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Effect of tooth deformation on contact ratio and tooth stressesin plastic spur gears

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Abstract—**This paper deals with the effect of deformation on contact ratio and stress behavior of plastic spur gear. It is shown that when one tooth of gear comes into contact with pinion tooth it gets some amount of deformation and due to thisdeformation, the behavior of second tooth coming in contact changes affecting the contact ratio. The contact ratio in actual practice differs from the theoretical results. For getting deformation and stresses on gear tooth, FEA is done. Results obtained Indicate that in actual practice contact ratio is higher as compared to the theoretical results in case of plastic gears.**

I. Introduction

Plastic gears are widely used now in many applications like electronic power steering, robots. It needsto understand the behavior of plastic gears as it is significantly different than metal gears. As modulusof elasticity of plastic gears are much less compared to metal gears, their behavior is different. Because of thelow elasticity the amount of deformation in plastic gears are much higher than metal gears. In metal gears, the deformation is very less. We can say it is negligible in metal gears, while in case of plastic gears the deformations are high. As the gear tooth in contact deforms , it will affect the behavior of the next tooth coming into contact.

In the proposed work, one initial position of gear is taken as the case 1, and then rotation of somedegree is given in each case and the deformation on first tooth which is in contact and stresses onsecond tooth is obtained. Contact ratio is calculated for the cases which is theoretical contactratio. After finishing, new cases are taken in which deformation on first tooth is taken intoconsideration for finding contact points on second tooth and then again the stresses are obtained. Thestresses obtained by both method, one without taking into consideration the effect of deformation andsecond by taking into consideration the effect of deformation,were compared.

1.1. Theoretical and actual contact ratio

The figure given below shows the path of contact while gear rotation. The line passing through A anA' is line of action which is cutting the addendum of gear and addendum of pinion at A' and Arespectively. This distance AA' is the distance through which the tooth remains in contact. In otherwords when the contact between the tooth of pinion and gear starts at the point when the addendum ofgear crosses the line of action which is point A' and the contact ends at the point when the addendumof pinion crosses the line of action which is point A. So we can say that AA is length of contact.

1.2. Deformation in gear tooth

When the gears are rotating they are transmitting power and forces like tangential, normal, radial, actsupon its tooth. Due to these forces gears deform at the point of contact. However in most of the casesthis deformation is very minor and within elastic limit, but it affects the behavior of the gear tooth.In the figure both, the original and deformed profile of a tooth is shown. The circle indicates thedeformation in tooth 1 due to loading. This deformation causes the next tooth, tooth 2 to come intocontact earlier. That means if the deformation is not considered the length of action would be AA butif we consider the deformation, the length of action is changed compared to AA because the tooth 2comes in contact with corresponding pinion tooth before the point A.

In this way the length of action is affected by the deformation in tooth. The deformation in toothdepends on the load acting on it, but the main criterion effecting the deformation is materialproperties. The material with lower modulus of elasticity will naturally deform more compared tomaterial having higher modulus of elasticity.

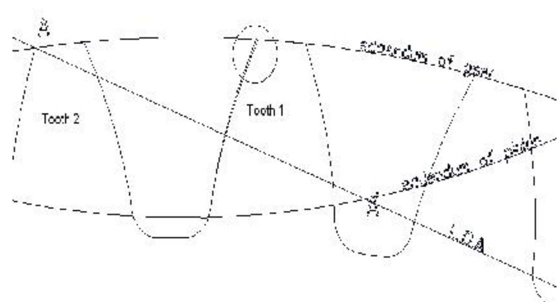


Fig.1: Tooth deformation

2. FEA OF PLASTIC SPUR GEAR WITH AND WITHOUT EFFECT OF DEFORMATION

2.1 Material properties and dimensions of the gear

Material considered is Sustamid 66 which has following

properties,

E (Modulus of Elasticity) : 3200 Mpa
V (poission's ratio) :0.35

Dimensions of gear

pressure angle	20°
Module m	6 mm
Addendum a	5 mm
Dedendum d	6.5 mm
Zg44	
N	500 rpm

2.2 Contact points

As per the dimensions of gear a 2d sketch is prepared according the geometry of gear. The involutewas sketched by the usual method. The gear profile was put in position where the first tooth contactbegins. It is as given in figure.

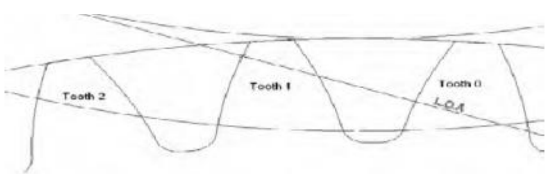


Fig.2. Contact points

The line of action crossing the tooth profile gives contact point at the particular position. In figure thatis shown by a marked point on tooth 1. Here two teeth are in contact tooth 0 and tooth 1,it wasassumed that gear starts rotating from this position. After getting the point the co ordinates of the pointwere found, this point was taken as first point of contact. For all 2d sketching, sketcher module of Pro - E was used.

2.3 Calculation of transmitted load

While gear when a single pair of teeth is engaged, this pair transmits the full load or the full load isthen applied on the one meshing tooth only. When double pair of teeth are engaged, the transmittedload will be divided between two meshing teeth:

Torque transmitted

$T = P/\omega$ (1)

The normal load applied on meshing teeth can be found as following:

$F = T/r_b$, Where $r_b = r.\cos ø$ (2)

The stress analysis problem in this study is assumed as a plane elastic problem, since the applied transmitted load is assumed to be distributed uniformly across the width of the meshing tooth.

Therefore the load had been depended per unit width of tooth as following:

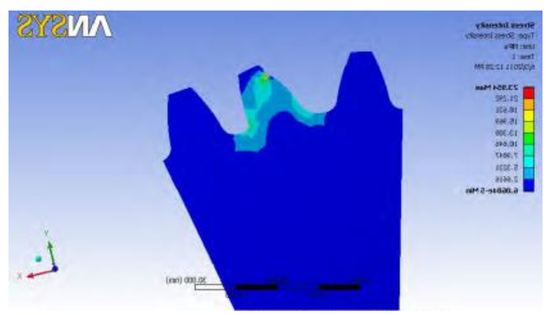
$F_n = F/b$ (3)

The component (F_x) and (F_y) will be

$F_x = F_n.\cos ø$
$F_y = F_n.\cos ø$

2.4 Finite Element Analysis

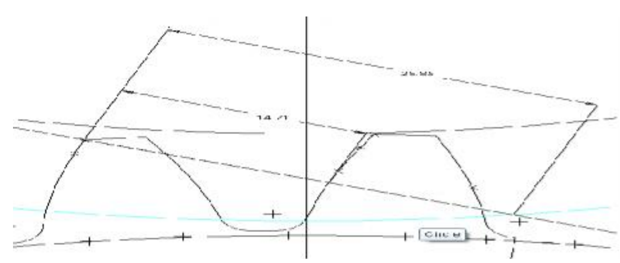
Analysis of each case was carried out in ANSYS by applying appropriate boundary conditions, loadsand then solving it. The model was eliminated from whole gear to the three tooth gear to reducecalculation time. Mesh Refinement was given at the needed areas . The calculated load was applied on the contact line and results were obtained.



Results in ANSYS

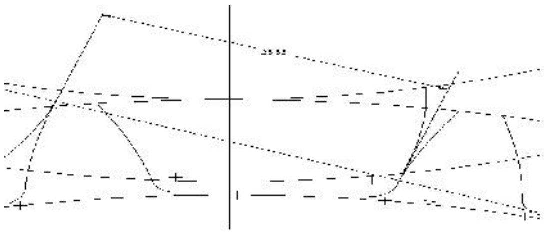
In the same manner the contact points and stresses on tooth 2, taking into account the deformation on tooth 1 are obtained.

3. CONTACT RATIO CALCULATIONS



Theoretical contact length

The Figure above shows the length of path of contact when deformation is not considered. And the
Figure below shows the length of path of contact in actual action.



Actual contact length

From both the cases contact ratios are calculated which are 1.7508 and 1.9532 respectively

4. RESULTS AND DISCUSSION

The stresses are obtained for both cases, one without the effect of deformation and second withthe effect of deformation. For both the cases stresses induced in the tooth 2 were different. Thisdifference was because of different contact points and different loading. The contact ratio with effect of deformation is .9532 which is higher than the theoretical one which is 1.7508. This difference in contact ratio is because of the increased time of contact resulting from the deformation. These results show the actual contact ratio and tresses are different than thetheoretical ones.

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