

Computer Simulation and Analysis of Two-Coordinate Position Electric Drive Systems

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Abstract – Analysis of some algorithms for position control of two-coordinate electric drive systems is presented in this paper. Models for computer simulation with various types of motors have been developed. Detailed studies by means of computer simulation and experimental research have been carried out. The results obtained can be used in the design and tuning of such types of drive systems with position control.

Keywords – Two-coordinate electric drive, Position control, Computer simulation.

I. INTRODUCTION

Two-coordinate electric drive systems are widely used in many industrial applications.

Generally, motions in these systems are formed by the respective trajectories along both coordinate axes. Control algorithms affect the performance, productivity and energy consumption [2], [3], [4].

Time shortening of the transient regimes at positioning is essential for mass production of parts, because it increases the respective machine effectiveness.

Mathematical modeling and computer simulation provide very good opportunities to explore different control algorithms aiming at optimizing of motion trajectories [2], [3], [5].

With respect to modernization of a class of machine tools some two-coordinate electric drives have been analyzed, allowing the choice of the appropriate once meeting the required performance. Models of such drives have been developed used for studying of different position control algorithms for the respective dynamic and static regimes at different operation modes.

II. FEATURES OF THE DRIVE SYSTEM

The simplified block diagram of the system under consideration is represented in Fig. 1, where the notations are as follows: CP – control panel; CD – control device; PC1 and PC2 – position controllers; SC1 and SC2 – speed controllers; CC1 and CC2 – current controllers; C1 and C2 – power converters; M1 and M2 – DC motors; SS1 and SS2 – speed sensors; DM1 and DM2 – driven mechanisms; CF1 and CF2 – current feedback blocks; SF1 and SF2 – speed feedback blocks; PF1 and PF2 – position feedback blocks; V_{pr1} and

V_{pr2} – position reference signals; V_{sr1} and V_{sr2} – speed reference signals; V_{cr1} and V_{cr2} – current reference signals; V_{pf1} and V_{pf2} – position feedback signals; V_{sf1} and V_{sf2} – speed feedback signals; V_{cf1} and V_{cf2} – current feedback signals; θ_1 and θ_2 – angular positions; S_1 and S_2 – linear displacements.

The set of achievements required for the drive system can be formulated as follows:

- forming the necessary motion trajectories at given position cycles;
- maximum starting torque to ensure good dynamics;
- reversible speed and torque control;
- compensation of the disturbances.

III. MODELLING OF THE DRIVE SYSTEM

The vector-matrix model of the DC motor drive under consideration is as follows:

$$\begin{bmatrix} \frac{d\theta_i}{dt} \\ \frac{d\omega_i}{dt} \\ \frac{di_{a_i}}{dt} \end{bmatrix} = \begin{bmatrix} 0 & 1 & 0 \\ 0 & 0 & \frac{K_{t_i}}{J_{\Sigma_i}} \\ 0 & -\frac{K_{e_i}}{L_{a_i}} & -\frac{R_{a_i}}{L_{a_i}} \end{bmatrix} \begin{bmatrix} \theta_i \\ \omega_i \\ i_{a_i} \end{bmatrix} + \begin{bmatrix} 0 \\ 0 \\ \frac{K_{c_i}}{L_{a_i}} \end{bmatrix} v_i + \begin{bmatrix} 0 \\ -\frac{1}{J_{\Sigma_i}} \\ 0 \end{bmatrix} i_{l_i}, \quad (1)$$

where: θ_i is angular position; ω_i – motor speed; i_{a_i} – armature current; K_{e_i} – back EMF voltage coefficient; K_{t_i} – torque coefficient; R_{a_i} – armature circuit resistance; L_{a_i} – armature inductance; K_{c_i} – amplifier gain of the chopper; v_i – input control signal of the power converter; J_{Σ_i} – total inertia referred to the motor shaft; i_{l_i} – armature current which is determined by the respective load torque; $i = 1, 2$ – number of the coordinate axes.

Both subsystems have identical cascade structures with subordinate regulation of currents, speeds and positions. Control loops optimization and tuning of the respective controllers have been done sequentially, starting from the innermost ones [1].

For the used mechanical gear maximum operating speed of the motor for the respective coordinate axis is chosen to be equal to the nominal value:

$$\omega_{\max_i} \leq \omega_{\text{nom}_i}. \quad (2)$$

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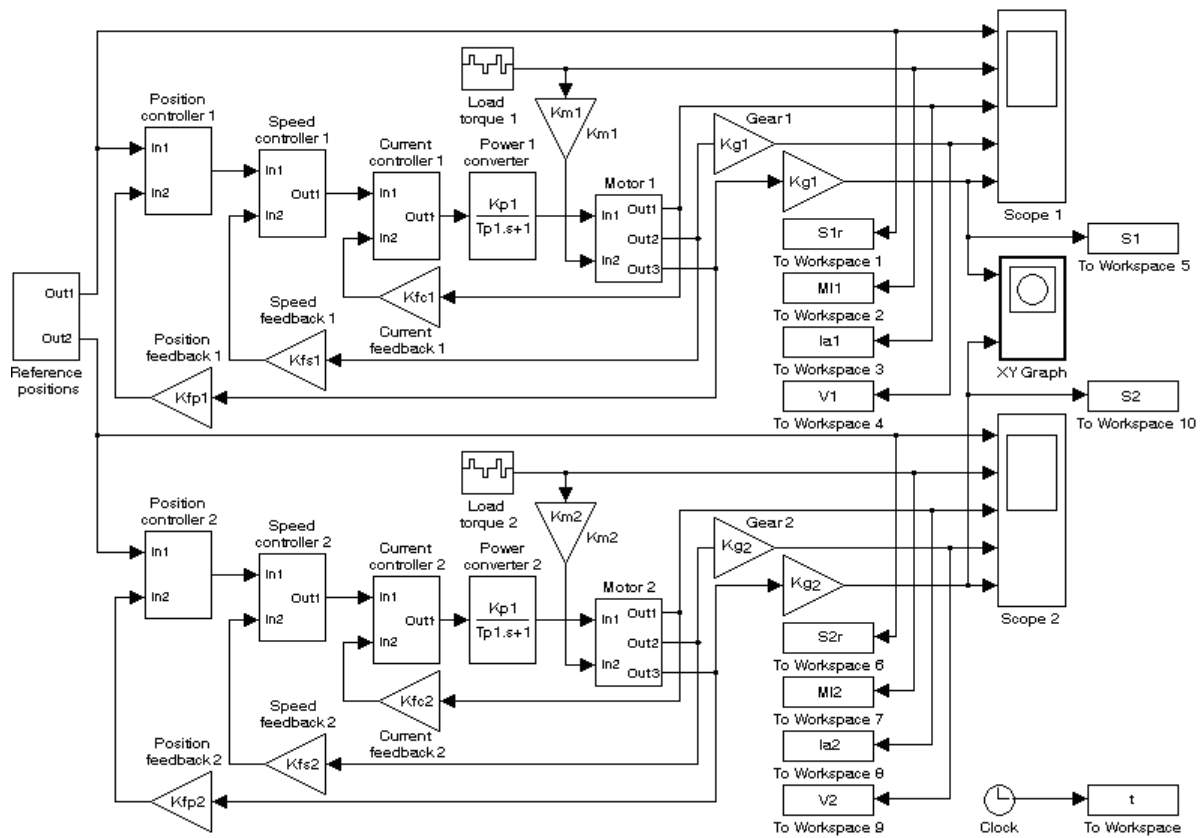


Fig. 3. Simulation model of the two-coordinate drive system.

In the MATLAB/SIMULINK environment some models of systems for two-coordinate electric drives have been developed with different types of motors. They allow for detailed studies of the respective static and dynamic regimes and analyses of performance. A simplified block diagram of one of the models is presented in Fig. 3.

IV. EXPERIMENTAL RESULTS AND ANALYSIS

The electric drives for both coordinate axes are identical. The DC motors used for modeling and computer simulation have the following parameters:

$$V_{nom_i} = 30 \text{ V}; I_{anom_i} = 15.7 \text{ A}; \omega_{nom_i} = 115.19 \text{ rad/s}.$$

Fig. 4 shows the time-diagrams obtained by computer simulation during processing a position cycle along the x coordinate. The set displacement S_{1r} , the load torque T_{l1} , the armature current I_{a1} , the displacement speed V_1 and the linear position S_1 along this coordinate axis are shown. Armature current is limited to the maximum admissible value I_{a1max} . The respective control loops setting provide compensation of the disturbances and smooth positioning without overshooting. The disturbances applied sequentially on the electric drive are $\Delta T_{l1} = \pm 0.25T_{l1nom}$

In Fig. 5 the trajectories of movement to the same final position have been shown, obtained through different algorithms of movement on both axes.

Fig. 5a represents a consecutive motion along the x and y

coordinates.

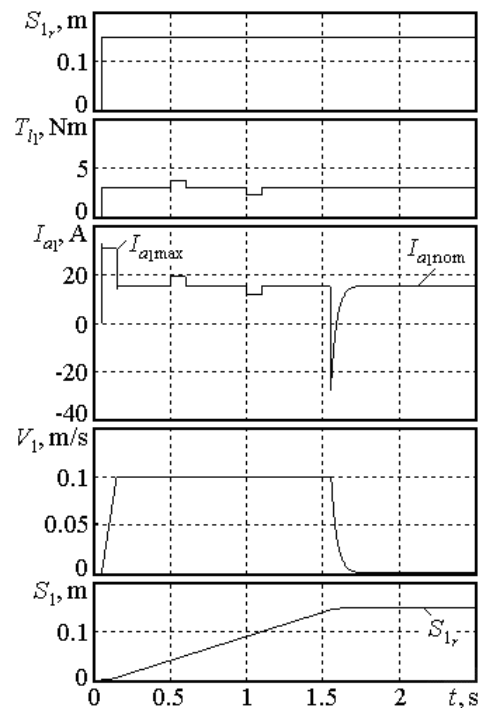


Fig. 4. Time-diagrams for a set position cycle along one axis.

Fig 5b shows the trajectory when simultaneous motion is performed along both coordinate axes.

Fig. 5b illustrates combined motion along the coordinate axes.

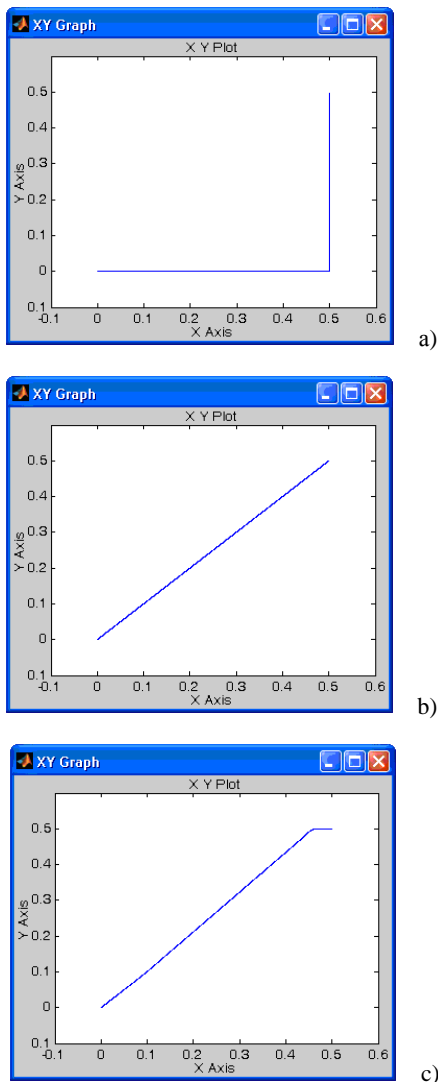


Fig. 5. Trajectories for different algorithms of control.

Detailed experimental studies have been carried out for different versions of controllers' tuning and operation regimes. Some time-diagrams are presented in Fig. 6, 7 and 8.

Fig. 6 shows a linear speed trajectory, obtained experimentally for displacements of 0.62 m along the coordinate axis x.

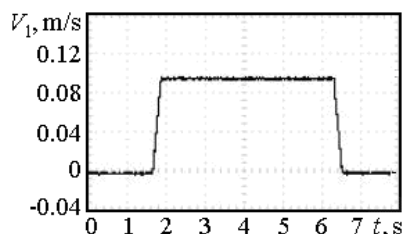


Fig. 6. Time-diagram of motion along the x coordinate.

A linear speed diagram, obtained for motion along the

coordinate axis y is represented in Fig. 7. The set distance in this case is 0.32 m.

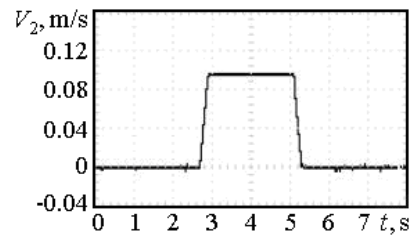


Fig. 7. Time-diagram for motion along the coordinate axis y.

Fig. 8 illustrates reverse control. The set distance in both directions is 0.32 m.

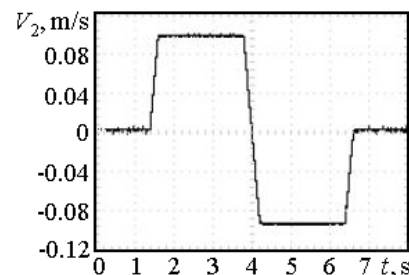


Fig. 8. Time-diagram illustrating reverse control along the axis y.

The behavior analysis shows that the presented position control algorithms provide for good performance suitable for practical applications.

V. CONCLUSION

Models for computer simulation of two-coordinate electric drive systems with various algorithms for position control have been developed.

On the basis of computer simulations and experimental studies the presented algorithms for position control have been analyzed.

This research and the results obtained can be used in the design and tuning up of such two-coordinate systems of electric drives.

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