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DESIGNING ROBOTIC MANIPULATOR ARM

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***Abstract:* Robotics is the branch of mechanical engineering, electrical engineering and computer science that deals with the design, construction, operation, and application of robots, as well as computer systems for their control, sensory feedback, and information processing. In the field of Robotics, one of the important parts is Kinematic modelling. Here, kinetic modelling was used for 3-link robotic arm manipulator. The kinematic modelling of the 3-link robotic arm manipulator with end effectors was carried out. In the following paper, kinematic equations were solved using Denavit-Hartenberg matrix. Then multi-body dynamics analysis was used to calculate different dynamic forces. Further, software analysis along with some mathematical formulation was done to verify the results.**

***Keywords:* Robotics, Kinematic Modelling, Denavit-Hartenberg model, Multi body dynamics**

I. INTRODUCTION

In engineering, Dynamics & Kinematics are important with respect to development of special robots. Dynamics is concerned with study of forces and torques and their effect on motion as opposed to Kinematics, which studies the motion of robots without considering forces acting on it. The aim of kinematics is to define position relative to reference frame & its origin. Kinematics is further sub-divided into two parts: Forward and Inverse kinematics. Forward and inverse, it is like a function and its inverse. In robotics, they normally refer for calculating the relations between end-effectors and joint angles. So for forward kinematics, the joint angles are the inputs, the outputs would be the coordinates of the end-effectors. On the other hand for inverse kinematics, the given inputs are the coordinates of the end-effectors, the outputs to calculate are the joint angles. This work presents the analysis, simulation, and design of a three-degree-of-freedom reconfigurable robotic arm. Actuation system was made up of High torque dc motors. An actuator is a type of motor that is responsible for moving or controlling a mechanism or system. A potentiometer was used for calculating the joint angle and then final position was obtained. Denavit–Hartenberg representation was used in the work. In Multibody dynamics analysis, dynamics of mutually-interconnected multiple rigid bodies is studied. The following work involved software analysis and mathematical formulation to check how bodies behave and move as a single system and what kinds of different forces are generated in the process with static analysis. The forward dynamic problem yields the motion of a Multibody system over a given time interval, as a consequence of the applied forces and given initial conditions.

II. MODEL OF ROBOT

The double arm robotic manipulator possesses a total of nine degree of freedom. 3D CAD Catia software was used to create the manipulator system. The payload on manipulator arm is of 1.2 kg. Forces were calculated at each joint for manipulator arm shown in Figure I.

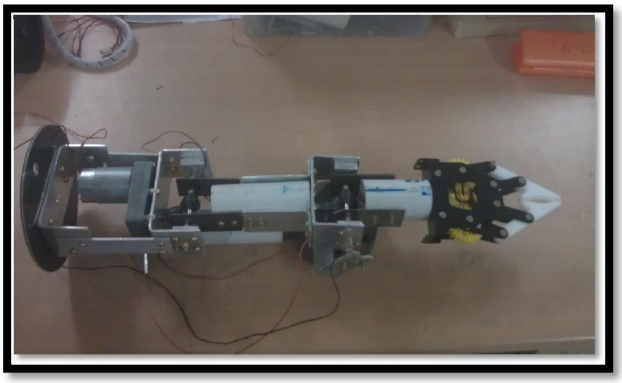

Figure 1: Manipulator Arm

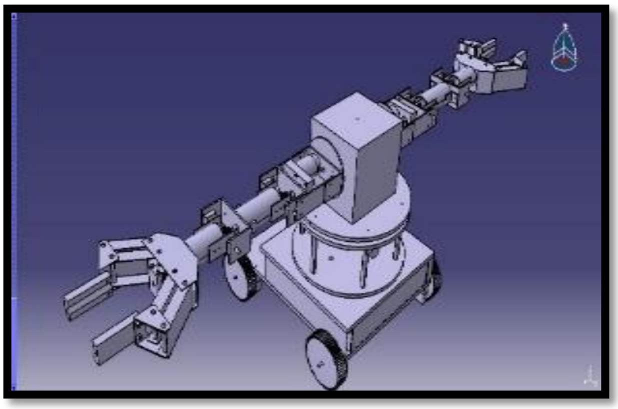

Figure 2: 3D CAD Model of Manipulator

III. APPROACH

A. Denavit-Hartenberg Convention

This is a convention used to attach a coordinate system to each link of a manipulator. The coordinate systems are attached according to the following rules :

- The origin of coordinate sytem i is located at the point of intersection of the axis of Joint $i + 1$ and the common normal between the axes of joints i and $i + 1$.

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- The z_i-axis is aligned with the axis of the $(i+1)^{th}$ joint. The positive direction of this axis can be chosen arbitrarily.
- The x_i-axis is aligned with the common normal of the i^{th} and $(i+1)^{th}$ joint axes and points form the i^{th} to $(i+1)^{th}$ the joint.
- The y_i-axis is determined using the right-hand rule.

The coordinate systems of the ground and effector links do not follow these rules. The coordinate system of the ground link can be chosen based on convenience as long as the z_0-axis is aligned with the axis of joint 1. The coordinate system of the end effector, also called the hand coordinate system, can also be chosen based on convenience as long as its x -axis is normal to the last joint axis.

B. Denavit-Hartenberg Parameters
Any serial manipulator can be described kinematically by specifying four parameters for each link.
Regardless of the physical construction of the actual link connecting two joints, their relative location can be described using two parameters:

- a_i : length of the common normal between the axes of joint i and $(i+1)^{th}$ joint . This is also known as the length of the link.
- α_i : angle measured from the axis of joint i to axis of joint $(i+1)$. This is also known as the twist of the link.

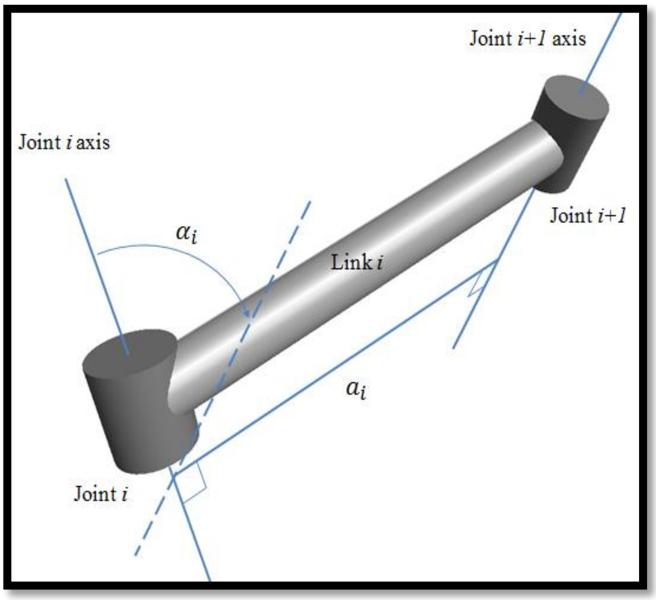

Figure 4: Length and Twist

Similarly, two more parameters can describe the locations of the links relative to each other:

- d_i : offset distance between the common normal of the axes of joint $(i-1)$ and joint i and the common normal of the axes of joint i and joint $(i+1)$. This is also known as the offset of the link.
- θ_i : angle between the common normal of the axes of joint $i-1$ and joint i and the common normal of the axes of joint i and joint $i+1$. This is also known as the angle of the joint.

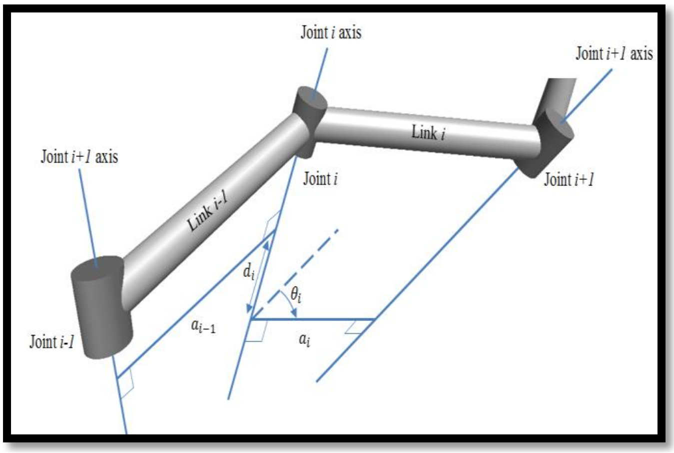

Figure 4: Offset and Angle

The arms of robotic manipulator arm are symmetric to each other & the results are calculated using relevant data.

Joint i	$\boldsymbol{\theta_i}$	$\boldsymbol{d_i}$ (mm)	$\boldsymbol{a_i}$ (mm)	$\boldsymbol{\alpha_i}$
0	θ_1	0	0	90°
1	θ_2	74	0	90°
2	θ_3	0	160	0
3	θ_4	0	0	0

TABLE 1: D-H PARAMETER FOR MANIPULATOR ROBOT

C. Denavit-Hartenberg Homogeneous Transformation Matrices
Using the DH convention and parameters, transformation matrices relating two successive coordinate systems can be established. They are called Denavit-Hartenberg Homogeneous Transformation Matrices. Four basic parameters for the matrix are translation about z_{i-1} axis by distance d_i , rotation about z_{i-1} by an angleθ_i, rotation about xi axis by an angle α_i, and translation along x_i axis by distance a_i .

$$A_i = Trans\,(z, d_i) Rot\,(z, \theta_i), Trans(\,x, \alpha_i)\; Rot\,(x_i\,, a_i)$$

Using above equation, the resultant H matrix is,
H = H_n= $A_1 * A_2 * A_3 * A_4$
H = -0.9425 0 0.2998 24.9887

$$\begin{bmatrix} 0 & 1 & 0 & 0 \\ -0.299 & 0 & -0.9425 & -160.061 \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

After this, we calculate static forces which are acting on all joints of arm. The basic mathematical equations are then composed for calculating forces acting at each joint of the arm. The values of the force acting at each joint have been stated below in table.

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Link	Weight (kg)	Length (mm)	Force, mg (N)
1	1.8	147	17.72
2	1.2	160	11.85
3	1.1	195	10.65

TABLE 2: MATHEMATICAL FORMULATION FOR FORCE

Mathematical solutions were examined and then compared with above stated work. For the purpose of Multi body dynamic analysis, the motion view module was taken into consideration. The software is justified for the durability, quality, and speed. The results are displayed here.

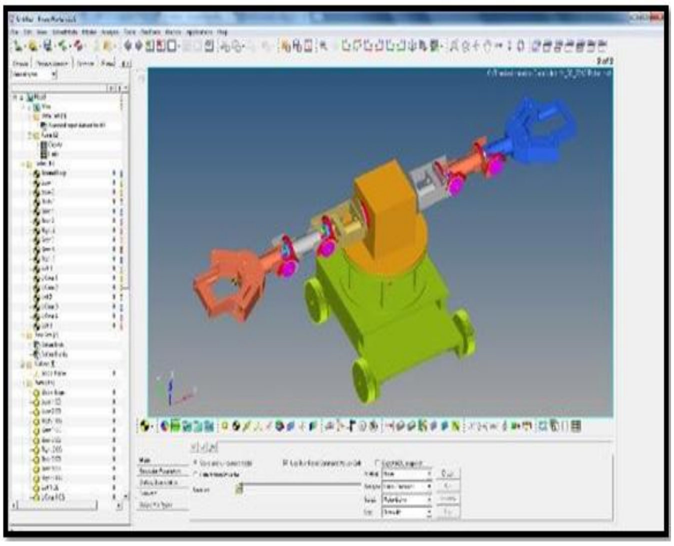

Figure 5: Multi Body Dynamics Analysis Using Software

IV. RESULTS

SN	JOINTS	EXPERIMENTAL RESULTS FOR FORCE	SOFTWARE RESULTS OF FORCE
1	Joint 1	17.72	18.00
2	Joint 2	11.85	12.00
3	Joint 3	10.65	9.86

TABLE III: FORCE RESULT COMPARISON

V. CONCLUSION

In this paper, static force equation was used to study payload characteristic. Also both experimental as well as software results were calculated to verify the study. It was found that both results are in good agreement. These results will help to choose proper actuators in the application of pick and place robot.

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