Stress Analysis of Bevel Gear Tooth using FEA

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ABSTRACT

Finite element analysis of stress and deformation on the three-dimensional bevel gear has been conducted in the present paper. Structure steel has been taken as a material of bevel gear. First a CAD model has been generated than the stress, deflection, safety factor and strain analyses have been conducted. Modelled bevel gear has 20 teeth and a load has been applied at one of the teeth of the gear. Effect of different meshing methods like fine, medium and coarse meshing have been studied, with this effect of different element sizes like 10mm, 5mm and 1mm have been considered. At the end their effects on the number of nodes and elements have been studied. Remote displacement boundary condition has been applied at the centre of the bevel gear. Maximum deflection of 32850mm, maximum von-misses stress 30.354MPa, maximum von-misses strain $15.835e^{-5}$ and minimum safety factor of 2.8398 have been found in the present study.

Introduction

Gears can be defined as a device used to transmit motion from one shaft to another shaft by direct contact. Every shaft has gears which are connected to each other by teeth. The two bodies have either rolling or sliding motion along the tangent at the point of contact. Along the common normal no motion is possible because in this case either one body will pierce into another body or a contact between them will break. There are wide ranges of gears utilized by industry, yet every one of these gears has the same reason, which is to transmit motion starting from one shaft to other. Gear can be classified as Parallel shaft which are spur and helical gears, while the other one are intersecting shaft which are bevel and spiral gears. The Present study focuses on the bevel gears. They are widely used in aircrafts, automobiles, and heavy engineering machines. They can be classified as, Straight bevel gears, Spiral bevel gears, Zerol bevel gears and Hypoid gears.

Literature Review


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2. **Stress and strength equations for bevel gear**

   In Bevel-gear mounting, one gear is often mounted outside the bearings. This can deflect the shaft and can impact on nature of tooth contact. Difficulty during in prediction of the stress in bevel-gear teeth is because of the tapered teeth. To have perfect line-contact going through the cone centre, the teeth must bend more at the large end than at the small end. To obtain this, load should be greater at the large end.

3. **Materials selection**

   The gear material should have high tensile and endurance strength to prevent failure against static load and dynamic load respectively. They also have low coefficient of friction and good manufacturability. Structure steel has been considered as a bevel gear material in the present study whose properties have been shown in the table 1.

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Thermal conductivity</td>
<td>60.5 W/m·C</td>
</tr>
<tr>
<td>Density</td>
<td>7850 Kg/m³</td>
</tr>
<tr>
<td>Specific heat</td>
<td>434 J/Kg·C</td>
</tr>
<tr>
<td>Coefficient of thermal expansion</td>
<td>1.2e⁻⁵°C⁻¹</td>
</tr>
<tr>
<td>Resistivity</td>
<td>1.7e⁻⁷ ohm·m</td>
</tr>
<tr>
<td>Yield strength (Compressive)</td>
<td>2.5e⁸ Pa</td>
</tr>
<tr>
<td>Yield strength (Tensile)</td>
<td>2.5e⁸ Pa</td>
</tr>
</tbody>
</table>

*Table 1: Properties of structure steel*

**Objective of Research**

- To find out the stress generated in the bevel when it gets loaded.
- To study the effect of different loading conditions.
- To study the different meshing methods used.
- To study the generated deflection under applying load.

**Problem Formulation and Proposed Research work**

Finite element (FE) tool ANSYS has been used for the mathematical modelling of the bevel gear. Different loading conditions have been considered. Stress and strain generated will be studied based on the loading condition. Effect of different meshing methods like coarse, medium and fine have been studied. Effect of element sizes (10, 5 and 1 mm) on the meshing has also been studied.

**Bevel gear geometry**

Geometry of the bevel gear has been modelled. A total of 20 numbers of teeth has been drawn on the circumference of the bevel gear. Figure 1 illustrates the geometry drawn of the bevel gear in a FE tool.

*Figure 1: Geometry of the bevel gear*
Meshing of bevel gear

Meshing is one of the most important parts of the finite element analysis (FEA). Fine, medium and coarse elements have been studied in the meshing methods. While effect of the element size has also been studied, three different element sizes have been considered to their effect on the number of nodes and number of elements. Table 2 has been prepared which represents the effect of all the meshing methods considered in the present study.

<table>
<thead>
<tr>
<th>Method</th>
<th>Nodes</th>
<th>Elements</th>
</tr>
</thead>
<tbody>
<tr>
<td>Coarse meshing</td>
<td>7135</td>
<td>3829</td>
</tr>
<tr>
<td>Medium meshing</td>
<td>12172</td>
<td>6709</td>
</tr>
<tr>
<td>Fine meshing</td>
<td>24752</td>
<td>14260</td>
</tr>
<tr>
<td>Meshing with element size 10mm</td>
<td>4175</td>
<td>2243</td>
</tr>
<tr>
<td>Meshing with element size 5mm</td>
<td>7534</td>
<td>4092</td>
</tr>
<tr>
<td>Meshing with element size 1mm</td>
<td>28161</td>
<td>16270</td>
</tr>
</tbody>
</table>

*Table 2: Effect of the meshing methods on the no. of nodes and no. of elements*

Application of boundary conditions

A load has been applied on one of the teeth of the bevel gear, while a remote displacement load has been applied at the centre of the bevel gear. Remote displacement load is a type of load which helps the gear to
rotate in the desired direction. In the present case gear has been allowed to rotate in the z-direction only while all the other types of movement either they are rotation or linear has been kept to zero ‘0’mm.

Results and Discussion
In the present case a bevel gear under the effect of a load and remote displacement has been studied. Effect of these boundary conditions on the stress, strain, total deflection, directional deflection and safety factor has been studied. On can notice the amount of stress, strain deflection and safety factor generated or required for a particular type of loading.
Figure 5: Directional deformation of bevel gear

Figure 6: Von-misses strain generated on bevel gear

Figure 7: Von-misses stress generated on bevel gear
Conclusion

- Remote displacement load has been applied at the centre of the bevel gear while load has been applied at one of the teeth of bevel gear.
- Effects of these boundary conditions on the stress, strain, total deflection, directional deflection and safety factor have been studied.
- Fine, medium and coarse elements have been studied in the meshing methods.
- Effect of the element size like 10mm, 5mm and 1mm have been considered and their effect on the number of nodes and elements have been studied.
- Maximum deflection of 32850mm, maximum von-misses stress 30.354MPa, maximum von-misses strain 15.835e-5 and minimum safety factor of 2.8398 have been found in the present study.

References