WEIGHT OPTIMIZATION OF HELICAL GEAR UNDER STATIC ANALYSIS

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ABSTRACT

The most fundamental component that plays a vital role in the mechanical power train system and industrial machineries are the gears. Though gears have a wide range of advantageous properties, its primary limitations are its weight and size. The gear weight optimization plays an important role in manufacturing industries. Stresses are developed at the contact point of the two gear during mating while transmitting power. Hence the goal of this study is to impart circular holes in the gear to reduce the weight of the gear. In order to optimize the weight of the gear some additional geometrical characteristics have been implemented and the corresponding variations in the stresses developed are noted. A finite element model of helical gear is considered for the study and static stress analysis is carried out using ANSYS and a comparative study on helical gear design and its performance based on various geometrical features are carried out.

Keywords: Helical gear, weight optimization, circular holes.


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1. INTRODUCTION

The velocity ratio of the machine reduces due to slip. For miniscule machining operations, a constant velocity ratio is essential and the only positive drive to achieve this is by means of gears or toothed wheels. For smaller distances between driver and the driven, gear drives are used. Helical gears have more advantages over spur gears. The edge of each gear tooth is inclined at a defined angle rather than the conventional parallel orientation, making the tooth shape a segment of a helix. Meshing is done either parallelly or in a crossed fashion which refers that the shafts are parallel to each other or are non-parallel respectively. Some types of non-parallel gears are known as "skew gears".
2. LITERATURE SURVEY

1. Sarfraz Ali N. Quadri, Dhanajay R. Dolas [1] Mass Reduction of Involute Spur Gear under Static Loading. American Journal of Mechanical Engineering and Automation. Explained that some geometrical features have been incorporated in the spur gear to optimize the weight and to know its effect on the development of stresses. A finite element model of spur gear is considered for the study and static stress analysis is carried out using ANSYS.

2. S. Jyothirmai, R. Ramesh, T. Swarnalatha, D. Renuka [2] The purpose of this study is to conduct a correlative research on helical gear design and its characteristics based on a variety of performance metrics over finite element as well as analytical approaches. The theoretical analysis for a single helical gear system based on

3. Krunalkumar Makwana, Purnank Bhatt [3] Optimization of gearbox to improve performance in gearbox. The goal of gear optimization is to decrease total mass of gears while assuring adequate stiffness. These are extensively used for scientific & research purposes. It is accurate & also has a number of built in functions which makes it versatile. American Gear Manufacturing (AGMA) standards have been assessed in Matlab.

4. Sameer Chakravarthy N C and B Subbaratnam [4] In Military vehicles of tracked type, the gearbox is defenseless to a significant amount of damage due to fatigue over its life time due to the active excitations caused by the terrain fluctuations. To satisfy this sole purpose, static analysis of the model was performed to ensure the model and the boundary conditions accuracy. Further, Modal Analysis is discharged to determine the dynamic characteristics of the gear model. The random load time history is renovated in to a frequency domain using Fast Fourier transform to obtain load Power Spectral Density (PSD).

5. Mr. Suhas Alkunte1, Dr. S.Y.Gajjal [5]. The sole purpose of this study is to insert a circular hole to reduce weight or mass of the gear. This study signifies the contact stress analysis between two spur gear teeth that were placed at different positions during rotation, making point contact with each other. In this study, the Pinion gear rotating from the initial contact point to final contact point produces 4 cases. The conclusion of these cases brings out the sequential position of contact stress between these two teeth.

6. Parth J. Bhatt, Assi. Prof. Pranav B. Bhatt [6] In this study, high speed helical gear used in planing machine will be analyzed. 3D models of high speed helical gear are designed using modeling software and simulation of the same is carried out through finite element software package. From the results obtained the main criteria corresponding to the gear failure is found to be the bending stresses of the gear tooth, which is the primary bending stress. This paper serves as a method to monitor the stresses induced in tooth flank and tooth fillet during meshing of the gears using finite element model.

7. Ashish Mogrekar, T. Preman Reynold Joseph and Vivek Karaveer [7] have elucidated the Finite Element Analysis of Spur Gear. This study shows the stress analysis pattern of the two spur gears meeting at a point. This is carried out using FEA method. The pattern is used to find maximum contact stress in the gears and the values are associated with theoretical Hertzian equation values. The two spur gears are made of steel and grey cast iron. These gears are designed, modelled, fabricated and assembled in ANSYS Design Modeler. Since Finite Element Method (FEM) is one of the easiest
and most accurate technique for stress analysis, this analysis is carried out using ANSYS 14.5.

3. MODELLING OF HELICAL GEAR
The gear model is generated using AutoCAD Inventor. The gear strength, material and other parameters are calculated using Kiss soft software (Software package for manufacturing of gears). The following are the dimensions and specifications of helical gear.

![Helical Gear pair](image)

**Figure 1** Helical Gear pair

3.1. Technical Specifications
(Geometry calculation according to ISO 21771:2007, DIN ISO 21771)
- Helix angle: 11
- Pressure angle: 20
- Module: 5
- Centre distance: 180 mm

3.2. Selection of Material
- Gear material: 18CrNiMo7-6
- Pinion material: 18CrNiMo7-6

3.3. Gear Specifications

<table>
<thead>
<tr>
<th>Parameters</th>
<th>PINION</th>
<th>GEAR</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of teeth</td>
<td>15</td>
<td>53</td>
</tr>
<tr>
<td>Face width</td>
<td>73 mm</td>
<td>68 mm</td>
</tr>
<tr>
<td>Pitch circle diameter</td>
<td>80 mm</td>
<td>280 mm</td>
</tr>
<tr>
<td>Base diameter</td>
<td>71 mm</td>
<td>253 mm</td>
</tr>
<tr>
<td>Tip diameter</td>
<td>91 mm</td>
<td>287 mm</td>
</tr>
<tr>
<td>Bore diameter</td>
<td>35 mm</td>
<td>100 mm</td>
</tr>
<tr>
<td>Speed</td>
<td>100 rpm</td>
<td>28.3 rpm</td>
</tr>
<tr>
<td>Torque</td>
<td>2134 Nm</td>
<td>7540 Nm</td>
</tr>
<tr>
<td>Hand of gear</td>
<td>Left</td>
<td>Right</td>
</tr>
</tbody>
</table>
4. FINITE ELEMENT ANALYSIS
In Finite element method, complicated structure is segmented into a defined number of smaller structures called as elements. The material properties and governing equations are taken into account over these elements and the field quantity represented as undetermined values at the corners are called as the nodes. Thus the complex structure is converted into a problem with finite degrees of freedom. This process which contains the loading and end conditions will correspond to a set of equations and the solution for these equations will give the approximate behavior of the complex model.

4.1. Static Analysis
A static load is a fixed force acting on a member. To be stationary, the force or moment at the point should be of no change in magnitude and direction or at the point of application of load.

4.2. Boundary Conditions
The finite element model is meshed. Remote displacement is applied to both the gear and pinion. For pinion all the six degrees of freedom is constrained and it is set to zero but in gear rotation about Z axis is set free and all the other degrees of freedom are set to zero.
- Moment is applied to the gear (about Z axis).
- No separation contact is given to the contact portion of the gear pair.

4.3. Geometries Selected
There are various structural geometries available for material removal in gears. Among much geometry available these two particular geometries have been selected for further analysis in this helical pair. They are
Circular holes (2 holes, 4 holes, 6 holes, 8 holes, 10 holes, 12 holes, 14 holes)
Slot (2 slots, 4 slots)

4.4. Solution
Equivalent stress (von mises stress) is added for finding solution.
- Sequentially total deformation and maximum shear stress is also added.
- Further contact tool and safety factor for the helical gear pair is also added.

5. RESULT ANALYSIS
In result analysis different geometries like 2 holes, 4 holes, 6 holes, 8 holes, 10 holes, 12 holes, 14 holes, 2 slots, and 4 slots were applied and their corresponding weight reduction and increase in stresses are calculated.

For each iteration the percentage increase in stress and percentage decrease in weight are listed as shown below
5.1. Results of Different Geometries

Table 2 Results

<table>
<thead>
<tr>
<th>Specification</th>
<th>Stress (Mpa)</th>
<th>Mass (kg)</th>
<th>Percentage decrease in weight (%)</th>
<th>Percentage increase in stress (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Actual</td>
<td>460.02</td>
<td>30.116</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>2 holes</td>
<td>460.27</td>
<td>29.036</td>
<td>2.5</td>
<td>0.015</td>
</tr>
<tr>
<td>4 holes</td>
<td>466</td>
<td>28.611</td>
<td>4.99</td>
<td>1.26</td>
</tr>
<tr>
<td>6 holes</td>
<td>473.34</td>
<td>27.858</td>
<td>7.5</td>
<td>2.86</td>
</tr>
<tr>
<td>8 holes</td>
<td>478.9</td>
<td>27.106</td>
<td>9.995</td>
<td>4.06</td>
</tr>
<tr>
<td>10 holes</td>
<td>485.22</td>
<td>26.353</td>
<td>12.5</td>
<td>5.48</td>
</tr>
<tr>
<td>12 holes</td>
<td>494.7</td>
<td>25.5</td>
<td>15.34</td>
<td>7.54</td>
</tr>
<tr>
<td>14 holes</td>
<td>505.89</td>
<td>24.848</td>
<td>17.49</td>
<td>9.97</td>
</tr>
<tr>
<td>4 slot</td>
<td>900.44</td>
<td>28.571</td>
<td>5.13</td>
<td>95</td>
</tr>
<tr>
<td>2 slot</td>
<td>775.41</td>
<td>29.602</td>
<td>1.71</td>
<td>68.5</td>
</tr>
</tbody>
</table>

5.2. Comparison of Analytical and ANSYS Result

Table 3 Comparison of properties

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Analytical</th>
<th>Ansys</th>
<th>Error</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stress (N/mm²)</td>
<td>469.64</td>
<td>460.02</td>
<td>2.01</td>
</tr>
<tr>
<td>Factor of safety</td>
<td>1.81</td>
<td>1.847</td>
<td>2.04</td>
</tr>
</tbody>
</table>

5.3. Stress Analysis

Figure 2 Actual Gear

Figure 3 Gear with 2 Holes

Figure 4 Gear with 4 Holes

Figure 5 Gear with 6 Holes
6. CONCLUSION

From the above analysis it is concluded that, there is a simultaneous weight reduction and increase in stress considerably in two geometries namely 10 holes and 12 holes geometry with weight reduction of about 15%. The above two geometries are considered as optimal solution because the stress induced after producing holes is less than the allowable stress of the material. Thus the optimal solution for weight reduction in given helical pair is 10 holes geometry and 12 holes geometry.
REFERENCES


