Abstract—Structural optimization tools and computer simulations have gained the paramount importance in industrial applications as a result of innovative designs, reduced weight and cost effective products. Especially, in aircraft and automobile industries, topology optimization has become an integral part of the product design process. In this project, topology optimization has been applied on various components of scrap baling press and 5Ton hydraulic press using ANSYS WORKBENCH software. Suitable loads and constraints are applied on the initial design space of the components. An integrated 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. In this project, we showed 26.26 percent cost reduction in scrap baling press. And we fabricated 5ton hydraulic press with cost reduction of 24.54 percent.


I. INTRODUCTION

A. About shape optimization

Today, all the modern manufacturing enterprises are striving to develop best optimized reduced weight and cost effective products that meet the intended design functionality and reliability.

In this scenario, structural optimization tools like topology and shape optimization with manufacturing simulations are becoming attractive in product design processes. These tools also aid in reducing product development times [1].

In last few years, shape optimization has emerged as the valuable tool to develop new design proposals especially in automobile and aircraft industries [2]. This result in an innovative design proposal irrespective of dependency of the designer experience and conventional design approaches. In recent years aircraft industries have exploited the full benefits of optimization driven design.

B. About scrap baling press

Pneumatic scrap baling presses are designed for processing plastic, ferrous or non-ferrous scrap in all forms. These machines are capable of compressing various leftover, housing of junk, cab, metal structural, metallic chips into cuboids bales.

C. Components of the scrap baling press (Charging box assembly)

1) Pressing cylinder
2) Lid cylinder
3) revised July 6, 2011 Trunion
4) Cylinder mounting plate
5) Cylinder and top door holding plate
6) Top door
7) Side door
8) Side wear plate
9) Base wear plate
10) Base plate
11) Front door
12) Front door stopper

D. Specification of the press

<table>
<thead>
<tr>
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<td>9</td>
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</table>

E. Charging box parts

1) Front door
2) Front door stopper
3) Base plate
4) Pusher plate  
5) Left door  
6) Right door

F. Hydraulic press

A hydraulic press is a hydraulic mechanism for applying a large lifting or compressive force. It is the hydraulic equivalent of a mechanical lever, and is also known as a Bramah press after the inventor, Joseph Bramah, of England. He invented and was issued a patent on this press in 1795. As Bramah (who is also known for his development of the flush toilet) installed toilets, he studied the existing literature on the motion of fluids and put this knowledge into the development of the press. Hydraulic presses are the most commonly-used and efficient form of modern press.

G. Principle

The hydraulic press depends on Pascal's principle: the pressure throughout a closed system is constant. At one end of the system is a piston with a small cross-sectional area driven by a lever to increase the force. Small-diameter tubing leads to the other end of the system.

Pascal's law: Pressure on a confined fluid is transmitted undiminished and acts with equal force on equal areas and at 90 degrees to the container wall.

A fluid, such as oil, is displaced when either piston is pushed inward. The small piston, for a given distance of movement, displaces a smaller amount of volume than the large piston, which is proportional to the ratio of areas of the heads of the pistons. Therefore, the small piston must be moved a large distance to get the large piston to move significantly. The distance the large piston will move is the distance that the small piston is moved divided by the ratio of the areas of the heads of the pistons. This is how energy, in the form of work in this case, is conserved and the Law of Conservation of Energy is satisfied. Work is force times distance, and since the force is increased on the larger piston, the distance the force is applied over must be decreased.

II. VALUE ENGINEERING

Value engineering (VE) is a systematic method to improve the “value” of goods or products and services by using an examination of function. Value, as defined, is the ratio of function to cost. Value can therefore be increased by either improving the function or reducing the cost. It is a primary tenet of value engineering that basic functions be preserved and not be reduced as a consequence of pursuing value improvements.

III. UNIVERSAL TESTING MACHINE

A universal testing machine, also known as a materials testing machine or materials test frame, is used to test the tensile stress and compressive stress of materials. It is named after the fact that it can perform many standard tensile and compression tests on materials, components, and structures.

IV. PROBLEM STATEMENT

A. Problem statement

We are design and analyze a scrap baling press. The company needs, cost reduction in the baling press. The charging box assembly is one of the parts of the press. The weight of the box is above 1000kg. Approximate cost is Rs. 3 lakhs. Saving is very important in their future projects. Design upgrading is also their need to meet global competition. Our work is to analyze the need of the company. We are analyzing only the charging box structures.

B. Problem statement

The project needs reduction in thickness of the hydraulic press frame. The thickness of the frame is 10mm. We have analyzed that whether it is possible to reduce the thickness of the frame or not.

V. DESIGN APPROACH

A. Density of material

Material: MS
- Diameter =16mm
- Length=56.2mm
B. Readings

<table>
<thead>
<tr>
<th>S.N</th>
<th>Load(P) kgf</th>
<th>Extensometer reading</th>
<th>Extension(\Delta l) mm</th>
<th>Stress, N/mm²</th>
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C. Tension test on mild steel rod

- Original diameter=11.9mm
- Neck diameter=7.5mm
- Extension length=235mm
- Gauge length=220mm
- Least count=0.01

During experiment, the following readings are also taken
Ultimate load=7130kg
Breaking load=5500kg
Yield load=3750kg
Change in length of the rod=235mm
Original length of the rod=220mm

D. Calculations of the MS material properties

- Ultimate stress
  = ultimate load/original area
  = (7130*9.81)/(\pi*5.95²)=628.89N/mm²
- Breaking stress
  =breaking load/original area
  = (5500*9.81)/(\pi*5.95²)=485.12N/mm²
- Yield stress
  =yield load/original area
  = (3750*9.81)/(\pi*5.95²)=330.762N/mm²
- Percentage of elongation
  = (change in length/original length)*100
  = (235-220)/220*100=6.82%
- Percentage of reduction in area of cross section
  = (original area-neck area)/original area*100 =60.28%
  Neck area=\pi*3.75²=44.179mm²

Original area=\pi*5.95²=111.22mm²
- Actual breaking stress
  =breaking load/neck area
  = (5500*9.81)/(\pi*3.75²)=1221.29N/mm²
- Young’s modulus, E=2.2*10⁵N/mm²

E. Calculations of stress acts on various parts of the Scrap Baling Press

a) Determining stress acts on base plate
Pressure from lid cylinder = 300bar =30N/mm²
Diameter of the lid cylinder = 160mm

We know that,
Pressure = (Force/Area)
Force = (Pressure*Area)
=30*(3.14*160²)/4
=603.18KN

Area of the base plate= (1450*548)=794600mm²
Stress acts on base plate = (Force/Area) = (603.18*10¹)/794600 =0.759 N/mm² =7.59 bar

b) Determining stress acts on front door
Pressure from pressing cylinder= 300bar =30N/mm²
Diameter of the pressing cylinder= 250mm
We know that,
Pressure = (Force/Area)
Force = (Pressure*Area)
=30*(3.14*250²)/4
=1472.62KN

Area of the front door= (400*364)=145600mm²
Stress acts on front door = (Force/Area) = (1472.62*10¹)/145600 =10.11 N/mm² =101.11 bar

c) Determining stress acts on right side door and left side door
Maximum force acts on the door =1472.62KN
Area of the door = (1450*360)=522000mm²
Stress acts on front door = (Force/Area) = (1472.62*10¹)/522000 =2.82 N/mm² =28.2 bar

d) Determining force acts on the MS plate of 5Ton Hydraulic Press
Force acting on the cylinder = 5Ton=5000N
Number of nodes chosen on the MS plate = 24
Therefore, force acting on the MS plate = (5000/24) =208.33 N

e) Determining Von Mises stresses from various components of Scrap Baling Press for new design
TABLE 1: VON MISES STRESSES

<table>
<thead>
<tr>
<th>S.No</th>
<th>Component</th>
<th>Obtained stress (N/mm²)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Front door</td>
<td>250.722</td>
</tr>
<tr>
<td>2</td>
<td>Front door stopper</td>
<td>145.769</td>
</tr>
<tr>
<td>3</td>
<td>Pusher plate</td>
<td>17.0880</td>
</tr>
<tr>
<td>4</td>
<td>Base plate</td>
<td>205.290</td>
</tr>
<tr>
<td>5</td>
<td>Right door</td>
<td>63.3010</td>
</tr>
<tr>
<td>6</td>
<td>Left door</td>
<td>67.3810</td>
</tr>
<tr>
<td>7</td>
<td>Frame</td>
<td>68.1100</td>
</tr>
</tbody>
</table>

We know that, the yield stress obtained in UTM testing is 330.762N/mm². From the above tabular column, the obtained stresses are less than the yield stress. Therefore, our new design is safe.

VII. PROCEDURE FOR TOPOLOGY OPTIMIZATION ANALYSIS

1) First, the front door part (component) is created in ProE software.

2) The model is saved by using .igs extension in ProE.

3) Now, the model is opened in ANSYS for analyzing stress distribution.

4) Open the model in Simulation, establish units, and set up a shape optimization analysis.

5) From the main menu, choose Units> U. S. Customary (in, lbm, lbf, °F, s, V, A).

6) Choose New Analysis> Shape Optimization from the toolbar.

7) Specify boundary conditions and loads. The shape optimization analysis will show where material can be removed from the structure with minimal impact for the given load condition. Apply fixed support by selecting the face shown and choosing Supports>

8) Specify the target volume reduction as a percentage of the original volume. The analysis removes material while maximizing the stiffness, that is, removes material that contributes least to the stiffness of the structure under the given loading conditions. Highlight the Solution folder and choose Shape from the toolbar. Set Target Reduction.

9) Solve the analysis. Choose Solve from the toolbar.

10) Review the results of the shape optimization analysis. Highlight the Shape Finder object. The results show suggested areas of material removal.

11) Simulation of front door is done in ANSYS WORKBENCH.

12) Result from ANSYS WORKBENCH report.

13) From the step 10, we should mark where the materials can be removed.

14) Now, optimized model should be drawn in ProE software.
15) The optimized model should be analyzed by ANSYS software.
16) The weight of the optimized component can be found by using ANSYS WORKBENCH software.

17) Similarly, the other components can also be optimized.

A. Inputs and Outputs of Other Components

1) Front door stopper

2) Base plate

3) Left door

4) Pusher plate

5) Right door

6) Hydraulic Press

VIII. COST ANALYSIS

A. Shape optimization results for Scrap Baling Press

B. Percentage of weight reduction

\[ \text{Percentage of weight reduction} = \left( \frac{\text{Weight reduction}}{\text{Current design weight}} \right) \times 100 \]

\[ = \left( \frac{177.504}{673.237} \right) \times 100 \]

\[ = 26.36\% \]

C. Calculation of cost reduction for Scrap Baling Press

1) Total cost before topology optimization

Material cost per kg = Rs.50
Material cost for 673.23 kg = (673.23*50) = Rs.33661.50
Fabrication cost per kg = Rs.25
Fabrication cost for 673.23 kg = (673.23*25) = Rs.16830.75

Total cost = (33661.50 + 16830.75) = Rs.50492.25

2) Total cost after topology optimization

Material cost for 495.73 kg = (495.73*50) = Rs.24786.50
Fabrication cost for 495.73 kg = (495.73*25) = Rs.12393.25

Total cost = (24786.50 + 12393.25) = Rs.37179.75

3) Cost reduction of Scrap Baling Press

Percentage of cost reduction = \[ \frac{(50492.25 - 37179.75)}{50492.25} \times 100 \]

= 26.26%

D. Shape optimization results for 5Ton Hydraulic Press

TABLE 2: COMPARISON OF CURRENT DESIGN AND NEW DESIGN WEIGHT FOR SBP

<table>
<thead>
<tr>
<th>Components</th>
<th>Current design weight (kg)</th>
<th>New design weight (kg)</th>
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</tr>
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<tr>
<td>Front door</td>
<td>65.000</td>
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<td>Right door</td>
<td>182.70</td>
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<tr>
<td>Left door</td>
<td>182.70</td>
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<td>Pusher plate</td>
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<td><strong>Total</strong></td>
<td><strong>673.23</strong></td>
<td><strong>495.73</strong></td>
<td><strong>177.5</strong></td>
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TABLE 3: COMPARISON OF CURRENT DESIGN AND NEW DESIGN WEIGHT

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<th>Components</th>
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<tr>
<td>Frame</td>
<td>432.8</td>
<td>326.59</td>
<td>106.21</td>
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</table>

E. Percentage of weight reduction

\[ \text{Percentage of weight reduction} = \left( \frac{\text{Weight reduction}}{\text{Current design weight}} \right) \times 100 \]
IX. PHOTOGRAPH OF 5TON HYDRAULIC PRESS

X. CONCLUSIONS

Optimization design is compared to the actual part design that is being manufactured for the scrap baling press and hydraulic press. It is inferred that under the same loading conditions, constraints and intended design purposes, shape optimization results in better and more reliable design. A designer can produce the best optimized design without much dependency of his experience and previous design options and practices.

Shape optimization is a promising tool to explore optimal solutions to engineering products. Benefits are numerous, including: load path visualization, weight savings, systems design space, ballistic protection, and improved fatigue resistance.

These benefits offer a compelling incentive to employ this technology into the current design process to increase the performance of our products, adding value for our customers.

In this project, we have shown 26.36 percent volume reduction for scrap baling press and 24.54 percent for hydraulic press. We have also fabricated 5Ton hydraulic press by employing topology optimization.

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[5] Muller, O; Albers, A; Sauter, J; Allinger, P. “Topology Optimization of Large Real World Structures, NAFEMS World Congress 1999”, 26-28, April 1999, Newport (Rhode Island), USA

Muni Prabaharan had received his Bachelor of Engineering (Mechanical) with Gold Medal from Anna University, Chennai, Tamilnadu, India in 2010. He had done 65 scientific papers at International and National level as Lead author. Currently, he is working in Hyderabad, India as Design Engineer for New Product Design with Mahindra Satyam, Integrated Engineering Solution. His research interests include Structural Analysis, Computer Aided Engineering, Computer Aided Designing, Design for Recycling and Project Management. He is incorporating Six Sigma in Design application in his current role. The President of World Forum invited him as “Ambassador” for India. He honored as Outstanding Intellectual in the 21st Century, Top 100 Educators 2011, Man of the Year and International Peace Prize. He is the fellow member of IACSIT and International Peace Prize. He is the life member of American Welding Society (AWS) and Indian Welding Society (IWS).

Prof. V.Amarnath has obtained his Bachelor of Engineering (Mechanical Engineering) and Master of Engineering (Production Engineering) from Bharathiar University, Coimbatore, Tamilnadu, India in the years 1991 and 1992 respectively. He had also received his Master of Business Administration (MBA in Production Management) from Bharathiar University in the year 1997. He has worked in Industries like Lakshmi Machines Works Ltd. and K.G.Denim Ltd. at various capacities. From 2001 onwards he has been working in the Department of Mechanical Engineering of Sri Ramakrishna Engineering College, Coimbatore, Tamilnadu.

His research areas include Metal Joining, Materials Engineering and Industrial Engineering. The projects guided by him had received “Innovative students projects award” instituted by National Academy of Engineering, New Delhi for five times in the years 2002, 2004, 2006, 2007 and 2009. He has undergone several training programmes in the areas of Metal Joining and Materials Engineering. He is the life member of American Welding Society (AWS) and Indian Welding Society (IWS).