

INVESTIGATION AND STRUCTURAL ANALYSIS OF SPUR GEAR USING ANSYS

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Abstract - Gear is a rotating machine part having a cut a toothed wheel. It is an important element for mechanical power transmission's system. The use of these gears filed from tiny wrist watches to huge machinery equipment gears from vital elements of mechanism in many machines such as gear box, automobile, aerospace industry, rolling mills, and transmitting machinery, marine engines, and the like. Spur gear has straight tooth and unit area parallel to the axis of the wheel. In A general action of spur gear subjected to two types of cyclic stress: contact stress and bending stress. The bending stress and total deformation of toothed gear taken into account to predominate objective for contemporary gear style. In this paper work, estimate the root-bending stress and total deformation of a spur gear tooth. The dimension of the gear is taken from practical understanding spur gear use in gear box of commercial vehicle of TATA Motors and it analyzed for different torque specifications of the three different vehicle models of TATA Motors using ANSYS (Workbench) software considering an alloy steel as tooth material. This study is based on the manufacturing of spur gear wheel using a material alloy steel at the critically stressed section by using a FEA software analysis. We use cantilever beam concept and Castigliano's theorem for analytical calculation of gear design, has also been excogitated in the present work.

Key Words: FEA (Finite element analysis), HPT (Height of Parabolic Teeth), Lewis Form Factor,

1. INTRODUCTION

Gearing is a critical component in a mechanical power transmission system and in most industrial rotating machinery. Gear is a wheel with teeth shaped, it transmits rotational motion from one wheel to another wheel the most effective means of transmitting power in future machines due to their high degree of reliability. In the industry rapid use of gear such as heavy shipbuilding's, automobile manufacture and office automation tools will necessitate a refined application of gear technology. The gear box is the second element of the power train in an automobile. Gears are used to change the torque and speed of vehicle according to types of road and load. By using of gear box in vehicle its changes the engine speed into torque when climbing hills and when the vehicle required. Main functions of a spur gear in gear box are as follows:

1. By providing the torque required to move the vehicle under a various types of road and load conditions. It's done, by changing the gear ratio between the engine crankshaft and vehicle drive wheels.
2. Be shifted into reverse therefore the vehicle will move backward.
3. Be shifted into neutral for beginning the engine.

Sometimes, it's also called as torque converter. In this, analysis the characteristics of involutes spur gears in a gearbox will be studied using Ansys Software. Spur gear is the most commonly used gear type. They characterized by teeth which are perpendicular to the face of the gear. Spur gear are most commonly available and generally the least expensive. It is mostly use in gear motors and gear pumps, automobile gear box etc. Among a various types of gear the profile of the spur gear tooth is in the shape of an involutes curve and it remains identical along the entire width of the gear wheel. Spur gear with involutes profile is the simplest considering the design and manufacturing cost. The pinion is manufacture from a harder material than the wheel. Spur gear is commonly selected to have a ratio range of between 1:1 and 1:6 with a pitch line velocity up to 25 m/s. Operating efficiency of spur gear up to 98-99%. Spur gear is use in gear box of in a commercial vehicle of TATA Motors as an idler gear. In this paper work we use idler gear of commercial vehicle of gear box and static analysis of the spur gear in the existing automobile gear box are discussed with various torque specifications. On the basis of that study, the analysis of both cast steels and composite materials was analyzed in the application of gear box which is used in automobile vehicles. Composite materials are capable of using in automobile vehicle gear boxes up to 1.5KN in their work, have shown the design and analysis of a composite gear wheel made from 50% carbon fibers in epoxy resin matrix and compared to steel gear, 0.5324% lesser stress and 55.619% reduction in total deformation has been found for the composite gear[2].

2. MATERIAL PROPERTY

For casting of spur gear used a material alloy steel. Alloy steel is resist to rust, high durability, high strength and corrosion resistance that make a alloy steel as a popular material for spur gear casting. For design of gear we take a 20° full depth involutes spur gear made from alloy steel [3]. The alloy steel contains 0.18-0.23 carbon, 96.9-98.02 iron,

0.4-0.7 nickel, 0.7-0.9 Mn and 0.15-0.35 Si. The other designation of this material is shown in Table-1.

Table -1: Material Property

Properties	Units	Value of alloy steel
Elastic module	N/m ²	2.1×10 ⁵
Poisson ratio	N/A	0.28
Shear module	N/m ²	7.9×10 ⁵
Mass density	Kg/m ³	7700
Tensile strength	N/m ²	723825600
Thermal conductivity	W/mk	50
Specific heat	J/kgk	460

3. DESIGN PARAMETERS

Spur gears are using since ancient times period. For the design, specification, discuss of spur gear system it is necessary to know the terminology and concepts related of spur gear wheel system. We are taken a standard model of spur gear for designing of the involutes profile spur gear [4]. The following parameters are taken for the design of 20° full depth spur gear model.

Table- 2: Design Parameter for Solid Model

Parameters	Notations	Value
Module	m (mm)	10
Pitch circle diameter	d (mm)	180
Teeth in gears	Z	18
Base circle diameter	D _b (mm)	69.145
Outside circle diameter	O _d (mm)	200
Clearance	(mm)	1.57
Hole depth	(mm)	22.5
Thickness of the tooth	t(mm)	15.71
Face width	b(mm)	54
Circular pitch	(mm)	31.4
Pressure angle	φ (Degree)	20

The gear is using for transmit the force or motion is known as the drive gear and the gear attached with the drive gear is known as the driven gear. Gears are used to control power. For the torque specification, we take the value of three different commercial vehicle of TATA Motors are given below [5, 6, 7].

Table- 3: Specification of commercial vehicle of three different models

Parameter	Tata super ace mint	Tata super gold	Tata ace zip
Engine capacity	1396 cc	702cc	610CC
Maximum engine output	70HP@4000 rpm	16HP@3200 rpm	12HP@3000rpm
Maximum engine torque	140Nm3000 rpm	39 Nm @ 2000 rpm	35Nm@1800rpm
Fuel tank capacity	38 L	30 L	10L
Tyres	165 R14 LT 8PR	145R12 LT 8PR	145/80R12 LT6PR
Wheel base	2380	2100	1650
Width	1565	1500	1480
Length	4340	3800	3020
Height	1858	1845	1800
Front track	1340	1300	1256
Rear track	1320	1320	1316

4. SOLID MODELING OF GEAR

4.1 Generation of 3d Model of Gear Pairs in Solid Works

SOLIDWORKS uses a 3D design approach. We design a part, from the initial sketch to the final result, we create a 3D model. From this model, we can create a mate components consisting of parts or subassemblies to create 3D assemblies. The SOLIDWORKS software is a mechanical design automation application that lets designers quickly sketch out ideas, experiment with features and dimensions, and produce models and detailed drawings. Concepts Parts are the basic building blocks in the SOLIDWORKS software. Assemblies contain parts or other assemblies, called subassemblies. A SOLIDWORKS model consists of 3D geometry that defines its edges, faces, and surfaces.



Figure 1 solid works 3D model 18 teeth



Figure 2 Spur gear tooth

Mapped Mesh Type	Hexa
Surface Mesh Method	Program Controlled
Element Order	Global Setting
Src/Trg Selection	Automatic
Sweep Element Size	100. µm
Mesh Based Defeaturing	Off
Minimum Edge Length	492.25 µm
Write ICEM CFD Files	No

4.2 Meshing

Meshing is an integral part of the computer-aided engineering simulation process. The mesh influences the accuracy, convergence and speed of the solution. Furthermore, the time it takes to create and mesh a model is often a significant portion of the time it takes to get results from a CAE solution. From easy, automatic meshing to a highly crafted mesh, ANSYS provides the ultimate solution. Once the best design is found, meshing technologies from ANSYS provide the flexibility to produce meshes that range in complexity from pure hex to highly detailed hybrid; a user can put the right mesh in the right place and ensure that a simulation will accurately validate the physical model.

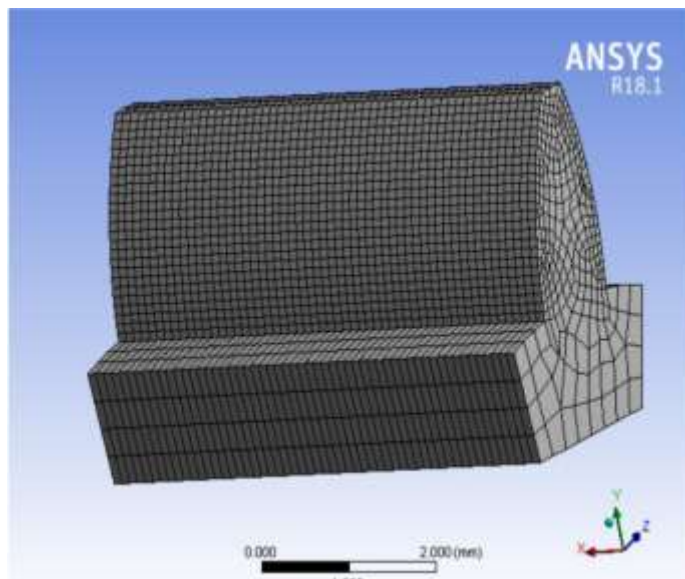


Figure 3 Meshed spur gear tooth

Table- 4: Mesh Controls

Face Sizing	Multi Zone
State	Fully Defined
Suppressed	No
Element Size	100. µm
Method	Multi Zone

5. ANALYTICAL CALCULATION

By using relation of maximum bending stress (σ_b) and deflection (δ) based on the above design specifications from the Table 2, and considering alloy steel as a tooth material the analytical calculation is carried out.

5.1 Calculation for Bending Stress

(1) Calculating a bending stress for TATA SUPER GOLD, Consider torque $T = 39$ N-m at 2000 rpm. The tangential load is often found from the below:

$$F_t = \frac{2T}{d}$$

Where d is pitch circle diameter. We putting the value of pitch circle diameter and torque in above equation.

$$F_t = \frac{2 \times 39}{180 \times 10^{-3}} = 433.3 \text{ Nm} \tag{1}$$

The theoretical bending stress is determined by given equation:

$$\sigma_b = F_t / m.b.Y$$

Where

$$Y = \text{Lewis form factor } (0.308).[8]$$

$$b = \text{Face-width}$$

From the table 2 we putting the value in above equation

$$\sigma_b = \frac{433.3}{10 \times 54 \times 0.308} = 2.605 \text{ MPa}$$

(2) Calculating a bending stress for TATA ZIP ACE, Consider torque $T = 35$ N-m at 1800 rpm. The tangential load is often found from the below:

$$F_t = \frac{2T}{d}$$

Where d is pitch circle diameter. We putting the value of pitch circle diameter and torque in above equation.

$$\sigma_b = \frac{2 \times 35}{180 \times 10^{-3}} = 388.88 \text{ Nm} \quad (2)$$

The theoretical bending stress is determined by given equation:

$$\sigma_b = F_t / m.b.Y$$

Where

Y = Lewis form factor

b = Face-width

From the table 2 we putting the value in above equation

$$\sigma_b = \frac{388.88}{10 \times 54 \times 0.308} = 2.33 \text{ MPa}$$

5.2 Calculation of Deflection

Deflection of spur gear when load is applied at tip of tooth is calculated by using equation:

$$\delta = \frac{16.F_t.h^3}{E.b.t^3}$$

Lewis form factor is given by

Y = t² / (6hm) is known as Lewis form factor

By use of Lewis from factor we calculate the value of h=13.33. The value of elastic module is taken from alloy steel material from Table 1.

- (1) Calculating a deflection for TATA SUPER GOLD at given torque T = 39N-m at 2000 rpm. The value of F_t is taken from equation (1).

$$\delta = \frac{16 \times 433.3 \times 13.33^3}{2.1 \times 10^5 \times 54 \times 15.7^3} = 0.0003741 \text{ mm}$$

- (2) Calculating a deflection for TATA ZIP ACE at given torque T = 35 N-m at 1800rpm. The value of F_t is taken from equation (2).

$$\delta = \frac{16 \times 388.8 \times 13.33^3}{2.1 \times 10^5 \times 54 \times 15.7^3} = 0.0003741 \text{ mm}$$

Table 5 Theoretical deflection and stress at specific torque condition alloy steel.

Commercial vehicle model of Tata motors	Tata SUPER Gold	Tata Ace Zip
Torque (N-m)	39	35
Tangential Load	433.3	388.88
Theoretical Stress (MPa)	2.605	2.33
Theoretical Deflection (mm)	0.0003741	0.0003357

6. FEA ANALYSIS AND SOLUTION

This analysis is based on the investigating the bending stress and deflection at the tip of tooth of spur gear in the desirable limits to get a practical validation for the theoretical result. Static analysis, performed in ANSYS (Workbench 18.1). ANSYS is engineering simulation software that predicts with confidence about the performance of the product under the real-world environments incorporating all the existing physical phenomena.

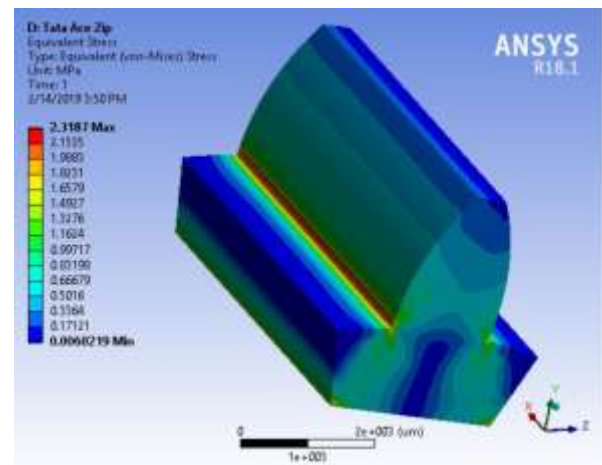


Fig. 4 Equivalent stress of spur gear tooth for Tata Ace Zip

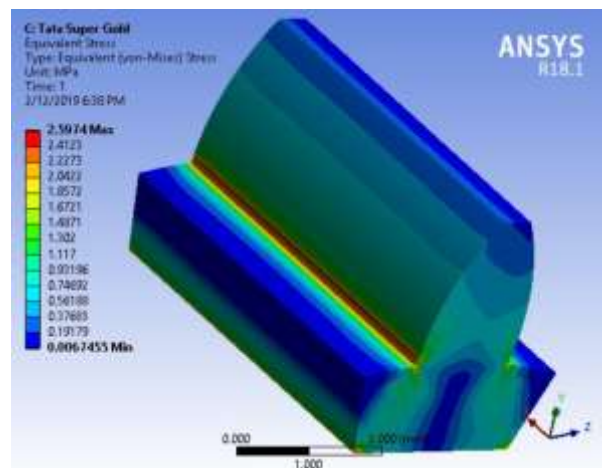


Fig. 7.2 Equivalent stress of spur gear tooth for Tata Super Gold

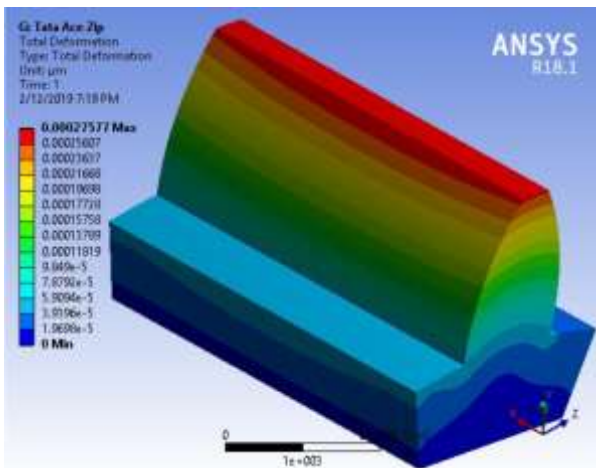


Fig. 7.4 Total deformation of spur gear tooth for Tata Ace Zip

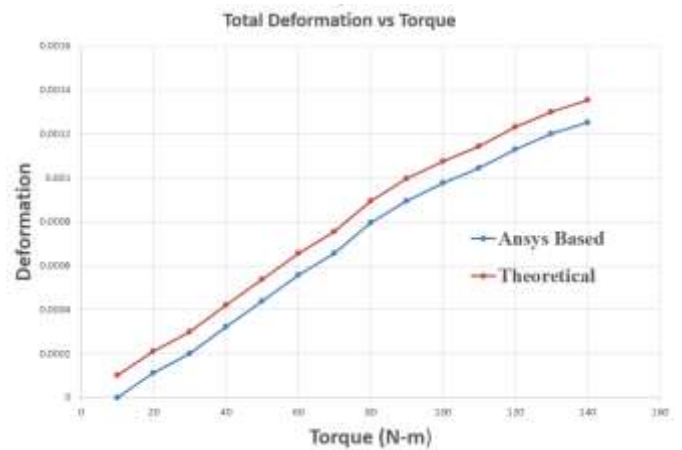


Fig 7.8 Variations of Deformation at Different Torque Conditions

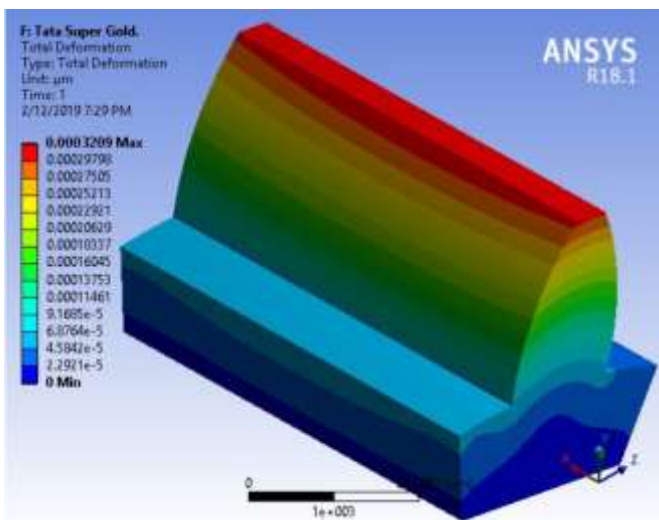


Fig. 7.5 Total deformation of spur gear tooth for Tata Super Gold

Table No 6 Comparison between Theoretical stress and ANSYS based Von Mises stress for Commercial vehicle models at specified torque conditions.

Commercial vehicle model	Tata Ace Zip	TATA Super Gold
Tangential Load	388.8	433.3
Torque(N m)	35	39
Theoretical Bending stress (MPa)	2.33	2.605
ANSYS based Von Mises stress (MPa)	2.3187	2.5974
% Accuracy	99.51	99.70
% Error	0.4849	0.2917

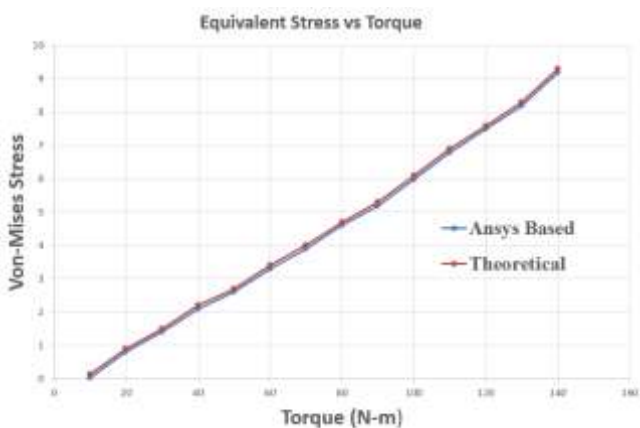


Fig 7.7 Variations of Stresses at Different Torque Conditions

Table No 7 Comparison between Theoretical deflection and ANSYS based deflection for Commercial vehicle models at specified torque conditions

Commercial vehicle model	TATA ACE ZIP	TATA ACE ZIP
Torque (N m)	35	39
Theoretical Deflection(mm)	3.3575×10^{-4}	3.7418×10^{-4}
ANSYS based Total Deformation(mm)	0.00027577	0.0003209
%Accuracy	82.13	85.76
% Error	17.86	14.23

6.1 Conclusion

The ANSYS based results and theoretical results are compared with two distinct transmission specifications in connection with the different commercial vehicle models of TATA Motors. The aim of this structural analysis is to be investigating the bending stresses and the deflection on the tooth of a spur gear to obtain a practical validation for the theoretical results. At the torque condition 35Nm @1800rpm Von-Mises stress become 2.3187MPa. By the Table 6 it clearly seen if we increase the torque condition error % is become lesser and lesser and theoretical and Von Mises stress is closer to each other. Also, for the deflection AT 35Nm@1800rpm ansys based deflection is become 0.00027577 mm. By the Table 7 the decreasing the torque conditions % error is become higher. Some study is based on reduction of gear material by this analysis it is seen the tooth of the gear are critically stressed. So, for we suggest that gear tooth is made for better properties material than the core.

REFERENCES

- 1) V.B. Bhandari, Design of Machine Elements, 2nd ed. New Delhi, India, McGraw Hill Education, ISBN:0-07-061141-6, 2009
- 2) A.R. Nayak, Design and analysis of the composite spur gear, International Journal of Advanced Technology in Engineering and Science (IJATES), Volume No.03, Issue No. 06, June 2015
- 3) http://www.engineering108.com/Data/Engineering/Mechanical/Handbooks/machine_design_databook.pdf.
- 4) S.Mahendran, K.M.Eazhil, L.SenthilKumar; "Design And Analysis of Composite Spur Gear", IJRSI, Volume I, Issue VI, November 2014, ISSN 2321 – 2705
- 5) <https://ace.tatamotors.com/tata-trucks/tata-ace-gold/specifications/tata-ace-gold-specifications.aspx>
- 6) <https://acezip.tatamotors.com/specifications/tata-ace-zip-bs-iv-specifications.pdf>
- 7) <https://superacemint.tatamotors.com/tata-trucks/tata-super-ace-int/specifications/tata-super-ace-mint-specifications.aspx>
- 8) http://www.roymech.co.uk/Useful_Tables/Drive/Gears.html

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