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STEADY-STATE THERMAL STRESS ANALYSIS OF GEARBOX CASING BY FINITE ELEMENT METHOD

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Abstract - This paper contains the gearbox casing analysis by finite element method (FEM). In previous study the thermal stresses have been affected on the performance of gearbox casing during the running conditions. So, this problem solve by thermal stress analysis method. Thermal stress analysis is the process of analyzing the effect of thermal and mechanical loads, and heat transfer of gearbox casing. In this paper, thermal stresses have been analyzed on gearbox casing, and thus temperature field has been coupled to the 3-Dimensional structure model using Fem. Paper also describes convection effect between the inner-surface of casing and the circulating oil which has been found small and thus neglected. Study of equivalent von-mises stresses in inner and outer gearbox casing with the coupled method has been done using ANSYS software. Result shows thermal stress analysis and deformation value under the action of force and heat. Result finds the thermal stress of the gearbox casing is 68.866 Mpa and 0.15434 mm for the deformation of the gearbox casing.

Keywords - *Finite element analysis, Gearbox casing, Heat transfer, Thermal stresses.*

I. INTRODUCTION

Gearbox is an important component of heavy machinery. The gearbox casing plays a vital role as they house the transmission components. The different components housed are gears, bearings, shafts and oil [1] [3] [5]. Temperature is produced due to friction heat, the faster the speed the generation of heat increases, so the temperature of the gearbox is imbalanced and also it makes the heat transfer steady [1][3], the process has many factors. The heat transfer is related to the overall size of gearbox and wall thickness, so the inside and outside temperature differences are measured for analysis [4]. Heat leads to the rise the temperature of component and large hot deformation and gear engage accuracy is also affected [3].

Thermal analysis works on the basic theory of steady-state heat conduction and heat convection, the total value of temperature and heat flux on the gearbox are calculated, along with heat dissipation value of each part in gearbox casing. Temperature was generated stress during the heat increases on the gearbox casing body. The effect of temperature stress field, the non-uniform loading along casing at time, casing creep deformation under the condition of temperature field should also be considered [7]. So, the gearbox casing was deformed during of the more thermal stresses produced by temperature generated.

Stress analysis is engineering discipline that determines the stress in materials and structures subjected to static and dynamic forces or loads. A thermal stress analysis is required for the study and design of structures, e.g., tunnels, mechanical parts and structural frames among others, under prescribed or expected loads. There are many engineering problems which require thermal stress analysis, because the objects are subjected to thermal load. In order to solve the problems, it is necessary to know the stationary and transient temperature distribution prior to the stress analysis. Thermal stress analysis is a critical factor in design of many mechanical product and system. Some research had been done, but they did not find measures or schemes deformation [7]. So, solve the thermal stresses effects problem on the gearbox casing by used to Finite Elements Method.

FEA method is used to analyze static and thermal-structural coupled properties of the case and steady temperature fields of case and transmission parts in high-speed class. The consideration of the effects on gearbox in the action of thermal and structural load, gearbox stress distribution can be satisfied for working condition by thermal-structural coupled analysis using ANSYS.

The main aim of the thermal stress analysis is usually to determine whether the element or collection of elements, usually referred as a structure, can safely withstand the specified thermal load. Thermal stresses have traditionally been analyzed by using strength of materials and structures of gearbox casing.

The main objectives of the work to impotence have to show in below.

- To carry out thermal stress analysis using ANSYS software for analyzing thermal load and temperature effect in the gearbox casing.
- In future for optimization and design modification of gearbox casing for better output performance.
- Reverse engineering is also possible in design of gearbox casing.

II. METHOLOGY OF MODLING AND ANALYSIS

Thermal stress field of gearbox casing has been analyzed under the condition of temperature load further in this paper. Then the temperature distributions are translated to thermal loads in the finite element model to calculate stress and deformation in the gearbox casing using commercial software ANSYS. FEA outsourcing thus helps in efficient managing of thermal loads, temperature distribution and heat transfer rates in any mechanical component and system. The thermal boundary conditions are discussed and the attempts to overcome these are described using a combination of heat transfer theory and experimental results [2].

A. Model Preparations for Analysis

1. Assembly modeling of Gearbox Casing in PRO-E

To check the temperature reaction of the gearbox casing for the given temperature data during the operation, the 3-D assembly modeling of gearbox casing is required. The detail of gearbox casing modeling is defined in Table 1 and Figure 1.

Table 1. Details of parameters for Gearbox casing Model

Definition	
Type	Creo Parametric
Length Unit	Millimeters
Bounding Box	
Length X	1572. mm
Length Y	800. mm
Length Z	535. mm
Properties	
Volume	1.7793e+008 mm³
Mass	1.2811 t
Material Properties	
Assignment	Gray Cast Iron
Poisson's ratio	0.28
density	7200 kg m^{-3}
Thermal expansion	$1.1\times E^{-5}$ C^{-1}
Thermal conductivity	52 $wm^{-1}C^{-1}$

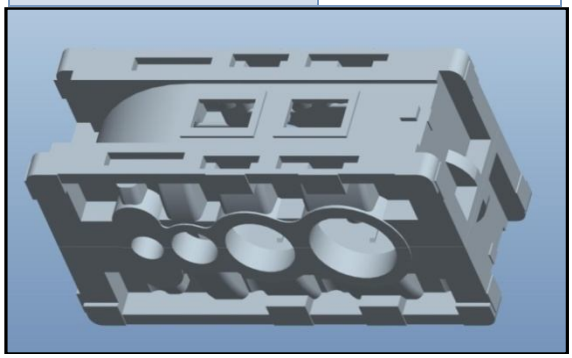

Fig. 1 : 3-Dimesional Assembly modeling of Gear Case in Pro-E

2. Mesh Strategy

The details of mesh strategy are defined in Table 2 and Figure 2. This mesh is applied to whole object as one body meshing. Here to use a Tetrahedron Elements Method to use for solve the gearbox casing model and also Patch Method effect is used to find the maximum effects shown to generated heat on the bearing holes as shown in Figure 2.

Table 2. Details of meshing strategy

Object Name	*Mesh*
State	Solved
Defaults	
Physics Preference	Mechanical
Relevance	100
Advanced and Sizing	
Relevance Centre	Fine
Element Size	15.0 mm
Shape Checking	Shape Checking
Element Midside Nodes	Program Controlled
Straight Sided Elements	No
Initial Size Seed	Active Assembly
Smoothing	High
Transition	Fast
Statistics	
Nodes	840471
Elements	528932

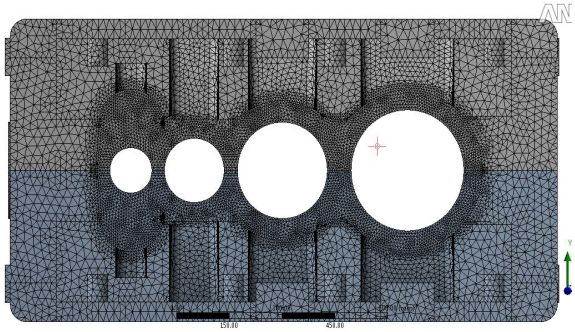

Fig. 2 : FEA model of gearbox casing

3. Boundary Condition And Applied Load

This section describes the details of applied load and boundary condition of thermal stress analysis.

A. Thermal boundary condition

A thermal analysis has been performed using temperatures history data. The details of the temperatures are in Figure 3.

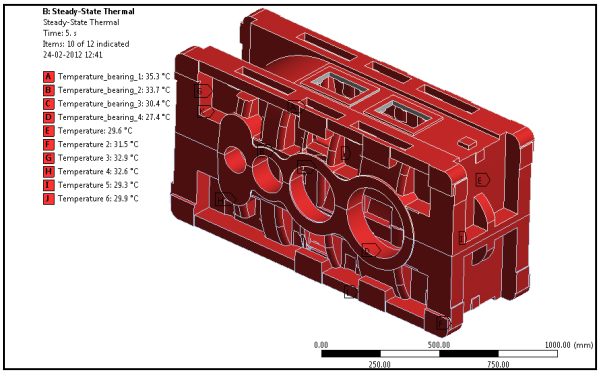

Fig. 3 : Thermal boundary condition of gearbox casing

B. Mechanical boundary condition

The exact condition of mechanical performances with the fixed support is shown in the Figure 4.

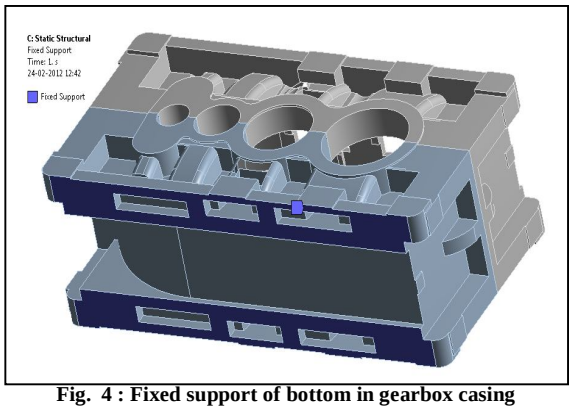

Fig. 4 : Fixed support of bottom in gearbox casing

In this analysis, bearing radial and axial loads are applied of the bearings to the surface according to the Figure 5

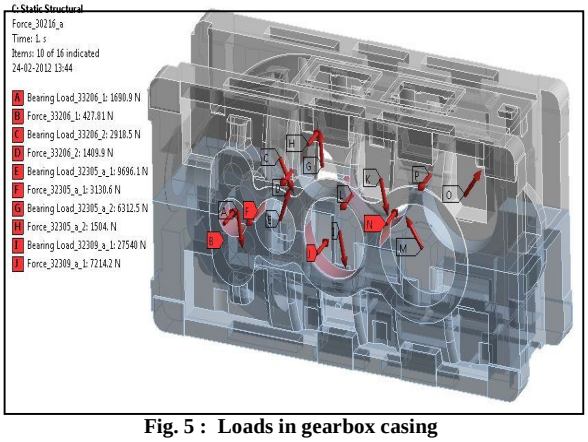

Fig. 5 : Loads in gearbox casing

C. Use parameters for the analysis

The bearing loads have been applied on the gearbox casing by running conditions. So, the bearing load parameters are shown in below Table 3. This load table has been found to the Bearing-X software.

Table 3: Bearing load table

ANSYS Code	Bearing No.	RADIAL Load Components (N)		AXIAL Load mponent (N)
A,B	33206	244.86	-1673.10	-427.81
C,D	33206	1408.33	-2556.18	1409.88
E,F	32305-A	3600.04	9003.05	3130.55
G,H	32305-A	-461.86	6295.56	-1504.00
I,J	32309-A	5894.60	-26902.22	-7214.23
K,L	32309-A	4956.41	-20720.01	13204.41
M,N	32013-X	-19412.73	25446.91	-12483.45
O,P	30216-A	8770.36	11106.01	3884.64

These bearing loads were applied in the mechanical analysis for found the actual effects of stress on gearbox casing.

III. RESULT AND DISCUSSION

The results of thermal-stress coupled analysis are captured in ANSYS 14.0

A. Result of Temperatures effect and Heat flux Analysis

The temperature effect and heat flux field results are shown in Figure 6 and Figure 7.

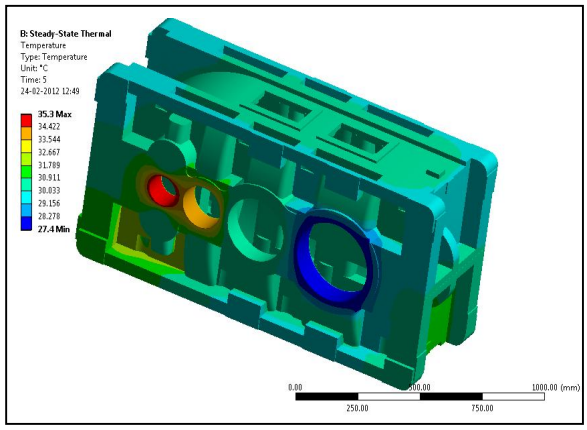

Fig. 6 : Temperatures effect on gearbox casing,

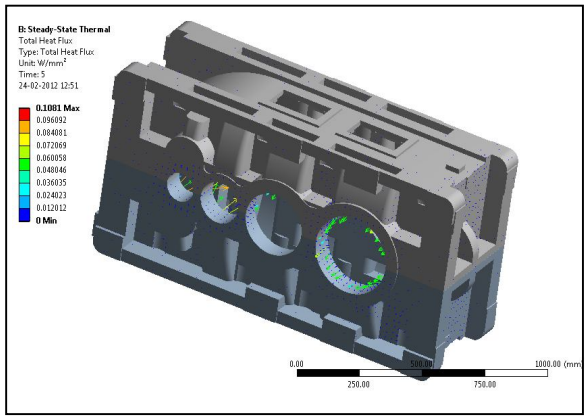

Fig. 7 : Heat flux of gearbox casing

From these results, it is found that during temperature increases on the casing due to bearing loads and oil temperature.

B. Result of Thermal Stress Analysis

Thermal analysis results are transferred to Mechanical analysis for the thermal load effect produced in the gearbox casing. This mechanical and thermal load produces thermal stresses and deformation in the gearbox casing as shown in Figure. 8 and Figure 9 for thermal stress in upper and lower casing body. The stress field shown in the figure is equivalent thermal stress field, to determine whether casing reaches its yield limits. In Figure 8 and Figure 9, the maximum equivalent stress of the upper and lower casing models in table 4. Both figures show theoretical and practical data for use casing strength design under the temperature field.

Gearbox casing deformation has been shown in Figure 10. The maximum displacement of the casing is found, taking place in the formation shown in Table 4. The deformation in Figure 10 is magnified in

order to see the relative positions of deformation, and thermal and mechanical loads data are used.

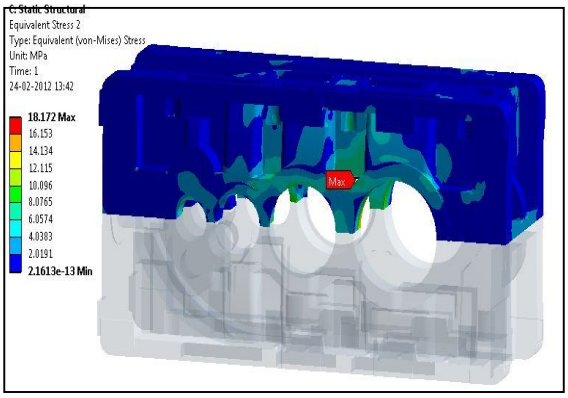

Fig. 8 : Von-mises stresses on upper gearbox casing

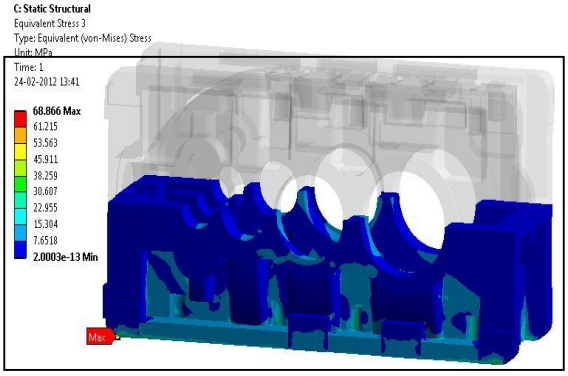

Fig. 9 : Von-mises stresses on lower gearbox casing

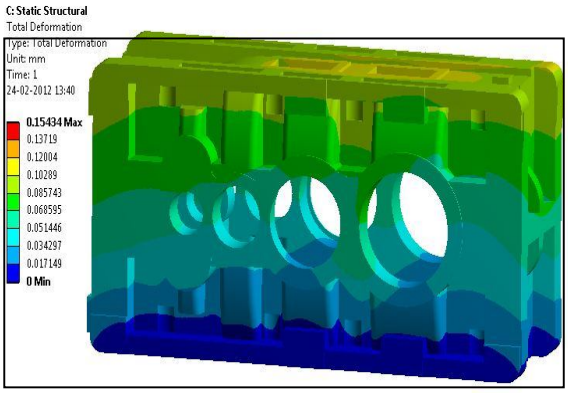

Fig. 10 : Deformation of gearbox casing

C. Result Table

Result table 4 as shown in below for the thermal stresses and deformation on the gearbox casing is found by thermal stress analysis method.

Table 4 Results Table

components	Results
Upper gearbox casing	18.172 Mpa
Lower gearbox casing	68.866 Mpa
Deformation of gearbox casing	0.15434 mm

IV. BENEFITS SUMMARY

- The implementation of thermal stress analysis has helped in developing an optimum design.
- It has helped in selection of appropriate material for cost effective design.
- Reduced prototype development and testing time.

V. CONCLUSION

In this paper, study has been carried out to evaluate thermal stress analysis of the gearbox casing using commercial software ANSYS. ANSYS finite element package can be used to simulate both mechanical and thermal stress in the gearbox casing structure. The temperature has an influence on the increase of produced stresses and deformations. Thermal stress analysis is to find out the total amount of stresses and deformation of any structural component by thermal and mechanical load. The gearbox casing is manufactured from cast iron. The temperature has an influence on the values of the principal stresses arising in the gearbox casing.

The maximum equivalent stress of the upper and lower casing models are 18.172 MPa and 68.866 MPa respectively. Also the maximum displacement of the casing it is found 0.15434 mm. In practice thermal stress analysis is also important factor for the optimum design and reverse engineering of any mechanical structure and system.

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