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MODELING & STATIC ANALYSIS OF SPUR GEAR

Peruboina Nagavasavi[1], Govindaiah.T[2]

[1]Pursuing M.Tech, [2]Assistant Professor, Nalanda Institute of Engineering and Technology(NIET), Siddharth Nagar, Kantepudi(V), Satenepalli (M), Guntur Dist, AP, (India)

ABSTRACT

Gears have become most usual component in mechanical transmission system. In Spur gears are generally utilized as a part of the applications varying from household things to substantial building applications. In this present work the static structural and modal analysis is performed on gear tooth by varying the material of gear. Polymer composite materials have some features like high elasticity, noiseless and accuracy in power and motion transmission, lubricant free which enhanced their existence. In this the gear is modeled in CAD software tool CATIA V5 R18. Static and model analysis on gear is performed using ANSYS14.5 for these purpose three types of materials namely Cast Iron, Structural Steel and Carbon Fiber composite were considered.

In this we execute modal analysis to calculate the deformations at different frequencies and stress with deformations induced by applying force on tooth. The frequencies and natural mode shape results are obtained by modal analysis under free vibration. The frequencies and related mode shapes are represented by the Eigen values which came by solving problems. The analysis is thus carried out making a comparison for a Cast Iron, structural steel spur gear and carbon fibre epoxy resin composite spur gear.

I. INTRODUCTION

GEAR:

A toothed machine part for example a wheel or chamber that work with another toothed part to transmit movement or to alter speed or direction.

Types of Gears:

1. **Parallel**
- Spur gear
- Helical gear
- Rack and pinion

2. **Intersecting**
- Bevel gears

3. **Non – Intersecting and Non parallel**
- Worm gears

The main purpose of Spur Gear is to transform power in the modern mechanical engineering world. The sizes of the gears varies from small size to large size depending on use of them in watches, marine speed reducers, bridge lifting mechanism and rail road turn table drivers. Spur gears form essential elements of ancillary and main mechanism in machines like metal cutting machine tools, automobiles, tractors, rolling mills, hoisting and transmitting machinery etc.,

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The four disappointment modes in rigging frameworks are tooth bowing exhaustion, contact weakness, surface wear and scoring. Two sorts of teeth harm can happen on apparatuses under repeated stacking because of exhaustion; to be specific the setting of rigging teeth flanks and tooth breakage in the tooth root. Tooth breakage is obviously the most exceedingly bad harm case, subsequent to the rigging could have truly hampered working condition or even be devastated. In light of this, the anxiety in the tooth should dependably be carefully concentrated on in all handy rigging application. The weariness procedure prompting tooth breakage is isolated into split start and split producing period. Be that as it may, the split start period for the most part record for the large portion of administration life, particularly in high cycle exhaustion.

The first break can be shaped because of different reasons. The most common reasons are brief over-burden, material failures, deformities because of mechanical or warm treatment and material exhaustion. The initial split then spreads under impulsive loading until some critical length is come to, when a complete tooth breakage happens. The administration life of a rigging with a break in the tooth root can be determined tentatively or numerically (Ex. with limited component technique).The exhaustion life of parts subjected to sinusoidal using so as to stack can be assessed combined harm hypotheses. Their expansion to uninformed burden weakness, through straight forward, may not be extremely exact attributable to basic dissipate show by the weariness wonders. Because of the many-sided quality in geometry and loading on the structure, the limited component technique is ideally embraced.

II. NOMENCLATURE OF SPUR GEAR

Module

Gear module is defined as the ratio between diameter and number of teeth.

m = d/N

Face Width

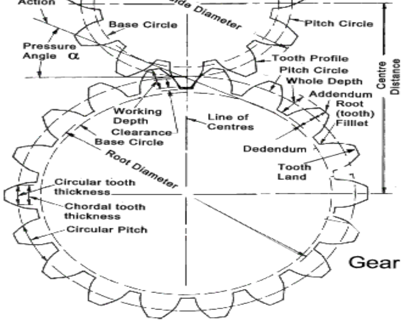
Face width is characterized as the width along the contact surface between the gears.

Tooth Thickness

Tooth thickness is defined as the thickness of the tooth along the pitch circle.

Addendum

The addendum is term referred as the radial distance between the pitch circle and the top land of gear.



DEDENDUM

Dedendum is defined as the radial distance between the pitch circle and the bottom land of the gear.

PRESSURE ANGLE

The angle between the line joining the centers of the two gears and the common tangent to the base circles is called pressure angle.

MATHEMATICAL CALCULATIONS

I. Compressive stress, σc = 0.7 (i+1)/a*√{(i+1/ib)*E[mt]}

II. Bending stress, σb = 0.7(i+1) (Mt) / {a x b x mnxYv}

The hypothetical configuration computations are performed utilizing the data parameters, for example, power for marine rapid motor, pinion pace, gear proportion, weight point and so on i.e

Power (P), = 900kw

Speed of pinion (N), = 3500rpm

Gear proportion (i), = 7

Materials of Gear:

Depending upon the strength and service conditions like wear and noise etc., the material used to manufacture gear differs. Metallic and Non- metallic materials are used for manufacturing gears. Due to its good wearing properties, excellent machinability and ease of producing complicated shape by casting technique Cast Iron is the material generally used and other materials like structural steel, carbon fiber etc. are materials used. For making high strength gears plain carbon steel or alloy steel can be used. The heat treatment process increases the toughness and tooth hardness of steel gears.

Material Properties

Material Name / Properties	**Structural Steel**	**Cast Iron**	**Carbon Fiber**
Young's Modulus (E)	2e^5 MPA	165e^3 MPA	450 GPA
Yield Strength (Y)	250 MPA	250 MPA	52 MPA
Poisson's Ratio (μ)	0.30	0.28	0.30
Density(ϱ)	7850 KG/M^3	7200 KG/M^3	1800 KG/M^3
Tensile Ultimate	460 MPA	350 MPA	540 MPA

Steel

Steel is the most vital material, and extensive variety of properties found in Iron and carbon. The strength of iron-carbon composites, especially after warmth treatment, has been exploited for a great many years (since the "Iron Age"). Modern steels and ferrous composites for the most part have been created subsequent to the Industrial Revolution.

Mild steel contains 0.1-0.2%C. They are low-cost, solid steels utilized for development, transport and bundling.

All variety of steels has a high density and a high Young's modulus. Cold working process makes mild steel stronger.

Mild steel corrosions easily, and must be secured by painting, galvanizing or by different coatings.

Cast Iron

Cast irons have similar properties when compared to steels, being iron composites of high carbon content (2-4%). The strength of iron-carbon composites, especially after warmth treatment, has been misused for a great many years (since the "Iron Age"). Industrial Revolution made the existence of mostly used materials like modern steels and ferrous alloys.

Cast irons costs low, casting of high carbon alloys of moderate strength can be simply formed. Cast irons have high density and Young's modulus. They have tendency to have poor durability, yet their strength and durability can be enhanced and warmth treatment.

Cast irons corrosion easily, and must be secured by painting or different coatings.

Carbon Fibers

Carbon fibers are the material comprising of greatly thin filaments about nano size of 0.0005–0.010 mm in breadth and made for the most part out of carbon molecules. Carbon fiber, or Graphite fiber, carbon graphite or CF of the carbon iota's are combined and reinforced in minute pieces that are pretty much adjusted parallel to the long axis of the fiber. The crystal position and arrangement makes the fiber exceptionally strength for its size. A few thousand carbon fibers are reinforced and curved together to shape a yarn, which may be utilized by own or woven into a fabric.

The properties of carbon filaments, for example, high rigidity, high adaptability, high temperature resistance, low weight, and low warm extension make them extremely well known alongside different games rivalry additionally in Mechanical, structural, aviation, military and engine world. Cost of glass fibers or plastic fibers is less when compared to carbon fibers.

Modeling of Gear

Dimensions	**Unit**	**Symbol**	**Values**
Number of teeth	-	Z	18
Pitch circle diameter	Mm	D	166
Pressure angle	deg^0	Ø	15
Addendum radius	Mm	R_A	91
Dedendum radius	Mm	R_D	78
Face width	Mm	B	40
Shaft radius	Mm	R_S	18

III. FINITE ELEMENT ANALYSIS (FEA)

FEA is the functional utilization of the finite element method (FEM), which is utilized by architects, and scientists to scientifically model and numerically understand extremely complex structural, liquid, and multi phasic issues. FEA programming can be used in extensive variety of businesses, yet is most generally utilized as a part of the aeronautical, biomechanical and locomotive industries.

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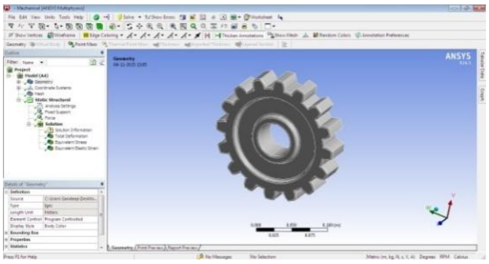
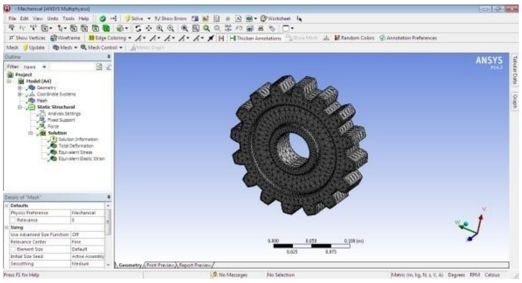
A finite element (FE) model contains an arrangement of points, called "hubs", which frame the state of the outline. Joined with these hubs are the finite elements themselves which frame the finite element mesh and contain the material and basic properties of the model, characterizing response of it in specific conditions. The density of the finite element mesh may differ all through the material, contingent upon the foreseen change in stress levels of a specific part. Areas that experience high changes in stress for the most part require a higher mesh density than those that experience little or no stress variation. Purposes of interest may incorporate crack purposes of beforehand tried material, fillets, corners, complex point of intersect, and high-stress regions.

IV. STRUCTURAL AND MODAL ANALYSIS FOR GEARS MADE OF DIFFERENT MATERIALS

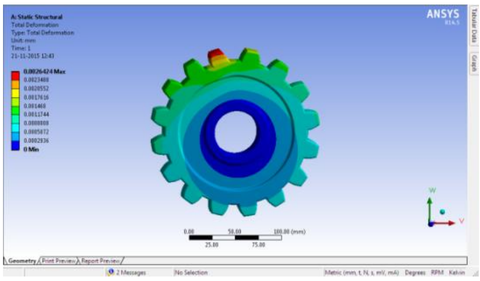
Material Type: Cast Iron



Meshed Model



Total Deformation observed



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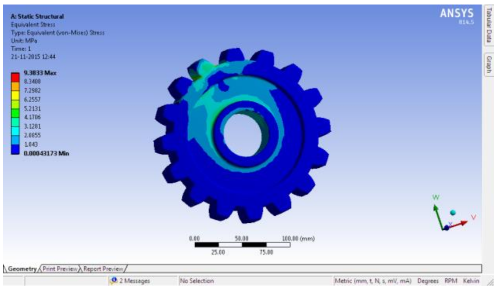
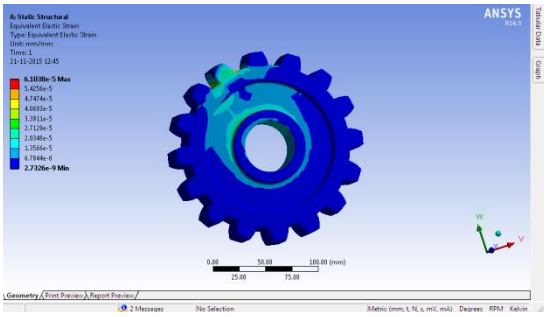
Total Deformation on spur gear made of Cast Iron

Von misses stress



Von-mises Stresses Distribution in spur gear made of Cast Iron

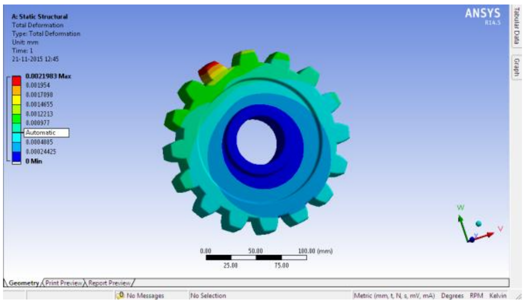
Strain observed



Strain Induced in Spur gear made of Cast Iron

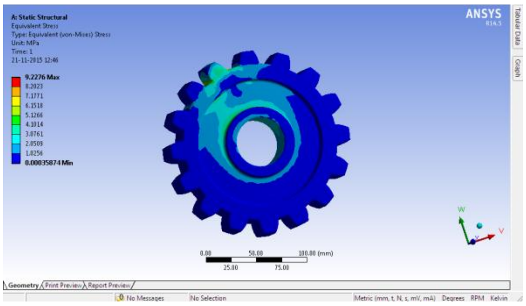
Material Type: Structural Steel

Total Deformation



Total Deformation on Spur made of Structural steel

Von misses stress



Von-mises Stresses Distribution in Spur gear made of Structural steel

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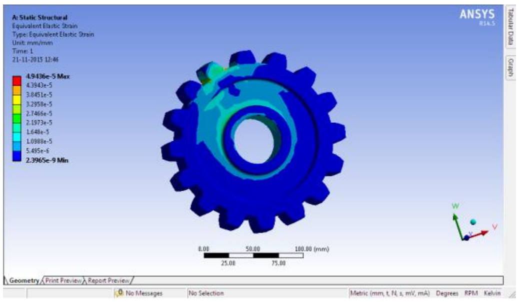
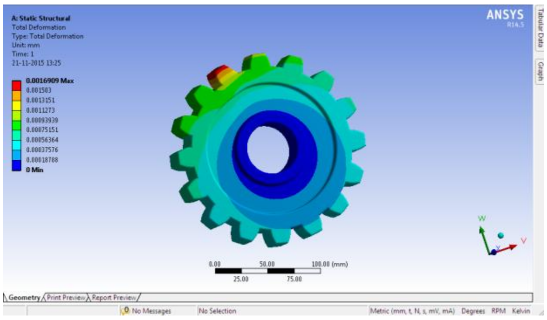
Strain



Strain Induced in Spur gear made of Structural steel

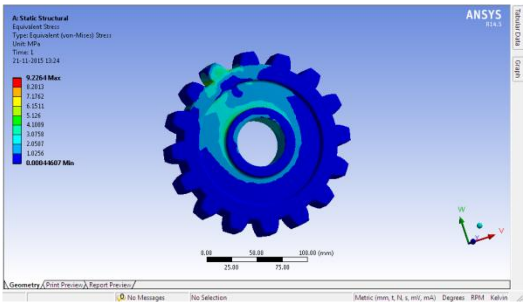
Material Type: Carbon Fiber

Total Deformation



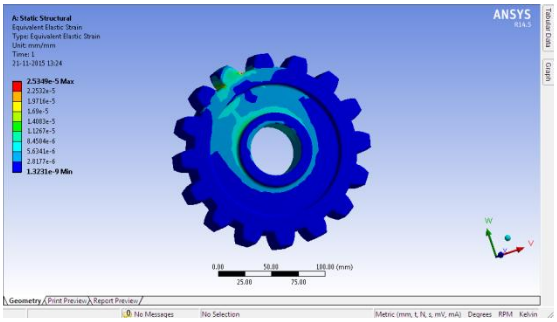
Total Deformation on Spur gear made of Carbon Fiber

Von misses stress



Von-Mises Stresses Distribution in Spur gear made of Carbon Fiber

Strain



Strain Induced in Spur gear made of Carbon Fiber

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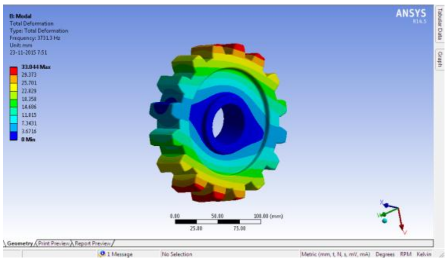
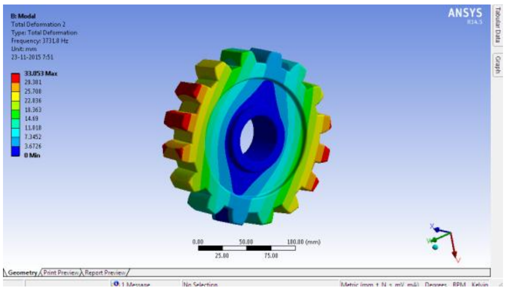
Modal Analysis for different materials:

Material type: Cast Iron

Mode 1:



Mode 2:



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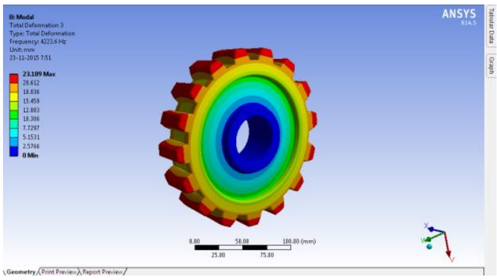

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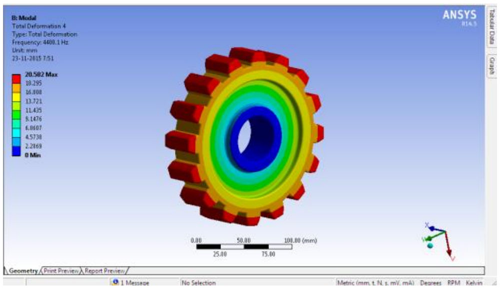
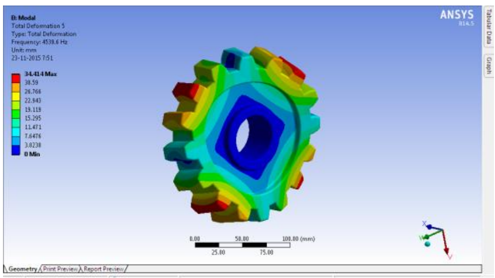
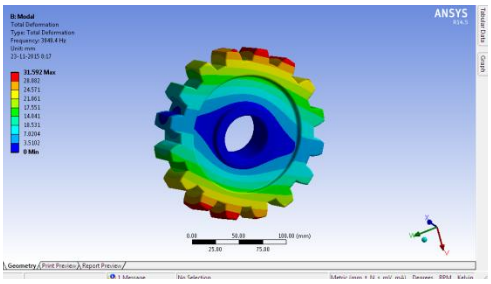


Mode 5:



Material Type: Structural steel

Mode 1



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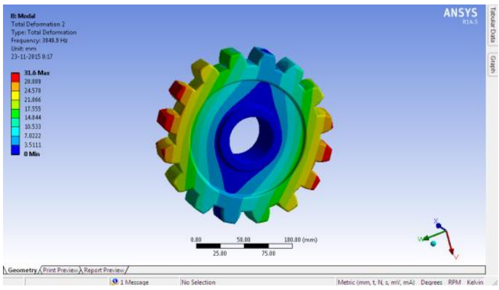

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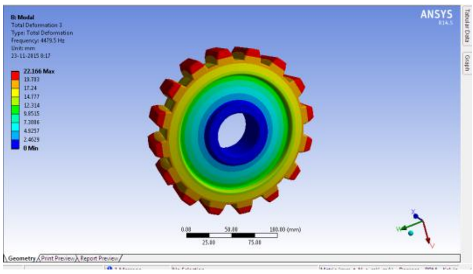

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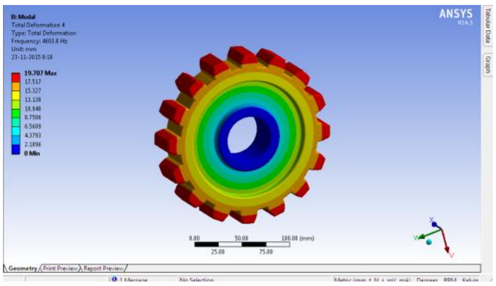
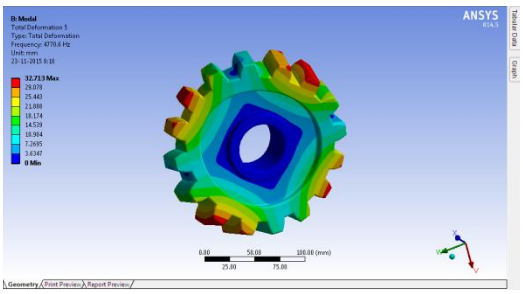


Mode 5



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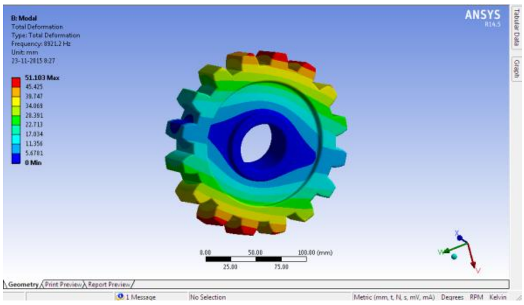
Material Type: Carbon Fiber

Mode 1



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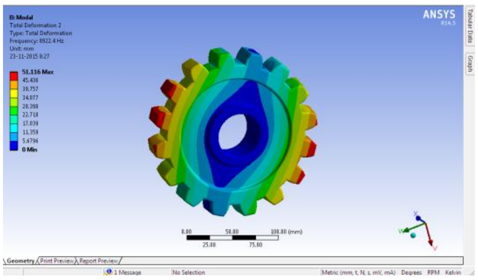

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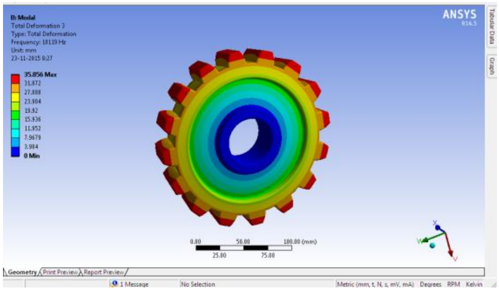

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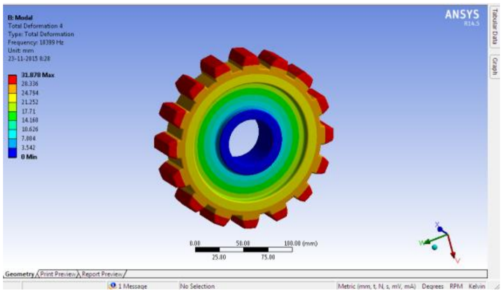

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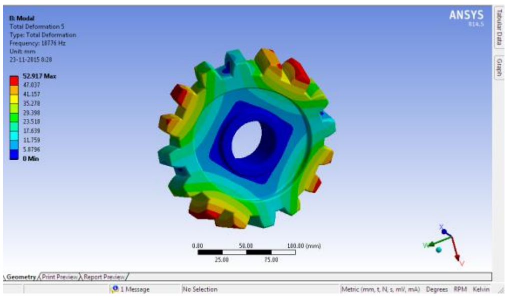

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V. RESULTS AND DISCUSSION

Numerical values obtained during analysis

Values observed during structural analysis of Gear

S.No	Material type	Displacement (mm)		Von-Mises stress		Strain	
		min	Max	Min	Max	min	Max
1	CAST IRON	0	0.002642	0.00431	9.3033	2.732e-9	6.103E-5
2	STEEL	0	0.0021903	0.00387	9.2276	2.390e-9	4.943E-5
3	CARBON FIBER	0	0.0016909	0.00464	9.2264	1.323e-9	2.534E-5

Table 1

Values observed during modal analysis of Gear

S.No	Material	mode 1	mode 2	mode 3	mode 4	mode 5
1	CAST IRON	3731	3732	4223	4400	4539
2	STEEL	3949	3949	4479	4603	4770
3	CARBON FIBER	8921	8922	1e3	1e3	1.07e3

Table 2

- The deformation observed in the case of carbon fiber composites are less when compared to structural steel and cast iron spur gear.
- The stress valuesobserved in the Spur gear made of carbon fiber composites are less when compared to others.
- From the modal analysis of three spur gears it is understood that the natural frequency of carbon fiber-epoxy resin composite spur gear is very high when compared to steel and cast iron spur gears.

VI. CONCLUSION

Finite element analysis of spur gear is done to determine the maximum stress and also deformation by ANSYS 14.5. From the analysis result on different materials like Cast Iron, Structural Steel and Carbon Fiber of spur gear total deformation observed is comparatively less when compared between cast iron and carbon fiber. The three dimensional stresses observed are less when compared to the other materials. The deformation value of structural steel is more than other materials. So in future scope the gear with cast iron material can be replaced by carbon fiber material. So the use of carbon fiber which is having high strength can replace the most of the other materials in manufacturing of other components such as in drive shafts and also in less power applications. The percentage of weight reduction is more in carbon fiber and has many properties high conductivity, low coefficient of thermal expansion, noise less, corrosion resistance.

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AUTHOR DETAILS

	P.Nagavasavi, pursuing M.Tech (CAD/CAM) from Nalanda Institute of Engineering and Technology(NIET), Siddharth Nagar, Kantepudi village, Satenepalli Mandal, Guntur dist, AP, INDIA.
	Govindaiah.T, working as Assistant Professor (CAD/CAM) from Nalanda Institute of Engineering and Technology Siddharth Nagar, Kantepudi village, Satenepalli mandal, Guntur dist, AP, INDIA.