



e-ISSN: 2319-8753 | p-ISSN: 2347-6710

# IJRSET

International Journal of Innovative Research in  
**SCIENCE | ENGINEERING | TECHNOLOGY**



# INTERNATIONAL JOURNAL OF INNOVATIVE RESEARCH

IN SCIENCE | ENGINEERING | TECHNOLOGY

Volume 13, Issue 6, June 2024

**ISSN** INTERNATIONAL  
STANDARD  
SERIAL  
NUMBER  
INDIA

Impact Factor: 8.423

9940 572 462

6381 907 438

[ijirset@gmail.com](mailto:ijirset@gmail.com)

[www.ijirset.com](http://www.ijirset.com)

# **Modelling & Simulation of Robotic Pick and Place Arm by 2 and 3 Degrees of Freedom**

**Gummanur Bheemesh, M. Satya Narayana, E. Azas**

PG Student, Department of Mechanical Engineering, Bheema Institute of Technology & Science, Adoni, India

Asst. Professor, Department of Mechanical Engineering, Bheema Institute of Technology & Science, Adoni, India

HOD, Department of Mechanical Engineering, Bheema Institute of Technology & Science, Adoni, India

**ABSTRACT:** This paper discusses the design and Modelling of a pick and place robotic arm by 3-Degrees of freedom & 2-Degrees of freedom. The robotic arm is intended for educational purposes. In this project we are designing the robotic arm for improved accuracy by using servos to power the joints in the robotic arm. We are designing the robotic arm using CATIA software & Ansys workbench. The project covers the procedure for selection of the servos used to power each joint of the arm in details. We are selecting Aluminum to fabricate the components of the robotic arm. The torque exerting at each of the joints is going to calculate in this project and a servo with the required torque rating is being selected for each joint. The scientific modeling of two degrees of opportunity robot arm is created and displayed in this paper. The show is based on a set of nonlinear moment arrange conventional. The control calculation is extended on the inferred scientific conditions to control the robot arm in joint point position and the coupling impact of the robot arm was decoupled to pick up adequate opportunity to control each arm openly

## **I. INTRODUCTION**

The diverse sorts of electric motors utilized as actuators for robotized applications are arrange current (DC) motors, stepper motors and servo motors. The controller is the foremost parcel that shapes information and carries out instructive in a robot. It is the robot's 'brain' and controls the robot's improvements.

It is more often than not a computer of a few sort which is utilized to keep data almost the robot and the working prepare and execute programs which work the robot. It contains programs, information calculations, rationale examination and different other handling exercises which empower the robot to perform its planning function.

End-effector could be a gadget at the conclusion of a mechanical arm, outlined to connected with the open world. The precise nature of execution of this gadget depends on the application of the robot.

Ordinary capacities of the end-effector comprise of getting a handle on, pushing, and pulling, bending, utilizing apparatuses, performing inclusions, welding, and different sorts of gathering exercises. Hence, the major sorts of robot end-effectors are:

Grippers:

Grippers are the foremost utilized sort of end-effectors. They can utilize distinctive holding strategies (such as vacuum or utilize of fingers).

Fabric expulsion instruments:

These incorporate cutting, boring and deburring apparatuses introduced as robot apparatuses.

## 1.1 HARDWARE DESCRIPTION

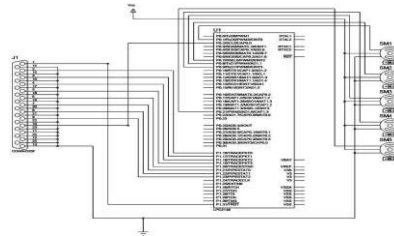


Figure 2 shows up the square chart of a 5 Degrees of opportunity robot arm control utilizing LabVIEW and ARM controller. The gear setup contains a PC (Person Computer).

Ann controller (LPC2148) and Dexter ER-2 a overpowering 5 Degree of opportunity mechanical arm. PC utilized inside the show work is DELL Optiplex380 which is competent of intrude a contraption through parallel communication and serial communication.

LPC2148 is an ARM7TDMI-S based high• execution 32-bit RISC Microcontroller with 6 PWM channels. The depiction of robot arm was inspected inside the mechanical setup section.

Dell OptiPlex 380 comprises of one parallel printer harbour with the base addresses of 0x338 and 0x778. A gadget can be interfaces to the PC utilizing DB25 parallel printer harbour connector at the raise conclusion of the computeFig. 1.3 Schematic of Robot Arm Control Using LabVIEW and ARM

## II. LITERATURE SURVEY

Certainly! Let's explore some literature related to 2-Degrees of freedom robotic arms. These arms are fascinating devices used in various applications, from industrial automation to research and development. Here are some notable studies:

### “Modeling of 2- Degrees of freedom Robot Arm and Control”:

This paper talks about modeling a 2-Degree of freedom robot arm by Ayodeji Okubanjo, Oluwadamilola Oyetola, Martinsifeko, Olawale Olaluwoye, and P. O. Alao. The model is made from nonlinear second-order ordinary differential equations. To get the right, they used Lagrangian and Euler-Lagrange equations. For control, they used proportional-integral-derivative (PID) controllers. The simulation was done with MATLAB and Simulink. It showed good control in joint space.

### A Comparative Analysis of Control Methods Applied to Horizontal 2- Degree of freedom Robotic Arm”:

This ponder investigates different sifting control calculations and compares their execution on a 2-Degree of opportunity flat mechanical arm through broad reenactments. The center is on accomplishing precise and strong way arranging and execution for mechanical robots. Here's a fun paper about a robot arm! The paper talks about how they controlled a 3D robot arm using a fancy controller called ST-FSMC. They used math to check if the robot arm would stay balanced. The team used a program called

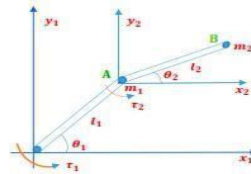
## III. METHODOLOGY

The elements of 2-Degrees of flexibility displayed employing a set of nonlinear, second-order, standard differential conditions and to mimic the flow precisely the and --- was embraced. Euler's detailing is chosen for its effortlessness, vigor energetic auxiliary property and negligible computational blunder as compared to Newton-Euler illuminate the inferred numerical show. The definition of the scientific model is considered significant within the investigate since the control methodology is explored based on these determined elements conditions, thus the show must be precisely anticipated to speak to the energetic behavior of the robot arm.

calculation is extended on the determined numerical show to control the development of the robot arm inside the



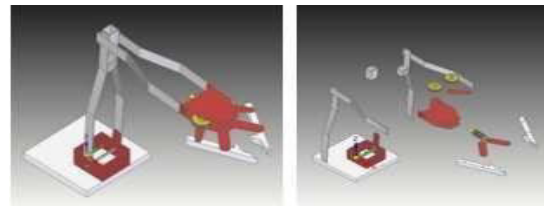
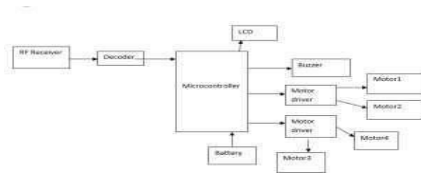
required direction or workspace; thus, we advance appropriate controller parameters for appropriate controlling of the robot arm inside the desired direction.



**Working principle.**

Recreation considers based on MATLAB and Simulink are performed taken into the thought the gotten PID controller parameters and the gotten parameters are utilized to approve the numerical demonstrate within the joint space. The assessment of the comes about gotten is displayed and examined broadly concerning accomplishment as well as giving suggestions for advance work. This work covers texture choice, arrange, programming, and creation of a fundamental computerized arm system. It as well covers the utilization unpretentious components of the assurance of the kinematic conditions and working standards.

**Definition of Degree of freedom:** In the context of robotics or mechanical systems, a degree of freedom represents an independent motion. For example, in a Cartesian coordinate system, you have three axes: X, Y, and Z. Each axis represents a degree of freedom. In a 3 Degree of freedom system, you typically have three such independent motions.



**IV. MATHEMATICAL MODEL OF 2- DEGREES OF FREEDOM ROBOT ARM**

First, the kinetic and the potential energies of the system are calculated, the kinetic energy of the manipulator as function of joint position and velocity is expressed as:

$$K(\theta, \dot{\theta}) = \frac{1}{2} \dot{\theta}^T M(\theta) \dot{\theta} = \frac{m_i v_i^2}{2} \tag{1}$$

where,  $M(\theta)$  is the  $n \times n$  manipulator mass matrix and the subscript  $i$  denote 1 and 2.

Hence, the total kinetic energy of the robot arm is the sum of the kinetic energies ( $K_1$  and  $K_2$ ) of the individual link.

$$K(\theta, \dot{\theta}) = \sum_i^n K_i(\theta, \dot{\theta}) \tag{2}$$

$$K(\theta, \dot{\theta}) = \frac{m_1 v_1^2}{2} + \frac{m_2 v_2^2}{2} \tag{3}$$

To calculate  $K_1$  and  $K_2$ , are differentiated the position equations for  $m_1$  at A as well as  $m_2$  at B are written and subsequently, we differentiate the respective positions using inner product to obtain their corresponding velocity.

$$x_1 = l_1 \sin \theta_1 \tag{4}$$

$$y_1 = l_1 \cos \theta_1 \tag{5}$$

$$x_2 = l_1 \sin \theta_1 + l_2 \sin(\theta_1 + \theta_2) \tag{6}$$

$$y_2 = -l_1 \cos \theta_1 - l_2 \cos(\theta_1 + \theta_2) \tag{7}$$

Considering velocity, it is defined as,

$$\frac{d}{dt} \begin{bmatrix} x \\ y \end{bmatrix} = \begin{bmatrix} \dot{x} \\ \dot{y} \end{bmatrix} \tag{8}$$

The mathematical model of a 3-degrees-of-freedom robot arm involves describing the relationships between the joint angles (or displacements) and the position and orientation of the end. This mathematical model is crucial for tasks such as trajectory planning, control algorithm design, and simulation. Here's a general approach to developing the mathematical model of a 3-Degree of freedom robot arm:

## V. MATERIAL SELECTION

When selecting materials for a robotic arm, we need to consider a few important properties like strength, lightness, availability, and ease of cutting. It's super crucial that the material is strong enough to handle the weight that the motors, other links, and payload put on each arm link. And hey, using a lightweight material can help reduce the torque needed for the robotic actuators, which saves money.

## VI. ROBOTIC ARM STRUCTURE

As prior expressed within the early on chapter of this report, the automated arm has degrees of flexibility with the consideration of the gripper. A CAD (Computer Helped Drafting) demonstrates of a automated arm structure was outlined and rendered utilizing Autodesk's AutoCAD® and CATIA computer program. The CAD show is appeared in Figure 1.

## VII. APPLICATIONS

Applications of 3 Degree of freedom Robot Arm:

1. Pick-and-Place Operations: Efficiently move objects from one location to another within a limited workspace.
2. Assembly Tasks: Perform assembly operations where components need to be manipulated and assembled in a controlled manner.
3. Machine Tending: Load and unload parts from machines such as Computer numerical control machines or 3D printers.

**Applications of 2-Degree of freedom Robot Arm:**

1. Simple Manipulation Tasks: Perform basic manipulation tasks such as moving objects along a plane or rotating objects about an axis.
2. Educational Purposes: Provide a simple platform for learning about robotics and basic kinematics.

**Advantages:**

**Advantages of 3-Degrees Robot Arm:**

1. Enhanced Workspace Coverage: The additional degree of freedom allows for a larger workspace coverage, enabling the arm to reach more positions and orientations.
2. Improved Manipulation Capabilities: The extra degree of freedom enables the arm to perform more complex manipulation tasks such as orienting objects in 3D
3. Versatility: 3-Degrees of freedom arms are more versatile and suitable for a wider range of applications compared to 2-Degrees of freedom arms.

**Advantages of 2-Degrees of freedom Robot Arm:**

1. Simplicity: 2-Degrees of freedom arms are simpler in design and control compared to 3-Degrees of freedom arms, leading to easier construction and maintenance.
2. Cost-Effectiveness: Due to their simpler design and fewer components, 2-Degrees of freedom arms are generally more cost-effective to manufacture and deploy.

**Disadvantages:**

**Disadvantages of 3-Degrees of freedom Robot Arm:**

1. Complexity: The additional degree of freedom introduces complexity in the design, control, and kinematics of the arm compared to 2-Degrees of arms.
2. Increased Cost: 3-Degrees of freedom arms are generally more expensive to manufacture and deploy compared to 2-Degrees of freedom arms due to their additional components and complexity.

**Disadvantages of 2-Degrees of freedom Robot Arm:**

1. Limited Manipulation Capabilities: With fewer degrees of freedom, 2-Degrees of freedom arms have limited manipulation capabilities compared to 3-Degrees of freedom arms, restricting their ability to perform complex tasks.
2. Reduced Workspace Coverage: 2-Degrees of freedom arms have a more limited workspace coverage compared to 3-

Degrees of freedom arms, limiting their reach and

**VIII. DIFFERENCES BETWEEN 2 DEGREES OF FREEDOM & 3 DEGREES OF FREEDOM**

Aspect	2-Degrees of freedom Robot Arm	3-Degrees of freedom Robot Arm
Degrees of Freedom (DOF)	Two joints, providing two degrees of freedom.	Three joints, providing threedegrees of freedom.
Motion Capability	Limited to simple planar motion or rotation.	Capable of more complex motion and orientation in 3Dspace.
Workspace Coverage	Typically has a more restricted workspace.	Provides a larger workspacecoverage.
Complexity	Simpler in design, construction, and control.	More complex in design, construction, and control.
Manipulation Capability	Limited manipulationcapabilities.	Enhanced manipulationcapabilities.
Applications	Suitable for tasks within a confined workspace.	Widely used in industrial automation, manufacturing, andresearch.
Control Complexity	Easier to implement and control due to fewer Degree of freedom.	Requires more sophisticated control algorithms.
Examples	Robotic arms with shoulder and elbow joints.	Robotic arms with shoulder, elbow, and wrist joints.
Efforts	Simple pick-and-placeoperations.	Assembly tasks with multiple orientations.

**IX. CALCULATION**

**2- Degrees of freedom & 3-Degrees of freedom Robotic Arm**

For a 2-Degrees of freedom robotic arm with two rotational joints (shoulder and elbow), the forwardkinematics can be calculated using the Denavit-Hartenberg (DH) parameters. Here's a simplified overview of the process:

$$T_i^{i-1} = \begin{bmatrix} \cos(\theta_i) & -\sin(\theta_i) \cos(\alpha_i) & \sin(\theta_i) \sin(\alpha_i) & a_i \cos(\theta_i) \\ \sin(\theta_i) & \cos(\theta_i) \cos(\alpha_i) & -\cos(\theta_i) \sin(\alpha_i) & a_i \sin(\theta_i) \\ 0 & \sin(\alpha_i) & \cos(\alpha_i) & d_i \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

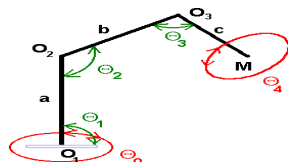
Let's compute the transformation matrices for the 2-DOF robotic arm using the DH parameters we defined earlier:

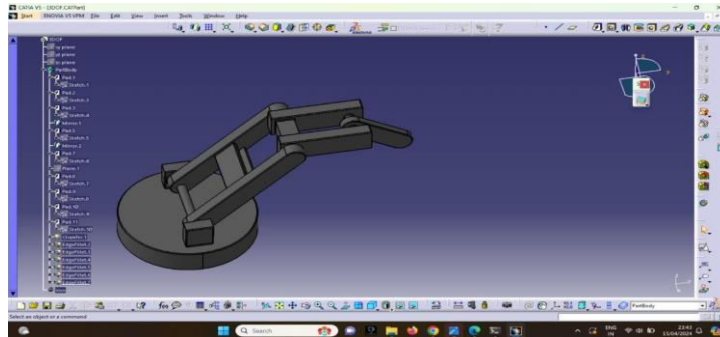
1. For Joint 1 (Shoulder):

$$T_1^0 = \begin{bmatrix} \cos(\theta_1) & -\sin(\theta_1) & 0 & 0 \\ \sin(\theta_1) & \cos(\theta_1) & 0 & 0 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

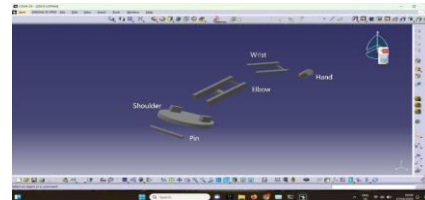
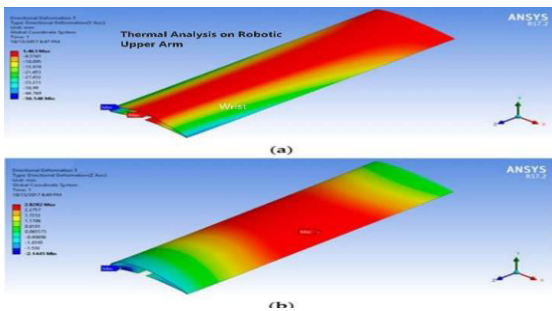
1. For Joint 2 (Elbow):

$$T_2^1 = \begin{bmatrix} \cos(\theta_2) & -\sin(\theta_2) & 0 & l_1 \cos(\theta_2) \\ \sin(\theta_2) & \cos(\theta_2) & 0 & l_1 \sin(\theta_2) \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix}$$





**Thermal Analysis:**

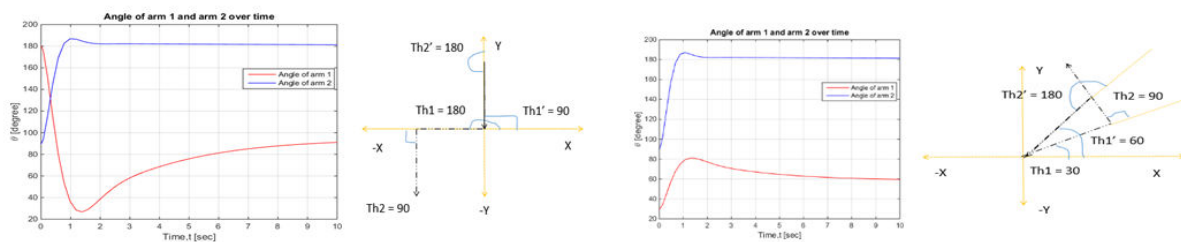


**Thermal analysis** is a technique used to analyse the time and temperature at which physical changes occur when a substance is heated or cooled. It provides insights into how a material behaves under varying temperature conditions. Let's delve into the basics and applications of thermal analysis:

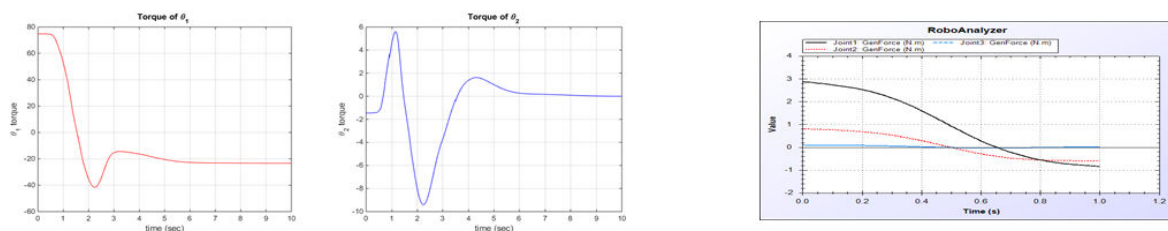
**Methods of Thermal Analysis:**

**Differential Scanning Calorimetry (DSC):** Measures the heat flow associated with phase transitions, such as melting, crystallization, and glass transitions.

**Result:**



**Fig:9.13 The angle positions of the arm**

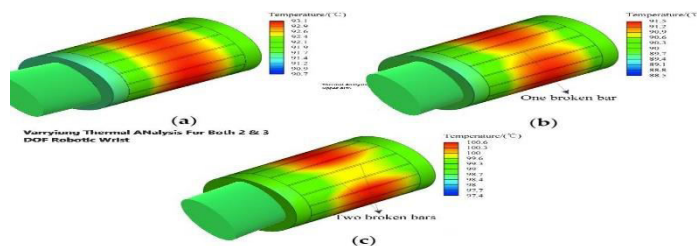


**Fig:9.15 Torque of theta 1**



## X. CONCLUSION

In this study, we designed and modeled a pick-and-place robotic arm with both 3-DOF and 2-DOF configurations. The primary focus was on project purposes, emphasizing improved accuracy through servo-powered joints. CATIA software and Ansys Workbench facilitated the design process, while aluminum was chosen for component fabrication. Mathematical modeling, based on nonlinear second-order ordinary differential equations, allowed us to control the robot arm's joint angles effectively. By decoupling the coupling effect, we achieved the desired freedom for precise arm manipulation.



Overall, this project contributes valuable insights into robotic arm design and control.

Leveraging CATIA software, we meticulously crafted the robotic arm's components. Aluminum, known for its lightweight and robust properties, was our material of choice. The selection process involved evaluating torque requirements at each joint. Properly sized servos were crucial for smooth operation. As an educational tool, our robotic arm provides hands-on experience in robotics, mechanics, and control theory.

## REFERENCES

1. R. M. Murray, Z. Li, and S. S. Sastry, *A Mathematical Introduction to Robotic Manipulation*, vol. 29. 1994.
2. M. V. Mark W. Spong, Seth Hutchinson, "Robot dynamics and control," in *Robot Dynamics and Control*, First., Wiley, 2004, pp. 187–221.
3. C. R. A. Rocha, C. P. Tonetto, and A. Dias, "Robotics and Computer-Integrated Manufacturing (CIM)
4. Comparison between the Denavit – Hartenberg and the screw-based methods used in kinematic modeling of robot manipulators \$," *Robot. Comput. Integr. Manuf.*, vol. 27, no. 4, pp. 723–728, 2011.
5. J. Vertutt, "General Design Criteria for Manipulators," vol. 16, no. iii, pp. 65–70, 1981.
6. Amin, A. T. M., Rahim, A. H. A. & Low, C. Y. (2014). Adaptive controller algorithm for 2-DOF humanoid robot arm. *Procedia Technology*, 15, 765–774
7. Bonkovic, M., Stipanicev, D. & Stula, M. (1999). Control of robot arm approach by Fuzzy Pattern comparison technique. Springer, Berlin, Heidelberg, 246 – 252
8. Branch, I. (2012). A new method for position control of a 2-DOF robot arm using neuro – fuzzy controller. *Indian Journal of Science and Technology*, 5(3), 2253–2257.
9. Craig, J. J. (2005). *Introduction to Robotics*. IEEE Expert, (3rd ed., Vol. 1). Pearson Education International.
10. David, I & Robles, G. (2012). PID control dynamics of a robotic arm manipulator with two degrees of freedom. *Control de Processos Y Robotica*, 1–7.
11. Gea, J. de, & Kirchner, F. (2008). Modelling and simulation of robot arm interaction forces using impedance control. *Proceedings of the 17th World Congress*, 15589– 15594
12. Guler, S. & Ozguler, A. B. (2012). Tracking and regulation control of a 2-DOF robot arm with unbalance. 2012 17th International Conference on Methods and Models in Automation and Robotics (MMAR)





INTERNATIONAL  
STANDARD  
SERIAL  
NUMBER  
INDIA



# INTERNATIONAL JOURNAL OF INNOVATIVE RESEARCH

IN SCIENCE | ENGINEERING | TECHNOLOGY

 9940 572 462  6381 907 438  [ijirset@gmail.com](mailto:ijirset@gmail.com)



[www.ijirset.com](http://www.ijirset.com)

Scan to save the contact details