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Design and Structural Analysis of a 1000 Ton Hydraulic Press Frame Structure

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***Abstract*—Using the optimum resources possible in designing the hydraulic presses frame can effect reduction in the cost of the hydraulic presses. By optimizing the weight of material utilized for building the structure. An attempt has made has been made in this direction to reduce the volume of material. In this project structural analysis followed by mass minimization of H-frame type hydraulic press based on topology optimization method. This press has to compensate the force acting on the working plates and has to fulfil certain critical constraints. The frame structure has to withstand the forces generated while in operation and it is essential to calculate mechanical properties like total deformation and developed on the machinery. Hence, here work has been being carried out on 1000 ton press machine.**

With regarding to design specification, stress distribution, and cost, are focused are focused on optimized design. The methodology followed in work is comparison induced in machine for different thickness used for construction of frame and column of the H-frame type hydraulic press.

***Index Terms*—Hydraulic press, Quality, Optimization, plates, design specification**

I. Introduction

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 1000-ton four frame plate 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.

A hydraulic press is a machine using a hydraulic cylinder to generate a compressive force. Frames and column and cylinder are the main components of the hydraulic press. In this project H type hydraulic press frame and column are designed by the design procedure. Press frame is analysed to improve its performance and quality for press working operation.

II. Hydraulic Press Components

Basically all presses are same in their basic constitution. They have four main major components.

1. *Hydraulic cylinder:* Hydraulic cylinder converts the pressure energy in hydraulic fluid into useful pressing force.
2. *Press body:* It withstands the force developed by the hydraulic cylinder.
3. *Power pack unit:* This unit supplies pressurized hydraulic fluid in the cylinders under controlled pressure and flow.
4. *Control panel:* Control panel governs over-all operation and performance of a press. Presses are designed and manufactured in different shapes and sizes to suit the specific production, accuracy, strength requirement, and economic constraints.

A. *Classification of Hydraulic Presses*

Depending on their shapes, design and they could be divided into six broad categories.

Round column press, fabricated column press, Close-frame press, C-Frame press, fabricated chamber press, Non-Conventional press.

1) *Round Column Press*

Main features of these types of presses are their round columns. In these types of presses top and bottom platen are fabricated and machined individually and then held together by means of round columns and nuts. As all the components could be machined individually and accurately hence these types of presses are most accurate types of presses, as compared to all other types of presses. (Columns are also referred as pillars).

Round column presses could be further sub-divided into three categories.

Two columns press, three columns press and four columns press

a) *Two Column Press*

In case of two columns press, top and bottom platens are tighten together by means of only two round columns. Hydraulic presses, which are required to be very accurate and pressing load always remain at the central axis of main cylinder, and also there is no chance of taking any eccentric load, then two column types of presses are used.

b) Three Column Press

In three column presses, top and bottom plates are tightened together by means of three round columns. Old aluminum and copper extrusion presses of higher capacity were designed in this way. These presses were horizontal, high speed and made for mass production. Three -column design is stronger than two-column design. Advantage of this type of design in case of extrusion press is that ample space is available for shearing the rejected billet and loading red hot billets in container by means of overhead crane.

c) Four Column Press

In four columns presses top and bottom platen are tighten together by means of four round column. These types of presses are widely used in industry as compared to other type where accuracy is more critical between Dies. For example, power compacting presses, plastic injection molding machine etc.

B. Fabricated Column Press

In this type of presses top and bottom platens are permanently welded together with the help of fabricated columns. Fabricated column presses are sturdier, economical and has less deflection under load as compare to round column presses. Fabricated column press also could be divided into two categories, Fabricated Four-column press & Fabricated Two-column press or H-Frame press

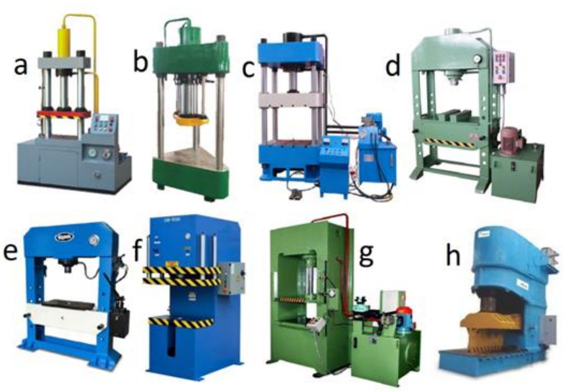

Fig. 1. Various types of hydraulic press frames, (a) Two Column Press, (b) Three Column Press (c) Four Column Press (d) Fabricated Four Column Press (e) Fabricated Two Column Press or H-Frame Press (f) C-Frame Press (g) Close-Frame Press (h) Fabricated Chamber Press

1) Fabricated Four Column Press

High capacity hydraulic presses with large size table are manufactured on the design of fabricated four-column press. As it is sturdier and gives ample space to work and inspect pressing operation from all sides, as compared to, two-column press. For example, deep drawing press for automobile body, punching and blanking of large size of M.S. Steel etc.

2) Fabricated Two Column Press or H-Frame Press

Medium and low capacity and economical presses are manufactured on the design of fabricated two-column or H Frame press. In low capacity presses rolled M.S. channel or I-section are used as side column and in case of medium capacity press it is fabricated from steel plate. Rubber mounding, variable-day-light presses used in garages are example of H Frame press.

3) C-Frame Press

In these types of presses, press-body is of C-Shaped. When free space required from three sides of press table to work for loading and unloading of pressed component then this type of presses are designed.

These types of presses are most fragile, susceptible to deflection and cracking from inside corners, if not designed and used correctly as compared to other type of press. As main cylinder placed eccentric to central axis of press-body, it applies eccentric load on press-body hence heavier press body is required as compared to same capacity of other type of press. These types of presses are also called as single press. Some example of C-Frame presses are as follows.

4) Close-Frame Press

In case of close-frame press, overall structure of press is in a shape to square ring. In case of small size of presses, they are made by cutting window in steel plates and assembling together two or more such plates to make a press-body. In this type minimum welding is required as top, bottom and side columns are all internal. In case of large presses required for general fabrication, such as dishing, plate-bending, straightening and pre-pinching of plates for rolling’s top, bottom platens and side columns are fabricated separately then welded together. Difference between fabricated column press and close-frame presses are as follow.

5) Fabricated Chamber Press

In this type of hydraulic press a steel fabricated box-structure or container form the main body of hydraulic press. Main cylinder, various doors, feeding arrangement auxiliary cylinder are mounted on these fabricated box-structure as per the requirement of production and operation. Fabricated chamber act as load bearing member of press. Some time they also act on container for material to be compressed. Bailing presses and extrusion press are some of the example of these types of presses.

C. Finite Element Analysis of Hydraulic Press Frame Structure

The main objective of a finite element analysis is to calculate effects of loading conditions on frame structure. Usually it is used to determine the displacement, stresses, strains and force reactions in structures or components when subjected to loads that do not induce damping and inertia effects. Assumptions are considered for loading and response conditions i.e., the loads and structures response are assumed to static independent of time.

III. Computer Aided Design Modelling of Hydraulic Press Frame

Geometry cleaning and simplification has been done on Hydraulic Press Assembly. Finite element models to perform static structural analysis for frame. Appropriate element sizes, refinement and quality parameters have been maintained to ensure accurate results. Proper mesh connections have been maintained. All components are connected through beam elements and all electronic components are fixed through bonded contacts. All components in press are modelled with shell elements with appropriate thicknesses and orientations.

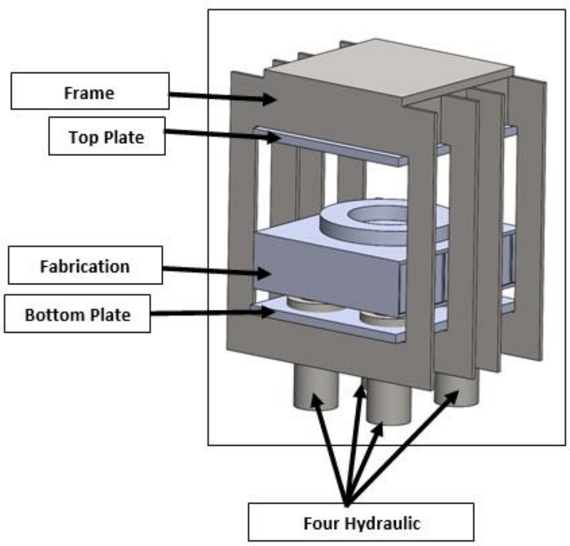

Fig. 2. Geometry model of hydraulic press

Hydraulic press structure Components

1. Frame Structure
2. Top plate
3. Bottom plate
4. Fabricated Box
5. Hydraulic cylinders

A. Finite Element Mesh

Fig. 3. Element model with 2D shell elements

Geometry of the hydraulic press frame is converted into step format and imported into ansys workbench. Meshing of hydraulic press assembly are carried out in ANSYS Workbench software and below are the discretization parameters followed.

Geometry cleaning and simplification of assembly has been done in design modeler.

Frame structure, top plate and bottom plate are converted into surfaces by using mid surface option.

Mid surface parts are discretised with 2D elements (Shell elements) of sizing 25 mm.

Appropriate thickness is assigned to each and every component of the assembly.

Recommended mesh quality is maintained for quality analysis results.

TABLE I
Materials of Construction

S. No.	Mild Steel Parameters	Value	Units
1	Density	7801	Kg/m^3
2	Young's modulus	200	GPa
3	Poisson's ratio	0.3	-
4	Yield stress	410	MPa
5	Ultimate Tensile Strength	650	MPa

B. Loads and Boundary Conditions

a) A load of 1000 ton applied vertically upwards on the upper ring plate.
b) Reaction load of 1000 tons applied vertically downwards on the lower ring plate.
c) Standard earth gravity of 9810.66 mm/sec^2 applied vertically downwards.
d) Bottom base of the frames structure is fixed in all degrees of frame.

C. Results of Hydraulic press Assembly before Optimization

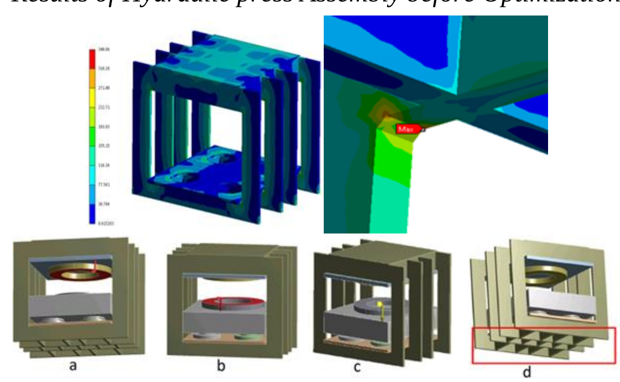

Fig. 4. Equivalent (Von-Mises) stress

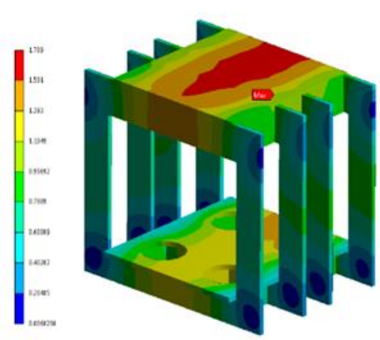

Fig. 5. Total deformation

Maximum equivalent stress was found at corner of the frame structure and its magnitude is 349.06 MPa & Maximum deflection on top plate was found to be 1.78mm.

D. Results of Hydraulic Press assembly after Optimization

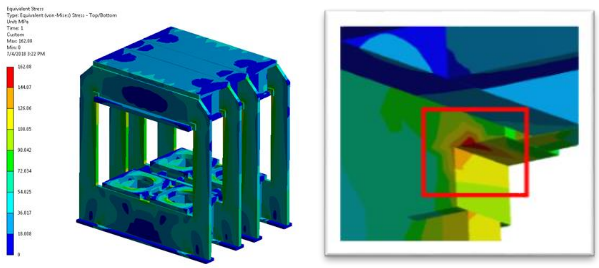

Fig. 6. Equivalent (Von-Mises) stress

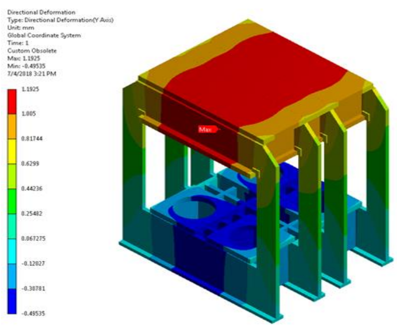

Fig. 7. Total deformation

Maximum equivalent stress was found at corner of the frame structure and its magnitude is 162.08 MPa and Maximum deflection on top plate was found to be 1.19 mm.

IV. Conclusion

Thousand ton hydraulic press frame structure has been designed, analyses and optimized. Fundamental design calculations for the Frame structure have been performed and detailed stress analysis has been performed on the structure. Topology optimization for the frame has been performed to optimize the plate thickness used in fabrication of the frame. Substantial weight reduction has been achieved by performing topology optimization based on stress and deflection. Maximum equivalent von-mises stresses and deflections obtained for various design configurations are tabulated and reported which gives a detailed understanding of the effect of design changes on deflection and stress concentrations of the structure. Equivalent Von Mises-Stress and deflections obtained for the final design are well within the material yield limits.

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