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Structural Stress Analysis of Reduction Helical Gear box Casing

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ABSTRACT:-*The gearbox housing design process for the industrial applications has been significantly refined through the proper utilization of finite element analysis tools. These advanced capabilities enable to directly import gearbox housing CAD geometry into the finite element analysis tools. Complex casting casings can be analyzed within very short duration of time. These tools can be effectively used in the structural modifications & optimizations of the complex housings, which subsequently reduce the cost of material & further manufacturing processes. Correlation approach is required between computer aided design & experimental validation for fast design decision making process. This paperdescribes the correlation study for verification of analytical stress calculation & comparison between experimental stress analysis techniques.*

Index Terms*:-Experimental stress verification, strain gauging Linear structural analysis.*

I. INTRODUCTION

The aim of this research work is to describe a static stress correlation study as performed on structural elements of industrial gearboxes, specifically helical gearboxes.

The helical gearbox which is a simple parallel shaft gearbox, transfer the torque & speed which was received from prime mover to the specific application. All the internals like pinion shafts, gear wheels, bearings are rigidly supported by casing. Casing must be sturdy so as to sustain all types of loads received from application& bearing reactions.

The gearbox casing design is very critical design step, because it decides the working behavior of total gearbox assembly in the full load condition. Deflection of casing affects gear tooth meshing. The gearbox casing analysis is very essential because to predict total gearbox behavior under different operating conditions.

II. GEARBOXES TYPES & ITS ANALYSIS

There are two main types of gearboxes used in the mechanical field.

1) Industrial gearboxes
- Helical gearboxes
- Planetary gearboxes
- Bevel gearboxes
- Worm gearboxes

2) Automobile gearboxes.
- Constant mesh gearboxes
- Sliding mesh gearboxes
- Synchromesh gearboxes

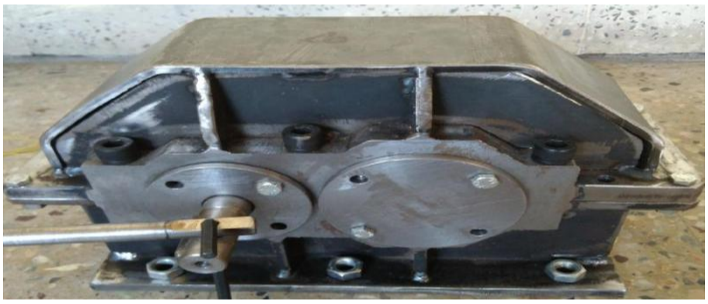

Fig. 1. Fabricated helical gearbox

In the industrial practice, there are various types of analysis are carried out for gearboxes, as below.

- Linear Static analysis.
- Dynamic analysis
- Fatigue analysis.
- NVH analysis.

III. LINEAR STATIC ANALYSIS FOR HELICAL GEARBOX

The linear static analysis means no variation in the load value with respect to time (e.g. Dead weight). Analyst has to conclude whether the component is safe or failed by comparing the maximum stress value with yield or ultimate stress.

1. Problem Definition

This chapter describes study of the helical gearbox whose linear static analysis to be performed. Studying the actual working conditions input like constraints, boundary conditions, 3D geometry of the object, Material property details etc.

2. Creating and Meshing the 3D Model

Modeling is based on a Conceptual understanding of the physical system and judgment of the behavior of the structure under load. The Pre-Processing mainly involves the modeling of the 3-D components like gearbox casing & internals. Hyper mesh is used for preprocessing. The casing model is discretized into number of finite elements. 2D meshing is of quadrilateral type& 3D meshing is of tetragonal type.Nodes and element types are so selected so that the analysis is sufficiently accurate. Aspect ratio & Jocobian kept near to unity for better accuracy.

The bearing reactions calculated by considering respective torque values per stage. The helical gearing produces both radial & thrust loads on bearings. The load directions are dependent upon the direction of rotation of gear pair. So the bearings of parallel shaft industrial helical gearboxes induce different reaction for same torque in the same ratio stage.

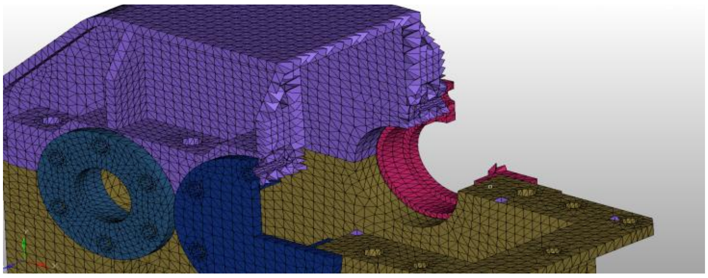

Fig.2. 3D mask view of meshing

3. Material data & boundary conditions

The basic material properties details like E, υ, ρ, σ, σ-ε, S-N curve etc. are collected for both FG 260 & structural steel. The clear understanding of functionality& application of the gearbox would help in deciding appropriate load cases & constraints.

Due consideration should be given to all possibilities like overloading from prime mover, application loads, application foundation vibration effect, surface finish of friction components, & process induced stresses. The gearbox casing could be manufactured by casting & fabrication process. The casting method uses grades of FG 260, SG 410 etc. The fabrication process is in the material of structural steel confirming to IS: 2062.

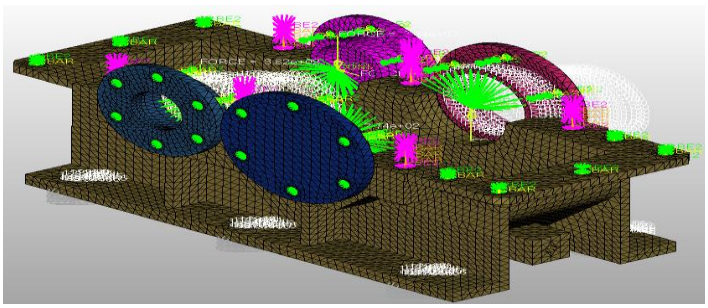

Fig.3. Constraint & load condition

4. FEA Result and Discussion

The gearbox casing analyzed by using hyper mesh & Optistruct solvers. The static analysis gives result output in terms of stress& deflection. The result shows the higher & lower stress areas which have the chances of improvement of stress values.But during size & weight optimization of casing, care should be taken about the manufacturing constraints in terms of minimum wall thickness of casing to avoid distortion during stress relieving cycle, material availability etc.

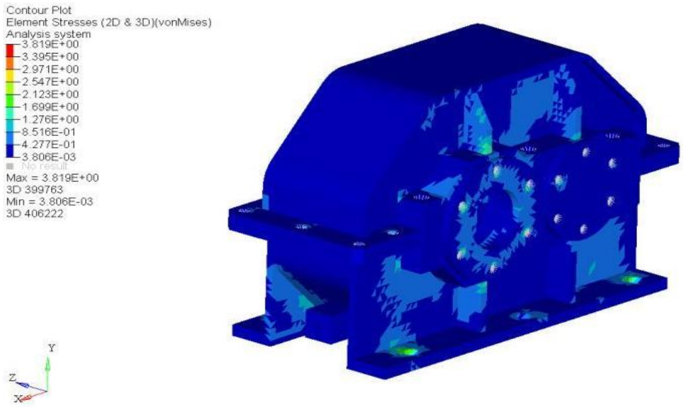

Fig. 4. Stress contour plot

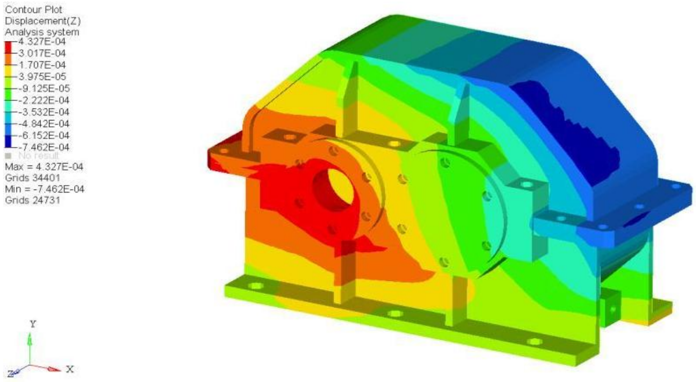

Fig. 5. Displacement contour plot 1

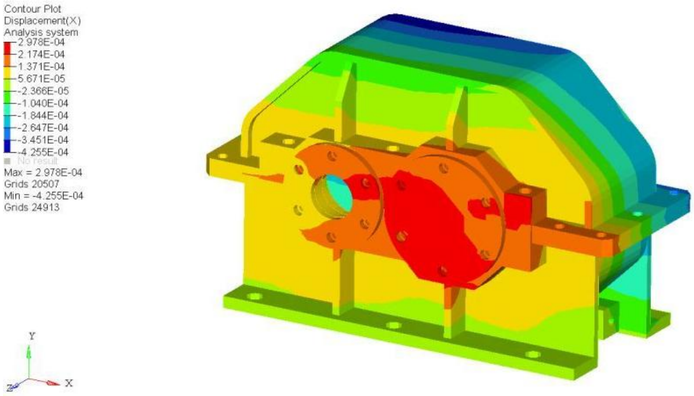

Fig. 6. Displacement contour plot 2

5. Experimental setup

Strain gauges were invented by Edward Simmons. The meaning of strain gauge is a sensor to measure deformation. Most probably used strain gauges are of foil type having constantan wire. The application of forces like dead weight, pressure, etc. results in change in electrical resistance of wire. It is connected to Wheatstone bridge & change in resistance could be measured. The output received from strain gauges is in terms of millivolts & this receives at the end of Whetstones Bridge. As the output voltage is having very less magnitude in terms of mV, so we can use voltage amplifier to get amplified voltage magnitude.

The 3 types of electric Wheatstone bridge circuits are used in strain gauging process. Quaterbridge, half bridge, & full bridge.

The selection of these bridge circuits depends upon the accuracy level required. The accuracy level varies from high to low for full bridge to quaterbridge circuit.

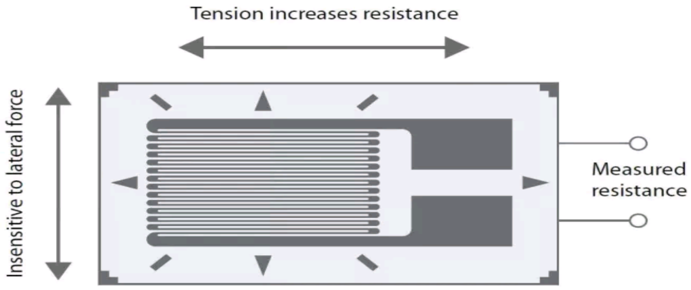

Fig. 7. Strain gauge terminology

For static analysis, leverage loading arrangement is used to apply the input torque to the pinion by changing the dead weight, instead of providing the input torque from the motor. The loading of gear box is made with the help of a lever of 500 mm in length which is connected to input shaft &on which a pan is attached for the purpose of addition of weights.The output shaft is having a key slot which can be locked in the gear box casing.

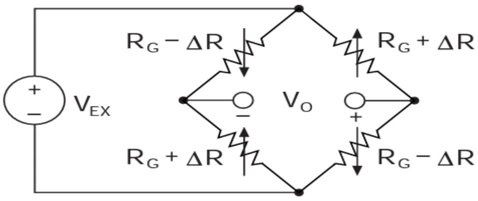

Fig.8. full bridge Wheatstone circuit

$$\frac{v_o}{v_{ex}} = -gf \times \varepsilon$$

v_o is the output voltage from strain gauge.
v_{ex} is the input voltage given for whetstone bridge.
gf is the gauge factor of selected strain gauge.

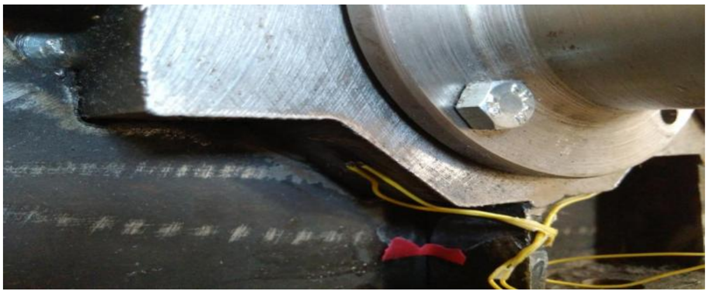

Fig. 9. Strain gauge positions

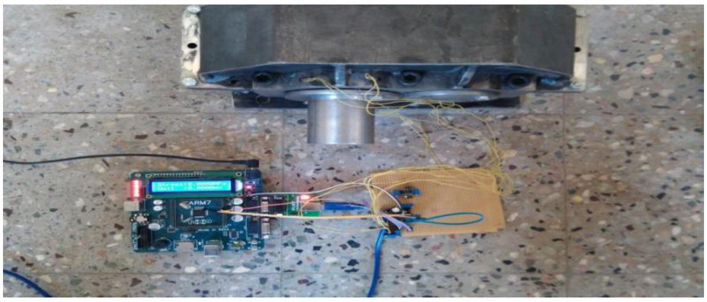

Fig. 10. Experimental setup

The strain gauge sensors are used to measure the strains in the gearbox. The strain gauges used are of 350Ω resistance, 10mv max. Output voltage capacity. The Loctite 415 grade used to stick the strain gauges on the gearbox casing. The positions of strain gauges & its direction are decided by studying the force flow direction in the casing.

The Wheatstone bridge circuit is used & output from strain gauge is given to bridge & then after to strain gauge indicator. The strain gauge shows the strain values received from sensor.

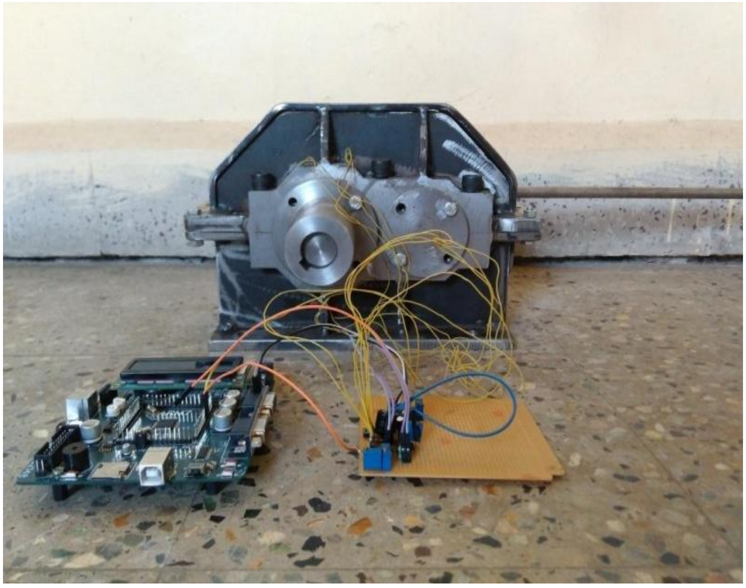

Fig. 11. Load cases

Full bridge circuit uses the all four strain gauges & this is one of the accurate methods of strain measurement. Strain gauge indicator indicates the strain values & some indicates the directly stress induces on the casing.

6. Validation

The stress values obtained by Finite Element Method for helical gear casing will be validated by comparing results obtained from experimental method. The correlation between these two methods could be in the range of 80-90 %.

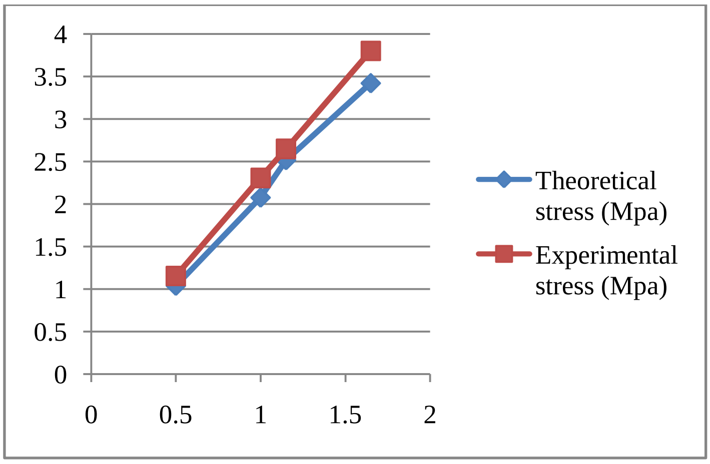

Table 1. Correlation graph against applied torque

IV. CONCLUSION

The aim was to reduce the weight of the casing. For that we have did several design modifications in the gearbox geometry of casing in terms of size & shape optimization. The casting material of current design is changed to structural steel. Further experimental model using structural steel was prepared and tested for the industry and results were obtained for same conditions. Which also confirmed the lowest stress deformation for structural steel and also both analytical and experimental results were compared and were almost same.

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