

Structure Frame Analysis & Design Optimization of Metal Forming Heavy Duty Hydraulic Press

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ABSTRACT: Metal forming is one of the manufacturing processes which are almost chip less. These operations are mainly carried out by the help of presses and press tools. These operations include deformation of metal work pieces to the desired size and size by applying pressure or force Press machine always working under impact load condition. Because of continuous impact load, frame of press machine always experience continuous tensile stress. Press machine Continuous deals with stress and because of that frequently structural failure problem occurred in machine. Instead of sharp corner in C-plate fillet is provided, then it is useful to reduce failure in structure. Amount of fillet is depends on load condition experienced by frame and that can be analysed by using FEM Tool. It is also helpful to reduce thickness of plate of frame structure so that material saving and cost benefit will be considerable It is only the 3D models that could satisfy all the requirements for examining the general stressed state of the carrying metal construction. With regard to this, the creation of 3-D models for researching and analysing the behaviour of a metal forming hydraulic press, becomes the main goal of the present work. In the initial phase of the study, conventional design calculations proposed by Indian Standard Rules were performed. The press design was modelled with solids, Loads and boundary conditions were applied to solid model. Assign material to the solid model. Finite Element meshes were generated from the solid model. After a comparison of the finite element analyses, and the conventional calculations, the analysis was found to give the most realistic results. As a result of this study, a design optimization for a heavy duty meal forming hydraulic press has been done.

KEYWORDS: Text detection, Structure Frame analysis, Optimization, FEM, Modelling.

I. INTRODUCTION

Press working techniques utilizing large quantities of economical tooling equipment design and it quickly, accurately and economically cold working of mild steel and other ductile materials. The component produced range over an extremely wide field and is used throughout industry for economical production of quantities of pressing; consideration has to be given to the rate of production, the cost of the press tool to be employed. Press may be defined as the chip less manufacturing process by which various components are made from sheet. Mostly press use fabricated parts of incite shape with thin walls. It uses large force by press tools far short time interval which results in cutting a shaping the sheet metal. In the early days, metal forming press use simple crank and lever mechanism that convert rotating motion into linear motion with the help of punch/ram. The rotating motion achieved by motor and linear motion achieved by punch or ram, punch applied on work piece. In the most function of press frame is absorb the force which generated by rotating parts and processing, to provide a precision guidance of other part and support the main drive system and other necessary auxiliary system. In press machine larger area of press frame and also it's higher weight of all among parts. Press machine total area of frame 60-70%. So the more importance of press frames and it's design parameter. According to IS 8064:2002 standard, press classified into two principle categories as hydraulic presses which operate on the principle of hydrostatic pressure. Mechanical press which utilized kinematic linkage of elements to transmit power. Metal forming is one of the manufacturing processes which are almost chip less. These operations are mainly carried out by the help of presses and press tools. A mechanical power press is a machine used to supply force to a die

International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

Vol. 4, Issue 8, August 2015

that is used to blank, form, or shape metal or non-metallic material. Thus, a press is a component of a manufacturing system that combines the press, a die, material and feeding method to produce a part. A mechanical power press is a machine used to supply force to a die that is used to blank, form, or shape metal or non-metallic material. Thus, a press is a component of a manufacturing system that combines the press, a die, material and feeding method to produce a part. Economy of construction and unhindered access to the die area. Inclined models and those with moveable beds or tables also offer a great deal of versatility, making them particularly useful for short run production or job shop applications. The drawback of the open frame design is the fact that such presses are generally limited in practice to the use of single dies. This is a result of several factors including the lack of stiffness and the typically small force capacity and die area of open frame presses.

II. RELATED WORK

The finite element method (FEM), sometimes referred to as finite element analysis (FEA), is a numerical technique used for finding the approximate solution to the complex engineering problems. It consists of two main parameters i.e. nodes and elements. The method essentially consists of assuming the piecewise continuous function for the solution and obtaining the parameters of the functions in a manner that reduces the error in the solution. The process of representing a physical domain with finite elements is referred to as meshing, and the resulting set of elements is known as the finite element mesh. The finite element method can analyse any geometry, and solves both stresses and displacements with respect to the known applied loads. In this study finite element meshing, is carried out by means of the Autodesk Inventor commercial package.

Conventional Design Calculation:

Step: - 1. Prepare a Load Diagram:-



Step: - 2. Calculate the Bending moment i.e. M

$$M = \frac{w \times l}{4}$$

$$M = \frac{F \times l}{4}$$

$$M = \frac{300 \times 1000 \times 3000}{4} \text{ kg.mm}$$

$$M = 225000 \times 10^3 \text{ kg.mm} \times 9.81$$

$$M = 2207.25 \times 10^6 \text{ N-mm}$$

Step:-3. Now the bending moment equation can be written as,

$$\frac{M}{I} = \frac{\sigma b}{Y}$$

Re arranging above,

$$\sigma b = \frac{M}{I} Y$$

But $\frac{I}{Y} = Z \times X$ (i.e. section modulus)

Allowable σb i.e. yield strength is 125 N/Seq.mms

$$125 = \frac{2207.25 \times 10^6}{ZXX}$$

$$ZXX = \frac{2207.25 \times 10^6}{125} \cdot \frac{Nmm \times mm^2}{N}$$

$$\therefore ZXX = 17658000 \text{ mm}^3$$

We know that the section modulus of a rectangle hollow pipe as per Tata Structure pipe standard catalogue is,

Pipe section = 300 X 200

Section Modulus i.e. $Z = 890390 \text{ mm}^3$

If we divide our calculated section modulus i.e.

$$Z = \frac{17658000}{2} \text{ mm}^3 \text{ by } 2$$

We will get $Z = 8829000 \text{ mm}^3$

This value is less than standard section modulus

If we make the standard rectangular pipe section double in size, it can withstand the 300 tons load.

Therefore, our final beam size will be,

600 X 400 mm in size

But, we cannot use a standard pipe as a beam &

Hydraulic press, so we rearrange our final section size as under & make it as Wedded

When we, calculated the section modulus of the above section, we will get the same values.

The final size of the beam of plates as under,

Dim pl. 1 = 400 x 3000 x 12 mm

Dim pl. 2 = 600 x 3000 x 12 mm

Dim pl. 3 = 400 x 3000 x 12 mm.

Design hydraulic cylinder for 300 ton force:-

Force = 300 Tons

W. Pressure = 250 kg/cm²

Design Pressure = 375 kg/cm².

Calculate the area/bore of cylinder:-

$$\therefore \text{Pressure} = \frac{\text{Force}}{\text{Area}}$$

$$\therefore P = \frac{F}{A}$$

Area i.e. $A = F/P$

International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

Vol. 4, Issue 8, August 2015

$$\text{Area (A)} = \frac{\pi}{4} \times d^2 = \frac{300 \times 1000}{375} \cdot \frac{Kg}{Kg} \times \text{cm}^2$$

$$\therefore \frac{\pi}{4} \times d^2 = 800 \text{ cm}^2$$

$$\therefore d^2 = \frac{800}{0.7853} \text{ cm}^2$$

$$d^2 = 1018.59 \text{ cm}^2$$

$$\therefore d = 31.91 \text{ cm} = 319 \text{ mm}$$

Calculate the wall thickness of cylinder to withstand design pressure of 375 kg/cm².

$$\text{Thickness } t = \frac{P \times R}{2 \times S \times E - 0.6 \times P}$$

Here P=design pressure=375 kg/cm²

R=radius of cylinder i.e. I.D. =159.5 mm

S=Yield strength of ASTM 106 Gr. B. Material

S=2460 kg/cm² = 241.326N/mm²

SA=Allowable Y.S.=120.663 N/mm²

E=1.

$$\therefore t = \frac{36.78 \times 159.5}{2 \times 120.663 \times 1 - 0.6 \times 36.78}$$

$$\therefore t = 26.75 \text{ mm} = 28 \text{ mm}$$

\therefore Final Diameter of Barrel is

$$D_B = 159.5 + 159.5 + 28 + 28$$

$$D_B = 375 \text{ mm}$$

Design of End Cap for Hydraulic Cylinder:-

Internal Pressure=375 kg/cm²

Ratio of $\frac{R}{r}$	1.25	1.5	2	3	4	5
Value of 'C'	0.592	0.976	1.44	1.88	2.08	2.196

$$= 36.78 \text{ N/mm}^2$$

Inside Dia i.e. Di=319 mm

Material of Plate = IS:2062 E 250 B

i.e. Mild Steel

Y.S.=250 N/mm²

Allowable Y.S σ_a = 165 N/mm²

\therefore Force F=300 tons

$$= 2943 \text{ KN}$$

\therefore Thickness of end Plate /cover can be calculated as,

$$t_{\text{cap}} = \sqrt{K \times \frac{P}{f_t} \text{ or } \sigma_a}$$

Where k= Constant ,k=0.162

$$t_{\text{cap}} = \sqrt{(0.162 \times \frac{36.78}{165}) \times 319}$$

$$t_{\text{cap}} = 0.19 \times 319$$

$$\therefore t_{\text{cap}} = 60.61 \text{ mm}$$

$$t_{\text{cap}} \approx 65 \text{ mm}$$

Design of Gland:-

The Empirical Formula is given by,

$$t^2 = \frac{C \times W}{\sigma_a}$$

Where, t= Thickness of Gland bush

W or F = Load acting on Gland

σ_t = Allowable tensile stress

C=Empirical Constant

Value of "C" could be selected from following table.

$$\therefore C = \frac{R}{r}$$

\therefore Where, R= Pitch circle Dia where, gland to be batted to Cylinder Flange.

$$\therefore R = 375 + 50 + 50 = 475 \text{ MM}$$

$\therefore r$ = Diameter of piston rod

$$\therefore r = 180 \text{ mm (say)}$$

$$\therefore \frac{R}{r} = \frac{475}{180}$$

$$\therefore \frac{R}{r} = 2.63 \text{ So } C = 1.66$$

$$\text{Now, } t^2 = \frac{1.66 \times 3000 \times 9.81}{205}$$

$$t^2 = 23831.12$$

$$\therefore t = 154 \text{ mm}$$

Now, calculate the stress produced in the beam due to 300 ton applied load.

1} the cylinder mounting should be equal to or slightly smaller than beam plate in width and length of the plate depends upon the End Cap Diameter of Cylinder.

2} the place where cylinder is fitted should be machined properly so that central axis of cylinder should be as per requirement of press body.

3} where cylinder applies load on component to be process it equally pushes back the plate on which it is mounted. If the plate on which it is mounted is perfected matching to cylinder, this cylinder will apply a uniformly distributed load. And if surface is not matching properly then will apply a concentrated load. Therefore, in our case, the cylinder mounting plate dimensions are,

400 X 500 X 12 mm thk

$$\therefore \text{Area of plate i.e. } A_m = 400 \times 500$$

$$A_m = 200000 \text{ mm}^2$$

$$\therefore \sigma = \frac{300 \times 1000 \times 9.81}{200000}$$

$$\therefore \sigma = \frac{2943000 \text{ N}}{200000 \text{ mm}^2}$$

$$\therefore \sigma = 14.715 \text{ N/mm}^2$$

$$\therefore \sigma = 150 \text{ kg/cm}^2$$

International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

Vol. 4, Issue 8, August 2015

III. ANALYSIS OF REDESIGNED 3-D MODEL

The hydraulic press frame redesigned after the comparison between analytical calculation & its FEA results. Same procedure adopted for applying the forces & simulation of redesigned hydraulic press frame obtained.

- A. As per shown to below figure, two downward forces of magnitude 150T i.e. 1471500 N each have been applied on the bed of hydraulic press. Due to the equal & opposite reaction of hydraulic cylinder, a single force of 300T i.e. 2943000 N is generated on the mounting plate of hydraulic cylinder & this force is transferred to the upper side of frame, as the mounting plate is welded with the upper frame.

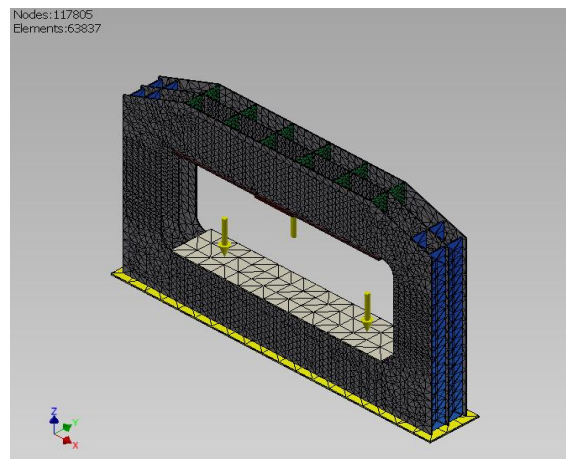


Fig-(A)

- B. As per below fig. applying forces, constraints and contacts of type bonded, convert the problem to linear static structural solution and a direct solver is used.

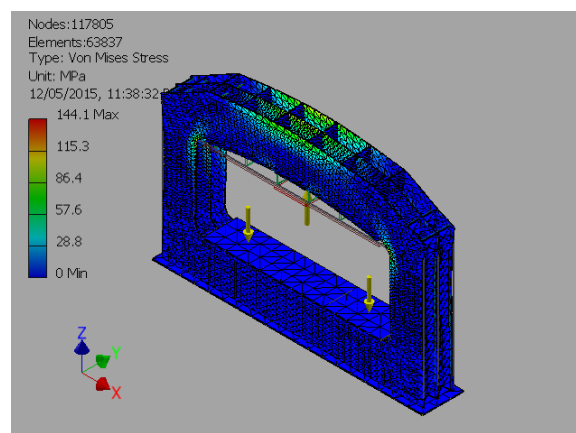


Fig-(B)

International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

Vol. 4, Issue 8, August 2015

C. As per below fig. Von Mises Stress & displacement of the structure can be found out. It represents the stress at different places so, that the actual load condition can be known easily & from that it conclude after the analyse the optimization of structure can happen.

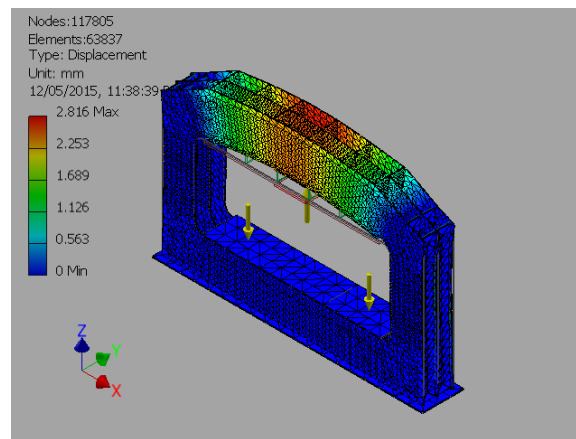


Fig-(C)

IV. EXPERIMENTAL RESULTS

After the redesigned 3-D basic model is analysed and results acquired, following values occurred listed in below Table.

S. No.	Specification	FEA Values of Redesigned Model
1	Max. Stress	144.1 N/mm ²
2	Min. Safety Factor	1.74
3	Max. Displacement in Y-Direction	2.81 mm
4	Self Mass	32.178 T

Table: FEA Values of Redesigned Hydraulic Press Frame

From the above table, it is clear that the maximum stress & displacement which is obtained from the Finite Element Analysis of redesigned hydraulic press frame lies within the considerable parameters. While doing the finite element analysis, the required result convergence value has been set to 10%. After the completion of finite element analysis, the convergence rate found to be 3.638% that means finite element results are 96% correct as per the assigned environment, which can be clearly seen in Fig. With maintaining Stress & safety factor in the limit self-mass of the hydraulic press frame can be reduced to 32.178 T against 43T of existing frame.

International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

Vol. 4, Issue 8, August 2015

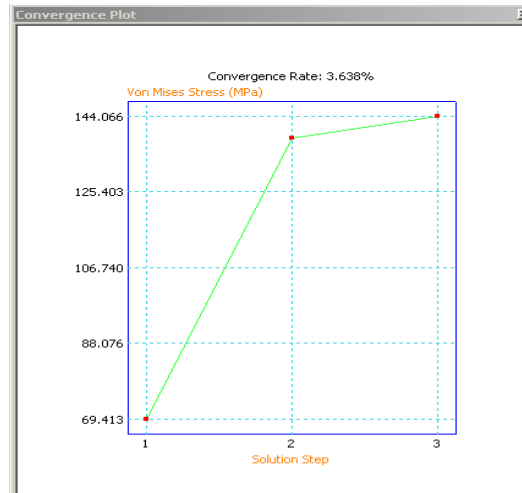


Fig (C)

V. CONCLUSION

In this work, the FEA study has been carried out on the existing welded structure of a hydraulic press machine of a 300 tonne nominal operational load. The self-mass of the hydraulic press frame structure can be reduced from 43T of existing to 32.178 T. The accuracy of the FEA analysis has been evaluated

Sr. No	Specification	FEA Values of Existing Model	FEA Values of Redesigned Model
1	Max. Stress	95.92 N/mm ²	144.1 N/mm ²
2	Min. Safety Factor	2.61	1.74
3	Max. Displacement in Y-Direction	1.85 mm	2.81 mm
4	Self-Mass	43 T	32.178 T

Table: Evaluation of FEA results of Existing & Redesigned Hydraulic Press Frame Model

From the table, In redesigned model, the dmax. Stress, safety factor and deflection mention above, lies within a range. It is clearly seen that the maximum stress & displacement which is obtained from the Finite Element Analysis are within the limits compared to the same of existing hydraulic press frame. Whereas the safety factor is still on acceptable side compared with the existing one. Thus from the above results, we can state that the design optimization of existing hydraulic press frame has been done without compromising the strength & rigidity of the structure. This new design succeeds in reducing the overall mass of the hydraulic press frame by 25%.

From the foregoing the following can be concluded:

1. The present experimental modification on the present hydraulic press enables it to be used in the process of metal working application.

International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

Vol. 4, Issue 8, August 2015

2. A plane stress FEA model was used successfully to optimize the design of the press structure. This suggested that a new design of the press structure which converged to within 4% . The analysis of this model was thorough at a minimum cost of material and analysis time.
3. The mass of the current hydraulic press frame get reduced by 25% using FEA analysis.

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