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Structural Design and Analysis of 100 Ton Hydraulic press

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Abstract - *This work of paper is to develop a 3D model of hydraulic press of capacity 100 Ton by using optimization technique and FEA techniques. As the budget of the company is limited, they need to select a machine design which can withstand high load in working condition. For making the complete design from the beginning of process till the end Solid Edge simulation software used. To minimize the material usage and money being spent on hydraulic press, the design is made in an optimize manner so that there is less machining process.*

Key Words: *Manual calculation, Finite Element Method, Hydraulic press, Solid Edge, Analysis, Optimization.*

1.INTRODUCTION

A hydraulic press is a machine which is designed to develop a compressive force. It works on the bases of pascal's law, the pressure throughout a closed system is constant. Crown, gateway, bed, and cylinder are the main components of the press. In this work a hydraulic press is designed on the bases of fundamental calculation, later it's analyzed in Solid Edge software. An integrated approach is chosen to verify the structural performance and stress distribution are identified using Solid Edge. According to the structural values the dimensions of the structure are modified to perform better.

2. LLITERATURE REVIEW

The design and analysis of hydraulic presses have been extensively explored in various research works. V.B. Bhandari's book "Design of Machine Elements" provides fundamental insights into machine element design, which serves as a basis for hydraulic press design [1]. D. Ravi's study focuses on the computer-aided design and analysis of power presses, offering valuable methodologies for optimizing press designs [2]. O.O. Ojo's research delves into the design, fabrication, and structural analysis of a 5-ton hydraulic press and Mold machine, shedding light on its application in crucible production [3]. N.A. Anjum's work presents the design, fabrication, and manufacturing of a 100-ton hydraulic press tailored for equal channel angular pressing, contributing to advancements in press technology [4]. Mohammed Iqbal Khatib's study focuses on the design and fabrication of a 5-ton hydraulic press machine, providing insights into its construction and operation [5]. Akshay Vaishnav's research on the design optimization of hydraulic press plates using finite element analysis offers methods to enhance press performance [6]. B. Parthiban's study on the design and analysis of C-type hydraulic press structures and cylinders provides a detailed exploration of press components and their structural integrity [7]. Deepak Annasaheb More's work on the design, development, and optimization of hydraulic presses offers strategies for improving press efficiency and performance [8]. Muni Prabaharan and V. Amarnath's research on the structural optimization of hydraulic presses and scrap baling presses highlights the importance of cost reduction and topology optimization in press design [9]. Furthermore, Sultan Thipprakmas and Wiriyakorn Phanitwong's study on process parameter design in V-bending processes using the Taguchi technique contributes to understanding press forming processes [10]. Malachy Sumaila's research on the design and manufacture of a 30-ton hydraulic press provides practical insights into press manufacturing processes [11]. Zhang and Wang's study on the structural analysis and design of double-acting hydraulic presses offers innovative design approaches [12]. Additionally, Martin Zahalka's research on modal analysis of hydraulic press frames and Karel Raz and Kubec Vaclav's study on the use of hydraulic presses in the production of large rings provide insights into press frame dynamics and industrial applications [13, 14]. S.M. Bapat and Dessai Yusufali's work on the design and optimization of a 30-ton hydraulic forming press machine contributes to the development of efficient press systems [15].

These research works collectively contribute to advancing the field of hydraulic press design and optimization, offering valuable insights and methodologies for improving press performance, efficiency, and reliability.

3.METHODOLOGY

In the design and analysis of a hydraulic press, various steps are followed to ensure structural integrity and performance. These include 2D model development, fundamental calculations, 3D model development using Solid Edge, mesh generation, application of boundary conditions, stimulation, and assessment of results. If the results meet acceptable conditions, the design is concluded; otherwise, the model is re-engineered.

1. 2D Model Development: The initial step involves the development of a 2D model, which acts as a foundation for the subsequent 3D model. This step lays out the basic geometry and dimensions of the hydraulic press components.

2. Fundamental Calculations: After the 2D model is established, fundamental calculations are performed to ensure the design meets the required specifications and safety factors. These calculations determine the required dimensions and load-bearing capacities of each component.

3. 3D Model Development using Solid Edge: The 2D model is then utilized to create a detailed 3D model using Solid Edge software. The 3D model allows for a more comprehensive visualization of the hydraulic press components and their assembly.

4. Mesh Generation: Following the development of the 3D model, mesh generation is carried out to divide the model into finite elements. This step is essential for the subsequent analysis using Finite Element Analysis (FEA).

5. Boundary Conditions Applied: Boundary conditions are applied to the model to simulate real-world operating conditions. These conditions include loads, constraints, and other external forces that the hydraulic press will experience during operation.

6. Stimulation: The model is then subjected to stimulation using Solid Edge simulation and analysis software. This process involves analyzing the stress, strain, and deformation of the hydraulic press components under the applied loads.

7. Result and Feasibility Assessment: After the stimulation, the results are evaluated to determine if they meet the acceptable criteria. If the results are within the acceptable range, the design is concluded. However, if the results are not satisfactory, the model is re-engineered to address the identified issues.

4.Problem Identification

The main components like top plate, guide ways and bed are subjected to continuous load which causes arise the formation stress at the time of working condition. So, for this stress distribution is obtained for each part.

Requirement:

Cylinder working pressure: 300 Bar

Cylinder testing pressure: 450 Bar

Force extracted by the cylinder: 100 Ton

Stroke of cylinder: 400 mm

4.1. Design Calculation of Hydraulic Press

Every design begins with fundamental calculation by applying various kid of stress development.

Design of hydraulic cylinder:

The work of hydraulic cylinder is to generate compressive force ($F_)$), with a pressure (P) during the forward stroke.

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

Where A = cross sectional area of piston = $\frac{\pi}{4} d^2$ in mm^2

From this piston diameter or the bore of the cylinder can be determined.

For finding wall thickness of cylinder:

Circumference failure $\sigma_{th} = \frac{Pd}{2t}$

Longitudinal failure $\sigma_{tl} = \frac{Pd}{4t}$

4.2. Analysis and Testing

The components of hydraulic press are designed in Solid Edge software for working load of 100 Ton with the factor of safety 1.5 (i.e., designed load of 150 Ton). The following details are material properties used for components in hydraulic press.

Table 1: Materials used and their properties

Part Name	Material of used	Density Kg/m³	Yield Strength (MPa)	Modulus of Elasticity (MPa)
Cylinder	Aluminum 7075 T6	2712	275	71000
Piston and piston rod	Hard chrome plated steel	7833	262	210000
Frame	Structural steel	7833	262	210000

FEA is performed using Solid Edge software to determine the stress acting in it. Below shown images are related to the output from the analysis.

For the analysis of the cylinder, 300 bar of hydraulic pressure is applied inside the cylinder and by constrain at the holder which is permanently joined by the means of welding.

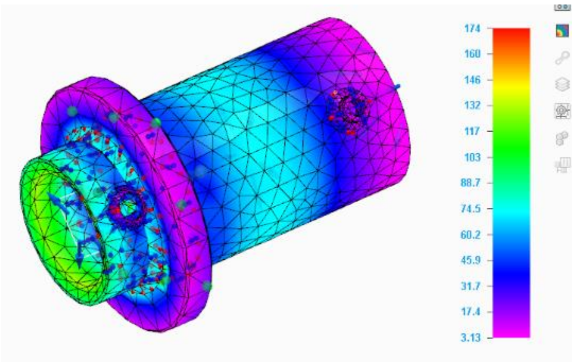

Figure 1: Stress analysis on cyclinder

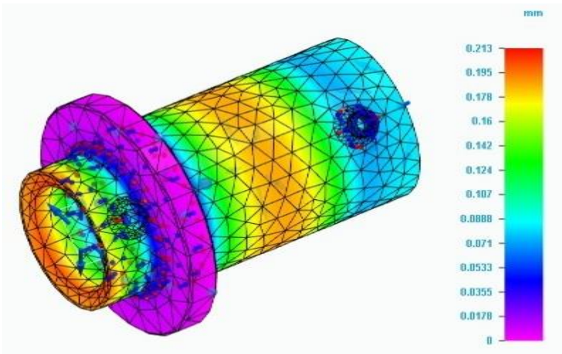

Figure 2: Deformation of cyclinder

The component named cylinder has the minimum displacement of 0 and maximum of 0.213 mm and is considered to less deformation. The induced stress lies in minimum of 6.13 Mpa to maximum of 174 Mpa which is less compared to allowable stress of 275 Mpa. So, the component design is said to be safe.

On the top of piston, a hydraulic pressure of 300 bar acts which cases the deformation on piston and buckling on the rod which is directly connected to the piston. For this the constrains are made at the bottom of the piston as shown below.

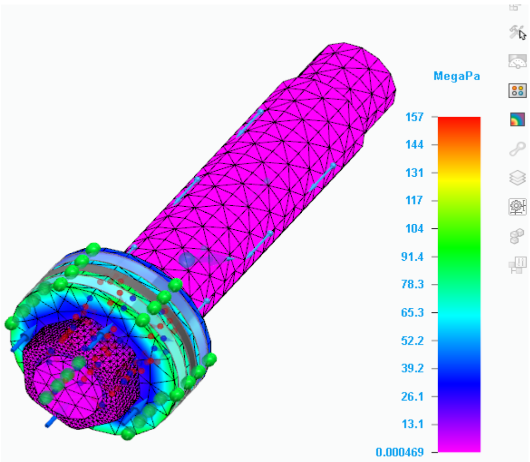

Figure 3: Stress analysis on piston and piston rod

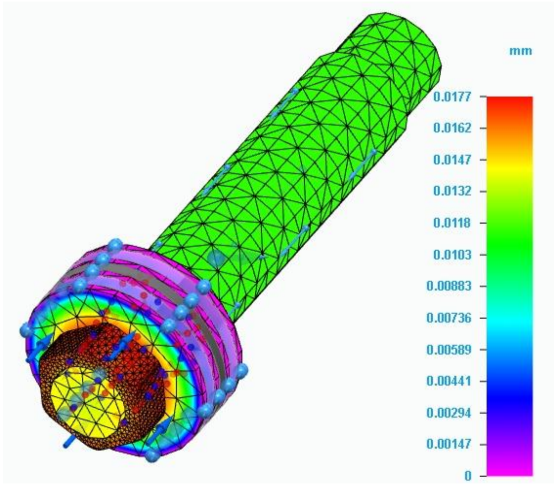

Figure 4: Deformation of piston and piston rod

The component piston has the minimum displacement of 0 and maximum of 0.01177 mm and is considered to less deformation. The induced stress lies in minimum of 0.000469 Mpa to maximum of 157 Mpa which is less compared to allowable stress of 265 Mpa. So, the component design is said to be safe.

The complete structure needs to be analyzed because after assembly of a components or a machine there will be different kind of moments which can't be analysis. By this we can also identify the weaker part and critical damages in machine by changing positions of specimens, and the moments. The surface which gets contacted with the ground is taken as the constraints.

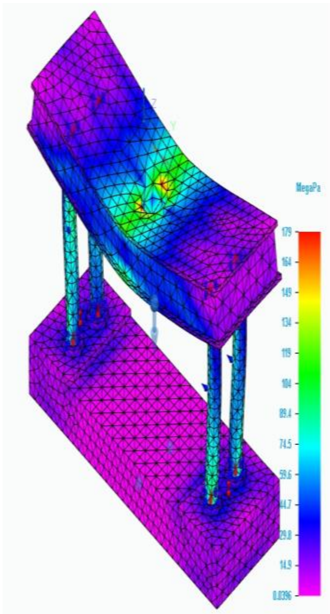

Figure 5: Stress analysis on frame

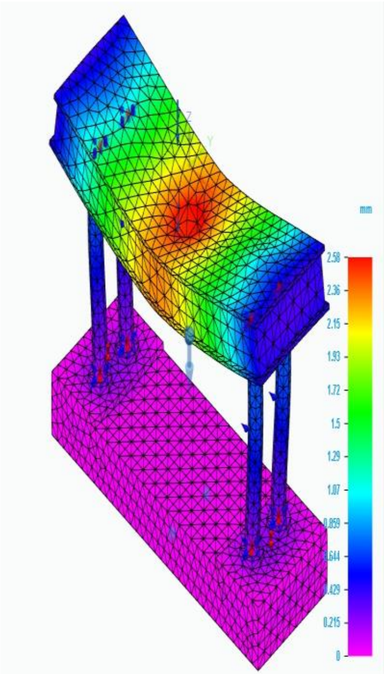

Figure 6: Deformation of frame

The complete structure is made of different material. By taking the average of allowable stress its assumed maximum allowable stress as 220 Mpa. The deformation in the complete machine is 2.58 mm as maximum and maximum induced stress is 179 Mpa. So, the obtained values are in acceptable range. So, the design is safe.

5.Result

The following is the summary of the results obtained from the analysis using Solid Edge simulation software. The results are as follows: -

Table 2: Analysis data output

Part Name	Max Stress (MPa)	Deformation (mm)
Cylinder	174	0.213
Piston and piston rod	157	0.0177
Frame	179	2.58

6. CONCLUSIONS

As shown in the result section Max Stress are option with a F.O.S of 1.5. The obtained stress is with the limit. So, the structural design developed for 100 Ton hydraulic press is safe and satisfies the conditions of engineering.

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