Topological Optimization Approach for Design of Bell Housing of Leather Shaving Machine by using FEA

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Abstract - *This paper is about Topological Optimization for Design of Bell Housing of Leather Shaving Machine by using FEA. Reduce weight of components help to attenuate load on environmental resources .This efforts for reduction of weight by using topology optimization. Bell Housing has been modelled using solid works First conducted analysis on existing Housing with calculating the forces acting on Housing in order to find out Max. Displacement and stress induced were carried using Altair Hyperworks and solver used is optistruct. After that topology optimization is carried out by applying manufacturing constraint and minimum dimension. Again prepare cad model as per topology result using Ossmooth and carried analysis on optimized model. From that analyzed results, Displacement and stress are lower than existing bell housing model. From result it was found that current design is safe also save material cost of component, here Prototype is developed on FDM 3D Printer which helps reducing material wastage and time associated with tooling (for Forming) and it allows a complex shape to be produced directly and automatically from its 3D CAD model usually within hours. Finally reduced cost by 416/- and total reduced weight by 27 % of current bell housing design. Topology optimization analysis is carried out in Hyperworks which yielded in structural optimized design.*

Keywords: Hyperworks, Optistruct, Leather Shaving Machine, Structural Optimization, Geometrical Optimization, Rapid Prototyping.

1. INTRODUCTION

Now a day's manufacturing organization are trying developed product having in optimized manner, because due to increase in price of natural resources, cost of producing mechanical components is going to increase. In the other side number of competitors entering in the market having policy of lower competitive prices, so here it is a big problem of maintaining sales number of the product. So manufacturing industries are continuously trying to achieve fast product development and cost effective product by using various design tricks and structural optimization tools. Structural Optimization helps to reduce material cost. Structural Optimization is a method of obtaining the best result under the given circumstances. Structural optimization has various types such as topology, size & shape optimization.

Topology optimization is extremely useful engineering technique especially at the concept design stage. It is common practice to design depending on the designer's experience at the early stage of product development.

It is vital to scale back the event times from the initial concept development stage to the mass production stage. Much trial and error occurs from the initial design to mass production to verify the performance and durability and other design criteria. Computational simulations for reducing such trials and errors are generally utilized and have proven to be useful tools in many areas. The ability of using CAD/CAE has become one of the core technologies nowadays because of shortened development periods. These efforts for the optimum design can give large effects at the initial design stage of parts. Design capabilities at the initial concept design stage play essentially important roles in the automotive parts design. The wrong design direction leads to very expensive costs and long times to recover to the right design direction. As a result, researches and developments for the design capabilities to get the initial robust design could affect the competitiveness of the products in these global and extremely competitive times. Topology optimization method of the structure can give the right design direction at the early development stage.

In the past 20 years, topology optimization has become an active research field and thus the related algorithms developed create a robust approach to perform innovative and efficient conceptual design activities. To be specific, topology optimization is powerful because the related algorithms are applied to a broad range of design problems governed by different physical disciplines, i.e. solid mechanics, fluid dynamics and thermal dynamics.

Optimization has become an active research field to perform

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innovative and efficient conceptual design because they can help engineers to think out of the box to generate innovative design ideas, even for those designs of already highly engineered products. Furthermore, this optimization is efficient because automated optimization processes are employed to get the conceptual designs rather than the traditional trial-and-error approach.

By using this structural optimization method we are going to design Bell Housing for optimum weight. Due reduction in weight of component, amount of material required is reduced which also reduce the cost of component. Finally it will help company to decrease manufacturing cost of component, so here benefit to company to increase sale in market by lowering cost with maintain same performance also overall reduced load on environmental resources and carbon emission in the environment.

Fig 1: Bell Housing

2. PROBLEM DEFINITION

Today's most of manufacturing and other industries are trying to reduce manufacturing cost of product by optimizing weight of the product. Tannery industry is one of most common industry which also trying to reduce manufacturing cost. Leather shaving machine is an important machine tool in a Tannery industry. During discussion with the company, we observed that the company desires to optimize the weight of some parts in a Leather shaving machine without changing of material and load bearing capacity.

Presently, company needs to optimize the weight of Bell Housing. The Bell Housing is used for holding motor and pump assembly of hydraulic power pack. In this assembly motor at left side weighs 45 Kg and pump at right side weighs 10 Kg. Current Bell Housing weighs 22Kg and made of Grey Cast Iron. Thus it is necessary to reduce the weight of Bell Housing.

3. OBJECTIVE

1. To analyze the stresses acting on Bell Housing and to find the maximum displacement due to applied load.
2. To perform the optimization of Bell Housing by using displacement constraint.
3. To optimize the structural design of the Bell Housing using Topology optimization method without reduction in load bearing capacity.
4. To use the additive manufacturing process such 3D printing to produce prototype of optimized structure of the component.
5. To test the optimized Bell Housing for compressive load using Universal Testing Machine as per IS1828 (Part 1): 2005 (ISO 7500-1:2004)

4. METHODOLOGY

CAD model of Bell Housing is designed in Solidworks. It is then imported in Hyperworks. Then geometrical cleanup and meshing has been done. All elements are 3D Tetramesh (volume mesh).Tetra elements give enhanced result in linear static analysis as compared to other types of elements, therefore the elements used in this analysis is tetra elements. Gray Cast Iron has been used for Bell Housing. Apply boundary conditions to meshed model in Hypermesh. Static analysis was performed by using Optistruct. Here we get minimum Displacement and maximum Stress value which will be design constrains for topology optimization in optistruct software. After conduction of optimization, results are imported in iges format in solidworks. Again made design changes as per manufacturing requirement. Optimized model again took for reanalysis for validation of displacement value lower than or equal to existing model.

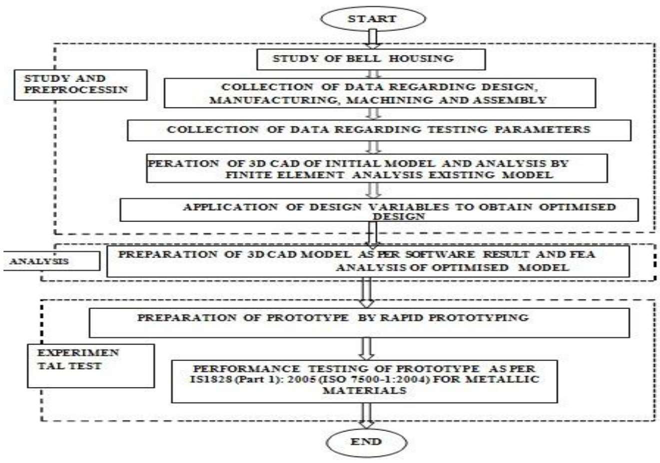

Chart -1: Methodology

5. DESIGN PARAMETERS

Total Force on Bell Housing:

1. load on housing is weight of 5 hp crompton electric motor Left side rested on 4 nut bolt Load in 45 kg Considering force factor of safety 1.5 - so force is 662.175N.
2. Hydraulic pump at right side rested on 4 nut bolt force is 147.15N

Table 1: Properties of Material

Parameters	Quantity
Elastic Modulus (E)	66178 N/mm2
Poisson's Ration (Nu)	0.27
Density(RHO)	7200 Kg/m3
Force on Bell Housing	662.17N, 147.15N
Weight before optimization	22Kg.

5.1 Analysis before optimization and Optimization

1. Static Analysis

Static analysis is done by using Optistruct Solver. Inputs were given in terms of single point constraints, load cell and rigid body elements along with magnitudes. It shows that the maximum static displacement is 0.0002 mm under compression. Maximum Stress induced is 3.81 N/mm2.

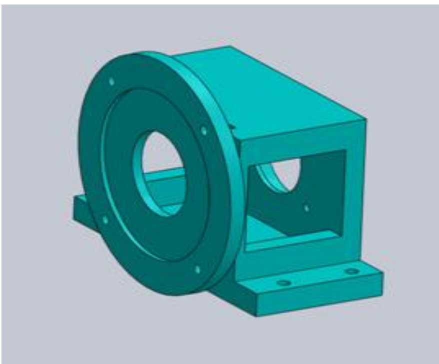

Fig. 2: CAD Model of Existing Component

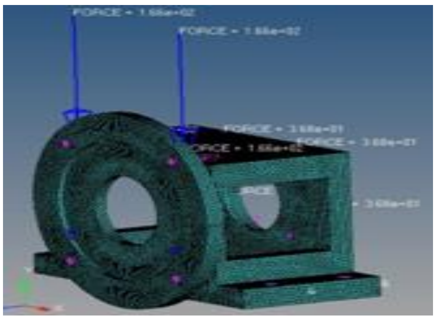

Fig. 3: Meshing and Load application

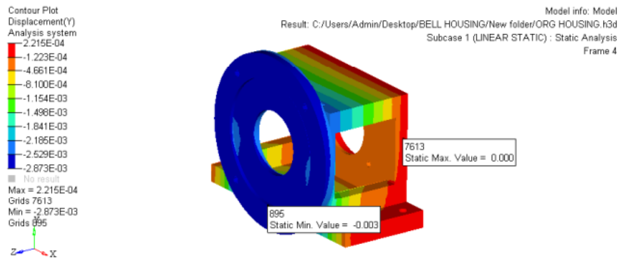

Fig. 4: Initial analysis in Hyperworks

Table 2: Results after initial analysis

Parameter	Quantity
Maximum Displacement	0.0028 mm
Maximum Stress Induced	3.81 N/mm2

2. Geometrical optimization by using Optistruct

Geometrical Optimization is defined as finding out the best possible material distribution in selected design space with considering the given sets of objective and design constraints and responses. Reponses like volume fraction, weighted component and displacement were established. Also assigning design and non-design area is necessary. Material is removed from design area.

Design objective was Minimum weight compliance. Optimization algorithm works to find the optimal solution(s) to a given computational problem that maximizes or minimizes a particular function. Total 25 iterations took place for optimization. After running optimization results are viewed in Hyperview.

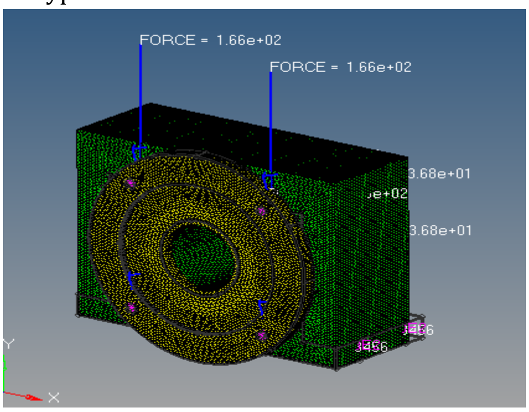

Fig. 5: Creation of Design Variables for Geometrical Optimization

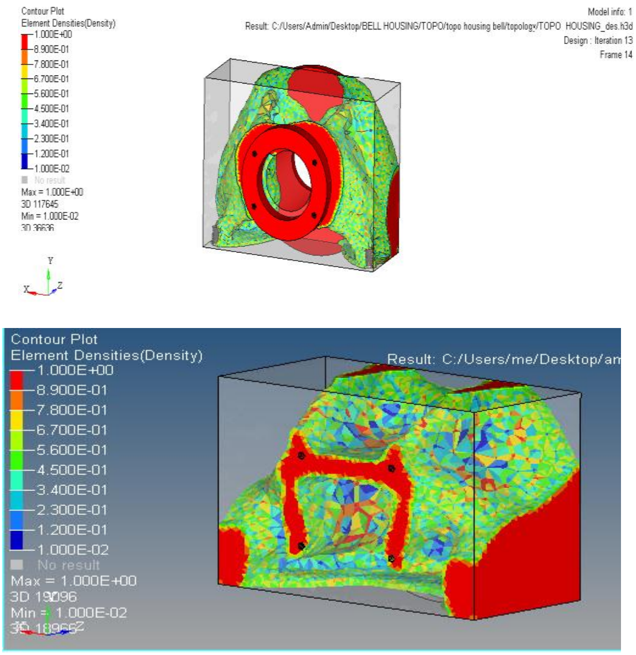

Fig. 6: Element with high densities and high stress.

5.2 Redesigning Optimized model in CAD software and Re-analysis in Optistruct

Using CAD software Solidworks redraw the component as per inputs from OSSmooth. Unnecessary material is removed and component is redeveloped with the help of design engineer in company. Again its static analysis has been done in Hyperworks. It is very important that new designed component should remain within its initial limits. Again apply all meshing conditions, initial boundary conditions and check the result. Compare displacement and stress of optimized model with original model and insure that it should not exceed values of original model. Fig. 8 shows displacement result of optimized Bell Housing. Displacement of optimized Bell Housing is 0.0012mm (<0.0028mm of original model).

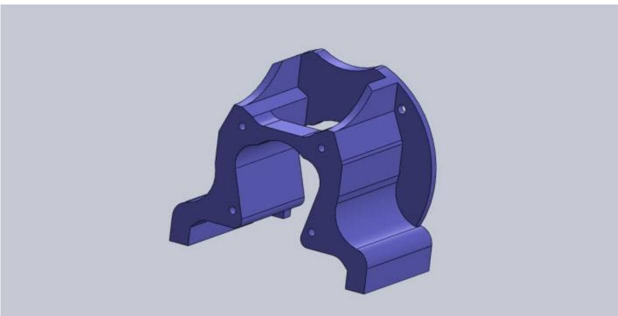

Fig. 7: Redesigned CAD model

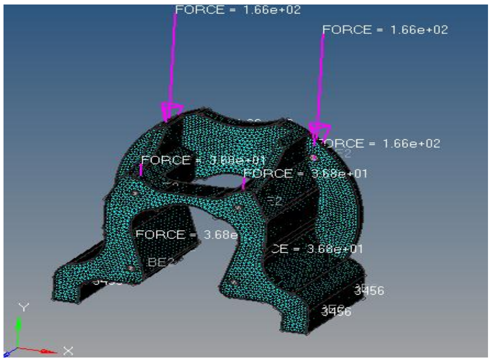

Fig. 8: Meshing and Load Application on new model in Hyperworks

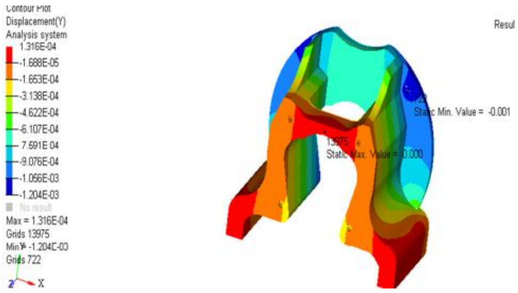

Fig. 9: Analysis of optimized Model

Table 3: Results after final analysis

Parameters	Before Optimization	After Optimization
Max. Displacement (mm)	0.0028	0.0012
Max. Stress (N/mm2)	3.81	2.20

5.3 Development of pattern/prototype on 3D Printer

Fig 10: Prototype made by using 3D printer

A prototype has been made on 3D Printer to make pattern for casting. Then the prototype has been tested under double loading condition to validate the design safety.

6. RESULT AND VALIDATION

From table it is observed that optimized Bell Housing sustain present operating load conditions.

Table 4: Final Result

Parameters	Before Optimization	After Optimization
Max. Displacement (mm)	0.002 8	0.0012
Max. Stress (N/mm2)	3.81	2.20
Weight (kg)	22	2
Reduction in weight	22 -16.06= 5.94kg (27%)	
Raw material cost saved per Bell Housing	5.94 * 70 = Rs.416/-	
Total cost saved per year (Say 50 Machines)	416*50= Rs.20800/-	

7. CONCLUSION

1) The values obtained for the maximum Von Mises stress and maximum displacement are lower than safe limit. Initial Von Mises Stress was 3.81 N/mm2 and the Final Von Mises Stress is 2.20 N/mm2. Initial Displacement was 0.0028 mm and Final Displacement is
0.0012 mm.

2) The Geometrical optimization produces an optimized material distribution (for weight optimization) against a set of loads and constraints within a given design space. Initial weight was 22 kg and final weight is 16.06 kg (27% Reduction). Total cost saved per Bell Housing is Rs. 416/-

FUTURE SCOPE

Every component of Leather Shaving Machine can be optimized for the purpose of weight reduction. This is will reduce total manufacturing cost for every machine.

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