Design Modelling And Finite Element Analysis Of Double Helical Gearing System For High Speed Compressor Engines

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Abstract: High speed gears are designed to transmit power through parallel or, less commonly, perpendicular axes. The unique tooth structure of a gears consists of two adjacent, opposite helixes that appear in the shape of the letter ’V’. Helical gears with multiple teeth on both sides are engaged during rotation, distributing the work load and offering quiet operation. However, due to their tooth structure, double helical gears nullify the axial thrust typical of helical gears. The gear set's teeth may be manufactured so that tooth-tip aligns with the opposite tooth-tip, or so tooth-tip aligns with the opposite gear’s tooth trough. In this project, high speed gears are used in a compressor gear box will be designed and modeled in 3D modeling software CATIA. Static analysis, Modal analysis and Fatigue analysis will be done on the gears in Ansys. Different materials are analyzed for comparison Structural Steel, Cast Iron and Alloy Steel. The better material is determined from this analysis.

Keywords: Helical Gears; 3D Modeling Software CATIA;

I. INTRODUCTION

The term “Gear” is defined as a machine element used to transmit motion and power between rotating shafts by means of progressive rendezvous of projections called teeth. Invention of the gear cannot be attributed to one individual as the development of the toothed gearing system evolved gradually from the primitive form when wooden pins were arranged on the periphery of simple, solid, wooden wheels to drive the opposite member of the pair. These wheels served the purpose of gears in those days. Gears are used in most types of machinery. Like nuts and bolts, they are common machine elements that will be needed from time to time by almost all machine designers. Gears have been in use for over many years, and they are an important element in all machinery used now days.

Type of gears
There is a wide Variety of types of gears in existence, each serving a range of functions. In order to understand gearing, it is desirable to classify the more important types in some way. One approach is by the relationship of the shaft axes on which the gears are mounted. As listed in Table, shafts parallel. Intersecting or non intersecting and non parallel.

II. PROBLEM DEFINITION

The objective of this project is to make a 3D model of the helical gears used in a compressor gear box, is designed and modeled in 3D modeling software Solid works and Catia. Static analysis, Modal analysis and Fatigue analysis is done in Ansys.

III. METHODOLOGY

A 3D model of the gear using solid- works software is generated and imported to ANSYS to Perform Static analysis on the gear. Modal analysis is Performed on the gear, Different materials are analyzed for comparison of Cast Steel, Cast Iron, structural steel, Based on the results obtained, some design changes are implemented to get better material for gear.

IV. LITERATURE REVIEW

Negash Alemu, 2007. This thesis investigates the characteristics of an involute helical gear system mainly focused on bending and contact stresses using analytical and finite element analysis. To estimate the bending stress. From the results of this study, the following specific conclusions are drawn: The strength of the gear tooth is a crucial parameter to prevent failure. It is also shown that the development of finite element analysis model of the equivalent contact cylinders to simulate the contact stress between two gears reasonably. Based
on the result from the contact stress analysis the hardness of the gear tooth profile can be improved to resist pitting failure. The face width and helix angle are an important geometrical parameters during the design. As it is expected, in this work the maximum bending stress decreases with increasing face width and it will be higher on gear of lower face width with higher helix angle.

Aarthi Vaidyanathan, 2009. In this study, a test methodology for measuring load-dependent (mechanical) and load independent power losses of helical gear pairs is developed. A high-speed four-square type test machine is adapted for this purpose. Several sets of helical gears having varying module, pressure angle and helix angle are procured, and their power losses under jet lubricated conditions are measured at various speed and torque levels. The following conclusions can be made based on the experimental study: The gear module and pressure angle are more significant than the helix angle in terms of their influence on gearbox power losses. Similar to the findings of Petry-Johnson and Moorhead, the gearbox mechanical power loss almost linearly with rotational speed and shows an increase beyond a linear relationship with input torque. The measured spin power loss values for every gear set tested were very close to each other, suggesting that gear parameters varied are not critical to spin losses, confirming results of Seetharaman and Kahraman.

Raghava Krishna Sameer, V.Srikanth, 2014. This study presents a One of the main reason of the failure in the gear is bending stresses and vibrations also to be taken into account. But the stresses are occurred due to the contact between two gears while power transmission process is started. Due to meshing between two gears contact stresses are evolved. The strength of the gear tooth is important parameter to resist failure. In this study, it is shown that the effective method to estimate the contact stresses using three dimensional model of both the different gears and to verify the accuracy of this method. Can be improved to resist pitting failure a phenomena in which a small particle are removed from the surface of the tooth that is because of the high contact stresses that are present between mating teeth. Failure theory by which the design aspects are to no changed to reduce the contact stresses.

B.Venkatesh .V.Kamala, A.M.K.Prasad, 2010. The main objective of this study is to structural analysis on a high speed helical gear used in marine engines, have been carried out. The dimensions of the model have been arrived at by theoretical methods. The stresses generated and the deflections of the tooth have been analyzed for different materials. Finally the results obtained by theoretical analysis and Finite Element Analysis are compared to check the correctness. Results indicate that: Bending, compressive, Von-misses stresses were obtained by theoretical and Ansys software for Aluminum alloy. The obtained stresses by ANSYS are less than that of the theoretical calculations. From the results, it is observed that the bending and compressive stresses of aluminum alloy (ceramics) are less than than of the other material like steel. Aluminum alloy reduces the weight up to 5567% compares to the other materials. Aluminum is having unique property (i.e. corrosive resistance), good surface finishing, hence it permits excellent silent operation. Weight reduction is a very important criterion, in order to minimize the UN balanced forces setup in the marine gear system, there by improves the system performance. Hence aluminum alloy is best suited for marine gear in the high speed applications. The designed gear set have been manufactured using gear hobbing technique and finished by gear shaving operation and tested for the strength of the gear teeth.

V. AIM OF THE PROJECT

Optimal design of gears requires the consideration of the two type parameters: Material and geometrical parameters. The choice of stronger material parameters may allow the choice of finer geometrical parameters and vice versa. Very important difference among these two parameters is that the geometrical parameters are often varied independently. On the other hand, material parameters can be inherently correlated to each other and may not be varied independently. Because of widely varying requirements, gears are produced from a wide variety of materials. These materials include plastics such as nylon, powdered metals, brasses, bronzes, cast or ductile irons, and steels. Many types of steels, including stainless steel and tool steel, are used.

The thrust forces impose reactions on the bearings. This increases the size and cost of bearings. The thrust forces on input and output shafts can be eliminated by using herringbone or double helical gears.

The main aim of this project is to optimize the better material for double helical gears by performing analytical investigations. Structural, Modal and Random Vibration analysis is performed by varying materials to determine better material by observing stresses, deformations, frequencies and shear stresses. The materials considered are Alloy Steel, Cast Iron, and Structural Steel.

VI. MATERIAL SELECTION

Gear Material Selection material with best characteristic among alternatives.
STEEL

Density = 7850 Kg/m$^3$
Young’s Modulus (EX) = 200 Gpa
Poisson’s Ratio (PRXY) = 0.3

CAST IRON

Density = 7810 Kg/m$^3$
Young’s Modulus (EX) = 240 Gpa
Poisson’s Ratio (PRXY) = 0.370

CAST STEEL

Density = 7860 Kg/m$^3$
Young’s Modulus (EX) = 207 Gpa
Poisson’s Ratio (PRXY) = 0.29

Design Considering the module =5,
number of teeth = 18 and 20 full depth.

Speeds are considering as N = 1000 rpm
Power transmitted = 15 KW

**Torque**

For 10000 rpm, T = 153.3 N-m

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Symbol</th>
<th>Formula</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pressure angle</td>
<td>$\phi$</td>
<td>$1^*m$</td>
<td>20°</td>
</tr>
<tr>
<td>Helix angle</td>
<td>$\alpha$</td>
<td>$1.25^*m$</td>
<td>20°</td>
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<tr>
<td>Module</td>
<td>m</td>
<td>$2.25^*m$</td>
<td>5mm</td>
</tr>
<tr>
<td>Addendum</td>
<td>$a_a$</td>
<td>$1.5708^*T_p$</td>
<td>5mm</td>
</tr>
<tr>
<td>Dedendum</td>
<td>$d_a$</td>
<td>$m *T_p$</td>
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<tr>
<td>Minimum total depth</td>
<td></td>
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<td>11.25mm</td>
</tr>
<tr>
<td>Thickness of tooth</td>
<td>t</td>
<td></td>
<td>10.25mm</td>
</tr>
<tr>
<td>Number of teeth</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Gear</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Diameter of gear</td>
<td>$D_g$</td>
<td>$m *T_g$</td>
<td>270mm</td>
</tr>
<tr>
<td>Circular pitch</td>
<td>$P_c$</td>
<td>$\pi^*m$</td>
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</tr>
<tr>
<td>face width</td>
<td>b</td>
<td>$2.3Pc/tan\alpha$</td>
<td>62.8mm</td>
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<tr>
<td>Work depth</td>
<td></td>
<td>$2^*m$</td>
<td>10mm</td>
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<tr>
<td>Fillet radius</td>
<td></td>
<td>$0.4^*m$</td>
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<tr>
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<td>10.25mm</td>
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<tr>
<td>Total thickness</td>
<td>$T_t$</td>
<td>$1.5708^m$</td>
<td>7.854m</td>
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<tr>
<td>Minimum clearance</td>
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<td>$0.25^m$</td>
<td>1.25mm</td>
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</table>

Diameter of gear $D_g = m * T_g = 5 *54 = 270$ mm

Circular pitch $P_c = \frac{\pi^*D_g}{T} = \frac{3.14^*270}{54} = 15.7 mm$

Face width $b = 4 \pi m = 4^*3.14^*5 = 62.8$ mm

Tangential force $W_t = \frac{2000^*T}{D_g} = \frac{2000^*143.3}{270} = 1061.481 N$

Normal force $W_n = \frac{W_t \tan \alpha}{\sin \alpha} = \frac{1061.481^*\tan 20^o}{\sin 20^o} = 1129.60$ mm

VII. **MODELLING AND ANALYSIS**

Figures showing the modeling and stress analysis of Gears
VIII. RESULTS

![Graph showing comparison of stress values for different materials]

IX. CONCLUSIONS

Structural, Modal and Fatigue analysis is done on the herringbone gears for different materials Alloy Steel, Cast Iron and Structural steel. By observing structural analysis results, the stress values are less than the permissible strength for all materials. The deformation and stress values are less for Cast Iron than Structural Steel and Alloy Steel. By observing the modal analysis results, the frequency values are less for Structural Steel so vibrations will be less when Structural Steel and the deformation is also less. By observing the fatigue analysis results, the damage is less for Alloy Steel than other materials. So it can be concluded that using Alloy Steel is better for this application due to the analysis results.

X. REFERENCES


