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

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# Design, Simulation, and Analysis of a 6-axis Robot using Robot Visualization Software

Ramavath Mallikarjuna Naik, Shreenivas

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

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

**ABSTRACT:** In this advanced technological world, robots play an important role in achieving the tasks of a human. Robots have become an essential aspect of the industry, need well-trained engineers to optimize the robot manipulator. To obtain the optimum elements of the work to be carried, a systematic approach required to design, simulate, and analysis of customized robots. The SolidWorks software is used to design the robot and analysed using the SolidWorks Simulation Xpress and motion study. The robot visualization software: Robo Analyzer used to analyse the robot kinematics and dynamics. This 3-dimensional software's help to improve the skills and knowledge of industrial robots. Robot design, simulation, and analysis require the use of 3-dimensional software in the event of an invention needed to develop the high-quality design and improved speed where the industry needs.

**KEYWORDS:** Robot visualization, SolidWorks, Robo Analyzer, Robot manipulator, Industrial robots.

## I. INTRODUCTION

In the century, the automation industries are growing with the increasing market and with huge demand in the development of advanced technology. The huge demand in the automation, the conventional technique has been replaced. Many industries are nowadays looking for automation technology rather than the traditional method due to the market.

The disadvantages of the traditional way force the industrialists to look towards the automation technology. In the automation technology, flexible automation creates massive demand in the automobile, aerospace, electronics, medical, etc. as compared to fixed automation. In the field of flexible automation, industrial robots have reached almost all the industries due to its n-number of applications.

With the increasing demand for industrial robots, the engineers must design, simulate, and analyze the optimization of manipulator joints and end effectors using robot visualization software.

The robot manipulator is a combination of link lengths, joint angles, and kinematic mechanisms, regarded as a complex system. It includes engineering principles and laws during the design and development of the robot. Exceptional design decisions are required while integrating complex components during the beginning of the design.

A combined knowledge such as mechanical, electrical, electronics, and computer software is essential to develop robotic systems and manage the functionalities of the robotic system. To minimize the system complexity and functionalities of the system, the proposed software tools help the robotic engineers to optimize the design and help to analyze the robot system from the beginning of the process.

In this paper, an attempt has been made to optimize the design and analyze the system specifications. The article enumerates the kinematic model, visualization of robot motion, and motion study of the 6-axis robot using solid works and Robo Analyzer visualization software.

Throughout history, it has been frequently assumed that robots will one day be able to mimic human behavior and manage tasks in a human-like fashion.

Many robots do jobs that are hazardous to people such as defusing bombs, and mines, and exploring shipwrecks. Robotic devices are used in all aspects of our world. Whether in automation for factories and businesses, personal prosthetics, or used for off-world exploration in space and on other planets, we rely on robotics every day to reduce.



**Pneumatics in Material Handling**

Pneumatic systems usually operate at a much, lower pressure than hydraulic systems do, pneumatics holds many advantages that make it more suitable for many applications. Because pneumatic pressures are lower, components can be made of thinner and lighter- weight materials, such as aluminum and engineered plastics, whereas hydraulic components are generally made of steel and ductile or cast iron. Hydraulic systems are often considered rigid,

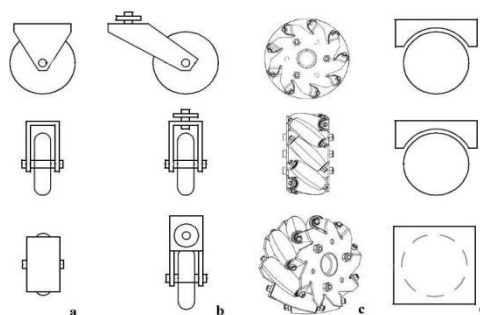
Pneumatics also holds advantages over electromechanical power transmission methods. Electric motors are often limited by heat generation. Heat generation is usually not a concern with pneumatic motors because the stream of compressed air running through them carries heat from them. Furthermore, because pneumatic components require no electricity, they don't need the bulky, heavy, and expensive explosion-proof enclosures required by electric motors. Electric motors, on the other hand, can overheat and burn out if overloaded.

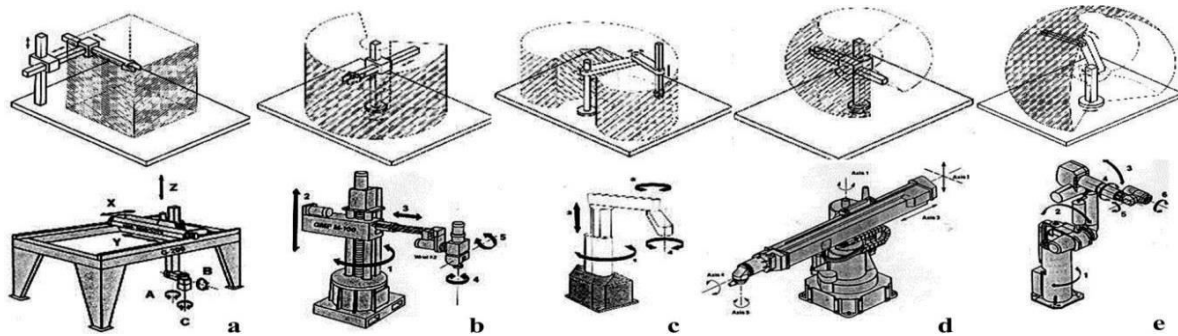
Moreover, torque, force, and speed control with pneumatics often require simple pressure- or flow control valves, as opposed to more expensive and complex electrical drive controls. And as with hydraulics, pneumatic actuators can instantly reverse direction, whereas electromechanical components often rotate with high momentum, which can delay changes in direction

**Operation of The Pneumatic System**

To affect mechanical motion, pneumatics employs the compression on of gases, based on the working principles of fluid dynamics in the concept of pressure. Any equipment employing pneumatics uses an interconnecting set of components: a pneumatic circuit consisting of active components such as a gas compressor, transition lines, air tanks, hoses, open atmosphere, and passive components. Compressed air is supplied by the compressor and is transmitted through a series of hoses. Air flows are regulated by valves and the pneumatic cylinder transfers the energy provided by the compressed gas to mechanical energy. Aside from compressed air, inert gases are also applied particularly for self-contained steams. Pneumatics is applied in a wide range of industries, even in mining and dentistry. The majority of industries use gas pressures of about to pounds/ sq inch.

To control the system, only ON and OFF are used and the system consists only of standard cylinders and other components, making it simpler than hydraulics. Pneumatic systems require low maintenance and have long operating lives. Lastly the working fluid .





## II. DESIGN SPECIFICATIONS

Preparing a design specification is one of the most primary tasks involved in the design process. This document intends to show what one is trying to achieve and not what one will finally end up with. Practically it is a set of clear cut requirements or critical parameters that helps in answering the problem at hand. For a design to be successfully implemented, it has to adhere to these important characteristics of the design specifications.

As the work progresses we get to understand the project better and new information and knowledge gathered from the work lead to improvisation of the initial parameters and as a result the design specification constantly get evolved. Thus this documentation gives a detailed description of what is the intended task with the product and how it can be achieved.

This chapter has been divided into two separate sections, one dealing with the design specification of the robotic manipulator and the other dealing with the design specification of the mobile robotic platform.

A simple search for a robot design leads to a wide collection of information on the internet or in the market and to decide from this is a tedious task. The design requirements for both the manipulator and mobile platform have been extensively studied through literature survey and product survey. The study of design principles behind numerous robots available in the market and in the laboratories led to a precise understanding of our requirement.

### 1. Design Specifications of the Robotic Manipulator

A robotic manipulator is basically a chain of rigid bodies called links interconnected to one another by joints. The chain of links has an end-effector attached to it on one end and the other end is fixed to the base. The objective of the manipulator is to handle objects by controlling both the position and orientation of the end-effector by following a planned trajectory within its workspace as programmed.

Both are five-axis articulated robotic manipulators with tool pitch and roll motions. They use closed-loop position control with DC motors and incremental encoder for joint actuation.

They are electric driven and has point-to-point motion control. The physical structure of these robots is such that the base motor is fixed vertically and the motors for the motion of the shoulder joint, elbow joint and tool pitch fixed horizontally onto the body and this body is then fixed on to a base motor.

Also, the end effector's roll motion and the gripper mechanism are separately powered by smaller drives mounted at the end effector itself. These joints are actuated through chain and sprocket mechanism.

#### 1. Fundamental Design of the Robotic Manipulator

The manipulator is powered by DC motors fixed at the body. This distributes the weight effectively and also helps in reducing the load on motors considerably unlike in designs with the motor fixed at the joints. The body is fixed on to a vertically placed motor at the base (Fig.3.2 b). In between the body and the end effector there are two links, these links are interconnected by joints at the shoulder and the elbow (Fig.3.2 c & d).



These links are actuated through chain and sprocket mechanism. The end effector’s pitch motion (Fig.3.2 e) is also controlled by a drive at the body. Two separate servo motors fixed on the end-effector actuate its roll motion (Fig.3.2 f) and the gripping mechanism.

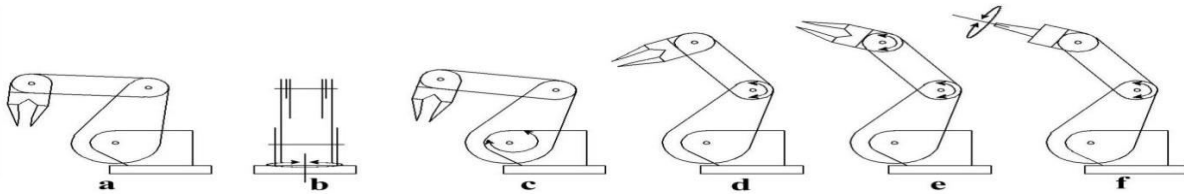


Fig.3.2 Various Motions of the Manipulator Parts

The basic dimensions of the manipulator are as shown in Fig.3.3. The shoulder joint is about 95mm from the base. The two links in between the end-effector and the body is about 170mm each. The length of the end-effector from the joint to the tip of the gripper is 135mm.

The rotational limitation of each link is illustrated in Fig.3.4. The shoulder joint link 1 can rotate a total of 120 degrees back and forth. Similarly link 2 can rotate a total of 220 degrees back and forth and the end-effector can rotate 180 degrees about its joint. The body attached to the vertically mounted motor rotates the manipulator perpendicularly through an angle of 340 degrees.

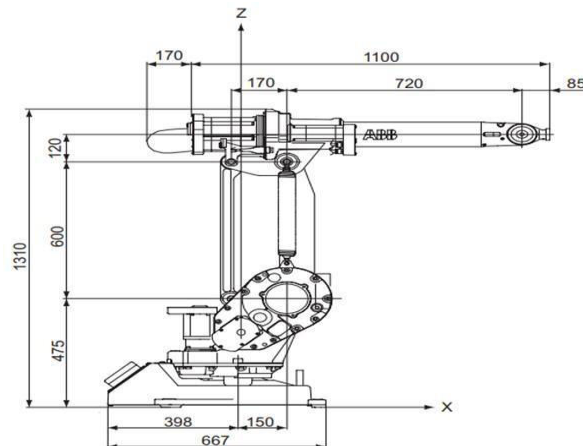


Figure . Dimensions in ABB IRB specifications.

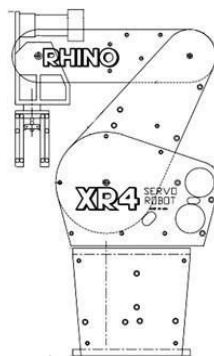


Figure . GUI of Robo Analyzer

1. Robot model in Robo Analyzer

Once the DH parameters of a robot arm are extracted, it is easy to create a skeleton model of the virtual robot in Robo Analyzer software.

The simple GUI of the Robo Analyzer allows to enter the values in DH parameters, and the virtual model of the robot is instantly created. A screenshot of IRB robot's skeleton model is shown in Figure.

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**III. FORWARD KINEMATICSOFTHE -AXIS ROBOT**

In forward kinematics, joint angles are prescribed, and the position and orientation of the end-effector of the robot arm are determined. A homogenous transformation matrix from the base of the robot to the end-effector of X dimension is derived based on the DH parameters.

Where,  $R \times$  represents the orientation of the end-effector using direction cosine methodology and  $[x,y,z]^T$  represent its position vector concerning the reference frame.

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Where,  $R \times$  represents the orientation of the end-effector using direction cosine methodology and  $[x,y,z]^T$  represent its position vector concerning the reference frame. The homogenous transformation matrix operation can be visualized in the RoboAnalyzer by entering the input values in the DH table provided in the RoboAnalyzer. An example of the position of the end-effector is as given in Figure .

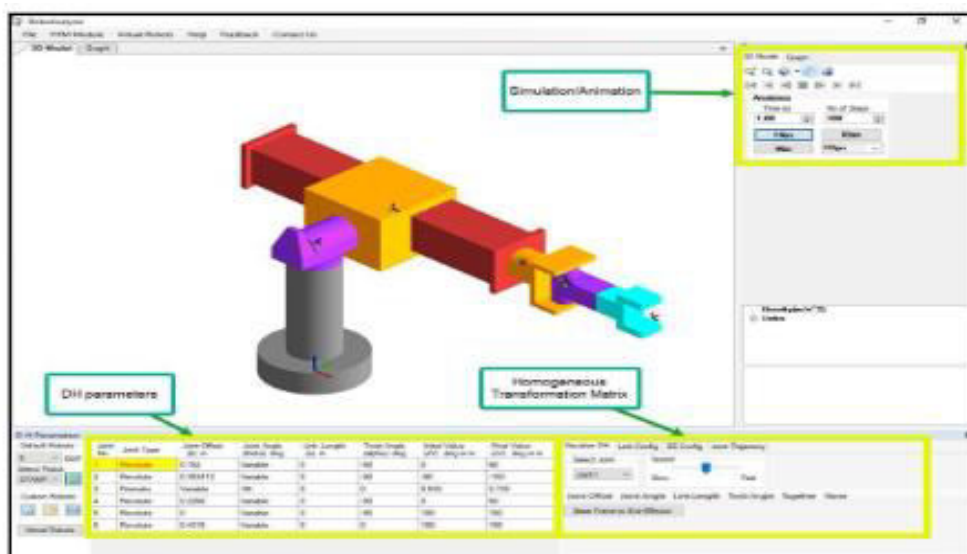


Figure . Homogenous Transformation Matrix in RoboAnalyzer.

The homogenous transformation matrix can be verified and visualized in the graph. Figure shows the position of the end-effector in  $[x,y,x]^T$  space. The x-axis of the graph represents the simulation

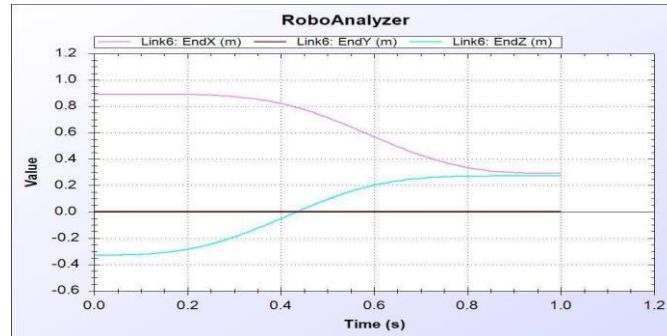


Figure . Graphical representation of the position of the robot end-effector in RoboAnalyzer software.

### Visualization of the Robot Motion

Visualization of the motion of the robotics is quite tricky without any aid of a software tool. Robot visualization software plays an important role here by helping to visualize the robot path in D space along with the path traced by the end-effector.

Roboanalyzer allows the user to enter the required DH-parameter. Once the parameters are entered, the forward kinematics operation is performed to simulate the robot. It also shows the pose of the end-effector in the matrix, as shown in figure

Robo Analyzer also includes a Virtual Robot Module (VRM) that allows a user to use a teach pendant-style interface to operate one of the preloaded industrial robots, as shown in figure

## V. INVERSE KINEMATICS

Inverse kinematics analysis deals with determining the joint angles for the prescribed position and orientation of the end-effector of the robot arm in D - space. Inverse kinematics requires mathematical derivations to achieve the solutions for the given pose of the robot. As the number of degree of freedom increases the amount of inverse kinematics solution also increases.

The Robo Analyzer has inverse kinematics module where a user can choose a robot. The software shows multiple solutions in the case of inverse kinematics. Figure shows an example of inverse kinematics in Robo Analyzer

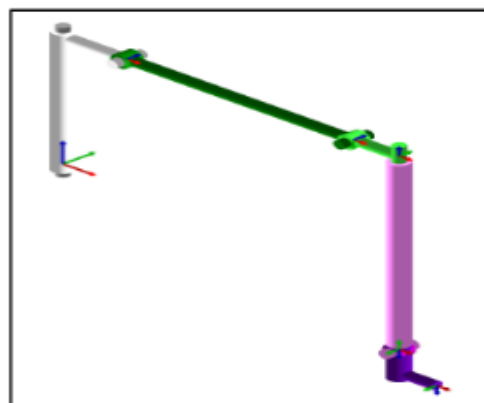


Figure . Inverse Kinematics analysis showing all possible solutions.



## VI. CONCLUSION

The -axis robot is designed using SolidWorks software and studied the motion analysis using robot visualization software. The robot kinematic and dynamic model of the -axis robot has been developed based on the customized design using robot visualization software such as Robo Analyzer.

The optimization of the design, kinematic and dynamic model and motion studies has been successfully analyzed and proposed to the robotic engineers to reduce the effort and cycle time in the automobile, aerospace, electronics, medical, etc. industries

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