Failure Analysis of Lathe gear using Finite element approach

Surendra Dewangan¹, Dr. M.K. Pal²
¹,²Mechanical Engineering Department, Bilai Institute Of Technology, Durg.

Abstract— In this paper failure analysis of a spur gear of lathe machine has been analyzed by using finite element approach. Here, a computational model of spur gear of lathe machine has been model by using ANSYS geometrical module. The parametric stress analysis of a Spur gear is been done in order to optimize the performance parameters of spur gear during subjected to static and dynamic loads. The influence of various parameters such as number of tooth, tooth face width, transmission ratio on bending stress and contact stress has been analyzed by developed computational code in MATLAB.

Keywords— Spindle, FEA, Deformation

I. INTRODUCTION

In engineering and automobile, Gear tooth play very imperative role as an essential part of engineering. The designers and manufacturers mostly adopt involute and evolute techniques to design a spur gear tooth. Due to higher degree of compactness and reliability Gears will overcome as a significant machine element designed for transmitting power in future technology.

Due to Advancement in science and technology, computers are well upgraded and becoming more influential device, that is why people tend to adopt numerical approach to develop theoretical model to envisage the effects. Due to less restrictive assumptions numerical methods are used since they provide more accurate solution. In order to attain accurate results correct model and solution method should be implemented along with reasonable computational time helps in validating result as per the trend.

II. METHODS REPORTED IN OPEN LITERATURE

Until the mid 20th century all gear design was based upon Lewis (1893) original bending equation. Lewis based his analysis on a cantilever beam and assumed that failure will occur at the weakest point of this beam. Lewis considered the weakest point as the cross-section at the base of the spur gear.

Ramamurti and Rao 1988 use fem and cyclic symmetry approach for the stress analysis of spur gear teeth. The contact line load at one such substructure leads to an asymmetric loading of the wheel as a whole. This force system is resolved into a finite Fourier series to calculate the static stresses. [1]

Daniewicz and Moore 1998 increases fatigue life of gear by introducing compressive residual stresses is prestressing or presetting nad applied to AISI 1040 steel spur gear teeth were individually preset using a single tooth bending fatigue fixture. [2]

Faydor et. al 2005 presents new computerized developments in design, generation, simulation of meshing, and stress analysis of gear drives and give numerical example for a developed theory.[3]
Lingamanaik and Chen 2012 uses metallurgical operation i.e Carburisation and quenching on automotive gears in order to improve wear properties by promoting martensite transformation and formation of a case hardened surface layer. [4] Since The martensite transformation causes a volumetric expansion which puts the surface into a ‘compressive’ residual stress state which promotes fatigue resistance.

Sheng and Kahraman 2014 propose a physics model to calculate the micro-pitting behavior on contact surfaces of spur gears operating under the mixed lubrication condition. The transient mixed elasto hydrodynamic lubrication model of Li and Kahraman [5] forecast surface normal and tangential tractions, capturing the transient effects related with the time-varying contact radii, surface velocities and normal tooth force for spur gear.

Lu and Litvin [6] analyze the tooth surface contact and stresses for double circular-arc helical gear drives and FE method is use to investigate load share and contact ratio for aligned and misaligned gear.

Lingamanaik and Chen 2012 uses metallurgical operation i.e Carburisation and quenching on automotive gears in order to improve wear properties by promoting martensite transformation and formation of a case hardened surface layer. [7]

The transient mixed elasto hydrodynamic lubrication model of Li and Kahraman [8] forecast surface normal and tangential tractions, capturing the transient effects related with the time-varying contact radii, surface velocities and normal tooth force for spur gear.

Abbas et. al 2012 design spur gear using Cubic Trigonometric Bézier function with two shape parameters and it has more flexibility for the interactive design due to low degree and presence of shape parameters and analyzed by (FEA) for the applicability of the tooth design. [10]

III. MATHEMATICAL MODELLING

The geometry of the problem herein investigated is depicted in Fig. 1.
Figure 1 Model Configuration

The FEM Formulation

Figure 2 Infinitesimal element showing stress state [9].

Displacement

\[ \mathbf{U} = \{u(x, y, z), v(x, y, z), w(x, y, z)\} \]

Cauchy’s Stress tensor =

\[
\boldsymbol{\sigma} = \begin{bmatrix}
\sigma_{xx} & \tau_{xy} & \tau_{xz} \\
\tau_{yx} & \sigma_{yy} & \tau_{yz} \\
\tau_{zx} & \tau_{zy} & \sigma_{zz}
\end{bmatrix}
\]

The strain-stress relations (Hooke’s law) for isotropic materials are given by [9]:

\[
\begin{align*}
\varepsilon_{xx} &= \frac{1}{E} (\varepsilon_{xx} - \nu \varepsilon_{yy} - \nu \varepsilon_{zz}) \\
\varepsilon_{yy} &= \frac{1}{E} (-\nu \varepsilon_{xx} + (1 - \nu) \varepsilon_{yy}) \\
\varepsilon_{zz} &= \frac{1}{E} (-\nu \varepsilon_{xx} - \nu \varepsilon_{yy} + (1 - \nu) \varepsilon_{zz}) \\
\gamma_{xy} &= \frac{1}{2} (\gamma_{xy} + \gamma_{yx}) \\
\gamma_{yz} &= \frac{1}{2} (\gamma_{yz} + \gamma_{zy}) \\
\gamma_{zx} &= \frac{1}{2} (\gamma_{zx} + \gamma_{xz})
\end{align*}
\]

Strain-Displacement relations are:

\[
\begin{align*}
\varepsilon_{xx} &= \frac{\partial u}{\partial x} + \gamma_{xy} \frac{\partial y}{\partial x} + \gamma_{xz} \frac{\partial z}{\partial x} \\
\varepsilon_{yy} &= \gamma_{yx} \frac{\partial y}{\partial x} + \frac{\partial v}{\partial y} + \gamma_{yz} \frac{\partial z}{\partial y} \\
\varepsilon_{zz} &= \gamma_{zx} \frac{\partial z}{\partial x} + \gamma_{zy} \frac{\partial z}{\partial y} + \frac{\partial w}{\partial z} \\
\gamma_{xy} &= \frac{\partial u}{\partial y} + \frac{\partial v}{\partial x} \\
\gamma_{yz} &= \frac{\partial v}{\partial z} + \frac{\partial w}{\partial y} \\
\gamma_{zx} &= \frac{\partial w}{\partial x} + \frac{\partial u}{\partial z}
\end{align*}
\]
IV. RESULTS AND DISCUSSION
The parametric study of effect of face width, Pressure Angle, varying load, no. of teeth on Spur gear is carried out. The MATLAB results are validated with literature and by Analytical calculation for a few cases are also illustrated.

<table>
<thead>
<tr>
<th>No of teeth (N)</th>
<th>MATLAB Stresses (MPA)</th>
<th>3D Stresses (ANSYS) (MPA)</th>
</tr>
</thead>
<tbody>
<tr>
<td>22</td>
<td>130.1847</td>
<td>131.53</td>
</tr>
<tr>
<td>23</td>
<td>126.8841</td>
<td>126.28</td>
</tr>
<tr>
<td>25</td>
<td>122.2941</td>
<td>123.89</td>
</tr>
<tr>
<td>28</td>
<td>120.4364</td>
<td>122.94</td>
</tr>
<tr>
<td>30</td>
<td>119.0751</td>
<td>120.45</td>
</tr>
<tr>
<td>34</td>
<td>117.4243</td>
<td>117.45</td>
</tr>
</tbody>
</table>

Figure 3 3-D Von-Mises Stress for Gear with 19 Teeth

Figure 4 3-D Von-Mises Stress for Gear with 24 Teeth

Figure 5 3-D Von-Mises Stress for Gear with 25 Teeth
Effect of number of tooth and tooth face load in bending stress

![Graph showing variation of bending stress with respect to tangential load and number of gear teeth.]

*Figure 8 Variation of Bending Stress with respect to Tangential load and no. of Gear Teeth*
In figure 8 shows the Variation of Bending Stress with respect to Tangential load and no. of Gear Teeth. It can be conclude that on increasing no.of teeth with respect to tangential load the bending stress increases linearly. As more the load more will be the bending. Such bending stress can be overcome by increasing no. of teeth.

Therefore during design of gear no. of teeth plays a crucial role in selection of gear performance parameters such dynamic factor kv, over load factor ko and j geometry factor.

**Effect of face width and transmission ratio on contact stress**

![Graph showing Variation of Contact Stress with respect to Transmission Ratio for different Face width](image)

*Figure 9 Variation of Contact Stress with respect to Transmission Ratio for different Face width*

Figure 9 shows the Variation of Contact Stress with respect to Transmission Ratio and Face width. From this it can be concluded the on increasing no. of teeth in form of transmission ratio contact stress drastically decreases and the same treads is also noticed on increasing face width of gear.

**V. CONCLUSION**

From the failure analysis of spur gear flowing conclusions have be drawn which are as follows:

- The variation between the MATLAB and ANSYS result is in the range of ±.0122 to ±.02014.
- It was observed that the stresses generated on spur gear teeth changes with the number of teeth.
- Contact ratio and overlapping of gear get reduced as pressure angle increases.
- It can highly be recommended that in order to increase load carrying capacity of tooth pressure angle such be increased.

**REFERENCES**


