Weight Optimisation Of Wind Mill Shaft By Composite Material Using FEA

Ramkuvar N V[1], Mankar R L[2]

[1] PG Scholar, Mechanical Engineering, [2]Jai Hind College of engineering, Maharashtra,India
[2] Mankar.R.L, Mechanical Engineering, [2]Jai Hind College of engineering, Maharashtra,India

ABSTRACT

This contribution deals with the simulation of Shaft made up of complex part (i.e.composite materials). There is need of low density and high Tensile strength of any shaft which will increase its working efficiency and reduce weight. Initially the existing shaft is solid then converted into hollow and finally composited of same diameter. This all three are tested under FEA and results are compared with each other for better one. The composite layered (Glass Fibre or Carbon Fibre which ever is the best from both) trying with different Fibre Orientations on outer diameter of shaft. The different fibre angle gives different effect to the shear stress von mises stress and deformations. The results are compared from numerical analysis and we get the better fibre angle for good strength shaft. In this way wind mill shaft will get optimized by getting good results of composite shaft by comparison with existing.

Keyword : - *composite materials, carbon fibre, and fibre orientation.*

1. 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. Composite materials (composites for short, distribution shown on Figure 1.1) 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.Laminates are composite materials consisting of fillers and reinforcements in the form of fibers / fabrics. Fillers are used as resins of different types depending on application and desired properties.

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 figure. Power = 7.5 kW, Speed of rotor = Max. 820 rpm ,Wind speed = Max. 15 m/s, Rotor Weight = 12.8 kg = 128 N Shaft , Material as: AISI 1045 (Steel), S_{yt} = 310 N/mm^2, S_{ut} = 565 N/mm^2

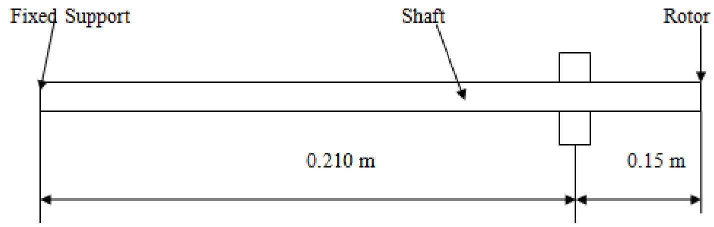

Fig 1.1.1 Wind Mill Shaft

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

1.2 Objectives

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

2. LITERATURE REVIEW

2.1 Review of papers

1) B.James Prasad Rao et.al. [2016], this paper is related to investigations on Carbon Reinforced plastics (CFRP) and Glass Fiber Reinforced Plastics (GFRP) composite hollow shafts for automobiles. Failure analysis has been carried out using maximum stress criteria and it is found that the failure torque is well above the design torque level. Weight reduction can be primarily achieved by the introduction of better material.
2) Nikhil V Nayak [2014], Fiber-reinforced polymer composite materials are fast gaining ground as preferred materials for construction of aircrafts and space crafts. In particular, their use as primary structural materials in recent years in several technology-demonstrator front-line aerospace projects world-wide has provided confidence leading to their acceptance as prime materials for aerospace vehicles. This paper gives a review of some of these developments with a discussion of the problems with the present generation composites and prospects for further developments.
3) Mayuri U Waghmare [2014], 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.
4) O. Montagnier et.al.[2013], This study deals with the optimisation of hybrid composite drive shafts operating at subcritical or supercritical speeds, using a genetic algorithm. A formulation for the flexural vibrations of a composite drive shaft mounted on viscoelastic supports including shear effects is developed. In particular, an analytic stability criterion is developed to ensure the integrity of the system in the supercritical regime. Then it is shown that the torsional strength can be computed with the maximum stress criterion.
5) Patil Deogonda et. al. [2013], concluded in the paper that 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.
6) The paper of Darren A. Baker et. al. [2013], 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.

2.2 Comments on Review Paper

This all papers are related to optimization of components with the help of composite material. Many of them used Glass fibre and Carbon fibre as a composite Materials. Some of them also discuss about the components getting lighter weight after using composite material as layered on same and also making it hollow.

2.3 Research Gap

From the study of above papers following are the findings:

- Shaft is key elements of the most of the power generation/transmission systems.
- So there is necessity to concentrate on making shaft strong reliable as well as less costly/ less heavy.
- Here some researchers attempted to use latest concept as composite materials on shafts at some orientations of fibre angle.
- So there is scope to work on such composite materials .
- Shaft can be made of lighter weight.

3. STUDY OF COMPOSITE MATERIAL AND ITS APPLICATION IN TRANSMISSION SYSTEM

- 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.

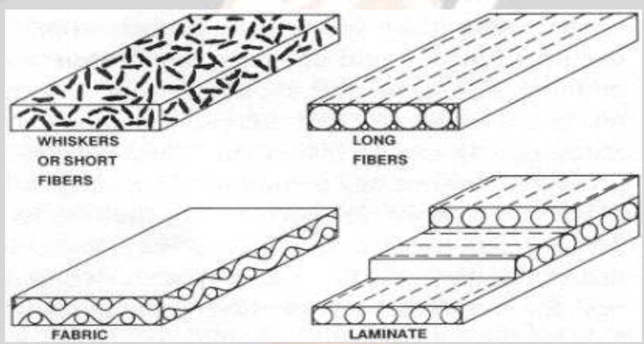

Fig 3.1.1 Composite Materials structures

- 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.

- 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 fiber glass 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.

3.1 Properties of Material Selected

1) For Epoxy Carbon UD (230 GPa) Prepreg Shaft**.**

TABLE 3.1.1 Epoxy Carbon UD (230 GPa) Prepreg

Density	1.49e-006 kg mm^-3

TABLE 3.1.2 Epoxy Carbon UD (230 GPa) Prepreg Orthotropic Elasticity

Young's Modulus X direction MPa	Young's Modulus Y direction MPa	Young's Modulus Z direction MPa	Poisson's Ratio XY	Poisson's Ratio YZ	Poisson's Ratio XZ	Shear Modulus XY MPa	Shear Modulus YZ MPa	Shear Modulus XZ MPa
1.21e+005	8600	8600	0.27	0.4	0.27	4700	3100	4700

2) For Hollow 1045 Steel

TABLE 3.1.3 Structural Steel Isotropic Elasticity

Temperature C	Young's Modulus MPa	Poisson's Ratio	Bulk Modulus MPa	Shear Modulus MPa
	2.e+005	0.3	1.6667e+005	76923

TABLE 3.1.4 Structural Steel Constants

Density	7.85e-006 kg mm^-3

3.2 Design Of Shaft

- Specifications:

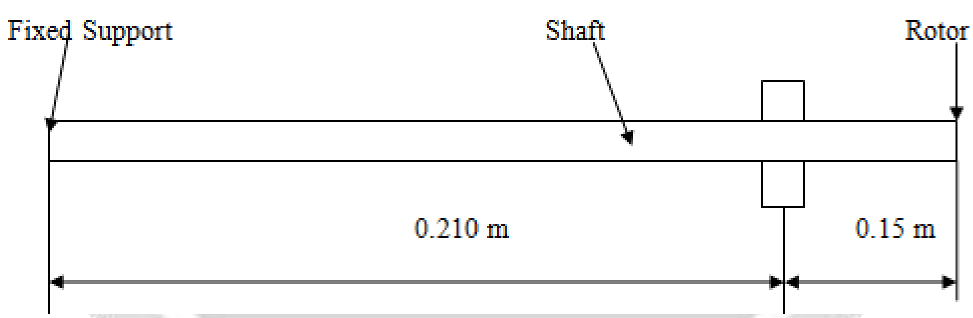

Fig 3.2.1 Wind Mill Shaft

Power = 8.0 kW
Speed of rotor = Max. 820 rpm
Wind speed = Max. 15 m/s
Rotor Weight = 12.8 kg = 128 N
Shaft Material as: AISI 1045

$S_{yt} = 310$ N/mm^2
$S_{ut} = 565$ N/mm^2

- **Design:**

Shaft Material as: AISI 1045
For Suddenly applied load-

$K_m = 1.8 \quad K_t = 1.8$

$d_i/d_o = C = 0.6$ (Standard ratio)

According to ASME Standard:

$0.30\ S_{yt} = 0.3 * 310 = 93$ MPa

$0.18\ S_{ut} = 0.18 *565 = 101.7$ MPa

Selecting lower of the two is 93 MPa, and there are no key ways on the shaft, So, τ_{max} = 93 MPa

Torque:

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

$$8000 = \frac{2\,\pi * 820\, T}{60}$$

$$T = M_t = 93.1638 \text{ N-m} = 93.1638 \times 10^3 \text{ N-mm}$$

OR

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

$$= \frac{60 \times 10^6\,(8)}{2\pi * 820}$$

$$= 93.1638 \times 10^3 \text{ N-mm}$$

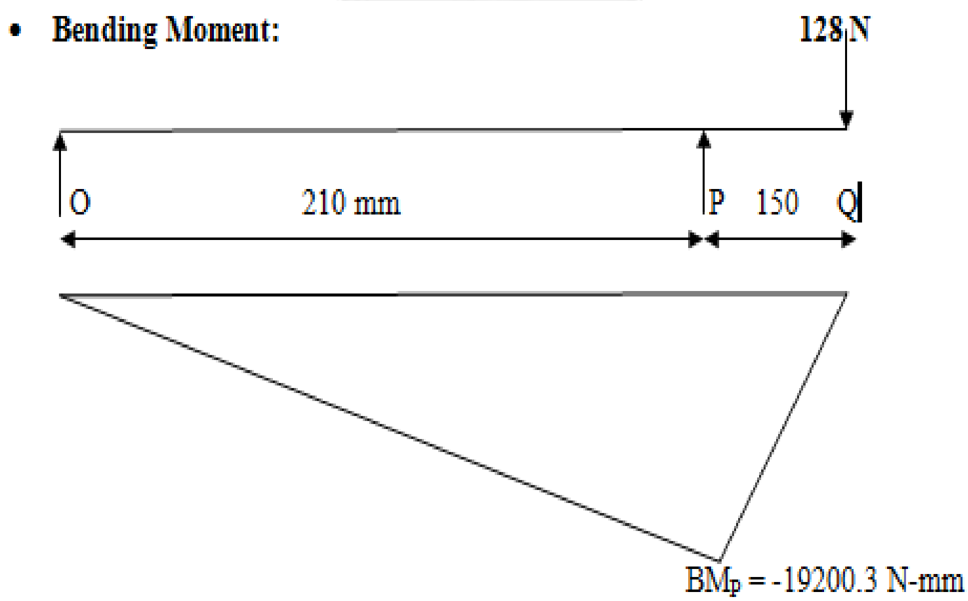

Fig 3.2.2 Bending Moment Diagram

$$R_o + R_P = 128 \quad \text{------------- (a)}$$

Taking moment @ O,

$$R_p \times 210 - 128 \times 360 = 0$$

$$R_p = \frac{128 \times 360}{210}$$

$$R_p = 219.43 \text{ N}$$

Using equation (a),

$$Ro = -91.43 \text{ N}$$

$$\text{BM at O} = R_P \times 210 - (128*360) = 0$$

$$\text{BM at P} = -210 \times 91.43$$

$$= -19200.3 \text{ N}$$

$$\text{BM at Q} = 0$$

$$\text{Net BM at P} = -19200.3 \text{ N-mm}$$

Using maximum shear stress theory,

For Solid Shaft,

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

$$93 = \frac{16}{\pi d^3}\sqrt{(2 * (-19200.3))^2 + (1.5 * 93.1638 * 10^3)^2}$$

$$d = 19.9469 \text{ mm} = 20 \text{ mm}$$

3.3 Analysis of Existing Solid Shaft

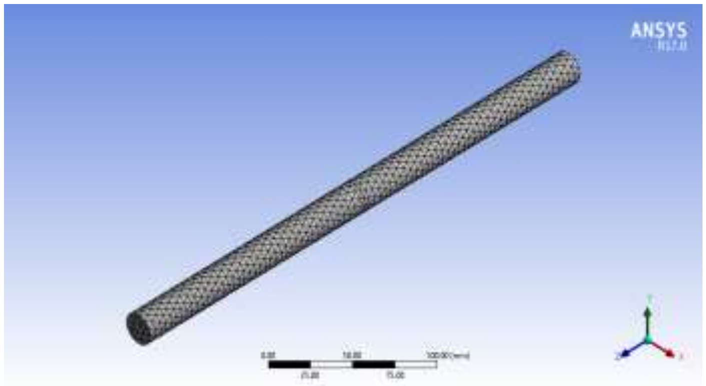

Fig 3.3.2 Meshing (Tetrahedral)

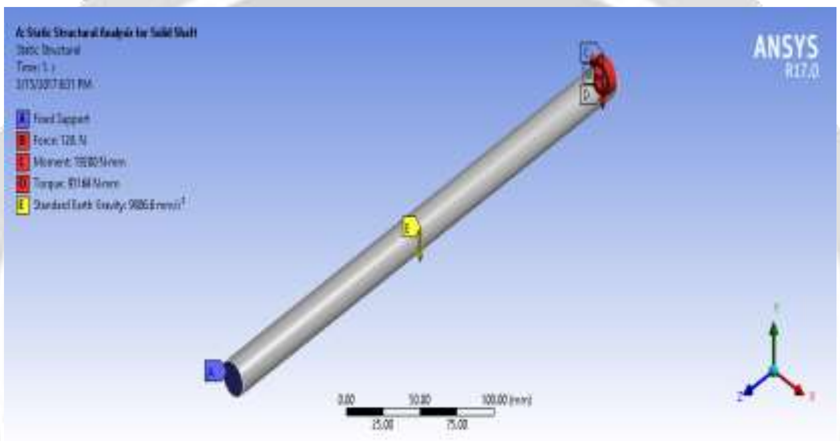

Fig:3.3.3 Boundary Conditions

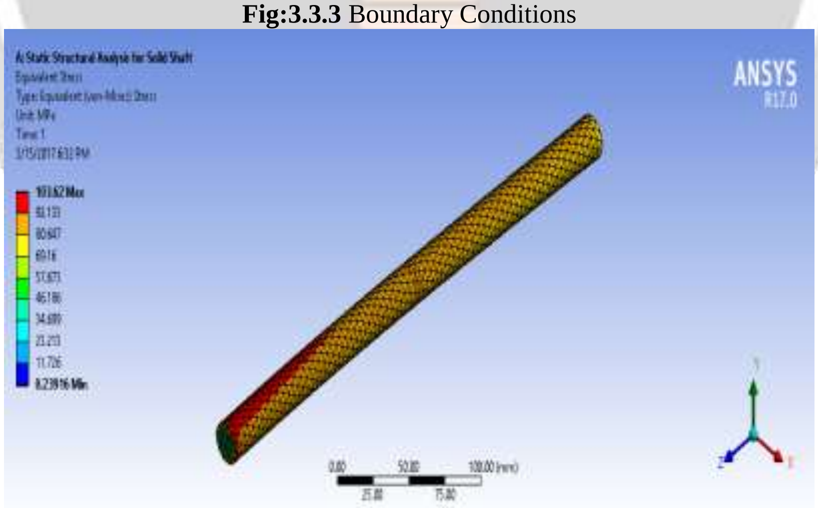

Fig 3.4.5 Von Mises stresses

3.5 Analysis of Composite Solid shaft

TABLE 3.5.2 Statistics

Nodes	5580
Elements	5549

TABLE 3.5.3 Model (C2) > Static Structural (C3) > Solution (C4) > Results

Type	Total Deformation	Equivalent (von-Mises) Stress	Maximum Principal Stress	Maximum Shear Stress	Equivalent Elastic Strain	Maximum Principal Elastic Strain	Maximum Shear Elastic Strain
Results							
Minimum	0. mm	1.5457 MPa	-8.0536e-002 MPa	0.89163 MPa	9.9999e-005 mm/mm	3.2753e-005 mm/mm	1.1505e-004 mm/mm
Maximum	0.84333 mm	40.364 MPa	37.703 MPa	21.807 MPa	3.8124e-004 mm/mm	2.234e-004 mm/mm	4.4634e-004 mm/mm

TABLE 3.5.4 Epoxy Carbon UD (230 GPa) Prepreg > Orthotropic Elasticity

Young's Modulus X direction MPa	Young's Modulus Y direction MPa	Young's Modulus Z direction MPa	Poisson's Ratio XY	Poisson's Ratio YZ	Poisson's Ratio XZ	Shear Modulus XY MPa	Shear Modulus YZ MPa	Shear Modulus XZ MPa
1.21e+005	8600	8600	0.27	0.4	0.27	4700	3100	4700

3.6 Result

Shaft- 20 mm	**Stress, MPa**	**Shear Stress, MPa**	**Deformation, mm**	**Weight, kg**
Steel	103.62	57.587	1.5136	0.88781
Composite **ECF UD- 0/0/0/0**	40.364	21.807	0.8433	0.46166
Change	61.05%	62.13%	44.28%	46.87%

We can see from above results that composite shaft of same dimensions and loading gives very good results in stress, deformation as well as weight; compared to solid shaft. So from this we get the scope for using the composite material for weight reduction.

4. CONCLUSIONS

1) The results we got for hollow shaft with composite materials are showing good improvement compare to Solid/hollow steel shaft.
2) From orientations 45/45/60/60 shows safe results and is selected for further work.
3) Finally selected material Epoxy Carbon UD (230 GPa) Prepreg shows less weight (48 %) compare to steel solid shaft.
4) Overall reduction using Composite layers (Compare to existing shaft) in Von-mises stress is 3.33 %, 4.71 % in Shear Stress and 33.38 % increase in deformation.

5. ACKNOWLEDGEMENT

I hereby declare that the seminar entitled “Weight Optimisation Of Wind Mill Shaft By Composite Material Using Fea”submitted by me to Jaihind College of Engineering in partial fulfilment of the requirement for the award of the degree of MASTER OF ENGINEERING in Mechanical department is a record of bonafide project work carried out by me under the guidance of Prof. Mankar R L. I further declare that the work reported in this seminar has not been submitted and will not be submitted, either in part or in full, for the award of any other degree or diploma in this institute or any other institute or university.

6. REFERENCES

[1] James Prasad Rao,“Design And Analysis Of Automotive Composite Propeller Shaft Using Fea” B, D.V Srikanthb, T.Suresh Kumarc, L.Sreenivasa Raod A Department Of Mechanical Engineering, Joginapally Br Engineering College,Yenkapally(V), Moinabad(M), R.R(Dist),Hyderabad-500075, India, Yenkapally(V), Moinabad(M), R.R(Dist), Hyderabad-500075, India.

[2] Nikhil V Nayak “Composite Materials In Aerospace Applications”,International Journal Of Scientific And Research Publications, Volume 4, Issue 9, September 2014 1 Issn 2250-3153.

[3] Mayuri U Waghmare, “Optimization & Verification Of Drive Shaft Parameters For Wind Mill”, International Engineering Research Journal Page No 1123-1130.

[4] O. Montagnier A, Ch. Hochard B “optimisation Of Hybrid High-Modulus/High-Strength Carbon Fibre Reinforced Plastic Composite Drive Shafts”,A Écoles D’officiers De L’armée De L’air (Eoaa), Centre De Recherche De L’armée De L’air (Crea), Ba 701, 13361 Salon Air, France B Laboratoire De Mécanique Et D’acoustique (Lma), 31 Chemin Joseph Aiguier, 13402 Marseille Cedex 20, France.

[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] 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.