Analysis and Fabrication of Frame and Cylinder of 60 Ton Hydraulic Press

T. Pradeep Kumar, S. Raj Kumar, R. Govindaraj and K.M. Eazhil

Abstract--- Our paper deals with the implementation of "Finite Element Analysis" for analysis and optimization of 'C' type hydraulic 60ton press frame and cylinder. The main aim is to reduce the weight of the hydraulic presses without reducing the quality of the output. A hydraulic press is a machine using a hydraulic cylinder to generate a compressive force. Frame and cylinder are the main components of the hydraulic press. Press frame and cylinder are analyzed for optimization. Structural analysis has become an integral part of the product design. The frame and cylinder are modeled by using modeling software Creo 1.0. Structural analysis has been applied on hydraulic press frame and cylinder by using analyzing software Ansys 15.0. An integrated approach has been developed to verify the structural performance and stress strain distributions are plotted by using ANSYS software. According to the structural values the dimensions of the frame and cylinder are modified.

Keywords--- Hydraulic Presses, Optimization, Ansys.

I. INTRODUCTION

A. Hydraulic Press

A hydraulic press is a machine using the hydraulic cylinder to generate a compressive force. In hydraulic press, force generation, transmission and amplification are achieved by using pressurized fluid.

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The liquid system exhibits the characteristics of a solid and provides a more positive and a rigid medium of power transmission and amplification of force. In a simple application, a smaller piston surface transfers fluid under high pressure to a cylinder having a larger piston surface area, thus amplifying the pressure and force. There is a very easy transmissibility of a large amount of energy with practically maximum force amplification. It also has minimal inertia effect.

Types of Hydraulic Press: Presses are designed and manufactured in different sizes and shapes to suit the specific application in production, accuracy, strength requirement, and economic considerations.

Depending on the structure, shape, and design they could be divided into five broad categories.

1. Round column press
2. Fabricated column press
3. Closed frame press
4. C-frame press
5. Fabricated chamber press

B. "C" Type Press Frame

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.

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.

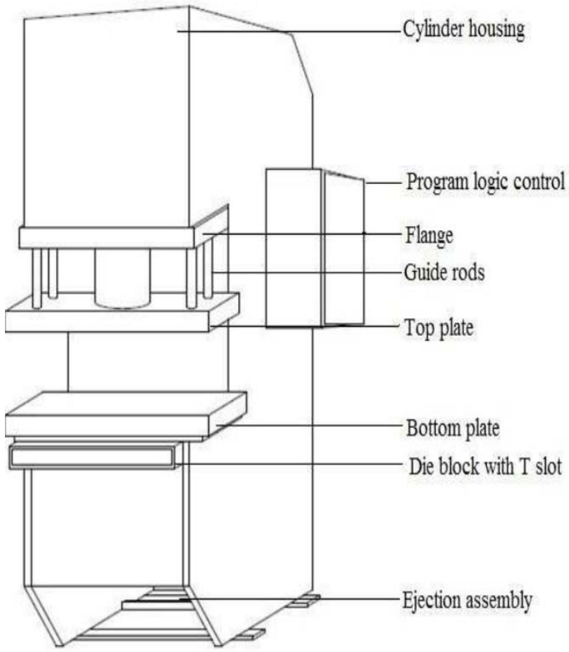

Figure 1: 'C' Type Press Frame

C. Hydraulic Cylinders

Cylinders are linear actuators which converts fluid power into mechanical power. They are also known as actuators. Hydraulic cylinders are used in high pressure and produce large force and precise movement. For this reason they are constructed of strong materials such as steel and designed to withstand large forces.

D. Types of Hydraulic Cylinders

Hydraulic cylinders are generally classified in to three common types based on their operation

- Single acting cylinders
- Double acting cylinders
- Displacement cylinders

E. Double Acting Cylinders

A double-acting cylinder is a cylinder in which the working fluid acts alternately on both sides of the piston. It has a port at each end, supplied with hydraulic fluid for both the retraction and extension of the piston. A double-acting cylinder is used where an external force is not available to retract the piston or where high force is required in both directions of travel.

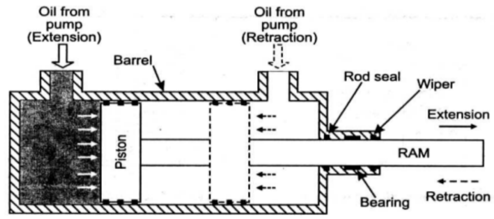

Figure 2: Double Acting Cylinder

II. LITERATURE SURVEY

Automotive chassis is an important part of an automobile. The chassis serves as a frame work for supporting the body and different parts of the automobile. Also, it should be rigid enough to withstand the shock, twist, vibration and other stresses. Along with strength, an important consideration in chassis is to have adequate bending stiffness for better handling characteristics. So, maximum stress, maximum equilateral stress and deflection are important criteria for the design of chassis. This report is the work performed towards the optimization of the automotive chassis with constraints of the maximum shear stress, equivalent stress and deflection of chassis under maximum load. Structural systems like the chassis can be easily analyzed using finite element techniques. A sensitivity analysis is carried out for weight reduction. So proper finite element model of the chassis is to be developed. The chassis is modelled in PRO-E. FEA is done on the modelled chassis using ANSYS WORKBENCH.[1]

In the Attempt to alleviate the problem of the dearth of the equipment in our laboratory in most of our higher institutions a 30 ton hydraulic press was designed, constructed and tested using locally sourced materials. The principal parameters of the design included the maximum load (300kN), the distance the load resistance has to move the system pressure, the cylinder area and the volume flow rate of the working fluid. The major components of the pore design include the cylinder and piston arrangement, the frame and the hydraulic circuit. The machine was tested for performance with a load of 10kN provided by two compression springs of constant 9N/mm each arranged in parallel between the upper and lower platens and was found to be satisfactory. The cost estimate for the hydraulic press was N4789000 at prices in Benin city, Nigeria, as at time of press manufacture.[2]

Structural optimization tools and computer simulation are very important in industry application as a result of innovative design, weight reduction and cost effective components. Especially, in automobile and aircraft industries, structural optimization has become an integral part of the product design process. In this project, topology optimization has been applied on many components of scrap baling press of 5 ton hydraulic poor using ANSYS WORKBENCH software. Suitable constrains and loads are applied on the initial design of the components. An approach has also been developed to verify the structural performance by using ANSYS SOFTWARE. At the end, shape optimized design model is compared with the actual part that is being manufactured for the press. It is inferred that topology optimization results in a better and innovative product design.[3]

This paper deals with the FEA implementation for analysis and optimization of 'C' type hydraulic 200ton press. The main aim is to reduce the cost of the hydraulic presses without reducing the quality of the output. Using the best possible resources possible in designing the hydraulic presses frame can affect this decrease in the cost of the hydraulic presses. One way of doing it will be the optimizing the quantity of material utilized for building the complete structure. An effort has been made in this way to decrease the weight of material. So in this case we consider an industrial application project consisting of mass minimization of a gap type hydraulic press or 'C' type hydraulic press.[4]

III. WORKING METHODOLOGY

A. Frame Optimization

The structural optimization of the frame depends on pressing force, this determines the required rigidity, dimensions of the dies influencing the size of the tool area, work area accessibility that determines on the shape of the press frame.

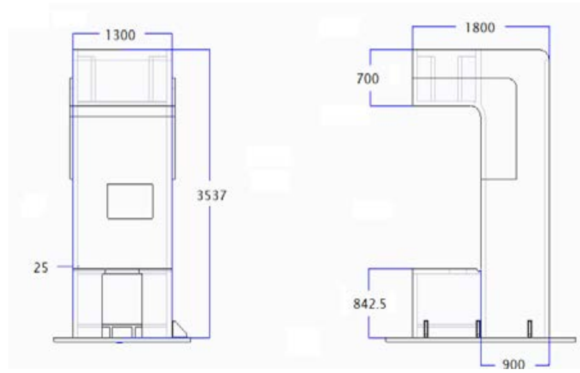

Figure 3: Theoretical Determination of Stresses

B. Determining the Dimensions

This is the first step of optimization process. As the frame is already fabricated, the press frame is measured to determine the dimensions for the optimization process. This includes the types of section used and thickness of the plate

- Tensile strength= 410 $\times 10^6$ N / mm^2
- Density= 7850 kg/ m^2
- Young's Modulus= 2.1 5 2 $\times$10 N /mm^2.
- Poisons Ratio= 0.3.
- Factor of Safety= 4.0
- Max Allowable Stress σ =410/4 σ = 102 N/mm^2
- Material used = Mild Steel (IS2062)

The Frame Subjected to Direct Tensile Stress and Bending Stresses

- $\sigma_{total} = \sigma_{tensile} + \sigma_{bending}$ N/ mm^2
- σ_{total} = {P/A + [Mb x Y]/I}

Where
- σ = Permissible stress in N/mm^2
- P = Applied load/ Force in N , P = 588600 N
- A= Area of the plate section in mm^2
- Mb = Bending moment in N. mm
- x= Perpendicular Distance in mm
- y = Distance from the neutral surface to mm
- I = Moment of inertia in mm^4

Breadth b = 900 mm Depth d= 25mm

Area $= b\times d = 22500\ mm^2$

$\sigma_{tensile} = 588600/22500 = 26.16\ N/mm^2$

$\sigma_{bending} = [Mb \times Y]/I$

- Bending moment $Mb = [P/2] * X$
- Perpendicular Distance x= 11850 in mm
- $Mb = 294300\times 11850$ $Mb = 3487455000$ N.mm
- Y= 25 mm

Inertia for rectangular plate sections $I = [b^3 d/12]\ mm^4$

$I = [900^3 \times 25 / 12]$

$I = 1518750000\ mm^4$

$\sigma_{bending} = (3487455000 \times 25) / (1518750000)$

$\sigma_{bending} = 57.41\ N/mm^2$

$\sigma_{total} = 83.57\ N/mm^2$

It is safe as it is under maximum allowable stress

C. Finite Element Analysis of Frame

The frame is analysed for stresses in ANSYS WORKBENCH 15.0 for the modification for dimensions to reduce the weight. The image shows the deformation and stress distribution with concentration on the frame.

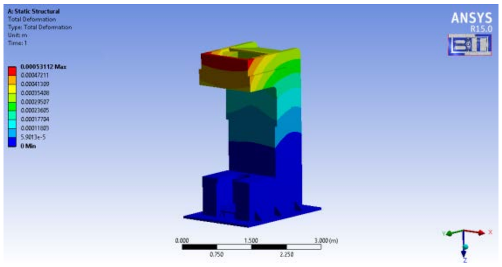

Figure 4: Total Deformation Analysis

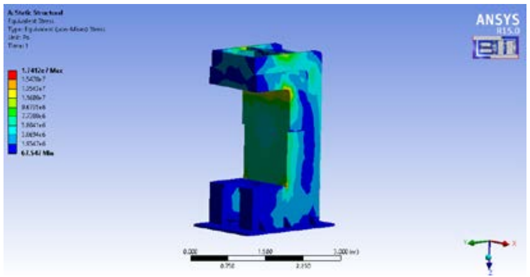

Figure 5: Stress Analysis

D. Modification of Frame

As the stress is within the limit the frame plate thickness reduced by 3mm in modelling software CREO 1.0 then the analysis is again done the images shows the deformation and stress distribution with concentration on the frame after the modification of the frame.

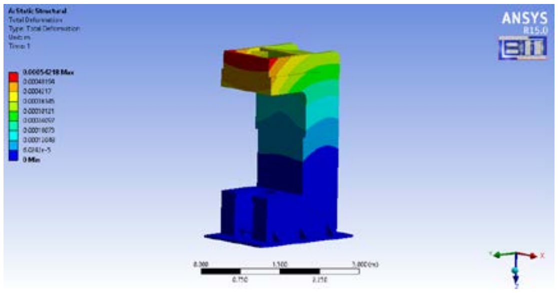

Figure 6: Total Deformation Analysis

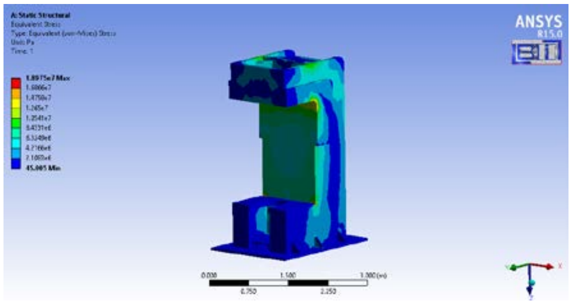

Figure 7: Stress Analysis

Weight of frame before modification = 19244 kg

Volume of frame after modification = $2340511582\ mm^3$

$= 2.340511582 \times 7850$

Weight of frame =18358 kg

Total reduction weight = 19244 -18358.= 886kg

As the target weight reduction is not reached the “SHAPE OPTIMIZATION ANALYSIS” in ANSYS WORKBENCH 15.0 is done to reduce the weight up to target level

E. Shape Optimization Analysis of Frame

Shape optimization analysis is an integrated part of Finite element analysis. In this type of analysis the stress values are calculate. According to that data the places where the material can be removed are showed without much increase in deformation of the structure, The removable materials are shown with the help of colour differentiation, the below diagram shows the shape optimization analysis of frame.

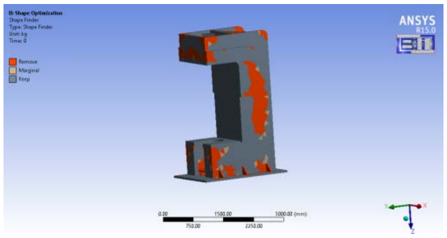

Figure 8: Shape Optimization

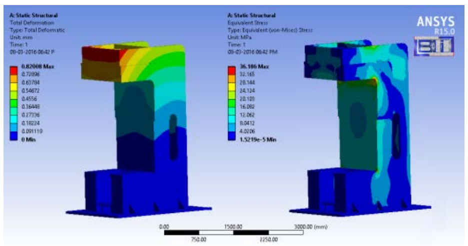

Figure 9: Total Deformation and Stress Distribution

Volume of frame before Shape Optimization $= 2340511582\ mm^3$

$= 2.340511582 \times 7850$

Weight of frame $= 18373$ kg

Volume of frame after Shape Optimization $= 2307619862\ mm^3$

$= 2.307619862 \times 7850$

Weight of frame $= 18113$ kg

Total reduction in weight $= 258$ kg

F. Cylinder Optimization

The structural optimization of the Cylinder depends on oil pressure, this determines the required rigidity, dimensions of the Cylinder influencing the size of the piston rod,

G. Determining of Dimensions

Pressure $= 375 kg/cm^2$

Force $= 588600$ N

H. Calculation to Verify Dimensions and Stresses

Area $=$ [force/pressure]

$= [60000/375] = 160\ cm^2$

Area $= [\pi/4 \times d^2]$

$160 = [\pi/4 \times d^2]$

D = 142.7mm

Thickness of cylinder (t) $t = d/2[\sigma_t + p/ \sigma_t + p]^{1/2} - 1$

Here the stress acting on the cylinder wall is tensile

The maximum allowable tensile stress for Mild steel IS2062 is

$\sigma_t = 225\ kg/cm^2$

$t = 23.56 = 24mm$

I. Finite Element Analysis of Cylinder

The cylinder is analysed for stresses in ANSYS WORKBENCH 15.0 for the modification for dimensions to reduce the weight. The image shows the deformation and stress distribution with concentration on the cylinder.

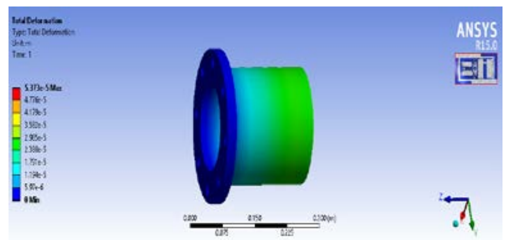

Figure 10: Total Deformation Analysis

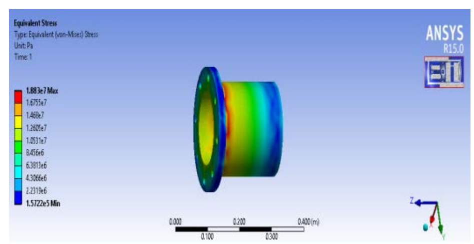

Figure 11: Stress Analysis

The material is changed because the stress is almost reached the limit, to reduce weight then the analysis is again done the images shows the deformation and stress distribution with concentration on the cylinder after the modification of the cylinder.

The new material used is forged aluminium alloy (EN-AW7075-T6). This material is widely used for hydraulic cylinders nowadays, due to its properties.

J. The Mechanical Properties are

Tensile stress = 520Mpa

Density $= 2.810 g/ cm^2$

Young's modulus = 7.1e10 Pa

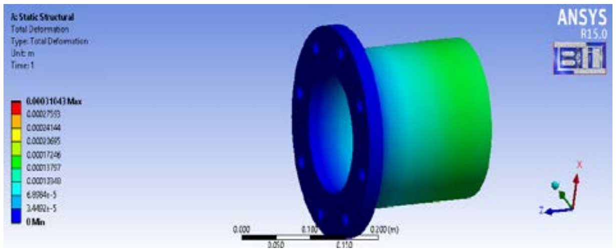

Figure 12: Total Deformation Analysis

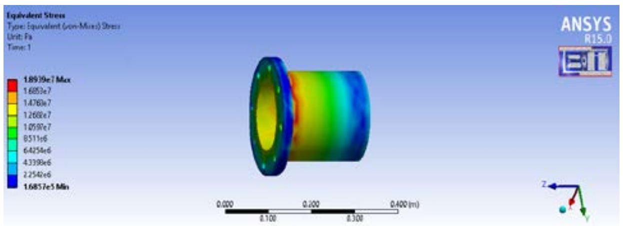

Figure 15: Stress Analysis

Volume of cylinder before modification = 1946779 mm^3

= 1946779 x 7850

Weight of cylinder = 15.28kg

Volume of cylinder after modification = 1946779 mm^3

= 1946779 x 2810

Weight of cylinder = 5.470 kg

Total reduction weight = 15.28-5.470

= 9.81kg

IV. RESULT

Optimization of Frame

The frame of the hydraulic press is optimized using two methods

- By reducing the thickness of frame by 3mm: The material removed by this method is = 872kg
- By doing an shape optimization analysis in ANSYS
  1. The material removed by shape optimization analysis = 258kg
  2. The total material removed in frame = 1144kg
  3. The cylinder of the hydraulic press is optimized using this method
- By changing the material of the cylinder the weight is reduced

The weight is reduced by changing the material = 9.8kg

Total weight reduced =1144+9.8 = 1153.8 kg

The below table shows the comparison of stress and deformation results before and after weight reduction of frame and cylinder

Table 1: Comparing Results of Frame

FRAME	Before	After
Total deformation	0.53mm	0.82mm
Total stresses	1.741e+7 Pa	3.618e+7 Pa

Table 2: Comparing Results Of cylinder

CYLINDER	Before	After
Total deformation	0.0537mm	0.31mm
Total stresses	1.883e+7 Pa	1.893e+7 Pa

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