AUTOMATION OF DRIVING IN TUNNELLING

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Abstract: This paper deals with the problems of automation in the construction of mine workings and specialized tunnels. The problems under consideration are mathematical simulation of the automation object (tunnel driving set), synthesis of the control algorithm as well as the whole system study. Technical characteristics of the developed system for automatic control of tunnel driving set are given.

Key words: mine working, tunnel, tunnel driving set, high maneuverability, automated control system.

The driving set of equipment is indispensable in the technological process of transport, hydrotecnical, service and other kinds of tunnelling. The problem in question is to raise the efficiency of driving shield sets, to improve labour conditions, providing safe operation as well as preconditions in transition to tunnelling without constant people presence in face by optimization of constructive equipment parameters and creating systems of control and operating shield driving processes. The problem stated makes it necessary to study the dynamic characteristics of tunnel driving set of and develop its mathematical models in order to define stability, controllability and observability of a driving shield as well as the synthesis of algorithms for automated controlling and operating the equipment, to develop methods and main stages of finding the parameters of driving set of as well as the synthesis of systems and means of operating them. In considering the technology of control for driving the shield along the preset trajectory in space one must have a mathematical description of a shield as an object of control.

The tunnel driving set consists of a driving shield, a distance ring and mechanisms for erecting a constant support, loading the waste to the cars within the set.

The driving shield and the distance ring form a mechanized support. The joint between the shield and the distance ring can be considered hinge-like with two degrees of freedom, which greatly increases the maneuverability of the shield.

Mathematical simulation of the tunnel driving set has been performed by meaner of Lagrange equations of the second order.

The analysis of external actions and operating effects has shown with a sufficient accuracy it is possible to divide and to examine independently the equipment set motion in horizontal and vertical planes. The system motion in each plane is described by a set of three differential equations of second order.

The mathematical model developed (Fig.1) for the tunnel driving set takes into account its constructive parameters and the interaction with adjacent strata where c_1, c_2, c_3 are the coefficients taking into account the mass-geometrical parameters of tunnel driving set: x_1, x_2, x_3 are the coordinates of the initial and final points of the shield and that of the distance ring, x_4, x_5, x_6 are the velocities of those points movement: B_1, B_2 are the coefficients taking into account the properties of the adjacent strata, U – controlling action [1].

Let's represent the mathematical model of the object in vector – matrix form

$$\dot{x} = Bx + AU,$$

where X - is the vector of the output coordinates;
U - is the controlling action;
B - is the object matrix.
A - is the matrix of controlling actions.

The system of automatic control for the tunnel driving set, which provides a predetermined accuracy of the equipment control in the designed direction and satisfies the main requirements of the mine shielding machines automation has been developed.

Mathematical model studies have shown that as an object of movement control the tunnel driving set has no dynamic stability of its own, therefore, to make it perform stable movements according to the predetermined trajectory, the system of control is necessary. The algorithm synthesis of controlling the movement of tunnel driving set has been performed by the method of condition parameters [2].

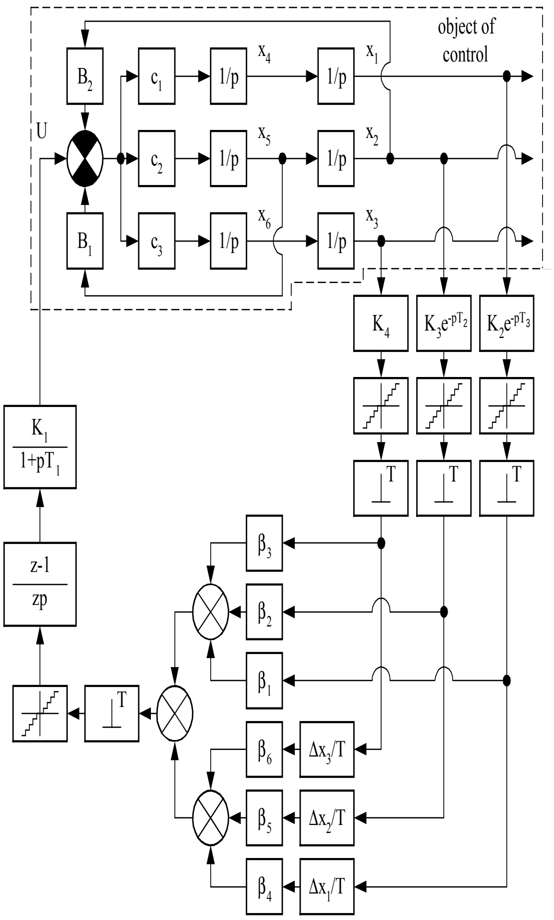

Fig.1. Structural scheme of controlling tunnel driving set.

Then, we can find the vector of the controlling actions from the following equation:

$$u[kT] = A_1(T)^{-1}\{W(T)^{-1}x[(k+1)T] - x[kT]\},$$

where *W(T)* - is the matrix of weight coefficients;

$A_1(T)$ - is the matrix of controlling action related to the matrix of weight coefficients;

T - is the period of discretization.

As a result of synthesis, the row vector of control coefficients is

$$\beta = [\beta_1, \beta_2, \beta_3, \beta_4, \beta_5, \beta_6],$$

its multiplication by the column vector

$$x = [x_1(0), x_2(0), x_3(0), x_4(0), x_5(0), x_6(0)]^T$$

of initial conditions gives the value of the controlling action.

The structural scheme of the control system of the tunnel driving set movement is shown in Fig.1, K_1, K_2, K_3, K_4 are the gain factors of the actuating mechanism, position pickups of the primary and final points of the shield, final point of the distance ring in the tunnel driving set, T_1 – is the time constant of the actuating mechanism, T_2, T_3 is the time of delay.

The study of the control system of tunnel driving set was intended to remove the object from a deviation position to the predetermined trajectory. The graphs of the transient processes are shown in Fig.2.

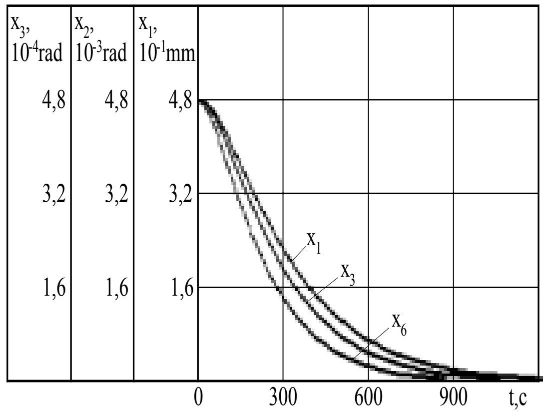

Fig.2. Graphs of transient processes of tunnel driving set movement.

Technical system characteristics:

- distance - 200 meters;
- location accuracy - 10 mm;
- shield driving accuracy - 50 mm;
- operating temperature range from 10 ^{0}C up to + 45 ^{0}C;
- relative humidity from 20 ^{0}C up to 95 ^{0};
- supply voltage - 36/220 V;
- consumed power - 300 W;
- apparatus mass - 100 kg.

Experimental study of the system operating the equipment movement has confirmed the operability and reliability of the system for automatic shield driving on various road sections. This system of control can be used in various types of tunnel driving set.

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