1. INTRODUCTION

A fixture is a work-holding or support device used in the manufacturing industry. Fixtures are used to securely locate (position in a specific location or orientation) and support the work, ensuring that all parts produced using the fixture will maintain conformity and interchange ability. Fixture is a work holding or support device used in manufacturing industry. Fixtures are used to securely locate (position in a specific location) and support the work, insuring that all parts produced using the fixture will maintain conformity and interchange ability. Using the fixture improves the economy of production by allowing smooth operation and quick transition from part to part, reducing the requirement for skilled labor by simplifying how work piece are mounted and increasing conformity across the production run. The fixtures primary purpose is to create a secure mounting point for a work piece allowing for support during operation and increased accuracy, precision, reliability and interchange ability in the finished parts. It also serves to reduce working time by allowing quick setup and by smoothing the transition from part to part. Using a fixture improves the economy of production by allowing smooth operation and quick transition from part to part, reducing the requirement for skilled labor by simplifying how work pieces are mounted, and increasing conformity across a production run. A fixture differs from a jig in that when a fixture is used, the tool must move relative to the work-piece; a jig moves the piece while the tool remains stationary.

1.1 Problem Statement

The purpose of this project is to eliminate the manual handling of the steering wheel and design the tilting fixture for holding the steering wheel, such that it reduces the lead time and improves the productivity and cost.

1.2 Background of Invention

Existing fixture for assembly of steering wheel have no degree of freedom. Therefore, workers may get fatigue and it becomes tedious to perform operations like screwing, fitting of pedal switch and limit switches. However, these existing methods have their own disadvantages. To overcome these difficulties, the design of fixture is required to be modified such that all operations can be done properly with less fatigue on worker, it will improve the productivity and will reduce the lead time.

1.3 Objective

1. To design the fixture

2. To implement low-cost automation

3. To minimize labor fatigue and lead time

4. To reduce overall cycle time and increase productivity

1.4 Requirement of the steering wheel fixture

Following are the requirements of the fixture for steering wheel to assemble paddle switch to the wheel body.

1. The steering wheel should be properly fixed on the fixture such that it has only one degree of freedom i.e. rotation about z-axis

2. Two screws of M4 size are to be inserted in the steering wheel. One screw at the left and the other to the right. The screw is at such an angle that the steering wheel is required to be tilt at 900 to either side.

3. After tilting, the wheel should be locked at that position with some locking arrangement.

4. The screw should be easily accessible by automatic screw driver which is moving along a vertical axis.

1.5 Necessity of Fixture Design

Generally, in order to maintain the work piece stability during a machining process, an operational fixture has to satisfy several requirements to fully perform its functions as a work holding device. The following constraints must be observed while designing a viable fixture.

Geometric constraint: Geometric constraint guarantees that all fixture elements have an access to the datum surface. They also assure that the fixture components do not interfere with cutting tools during a machining operation. In addition to these requirements, a fixture design should have desirable characteristics such as quick loading and unloading, minimum number of components, accessibility, design for multiple cutting operations, portability, low cost, etc.

Deterministic location: The work piece is constrained by locators so that it is presentable for the machining operation. Locating errors due to locators and locating surfaces of the work piece should be minimized so as to accurately position the work piece within the machine coordinate frame.

2. LITERATURE SURVEY

Shivaji Mengawade, Vaibhav Bankar, Pratik P Chaphale[1]This paper states that fixture provides the manufacturer for flexibility in holding forces and to optimize design for machine operation as well as process function ability. It reduces or sometimes eliminates the efforts of marking, measuring and setting of workpiece on a machine and maintains the accuracy of performance. The workpiece and tool are relatively located at their exact positions before the operation automatically within negligible time. So it reduces product cycle time. Variability of dimension in mass production is very low so manufacturing processes supported by use of jigs and fixtures maintain a consistent quality. Due to low variability in dimension assembly operation becomes easy, low rejection due to less defective production is observed. It reduces the production cycle time so increases production capacity. Simultaneously working by more than one tool on the same workpiece is possible. The operating conditions like speed, feed rate and depth of cut can be set to higher values due to rigidity of clamping of work piece by fixtures. Operators working become comfortable as his efforts in setting the work piece can be eliminated. Semi-skilled operators can be assigned the work so it saves the cost of manpower also. There is no need to examine the quality of produce provided that quality of employed fixtures is ensured. This paper concludes that fixture reduces or sometimes eliminates the efforts of marking, measuring and setting of workpiece on a machine and maintains the accuracy of performance.

V. R.Basha, J.J. Salunke[2]. In this paper, a literature survey of fixture design and automation over the past decade is proposed with the introduction on the fixture applications in industry and the significant works done in the design field, including their approaches, requirements and working principles are discussed. With the advent of VMC machining technology and the capability of multi-axis machines to perform several operations and reduce the number of set-ups, fixture design task has been somewhat simplified in terms of the number of fixtures. The rapid development through the computer aided fixture design (CAFD) in manufacturing of modified fixture design has an immense role for to reduce the designing time and application of Flexible

Manufacturing System (FMS) has added to the requirement for more flexible and cost-effective fixtures. Traditional fixtures (dedicated fixtures) which have been used for many years are not able to meet the requirements of modern manufacturing due to the lack of flexibility and low reusability. The replacement of dedicated fixtures by modular and flexible fixtures is eminent in automated manufacturing systems. Fixtures are constructed from standard fixture elements such as base-plates, locators, supports, clamps, etc. These elements can be assembled together without the need of additional machining operations and are designed for reuse after disassembly. The main advantages of using modular fixtures are their flexibility and the reduction of time and cost required for the intended manufacturing operations. Automation in fixture design is largely based on the concept of modular fixtures, especially the grid-hole-based system. Traditionally, fixture design is a manual process and demands an expert's Knowledge and skilled engineering. . In this paper, a literature survey of fixture design and automation over the past decade is proposed with the introduction on the fixture applications in industry and the significant works done in the design field, including their approaches, requirements and working principles are discussed. Finally, some prospective research trends are also discussed.

Ford Global Technologies,[3]. In this paper, An alignment tool for a steering wheel, where the steering wheel is mounted on a steering column and the tool is configured to attach to the steering wheel. The tool includes a wheel orientation mechanism including a first tilt sensor, reporting a clockwise angle of the steering wheel, and a tilt monitoring mechanism that includes a second tilt sensor to report a tilt angle of the steering column.

Ray Garnet Armstrong ,James Anthony Smazenka, Richard Kremer Riefe, [4].In this paper, The steering column tilt assembly has a tilt housing that is pivotally attached to a fixed housing. A fixed shoe is attached to the fixed housing. A pivoted shoe is pivotally attached to the tilt housing. A shoe release lever has a wedge surface that holds the pivoted shoe in engagement with a fixed shoe when in a locked position.

Chen Luo, LiMinZhu,Han Ding[5] In his paper Two-Sided Quadratic Model for Work piece Fixturing Analysis, 2011 proposed that presents a novel model for work piece positioning analysis. Existing fixturing models mayunder estimate the positioning error due to neglect of the curvature of one or both contacting bodies.

S. Kashyap W.R. DeVries[6]. In their paper Finite element analysis and optimization in fixture, proposed with minimizing deformation of the work piece due to machining loads about fixturing support positions, especially in thin castings.

Antonio Carlos Valdiero, Ivan Jr. Mantovani, Andrei Fiegenbaum, Giovani P. B. Dambroz, and Luiz A. Rasia[7]. The aim of authors in this work is to develop automation through a classic methodology for a manufacturing cell to minimize errors and facilitate the sequential logic conception. The rise of industrial automation seeks to optimize productive processes to raise quality of manufacture, decrease production time, and minimize risks of accidents and ergonomics. This paper presented the development of a pneumatically driven manufacturing prototype for low cost automation. It is intended to contribute to future applications of mechatronic systems that attend the needs of increasing productivity, reducing costs, and improving work safety. Moreover, the pneumatically actuated manufacturing cell can be easily integrated into robotic cells and its programming can be synchronized with the planning, modeling, and control of robotic manipulators in Flexible Manufacturing Systems (FMS).

R. Förstmann; J.Wagner ; K. Kreisköther ; A. Kampker; D. Busch[8] As product varieties rise and lifecycles shorten, development approaches need to be adapted. Current trends aiming to solve the dissonance of reduced time to market and increased product variety include agile methods. In this context not only product design processes need to be adapted but also development of production processes and manufacturing equipment. At the example of fixture design, this paper presents an approach which allows an agile provision as well as a reconfiguration of equipment. The solution presented consists of a fixture design concept consisting of design rules which allow implementation into a tool for automated fixture design.

Vaibhav Ingle, L P Raut, Sandesh Potnis[9] This work presents a new approach for the reduction of process cycle time and its impact on a company's competitive edge.

Reduction in cycle time has been gaining significant attention in recent times. The shorter cycle times effect in higher consumer satisfaction, lower manufacturing rate, higher yield, and better potential given tool inventory and facility constraints. This research paper provides a brief review of core approaches related to cycle time and also describes a methodology for cycle time reduction in any manufacturing and automobile production industry. It includes the assessment and potential gains of the projected cycle time reduction methodology. Manufacturing Time based challenge is an organized way focusing on reduction of total throughput time in manufacturing firm. Reduce time has a cascading influence on value and worth. As cycle times are reduced, output increases equally. If reduction in cycle time is fifty percent and work in process inventory is twice turns causes output to increase from twenty to seventy percent. As output increases, resource capacity is freed. Two major effects take place: expenses turn down, and the manufacturing firm becomes capable of producing considerably more output with fewer assets: a successful arrangement.

Hiten Patel, Sanjay C. Shah have analysed methods to reduce cycle time in their paper. This paper presented a research work on Reduction in process cycle time in manufacturing industry. This research paper is able to present insights into how the manufacturing layout parameters (like process time, work in process, and assignment of an inspection station) influence manufacturing system functioning (like total Process cycle time and throughput). An especially significant result is that increasing process cycle time at one work unit can reduce both total process cycle time and throughput. One of the most noteworthy accomplishments in keeping the price of products low is the gradual shortening of the production cycle. The longer an article is in the process of manufacture and the more it is moved about, the greater its ultimate cost. (Henry Ford 1926). This research thesis key contribution is to describe a number of cycle time reduction challenges and demonstrate the ways and by using time study and scares approach that help to meet them.

3. DESIGN OF FIXTURE

3.1 Fixture Design

Fixture plate shape is designed to provide balancing after tilting. Plate is symmetric about vertical axis passing through its centre of gravity. Thickness of plate is selected arbitrarily based on diameter of hole in the steering wheel. Width of plate is taken as the base diameter of steering wheel. Pneumatic circuit is designed further on the basis of force exerted during tilting of plate.

3.2 Fundamental principles of fixture design

- **Locating Points**: Good facilities should be provided for locating the work. The article to be machined must be easily inserted and quickly taken out from the jig so that no time is wasted in placing the workpiece in position to perform operations. The position of workpiece should be accurate with respect to tool guiding in the jig or setting elements in fixture.
- **Fool Proof**: The design of jigs and fixtures should be such that it would not permit the workpiece or the tool to inserted in any position other than the correct one.
- **Reduction of Idle Time**: Design of Jigs and Fixtures should be such that the process, loading, clamping and unloading time of the workpiece takes minimum as far as possible.
- **Weight Of Jigs And Fixtures**: It should be easy to handle, smaller in size and low cost in regard to amount of material used without sacrificing rigidity and stiffness.
- **Materials For Fixtures**: Usually made of hardened materials to avoid frequent damage and to resist wear. Example MS, Cast iron, Die-steel, CS, HSS.
- **Clamping Device**: It should be as simple as possible without sacrificing effectiveness. The strength of clamp should be such that not only to hold the

work piece firmly in place but also to take the strain of the cutting tool without springing when designing the jigs and fixtures.

3.3.1 Input Data

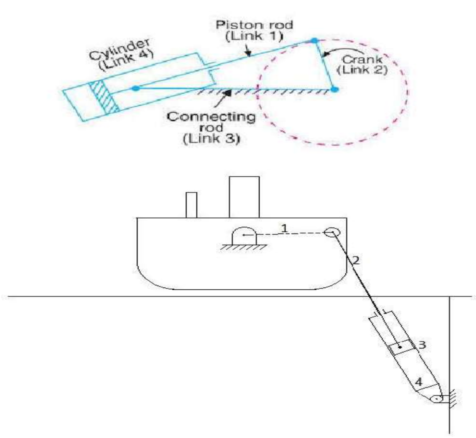
Operating Pressure = 6 bar (5 to 6 bar)

Required tilting angle = 450 (clockwise & counterclockwise)

Weight of steering =1.5 kg (15 N)

3.3.2 Basic Mechanism

Oscillating cylinder mechanism used which is an inversion of slider crank mechanism. By fixing link 3 of the slider crank mechanism, third inversion is obtained. Now, link 2 again acts as a crank and link 4 oscillates. The mechanism contains one sliding pair and two turning pairs. As shown in Fig. link 4 is made in the form of a cylinder and a piston is fixed to the end of link 1. The piston reciprocates inside the cylinder pivoted to the fixed link 3. The arrangement is known as oscillating cylinder engine, in which as the piston reciprocates in the oscillating cylinder, the crank rotates. The wheel orientation mechanism used in tilting fixture assembly including a first tilt sensor, reporting a clockwise angle of the steering wheel, and a tilt monitoring mechanism that includes a second tilt sensor to report a tilt angle of the steering column.



1. Crank
2. Connecting rod
3. Slider
4. Cylinder

Fig No. 3.1 Basic actuating mechanism (oscillating cylinder)

3.3.3 Material Selection

Table No. 3.1 Material Properties

CONTENTS	MILD STEEL	ALUMINIUM	CAST IRON
Material Cost	Low	Medium	High
Wear Resistance	Medium	Low	High
Thermal Expansion	Low	High	Medium
Resistivity Coefficient (ohm-m)	15 * 10^ -8	2.65*10^-8	100*10^-8
Density (kg/m^3)	7850	2.7	6800
Specific Heat (KJ/KgK)	0.510	0.900	0.46
Melting Point (F)	2750	1220	2300
Hardness (BHN)	130	170-187	415
Temperature Coefficient (°C)	6.66*10^-2	3.8*10^-2	-

From the above comparison mild steel is selected as the material for fixture

Composition: Mild steel is an Iron-carbon alloy containing less than 0.25 percent carbon which makes it more ductile and less hard thus rendering it unsuitable for structural work, Most suitable for jigs and fixtures applications as It is the economical and most widely used material in jigs and fixtures.

Properties of mild steel:

1. Castability: Mild steel is also easy to work with but cast iron has higher castability.

2. Hardness: Mild steel can be hardened and tempered by using relevant processes.

3. Strength

3.1 Compressive strength

The compressive strength of cast iron is 6.3 – 7.1 tonnes / sq. cm. It's ultimate tensile strength is 1.26 – 1.57 tones / sq. cm. The compressive strength of mild steel is 4.75 – 25.2 tonnes / sq. cm.

3.2 Tensile strength

Its ultimate tensile strength is 5.51 – 11.02 tonnes / sq. cm. This clearly shows that mild steel is a better option than cast iron when it comes to ultimate tensile strength. However, cast iron has better compressive strength than mild steel. Due to this, it will have greater resistance against breaking under compression. This also makes it quite durable and ideal for rugged use. It will not show signs of wear and tear easily and you can expect long term performance from cast iron.

4. Usability

Mild steel is especially desirable for construction due to its weldability and machinability. Because of its high strength and malleability it is quite soft. This means that it can be easily machined compared to harder steels. Use of mild steel in engineering applications is the most economical alternative to other engineering materials.

3.3.4 Design of fixture plate

Fixture plate shape is designed to provide balancing after tilting. Plate is symmetric about vertical axis passing through its centre of gravity.

A bolt is to be fitted on the top which is having diameter same as hole diameter in steering wheel. By using principle of location one locating pin is to be attached on the top to avoid turning of steering wheel about vertical axis.

Thickness of plate is selected arbitrarily based on diameter of hole in the steering wheel. Width of plate is taken as the base diameter of steering wheel.

Following are the plate specifications.

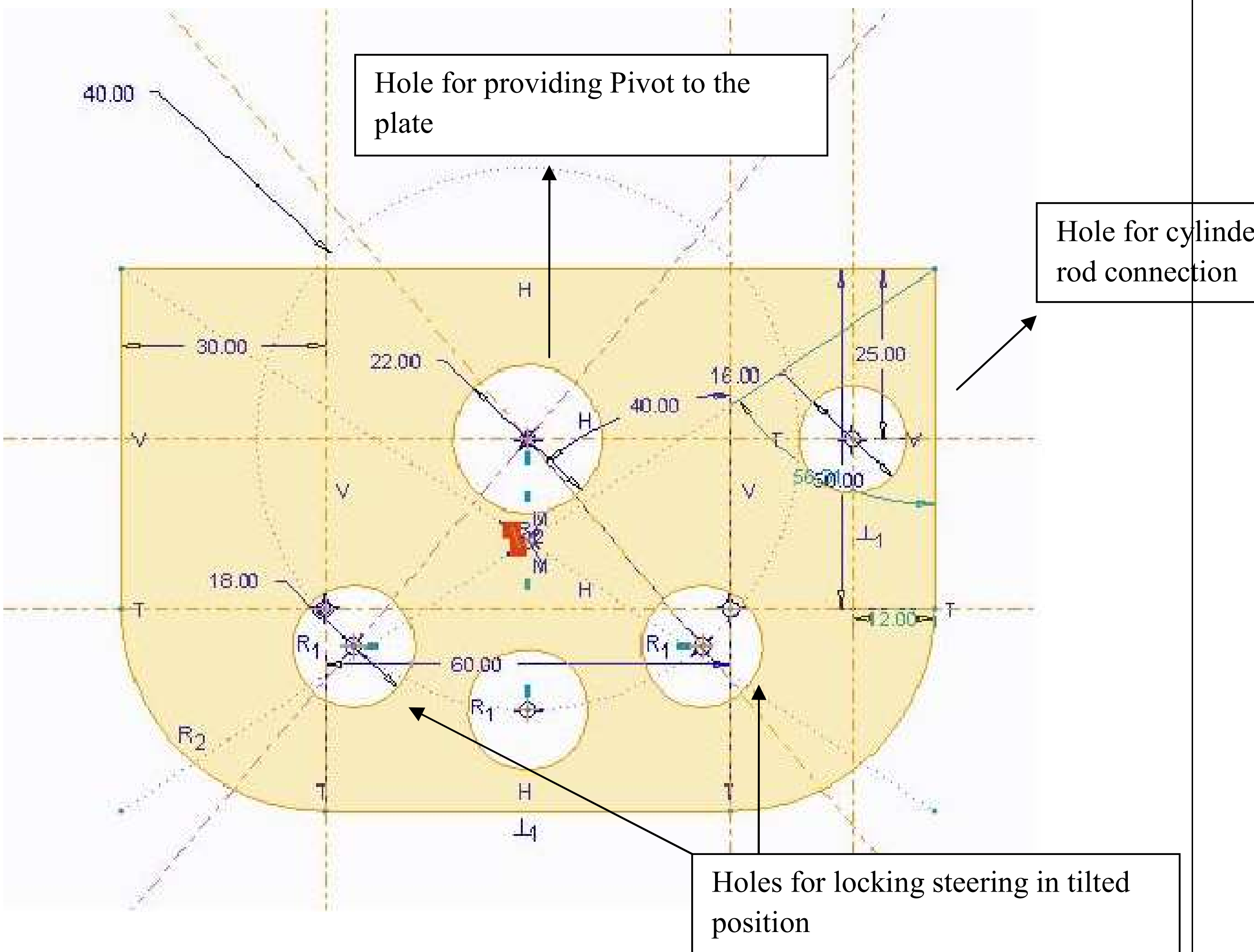


Fig No.3.2 Fixture Plate

3.4 Pneumatic Circuit Design

It is very essential to use reliable clamping device and fixtures to reduce ambiguity in assembly of components. The setup cost should be as less as possible as it increases the overall cost of the product. Setup costs are mostly associated with fixtures. Thus using pneumatic system the setup costs is reduced to some extent. It is also easy to operate. Fast operation of pneumatic system leads to time saving hence increases productivity.

3.5 Pneumatic circuit layout

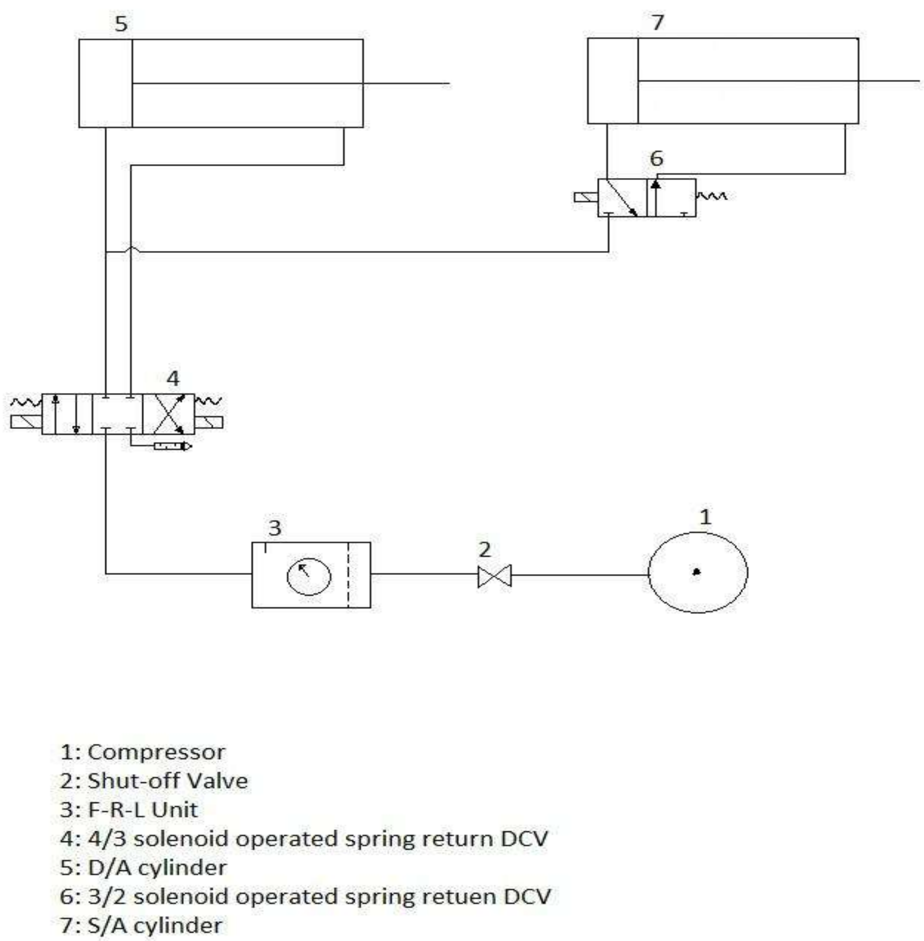


Fig No. 3.3 Pneumatic circuit layout

3.6 Working of Pneumatic circuit

Compressed air is passed through FRL unit. Cylinder is half extended at initial position and DCV at middle position. When the steering is attached to the rod the solenoid operated DCV gets actuated in first position and the steering gets attached in first position and the steering gets tilted in anticlockwise direction. A sensor is placed near the steering and after getting tilted , the sensor actuates the 3/2 DCV. This actuates locking cylinder which is used to lock the plate at a position. Once this plate gets locked at a particular position, the automatic screw driver tightens the screw then operating the switch the solenoid gets energized. The 4/3 DCV gets actuated in 3rd position and thus the cylinder retracts fully and the steering gets tilted in clockwise direction and gets locked by the locking cylinder. Again the automatic screw driver is used for screw tightening.

3.6.1 The advantages of pneumatic systems

Using of Pneumatic control system has offered the following advantages

(i) High effectiveness

(ii) High durability and reliability

(iii) Simple design

(iv) High adaptability

(v) Safety

(vi) Easy selection of speed and pressure

(vii) Environmental friendly

(viii) Economical

3.6.2 Limitations of Pneumatic Systems

Although pneumatic systems possess a lot of advantages, they are also subject to many limitations.

(i) Low loading

(ii) Uneven moving speed

3.7 Cylinder Selection from Manufacturer's Catalogue

Cylinder for tilting the fixture plate about a pivot and determination of Force to be balanced

Volume of plate =184.274 cm^3

Material selected, MILD STEEL

Density of MILD STEEL material = $\rho = \frac{mass}{volume}$ =7.85 gm/cm^3 (3.1)

Weight of plate = Volume × ρ (3.2)

= 184.274 cm3 × 7.85 gm/cm^3

=1500 gm

=1.5 kg = 15 N

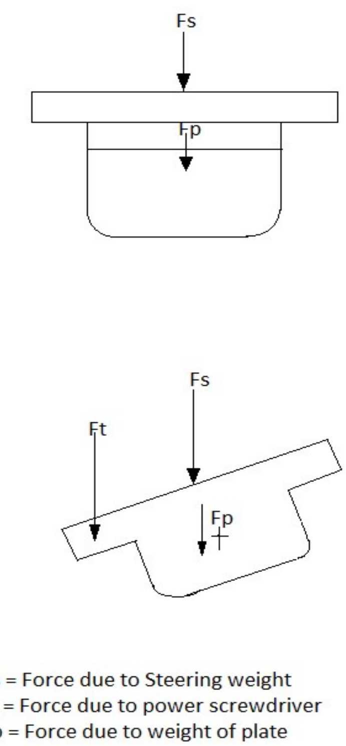


Fig No. 3.4 Free Body Diagram

Steering is to be tilted by 40°

i. The moment about Centre is to be balanced by Cylinder force

Weight of steering =1.5 kg =15 N

Force of screwdriver during tightening =50 N (Approximately)

Weight of the plate =15 N

ii. Displaced Centre of gravity is with moment

Steering = 15 N × 0.06

= 0.9 N

Plate = 15 N × 0.0225

= 0.0225N

Screwing force = 50 N × 0.2

= 10 N

iii. Total moment balanced by cylinder

= Moment of steering + Moment of Plate + Screw force moment

= 0.9+0.0225+10

= 10.9225 N

Force on cylinder = $\frac{Total\ moment}{Eccentricity} = \frac{10.9225}{0..2}$ (3.3)

=390.12 N

Selecting cylinder from FESTO DNC series cylinder catalogue depending on force exerted at 6 bar. DNC-32-80-PPV-A is selected.

Fig. No.3.5 Festo DNC 32-80-PPV

Bore of Cylinder = 32mm

Stroke of cylinder = 80 mm

This cylinder is selected for pivoting purpose. It requires a clevis foot mounting for pivoting. Hence FESTO Clevis foot LBG series 31761 for 32 dia. Cylinder is selected.

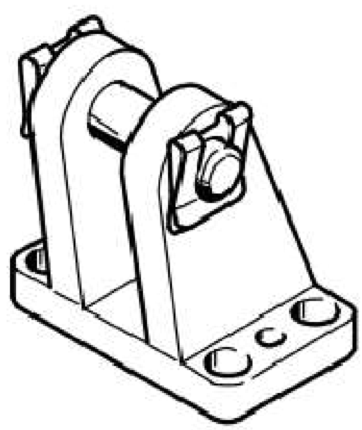


Fig no. 3.6 Clevis foot mounting

Shearing Failure checking

Cylinder force =400 N

Checking for Double Shear

Considering Maximum Shear Stress Theory

Shear strength = 0.5 × Tensile strength

= 0.5 × 400

=200 MPa

As per given Profile center hole for tilting wheel is 15 mm diameter

Shear stress is at joining Pneumatic tilting cylinder with plate

Force acting by cylinder =400 N

Shear stress $\tau = \frac{Force}{Area}$ (3.4)

$= \frac{400}{2\times\frac{\pi}{4}\times15\times15}$ = 1.13 N/mm^2

Hence design is safe.

Cylinder for Locking the Plate in Tilted Position

In order to have ease of maintenance and interchangeability of parts the cylinder for locking purpose is selected from the same FESTO series. Cylinder DNC-32-40-PPV-A is selected which is having comparatively shorter stroke length.

3.8 Design of bearing at center hole of 32mm Dia.

Design of bearing

Selection of bearing

For low and medium load -ball bearing are used

The expression for equivalent dynamic load

$$P = X \times Fr + Y \times Fa$$

P= equivalent dynamic load (N)

X=radial factor

Y=thrust factor

Fr= radial load(N)

Fa=axial load(N)

For ball bearing there is no axial load

Therefore $P = X \times Fr$

Bearing is subjected to pure radial load

$$P = Fr = 60N$$

Life of bearing in millions of revolution

Therefore,

$$L_{10} = 60nL_{10h}/10^6$$

L10h =Life of bearing in hours (10000 hrs)

$$L_{10} = 60 \times 10 \times 10000/10^6$$

$$L_{10} = 6\ milllion\ revolutions$$

$$C = P(L_{10})^3$$

$$C = 60 \times (6)^{0.3}$$

$$C = 102.7061\ N$$

Where, C=Dynamic load capacity

Shaft diameter is 15 mm therefore we can use the bearing 61802,6002,6202,6302 all are suitable for dynamic load.

Hence we selected the bearing 6002.

3.9 Selection of DCV for actuation

FESTO CPV-VI 14 series valve is selected because of the following advantages

i. The CPV valve terminal has a unique design. It provides the flexible combination of pneumatic performance, electrical connection technologies and a wide range of mounting options.

ii. The pneumatic multiple connector plate supports space-saving installation in control cabinets.

iii. In many cases the valve terminal can be installed in the previously unused wall area of the control cabinet. There is no need to connect the valves in the control cabinet.

iv. All tube couplings can be laid externally. Instead of individual holes, the pneumatic multiple connector plate requires only one rectangular cutout.

v. The generously sized flow ducts and powerful flat plate silencers ensure high flow rates.

vi. All valves are in the form of valve slices. They are optimised for flow performance and are also extremely compact.

vii. This saves space and reduces costs.

viii. The cubic design permits exceptional performance yet a comparatively low weight. The benefits of this design are obvious when the valve terminal is used on a drive in a moving installation.

ix. However, robustness must not be sacrificed in favor of compactness. The connecting threads and mounting attachments are metal.

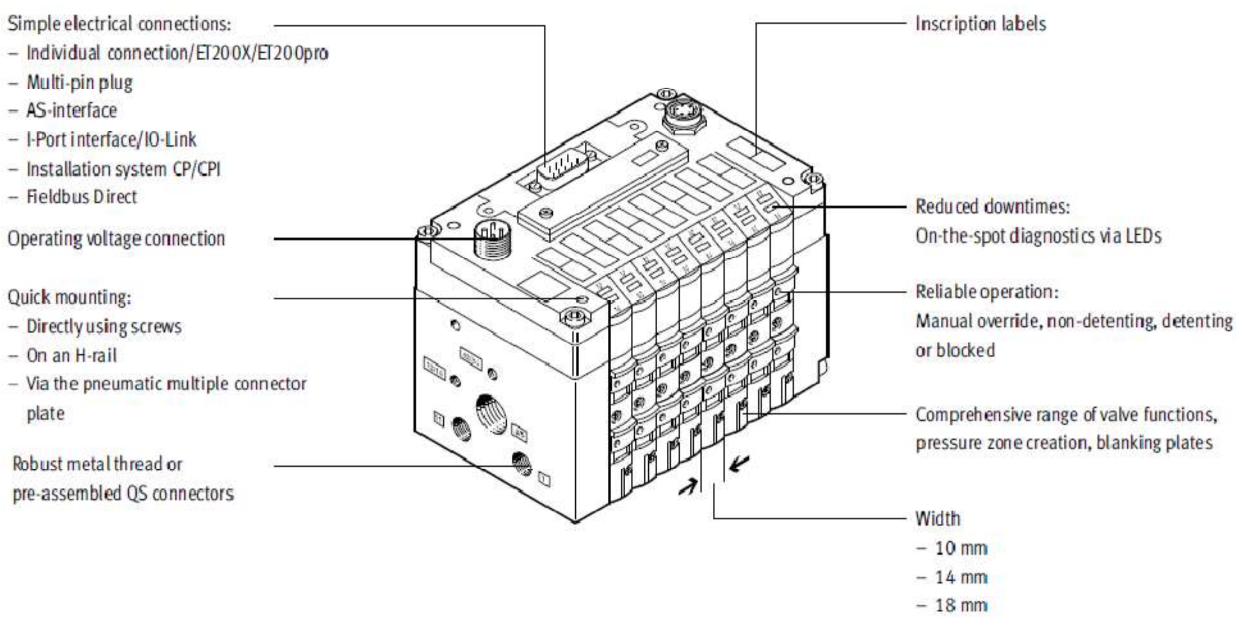


Fig No. 3.7 CPV-VI 14 DC Valve

3.10 Design of rods

Total weight of steering wheel= 3 kg

To design the shaft

Weight =30N

We have used mild steel material. Therefore crushing stress for mild steel is 250 MPa.

Factor of safety =1.5

Allowable stress= 250/1.5=166.66

$$Stress = \frac{Load}{Bearing\ area}$$

$$166.66 = \frac{30}{20 \times D}$$

$$D = 9 \times 10^{-3} mm$$

Moment on the centre of shaft

Moment = Reaction in each support × Distance between centre of support to centre of rod

$$M = 30 \times 24 = 720\ N - mm$$

$$\frac{M}{I} = \frac{\sigma}{y}$$

$$\frac{720}{(\frac{\pi}{64})d^4} = \frac{166.66}{\frac{d}{2}}$$

$$d^3 = \frac{720}{(\frac{\pi}{64}) \times 333.32}$$

$$d^3 = 44.00049\ mm$$

$$d = 3.53\ mm$$

But available rod from the scrap is 24 mm in diameter. So from bearing and spacer diameter consideration the diameter of rod is rounded up to 15mm.

3.11 Design Summary Sheet For Components

Table No. 3.2 Design summary sheet

Sr. No.	Part Name	Input	Formula	Parameter
1	Shaft	Force=30 N	$\tau = \frac{F}{2(\frac{\pi d^2}{4})}$	D = 15mm
2	Shaft	Force=30 N	$\sqrt{\frac{16M}{6\pi}}$	D=3.15mm
3	Thickness of support plate	Force=15 N	$F = P \times D \times l$	l = 18mm
4	Diameter of shaft a support plate	Force=15 N	$\tau = \frac{F}{\frac{\pi d^2}{4}}$	d = 15mm
5	Cylinder selection	F1 = 15N E1 = 0.06m F2 = 50N E2 = 0.2m	$F1 \times E1 = F2 \times E2$	Force required in cylinder= 390N
6	Pin Mounting	F=400 N D=15	$\tau = \frac{F}{\frac{\pi d^2}{4}}$	D = 12mm
7	Bearing	F=60 N	$P = X \times Fr + Y \times Fa$	C=102.7061 Bearing 6002

4. SIMULATION USING SOFTWARE- ANSYS

Version – ANSYS 17.0 - ANSYS 17.0 delivers solutions faster so that you can make better design decisions earlier in the product development cycle. We've made improvements across the entire workflow, from modeling to post processing, radically accelerating results without compromising accuracy.

Preprocessing also called Meshing is the first step in solving a problem in Finite Element Analysis Here the entire domain is discretized (divided) into meaningful divisions often called "Elements". These elements form the building block on which the Boundary conditions and external effects are specified.

4.1 Stress and deformation analysis of Fixture Plate

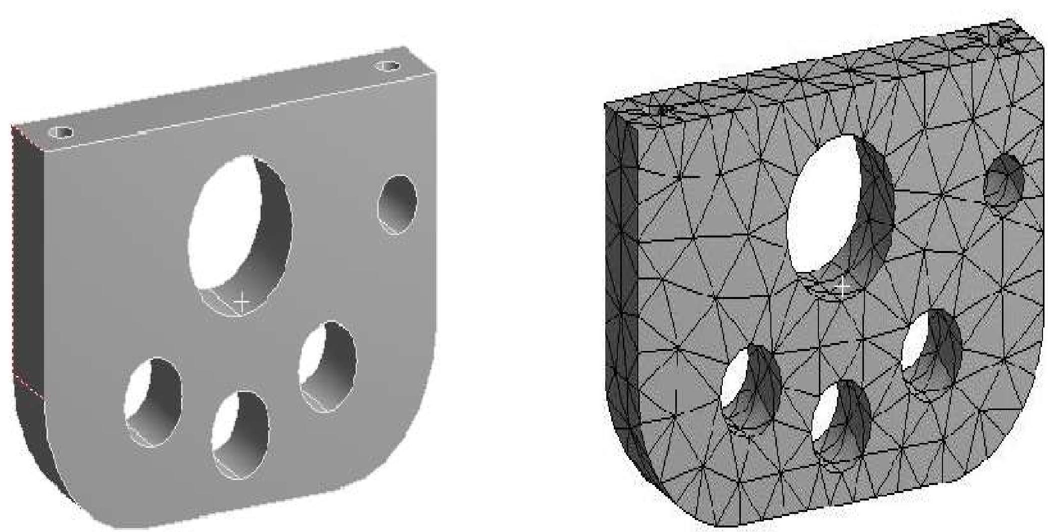


Fig No. 4.1 Part drawing and meshing of Fixture plate

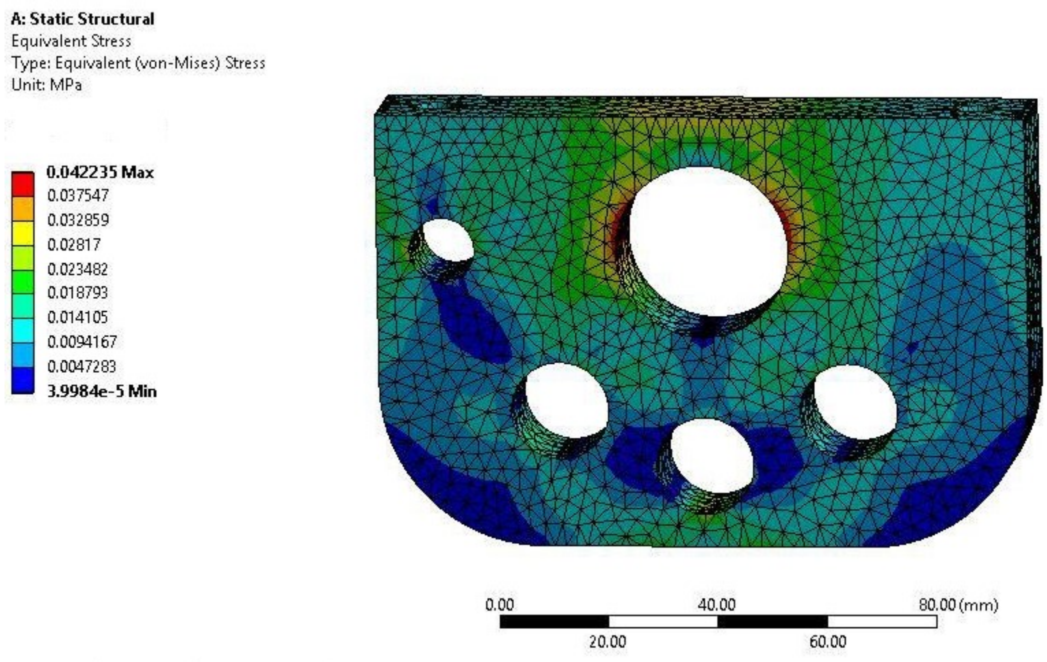


Fig No. 4.2 Stress distribution of fixture plate

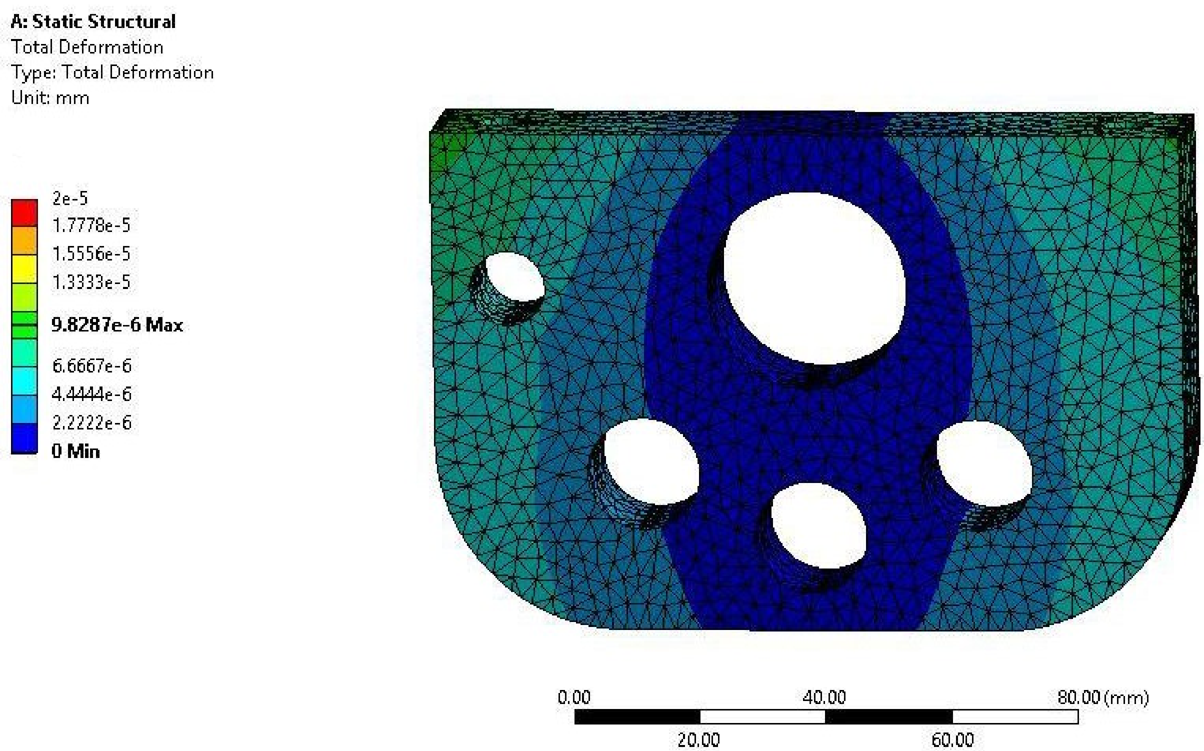


Fig. No. 4.3 Deformation of Main Plate

From the above results it is clear that, the maximum stress is induced at central hole which is 0.042235 MPa well below the safety limit. It is happened because load on the plate is very less. The maximum deformation is 2*e-5 mm which is also negligible for this application.

4.2 Stress and deformation analysis of Central Pivot Pin

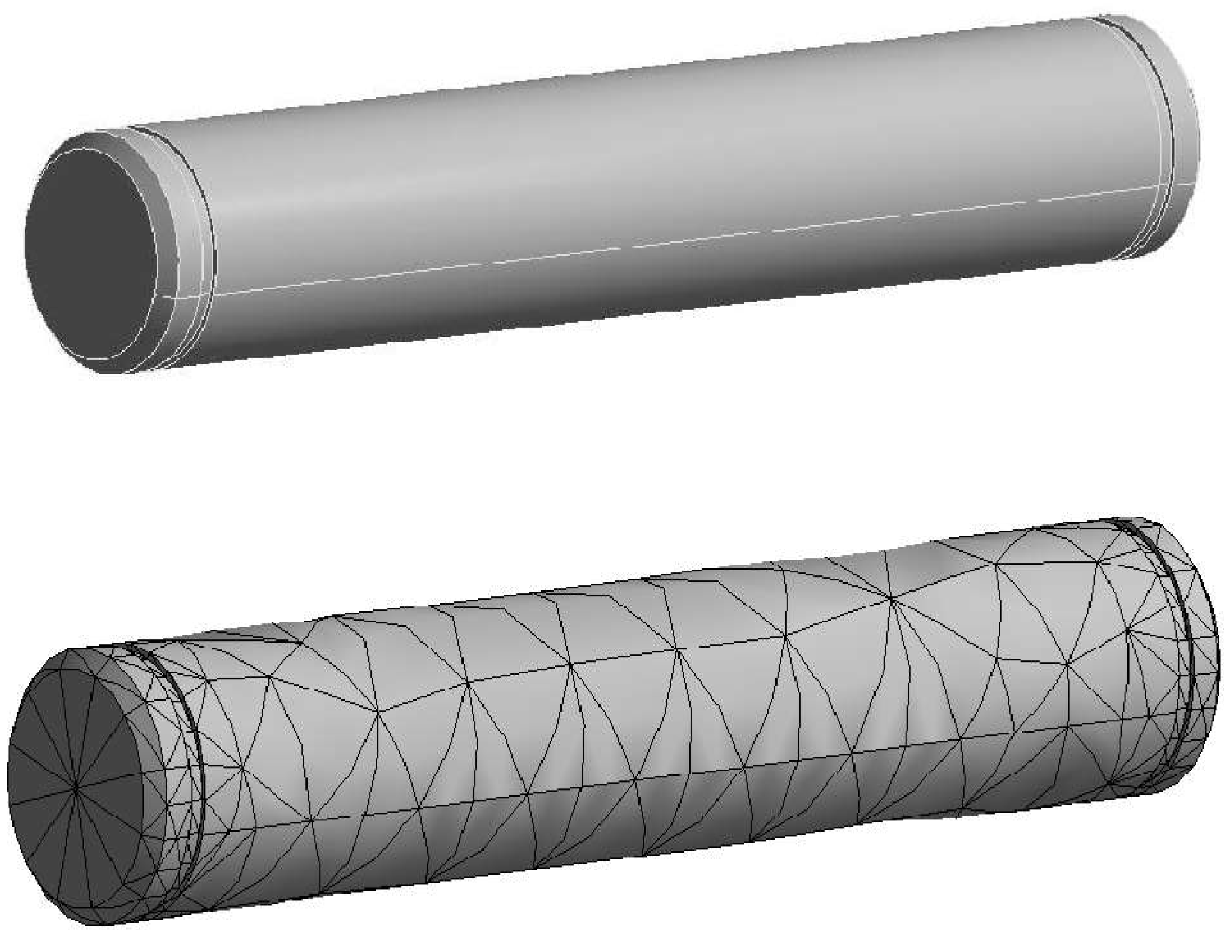


Fig No. 4.4 Part drawing and meshing of pivot pin

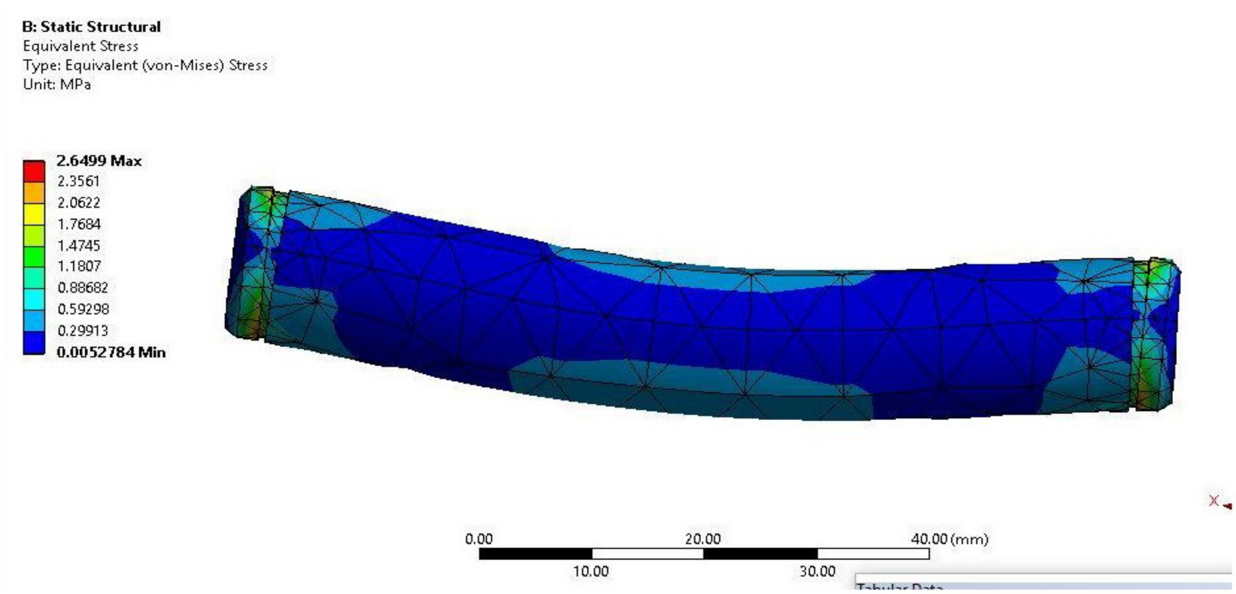


Fig. No. 4.5 Stress Distribution of central pivot pin

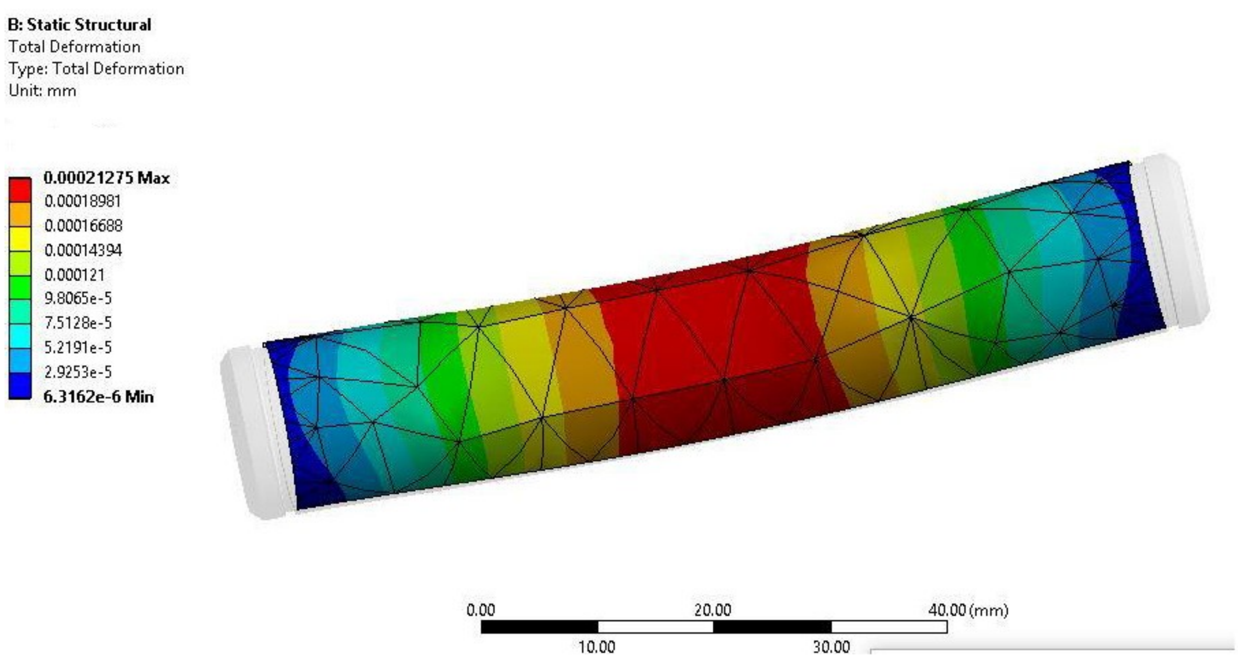


Fig. No. 4.6 Deformation of central pivot pin

The Maximum stress is induced in the ends where support is given. The stress is of 2.6499 MPa maximum which is below permissible stress. The maximum deformation takes place at the centre of rod. Maximum deformation is 0.00021275mm.

4.3 Stress and deformation analysis of Vertical Plate

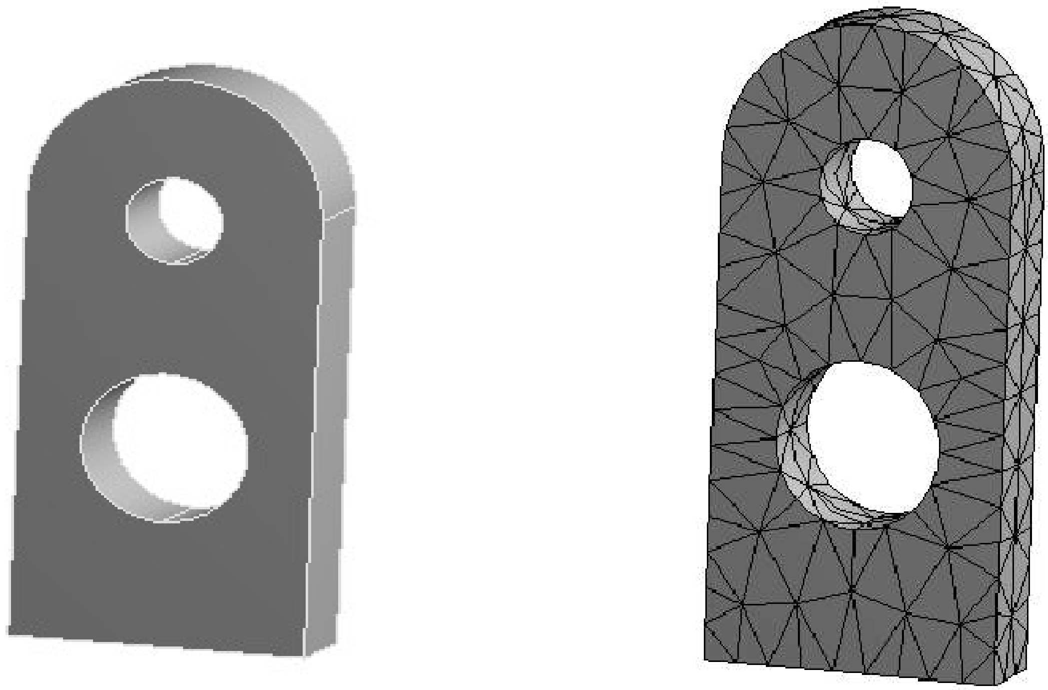


Fig No. 4.7 Part drawing and meshing of vertical plate

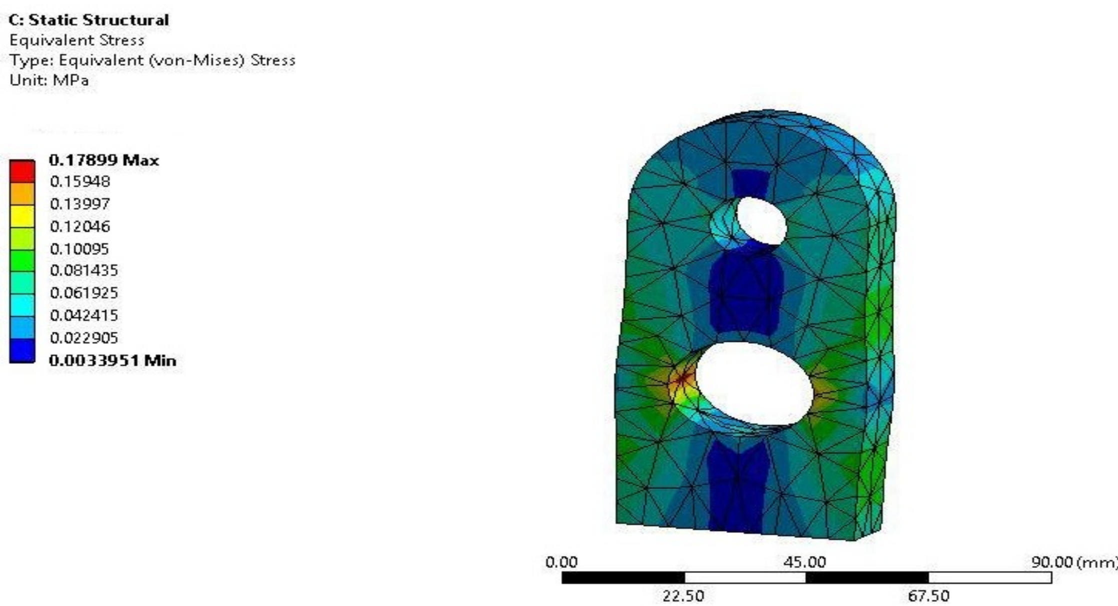


Fig. No. 4.8 Stress distribution of vertical Plate

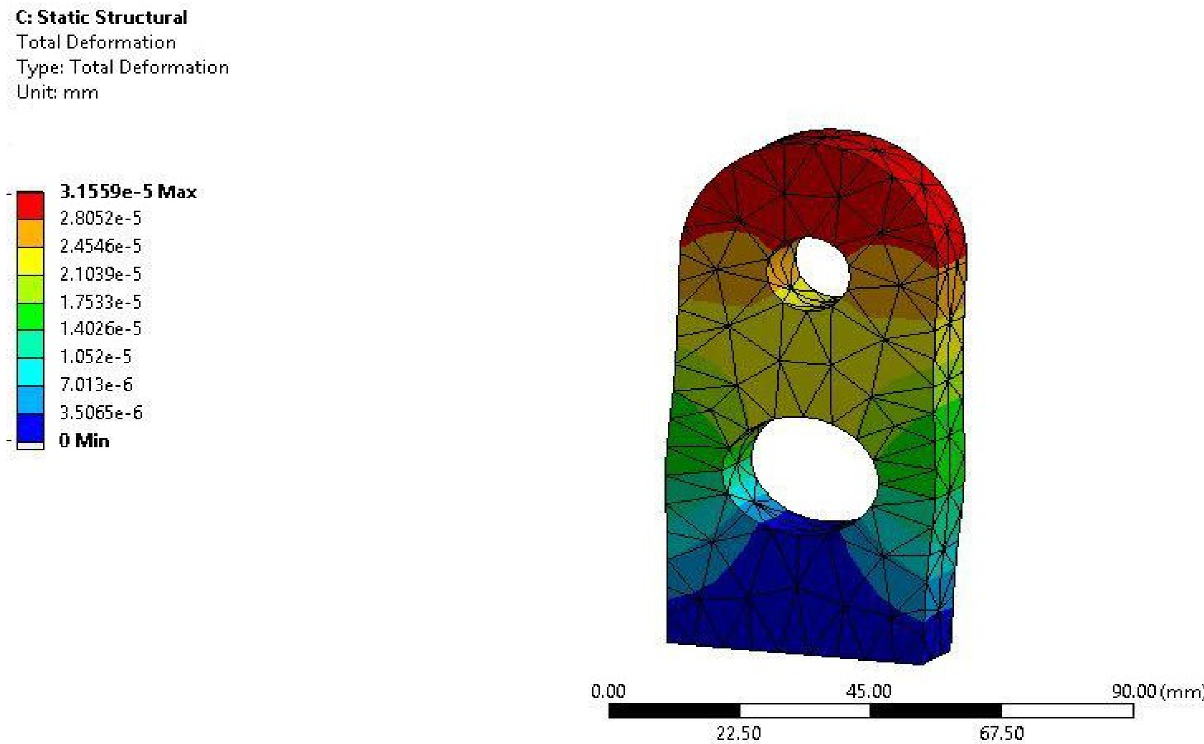


Fig. No. 4.9 Deformation of vertical Plate

The maximum stress occurs at pivot hole which is of the order 0.17889 MPa. Design is safe because the maximum stress induced is very low than the permissible stress value. Maximum deformation under loading occurs at top of the support plate which is having the value of 3.1559e-5 mm.

4.4 Stress and Deformation analysis of Clevis foot mounting

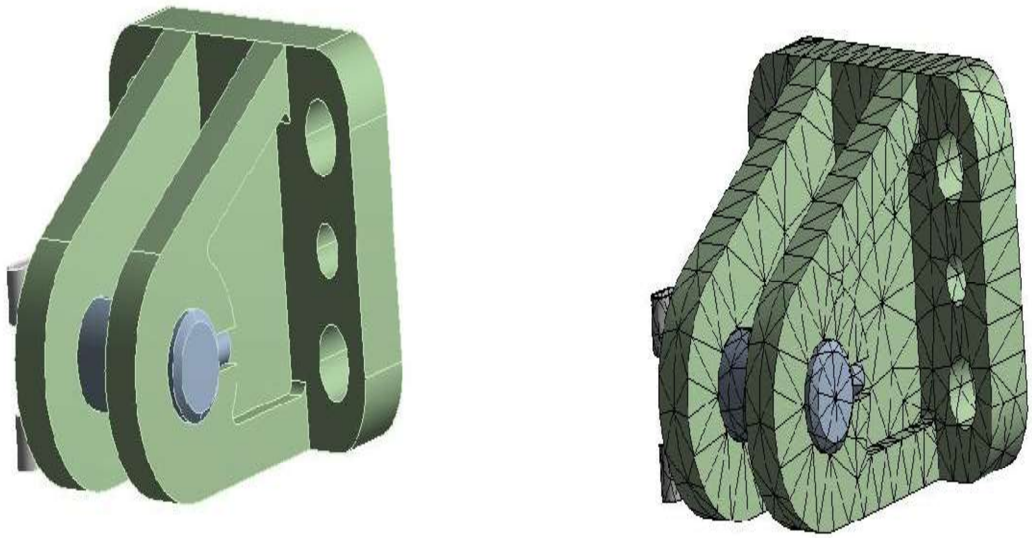


Fig No. 4.10 Part drawing and meshing of Clevis foot mounting

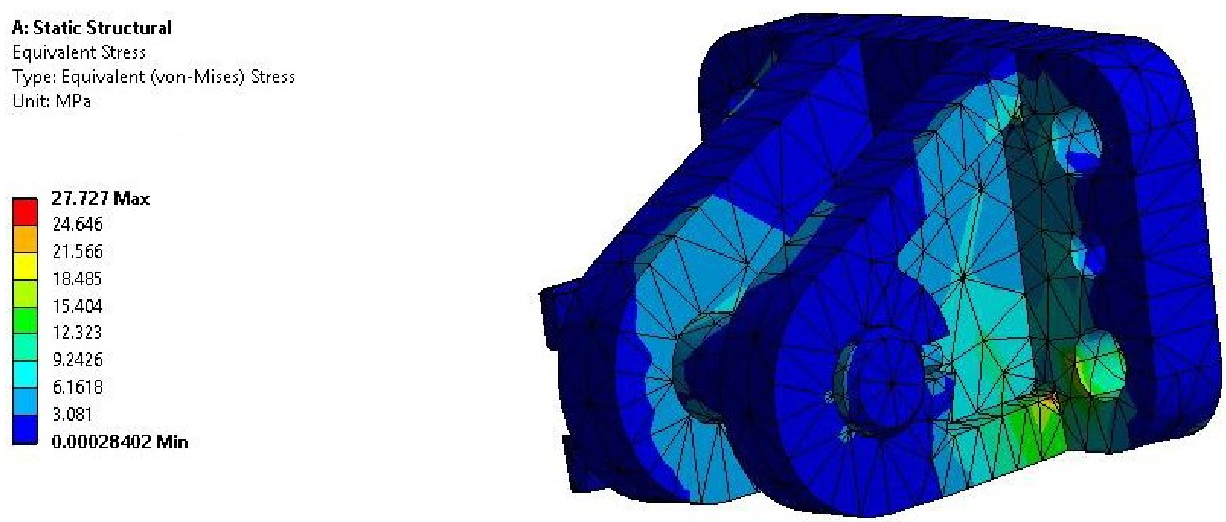


Fig No. 4.11 Stress distribution of Clevis foot mounting

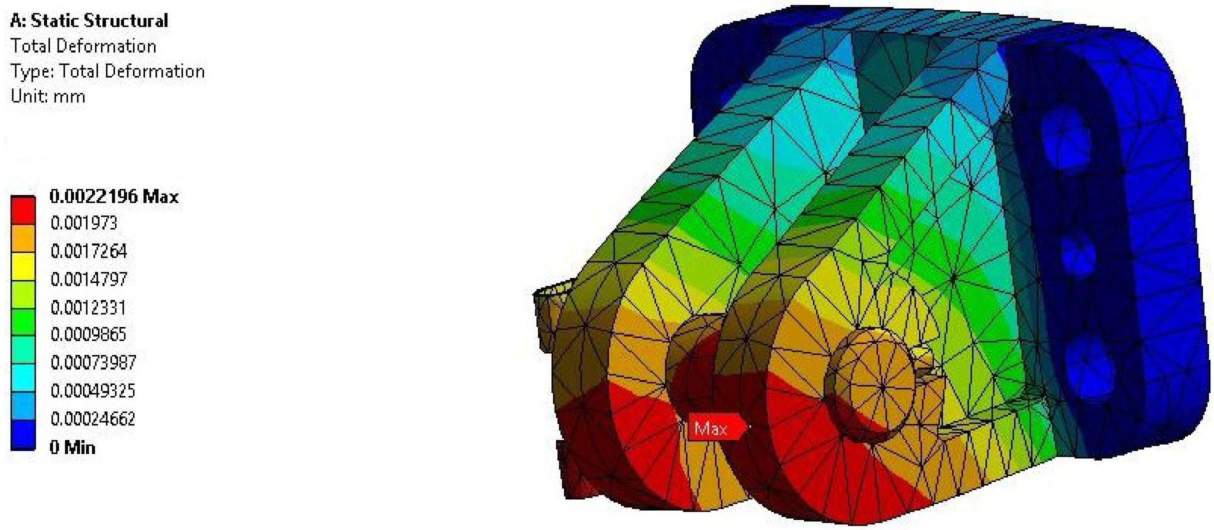


Fig No. 4.12 Deformation of Clevis foot mounting

In the mounting there is stress concentration due to corners. Maximum stress occurs at one of such corners which is of 27.727 MPa. Deformation under service loading is approximated as 0.0022196 mm maximum. This is indicated by red colored zone in the snapshot.

5. MANUFACTURING OF FIXTURE COMPONENTS

5.1 Process sheets for the components

Process Sheet is a formal document that includes a series of performance instructions and guidelines regarding a specific **process** or its part, and that describes the operating parameters and settings for the **process** to produce an associated product, service or other outcome.

Machining Time Calculations

$$Stock\ size = 150 \times 100 \times 15$$

Diameter of milling cutter= 40 mm

$$Tot \quad travel = no.of\ teeth \times \frac{feed}{teeth} \times RPM$$

$$= 4 \times 0.2 \times 16 = 5.8593 \approx 6$$

$$Total\ time = 6 \times 4 = 24\ mm$$

End mill cutter Size=10 mm

No. of teeth= 10

Length of travel= 340 mm

$$Time = \frac{length\ of\ travel}{total\ travel\ time}$$

$$= \frac{340}{300 \times 0.2 \times 10}$$

$$= 0.566\ min$$

$$5\ rough + 1\ Smooth = 6\ Cuts$$

$$Total = 0.566 \times 6 = 3.39\ min \approx 4\ min$$

Time required for drilling diameter of 32 mm hole

$$Time = \frac{35}{60 \times 0.1}$$

$$= 5.833\ min$$

Time required for reaming diameter of 32 mm hole

$$Time = \frac{35}{20 \times 60 \times 0.1}$$

$$= 2.9166\ min$$

$$Total\ time = 5.833 + 2.9166 = 8.749\ min$$

Time required for drilling diameter of 18 mm hole

$$Time = \frac{25}{0.1 \times 280}$$

$$= 0.892\ min$$

Time required for reaming diameter of 18 mm hole

$$Time = \frac{25}{0.01 \times 280 \times 12}$$

$$= 0.7442\ min$$

$$Total\ time = 0.892 + 0.7442 = 1.636\ min$$

Time required for drilling diameter of 12 mm hole

$$Time = \frac{25}{0.1 \times 400}$$

$$= 0.625\ min$$

Time required for reaming diameter of 12 mm hole

$$Time = \frac{25}{0.01 \times 400 \times 8}$$

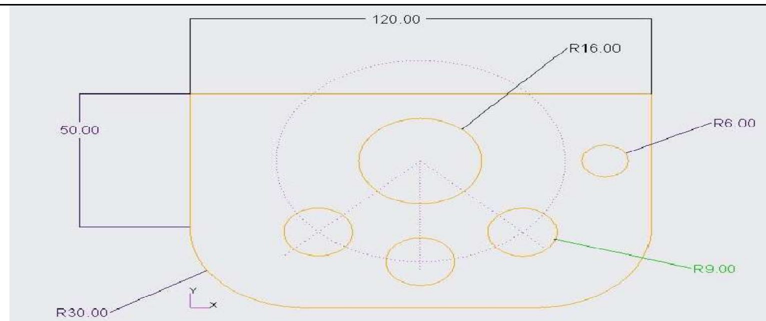
$$= 0.78125$$

$$Total\ time = 0.625 + 0.78125 = 1.4\ min$$

5.1.1 Process sheet for Fixture plate

Table No. 5.1 Process Sheet for fixture plate

Component No. 1
Name of Component - Fixture plate
Material - Mild steel
(140 100 mm 24 mm) Plate
Tools - Milling Machine



Step No.	Description of step	Fixture or gauges	Measuring tool	Cutting tool
1	Face milling (rough)	Milling fixture	Vernier caliper and spirit level	Face mill ø
2	Face milling (finish)	Milling fixture	Vernier caliper	Face mill ø
3	End milling till 120*80 mm	Milling fixture	Vernier caliper	End mill ø
4	Contour milling for radius 30 mm at 2 bottom corner	Milling fixture	Radius gauge	End mill ø
5	Centre drilling of hole 1	Drilling fixture	Vernier caliper	Centre drill
6	Drilling of 32 mm hole (rough)	Drilling fixture	Vernier caliper	Drill bit ø 32 mm
7	Reaming of 32 mm hole (finish)	Drilling fixture	Vernier caliper	Reamer ø 32 mm
8	Centre drill for 3 holes	Drilling fixture	Vernier caliper	Centre drill
9	Drill 3 holes of 18 mm diameter	Drilling fixture	Vernier caliper	Drill bit ø 18 mm
10	Reaming 3 holes of 18 mm diameter	Drilling fixture	Vernier caliper	Reamer ø 18 mm

Machining time calculations

Length of travel = $3 \times 105 = 315\ mm$

$$Time = \frac{350}{4 \times 0.2 \times 160} = 2.7343$$

$$Total\ time = 2.7343 \times 8 = 21.875\ min \approx 22\ min$$

$$Time\ required\ for\ contouring = \frac{252.11}{300 \times 0.2 \times 10} = 0.42\ min$$

$$5\ Rough + 1\ smooth = 6\ cuts$$

$$Total\ time = 0.42 \times 6 = 2.5211\ min \approx 3\ min$$

Time required for drilling diameter of 26 mm hole

$$Time = \frac{35}{250 \times 0.1} = 1.4\ min$$

$$total\ time = 1.4 \times 2 = 2.8\ min \approx 3\ min$$

Time required for reaming diameter of 26 mm hole

$$Time = \frac{35}{16 \times 250 \times 0.1} = 0.875\ min$$

$$total\ time = 0.875 \times 2 = 1.75\ min \approx 2\ min$$

$$total\ time\ for\ 2\ pieces = 2.8 + 1.75 = 4.55\ min = 5\ min$$

Time required for drilling diameter of 15 mm hole

N=380 RPM

$$Time = \frac{25}{380 \times 0.1} = 0.65\ min$$

Time required for reaming diameter of 15 mm hole

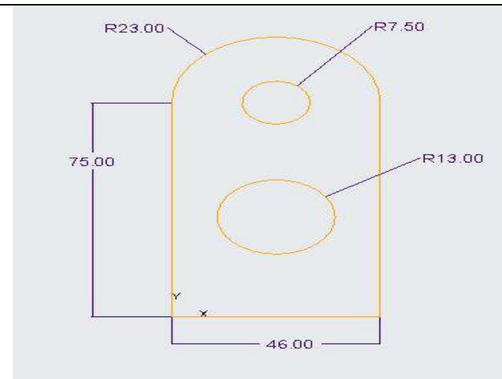
$$Time = \frac{25}{10 \times 380 \times 0.01} = 0.65\ min$$

$$total\ time\ for\ one\ hole = 1.3\ min$$

$$total\ time\ for\ 2\ pieces = 2.6\ min$$

5.1.2 Process sheet for Support plate

Table No. 5.2 Process Sheet for Support Plate

Component No. – 2 Part name –Support plate Quantity – 2 Material – Mild steel (52 105 mm 20 mm) Tools – Milling machine				
Step No.	**Description of step**	**Fixture**	**Measuring tool**	**Cutting tool**
1	Face milling (rough)	Milling fixture	Vernier caliper and spirit level	Face mill
2	Face milling (finish)	Milling fixture	Vernier caliper	Face mill
3	End milling till 1 mm	Milling fixture	Vernier caliper	End mill
4	Contour milling for radius 23 mm at one end	Milling fixture	Radius gauge	End mill
5	Centre drilling of hole 1	Drilling fixture	Vernier caliper	Centre drill
6	Drilling of 25 mm hole (rough)	Drilling fixture	Vernier caliper	Drill bit 25 mm
7	Drilling of 26 mm hole (finish)	Drilling fixture	Vernier caliper	Drill bit 26 mm
8	Centre drill for 15mm hole	Drilling fixture	Vernier caliper	Centre drill
9	Drill holes of 15mm diameter	Drilling fixture	Vernier caliper	Drill bit 15 mm

Machining time calculations

Stock material=$20 \times 90\ mm$

$$Rough\ Facing = \frac{15}{320 \times 0.1} = 0.46\ min$$

$$Finish\ Facing = \frac{15}{320 \times 0.8} = 0.58\ min$$

$$total\ number\ of\ cuts = 6\ rough + 2\ finish = 8\ cuts$$

$$total\ time = 0.4687 \times 6 + 0.58 \times 2 = 3.58\ min \approx 4\ min$$

Turning to reduce dimension 20mm to 18 mm for total length

$$time\ for\ rough\ finishing = \frac{89}{250 \times 0.2} = 1.78\ min \approx 2\ min$$

$$time\ for\ finishing = \frac{89}{250 \times 0.1} = 3.56\ min \approx\ 4\ min$$

$$total\ time = 5.34\ min$$

Turning to reduce dimension 18 mm to 12 mm for 79 mm length

$$time\ for\ rough\ turning = \frac{79}{250 \times 0.2} = 1.58\ min \approx 2\ min$$

$$time\ for\ finish\ turning = \frac{79}{250 \times 0.1} = 3.16\ min \approx 4\ min$$

$$Total\ time = 2\ Rough + 1\ Finish = 6.32\ min$$

Turning to reduce dimension 12 mm to 10 mm for 27 mm length

$$time\ for\ rough\ turning = \frac{27}{250 \times 0.2} = 0.54\ min$$

$$tim\ \ for\ finish\ turning = \frac{27}{250 \times 0.1} = 1.08\ min$$

$$total\ time = 1.62\ min$$

Time required for grooving

$$time = \frac{1}{250 \times 0.01} = 0.4\ min$$

5.1.3 Process Sheet for Centre rod for pivot

Table No. 5.3 Process Sheet for Centre rod for pivot

Component No. – 3 Part name – Pivot rod at centre Quantity – 1 Material– Mild steel (20mm*90mm) Tools – Lathe machine				
Step No.	**Description**	**Fixture**	**Measuring tool**	**Cutting tool**
1	Facing till length 70 mm	3 Jaw chuck	Vernier caliper	Single point cutting tool
2	Rough turn diameter 16 mm	3 Jaw chuck	Vernier caliper	Single point cutting tool
3	Finish turn diameter 15 mm	3 Jaw chuck	Vernier caliper	Single point cutting tool

Machining time calculations

$$Stock\ material = \emptyset 16 \times 75\ mm$$

$$time\ for\ rough\ facing = \frac{10}{0.1 \times 320} = 0.3125\ min$$

$$time\ for\ finish\ facing = \frac{10}{0.08 \times 320} = 0.39\ min$$

$$Total\ time = 4\ Rough + 2\ Finish = 6\ Cuts$$

Turning to reduce dimension 16 mm to 15 mm for 75 mm length

$$time\ for\ rough\ turning = \frac{75}{250 \times 0.2} = 1.5\ min$$

$$time\ for\ finish\ turning = \frac{75}{250 \times 0.1} = 3\ min$$

$$total\ time = 4.5\ min$$

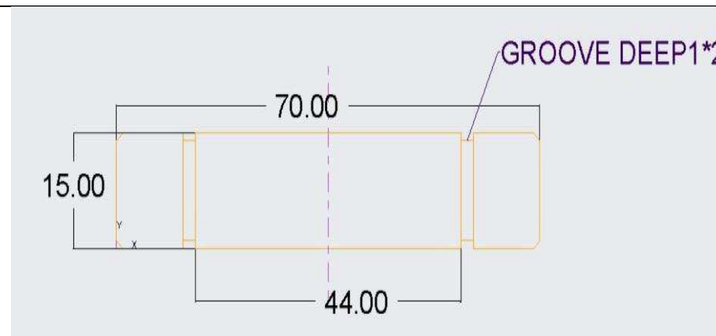
Time required for grooving

$$Time = \frac{1}{250 \times 0.1} = 0.4\, min$$

$$total\ time\ for\ 2\ grooves = 0.8\, min$$

5.1.4 Process sheet for pin to attach cylinder rod to plate

Table No. 5.4 Process sheet for pin to attach cylinder rod to plate

<table>
<tr><td colspan="2">Component No. – 4
Part name – Pin rod
Quantity – 1
Material – Mild steel (Dia. 20 mm)
Tools – Lathe machine</td><td colspan="3">
</td></tr>
<tr><td>Step No.</td><td>Description</td><td>Fixture</td><td>Measuring tool</td><td>Cutting tool</td></tr>
<tr><td>1</td><td>Facing till length</td><td>3 Jaw chuck</td><td>Vernier caliper</td><td>Facing Tool</td></tr>
<tr><td>2</td><td>Rough turn to Dia 19 mm</td><td>3 Jaw chuck</td><td>Vernier caliper</td><td>Single point cutting tool</td></tr>
<tr><td>3</td><td>Finish turn to Dia18 mm</td><td>3 Jaw chuck</td><td>Vernier caliper</td><td>Single point cutting tool</td></tr>
<tr><td>4</td><td>Reverse the job and hold from dia 18 mm side</td><td>3 Jaw chuck</td><td>Vernier caliper</td><td>Single point cutting tool</td></tr>
<tr><td>5</td><td>Rough turn to dia 12 mm till 72 mm length</td><td>3 Jaw chuck</td><td>Vernier caliper</td><td>Single point cutting tool</td></tr>
<tr><td>6</td><td>Finish turn to dia. 12 mm till 72 mm length</td><td>3 Jaw chuck</td><td>Vernier caliper</td><td>Single point cutting tool</td></tr>
<tr><td>7</td><td>Rough turn Dia. 10 till 20 mm</td><td>3 Jaw chuck</td><td>Vernier caliper</td><td>Single point cutting tool</td></tr>
<tr><td>8</td><td>Finish turn Dia. 10 till 20 mm</td><td>3 Jaw chuck</td><td>Vernier caliper</td><td>Single point cutting tool</td></tr>
<tr><td>9</td><td>Chamfer 1 × 45°</td><td>3 Jaw chuck</td><td>Vernier caliper</td><td>Single point cutting tool</td></tr>
<tr><td>10</td><td>Grooving at diameter 8 mm</td><td>3 Jaw chuck</td><td>Vernier caliper</td><td>Grooving Tool</td></tr>
</table>

5.2 Assembly of tilting fixture-3D drawing

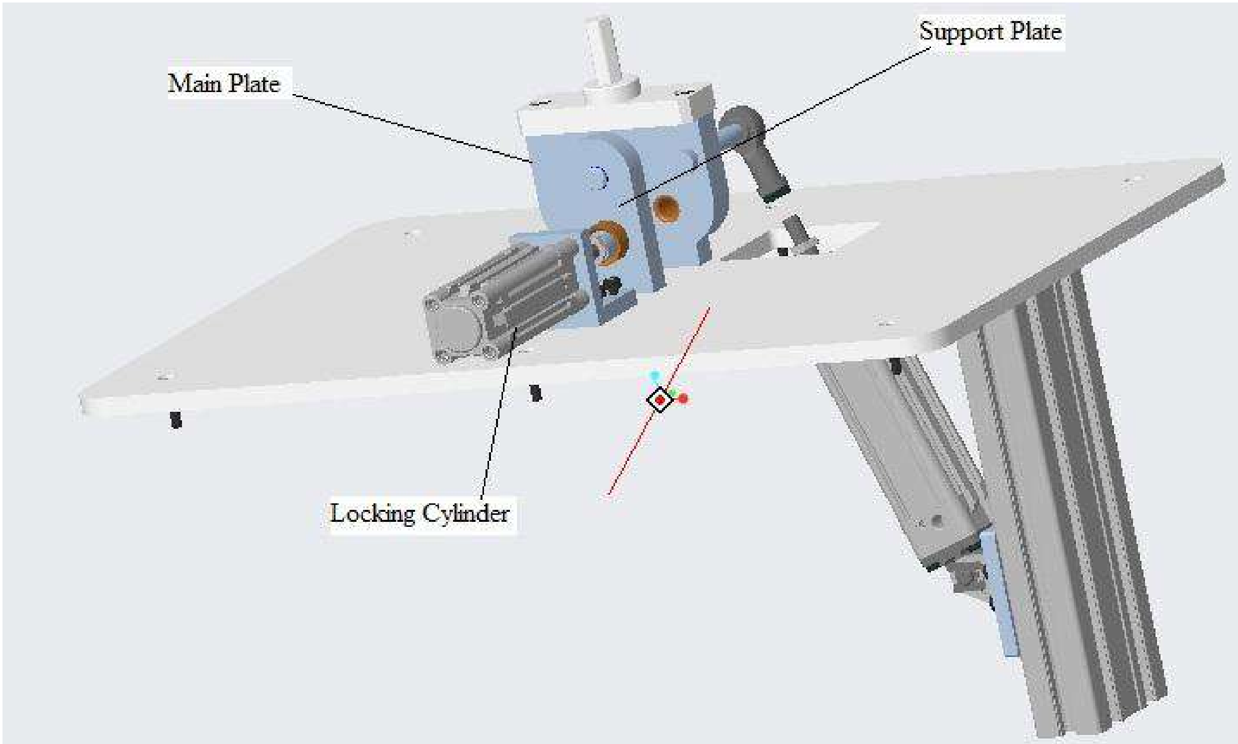


Fig. No. 5.1 Front view of assembly

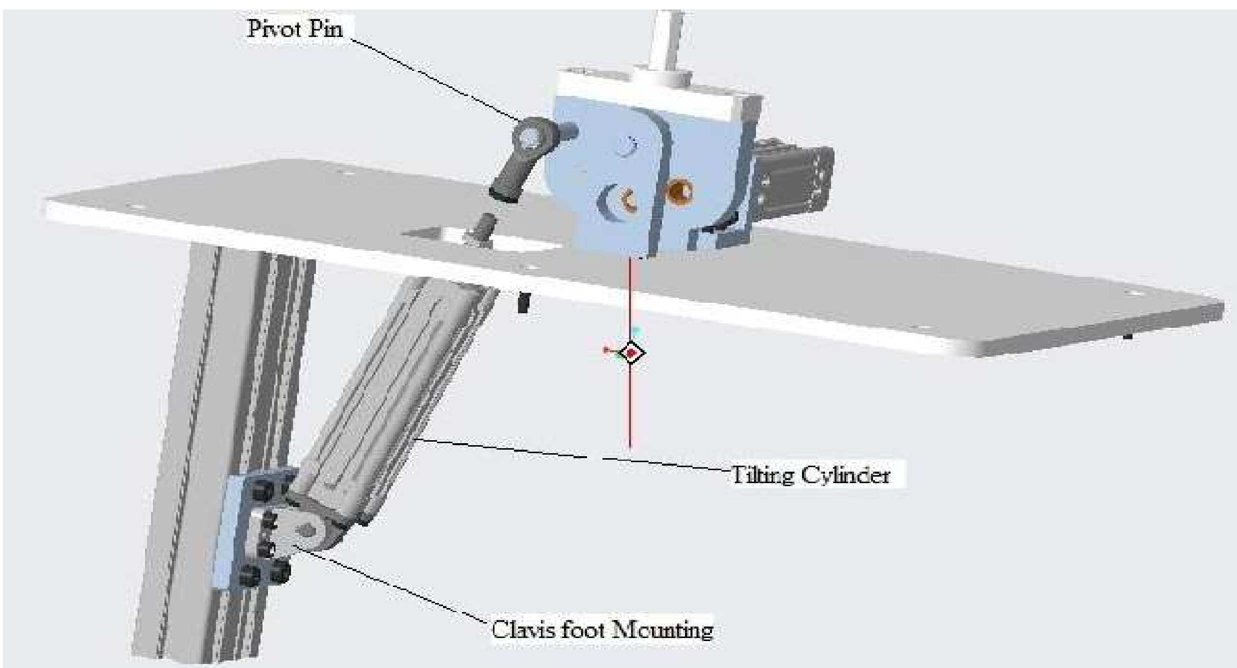


Fig. No. 5.2 Rear view of assembly

5.3 Assembly Procedure/work flow of Paddle Switch on Tilting Fixture

Fig No 5.3 Initial position of fixture

Step 1: Place the steering wheel on the fixture in the shown manner. Make sure it is placed properly.

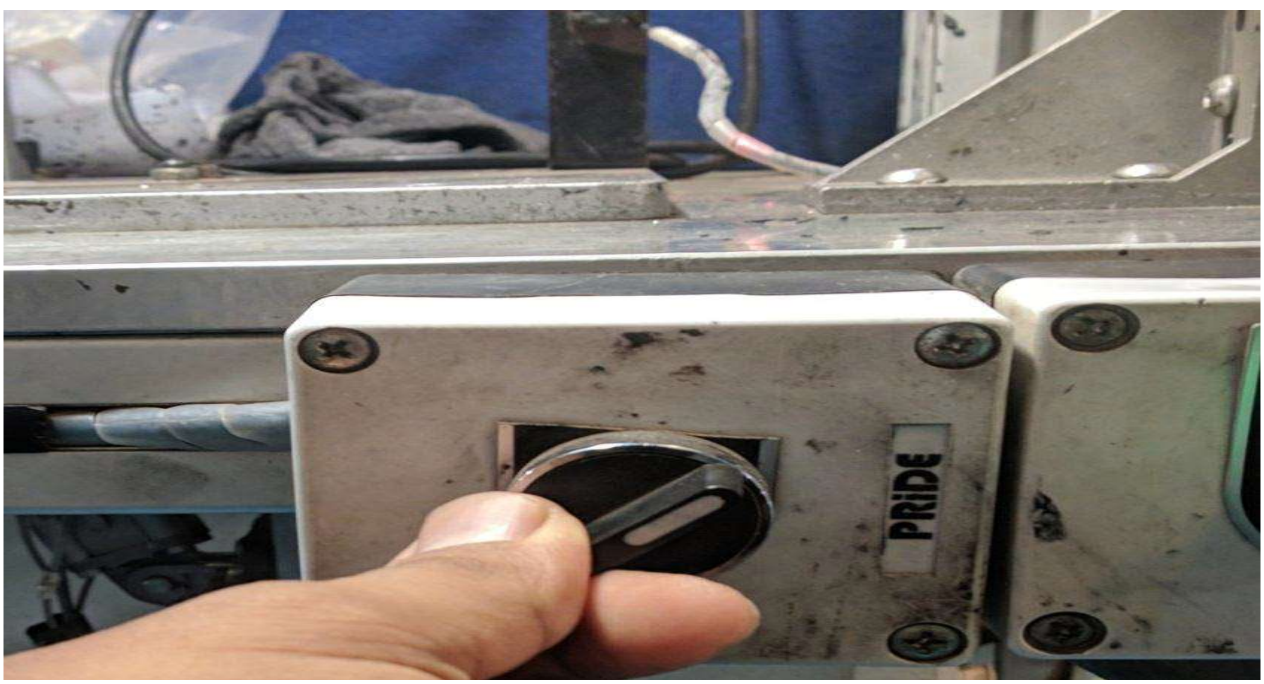


Fig No 5.4 Select switch to right

Step 2: Select the tilting switch to right side. Fixture will move towards right side.

Fig No 5.5 Wheel tilted to right side

Fig No 5.6 Snap paddle switch from bottom side

Step 4: Snap the paddle switch and fit it on the wheel. Check & verify for proper fitting.

Fig No. 5.7 M4-12mm screw

Fig No. 5.8 Screw positioning in the wheel

Step 5: Take M4-12mm screw and put it in the position shown in the above figure.

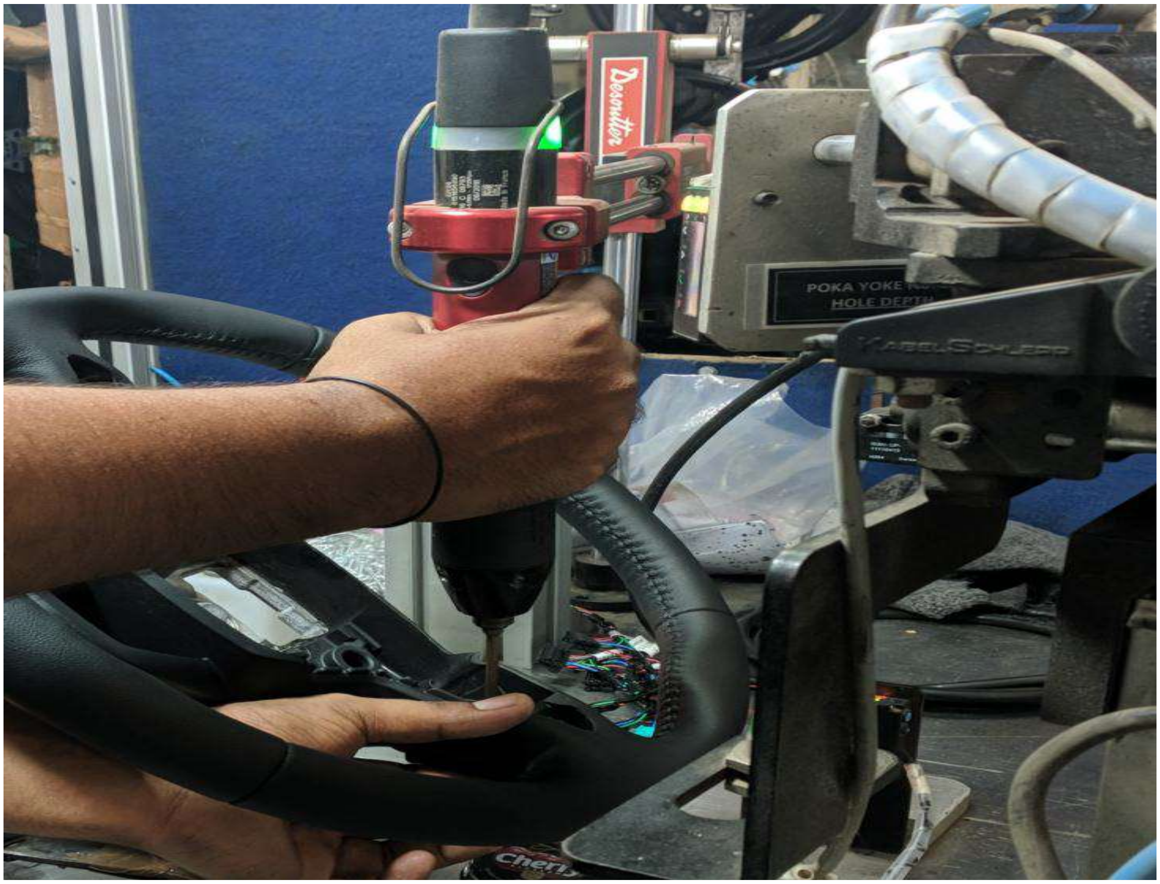


Fig No. 5.9 Fixing the screw in the wheel

Step 6: Fix the screw with the help of power screw-driver. Screw driver torque = 1.5+/-0.2 N.m. After screw operation and tightening green signal is shown in the top of screw driver.

Fig No. 5.10 Switch to left side

Step 7: Select the switch to left side.

Fig No. 5.11 Screwing of left side screw

Step 8: Repeat the same procedure used for right side and fix the paddle switch with the help of electric screw driver.

5.4 Cycle time calculations

The cycle time (flow time, or manufacturing lead time) of a job is the time required for the job to go through the factory. The time required at each station for the performance of the work is known as cycle time. Cycle time is normally larger than the service time. The cycle time at a station is the time interval between the completion or the starting of work on successive items, and, therefore includes both productive and non-productive work as well as any idle time.

Cycle time = Service time + Idle time

The cycle time depends on the total output required and the available time for production

Suppose,

T = Useful production time available per day and

Q = Daily output required in number of units

Shortening the job cycle time is very important for a factory, at least for the following reasons:

(1) Each job represents an opportunity cost for the factory. A long cycle time means it is difficult to convert the opportunity cost into profits in the short term.

(2) Long job cycle times result in the accumulation of work-in-progress (WIP), which makes the shop floor management a challenging task.

Cycle time for one assembly with manual setup = 95 seconds

Cycle time for one assembly with tilting fixture = 48 seconds

Consider an 8 hour shift. Excluding lunch break and other allowances a worker works for 6.30 hour.

6.30 hours = 23400 sec

Production with manual setup

$$\frac{23400}{95} = 240\,\frac{units}{shifts}/worker$$

With tilting fixture

$$\frac{23400}{48} = 490\ units$$

Therefore production is increased by **240 units**.

6. CONCLUSION AND FUTURE SCOPE

6.1 Conclusion

It is very essential to use reliable clamping device and fixtures to reduce ambiguity in assembly of components. The setup cost should be as less as possible as it increases the overall cost of the product. Setup costs are mostly associated with fixtures. Thus using pneumatic system the setup costs is reduced to some extent. It is also easy to operate. Fast operation of pneumatic system leads to time saving hence increases productivity.

According to the requirement of automated system, we have designed the fixture. The fixture plate is manufactured on the milling machine. Standard cylinders of FESTO are used. Then we have assembled the fixture. Tested for the 450 tilting angle, it has met the required tilting motion. Reed switches of FESTO are used to control the stroke length of the cylinders. Use of reed witches has benefitted the exact tilting angle of 450.

Allan bolts are used to assemble the components. Assembly procedure is depicted with the help of photographs in order to facilitate easy understanding to the workers. It is also explained in two regional languages i.e. Hindi and Marathi at the industry such that false indications are avoided. As the procedure is partially automated worker’s fatigue is reduced by a considerable amount.

6.2 Future Scope

Metal scanning sensors can be included to check after foaming process if the armature is in the foam or not. Proximity type sensors can be used.

Poka yoke can be implemented by using sensors. This will benefit the zero defect strategy by 100%. To establish poka yoke, sensors can be fitted on the frame which will scan the screw position after screwing.

This entire system can be automated by using PLC programming software. The sensors will be integrated with this software. Barcode scanning will be provided for paddle switches to keep record of material inward and outwards. This will help to keep track of work in process inventory records.

7. REFERENCES

Papers from Journal

1. Shivaji Mengawade, Vaibhav Bankar, Pratik P Chaphale, *(2016.)*, “A Review on Design and Analysis of Work Holding Fixture” *International Journal of Engineering Research and General Science Volume 4, Issue 2,*

2. V. R.Basha, J.J. Salunke(2015) “An Advanced Exploration on Fixture Design” *V. R.Basha Int. Journal of Engineering Research and Applications* www.ijera.com *ISSN: 2248-9622,Vol. 5, Issue 6.*

3. Ford Global Technologies, Llc 2013 “Tilt angle compensated steering wheel guage”

4. Ray Garnet Armstrong ,James Anthony Smazenka, Richard Kremer Riefe,2003 “steering column tilt assembly” .

Company Manuals

1. FESTO DNC cylinder manual

(https://www.festo.com/cat/bg_bg/data/doc_engb/PDF/EN/DNC_EN.PDF)

2. FESTO CPV-VI DC valves Manual

(https://www.festo.com/cat/en-gb_gb/data/doc_ENGB/PDF/.../TYP10-EN.PDF)

3. FESTO SMT/SME for T-slot Manual

(https://www.festo.com/cat/de_de/data/doc_engb/PDF/EN/SMX8_EN.PDF)