Modeling and Simulation Research of 4 DOF Manipulator

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Abstract

In the paper, the simulation model of 4 DOF manipulator worked out using SolidWorks and Matlab/Simulink environments have been presented. This model allow for visualization of movements, tracking of the trajectory, velocity and acceleration of any point of the system. The work was complemented by the results of sample simulation studies conducted for selected kinematic excitations.

Keywords: manipulator, modeling, simulation research, Matlab/Simulink

1. Introduction

Technological development causes an increase of customer requirements for new products. Currently on the market, products with high quality and functionality come in, this forces the engineers to design devices characterized by a variety of applying. However, the cost of production of the new device (prototype) and its tests is very large. During the design the modeling stage of a new construction or modification of an existing one plays an important role [Eberhard and Schiehlen 1998]. With the technological development we are dealing with the development of the software used for computer-aided design. Models made in such programs may not only be performed but also subjected to various types of simulation. However, it is complicated or even impossible to add the control in these applications. Therefore, very often modeling of control systems is performed in Matlab environment with Simulink module.

Matlab is intended to solve complex mathematical problems and generate a graphical visualization of the results. Its scope includes various fields of science and technology. Matlab also provides numerous extensions (toolboxes), among them support for neural networks or optimization problems. One of the extensions is the SimMechanics Toolbox which facilitates the creation of kinematic chains, simulation of their dynamics and visualization of results. Simulink is a tool that allows defining the structure of the control system of mechanisms of the created models and displaying their simulation with complete control during a specified working cycle. This module makes it possible to create, in the graphical window,
the structure of the control system which is built of various types of blocks representing dynamic objects, signal sources and measuring instruments.

In the paper, the authors present geometrical and simulation model of 4 DOF manipulator [Skalik et al. 2013, Skrobek 2013] elaborated with the use of SolidWorks [Lombard 2010] and Matlab/Simulink [Mrozek and Mrozek 2004, Chaturvedi 2010, Dabney and Harman 2003, Gran 2007]. This model makes it possible to carry out the kinematic studies as well as tracking of the trajectory, velocity and acceleration of any point of the system and tracking of the lifted load during the working cycle.

2. Simulation model

The simulation model has been created in SolidWorks program (geometrical model) and then implemented into the Matlab/Simulink environment [Cekus 2014, Cekus et al. 2014].

The worked out geometrical model of the analyzed manipulator is shown in Figure 1. This model consists of a gripping device (1, 2), a bunch (3), a forearm (4), an arm (5), a platform (6) and a stationary base (7). The movement of the elements takes place using gear-motors and servo-mechanisms. The servo-mechanisms used to move the bunch and to lock the jaws of the gripping device. In the other members gear-motors applied. The created geometrical model of manipulator is a simplification of the real object. The parts like washers, pins and bolts have been omitted, because they do not affect the simulation research.

Fig. 1. Parametrical geometrical model of the analyzed manipulator

The next stage of building the simulation model has been implementation of the CAD model in Matlab/Simulink environment. The result of this implementation has been SimMechanics model, which consists of a 3D virtual model (Fig. 2) and the block diagram (Fig. 3).
The SimMechanics model, obtained immediately after the implementation, in most cases not work properly, because the constraints imposed on the model in the CAD environment are not always adequately represented in the Matlab/Simulink program. In the present case, errors that appeared in the obtained model has been traced and corrected. For this purpose, several constraints had to be removed or replaced by other type of joint, which enabled the proper operation of the simulation model.

Fig. 2. Virtual model of manipulator in Matlab/Simulink

Fig. 3. The modified SimMechanics scheme of 4 DOF manipulator
The simulation research can be carried out after adding control signals (control functions), actuators and measuring instruments. Control functions are sent to the actuators (Joint Block) with the help of Joint Actuators blocks. In the analyzed model occur only the revolute joints, therefore Joint Block elements required movement parameters in the form of the angular position, angular velocity and angular acceleration. The model control module constituted the signal module containing the angular velocity of each of the drives in the form of trapezoidal signals, as well as integrated and differentiated blocks.

In order to improve the transparency of the block scheme, some blocks had been grouped together and transformed into the subsystem, additionally their appearance has been customized by using the masking process [Cekus et al. 2014].

The final SimMechanics diagram after grouping, masking process and adding the control module is illustrated in Fig. 3.

3. Sample results of simulation research

For the developed model of manipulator the simulation studies of a sample duty cycle have been carried out. This cycle was undergone according to the control functions adopted in the form of angular velocities.

![Control signals](image_url)
Fig. 5. Position of the manipulator bunch in the global coordinate system

Fig. 6. Changes of velocity of the manipulator bunch in the global coordinate system

Fig. 7. Changes of angular velocity of the manipulator bunch in the global coordinate system

Fig. 8. Changes of acceleration of the manipulator bunch in the global coordinate system
4. Conclusions

In this paper the simulation model of 4 DOF manipulator has been worked out. Construction of the model was possible thanks to the implementation of a CAD model made in SolidWorks in Matlab/Simulink environment. On the basis of the constructed model, the simulation research allowing for visualization of movements, tracking of the trajectory, velocity, angular velocity, acceleration and angular acceleration of any point of the system can be conducted.

The presented simulation model can be also used to optimization of the duty cycle of the manipulator as well as it will be further developed by:

- replacing the configuration of control operations assumed at the beginning with the motions performed by the operator in the real time,
- replacing the kinematic excitations with the help of impact of power transmission and control systems, which makes it possible to get the feedback.

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References


Skrobek D., 2013, Projekt manipulatora o czterech stopniach swobody, Bachelor's dissertation, Politechnika Częstochowska.


