“Contact Stress Analysis of Spur Gear by Photoelastic Technique and Finite Element Analysis.”

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Abstract :- Contact stress refers to the localized stresses that develop as two curved surfaces come in contact and deform slightly under the imposed loads. Also due to contact stresses wear takes place at gear tooth. Wear is nothing but progressive removal of metal from the surface. Consequently tooth thins down and gets weakened. Pitting is a surface fatigue failure of the gear tooth. It occurs due to misalignment; wrong viscosity selection of the lubricant used, and contact stress exceeding the surface fatigue strength of the material. Material in the fatigue region gets removed and a pit is formed. In this paper contact stresses find out by FEM method and experimental method by using the polariscope. And compare the FEM result with experimental result.

As we know gear is one of the most critical components in a mechanical power transmission system, failure of one gear will affect on the whole transmission system. Therefore it is necessary to find the root cause which result into failure of gear and try to eliminate these causes. Failure analysis is an engineering approach to determining how and why equipment or a component has failed.

Keywords - Contact stresses, Pitting.

INTRODUCTION:-

Wear is nothing but progressive removal of metal from the surface. Consequently tooth thins down and gets weakened. Pitting is a surface fatigue failure of the gear tooth. It occurs due to misalignment; wrong viscosity selection of the lubricant used, and contact stress exceeding the surface fatigue strength of the geometry of the contacting surfaces. Although these assumptions are needed for the classical procedures, their use raises questions about the accuracy and applicability of the results.

Photoelasticity is an experimental technique for stress and strain analysis which is particularly useful for members having complicated geometry, complicated loading conditions, or both. For such cases, analytical methods may be impossible, and analysis by an experimental approach maybe more appropriate.

material. Material in the fatigue region gets removed and a pit is formed. The pit itself will cause stress concentration and soon the pitting spreads to adjacent region till the whole surface is covered. Subsequently, higher impact load resulting from pitting may cause fracture of already weakened tooth. [2]

Gears analysis in the past was performed using analytical methods, which required a number of assumptions and simplifications. In general, gear analyses are multidisciplinary, including calculations related to the tooth stresses and to tribological failures such as like wear. Designing highly loaded spur gears for power transmission systems that are both strong and quiet requires analysis methods that can easily be implemented and also provide information on contact and bending stresses, along with transmission errors. The finite element method is capable of providing this information. The finite element method is very often used to analyze the stress state of an elastic body with complicated geometry, such as a gear.

The life and performance of gear teeth are directly related to the ability of the teeth to withstand contact stresses. Contact stresses may produce pitting within the contact area and eventually lead to tooth failure. In spite of the importance of contact stresses in gears, comprehensive analyses of these stresses have not been extensively reported in the literature. Indeed, most analyses are based upon procedures that require simplified assumptions about the material. Photoelastic method, a connection between optical and mechanical characteristics is given via the stress optic low [1]:

\[
\sigma_1 - \sigma_2 = (N*f_0/h)
\]

Where; \(\sigma_1\) and \(\sigma_2\) are the principal stresses at the point, \(N\) is a fringe number, \(h\) is a thickness of the photoelastic model (mm), and \(f_0\) is the material fringe value.

Contact ratio:-

Contact ratio is defined as the average number of tooth pairs in contact under static conditions, and
without errors and tooth profile modifications[4]. Note that this ratio is also equal to the length of the path of contact divided by the base pitch. Gears should not generally be designed having contact ratios less than about 1.20, because inaccuracies in mounting might reduce the contact ratio even more, increasing the possibility of impact between the teeth as well as an increase in the noise level.

Pitting:-

Pitting is a surface fatigue failure of the gear tooth[3]. It occurs due to misalignment, Wrong viscosity selection of the lubricant used, and Contact stress exceeding the surface endurance limit of the material. Material in the fatigue region gets removed and a pit is formed.

Initial pitting is caused by local areas of high stress due to uneven surfaces on the gear tooth. This type pitting can develop within a relatively short time, reach a maximum and with continued service polish to a lesser severity. It is most prominent with through-hardened gears and is sometimes seen with surface-hardened gears. Destructive pitting usually results from surface overload conditions that are not alleviated by initial pitting. If tooth surface hardness is within specified values, system over loads are usually the cause of such pitting.

**Gear specifications**

<table>
<thead>
<tr>
<th>GEAR DATA</th>
<th>EXTERNAL</th>
</tr>
</thead>
<tbody>
<tr>
<td>No of teeth</td>
<td>20</td>
</tr>
<tr>
<td>Module</td>
<td>4</td>
</tr>
<tr>
<td>Pitch circle diameter</td>
<td>80</td>
</tr>
<tr>
<td>Correction factor</td>
<td>0</td>
</tr>
<tr>
<td>Pressure angle</td>
<td>25</td>
</tr>
<tr>
<td>Root diameter</td>
<td>70</td>
</tr>
<tr>
<td>Span over teeth</td>
<td>3</td>
</tr>
<tr>
<td>Quality of gear</td>
<td>7 Class</td>
</tr>
<tr>
<td>Weight</td>
<td>1.05 Kg</td>
</tr>
</tbody>
</table>

| Table 1: Gear specifications |

![Fig.1: Auto-Cad drawing of spur gear.](image)

![Fig.2: Gear tooth assembly](image)

![Fig.3: Meshing of gear tooth](image)

![Fig.4(a): Boundary condition](image)

Analysis of gear tooth :-

1. The finite element model of meshed gear is generated using the tangential method of involute profile for spur gear tooth in Pro-E. Then, one pair of gear tooth is imported in ANSYS Workbench 12 as working the model. Therefore, the loss of accuracy associated with development of solid models using CAD (computer aided design) computer programs is minimized.

2. Modules for automatic generation of finite element models are integrated into the model in ANSYS Workbench version 12, static structural analysis system. Then, the generation of finite element models is accomplished for the cycle of meshing.

3. According to Faydor [5], boundary conditions and loading conditions for gear and pinion is applied as follows:
   - Nodes on the sides and bottom part of the rim portion of the gear are considered fixed as shown in Fig. 4(a)
After setting of boundary conditions for gear and pinion initiating the solver to compute the required results.

Results of load Vs contact stress

<table>
<thead>
<tr>
<th>Sr. No.</th>
<th>Load (N)</th>
<th>Contact stress (Mpa)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>300</td>
<td>10</td>
</tr>
<tr>
<td>2</td>
<td>400</td>
<td>14</td>
</tr>
<tr>
<td>3</td>
<td>500</td>
<td>16</td>
</tr>
</tbody>
</table>

Table 2 – Casted Gear Specifications

**Gear Casting:**

- Firstly prepared the mould by using the acrylic sheet [6]. The dimensions of the mould is 16*16.
- The required sheet dimensions are 12*12. And thickness is 10mm.
- The volume of sheet is 144 c.c. For every 100 c.c. of araldite 10 c.c. of hardener is to be mixed.
- I was taken 144ml araldite and 14 ml of hardener and mixed with each other.
- The mixture should be stirred in one direction continuously for 15 minutes till it is transparent.
- The mixture is ready to pouring in the mould for preparation of the sheet.
- This is the gear model after the machining. Which is use for the experimentation.

Experimental set up :-

Photoelasticity is an experimental method to determine the stress distribution in a material where mathematical methods become quite cumbersome. Unlike the analytical methods of stress determination, photoelasticity gives a fairly accurate picture of stress distribution even around abrupt discontinuities in a material. The method serves as an important tool for determining the critical stress points in a material and is often used for determining the stress concentration factors in irregular geometries.

Specifications of polariscope:-


2 quarter wave filters to generate circular polarized light

All filters with 360° angle scale and marking of the main optical axis

White light generated using a fluorescent tube and two incandescent lamps

Monochromatic light (colour yellow) generated using a sodium vapour lamp

Filters roller bearing mounted and rotating

Frame cross-arms height-adjustable

Generation of compression or tension forces by means of a threaded spindle

By stress optic law;
\( \sigma_1 - \sigma_2 = (N*f / h) \)

Fringe value[6],
\( f_{or} = \frac{8 \times p \times \pi \times D \times N}{\pi \times 0.355 x 30} = 4.69 \)

<table>
<thead>
<tr>
<th>Load</th>
<th>N</th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
<td>1.29</td>
</tr>
<tr>
<td>2.5</td>
<td>1.79</td>
</tr>
<tr>
<td>3</td>
<td>1.87</td>
</tr>
</tbody>
</table>

By stress optic law;
\( \sigma_1 - \sigma_2 = (N*f / h) \)
\( \sigma_1 - \sigma_2 = (1.29 \times 4.69 / 8) \)
\( \sigma_1 - \sigma_2 = 0.76 \text{ N/mm}^2 \)
\( \sigma_2 = 0 \)
\( \sigma_1 = 0.76 \text{ N/mm}^2 \)

\[
\frac{\sigma_m}{\sigma_p} = \frac{0.76 \times \frac{8}{10} \times \frac{1}{1}}{19.69}
\]

\( \sigma_m = 9.26 \text{ MPa} \)

RESULT AND DISCUSSION:-

Pitting is the surface fatigue failure which occurs due to repetition of high contact stresses. The failure starts with the formation of pits which continue to grow resulting in the rupture of the tooth surface. The results found by FEM method is nearly equal to results found by experimental method. Fig. 10 shows the graph of contact stresses Vs load.

CONCLUSION:-

The results found by FEM method is nearly equal to results found by experimental method. The module is an important geometrical parameter during the design of gear. Therefore selection of proper module size is an important factor before designing gear maximum contact stress decreases with increasing module.
Fig 10 :- Graph of contact stresses Vs Load

REFERENCES:-


