

Design And Manufacturing Of Low Cost Pneumatic Pick And Place Robot

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Abstract: The paper proposes a cheap and effective method for design and manufacturing of a three degree of freedom revolute jointed robotic arm. The design process begins by specifying top-level design criteria and passing down these criteria from the top level of the manipulator's structure to all subsequent components. With this proposed approach the sequential design intents are captured, organized and implemented based on the entire system objectives, as opposed to the conventional design process which aims at individual components optimization. By considering the mechanical arm's performance objectives, the design starts with modelling the integration of all the individual links constituting the manipulator. During the design process, modifications are made based on integrated information of kinematics, dynamics and structural analysis of the desired robot configuration as a whole. An optimum assembly design is then achieved with workable sub designs of the manipulator components. 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. Further with best machining process and cheapest material, catering the strength and machining requirements suitable materials are selected to fulfil the objective

Index Terms: cost, design, manufacturing, pneumatic, robot

1 INTRODUCTION

Robotics is the science of designing and building robots suitable for real life applications in automated manufacturing and other non-manufacturing environments." As per International Standards Organisation (ISO), it can also be defined as, "An industrial robot is an automatic, servo-controlled, freely programmable, multipurpose manipulator, with several areas for the handling of work pieces, tools or special devices. Variably programmed operations make the execution of a multiplicity of tasks possible." Here we are designing a robotic arm that is completely functional by pneumatic principles and thus reducing the complexity in designing, manufacturing and machining. This helps in reducing the overall cost of the robot right from designing to manufacturing since expensive electronic circuits are not used. When compared to electronic robot these pneumatic robots with simultaneous and sequential pneumatic circuits are capable of performing the same task automatically with assistance of even an unskilled labor which in turn reduces the running cost of the machine. These types of pneumatic robots can be used in places where repetitive action is required such as the assembly line and also in places where remote operation is required. The success and advancement of these types of robot depends mainly upon the complexity of the pneumatic circuit. Effective design increases the efficiency and application of these robots.

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2 DESIGN CONSIDERATIONS

2.1 System specification

Reach
Range
Work envelop
Load capacity

2.2 System configuration

Number of degrees of freedom
Joint configuration
Joint travel range
Drive configuration

2.3 System performance

System velocity and acceleration
Repeatability
Resolution
Accuracy
Component life and duty cycle

2.4 Detailed design of various components

Robot structures
Robot joints
Actuators
Transmission
Wiring and routing of cables and hoses

3 DESIGN OF RELIABLE MECHANICAL JOINTS

The function of a joint is to permit relative motion between two links or arms of a robot. It provides controlled relative motion between two links (input and output). Generally one joint provides the robot with one degree of freedom. There are various joints such as the linear joints, orthogonal joints, rotational joint, twisting joints and revolving joints. Of the given joints the rotational joints are easy to manufacture and is best suitable for our demand. Thus hinged joints are used. The cost of hinged joints is very less and can best satisfy our requirement. However based on the strength and weight to be lifted various types and quality of hinged joints is used.

4 MANIPULATOR DESIGN

A manipulator is generally mounted on a track or suspended from a track that is capable of reaching various distances and locations. It is used to move materials, tools and objects without direct human contact. It consists of two sections namely the body or arm and the wrist assembly.

4.1 Design of body

The body is used to position the object in the robot's work envelop. And thus by employing the concept of value engineering proper design can help reduce the weight of the body and also the amount of materials used. Generally to optimize both material cost and the manufacturing cost the arm is made up of different components and then is assembled together, thus saving the material and reducing the cost.

4.2 Design of wrist assembly

It is used for the orientation of the object in the work envelop. The end effector is attached to the wrist assembly. Wrist assembly has three degrees of freedom pitch, roll and yaw. However for simple pick and place application keeping in mind the complexity of manufacturing of the wrist assembly the end effector can be attached to the arm directly using hinged joints. Pneumatic cylinder is used for controlling the end effector. Thus contributes significantly in reducing the cost of the robot.

5 DESIGN OF END EFFECTOR

The arm is responsible only for positioning the object. It is the end effector that interacts with the object. The hand of the robot is considered as the end effector. The various end effectors are grippers, sprayers, grinders, welders and vacuum. Here we choose to use either a gripper or a vacuum. A gripper used for lifting and placing objects is simple to design and manufacture. A vacuum can use the pneumatic power and thus reduce the running cost and also perform complex tasks.

6 ROTATION OF THE ROBOT

For the robot to reach different locations and perform the tasks it has to rotate around its own axis. Thus depending up on the requirement either a stepper motor or a simple pneumatic cylinder can be used. A stepper motor needs electronic circuits for control and an additional bearing support for 360 degree rotation. However if a 90 degree span of rotation is sufficient then a pneumatic cylinder can be used. Here only one bearing to support the rotation is required. Thus significantly reducing the cost of the robot.

8 PNEUMATIC CIRCUIT

A pneumatic logic system is generally used to control the industrial robots. Since electronic circuits are not used thus precise and accurate pneumatic circuits are designed and implemented. Sequential circuits are designed so that each cylinder is actuated at proper sequence and are also kept active for the desired period of time. This is the only challenge in a low cost robotic arm is designing of the pneumatic circuit.

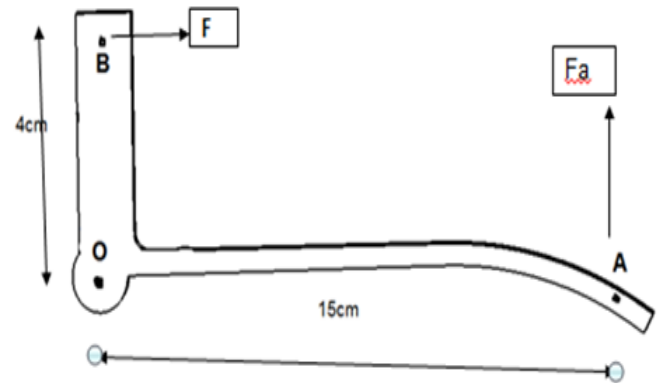
9 MATERIAL SELECTION

Material selection is one of the most important factors in reducing the cost of the robot. Materials are selected in such a way that there is no compromise in minimum design

requirement. Here to we choose to use a combination of iron and fiber reinforced plastic. Gripper and the upper body can be made of FRP because it provides sufficient strength to hold and lift the object and reduce the weight. The lower body and the base is made of iron in order to provide the required counter weight so that the stability of the robot is not lost. Depending upon the weight to be lifted the material selection varies. However to reduce the cost and ease of manufacturing we can use iron if weight considerations are not present.

10 CALCULATIONS

10.1 Calculations for end effector



Force (F_a) required for holding the work piece is 30 N

$$F_a = 30 \text{ N}$$

From figure 13: Take moment at point O,

Let force at point B be F and is equal to the force applied by the cylinder. F_a is the force required to hold the object

$$F_a \cdot 15 = F \cdot 4$$

$$F = 30 \cdot (15/4)$$

$$F = 112.5 \text{ N}$$

Thus 112.5N of force should be supplied by the pneumatic

10.2 Selection of end effector cylinder

Pressure (P) supplied by the cylinder = 4 bar

Let area of cylinder be A .

$$A = F/P$$

$$= 112.5 / (4 \cdot 10^5)$$

$$= 2.812 \cdot 10^{-4} \text{ m}^2$$

$$A = 3.14 \cdot d^2$$

$$d = 18.9 \text{ mm}$$

Since the available standard cylinder is of diameter 20mm and stroke length 75mm, the cylinder used for the end effectors are selected with the dimensions of 20mm x 75mm.

10.3 Selection of body cylinders

Pressure supplied to cylinder = 10 bar.

Assuming factor of safety as 2 the pressure supplied is assumed as 4 bar.

To lift an arm of 15kg,

$$\text{Pressure} = 4 \times 10^5 \text{ N/m}^2$$

$$\text{Area} = \text{force/pressure}$$

$$A = 15 \times 9.81 / (4 \times 10^4)$$

$$A = 3.678 \times 10^{-4}$$

$$A = 3.14 \times d^2$$

Therefore d = 21.6mm

Since the available standard cylinder is of diameter 25mm and stroke length 100 mm, the cylinder used for the arm lift are selected with the dimensions of 25mm x 100mm.

11 COST ESTIMATION

S.NO	PART	MATERIAL	QUANTITY	COST (INDIAN RUPEES)
1	Cylinder (25*100)	aluminium	3	2100
2	Cylinder (25*75)	aluminium	1	500
3	Upper body	Iron(Iron plates)	0.7 kg	31.5
4	Lower body	Iron(iron plates)	o.7 kg	31.5
5	Base plate	Iron(iron plates)	3 kg	135
6	Gripper	Iron(iron plates)	0.5 kg	22.5
7	Bearing	Stainless steel	1	1650
8	Solenoid valve	Plastic	4	1780
9	Tubes	plastic	15 meters	150
10	Average labor costs (India)			590
11	Average machining cost (India)			230
12	Total			7220

The dimensions are for lifting a load of up to 4 kg (average weight of object used in pick and place operations) and thus can be scaled to increase the load. Thus the robot can be manufactured at an estimated cost of \$120. This can be reduced further in case of mass production. This robot can be used in small applications such as an auxiliary mechanism during manufacturing and also for picking up objects less than 4 kg. However the capacity of the robot can be improved.

12 CONCLUSION

The effective design and manufacturing of 3 degree of freedom pick and place robot has been performed. The operation of various arm linkages and the end effector has been extensively tested and the required corrective measures were taken. Hence the objective of designing and manufacturing of a pick and place robot at low cost was successful and can be implemented to replace the expensive electronic robots. It's been proved that running cost of the robot is also very less. This will help to cut down labor and improve profits at very low initial investment.

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