Optimization of Industrial Gear box Casing

[1] **Balasaheb Sahebrao Vikhe**
Assistant Professor, Dept. of Mechanical Engineering, SVIT College Nasik, Maharashtra, India

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Abstract— This paper contains the study of Optimization of a three stage Commercial gearbox casing using Finite Element Analysis (FEA) Method. The gearbox casing is an important transmission component like gear and shafts. Thus the strength of gearbox casing is to be important parameter to be taken into account while designing. The 3D model is prepared by using Pro-E creo2.0 pre-processing is prepared by using Hypermesh 11.0 while FEM is solved by using Ansys 14.5 solver.
It was statically and dynamically analysed using simulation software Altair Hypermesh and Ansys. Static analysis is to find out the total amount of stresses and displacement of gearbox casing and End cover. Dynamic analysis is to find out theNatural frequency of casing. Optimization is based on Ansys Linear static and dynamic modal analysis results, which can be used to enhance the efficiency of the design process. Considering the results obtained from optimization, geometric model was modified and iterated until satisfactory results were achieved. The process is repeated until all specified criteria are met.

This process helps in finding the optimized design for the gearbox casing in which it has the best performance without any failure and with minimum Loads acting on the casing. After implementing optimization, weight of the gearbox housing will be reduced. FEA also be carried out on optimized design of the gearbox housing to check whether the optimized design is safe or not.

Keywords—**Gearbox casing, CAD, FEA, Optimization, Static analysis, Modal Analysis**

I. INTRODUCTION

The casing encloses completely different sets of gears, bearings to support the shafts. This Gear box is to reduce speed and increase torque. You'll find them between the prime mover (i.e.: motor, gas, diesel or external-combustion engine, etc.) and also the driven equipment: conveyors, mills, paper machines, elevators, screws, agitators, etc. in an exceedingly power transmission gear system, the vibrations generated at the gear mesh are transmitted to the gearbox housing through shafts and bearings. Casing could be a part of gear box, it provides support to shaft, bearing and thence the gear loading.

It is a bimetal casting made of grey forged iron viz., FG260 and FG220. This material selection is based on the factors of strength, rigidity, cost etc. For casting, there are several factors to be considered for better result like material properties, mechanical properties, chemical composition, fluidity, boundary clearance, thermal properties, etc. to meet all this criteria.

The main objective is to hold out analysis of gear case casing and finding out effective design of gear case with relevance cost.

II. Theory

Simulation is to be reliable tool in design and development of gearbox casing. The software's used within the analysis of gearbox casing are Hypermesh 11.0 for Pre processing and Ansys 14.5 for Post Processing. This method set up involves building 3D CAD Model of gearbox casing by Pro-E Creo, determining boundary conditions, studying the material properties and loading pattern.

It is divided into 2 domains:

1. Modal Analysis
2. Static analysis

1. Modal Analysis: To find out the natural frequencies of model. Block Lanczons technique is employed to solve the essential equation. The resonance conditions are evaluated with gear mesh frequency i.e. operative frequency.

Gear mesh frequency= $k*(\frac{N}{60})$ Hz

k= no. of teeth on gear

N = speed of shaft

To determine natural frequencies of element is useful for avoiding resonance, reducing noise, and as a meshing check.

2. Static Analysis: Static analysis of the gear case casing to search out the overall quantity of stresses and displacement. In static analysis there aren't any variations of force with relevance time.

III. METHODOLOGY

The problem under consideration will be modeled through four approaches:

A. CAD Modeling
B. Finite Element Meshing
C. Boundary Conditions
D. Finite Element Analysis
E. Optimization

A. CAD Modeling

The Fig.1 shows representation of gearbox casing. The important parametric quantity while designing gear box casing is ribbing which is to attain required strength. The CAD Model of gearbox casing specification is Length-1435mm Width-520mm Height- 800mm. The CAD model is imported into IGES file format to the FEM design software Altair Hypermesh 11.0.

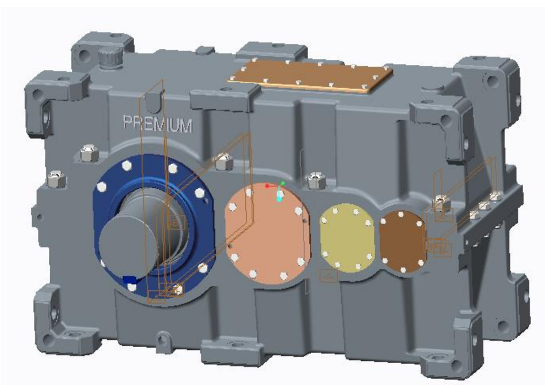

Fig.1 Existing CAD Model

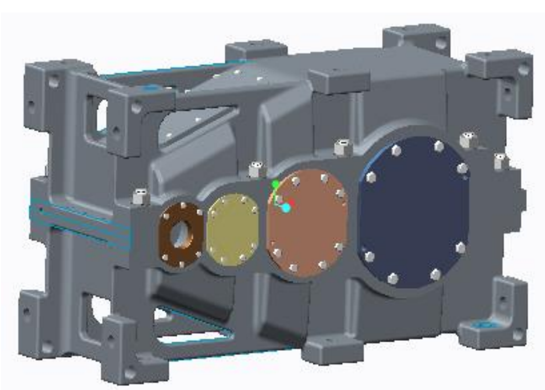

Fig.2 Optimize CAD Model

The CAD Model of gearbox casing specification is Length-1465mm, Width-540mm, Height- 870mm and wall thickness reduced from 16mm to 14mm.

The modified CAD model was subjected to same loading conditions, boundary conditions and material properties as mentioned in linear static analysis and dynamic modal analysis of existing model.

Table.1 Gearbox specification

Input Power	84kW
Input Speed	1000 rpm
Output speed	16 rpm
Unit size	15
Mechanical Rating Power	151kW
Ratio	63:1
Overhung load	150kN

B. FEM Model

The cad model in IGES format is imported in HyperMeshfor the preparation of FE model. Then geometry cleanup was done by using options like 'geom. Cleanup' and 'defeature' to modify the geometry data and prepapre it for meshing operation. Mesh model is prepared by using Hypermesh11.0. 2D Quad or tria meshing is carried out on all the outer and inner surfaces of the geometry, quads splits to trias and then converted to tetras. A 4-node Linear Tetra 3D solid elements are used to model of Gearbox and End covers. The element size selected for Casing and End covers mesh is 10mm. Gearbox model is meshed with about 207700 nodes 792400 elements.

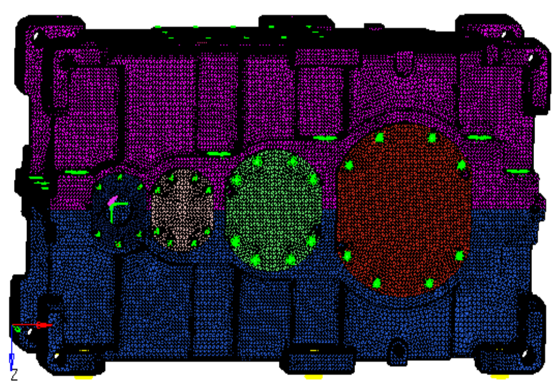

Fig.3 FEM Model

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Table.2 Meshing Quality

2D Cord Meshing	
Aspect Ratio	< 10
War Page	>5
Skew	< 45deg
Jocobian	> 0.6
3D Tetra Meshing	
Tet Collapse	> 0.1 to 0.5
Jocobian	> 0.5

C. Boundary Conditions

Boundary conditions can be applied to geometry, including faces, edges, curves, points, mesh points, vertices, nodes, elements or the entire model. There are various types of load applicable over gearbox casing. The Static load of transmission gear and drive shaft act on bearing hole it divide into two parts namely, Radial force and axial force on each gear have to analysis. These loads are applied to find the actual effect of stress and deformation on gearbox.

The force on each bearing tabulated as follows,

Table.3 Force on each bearing (N)

		X	Y	Z	Angle
Shaft 1	Bearing 1	-7350	4302	-15678	64.88
	Bearing 2	-1955	0	-5778	71.3
Shaft 2	Bearing 1	-3003	5238	31048	84.48
	Bearing 2	-10945	0	51154	77.92
Shaft 3	Bearing 1	-46475	16854	-124897	-68.59
	Bearing 2	3618	0	-98068	-92.11
Shaft 4	Bearing 1	24571	0	223497	96.97
	Bearing 2	41538	26394	-225651	-100.43

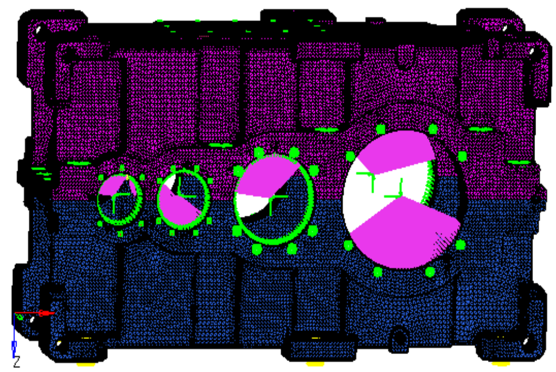

Fig.4 Loading on bearing location

Bearing Radial Forces on the housing are applied on the mass element which is spread over 120° (60° on each side of bearing resultant force direction) on housing through Rigid 1-D Element.

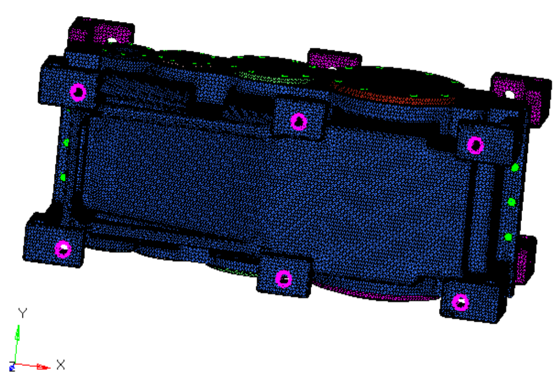

Fig.5 Constrained in all DOF

The Horizontal foot mounted Gearbox bottom casing is fix connected to the foundation via six bolting attachments. Resting face is constrained in all degree of freedom.

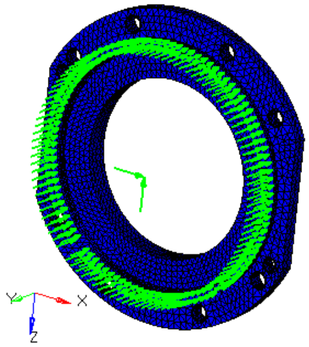

Fig.6 Axial loading on Catcher Cover

Bearing axial forces on the End covers in Y Direction are applied on the nodes at bearing Cir-clip location which is spread over 360° where bearing is axially restricted. They can also be applied to nodes or elements. Define magnitude, direction and position for forces as well as the corresponding constraints. The right relation between the loads is more important than the absolute magnitudes.

Results:-

1. Casing Maximum Displacement = 0.20 mm.
2. End covers Maximum Displacement = 0.15 mm
3. Max Von-Misses Stress observed = 642.09MPa. The stresses observed is concentric in nature thus the average stress in the component is 86.66MPa.Average stress is less than the yield strength of casing material so casing will be safe against load.
4. Max Von-Misses Stress observed = 307.08MPa. The stresses observed is concentric in nature thus the average stress in the component is 73.33MPa.Average stress is less than the yield strength of casing material so casing will be safe against load.
5. Natural frequency of casing is obtained using Ansys and compared with gear mesh frequency i.e. operating frequency. There is no resonance condition found thus the structure and existing design of gear box is safe. Difference between Natural Freq. and Gear mesh freq. 6.7%.

IV. Optimization

Optimization is a process of converging onto a final solution amongst a number of possible options, such that a certain requirements are best satisfied. The objective of the optimization problem is often some sort of maximization or minimization, for example minimization of stress or maximization of stiffness. The purpose of this optimization problem is to minimize the weight of beam without exceeding the allowable stress.

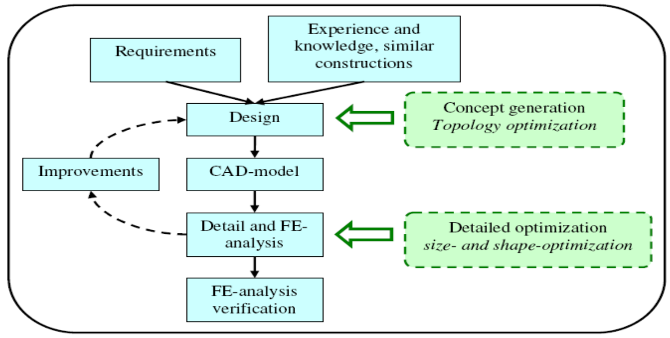

Fig.7 Overview of the design process

Optimization is based on Ansys Linear static and dynamic modal analysis results, which can be used to enhance the efficiency of the design process. The process is repeated until all specified criteria are met.

A. Shape Optimization

The shape optimization design is to place material in areas that truly need it and thin out unnecessary material from areas that are not important for correct function in order to obtain the minimum shape that satisfies all the necessary functional requirements, such as mechanical strength and rigidity.Shape optimization is used to stress relieving in some local regions where the stresses are still high.
Optimization Criteria

1. There must be same pattern for Top and Bottom casing.
2. It should be compatible for all unit size gearboxes.
3. Bearing area should not be changed.
4. Provision of oil pockets should be made for bearings.
5. Area of mounting should not be changed.

V. RESULT AND DISCUSSION

All machine component analysis, a component must be designed such that the stresses occurring during operation will not exceed material limits. The material limits are determined by material properties and some known deformation theories. Analysis has to conclude whether the component is safe or fail comparing the max stress value with yield or ultimate stress.

A. Static Analysis Results

Linear static analysis means that the computed response – displacement or stress is linearly related to force without vary with respect to time or that the time variation is insignificant. The applied force may be used independently or combination with each other. The load can be applied to multiple loading sub-cases, in which each sub-case represents a particular loading or boundary condition. Linear static is type of structural used to solve linear and also nan-linear problems.

Linear Static analysis used to determine the displacements, stresses, strains and forces in structures or components cause by static loads. The solver used for analysis Ansys 14.5.

Results

1. Static analysis

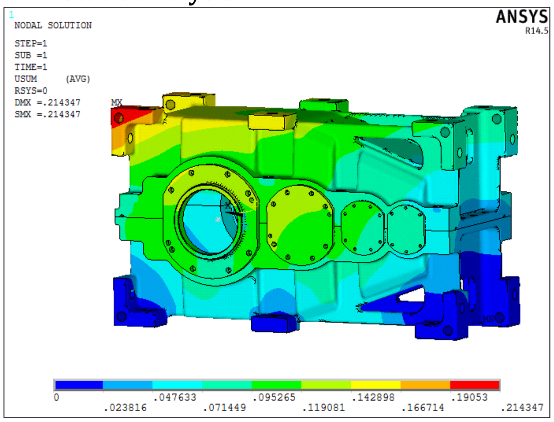

Fig.8 Displacement in gearbox casing

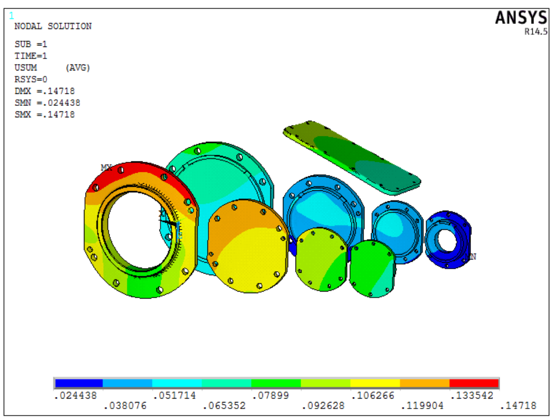

Fig.9 Displacement in Catcher covers.

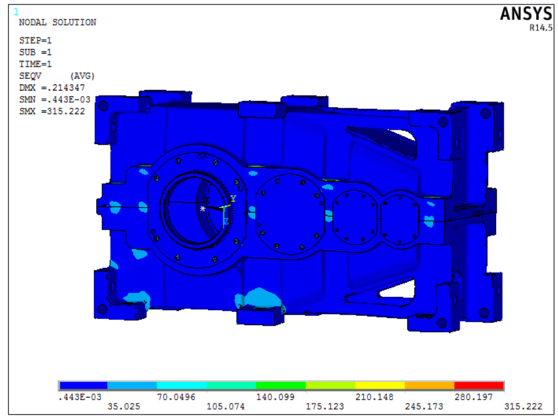

Fig.10 Von-misses stresses on gearbox casing.

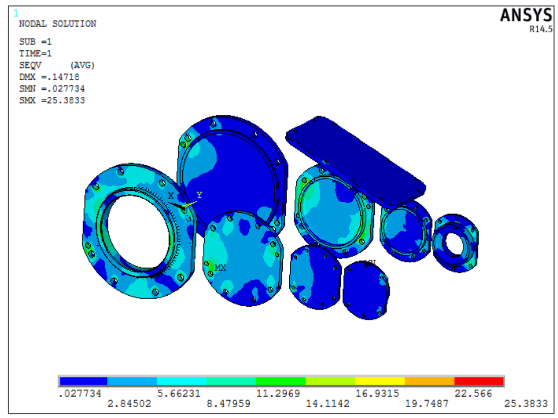

Fig.11 Von-misses stresses on Catcher Covers.

Results:-

1. Casing Maximum Displacement = 0.21 mm.

2. End covers Maximum Displacement = 0.15 mm.

Results:-

a) Max Von-Misses Stress observed = 315.22MPa. The stresses observed is concentric in nature thus the average stress in the component is 140.09MPa.Average stress is less than the yield strength of casing material so casing will be safe against load.
b) Max Von-Misses Stress observed = 25.38MPa. The stresses observed is concentric in nature thus the average stress in the component is 22.56MPa.Average stress is less than the yield strength of casing material so casing will be safe against load.

2. Modal Analysis

Modal analysis had performed in free-free condition, to find out first 10 natural frequencies of the model. Block Lanczos method is used to solve the basic equation

Table 8 Natural Frequency

Modes	Frequency
1	0.0000
2	1.97683E-04
3	3.16297E-04
4	1.09834E-03
5	1.39492E-03
6	2.34410E-03
7	257.10
8	332.58
9	339.03
10	370.51

Natural frequency of casing is obtained using Ansys and compared with gear mesh frequency i.e. operating frequency. There is no resonance condition found thus the structure and existing design of gear box is safe. Difference between Natural Freq. and Gear mesh freq. 9.8%.

VI. CONCLUSION

- Existing Gearbox casing weight 933 kg. Difference between Natural Freq. and Gear mesh freq. 6.7%.
- Shape optimization Gearbox casing weight 826kg hence up to 13% optimization possible than existing gearbox. Difference between Natural Freq. and Gear mesh freq. 9.8% it is greater than existing design of gear box.
- Natural frequency of casing is obtained using Ansys and compared with gear mesh frequency i.e. operating frequency. There is no resonance condition found thus the structure is safe.
- A parametric study was conducted on casing thickness, addition of rib, increasing rib thickness.

  (i) The effect of varying casing thickness on the natural frequencies of the gearbox casing was not significant, as compared to increase in the weight of the gearbox casing.

  (ii) The effect of addition of rib on the natural frequencies of the gearbox casing was significant, as compared to increase in the weight of the gearbox casing.

  (iii) The effect of increase of rib thickness on the natural frequencies of the gearbox casing was not significant, as compared to increase in the weight of the gearbox casing.

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