Comparative study of Composite material based on different materials, stacking sequence of a Hybrid Propeller Shaft for Heavy-Duty Trucks Using Ansys 18.1

Priya Vishwas

M.Tech. Scholar, Department of Mechanical Engineering, VEC Ambikapur, C.G. India

ABSTRACT

Due to their superior strength to weight ratio, composite constructions have many advantages over traditional metallic ones. Due to their benefits of having more specific stiffness, laminated composites are widely used for the torque carrying constructions. Composite drive shafts are having qualities of lighter, more durable, and higher critical speed drive trains. This research looks into various composite material combinations and different stacking sequences.

The sequences are considered in the opposite of the torque direction in order to afford an alternative of the conventional steel drive shaft. This shaft will be useful for auto motives. ANSYS 18.1 was used to calculate the natural frequency of the composite drive shaft.

Keywords: Drive shaft, ANSYS 18.1, Finite element method, Torsion.

1. INTRODUCTION

The conventional materials used for ordinary shafts are steel of grades 35C8, 45C8, 55C8 etc. generally. Alloy steels like nickel, nickel-chromium, or chrome-vanadium are utilized when great strength is needed. Because carbon fiber composite material has four times the specific stiffness of steel or aluminum, it has the potential to be manufactured in one piece, meaning that the fundamental natural frequency of the carbon fiber composite propeller shaft may be twice as high as that of steel or aluminum. Compared to metal propeller shafts, the composite propeller shaft has several advantages, including being lighter and producing less noise and vibration. Because of this, research into fiber-reinforced composite shafts with low specific weight and high strength to stiffness ratios has garnered a lot of interest from engineers in recent decades.

Fibre reinforced polymers often use such fibres as carbon, glass, and boron as reinforcement [1-16]. Thus, the use of natural fibres like cotton, banana, sisal, coir, and jute helps scientists display their work in a variety of applications. It has been noted that natural fibre composites have improved electrical, thermal, and insulating qualities as well as greater failure resistance.

2. LITERATURE REVIE

The maximum torsion capability of the hybrid aluminium/composite shaft was investigated by Mutasher in 2009 [17] they have considered the effect of various winding angles, layer counts, and stacking orders

for studies.
Lee et al. (2004) [18], have investigated and reported after their analysis that aluminium composite shaft have a mass reduction of 75% along with torque capacity enhancement of 160%.
Kim et al. 2001, [20] tested the composite propeller shafts and bonded joints with aluminium yoke. For this analysis, a composite single layer has been picked up, and authors reported that this combination of length, diameter and thickness have sufficient for 3500 Nm static torsion capacity.
The impact of fibre orientation angles and stacking order on the torsional stiffness, natural frequency, buckling strength, fatigue life, and failure modes of composite tubes was examined by Badie et al. in 2006 [29].
According to research by Talib et al. from 2010 [30], the drive shaft loses 46.07% of its buckling strength as the stacking sequence goes from the best to the poor.

3. PROBLEM FORMULATION

To determine the ideal material combination for a composite shaft that can endure torsion and have a longer lifespan, a comparison analysis will be conducted using the base paper B James Prasad Rao. Therefore, the torsional rigidity and natural vibration of a drive shaft composed of composite material with diverse materials, such as carbon fiber, aramid fiber, and boron, with different stacking sequences, will be analyzed.
In such a loading state, the influence of these will be found by applying clockwise and counter clockwise torque.

3.1. Validation of result

As per the base paper, for the composite propeller shaft, technical data are have been taken as:
Propeller shaft length = 1730 mm
The radius (Mean) of the shaft = 40 mm
Composite shaft thickness = 4.578mm
(Carbon/epoxy shaft)
Realistic Torque (Maximum) = 2030 N-m
Stacking sequence 45°/-45°/45°/-45°
Ansys 18.1 software was used for the analysis, shear stress between layers have been shown by the figures and also presented in Table -1. The values are placed column wise and comparison have been made with the base paper
Figure 1 represents the shear stress of carbon epoxy shaft for layer 1 top side, all the contour figures have not been shown in this fig. The others value of shear stress is represented with their following values in Table 1.

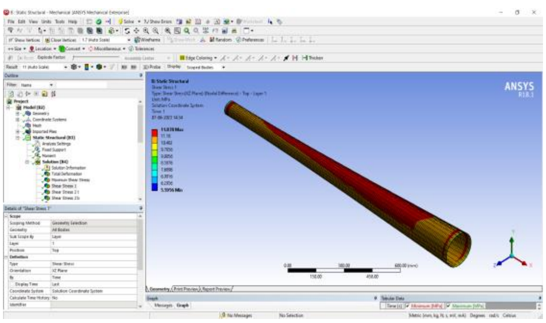

Figure 1: Shear stress in the carbon epoxy shaft for layer 1 (top side)

Figure 2 depicts the shear stress in the carbon epoxy shaft for layer 4 top side, as composite is made in sandwich system therefore while application of torsion, stresses will be induced between the two successive layers that is represented in these contours figure.

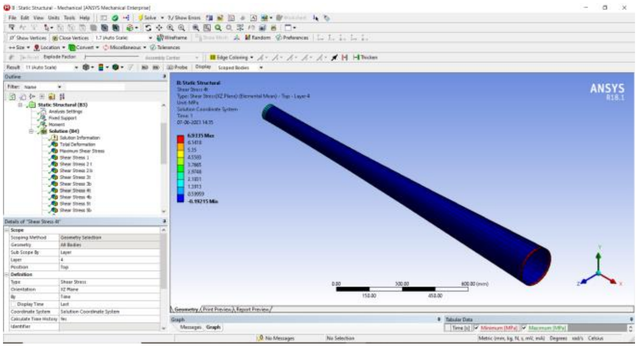

Figure 2: Shear stress in the carbon epoxy shaft for layer 4 (top side)

Figure 3 depicts the shear stress in the carbon epoxy shaft for layer 4 bottom side.

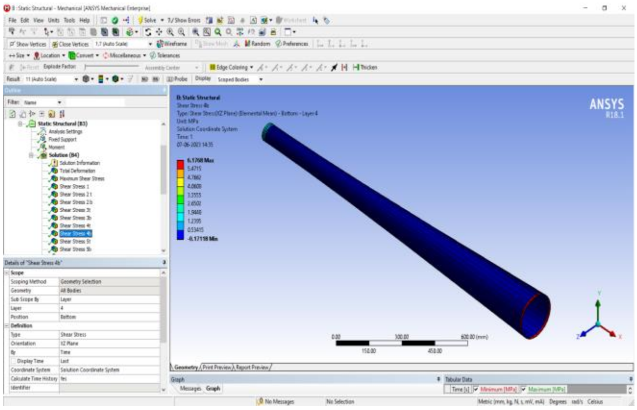

Figure 3: Shear stress in the carbon epoxy shaft for layer 4 (bottom side)

Figure 4 depicts the shear stress for carbon epoxy for layer 6 topside, the maximum value of shear stress has been measured.

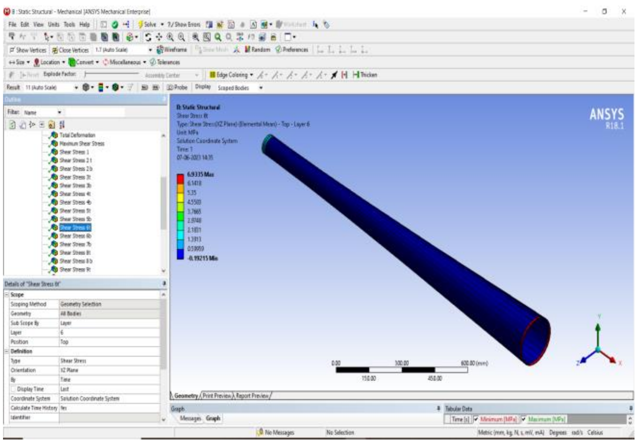

Figure 4: Shear stress in the carbon epoxy shaft for layer 6 (topside)

Figure 5 depicts the shear stress in the carbon epoxy shaft for layer 6 bottom side, for the analysis the drive shaft was considered as fixed from one end as one end is towards the wheel and it takes a lot of effort to overcome inertia and bring the wheels in motion the other side is connected towards the engine side which delivers the torque therefore, torque is applied as mentioned in the base paper.

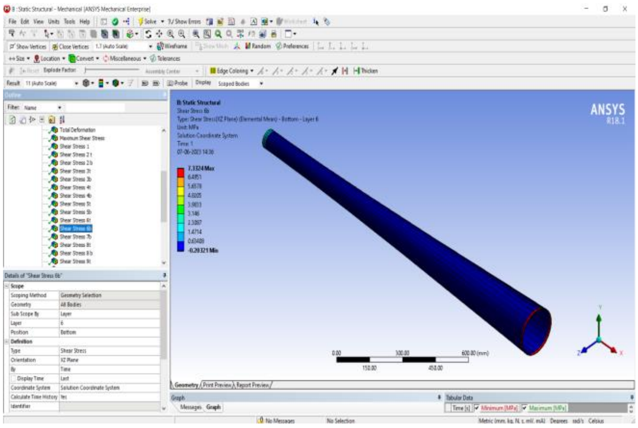

Figure 5: Shear stress in the carbon epoxy shaft for layer 6 (bottom side)

Figure 6 depicts the shear stress in shaft for carbon epoxy for layer 8 bottom side

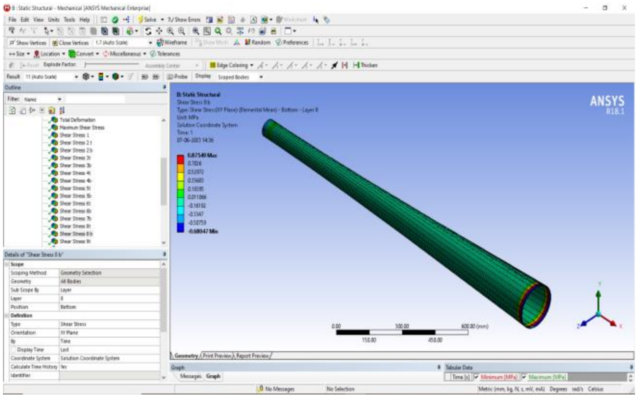

Figure 6: Shear stress in the carbon epoxy shaft for layer 8 (bottom side)

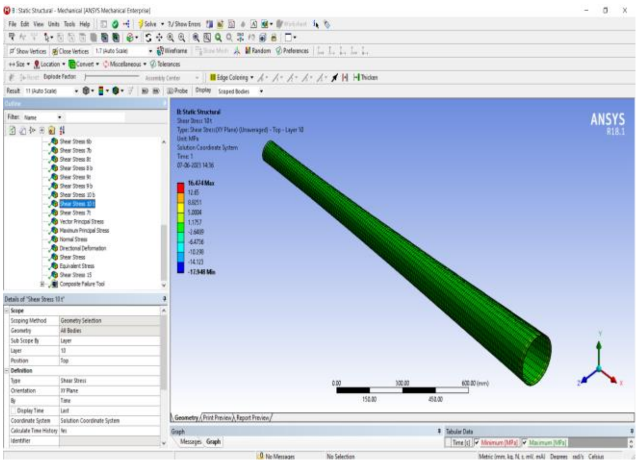

Figure 7: Shear stress in the carbon epoxy shaft for layer 10 (top side)

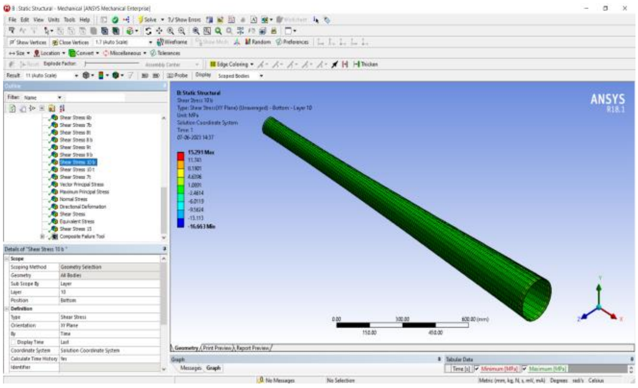

Figure 8: Shear stress in the carbon epoxy shaft for layer 10 (bottom side)

4. RESULTS

4.1. Relative study for the different materials

In this segment, carbon/epoxy shaft is altered with boron/epoxy and aramid/epoxy, and after that their comparative study will determine the who better material amongst the three types is.

Table-2 shows the different material properties which have been obtained from [13], [31] respectively.

Table 2: Material Properties

Material's Name	E1 (GPa)	E2 (GPa)	Poisson's ratio	G12 (GPa)	G23 (GPa)	G31 (GPa)	Density (g/cm^3)
Boron/Epoxy	204	18.5	0.23	5.59	__	__	2.00
Aramid/Epoxy	20.4	8.90	0.31	1.64	3.03	1.64	1.23

Table 3: Assessment of Altered Material Composite Shaft

Material Name	Shear stress Layer 1 Top (MPa)	Shear stress Layer 6 bot (MPa)	Shear stress Layer 10 bot (MPa)	Max Shear stress (MPa)	Von Mises stress (MPa)
Boron/ Epoxy	0.0033	.0018	9.8391	191.99	368.08
Aramid/Epoxy	19.848	3.372	21.541	87.75	151.99

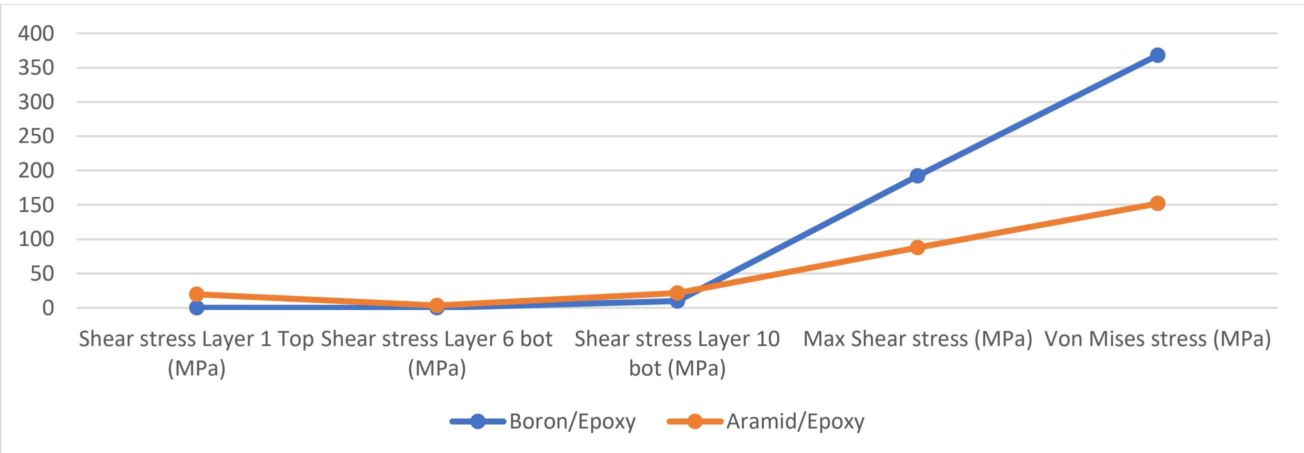

Fig 4.1 Comparison of different materials composite shaft

From table 3 it can be seen that, shear stress between the two layers are varying and not giving a clear consensus. From the basis of numerical value maximum shear stress and Von-mises stress for aramid/epoxy is a better material among the others for automotive propeller shaft.

4.2. Comparative study based on stacking sequence

In this section, data for the aramid-epoxy type shaft was considered, and for this type of shaft stacking sequence as presented in Table 4 were taken, and for these values comparative study will be done.

Table 4: Stacking Schemes

S.No.	Stacking definition
Case 1	0°/90°/45°/-45°/45°/-45°/45°/-45°/45°/-45°
Case 2	45°/-45°/45°/-45°/0°/90°/45°/-45°/45°/-45°
Case 3	0°/45°/-45°/45°/-45°/45°/-45°/45°/-45°/90°

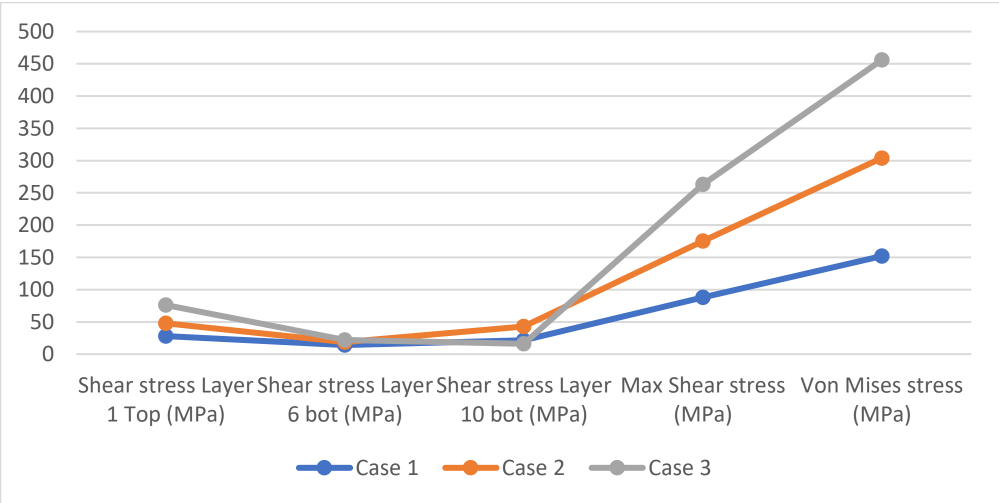

Fig 4.2 Comparison of different stacking sequence composite shaft

For the different values of stacking sequences, the resultant stress between the two layers has been changed.

The shear stress between the two layers has also found to be changed, whereas the shear stress between the successive layers, for two different cases remain unchanged.

But the value of maximum shear stress and von Mises stress have not changed for all these three cases, which have been presented.

Based on the results Layer-1 top, layer-6 bottom, and layer-10 bottom have been chosen randomly and used to compare all these cases. By the present obtained result, it can be stated that stacking sequence plays a vital role in manufacture of composites.

Limitations

1. The fabrication of composite shafts has been significantly hampered by the cost constraints present in a mass production industry.
2. Aramid-epoxy material for the manufacturing of shaft could be expensive.
3. Impact analysis should also have needed to be performed for the drive shaft, because it has to bear dif-

ferent kinds of shocks which may lead to failure.
4. When drive shaft got failed than, its plastic welding can be done for its repair.

.

5. CONCLUSION

For present work, three changed materials, namely boron-epoxy, aramid-epoxy and three changed stacking sequences have been considered.

Two different directions of torque rotation, one is clockwise and another is counter clockwise and their natural frequencies have been analyzed. For these all finite element modelling has been done and numerical problem is analyzed by the help of ANSYS 18.1 workbench.

The main results obtained as:

1. Among the three materials aramid-epoxy type is delivered maximum as comparison with boron and carbon/epoxy composite shafts.
2. Among the three stacking sequences, where the angle of fiber direction is changed that exhibiting change in the shear stress between the two layers.
3. Furthermore, it also can be determined that stacking sequence of shaft have important factor so stacking sequence should be select as per the application in automotive.

References

1. B. James Prasad Rao, D.V Srikanth, T.Suresh Kumar, L.Sreenivasa Rao, "DESIGN AND ANALYSIS OF AUTOMOTIVE COMPOSITE PROPELLER SHAFT USING FEA" International Conference on Materials Research and. Applications ISSN: 3673–3679 Materials Today: Proceedings 3 (2016) pp.3673-3679.
2. Serge Abrate, "Optimal design of laminated plates and shells" Composite structures ISSN: 02630-8223, 1994.
3. Lien-Wen Chen Wen-Kung Peng, "The stability behaviour of rotating composite shafts under axial compressive loads" 253-263, 1998.
4. Dr. Oliver A. Bauchau "Optimal design of high speed rotating graphite epoxy shafts" Journal of Composite materials Vol 17- March 1983.
5. O.A Bauchau, T.M Krafchack and J.F Hayes, "Torsional buckling analysis and damage tolerance of graphite/epoxy shafts" Journal of Composite materials Vol 22- March 1988.
6. P. Beardmore C.F Johnson, "The potential for composites in structural automotive applications" Composites Science and Technology 0266-3538, 1986.
7. Safa Ben Arab, Jose Dias Rodrigues , Slim Bouaziz , Mohamed Haddar, "A finite element based on equivalent single layer theory for rotating composite shafts dynamic analysis" Composite structures ISSN: 02630-8223, 2017.
8. L. Librescu, A.A Khdeir, "Analysis of symmetric cross ply laminated elastic plates using a higher order theory: Part-I stress and displacement" Composite structures ISSN: 02630-8223, 1988.
9. H. Ghoneim D. J. Lawrie, "Analysis of the Flexural Vibration of a Composite Drive Shaft with Partial Cylindrical Constrained Layer Damping Treatment" Journal of Vibration and Control, 2006.
10. Krupa Prasad, Aiswarya .S, "Finite Element Modelling and Buckling Analysis of Delaminated Composite Plates" International Journal of Science and Research Volume 5 Issue 7, July 2016.
11. S.Rajendran and D.Q.Song, "Finite Element Modelling of Delamination Buckling of Composite Panel Using ANSYS" Proceedings of 2nd Asian ANSYS User Conference, Nov 11-13, 1998, Singapore.

12. D.Dinesh, F.Anand Raju, “Optimum Design And Analysis Of A Composite Drive Shaft For An Automobile By Using Genetic Algorithm And Ansys”, International Journal Of Engineering Research And Applications Vol. 2, Issue4, July-August 2012, Pp.1874-1880.
13. P. Satheesh Kumar Reddy and Ch. Nagaraju, “Weight optimization and Finite Element Analysis of Composite automotive drive shaft for Maximum Stiffness”, 5th International Conference of Materials Processing and Characterization, Proceedings 4 (2017) 2390–2396.
14. Yefa Hu, Mo Yang, Jinguang Zhang, Chunsheng Song and Weiming Zhang, “Research on torsional capacity of composite drive shaft under clockwise and counter-clockwise torque”, Advances in Mechanical Engineering, 2016.
15. Ercan Sevkat, Hikmet Tumer, “Residual torsional properties of composite shafts subjected to impact loadings” Materials and Design (2013) 956–967.
16. M.A. Badie, E. Mahdi, A.M.S. Hamouda, “An investigation into hybrid carbon/glass fibre reinforced epoxy composite automotive drive shaft,” Materials and Design 32 (2011) pp. 1485–1500.
17. S.A. Mutasher, “Prediction of the torsional strength of the hybrid aluminium/composite drive shaft,” Materials and Design 30 (2009) pp. 215–220.
18. Dai Gil Lee, Hak Sung Kim, Jong Woon Kim, Jin Kook Kim, “Design and manufacture of an automotive hybrid aluminium/composite drive shaft,” Composite Structures 63 (2004) pp. 87–99.
19. Y.A. Khalid, S.A. Mutasher, B.B. Sahari, A.M.S. Hamouda, “Bending fatigue behaviour of hybrid aluminium/composite drive shafts” Materials and Design 28 (2007) pp. 329–334.
20. JIN KOOK KIM, DAI GIL LEE, AND DURK HYUN CHO, “Investigation of Adhesively Bonded Joints for Composite Propeller Shafts,” Journal of Composite Materials 2001. Vol. 35 pp. 999-1021.
21. Charles W. Bert and V. Sudhakar Reddy, “CYLINDRICAL SHELLS OF BIMODULUS COMPOSITE MATERIAL,” School of Aerospace, Mechanical and Nuclear Engineering University of Oklahoma.
22. S. Rajendran and D.Q. Song, “Finite Element Modelling of Delamination Buckling of Composite Panel Using ANSYS”, Proceedings of 2nd Asian ANSYS User Conference, Nov 11-13, 1998, Singapore.
23. T. Rangaswami, S. Vijyanarangan, R.A Chandrashekhar, T.K. Venktesh and K Anantharaman, “Optimal design and analysis or automotive composite drive shaft,” International Symposium of research student on material science and engineering, 2002-2004 Chennai.
24. Yeow Ng, Al Kumnick, “Determination of cross ply laminate stacking sequences for the compression testing of a unidirectional boron epoxy material,” SAMPLE fall Technical conference- Dallas, Nov 6-9.
25. Duncan J. Lawrie, “Development of a high torque density, flexible composite driveshaft,” American helicopter society 63rd annual forum, Virginia Beach, VA, may 1-3, 2007.
26. Robert M. Jones, “Mechanics of composite materials,” Taylor & Francis, 2nd edition.
27. M.A.K Chowdhuri, R.A Hossain, “Design Analysis of an automotive composite drive shaft,” International Journal of engineering and technology Vol. 2(2), 2010, 45-48.
28. A tutorial on “Composite analysis in ANSYS”, ANSYS Inc.
29. M. A. Badie, A. Mahdi, A. R. Abutalib, E. J. Abdullah and R. Yonus, “AUTOMOTIVE COMPOSITE DRIVESHAFTS: INVESTIGATION OF THE DESIGN VARIABLES EFFECTS,” International Journal of Engineering and Technology, Vol. 3, No.2, 2006, pp. 227-237.
30. A.R. Abu Talib, Aidy Ali, Mohamed A. Badie, Nur Azida Che Lah, A.F. Golestaneh, “Developing a

hybrid, carbon/glass fibre-reinforced, epoxy composite automotive drive shaft" Materials and Design 31 (2010) pp. 514–521.
31. Mateen Tariq, Salman Nisar, Aqueel Shah, Sohaib Akbar, Muhammad Ali Khan, Sohaib Zia Khan, "Effect of Hybrid Reinforcement on the Performance of Filament Wound Hollow Shaft" Composite Structures (2017).