Design and Analysis of Robot Arm using Matlab & ANYSYS

* Ramanideepthi Tanneeru, *Ajay Jandrajupalli, #B. Kiran Kumar

*Student (M.Tech-CAD/CAM) , Department Of Mechanical Engineering, Layola Institute of Technology & Management, Dhulipalla, Sattenapalli, Guntur.

*Asst. Professor, Department Of Mechanical Engineering, Layola Institute of Technology & Management, Dhulipalla, Sattenapalli, Guntur.

#Asst. Professor, KKR&KSR Inst. Of Tech & Sciences, Vijanampadu, Guntur.

Abstract

In today's society, robots are used in various areas especially in those where high precision is required. Robots have improved life standards and we are upgrading their performances in order to make our lives easier and more comfortable. Many applications in the field of medicine and industry use different kind of motor-based systems such as robots because of their wide-range of sufficient characteristics like the fact that they can be used as constant power devices with accurate positioning and fast response. This paper describes implementation of the proposed remote control of the stepper motor and robotic arm. In this work a motorized robot arm with a single degree of freedom is designed. For this design control algorithm was developed by MATLAB software which is widely used in controlling application. The results of the control system are also described.

Keywords: *Robotic Arm, Transient analysis, BEAM Specifications, Motor, Control System, MATLAB, ANSYS.*

I. INTRODUCTION

Many researches have been made in the field of the remote control. These researches have improved certain aspects of industry, medicine, military, etc. The benefits of remote control are numerous such as: operating in hazard environment, telemedicine, missile guidance, etc. The most important characteristic of remote control is operating in real-time. Many applications in the field of medicine and industry use different kind of motor-based systems especially stepper motors because of their wide-range of sufficient characteristics like the fact that they can be used as constant power devices with accurate positioning and fast response.

The electrical/electronics industry (including computers and equipment, radio, TV and communication devices and equipment and medical, precision and optical instruments) was the second main driver of the recovery of robot sales in 2010. The worldwide shipments of industrial robots almost tripled in 2010 to 30,745 units up from 10,855 units in 2009. The share of the total supply was about 26%. After strong investments in robots in 2004 and 2005, installations slowed down between 2006 and 2009.

After years of continuing growth, the rubber and plastics industry reduced robot investments in 2008 and 2009 from the peak level of about 14,800 units to 5,800 units. In 2010, sales increased by 54% to 8,940 units which is still far below the peak level. Share of the total supply was about 8%.

The food and beverage industry increased robot orders by 32% to almost 4,350 units, accounting for a share of 4% of the total supply. About 58% of the worldwide robot sales to this industry were made in Europe.

In 2010, sales to the metal products industry recovered by 63% to about 4,500 units which was only half of the volume of 2008. In 2009, only about 2,700 robots were ordered by this industry.

Regarding the machinery industry, there were no separate data available for North America. The data for North America for this sector are included in metal products.

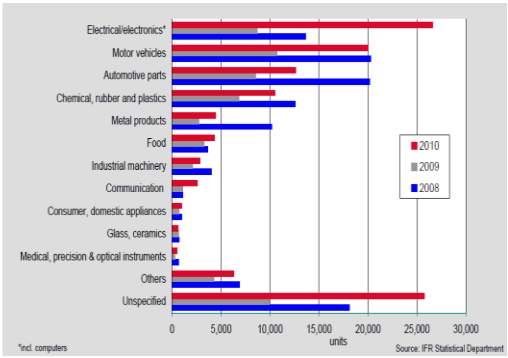


Figure 1 Demand of Industrial Robots in Various Fields

Sales to all other countries recovered just moderately by 37% to about 2,900 units which was only about 70% of the volume of 2007 and 2008. Until 2008, robot supplies to the metal and machinery industry as well as to the food and beverage industry were continuously growing.

A robotic arm is a robotic manipulator, usually programmable, with similar functions to a human arm. The links of such a manipulator are connected by joints allowing either rotational motion or translational displacement. The links of the manipulator can be considered to form a kinematic chain. A robot may be designed to perform any desired task such as welding, gripping, spinning etc., depending on the application. For example robot arms in automotive assembly lines perform a variety of tasks such as welding and parts rotation and placement during assembly.

A rotation of 99 degrees is given to the robot arm in a minimum time (.02seconds) by supplying power to the robot arm using a switch. Further the arm will settle down with critical damping to an angle of 90degrees. The FE modal analysis has been performed for the robotic arm to find the natural frequency.

Transient analysis is performed to note the displacement, velocity and accelerations during its motion. However, the use of feedback can lead to an unstable system whose output may oscillate or even go to infinity with a small input signal. Stability determination is therefore an important design consideration. One specification for absolute stability requires that the poles of the transfer function must be in the left half of the s-plane. Absolute stability, often specified in the frequency domain, is essential and necessary but not sufficient.

Frequency domain specifications relating to relative system stability may also be given. For relative stability, a certain phase margin and gain margin may be specified to ensure that the system will remain stable although some parameters change due to temperature changes, aging or other environmental changes.

If a system is stable, then other performance criteria, specified in either the time or frequency domain, may be considered to meet the performance requirements. Short-term, or transient, response specifications such as rise-time or percent overshoot to a unit step function input may be given. Fortunately, the advance control calculation can be solved with the help of using MATLAB software.

In industrial automation the control of motion is a fundamental concern. Putting an object in the correct place with the right amount of force and torque at the right time is essential for efficient manufacturing operation. Feedback comparison of the target and actual positions is done in motion control system. This comparison generates an error signal that may be used to correct the system, thus yielding repeatable and accurate results. The goal is to design a compensation strategy so that a voltage of 0 to 10 volts corresponds linearly of an angle of 0 degrees to an angle of 90 degrees.

II. SYSTEM MODELING & ANALYSIS

DC motor is used to drive a robot arm horizontally as shown in Fig. 3. The link has a mass, M=5Kg, length L=1 m, and viscous damping factor D = 0.1. Assume the system input is a voltage signal with a range of 0-10 volts. This signal is used to provide the control voltage and current to the motor. The motor parameters are given below. The goal is to design a compensation strategy so that a voltage of 0 to 10 volts corresponds linearly of an angle of 0˚ to an angle of 90˚. The required response should have an overshoot below 10%, a settling time below 3 second and a steady state error of zero.

A DC motor with armature control and a fixed field is assumed. Field current is a maintained constant from separate source while the voltage applied to the armature is varied. DC motors feature a speed, which is proportional to the counter EMF.

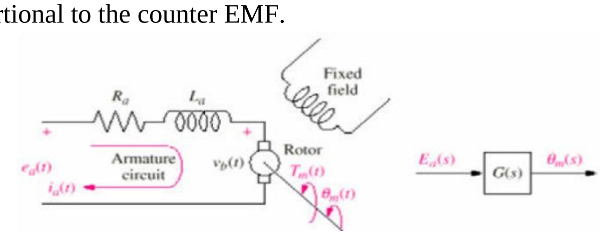


Figure 2 Design Model DC Motor

This is equal to the applied voltage minus the armature circuit IR drop. At rated current, the torque remains constant regardless of the dc motor speed (since the magnetic flux is constant) and, therefore, the dc motor has constant torque capability over its speed range. The electrical model of DC motor is shown in fig. 2.

The electrical Specifications of DC motor used in this Robotic Arm is listed in Table. 1.

The motor parameters are given below.

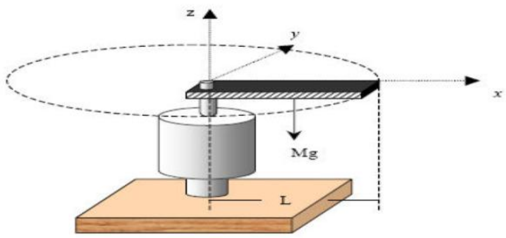


Figure 3 Robot Motor Horizontal arm

Table 1 Specifications of Motor in Robotic Arm

Parameter	Specifications
Mass of the link	5 kgs
Length of the link	1mt
Viscous damping factor	0.1
Voltage signal range	0-10 volts
Response overshoot	<10%
Steady state error	0
Ja	0.001 kg-sm/s
Da	0.01 N-m s/rad
Ra	1 Ohm
La	0H
Kb	1 V-s/rad
Kt	1 N-m/A

BEAM3 Element Description

BEAM3 is a uniaxial element with tension, compression, and bending capabilities. The element has three degrees of freedom at each node: translations in the nodal x and y directions and rotation about the nodal z-axis.

Table 2 Beam 3 Specifications

Real constants-For BEAM 3

Parameter	Specifications
h	0.04m
b	0.016 m

Material Properties	
Young's Modulus	2el 1 N/m2
Density	7800 kg/m3
Poisson's ratio	0.3

Boundary conditions	At node 1: UX, UY, UZ, ROTX and ROTY = 0

BEAM3 Input Data

BEAM3 Geometry shows the geometry, node locations, and the coordinate system for this element. The element is defined by two nodes, the cross-sectional area, the area moment of inertia, the height, and the material properties. The initial strain in the element (ISTRN) is given by J/L, where J is the difference between the element length, L (as defined by the I and J node locations), and the zero strain length.

III. CONTROL SYSTEM DESIGN AND ANALYSIS

A negative closed loop feedback control system with forward controller and corresponding Simulink model shown in Figure .4(a)(b) are to be used . Our design goal is to design, model, simulate and analyze a control system so that a voltage input in the range of 0 to 12 volts corresponds linearly of an Robot arm output angle range of 0 to 180, that is to move the robot arm to the desired output angular position, θL, corresponding to the applied input voltage, Vin, with overshoot less than 5%, a settling time less than 2 second and zero steady state error. The error signal, e is the difference between the actual output robot arm position, θL , and desired output robot arm position.

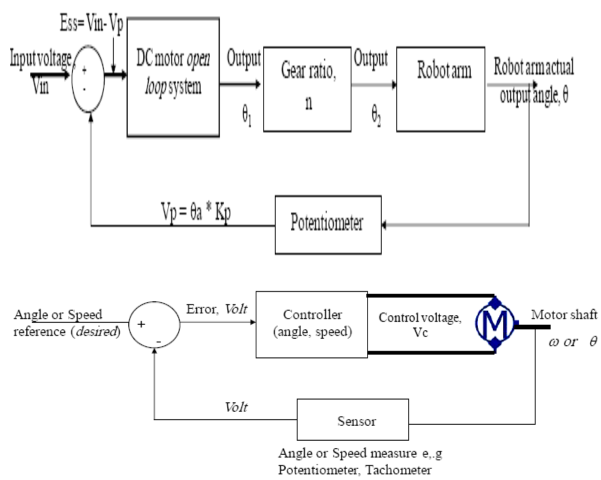


Figure 4(a&b) Two Block Diagram Representations of PMDC Motor Control

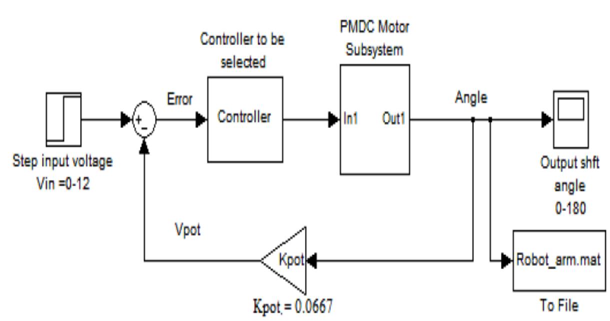


Figure 5 Preliminary Simulink Models for Negative Feedback with Forward Compensation

To calculate the error, we need to convert the actual output robot arm position, into voltage, V, then compare this voltage with the input voltage Vin, the difference is the error signal in volts. Potentiometer is a popular sensor used to measure the actual output robot (arm) position, θL ,convert into corresponding volt, Vp and then feeding back this value, the Potentiometer output is proportional to the actual robot arm position, θL, this can be accomplished as follows: The output voltage of potentiometer is given in the below Eq., in this equation: θL :The actual robot arm position. Kpot the potentiometer constant; It is equal to the ratio of the voltage change to the corresponding angle change, and given below Eq. Depending on maximum desired output arm angle, the potentiometer can be chosen, for our case Vin= 0:12, and output angle = 0:180 degrees, substituting, we have:

Vp= θL*Kpot

$$Kpot=\frac{(Voltage\ \ Change\,)}{(Degree\ \ Change\,)}=\frac{12-0}{180-0}=0.0667V/deg$$

The value (0.0667), means that each one input volt corresponds to 180/12= 15 output angle in radians , to obtain a desired output angular position of 180 , we need to apply 12 volts, to obtain an angular position of 90 we need to apply (90*0.0667= 6.0030 Volts).

IV. RESULTS & CONCLUSIONS

The control system for a motorized robot arm has been designed. Taking the inputs as motors inertia of 0.4177kg.m^2, voltage of 10V, back emf of 1, torque constant of 1, gear ratio of 1 and a friction of 0.11.Initially the system doesn't reach any steady state. Therefore to bring the system to a stable position a feedback is created by using a proportionality constant of 0.111 and the gear ratio of 1. The system rotates about 90 degrees and reaches a steady position after approximately 50 seconds. The results are studied using MATLAB software.

Now another study is made using PID controller feedback system. In this system we vary the values of proportional gain, derivative gain and integral gain. The required settling time is obtained by changing these values.

The settling time can be reduced by increasing the integral gain factor. The overshoot can be reduced by increasing the values of derivative gain factor. Modal analysis by using ANSYS is performed for the considered robot arm and it is found first five natural frequencies to avoid the possibility of resonance occurrence in the robotic arm by applied force frequency in the range of 43.037Hz to 497.103 Hz. Also transient analysis is performed to find the maximum displacements, velocities and accelerations for the robot arm as it was subjected to suddenly applied rotation. The maximum values of displacement, velocities and accelerations have been found and it is understood that they are within allowable limits.

In the present work the motion control of a robot arm is carried out. It can be further improved by using Velocity and Acceleration feedback controls this analysis may be carried out by considering the robot arm with different materials like composite, smart material etc.

Table 3 Model Analysis

DESCRIPTION	FREQUENCY (HERTZ)	MAXIMUM DEFLECTION (mm)
First mode	2.27E-03	0.770278
Second mode	43.037	0.893815
Third mode	139.432	0.894239
Fourth mode	290.813	0.894127
Fifth mode	497.103	0.893815

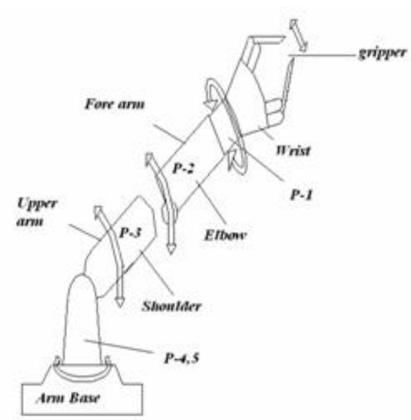


Figure 4 Cross Section of Designed Arm

Table 4 Transient Analysis

DESCRIPTION	RANGE OF VARIATION	MAXIMUM ABSOLUTE VALUE
Displacement in X-Direction(m)	0 to 1*10-10	1*10-10
Displacement in Y- Direction (m)	0 to 5.7*10-6	5.7*10-6
Angular Displacement about Z-axis(rad)	0 to 1.77	1.77
Velocity in X- Z-axis(rad)	0 to 1.25*10-6	1.25*10-6
Velocity in Y- Direction	4.1 to 4.4*10-2	4.410-2
Angular Velocity About Z-axis(rad/s)	0 to 1450*103	1450*103
Acceleration in X- Direction(m/s2)	0 to 1.25	1.25
Acceleration in Y- Direction(m/s2)	400 to 800*101	800*101
Angular Acceleration About Z- Axis(rad/ s2)	0 to 1450*109	1450*109

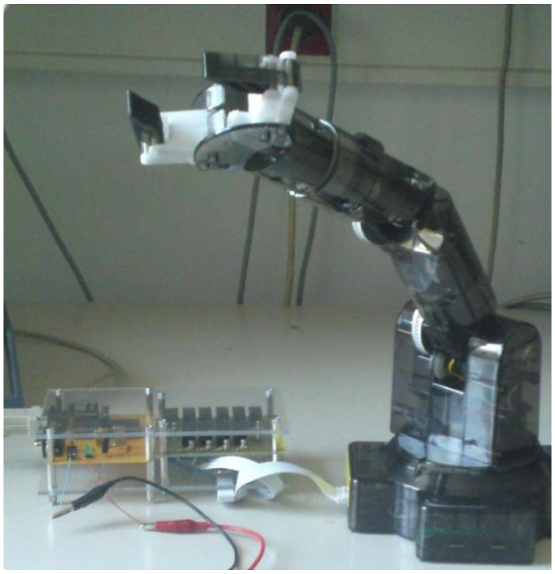
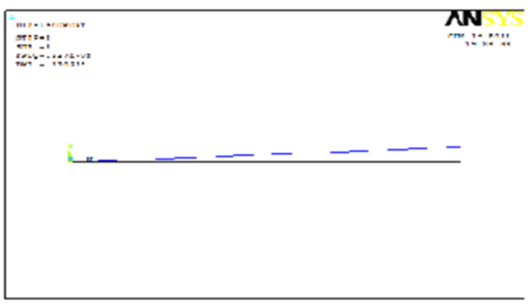
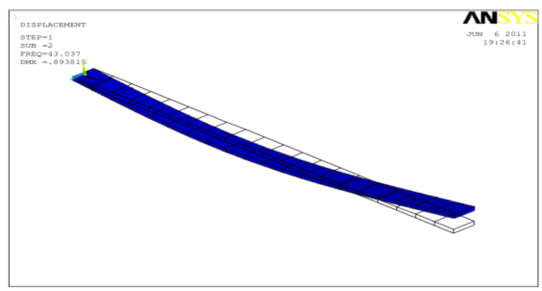


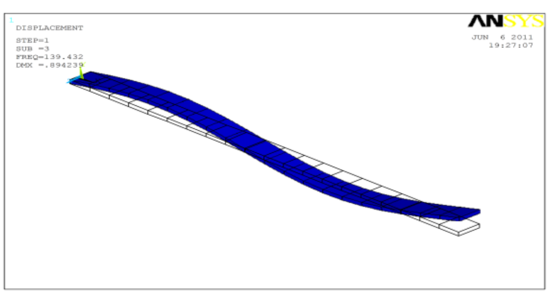
Figure 7 Designed Model of Robot Arm



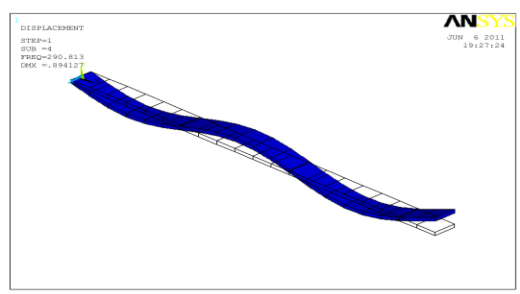
(a)



(b)



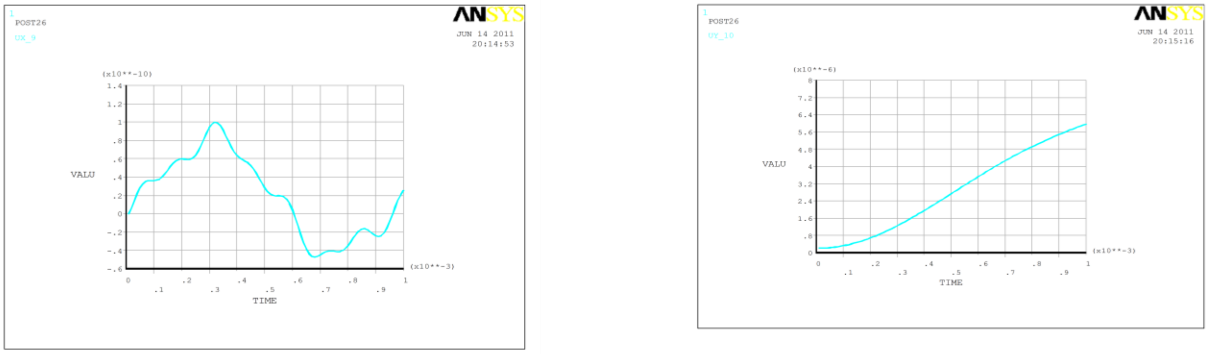
(c)



(d)

(a) - First natural Frequency
(b) - Second natural Frequency
(c) - Third natural Frequency
(d) - Fourth natural Frequency

Figure 5 Model Analysis



(a) (b)

Figure 6 Velocity in X & Y Direction

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