THE PILOT STUDIES OF THE PNEUMATIC ROBOT CONTROL SYSTEM WITH USE OF THE ELECTRIC STEP MOTOR DRIVE CRANE DISTRIBUTOR

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Abstract

The pilot studies of a control system of the pneumatic robot with use of the crane distributor with the drive from the step electric step motor are conducted. The natural model of a crane pneumatic distributor with the drive from the electric step motor is created and tested. Tests confirmed operability of model; the pilot unit on the basis of the pneumatic FGM-9C robot with application of the offered control system is developed, and the pilot studies of its dynamic characteristics are conducted; the error of positioning of an action of the robot at operating load 0.1kg made ~ 0.14 mm (or 0.11%) at a fiducial probability 0.993.

The comparative research with the existing analog which showed is conducted that, when using of the offered control system and depending on the given program of work, quick action at achievement of terminating provisions of output links of the robot increases, adjustment of speed, and also positioning of an action of the robot in the intermediate provisions due to program control by the step engine is possible; it is established that quick action of the offered control system is 16.7% higher in comparison with system with use of the next analog. Results of the pilot studies testify to improvement of quality indicators of control of the pneumatic robot, namely accuracy of positioning with preservation of high quick action.

Keywords: Control system, pneumatic robot, crane pneumatic distributor, electric step motor, quick action, accuracy of positioning.

1. Introduction

Pneumatic robots are widely used in different types of productions. They are used in many technological processes and operations. But there is an important lack of pneumorobots, it is that there is no opportunity flexibly to operate positioning of actions in the ranges of their possible movements. Also topical issue of increase of accuracy of positioning of drives of such robots in the intermediate provisions that would allow to expand ranges of application and
extent of use in the existing technological processes and operations [1-3]. Results of part of imitating and pilot studies of a control system of the pneumatic robot with use of the crane distributor with the drive from the electric step motor are given in work.

2. Research Methods

For the solution of the existing problem methods of mathematical model operation, the theory of automatic control, programming, a simulation modeling on ECM, and also the pilot studies of dynamic characteristics and accuracy of positioning of operating mechanism of the pneumatic robot are used.

3. Research Results and Discussion

Calculated and imitating researches [4-8] of a control system of the pneumatic production robot showed possibility of increase of characteristics of the robot, as was put in a problem of check during the pilot studies.

During the pilot studies of a control system of the pneumatic robot with use of the crane pneumatic distributor with the drive from the electric step motor, research problems of parameters of quick action and accuracy of positioning were set.

The imitating model [5, 8] of the pneumatic robot having a crane pneumatic distributor with the drive from the electric step motor is presented in figure 1. The model is made of standard blocks of graphic language of model operation of the MSTC 3.7 program.

![Block diagram of imitating model of operation of the pneumatic robot.](image)

Blocks of functions contain coefficients of polynomials of the transfer functions made according to the differential equation describing duties of components of the pneumatic robot. The operating influence sets the law of change of position of the electric step motor which in turn regulates extent of opening of working windows of a crane pneumatic distributor. Besides, it is possible to allocate influence of air pressure on work of system, and influence of the law of change of load of an operating mechanism of the robot. The Surge characteristic block is the receiver of an output
signal of imitating model. After a task of parameters of an integration and carrying out calculation, received a surge characteristic of operation of the pneumatic robot (Fig. 2).

![Fig. 2 - The schedule of transient phenomenon received according to the program of calculation of imitating model of the production robot.](image-url)

The solvency of a control system is checked during practical experiments. As a basis for the pilot unit the pneumatic production FGM-9C robot (Fig was taken. 3). The production FGM-9C robot is intended for automation and mechanization of auxiliary technological operations of loading, unloading, installation, removal of details and preparations from the served processing equipment when mechanoprocessing, pressing etc.

![Fig. 3 - Scheme of the pilot unit.](image-url)

The pilot unit consists of the following elements: PC1 - a pneumatic cylinder of 1 promotion retraction of a hand; PC2 – a pneumatic cylinder 2 rises; PC3 – a pneumatic cylinder 3 mechanisms; REP – the rotary pneumoengine of lamellar type; CAPB – the block of preparation of compressed air; the block gives out a working pressure of air of 4 kgf/cm2 (bar); PDB – the block of pneumatic distributors (KPR1 - KPR7); SE – a legend of step engines; WM – a meter of a way, is the sensor of the linear situation works by the principle of magnetostriction, in installation the
measuring instrument of a way of Micropulse BTL of Balluff firm is used; the electrical power unit and strengthenings (transformer) – strengthens the signals of management arriving from a payment of management which is established in situ to CNC, this block, in fact, is a part of the CNC block, but for consideration of the pilot unit is removed separately; the CNC block – the block of numerical program control is the computerized control system intended for control of the robot pneumoequipment; The Controller is a control apparatus, but during experiment carries out functions of the registrar of the data arriving from a meter of a way; from this block data are transferred to the block of filing, visualization, processing and the analysis of data. As the controller the multi-channel program IMA-GO500 regulator was chosen; The Interface module – analog type, is also used the RS 422 interface for communication with the sensor of SP; The Block of filing, visualization, processing and the analysis of data – represents ECM with the software (PowerGraph 3.3) established on it for a logging and the analysis of data on operation of the robot.

Experiment by determination of accuracy consisted in the test of repeatability of a point – multiple repetition of operation on movement of details and preparations (everyone weight from 0.05kg to 0.2kg), at various promotion of pneumatic cylinders: one third of the maximal course of promotion, half and maximal length of promotion of pneumatic cylinders. These indexes of promotion of pneumatic cylinders were reached due to program regulation of electric step motors of crane pneumatic distributors. Results of measurement are analyzed as deviation range from mean value of provisions of a point. Process of management of the step engine of a crane pneumatic distributor allows to regulate opening of windows of the distributor, so and operation of pneumoengines.

Therefore, according to the obtained data on kind of work of PC perhaps graphically to show the range of opening of windows of a crane pneumatic distributor. In figure 4 characteristics of opening of a crane pneumatic distributor are shown.

![Fig. 4 - Surge characteristics of work of a crane pneumatic distributor: u – movement of an output link of the robot (a hand pneumatic cylinder), t – transient period.](image-url)
These characteristics (Fig. 4) show transient phenomenons of work of the managing director of a crane pneumatic distributor of a pneumatic cylinder of promotion retraction of a hand.

1 – The imitating estimated performance received by a simulation modeling;

2 – The characteristic at average opening of a window of a pneumatic distributor;

3 – The characteristic at minimum opening of a window of a pneumatic distributor;

4 – The experimental characteristic, at the maximal opening and combination of windows of a pneumatic distributor;

5 – The experimental characteristic of work of a sleeve pneumatic distributor (ZPD).

It is apparent that the characteristic 1, considers not all coefficients therefore it nevertheless "linear", the characteristic 4, on the contrary, considers and shows the composite dynamic components which cannot be considered in mathematical model.

Such combination of characteristics gives an idea of accuracy of model operation. Applied comparison of an average experimental surge characteristic with the characteristic received as a result of imitation, with a margin error no more than 12,3% to check of adequacy of the obtained data.

Analog of the offered regulating system and distribution is the sleeve pneumatic distributor. sleeve distribution found broad application in equipment as the regulating equipment for hydraulic and pneumatic systems. However unlike the offered system, sleeve distributors have two provisions of work: closed or opened. Such duty is caused by that as the working drive in them electromagnets with mechanical springs are applied. When giving current changes situation for an electromagnet, a sleeve, that is opens. Respectively the actuation medium goes to the necessary cavities of the robot. At shutdown of giving of electric current to an electromagnet the sleeve comes back to tentative situation with the help of a mechanical spring.

If to apply a crane pneumatic distributor with management from a step electric motor, it is possible not only the direction of a working stream in the necessary drives of the robot, but also the operated stream throttling. Thereby regulation of duties of drives of the robot is possible. And also the perhaps smoothly varying braking of the drive in the intermediate provisions of an action. Evaluation of the work of drives of the robot was carried out by comparison of quick action of a crane pneumatic distributor and the next analog – an on-off sleeve pneumatic distributor. Figure 5 shows the received comparative characteristics. The characteristic 1 in figure 5 corresponds to the characteristic 4 in figure 4, and the characteristic 2 corresponds to the characteristic of the 5th figure 4.

When comparing it is visible that the crane pneumatic distributor works quicker, than the analog, a difference makes 16,7%. 
It is considered that the pneumatic drive is rough on accuracy of work and usually requirement for smoothness of braking is not imposed to its work. To raise accuracy and smoothness of operation of such drive the operated throttling of a stream of air and use of additional technical means allows: controllers and sensors of situation working by the principle of magnetostriction.

The assessment of accuracy of positioning was carried out for a crane pneumatic distributor at multiple repetition of driving of the loaded drive. In experiment a half of range of driving of a pneumatic actuator of a hand of the robot (coordinate of y of working space of the robot) was taken for a reference point. In indications of the sensor the middle of range of movement of a hand of the robot corresponds 124,05mm, the initial index of the sensor 48,8mm and a terminating index of the maximal promotion makes 199,3mm. During experiment 100 repetitions of driving of the loaded robot hand drive are carried out.

![Graph](image)

**Fig. 5 - Comparative surge characteristics: 1 - the experimental characteristic, crane pneumatic distributor; 2 - the experimental characteristic, sleeve pneumatic distributor.**

![Graph](image)

**Fig. 6 – Data of experiment according to accuracy of positioning of an output link of the pneumatic robot at program value of a position on a mark 124,05mm.**

According to the experimental data it is visible that accuracy of positioning of an action the pneumatic drive is satisfactory and corresponds to a mean squared error of 0,138 mm. The approximating straight line in figure 6, indicates a particular tendency in dynamics of work of an output link. The trend is caused by an objective physical factor – tem-
perature expansion of links of a kinematic chain of the robot. It is possible to compensate this phenomenon, having entered the amendment changing number of steps of turn of the operating step engine of a crane pneumatic distributor into the program of work. But if this made amendment strongly influences quick action, perhaps small increase of a working pressure of air in system. Accuracy can be increased by creation of a counter-pressure in an opposite cavity of the pneumoengine, but in this case traveling speed of an action of the robot decreases, and achievement of the necessary point of positioning in the intermediate situation takes more time. Smoothness of braking at promotion length 124mm is reached by regulation of operation of the step engine of a crane pneumatic distributor. Promotion of a link on the intermediate position is reached by turn of the step engine on 15 steps, that is the window of a crane pneumatic distributor will open approximately on a half, then on the step engine the pilot signal for the inverse turn is given, thus the window of a crane pneumatic distributor is blocked and the link stops. At such duty, quick action decreases, approximately on 2 sec. if to conduct comparison with the full speed of promotion of an output link.

![Graph](image.png)

**Fig. 7 – The experimental assessment of smoothness of braking of the drive of a hand of the pneumatic robot.**

In figure 7 the slope angle of the characteristic shows speed of driving, and its look characterizes smoothness of braking.

4. **Summary**

The pilot studies of a control system of the pneumatic robot with use of the crane distributor with the drive from the electric step motor are conducted. Data of experiments testify to improvement of indexes of quality of control of the pneumorobot.

5. **Conclusion**

Thus, the developed control system improves principal specifications of the pneumatic production robots, and also expands technological use of such robots in mechanical engineering.

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