MODELING AND STRESS ANALYSIS OF COMPOSITE MATERIAL FOR SPUR GEAR UNDER STATIC LOADING CONDITION

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Abstract-
Spur gear is the simplest & widely used in power transmission system. A spur Gear is generally subjected to bending stress which causes teeth failure. However it is observed that performance of the spur gear is not satisfactory in certain applications and therefore it is required to explore some alternate materials to improve the performance of the spur gears. Composite materials provide adequate strength with weight reduction and they are emerging as a better alternative for replacing metallic gears. In this work, A metallic gear of Alloy Steel is replaced by the composite gear of 30% Glass filled Poly-ether-ether- Ketone (PEEK). Such Composites material provides much improved mechanical properties such as better strength to weight ratio, more hardness, and hence less chances of failure. In this work, an analysis is made with replacing metallic gear with composite material such as PEEK so as to increase the working life of the gears to improve overall performance of machine. Finally the Modeling of spur gear is carried out using SOLID WORK and bending stress analysis of spur gear is carried out using ANSYS V14.

Keywords- Composite Material, Modeling, Bending stress, Static Load, Finite element analysis.

INTRODUCTION

Composite materials are engineered materials made from two or more constituent materials with significantly different physical or chemical properties which remain separate and distinct on a macroscopic level within the finished structure. The upcoming requirement of power saving and efficiency of mechanical parts during the past few years increased the use of composite materials.

Composite materials are preferred in place where lighter materials are desired or required without sacrificing strength. nowadays, composite materials are used in large volume in various engineering structures including spacecrafts, airplanes,automobiles, boats, sports' equipments, bridges and buildings. Widespread use of composite materials in industry is due to the good characteristics of its strength to density and hardness to density.

Parameters	GF 30 PEEK	NICKEL CHROME STEEL
DENSITY	1320 kg/m^3	7800 kg/m^3
MODULUS OF ELASTICITY	4000-4200 Mpa	200000 Mpa
TENSILE STRENGTH	90-100 N/mm^2	413.61 N/mm^2

Table 1. Properties of Materials

BACKGROUND

The spur gear transmits mechanical energy from a prime mover to an output device. The spur gears are used in heavy and low duty mechanical devices. But in this study we have emphasized on the low duty application like Textile machines, Printing press machines, Robotic mechanism etc. The major problems observed with existing metallic Spur gear are

- Existing gear is made of metal component provides poor weight to strength ratio.
- Metallic parts lead to corrosion so need to properly shielded.
- More wear in between the gears so required proper lubrication.
- Gears are getting costly due to increasing metal prices.
- Due to poor weight to strength ratio power losses in gear are higher.

Thus gear needs to be redesigned providing energy saving by weight reduction, providing internal damping, reducing lubrication requirements without increasing cost. Such a scope is provided by application of composite material providing solution to other existing problems in current gears available. Therefore this work is concerned with the replacement of existing metallic gear with composite material gear in order to make it lighter and increasing the efficiency of mechanical machines

LITERATURE REVIEW

R. Yakut et al. The purpose of the paper is to examine the load capacity of PC/ABS spur gears and investigation of gear damage. Further in this study usability of PC/ABS composite plastic material as spur gear was investigated and was defined that PC/ABS gears were tested by applying three different loading at two different numbers of revolutions on the FZG experiment set.The experiment result summarized that the usage of PC/ABS materials brings an advantage in many industrial area because such materials are durable against flame, air, ultraviolet lights and holding lower moister than PA66 GFR 30 materials. The another result of this study was that good operating condition are comprised at low numbers of revolution and the tooth loads. Further the suitable environmental condition must be revolutions and the tooth load for gears. PC/ABS gear should be preferred at low tooth and unwanted high power transmission.[1]

V. Siva Prasad et al. This paper describes design and analysis of spur gear and it is proposed to substitute the metallic gears of sugarcane juice machine with polymer gears to reduce the weight and noise. A virtual model of spur gear was created in PRO-E, Model is imported in ANSYS 10.0 for analysis by applying normal load condition. The main purpose of this paper to analysis the different polymer gears namely nylon, polycarbonate and their viability checked

with counterpart metallic gear like as cast iron. Concluding the study using the FEA methodology, it can be proved that the composite gears, if well designed and analysed, will give the useful properties like as a low cost, noise, Weight, vibration and perform its operation similar to the metallic gears. Based on the static analysis Nylon gear are suitable for the application of sugarcane juice machine under limited load condition in comparison with cast iron spur gears.[2]

Vivek Karaveer et al. This paper presents the stress analysis of mating teeth of the spur gear to find maximum contact stress in the gear tooth. The results obtained from finite element analysis are compared with theoretical Hertz equation values. The spur gear are modeled and assembled in ANSYS DESIGN MODELER and stress analysis of Spur gear tooth is done by the ANSYS 14.5 software. It was found that the results from both Hertz equation and Finite Element Analysis are comparable. From the deformation pattern of steel and grey cast iron, it could be concluded that difference between the maximum values of steel and grey CI gear deformation is very less.[3]

Mahebub Vohra et al. In this paper, Metallic material Cast iron and Non Metallic material Nylon are investigated. The stress analysis of the lathe machine headstock gear box are analyzed by finite element analysis. Analytical bending stress is calculate by two formula Lewis formula and AGMA formula. Analytical results is compared with the finite element method result for validation. Concluding the study, we observed that finite element method software ANSYS have values of stress distribution were in good agreement with the theoretical results. Besides non metallic material can be used instead of metallic material because non metallic material provide extra benefits like as less cost, self lubricating, low noise, low vibration and easy manufacturing.[4]

M. Patil et al. The objective of this paper is to study the free vibration behavior of composite spur gear using finite element method which is also known as first order shear deformation plate theory (FSDT). The finite element analysis has been carried out for composite gear as a 4 nodded and 8 nodded quadrilateral element with each nodes has five degree of freedom. Finite element formulation of composite gear is modeled and coded using MATLAB. Based on the numerical analysis which is carried out for of spur gear the following important conclusion can be drawn. The developed MATLAB code is validated with the available result and it can be concluded that the present FE code result are in good agreement with those of reference. Fundamental frequencies obtained for composite spur gear using MATLAB are presented. It is found that natural frequency increases with increase in fiber orientation.[5]

Nitin Kapoor et al. In this paper the parametric model of differential gear box is developed using some parameters i.e. (number of teeth, Pressure angle, helix angle, tooth thickness, module) in CATIA-V5 and weight analysis of differential gear box for different material (aluminium alloy, alloy steel, cast iron, Glass filled Polyamide) under static loading condition using FEA. The case study

shows that the composite material can be used effectively in place of metallic material because the weight of Glass filled Polyamide composite material of differential is reduced by 60% Comparing with the traditional materials (Aluminium alloy, Alloy Steel, Cast iron). So, we conclude that Glass filled Polyamide Composite material is selected as a best material for differential gear box.[6]

A.D. Dighe et al. In this study the comparative performance spur gear of 30% Glass filled PA66 and 30% Glass filled PEEK was investigated at different torque and speed. Wear test of the spur gear pairs and the experiment spur gear tooth were performed on a FZG test machine. A weight loss is measured by 0.0001g sensitive weighing machine and the tooth temperature of gear is measured by Impact infrared thermometer. After summarized the experimental result of PA66 GF30 gears and PEEK GF30 gears are at different torque and speeds. The tooth temperature increases with increase in torque and increased temperature resulted into thermal softening of gear tooth which further increases specific wear rate. The comparative results of PA66 GF30 and PEEK GF30 gears show that the specific wear rate of PA66 GF30 is much higher than PEEK GF30 at all torque and speeds. Therefore the torque transmission capacity of PEEK GF30 is higher than PA66 GF30.[7]

Pradeep Kumar singh et al. In this paper using ANSYS workbench software, bending stress, contact stress and static load on the tooth of spur gear drive is found. The Hertz theory and Lewis formula also are used for theoretical calculation of contact stress and bending stress of spur gear. We observed that Theoretically results obtained by Lewis formula and Hertz equation are comparable with finite element analysis of spur gear, keeping in mind the comparison we can conclude that the finite element analytical result can be better as a problem solving software and used for other analyzing purpose.[8]

MODELING OF THE SPUR GEAR

By the design calculation, the modeling of the spur gear is done using SOLID WORK premium 2013.

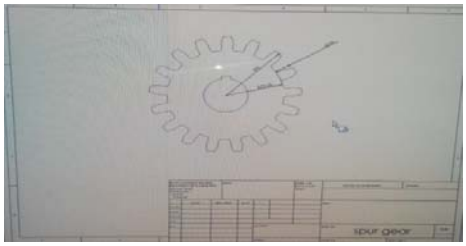
The input parameter for modeling of spur gear are given in Table 2.

Description	**Symbol**	**Values**
Number of teeth	Z	17
Pressure angle	α	20°
Module	m	10mm
Pitch circle diameter	d	170mm
Face width	b	100mm
Addendum circle dia.	d_a	190mm
Dedendum circle dia.	d_f	145mm

Table 2. Geometry of spur gear

SOLID MODEL OF SPUR GEAR

FIG 1. 2-D Part design of Spur Gear



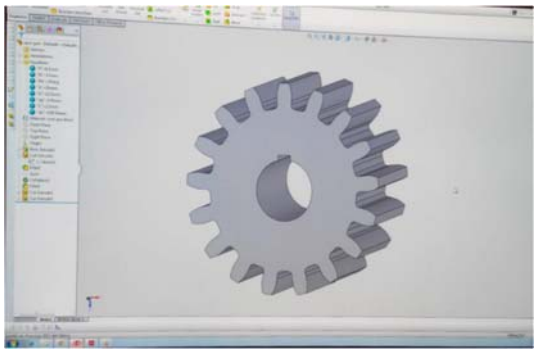


Fig 2. Part design of Spur Gear

FINITE ELEMENT ANALYSIS OF SPUR GEAR

Bending stress of spur gear teeth is generally calculated by analytically and finite element method. In this chapter, static finite element method is applied on the spur gear teeth for a different material of a spur gear. Analytical bending stress is calculated by AGMA formula. Analytical result is compared with the finite element method result for validation

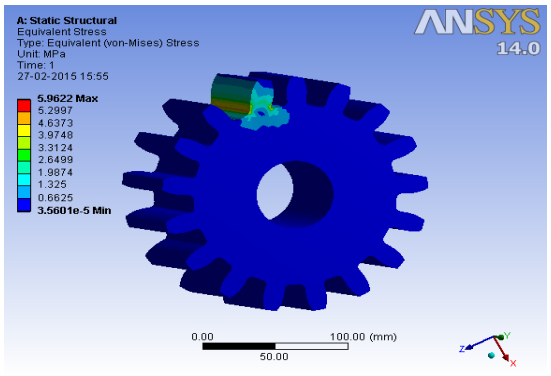


Fig 3. von-Mises stress for GF 30 PEEK

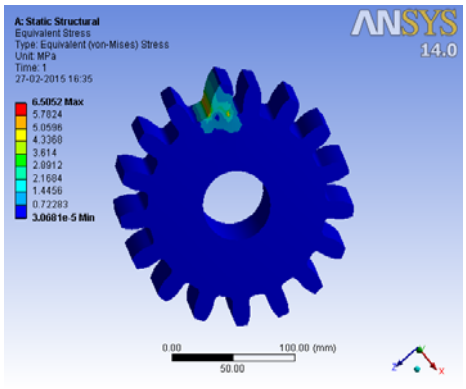


Fig 4. von-Mises stress for ALLOY STEEL

RESULT

Material	Maximum stress induced(MPa)	
	Analytical Procedure	FEM Procedure
Alloy Steel	2.77	6.5052
GF 30 PEEK	2.77	5.9622

CONCLUSION

The objective of current work is to replace the alloy steel spur gear with GF 30 PEEK composite spur gear. For that, analytical and finite element method are applied for determining bending stress of gear tooth. The obtained FEA result is compared with the analytical result and found that both result are comparable. Result shows that by stress analysis the strength of the GF 30 PEEK spur gear is more when compared with alloy steel spur gear.

Also the density of the GF 30 PEEK is very less when compared with alloy steel. So we can conclude that the alloy steel spur gear canbe replaced by GF 30 PEEK(composite) spur gear due to its high strength, low weight and damping characteristics.

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