Structural Analysis and Contact Stresses Developed in Helical Gear using Helix Angle for Different Materials

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Abstract— An extensive research carried out to understand the contact stresses, Von-misses stresses in a Helical gear in recent years. The contact stresses can be analyzed and evaluated by using different parameters such as helix angle ,varying load and material, etc. among all parameters helix angle plays a vital role. “Helix angle” is used to evaluate contact stress developed and deformations in a helical gear. In this paper a study has been made on contact stresses developed in a helical gear and their respective deformations at various helix angles 100 , 150 , 200 for different composite materials i.e. Steel, Al-SiC, C-SiC. Further analysis carried out on Von-misses stresses developed using ANSYS that shows the Composite gears offer improved properties over steel alloys and these can be used as better alternative for replacing metallic gears.

Key words: Aluminum Silicon Carbide, Carbon Epoxy, Carbon Fiber Silicon Carbide

I. INTRODUCTION

Gears are one of the oldest of humanity’s inventions. Nearly all the devices we think of as machines utilize gearing of one type or another. Gear technology has been developed and expanded throughout the centuries. In many cases, gear design is considered as a specialty. Nevertheless, the design or specification of a gear is only part of the overall system design picture. From industry’s standpoint, gear transmission systems are considered one of the critical aspects of Contact Stress Analysis.

The understanding of the behavior when gears are in mesh is extremely important if one wants to perform system monitoring and control of the gear transmission system. Although there are large amount of research studies about various topics of gear transmission, the basic understanding of gears in mesh still needs to be confirmed. Pitting is a surface fatigue resulting from repetitions of high contact stress. The surface fatigue mechanism is not definitively understood. The contact affected zone, in the absence of surface shearing traction's, entertains compressive principal stresses.

II. DESIGN OF HELICAL GEAR PAIRS

- Building the model
- Obtaining the solution
- Reviewing the results.

1) Modeling: the part is modeled using Catia -V5 and saved in .stp format.
2) Analysis: the part model is imported to Ansys for analysis.

A. Finite Element Generation/ Meshing

ANSYS simulation provides two forms of automated meshing. Fully automatic and manually directed automatic.. Pre-processor allows the user to generate nodes and elements automatically at the same time allowing control over size and number of elements.

There are various types of elements that can be mapped or generated on various geometric entities. The elements developed by various automatic element generation capabilities of Pre-processor can be checked element characteristics that may need to be verified before the finite element analysis for connectivity, distortion-index etc. The requirements of good mesh are as follows

- Nodal locations should be precise and should not go beyond the boundary.
- Various element types and shapes should be available to provide the user with more flexibility to meet the compatibility and requirements.
- Mesh gradation or mesh smoothing should be possible for users to control the mesh size.
- To convert from one element type to another should be possible.
- Element aspect ratio should be close to one for better results.
- Mesh geometry and topology or mesh orientation should be uniform.

Engineers usually prefer the spur gear because the Spur gears are easier to design and manufacture. When power is transmitted between parallel shafts. There are, however, some design considerations like greater contact ratio, greater strength, and some operational requirements, such as, noiselessness, smoother engagement of meshing of teeth, for which the use of helical gears is preferred. When pair of parallel helical gears mesh, the following conditions must be satisfied for proper running of the set:

- The gears must have helix angles of equal value
- The gear teeth of each member must have the same module, and
- The gear teeth of each member must have opposite helices, that is, one gear must have right-handed helical teeth while the other must have left-handed ones

B. Solution

The solution phase deals with the solution of the problem according to the problem definitions. All the tedious work of formulating and assembling of matrices are done by the computer and finally displacements or deformation values are given as output.

Computer Aided Engineering (CAE) plays a vital role in validating the design and optimizing the process conditions. Software such as ANSYS is well known for structural and thermal analyses. It helps to improve the part quality, service life and to reduce the part cost by optimizing the part size. This software uses various computer simulation techniques to analyze and execute the results.

The result interpretation requires sound knowledge of the material, process, design and machining. Even though the results are not 100% accurate, it is acceptable one.

The accuracy varies because of various factors such as, selection of unsuitable elements, deficiencies in individual elements, poor assessment of output data, masking of important features, lack of standardization between system codes, etc.

The below figure shows the Von-mises stress (contact stress) for different helix angle of steel material. They are 10deg, 15deg, 20deg, helical gear pairs.

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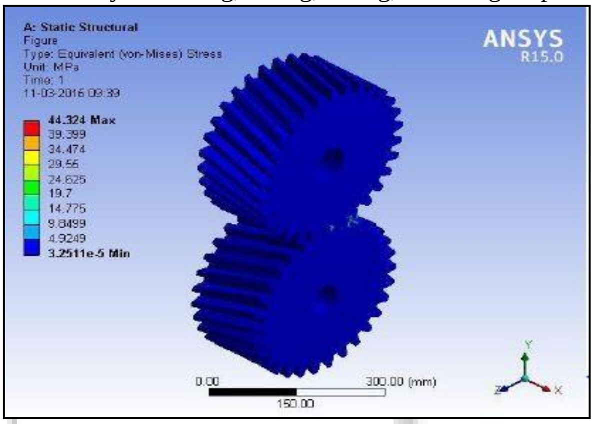
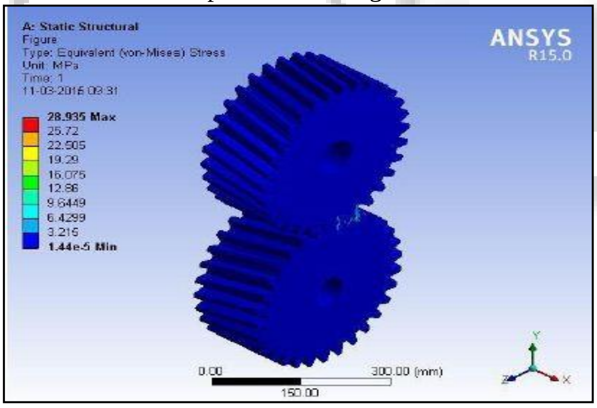
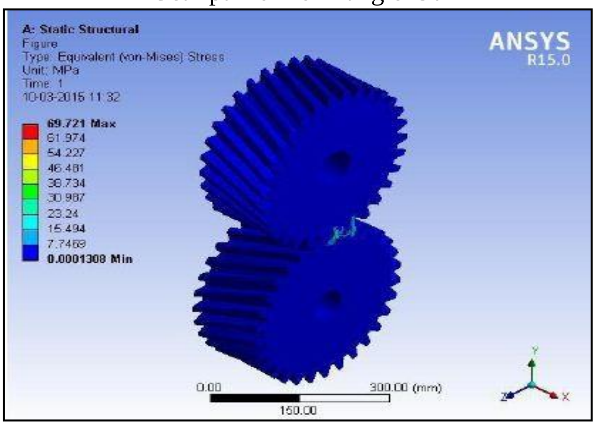


Gear pair of helix angle 10o



Gear pair of helix angle150

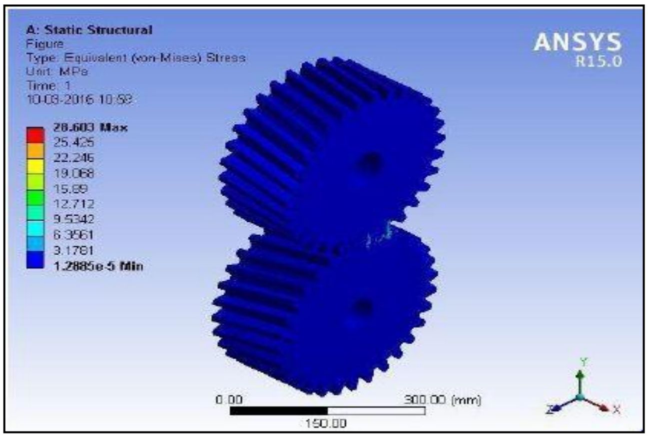


Gear helix angle 20^0

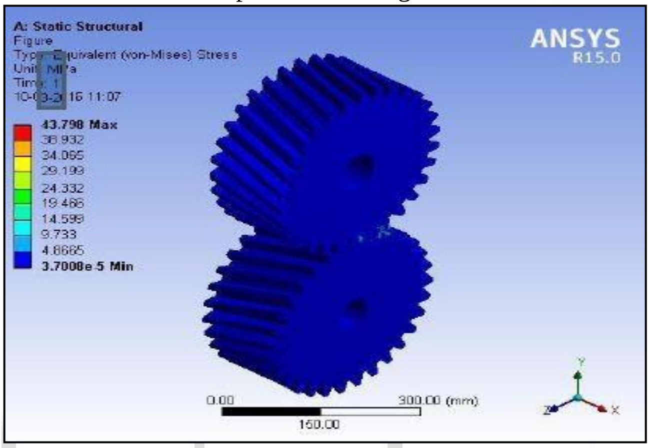
Fig. 1 Von-Mises stress (contact stress) for different helix angle of steel material

The below figure shows the Von-Mises stress (contact stress) for different helix angle of material.

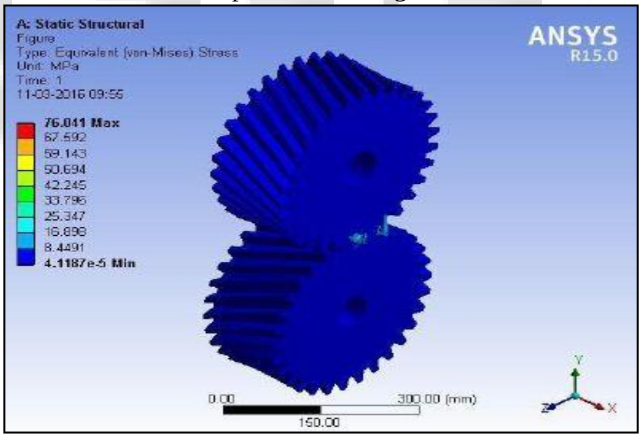
They are 10deg, 15deg, 20deg, helical gear pairs.



Gear pair of helix angle 10^o



Gear pair of helix angle 15^o



Gear pair of helix angle 20^o

Fig. 2: The Von-Mises stress (contact stress) for different helix angle of material

III. ASSUMPTION

- Gear profile: 20 degree full depth involute profile (standard)
- Normal pressure angle (α): 20 degree
- Helix angle (β): 16 degree
- Minimum no. of teeth on pinion (Zp) = 20
- Normal module (Mn) = 5

IV. MATERIAL PROPERTIES

The main objective of this research work is to study the structural and vibrational characteristic of composite material gear for the heavy duty transmission system as compared to conventional steel alloy gear assembly. The considered materials are the carborized steel 10c4 with case hardening according to the IS 1570, the Metal matrix composite composite (MMC) materials Al-SiC The Al-SiC composite selected have AL 6061 matrix with 18% SiC reinforcement materials, and carbon fiber reinforcement in silicon carbide matrix.

The conventional steel alloy used for the gear material has disadvantages such as low specific stiffness and strength and high weight. Substituting the composite material for the gear have advantage of higher specific strength, less weight, high damping capacity, longer life, high critical speed and greater torque carrying capacity and can results in considerable amount of weight reduction as compared to steel The composite material have the orthotropic elastic behavior rather than linear elastic properties.

The condition for analysis has been assumed as static. For FEA analysis of gear manufactured from composite Young's modulus is calculated theoretically and Young's Modulus and Poisson's ratio for alloy steel have been taken from design data book.

Young's modulus of a composite material is anisotropic (varies with direction) and can be estimated using the rule-of-mixtures. The various mechanical properties of the selected material were given in the table below.

Properties	Units	Steel 10C4	AL-SIC (20% SIC)	Carbon/ Epoxy	CVI – C/SIC
Young's modulus	GPa	210	150	450	95
Poission ratio	-	0.3	0.3	0.3	0.3
tensile strength	MPa	500	420	52	310
Density	Kg/m^3	7850	2810	1800	2100

Table 1: Properties

V. MESHING OF GEAR ASSEMLY

For the analysis of the gear assembly to study its structural behavior at different loading condition an 3D model of the gear assembly were made in CATIA V-5 and were imported in ANSYS for analysis software as an .stp file format .After importing the model in ANSYS the appropriate material were assigned to the model and then meshing were done in ANSYS which divide the whole body into small tetra hydral element connected by nodes. The total node and element for the two were given.

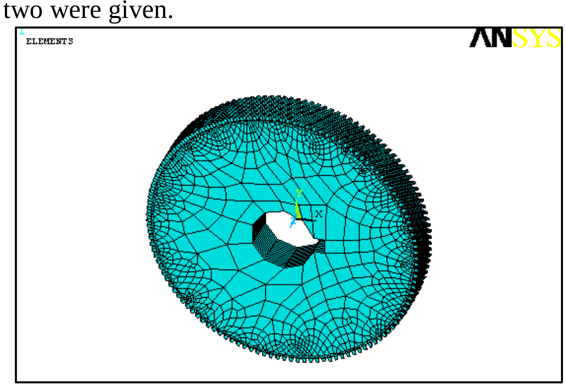


Fig. 3: Gear Assembly

VI. BOUNDARY CONDITION

For the purpose of analyzing and to simulate the real condition the frictional less support is applied on inner rim of the pinion gear as well as the frictionless support is applied on the inner rim of gear to allow its tangential rotation but restrict from radial translation. Moment of moment of the appropriate magnitude equal to the torque consider in N-m is applied on the inner rim of pinion in clockwise direction as a driving.

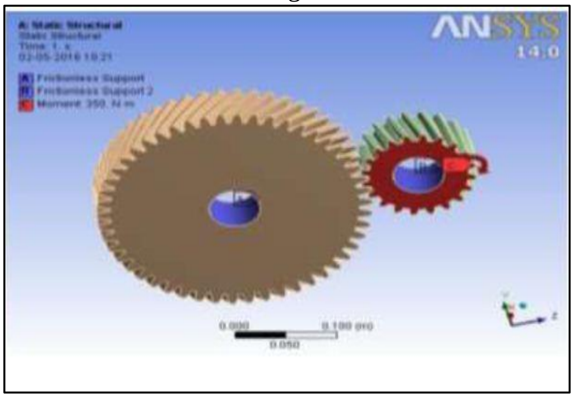


Fig. 4: Boundary Condition

VII. STATIC STRUCTURAL ANALYSIS

A static structural analysis were done to analyze the behavior of the structure under the steady loading conditions, while ignoring inertia and damping effects, such as those carried by time varying loads. All types of non-linearity are allowed such as large deformations, plasticity, creep, stress stiffening, contact elements etc. this result will determined whether the structure will withstand for the applied external loads.. If the stress values obtained in this analysis crosses the allowable values it will result in the failure of the structure in the static condition itself. To avoid such a failure, this analysis is necessary.

VIII. RESULTS AND DISCUSSIONS

In this project the FEA based analysis tool were used to study the structural behavior of the different composite material under the given boundary conditions by determining the total deformation, Equivalent Von misses stress, for each composite material and then the comparison were done In the Ansys the region with high stress were shown in red color while the region having less stress were shown in blue color. The FEM based structural analysis simulation results of steel and the Al-SicC composite at different torque condition were shown below as:

AT TORQUE = 350 N-M AT 4000 RPM

A. For Conventional Steel Material

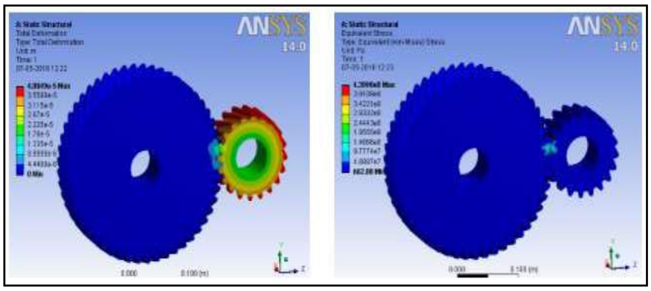


Fig. 5: For Conventional Steel Material

B. For the Aluminum silicon carbide composite (Al-SiC)

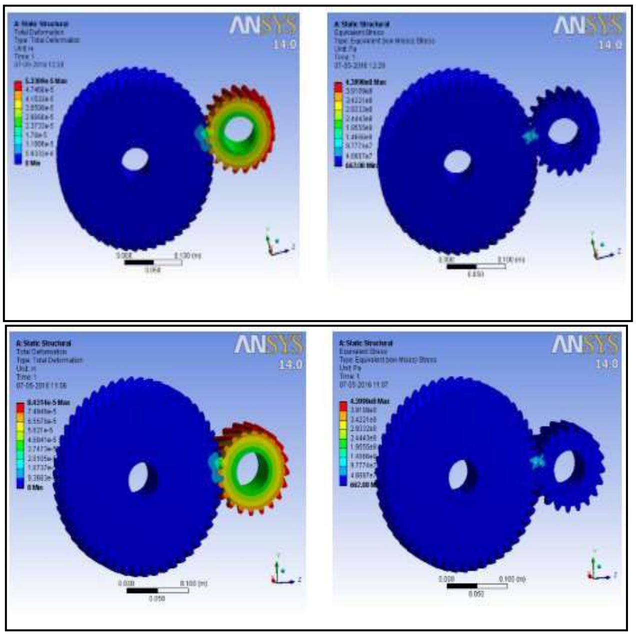


Fig. 6: For the Aluminum silicon carbide composite (Al-SiC)

AT TORQUE = 400 N-m AT 3500 RPM

C. For conventional steel material

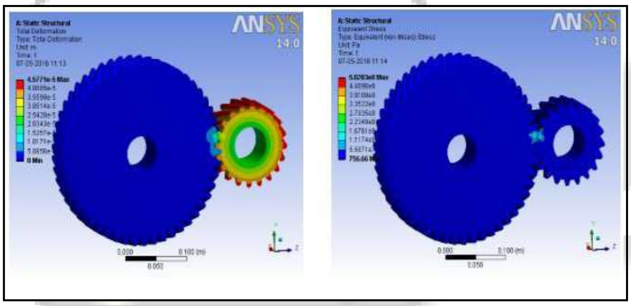


Fig. 7: For Aluminium silicon carbide composite (Al-SiC)

D. For Aluminium silicon carbide composite (Al-SiC)

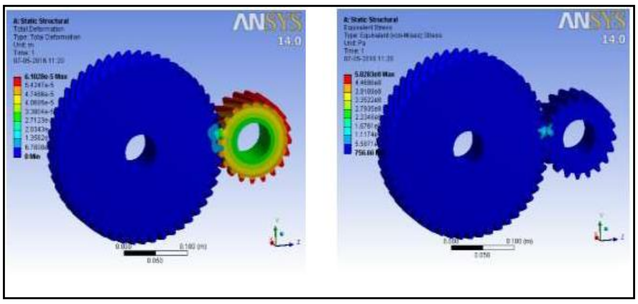


Fig. 8: For Aluminium silicon carbide composite (Al-SiC)

E. For Carbon fibered silicon carbide composite

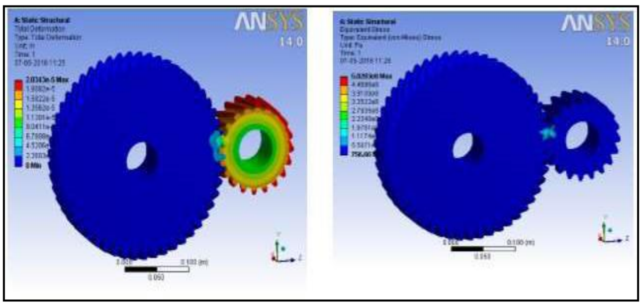


Fig. 9: For Carbon fibered silicon carbide composite

Torque Conditions	Equiovalent Stress (Von-Misses) MPa		
	steel	Al-SiC	C-SiC
350 N-m	429.2	438.64	438.7
400 N-m	542.5	562.9	563.5

Table 2: Torque Conditions

Torque Conditions	Total Deformation (m)		
	steel	Al-SiC	C-SiC
350 N-m	4e-5	5.2e-5	8.53e-5
400 N-m	4.3e-5	6.1e-5	9.63e-5

Table 3: Torque Conditions

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