

# Stress Analysis of SIC Reinforced Polyester Nano Composite Spur Gear

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## Abstract

Gears are most powerful machine element to transmit the motion between rotating shaft. It acts as a dominating transmission system from many years ago. In this study, we analyzed a spur gear machine tool for special application using theoretical method and Finite element analysis. Here, the bending stress on the spur gear is analyzed since these stresses induced play a vital role in gear life. The analysis presented the effect of gear material on induced bending stress. Finally results of theoretical method and Finite element analysis were determined and when compared gives a better results.

**Keywords:** Spur gear, Finite element analysis, ANSYS workbench.

## 1. Introduction

Gear is a mechanical element used to transmit power and motion by progressively engagement of teeth. Using belt drive and other method of power transmissions slipping occurs. To overcome the problem of slipping gears are employed which produce a positive drive with uniform angular velocity. The main aim of gear drive system is to transmit high power with smaller dimension of driving system which can be constructed with minimum manufacturing cost and runs reasonably free of vibration and noise. So design should be economically sound and feasible. Finite Element Analysis is a numerical method of analysis for solving many problems in engineering disciplines. It is a powerful tool for engineering analysis to solve problems from very simple to complex. FEA works with different levels of geometry idealization and gives results with better accuracy.

There are several types of gear available but the simplest and widely used gears are the one which used to transmit determined speed ratio between two parallel shafts at defined distance.

Spur gear is type of gear having teeth straight and are parallel to the wheel axis. Here parallel and co-planar shafts are used to connect the gear. Such arrangement is referred as spur gear. The merits of spur gear are easy to design, low maintenance and economical to manufacture and they impose only radial load on the bearings. Helical gears have their teeth inclined to the shaft axis which is in the form of a helix. These gears can carry high load compare to other gears. Single helical gears impose both radial loads and thrust loads on their bearings and so require the use of thrust bearings.

Bevel gears also called as Miter gears which are connected by intersecting coplanar shaft. Straight bevel gears can be used on shafts at any angle, but right angle is the most commonly used. The teeth of straight bevel gears are tapered in both thickness and tooth height.

Worm gears are used to transmit power at right angle and employed where high speed reductions ratios are required. The shafts of worm gears lie in parallel planes and may be skewed at any angle between zero and a right angle. Worm gears are quiet, vibration free and give a smooth output. Worm gears and worm gear shafts are almost invariably at right angles. Faydor L.Litvin et.al (1) investigated asymmetric modified spur gear drives. He developed geometry of gear drive to localize the contact of bearing. Then stress analysis of symmetric and asymmetric spur gear have performed. The result revealed that there is a reduction of bending and contact stress on an asymmetric spur gear. J.D.Andrew et al. (2) analyzed using finite element method to determine fillet stress distribution. Here spur gear profiles of external and internal type are considered. The predicted results are compared with the photo elastic experiments. L.Fredette et al. (3) summarized reduction of stress in spur gear using stress relief feature. Here, holes were drilled on a part of gear especially in critical area to relief stress. Using finite element method the stress were analyzed by varying the hole size diameter. The obtained results were crosschecked by photo elastic testing method. V.Rajaprabakaran et al. (4) analyzed stress analysis of spur gear teeth. In this fatigue failure of tooth gear occurred due to repeating stress. Here different hole size are added on gear tooth at various location to reduce the concentration of stress. The result depicts that a aero shape fin type hole gives better results.

Vivek Karaveer et al. (5) studied the modeling and finite element analysis of spur gear. He analyzed the maximum contact stress in the mating spur gear teeth. Using finite element analysis this process are carried out and compared with theoretical models. T.Veere Pratap Reddy et al. (6) investigated the contact pressure analysis of spur gear using finite element analysis. This paper explained the stress analysis on involute spur gear teeth. The results obtained by analytical method are compared with Hertz equation. The result conveys that as the module of gear increases the contact pressure decreases for a set of gears.

Santosh S.Patil et al. (7) studied the contact stress analysis of helical gear in static condition. Here different angle of gear sets are employed. Using three dimensional finite element analyses were carried out. The report conveyed that there is variation of contact stress with helix angle. The results are compared with theoretical data. P.Ravikanth Raju et al. (8) studied using CAD and CAE modification of spur gear teeth. Here the strength of the gear tooth profile is improved by modifying the gear geometry. The gear tooth damaged is avoided by modification in root fillet. The modified teeth are compared with standard dimension. The result explained that circular root fillet type is better for lesser number of pinions. Hariharan et al. (9) explained the spur gear tooth analysis to reduce the stress. Here different studies are carried out on contact point of gear tooth profile. The different stress relief feature is introduced in the gear geometry to find out the fatigue failure in gear. M.S.Hebbal et al. (10) analyses a study on reduction in fillet stress using stress relieving feature of various shape. Here a combination of circular and elliptical stress relief feature are introduced and result is summarized. The result obtain were better when compared to circular stress relief feature. Andrzej et al. (11) presented a comparative analysis of strength of tooth using ISO and AGMA standards. Here a model is developed and simulations are carried out using finite element methods. Different parameters are considered and analysis is carried out gives a data for modification of gear standards.

Seok at al. (12) summarized the contact stress analysis for a pair of mating gear during dynamic condition. Here spur and helical gear are investigated between two gear teeth at different point of contact during rotation. The results depicts that contact stress on a gear set is more severe than AGMA standard. S.Vijayarangan et al. (13) studied stress analysis of composite spur gear using finite element approach. Here static stress analyses are carried out on orthotropic material. The obtained results are compared with gear made of mild steel. The result confirmed that graphite epoxy composite gear gives better power transmission. Yogesh C.Hamand et al. (14) analyzed stresses and deflection of sun gear by theoretical and ANSYS method. Here stresses on sun gear, deflection and various forces acting on gear tooth are analyzed. The results obtained from ANSYS are compared with theoretical data. S.Patil et al.

(15) evaluated the contact pressure on a gear pair using finite element analysis. Here a model is created and studied is carried out along the line of action. The results are verified using twin disc experimental results and Hertz equation.

From the above literature survey lot of research work are carried on stress analysis of helical gear and spur gear set using finite element analysis. Here, a spur gear from grinding machine is selected and design specifications are noted .Using Pro-e software spur gear assembly is modeled and finite element analysis were carried out to determine the stress on the mating part. The material is replaced and further analyses were performed to determine the bending stress on spur gears.

Table 1: Material Properties

S.No	Tensile Strength (N/mm <sup>2</sup> )	Compressive Strength (N/mm <sup>2</sup> )	Flexural Strength (N/mm <sup>2</sup> )	Impact Strength (J/m)	Hardness HRB	Water absorption (%)
1	106	515.5	12.3	29	75	.001

Parameter	Driving gear	Driven gear
Pressure angle (degree)	20	20
Number of teeth	18	45
Module (mm)	5	5
Face width (mm)	47.25	47.25
Root circle diameter (mm)	77.5	212.5
Tip diameter (mm)	10	235

## 2. Modelling

The sketch of 3D Spur gear and its assembly parts are shown in below figure.

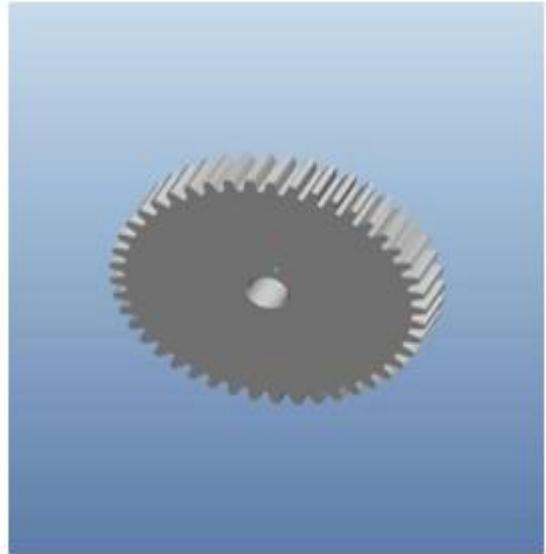


Fig. 1: Three dimensional Wheel



Fig. 2: Three dimensional Spur gear pair

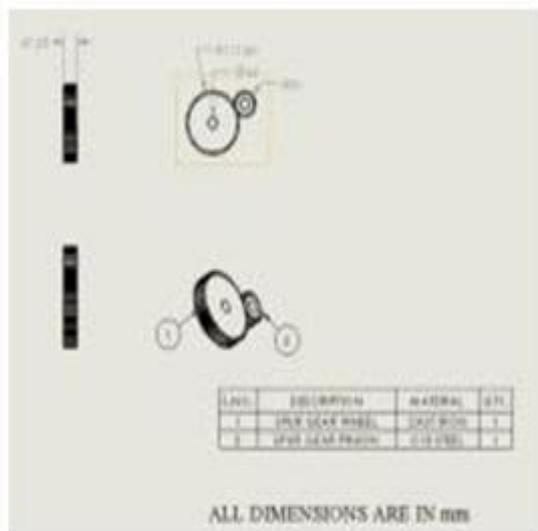


Fig. 3: Spur gear sketching

### 3. Theoretical Analysis of Bending Stress

There are two major stresses developed during spur gear action. They are bending and contact stresses. The bending stresses are analyzed theoretically by Lewis equation. In spur gear set a pinion gear is made of C15 steel and gear wheel is made of Cast iron grade 30. Here theoretical calculation is performed for gear set. The data specification is obtained from spur gear pair in stone crusher application. From the data the speed of pinion gear is 900 rpm, power supplied is 2.5 kW, gear ratio is 2.5 and pressure angle is 20. The gear life of spur gear is 10000 hours. Assume, life of spur gear is 10000 hours.

$$N = 10000 \times 60 \times 90 = 54 \times 10^7 \text{ cycles.}$$

The torque value is calculated for spur gear using

$$M_t = M_t \times K \times K_d \tag{1}$$

$M_t = 238.73 \text{ Nm}$ ,  $K \times K_d = 1.3$  Design torque  $M_t = 310.35 \text{ Nm}$ .  
 $K_{bl} = 1$ ,  $n = 2$ ,  $k\sigma = 1.2$ ,  $\sigma_1 = 232.2 \text{ N/mm}^2$   
 Design bending stress =  $132.625 \text{ N/mm}^2$   
 Where,  $CR = 22\text{HRC} = 63$ , for C15 steel,  $K_{cl} = 0.585$

$$= 810.81 \text{ N/mm}^2$$

Where,  $\Psi = 0.3$  (2)

$$= 136 \text{ mm}$$

Let assume Number of teeth on pinion ( $Z_1$ ) is 18 and ( $Z_2$ ) is 45 and is calculate using  $Z_2 = i \times Z_1$

Then further the module is calculated and Centre distance is revised

$$m = \frac{2a}{Z_1 + Z_2} = 4.56 \text{ mm} \tag{3}$$

Here we are determined the induced bending stress and compressive stress and compare the value with the allowable stress to check the design condition.

Induced compressive stress =  $684.76 \text{ N/mm}^2$

Design is safe that is  $\sigma_c < \sigma_c$

For Cast iron grade 30 wheels,

From Equation 2 the allowable bending stress is calculated for wheel,

$$K_{bl} = 0.918, n = 2, k\sigma = 1.2, \sigma_1 = 130.5$$

From Equation 3 the allowable compressive stress is determined

$$HB = 260, K_{cl} = 0.879, \sigma_c \text{ wheel} = 525.64 \text{ N/mm}^2$$

Therefore induced bending stress on wheel is  $68.75 \text{ N/mm}^2$  which is less than allowable bending stress on wheel.

Hence design is safe.

### 4. Finite Element Analysis Using Ansys Work Bench

The spur gear of stone crusher machine is modeled in Creo. The assembled model which is saved in IGES format is imported to ANSYS workbench for static loading analysis. A frictionless support is given at Centre face of pinion and wheel of spur gear and rotational speed of 900 rpm is applied on the pinion gear. The loading condition on assembled model is shown in figure 5 and figure 6 represents the meshed spur gear. The bodies of all spur gear are discretized in the form of tetrahedron shape meshing. A tetrahedron has 4 vertices, 6 edges, and is bounded by 4 triangular faces. The tetrahedral volume mesh can be generated automatically. This type of meshing gives more accurate results when compare to other meshing type. The loading condition are shown in Table 3.

Table 3: Loading Conditions

Rotation speed (rpm)	Support
900	Frictionless support at Centre face
900	Frictionless support at Centre face

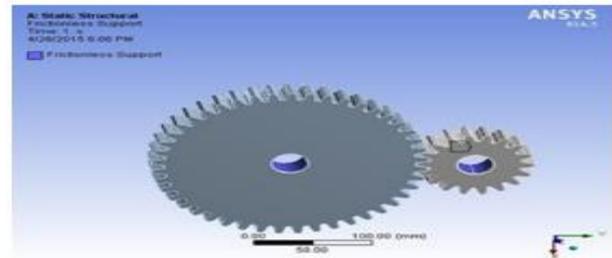


Fig. 4: Loading condition

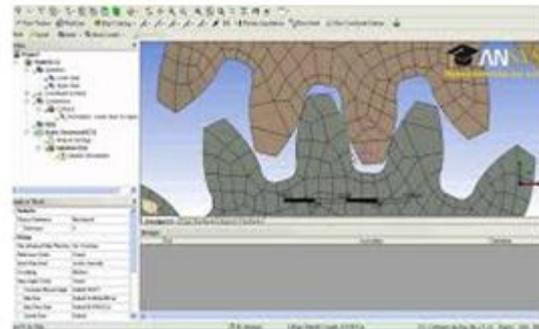


Fig. 5: Meshing

Here the spur gear made nPMC are analyzed for bending stress under static loading condition. The loading condition on the model is performed in ANSYS software. The results of both the analyzed spur gear model are shown in figure 7 and figure 8 respectively. The stress distribution of the model will be displayed at left side of window. The colour range shows the maximum stress value to minimum stress value.



Fig. 6: Bending stress on gear

### 5. Results and Discussions

The results of Theoretical bending stress and Finite element analysis method for material are compared which is shown in table 4.

Table 4: Bending Stress

Gear material	Theoretical Bending stress (Mpa)	Finite element method (Mpa)
nPMC Sample 1	65	53
nPMC Sample 2	60	50

## 6. Conclusion

In this study the bending stress developed under a spur gear pair of stone crusher machine with static loading is calculated using Theoretical and Finite element analysis method. The result obtained which are quiet favorable with a small percentage difference. Here, nPMC wheel is analyzed. It shows that bending stress induced at the mating point and maximum bending stress is approximately 53Mpa. Other is revealed that maximum bending stress is 50 Mpa. Using both the material pairs safe modeled can be designed.

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