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Design, analysis and development of composite spur gear under static loading condition using ansys workbench

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Abstract
Gear design and its analysis plays a major role in a mechanical field. There are many applications such as automobile, aerospace, marine. In these applications power transmission gear is to be critically analyzed. Now days more researchers are focusing on gear design using composite material to achieve better results than existing conventional material. In this work design, analysis and development have been carried out composite material spur gear which can be used for marine application. The spur gear is modelled in Solidworks 2016 & imported into Ansys workbench for static structural analysis. Comparison have been made between Aluminium alloy and new composite material on the basis of Von-Mises stress, Total deformation at different torque value have been analysesd. From this analysis it is concluded that if the torque increases, Von-misses stress and deformation of both composite and aluminium alloy are increasing. But when compared to aluminium alloy, composite materials have indicated lesser values of stresses and deformation. So it is feasible to use this composite material spur gear for the marine applications.

Keywords: Spur gear, composite material, solidworks 2016, ansys workbench

1. Introduction
In a mechanical power system gearing is one of the most critical component. A gear is a rotating component which is having teeth and it meshes with another toothed part. These devices can change torque, speed, and direction and power source. Gear drive called as positive drive since it transmits the motion between two shafts without any slip. Spur gears are the most common used gear which is having strength teeth and are mounted parallel to shaft axis. These gears have wide applications such as metal cutting machines, power plants, marine engine, fuel pumps, washing machine [1]. P.B. Pawara *et al*. have proposed analysis of composite material spur gear under static loading condition. They have concluded that Al-SiC composite prepared by stir casting provides improved hardness, Tensile strength over base metal. Better results have been obtained at 18% SiC is added. Almost 3-4% difference has been observed between theoretical and FEA values of bending stress [2]. Anuj Nath et.al have studied design and analysis of the composite spur gear. It was concluded that the stress induced, deformation and weight of the composite spur gear is less as compared to the cast steel spur gear. So, Composite materials are capable of using in automobile vehicle gear boxes [3]. Harshal P. Rahate *et al*. have proposed finite element analysis of composite spur gear for contact stress. It is observed that stress is reduced by nearly 25% due to the use of composite material [4]. Utkarsh. M. Desai *et al*. have investigated modelling and stress analysis of composite material for spur gear under static loading condition. It was reportd 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 compared with alloy steel. So alloy steel spur gear can be replaced by GF 30 PEEK(composite) spur gear due to its high strength, low weight and damping characteristics [5]. S. Mahendran *et al*. have proposed design and analysis of composite spur gear. In that they studied weight reduction and stress distribution of spur gear for cast steel and composite materials. From these analysis they got the stress values for composite materials is less as compared to the cast steel spur gear [6]. Pradeep Kumar Singh et.al have studied stress analysis spur gear design by using ansys workbench. They conclude that theoretically result obtained by Lewis formula and hertz equation and result found by comparable with finite element analysis of spur gear [7].

M. Keerthi *et al*. have studied static & dynamic analysis of spur gear using different materials. It was concluded that the stress values are calculated for composite materials is approximately same as compared to the structural steel, gray cast iron and aluminium alloy. So, Composite materials are capable of using in automobile vehicle gear boxes instead of existing cast steel gears with good results.

2. Objective of present work

The objective of the present work is to find out composite material spur gear for marine application instead of base Aluminium alloy. The material change as above reduces the stress distribution, total deformation weight of spur gear almost nearer to base alloy. A new gear which has been made by this new composite, designed and modelled in "solid works" software then it has been imported in Ansys workbench for analysis purpose. The result of analysis of base Al alloy gear and composite gear have been compared for further studies.

2.1 Analytical Design

a) Application- 19 ski Boat

Engine - Inboard Gasoline
Reduction gear ratio - 1.23 to 1
Maximum engine horse power - 236 @4200rpm
Maximum engine torque – 343ft-lbs @ 2900 rpm
Now, 343 ft-lbs = 465 N-m …

P= $\frac{2\pi NT}{60} = \frac{2\pi\times 2900\times 465}{60}$ = 141.214 Kw

Design Torque = Mt kd K…… kd K-from data book
= 465 × 1.3= 604 N-m

b) Determination of minimum centre distance

$$a \geq (i+1)\sqrt[3]{\left(\frac{0.74^2}{\sigma_c^2}\right)\frac{E[M_t]}{i\Psi}}$$

$$a \geq (1.23+1)\sqrt[3]{\left(\frac{0.74^2}{550^2}\right)\frac{70*10^3[604*10^3]}{1.23*0.3}}$$

σ_c = 550 mpa from research paper
E = 70 × 10^3
i = 1.23
φ = 0.3…from design data book
$a \geq$ 132 mm

c) Determination of minimum module

$$m \geq 1.26\sqrt[3]{\frac{M_t}{Y[\sigma_b]\,\Psi_m z_1}}$$

$$m \geq 1.26\sqrt[3]{\frac{604\times 10^3}{0.308\times 76.10\times 10\times 18}}$$

(φ_m = 10, Y= 0.308, σ_b = 76.10 Mpa, Z1 = 18)
m ≥ 6.59 = 8
Z= 23
i = Z_2 / Z_1
D_{PINION} = 18 × 8 = 144 mm
D_{gear} = 23 × 8 = 184 mm

Final centre distance = $\frac{D_{PINION}+D_{gear}}{2}$ = 184 + 144 /2 = 164 mm

Face width of Pinion = 164 × 0.3 = 49.2 mm
F = T/ (d/2)
F = 604 × 1000 / 72
Load (F) = 8388.88 N

Using Lewis equation,
Tangential load,

F = b × y × m × σ b = 80 × 0.308 × 8 × σ_b= 42.55N/mm2
Y= Lewis form factor=0.308

The maximum allowable stress = 8.7413N/mm2.
Ultimate tensile strength for composite = 228.32 Mpa
Allowable stress for composite = ultimate tensile strength/3
=228.32 /3 = 76.10 N/mm2 > 8.7413N/mm2
So, the design is safe.

d) Calculations of gear tooth properties

Module = 8
No of teeth on pinion = (Z1) = 18
Pitch circle diameter = m × z = 18 × 8= 240 mm
Base circle diameter = D cos α = 144 × cos(20) = 135.31mm
Outside circle diameter = (z+2) × m= (18+2) × 8 = 160mm
Clearance = circular pitch / 20 = 1.25 mm
Dedendum = addendum + clearance = 8+ 1.25 = 9.25
Dedendum circle diameter = P.C.D - 2 × dedendum = 144 – 2 (9.25) = 125.5
Fillet radius= circular pitch / 8 = 3.14 mm
Diametral pitch = Number of teeth / P.C.D =18/ 144 = 0.125
Hole depth = 2.25 m = 2.25 × 8 = 18mm
Thickness of tooth = 1.5708 × m = 1.5708 × 8 = 12.56mm

2.2 Material selection and Modeling

Composite materials are being used in an ever-increasing variety of products and applications, as more and more industries realize the benefits that these materials offer. The composite material means two or more material added by some percentage in base material called reinforcement. The result of this reinforcement is better properties obtained than those of individual material. In this study Al 5052 is used as the base material and chromium, Graphite and Titanium added as reinforcement by volume of 3% each.

a) Properties of Composite Material

Density - 2.96 g/cc
Hardness, Brinell - 51
Tensile Strength (Ultimate) - 228.31MPa
Tensile Strength (Yield) – 112.89 MPa
Modulus of Elasticity- 81 Gpa
Poisson's ratio- 0.34

Al 5052-O have taken as aluminium alloy to compare the results with composite material. Because this is the highest strength alloy of the more common non heat-treatable grades. Fatigue strength is higher than most aluminum alloys. This type of grade particularly suitable in marine atmosphere and salt water corrosion. Used in a wide variety of applications from aircraft components to home appliances, marine and transportation industry parts, heavy duty cooking utensils and equipment for bulk processing of food.

b) Properties of Al 5052-O
Density - 2.68 g/cc
Hardness, Brinell - 47
Tensile Strength (Ultimate) -193MPa
Tensile Strength (Yield) - 89.6 MPa
Modulus of Elasticity- 69.3 Gpa
Poisson's ratio- 0.33

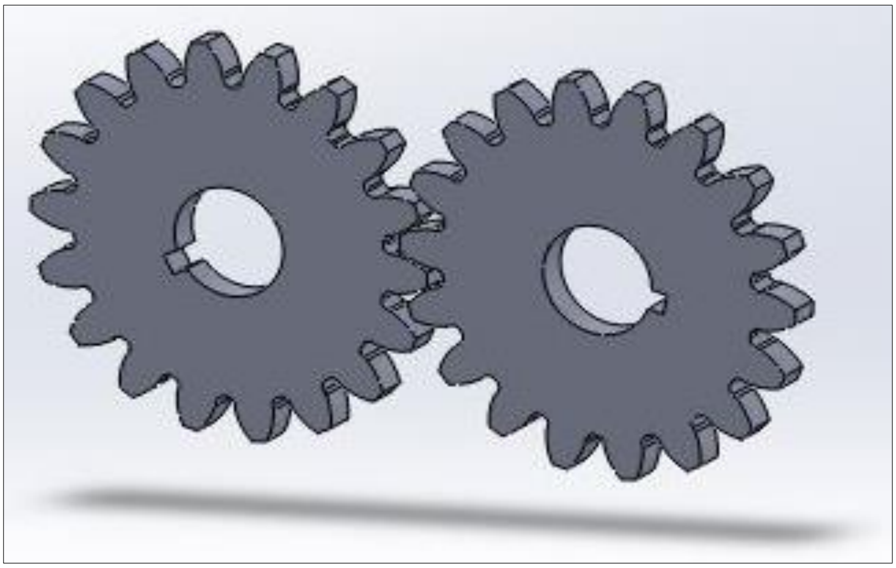

Fig 1: Spur Gear Assembly

3. Results and Discussions

The designed spur gear model imported to Ansys workbench and analysis have been carried out at different torques. From this analysis of von misses stress and total deform The Fig.2,3 shows the stress and deformation of composite material and Aluminium alloy gear respectively nearly at 265 N-m..ation for both composite and aluminium alloy have been taken. The Fig.4,5 shows the stress and deformation of composite material and Aluminium alloy gear respectively nearly at 365 N-m. The Fig.7,8 shows the stress and deformation of composite material and Aluminium alloy gear respectively nearly at 465 N-m.

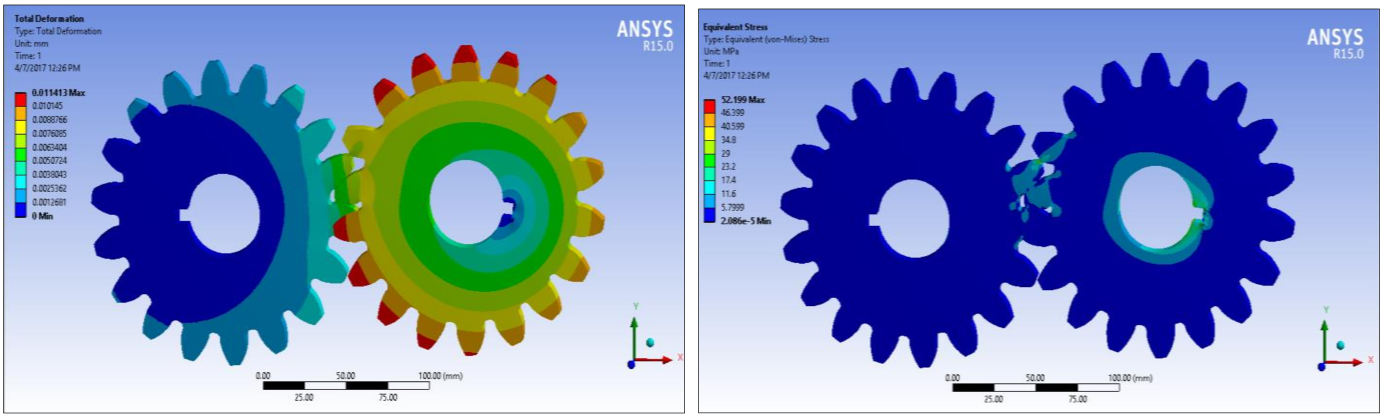

Fig 2: Von-Mises Stress Distribution and Total Deformation of Composite material for T= 265 N-m

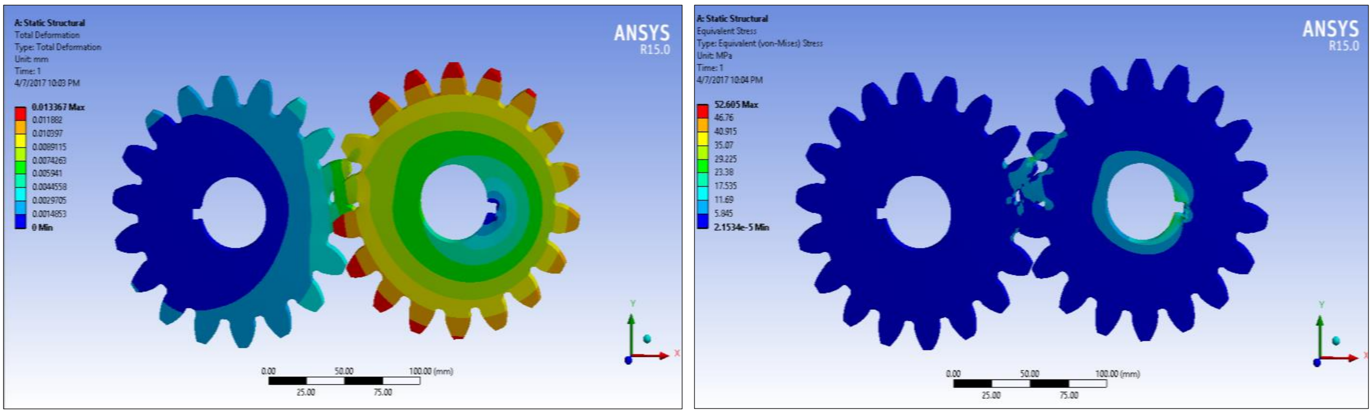

Fig 3: Von-Mises Stress Distribution and Total Deformation of Aluminium alloy for T= 265 N-m

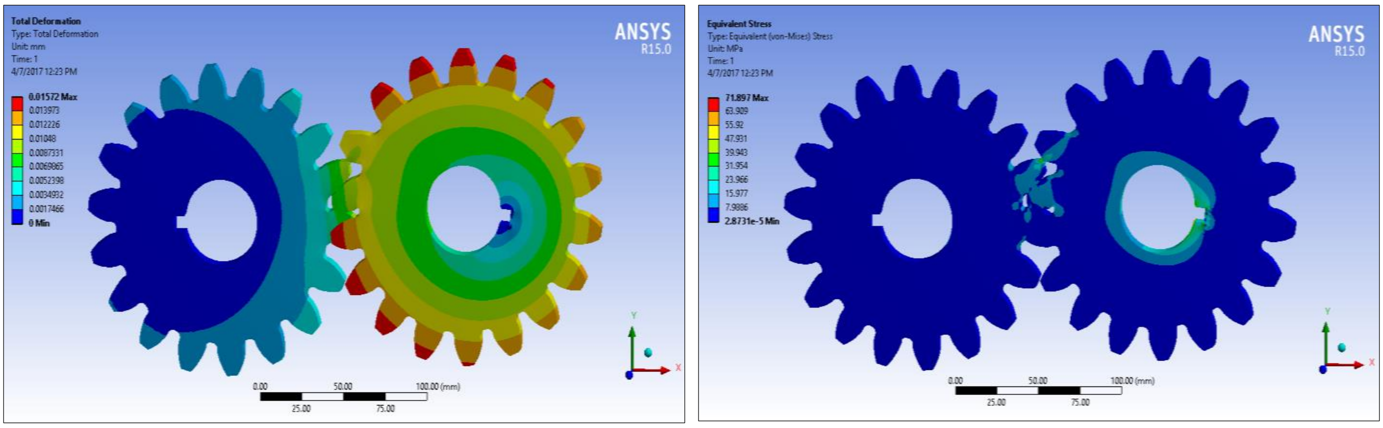

Fig 4: Von-Mises Stress Distribution and Total Deformation of Composite material for T= 365 N-m

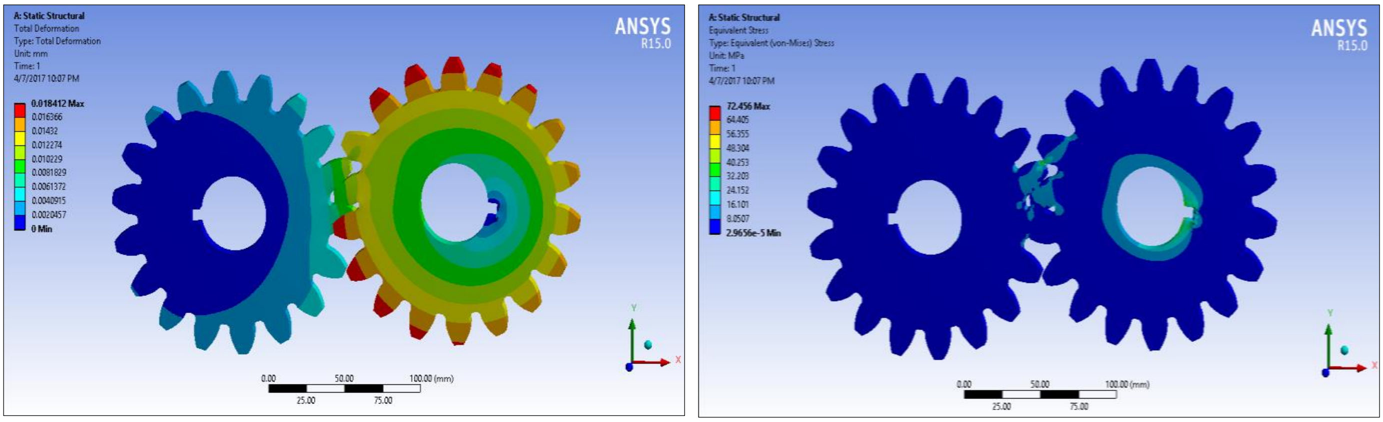

Fig 5: Von-Mises Stress Distribution and Total Deformation of Aluminium alloy for T= 365 N-m

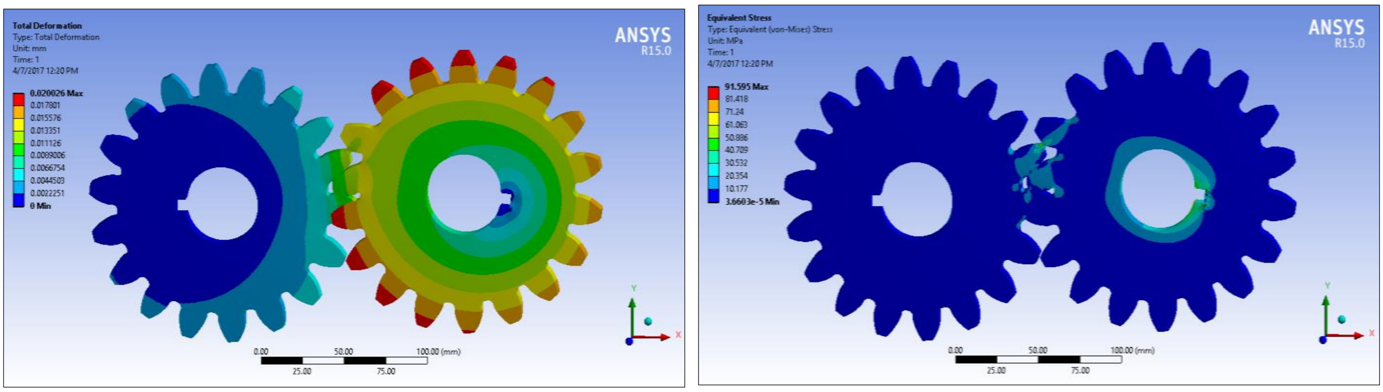

Fig 6: Von-Mises Stress Distribution and Total Deformation of Composite material for T= 465 N-m

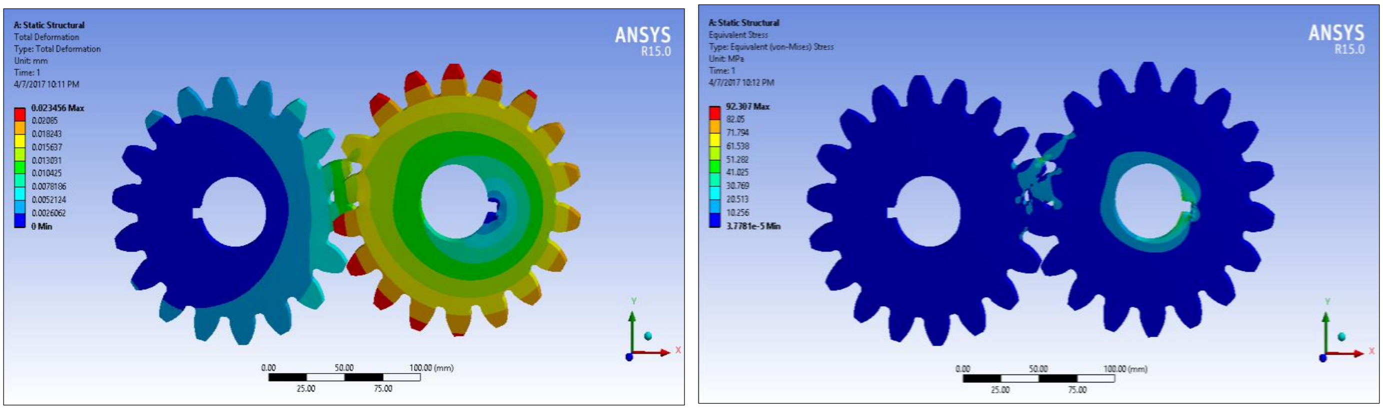

Fig 7: Von-Mises Stress Distribution and Total Deformation of Aluminium alloy for T= 465 N-m

Table 1: Comparison between composite material gear and aluminium alloy gear

Material	Torque (N-m)	Von-Misses Stress (Mpa)	Total Deformation (mm)
Composite Material	265	52.199	0.011413
	365	71.897	0.01572
	465	91.595	0.020026
Aluminium Alloy	265	52.605	0.013367
	365	72.456	0.018412
	465	92.307	0.023456

As shown in table 1 Von mises stress varies for composite material in the range of 52.199-91.595 Mpa and total deformation varies in the range of 0.0114 to 0.0200 mm. For aluminium alloy Von misses stress varies in the range of 52.605 to 92.307 Mpa and total deformation varies in the range of 0.0133 to 0.0234 mm, which is slightly higher. Composite material have shown better result because it contains reinforcements materials like Titanium, Graphite and chromium and which leads to increase mechanical properties.

4. Conclusions

The Design and analysis of new composite spur gear under static loading condition has been presented in this work using Ansys Workbench. From this analysis it is concluded that if torque increases Von-misses stress and total deformation increases for both composite material and Aluminum alloy. But composite material have shown lesser values than Aluminum alloy. Because of the presence of Titanium, Graphite and Chromium reinforcements, the tensile strength of composite gear has increased. Also due to increase of stiffness of material the modulus of elasticity and Poission's ratio also increased. Hence it is clear that the feasible to use this composite material for marine applications as it shows better mechanical properties which suits for marine applications.

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