COMPARISON ANALYSIS OF STANDARD AND ADDENDUM MODIFIED SPUR GEAR TOOTH

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Abstract:

Here a plastic spur gear is considered for modeling and analysis. Plastic gears are used in low power drive applications and successfully replace metals and contribute superior performance. The advantages of plastic gears are noise reduction, cost savings, chemical resistance and weight reduction. In the involute system of gearing, interference is a serious defect which hampers conjugate action [5]. Hence the use of profile corrected gears is recommended. The reasons for profile correction are to avoid undercutting, interference and to increase the strength at the root and flank of the tooth. The type of profile correction adopted is the S_o gearing.

The involute spur gear model for both standard and profile corrected tooth was developed using the modeling software PRO-E. This model is then imported to an analysis software ANSYS-8. The results of the FEM analysis from are validated for profile corrected and standard spur gear tooth.

Key words; Profile correction, Bending stresses, von-mises stress.

1.INTRODUCTION

Plastic gears are powerful means of cutting the drive cost, weight, noise and wear. In applications ranging from automotive components to office automation equipments, polymers successfully replace metals and contribute superior performance. Thermoplastic and thermosetting polymers have long provided alternatives to metals in low powered, unlubricated gear trains. Injection molded thermoplastic gears have better fatigue performance. Plastic gears usually can be used as molded and require no finishing. The following are the advantages of plastic gears; Noise Reduction, cost savings, durability, chemical resistance and weight reduction.

The finite element method is used to analyse the stresses in gears. The bending stresses calculated using ANSYS 10.0 were compared to the results obtained with analytical methods. The purpose of this thesis is to develop a model of the plastic spur gear to study and predict its stress state for different modules, and different correction factors.

2.OBJECTIVES OF THE RESEARCH: The objective of this thesis is to study the stress state of a standard and profile corrected plastic spur gear by first developing a model using Pro-E modeling software and subsequent meshing of the model by using hyper mesh and analysis using ANSY 10.0 analysis software.

To generate the gear tooth profile of the standard spur gear, profile corrected gear and to predict the effect of gear bending stresses using a three - dimensional and two - dimensional model.

To compare the results of the stress analysis for profile corrected and standard spur gear.

3.GEAR BENDING STRESS

Among the several failure mechanisms for spur gears, failure due to bending stresses is very important. When the loads are too large, bending failure will occur. Bending failure in gears is predicted by comparing the calculated being stress to experimentally - determined allowable fatigue values for the given material. This bending stress equation was derived from the Lewis formula. The gear tooth is considered as a cantilever beam under load. The ability of the tooth to resist tooth breakage at the root is often referred to as the beam strength. The tooth load F_N is supposed to act at the tip corner. Load F_N acts along the line of action at pressure angle and when referred to Pitch point P. At the intersection of the line of action and the centre line of the tooth, this force F_N is resolved as.

Radial components - $F_N \sin \alpha$

and Tangential component - $F_N \cos \alpha$

Tangential Tooth load,

$F_t = mb\, \sigma_b\, Y$

Where, m = module, b = face width, σ_b = design stress and

Y = Lewis Form factor

$$\text{Stress, } F_s = \frac{F_t \times \text{Height}(h)}{\text{Section Modulus}(Z)}$$

The load is calculated for various numbers of teeth assuming a pressure angle of 20^0 and a full - depth involute. The Lewis form factor is dimensionless and is also independent of tooth size and only a function of shape. This analysis considers only the component of the tangential force acting on the tooth, and does not consider the effects of the radial force, which will cause a compressive stress over the cross section on the root of the tooth. When the load is at top of the tooth, usually there are atleast two tooth pairs in contact. In fact, the maximum stress at the root of tooth occurs when the contact point moves near the pitch circle because there is only on tooth pair in contact and this teeth pair carries the entire torque. When the load is moving at the top of the tooth, two teeth pairs share the whole load. If one tooth pair was considered to carry the whole load and it acts on the top of the tooth this is adequate for gear bending stress fatigue.

3.1 Gear Parameters used

Gear Type	:	Standard Involute, Full - Depth Tecth
Material	:	NYLON - 66 (Plastic)
Modulus of Elasticity	:	2826 N / mm^2
Module	:	7,8,9 10
Pressure Angle	:	20^0

4.PROFILE CORRECTION OF GEARS

The tip of the driven tooth comes in contact below the base circle of the driver due to this no conjugate action takes place this phenomenon has been termed as interference in gear technology. While generating gear teeth if there is interference, then a recess is cut at the root of the tooth. This removal of material is known as under cutting. For certain situations the pinion might have to be designed with the number of teeth less than the stipulated minimum number of teeth to avoid undercutting. This phenomenon is known as profile correction of gear tooth.

In gear technology, the profile correction is also termed as addendum modification (or) profile displacement (or) profile shift. We generally use the terms correction and correction factors respectively.

S	-	Plus Gears +ve correction
S	-	Minus Gears -ve correction
x	-	Profile correction factor

4.1 Advantages of Positive Correction

1. To avoid interference
2. Tooth strength will increase
3. Load capacity will increase
4. Betterment of sliding and contact relations
5. We can attain a predefined centre distance
6. To shift the beginning of the effective profile away from the base circle

4.2 Types of Corrected Gears

There are two Types

i. So - Gearing

ii. S - Gearing

i. So Gearing

In So-gearing, the two components of the mating pair of gears receive numerically equal factors but these two factors are algebraically of opposite sings. In general, the pinion is provided with +ve correction and gear with negative correction. In this S+ gear is the pinion and S minus gear is wheel. The so gear is also called long and short addendum system.

ii. S Gearing

In S-gearing, the sum of the profile correction factors is not equal to zero. It is either positive (or) negative but the sum of these two factors will almost all the cases is positive in order to take the advantage of positive correction. In this S-gearing, the centre distance is keep on changing, because the pressure angle keeps on charges because the pitch circles cannot meet at a point.

Correction Factor	$+x = 0.62, +0.43$ and -0.43
No. of teeth	Z_1
Pitch circle diameter	$d_1 = Z_1 m$
Tip circle diameter	$da_1 = d_1 + 2m + 2x, m$
Root circle diameter	$dr_1 = d_1 - 2(1.25 - x_1) m$
Tooth thickness on pitch circle	$S_1 = \pi m/2 + 2x, m\tan\alpha$
Base circle diameter	$d\cos\alpha$

The type of correction adopted is the S-o gearing.

5.MODELING AND ANALYSIS

In this section, the profile of the involute spur gear tooth was generated using the modeling software Pro-E (Wild fire 2). First, the four different circles representing the Addendum, pitch circle, base circle and the dedendum are drawn using the sketch tool. Using the extrude tool and the pattern tool the full gear model is developed. Then by using the sketch tool and extrude tool the bore diameter is created. The single tooth profile is then selected meshed using hyper mesh and imported through IGES file conversion to the ANSYS file.

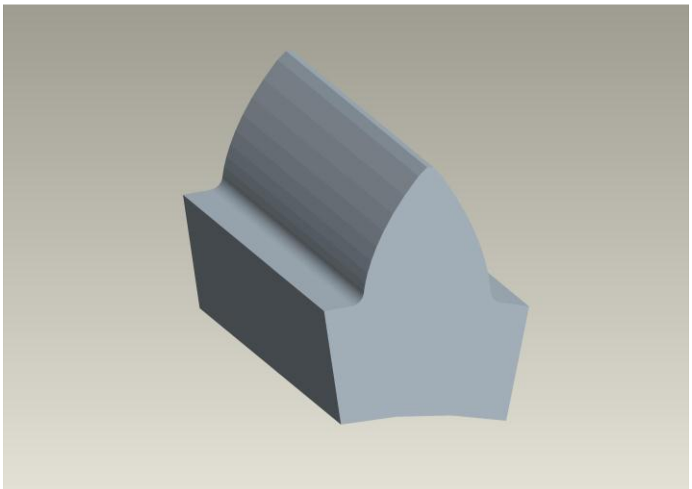


Fig No 1: Profile corrected spur gear model

m=9, ϕ = 20^0, correction factor = +0.62

The analysis consists of discretization of the given domain into a collection of pre-selected elements, derivation of element equations for all typical elements in mesh, imposition if boundary conditions, solution and post processing of results. The gear tooth at the fillet region is discretized into very small elements. Here the element type is considered as 8 node 82 plane element. Large von-mises stresses are at the root of the tooth. They are equal to the tensile stresses. The tensile stresses are the main cause of the crack failure, if they are large enough. That is why cracks usually start fram the tensile side. From the Lewis equation if the diameters of the pinion and gear are always kept the same and the number of teeth was changed, the module will be changed.

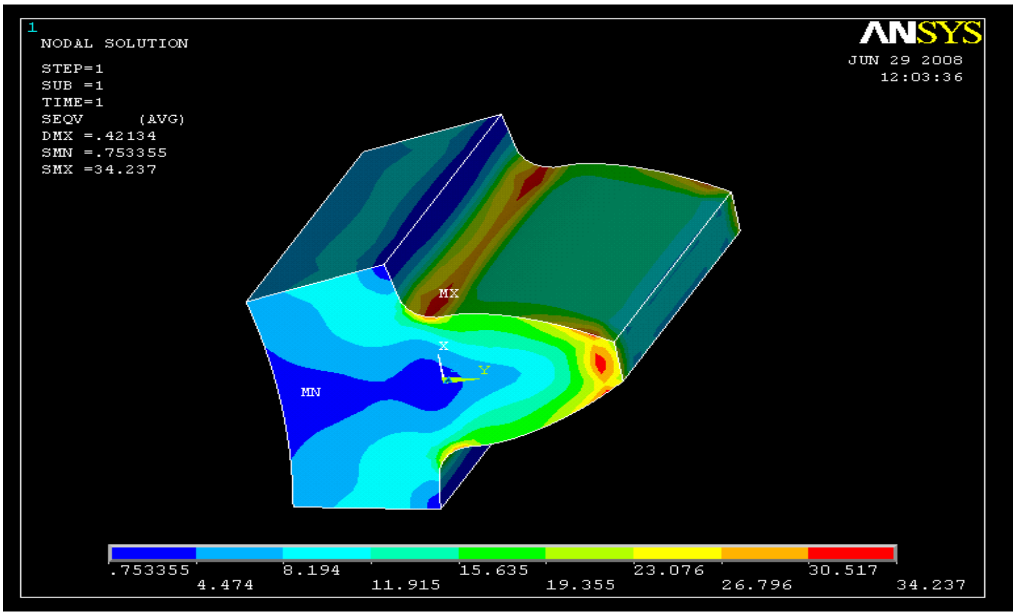


Figure 2 : Stress contour – Von – Mises Stress of Standard Plastic Spur Gear for m = 9, correction factor = 0

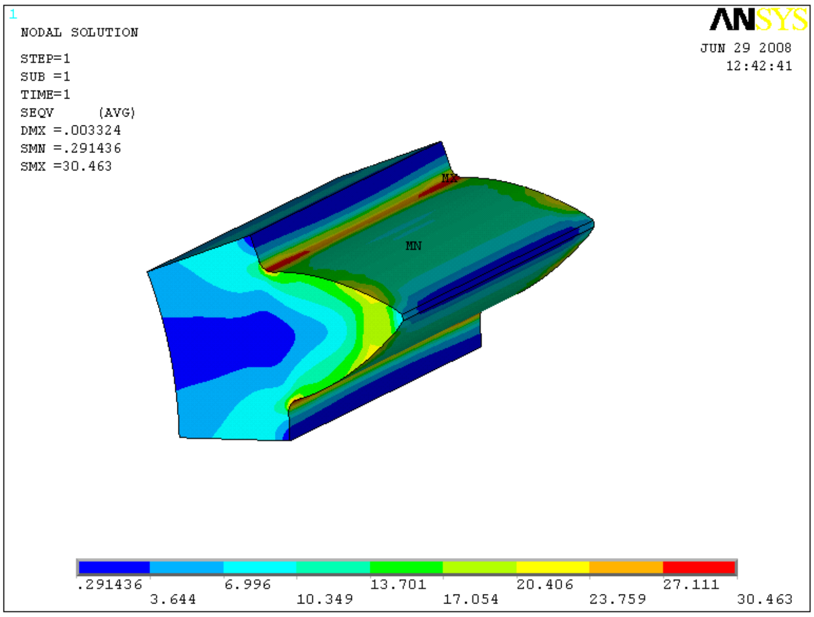


Figure 3 : Stress contour – Von – Mises Stress of Profile Corrected spur gear for m = 9, correction Factor = +0.62

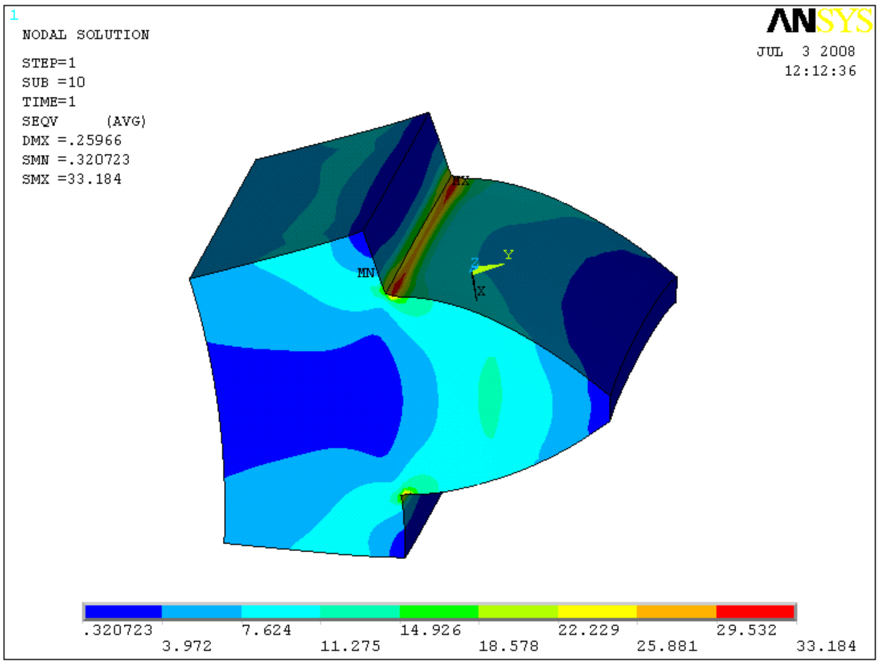


Figure 4 Stress contour – Von – Mises Stress of Standard Plastic Spur Gear for m = 9, correction factor = + 0.43

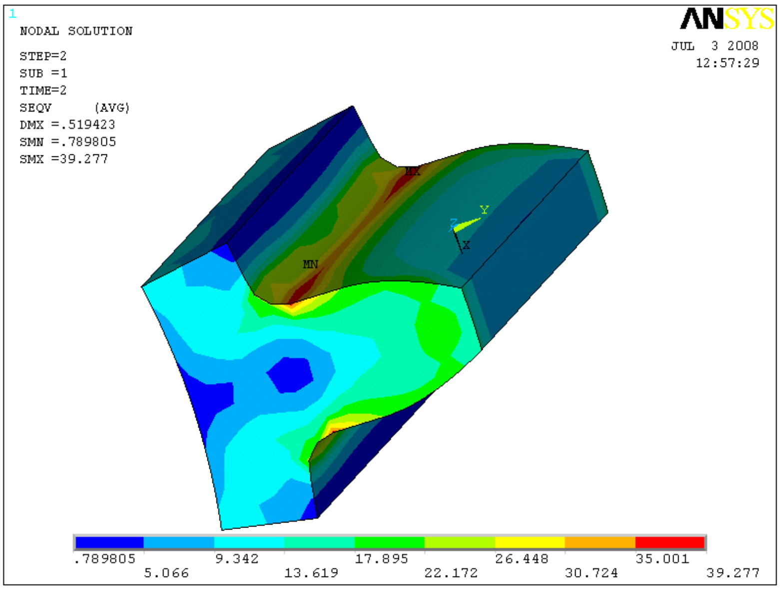


Figure 5. **Stress contour – Von – Mises Stress of Standard Plastic Spur Gear for m = 9, correction factor = - 0.43**

6. RESULT OF STRESS ANALYSIS

The results of stress analysis are as given below:

Table 6:1Von-Mises Stress Values of Standard Plastic Spur gear for different modules

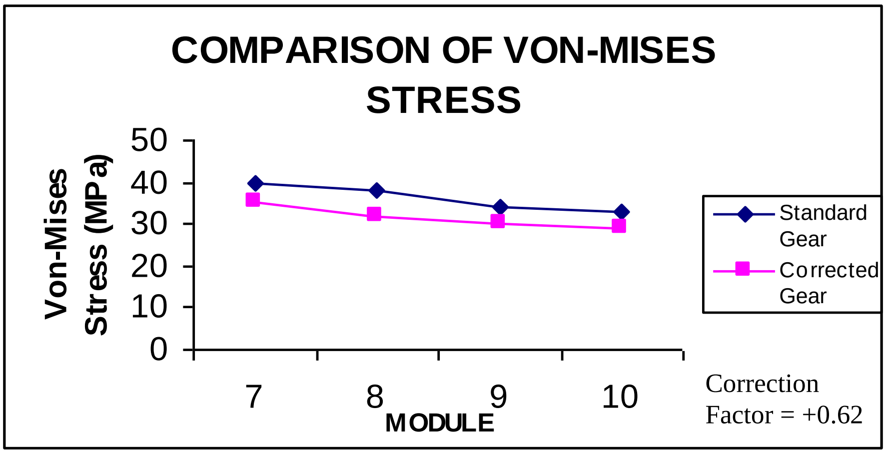
Module (mm)	Von-Mises Stress (MPa)
7	40
8	38
9	34
10	33

Table 6.2:Von-Mises Stress Values of Profile Corrected Plastic Spur gear for different modules

Module (mm)	Von-Mises Stress (MPa)
7	35
8	32
9	30
10	29

Table 6.3.Von-Mises Stress Values of Profile Corrected Plastic Spur gear for different correction Factors

Correction Factors (x)	Von-mises stress (MPa)
+0.62	30
+0.43	33
0	34
-0.43	39
-0.62	45



Graph 1 : Comparison of Standard Tooth Results

7. CONCLUSION

In this paper, the stress analysis of the standard and profile corrected plastic spur gear teeth was done. The spur gear tooth geometry was created using the modeling software PRO-E. The meshing was done through CAE software HYPERMESH. Subsequently analysis of the meshed model was carried out using analysis software ANSYS 10.0. It is concluded that maximum stress concentration occurs at the root of the gear tooth and by increasing the module the load carrying capacity is increased. Also the load carrying capacity is more for profile corrected gear tooth. It was found that the root stress value decreases as the correction factor increases. The results of the stress analysis for different modules are compared for the standard plastic spur gear and the profile corrected plastic spur gear with different correction factors.

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