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Optimization & Verification of Drive Shaft Parameters for Wind Mill

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***Abstract*—Optimization & verification of drive shaft using composite material deals with the possibility of simulation of complex parts made from polymer-composites with CAD/CAM/CAE software. First part of contribution is aimed on describing the basis of fibre composites and its behaviour under load. Main reason of choosing carbon fibre as material for innovative parts depends on low density and high tensile strength. Thus carbon fibre composites are frequently used at automotive and sporting goods production, parts from these industries were selected. Design of composite parts in the past consisted of many trials, prototyping and testing. With the advanced technology & analytical software the tedious & expensive work can be managed.**

Second part will lead to different studies performed in Simulations and describes the stress and weight comparisons made from Steel, Carbon fibre, Glass fibre composites. The optimization for weight and strength of the shaft based on fibre orientations and thickness of fibre's will be done.

I. Introduction

Carbon fiber composites, particularly those with polymeric matrices, have become the dominant advanced composite materials for aerospace, auto-mobile, sporting goods, and other applications due to their high strength, high modulus, low density, and reasonable cost. For applications requiring high temperature resistance, as required by spacecraft, carbon fiber carbon-matrix composites (or carbon-carbon composites) have become dominant. As the price of carbon fibers decreases, their applications have even broadened to the construction industry, which uses carbon fibers to reinforce concrete.

Design of composite parts in the past consisted of many trials, prototyping and testing, resulting in increased production costs. With the advances of technology and performance of personal computers came on the analytical range of 3D CAD software to enable the design and analysis in a virtual environment. This eliminates the tedious and expensive, often limiting the design process: test - mistake. Often the designer neglects the preparatory phase in order to reduce costs and propose over equipped components, which today is highly inappropriate.

1.1 Composite Materials

Composite materials (composites for short, distribution shown on Figure 1) are made simultaneously by two or more materials with vastly different mechanical and / or chemical properties which remain separate and are clearly observable in macroscopic or microscopic scale inside the finished part. There are two categories of materials involved: reinforce and filler. At least one piece from each category must necessarily be present. Filler surrounds and supports the reinforcement to maintain mutual relative position. Reinforcement is adding its special mechanical properties in order to improve the mechanical properties of filler. Synergy produces mechanical properties unattainable by individual participating materials and a wide range of fillers and reinforcement allows the designer to select the most appropriate product mix.

II. Literature Review

Chris J. Burgoyne, [1] studied the different applications of composite materials in the area of construction. Where the materials used for structures are all characterized by low creep, as would be expected when the structures must resist significant permanent loads. For most applications, the higher stiffness fiber, i.e. carbon, glass and polyester, are used. The use of GFRP composites for complete structures is proving to be economic when there are access difficulties for building conventional heavy structures. The use of polyesters as soil reinforcement is also commercially successful, due to their resistance to corrosion in potentially aggressive soil conditions. Other applications have not yet taken off commercially. It also concluded that there is some scope for the use of composite reinforcement, but only in areas where rapid corrosion of steel is to be expected and only when deflections are not the limiting factor.

Branislav Duleba et. al. [2] in his paper describes the possibilities of use of carbon fiber composite in wide range of application. Carbon fiber composites, particularly those with polymeric matrices, have become the dominant advanced composite material for many industries due to their high strength and low density. He First tested model was design of rear upper arm from complex model of roadster, made with cooperation with students. This study shows, that use of normal carbon fiber composite at this part is not advisable, because possible faults of material can occur at area connected to bushings and chassis. As the goal of his whole study was to make the chassis as light as possible, simulation shows that there is the need of changing the material of composite or apply more layers of composite. At the end of paper the technique of production of test model was described. Technique called core wrapping was used by him, where the core made of Styrofoam was wrapped by layers of carbon fiber and epoxy resin.

The paper of Darren A. Baker et. al. [3] discusses about recent advancements in carbon fiber materials. Review of the authors provide the context of subject matter importance, a cost comparison of potential low-cost carbon fibers, a brief review of historical work, a review of more recent work, and a limited technical discussion followed by recommendations for future directions. As the available material for review is limited, the author includes many references to publicly available government documents and reviewed proceedings that are generally difficult to locate.

Luiz Claudio Pardini and Maria Luisa Gregori [4] in their work present ab-initio predictions of elastic constants and thermal properties for 2.5D carbon fiber reinforced carbon-silicon carbide hybrid matrix composites, by using the homogenization technique. The homogenization technique takes properties of individual components of the composites (fiber and matrix) and characteristics of the geometrical architecture of the perform to perform calculations. Ab-initio modeling of mechanical and thermal properties is very attractive, especially during the material development stage, when larger samples may be prohibitively expensive or impossible to fabricate. The modeling of properties by this simple method allows avoiding costly testing and reducing time consuming specimen preparation.

It also concluded that the Z-direction reinforcement allows higher delamination resistance and endurance on thermal stresses generated by heat treatment processing, and also the inter laminar fracture toughness is improved. An increase in the carbon fiber volume fraction, results in higher elastic properties, but nevertheless decreases the thermal conductivity.

The aim of this work was to investigate the development and mechanical characterization of new polymer composites consisting of glass fiber reinforcement, epoxy resin and filler materials such as TiO_2 and ZnS. The newly developed composites are characterized for their mechanical properties. Experiments like tensile test, three point bending and impact test were conducted to find the significant influence of filler material on mechanical characteristics of GFRP composites. The tests result have shown that higher the filler material volume percentage greater the strength for both TiO_2 and ZnS filled glass epoxy composites, ZnS filled composite show more sustaining values than TiO_2.

Tensile, Bending and Impact strength increases with addition of filler material, ZnS filled composite shows significantly good results than TiO_2 filled composites, Impact toughness value for unfilled glass composite is more than filled composite is concluded in the paper by Patil Deogonda et. al. [5]

H. Kim et. al. [6] proposed that the out-of-plane properties can still be increased further by using CNMs via effective processing techniques. It is also time to consider scale-up processing more seriously 20 years after the first discovery of CNTs. So far, aligned CNTs on carbon fibers have shown most promising results in mechanical property enhancement for carbon fiber composites, but this may be the most expensive method to incorporate CNTs into carbon fiber composites and has a limitation for scale-up processing. Hence, economical and effective processing methods should be devised further to see more real life applications of CNMs for carbon fiber composites.

Mark Bruderick et. al. [7] discusses about the carbon fiber origin and applications of the same in Automobile industry. The design and analysis, materials, process, and performance of these innovative composite structures are discussed.

This work presents the three Viper structural systems that employ the high modulus of carbon fiber SMC to achieve exceptional stiffness in lightweight structures. Mass reductions and stiffness improvements are recorded by carbon fiber over glass fiber.

III. PROBLEM DEFINITION

Design and optimize the shaft (Using composite Material and hollow shaft) for the application of wind mill - shown in below fig.

Power = 1 kW

Speed of rotor = Max. 650 rpm

Wind speed = Max. 16 m/s

Rotor Weight = 11.2 kg = 110 N

Shaft Material as: 40C8

Syt = 380 N/mm2

Sut = 650 N/mm2

Bearings - To be selected

Shaft – Present shaft is Solid (To reduce weight we are going for hollow shaft with composite layered material.)

MATH

Recommended values for Km & Kt

Nature of load		*Km*	*Kt*
1) Stationary Shafts			
a)	*Gradually applied load*	*1.0*	*1.0*
b)	*Suddenly applied load*	*1.5-2.0*	*1.5-2.0*
2) Rotating Shafts			
a)	*Gradually applied load*	*1.5*	*1.0*
b)	*Suddenly applied load with minor shock*	*1.5-2.0*	*1.5-2.0*
c)	*Suddenly applied load with heavy shock*	*2.0-3.0*	*1.5-3.0*

B. Equations

1. Torque :

$$\text{Power} = \frac{2\pi N T}{60}$$

2. Using maximum shear stress theory,

For Solid Shaft,

$$\tau = \frac{16}{\pi d^3}\sqrt{(Km * Mb)^2 + (Kt * Mt)^2}$$

For Hollow Shaft,

$$\tau = \frac{16}{\pi do^3 (1 - C^4)}\sqrt{(Km * Mb)^2 + (Kt * Mt)^2}$$

IV. MODELING OF SHAFT & SOFTWARE USED :

Modeling

Modeling is the process of producing a model; a model is a representation of the construction and working of some system of interest. A model is similar to but simpler than the system it represents. One purpose of a model is to enable the analyst to predict the effect of changes to the system. On the other hand, a model should be a close approximation to the real system and incorporate most of its salient features, on the other hand, it should not be so complex that it is impossible to understand and experiment with it. A good model is a judicious tradeoff between realism and simplicity.

Geometric Modeling-

The geometric modeling is used to represent the geometry in terms of points, curves. It stores enough information to fully describe the boundaries and the topology of the object. Fig. below shows the geometric modeling of the structure with coordinate system used for Finite Element Analysis. During the present study, the geometry of the conveyor frame is developed using CATIA V5 R20. Geometric modeling is done in parametric way; so that effect of change in dimension on quantities can be obtained by changing the parameter only.

CATIA V5 R20

CATIA V5 provides three basic platforms: P1, P2 and P3. P1 is for small and medium sized process oriented companies that wish to grow toward the large scale digitized product Definition. P2 is for the advanced design engineering companies that require product, process and resource modeling. P3 is for the high-end design application and is basically for Aerospace Industry, where high quality surfacing or class-A surfacing is used for designing. A good feature is that any change made to the external data is notified to user and the model can be updated quickly. A workbench is defined as a specified environment consisting of a set of tool, which allows the user to specific design tasks in a particular area.

V. ANALYSIS OF STEEL SHAFT & COMPOSITE SHAFT

Analysis of various orientations angles :

Fiber Orientation :

The strength and stiffness of a composite build up depends on the orientation sequence of the plies. The practical range of strength and stiffness of carbon fiber extends from values as low as those provided by fiberglass to as high as those provided by titanium. This range of values is determined by the orientation of the plies to the applied load. Proper selection of ply orientation in advanced composite materials is necessary to provide a structurally efficient design. The part might require 0° plies to react to axial loads, ±45° plies to react to shear loads, and 90° plies to react to side loads.

Because the strength design requirements are a function of the applied load direction, ply orientation and ply sequence have to be correct. It is critical during a repair to replace each damaged ply with a ply of the same material and ply orientation. The fibers in a unidirectional material run in one direction and the strength and stiffness is only in the direction of the fiber. Pre-impregnated (prepreg) tape is an example of a unidirectional ply orientation.

The fibers in a bidirectional material run in two directions, typically 90° apart. A plain weave fabric is an example of a bidirectional ply orientation. These ply orientations have strength in both directions but not necessarily the same strength.

The plies of a quasi-isotropic layup are stacked in a 0°, –45°, 45°, and 90° sequence or in a 0°, –60°, and 60° sequence.

These types of ply orientation simulate the properties of an isotropic material. Many aerospace composite structures are made of quasi-isotropic materials.

Stress & Deformation Result :

90/0/90/0

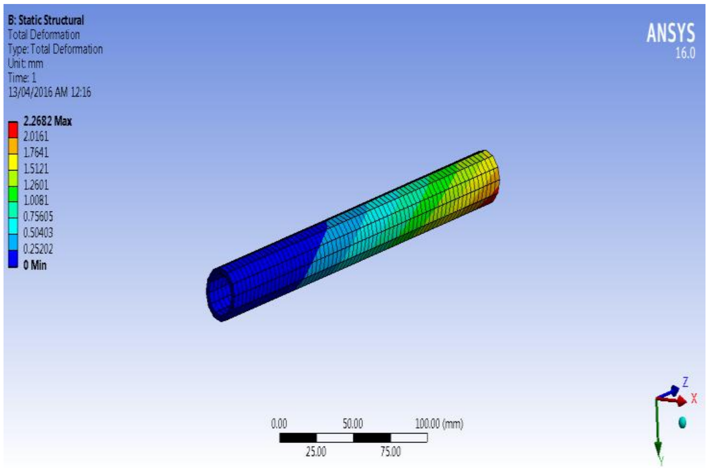


Fig 1: Deformation on Shaft (For 90/0/90/0) orientation

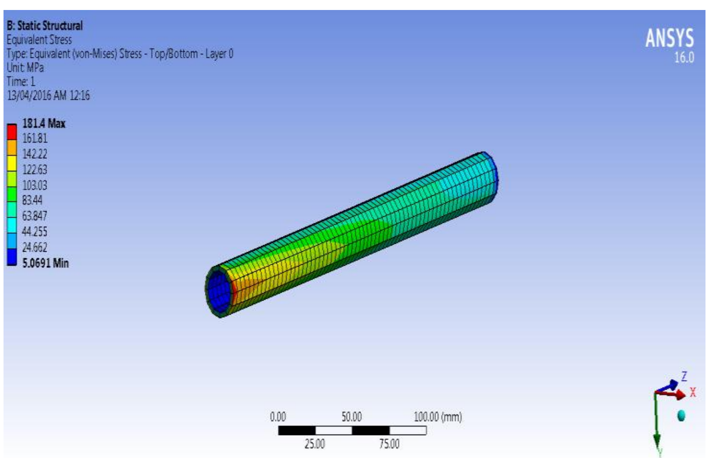
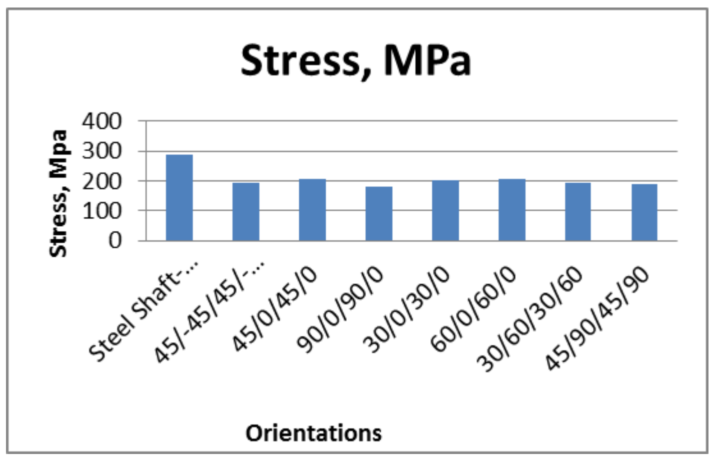


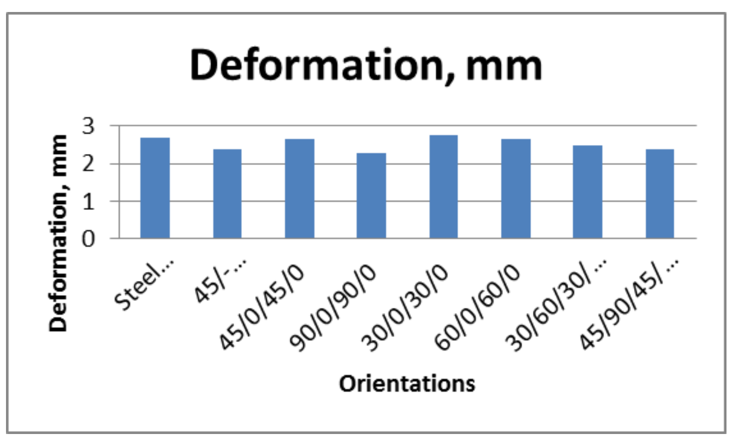
Fig 2 : Stresses on Shaft (For 90/0/90/0) orientation

From above results it can be see that orientation 90/0/90/0 gives better result. So, using it for further analysis of different materials.
From above results it can be seen that the stresses in Steel shaft are higher than composite shaft by 32.44%.

Sr No	Orientations	Stress, MPa	Deformation, mm
0	Steel Shaft-Hollow	287.96	2.6686
1	45/-45/45/-45	194.54	2.3765
2	45/0/45/0	206.02	2.6476
3	90/0/90/0	181.4	2.2682
4	30/0/30/0	200.99	2.7517
5	60/0/60/0	206.02	2.6476
6	30/60/30/60	195.13	2.4769
7	45/90/45/90	188.78	2.3782



Graph 1: Orientations and respective stresses



Graph 2: Orientations and respective deformations

Table 1: Results of angle orientation

Material Selected for further analysis:

1. Carbon Epoxy – Woven
2. E-Glass Epoxy
3. Resin Epoxy

Carbon Epoxy – Woven

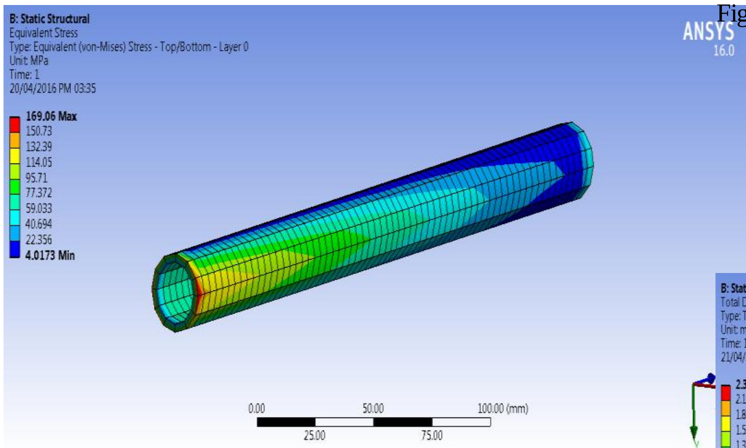


Fig 3 : Stresses using Carbon Epoxy- Woven Material

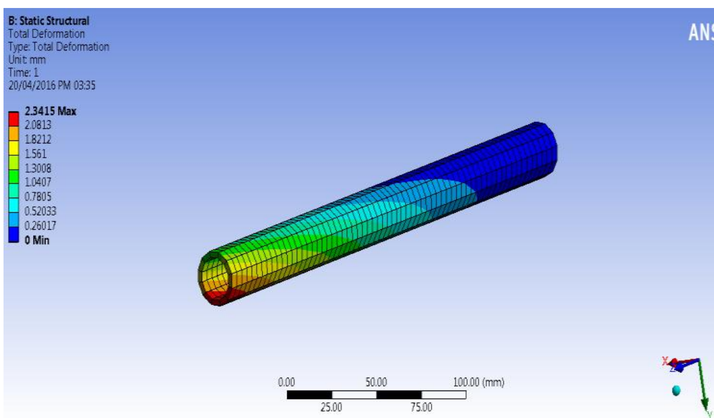


Fig 4 : Deformation using Carbon Epoxy- Woven Material

2 . E-Glass Epoxy

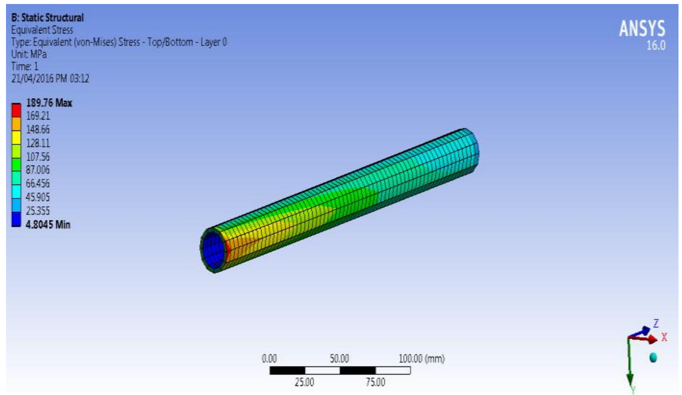


Fig 5 : Stresses using E-Glass Epoxy Material

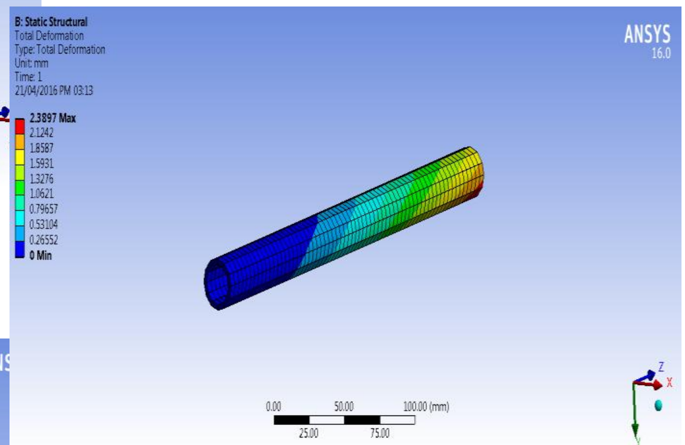


Fig 6 : Deformation using E-Glass Epoxy Material

3 . Resin Epoxy

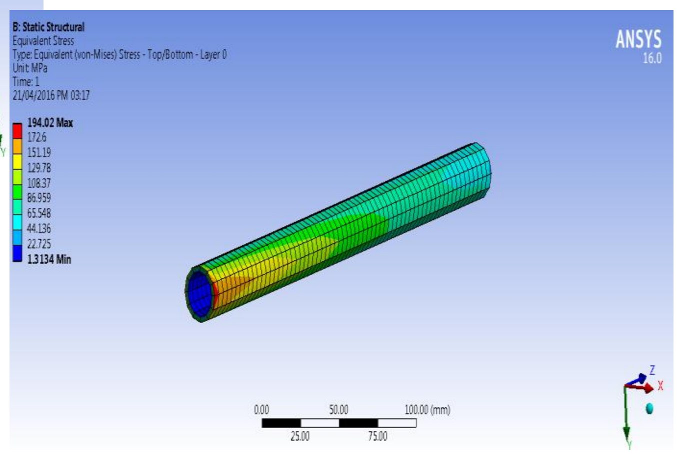


Fig 7 : Stresses using Resin Epoxy Material

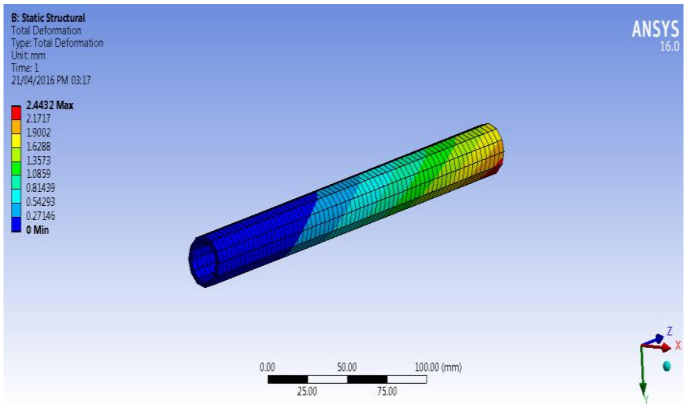


Fig 8 : Deformation using Resin Epoxy Material

Table 2: Results for various composite materials

90/0/90/0 Carbon EpoxyUD	181.4 N	2.2682 mm
90/0/90/0Carbon Epoxy Woven	169.06 N	2.3415 mm
90/0/90/0E-Glass Epoxy	189.76 N	2.3897 mm
90/0/90/0Resin Epoxy	194.02 N	2.4432 mm

Carbon Epoxy with Woven (90/0/90/0) gives better results among selected materials.

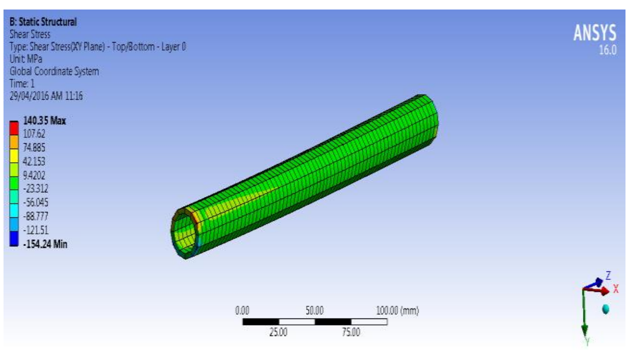


Fig: Shear Stress for Carbon Epoxy woven – Orientation 90/0/90/0)

V . VALIDATION AND RESULTS

VALIDATION:

Validation or Verification, in engineering is, `confirming that a product or service meets the needs of its users.'
Software results should be compared with appropriate theoretical results whenever possible. In most cases, one would use theory to obtain order-of-magnitude estimates rather than to make a head-to-head comparison since presumably FEA is being used because a theoretical solution is not available.

Numerical solution method is approximate method. The results obtained from FEA analysis depend on the mesh. An important step in the analysis is to make sure that the mesh resolution is adequate for the desired level of accuracy. This is done by refining the mesh and comparing results obtained with different levels of mesh resolution.
So the numerical result has to be compared with either Analytical results or with Experimental results, to ensure as per requirement working and the safety of the component.

TABLE 3 : TEST RESULTS

Condition	Orientation of layer	Material	Angle of Twist (Deg)		
			Reading 1	Reading 2	Avg rdng
Solid Shaft	-	Steel	3.02	3	3
			Reading 1	Reading 2	Avg rdng
Hollow Shaft	-	Steel	3.5	3.5	3.5
			Reading 1	Reading 2	Avg rdng
Composite Shaft	90/0/90/0 (Woven)	Steel (hollow) and Carbon Epoxy layer	4.90	5.05	5.0

VI . SAMPLE CALCULATION FOR SHEAR STRESS FROM ANGLE OF TWIST:

For Solid Shaft :

G = 83000000000 Pa.
θ (Degree) = 3^0
θ (rad) = 0.052358
r = 9mm
L = 300 mm

$$\frac{\tau}{r} = \frac{G\theta}{L}$$

$$\tau = \frac{G\theta r}{L}$$

$$\tau = \frac{83 \text{ X} 10^9 \text{ X } 0.052358 \text{ X } 9}{300}$$

τ = 130372250 Pa.

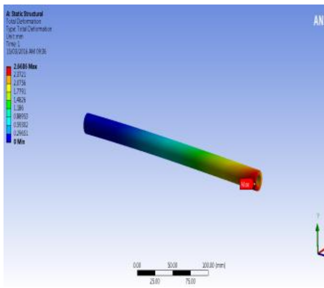
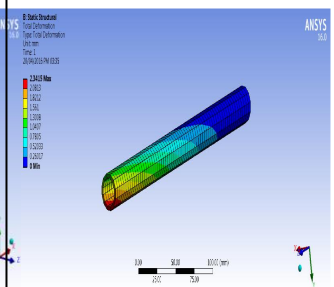
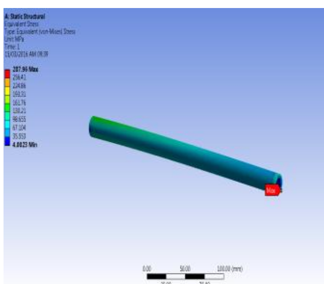
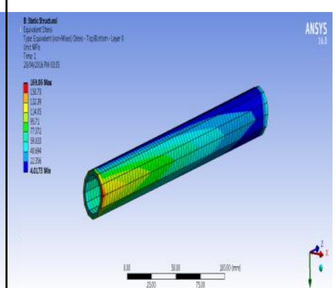
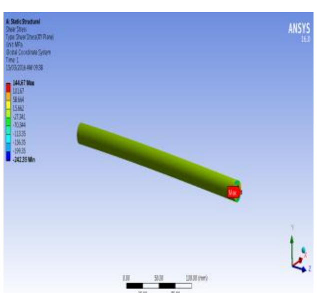
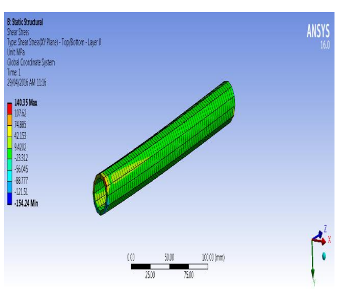
Existing Consideration- Hollow Steel Shaft	Final Design- Hollow Composite Shaft
 Deformation: 2.6686 mm	 Deformation: 2.3415 mm
 Von Misses Stress: 287.96 MPa	 Von Misses Stress: 169.06 MPa
 Shear Stress: 144.67 MPa	 Shear Stress: 140.35 MPa

TABLE 4: RESULT COMPARISON FOR EXISTING AND OPTIMIZED SHAFTS :

Parameters	Existing Hollow Shaft	Suggested Composite Shaft
Material	Steel Hollow	Hollow Steel + Carbon epoxy layer (90/0/90/0)
Von-Misses Stress	287.96 MPa	169.06 MPa
% Change in Stress	Composite shaft has 41.29 % less Stress than Steel hollow shaft (For same dimensions)	
Shear Stress	144.67 MPa	140.35 MPa
% Change in Stress	Composite shaft has 2.98 % less Stress than Steel hollow shaft (For same dimensions)	
Deflection	2.6686 mm	2.3415 mm
% Change in Deflection	Composite has 12.25 % less deflection than Steel hollow shaft (For same dimensions)	

VIII. CONCLUSION

The results we got for hollow shaft with composite materials are showing good improvement compare to Solid/hollow steel shaft.

From orientations 90/0/90/0 shows safe results and is selected for further work.

Material Carbon epoxy- woven shows less stress (6.80 %) compare to Carbon Epoxy-UD and hence finally suggested for hollow composite Shaft.

Overall reduction using Composite layers (Compare to existing hollow shaft) in Von-misses stress is 41.29 %, 2.98 % in Shear Stress and 12.25% in deformation.

REFERENCES

[1] Chris J. Burgoyne, Cambridge, UK "Advanced Composites in Civil Engineering in Europe" at Structural Engineering International report 4/99.

[2] Branislav Duleba, Frantisek Greskovic "Simulation of Loading the Polymer/Carbon Fibre Composites and Prediction of Safety Factors" at International Journal of Engineering and Innovative Technology (IJEIT) ISSN: 2277-3754, Volume 2, Issue 8, February 2013.

[3] Darren A. Baker, Timothy G. Rials "Recent Advances in Low-Cost Carbon Fibre Manufacture from Lignin" at Journal of Applied Polymer Science DOI: 10.1002/APP.39273, 2013.

[4] Luiz Claudio Pardini, Maria Luisa Gregori "Modelling elastic and thermal properties of 2.5D carbon fibre and carbon/SiC hybrid matrix composites by homogenization method" at International Journal of Aerospace Technology Management, Sao Jose dos Campos, Vol.2, No.2, pp. 183-194, May-Aug., 2010.

[5] Patil Deogonda, Vijaykumar N Chalwa "Mechanical Property of Glass Fibre Reinforcement Epoxy Composites" at International Journal of Scientific Engineering and Research (IJSER) ISSN (Online): 2347-3878 Volume 1 Issue 4, December 2013.

[6] H. Kim, H. T. Hahn, E. Bekyarova, E. Oh, G. Lee "Carbon Fibre Composites Reinforced With Carbon Nano materials" at 18th International Conference On Composite Materials.

[7] Mark Bruderick, Douglas Denton and Michael Shinedling, 0f DaimlerChrysler Corporation and Michael Kiesel, Quantum Composites Inc. "Applications of Carbon Fibre Smc for the Dodge Viper" Case Study.