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ISSN : 2348 - 5612 | Volume : 04 , Issue : 11 | October – December 2017

Hydraulic Press Design by size Optimization Method and FEA Solution

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Abstract - Metal forming is a process which is done by deforming metal work pieces to the desired shape and size using pressing or hammering action. Hydraulic presses are being used for forming and pressing operations with wide range of capacities. Hydraulic press machine works under continuous impact load. Because of this continuous load, tensile and compressive stresses are experienced in various parts of machine. These stresses cause permanent deformation in some parts of machine. This work is based on optimization of a 250-ton four pillar type hydraulic press considering constraints like design, weight and cost. The work is focused on design and optimization of top plate of the press machine. Top plate holds the hydraulic cylinder and is one of the most critical parts of the machine. The design is based on sizing optimization method and the results are validated by Finite Element Method with proper boundary conditions. The CAD modeling has been carried out by PTC CREO and for FEA, ANSYS software is used. Design Optimization of Hydraulic Press Plate using Finite Element analysis.

Keywords: CAD, Finite Element Analysis, Hydraulic press, Optimization.

I. INTRODUCTION

Press work is a method of mass production involving the cold working of metals, usually in the form of thin sheet or strip. Press working is one of the extensively employed methods of fabricating parts of intricate shapes with thin walls. Press working processes make use of large forces by press tools for a short time interval which results in cutting or shaping the sheet metal. Since, press working does not involve heating of the parts, close tolerances and high surface finish can be obtained on the part. Since presses can produce components at fairly fast rates, the unit cost of labour for operating the press is fairly low.

A hydraulic press produces a great deal of force from the application of a small amount of force to the small piston. A hydraulic press is a press that uses liquid pressure to make a small force applied to a small piston produce a large force on a larger piston.

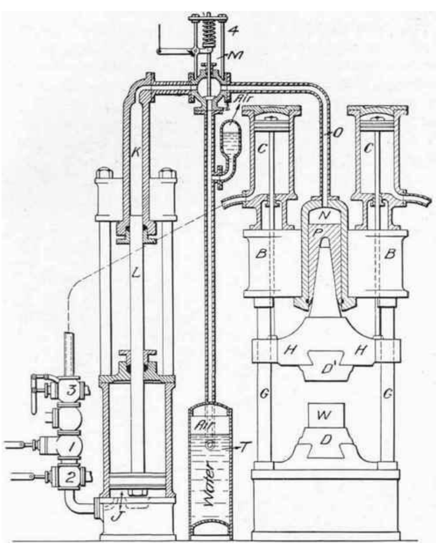

Figure 1 hydraulic press

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1.1. Working principle

The working drive of press has evolved from Mechanical to Hydraulic and even Pneumatic. With the advancement in technology, integration of electronics and electrical devices with mechanical devices has now been possible. These new Hydraulic and Pneumatic presses have better capacity and are far more reliable and easy to maintain [1]. Mainly due to high working capacity of these presses, they are ubiquitous and preferred over mechanical presses. Also maintainability is one of the key factors behind the proper functionality of these presses.

Hydraulic press works on Pascal's law according to this law "In a fluid at rest in a closed container, a pressure change in one part is transmitted without loss to every portion of the fluid and to the walls of the container".

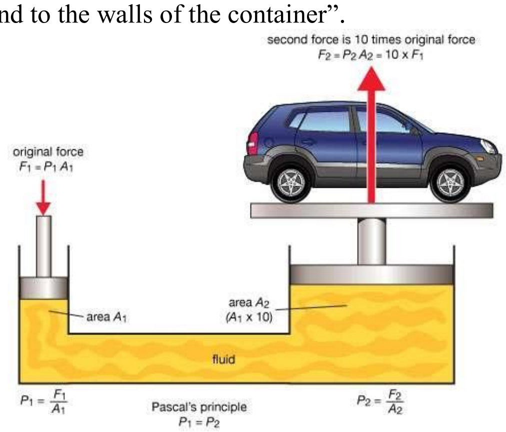

Figure 2 Pascal's law

Hydraulics uses incompressible liquids so the applied pressure from one end (small arrow) is equal to the desired pressure on the other end (big arrow).

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ISSN : 2348 - 5612 | Volume : 04 , Issue : 11 | October – December 2017

The big arrow is pointing toward a piston that is free to move, and is sometimes connected to a rod. When the force is applied, the piston moves up or down.

The equations are:

Pressure 1 = pressure 2

$$\frac{F1}{A2} = \frac{F2}{A1}$$

$$F2 = \frac{F1A1}{A2} \quad \ldots\ldots\ldots\ldots\ldots\ldots (1)$$

Pressure is equal to the force divided by the area on which it acts. According to Pascal's principle, in a hydraulic system a pressure exerted on a piston produces an equal increase in pressure on another piston in the system. If the second piston has an area 10 times that of the first, the force on the second piston is 10 times greater, though the pressure is the same as that on the first piston. This effect is exemplified by the hydraulic press.

Where,

F -is the force applied

P -is the pressure transmitted

A -is the cross sectional area

1.2. Types of presses

Presses are categorized into various types

- Power press
- Mechanical press
- Eccentric press
- Pneumatic press
- Arbor presses
- Laminating presses
- C- frame presses
- Assembly presses
- H- frame presses

1.3. Hydraulic press vocabulary

1) **Cylinder -** Cylinder assembly consists of a cylinder, piston, ram, packing, and seals. Piston diameter and oil pressure determine the force (tonnage) that a given press can deliver.
2) **Frame -** The main structure of the press containing the cylinder(s) and the working surfaces.
3) **Stroke Control -** Stroke length can be set for any distance within the stroke limits of the cylinder. Adjustments include: top of stroke, pre-slowdown point, and bottom of stroke.
4) **Throat Clearance -** The distance from the vertical centreline of the ram to the frame member behind the bed. This distance determines the largest diameter piece that can be positioned with the part centerline under the center of the ram.
5) **Daylight -** The vertical clearance from the top of the bolster to the underside of the ram in its maximum up position. This term sometimes is confused with the mechanical press term "shut height". Shut height is the clearance over the bed with the ram full down. "Daylight" describes the maximum vertical capacity of the press.
6) **Bolster -** A plate or structure mounted on the bed. Hydraulic press manufacturers provide a removable bolster on most models.
7) **Bed -** Flat, stationary machined surface that supports the bolster or dies.
8) **Dual Palm Button Controls -** A common method of actuating hydraulic presses. Both buttons must be depressed at the same time to bring the ram down requiring the operator to use both hands. Control circuits include non-repeat and anti-tie down features.
9) **Work Height -** The distance from the floor to the top of the bolster.

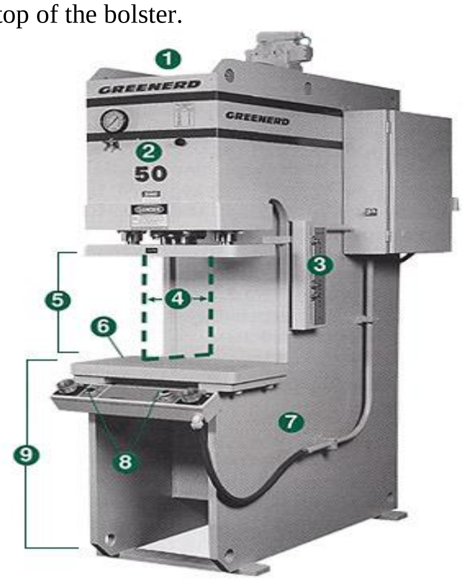

Figure 3 part of hydraulic press

II. LETRATURE REVIEW

1. **Akshay Vaishnav (2016)** explain the metal forming is a process which is done by deforming metal work pieces to the desired shape and size using pressing or hammering action. Hydraulic presses are being used for forming and pressing operations with wide range of capacities. Hydraulic press machine works under continuous impact load. Because of this continuous load, tensile and compressive stresses are experienced in various parts of machine. These stresses cause permanent deformation in some parts of machine. This work is based on optimization of a 250-ton four pillar type hydraulic press considering constraints like design, weight and cost. The work is focused on design and optimization of top plate of the press machine. Top plate holds the hydraulic cylinder and is one of the most critical parts of the machine. The design is based on sizing optimization method and the results are validated by Finite Element method with proper boundary conditions. The CAD modeling has been carried out by PTC CREO and for FEA, ANSYS software is used.

2. **Gebremichael Tasew (2018)** describes Hydraulic bending machine is a common tool in the machine shop that is used to bend a piece of plate. Bending machines in different type found in small and large scale industries which

have limitation on utilizing cylinder force, that entire machine loses cylinder force without any function. The main objective of this project is to develop one hydraulic cylinder driven 5mm thickness stainless steel plate bending machine with low cost and light weight. For reducing the weight and the cost of the machine use only one hydraulic cylinder and maximize the hydraulic cylinder bending load by the help of right angle lever. In this paper generate an innovative idea for handling loss of cylinder force. As a result the machine become low in cost and light in weight simple operation and high competitive marketable machine. The main component of the machine is lever, lower die, punch, frame, table and double acting hydraulic cylinder.

3. **G. C. Mekalke (2017)** focuses on automation of a press tool for production of sheet metal components. The operation of press tool consists of sequence of operations. This sequence of operations had to automate for increase in productivity. For that purpose, PLC is used from Bosch Rexroth, Germany made. With the help of DTMF module it was made possible to operate the press by using mobile calling from remote locations. In this article, the press thus designed served for the purpose with 73% reduction in production time, with enhanced quality and helped in enabling mass production by eliminating several processes such as marking, cutting done with the help of a cutter, shaping, and so on.

4. **N. A. Anjum (2017)** explain different mechanical presses used to deform or press the material through dies to convert into useful product by applying different conditions like temperature, pressure, speed of ram etc. These material deformation techniques not only used to produce finished products but also to increase the strength of the material by introducing severe plastic deformation. Equal channel angular pressing (ECAP) is a technique used to increase the strength of materials by introducing severe plastic deformation through grains refinement. The ECAP die consisting of two channels intersecting at 90 degree was designed and manufactured to perform angular extrusion. The load was calculated through mathematical modeling. A hydraulic press equipped with conventional temperature control furnace, sensor based limit switches, pressure controlled mechanism and with variable speed control was designed, fabricated and manufactured at UET Taxila. The material used for the fabrication purposes is mild steel. The major designing parameters included stroke length, maximum load, pressure, cylinder bore, sealing mechanism and volume flow rate of working fluid.

5. **Bhushan V.Golechha, (2017)** also said about cold stamping process. The machine used for press working is known as press. This Project work deals with the design, Finite element analysis and structural optimization of 10 Ton Pneumatic Press Machine. The aim is to reduce the weight and cost of the Pneumatic press without reducing the quality of the output. Using the best possible resources in design can affect decrease in the weight and cost of the press machine. One way of doing it is the optimizing the volume of material utilized for building the complete structure of machine .Here we have consider an industrial application project consisting of mass minimization of a Pneumatic press. For analysis Purpose ANSYS Software has been used.

6. **Gourav Suresh Kanhe (2017)** Bending of plates and sheets are extensively used to produce the parts such as flanges, angles etc. In bending operation a flat sheet metal is formed into a curved by the applying the bending stress. By the help of die the punch sheet gets bend plastically without change in thickness. This project is rooted on the urge of Daulat Industries, Nagpur. The aim of the project is to design a sheet bending machine which is capable of bending 5mm thick stainless steel sheets of 8ft wide and 4ft length in size. In this research we will develop a CAD model of sheet bending machine and optimization of machine using FEA. This paper is majorly based on the literature review, and also contains needs to design, research methodology of the project. Of the present study is the validation and application of a CFD-based methodology to quantify the hydrodynamic roughness produced by any surface, including viscous oil coatings and befouled surfaces.

III. OBJECTIVE

1. The work is focused on design and optimization of top plate of the press machine.
2. The design is based on sizing optimization method and the results are validated by Finite Element method with proper boundary conditions.
3. Reduce the weight and cost of component by using sizing optimization method.
4. Comparing all design by using ANSYS software.
5. The new design is more durable, equivalent stress and deformation is very low comparing other design.
6. The weight of hydraulic plate is low by using same material.
7. The cost of hydraulic plate is reducing.

IV. PROPOSED METHODOLOGY

The hydraulic press is studied for two configurations. In first configuration using base Plate design and in second configuration is top plate design. The CATIA provides the following approaches for model generation: Creating a solid model within CATIA. The ANSYS software is used for the structural analysis of the base plate and top plate. The equations to steady is solved when static or dynamic load is applied on any part of hydraulic press, then along simple stress, compressive stress, shear stress and also developed bending stress.

Based on the theoretical calculations and design, we can model and simulate the system into various software packages for validation. The theoretical calculations are based on conventional machine design using a set of equations. This gives the basic idea of the design of the product.

The following methodology steps are,

1. Collecting information and data related to the hydraulic press plate.

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2. A fully parametric model of the hydraulic press plate is generated using catiav5
3. Model obtained in Step 2 is analysed using ANSYS 15.
4. Manual calculations are done.
5. Finally, we compare the results obtained from ANSYS

The theoretical calculations and design, we can model and simulate the system into various software packages for validation. The theoretical calculations are based on conventional machine design using a set of equations. This gives the basic idea of the design of the product.

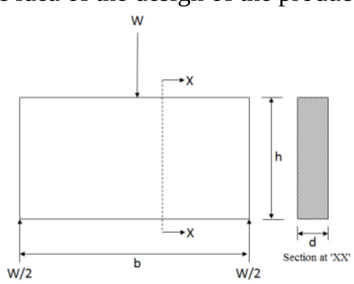

Figure 4 Load case

When a static or dynamic load acts on any part of hydraulic press, then along with simple, tensile, compressive, shear stress, it also develops bending stress.
Consider a beam subjected to a bending moment M,
The bending equation is given by,

$$\frac{M}{I} = \frac{\sigma b}{Y} \quad \text{..............................} \quad (1)$$

Where,
M = Bending moment at the given section
σ_b =Bending stress
I = Moment of inertia of the cross-section about the neutral axis.
y = Distance from the neutral surface to the extreme fiber
Bending moment is given by,

$$M = \frac{W\times b}{4} \quad \text{........................} \quad (2)$$

$$M = \frac{2500000\times 860}{4} = 5.375e8 \text{ N-mm}$$

Moment of inertia of the cross-section about the neutral axis

Moment of inertia of the cross-section about the neutral axis,

$$I = \frac{db^3}{12} \quad \text{..........................} \quad (3)$$

$$I = \frac{60\times(558.6)^3}{12} = 8071e8 \text{ mm}^4$$

$$Y = \frac{b}{2} \quad \text{.............................} \quad (4)$$

$$Y = \frac{558.6}{2} = 279.3 \text{ mm}$$

Putting these values in Eq. (1)

$$\sigma_b = \frac{M\times Y}{I} \quad \text{...............................} \quad (5)$$

$$\sigma_b = \frac{5.375e8 \times 279.3}{8.91e8}$$

$$\sigma_b = 172.09 \text{ N/mm}^2$$

The ultimate tensile strength of mild steel is,

σ_{Uts} = 460 MPa,

Considering Factor of Safety = 2.5 for the given structure.

According to Maximum Principal stress theory

$$\sigma_{allowble} = \frac{\sigma_{uts}}{FOS} \quad \text{.........} \quad (6)$$

$$\sigma_{allowble} = \frac{460}{2.5}$$

$$\sigma_{allowble} = 184\ Mpa$$

So, $\sigma_b = \sigma_{allowble}$

4.1. Material property

Mild steel is use to design analysis of hydraulic plate due to height strength property.

Table 1. Material properties

Material	Mild Steel
Density	7850 Kg/m^3
Young's modules	210 GPa
Poison ration	0.3
Tensile yield strength	410 a

4.2. 4.2 Building the model

The CATIA provides the following approach for model generation: Creating a solid model within CATIA. Every design starts with the conventional calculations by applying various fundamentals of design. The top plate is subjected to pure bending stress during the operation. Therefore, design considerations are essential for plates subjected to bending stress. The dimensions of base plate, used for top plate

Table 2. Geometrical dimensions

Constraint	Value
Breath (b)	860 mm
Height (h)	558.6 mm
Depth (d)	60 mm
Maximum applied load	250 ton

Here the bending stress acting on the base plate is less than the allowable stress of the plate material. Hence, we can conclude that the given design of base plate for design top plate is safe.

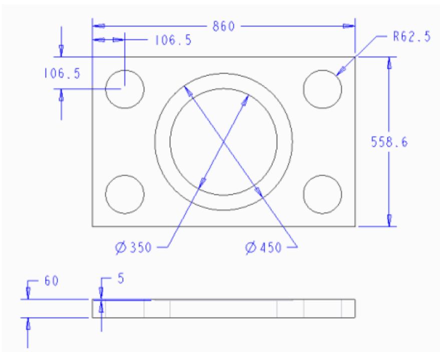

Figure 5-a Base plate sketch

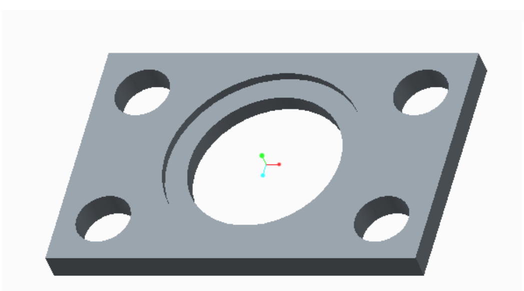

Figure 5-b Base plate CAD model

4.3. Top plate design

The top plate has been designed by putting rib structure onto the base plate. The design of rib structure is based on experiments and practice. In present work, the design is done to withstand the maximum deformation of 0.3 mm/m. This value is taken as per the requirement of industry and from various benchmark data. Here, three different designs of top plate are presented using sizing optimization method.

Here, the maximum capacity of the machine is 250-tonns. So, the design of all components will be based on maximum applied load. The hydraulic cylinder is mounted onto the top plate so it will carry that amount of force at the time. The design of top plate is based to several iterations. From these iterations, the optimum design is selected. For this work, PTC CREO software is used for 3D modelling.

In all design iterations the shape and size of rib structure is varied according to design requirements.

1) Iteration-1:

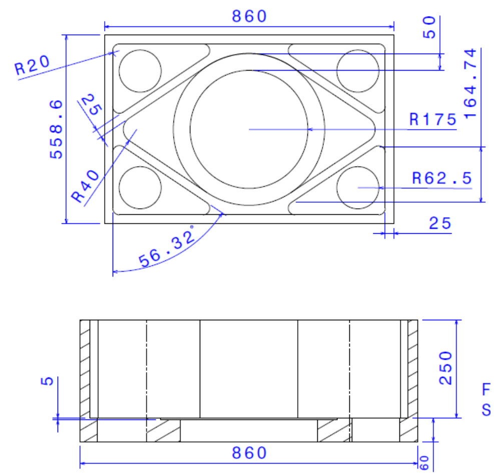

Figure 6-a Iteration-1 sketch

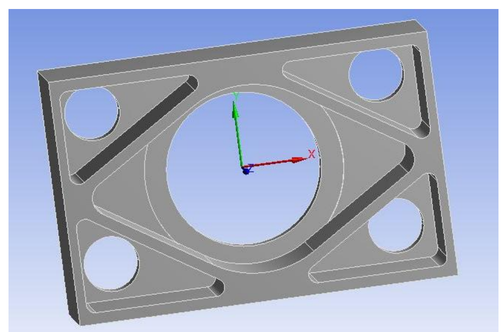

Figure 6-b Iteration-1 CAD model

2) Iteration-2:

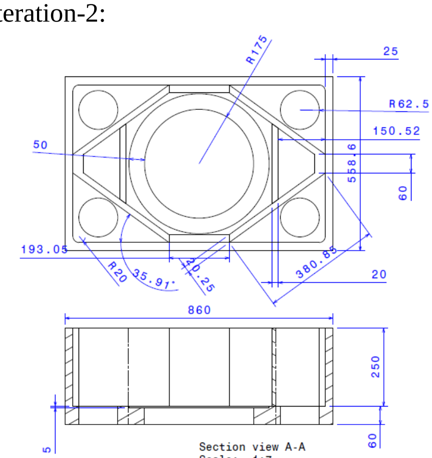

Figure 7-a Iteration-2 sketch

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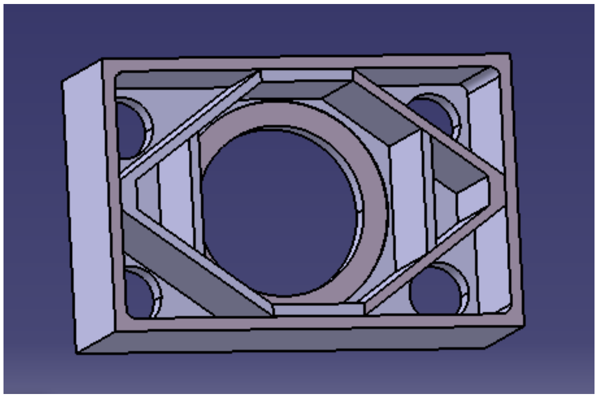

Figure 7-b Iteration-2 CAD model

3) Iteration-3:

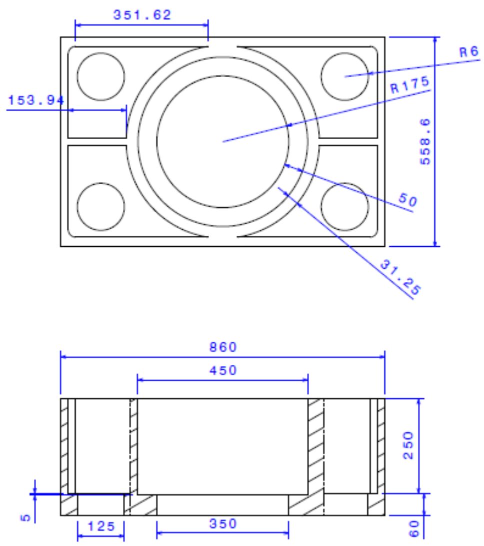

Figure 8-a Iteration-3 CAD model

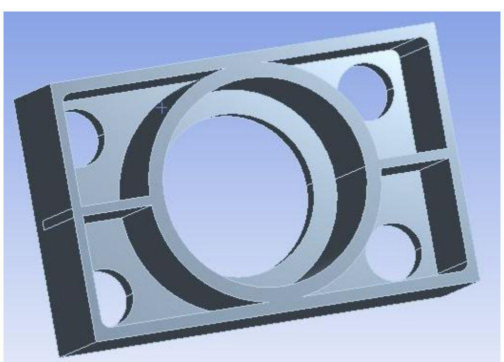

Figure 8-b Iteration-3 CAD model

4.4. Meshing

ANSYS Meshing includes intelligent, general-purpose, automated high-performance type of product. It delivers the most suitable work for exact, proficient Multi physics arrangements. A work appropriate for a particular investigation can be created with a solitary mouse click for all parts in a model. For the master client who needs to tweak on it give full controls over the alternatives used to create the work are accessible. The energy of parallel preparing is consequently used to decrease the time you have to wait for mesh generation.

1) Meshing iteration-1

The mesh created in this work is shown in figure No.4.7. The total Node is generated 6534 & Total No. of Elements is 3356 for iteration-1

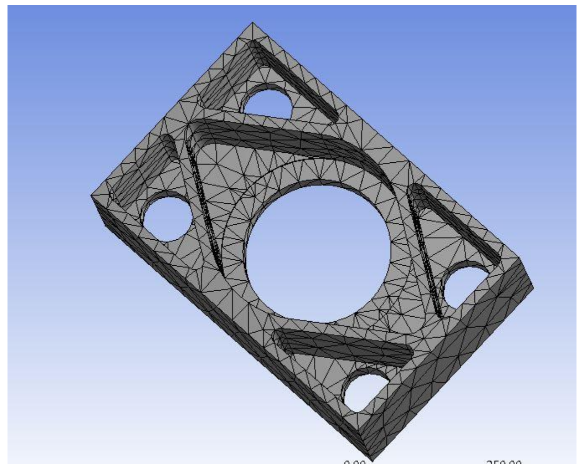

Figure 9 meshing iteration-1

2) Meshing iteration-2

The mesh created in this work is shown in figure No.4.7. The total Node is generated 7542 & Total No. of Elements is 3951 for iteration-1

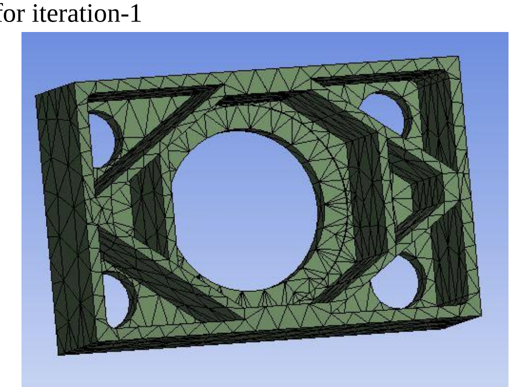

Figure 10 meshing iteration-2

3) Meshing iteration-3

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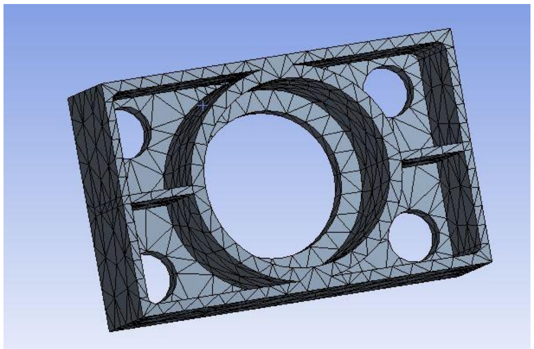

Figure 11 meshing iteration-3

4.5. Boundary condition

1) Fixed support

After applying meshing use fixed support command, the fixed support for all three iteration as show in figure 12, 13 and 14 respectively.

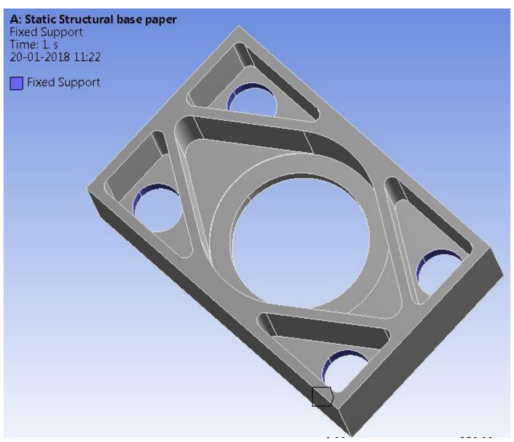

Figure 12 fixed support in iteration-1

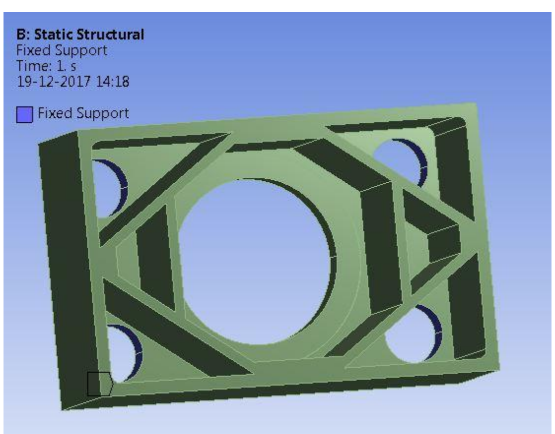

Figure 13 fixed support in iteration-2

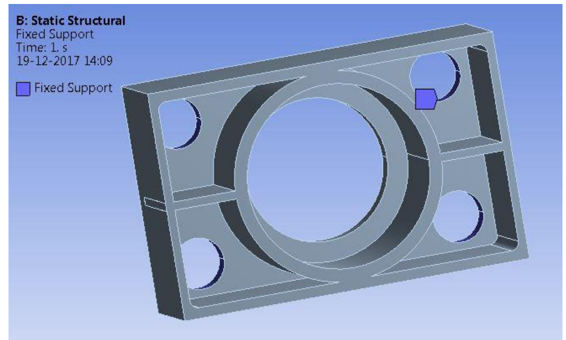

Figure 14 fixed support in iteration-3

2) Force

Maximum load apply on top plate is 250 ton in middle of plate and all four hole are fix.

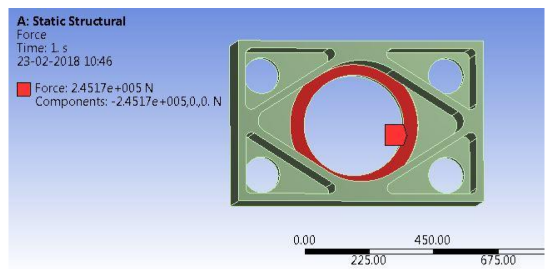

Figure 15 Applying force in iteration-1

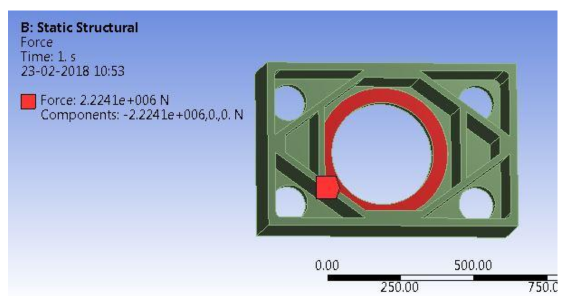

Figure 16 Applying force in iteration-2

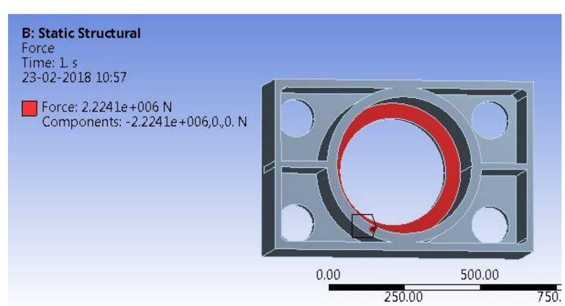

Figure 17 Applying force in iteration-3

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V. RESULTS

For solution of the above problem statement the Finite Element Analysis method is used. This method is preferred because it allows a much closer topological resemblance between the model and the machine. With development of advanced computers and FEA software packages, it is now easy to implement this method comprehensively.

In this case, a 250-ton of load is applied at the middle of the plate, where the cylinder is rested. All four holes at the corner will remain fixed, because it is supported by pillars in actual machine. For FEA simulation, ANSYS software package is used.

Here, primarily two results are obtained in ANSYS, total deformation and maximum von-Mises stress. Based on these results, the optimum design is selected. These results can be obtained by applying proper boundary conditions in ANSYS Workbench.

5.1. The results of FEA simulations

1) Iteration-1

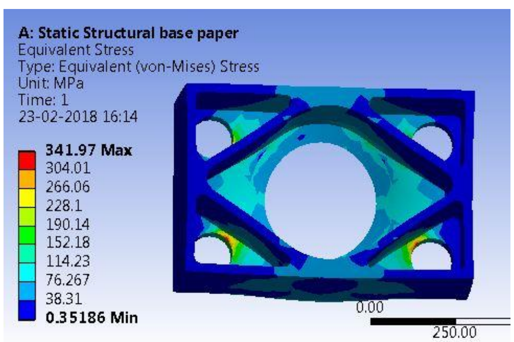


Figure 18 Iteration-1 equivalent stress

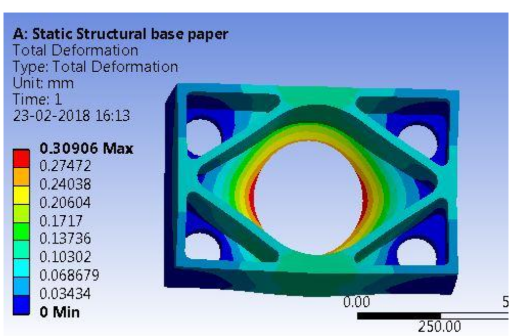


Figure 19 iteration-1 total deformation

2) Iteration-2

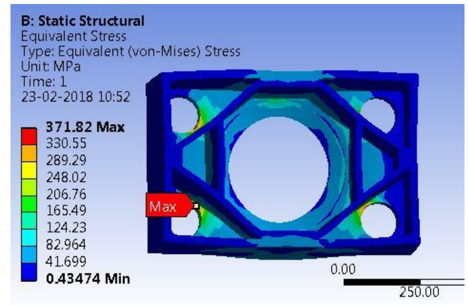


Figure 20 Iteration-2 equivalent stress

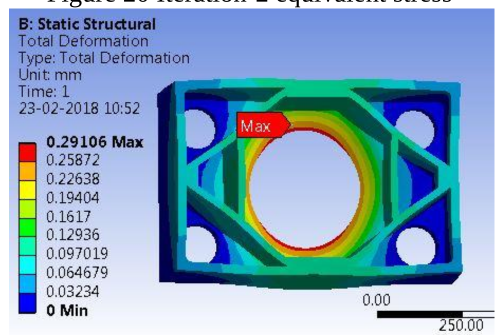


Figure 21 iteration-2 total deformation

3) Iteration-3

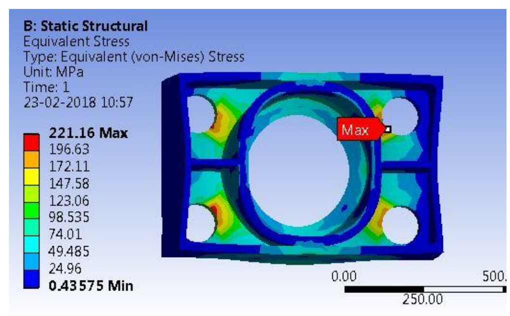


Fig 22 Iteration-3 equivalent stress

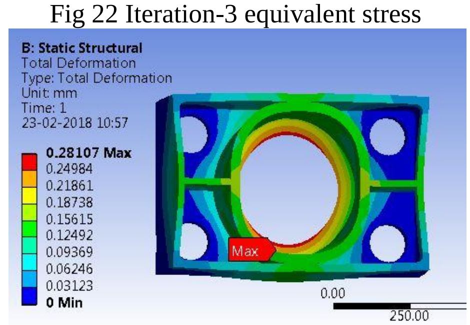


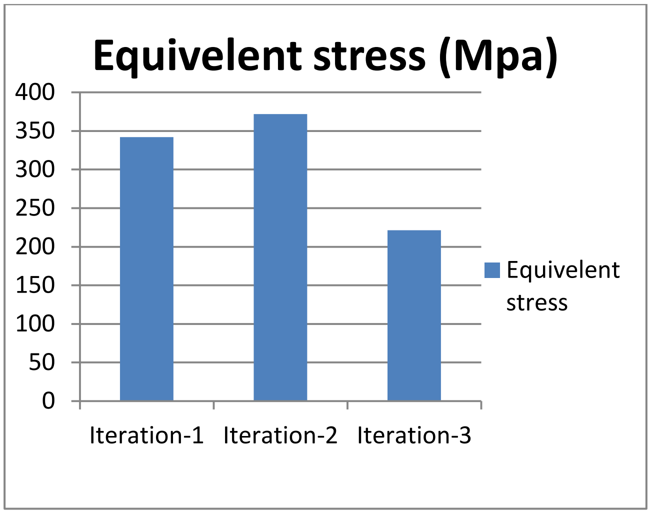
Figure 23 iteration-3 total deformation

The simulation is performed by taking 250 mm of rib height for all three iterations. For all designs, the results are obtained as follows

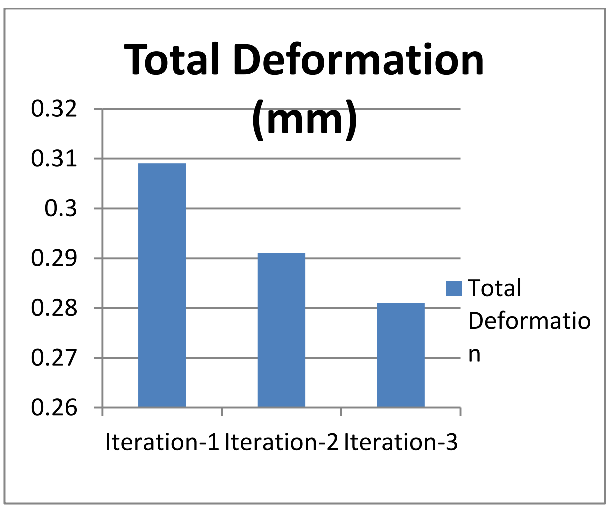
Table 3 ANSYS Result

Plate	Max. Stress (von-Mises) MPa	Deformation (mm)	Weight (Kg)

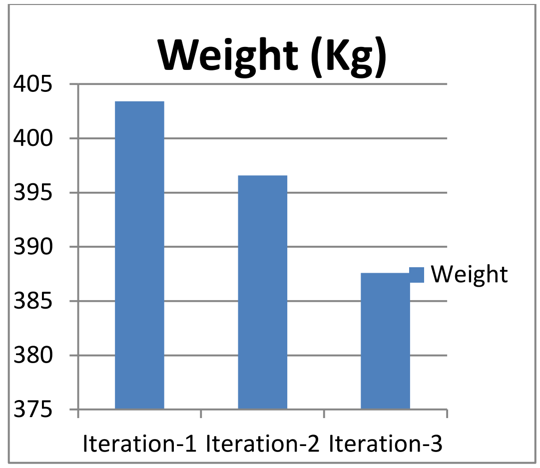
Iteration-1	341.97	0.30906	403.43
Iteration-2	371.82	0.29106	396.57
Iteration-3	221.16	0.28107	387.6



Graph 1 Comparing equivalent stresses



Graph 2 Comparing Total deformations



Graph 3 Comparing Weight

VI. CONCLUSION

From sizing optimization method, the design is modified by incremental iteration approach. For 250 mm of rib height, the FEA results were obtained. It is found that Iteration-3 is optimum design and has deformation under desired values. Also the maximum von-Mises stress for that design is less than the ultimate tensile stress of the material, so this design is safe.

The above result can be show that design-3 (iteration-3) given maximum equivalent stress is under the ultimate stress and total deformation is less then design-1 (iteration-1), and weight of plate is also less in other design. The maximum equivalent stress is iteration-3 is 221.16 MPa, total deformation of iteration-3 is 0.28107 and weight of iteration-3 is 387.6.

So, from the above results, it is concluded that design-3 can be proposed for manufacturing. It has much lower weight compared to other designs, so material cost can be saved. Also it fulfils all the design constraints. It can be manufactured by casting method.

VII. FUTURE SCOPES

Hydraulic plate are used in all industries, the new design is more durable, light weight and also cost effective.

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