International Journal of Innovative Research in Science and Engineering
Vol. No.2, Issue 12, December 2016
www.ijirse.com
ISSN (O) 2454-9665
ISSN (P) 2454-0663

WEIGHT REDUCTION OF WIND MILL SHAFT USING COMPOSITE MATERIAL USING ANSYS

Mr. Yogesh Digambar Kale[1] , Prof.B.D.Garje[2]

[1]PG Students, [2]Workshop Superintendent,
Mechanical Department, DYPIET, Ambi, Pune (India)

ABSTRACT

This contribution deals with the possibility of simulation of complex parts made from polymer-composites with CAD/CAM/Ansys software. First part of contribution is aimed on describing the basis of fiber composites and its behaviour under load. Main reason of choosing carbon fiber as material for innovative parts depends on low density and high tensile strength. Thus carbon fiber composites are frequently used at automotive and sporting goods production, parts from these industries were selected.

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

Keywords: Ansys, Carbon steel ,Composite materials

I INTRODUCTION

1.1 Problem Statement

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

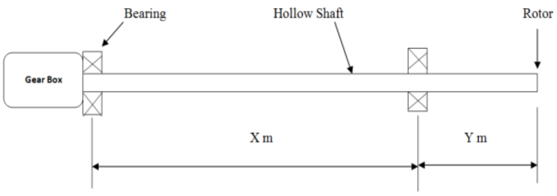


Fig 1: Design of Shaft for composite material

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

1.2 Previous work

1. Analysis of Carbon steel shaft is done.
2. Rigidity of steel shaft causes failure of the shaft of wind mill.
3. It is suggested in literature review [8] to use composite shaft for weight reduction.

1.3 Purpose

Based on literature review, there seem to be wide scope in working on weight reduction of windmill shaft by composite materials.As solid shaft are made of steel which is very heavy and it has to transmit large wind forces to the front bearing and to the gear box.Shaft made of composite materials will reduce the weight ,increase the strength and provides flexibility which will reduce the failure of shaft due to rigidity.

1.4 Details of Composite Materials

A composite material is made by combining two or more materials – often ones that have very different properties. The two materials work together to give the composite unique properties.

However, within the composite you can easily tell the different materials apart as they do not dissolve or blend into each other.

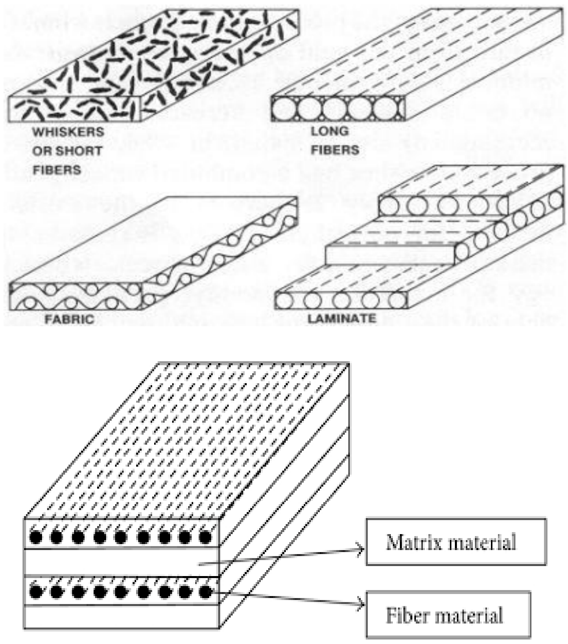


Fig 2: Composite Materials structures

1.4.1 Natural composites

Natural composites exist in both animals and plants. Wood is a composite – it is made from long cellulose fibers (a polymer) held together by a much weaker substance called lignin. Cellulose is also found in cotton, but without the lignin to bind it together it is much weaker. The two weak substances – lignin and cellulose – together form a much stronger one. The bone in your body is also a composite. It is made from a hard but brittle material called hydroxyapatite (which is mainly calcium phosphate) and a soft and flexible material called collagen (which is a protein). Collagen is also found in hair and finger nails. On its own it would not be much use in the skeleton but it can combine with hydroxyapatite to give bone the properties that are needed to support the body.

1.4.2 Early composites

People have been making composites for many thousands of years. One early example is mud bricks. Mud can be dried out into a brick shape to give a building material. It is strong if you try to squash it (it has good compressive strength) but it breaks quite easily if you try to bend it (it has poor tensile strength). Straw seems very strong if you try to stretch it, but you can crumple it up easily. By mixing mud and straw together it is possible to make bricks that are resistant to both squeezing and tearing and make excellent building blocks.

Another ancient composite is concrete. Concrete is a mix of aggregate (small stones or gravel), cement and sand. It has good compressive strength (it resists squashing). In more recent times it has been found that adding metal rods or wires to the concrete can increase its tensile (bending) strength. Concrete containing such rods or wires is called reinforced concrete.

1.5 Making Composites

Most composites are made of just two materials. One is the matrix or binder. It surrounds and binds together fibers or fragments of the other material, which is called the reinforcement.

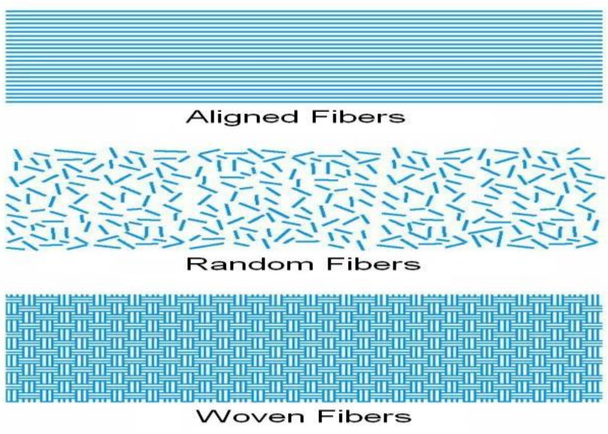


Fig 3 : Arrangement of Fibers

1.6 Objectives

1. Study of composite materials used through literature.
2. Weight reduction of Shaft
3. Strength improvement using Composite material and study of effect of fiber orientations on strength.

II LITERATURE SURVEY

Chris J. Burgoyne, [1] studied the different applications of composite materials in the area of construction. Where the materials used for structures are all characterised by low creep, as would be expected when the structures must resist significant permanent loads. For most applications, the higher stiffness fibres, 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.

ISSN (O) 2454-9665
ISSN (P) 2454-0663

Branislav Duleba [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 modelling 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 modelling 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 fibre 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.

ISSN (O) 2454-9665
ISSN (P) 2454-0663

Tensile, Bending and Impact strength increases with addition of filler material, ZnS filled composite shows significantly good results than TiO2 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.

Saket S. Patil, Ajitabh Pateriy [8] 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 fiber composites and its behaviour under load. Main reason of choosing carbon fiber as material for innovative parts depends on low density and high tensile strength. Thus carbon fiber composites are frequently used at automotive and sporting goods production, parts from these industries were selected.

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

Hyoung Woo Lee[9] states that Rotor shaft is one of the main parts for wind turbine, and as the wind turbine system is being enlarged, a study for the weight reduction of the rotor shaft is essential. He conduct study for the optimal design of hollow shape rotor shaft, using the Finite Element Analysis. The basic design was made using Topology Analysis to create the main form of the hollow shape. By using the Parameter Analysis for the scale and the aspect ratio based on the main shape, he decided outline dimensions including the flange diameter and the shaft length. Also, by using DOE(Design of Experiments) and Response Surface Method, he analyzed the influence and sensitivity of the weight and the stress between design factors. Lastly, he gained the optimal dimensions of each design factor by using the Optimal Design method. As the result, the weight of the hollow rotor shape has decreased about 37% compared to the solid shape.

Zorana Posteljnik & Slobodan Stupar & Jelena Svorcan Ognjen Peković1 & Toni Ivanov[10] This paper discusses in detail possible approaches to optimization of a somewhat less known type of wind turbines, particularly suitable for small consumers. In order to perform full aerodynamic and structural shape optimization of a small-scale vertical-axis wind turbine, a Double-multiple stream tube model code, known to provide good results in stationary working regimes, was complemented by a finite element analysis and implemented into a multi-objective particle swarm algorithm. For the purpose of shortening the total time needed for aerodynamic computation, the performed numerical simulations were two dimensional and experimentally measured static airfoil data were used. The used aerodynamic model was validated against the available experimental data of similar wind turbines. The subsequent structural analyses of the composite turbine blades were performed by applying computed maximal aerodynamic forces together with gravitational and inertial loads. By employing various input and output parameters different multi-objective optimization strategies were analyzed and compared and their applicability was demonstrated.

He investigated input parameters included: wind turbine rotor diameter, blade length, chord and airfoil, composite shell thickness, laminate lay-up and ply orientations, while optimization goal functions and constraints comprised rated power, cut-in and optimal wind speed, blade mass, tip deflection, failure index and blade natural frequencies. The fidelity an accuracy of proposed methodologies can be increased by employing more complex numerical models which can easily be implemented into the code.

Ramiro Carneiro Martins,Carlos M. C. G. Fernandes, Jorge H. O. Seabra[11]studied about the oil viscosity specification for wind turbine gear oils is ISO VG 320, although there are quite different viscosity indexes oils for that viscosity specification. This work evaluates the behaviour of different base oil formulations, since polyalphaolefin (PAO), mineral, ester and polyalkeleneglycol (PAG) that withstand quite different viscosity indexes. The oils evaluation was done in rolling bearing tests and gear tests. Their behavior was compared for operating conditions in the range observable in a wind turbine gearbox. The experimental results showed considerable differences between the different oils and it was observed that depending on the contact type the relative behaviour of the lubricants would change, i.e., the best lubricant for the rolling bearing would not imply the best result on the gear tests.The gear geometry is also very important toward the transmission efficiency, once using a low loss gear concept a decrease of up to 25% in torque loss could be achieved.

K. Vinoth Raj, N. Shankar Ganesh and T. Elamaran[12] states that energy is one of the crucial inputs for social-economy and human lives. The sources of energy are mainly from fossil fuels like oil, coal, etc., and also from renewable energy like wind hydro, geothermal energy etc. Wind energy is converted to electrical energy by means of wind turbines which are installed in regions where the wind speed is more and these are mounted on steel structured towers. The tower of a windmill is mainly affected by various loads acting on it, such as air forces, rotating rotor forces, blade weights, and atmospheric temperatures. Therefore the tower will soon be meeting with failure. Practically, it is impossible to check the failures of the components in running condition. Also, it is very difficult and makes a lot of losses (material, cost, time, etc.). Hence with the help of FEA SOFTWARE different materials have been analyzed and it was found that the AISI 302 stainless steel material deflection was low

Dr. Abdullateef A. Jadallaha*,Dr .Dhari Y. Mahmooda and Zaid A. Abdulqader [13] studied about the development of performance prediction is one of the most important aspects of the design of wind turbines. In this paper, a developed methodology is used to predict the optimal performance of the horizontal axis wind turbine in terms of the most critical parameters such as tip speed ratio, pitch angle, blade number and wind speed. Interesting generalized performance maps were conducted. Results show that low pitch is recommended for low wind speed regime. A range of (5 to 11) of tip speed ratio is found an optimum within the constraints considered. The interplay

International Journal of Innovative Research in Science and Engineering
Vol. No.2, Issue 12, December 2016
www.ijirse.com
ISSN (O) 2454-9665
ISSN (P) 2454-0663

of cut in speed with the remaining parameters is also studied and their effect on power and torque are explored. Several results were presented for a three bladed wind turbine is it is preferred by many manufacturers and researchers

R. I. Mustafaev and L. G. Gasanova [14] It is suggested that the torque-power characteristics of wind-power facilities equipped with electric machines with frequency converters should be considered in four regimes. The first regime is extends from the startup of a wind-power facility (WPF) to the beginning of the adjustment of its rotational frequency, the second regime is the adjustment of the WPF rotational frequency, the third regime is extends from the upper boundary of frequency adjustment to the nominal power, and the fourth regime is the nominal range of wind speeds.

III DESIGN OF SHAFT

Specifications:

Power = 7.5 kW

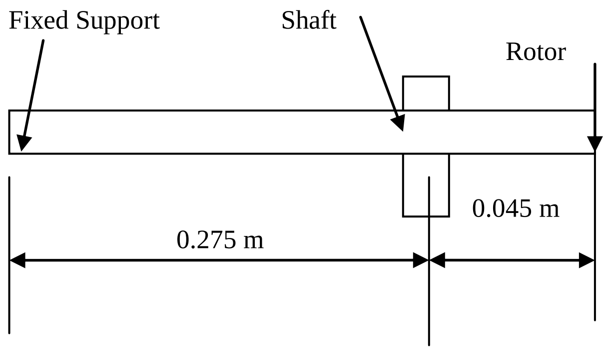
Wind speed = Max. 20 m/s

Rotor assembly Weight = 27.2 kg = 272 N

Shaft Material as: 40C8

S_{yt} = 390 N/mm^2

S_{ut} = 610 N/mm^2



Design

Shaft Material as: 40C8

S_{yt} = 390 N/mm^2

S_{ut} = 610 N/mm^2

ISSN (O) 2454-9665
ISSN (P) 2454-0663

- Recommended values for K_m and K_t.

Nature of load	K_m	K_t
1. Stationary shafts		
(*a*) Gradually applied load	1.0	1.0
(*b*) Suddenly applied load	1.5 to 2.0	1.5 to 2.0
2. Rotating shafts		
(*a*) Gradually applied or steady load	1.5	1.0
(*b*) Suddenly applied load with minor shocks only	1.5 to 2.0	1.5 to 2.0
(*c*) Suddenly applied load with heavy shocks	2.0 to 3.0	1.5 to 3.0

Table – 1 Recommended values of Km and Kt

For Suddenly applied load (Given)

$K_m = 2.0 \quad K_t = 1.5$

$d_i/d_o = C = 0.6$

According to ASME Standard:

$0.30\ S_{yt} = 0.3 * 390 = 117$ MPa

$0.18\ S_{ut} = 0.18 * 610 = 109.8$ MPa

lower of the two is 109.8 MPa, and there are no key ways on the shaft,

So, $\tau_{max} = 109.8$ MPa

Torque:

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

$$7500 = \frac{2\,\pi * 1440\,T}{60}$$

$T = M_t = 49.7359$ N-m $= 49.7359 \times 10^3$ N-mm

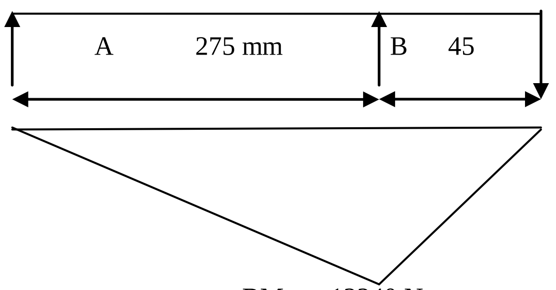
OR

$$M_t = \frac{60 \times 10^6\,(kW)}{2\pi\,N}$$

$$= \frac{60 \times 10^6\,(7.5)}{2\pi * 1440}$$

$= 49.7359 \times 10^3$ N-mm

Bending Moment: **272 N**



$BM_B = -12240$ N-mm

International Journal of Innovative Research in Science and Engineering
Vol. No.2, Issue 12, December 2016
www.ijirse.com
ISSN (O) 2454-9665
ISSN (P) 2454-0663

$R_A + R_B = 272$ ------------- (a)

Taking moment @ A,

R_B x 275 – 272 x 320 = 0

$R_B = \frac{272 \times 320}{275}$

R_B = 316.50 N

Using equation (a),

R_A = -44.5 N

BM at A = R_B x 275-(272*320) = 0

BM at B = -272 x 45

= -12240 N

BM at C = 0

Net BM at B = -12240 N-mm

Using maximum shear stress theory,

For Solid Shaft,

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

$$109.8 = \frac{16}{\pi d^3} \sqrt{(2 * -12240).^2 + (1.5 * 49.7359\ x10^3).^2}$$

d = 15.3854 mm = 16 mm

IV FEA ANALYSIS OF EXISTING SHAFT

The finite element method (FEM), sometimes referred to as finite element analysis (FEA), is a computational technique used to obtain approximate solutions of boundary value problems in engineering. Simply stated, a boundary value problem is a mathematical problem in which one or more dependent variables must satisfy a differential equation everywhere within a known domain of independent variables and satisfy specific conditions on the boundary of the domain. Boundary value problems are also sometimes called field

problems. The field is the domain of interest and most often represents a physical structure. The field variables are the dependent variables of interest governed by the differential equation. The boundary conditions are the specified values of the field variables (or related variables such as derivatives) on the boundaries of the field. Depending on the type of physical problem being analyzed, the field variables may include physical displacement, temperature, heat flux, and fluid velocity to name only a few.

International Journal of Innovative Research in Science and Engineering
Vol. No.2, Issue 12, December 2016
www.ijirse.com
ISSN (O) 2454-9665
ISSN (P) 2454-0663

4.1 Analysis of existing Shaft:

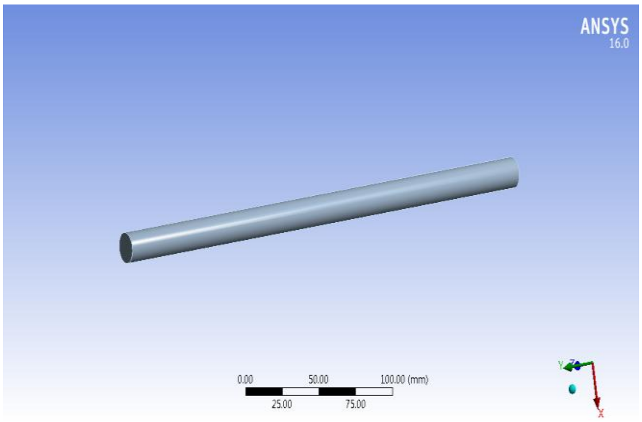


Fig 4: Shaft imported in ANSYS 16.0

Loading: (Torque)

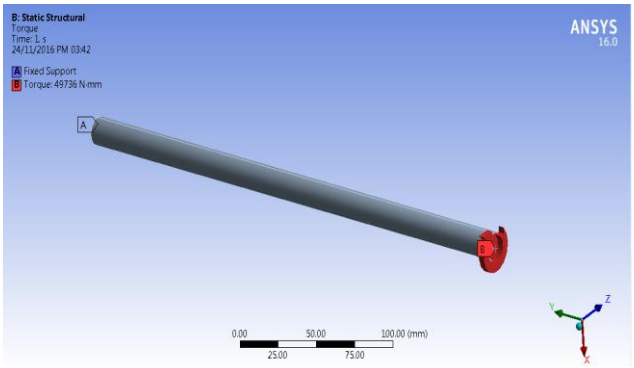


Fig 5: Boundary Conditions -Fixed Support and Torque applications on shaft

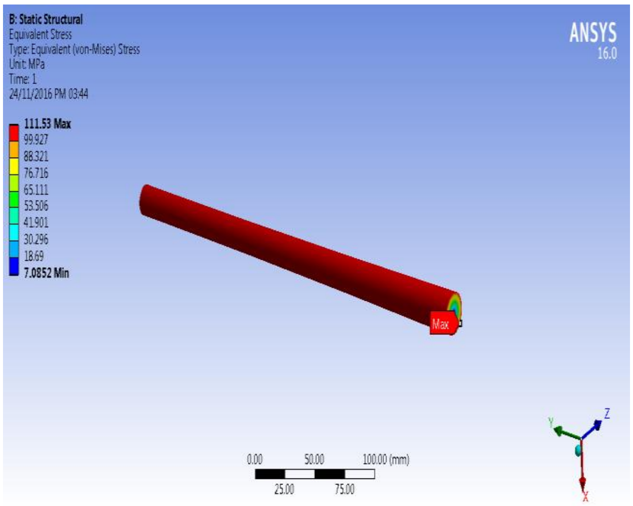


Fig 6: Von-mises Stress on shaft, MPa

International Journal of Innovative Research in Science and Engineering
Vol. No.2, Issue 12, December 2016
www.ijirse.com
ISSN (O) 2454-9665
ISSN (P) 2454-0663

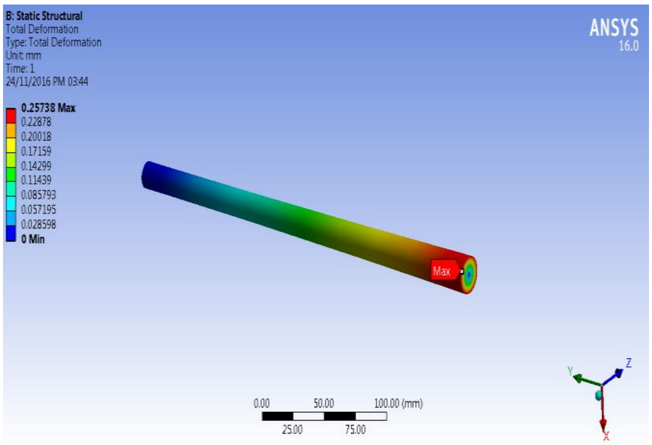


Fig 7 : Deformation of shaft, mm

V SUMMARY

- ✓ Study of shaft in transmission system is done.
- ✓ Study of Composite materials and their basics are studied in detail.
- ✓ Design of shaft for said application is done along with modeling and analysis of the same.
- ✓ Analysis gives stress result (For combined loading) as 136.49 MPa, Shear Stress as 65.477 MPa and deformation as 1.5282 mm.

VI CONCLUSION

Analysis of carbon steel shaft for suddenly applied load is done on ansys which will give result of Shear Stress as 65.477 MPa and deformation as 1.5282 mm.

ACKNOWLEDGEMENT

I would like to take this opportunity to thank one and all that provided their valuable advice and guidance without which this research paper would not have been completed. I thank all who have helped me directly or indirectly but some in particular have to be singled out since they have given me more than just guidance.

My profound thanks to my guide Prof. B.D.Garje Workshop Superintendent of Mechanical Engineering DYPIET, Ambi, for his invaluable advice and constant encouragement to complete this research paper.

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 Fiber 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 Fiber Manufacture from Lignin" at Journal of Applied Ploymer Science DOI: 10.1002/APP.39273, 2013.

4] Luiz Claudio Pardini, Maria Luisa Gregori "Modeling elastic and thermal properties of 2.5D carbon fiber 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 Fiber 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 Fiber Composites Reinforced With Carbon Nanomaterials" at 18th International Conference On Composite Materials.

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

8] Saket S. Patil, Ajitabh Pateriy, IORD Journal of Science & Technology E- ISSN:2348-0831 Volume 3, Issue 1 (Mar–April 2016) PP 120-125

9] Hyoung Woo Lee , International Journal of Emerging Technology and Adv.Engineering (ISSN 2250-2459, ISO 9001:2008 Certified Journal , Volume 5, Issue 11, November 2015)

10] Zorana Posteljnik & Slobodan Stupar & Jelena Svorcan & Ognjen Peković &Toni Ivanov Struct Multidisc Optim (2016) 53:277–290 DOI 10.1007/ 0158- 015-1329-6, 4 August 2015 /Published online: 22 September 2015 Springer-Verlag Berlin Heidelberg 2015

11] Ramiro Carneiro MARTINS,Carlos M.C G. FERNANDES, Jorge H.O.SeabraINEGI, Universidade do Porto, Porto, Portugal2 Faculdade deEngenharia, Universidade do Porto, Porto, 09 November 2015© Springerlink.com

12] K. Vinoth Raj, N. Shankar Ganesh and T. Elamaran , S. Sathiyamoorthy et al.eds.), Emerging Trends in Science,Engineering and Technology, Lecture Notes in MechanicalEngineering,DOI: 0.1007/978-81-322-1007-8_8, © Springer India 2012

13] Dr. Abdullateef A. Jadallaha*,Dr .Dhari Y. Mahmooda and Zaid A.dulqader Int. J. of Multidisciplinary and Current research, Jan/Feb 2014 ISSN: 2321- 3124 15 January 2014, Vol.2 (Jan/Feb 2014 issue)

14] R. I. Mustafaev and L. G. Gasanova, ISSN 1068-3712, Russian Electrical Engineering, 2009, Vol. 80, No. 7, pp. 406–411. © Allerton Press, Inc., 2009. Original Russian Text © R.I. Mustafaev, L.G. Gasanova 2009, published in Elektrotekhnika, 2009, No. 7, pp. 53–58.