Design and Analysis of Pneumatic Pick & Place Mechanism

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Abstract— In present situation the industrial manufacturers has brought new trends in pneumatic applications in industrial area because due to the continuous availability of compressed air. This project is motivated to reduce time consumed for unloading of the engine valve. This paper proposes a cheap and effective method for design and manufacturing of a two degree of freedom revolute pneumatic pick and place mechanism. With this proposed approach the sequential design intents are captured, organized and implemented based on the entire system objectives. 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 configuration as a whole. An optimum assembly design is then achieved with workable sub designs of the components. As a result, the proposed approach for 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.
Key words: Fatigue, Low Cost Automation, Profitability

I. INTRODUCTION

Automation is the science of designing and building mechanism suitable for real life applications in automated manufacturing and other non- manufacturing environments. As per International Standards Organization (ISO), it can also be defined as, ―An industrial robot is an automatic, servo-controlled, and 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 pick and place mechanism 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. 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 de-pends mainly upon the complexity of the pneumatic circuit. Effective design increases the efficiency and application of these robots. In industrial applications, there are some conditions where human can't be involve such as hazard-ous environmental conditions, in a repetitive task to be done many times and where accuracy should be maintained every time in a single task.

In the proposed system of robotic vehicle with pick and place robotic arms, the cost of the system will vary according to the size of the vehicle, arms and it's capability where we consider those arms based on the weights of the objects to be carried out with robotic vehicle.

Eaton provides global (Original Equipment Manufacturer) OEMs in the auto-motive and commercial vehicle products designed to reduce fuel consumption and improve overall efficiency, productivity, vehicle power and control over it. Today, Eaton is well known in the automotive industry with efficient compressors and high-tech valve train, among other well-known products such as power transmission fluid, differential gears, valves, fuel vapour and plastic used in the engines.

A. *Objectives of Project:*

1) The whole mechanism should be based on low cost automation.
2) The production rate should increase.
3) The workers fatigue should decrease.
4) To reduce the idle time.
5) To reduce scrap.
6) To improve overall efficiency of the process.
7) Effective utilization of the resources.
8) To increase profitability.

II. LITERATURE REVIEW

Unloading can enhance the production rate if they are properly designed. Un-loading mechanism serves both Purposes i.e. Work holding and positioning mechanism. Work holding mechanism consists of work piece detection.

V. R. Kale, V. A. Kulkarni (2012) has discussed about the design of different parts of an automated high speed machine to assemble the parts of pick and place mechanism. The Project deals with an automated material handling system. This mechanism assembly system perform various processes in assembly line which include clamp body, die feeding, in seating the die into clamp body and dividing the reject clamp and successfully assembled clamp into their own tray. They have design a cost effective, minimum maintenance and high speed machine for industry application.

Shaikh Asma, J Santhi (2013) in has discussed about impact of the application sequence of multi clamps on piece machine accuracy, they have analyzed and optimized clamping sequence. A new methodology that takes into account is varying contact forces and friction force during clamping is presented for the first time.

Anthony Cowley, Benjamin Cohen (2014) presented the design of a pneumatic operated pick and place mechanism which can be controlled with force. An electromechanically controlled system was designed, fabricated and tested. Test results had shown that the designed system was capable of controlling unload-ing force with an accuracy of ±1 N over the full range of 487 N with rather fast response time of 200 msec. Recent approaches to perception for automation has moved beyond standard pick and place mechanism by applying a variety of new sensing elements to the problem.

William Marshall, Camillo J. Taylor (2011) the advantage of high energy density, deep penetration, high precision and strong adaptability, the laser weldingas a kind of advanced welding technology is widely used in machining, auto-mobile, steel, medical and other industrial fields. In general, the laser welding has higher productivity and better quality than traditional welding methods. However, there are lots of problems in the welding process of car body parts, such as curve welding seam, low assembly precision, large gap in welding area, etc., which were described in reference. In the process of complex curved surface parts welding, the laser welding head should keep a constant distance to the surface of the sheet in order to eliminate the gap between the plates and make the position of the laser beam focus be unchanged for good welding quality. Therefore, a mechanical clamping device fixed directly on a multi-degree of freedom robot manipulator to solve the problem of easy deformation of sheet metal plates should be designed.

Robots have their historical past though they came into existences only in 1961 when UnimationInc, USA introduced the first servo- controlled industrial robots. Early development dating back to 500B.C shows that the Egyptians, Indians, the Chinese, and the Romans built many automatics puppets which imitate the movement of animals and birds. The Chinese built many amusing devices that depicted sequential motions. Also, the early men discovered many mechanisms and exhibited their innovation skill in building ships and introduced looms to weave.

Various robot institutions propagate the ideas and ideologies of robotics to the profession. Some of the pioneering institutions are the Japan industrial Robot Association (JIRA, 1971).

III. Methodology

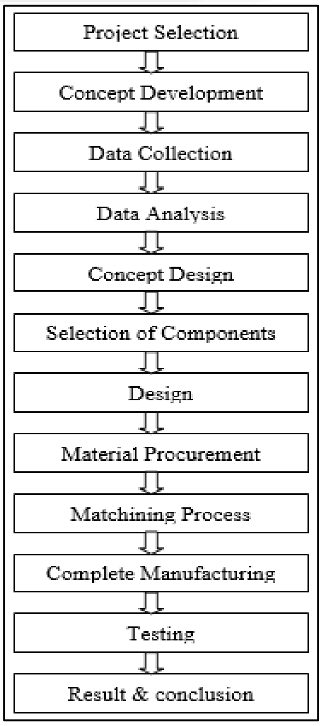


Fig. 1: Flowchart of Methodology

In design and analysis of pneumatic pick & place mechanism proper steps are to be followed. First of all, process planning is to be done. The best way to design the methodology is to prepare a flow chart of the steps to be carried out.

A. Pick and Place Mechanism

The different types of pick and place system which are available are mentioned below:

1) Hydraulic Pick & Place System:

Hydraulic cylinders (also called linear hydraulic motors) are mechanical actua-tors that are used to give a linear force through a linear stroke. Hydraulic cylin-ders are able to give pushing and pulling forces of many metric tons with only a simple hydraulic system. Very simple hydraulic cylinders are used in presses; here, the cylinder consists of a volume in a piece of iron with a plunger pushed in it and sealed with a cover. By pumping hydraulic fluid in the volume, the plunger is pushed out with a force of plunger-area pressure.

More sophisticated cylinders have a body with end cover, a piston rod, and a cylinder head. At one side the bottom is, for instance, connected to a sin-gleclevis, whereas at the other side, the piston rod is also foreseen with a single clevis. The cylinder shell normally has hydraulic connections at both sides; that is, a connection at the bottom side and a connection at the cylinder head side. If oil is pushed under the piston, the piston rod is pushed out and oil that was between the piston and the cylinder head is pushed back to the oil tank.

These systems are suitable for heavy components unloading. This uses oil as working medium. Initial cost is high.

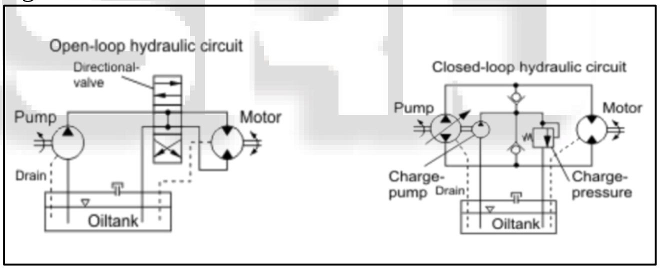


Fig. 2: Schematic of Hydraulic Pick and Place

2) Magnetic Pick and Place System:

In automation equipment, for example, the wafer or press manufacture fields need a special requirement of the PPM to move a workpiece from an initial position to a target position as shown in figure 4a. Figure 4b shows the PPM is designed by using a PMSM to drive the rotational arm and its output motion is required to satisfy the requirements of high speed and low vibrations. There are two linear scales to measure the displacements of the output arm in the X1 and Y1 directions.

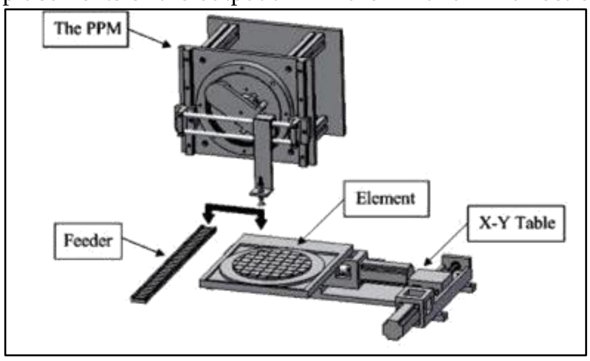


Fig. 3: Application of Magnetic PPM

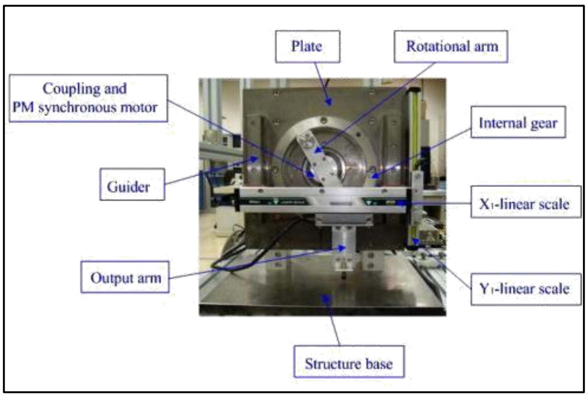


Fig. 4: Experimental Setup of Magnetic PPM

3) *Pneumatic Pick and Place System:*

Although initial cost is often the driving force for using pneumatic pick-and-place systems instead of electromechanical solutions, it's not the only reason. Pneumatic devices have a greater force density than many electromechanical solutions, which enables them to be a smaller and lighter, lowering space needs and energy costs. They can be also installed without requiring complex software programming of controllers, as their operation is simpler with a single path of travel.

In applications with contaminates, such as possible splashes, electromechanical systems pose more danger and are more likely to fail. Furthermore, electrome-chanical pick-and-place systems for these types of applications usually require specialized certifications and have a relatively small pool of vendors, thus mak-ing them quite expensive. Pneumatic systems are not only safer in wet or corro-sive environments, they can also withstand numerous cleanings. The pneumatic devices can be mounted close to the process while the associated electronics are housed in a cabinet well away from possible damage, simplifying installation and maintenance. Moreover, since controls for a pneumatic system are typically smaller than servo drives, internal space requirements in the control cabinet are reduced. A pneumatic system is simpler than an electromechanical system in terms of design, programming, installation, and maintenance—and good engi-neering practice dictates the use of the simplest solution that meets application requirements.

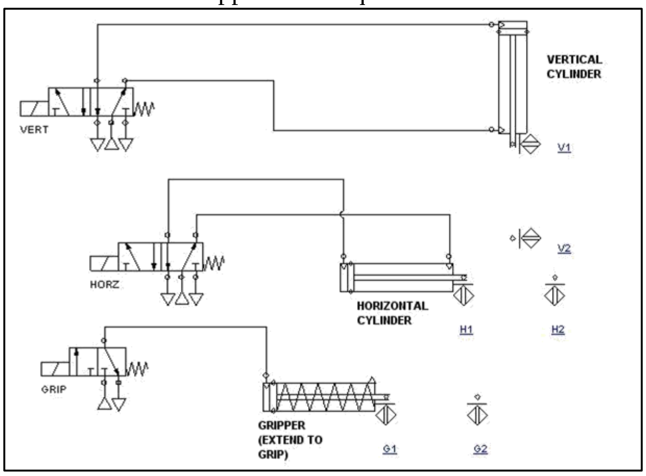


Fig. 5: Pneumatic Pick & Place System

4) *Reasons for Selection of Pneumatic System:*

Fluid power system is a power transmission system in which, the transmission of power takes place by means of " oil under pressure" or " compressed air ".

Pneumatic devices have a greater force density than many electromechanical solutions, which enables them to be a smaller and lighter, lowering space needs and energy costs. They can also be installed without complex components like controllers, as their operation is simpler with a single path of travel. In applica-tions with contaminates, such as possible splashes, electromechanical systems pose more danger and are more likely to fail. Furthermore, electromechanical pick-and-place systems for these types of applications usually require special-ized certifications and have a relatively small pool of vendors, thus making them quite expensive.

Pneumatic systems are not only safer in wet or corrosive environments, they can also withstand numerous cleanings. The pneumatic devices can be mounted close to the process while the associated electronics are housed in a cabinet well away from possible damage, simplifying installation and maintenance. Moreo-ver, since controls for a pneumatic system are typically smaller than servo drives, internal space requirements in the control cabinet are reduced.

Pneumatics system is very fast in operation. This is because of very low viscos-ity of compressed air.Pneumatics system works well even in hot surroundings. Pneumatics systems are very clean.Pneumatics system is better because it doesn't generate any spark and hence no chance of explosion and fire hazard.Air is freely available in nature.Up to 110 picks per minute possible.Up to 50% shorter cycles possible by using pneumatic units.100% compatibility with modules from the SCHUNK modular system for mod-ular assembly automation.Up to 100% less cable breakage by using the electric PPU-E pick & Place unit, since there are no moving motor cables

B. *Working of pick and place mechanism*

The cylinder 1 of stroke length 150 mm is attached inclined at an angle 32° with the rear end fixed at vertical plate and the rod end hinged using piston eye and a clevis foot mounted on the horizontal plate. Air is compressed at 6 bar in recip-rocating compressor. The compressed air is supplied through pneumatic tubes of 6 mm OD to the FRL unit. In FRL the impurities in compressed air are removed, as per requirement pressure is regulated and finally air is lubricated using fine oil droplets. The cylinder 2 of 200 mm stroke length is fixed below the horizontal plate using foot mounts. Firstly the stroke length 200 mm cylinder is actuated by using 5/2 solenoid FCV and pushes the guide plate in forward direction which eventually reaches the valve, to be unloaded. Afterwards the cylinder 1 with stroke length 150 mm is actuated with the 5/2 solenoid FCV in forward direction and pushes the horizontal plate in downward direction and in some angle be-tween 21°- 25°. This completes the first operation set of the system. Now the cylinder stroke length 150 mm retracts and makes the system horizontal. And finally the cylinder 2 stroke length 200 mm actuates in reverse stroke and this completes the cycle of operation of system.

1) Components of the Pneumatic System:

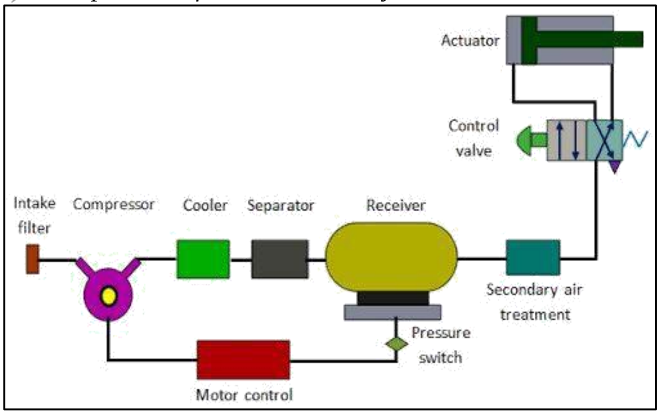


Fig. 6: Basic Pneumatic System

2) Design Calculations of Pneumatic System

Stoke length = 150 mm
Piston rod diameter = 10 mm
Diameter of Piston=32mm

a) Cylinder Thrust:

F = Cylinder thrust in kg
D = Dia. of piston in mm
d = Dia. of piston rod in mm
P= Compressed air pressure= 6 bar

b) Double acting in forward stroke:

F= $(\pi/4D^2)*P$
$= (\pi/4*(32^2))*6$
$= 472.55$ N≈473N

c) Double acting in return stroke:

F = $(\pi/4*(D^2)-(d^2))*p$
$(\pi/4*(32)^2-(10^2))*6$
405.2 N≈405N

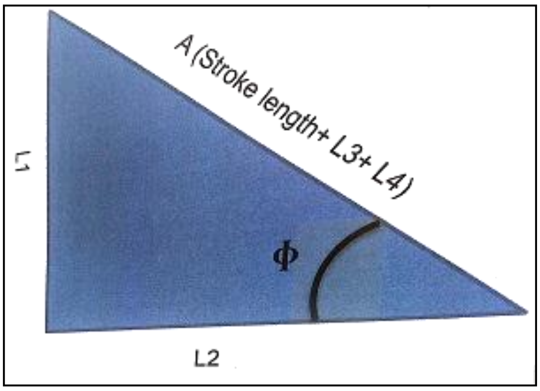
– Standard cylinders DNC-EL, standard hole pattern, with end-position locking

Piston ∅, 32	Force, N
Theoretical Force Advancing	483
Theoretical Force Retracting	415
Holding Force	500

Table 1: Technical data of cylinders DNC-EL

Air consumption:
Free air consumption = [(2*Piston area–Rod area) x Stroke x Cycles permin.]
$[(2*(\pi/4*(32^2)-(\pi/4*(10^2)) X 150 X 20]$
= 412.8786 LPM

Angle Calculations:



L1- Length of plate 1= 138.59 mm
L2- Length of plate 2= 191.8035 mm
L3- Length of swivel flange
L4- Length of clevis foot
Let, m=mass of whole mechanism=7 kg
P=pressure in the cylinder=6 to 10 bar
P=(m*g)/A=(68.67)/A
Where, A=area
For P=8 bar
A=85.84^2
F=68.67 N
From Pythagoras' theorem,
$(A)^2 = (L1)^2 + (L2)^2$
$(A)^2 = 200.66^2$
$\emptyset = \tan^{-1}(L1/L2) = 32.18°$

IV. Calculation for Stresses

A. Analytical

1) C-Plate

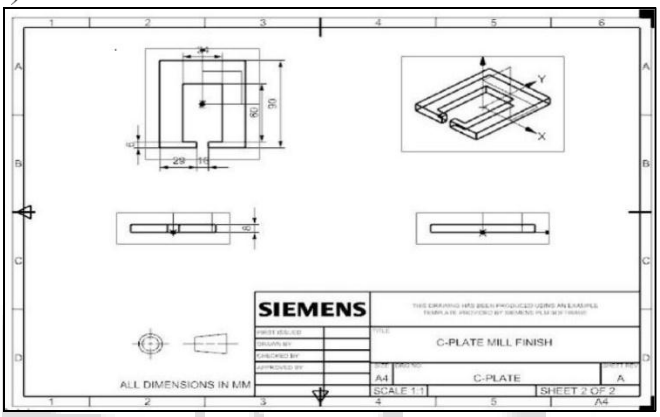


Fig. 7: Drafting of C-Plate

Material Selection

		Ultimate Tensile	Yield Tensile
Name	Description	Strength	Strength
		N / mm 2	N / mm 2
Structural Steel	SG355	460	250

Table 1: Material Properties for C-Plate

Stresses induced in C-Plate

$\sigma = \left(\frac{M}{Z}\right) + (AE\alpha\Delta T)$

$\sigma = \left(\frac{473*74}{\left(\frac{1}{6}\right)*74*8^2}\right) + (6*8*200*1.2*10^{-3} + 900)$

$\sigma = 44.9$ N/mm^2

$\sigma_{all} = \frac{S_{yt}}{N_f}$

Assume N_f=2

$\sigma_{all} = \frac{250}{2}$

$\sigma_{all} = 125$ N/mm^2

Hence, $\sigma_{act} < \sigma_{all}$

Guide Plate:

Bending Stresses induced in Guide Plate

$\sigma = \left(\frac{M}{Z}\right)$

$\sigma = \left(\frac{473*sin32*183}{\left(\frac{1}{6}\right)*90*14^2}\right)$

$\sigma = 16.23$ N/mm^2

$\sigma_{all} = \frac{S_{yt}}{N_f}$

Assume N_f=2

$\sigma_{all} = \frac{250}{2}$

σ_{all} = 125 N/mm^2

Hence, $\sigma_{act} < \sigma_{all}$

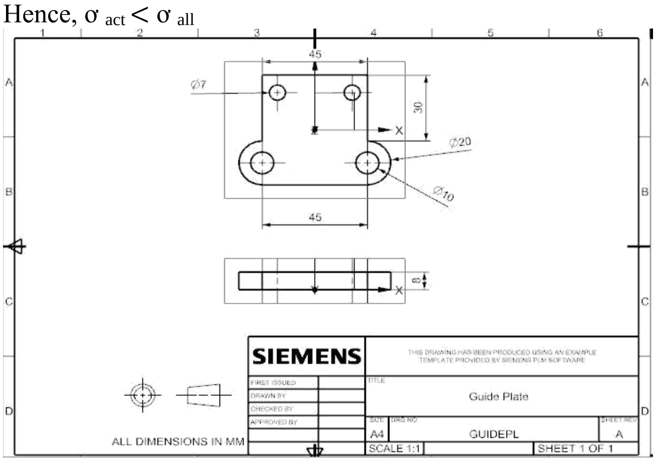


Fig. 8: Drafting of Guide Plate

B. Material Selection

Name	Description	Ultimate Tensile Strength N / mm 2	Yield Tensile Strength N / mm 2
Structural Steel	SG355	460	250

Table 2: Material Properties for Guide Plate

C. Horizontal Plate:

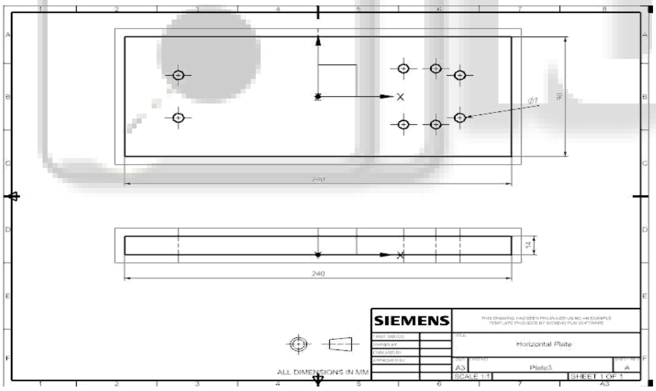


Fig. 17: Drafting of Horizontal Plate

1) Material Selection

Name	Description	Ultimate Tensile Strength N /mm ^{2}	Yield Tensile Strength N / mm^2
Structural Steel	SG355	460	250

Table 3: Material Properties for Horizontal Plate

Bending Stresses induced in Horizontal Plate

$\sigma = \left(\frac{M}{Z}\right)$

$\sigma = \left(\frac{473*sin32*183}{\left(\frac{1}{6}\right)*90*14^2}\right)$

σ =16.23 N/mm^2

$\sigma_{all} = \frac{S_{yt}}{N_f}$

Assume N_f=2

$\sigma_{all} = \frac{250}{2}$

σ_{all} = 125 N/mm^2

Hence, $\sigma_{act} < \sigma_{all}$

2) Vertical Plate:

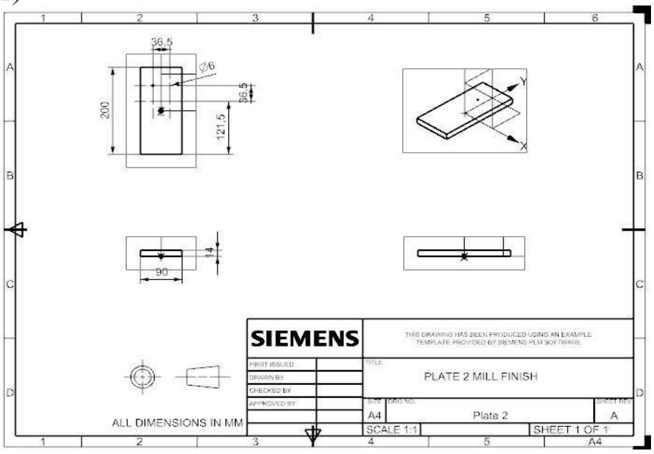


Fig. 9: Drafting of Vertical Plate

3) Material Selection

Name	Description	Ultimate Tensile Strength N /mm 2	Yield Tensile Strength N /mm 2
Structural Steel	SG355	460	250

Table 4: Material Properties for Vertical Plate

a) Tensile Stresses induced in Vertical Plate

$\sigma = \left(\frac{Force}{Area}\right)$

$\sigma = \left(\frac{473*cos32*140^2*60}{\left(\frac{1}{6}\right)*90*14^2*200^2}\right)$

σ =3.946 N/mm^2

$\sigma_{all} = \frac{S_{yt}}{N_f}$

Assume N_f=2

$\sigma_{all} = \frac{250}{2}$

σ_{all} = 125 N/mm^2

Hence, $\sigma_{act} < \sigma_{all}$

V. ANSYS

A. C-Plate:

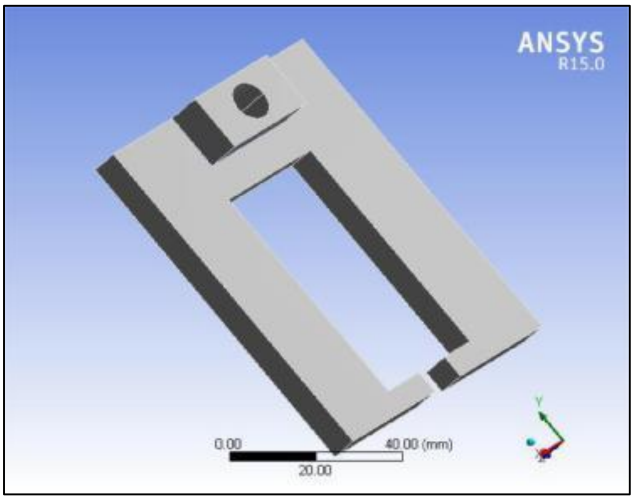


Fig. 10: CAD Model of C-Plate

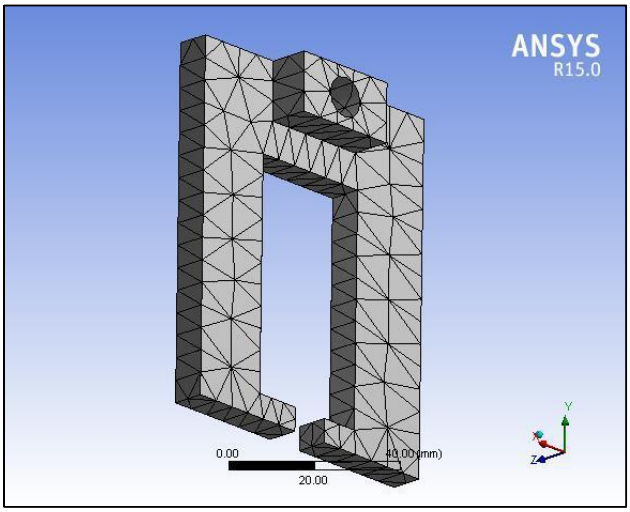


Fig. 11: Meshing of C-Plate

Object Name	Equivalent Stress
State	Solved
Definition	
Type	Equivalent(Von-Mises) Stress
Results	
Minimum	0 MPa
Maximum	72.338 MPa

Table 5: Result for C-Plate

B. Guide Plate:-

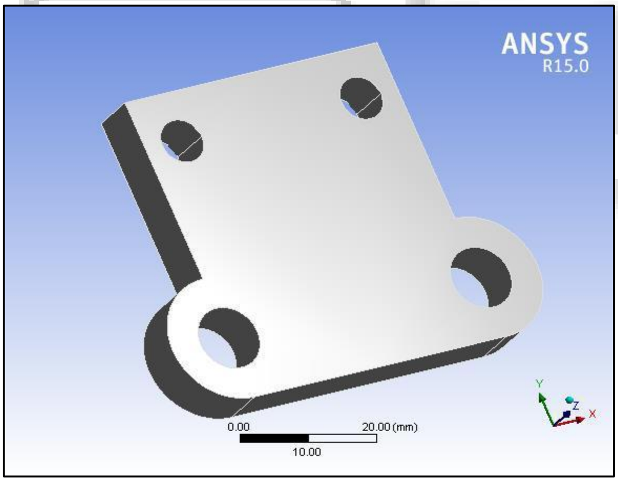


Figure 12: CAD Model of Guide Plate

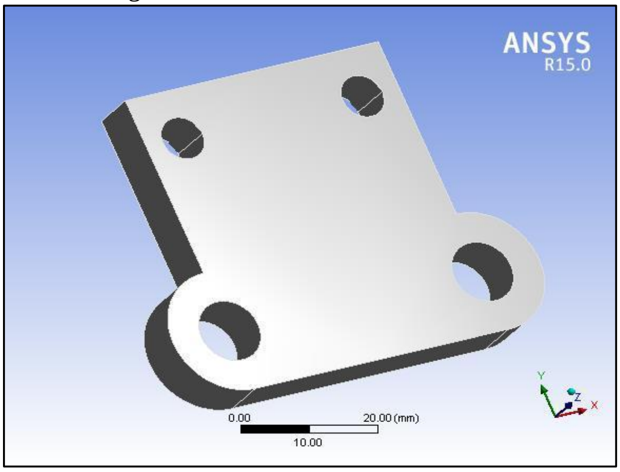


Fig. 13: Meshing of Guide Plate

Object Name	Equivalent Stress
State	Solved
Definition	
Type	Equivalent(Von-Mises) Stress
Results	
Minimum	0.12882 MPa
Maximum	59.607 MPa

Table 6: Result for Guide Plate

C. Horizontal Plate:-

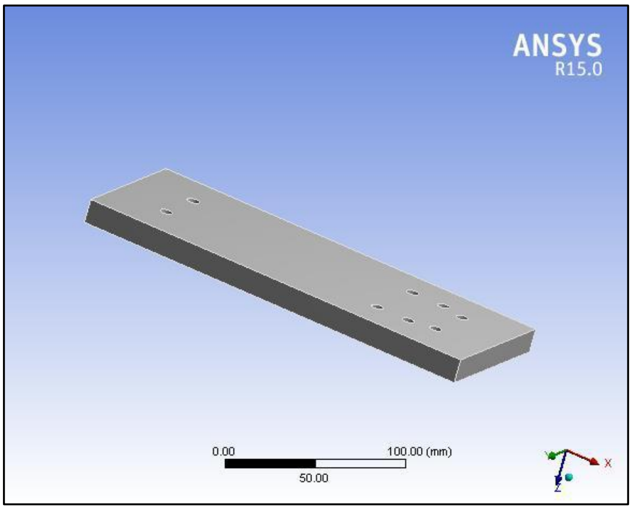


Fig. 14: CAD Model of Horizontal Plate

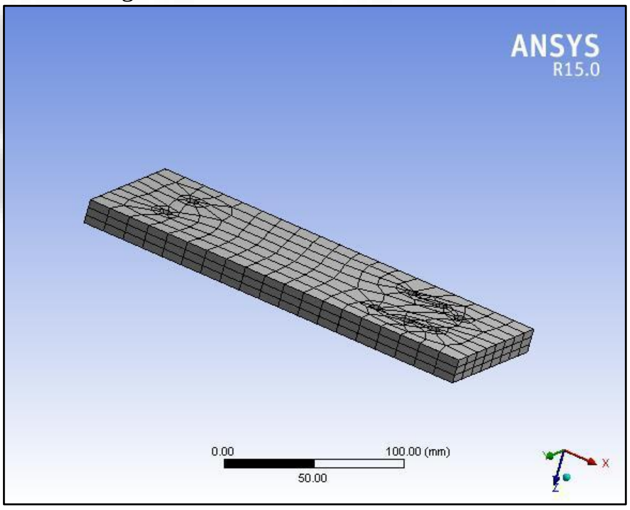


Fig. 15: Meshing of Horizontal Plate

Object Name	Equivalent Stress
State	Solved
Definition	
Type	Equivalent(Von-Mises) Stress
Results	
Minimum	0 MPa
Maximum	12.772 MPa

Table 7: Result for Horizontal Plate

D. Vertical Plate:-

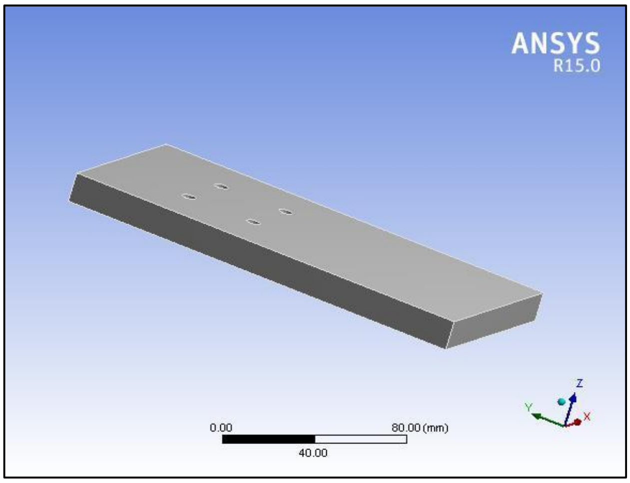


Fig. 16: CAD Model of Vertical Plate

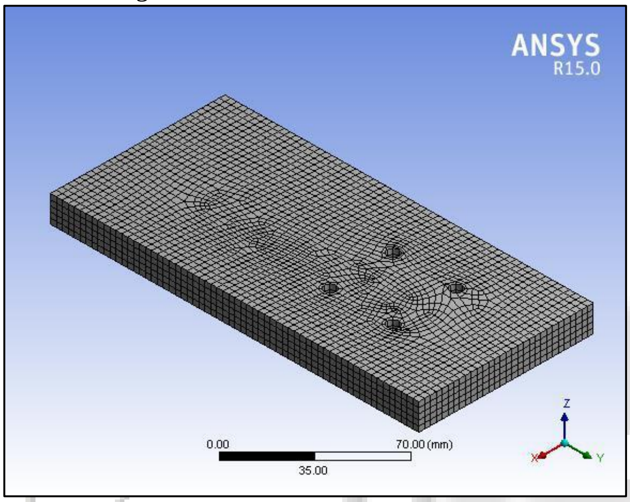


Fig. 17: Meshing of Vertical Plate

Object Name	Equivalent Stress
State	Solved
	Definition
Type	Equivalent(Von-Mises) Stress
Results	
Minimum	6.35e-5 MPa
Maximum	0.012 MPa

Table 8: Result for Vertical Plate

VI. RESULT

SR. NO.	Component	Allowable Stress N/ mm2	Analytical Stress N/ mm2	ANSYS Stress N/ mm2
1	C-Plate	250	156.7	72.34
2	Guide Plate	250	115.63	59.607
3	Horizontal Plate	250	21.63	12.772
4	Vertical Plate	250	0.225	0.012

Table 9: Comparison of Stresses

VII. CONCLUSION

We have selected pneumatic system for working of the Pick and Place Mecha-nism to solve industrial problem. To increase the rate of production and unload-ing of valves the pneumatic pick and place is best choice. Hence we choose study material for pneumatic operated unloading by differentiating and studying different material like structural steel, mild steel, etc. We have concluded that Mild Steel is our best choice for pneumatic operated unloading because it is without difficulty available and it possess great elastic strength. A CAD design has been created for this purpose and the same is analysed. Required changes were made according to the dynamic issues faced in the design.

- The design of the pick and place need to be studied to identify the mecha-nisms that could be used and which would be the most suitable.
- The material is selected by studying different materials thoroughly and then we selected MS.
- Required changes were made according to the dynamic issues faced in the design.
- A basic design is made with 10 important parts i.e. Pneumatic cylinder, carrier rods, C-Plate, Hinged Plates, Guide Plates, Guide rods, various pneu-matic joints, DCV, FRL etc.
- Analysis of all plates like C-Plate, Guide plate, Hinged Plates are also done with ANSYS software.

FUTURE SCOPE

- The mechanism can be modified to fully automatic pick and place mecha-nism by using PLC.
- The mechanism can be used in bottling plant for bottle unloading from the machine.
- Wireless pick and place technology can be implemented in near future with use of smart gadgets.
- It can be further extended for the path following applications such as weld-ing, gluing with more accurate positioning and smooth motion.

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