

DESIGN AND FABRICATION OF PNEUMATIC ROBOT

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Abstract : Robotic arm (also referred to as robotic manipulator) are mainly used to carry out highly repetitive, material handling and precision tasks such as spot welding, assembling, cutting, palletizing, spray painting etc in manufacturing industries. It is a device with similar attributes to that of a human arm and is best suited to hazardous environments where human intervention is highly undesirable. System that uses compressed air as its main source of energy are termed as pneumatic systems. Pneumatic driven systems are of lower cost than hydraulic and electromechanical systems and perform well in carrying out arduous work. Advantages of pneumatically actuated systems are mainly increased level of safety, cleanliness, variable load carrying capacity, simple configuration, minimum pollution, reliable, storage capability and high strength to weight ratio, ease of maintenance, high speed and fast transmission. The main behind the robotic arm is that it imitates the actions of human arm or hand. This project aims in design and fabrication of pneumatic robot for handling the objects. In this robotic arm is driven by the pneumatic actuators. This robot doesn't have any kind of sensors and is manually operated with the help of Direction Control Valves (DCVs). We developed a pneumatic robot driven by pneumatic actuators as a versatile end effector for material handling systems. The arm consists of pneumatic arm and pneumatic wrist. The hand mimics the human hand shape and can grasp objects that have different shapes and mechanical characteristics.

IndexTerms - *pneumatic robot, compressor, pneumatic actuators, feedback controls, DCV.*

1. INTRODUCTION

The population of Japan has started to decrease, leading many in the country to be concerned about its labor force shrinking. In industrial fields, automation of the factories is one way to make up for reduced man power. This leads to other advantages such as making production more efficient and cutting labor costs. Various robots have been used in factories, for example, welding robots and material handling machines in car factories. However, the work robots can perform is limited and there are difficulties adapting these to different environments. This is because most factory robots are controlled by only sequence control. Using only sequence controllers, it is difficult for the robots to work depending on the time and situation. Because of this, the robots cannot adapt to sudden changes in circumstances.

Pneumatic systems are becoming increasingly popular due to their high speed and force capability, as well as relatively low price and overall robustness. From the perspective of bio-robotics, pneumatic actuators are further desirable because they have many of the essential properties of biological muscle at the mechanism level – which we believe is quite different from trying to re-create those properties using feedback control. In particular as the joint moves in the direction of actuated force, the chamber volume increases and thus the pressure/force drops, resulting in stiffness. This stiffness can be tuned by activating opposing cylinders, much like a biological limb becomes stiffer when antagonist muscles co-contract. The actuator has an internal activation state (air mass in the case of pneumatics, calcium concentration in the case of muscles) whose dynamics make the entire system 3rd-order. The latter dynamics effectively introduce a low-pass filter between command signals and forces, with similar time-constants for muscles and pneumatic cylinders. Since the actuators are often linear they can be mounted in a way reminiscent of muscle attachment to the skeleton, resulting in moment arms which vary with joint angle. The high force output makes gears and other amplification mechanisms unnecessary, which in turn results in uniquely compliant systems capable of dynamic interactions with the environment. One could argue that some of these properties are unnecessary complications. However, if we are serious about understanding the principles of biological control and replicating those principles in synthetic systems, it would be a mistake to ignore the fact that biological control has evolved in the context of the muscular-skeletal plant and is profoundly shaped by the unusual properties of this plant.

Due to the highly nonlinear properties of pneumatic modeling and uncertainties of various parameters, the control problems become challenging for systems with high precision requirement on force and position. Various approaches have been proposed to cope with these problems. Early applications used a linearized state space model to develop an optimal regulator for a fixed operating point. Later, adaptive control was used for actuating an air power robot.

PROBLEM STATEMENT:

The industrial robots are mainly operated by means of hydraulic or electrical actuating system. Hydraulic actuators require many complementary parts, including a fluid reservoir, motor, pump, release valves, and heat exchangers, along with noise reduction equipment which increase the cost. Whereas, Electrical actuators are not suited for all environments, unlike pneumatic actuators, which are safe in hazardous and flammable areas and a continuous running motor will overheat, increasing wear and tear on the reduction gear. Pneumatic systems are very useful to overcome these disadvantages of hydraulic and electrical systems. Compared to both, pneumatics is cost effective and suitable to use in different kinds of environment.

2. LITERATURE REVIEW

Santosh Et al [1] aimed to Design and Fabricate pneumatic arm for pick and place of cylindrical objects. The handling of materials and mechanism to pick and place of object from lower plane to higher plane and are widely found in factories and industrial manufacturing. The designed pneumatic arm consists of two cylinders, a shaft works with lead screw mechanism capable of converting motion of piston to rotational motion of with the help of compressed air.

Frank Daerden Et al [2] intended an introduction to and an overview of Pneumatic Artificial Muscles (PAM's). These are pneumatic actuators made mainly of a flexible and inflatable membrane. The authors explained about the PAM's concept & way of operation, properties of these actuators and classification & review.

Biswas Palok Et al [3] had designed and assembled a 3 axes articulated pneumatic robotic arm in this project along with its control systems. Pneumatic rod less linear actuators was used as the main drive system for the robotic arm and was controlled by 5/3-way proportional directional control valve. Two control systems are designed for the robotic arm: Programmable logic Controller (PLC) and Aurdino UNO micro controller. It employed open loop control with PLC at first and closed loop PID control using Aurdion UNO in latter part of the study.

Rakesh N Et al [4] proposed a cheap and effective method for design and manufacturing of a three degree of freedom revolute jointed robotic arm. By, considering the mechanical arm's performance objectives, the design starts with modeling the integration of all the individual links constituting the manipulator. As a result, the proposed approach for manipulator design yields substantially less number of iterations, automatic propagation of design changes and great saving of design efforts.

Santosh S Gudi Et al [5] discussed about the design of pneumatic suction mechanism based vertical surface climbing robot. Suction cup mechanism has superior performance due to greater gripping capability which ensures more payload and task specific tool carriage.

Feng Ni Et al [6] had presented the development of a new type of robot capable of vertical and directional jumping. The robot uses soft silicon elastomer based pneumatic actuators as legs that accelerate the platform upwards by rapid pressurization.

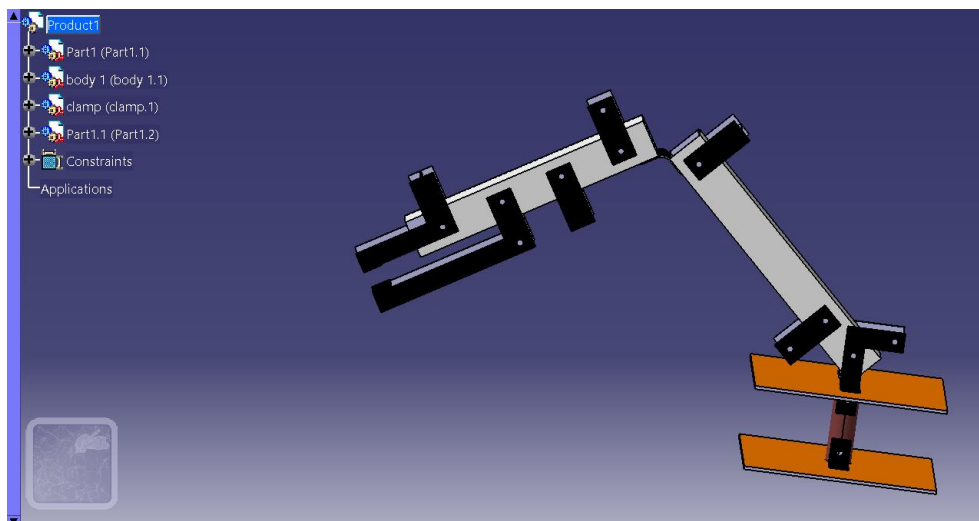
Emanuel Todorov Et al [7] reported results on modeling and control of a 2-dof robot as well as preliminary results on state-of-the-art 38-dof humanoid and able to achieve end-effector control of the highly redundant arm of the humanoid. This was done by building parametric models, fitting them to experimental data, designing and optimizing their performance.

Xu Sun Et al [8] proposed a novel self-assembling method with a planar pneumatic system. Inflation of pouches translates into shape changes, turning a sheet of composite material into a complex robotic structure. This new method enables a flat origami-based robotic structure to self-fold to desired angles with pressure control.

S.N.Teli Et al [9] has Designed and Fabricated pneumatic arm for pick and place of cylindrical objects. The handling of materials and mechanism to pick and place of object from lower plane to higher plane and are widely found in factories and industrial manufacturing. The designed pneumatic arm consists of two cylinders, a shaft works with lead screw mechanism capable of converting motion of piston to rotational motion of with the help of compressed air.

Kouichi Watanabe Et al [10] proposed a mechanical compliance control system as new pneumatic arm control system. The main feature of the proposed system is that the two desired pressure values are calculated by using two other desired values, the end compliance of the arm and the end position and posture of the arm.

3. DESIGN OF BASE

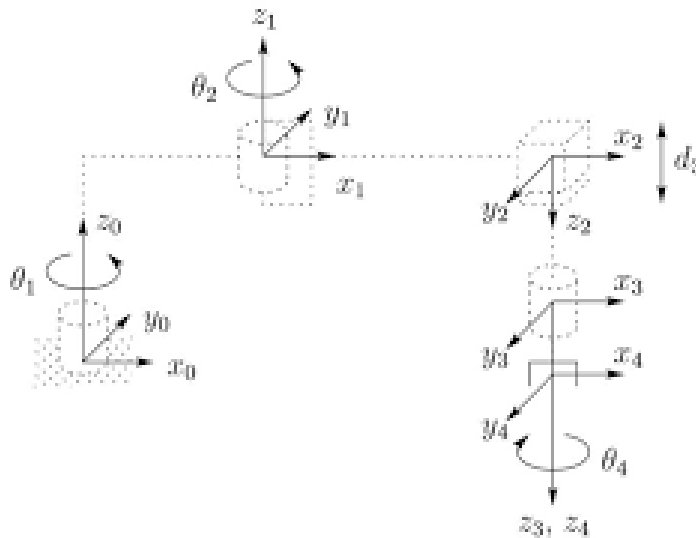


3.1 Pneumatic Robot

4.DENAVID – HARTENBERG NOTATION

4.1 D-H Notation

In mechanical engineering, the Denavit–Hartenberg parameters (also called DH parameters) are the four parameters associated with a particular convention for attaching reference frames to the links of a spatial kinematic chain or robot manipulator.



4.1 D-H Notation

A commonly used convention for selecting frames of references in robotics applications is the Denavit-hartenberg(D-H)convention which was introduced by Jacques Dehavit and Richard Hartenberg. In this convention, coordinate frames are attached to the joints between two links such that one transformation is associated with the joint, [Z], and the second is associated with the link [X]. The coordinate transformations along a serial robot consisting of n links form the kinematics equations of the robot.

where [T] is the transformation locating the end-link.

In order to determine the coordinate transformations [Z] and [X], the joints connecting the links are modeled as either hinged or sliding joints, each of which have a unique line S in space that forms the joint axis and define the relative movement of the two links. A typical serial robot is characterized by a sequence of six lines S_i , $i = 1, \dots, 6$, one for each joint in the robot. For each sequence of lines S_i and S_{i+1} , there is a common normal line $A_{i,i+1}$. The system of six joint axes S_i and five common normal lines $A_{i,i+1}$ form the kinematic skeleton of the typical six degree of freedom serial robot. Denavit and Hartenberg introduced the convention that Z coordinate axes are assigned to the joint axes S_i and X coordinate axes are assigned to the common normal $A_{i,i+1}$.

This convention allows the definition of the movement of links around a common joint axis S_i by screw displacement.

$$[Z_i] = \begin{bmatrix} \cos \theta_i & -\sin \theta_i & 0 & 0 \\ \sin \theta_i & \cos \theta_i & 0 & 0 \\ 0 & 0 & 1 & d_i \\ 0 & 0 & 0 & 1 \end{bmatrix},$$

Where θ_i is the rotation around and d_i is the slide along the Z axis—either of the parameters can be constants depending on the structure of the robot. Under this convention the dimensions of each link in the serial chain are defined by the screw displacement around the common normal $A_{i,i+1}$ from the joint S_i to S_{i+1} , which is given by

$$[X_i] = \begin{bmatrix} 1 & 0 & 0 & r_{i,i+1} \\ 0 & \cos \alpha_{i,i+1} & -\sin \alpha_{i,i+1} & 0 \\ 0 & \sin \alpha_{i,i+1} & \cos \alpha_{i,i+1} & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix},$$

where $\alpha_{i,i+1}$ and $r_{i,i+1}$ define the physical dimensions of the link in terms of the angle measured around and distance measured along the X axis.

In summary, the reference frames are laid out as follows:

1. The z – axis is in the direction of the joint axis.
2. The x – axis is parallel to the common normal: $x_n = z_n * z_{n-1}$
3. The y – axis follows from the x and z axis by choosing it to be a right handed co-ordinate system.

4.3 D-H Matrix

It is common to separate a screw displacement into the product of a pure translation along a line and a pure rotation about the line, so that

$$[Z_i] = \text{Trans}_{Z_i}(d_i) \text{Rot}_{Z_i}(\theta_i),$$

Using this notation, each link can be described by a coordinate transformation from the concurrent coordinate system to the previous coordinate system.

$${}^{n-1}T_n = \text{Trans}_{z_{n-1}}(d_n) \cdot \text{Rot}_{z_{n-1}}(\theta_n) \cdot \text{Trans}_{x_n}(r_n) \cdot \text{Rot}_{x_n}(\alpha_n)$$

The matrices associated with these operations are:

$$\text{Trans}_{z_{n-1}}(d_i) = \begin{bmatrix} 1 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 \\ 0 & 0 & 1 & d_n \\ 0 & 0 & 0 & 1 \end{bmatrix},$$

$$\text{Rot}_{z_{n-1}}(\theta_n) = \begin{bmatrix} \cos \theta_n & -\sin \theta_n & 0 & 0 \\ \sin \theta_n & \cos \theta_n & 0 & 0 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

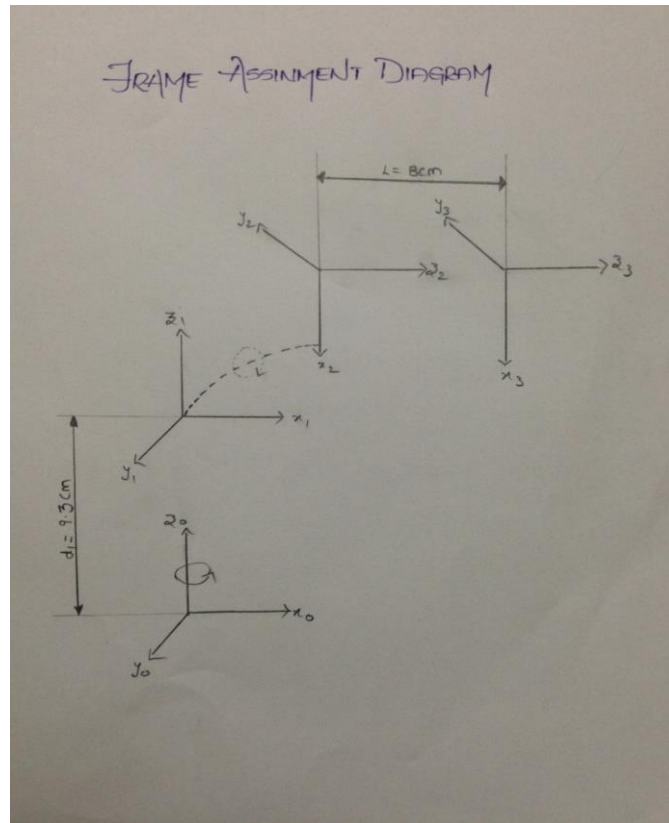
$$\text{Trns}_{x_n}(r_n) = \begin{bmatrix} 1 & 0 & 0 & r_n \\ 0 & 1 & 0 & 0 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

$$\text{Rot}_{x_n} = \begin{bmatrix} 1 & 0 & 0 & 0 \\ 0 & \cos \alpha_n & -\sin \alpha_n & 0 \\ 0 & \sin \alpha_n & \cos \alpha_n & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

That gives:

$${}^{n-1}T_n = \begin{bmatrix} \cos \theta_n & -\sin \theta_n \cos \alpha_n & \sin \theta_n \sin \alpha_n & r_n \cos \theta_n \\ \sin \theta_n & \cos \theta_n \cos \alpha_n & -\cos \theta_n \sin \alpha_n & r_n \sin \theta_n \\ 0 & \sin \alpha_n & \cos \alpha_n & d_n \\ 0 & 0 & 0 & 1 \end{bmatrix} = \begin{bmatrix} & R & T \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

where R is the 3×3 submatrix describing rotation and T is the 3×1 submatrix describing translation.



4.3 Frame Assignment Diagram

	(T_z, D_i)	(T_z, θ_i)	(T_x, a_i)	(T_x, α_i)
	$D_i(\text{cm})$	θ_i	a_i	α_i
T_1	9.3	90	0	0
T_2	0	35	8	90
T_3	0	0	2.5	0

$${}^{i-1}A_i = T(z-d_i) * T(z-\theta_i) * T(x-a_i) * T(x-\alpha_i)$$

$$= \begin{bmatrix} \cos \theta_i & -\sin \theta_i & 0 & 0 \\ \sin \theta_i & \cos \theta_i & 0 & 0 \\ 0 & 0 & 1 & d_i \\ 0 & 0 & 0 & 1 \end{bmatrix} * \begin{bmatrix} 1 & 0 & 0 & d_i \\ 0 & \cos \alpha_i & -\sin \alpha_i & 0 \\ 0 & \sin \alpha_i & \cos \alpha_i & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

$$= \begin{bmatrix} \cos \theta_i & -\sin \theta_i \cos \alpha_i & -\sin \theta_i \sin \alpha_i & \cos \theta_i a_i \\ \sin \theta_i & \cos \theta_i \cos \alpha_i & \cos \theta_i \sin \alpha_i & \sin \theta_i a_i \\ 0 & \sin \alpha_i & \cos \alpha_i & d_i \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

$${}^0T_1 = \begin{bmatrix} \cos(90) & 0 & \sin(90) & 0 \\ \sin(90) & 0 & -\cos(90) & 0 \\ 0 & 1 & 0 & 9.3 \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

$${}^1T_2 = \begin{bmatrix} \cos(35) & 0 & \sin(35) & 0 \\ \sin(35) & 0 & -\cos(35) & 8 \sin(35) \\ 0 & 1 & 0 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

$${}^2T_3 = \begin{bmatrix} \cos(0) & 0 & \sin(0) & 2.5 \cos(0) \\ \sin(0) & 0 & -\cos(0) & 2.5 \cos(0) \\ 0 & 1 & 0 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix}$$



$${}^0T_3 = {}^0T_1 \times {}^1T_2 \times {}^2T_3$$

$$= \begin{bmatrix} 0 & 0 & -1 & 0 \\ 0.819 & 0.573 & 0 & 2.04 \\ 0.57 & -0.81 & 0 & 6.01 \\ 0 & 0 & 0 & 1 \end{bmatrix} = \begin{bmatrix} n_x & o_x & a_x & d_x \\ n_y & o_y & a_y & d_y \\ n_z & o_z & a_z & d_z \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

$n_x = 0$	$o_x = 0$	$a_x = -1$	$d_x = 0$
$n_y = 0.819$	$o_y = 0.573$	$a_y = 0$	$d_y = 2.04$
$n_z = 0.57$	$o_z = 0.81$	$a_z = 0$	$d_z = 6.01$

5. FINAL OUTPUT RESULT



5.1 Complete assemble views of pneumatic robot

6. CONCLUSION

This project work has provided us an excellent opportunity and experience, to use our limited knowledge. We gained a lot of practical knowledge regarding, planning, purchasing, assembling and machining while doing this project work. We feel that the project work is a good solution to bridge the gates between the institution and the industries.

We are proud that we have completed the work with the limited time successfully. The **FABRICATION OF PNEUMATIC ROBOT** is working with satisfactory conditions. We understand the difficulties in maintaining the tolerances and also the quality. We have done to our ability and skill making maximum use of available facilities.

Thus we have developed a “**FABRICATION OF PNEUMATIC ROBOT**” which helps to achieve More accurate performance for small scale industries by replacing the hydraulic and electric actuators for industrial warehouses. Pneumatic source eliminates the usage of heavy motors and electrical sensors which helps in cost reduction. By using more techniques, they can be modified and developed according to the applications.

7. FUTURE SCOPE

Pick and place robotic arm can reduce the human efforts by automatic handing of material, an automatic, servo controlled, freely programmable, multipurpose manipulator, with several areas for the handling of work pieces, tools or special devices. By using modern materials as cellular titanium & nano crystalline aluminum, a light weight robotic arm can be manufacture.

A programmable logic controller (PLC) or programmable controller is an industrial [digital computer](#) which has been [ruggedized](#) and adapted for the control of manufacturing processes, such as [assembly lines](#), or [robotic](#) devices. PLCs are powerful, resilient machines designed specifically to operate in a harsh factory environment. They have enormously flexible input/output (I/O) capacity and feature user-friendly man-machine-interfaces (MMI) or graphical user interfaces (GUI). With the help of PLC, an industrial robot can manage multiple [assembly](#) lines all funneling parts to [packaging](#) and [palletizing](#) which must package the right parts in the correct order at a precise time. PLCs to robots increase flexibility, reliability & speed of response and also decreases the cost.

Also with the help of PLC and other programming controls like Aurdino, we can make this robot to move from one place to other place to transfer the materials without any human interface.

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