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DEVELOPMENT OF CONTROL SYSTEM FOR AUTOMATED MANIPULATOR

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Abstract. The paper is devoted to investigation of manipulators for plating lines and their modes of operation, as well as the development of a control system for gantry autooperator (LLC KTM-2000). The manipulator motion cyclograms for a given technological regulations were developed and presented.

Keywords: autooperator, cyclogram, control system.

Introduction

The automated manipulator (autooperator) is designed to work with special attached instruments for transferring products between technological positions in the galvanic lines for plating aluminum parts.

There are defined four main types of autooperator: Console, Trolley, Telpher, and Portal. Types of control systems for autooperator are defined as:

- Manual control system (CS) with exact stop; the number of serviced positions is limited to 36; control by pendant console; the number of manipulators under control is equal to one.
- CS with the exact stop at a given position defined by button; control by the stationary console; the maximum number of manipulators under control is equal to two.
- Automatic CS with precise stop in technological positions, controlling the time spent in processing baths; control of rectifiers; control of the emergency limit switches; locking in positions of loading and unloading if busy or unready; the maximum number of manipulators under control is equal to three (Novikov 2006).

Console autooperator

Automated manipulator is designed to move parts fixed on hanger's cathode rod. Console autooperator can operate in the following modes:

- Manual control mode;
- Motion to the position defined by button under supervision of the control system.

Using manual control automated manipulator moves up, down, forward and backward only when the corresponding button on the pendant push-button console is pressed. Console consists of four motion control buttons: up, down, forward and backward.

In elevator mode the position is selected by pressing the button on the remote console of CS. Each position has a corresponding button with number and name.

Electric gear motors for vertical and horizontal movement have an integrated brake system.

Trolley autooperator

Automated manipulator is designed to move the parts on the cathode rod hangers or in a drum container. Operating mode selection is made manually by a switch on control panel. Trolley autooperator can operate in the following modes:

- Manual control mode;
- Motion to the position defined by button under supervision of the control system;
- Automatic control mode.

In manual control mode automated manipulator operates in hoist mode moving up, down, forward, and backward by pressing the corresponding button on the remote control console.

In elevator mode the position is selected by pressing the button on the remote console of CS. Each position has a corresponding button with number and name.

In automatic control mode manipulator performs motion under supervision of automatic CS with exact stops defined by sensors. In this case the control signals from the

remote control console are ignored. In automatic mode, the horizontal transportation is provided from any existing position to the defined position in elevator mode or executing the predefined program, and the vertical transportation – from the lower position to the upper limit and vice versa. Operations in automatic control mode are selected using keyboard on remote console of control system.

Telpher autooperator

Automated manipulator is designed to move the parts on the cathode rod hangers or in a drum container. Control of manipulator is operated by pendant console. One of two modes of operation can be selected: "RUN" or "SETUP".

In "RUN" mode the control of autooperator is performed by commands from pendant console: move up, down, forward and backward. The autooperator movement in the horizontal direction is performed by pressing the appropriate key buttons: forward or backward, stop – when button released (300–500 mm to the defined position, with a preliminary reduction of horizontal velocity after releasing the button and with a stop at the exact position signal from the stop sensor).

Automated manipulator performs strictly horizontal transportation between defined positions, and vertical movements – from the uppermost position to the lowest and vice versa.

To ensure accurate positioning the automated manipulator use signals from distance proximity switches, installed on brackets at each technological position.

There are installed metal labels in specified places and sensor induces stop signal to the motor control unit if this label was detected in horizontal motion, and brakes are activated.

In the "SETUP" mode automated manipulator operates in hoist mode when moving up, down, forward and backward is performed only when the corresponding button on the keypad is pressed and holds. Horizontal movement of autooperator in setup mode is performed at low speed.

Portal autooperator

Automated manipulator is designed to move the parts on the cathode rod hangers or in a drum container. Operating mode selection is made manually by switch. Portal autooperator can operate in the following modes:

- Manual control mode;
- Motion to the position defined by button under supervision of the control system;
- Automatic control mode.

In manual control mode automated manipulator operates in hoist mode moving up, down, forward and backward only when the corresponding button on the remote control console is pressed.

In elevator mode the position is selected by pressing the button on the remote console of CS. Each position has a corresponding button with number and name.

In automatic control mode manipulator performs motion under supervision of automatic CS with exact stops defined by sensors. In this case the control signals from the remote control console are ignored. In automatic mode, the horizontal transportation is provided from any existing position to the defined position in elevator mode or executing the predefined program, and the vertical transportation – from the lower position to the upper limit and vice versa. Operations in automatic control mode are selected using keyboard on remote console of control system (Karpovich 2013a).

Control modes

Control mode "SETUP". Work-operator performs remote autooperator switch to <SETUP> position. If motion direction button is pressed and hold, automated manipulator starts moving at low speed. When the button is released, the automated manipulator stops moving. Similarly, the vertical movement is controlled by the console when corresponding buttons are pressed.

Control mode "MANUAL". The control is performed by pressing and holding the selected direction of travel "Left" or "Right" buttons, and automated manipulator accelerates to the defined maximum speed (with a large range of movement). Next, at 150–200 mm to the desired working position, the operator releases the button and automated manipulator goes to a low speed, until the sensor founds the label mounted on the tub, and provides a stop signal. Vertical movement is initiated by pressing and keeping hold buttons "up" or "down" until the indicator on the remote console shows, respectively, "Top is reached" or "Bottom is reached".

Control mode "SEMIAUTOMATIC" (elevator mode, using positioning buttons). The control is performed by pressing button of the desired position. Each of the products in the line has a numbered button corresponding to the position, when pressed, automated manipulator, which is in any other position, starts to move and accelerates to the defined maximum speed. When the position sensor mounted on the line founds the braking label autooperator goes low speed and stops at the center of the sensor. Vertical movement is initiated by pressing buttons "up" or "down" where in contrast to the "MANUAL" mode, the hold is not required.

Control mode "AUTOMATIC". Automated control system provides the exact stop in the technological positions, control of the time spent in processing baths, control of rectifiers, control of the emergency limit switches, locking in positions of loading and unloading if busy or unready; the maximum number of manipulators under control is equal to three (Novikov 2006).

Design and investigation

Portal for example – Autooperator KTM.

Design of a control system for the automated manipulator for plating lines requires solving a number of problems:

- Ensure defined positioning accuracy;
- Ensure defined process time in bath;
- Ensure defined movement algorithm (defined by software).

The manipulator is designed to work only with special attachments – to carry the rod with products between technological operations in the plating line for machining aluminum parts. Structure of autooperator is presented in Fig. 1.

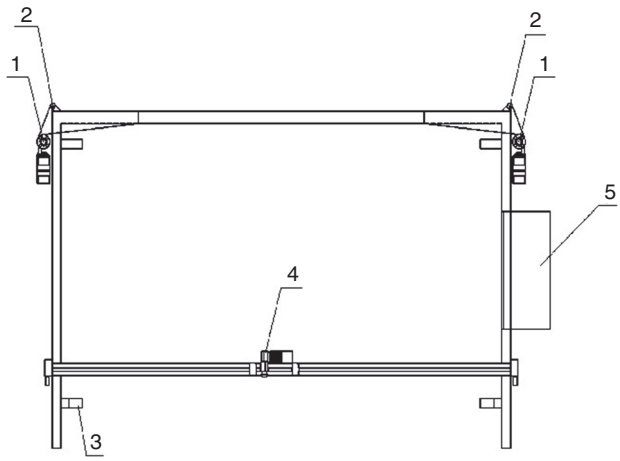

Fig. 1. Structural diagram of the autooperator: 1, 4 – Gear motor; 2 – Transport belt; 3 – Traverse; 5 – Electrical cupboard

There are three operational modes of designed autooperator: Manual, Service and Automatic.

The horizontal motion of manipulator (movement of the paddle left/right) is only possible in case when Linkage is at the upper/lower end (GE 1-3, 2-3, 1-4, 2-4).

Stopping the arm over baths is made using inductive sensor signals (GE 3-1, 3-2). To determine the location of suspension in the bathroom on the frame the manipulator is equipped with an optical sensor on the top edge of the bath (GE 3-5, 3-6).

In case of malfunction, to prevent accidents the stop of manipulator will be made using limiting switches (GE 3-3, 3-4). Operation with activated limiting switches is prohibited.

The vertical movement (raise/lower traverses) of parts happens at the same speed. Stop the hoist in extreme positions occurs automatically when inductive sensors (GE 1-1, 2-1) are triggered. To prevent accidents inductive sensors are duplicated with limiting end switches (GE 1-3, 2-3, 1-4, 2-4) (Karpovich 2013).

There are defined such technological positions:

- Mounting parts on the rod;
- Degreasing;
- Etching (alkaline);
- Washing in hot water;
- The two-stage washing in cold running water;
- Clarification of details (sulfuric acid);
- Anodizing details (sulfuric acid);
- The two-stage washing in cold running water;
- Rinsing in demineralized water;
- Electrochemical (chemical) staining;
- The two-stage washing in cold running water;
- Hot seal;
- Drying;
- Removing parts from the rod.

There are the following input signals in this process:

S0 – switching-on of system;
S1, 2 – left (right) yoke in the upper position;
S3, 4 – left (right) cross member in the lower position;
S5 – suspension on the ramp (in the bath);
S6 – autooperator over degreasing bath;
S7 – autooperator on the etching bath E6;
S8 – autooperator over the bath with warm wash;
S9, 10 – autooperator over the bath of 1st (2nd) stage cold wash;
S11 – autooperator over the lighten bath;
S12 – autooperator over the anodizing bath
S13, 14 – autooperator over the bath of 1st (2nd) stage cold wash;
S15 – autooperator over the demi-washing bathtub;
S16 – end position of the autooperator.

Output values are the motor control signals:

Y1, 2 – raise the left (right) traverse;
Y3, 4 – lower the left (right) traverse;
Y5, 6 – move the frame of autooperator (conveyor).

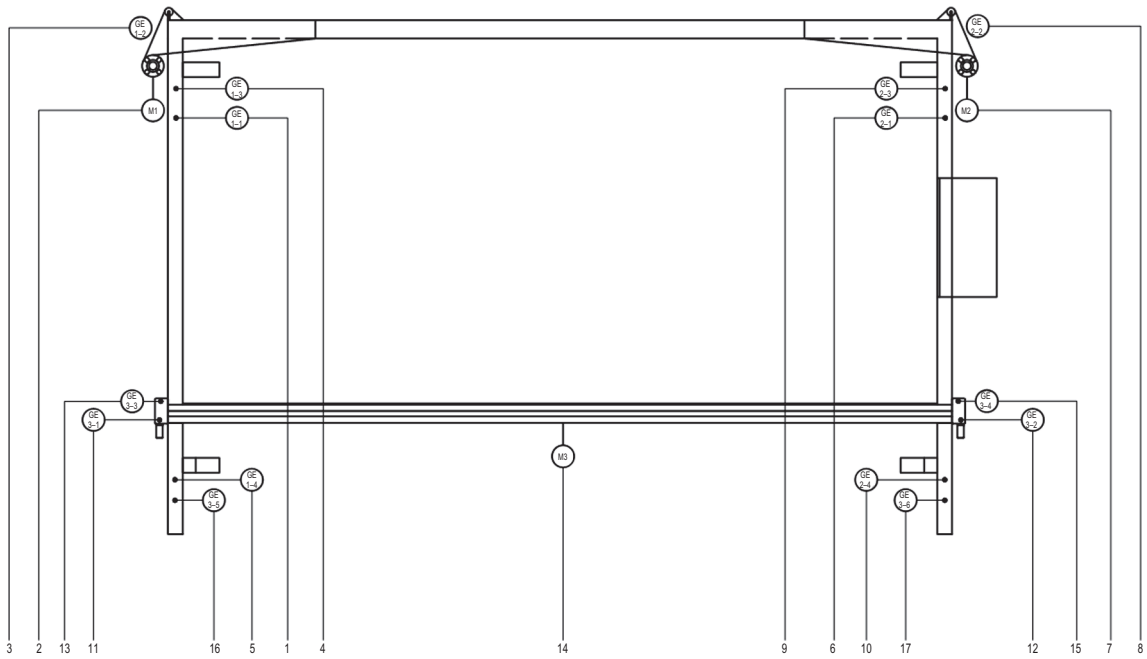

Fig. 2. Functional diagram of automation autooperator

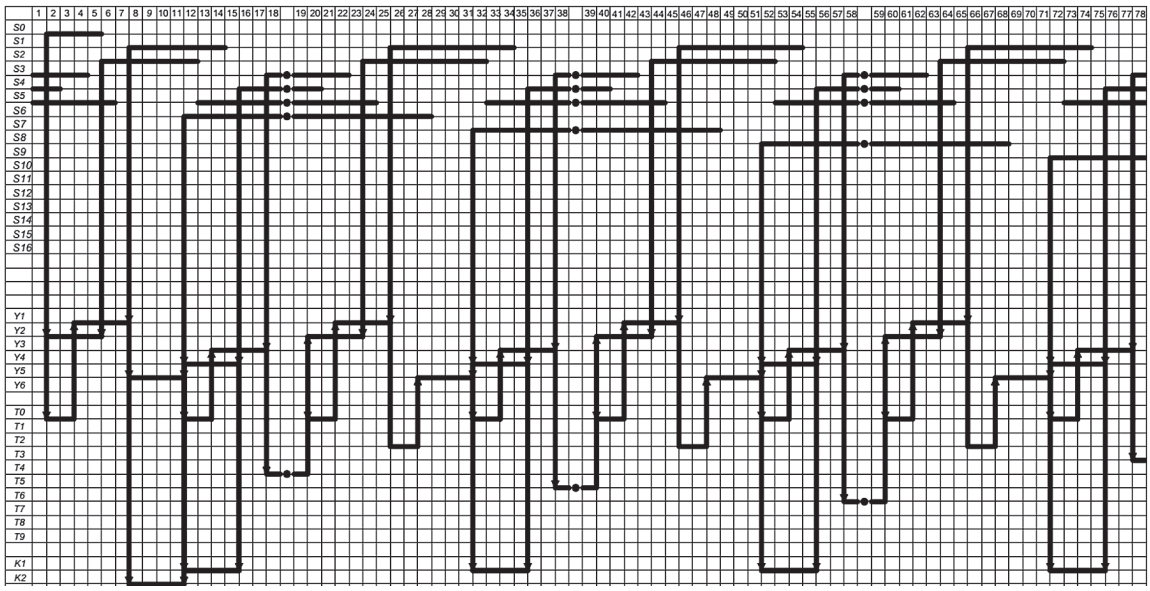

Fig. 3. The movement cyclogram of autooperator

Also for creating sequence diagrams were used nine timers and two relays (K1, K2):

T0 – delay 1 s;
T1 – delay 10 s;
T2 – delay 20 s;
T3 – delay 60 s;
T4 – delay 600 s;
T5 – delay 900 s;
T6 – delay 120 s;
T7 – delay 350 s;
T8 – delay 1800 s;
T9 – delay 100 s.

Structural synthesis of control system:

$$Y1 = \overline{T0 \cdot S1};$$

$$Y2 = \overline{T3} \cdot \left(S0 + \overline{T3} + \overline{T4} + \overline{T5} + \overline{T6} + \overline{T7} + \overline{T8} + \overline{T9}\right);$$

$$Y3 = \overline{T0 \cdot S3};$$

$$Y4 = \overline{S4 \cdot K1} \cdot \left(S6 + S7 + S8 + S9 + S10 + S11 + S12 + S13 + S14 + S15 + S16\right);$$

$$Y5 = S2 \cdot \overline{K2} \cdot \left(\overline{S6} + \overline{S10} + \overline{S14}\right) + \overline{T2} \cdot \left(S6 + S7 + S8 + S11 + S12\right) + \overline{T1} \cdot \left(S10 + S14 + S15\right);$$

$$T0 = S0 \cdot \overline{T0 \cdot S5} + \overline{T0} \cdot K1 \cdot (S6+S7+S8+S9+ S10+S11+S12+S13+S14+S15+S16) + \overline{T0} \cdot S1 \cdot (S6+S7+S8+S9+S10+S11+ S12+S13+S14+S15);$$

$$T1 = S1 \cdot \overline{T1} \cdot (S10+S14+S15);$$

$$T2 = S1 \cdot \overline{T2} \cdot (S6+S7+S8+S11+S12);$$

$$T3 = S3 \cdot \overline{T3} \cdot (S9+S10+S13+S14);$$

$$T4 = S3 \cdot \overline{T4} \cdot S6;$$

$$T5 = S3 \cdot \overline{T5} \cdot S7;$$

$$T6 = S3 \cdot \overline{T6} \cdot S8;$$

$$T7 = S3 \cdot \overline{T7} \cdot S11;$$

$$T8 = S3 \cdot \overline{T8} \cdot S12;$$

$$T9 = S3 \cdot \overline{T9} \cdot S15.$$

Conclusions

As a result of this work the control system of automated manipulator was developed. Sequence diagram for a given technological process was created, as well as compiled structural synthesis of control system. The obtained experience can be used in methodology development for control system of automated manipulator design.

References

Karpovich, D. S. 2013. Strukturnyj sintez SAU avtooperatora dlja gal'vanicheskih linij ceha anodirovanija SP „KTM 2000" // Sozdanie novyh i sovershenstvovanie dejstvujushhih tehnologij i oborudovanija nanesenija gal'vanicheskih i ih zameshajushhih pokrytij: materialy 3-go Respublikanskogo nauch. tehnich. seminara, 5–6 dekabrja 2013 g, Minsk, BGTU, 88–91.

Karpovich, D. S. 2013a. Avtooperator dlja gal'vanicheskih linij gruzopod#emnost'ju do 250 kg, *Informacionnye tehnologii i sistemy 2013 (ITS 2013): materialy mezhdunarodnoj nauchnoj konferencii*, BGUIR, 23 oktjabrja 2013 g, Minsk, Belarus'. Redkol. L. Ju. Shilin. BGUIR.

Novikov, A. E.; Darinceva, A. B. 2006. *Gibkie avtomatizirovannye gal'vanicheskie linii: hrestomatija*. Ekaterinburg: GOU VPO UGTU – UPI. 221 p.

AUTOMATINIO MANIPULIATORIAUS VALDYMO SISTEMA

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Santrauka

Analizuojama galvaninio padengimo linijos automatinio manipuliatoriaus valdymo sistema, apibendrinamos išvados. Pateiktos pagal nustatytą technologinio proceso aprašą sudarytos judėjimo ciklogramos bei loginės funkcijos.

Reikšminiai žodžiai: valdymo sistema, automatinis manipuliatorius, ciklograma.