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Design and analysis of spur gear by using composite material

Patel Nirav .. [1] Jay P. Joshi [2],
[1] PG Scholar, CAD/CAM, V.V.P Engineering Collage, nirav7566@gmail.com
[2] Assistant Professor, Guide, V.V.P. Engineering College, jayjoshi_vvp@yahool.com

Abstract
Gearing is one of the most critical components in a mechanical power transmission system, and in most industrial rotating machinery. It is possible that gears will predominate as the most effective means of transmitting power in future machines due to their high degree of reliability and compactness. In addition, the rapid shift in the industry from heavy industries such as shipbuilding to industries such as automobile manufacture and office automation tools will necessitate a refined application of gear technology. Design the spur gear to study the weight reduction and stress distribution for cast steel and composite materials and to design the spur gear model using Creo software. After Creating a model of spur gear analysis will be Carried out from gear made up cast steel and composite material in ANSYS Environment. Finally, comparing and analysing of the composite gear with existing cast steel gear is to be done.
Keywords: *spur gear, composite gear ,load calculation, ansys and comparision between them.*

I. INTRODUCTION

Spur gears are the most common type of gears. They are used to transmit rotary motion between parallel shafts. Gears are used for a wide range of industrial applications. They have varied application starting from textile looms to aviation industries. They are the most common means of transmitting power. They change the rate of rotation of machinery shaft and also the axis of rotation. For high speed machinery, such as an automobile transmission, they are the optimal medium for low energy loss and high accuracy. Their function is to convert input provided by prime mover into an output with lower speed and corresponding higher torque. Toothed gears are used to transmit the power with high velocity ratio. During this phase, they encounter high stress at the point of contact.

Fig (1): spur gear

Material Selection: In today's era gears are manufactured from,
1] Cast steel.
And the proposed composites material is

(1) **Epoxy carbon _UD_395GPA**
(2) **Epoxy carbon _UD_230GPA**

Epoxy Resin:

Epoxy resins square measure wide utilized in filament-wound composites and square measure appropriate for molding prepress. fairly stable to chemical attacks and are glorious adherent shaving slow shrinkage throughout activity and no emission of volatile gases. These blessings, however, build the employment of epoxies rather costly. Also, they can't be expected on the far side a temperature of 140ºC. Their use in engineering square measures wherever service temperatures are higher, as a result, is dominated out.

The applications for epoxy-based materials area unit intensive and embody coatings, adhesives and composite materials like those exploitation carbon fibre and fiberglass reinforcements. The chemistry of epoxies and therefore the vary of commercially accessible variations permit cure polymers to be created with are awfully broad vary of properties. In general, epoxies area unit well-known for his or her glorious adhesion, chemical and warmth resistance, sensible-to-excellent mechanical properties and extremely good electrical insulating properties.

Properties of Composites (50% Carbon Fibers in Epoxy Resin Matrix):

Density	1800 kg/m
Young modulus	450 GPa
Poisson's ratio	0.30
Tensile strength	52 MPa
Compressive strength	600 MPa

Table(1): Properties of Composites

Epoxy resins area unit simply and quickly cured at any temperature from 5°C to 150°C, looking on the selection of activity agent. one amongst the foremost advantageous properties of epoxies is their low shrinkage throughout cure that minimizes cloth print-through and internal stresses. High adhesive strength and high mechanical properties are increased by high electrical insulation and sensible chemical resistance. Epoxies notice uses as adhesives, caulking compounds, casting compounds, sealants, varnishes and paints, in addition as laminating resins for a spread of business application

II. LITERATURE REVIEW

In this paper, literature has been critically reviewed involving various studies carried out by various researchers related to the field of designing and analysis of Differential gearbox. Differential gearbox is an important part of the automobile i.e. used for transmitting different speeds, while for most vehicles supplying equal torque to each of them.

Sandip c. dhaduti [1] Gears made from composite materials are widely used in many power and motion transmission applications. Due to lower weight to stiffness ratio, composite gears may be replaced by conventional material gears in power transmission systems. Design of gears with asymmetric teeth enables to increase load

capacity, reduce weight, size and vibration level. This article includes a summary of asymmetric gear design parameters, new developments of asymmetric spur gear and their application in various fields of engineering applications. Involute spur gears with asymmetric teeth could provide greater flexibility in designing of gears for different application areas due to non-standard design procedures. It allows to analyse a wide range of parameters for all possible gear combinations in order to find the most suitable solution for a particular application. The asymmetric tooth geometry allows for an increase in load capacity while reducing weight and dimensions for some types of gears. It becomes possible by increasing of the pressure angle and contact ratio for drive sides

Sangamesh Herakal, et al [2]. The objective of this paper is to study the free vibration behavior of composite spur gear using finite element method.

In the present investigation, Finite element model for gear is formulated to study the free vibration behaviour of composite spur gear. Effect of fibre orientation and dynamic analysis of composite gear has been studied. Based on the numerical analyses carried out for dynamic analysis, the following important conclusions can be drawn:

Finite element formulation of composite gear is modelled and coded using MATLAB.

The developed MATLAB code is validated with the available results and it can be concluded that the present FEA code results are in good agreement with those of reference.

Fundamental frequencies are obtained for composite spur gear using MATLAB are presented. It is found that natural frequency increases with increase in fiber orientation.

Utkarsh M. Desai et al. [3] In this paper 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.

By the above exhaustive literature review, we can say that the gear needs to be redesigned providing energy saving by weight reduction, providing internal damping, reducing lubrication requirement without increasing cost. 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.

N.Lenin Rakesh et al. [4].The need for this project is that in earlier time's design of any machine element were carried out manually. This was tedious and time consuming. In this emerging world of technology, new software's are introduced. So, here a simple machine element, a spur gear is modelled using a modelling software Pro-E and using software ANSYS. The theoretical stresses of both bending and contact stress is found manually and then analyzed in ANSYS software. The readings are shown in the tabular column. It is found that comparing with manual results; results are approximate or closer to it.

T.Shobha Rani et al. [5] The creep nature of metallic spur gear results in the deficiency because of the deformation of teeth when pressure angle of 20 acting on it. At the replacing points of tooth between driving and driven the disturbances such as in-evitable random noise, elastic deformation and manufacturing error, alignment error in assembly all these together causes the high level of gear vibration and noise and leads to loss in efficiency. The main motto is to reduce the deformation of teeth, by replacing the metallic cast iron gear with Nylon gear and proved that the deformation of Nylon gear is less compared to metallic and polycarbonate. Since the deflections are less the efficiency of nylon spur gear is more than the cast iron spur gear, results in less noise and long life, The metallic gear results is more deflection compared to nylon and polycarbonate, the cost price and life of nylon is also good. When we replace the metallic spur gear with nylon gear there would be better results.

Nitin kapoor et al. [6], The main objective of this paper is to developed parametric model of differential Gearbox by using CATIA-V5.Glass filled polyamide composite and metallic materials (Aluminium alloy, Alloy Steel and Cast Iron) are also being performed and found to be lower for composite material. CATIA is used to develop various parametric models. Glass filled polyamide composite material is used for gears and are analysed using ANSYS for equivalent (Von-Misses) stress, displacement and maximum shear elastic strain for different revolutions under static conditions. Comparisons of various stress and strain results with Glass filled polyamide composite and metallic materials are also being performed and found to be lower for composite material. So Glass Filled Polyamide composite material is selected as a best material for Differential gear box.

L. kavin Rajkumar et al.[7] In this paper study is to analyse the stress in gear tooth and to reduce the stress in the gear tooth. An ansys analysis of spur gear is used in this paper. A Finite Element model with aero-fin shaped hole along the stress flow direction that it gives better results. This paper is to reduce the stress in the spur gear contact tooth. This study gives the better result when an aero-fin hole is introduced and reduces the stress in the gear teeth..

III. OBJECTIVE

- The designed composite spur gear is compared with the existing gear material, which is a cast steel spur gear.
- The tool which is used for analyses of spur gear made out from composite and cast steel is ANSYS.
- In this, the analyses of loading and stress are to be performed for both composite and cast steel materials.
- The final outputs of these analyses for both the materials are to be compared with analytical results.

IV. PARAMETERS OF GEAR

Parameter of gear	Gear -1	Gear -2
Module (m)	6	6
No of teeth (N)	25	76
Tooth thickness(t)	9.42 mm	9.42 mm
Root fillet	1.2 mm	1.2 mm
Addendum (Da)	162 mm	468 mm
Dedendum (Dd)	135 mm	441 mm
Base circle dia (Dd=b)	140.953 mm	428.499 mm
Material	Cast steel	Cast steel

Table(2): Parameters of Gear

Gear Design Parameter	Gear -1	Gear -2
Pitch diameter(D)	150 mm	456 mm
Pitch Radius (R)	75 mm	228 mm
Base Circle Diameter (DB)	145.22 mm	454.44 mm
Base Circle Radius (RB)	72.61 mm	227.22 mm
Addendum (a)=1/P	0.05307mm	0.05307mm
Dedendum (d)= 1.157/p	0.06141mm	0.06141mm
Outside Diameter (DO)=D+2*a	150.106mm	456.106mm
Outside Radius (RO)	75.053mm	228.053mm
Root Diameter (DR)	149.877mm	455.877mm
Root Radius (RR)	74.938mm	227.938mm
GearToothSpacing (GT)=360/T	14.5 degrees	4.7368 degrees

Table(3):Gear Design Parameter

Fig (2):3D Model of gear in Creo (25 Teeth)

Fig (3): 3-D Model of gear (76 Teeth)

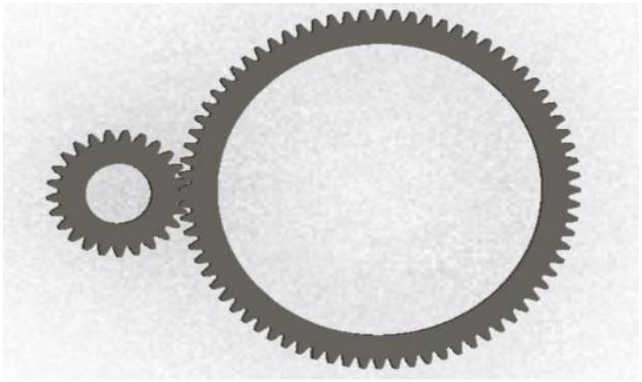


Fig (4): Assembly of spur gear

- **Load calculation:**

$$Fr = Ft / \cos\varphi$$

$$Ft = 2T / Dp$$

$$T = 63025\,p / n$$

$$fn = ft * \tan\theta$$

Where, T=1624 Nm

φ = pressure angle= 20^o

Force	Gear 1	Gear 2
Ft	21663.55 N	7126.17 N
Fn	7884.88 N	2593.71 N
Fr	20357.07 N	6696.4 N

Table(4):Load Calculation

V. MODELLING OF SPUR GEAR

According to path of project this step is concerned with creating a model of spur gear model.

VI: ANALYSIS

- **Deformation:**

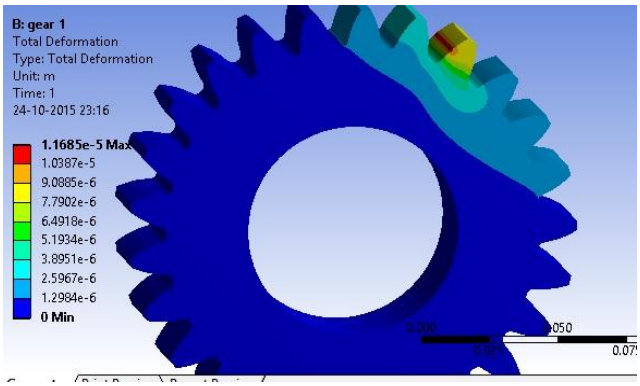


Fig (5): Deformation of Gear 1 for cast steel (25 teeth)

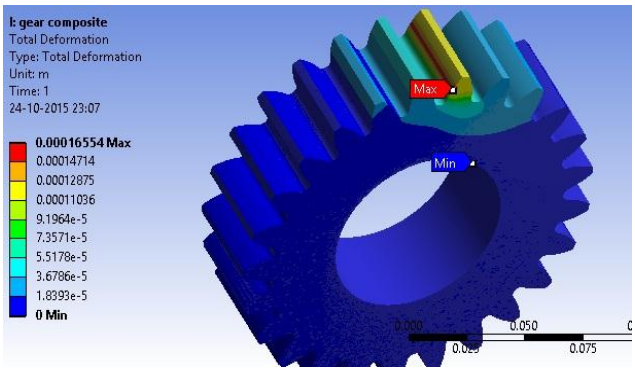


Fig (6): Gear 1 composite material (25 teeth)

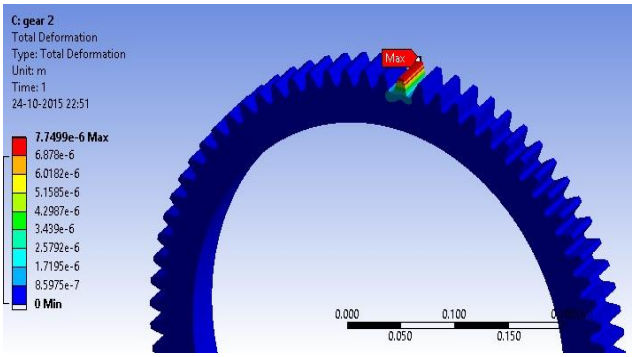


Fig (7): Gear 2 for cast steel (76 teeth)

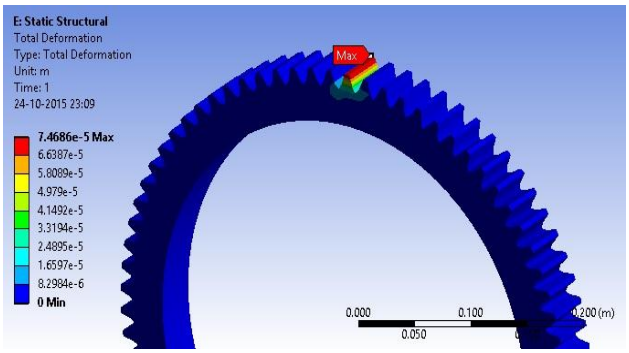


Fig (8): Gear 2 for composite material (76 teeth)

➢ **Von-Mises Stress:**

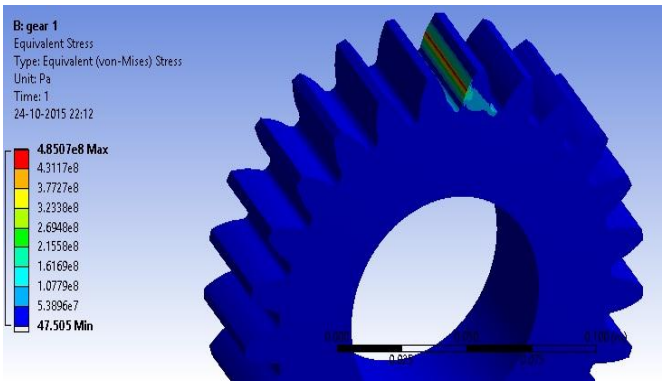
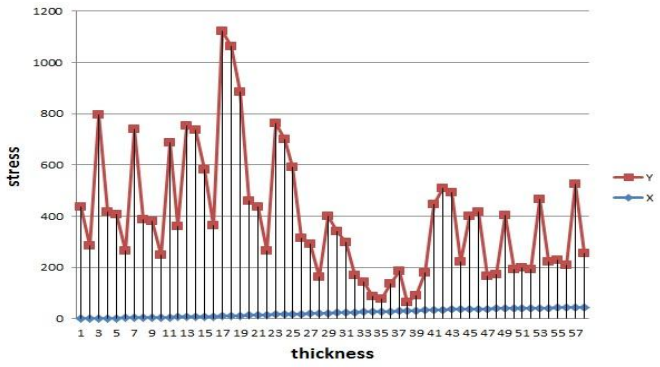


Fig (9): Stress of Gear 1 for cast steel (25 teeth)



Layer by Layer von-mises Stress v/s thickness for Composite Spur Gear 1 (25 Teeth)

➢ **Root Mean Squre:**

R.M.S = $\sqrt{(X1)^2 + (X2)^2 + (X3)^2 + \ldots\ldots\ldots \div \eta i}$

$= \sqrt{27582.48} \div 58$

= 475.66 Mpa

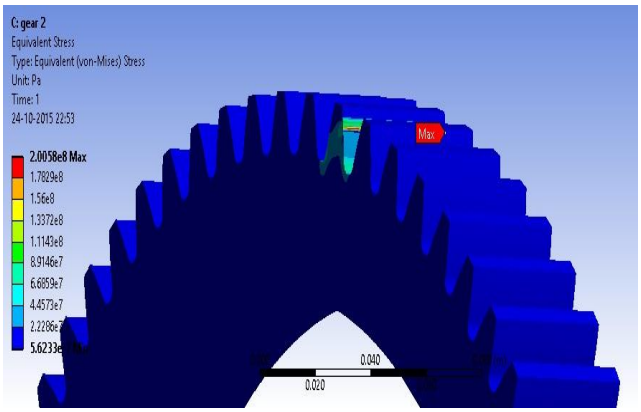
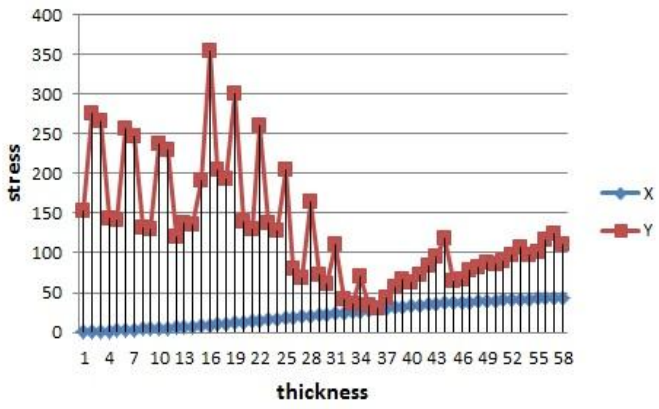


Fig (10): Von Mises Stress Analysis of spur Gear 2 for cast steel (25 teeth)



Layer by Layer von-mises Stress v/s thickness for Composite Spur Gear 2 (76 Teeth):

➢ **Root Mean Squre:**

R.M.S= $\sqrt{(X1)^2 + (X2)^2 + (X3)^2 + \ldots\ldots\ldots \div \eta i}$

$$= \sqrt{1289442} \div 58$$

= 149.10 MPA

	Cast steel		Composite material	
	Gear 1 (25 teeth)	**Gear 2 (76 teeth)**	**Gear 1 (25 teeth)**	**Gear 2 (76 teeth)**
Weight	4.632 kg	16.77 kg	1.158 kg	4.19 kg
Deformation	1.16 * 10^-5 m	7.749 *10^-6 m	16.55*10^-5 m	74.6*10^-6m
Von-mises Stress	485.05 Mpa	200.5 Mpa	475.66 Mpa	149.10 Mpa

Table(4): Comparison between Cast steel and composite materials

VII. CONCLUSION

- From this analysis I saw that stress is mainly induced in gear teeth area.
- From this analysis I got stress and deformation in composite gear is less than gear made from cast steel.
- The study of weight reduction of spur gear made from cast steel and composite materials was carried out and weight of composite gear is $1/4^{th}$ of cast steel gear.
- So from this analysis results, I conclude that, the stress, deformation and weight of the composite spur gear is less as compared to the cast steel spur gear.

VIII: REFERENCES

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