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STRESS TENSION AND DEFORMATION STUDY IN TEETH OF A CYLINDRICAL SPUR GEARS

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ABSTRACT

A gear is a rotating part of a machine with teeth alongside the circumference to transmit torque to one or more rotating gears along a tangential direction. The teeth of a spur gear prevent any kind of slip or deformation and allow to transmit the torque with a force considerably higher than normal gears. To transmit the rotational constant movement, the teeth profile must be designed so that during the transmission, the common normal must pass through a fix point placed on the centre line.

Keywords: spur gear, stress tension, torque

1. INTRODUCTION

To be able to transmit torque, a gear can be attached to any kind of device that has teeth that match with the teeth on the gear. The rotation of any gear causes the movement of other gears. In this way the rotation movement can be transferred from a spot to another, from a shaft to crankshaft, for example.

Though, many times gears are used to transmit rotation from a spot to another of a mechanism or ensemble, they can be used to transmit amplified or diminished forces.

2. THEORETICAL BACKGROUND

We take for example two gears without any kind of specification for the teeth profile.

- index 1 – driving gear
- index 2 – driven gear
- N-N – Common normal of teeth in contact point B
- T-T – Common tangent for the same point
- O_1 and O_2 are the gear centres, considered as fixed.

From these points we shall draw the perpendiculars O_1K_1, O_2K_2 on N-N.

The B point is obtained by joining B_1 and B_2 points. $B_1=B_2=B$

Speed in this contact point $B_1=B_2=B$:

$$\bar{v}_1 = \bar{\omega}_1 \times \overline{O_1B_1} = \bar{\omega}_1 \times \overline{O_1B}$$

$$\bar{v}_2 = \bar{\omega}_2 \times \overline{O_2B_2} = \bar{\omega}_2 \times \overline{O_2B}$$

with $\bar{v}_1 \perp \overline{O_1B}$ and $\bar{v}_2 \perp \overline{O_2B}$.

Speeds are decomposed on the normal and tangent direction of the contact profile:

$$\bar{v}_1 = \bar{v}_{1t} + \bar{v}_{1n}$$

$$\bar{v}_2 = \bar{v}_{2t} + \bar{v}_{2n}$$

$i = \omega_1 / \omega_2$ - is constant if the flanks of the teeth stay permanently in contact.

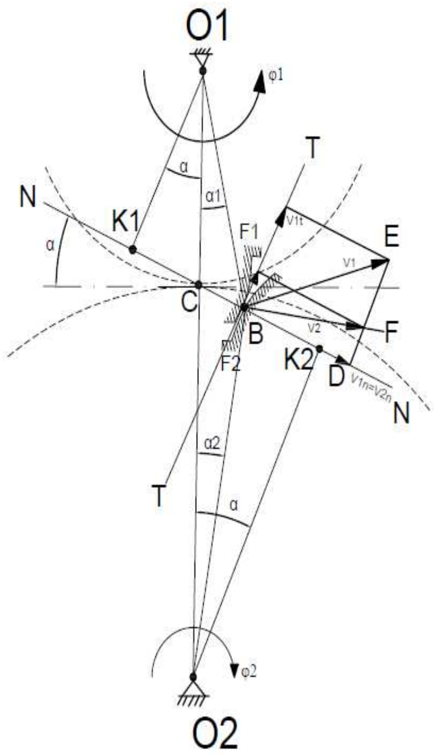

Fig.1

Profile F_2 will be permanently driven by F_1 if $\bar{v}_{1n} = \bar{v}_{2n}$.

If $\bar{v}_{1n} > \bar{v}_{2n}$, profile nr F_1 plastically deforms profile nr F_2.

If $\bar{v}_{1n} < \bar{v}_{2n}$, profile F_2 has its own speed and it is not driven anymore by F_1, meaning that it will drag behind.

$\bar{v}_{1t} \neq \bar{v}_{2t} \Rightarrow$ the relative movement of the profiles is of rolling and sliding . At the level of the contact point C, the tangential speeds are zero: allowing a pure movement of rolling. O_1C and O_2C - circles of pitch.

Fundamental Law of Gear-Tooth Action

We calculate the modulus of $\bar{v}_{1n}$ and $\bar{v}_{2n}$.

$$\Delta BED \approx \Delta O_1K_1B \Rightarrow \frac{v_{1n}}{v_1} = \frac{O_1K_1}{O_1B} \Rightarrow v_{1n} = v_1 \frac{O_1K_1}{O_1B}$$

$$\Delta BFD \approx \Delta O_2K_2B \Rightarrow \frac{v_{2n}}{v_2} = \frac{O_2K_2}{O_2B} \Rightarrow v_{2n} = v_2 \frac{O_2K_2}{O_2B}$$

The absolute value of the periferic speeds of points B_1 and B_2 are written as:

$v_1 = \omega_1 * O_1B$; $v_2 = \omega_2 * O_2B$

If $\bar{v}_{1n} = \bar{v}_{2n} \Rightarrow \omega_1 * O_1K_1 = \omega_2 * O_2K_2$

or $\frac{\omega_1}{\omega_2} = \frac{O_2K_2}{O_1K_1}$, $i = \omega_1 / \omega_2 = \text{constant}$,

$O_2K_2 / O_1K_1 =$ constant, only if the normal N-N keeps its position from the centre of the gears. In an involute spur gears, the transmission ratio is equal with the inverse ratio of the base diameters.

$$i = \frac{\omega_1}{\omega_2} = \frac{d_{b2}}{d_{b1}}$$

3. CREATING GEOMETRY

The next step includes the analysis of the gear spur with finite element method. Firstly the 3D solid model of the gear spur was generated in AutoCAD and then imported in ANSYS Workbench. Fig. 2 show the geometry of the model exported from AutoCAD to ANSYS.

Fig.2 CAD model

Table 1. Main dimensions

Distance between axes	208 [mm]
Diameter head	240 [mm]
Rolling diameter	200 [mm]
Base diameter	175 [mm]
Tooth height	55 [mm]
Tooth thickness	25 [mm]
Number of teeth on wheel	13

4. ANALYSIS OF THE GEAR SPUR USING ANSYS WORKBENCH

The model, witch was generated in AutoCAD, was transferred to AnSYS Workbench, and then prepared for analysis. Firstly the model was meshed. The model consists of 1496 elements and 9940 nodes. The components were defined as solid bodies. After the meshing process, the boundary conditions were defined. Then the rotation was predefined to 180 degrees for the driving gear, and a torque of 10 Nm for the driven gear.

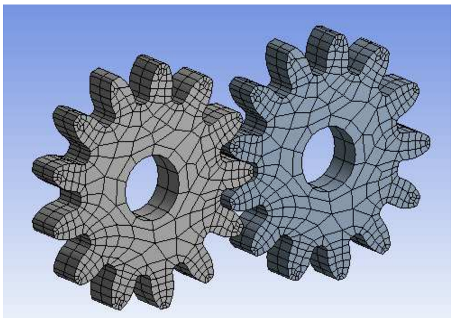

Fig.3 Mesh detail

5. DEFINITION OF MATERIAL PROPERTIES

The material used for this numerical simulation is a high strength steel with stress at which the flow begins $\sigma_c = 325\text{MPa}$ and the stress at which rupture begins is 500 MPa. The modulus of elasticity is E=2,1•10^5 MPa and Poisson's ratio υ=0.3.

6. RESULTS

The presentation dealt with contact stress considering contact ratio, approach angle, contact and length of contact. The stress was more than the correct value of contact stress obtained from approximating tools. In order to apply finite element method for contact analysis, a special technique was used to distinguish between the two parts of the contact regions. One was the first body named target region and the other body was named contact region. At the end of the contact, the stress increased suddenly to a high value almost close to the maximum value.

After the analysis, the stress results were **174,66 MPa** which is acceptable considering that the melting point of the steel used is 325 MPa.

Total deformation was found in the tip of the tooth area, and had a maximum value of **0,45 mm**.

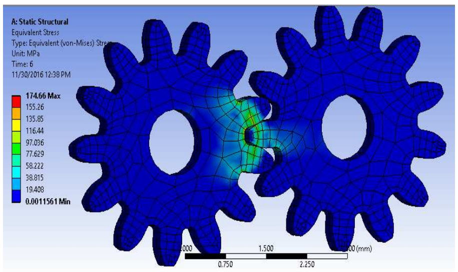

Fig. 6 Equivalent stress

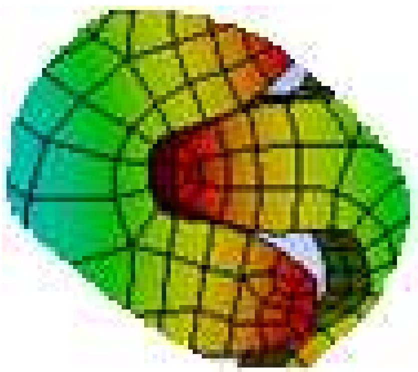

Fig.7 Total stress detail

7. CONCLUSIONS

The finite element analysis of spur gear is done to determine the maximum contact stress with AnSYS 15.0. The finite element method is most widely used to find a real model of the geared set using the stress analysis in the pair of gears. The development of finite element analysis model of the spur gear assembly, in order to simulate numerical the contact stress and bending stress, became more significant for the design of gears.

We conclude that analysis software can be used for other analyzing purposes.

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