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Stress analysis of composite spur gear using ansys workbench

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Abstract
A spur Gear is in working condition subjected to stresses, which causes failure of teeth. Due to this performance of gear affected and power transmitting capacity decreases. To overcome this problem, it is essential to find out any other material which will improve the performance of spur gears. In this present paper, stress analysis have done with replacing aluminum alloy gear with new composite material using Ansys workbench. For this the marine application has taken for design and model of spur gear is carried out in Solid works 2016. When a pair of spur gear tooth is considered, it is generally subjected to two cases of cyclic stress: contact stress and bending stress. It is not possible to reach both stress to their maximum values at the same point of contact fatigue. So, in many applications such as aerospace, automotive, marine to minimize this type of failure, analysis is carried out in the design stage and on the basis of results modifying tooth surfaces or production method. From this analysis, it is concluded that stress values for the new composite material have indicated lesser than aluminum alloy. So, it is better to use this composite material spur gear for the marine applications.

Keywords: Spur gear, Al5052, composite material, solid works 2016, ansys workbench, frictional stress, stress intensity

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 [1]. Ram Krishna Rathore *et al*. have studied bending stress analysis & optimization of spur gear. They have concluded that the optimization study of keeping the hole along the profile of the tooth that the effect of any feature like a hole anywhere above the dedendum and in the tooth, leads to an increase in the stresses in the fillets. The choice of the size and location of the elliptical hole is not a simple process, due to the nonlinear variations in a complex geometry [2]. V. Rajaprabakaran *et al*. have studied spur gear tooth stress analysis and stress reduction. They have proposed that, to relieve stress from the maximum value to as minimum as possible. So, the highest point of contact of teeth is selected as pressure application point which causes highest stress. Stress relieving feature having a shape of aero-fin is used in the path of stress flow which helped to regulate stress flow by redistributing the lines of force [3]. Krishanu Gupta *et al*. have studied effect of pressure angle of spur gears on bending and contact stresses: a comparative study using finite element software. They have concluded that the equivalent stresses and strains of the symmetric involute spur gears were studied through finite element meshing simulation for finding out the gear pair with least stress when the pressure angles are increased from 14.5° to 30°. This paper finds a comprehensive study on the variation of static stresses with four different pressure angles that might be developed in spur gear teeth using a commonly used finite element based software package [4]. Sameer Chakravarthy N C *et al*. have presented finite element analysis and fatigue analysis of spur gear under random loading the maximum power content is at the frequency 278.99. Due to the stress PSD response given input at critical node 7311, life obtained by FEM is 5.8 x 10

cycles whereas life obtained by experiment is 6.5 x 10 cycles [5]. 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 [6]. R. Vigithra has presented design and analysis of Nano composite spur gear. It is observed that when compared to the steel spur gears the percentage weight reduction is nearly 50 percent and has many more characteristics such as corrosion resistance, wear resistance, noiseless, lubricant free, high resilience, precision gearing, high strength to weight ratio, low co-efficient of thermal expansion, high electric conductivity etc.

Objective of Present work

The objective of the present work is to find out composite material spur gear for marine application instead of base Aluminum 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.

Prepartion of composite

Composite Material

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. 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.

Table 1: Reinforcement Details

Specimen 1	Specimen 2	Specimen 3
Al-5052 - 93%	Al-5052 - 92%	Al-5052 - 91%
Graphite - 3%	Graphite - 3%	Graphite - 3%
Chromium - 3%	Chromium-3%	Chromium-3%
Titanium - 1%	Titanium - 2%	Titanium – 3%

Fig 1: Gear Fabrication

Table 2: Composite Spur Gear

Parameter	Value
Young's Modulus (E)	70 Gpa
Poisson's Ratio	0.33
Tensile Strength (Ultimate)	193 Mpa
Tensile Strength (Yield)	80.6 Mpa
Density	2680 kg/m3

Table 3: Properties of Al 5052-O

Parameter	Value
Young's Modulus (E)	81 Gpa
Poisson's Ratio	0.34
Tensile Strength (Ultimate)	228.31 Mpa
Tensile Strength (Yield)	112.89 Mpa
Density	2960 kg/m3

Table 4: Composite Material Gear Properties

Parameter	Specimen-1	Specimen-2	Specimen-3
Hardness, Brinell	48	51	55
Tensile Strength (Ultimate) (Mpa)	196.25	210.51	228.312
Density (Kg/m3)	2962	2985	2992
Modulus of Elasticity (Gpa)	70	76	81

As already mentioned in table No 2, for comprasion of stresses in Ansys workbench the Properties specimen 3 has taken as composite material properties aluminium 5052- O as aluminium alloy.

Spur gear model

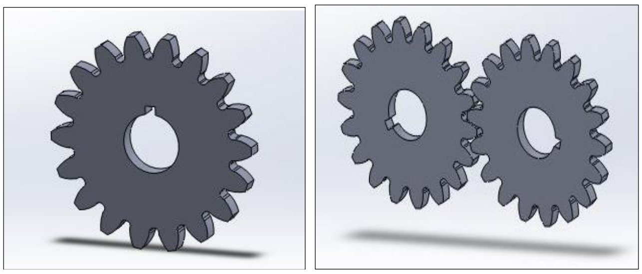

Fig 2: Spur Gear Models and Assembly

Results and discussions

The designed spur gear model imported to Ansys workbench and analysis is carried out at constant torque 365N-m. All stresses are as shown in fig.2, 3, 4, 5, 6, 7 for Aluminum alloy. The same stresses are as shown in fig. 8,9,10,11,12,13 for composite material.

Aluminum Alloy Gear

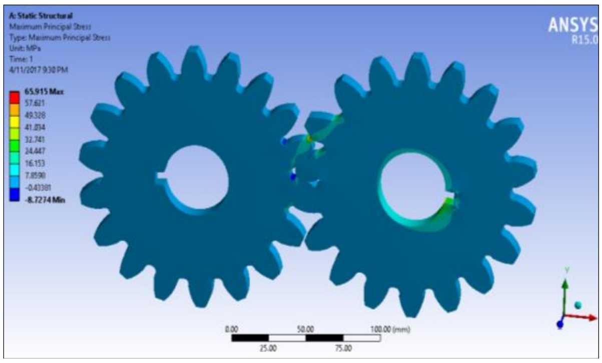

Fig 3: Maximum principle stress = 65.915 Mpa

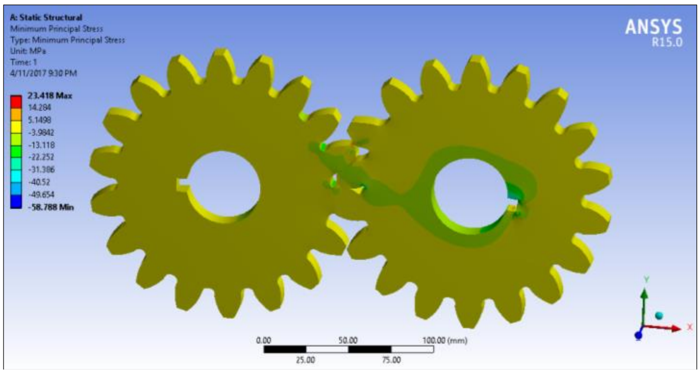

Fig 4: Minimum Principle Stress = 23.418 Mpa

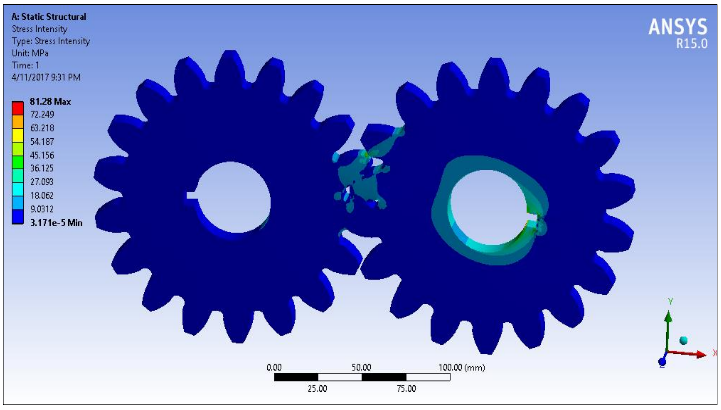

Fig 5: Stress Intensity = 81.949 Mpa

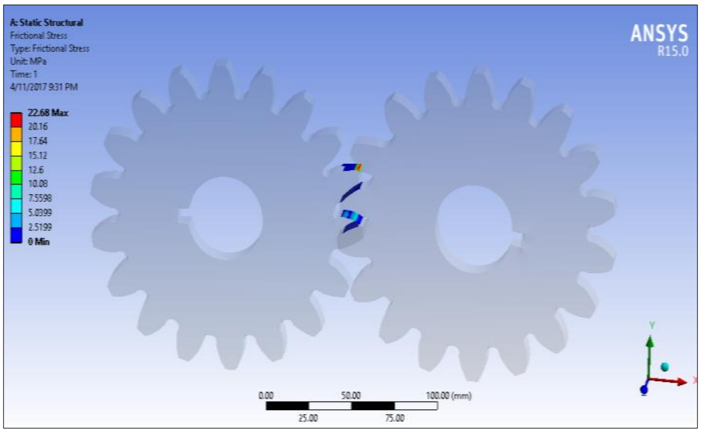

Fig 6: Frictional Stress = 22.64 Mpa

Composite Gear

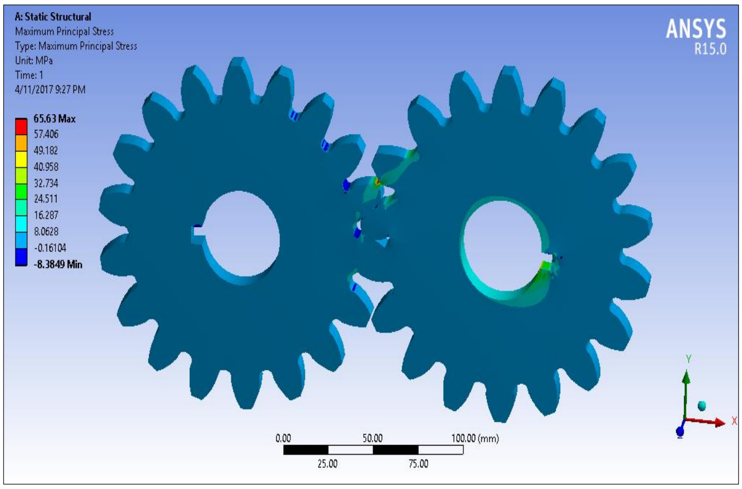

Fig 7: Maximum principle stress = 65.63 Mpa

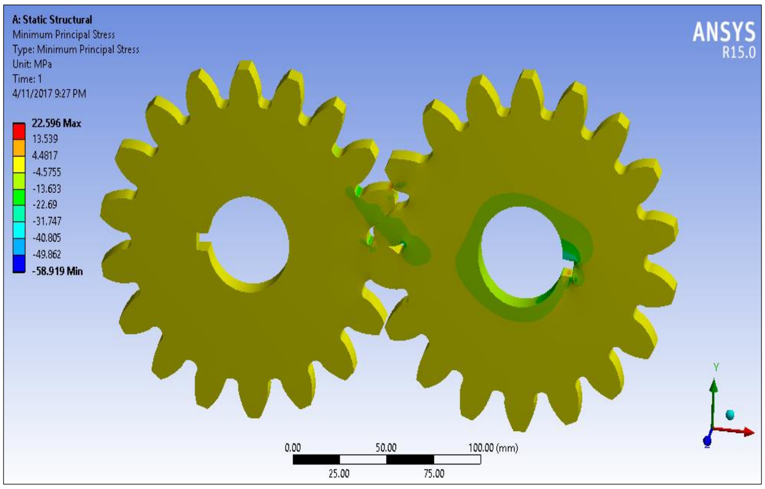

Fig 8: Minimum Principle Stress = 22. 596 Mpa

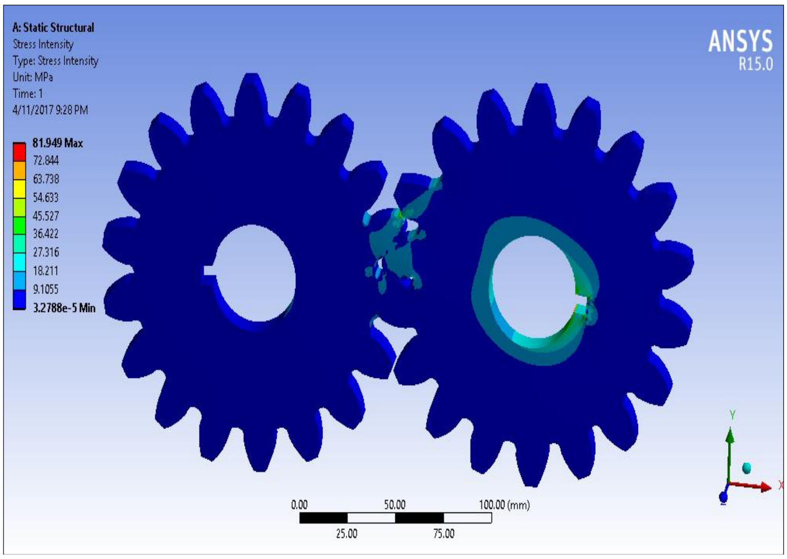

Fig 9: Stress Intensity = 81.28 Mpa

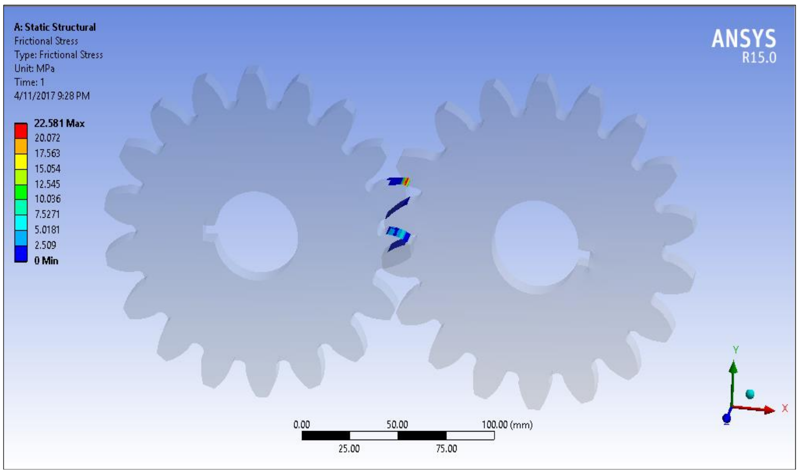

Fig 10: Frictional Stress = 22.581 Mpa

Table 5: Comparison of Stresses between Aluminium Alloy Gear and Composite Gear

Stresses in (Mpa)	Aluminium Alloy Gear	Composite Material Gear
Maximum Principle Stress	65.915	65.63
Minimum Principle Stress	23.418	22.596
Stress Intensity	81.949	81.28
Frictional Stress	22.64	22.581

As shown in Table 5 the stress values varies for composite material than aluminum alloy. Composite material have shown better result because it contains reinforcements materials like Titanium, Graphite and chromium and which leads to increase mechanical properties. Due to this bending strength of gear increases which is suitable for marine applications.

Conclusions
From this analysis, it is concluded that for constant torque aluminum alloy and composite material have indicated different results which is comparable. But composite material has shown lesser values of all related stress 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 Poisson's ratio also increased. Hence it is clear that the feasible to use this composite material for different applications specially Marine applications.

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