frac{k_1 f_1\sqrt{RT_M}\cdot\sqrt{{P_M}^2 - P^2}}{F_1(x_{0_1} + x)\sqrt{\xi_1}} - \frac{kP_1}{(x_{0_1} + x)}\cdot\frac{dx}{dt},$$

$$\frac{dP_2}{dt} = \frac{k \ \ f_2\sqrt{RT_M}}{F_2(S - x - x_{0_2})\sqrt{\xi_2}} \cdot \left(\frac{P_2}{P_M}\right)^{\frac{k-1}{2k}} \cdot \ldots$$

$$\ldots \cdot \sqrt{{P_2}^2 - {P_A}^2} + \frac{kP_2}{(S - x - x_{0_2})} \cdot \frac{dx}{dt}$$

At the set motion $\frac{d^2x}{dt^2} = 0$, $\frac{dP_1}{dt} = 0$, $\frac{dP_2}{dt^2} = 0$ and system of differential equalizations of signs kind:

$$P_1F_1 - P_2F_2 - P_A(F_1 - F_2) - N = 0, \qquad (1)$$

$$\frac{kf_1\sqrt{RT_M}}{F_1x\sqrt{\xi_1}} \cdot \sqrt{{P_M}^2 - {P_1}^2} - \frac{kP_1}{x} \cdot \frac{dx}{dt} = 0, \qquad (2)$$

$$-\frac{kf_2\sqrt{RT_M}}{F_2(S - x)\sqrt{\xi_2}} \cdot \left(\frac{P_2}{P_M}\right)^{\frac{k-1}{2k}} \cdot \sqrt{{P_2}^2 - {P_A}^2} + \cdots$$

$$\ldots + \frac{kP_2}{(S-x)} \cdot \frac{dx}{dt} = 0. \qquad (3)$$

We will designate: $\frac{dx}{dt} = v_{ш} = const$ it is speed of stroke, P_1 and P_2 are permanent pressures of set in a rod and piston chamber of pneumatic cylinder, P_M - it is main pressure of festering, P_A - it is atmospheric pressure, F_1,F_2 pneumatic cylinder, f_1, f_2 areas of the communicating opening of pneumatic cylinder , ξ_1, ξ_2 are coefficients of resistance of line of festering and exhaust line, x - is a coordinate of position of piston, S - is a maximal piston stroke, N - is force of resistance taking into account output-input ratio of pneumatic cylinder, k is an index of adiabatic (coefficient of Pyussona) R - gas permanent, T_M is an absolute temperature of gas. In a mathematical model we do not take into account a coordinate x_{0_1} and x_{0_2}, characterizing a volume spaces, that is intended for filling the compressed air to the moving-off of piston of pneumatic cylinder. We will transform the got equalizations as follows:

$$P_1F_1 = P_2F_2 - P_A(F_1 - F_2) - N_п, \qquad (4)$$

$$\frac{dx}{dt} = v_ш = \frac{f_1\sqrt{RT_M}}{F_1P_1\sqrt{\xi_1}} \cdot \sqrt{{P_M}^2 - {P_1}^2}, \qquad (5)$$

$$\frac{dx}{dt} = v_ш = \frac{f_2\sqrt{RT_M}}{F_2\sqrt{\xi_2}} \cdot \left(\frac{P_2}{P_M}\right)^{\frac{k-1}{2k}} \cdot \frac{\sqrt{{P_2}^2-{P_A}^2}}{P_2}. \qquad (6)$$

We will calculate factors in equalization (6) taking into account, that pressure in industrial pneumatic system does not exceed 8 barins usually. Then at any value of the set pressure p_2 in приделах from 1,5 to 8 barins taking into account the index of adiabatic of k=1,4 we will find limits of change of factor $\left(\frac{P_2}{P_M}\right)^{\frac{k-1}{2k}}$ in equalization (6) :

$$\left(\frac{P_2}{P_M}\right)^{\frac{k-1}{2k}} = 0{,}8 \ldots 1{,}0. \qquad (7)$$

We will define the turn-down of factor $\frac{\sqrt{{P_2}^2-{P_A}^2}}{P_2}$ preliminary transforming him as follows:

$$\frac{\sqrt{{P_2}^2-{P_A}^2}}{P_2} = \sqrt{1 - \left(\frac{P_A}{P_2}\right)^2} = 0{,}75 \ldots 0{,}99.$$
(8)

We will find the turn-down of work of two factors (7) and (8)

$$\left(\frac{P_2}{P_M}\right)^{\frac{k-1}{2k}} \cdot \frac{\sqrt{{P_2}^2-{P_A}^2}}{P_2} = 0{,}6 \ldots 0{,}99. \qquad (9)$$

Taking on a mean value of this work equal 0,8 equalization (6) we can write down as follows:

$$v_ш = 0{,}8\frac{f_2\sqrt{RT_M}}{F_2\sqrt{\xi_2}} \ . \qquad (10)$$

Putting (10) in equalization (5) we will find the size of the set pressure in the cavity of festering :

$$P_1 = \frac{P_M}{\sqrt{1+0{,}64\left(\frac{F_1}{F_2}\frac{f_2}{f_1}\right)^2\frac{\xi_1}{\xi_2}}} \ . \qquad (11)$$

We will find the set pressure in an exhaust cavity, putting the got expression (11) in equalization (4).

$$P_2 = \frac{1}{F_2}\left[F_1\frac{P_M}{\sqrt{1+0{,}64\left(\frac{F_1}{F_2}\frac{f_2}{f_1}\right)^2\frac{\xi_1}{\xi_2}}} - P_A(F_1 - F_2 - N)\right] \qquad (12)$$

In expressions (10), (11) and (12), we get the unknown geometrical parameters of pneumatic cylinder . With the purpose of choice of these parameters preliminary we will define the size of static load of N, operating on шток of pneumatic cylinder, taking into account an output-input of pneumatic cylinder ratio:

$$N = \frac{N_{п.с.}}{\eta} \ . \qquad (13)$$

Then, preliminary choosing pressure P_M in lines, that are within the limits of (5…8) barins supposing that static effort is 60%...70% from maximal effort operating in right part of equalization (4), on a catalogue [2] we pick up, preliminary, the diameter of pneumatic cylinder, areas F_1 и F_2, f_1 и f_2, motion of S of stroke Maximal effort we choose on a formula:

$$N_{max} = \frac{100\%}{(60...70)\%} \ . \qquad (14)$$

After preliminary determination of geometrical parameters of pneumatic cylinder we will define the real efforts operating in right part of equalization (4).

For this purpose at the beginning we will define the rate of movement of stroke:

$$v_{ш} = \frac{S}{t} , \qquad (15)$$

where: S is rod stroke, m;

t is time of working stroke, with

$$\left(\frac{f_2}{\sqrt{\xi_2}}\right) = \left(\frac{v_{ш} \cdot F_2}{0{,}8\sqrt{RT_M}}\right)^2 . \qquad (18)$$

Transforming expression (12) we find a size $\xi_1$resistances of line of festering taking into account expression (18) :

$$\xi_1 = \frac{\left(\frac{F_1 \cdot P_M}{F_2 P_2 + P_A(F_1 - F_2) + N}\right)^2 - 1}{0{,}64\left(\frac{F_1}{F_2 \cdot f_1}\right)^2 \cdot \left(\frac{v_{ш} \cdot F_2}{0{,}8\sqrt{RT_M}}\right)^2} \ . \qquad (19)$$

We will define pressure of P_1 in the piston cavity of cylinder taking into account expression (18) and (19) :

$$p_1 = \frac{P_M}{\sqrt{1 + 0{,}64\left(\frac{F_1}{F_2 \cdot f_1}\right)^2 \cdot \left(\frac{v_{ш} \cdot F_2}{0{,}8\sqrt{RT_M}}\right)^2 \cdot \xi_1}} \ . \qquad (20)$$

Subject to condition that pressure $P_1 > P_M$ it is necessary to increase pressure in the line of festering or choose a cylinder with a large diameter and again find pressure of P_1 and P_2.

We will define the area of communicating section of $f_2$line of exhaust, to provide set the rate of movement of stroke pneumatic cylinder $v_{ш}$. For this purpose we will transform expression (10) as follows:

$$\xi_2 = \left(f_2 \frac{0{,}8\sqrt{RT_M}}{F_2 \cdot v_{ш}}\right)^2 . \qquad (21)$$

Additionally coefficient of resistance ξ_2 exhaust tenches we will define on the semiempiric formula of A.C. Don.

Equating expression (6) and (10), shortening like term and erecting in a square we will get:

$$\left(\frac{P_2^{\frac{k-1}{2k}}}{P_2}\right)^2 \cdot \left(\sqrt{P_2{}^2 - P_A{}^2}\right)^2 = \left(0{,}8 \cdot P_M{}^{\frac{k-1}{2k}}\right)^2 \qquad (16)$$

We will transform the got expression (16) we find:

$$1 = \frac{1}{0{,}64 \cdot P_M{}^{\frac{k-1}{k}}}\left(P_2{}^{\frac{k-1}{k}} - \frac{P_A{}^2}{P_2{}^{\frac{k+1}{k}}}\right) . \qquad (17)$$

By the method of iteration from the half-scientist of expression (17) we find P_2 taking into account the before chosen pressure P_M in the line of festering.

We will express the relation of $\frac{f_2}{\sqrt{\xi_2}}$ from equalization (10) we will erect in a square

$$\xi_2 = \frac{\left(1 - \frac{\xi_2}{F_2}\right)}{2} . \qquad (22)$$

Equating equalizations (21) and (22), conducting transformation, we will get:

$$\frac{1{,}28 \cdot RT_M}{F_2 \cdot v_{ш}} \cdot f_2{}^2 + f_2 - F_2 = 0 \ . \qquad (23)$$

Deciding affected (23) quadratic we find the size of the communicating opening of line of exhaust of f_2, and on a formula (22) we determine the numeral value of resistance ξ_2.

Defining the parameters of pneumatic cylinder, we check up on-speed $v_{ш}{}^*$ on a formula (6). In case if on-speed $v_{ш}{}^*$ anymore required $v_{ш}$, we diminish the area of communicating section of f_2 and find the new value of resistance ξ_2. There are cases in opposite, we increase the value of f_2 and find a new value ξ_2. Whereupon we specify parameters ξ_1, P_1 и P_2

Diameter of d^2 communicating opening of line of exhaust we will define on a formula:

$$d_2 = \sqrt{\frac{f_2 \cdot 4}{\pi}} . \qquad (24)$$

By means of throttles on the exhaust opening of pneumatic cylinder we set the diameter of d_2, that will provide the required rate of movement of stroke

III. Results and discussion

The results of the got analytical model are worked out in programmatic the applied package MathCAD15 (*Fig 3*) Give an opportunity to draw conclusion about the robot of pneumatic cylinder of two-sided action with the external loading.

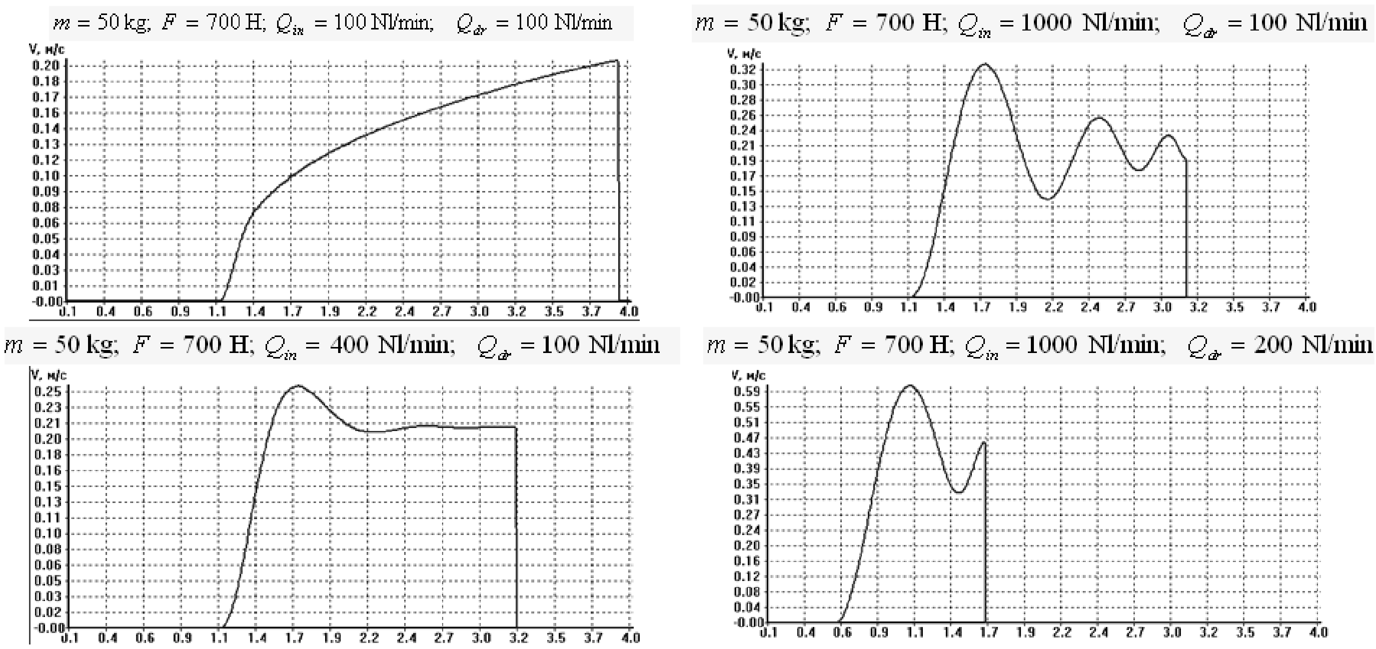

Figure 3. *Examples of process of advancement of cylinder of D=a 50 mm of h=a 400 mm*

IV. Conclusions

1. Time of outage and time of motion substantially depend on an expense on an exit and does not almost depend on an expense on an entrance.
2. On the set speed at the maximally possible loading a drive will go out at an expense on included in 2 times greater expense on an exit.
3. If it is necessary to provide stability of speed on 70…80% area of motion (minimizing time of acceleration and braking), then an expense on an entrance must be in 5 times a more expense is on an exit.
4. The set speed can be got the baffing of filling of cavity, when expense on an exit in 2 and more than times a more expense is on an entrance, however such method will allow to get stable speed, if loading will be variable.

REFERENCES

1.Ideljchik I.E. Matematicheskoe modelirovanie pressov v pnevmaticheskix privodov. - SPB: izdatelstvo Politex.universiteta, 2009. - 121c.

2.CAMOZZI. Bolshoj katalog pnevmaticheskoj armatyru.

3.Kikoin I.A. Tablizi fizicheskix velichin. Spravochnik. - M.: Mashinostroenie, 1976