Design Optimization of C Frame of Hydraulic Press Machine

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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.
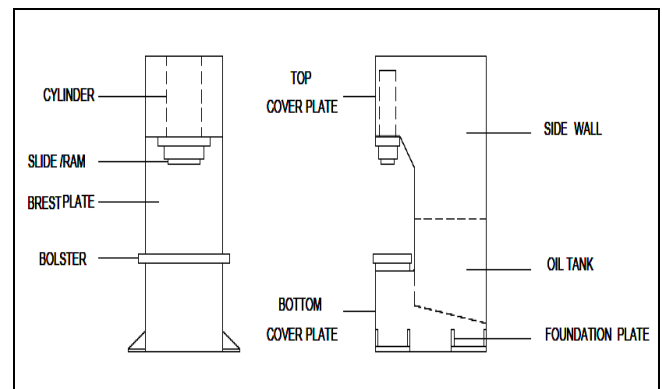

Fig. 1 Cross section of Typical C-Frame Press

TABLE I
TECHNICAL SPECIFICATION

Type	C Frame Hydraulic Press
Model	HCP-100(Hydraulic C Press of 100 ton capacity)
Material	ST42-W, Fusion welding Quality Steel (IS: 2062)

Mode of Operation	Manual /Automatic
Stroke/ Ram diameter	500 mm/ 200mm

Young's Modulus	2.1×105 N/mm^2
Poisson's Ratio	0.3

TABLE II
FUNCTIONAL SPECIFICATION

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

II. OBJECTIVE

Fig. 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.
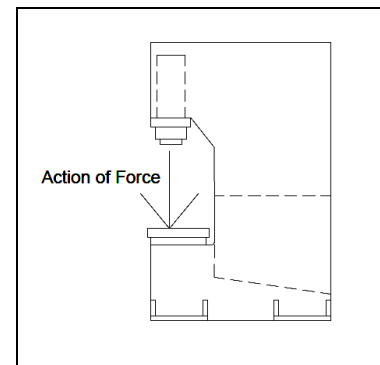

Fig. 3 Load on the work piece

TABLE III
MATERIAL SPECIFICATION

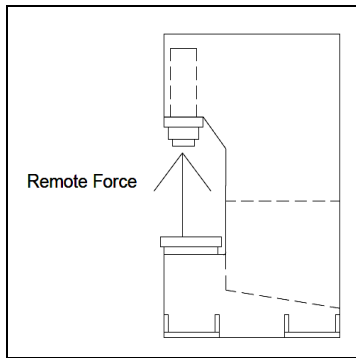| Designation	ST42W
Tensile Strength	460Mpa
Yield Strength	250Mpa
Density	7850 kgf/m^3

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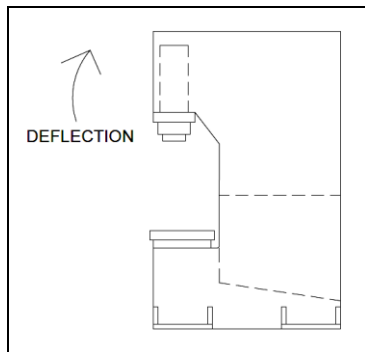

Fig. 5 Top Frame Deflection due to Remote Force

Fig. 6 Views of the Side Plate or C Frame section
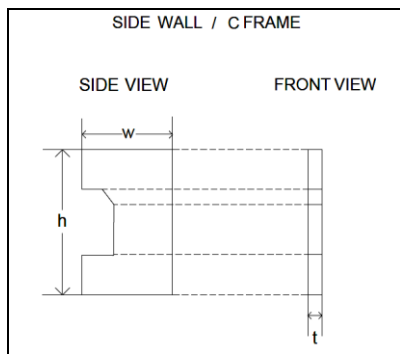
TABLE IV
DIMENSIONS OF THE SIDE WALL

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

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, Static Analysis is implemented. 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 the input variables are and how many input variables are the contributing factors to the output variables of interest. It is a lengthy process and Designed Experiments help to solve this lengthy process. Hence, we call this as 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.
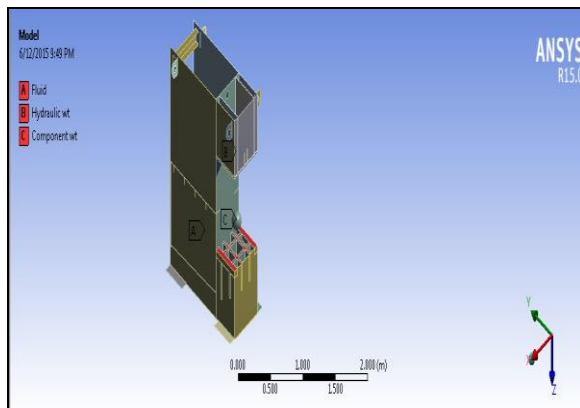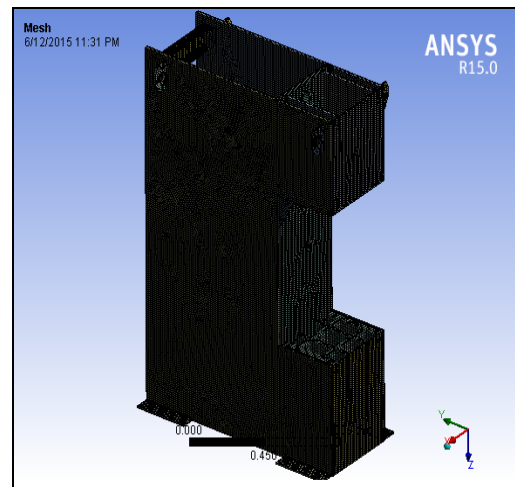
IV. FINITE ELEMENT ANALYSIS

Fig. 7 Model Creation
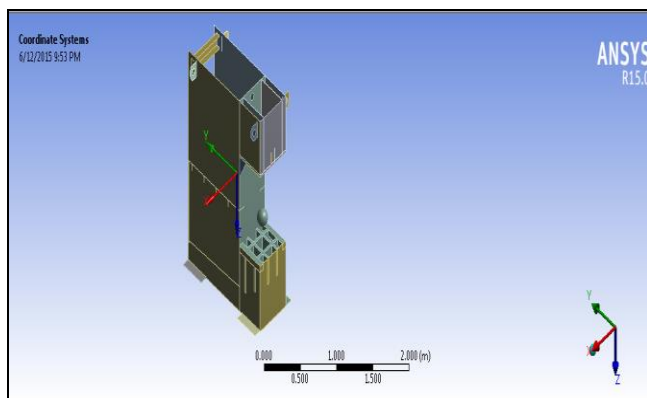

Fig. 9 Apply Mesh
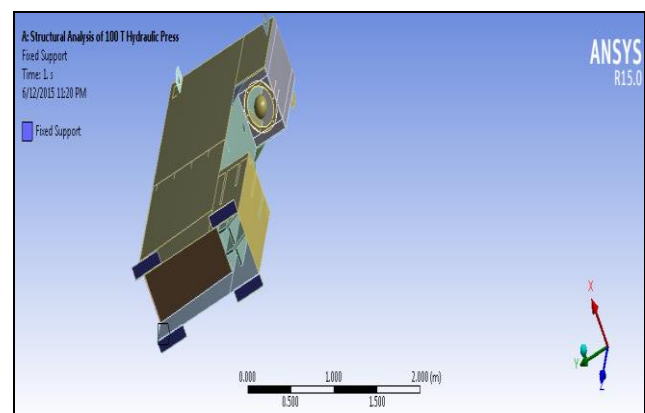

Fig. 8 Apply Coordinate system
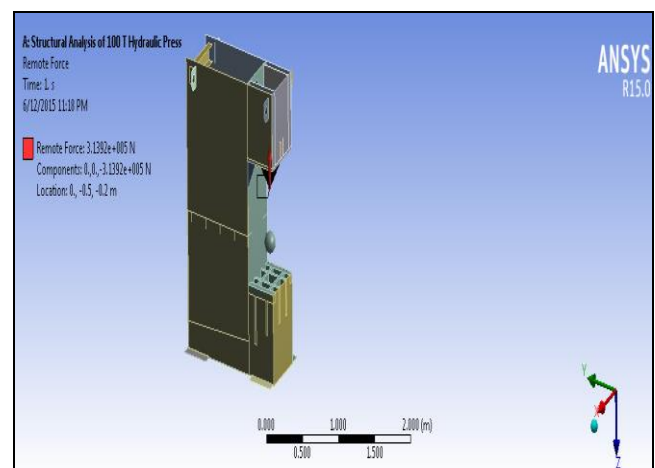

Fig. 10 Boundary conditions on the Foundation Plate

Fig. 11 Application of Load on the Top Frame
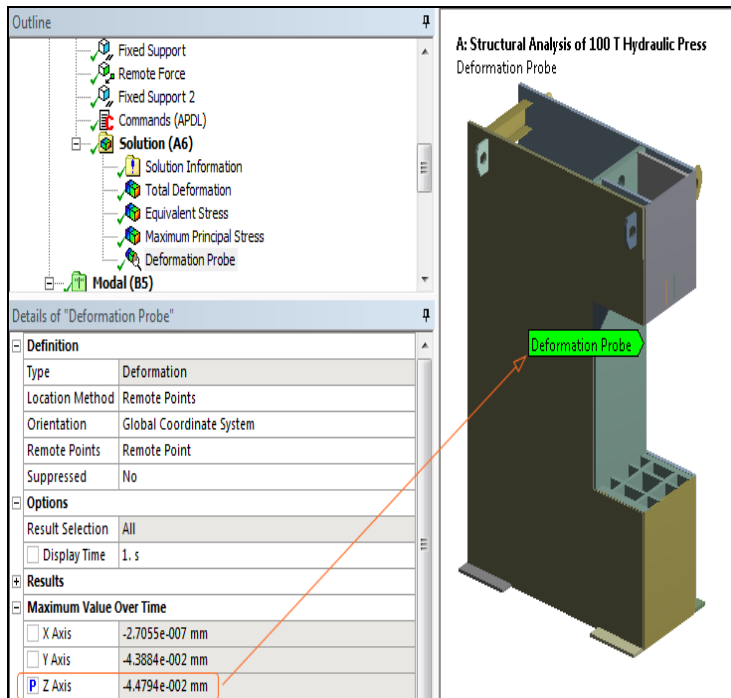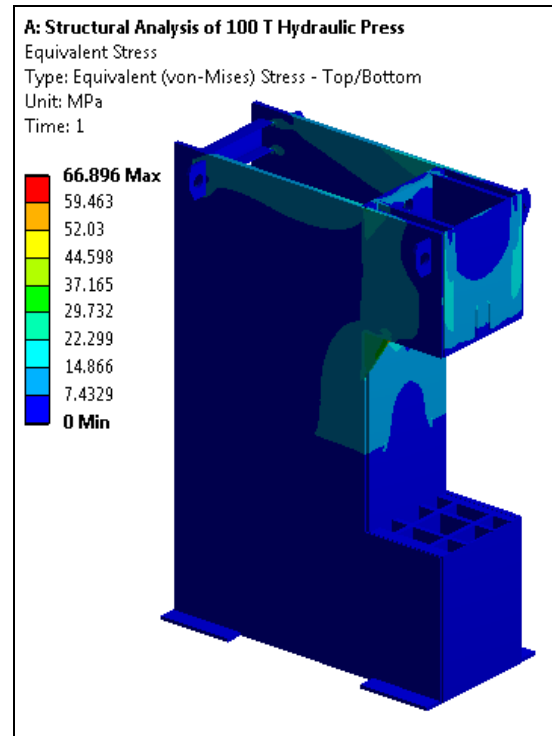
V. STRUCTURAL ANALYSIS RESULTS

Fig. 13 Equivalent Stress of the Original Model

Fig. 12 Original Model Top Frame Deformation along z axis

Fig. 14 Optimized Model Top Frame Deformation along z axis

Fig. 15 Equivalent Stress of the Optimized Model

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.

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.

VI. 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

TABLE V
BOX BEHNKEN DESIGN OF EXPERIMENT

Box Behnken D.O.E	25 mm plates	P30 - Deformation Probe Maximum Z Axis (mm)	P32 - Equivalent Stress Maximum (MPa)	P41 - Geometry Mass (kg)
Candidate Points/ No of Runs	P1	P30	P32	P41

1	18	-0.056093011	85.59301065	1638.775909
2	18.5	-0.055052318	83.83578085	1663.077865
3	19	-0.05405543	82.13983197	1687.379821
4	19.5	-0.053099297	80.52750981	1711.681777
5	20	-0.052181151	78.98312583	1735.983733
6	20.5	-0.051298462	77.5023308	1759.324849
7	21	-0.050448965	76.08448026	1783.626805
8	21.5	-0.050464414	76.9688169	1792.599047
9	22	-0.049632981	75.55569222	1816.901003
10	22.5	-0.048832506	74.17923837	1841.202959
11	23	-0.04806111	72.86636026	1864.544074
12	23.5	-0.047316995	71.60081056	1888.84603
13	24	-0.046598483	70.38143093	1913.147986
14	24.5	-0.045904178	69.20901319	1937.449942
15	25	-0.045329217	68.3302198	1959.561939

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

TABLE VI
MATERIAL MASS REDUCTION ANALYSIS

Model	Original	Optimized	Original	Optimized
Component	C Frame 1	C Frame 1	C Frame 2	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

VII. CONCLUSION

The criterion of failure used is Von- Mises theory. The Equivalent Stress of the Optimized Model is found to be well below the Design Stress, 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. 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 and the Fabrication cost is around Rs.15/kg. The total cost being Rs.65/kg. Hence, cost savings of around Rs.7800 per machine can be expected. By this, Design Optimization as well as Cost Optimization is obtained.

ACKNOWLEDGMENT

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.