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Design and erection of robotic arm operated by hydraulic power

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Abstract- Hydraulics is a technological system and applied science using engineering, chemistry and other sciences involving the mechanical properties and use of fluids. Hydraulic involves any movement, operation or effectiveness by means of liquid under pressure. Hydraulic Robotic Arm is a system which coupled by machines and hydraulics. The science behind hydraulics is Pascal's principle, because the fluid in the pipe is incompressible, the pressure is constant along all the direction. In hydraulic robotic arm the dynamic differential equations are built with the driving force of the hydraulic cylinder. This Arm is used to extend the flexibility of workstations by transporting material more efficiently and quickly between worktable, peripheral devices and assembly lines etc. Also they are able to do heavy weight jobs, which is difficult to execute for humans Robotic arm is hydraulically operated and controlled by syringes filled with water or any other liquid as well as makes a relationship between hydraulic system and end positions such as the gripper. This scheme interprets a simple approach to demonstrate the principle of hydraulic power by manufacturing and operating a robotic arm model from recycled materials. Hydraulic robotic arm has been designed and fabricated to grip and pick a small weight of 75 gram. Overall, the experiment using cardboard is better and convenient. So, the total angle of rotation for three DOF is increased in the experiment.

Keywords: Hydraulic, Pascal's law, Cardboard, Syringes, Gripper

1. Introduction

Recently, hydraulic system is used in modern industries widely as their high power to weight ratio, durability, controllability, reliability and accuracy. It is utilized in higher applications. These applications involve suspension system control, power steering control, testing material, Cam less engines, earth moving industries, load simulators, the control of multi axis robotic manipulators. In model base control system design, four steps are typically employed: (1) modeling a plant; (2) controller synthesizing; (3) plant simulating and controller together; (4) integrating the overall system. Therefore, modeling system is an important first step for model base system design. Hydraulic robotic arm is a model base system design. There are five categories of control. The most important for hydraulic control system is proportional solenoid valve and servo valve is like proportional solenoid valve. Basically, its valve spool position is made to vary directly in response to electrical current fed to the solenoid that drives it. The servo valve, it is designed initially for feedback control. It predates proportional solenoid valves and usually is based on controlling the position of the Proportional valves have higher uses over servo valves in the hydraulic system. Proportional valve is less expensive. This is suitable for industries weather as these have less prone to malfunction. Even proportional valves are easier to handle and service and these are called servo-solenoid valves. Robot Arm and Wrist Assembly (US06448217) [1]: In 1982, William J. Langer designed a robotic arm and wrist assembly. It uses a forearm assembly that provides motion. In three mutually perpendicular intersecting axes with rotation of axis of forearm. It includes mountings that permit low load on arm.

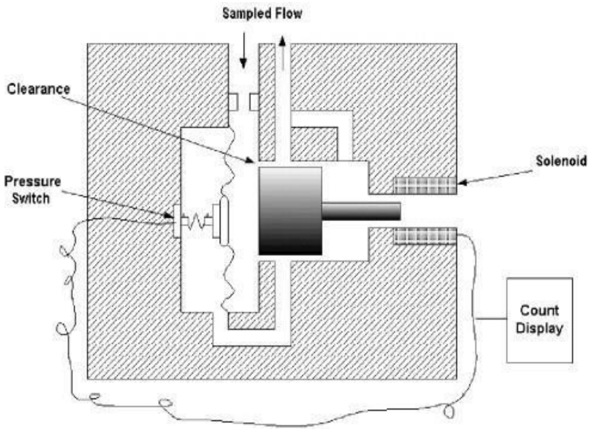

Fig 1 : Proportional solenoid valve

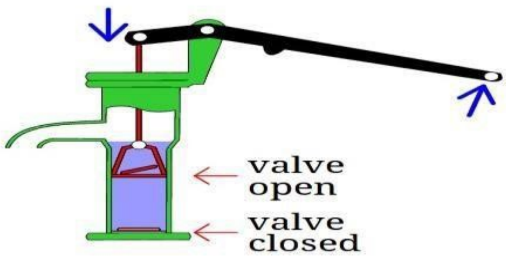

Fig 2 : Servo valve

The invention uses hydraulic system and rotary actuators for the wrist assembly. It includes mountings that permit low load on the arm and actuators. The movement of arm is achieved by using hydraulic power

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which actuates a double acting actuator which upon extension or retraction provides movement about a pivot point. To effect the rotation of the platform, a hydraulic motor is directly coupled to the platform. The major difficulties of excess load on arm and limited motion are overcome by use of flexure plates and tubular sections. The robotic arm is used for handling of tools and small equipment. It uses sensors, feedback loops, various hydraulic actuators and control valves that provide flexibility of operation. Hydraulic system contributes today in large number of types of applications, used in assembly processes and paper mills. It was not until the beginning of the industrial revolution when a British mechanic named Joseph Brahma applied the principle of Pascal's law in the development of the first hydraulic press. In 1795, he patented his hydraulic press, known as the Brahma's press. It proves that it started many years ago by using this Pascal's law and Brahma's application. It proves that pressure in one side of vessel would be 10 times than other side if the area is 10 times of that one side. Using this method and application, hydraulic system was developed and now we can move arm to grip and pick. Previously, Hydraulic arm was produced using cardboard and metal on the principle of hydraulic movements. That robotic arm entirely made with cardboard and a couple of syringes. To make the rotating platform, used an old pen cap as the axis on which the arm rotates. For metal body used a cylinder, it is now widely used in crane for digging and many purposes. In the metal on the principle of hydraulic movements. That robotic arm entirely made with cardboard and a couple of syringes. To make the rotating platform, used an old pen cap as the axis on which the arm rotates. For metal body used a cylinder, it is now widely used in crane for digging and many purposes. In the previous process, degree of freedom was maintained for each part to travel within the limited path to guide and pick up the small substance and to place these in another place. The complete mechanism consisted of a fixed vertical link. To it's free end is connected to horizontal link which is free to oscillate about the hinge in an up down way of motion. The entire mechanism was fixed on a rack and pinion to allow the degree of freedom of the mechanism as a whole to rotate by a specific angle. On this principle, there were invented hydraulic crane, is shown in figure (3.4). In this study, we will see the same mechanism with some modification in control process and hydraulic system etc.

Objectives of the studies are

1. To design and fabrication of a hydraulic arm that can grip and pick a substance.
2. To control the hydraulic arm by gesture commands using liquid.
3. To determine the degree of freedom of the arm.
4. To calculate the angle of rotation of the hydraulic arm

Fig 3: A typical used Hydraulic Crane

2. Experimental Setup

2.1 Experimental Theory :

PASCAL'S LAW In this project, incompressible fluids are used in hydraulic system, example: the force is transmitted by water from one point to another in the fluid. The main idea behind the project is Pascal's law. It is stated that "Any change in pressure at any point in any enclosed fluid at rest is transmitted equally to all arounds points in fluid". This principle is stated mathematically as: $\Delta \boldsymbol{P}=\boldsymbol{\rho g}(\Delta \boldsymbol{h})$ Where, $\Delta \boldsymbol{P}$ is the hydrostatic pressure (SI unit) or the pressure difference at two points within a fluid column, $\boldsymbol{\rho}$ is the fluid density (Kilogram per cubic meter in the SI system), $\boldsymbol{g}$ is the acceleration due to gravity (meter per second square). $\Delta \boldsymbol{h}$, is the difference in elevation between two points within the column.

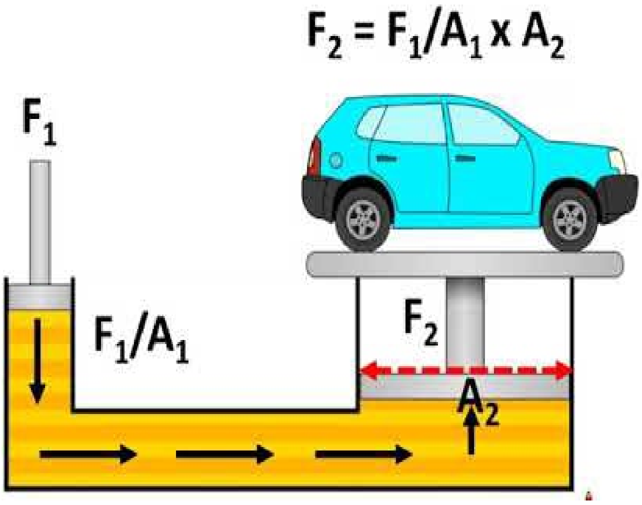

Fig 4: Application of Pascal's law in hydraulics.

2.1 : Pieces of cardboard: Various pieces of double corrugated cardboard are used to create the links, joints, grippers as well as the arms cardboard are recycled material, less cost and easy to carry.

Fig 5 : Cardboard

2.2 : Hard cardboard for Arms : Hard cardboards are used to make the arm so that it can carry a weight.

2.3 : Syringes : The syringes are used as hydraulic actuator, each are 10 ml in volume size. Total number of syringes used in the experiment is 8.

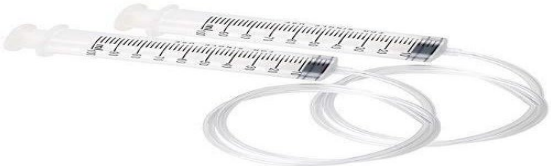

Fig 6 : Syringes

2.4 : Pipes & tubes : Tubes are of 0.75 m in length, four tubes are used, these are fitted in the opening of the syringes. And the fluid energy is transferred from one cylinder to another through the tube.

Fig 7 : Tubes

2.5 : Paper Tape : Paper tapes are used to make the arm more strong and more stable. Paper tape color is white. These are available at the market.

2.6 : Gripper : This is known as the end effector in robotics by which the whole experiment is obtained. The gripper can grip a substance and pick it to another place.

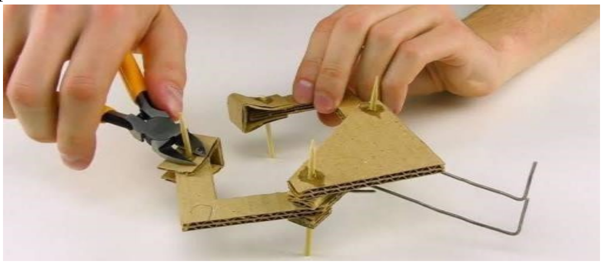

Fig 8 : Gripper

2.7 : Super glue : This fluid is used to attach two objects. In this experiment, a lot of super glue is used.

2.8 : Water, knife, ruler : Water is the working fluid in this experiment, the whole project is controlled by controlling water between the syringe and tube. Mineral water is used during working. Knife is a useful material for cutting the cardboards in the desired size and shape. By ruler, it could be possible to get the measurement in the correct way.

3. 3. Experimental Procedure

Before starting, make sure that all the equipment's are available. Here a double corrugated cardboard is used to make the base and arms as well as the gripper. It will result to a slightly weaker model preferably. The base cardboard area is 18*16 cm square. Firstly, for the arms we design the hard cardboard. Secondly, we will take a cardboard base to fix the arms on this base by screw. Then making holes on the arm for fixing it by hard wooden stick.

Fig 9 : Cutting the cardboard for the arms.

A syringe is considered as a simple reciprocating pump consisting of a plunger or piston that is fitted tightly within a cylindrical tube is known as barrel. Here, the syringe is used as a cylinder that performs the work of actuation. Syringes will work like the muscles of the arm of hydraulic system. In hydraulic robotic arm, the arm movements are maintained hydraulically by syringes. The Volume of syringe is 10 ml and the syringes is 8 in number is used in this experiment. The free movement of arms is done by using washer.

Fig 10 : 10 ml Syringe

Fig 11 : Various Syringe

The tube is fitted to the opening of the syringes that shows the direction the flow of water in and out of the barrel. The length of the tube is 0.75 m and the tubes are 4 in number is used in this experiment. Two syringes are joined by pipe and the glue is used to fix the pipe in the nozzle of syringe. Setting up the gripper at the end of the arm by wear controlled by the syringes.

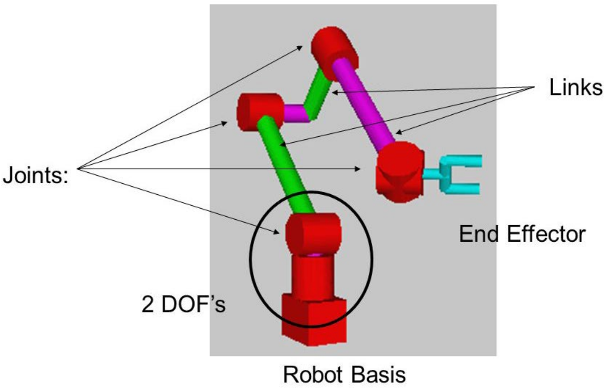

Fig 12 : Links and Joints

Now the syringes are filled with water to maintain the Pascal's law. There will be no bubbles or vacuum in the syringe. Then the syringes are setting in arms to freely move the arms by the applied of pressure using water or hydraulic. Now the hydraulic robotic arm is ready. We can check all the movements of hydraulic robotic arm. Thus, the hydraulic arm can be built.

Fig 13 : Hydraulic Arm

Steel wires are inserted within the inner holes and is bended them outwards so that it doesn't move outward. Then twist each one within the desired hole in the syringe and Cardboard of small two pieces are bended around a ruler to get the gripper end. Small rectangle pieces are cutting to get grip and set them both of ends. Then the syringe is fixed and fixed the triangular portion of gripper to the arm.

Fig 14: Gripper

3.1 Final Assembly of this Experimental Setup : At first, a cardboard base is selected and then the arm is fixed to it by screw as well as superglue. Here, many wooden stick are used to connect the links and various joints. After that, syringes and washers are used to for the free movement arms. Setting up the gripper at the end of the arms by wear controlled by the syringe. Finally, the syringes are filled with water to get the Pascal's law and the syringe opening is fitted by the tube. Thus, the arms as well as the gripper movement is controlled by hydraulic pressure.

Fig 15 : Assemble of the components.

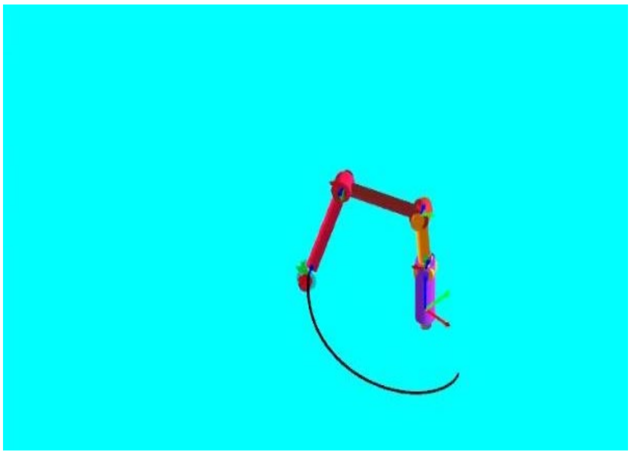

Fig 16 : 3D Model of Hydraulic Arm by RoboAnalyzer

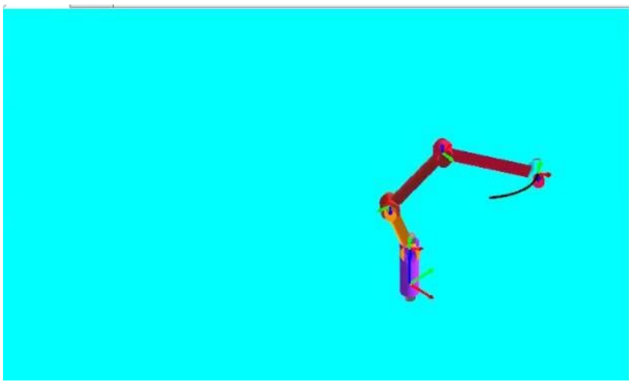

Fig 17 : D-H Parameters

4. Data calculation

Hard cardboard for base- 18*16 cm square
Hard cardboard for arms (Link 0)-13.5 cm
Hard cardboard for arms (Link 1)-20.0 cm
Hard cardboard for arms (Link 2)-25.0 cm
Number of syringes - 8
Volume of Syringes - 10 ml
Number of tubes - 4
Length of Tube - 0.75 m
Length of Steel wire - 9 cm
Density of water - 1 gram per milliliter

This chapter will discuss about the performance of hydraulic robotic arm. Results that have been found from the previous chapter is shown here with discussion.

5. Result and discussion

Degree of Freedom (DOF) of the arm

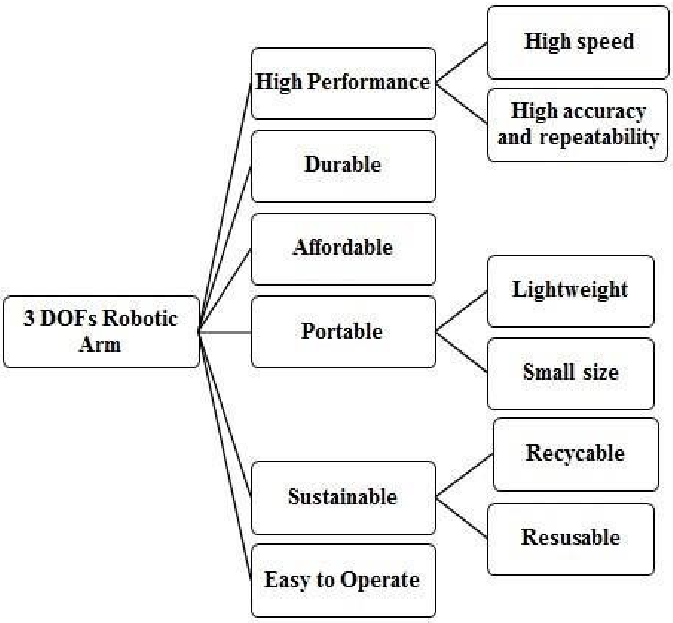

Fig 18 : Advantage of 3 DOF.

Degree of Freedom (DOF) of the arm – 3

Angle of base rotation, x - 50
Degree Angle of shoulder rotation, y - 85 Degree
Angle of elbow rotation, z - 70 Degree
Total Angle of rotation (x + y + z) - 205
Weight of the substance - Approx. 75 gm

The advantages of hydraulic robotic arm are given below:

1.Using in locomotive, may be a great use in production as well as packing field.
2.Efficient transmitter of power.
3.Good control accuracy.
4.Provides a constant pressure or force, no change in speed.
5.Safe and economical.
6.Easy to design and maintain.

Limitations of the study are

1. Any point on this arm can only move along a circular path.
2.Difficult to remove the leaks in hydraulic pipes.
3.Must be careful during handling hydraulic fluids.
4. Those fluid leaks may cause serious injuries in a hot area.

These project has several applications they are

1.Used in industries to grip and pick the products.
2.Used in mega factories in assembly line and paint the parts.
3.Breaks and steering on cars.
4. Hydraulic lifts, airplane wing flap, garbage trucks etc.

During the project completion , some problems are arrived such as

1.To vary the movement of the arm as well as the gripper.
2.To prevent the mixture of water and air in the barrel and tube
3.Light in weight so gripper can't grip heavy material.

Although some problem arrived, the project is successfully completed. The simple Hydraulic system is what makes this project really stand out and the fact that it is so convenient to build.

6. Conclusion

In this project, the main purpose is to design and fabricate of a hydraulic arm that could be controlled by hydraulic commands using water as well as to increase the angle of rotation for three degree of freedom. After struggling so long, it had been possible to complete the project. At the end, although it was difficult to grip things and pick a substance in another place but finally, after trying multiple times the arm functions are worked properly to perform the desired work of picking up the object of light weight.

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3. Good control accuracy.
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Notable findings are summarized below:
1.Three DOF of the arm is obtained by the hydraulic pressure as control signal.
2.There also has obtained the base rotation of 50 degrees, the shoulder rotation of 85 degrees and the elbow rotation of 70 degrees.
3.The angle of rotation is increased by almost 20 degrees.
4.Finally, hydraulic robotic arm has been designed and fabricated to grip and pick a small weight of 75 gm.

Overall the experiment using cardboard is better and convenient. So, the total angle of rotation for three DOF is increased in the experiment. As the objective was to design and fabricate the hydraulic arm with specific DOF and angle of rotation, the results show the experiment is nicely conducted. So, this project helps us to learn how human hands and arms function, and it taught us about hydraulic system.

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NOMENCLATURE

L : Length , cm
D : Density , gm/ml
DOF: Degree of freedom , Degree
W : Wight , gm
A : Area , cm square