Published by :
http://www.ijert.org

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 13 Issue 4, April 2024

Design and Topology Optimization of Bracket Type Housing for Multi Stage Gearbox

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***Abstract*— The current research paper deals with conventional design of gearbox housing having various mounting and arrangements for bearings as well as lubrication arrangements. The current research is focused on the design of gearbox housing in the form of bracket and the reduction of weight of gearbox housing is accomplished with the help of static analysis and topology optimization technique. The conventional gear box housing carrying lots of weight which can be reduced without compromising the strength, stability and load carrying capabilities. The comparison between conventional gear box housing and topology optimized housing is done on the basis of von-mises stress distribution and the deformation of model. The target of this research is focused on reducing the weight of gearbox housing by 60% or more.**

***Keywords*—Topology Optimization, FEA, Gearbox Housing, bracket type housing**

I. INTRODUCTION

Almost every industrial machinery requires prime mover, which are commonly electric motor or sometime diesel engines. But till date induction motors are widely used as a prime mover for various industrial equipment's. [1] The major limitation of induction motor is high speed and low torque and almost every machine needs low speed at high torque. To meet the machinery requirements of speed and torque, frequently the gearboxes are used to reduce speed and increase the torque of prime mover to required level. The gear boxes used for industrial applications are often high in weight and it was observed that most of the weight of gearbox carried by its housing. The gearbox housing performs several functions as providing supports to rest the gears carrying shafts and bearings, it sustains various loads and shocks developed during operations, it acts as lubrication tank, protecting gear units from dust and dirt.

Now a day's aluminum alloy gearbox housings are used in money types of industrial gearbox, but they are suitable for light load applications. The aluminum alloy has its own drawbacks as high price, higher care needed while machining, it rapidly wears under high load applications and also rate of wear increase with high speed, it has high coefficient of thermal expansion which leads gearbox unsuitable for high temperature applications, it has lower fatigue index than steel, its rate of corrosion rapidly increases when it come in contact with salt water. The steel gearbox housing weight and ultimately cost can be reduced by optimizing it. The topology optimization is well known mathematical approach towards reducing weight without compromising the strength of components.

The gearbox housing has to perform basic three functions

1. To withstand various forces acting on gearbox housing.
2. Acts as lubrication storage tank required to lubricate gear units present within gearbox housing.
3. To protect gear units and lubricant from unwanted foreign entities like dirt and dust.

II. LITERATURE REVIEW

Jeong Woo Chang et al. [2] In his study he optimized the compressor bracket, the structural analysis is done for static and dynamic load. He used the topology optimization technique and in the optimization multiple loading conditions are considered. The Altair software was used for topology optimization and new bracket model was developed in CATIA and about 31% weight reduction was achieved.

Nitesh Maruti Bade et al. [3] In their optimization study they concluded as the "Topology Optimization" is one of the powerful tool to reduce components weight without compromising stiffness, also it results in efficient and effective optimization, which leads to cost saving. The result of Topology Optimization of bracket has given reduction of weight by 1.98 kg which is near about 60 %

Baocheng Xie et al. [4] In their study, they found, for weight reduction topology optimization is effective redesign tool. They compare and analyzed optimized results basis of deformation, stress and strain. The overall weight of hinge bracket was reduced by 28 % without compromising the. Strength and functionality of hinge bracket.

Po Wu, Qihua Ma et al. [5] They processed the optimization of automobile engine bracket using finite element analysis techniques. The research paper has carried out optimization right from theoretical study, preparing mathematical model and solution methods. They observed after Topology Optimization the stiffness of bracket increase and overall weight of bracket has reduced to 40% without compromising the static characteristics

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Dheeraj Gunwant et al. [6] in this paper authors have analyzed four sheet metal brackets using Topology Optimization. The ANSYS Parametric Design Language used to find optimal material conditions in the brackets. The rectangular proposed model is finally converted to converged shape after optimization.

III. OBJECTIVES

1. Design a box type gearbox housing using conventional design method.
2. Redesign housing at design review level if required or if possible.
3. Topology Optimization for weight reduction.
4. Compare proposed design solution with Box type and bracket type housing design.

IV. TOPOLOGY OPTIMIZATION METHODOLOGY

1. First, design a gearbox housing by conventional design method then develop 3-D parametric model of gearbox housing in modeling software.
2. The 3D model imported to analysis software, in analysis software the material properties are assigned, various loads acting surfaces are defined and the fixed supports are also defined, then observe FEA results.
3. Then assign Topology Region along with percentage material removal margin, analyze result of Topology Optimization.
4. Then redesign CAD model as per topology results. Again repeat the FEA and analyze model for stress and deflection.
5. After finalizing redesign of gearbox housing compare optimized solution with old design solution.

V. DESIGN OF HOUSING

The gearbox housing has to handle 5 N-mtr input torque and 290 N-mtr output torque and its size should be 200 mm X 250 mm X 400 mm (L X W X H). The housings are normally design for stiffness. The stiffness can be determined by the displacement of any point on housing. The displacement of any point on gearbox housing occurs due to normal force acting on wall of housing [7].

The displacement of any point on housing can be determined by following formula [7].

$$X = g_0 \, g_1 \, g_2 \, g_3 \, \frac{F K^2 (1 - \mu)}{E t^3} \quad [7]$$

Where, X = displacement in mm

g_0 = connection coefficient between the loaded wall with adjoining walls.

g_1 = effect coefficient of boss in loaded wall.

g2 = effect coefficient for the unloaded holes and boss.

g3 = effect coefficient for the ribs and stiffeners.

F = normal force acting on loaded wall (N)

t = wall thickness without boss (mm)

K = largest rectangular dimension of wall under loading (mm)

μ = Poisson's ratio

E = Modulus of elasticity of materials, N/mm2

The above calculation gives us a completely enclosed box type gearbox housing solution, as shown in "fig. 1". The little more observation and calculation leads us towards the better solution, as if we remove two closing sides and reduce the length limited to only it can house the bearing housing the solution will become as "Bracket Type Housing", as shown in "fig 2".

VI. TOPOLOGY OPTIMIZATION

First the proposed solution for FEA is redesigned and it is as shown in "fig 2". For FEA the 3D model of solution is prepared using CATIA software.
The developed CAD model then exported to .stp file format in Ansys software. Before it the material properties are assigned. Here the material selected is considered as mild steel flat, as the mild steel flats are easily available with required size and it fulfils the requirements of mechanical properties, also they can machine easily.

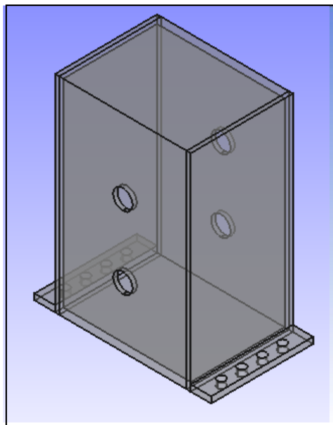

Fig. 1 Box type housing Design

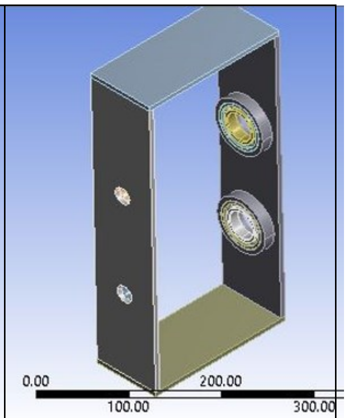

Fig. 2 Redesign as bracket type

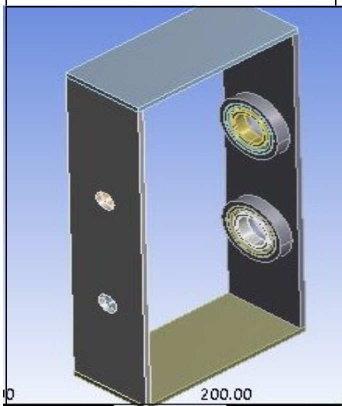

Fig. 3 CAD model

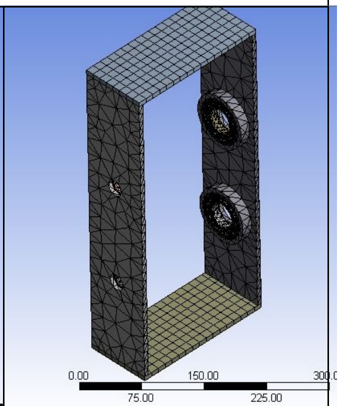

Fig.4 Mashing

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 13 Issue 4, April 2024

In next step for FEA the CAD model is imported in Ansys work bench and define meshing conditions to the model, we have used the tetrahedral type mesh with the default mesh size and mesh growth rate is 1.2. as shown in "fig. 4". Then in CAD model we define fixed supports at bearing where shaft is going to fit. The bearing housing is integrated to wall, to reduce the wall thickness. as shown in "fig. 5". After defining the fixed supports, the load position and magnitude is apply as shown in "fig. 6". The result of FEA are analyzed from fig. 7 and fig. 8.

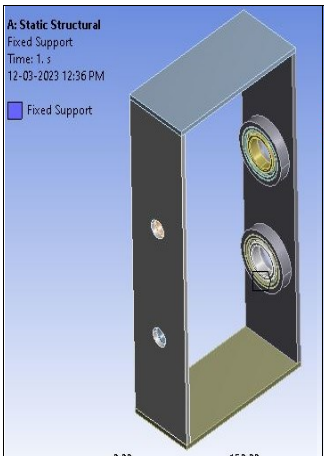

Fig. 5 Defining Fixed Supports

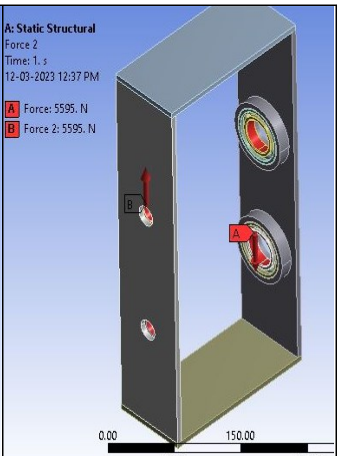

Fig. 6 Defining Load

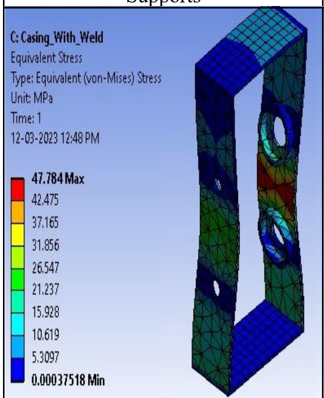

Fig. 7 FEA for Stress

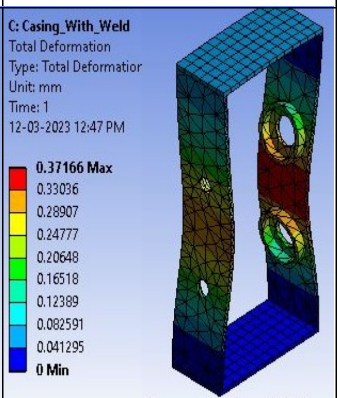

Fig. 8 FEA for Deformation

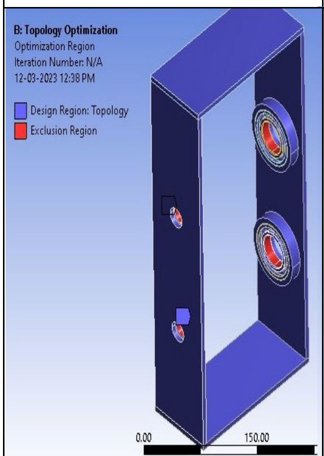

Fig. 9 Topology Optimization Region

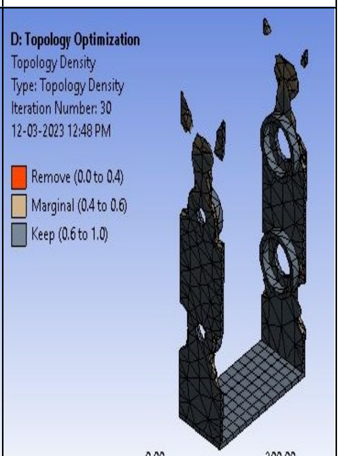

Fig. 10 Topology Optimization Solution

The proposed solution shows equivalent Von-mesh stress in "fig.7", the maximum 47.784 Mpa stress is induced and the maximum deformation is 0.37 mm shown in "fig. 8", both stress and deformation is within safe limits. So we will go for Topology Optimization of proposed solution.

Before Topology Optimization the software need some important information like optimization region. The Topology Region clearly defines where material removal is not allowed and where material can be removed, the Topology Region is shown in "fig. 9".

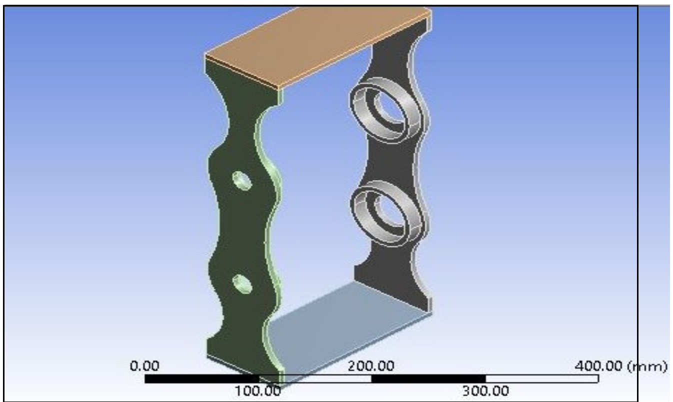

Fig. 11 Redesign of Housing on basic of Topology Optimization Solution

After defining the Topology Region run the Topology by providing allowable percentage of material removal, we have given 60% material removal, the result is shown in "fig10". The material left on bracket is observed carefully and bracket is redesigned again. The redesigned bracket CAD model is developed in CATIA modeling software and it is shown in "fig. 11".

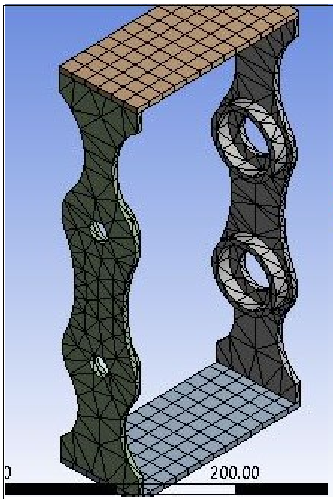

Fig. 12 Mashing

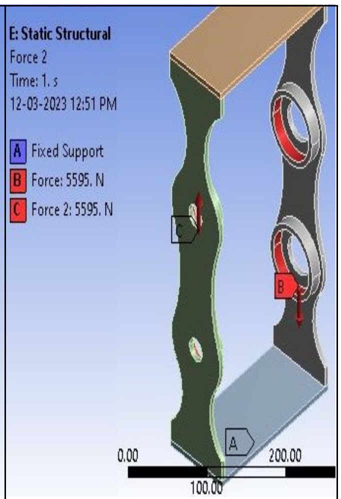

Fig 13 Defining Load

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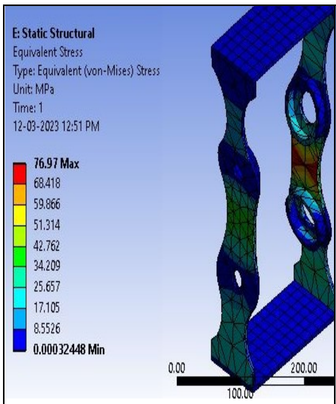

Fig 14 FEA for Stress

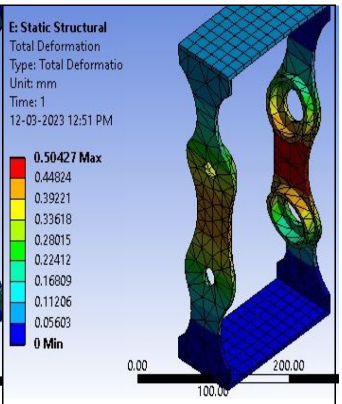

Fig 15 FEA for Deformation

"fig. 12" shows the mesh defined for FEA in the CAD model, the mesh used tetrahedral type mesh with the default mesh size and mesh growth rate is 1.2. In "fig. 13" the point of application of load are defined.

The FEA is done and results are shown in "fig. 14" and "fig. 15". The. Von-mesh stress goes maximum up to 76.97 Mpa and maximum deformation is up to 0.504 mm

VII. RESULT

The conventional design method gives completely enclosed solution and it involves in very high weight. The redesigned solution shows considerable reduction in weight. The bracket type housing cannot act as lubrication storage tank and bracket cannot protect gear units and lubricant from dirt and dust. This problem can also be solved by closing all sides of bracket housing by thin sheet. The following table shows comparison between box type gearbox housing, redesigned bracket type gearbox housing and Topology Optimized bracket type gearbox housing on the basic of weight.

TABLE. 1 RESULT COMPARISON OF TOPOLOGY OPTIMIZED BRACKET

SR. No	Name of Housing	Weight (kg)	% weight reduction
1	Box type Gearbox Housing Weight in (kg)	29 kg	----------
2	Bracket Type Gearbox Housing Weight in (kg)	5.43 kg	**81.28 %**
3	Topology Optimized Bracket type Gearbox Housing Weight in (kg)	4.503 kg	**84.47**

VIII. CONCLUSION

This paper attempted redesigning of box type gearbox housing to bracket type gearbox housing and the Topology Optimization of it. The result shows that the considerable amount of weight can be removed by using Topology Optimization Techniques. The present work shows near about 85 % weight of the Box Type Gearbox Housing reduced. The result also shows that the stress and deformation of newly designed Bracket Type Gearbox Housing not much increase.

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