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Mathematical Modelling and Simulation of Six Axis Robot for Industrial Application

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Abstract*: The proposed paper work is focused on the development of low cost six axis robot. The robot is modelled using mathematical model and it's compared with the simulation model in the real time environment condition. The modeling of the robot is designed in the modeling software and it is simulated in the Matlab software. This type of solving system is used to solve the many type of real time problems. The simulated result is compared with the mathematical model of the robot. Based on the testing the robot is redesigned in the modeling software. In this work sin wave is given has input and the robot is followed the sine wave.

***Index Terms*: Robot, Servo motor, mathematical model**

I. INTRODUCTION

Now a days robotics place a vital role in the industry and the education field. The robotics used in many application. In the robotics field the six axis robot is main used in the industry application like pick and place. Welding painting, and etc [1]. So the robot in the industries reduce the man effort and human fatigue, errors. Now a days all industries moving to the automation so the need of the six axis robot is high. To fabricate the six axis robot first design is the first phase. To design the robot modeling software used to design. Solid works software used to design the robot [2]. The dimension of the robot is depending upon the application. Based on the application the robot is fabricated. The robot mathematical developed in the manual method. This mathematical model is evaluated using the simulation software. The mathematical modeling is compared to the simulation models[3]. This method is used to evaluate the system before fabrication of the robot. This is leads to avoid the wastage of the fabricated robot. Many types of error is rectified in this method. Using the simmechanics module in the Matlab the robot is simulated in the real time environment condition. It demonstrate how the real time robots is working.

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The robot is simulated in the various environment condition so based on the simulation the robot is reconstructed in the design phase itself. It is avoid the wastage in the fabrications. After the simulation the robot is fabricated. After design the robot is analyzed in the analyzing software. This is used to avoid the structural breaks in the heavy load condition. In the fabrication the material is important parameter. Based on the material the robot weigh is determined and that used to decide the motor and other parameters[4]. For the prototyping purpose the PLA material used many works[5]. After the fabrication the robot is need to calibrate. There are many method available for the calibration. Kinematic calibration is used in industries [6]. Similarly the dynamics plays the major role in the fabrication. The dynamic analysis of the robot is need to carried before fabrication[7]. After the fabrication controlling of the robot is important factor. For the controlling purpose the controller boards is used. The controller board is connected to the actuators. This actuators is controlled based on the input given from the controller. The controller gives the output based on the program preloaded [8]. From the various literature the six axis robot s design in the modelling software and it's analyzed in the Matlab software using simmechanics it compared to the mathematical modelling. Its pre evaluating the process used to identify the problem before fabrication of the robot.

II. BUILDING A ROBOT MODEL

A. Cad model

Six axis robot is designed in the modeling software. The robot has six degrees of freedom. The robot consist of the base part, sholder1, sholder2 and the gripper part. The gripper part has three degree of freedom. The robot has a six motor for its rotation. This is helps to give the flexibility of the robot. The designed in the solid works software, were all parts design and assembled as per the industry application. The dimension of the robot is varying depending upon the application. Figure 1 shows the six axis robot model design in the solid works software.

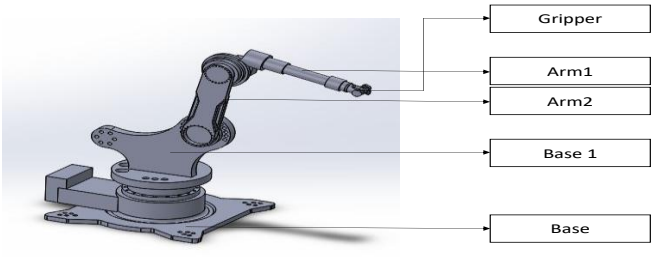

Figure 1. 3D model of the six axis robot.

The robot angle is controlled by the controller. Angle predefined angle based on the application.
The maximum angle of each joint is limited. Only the base joint is rotated full 360 degree all other joints rotation is restricted due to the parts collision.

B. Mathematical model and calculations

Mathematical modelling of the robot is used to calculate the angle and link length of the robot. Denavit and Hartenberg method is used find the angle and length. To calculate the position of the robot the frame assignment is important. Figure 2 shows the frame assignment of the robot.

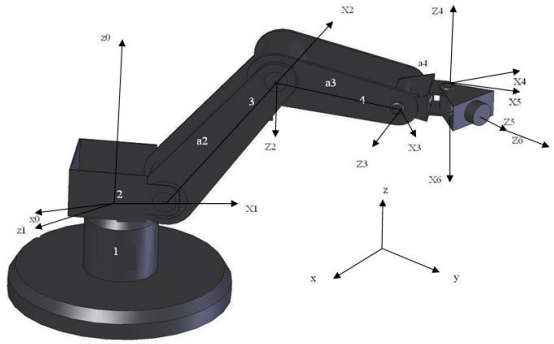

Figure 2. Frame assignment of the robot

I. Position calculation

From the DH parameter the position of the robot is calculated

$$P_x = [L_2(C_2C_3\text{-}S_2S_3) + C_2L_1]C_1$$
$$P_Y = [L_2(C_2C_3\text{-}S_2S_3) + S_2L_1]S_1$$
$$P_Z = L_2(S_2C_3\text{+}C_2S_3) + S_2L_1$$

Were,
L1, L2, L3 is the link length
C1, S1 is the cosθ and sinθ of joint one
Based on the application the length of the robot and angle calculated from the forward and invers kinematics of the robot. After the based on the input the robot is moved from one point to another location. It is compared to the Matlab simulation

III. MATLAB SIMULATION

Matlab is the tool used for the simulation the robot. in this work two type of evaluation method is used one is programming graph method and simmechanics method. For the programming method the robot link is modelled in the link and joint it is moved based n the input give. From this type of evaluation we know the position of the robot and collision of the robot is know from the graphical representation.

```
l1=Link ([0 0 1 pi/2]);
l2=Link ([0 0 5 0]);
l3=Link ([0 0 6 0]);
arm=SerialLink([l1,l2,l3],'name','trr');
q1=[0,0,0];
q2=[pi/2,0,0];
q=(1:1:100);
traj=jtraj(q1,q2,q);
arm.plot(traj)
q1=[pi/2,0,0];
q2=[pi/2,pi/2,pi/2];
q=(1:1:100);
traj=jtraj(q1,q2,q);
arm.plot(traj)
```

Were,
L1 link length 1
L2 link length 2
L3 link length 3
Q1 and q2 is angle
Traj is the command used to plot the robot in the graphical maner.
This is the programming used in the robot to find the position and volume of the robot. The figure 3 shows the graphical representation of the robot.

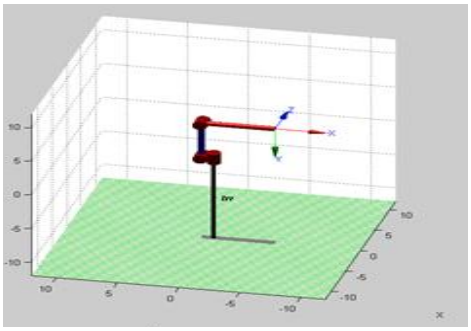

Figure 3. Graphical representation of the robot

The above mage shows the simple representation of the robot.

IV. TORQUE CALCULATION

Torque is the important parameter to choose the motor. In this robot six motors is used for the industrial application.
Base motor toque calculation
Torque = { ((weight of the base part + weight of all other components) * gravity) * perpendicular distance of the motor shaft }
From the above equation the torque of base motor is calculated. Other joint torque is calculated from the same logic.

V. MATLAB SIMMECHANICS SIMULATION

Simmechanics is the simple method to simulate model in the real time environment condition. The part of the robot is imported from the solid works software. In the solid works software specific simmechanics plug in is used to import the model from the solid works to XML file [3]. XML is the format used in the matlab. The xml model is imported n Simulink matlab tool. In the imported Simulink model all individual part f the robot is imported. That individual part is connected to the joints. The system is connected to the reference frame world and global coordinated system. This coordinated system is used to find location and position of the robot from the zero axis. The figure 4 shows the simmechanics model of the robot.

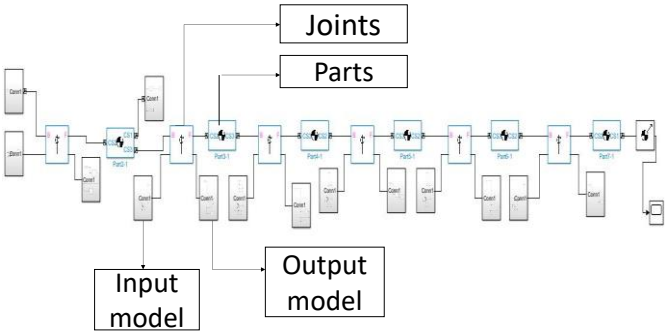

Figure 4. Simmechanics model of robot

The simmechanics model consist of the input, output and parts. The input model consist of the joint actuator and input value. Input values is either constant or real time values. The purpose of joint actuator is to convert the physical signal to Simulink signal. The figure 5 shows the input model of the robot.

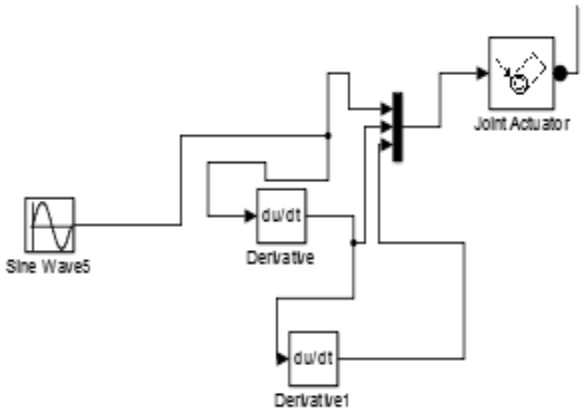

Figure 5. Input Module

The output model has the joint senor and scope. The joint sensor is used to convert the Simulink signal to physical signal. The scope module is used to display the output. The figure 6 show the output module of the robot.

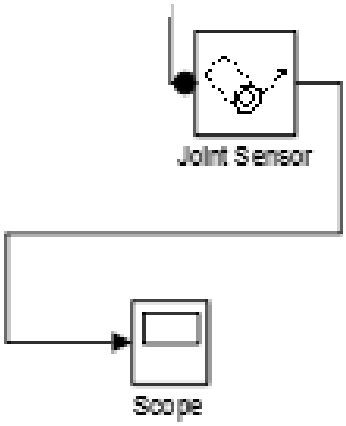

Figure 6. Output Module

Based on the input given the robot is move from the one position to another position. The figure 7 shows the simmechanics model and various position of the robot.

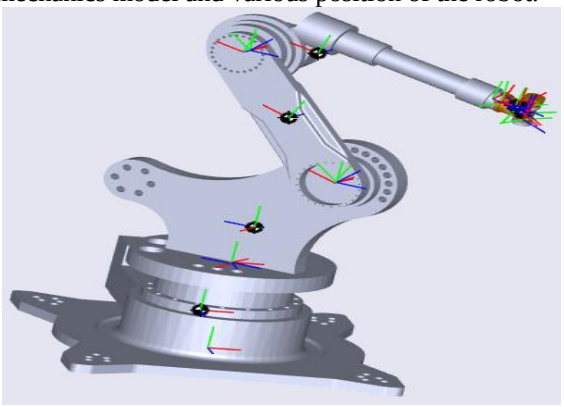

Figure 7 a . Simmechanis model

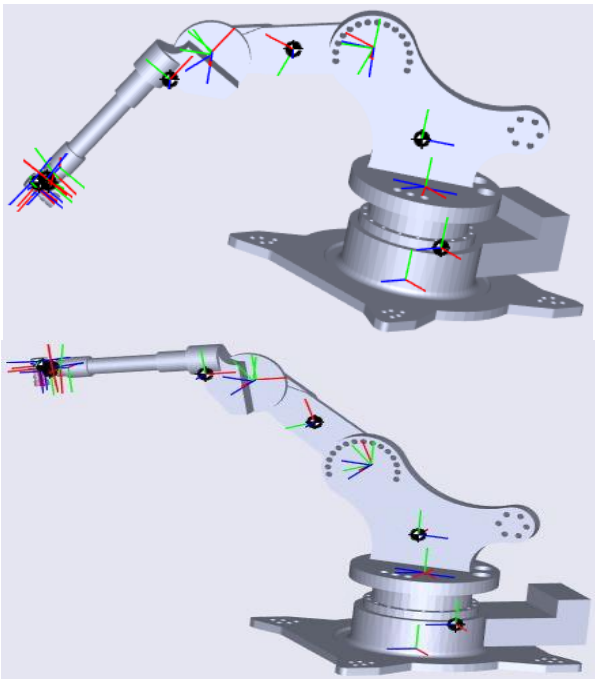

Figure 7 b . Various position of the robot

After the evaluation the model the fabrication is start. Based on the calculation and toque obtained the motor is selected. To controlling the motor controller is needed. For the prototyping purpose the Arduino microcontroller is used in the work. The robot model is fabricated using the 3d printing process. 3d printing is one the best method for prototype the real time model. For this work the PLA material is used to fabricate the robot.

VI. IMPLEMENTATION OF HARDWARE PART

A. Micro controller.

Micro controller is used to control the robot. Arduino ide is used to program the Arduino. Arduino has the analog and digital pins. This pins used to get the input from the user and it sent to the robot using output pins. In this work Arduino mega is used because of the more number of pin configuration needed. It's operating in the 5v so no need of external power supply. Working speed is high so the robot accuracy is high. Figure 8 is show the Arduino mega

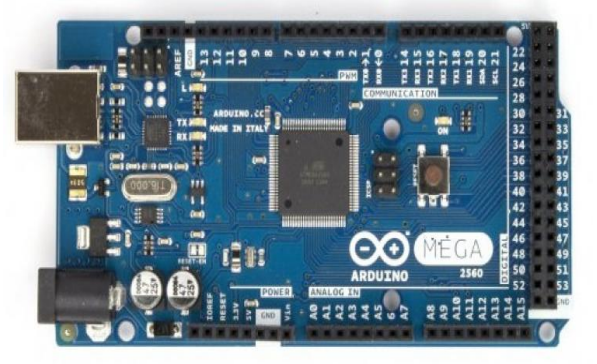

Figure 8. Arduino mega controller board

B. Servo motor

For the prototype purpose DC servomotor is used to demonstrate the model. It is has the pulse pin.

It's used to send pulse signal to the robot. Based on the input signal from the controller the motor is rotating. MG996 servomotor used in this work. It's having the 9.4 Kgf. Cm torque. Figure 9 shows the Mg996 servo motor.

Figure 9. Servo motor

C. Battery

The robot is powered by the power supply. The 12V battery used for the prototype purpose. The servo motor and controller board need the 12v power supply. The figure 10 show the battery used in the robot.

Figure 10. 12V battery

The above mentioned component used for the prototype model. The Arduino ide used to program the controller. Robot is moved based on the input given. The stability of the robot is controlled by the PID tuning.

VII. METHODOLOGY

A. Block Diagram of robot model

The below figure 11 shows the block diagram of the robot.

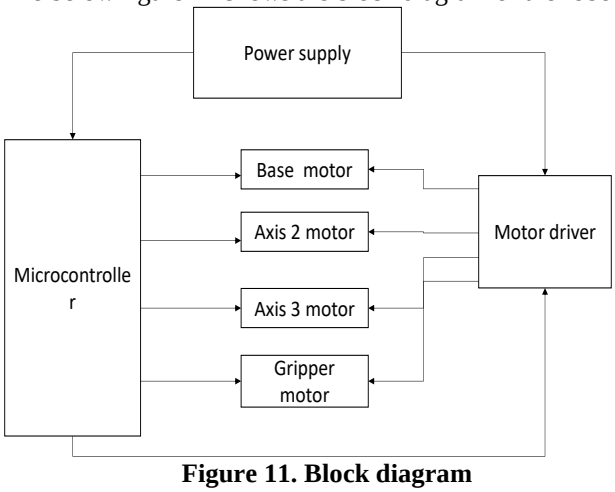

Figure 11. Block diagram

Arduino micro controller is programmed by the Arduino ide. Based on the pin used in the program the connection of the robot is made. The micro controller is connected to the motors based on the pulse given by the controller the motor is running.

VIII. RESULT AND DISCUSSION

The model is simulated in the Matlab software based on the input given the robot is moved from the one location to another location. In this work the input is given as sine wave Robot is followed the path and it gives the out as a followed path output. The figure 12.a, b shows the input and output of the robot.

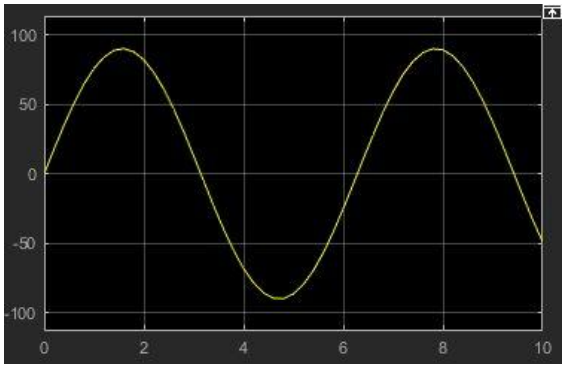

Figure 12 a. Input sin wave

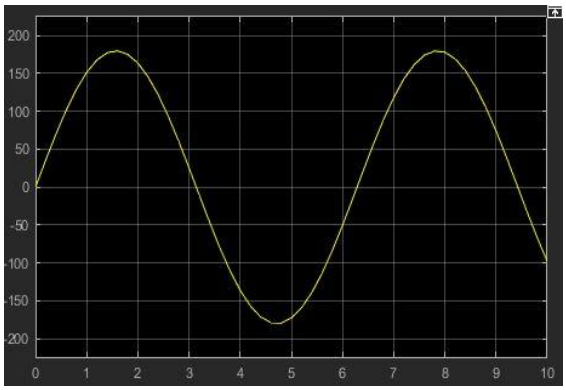

Figure 12 b. Output sin wave

IX. CONCLUSION & FUTURE WORK

The proposed work is testing the model before fabrication. The model simulated and tested in the Matlab software it is compared with mathematical model. Based on the testing the model is reconstructed in the design before fabrication. in this work robot is designed in the modelling software and imported in the Matlab software using simmechanics tools. After that the model is simulated in the Simulink environment in Matlab. Based on the input given the robot is moved. Future work of this proposed model is to control the robot using real time input given by the user. PID controller is used to tuning the parameters.

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