COMPARISON OF ANALYTICAL & FEA OF CONTACT ANALYSIS OF SPUR GEAR DRIVE

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Abstract : *The contact stress in the mating gears is the key parameter in gear design. This paper presents the contact stress analysis of the spur gear pair as first gear in the gearbox of Tata LPT 1112 truck to find maximum stress in the gear teeth. The contact stresses obtained from theoretical Hertz equation values are compared with the Finite Element Analysis (FEA) method. For the analysis, 17-4 PH steel, Brass and Aluminium are used as the materials of the spur gear. The spur gears are modeled and assembled in the CATIA V5 software and FEA is carried out using ANSYS 13.0 software. The results show that the contact stress obtained from theoretical Hertz equation is very less when compared to FEA results hence, both results are comparable.*

Key words: Contact stress, ANSYS, Spur gear, Hertz Equation, FEA.

1. INTRODUCTION

Gears are widely used in all type of machineries in industry. Ever since gear was known over 3500 years before, they become the integral part of every machine. The initial gear drives were simple and rod inserted mounted axially. They used to transmit rotational force or circular motion from one part to another. Pair of gears is used with lower speed cycle. The main difficulty by this system is when the loads and speed were raised the contact stresses were generated at the tip of contact where materials could not withstand these type of stresses due to high wear and contact area.

In gear pairs, the larger one is named as gear and smaller one is called pinion. When pinion acts a driver, it gives step down and results in increase in torque and decrease in the output speed. Gear acts as a driver; it results in step up drive and gives an output in decreases in torque and increase in output speed. Gears are used to create variation in the speed of rotation and to move rotational motion to different-axis.

Vivek Karaveer, Ashish Mogrekar and Preman Reynold Joseph explained analysis of stress of spur gear to find maximum contact stress in the teeth. They compared FEA analysis results with hertz contact equation for the materials grey cast iron and steel. They have created model in ANSYS Design Modeler and analysis is done using ANSYS software. They have concluded that stress values of steel and grey cast iron gear are comparable. S Mahendran, K M Eazhil, and Senthil Kumar they have studied the weight reduction and stress distribution, Impact analysis, torque loading of cast steel and composite materials for Tata Super Ace Model. Modeling of gear is done using SOLIDWORKS software and analysis is done using ANSYS software. They have compared and analyzed composite gear with cast steel. They have concluded that stress values, deformation and weight of the spur gear for composite material are less than cast steel.

Table – 1: Material properties

Property	17-4 PH steel	Brass	Aluminium
Density (g/cm^3)	7.78	8.4	2.70
Young's modulus (GPa)	196	105	70
Poisson's ratio	0.136031	0.357	0.3

2. OBJECTIVE

The main objective of this work is to carry out the contact stress analysis of the spur gear pair as first gear in the gearbox of Tata LPT 1112 truck. The contact stresses obtained from theoretical calculations are compared with the finite element analysis method. The analysis is carried out for different materials like 17-4 PH steel, Brass and Aluminium

3. PROJECT DESCRIPTION

3.1 Design of spur gear

The modeling is done using CATIA V5 software. The maximum contact stress of spur gear is determined during the transmission of Torque of 400N-m by using 17-4 PH steel, Brass, Aluminium materials, using finite element analysis.

Table - 2: Dimensions of spur gear

	Pinion	Gear
Pitch circle diameter (mm)	64	76
Face width (mm)	20	20
Number of teeth	32	38
Pressure Angle (^{0})	20^0	20^0

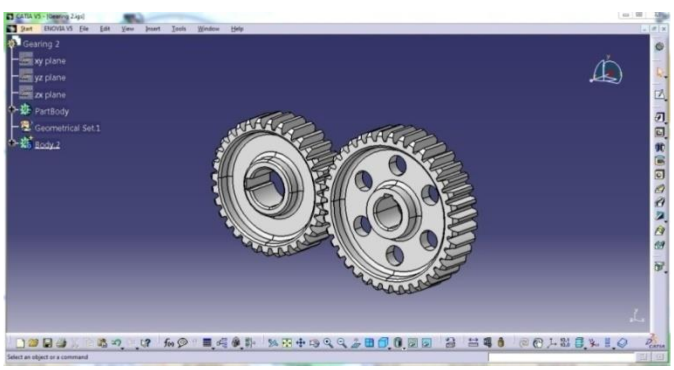


Fig-1: Assembly of spur gear drive set

4.2 Specifications and Design calculations

Table-3: Specifications

Model	TATA TRUCK
Engine	TATA LPT 1112 Truck (BSIII)
Engine capacity	3733cc
Maximum Power	125HP or 92KW
Maximum Torque	400Nm @ 1300-1500rpm
Maximum Speed in Top Gear	83Km/hour

Calculations

Gear Ratio = $\frac{N_P}{N_G} = \frac{T_G}{T_P} = \frac{1500}{Ng} = \frac{38}{32}$

$N_G = 1263.1579$rpm

Torque (pinion) = Force ×Distance

400Nm = F× 32mm

F = 12500N

Using Lewis equation,

Tangential load, F = $b*y*P_c*\sigma_b$

Y=0.134mm, F=12500N, P_c=6.2831mm, b=20mm

The maximum allowable stress σ_b = 742.3272Mpa

Ultimate tensile strength for 17-4 PH steel is = 1030Mpa

Allowable stress for cast steel = ultimate tensile strength/1.2

=1030/1.2 = 858.33Mpa > 742.3272Mpa

So, the design is safe.

4. Theoretical calculation of contact stress (Hertz equation)

Contact stress for 17-4 PH steel material

$$\sigma_c = \sqrt{\frac{F(1+\frac{R_1}{R_2})}{R_1 \times L \times \pi(\frac{1-\mu_1{}^2}{E_1}+\frac{1-\mu_2{}^2}{E_2})\sin\emptyset}}$$

$$= \sqrt{\frac{12500(1+\frac{32}{38})}{32\times 20\times\pi(\frac{1-0.1360^2}{196\times10^3}+\frac{1-0.1360^2}{196\times10^3})\sin20^0}}$$

σ_c= 1828.480MPa

5. Finite Element Analysis

5.1Meshing

In FEA analysis the computational domain is discretized into number of elements and the nodes of the elements are known as grid points. The process of discretizing the domain is called meshing. Fine Meshing is done with the size of 3mm.

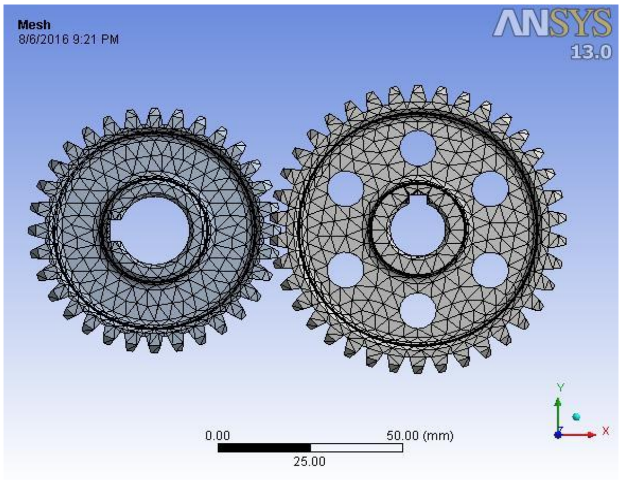


Fig-2: Typical view of meshed spur gear

5.2 Boundary condition

Frictionless support is applied on inner rim of the pinion and Frictionless support is applied on inner rim of Gear. Moment of 400 N-m is applied on the pinion in anticlockwise direction as the driving torque.

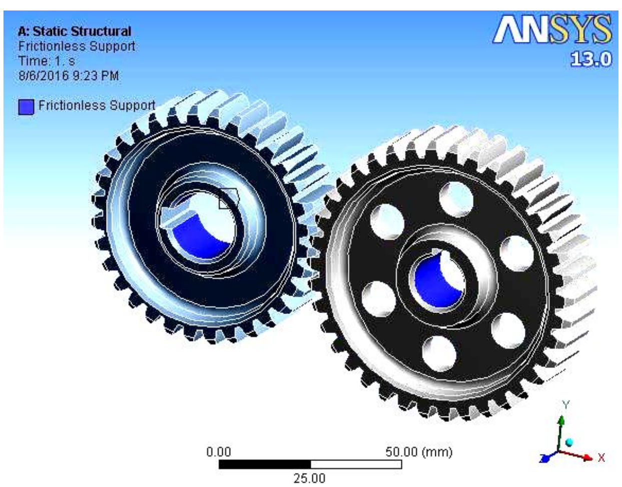


Fig-3: Boundary conditions on spur gear drive

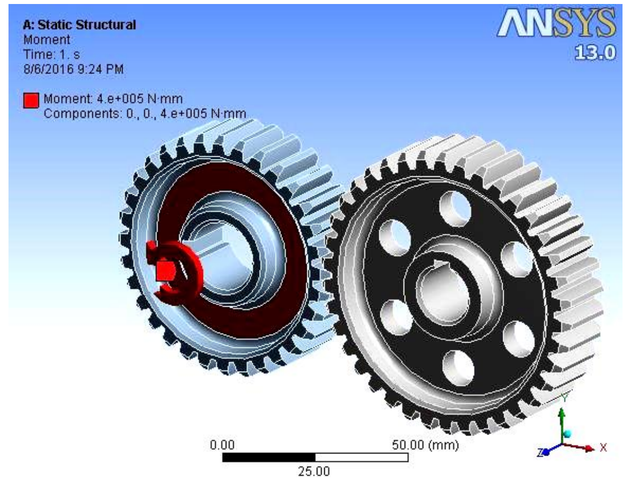


Fig-4: applying moment to pinion

6. Results and Discussion

6.1 FEA results of 17-4 PH steel

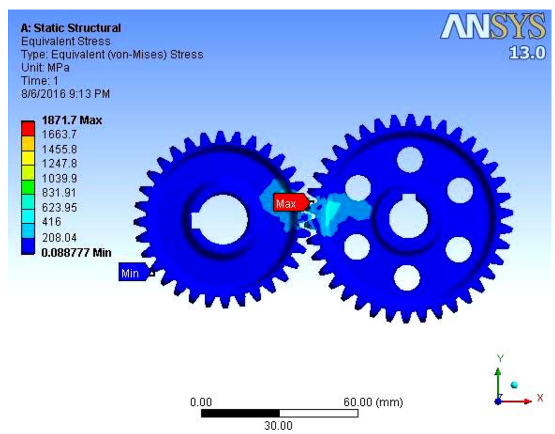
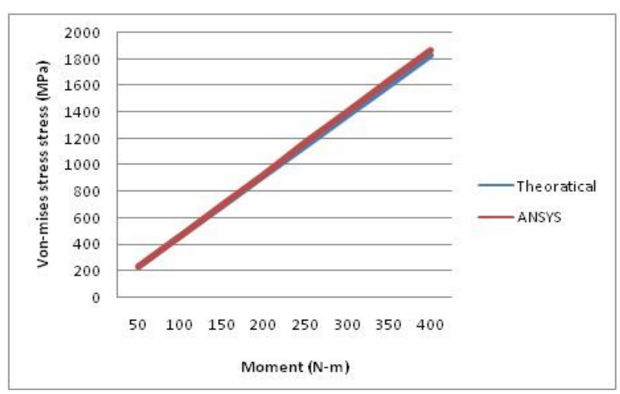


Fig-5: Equivalent (Von-Mises) stress



Graph no-1 Moment vs Von-mises stress for steel and steel

6.2 FEA results of Brass

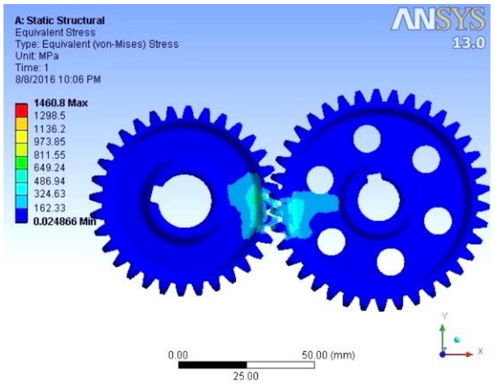
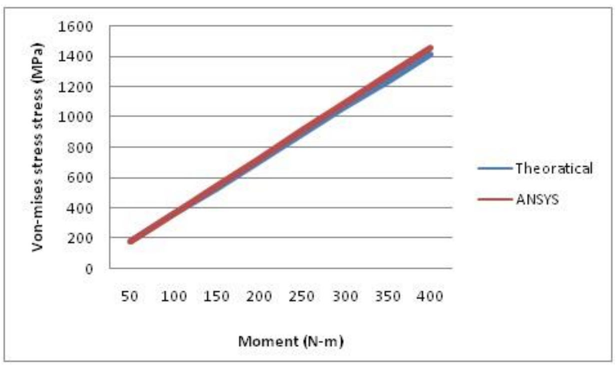


Fig.6 Equivalent (Von-Mises) stress



Graph no-2 Moment vs Von-mises stress for Brass and Brass

6.3 FEA results of Aluminium

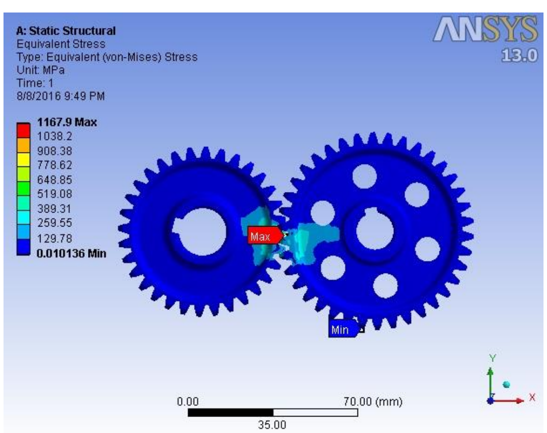
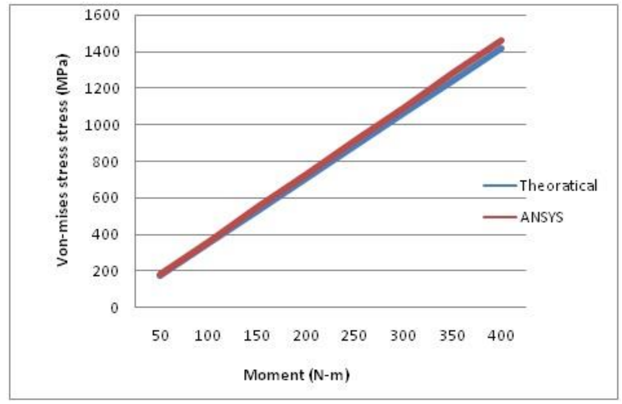


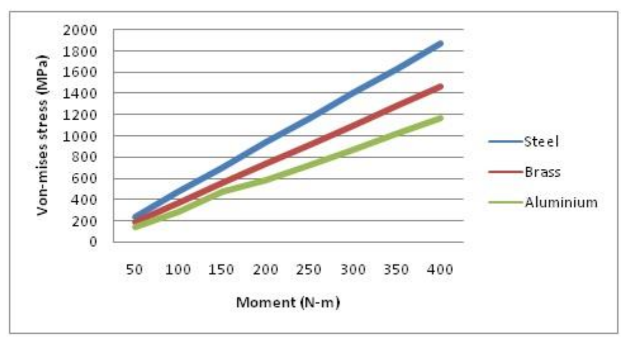
Fig-7: Equivalent (Von-Mises) stress



Graph no-3 Moment vs Von-mises stress for Al & Al

Table - 4: Comparison of contact stress obtained from Hertz equation with FEA results.

Material	Contact stress (MPa)		
	ANSYS	Hertz	Error
17-4 PH steel	1871.7	1828.48	2.36%
Aluminium	1167.9	1460.8	1.839%
Brass	1460.8	1419.40	2.916%



Graph no-4 Moment vs von-mises stress for Steel, Brass & Aluminium

7. CONCLUSION

The difference between theoretical contact stress results of spur gear drive and FEA results are very less. Hence both results are comparable. The theoretical Von-mises stress of 17-4 PH steel & FEA results of 17-4 PH steel are comparable. Similarly the theoretical contact stress of Aluminium, Brass material and FEA results are comparable. We conclude that the stress induced in the 17-4 PH steel material is higher than Brass and Aluminium and stress induced in the Brass material is higher than Aluminium therefore we suggest that aluminum material is best suited to minimize the stress in the gear drive.

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ACKNOWLEDGEMENT

We would like to thanks our BLDE engineering college principal and HOD of mechanical and Automobile engineering departments those who helped us to carry out this research and helped us to use the machines in workshop.

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