Design and Development of a Fixture For Inserting A Critical Module Assembly Inside the ring Main Unit (R.M.U.) Product

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Abstract- *In a company they are manufacturing two types of switchgears; Gas insulated switchgear (GIS) and air insulated switchgear (AIS). Ring main unit product (RMU) which is a part of GIS, consist of a heavy critical module assembly weighing about 35 kg enclosed in stainless steel tank. Currently this critical module assembly is manually inserted in stainless steel tank but due to its weight and small clearance it is very difficult for workers to assemble it and often causing injuries to hands of workers. 3 to 4 workers are needed for assembly of RMU product. The required fixture assembly should be compact due to the space constraints. So to carry out this assembly with less efforts, our aim is to design a compact & fixture which will be mechanically operated and we will be able to obtain the optimal solution to the existing problem, which will also reduce the manpower as well as required time for assembly of unit and to ensure the safety of workers.*

Keywords- Fixture, Jig, Manufacturing, Designing, Mechanical, Switchgear, Circuit breaker, RMU.

I. INTRODUCTION

In this fast moving world and life, it becomes very important to make the best use of time and money. It is rightly said that time saved is money saved. So we must not leave no stone unturned to make right and proper use of it..

In industries time saving is a very important aspect and hence they try to find the various ways, methods or say use of technology to do the same. So jigs and fixtures plays the very important and vital role in the field of automation. Fixture is a work holding or support device used in manufacturing industry Fixtures are used to securely locate (position in specific location or orientation)and support the work ensuring that all parts assembled using the fixture will maintain conformity and interchangability.

Using a fixture improves the economy of production by allowing smooth operation and quick transition from part to part , reducing the requirement of skilled labour by simplifying how assembly is mounted and increase in conformity across production run. Thus they are used various possible ways to reduce the time required to make the assembly of various parts. Though the GIS module is very costly unskilled workers finds difficulty to assemble the module as well as it needs experienced worker to work on it. By designing jigs and fixture unskilled worker can work on it easily which saves time as well as money.

For locating the assembly of RMU product , fixture employ pins, clamps and surfaces. These components ensure that the assembly is positioned correctly and inserting in same direction which is required. Surfaces provides support for assembly , pins allow for precise location at low surface area expense and clamps allow for workpiece to be removed or its position adjusted.

As a result design and manufacturing of fixture assumes a bigger and important role in increasing the productivity, profit, and growth of a company.

1.1 PROBLEM STATEMENT

At the time of assembly of critical module assembly into stainless steel tank there are lot of problems face by the workers due to complicated shape of tank as well as assembly as shown in figure. At time of assembly 3-4 workers require for assembly. Assembly has very less holding points so holding and insert in tank becomes very difficult task. Also it takes 15-20 minute for total insertion of assembly. Which results inefficiency of workers or divert mentality of workers due to extra work. Some times workers get injure at time of assembly.

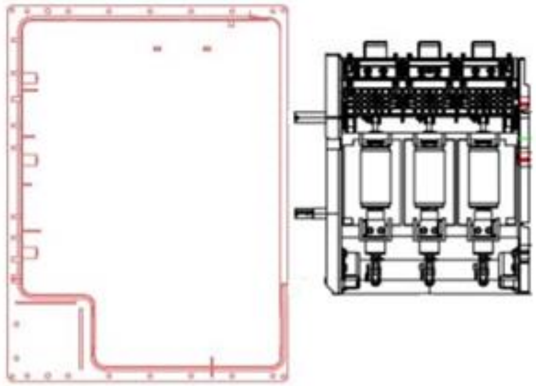


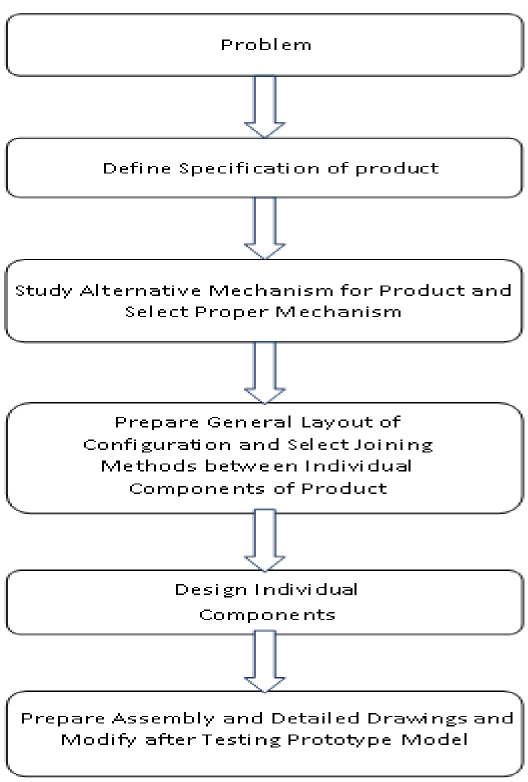
Fig 1.1 Stainless Steel Tank with Assembly

The RMU is nearly of cost Rs 1 lakh to 2 lakh so any damage of assembly part at time of insertion is not desirable and increase scrap cost of industry.

So our aim is to design and develop an compact system so that the module assembly can easily be inserted in the SS tank without disturbing other parts of the component.

II. METHODOLOGY

The basic procedure of design of fixture consists a systematic approach from given specifications about the functional requirements of a product to the complete description in the form of drawings of the final product. A logical sequence of steps, are as follows



III. DESIGN CALCULATIONS AND SIMULATION

3.1 Screw Jack Design

A power screw is a mechanical device used for converting rotary motion into linear motion and transmitting power. The main applications of power screws are as follows:

(i) to raise the load, e.g., screw-jack
(ii) to obtain accurate motion in machining operations, e.g., lead-screw of lathe
(iii) to clamp a work piece, e.g., a vice
(iv) to load a specimen, e.g., universal testing machine.

We have to design power screw with more strength. A trapezoidal thread has more thickness at the core diameter than a square thread. Therefore, a screw with trapezoidal threads is stronger than an equivalent screw with square threads. Such a screw has a large load carrying capacity.

The axial wear on the surface of trapezoidal threads can be compensated by means of a split-type of nut. The nut is cut into two parts along the diameter. When the threads get worn out, the two halves of the nut are tightened together. The split-type nut can be used only for trapezoidal threads. It is used in lead-screw of a lathe to compensate wear at periodic intervals by tightening the two halves.

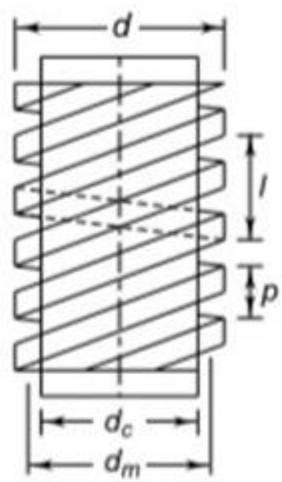


Fig 3.1 screw jack

Were,

L = lead
D = Nominal diameter
dc = Core diameter
dm = Mean diameter
p = Pitch

ϕ = Friction angle
α = Helix angle
Mt = Torque required to raise load
σ_c = Compressive stress
z = Number of threads
τ = Shear stress

Material selected = Plain carbon steel [2]
Ultimate tensile strength = s_{ut} = 340N/ mm^2 [2]

Factor of safety = 4
Mass = 40 kg
Weight = 40 x 9.81 = 392.4 N
Therefore, considering Weight (w) = 500 N

$\sigma_t = \frac{s_{ut}}{FOS}$ [4]
$\sigma_c = \sigma_t$

Compressive stress = tensile stress = $\frac{340}{4}$ = 85 N/mm^2
τ = transverse shear stress
τ = 0.5 x$\frac{s_{ut}}{FOS}$ = 0.5 x $\frac{200}{4}$ = 25 N/mm^2
Stress = $\frac{w}{\frac{\pi}{4}\times d_c^2}$ [4]
= $\frac{500}{\frac{\pi}{4}\times d_c^2}$
= 85N/mm^2

Diameter dc = 2.7367 mm
Nominal diameter d = 24 mm [Table 6.2 [4]]
Pitch = 5 mm

Size of screw:
p = 5
dc = d - p
d = 24 mm
dc=19 mm
19 mm > 2.7367 mm
Therefore design diameter is under safe limits

dm = d – 0.5 x p
dm= 21.5 mm
l = 5 mm
d = 24 mm
dc = 19 mm
dm = 21.5 mm

Using single start
l = p = 5 mm

tan α = $\frac{l}{\pi\, dm}$ [4]
=$\frac{5}{\pi X\ 19.5}$
α = 4.6660 degrees
tan ϕ = μ = 0.15
ϕ = 8.53 degrees
$Mt = \frac{w\ dm}{2}$ x tan($\phi + \alpha$) [4]
= $\frac{500\ X\ 21.5}{2}$ x tan (8.53 + 4.6660)
= 1260.2989Nmm
τ = 16 x$\frac{Mt}{\pi d_c^3}$ [4]
= 16x $\frac{1260.2989}{\pi X\ 19^3}$
= 0.9357 N/mm^2
$\sigma_c = \frac{w}{\frac{\pi}{4}\times d_c^2}$ [4]
= $\frac{500}{\frac{\pi}{4}\times 19^2}$
= 1.7634 N/mm^2

$\tau_{max} = \sqrt{\left(\frac{\sigma}{2}\right)^2 + T^2}$ [4]
= $\sqrt{\left(\frac{1.7634}{2}\right)^2 + 0.9357^2}$
= 1.2856 N/mm^2

Length of nut :

Refering table 6.4 from V.B. Bhandari
Permissible bearing pressure for screw jack s_b = 17 N/ mm^2
z = $\frac{4w}{\pi s_b (d^2 - d_c^2)}$ [4]
= $\frac{4\ X\ 500}{\pi\ X\ 17\ X\ (24^2 - 19^2)}$
= 0.1741 or 1 thread

Length of nut = zp
zp = 1 x 5 = 5 mm
1.5d = 36 mm
d < length of nut < 1.5d
Selecting optimum value in between, therefore
Length of nut = 30 mm

Transverse Shear Stress :

τ = 0.5 x p = .5 x 5 = 2.5
τ = $\frac{w}{\pi d t z}$ [4]
= $\frac{500}{\pi\ X\ 24\ X\ 2.5\ X\ 1}$

= 2.6525 N/mm^2
25 N/mm^2> 2.6525 N/mm^2

The transverse shear stresses in screw and nut are within safe limits.

Self-Locking Condition:

$\phi > \alpha$ [4]
8.53 > 4.6660
$\mu > \frac{l}{\pi\, dm}$
0.15 > 0.07402
It satisfies the condition for self-locking**.**

3.2 Selection of Bearings

Bearing is a mechanical element that permits relative motion between two parts, such as the shaft and the housing, with minimum friction. The functions of the bearing are as follows:

The bearing ensures free rotation of the shaft or the axle with minimum friction.

The bearing supports the shaft or the axle and holds it in the correct position.

The bearing takes up the forces that act on the shaft or the axle and transmits them to the frame or the foundation.

Bearings are classified in different ways

Depending upon the direction of force that acts on them, bearings are classified into two categories—radial and thrust bearings.

The most important criterion to classify the bearings is the type of friction between the shaft and the bearing surface. Depending upon the type of friction, bearings are classified into two main groups—sliding contact bearings and rolling contact.

Sliding contact bearingsare also called plain bearings, journal bearings or sleeve bearings. In this case, the surface of the shaft slides over the surface of the bush resulting in friction and wear. In order to reduce the friction, these two surfaces are separated by a film of lubricating oil. The bush is made of special bearing material like white metal or bronze. Rolling contact bearingsare also called antifriction bearings or simply ball bearings. Rolling elements, such as balls or rollers, are introduced between the surfaces that are in relative motion. In this type of bearing, Sliding friction is replaced by rolling friction.

A rolling contact bearing consists of four parts inner and outer races, a rolling element like ball, roller or needle and a cage which holds the rolling elements together and spaces them evenly around the periphery of the shaft. Depending upon the type of rolling element, the bearings are classified as ball bearing, cylindrical roller bearing, taper roller bearing and needle bearing. Depending upon the direction of load, the bearings are also classified as radial bearing and thrust bearing. There is, however, no clear distinction between these two groups. Certain types of radial bearings can also take thrust load, while some thrust bearings are capable of taking radial load .

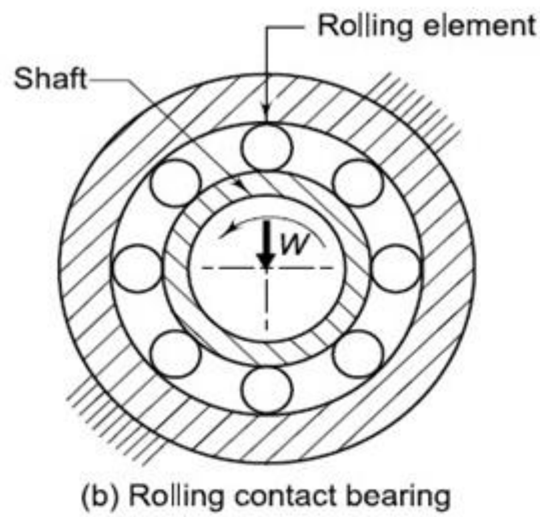


Fig 3.2 single groove bearing

Selection of Bearing Type :

For low and medium loads,ball bearings are used.

Noise becomes the important criterion for the selection of bearings. From noise consideration ,Point Contact creates less noise than Line Contact.

For such applications deep groove ball bearings are recommended.

Bearing Life for Industrial Applications

Machines used for Eight Hours of = 12,000-20,000hrs [Table 15.2[4]]

Case1:

Fr=1962N
n=125 rpm (assumed)
L10h=12,000 hrs

For single row deep groove ball bearing,

P=Fr=1962N

$L_{10}=\frac{60nL_{10h}}{10^6}$ [4]

$C = P(L_{10})_{1/3}$ [4]

Putting the values we get,
L10=90 mill.rev
C=8792.516N
n=28,000 rpm
Resubstituting the values,
d=45mm
Designation=6409
It cannot be selected as the weight is too high..

Case 2:

Fr=1471.5N
n=125rpm
L10h=12,000 hrs
By substituting in above formulas,we get
L10=90 mill.rev
C=6594.3870N
n=30,000 rpm
Resubstituting the values,
D=35mm
Designation=6407

It is also rejected. As we are in need of compact size this bearing is not selected as we need to reduce the weight again.

Case 3:

Fr=1275.3N
n=125 rpm
L10h=12,000 hrs
By substituting in above formulas,we get
L10=90 mill.rev
C=5715.135N
n=50,000 rpm
Resubstituting the values
d=25mm
Designation=6405

Here the bearing 6405 is selected as the inner bore diameter is accepted the weight of the fixture is reduced and it is made compact.

3.3 Design of Rod

Selection of material :

Mechanical properties require for design of shaft

- higher compressive strength.
- Should have excellent ability to damp vibrations
- Should have more resistance to wear

Material selected :

Grey cast iron (FG 400) having tensile strength =400 [Table 2.1 [4]]
And hardness 207–270HB [Table 2.1 [4]]
FOS =3

Design calculations:

Permissible bending stress for rod

$\sigma_b = \frac{S_{ut}}{fs} = \frac{400}{3}$ =133.33N/mm2

Calculation of bending moment:
Mb = P×L[4]
Where ,
P = load acting on each rod
L = length of rod
d = diameter of rod

Mb = $\frac{WL^2}{2}$ [3]

$\sigma_b = \frac{M_b \times y}{I} = \frac{32 \times M_b}{\pi \times d^3}$ [4]

Mb = $\frac{500 * L^2}{3*2}$

σb= $\frac{32*500*L^2}{6*\pi*24^3}$ =133.33 N/mm2
L= 46.59 mm

This value is safe for rod more than 46.59mm length loadcan not sustain by rod. But as per space constrain we have select less length which is safe.
So we have select L= 40mm

3.4 Calculation of Welded Joint :

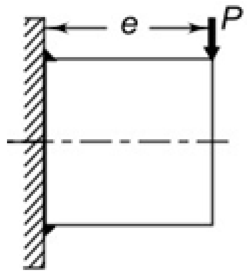


Fig 3.3 welded shaft

e = length of rod
P = load acting on rod
Primary shear stress :

г $= \frac{0.5 \times S_{yt}}{fs}$ [4]

г = 0.5 × 133.33 = 66.66N/mm2
Now ;

г $= \frac{P}{A} = \frac{P}{\pi D t}$ [4]

A = Area of weld = пDt[4]
Where ;
D = diameter of rod
t = thickness of welding

г $= \frac{500}{3 \times \pi \times 24 \times t}$

г $= \frac{2.221}{t}$

i) Bending stress

$$\sigma_b = \frac{M_b \times y}{I}$$ [4]

Where,
I = moment of inertia of an annular fillet
Mb = Bending moment
I = п×t×r3 [4]

$$\sigma_b = \frac{500 \times 150 \times 12}{\pi \times t \times 12^3} = \frac{166}{t}$$

ii) Maximum shear stress

$$г = \sqrt{\left(\frac{\sigma_b}{2}\right)^2 + г^2}$$

$$= \sqrt{\left(\frac{165}{2t}\right)^2 + \left(\frac{2.221}{t}\right)^2}$$ [4]

$$= \frac{83}{t}$$

iii) Size of weld

Since the permissible shear stress in the weld is 66.66 N/mm2 ,

$\left(\frac{83}{t}\right) = 66.66$

t = 1.25 mm

h = $\frac{t}{0.707}$

= 1.76 mm

3.5 Design of guide bush

The main purpose of guide bushes are use to support the base plate. In our design we have use 4 guide bushes for balancing as well as for support.

Selection of material:
Mechanical properties require for design of shaft

- higher compressive strength.
- Should have excellent ability to damp vibrations
- Should have more resistance to wear

Material selected :

Grey cast iron (FG 400) having tensile strength =400 and hardness 207–270HB

[Table 2.1[4]]
Design calculations:
Total load acting on the bush = weight of assembly + weight of fixture
Weight of assembly = 40 kg (for safe calculation take as 50 kg)
Weight of fixture = 150 kg (this is not exact value. We have take maximum weight of fixture it will not go beyond 150 kg as per design criteria.)

= (500 + 1500)N
= 2000 N

Each bush will carry load $= \frac{2000}{4} N$

= 500 N

Buckling load on column $= \frac{4 \times \pi^2 \times E \times I}{L^2}$ [3]

$$500 = \frac{4 \times \pi^2 \times 2.1 \times 10^5 \times \pi \times d^4}{64 \times 200^2}$$

d = 49 mm

Minimum diameter of guide bush which is difficult to manufacture so we have select 150 mm diameter bush guide.

3.6 Selection of L plate

Sheet metal is a widely used form of material that is used for a variety of different applications. Sheet metal is, basically, metal that has been rolled into thin sheets.[1] Manufacturing a component from sheet metal is a versatile and often cost-efficient alternative. During this project, information was gathered to help answer the questions stated in the problem definition. The purpose of these investigations was to learn about the processes relevant to the discussed methods of sheet metal forming and in turn, to be able to form the requested solution.

Fixture body,or tool body,is the major structural element of a fixture.It maintains the spatial relationship between the fixturing elements mentioned above.

The requirement of a fixture or the plate assembly is the deterministic location, total constraints, contained deflection, geometric constraints.

The main frame of fixture must be strong enough so that deflection of the fixture is as minimum as possible. This deflection of fixture is caused because of the various forces acting on it. The main frame or the main plate of the fixture should have the mass or capacity to prevent vibration and chatter.

The L-plate or the frame should be built from simple sections so that the frames may be fastened with screws or welded whenever necessary. Those parts of the L-plate that remain permanently with the fixture may be welded. Those parts that need to be frequent changing may be held with the screws. If clamping is done it should be fast enough and should require least amount of effort. Support points and other parts are designed in such a way that they may be easily replaced if they break.

C-sections are commonly used for small spans or light-duty applications, and are often formed from aluminum, steel and stainless steel. Whenever it is needed to reduce production costs or product weight in metal product manufacturing, I section or C sections can be used according to application without sacrificing quality and structural integrity.C-sections are commonly used for small spans or light-duty applications, and are often formed from aluminum, steel and stainless steel. While I-beams are strong they're not always easy to incorporate into fabrication. The problem is that they only have two parallel faces to mount to. Mounting to a face parallel to the web means adding angle to the flanges. C-section channel overcomes this by moving the web out to one edge of the flanges, changing the cross-section from an ―I‖ to a ―C‖ in the process.

3.7 Simulation Work

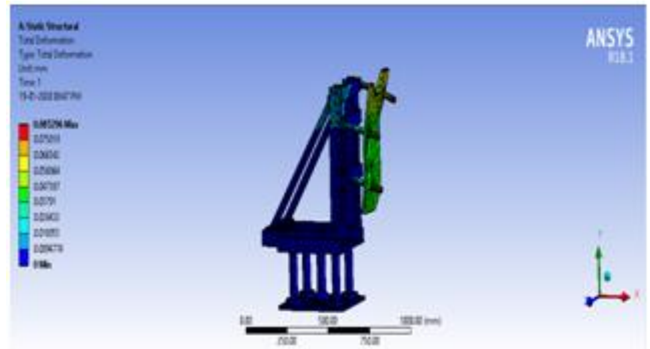


Fig 3.4 Total Deformation

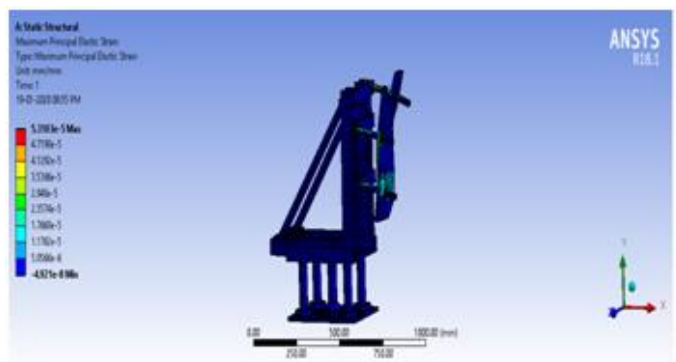


Fig 3.5 Maximum Principal Elastic Strain

Fig 3.6 Maximum Principal Stress

3.8 Final 3-D Model

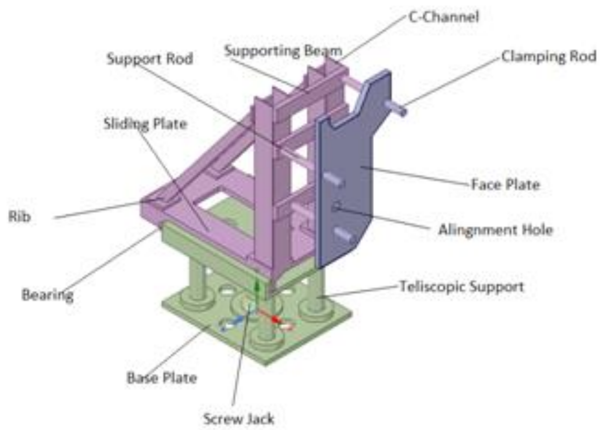
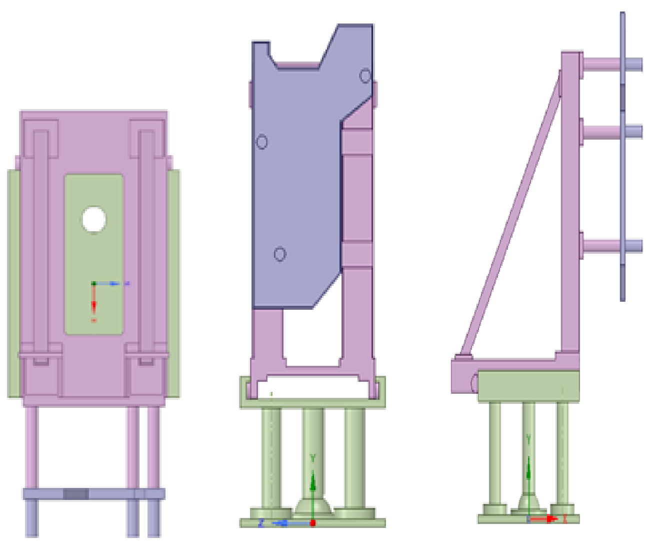


Fig 3.7Isometric view



Top view Front view Side view

Fig 3.8 Orthogonal view

IV. CONCLUSION AND SCOPE FOR FUTURE WORK

Assembling the RMU unit was a troublesome task .We were assigned the task to make the work easy and in less time with the space constraints provided. The main task given to us was to make their work easy to insert the module assembly in the (SS) tank as they were inserting it manually up to now. They are in need of a compact system to easily insert the critical module assembly in the (SS) tank.

We suggested them designs of the Fixtures. We had 2 to 3 ideas, which we proposed to them. The first idea was of a manipulator .They rejected it as it was not economical as well as there was space constraint. The next idea which was proposed was using a L plate assembly, which consist of a screw jack and a sliding assembly. The calculations were made and in the software the calculations were carried out, the result was that the weight of the fixture was too high. It was difficult to manufacture as well.

The changes were made in it and instead of a L-plate we took a C-Channel and the bearing mechanism for the sliding purpose. The calculations are completed and this system is compact as well as economical. The validation using the software is in process. After the validation the design will be sent to the company to the design department. When the design will be selected then we will start the manufacturing.

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