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Analysis of bending strength of helical gear by FEM

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Abstract:

Lewis equation is used for finding out the bending strength of a helical gear. This equation is based on certain assumptions. Various FEM are also based on this equation. Bending stress can also be found out by modified Lewis formula, AGMA standards etc. In this paper a comparison between Lewis equation and Ansys workbench is done.

Keywords: helical gear, bending strength, FEM

1. Introduction*:*

Lewis equation is used for finding out the bending strength of a helical gear. Various FEM are also based on this equation.

In this work bending strength of helical gear is found out with the help of three dimensional photoelasticity. A helical gearbox with 2.2 kW power transmitting at 760 rpm and

Number of Teeth = 30mm, Pitch circle Diameter = 60mm, Module = 2mm, Pressure Angle =20°, Helix Angle = $12^0 54'$, Addendum = 64mm, Base circle Diameter = 56.38mm, Dedendum = 55mm

2. Theoretical analysis

The finite element method is a numerical analysis technique for obtaining approximate solutions to a wide variety of engineering problems. The method originated in the aerospace industry as a tool to study stresses in complex airframe structures. It grew out of what was called the matrix analysis method used in aircraft design. The method has gained increased popularity among both researchers and practitioners.

2.1 Theoretical analysis By Lewis equation:

The analysis of bending stress in gear tooth was done by Mr. Wilfred Lewis known as Lewis equation. In the Lewis analysis, the gear tooth is treated as a cantilever beam as shown in fig. 4.1. The tangential component ($P_{t)}$ causes the bending moment about the base of tooth. The Lewis analysis is based on the following assumptions:

The effect of radial component (P_r) is neglected.

The effect of stress concentration is neglected.

At any time only one pair of teeth is in contact and takes the total load.

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It is observed that the cross- section of tooth varies from free end to fixed end. Therefore, a parabola is constructed with in the tooth profile. The advantage of parabolic outlines is that it is a beam of uniform strength [6].

In fig.2.2 at section XX,_______________ $M_b = P_t \times h$ ………..… (Eq.2.1)

$I = \left(\frac{1}{12}\right) bt^3$ ……………..(Eq. 2.2)

$y = \frac{t}{2}$ ………….. .(Eq. 2.3)

Here,

M_b = Bending Moment,

h = Height from root of tooth (dedendum circle to intersection of parabolas)

I = M.I of tooth about neutral axis and

t = thickness of tooth at root y = Distance of neutral axis from edge.

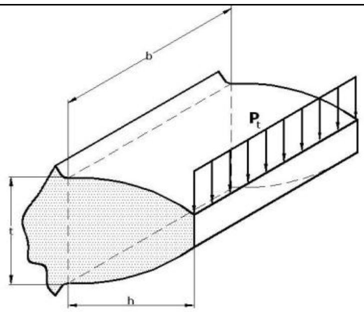

Figure 2.1 Gear Tooth As Cantilever Beam

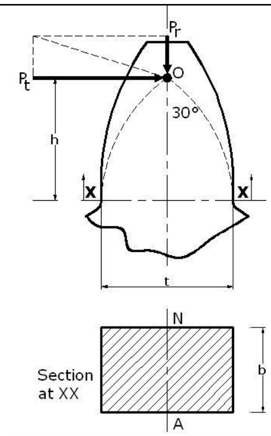

Figure.2.2 Gear Tooth As Parabolic Beam

The bending stress (σ_b) is given by

$$\sigma_b = \frac{M_{b\times} y}{I}$$ …………………..(Eq. 2.4)

Putting values of M_b, I, y and solving,

We get,

$$\sigma_b = \frac{P_t}{m \times b \times Y}$$ …………..(Eq. 2.5)

Here, Y is Lewis form factor

$$Y = \frac{t^2}{6 \times m \times h}$$ …………. (Eq. 2.6)

m= Module of gear, P_t = tangential component of load

Calculations:

The speed of helical gear (n) =760 rpm

Torque transmitted by helical pinion =M

Power transmitted by gear box (P) =2.2 KW

$$M_t = \frac{60 \times 10^6 \times p}{2 \times \pi \times n} \; N - mm \quad \text{..............} \qquad \text{(Eq.2.7)}$$

$$M_t = \frac{60 \times 10^6 \times 2.2}{2 \times \pi \times 760} \; N - mm \quad \text{.....} \qquad \text{(Eq.2.8)}$$

M_t = 27656.72 N-mm

Tangential component acts at pitch poin

$$P_t \times \left(\frac{d}{2}\right) = M_t \quad \text{......................................} \text{ (Eq. 2.9)}$$

Where d = Pitch circle diameter

P_t = 921.89 N

In order to determine bending stress, the helical gear is considered to be equivalent to a formative spur gear. The formative gear is an imaginary spur gear in a plane perpendicular to the tooth element.

Therefore for helical gear,

$$b' = \frac{b}{cos\varphi} = 24.58\text{mm}$$

$$Z' = \frac{Z}{cos^3\varphi} = 33$$

Y for Z' = 0.367

$$\sigma_b = \frac{P_t}{m \times b' \times Y} \quad \text{..........(Eq. 2.10)}$$

$$\sigma_b = \frac{921.89}{2 \times 24.58 \times 0.367}$$

σ_b **= 51.08 N/ mm^2 (theoretically)**

Therefore, theoretically bending strength of helical gear is = **51.08 N/ mm^2**

3. Solid Modeling And Modeling:

A solid modeling is done with Catia and then by using the hypermesh meshing is done. Analysis is done with Ansys Workbench 12.1.

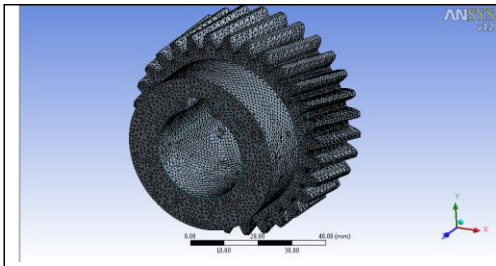	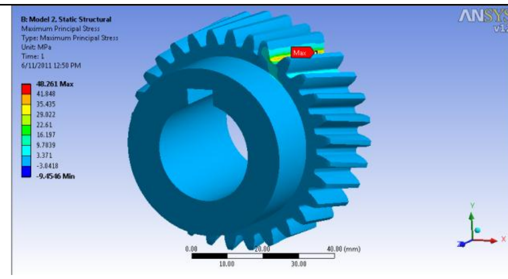
Figure 3.1. Meshing with Hypermesh	Figure 3.2 : Maximum Principal Stress plot

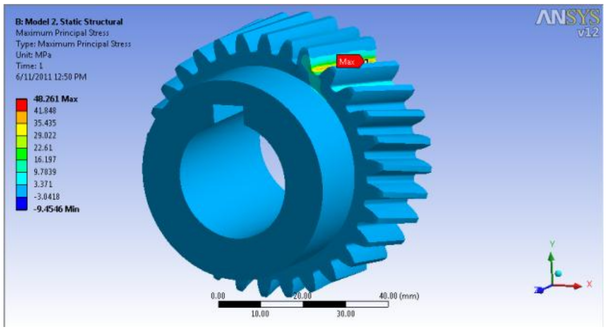

Figure 3.2 : Maximum Principal Stress plot

4. Result And Conclusion:

1)In helical gear the engagement between driver gear and driven gear teeth begins with point contact and gradually extends along the tooth surface. Due to initial point contact in helical gear the bending stresses produced at critical section (root of tooth) are maximum as compared to spur gear, which has kinematic line contact.

2)The calculation of maximum stresses in a helical gear at tooth root is three dimensional problems. The accurate evaluation of stress state and distribution of stress is complex task. The stresses produced at any discontinuity are different in magnitude from those calculated by elementary formulae.

3) In theory of helical gear we are considering that load is acting at one point and the stress is calculated. But, in case of FEM a continuous load is considered. So a pressure will act along the teeth of helical gear.

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