Structural Optimization of Front Pedestal of Cement Mixer Truck

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This paper describes roll of structural optimization in design process. Optimization can give idea of better design which can be helpful to reduce process time and cost of component. Optistruct a FEA based software can be used to optimize design for constraints like mass, volume, stress, strain, displacement. And optimization like Topology, Topography, Free Shape & Size can be performed. In this paper one optimization problem of front pedestal of cement mixer truck is discussed. New design of casting part is developed for the fabricated old part using the structural optimization concept. How to prepare new geometry from the result of optimization is shown. Further analysis of new design is done. Result comparison shows that how new concept is better than old design considering strength, manufacturing and cost of the component.

1. Introduction

New competitive products must meet the growing demands of the market. They must be light-weighted, resource-efficient, durable, stable, and have a low noise emission. At the same time, the product must be introduced quickly into the market. These demands can only be met if structural optimization tools are used in addition to established CAE, CAD, DMU, and PDM systems. Variation calculations and improvements can be carried out on the digital prototype at a very early project stage. Accordingly, the number of required prototypes can be reduced which results in possible time and cost savings. So far, the structural optimization tools have not been completely integrated in the design process. The new optimization tools will then speed up the product development process and improve its efficiency. Light-weighted, stiff and durable structures will offer end users a decisive edge over their competitors in the automotive and supplier industry, the aerospace and machine manufacturing industry as well as in the engineering service. [1]

2. Structural Optimization

Structural optimization techniques comprise various aspects. For example, the structural optimization may depend on the application fields, it will be used for. Then it is divided into size, shape and topology optimization. Topology optimization gives basic idea of topology after material removal process. Size optimization is used to optimize size by changing dimensions like thickness, radius of hole, length etc. shape optimization is used to get optimized shape. It changes shape of curve or fillet by either shrink or grow method. [2]

3. Homogenization Method

This method has been adopted in many papers. The original paper from Bendsoe and Kikushi a so-called Microstructure or homogenization based approach presented. According to Kaminski homogenization method is still the most efficient way for computational modeling of composite systems. Usually it is assumed that there exists some scale relation between composite components and the entire system. Essential disadvantage of all these techniques is impossibility of sensitivity analysis of composite homogenized characteristics with respect to geometrical scales relations. According to Sigmund, this method has the disadvantage that the determination and evaluation of optimal microstructures and their orientations is cumbersome if not unresolved. Furthermore, the resulting structures cannot be built since no definite length-scale is associated with the microstructures. However, it is still important in the sense that is can provide bounds on the theoretical performance of structures. [3, 4]

4. Hard/Soft Kill Method

One of the more commonly used methods is the hard-kill method and was introduced by Xie and Steven in 1993. This method relies on the idea of changing material properties (i.e. Young's Modulus) of the elements with less stress in the FEM to zero, essentially removing the material from the model. This method relies on two distinct parameters; the evolutionary rate and the removal rate. The removal rate (RR) determines the level of stress under which elements, if any, should be removed. This process is repeated for each convergence and the RR is increased by an increment called the evolutionary rate (ER). Once the stress level in all the design regions are below the objective stress level, the process is complete. Similar to the hard-kill method, the soft-kill method, first developed by Walther and Matteck, uses a comparable approach aside from the concept of turning the elements on and off. Instead the method uses a simple relationship on the stress levels in each element to vary its modulus. [5, 6]

5. Case Study of Front Pedestal.

Front pedestal is a component of cement mixer truck. It is made of material GR 50 Steel. It is used to support the gear box which rotates cement mixer. So load of cement mixer is distributed on front and rear pedestal. Company was using fabricated part initially. Using optimization tool new design for casting is to be generated. This can help to reduce cost and manufacturing time.

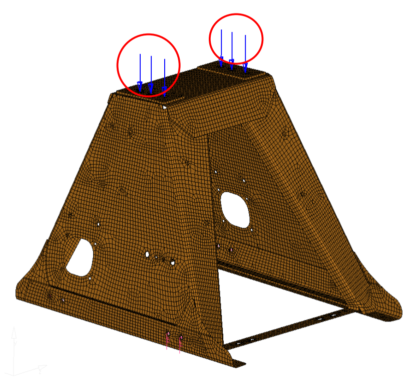

Figure 1. Fabricated part with Bolt load

5.1 Type of Loads

Here three different load cases are acting on front Pedestal.

1) Load of 20755 N on six bolt position in –Z direction (as shown in Figure 1)
2) Moment of 7.2E6 N-mm in –X direction at the height of 875 mm.

3) Braking force of 93412 N in X direction at the height of 1500 mm and Load of 20755 N on six bolt position in –Z direction.

5.2 Type of Constraints

1) All four bolt positions on back side are fully constrained.
2) Four bolt positions on front side is given spring element.

5.3 Pre Process in Hyper mesh

For optimization design space is given. The material of casting part is SAE J434 D700 alloy steel. The design space is meshed using software Hypermesh (as shown in Fig.2). Element size is 1. Type of element is solid Tetrahedral.

5.4 Post Process in Optistruct

After the meshing of component is completed post processing is done in optistruct. For topology optimization it is necessary to define design variable, response, objective, and constraint. Here total mass of design space is selected as a response. Objective is to minimize mass. And constraint is maximum stress that is 450 MPa. Software gives result in H3D file format which we can see in Hyperview (as shown in Fig.3). This gives the new shape which is optimized. It distribute the mass properly and remove the unnecessary mass. From the result new geometry is made using CAD software Unigrphics (as shown in Fig.4). This new geometry again meshed and its analysis was carried out for different load case. And results are compared with the result of fabricated part. [7]

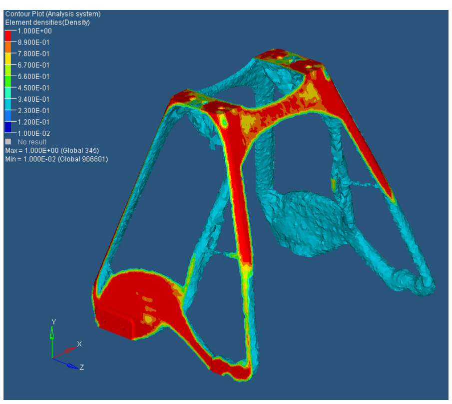

Figure 2. Result of Topology Optimization

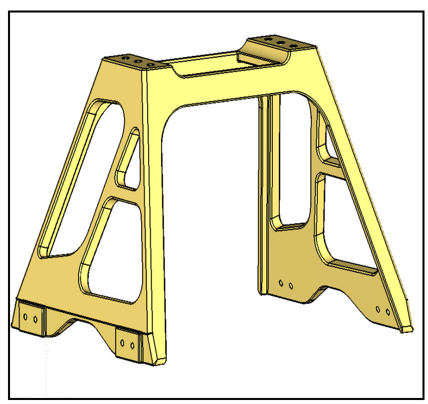

Figure 3. New Optimized Geometry

5.5 Material Property

SAEJ434 D700

E= 1.6 E5 Mpa
μ=0.25
ρ= 7.06 E-6 kg/mm^3

GR 50 Steel

E= 2.06 E5 MPa
μ=0.256
ρ= 7.79 E-6 kg/mm^3

6. Analysis of Component

Analysis was carried out in Abaqus. After the meshing of component loads and constraints are given. Run is given in Abaqus. Software gives the result in the ODB file format. Result shows that maximum stress comes near rigid elements. This we can avoid. Result comparison of fabricated part and casted part is given in table below.

Table 1. Result of Casted Part

Load Case	Maximum Stress (MPa)	Displacement (mm)
1	266.8	1.18
2	38.07	0.2036
3	1090	2.36

Table 2. Result of Fabricated Part

Load Case	Maximum Stress (MPa)	Displacement (mm)
1	737.65	1.77
2	53.77	0.09
3	3239.49	16.56

From the both result table we can see that maximum stress is higher in fabricated part for all the three load cases. For combined loading stress is exceeding yield strength in both parts. But the region is same as highlighted in the below figures. Stress is coming near holes. Here rigid elements are made, so we can consider it as a stress concentration and we can neglect such higher value of stress.

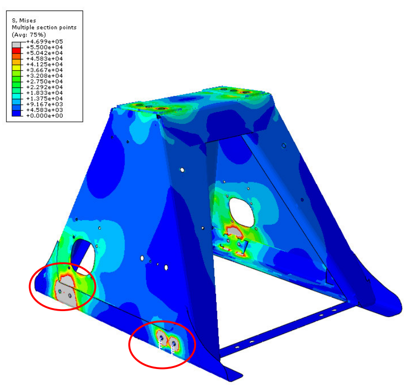

Figure 4. Stress Plot in fabricated part

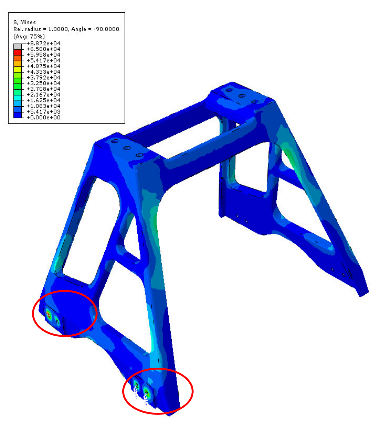

Figure 5. Stress Plot in Casting Part

7. Conclusion & Future Scope

Optimization is very useful tool to reduce the weight of component and can greatly reduce the cost of vehicle development. Benefits of new design over old design are given below.

1) After optimization there is 22% weight reduction in component. The weight of fabricated part is 227 Kg, while weight of casted part is 177 kg. So about 50 kg weight reduced.
2) New part can be easily designed with sand casting. This is comparatively easy process than fabrication.
3) Strength of new part is better than fabricated part.
4) Considering all factors like material cost and manufacturing cost, if company produce 1500 units/year then it can save 60000$ per year. This is very good from economic point of view.

Further we can do shape optimization for the same component. From the shape optimization we can have better idea of shape and we can improve our design.

Acknowledgement

I am thankful to my Head of Department Prof. V. R. Iyer, my course Coordinator Dr. D.S.Sharma, my guide Prof. N. D. Ghetiya. I am also very thankful to my industry guide Mr. Arshi Riaz Siddiqi and Mr.Sridhararababu Inala. Finally I am thankful to management of L&T e-ES, Vadodara for giving me permission to carry out my project work.

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