© 2015 IJEDR | Volume 3, Issue 2 | ISSN: 2321-9939

Design Optimization of C Frame of Hydraulic Press Machine

Ameet B. Hatapakki, U D. Gulhane
PG student, Associate Professor,
Department of Mechanical Engineering,
Finolex Academy of Management and Technology, Ratnagiri, India

***Abstract* - This paper attempts to acquire the FEA implementation for analysis and design optimization of C Frame of 100 ton Hydraulic Press Machine. Availability of limited resources for profit oriented manufacturing industries forces optimum use of available overall resources with a basic intention of cost saving approach. Design of a hydraulic press structure is of prime importance keeping in mind the design parameters and performance indicators and their relationship with proper knowledge of existing working conditions and application of load. By FEA implementation, attempts are being made to reduce the thickness of the plates for the C frame structure in order to save the material and its cost.**

***Index Terms* - C Frame, Hydraulic press, stiffness, Finite element method.**

I. INTRODUCTION

Press work is the most widespread among all the devices of forming metals and even some non-metals. In view of its great importance, proper design of these machines, in order to increase their performance and productivity, is considered very essential. The design concept of the press structure is undergoing rapid change, on account of the technological advancements in recent years. In a bid to replace cast iron, welded structures, which are lighter, are being employed. The performance of a hydraulic press depends, largely, upon the behavior of its structure during operation. However, these welded structures are becoming complicated and their accurate analysis, under given loading conditions is quite important to the structural designer. Press design methods have changed within a short span of time from empiricism to rational design methods; with the advent and widespread use of digital computers, it has now become feasible to develop analytical models and computer programs to apply numerical techniques with varying degrees of approximations to the design problems. The research on machine tool structures was stepped up by the application of the finite element method (FEM). This is a more generalized method in which a continuum is hypothetically divided into a number of elements interconnected at nodal points to calculate the strain, displacement and stress. The FEM is preferred because it permits a much closer topological resemblance between the model and the actual machine. It has been only recently employed for press structures. It is desirable in practice that the design analysis should be comprehensive and thorough at minimum cost and time. In complex structures, like hydraulic press welded frames, the concept of finite element method can be applied. Stiffness is the guiding factor for the design of a press frame.

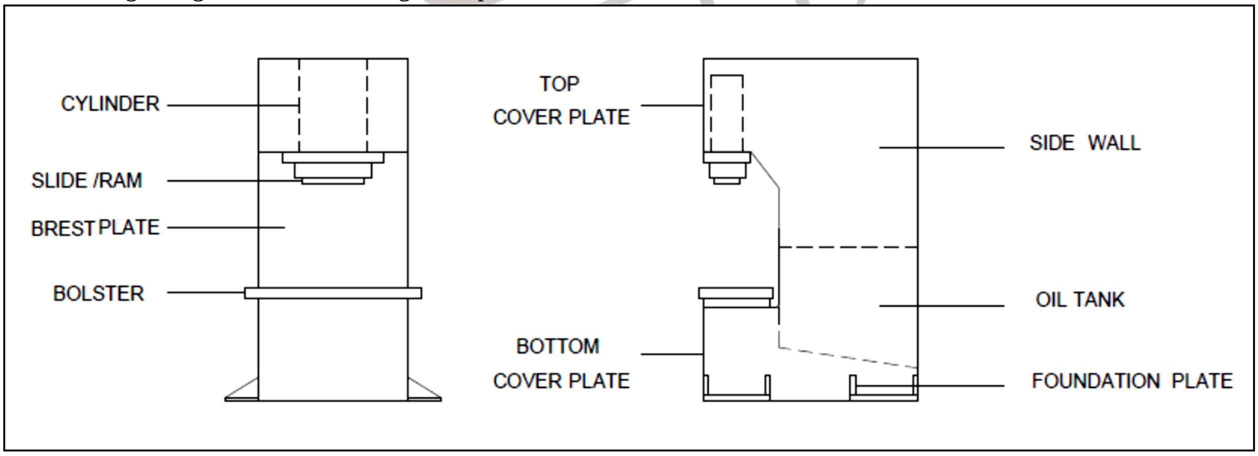

Figure 1 Cross section of Typical C-Frame Press

Table 1 Technical Specification

Type	**C Frame Hydraulic Press**
Model	HCP-100
Material	ST42-W, Fusion welding Quality Steel (IS: 2062)
Mode of Operation	Manual /Automatic

Stroke	500 mm
Capacity	100 tons
Ram Diameter	200mm

Table 2 Functional Specification

Approach Speed	48 mm/s
Pressing Speed	8 mm/s
Return Speed	85 mm/s
Oil Tank capacity	100 to 250 liters
Electric Motor capacity	11kW

Table 3 Material Specification

Designation	ST42W
Tensile Strength	460Mpa
Yield Strength	250Mpa
Density	7850 kgf/m^3
Young's Modulus	2.1 x 10^5 N/mm^2
Poisson's Ratio	0.3

II. OBJECTIVE

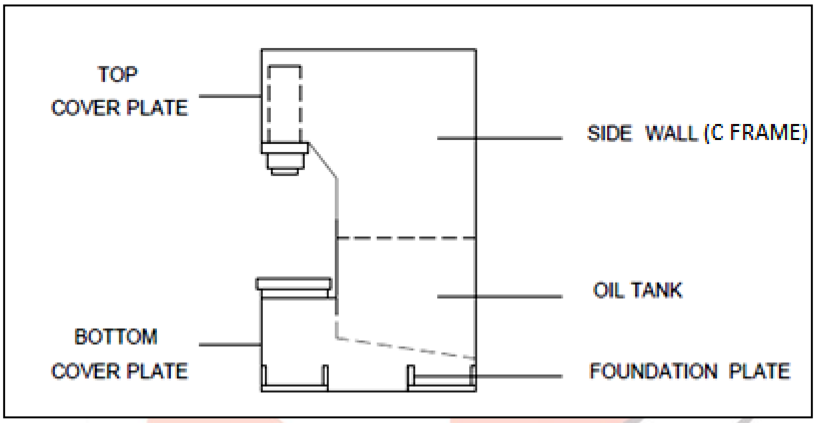

Figure 2 C Frame Press Details

This project is assigned by HYDROPACK INDIA PRIVATE LIMITED. The objective of this project is to optimize or minimize the thickness of the plates of the side wall or C-Frame, maintaining the top frame deflection of 50 microns. There are 2 side plates, one on each side.

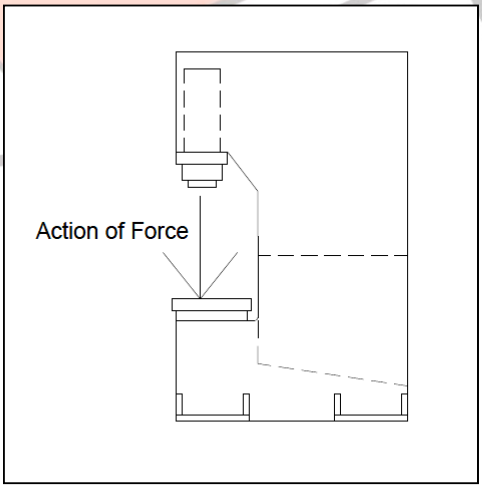

Figure 3 Load on the work piece

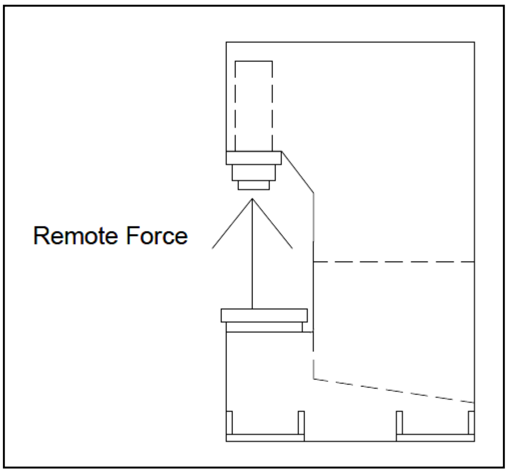

Figure 4 Remote Force on the Top Frame as a part of Reaction Force

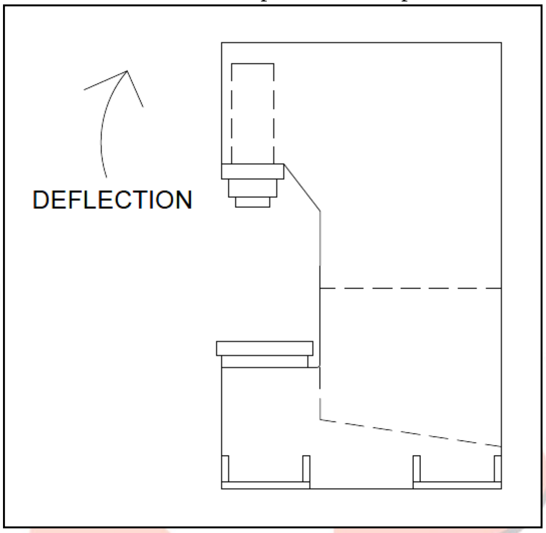

Figure 5 Top Frame Deflection due to Remote Force

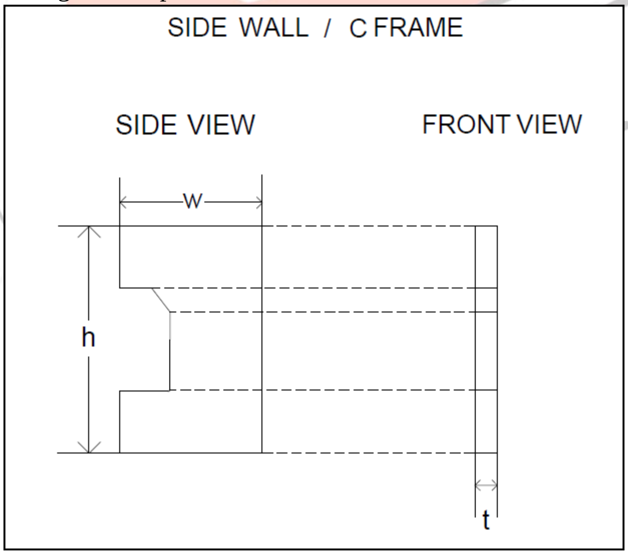

Figure 6 Views of the Side Plate or C Frame section

Table 4 Dimensions of the Side wall

Description	Dimension (mm)			No. of Plates
	Height (h)	Width (w)	Thickness (t)	
Side wall	2060	1400	25	2

III. METHODOLOGY

Finite Element Analysis is implemented. The Software analysis is done by ANSYS. Structural Analysis is the most common application of Finite Element Method. Under Structural Analysis, Modal Analysis and Static Analysis is implemented. Modal Analysis is used to determine the natural frequencies and mode shapes of a structure. Static Analysis is used to determine the displacements and stresses in the structure under linear static loading conditions. Design Exploration, part of the software process, is also used. The main purpose of Design Exploration is to identify the relationship between the performance of the product (output parameters) and the design variables (input parameters) and to identify the key parameters of the design and how they influence the performance. The first step of any design simulation is to create the simulation model. The input and output parameters are defined. The next step is to identify the design candidates by creating a response surface. The response surfaces will provide curves or surfaces that show the variation of one output parameter with respect to one or more input parameters at a time. In the process of engineering design, it is very important to understand what are the input variables and how many input variables are contributing factors to the output variables of interest. It is a lengthy process and Designed Experiments help to solve this lengthy process. The Simple Designed experiment used is Screening Design. Hence, this is called Response Surface Optimization which uses Screening Optimization technique. In this technique, we define the design space by giving the minimum and maximum values to be considered for each of the input variables. To compensate the insufficiency of this design, it is enhanced to include center point of each input variable in experimentations. The center point of each input variable allows a quadratic effect, minimum or maximum inside explored space, between input variables and output variables to be identifiable, if one exists. The enhancement is commonly known as response surface design. The Design of Experiment part of the response surface system will create the design space sampling. The type of Design of Experiment used is Box Behnken Design, which is a three level quadratic design.

IV. FINITE ELEMENT ANALYSIS

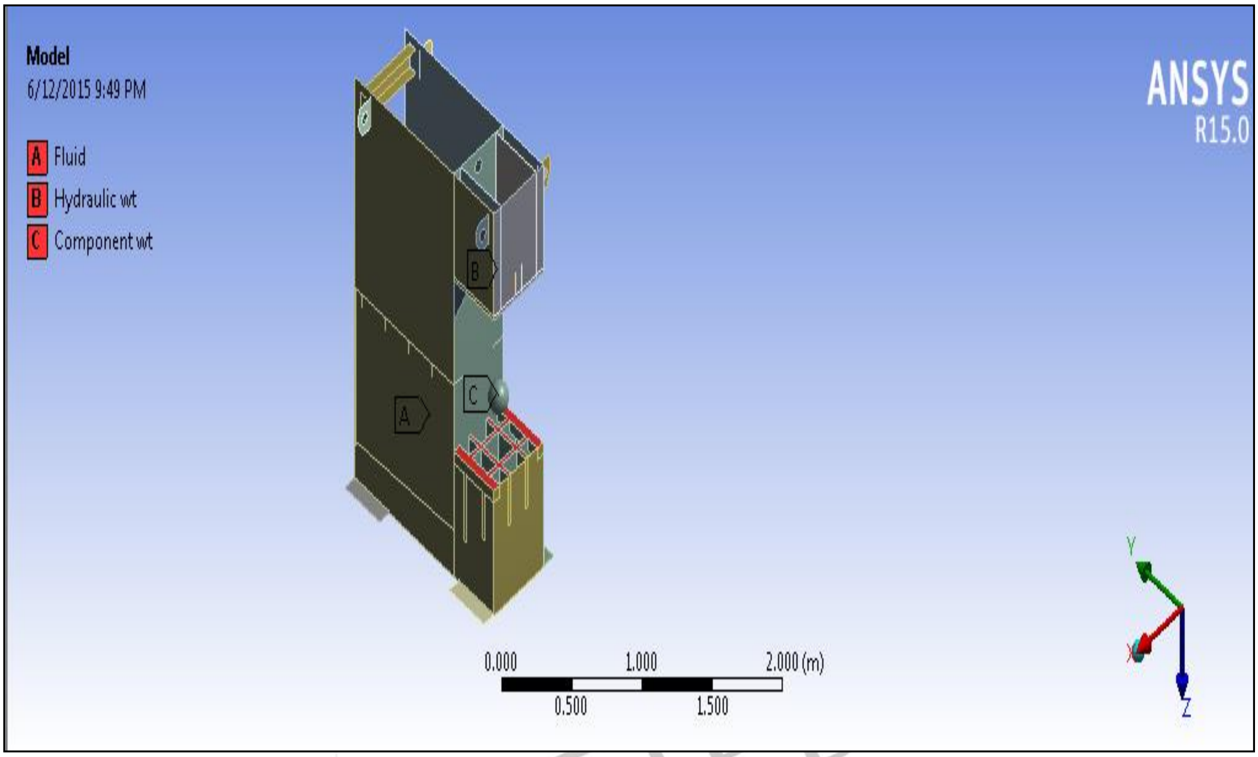

Figure 7 Model Creation

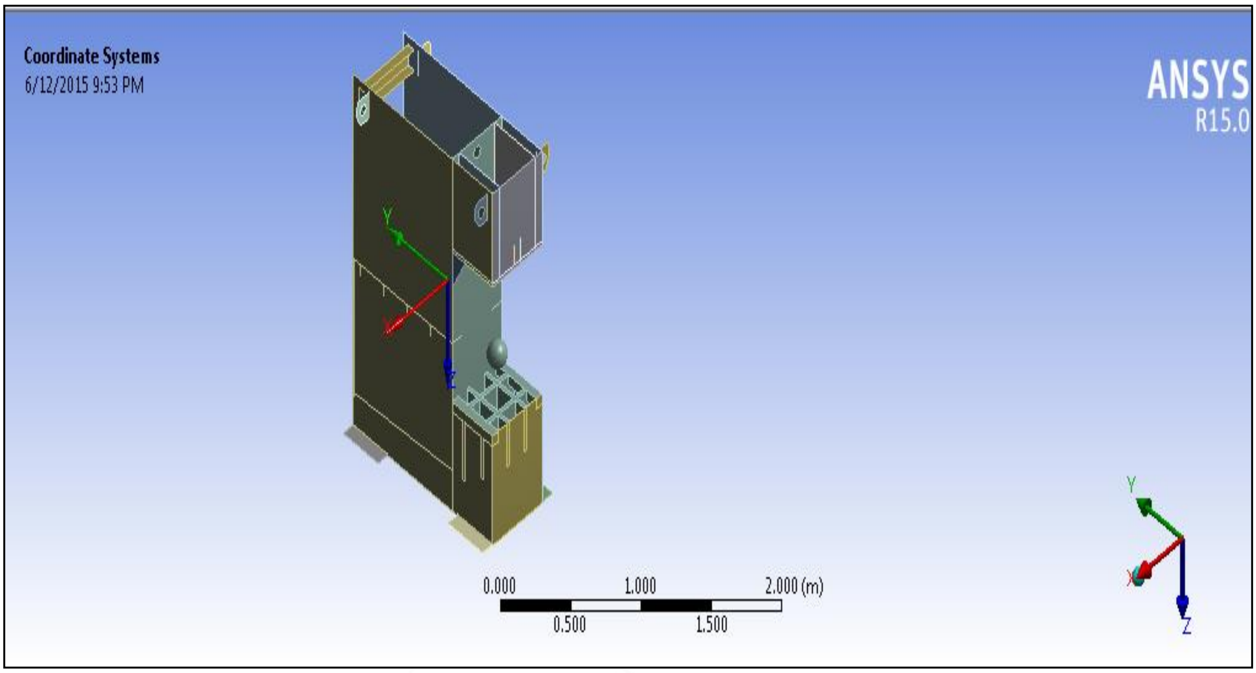

Figure 8 Coordinate System

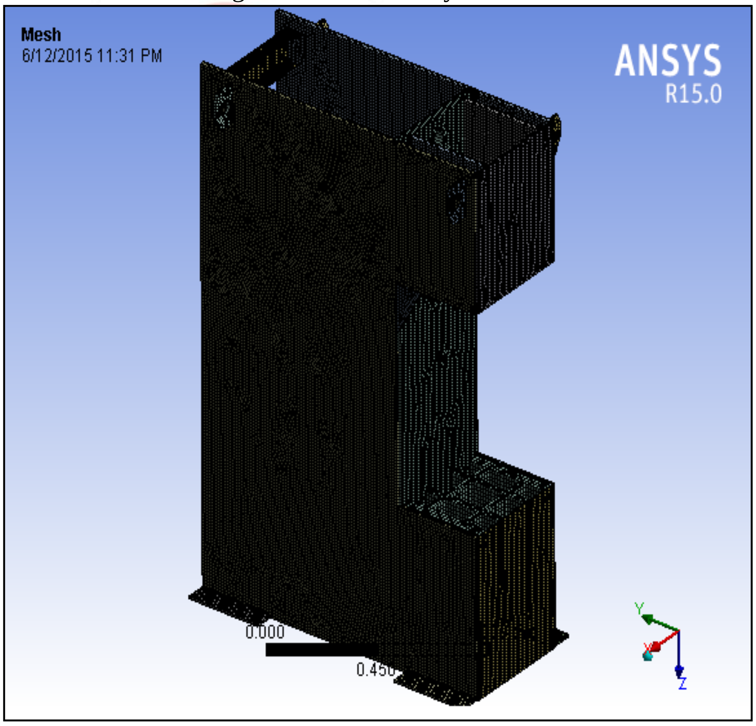

Figure 9 Mesh

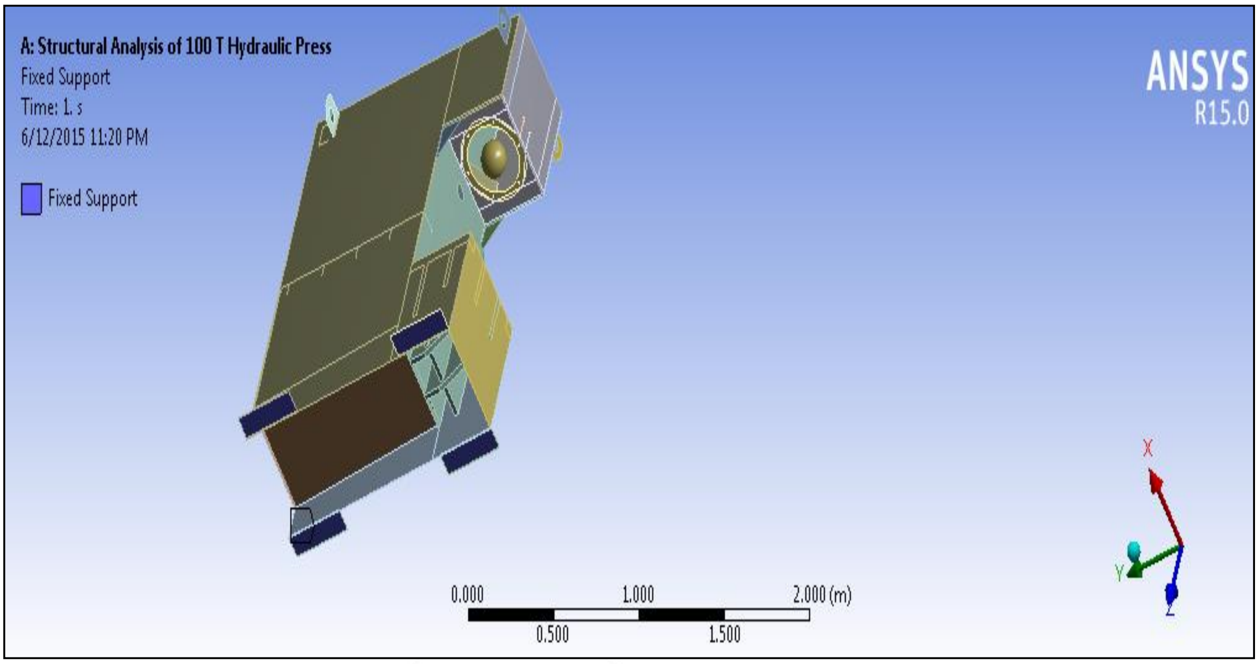

Figure 10 Apply Boundary Conditions

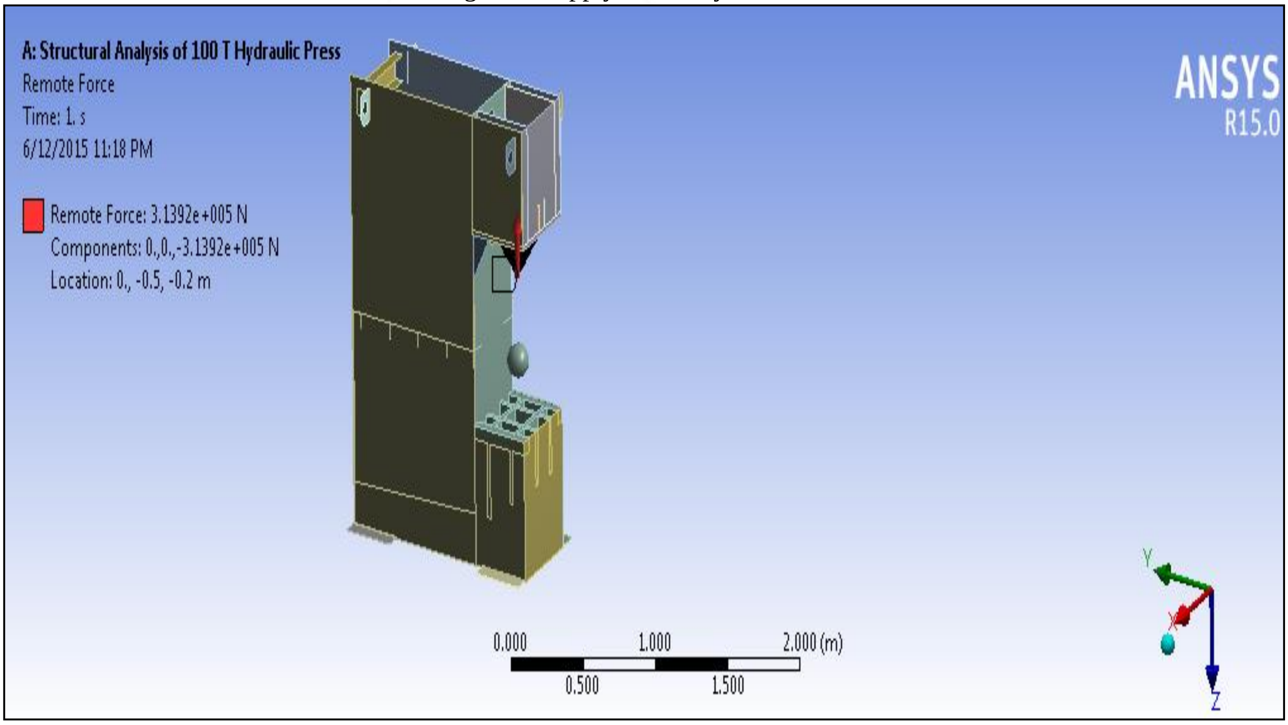

Figure 11 Application of Load

V. MODAL ANALYSIS RESULTS

Modal Analysis for 2 modes was found to be sufficient to understand the stiffness behavior and satisfy all the desired requirements.

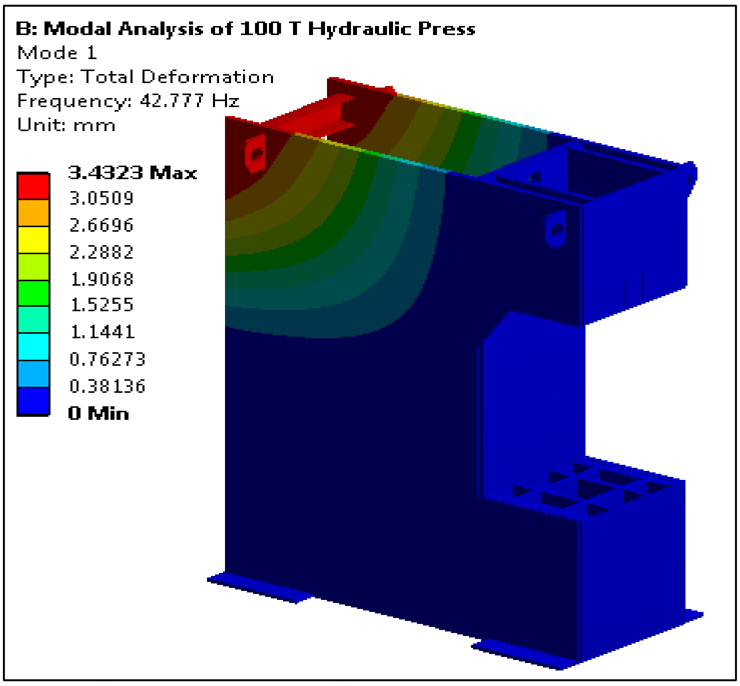

Figure 12 Mode 1 Original Model

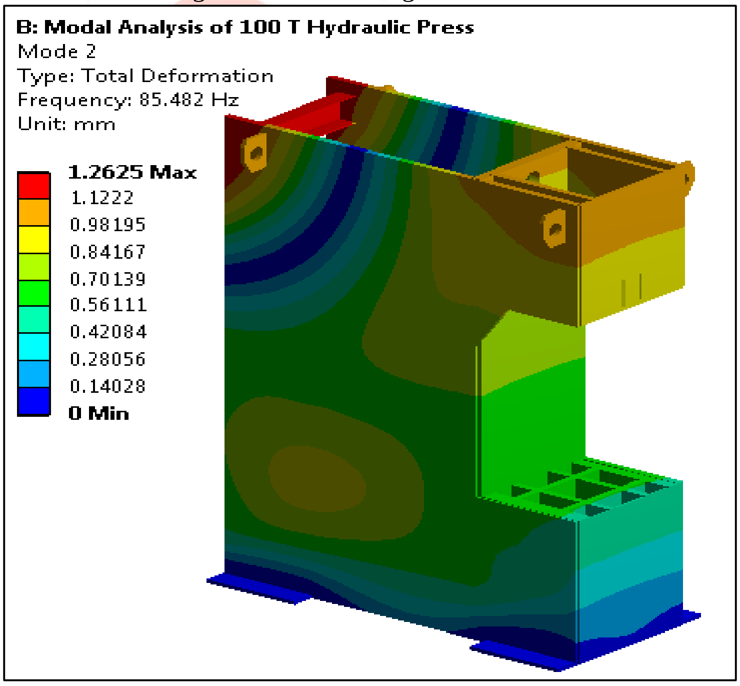

Figure 13 Mode 2 Original Model

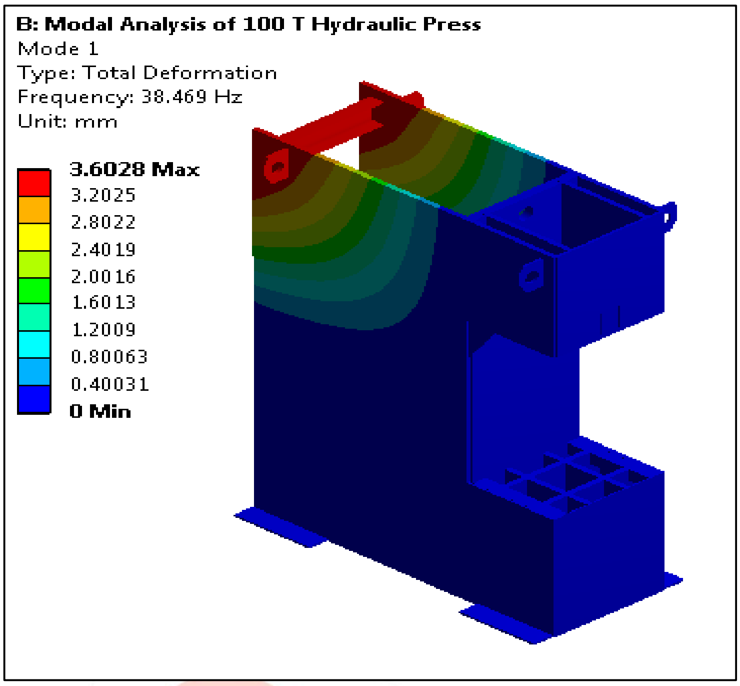

Figure 14 Mode 1 Optimized Model

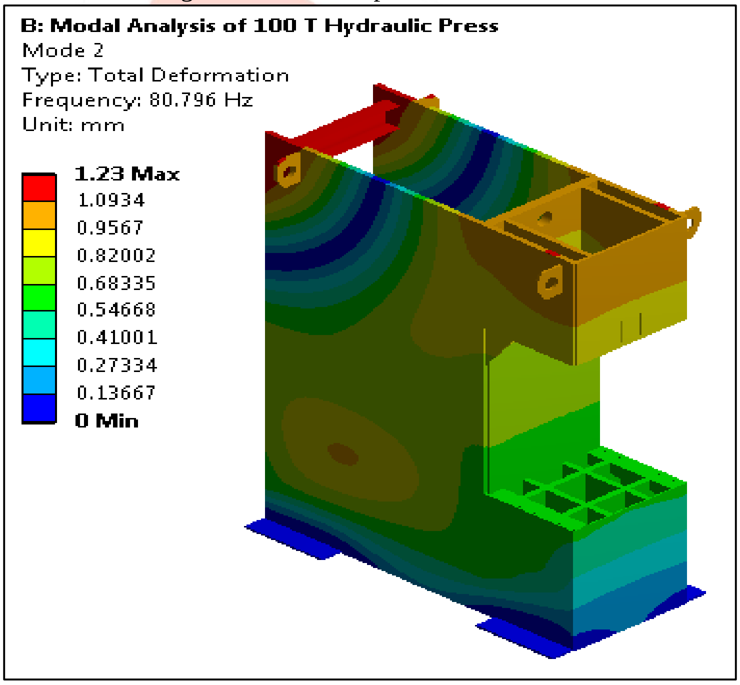

Figure 15 Mode 2 Optimized Model

VI. STRUCTURAL ANALYSIS RESULTS

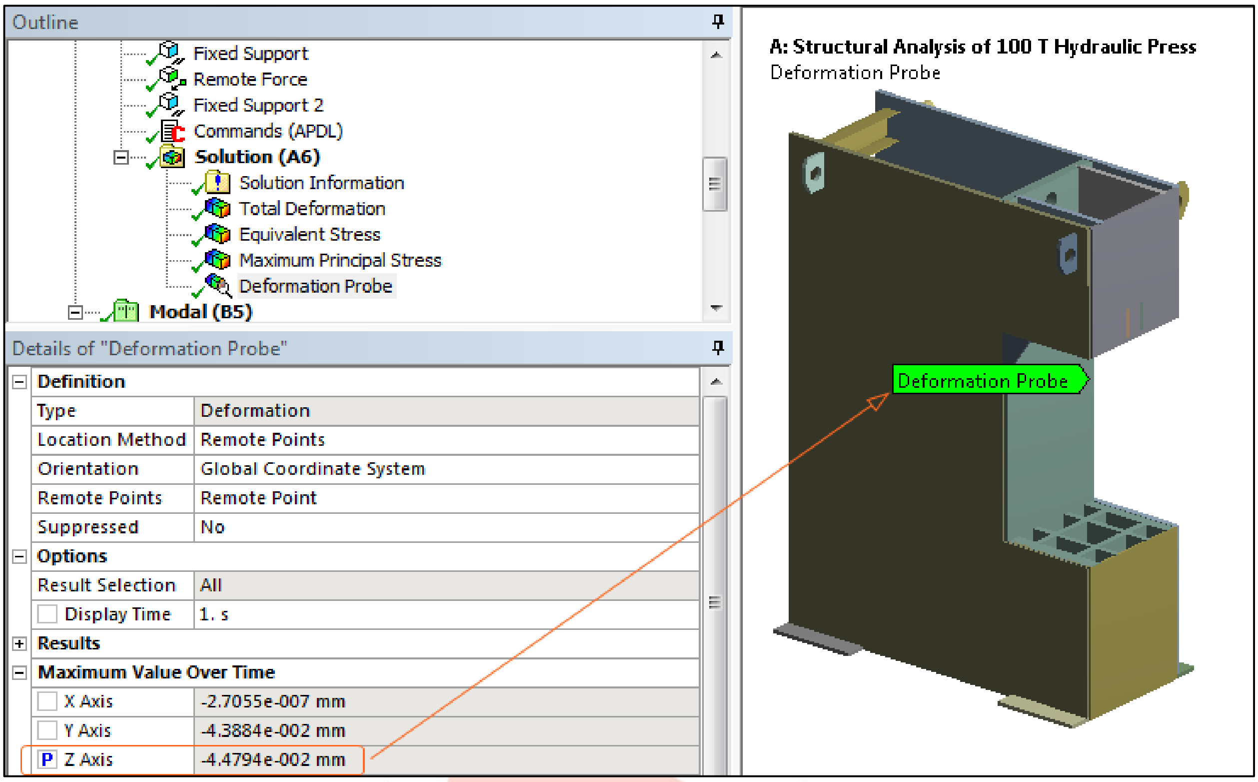

Figure 16 Original Model Top Frame Deformation along z axis

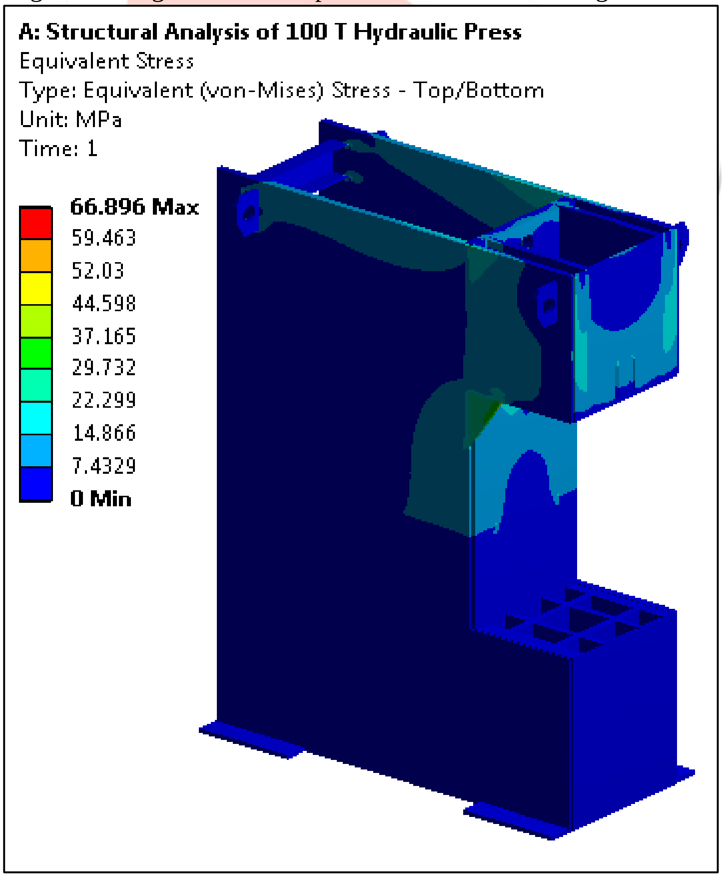

Figure 17 Equivalent Stress of the Original Model

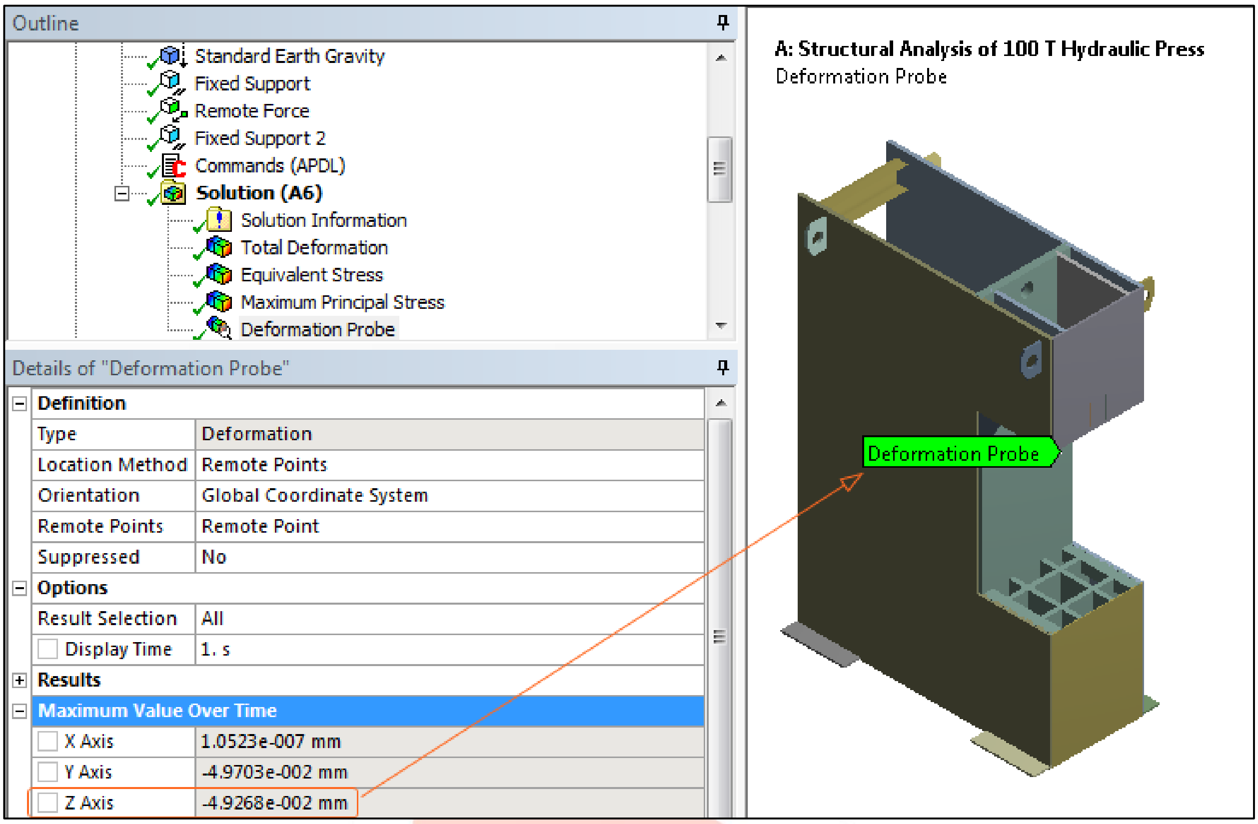

Figure 18 Optimized Model Top Frame Deformation along z axis

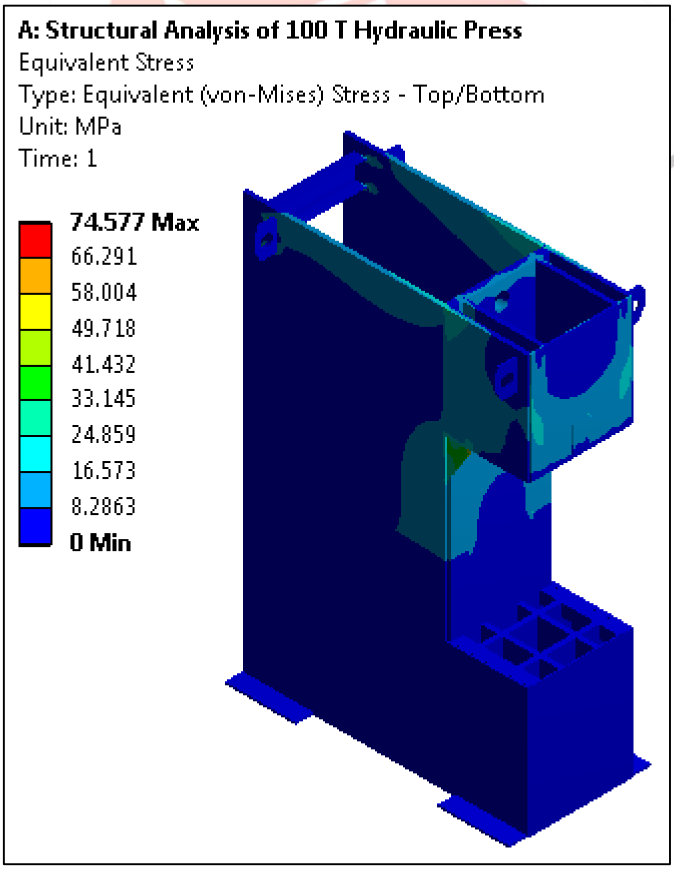

Figure 19 Equivalent Stress of the Optimized Model

VII. GRAPHICAL RESULTS

P1- Design Candidate Point (Input Parameter) which represents the thickness of the plates of 25mm.
P30- Deformation of the Top Frame (Output Parameter) along z axis in mm.
P31- Maximum Principal Stress (Output Parameter) in MPa.
P32- Equivalent Stress (Output Parameter) in MPa.

P41- Geometry mass (Output Parameter) in kg.

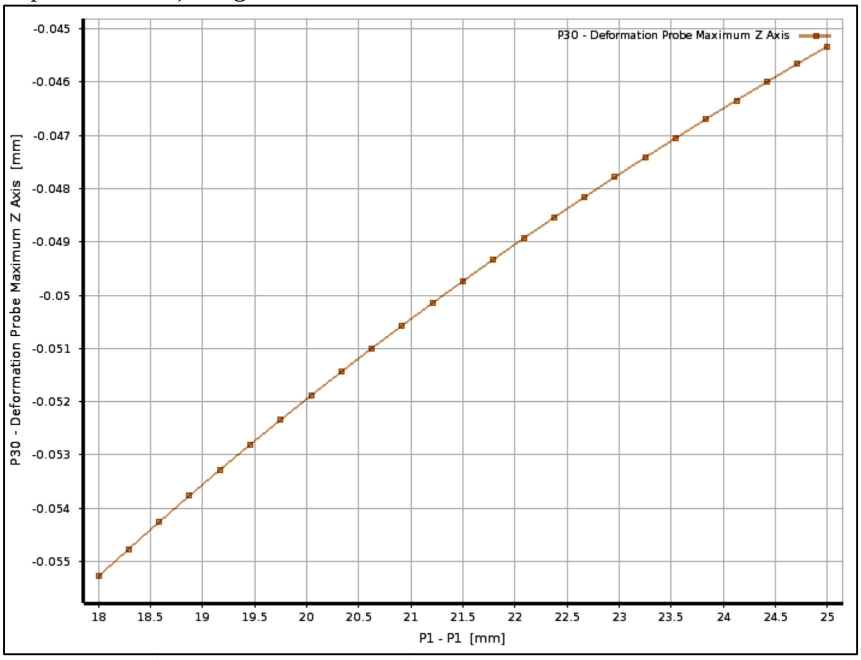

Figure 20 Variation of thickness of 25mm plates with the Deformation of the Top Frame along z axis

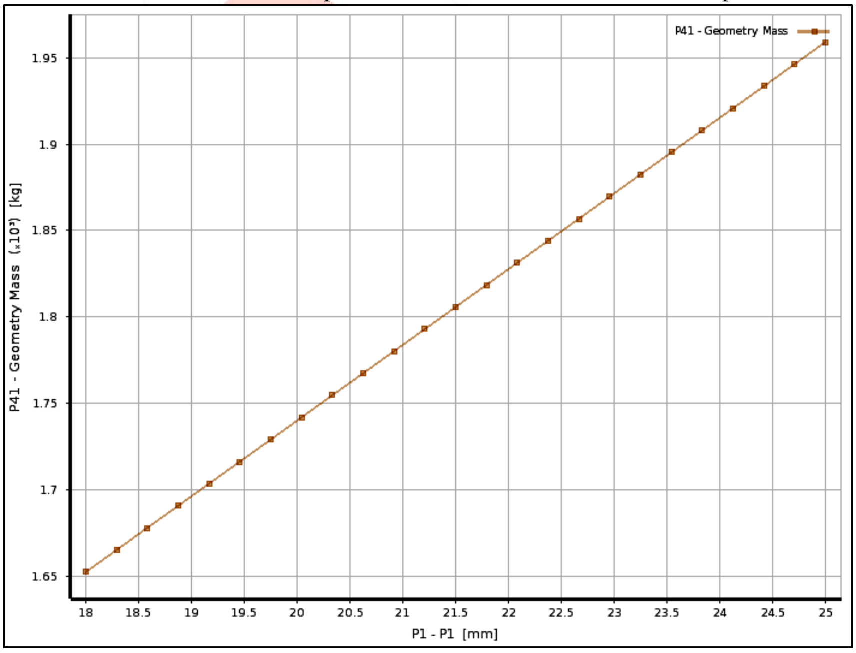

Figure 21 Variation of thickness of 25mm plates with the Geometry Mass

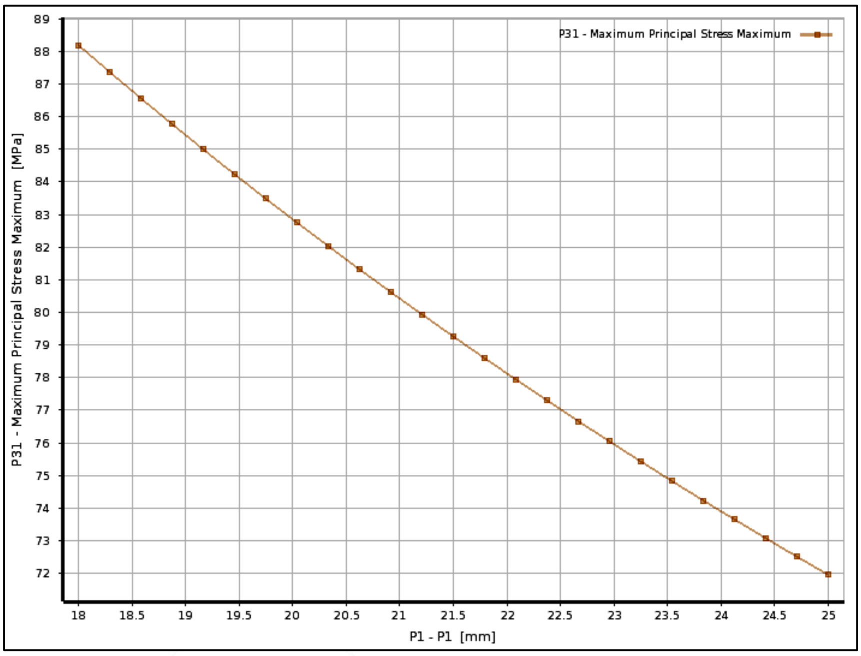

Figure 22 Variation of thickness of 25mm plates with the Maximum Principal Stress

VIII. DESIGN OF EXPERIMENT

A designed experiment is a series of runs, or tests, in which you purposefully make changes to input variables at the same time and observe the responses. In industry, designed experiments can be used to systematically investigate the process or product variables that affect product quality. After you identify the process conditions and product components that affect product quality, you can employ direct improvement efforts to enhance a product's manufacturability, reliability, quality, and field performance.

In statistics, response surface methodology (RSM) explores the relationships between several explanatory variables and one or more response variables. The main idea of RSM is to use a sequence of designed experiments to obtain an optimal response. This model is only an approximation, but uses it because such a model is easy to estimate and apply, even when little is known about the process. In statistics, Box–Behnken designs are experimental designs for response surface methodology. The Box-Behnken design is an independent quadratic design in that it does not contain an embedded factorial or fractional factorial design. In this design the treatment combinations are at the midpoints of edges of the process space and at the center. These designs require 3 levels of each factor. A Box-Behnken design is a type of response surface design that does not contain an embedded factorial or fractional factorial design. For a Box-Behnken design, the design points fall at combinations of the high and low factor levels and their midpoints.

Table 5 indicates Box Behnken Design of Experiment.

P1- Design Candidate Point (Input Parameter) which represents the thickness of the plates of 25mm.
P30- Deformation of the Top Frame (Output Parameter) along z axis in mm.
P31- Maximum Principal Stress (Output Parameter) in MPa.
P32- Equivalent Stress (Output Parameter) in MPa.
P41- Geometry mass (Output Parameter) in kg.

The thickness of the plate is varied at 3 levels, low, medium and high level with a difference of 0.5mm and the corresponding variation in response parameters is observed. By analyzing the table of Design of Experiments, an optimal response is chosen.

Table 5 Box Behnken Design of Experiment

Box Behnken D.O.E	25 mm plates	P30 - Deformation Probe Maximum Z Axis (mm)	P31 - Maximum Principal Stress Maximum (MPa)	P32 - Equivalent Stress Maximum (MPa)	P41 - Geometry Mass (kg)
Candidate Points/ No of Runs	P1	P30	P31	P32	P41
1	18	-0.056093011	90.23639982	85.59301065	1638.775909
2	18.5	-0.055052318	88.42838961	83.83578085	1663.077865
3	19	-0.05405543	86.68340766	82.13983197	1687.379821
4	19.5	-0.053099297	85.01896625	80.52750981	1711.681777
5	20	-0.052181151	83.42367883	78.98312583	1735.983733
6	20.5	-0.051298462	81.89266746	77.5023308	1759.324849
7	21	-0.050448965	80.42373733	76.08448026	1783.626805
8	21.5	-0.050464414	80.84464032	76.9688169	1792.599047
9	22	-0.049632981	79.40498345	75.55569222	1816.901003

10	22.5	-0.048832506	78.00325884	74.17923837	1841.202959
11	23	-0.04806111	76.66099409	72.86636026	1864.544074
12	23.5	-0.047316995	75.36652851	71.60081056	1888.84603
13	24	-0.046598483	74.11796476	70.38143093	1913.147986
14	24.5	-0.045904178	72.91463197	69.20901319	1937.449942
15	25	-0.045329217	71.95676739	68.3302198	1959.561939

From the Design of Experiments, the optimal response chosen is plates of thickness 22mm.

Table 6 Reduction in component mass of the Optimized Model

Model	Original	Optimized	Original	Optimized
Component	Side wall 1 Or C Frame 1	Side wall 1 Or C Frame 1	Side wall 2 Or C Frame 2	Side wall 2 Or C Frame 2
Material	ST42W	ST42W	ST42W	ST42W
Thickness (mm)	25	22	25	22
Mass (kg)	497.62	437.9	497.62	437.9
Reduction in Mass (kg)	-	59.72	-	59.72

IX. CONCLUSION

The thickness of 25mm plates is reduced to 22mm. The criterion of failure used is Von- Mises theory. The Yield Stress of the material is 250MPa. The Equivalent Stress of the Optimized Model is 74.577MPa which is found to be well below the Design Stress of 83.33MPa, assuming a Factor of Safety of 3. This concludes that the optimized design is safe. The deformation of the Top Frame of the Optimized Model is found to be 49.26 microns which is less than the desired limit of 50 microns. The Net component weight reduced which includes both the side walls or C Frames is approximately 120kg. Hence, the percentage of Net component weight reduced is 12%. Hence, the material is optimized. The Raw Material cost is around Rs.50/kg. Hence, cost savings of around Rs. 6000 per machine can be expected. By this, Design Optimization as well as Cost Optimization is obtained.

X. ACKNOWLEDGMENT

We acknowledge the authorities of the institute for their kind support and coordination.

XI. REFERENCES

[1] Malachy Sumaila and Akii Okonigbon Akaehomen Ibhadode,"Design and Manufacture of a 30 ton Hydraulic Press", AU J.T.14 (3): 196-200 (January 2011).

[2] A. G. Naik, N.K. Mandavgade, "FEA Implementation in Analysis and Optimization of Top and Bottom Frame for Hydraulic Cotton Lint Bailing Press", ISSN-2229-5518, Volume 3, Issue 7, July-2012.

[3] "Design and Analysis of Frame of 63 Ton Power Press Machine by using Finite Element Method" by H N. Chauhan and M P. Bambhania, ISSN-2249-555X,Volume 3, Issue 7, July 2013.

[4] "Analysis of stresses in the corner zone of a C Frame press" by U P.Singh, Eindhoven University of Technology/NL: P.C. Veenstra, Eindhoven University of Technology/NL (1); J.A.H.Ramaekers, Eindhoven University of Technology/NL, 1979.

[5] P. D. Murarka and S.P.Sinha," Computer-Aided Design of Hydraulic Press Structures", Vol. 10, No. 9, pp. 637-645, 1988.