Realization of Model of Robotic Arm S-430iF for Education Purposes

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Abstract: *In this paper is presented development and realization of model of industrial robot S-430iF for educational purposes. Model of robotic arm is realized by using Matlab, SolidWorks, Arduino IDE software and rapid prototyping technology - 3D printing. Robotic arm described in this paper is cheap and user-friendly solution for students to adopt basic knowledge about mechanics of multibody systems, from simulation to implementation in real model.*

Keywords: *industrial robot, robotic arm model; MATLAB; Rapid Prototyping;*

1. INTRODUCTION

Industrial robots are mechanically wary complex mechanism, with a lot of degrees of freedom. In general, industrial robots are modeled as open kinematic chain which is made of solid segments, connected each other with joints. Those joints are controlled with actuators (servo motors). Design and production of control system for industrial robots, require solving kinematics and dynamics of complex movement (relative movement) of multibody system. [1]

Calculations of kinematics and dynamics of robots are mathematically very demanding processes that require the use of matrix algebra. By using the computer software problem of demanding mathematical calculation is easily solved. [2] Development of computer technology and software trigger off solution for making models and simulations of robot movement in a very reliable way, before physical realization of expensive technology. These software simulations save a lot of time for development of industrial robot and saves a lot of money for expensive prototypes. Process of calculation and simulation of movement of a robot is described in detail in resent paper [3]

In this paper is described proceeding of realization of model of industrial robot S-430iF. It is cheap and user-friendly solution for students to adopt basic knowledge about mechanics of multibody systems, from simulation to implementation in real model. The hardware components are described and modification of 3D model which are necessary for realization of robotic arm using rapid prototyping technology. Software implemented in microcontroller is described as well. A proper discussion has been given.

2. BASIC ELEMENTS OF ROBOTIC ARM

Figure 1 presents an 3D model of robotic arm S-430iF and realized model. Most of the elements shown on the model are realized by PLA plastics using rapid prototyping technology. Time required for making robotic arm is about seven days, five days for 3D printing (100 hours, 1kg of PLA plastic), one day for assembling and one day for programming and testing.
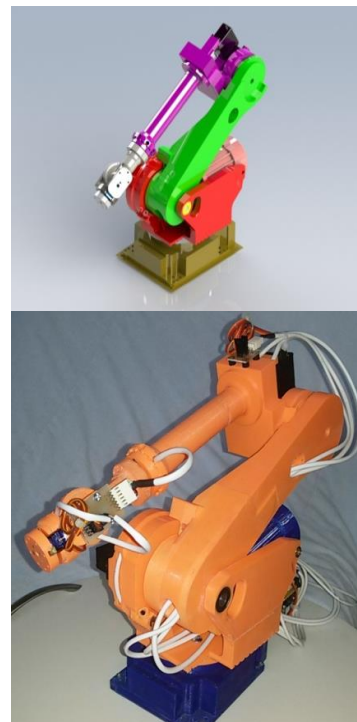

Figure 1. *3D model and realized model*

In order to create an educational model of industrial robot, it was necessary to make modifications on the 3D model of robot S-430iF. These modifications to the 3D model are made in order to make mounts for motors and sensors. The models are simplified so that they can be made on a 3D printer.

Block diagram of model of industrial robot S-430iF is presented in figure 2.
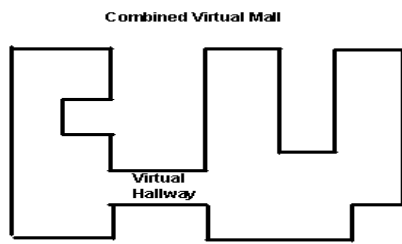
Figure 2. *Block diagram of model*

2.1. Arduino UNO controller

Arduino UNO is development board based on ATmega328 microcontroller. It has 14 digital input/output pins (of which 6 can be used as PWM outputs), 6 analog inputs, a 16 MHz quartz crystal, a USB connection, a power connector, ICSP connector. It contains everything needed to support the microcontroller; simply connect it to a computer with a USB cable. [4] This board supports a lot of extensional boards called "shields". Arduino UNO can be programmed form in development environment for microcontrollers, or in LabVIEW and MATLAB software.

2.2. RC servo motors

For this model of industrial robot RC servo motors are used. This type of motors is used because they are the cheapest, easy to buy. They are reliable and easy to control using PWM (Pulse Width Modulation) signal form microcontroller. Motors are very small, and inside, they have position feedback control with potentiometer and comparator. Construction of motor contains motor and gearbox. In this model of industrial robot, two types of RC servos were used. First one is AnalogServo - HD-10501MG (figure 3) with high output torque. The second one is Tower Pro Micro Servo 9g SG90 (figure 4) with small output torque and small dimensions.

Basic characteristics of motor AnalogServo - HD-10501MG:

- Power supply 4.8-6.0 VDC
- Speed 0.14sec/60°
- Working current 500mA
- Maximal torque 17 kg-cm
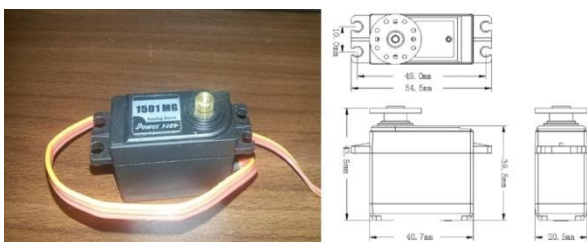- Maximal current 2500mA
- Mass 63±1g [5]

Figure 3. *AnalogServo - HD-10501MG [4]*

Basic characteristics of motor Tower Pro Micro Servo 9g SG90:

- Power supply 4.8-5.0 VDC

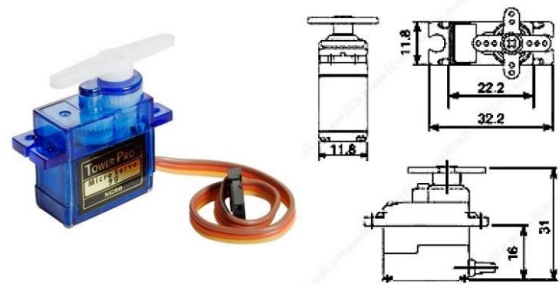- Speed 0.1sec/60°
- Maximal torque 1.8 kg-cm
- Mass 9g [5]

Figure 4. *Tower Pro Micro Servo 9g SG90 [6]*

3. PROGRAM

Programming of model of industrial robot has been done in Arduino IDE software. In this software the *VarSpeedServo.h* library was used. This library enables control up to eight RC servo motors with different speeds. Library is modification of standard *Servo.h*, which is modified by Korman who has added speed control. Later Philip van Allen has added possibility of waiting to finish motor movement. [7]

The most important method from this library is:

write(value, speed, wait)

which define angle that motor has to achieve, his speed and are the motors work synchronically. This notation enables to import matrix which contains rows with angles and rows with motor speed. Matrix like this can be formed in MATLAB simulation [3] with some additional code:

ugao=q*57.2957795;
brzina=qd*57.2957795*5;
matrica_za_arduino=cat(2,ugao,brzina);
matrica=int64(matrica_za_arduino);
where is:
ugao=q*57.2957795; code that converts angle form radian to degrees,
brzina=qd*57.2957795*5; code that converts angular speed form rad/s to °/s,
matrica_za_arduino=cat(2,ugao,brzina); code that forms matrix with angle and angular speed,
matrica=int64(matrica_za_arduino); code that convert matrix form real to integer type.

Conversion matrix to integer is necessary because method: **write(value, speed, wait)**can contain only integer data in it.

Matrix was copped from MATLAB and defined as matrix in Arduino IDE software with code:

```
int ub[41][14] = {
  {45, -90, -30, 0, 0, 0, 0, 0, 0, 0, 0, 0},
  {45, -90, -30, 0, 0, 0, 0, 0, 0, 0, 0, 1},
...
  {135, -108, 30, 60, 30, 180, 0, 0, 0, 0, 0, 0}
};
```

Then for every motor variable was created with code: **VarSpeedServo m1;**

In *setup* function output pins are declared. Those pins are related with variable for each motor. Main loop implements function **matlabProgram()**. In this function the start position is defined as well as sequential movement trough the matrix. By executing this function, the model of industrial robot moves as it has been defined in simulation.

This function is defined in such a way:

```
void matlabProgram()
{
  m1.write(45, 5, false);
  m2.write(90, 5, false);
  m3.write(60, 5, false);
  m4.write(180, 5, false);
  m5.write(0, 5, false);
  m6.write(180, 5, true);
delay(2000);
for (i = 0; i < 41; i++)
  {
   m1.write(ub[i][0], 1 + abs(ub[i][6]),
false);
   m2.write(180 + ub[i][1], 1 +
abs(ub[i][9]), false);
   m3.write(90 + ub[i][2], 1 +
abs(ub[i][10]), false);
   m4.write(180 - ub[i][3], 1 +
abs(ub[i][11]), false);
   m5.write(ub[i][4], 1 + abs(ub[i][12]),
false);
   m6.write(180 - ub[i][7], 1 +
abs(ub[i][13]), true);
delay(45);
  }
}
```

Part of code **1 + abs(ub[i][12])** is integrated because method form *VarSpeedServo.h* library doesn't support negative speed, and speed cannot be zero.

Figure 5 shows movement simulation of industrial robot and movement of model made from MATLAB calculation with associated diagrams.
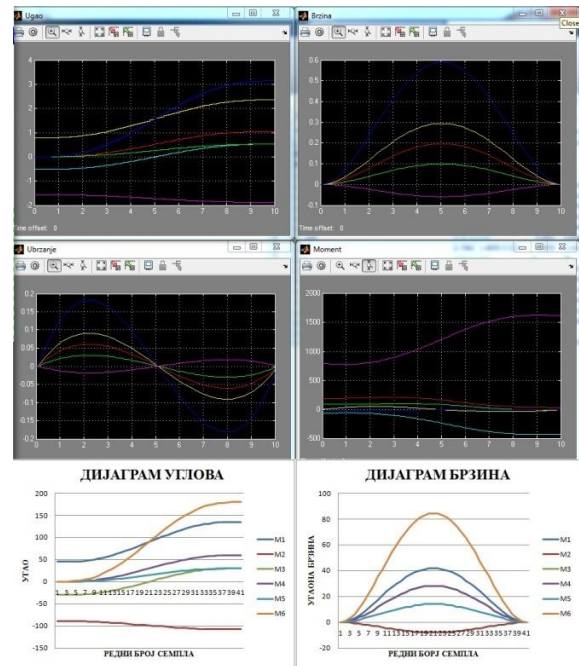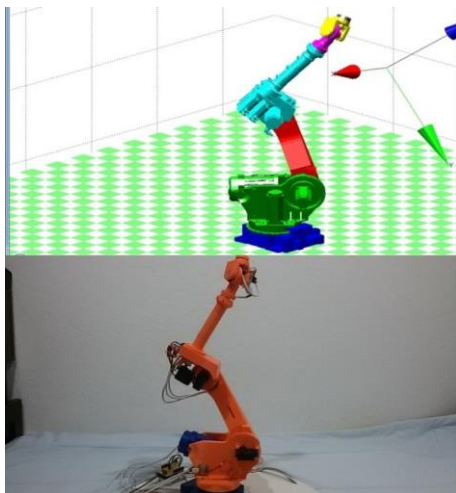
Figure 5. *Simulation of movement of industrial robotic arm and movement of real model with angle, speed, acceleration diagram*

4. CONCLUSION

The paper presents the realization of educational model of industrial robot S-430iF. For realization of this model a lot of different oriented programs were used. MATLAB for simulation a kinematics calculation, SolidWorks for modification of 3D models. Those 3D models are made using Rapid Prototyping -3D printing. Arduino IDE software was used for microcontroller programming. All these programs and technologies are learning in the department of mechatronics. The realized robot model of industrial robot is used in the realization of laboratory exercises. The main idea is to make simulations in MATLAB with different parameters, every student should have his set of parameters, and when they make simulation they can implement it on real model. This can help them to understand kinematics and programming of industrial robots. Further step is to make proper teaching material which should contain examples based on this platform.

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