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REVITALISATION OF INDUSTRIAL ROBOT CONTROL SYSTEMS

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Abstract: *The paper demonstrates the way of adapting control system of welding industrial robot produced by ASEA company. The aim was to adapt it to parameters of welding process using a new generation of welding machines. Control system based on card with FPGA processor made by National Instruments company was built instead of old system based on integrated circuit with a low integration scale and using signals from rate generators and transformators of angular position. Moreover, encoders were installed as positional and rotational speed sensors. For controlled system identification, there was used a model created in SimMechanics tool which is included in MATLAB environment. Data concerning location of centre of gravity, masses and moments of inertia for blocks of SimMechanics tool were obtained from independently made three-dimensional model of manipulation working parts of robot in Catia system. There were also used data on drivers features based on information from their rating plates.*

Keywords: Control system, Controlled system, MATLAB, SimMechanics, Direct-current motor.

1. Introduction

The research work is a result of cooperation with Hydrapres S.A. company that asked five universities in Northern Poland to modernise control systems of welding robots. One welding robot IRB-6, produced by ASEA, was given to each university.

The reason of research, presented by representatives of the ordering company, was a necessity to adapt control system of robots to the parameters of welding process using a new generation of welding machines (Morecki et al., 2002). The representatives stated that the robot producer was not interested in adapting robots to factory requirements. According to the robot producer, the only possibility was to purchase new robots. However, whole robots replacement was economically unjustified.

An expected result of the research was a control system with functionality similar to factory system which is characterised by higher speed of trajectory with maintaining or increasing the positioning accuracy of robot end-of-arm. Another requirement was a necessity of keeping the original robot motors.

2. Task of Revitalisation

The task of revitalisation is the control system of welding industrial robot IRB produced by ASEA presented in Fig. 1. The primary control system is based on a low integration scale circuits. The functions of the control system can be divided into three groups:

- **Low-level functions**: independently control of five direct-current motors carried by PID controllers based on feedback signals of resolver and rate generators placed on motor axes.
- **High-level functions**: implementation of any trajectory with set speed by using linear interpolation in three-dimensional space while controlling the welding process.

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- **Control functions**: monitoring the state of robot during operation, programming work movements, manual control.

Fig. 1: Primary robot control system – inside view.

3. Controlled System

Manipulation working parts of robot IRB-6 consist of base, body, arm, forearm and wrist ended by flange end-of-arm which is used for adjusting welding devices. Such design of segments provides to five degrees of freedom: rotation around the base, arm rotation, forearm rotation, wrist inclination, and flange end-of-arm rotation. Each motion of manipulation working parts are performed by actuators, which include direct-current motors as well as driven gears and tie bars. Each motor also includes a transformer of angular position and rate generator.

4. Specification of the Design of the Revitalised Control System

The basis for the development of a new control system was a decision of ordering company representatives regarding lack of economic prerequisites for purchase and adapting factory system. For technical reasons, modernisation of current control system was rejected, mainly because of the lack of suitable systems as well as no data about standards using in its build.

It was decided that FGPA processor (Field Programmable Gate Array) would be used for building a control system (Kozłowski at al., 2003). The processor is a type of programmable logic circuit. It has the same functionality as integrated circuit which is designed to implement a very specific task (such as installed into factory control systems of robots). However, it can be repeatedly reprogrammed after it has already been produced, purchased and installed in a target device.

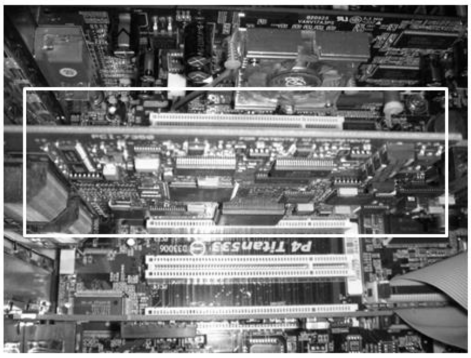

Fig. 2: The new control system. Card with FPGA processor (marked by white frame) placed in PC housing.

Due to financing from the Research and Development Funds in Kuyavian-Pomeranian Province, the card with FPGA processor produced by National Instruments company was used. This card can control eight electric drives in development version (powered and programmed by typical PC computer) within software used for its programming. A view of the new control system placed in PC housing is presented in Fig. 2.

Power-supply systems of direct-current motors were replaced. Power supplies that use power transistor were applied instead of power supplies based on transformers, which is presented in Fig. 3. The new power-supply system is several times smaller and the housing shown in Fig. 3 contains power supplies for four drives. Moreover, the new power-supply system provides a change of feed current parameters with higher accuracy (by one order of magnitude) and higher frequency to 200 Hz.

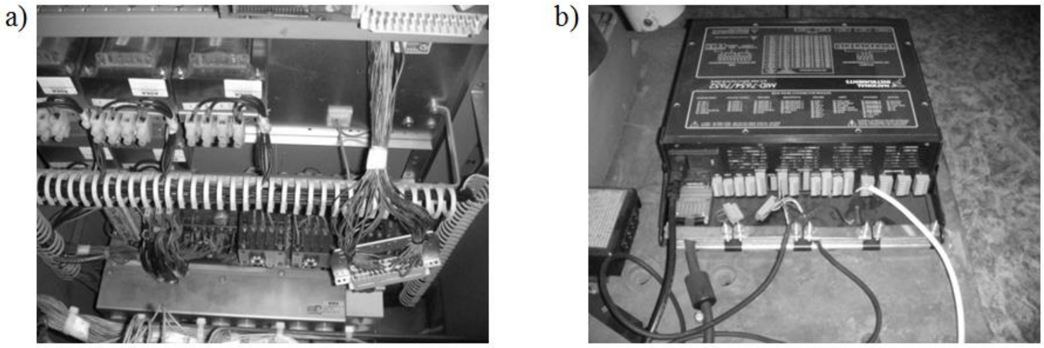

Fig. 3: Drive power-supply system of robot IRB-6: a) original; b) new.

The last elements of the control system were positional and rotational speed sensors placed on motor axes of robot. Instead of resolvers and rate generators, there were installed encoders with a resolution of 3600 positions per rotation. Installation of sensors required a development of interface system with dimensions selected in the way that new sensors fit the actuators housings, which is presented in Fig. 4.

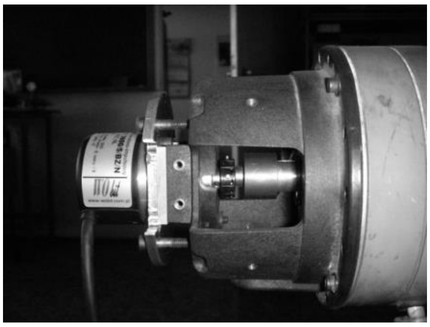

Fig. 4: Encoder with interface system placed on motor axis.

5. Identification of Controlled System

The main research issue was a necessity to perform an identification of controlled system, indispensable for correct programming of control system. A significant difficulty was an inability to obtain proper dynamic characteristics based on system dismantling and independent analysis its components. There was also no ability to analyse the controlled system because of no possibility of launching it.

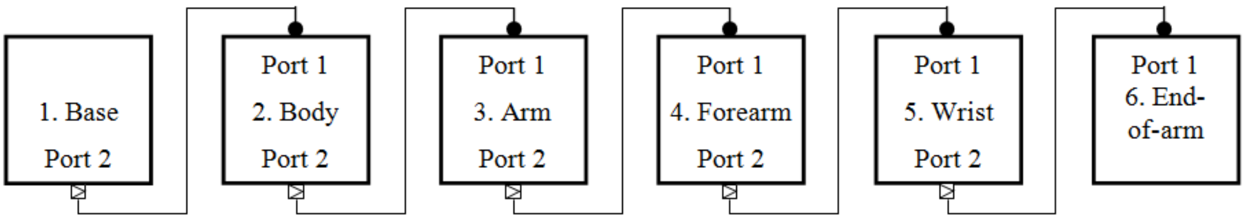

Fig. 5: Simulation model of robot manipulating working parts in SimMechanics tool.

SimMechanics tool, which is included in MATLAB environment, was used for controlled system identification. In a recognition tool, SimMechanics is a set of blocks libraries and special features of the simulations which symbolises physical bodies, constraints, actuators, powers and sensors that model their respective parts of devices. Created simulation model of robot is presented in Fig. 5.

Each block contains data about actual robot part. Basic blocks are built of elementary blocks. Each of them defines mechanical features of selected structural part of manipulator. Fig. 6 presents a sample block schemes of flange end-of-arm.

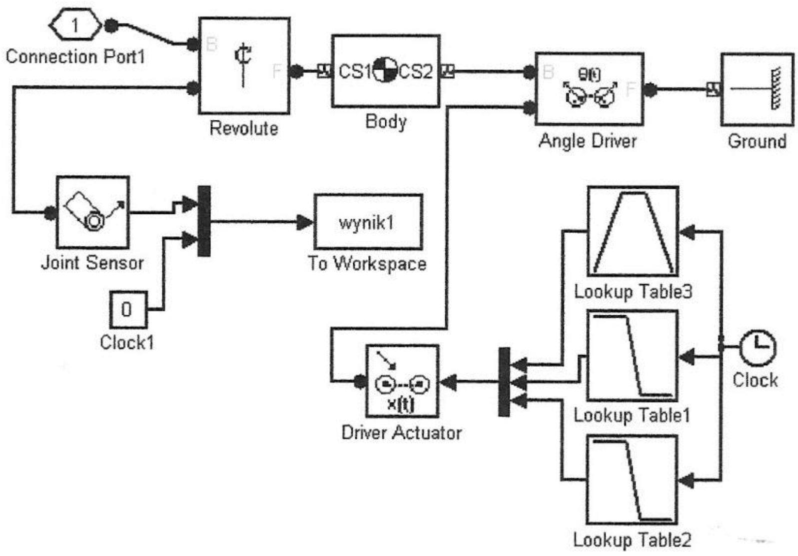

Fig. 6: Block scheme of end-of-arm in SimMechanics tool.

In Fig. 6, the blocks are connected by lines, each of which symbolises a different structural part of manipulator. The most important blocks are those with CS1 and CS2 symbols which determine mass as well as moment of inertia for robot working parts. Blocks of B and F symbols determine characteristic features of connections between parts and blocks labelled as 'Driver' define characteristic features of actuators (including clutches and gears). The other blocks are used for creating connections between working parts as well as entering parameters and observing results of simulation.

The data regarding centre of gravity location, masses and moments of inertia for blocks of SimMechanics tool were obtained from independently made three-dimensional model of manipulation working parts of robot in CATIA system. Basic data about features of actuators were obtained from rating plates placed on their housings.

This approximate model of robot manipulating working parts was put between the new control system and manipulating parts in the feedback loop. The purpose of this procedure was to obtain data from encoders. By iteratively performing series of basic motions of robot parts, while knowing their target position, feedback signal was observed. By entering feedback signal as a control signal into simulation model, model response was observed in the form of coordinates of robot end-of-arm location (or other characteristic point). By comparing the actual location of robot end-of-arm with coordinates from simulation, simulation variables were corrected and the results were corresponding to their values. Multiple repeating of this process for different working parts of robot as well as expected coordinates of characteristic robot parts obtained identification of controlled system.

6. Conclusions

Suggested way of controlled system identification, which involves creating an adapting simulation model, allows specifying a characteristic of dynamic objects for which the well know methods have failed. This is particularly important in the case of robots (systems) revitalisation, because the design documentation is often not known. Obtained simulation model allows design a new control system and its verification by "black box" method.

The cost of suggested control system is one third the cost of repair/replacement the primary control system. Additional sensors replacement allows increasing the accuracy of control system positioning. Application of FPGA processor allows increasing the speed of robot motions without sacrificing the accuracy of positioning while maintaining original actuators.

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