FINITE ELEMENT ANALYSIS OF COMPOSITE SPUR GEAR

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ABSTRACT

In this project, an attempt has been made to design, model and finite element analysis of spur gear using composite material. Conventional spur gears are made up of cast iron or mild steel. Composite material could be an alternative for conventional materials considering the advantage of less weight, rust formation and less maintenance. Modeling of spur gear is done using solid works and finite element analysis is done in Ansys. Based on the analysis results it is suggested that short carbon reinforced (SCF) nylon to be used in place of cast iron or mild steel for limited load applications under 1500 watts.

Keywords: SCF, Gears and FEA

1. INTRODUCTION

A gear is a rotating machine part having cut teeth, or cogs, which mesh with another toothed part in order to transmit torque, in most cases with teeth on the one gear being of identical shape, and often also with that shape on the other gear. Two or more gears working in tandem are called a transmission and can produce a mechanical advantage through a gear ratio and thus may be considered a simple machine. Geared devices can change the speed, torque, and direction of a power source. The most common situation is for a gear to mesh with another gear; however, a gear can also mesh with a non-rotating toothed part, called a rack, thereby producing translation instead of rotation.The gears in a transmission are analogous to the wheels in a crossed belt pulley system. An advantage of gears is that the teeth of a gear prevent slippage.

- To reduce weight of the spur gear
- To reduce rate of thermal distortion
- To compare the working stresses and displacements
- To reduce friction between the gears

To compare the strength of Short Carbon Fibre Reinforced (SCFR) nylon spur gear with Steel and Cast iron gearsIn transmissions which offer multiple gear ratios, such as bicycles, motorcycles, and cars, the term gear, as in first gear, refers to a gear ratio rather than an actual physical gear. The term is used to describe similar devices even when the gear ratio is continuous rather than discrete, or when the device does not actually contain any gears, as in a continuously variable transmission.

2. LITERATURE REVIEW

1. Zhong Hu & Mohammad Robiul Hossan: *Strength Evaluation and Failure Prediction of Short Carbon Fiber Reinforced Nylon Spur Gears by Finite Element Modeling*: In this paper, short carbon fiber reinforced nylon spur gear pairs, and steel and unreinforced nylon spur gear pairs have been selected for study and comparison. A 3D finite element model was developed to simulate the multi-axial stress–strain behaviors of the gear tooth. Failure prediction has been conducted based on the different failure criteria, including Tsai-Wu criterion. The tooth roots, where has stress concentration and the potential for failure, have been carefully investigated. The modeling results show that the short carbon fiber reinforced nylon gear fabricated by properly controlled injection molding processes can provide higher strength and better performance.

2. Shanavas S: *Stress Analysis of Composite Spur Gear*: This paper investigates the static stress characteristics of an involute composite spur gear system including bending stresses and contact stresses of gears in mesh and comparing it with the existing involute cast iron spur gear system. The aim is to replace the cast iron spur gear with Carbon fibre epoxy composite spur gear due to its high strength, low weight and damping characteristics. A pair of involute spur gear is modeled in a CAD system (SOLIDWORKS) and FEA is done by using finite element software ANSYS 13. The bending stresses in the tooth root and contact stresses were examined using a 3-D FEM model. The bending stress obtained by finite element analysis method is compared with bending stress obtained by Lewis equation and the contact stress obtained by finite element analysis method is compared with contact stress obtained by Hertzian equation.

3. Prashanth Banakar, H.K. Shivananda: *Preparation and Characterization of the Carbon Fiber Reinforced Epoxy Resin Composites*: The objective of this research was to gain a better understanding of Mechanical properties of epoxy resin composites reinforced with carbon fiber. The effect of fiber orientation of laminates has been investigated & experimentation was performed to determine property data for material specifications, the laminates were obtained by hand layup process .The laminates were cut to obtain ASTM standards. This investigation deals with the testing of tensile and flexural strength on a universal testing machine. The graphs that are obtained from the tests are documented. This research indicates that the mechanical properties are mainly dependent on the fiber orientation of laminated polymer composites.

4. M. Nayeem Ahmed, Dr. P. Vijaya Kumar, Dr. H.K. Shivanand, Syed Basith Muzammil: *A Study on Effect of Variation of Thickness on Tensile Properties of Hybrid Polymer Composites (Glassfibre-Carbonfibre-Graphite) and GFRP Composites*: Increase in demand of advanced materials to satisfy the requirements of aerospace and automotive industry viz. high modulus to density ratio, leads to the research in composite materials where an attempt is made to study the properties of composite materials by composing the different materials together to obtain the desired properties by reducing the weight as much as possible. Here an attempt is made to study the behavior and tensile properties of Hybrid polymer composite material by composing E-glass fibres, carbon fibres and graphite with epoxy resin 5052. By the variation of thickness, Tensile strength of hybrid composite is observed for each thickness and is optimized and compared with the properties of standalone glass fibre reinforced composites for the same variation of thickness. The comparison represents the enhancement of tensile strength and cost effectiveness by the introduction of multiple materials (Hybrid composites).

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3. SPUR GEAR DESIGN

Design Procedure

a. Power to be transmitted, pinion speed, gear ratio, life of gear drive and other working conditions are to be decided.

b. Note the design surface compressive stress and bending stress for the selected material from the PSG design data book table 9.

c. Based on surface compressive stress, determine the minimum centre distance required for the gear drive as

$$a \geq (i \pm 1)\sqrt[3]{\left\{\frac{0.74}{[\sigma_c]}\right\}^2 \frac{E[M_t]}{i\,\psi}} \text{ for a pressure angle of } 20^0$$

In the above equation,

a - Centre distance

i - Gear ratio = Z_2/Z_1

(i+1) for external gearing and (i-1) for internal gearing

[Mt] - Design torque

P - Power transmitted

Ψ - b/a = 0.3 from PSGDB 8.14

E-Equivalent young's modulus from PSGDB 8.14

d. Based on the beam strength or bending stress, determine the minimum module as

$$m \geq 1.26\sqrt[3]{\frac{[M_t]}{y[\sigma_b]\psi_m Z_1}}$$

$[\sigma_b]$ - Design bending stress

Ψ_m - b/a = 10 (Initially assumed)

Z_1 - Number of teeth on pinion

Y - Form factor corresponding to Z_1

e. After calculating the minimum module, select the next standard module from PSGDB 8.2.

f. After calculating the minimum module, select the next standard module and minimum centre distance as

$$Z_1 = \frac{2a}{m(i+1)}$$

g. Similarly, finalize the centre distance using the standard module and corrected number of pinion teeth as $a = \frac{mZ_1(i+1)}{2}$

h. Find out the PCD for pinion and gear using the formulas from PSGDB 8.25.

i. Calculate the face width "b" as b = Ψa

j. Calculate the pitch line velocity using

$$V = \frac{\pi\, d_1 n_1}{60\ X\ 1000}\ m/s$$

k. Determine the induced surface compressive stress and bending stress as

$$\sigma_c = 0.74\left(\frac{i \pm 1}{a}\right)^2\sqrt{\frac{(i \pm 1)}{aib}}\,E[M_t]\ for\ pressure\ angle\ = 20^0$$

and $\sigma_b = \frac{(i\pm1)[M_t]}{amby}$

(Here $y = form\ factor\ for\ corrected\ Z_1$)

l. Calculate the other parameters of gears and pinion using the formulas from PSGDB 8.25

Sl. no	Description	Material	
		Cast Iron	Mild Steel
1.	Power rating (watt)	1500	1500
2.	Gear ratio	4	4
3.	Tensile Stress (N/mm2)	350	500
4.	Design Bending Stress (N/mm2)	80	108
5.	Design Compressive Stress (N/mm2)	750	1320
6.	Young's Modulus (N/mm2)	1.7e5	2.15e5
7.	Centre Distance (mm)	70.5	52.27
8.	Module (mm)	2	2
9.	Corrected Centre Distance (mm)	75	55
10.	Pitch Circle Diameter d1 and d2	d1 = 30 d2 = 120	d1 = 22 d2 = 88
11.	Number of teeth Z1 and Z2	Z1 = 30 Z2 = 120	Z1 = 11 Z2 = 44
12.	Face width	20	20
13.	Addendum	2	2
14.	Dedendum	2.5	2.5
15.	Tooth depth	4.5	4.5

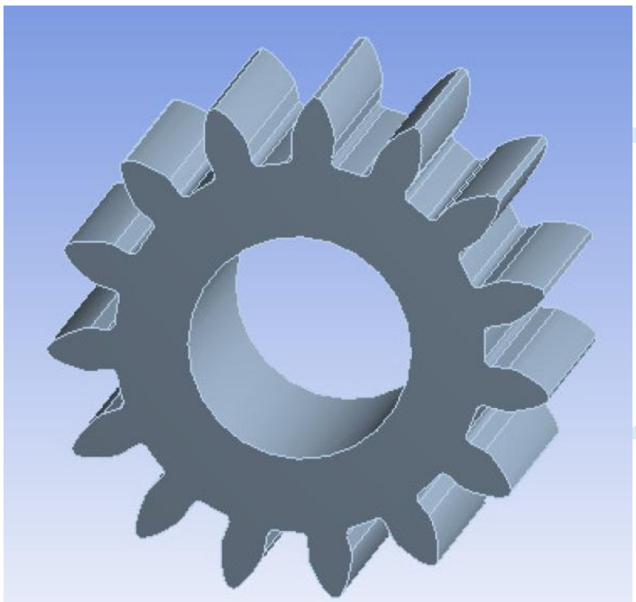
4. METHODOLOGY

- The following methodology has been adopted to achieve the project objective
- To develop a 3D model of spur gear using Solid works.
- To develop a finite element model of spur gear and solve the same using Ansys
- To plot the bending and contact stresses of different spur gears (Major mode of failure is Fatigue bending and Fatigue contact).
- Compare the results of different materials.
- Conclude the work based on the observations

5. MODELING

Modeling Methodology

Spur gear modeling is done using the solid works 2013. The gear parameters are modeled as per the design calculation.



Steps Involved in the Modeling of Spur gear

- The involute profile was created using the geometrical construction procedure.
- The single involute created was patterned using the circular array.
- The cross section of the spur gear was completed in the sketcher environment.
- The above created cross section was converted into a solid gear by extruding the gear to the face width calculated above.

ANALYSIS AND RESULTS

Finite Element Analysis:

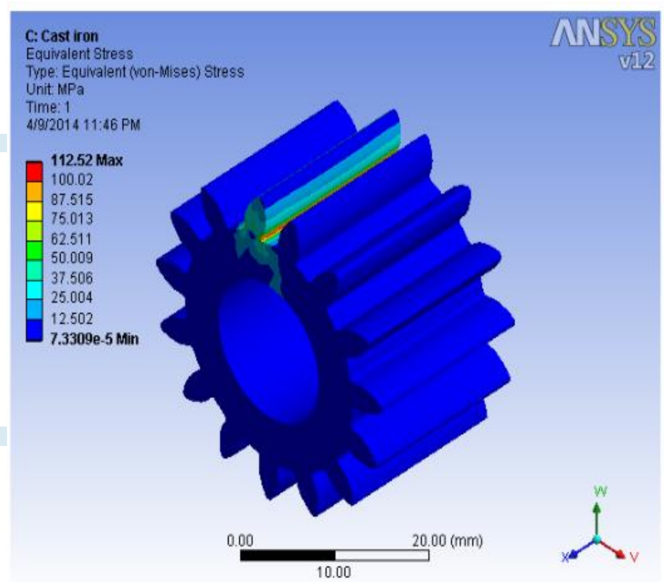
Finite element analysis of the spur gear is performed in ANSYS 14, a well known FEA tool. A variety of specializations under the umbrella of the mechanical engineering discipline (such as aeronautical, biomechanical, and automotive industries) commonly use integrated FEM in design and development of their products. Several modern FEM packages include specific components such as thermal, electromagnetic, fluid, and structural working environments. In a structural simulation, FEM helps tremendously in producing stiffness and strength visualizations and also in minimizing weight, materials, and costs.

FEM allows detailed visualization of where structures bend or twist, and indicates the distribution of stresses and displacements.

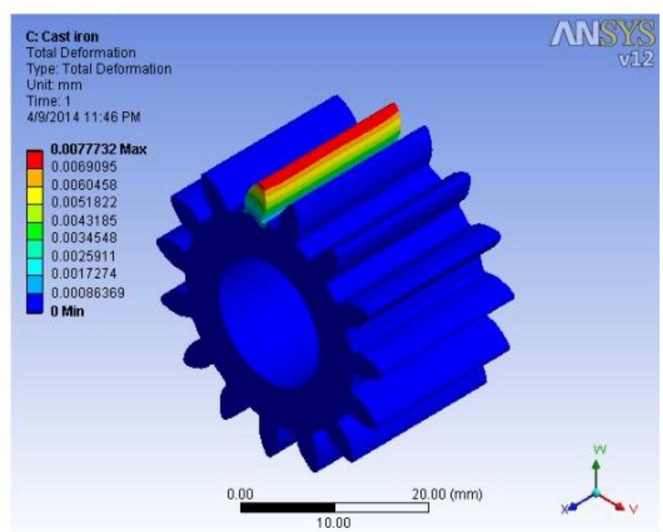
FEM software provides a wide range of simulation options for controlling the complexity of both modeling and analysis of a system. Similarly, the desired level of accuracy required and associated computational time requirements can be managed simultaneously to address most engineering applications.

FEM allows entire designs to be constructed, refined, and optimized before the design is manufactured.

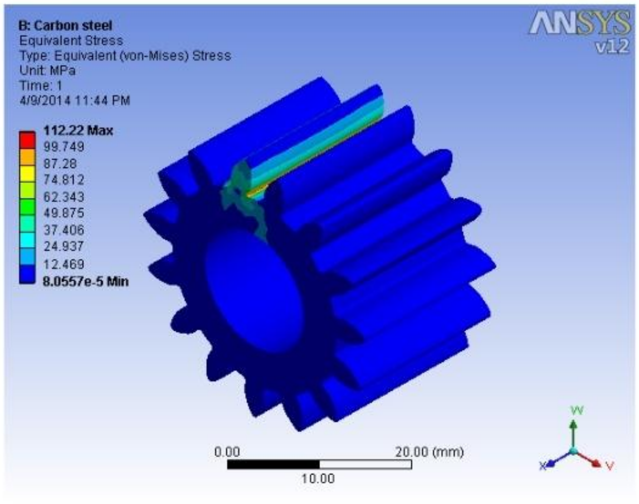
Analysis results



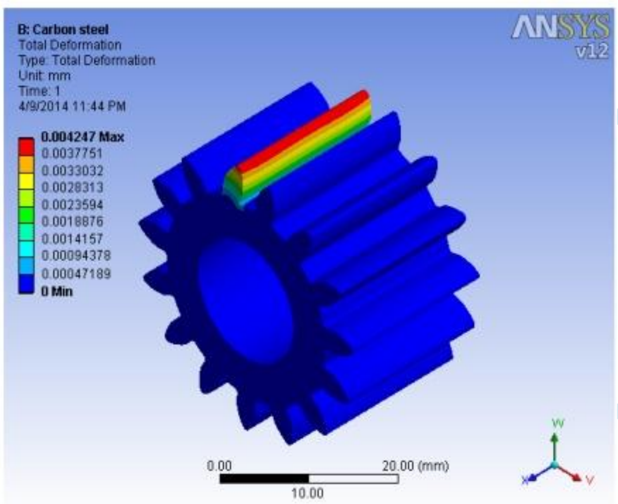
Cast Iron Gear Von Mises Stress Plot



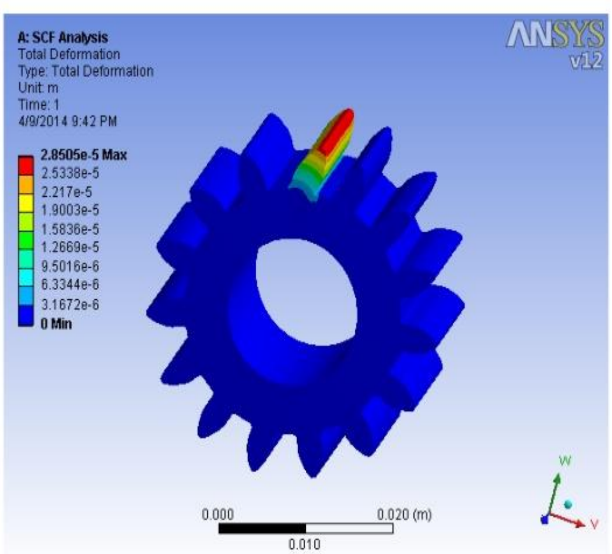
Cast Iron Gear Deformation Plot



Mild Steel Gear Von Mises Stress Plot



SCF Reinforced Nylon Gear Von Mises Stress Plot



SCF Reinforced Nylon Gear Deformation Plot

Results Summary

MATERIAL	SCFRN	C.I	M.S
Equivalent stress	112.36	112.56	112.22
Total deformation	0.02850	0.007773	0.00424
Shear stress	59.555	59.467	59.643

CONCLUSION

From the static analysis by increasing the pressure on the tooth flank surface we observed that the vonmises stresses and deflection values of the spur gear were increased. And the stress values are obtained for SCF reinforced spur gear are also under safe limit compared with Cast iron and Mild steel. According to the study, analysis, results it is recommend, SCF reinforced gears would be a best alternative for cast iron and mild steel gears under limited load applications up to 1500 watts.

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