MODELLING AND SIMULATION OF AS ROBOT

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Abstract: The research results of AS robot are presented. The robot has manipulation, drive and control systems. Graphic models of the AS robot were worked out in Simulink integrated with Matlab. The graphic models contain the mathematic models of these three systems. The settings of servo controllers were computed with have taken account the extreme values of motor effective inertias. The mathematic model of manipulator dynamics is taking into consideration the distribution of the link mass. These models have been used for the simulation of motion of the AS robot for exemplary straight line desired trajectory.

Keywords: simulation, modelling, manipulators, robot dynamics, robot control, robotics.

1. INTRODUCTION

The modelling and simulation results of AS robot are presented in this work. The characteristic of this robot is presented in work (Szkodny, 2004). Each robot possess manipulation, drive and control systems. The manipulation system of AS robot contains the manipulator with 6 degrees of freedom (D.O.F.). The manipulator is driven by means of drive system, which contains 6 direct current (D.C.) motors. These motors are controlled by means of the control system. This system contains 6 servos with feedback. The robot manipulator has seven links, which are connected by revolute joints. The base of AS manipulator is immobile link. Apart from the base, the manipulator has six links, which are direct driven by means of six D.C. motors. The armature current of the motors are controlled by means of six servos. Before design of computer simulation programs of the robot it is necessary to write following programs: solving direct problem of dynamics, estimating ranges of motor effective inertias and calculating the servo settings (Irzeński and Trybus, 1992). To write the program solving direct problem of dynamics the closed form of dynamics coefficients were used. The
closed form of the coefficients was obtained by means of the Matlab Symbolic Math Toolbox.In these coefficients appear mass parameters, which describes pseudoinertia matrix of links (Asada, *at al.*, 1983).

In Section 2, the graphic models of the AS robot are presented. The models were created by means Simulink library blocks. Next the graphic models were used to automatically creation applications in C language. The applications were created by means the Real Time Workshop, which is the extension of Simulink. In Section 3, an example of AS robot movement simulation, obtained by means the applications from second Section, is presented. The desired Cartesian trajectory had straight path shape. Section 4 contains summary of simulation researches.

2. GRAPHIC MODELS

Simulink integrated Matlab gives following possibility: modelling, simulation and analysis of continuous, discrete and continuous-discrete dynamic systems. The model of the dynamic systems we obtain by choosing and connecting appropriate blocks from Simulink Library. The blocks may calculate, read from indicated sets, write to indicated sets etc. It is possible to create subsystems contain more than one block. The models contains more than one subsystems will be named systems. Such models we will be named graphic models.

In this Section, the graphic models of subsystems and systems of the AS robot are presented. The graphic model of this robot contains subsystems of manipulator, servos and motors.

2.1 The AS Robot Model.

The graphic model of the **AS robot** (figure 1) contains six subsystems **Servo1÷Servo6** and

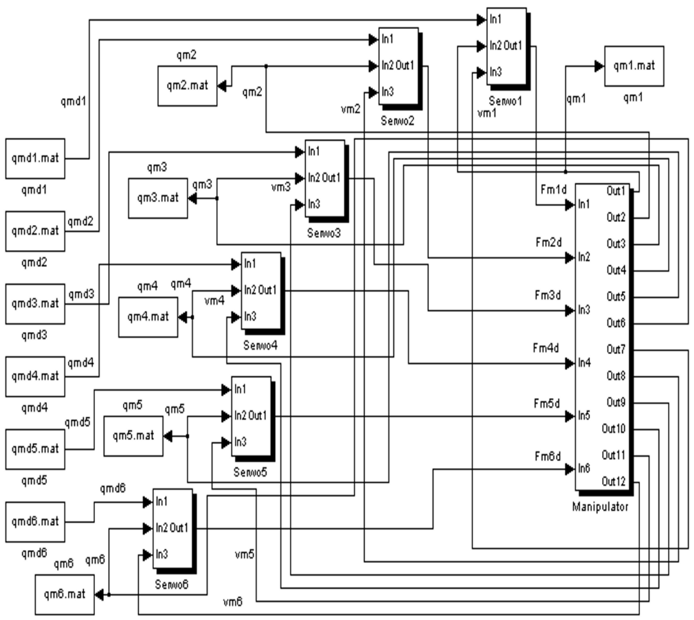

Fig. 1. The graphic models of AS robot.

Manipulator, which correspond to the mathematic models of six servos and the robot manipulator. The desired natural coordinates $\Theta_{1d} \div \Theta_{6d}$ are read from sets *qmd1.mat÷qmd6.mat*. by the blocks **qmd1÷qmd6.** The simulated natural coordinates $\Theta_1 \div \Theta_6$ are written into sets *qm1.mat÷qm6.mat*. by the blocks **qm1÷qm6.**

2.2 The Manipulator Model.

Dynamics of Manipulator. The manipulator of the AS robot has six links, which are direct driven. All joints of this manipulator are revolute with one D.O.F. Equations (1)-(3) describe the dynamics of the manipulator (Szkodny, 1995, 2004).

$$F_{mid} = F_{mir} + F_{mif}\,;\; i = 1,2,3,...,N\,; \qquad (1)$$

where F_{mid} is generalized driving force generated by ith motor, F_{mir} the ith motor resultant generalized driving force, F_{mif} the ith motor's generalized friction force.

$$F_{mir} = \sum_{j=1}^{6} D_{ij}\ddot{q}_j + \sum_{j=1}^{6}\sum_{k=1}^{6} D_{ijk}\dot{q}_j\dot{q}_k + D_i\,, \qquad (2)$$

$$D_{ij} = \sum_{p=\max(k,l)}^{6} Trace\left(\frac{\partial \mathbf{T}_p}{\partial q_i}\mathbf{J}_p\frac{\partial \mathbf{T}_p^T}{\partial q_j}\right),$$

$$D_{ijk} = \sum_{p=\max(i,j,k)}^{6} Trace\left(\frac{\partial^2 \mathbf{T}_p}{\partial q_j \partial q_k}\mathbf{J}_p\frac{\partial \mathbf{T}_p^T}{\partial q_i}\right),$$

$$D_i = -\sum_{p=i}^{6} m_p \mathbf{g}^T \frac{\partial \mathbf{T}_p}{\partial q_i}\bar{\mathbf{r}}_p\,. \qquad (3)$$

In equations (2)-(3) q_l is the lth link natural coordinates, $\mathbf{T}_p$ the homogeneous transformation describing the relation beetween pth link and base link, $\mathbf{J}_p$ the pth link pseudoinertia matrix, m_p the mass of the pth link, $\mathbf{g}$ the homogeneous form of gravitation vector $\vec{g}$, $\bar{\mathbf{r}}_p$ the homogeneous fom of vector describing gravity centers of the pth link in coordinate system associated with this link. The coefficient $D_{ii} = J_i$ is effective inertia of ith motor.

The matrices $\mathbf{T}_p$ describe the kinematics of links. The matrices we may express by equation (4).

$$\mathbf{T}_p = \mathbf{A}_1\mathbf{A}_2...\mathbf{A}_p\,;\; p = 1,2,3,...,6\,; \qquad (4)$$

where $\mathbf{A}_i$ is the homogeneous transformation describing the relation i-1st link and ith link. For revolute joints of the AS manipulator natural coordinates of link q_i are equal to link rotation angle Θ_i. The matrices $\mathbf{A}_i$ have following form

$$\mathbf{A}_i = Rot(z,\Theta_i)Trans(0,0,\lambda_i)Trans(l_i,0,0)Rot(x,\alpha_i)\,;$$

where λ_i, l_i, α_i, Θ_i are Denavit-Hartenberg

Table 1 The Denavit-Hartenberg Parameters

Parameters	α_i	l_i	λ_i	Θ_i
Unit	degree	metre	metre	degree
Link 1	90	0	0.765	0÷330
Link 2	-90	0	0	-90÷90
Link 3	90	-0.035	0.510	-90÷90
Link 4	-90	0	0	-90÷90
Link 5	90	0	0.315	0÷330
Link 6	-90	0	0	-90÷90

parameters. Table 1 contains values of these parameters. These parameters and the pseudoinertia matrices $\mathbf{J}_i$ in the S. I. units system are given in work (Asada, *at al.*, 1983). F_{mir} resultant generalized driving force of the ith motor is described by equation (5).