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Review of Design and Analysis of Composite Drive Shaft for Automotive Application

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A B S T R A C T

This research provides the planning and evaluation of a composite driveshaft for use in automobiles. The study's goal is to learn more about how composite materials might be used to improve driveshafts' functionality and effectiveness. The objectives encompass weight reduction, increased strength and stiffness, improved durability, and optimized performance under varying operational conditions.

Keywords: propeller shaft, Composites , Carbon/Epoxy, Glass/Epoxy fiber, light weight.

I. INTRODUCTION

Because of their superior mechanical qualities and potential for weight reduction, composite materials have garnered a lot of interest in a variety of technical applications. Drive shafts for automotive applications need careful planning and study, composites have shown promising results. When compared to more conventional materials like steel or aluminum, a composite drive shaft has several advantages, including reduced weight, higher strength, better durability, and improved performance.

The goal of this paper is to offer an in-depth look at the design and analytical considerations that go into making composite drive shafts for vehicles. By examining existing research, studies, and industry practices, this review aims to identify the key considerations, challenges, and composite drive shafts: recent developments in design and analysis.

The review begins by exploring the structural requirements and performance demands placed on drive shafts in automobiles. It examines the operating conditions, such as torque, rotational speed, and torsional vibrations, that drive shafts must withstand during vehicle operation. By understanding these load requirements, engineers can effectively design composite drive shafts to meet the specific performance criteria. Next, the review investigates the selection of composite materials for drive shaft applications. Mechanical properties of composite materials like carbon fiber-reinforced polymers (CFRP) and glass fiber-reinforced polymers (GFRP) are examined in relation to drive shafts. Strongness, stiffness, fatigue resistance, and cost are all considered while selecting materials.

Furthermore, the review examines the layup design of composite drive shafts. It investigates the arrangement and orientation of the composite layers to optimize torsional stiffness and bending strength while ensuring manufacturability. Different manufacturing techniques, such as filament winding, pultrusion, or autoclave molding, are evaluated for their effectiveness in achieving the desired layup design.

This study seeks to give insights, developments, and prospective topics for future research into the subject of composite drive shafts by analyzing the design and analytical elements of these components. By reading this review, engineers and researchers will have a better idea of how to enhance the design, production, and performance of composite drive shafts for use in automobiles.

II. COMPARATIVE STUDY

Finding out whether a composite drive shaft can effectively replace a conventional drive shaft consisting of two pieces of steel is the focus of this study. Since the weight of a car has a direct effect on its gas mileage, researchers are looking at composite materials that may help cut vehicle weight without sacrificing quality or durability. Because of this, it is important to design, examine, and evaluate several materials before settling on the optimal material for the drive shaft.

The composite drive shaft is not only lighter and quieter, but it also vibrates far less. Hollow cylinders are more common than solid cylinders because of their superior specific strength. The stress distribution is more uniform in a hollow round shaft than in a solid one, which is symmetrical around its center and greatest at its extremities. Hollow circular shafts are often utilized as an alternative to their solid counterparts. Advanced composite materials such as graphite, carbon, kevlar, and glass when mixed with suitable resins are commonly used due to their high specific strength/density and high specific modulus/density. Modern composite materials seem to be a natural match for applications using long power driver shafts (propeller shafts). The amount of torque they can withstand and the rate at which they spin may be modified by altering their elastic properties.

Static analysis may be used to determine the resultant displacements, stresses, strains, and forces in a structure or component subjected to loads that do not appreciably impact inertia and damping. However, a static analysis may take into consideration constant inertia loads such as gravity, spinning, and time-varying stresses. For the purposes of static analysis, it is expected that the loads and the structure's reactions would change gradually over time. Externally applied forces, moments, and pressures are all valid forms of loading for use in static analysis. Constant inertial forces, like gravity and centrifugal force, Punishments outside of zero are mandated. In the static condition, the structure will fail if the stress levels obtained in this research are higher than the allowable limits. In order to avoid making such a gaffe, it is crucial to conduct an inquiry of this kind.

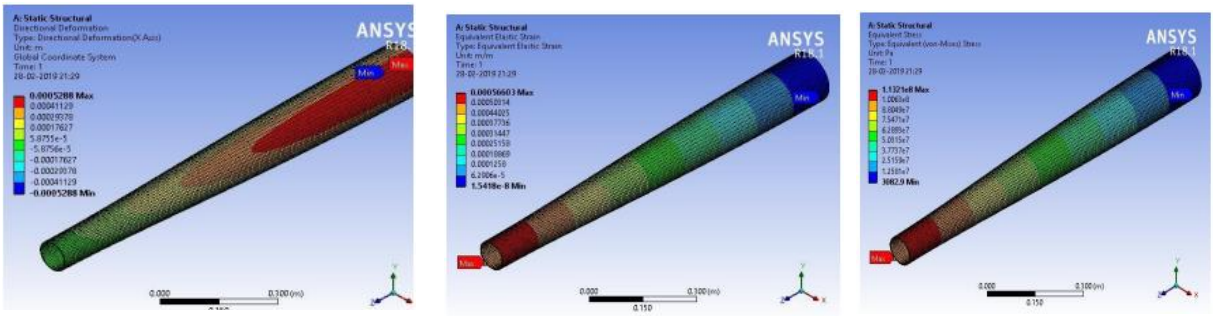

Figure 2: (a) Typical Total deformation and (b) Strain (c) Equivalent (von-Mises) Stress for steel

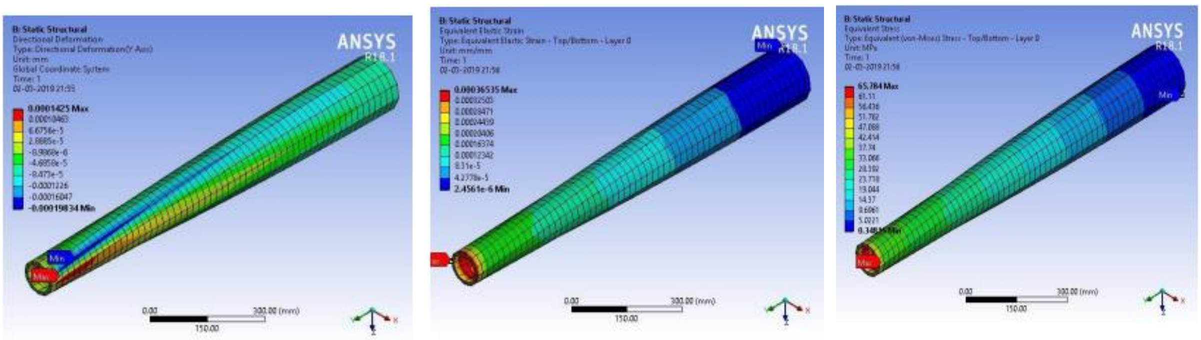

Figure 3: (a) Typical Total deformation and (b) Strain (c) Equivalent (von-Mises) Stress for Carbon/Epoxy

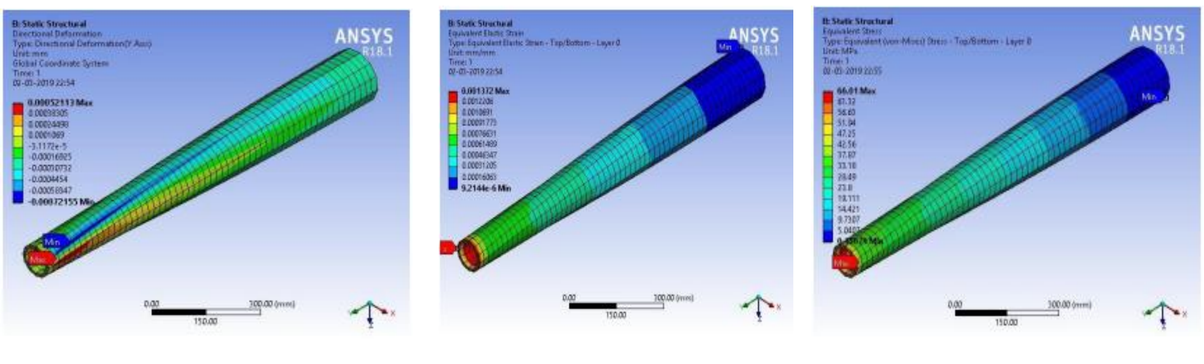

Figure 4: (a) Typical Total deformation and (b) Strain (c) Equivalent (von-Mises) Stress for Glass/Epoxy

During the design phase, engineers may utilize modal analysis to learn about a structure's or machine part's vibration characteristics including its natural frequencies and mode shapes. Modal analysis is becoming more relevant for drive shafts as one-piece designs become the norm.

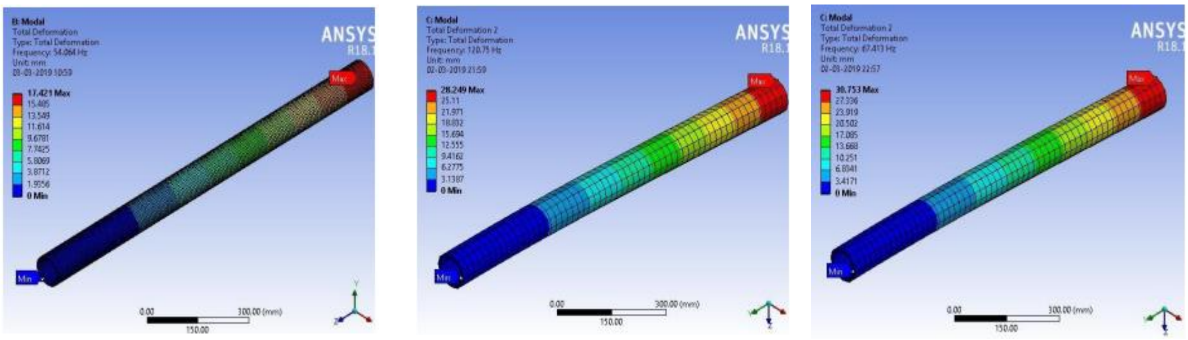

Figure 5: Mode 1 f1 for (a) steel (b) Carbon/Epoxy (c) Glass/Epoxy

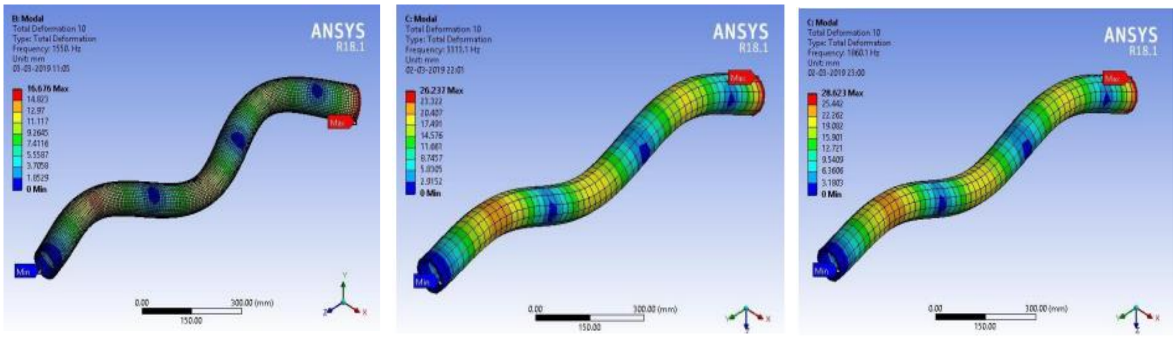

Figure 6: Mode 10 f10 for (a) steel (b) Carbon/Epoxy (c) Glass/Epoxy

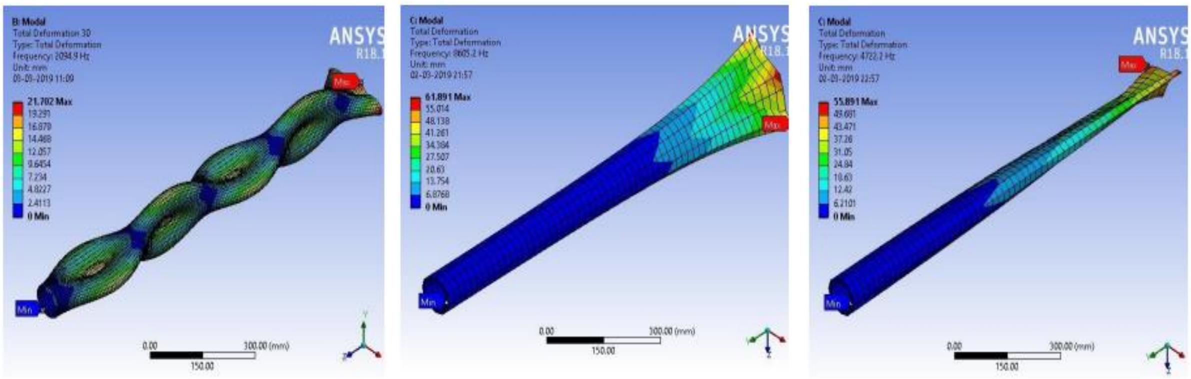

Figure 7: Mode 20 f20 for (a) steel (b) Carbon/Epoxy (c) Glass/Epoxy

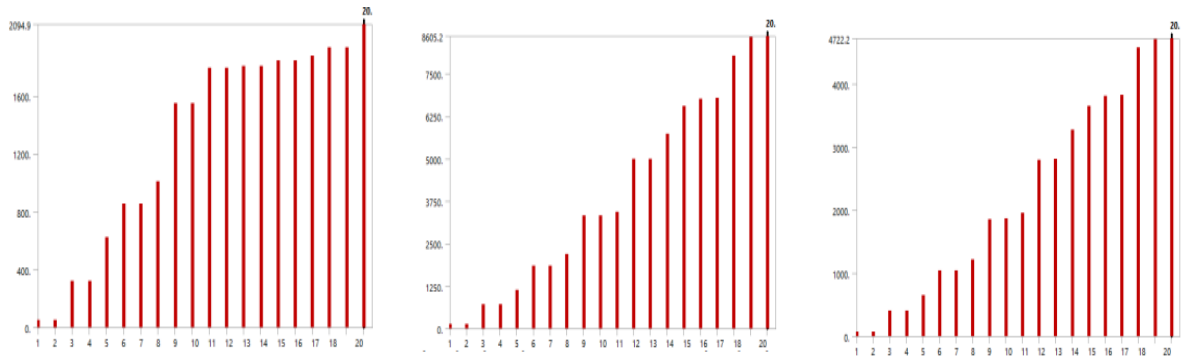

Chart -1: Number of modes versus. frequency variation. Frequency is shown along the Y-axis and the number of modes along the X-axis.

Results and discussion

Table 1: Results of Masses

	Steel	Carbon/ Epoxy	Glass/ Epoxy	Kevlar/ Epoxy	Boron/ Epoxy
Mass (Kg)	12.7	2.7	2.25	3.34	3.34
Mass Saving (%)	-	78.74	82.28	73.7	73.7

From the above table, it can be noticed that by using carbon/epoxy reduces the weight of the propeller shaft by 78.74%. Furthermore, by using glass/epoxy, 82.28% reduction in weight is obtained. For Kevlar/epoxy and boron/epoxy, 73.7% reduction is obtained. Hence, it is observed that glass/epoxy has maximum weight reduction in comparison with the other composite materials.

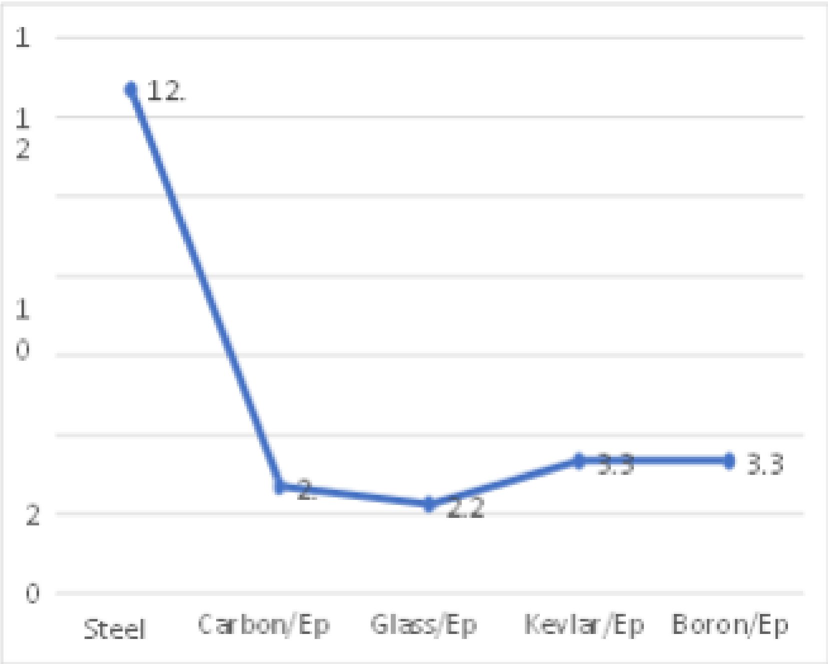

Chart -2: Mass Comparison of Materials

Table 2: Results of Directional Deformation

	Minimum (mm)	Maximum (mm)
Steel	-5.29E-01	5.29E-01
Carbon/Epoxy	-1.98E-04	1.43E-04
Glass/Epoxy	-7.22E-04	5.21E-04
Kevlar/Epoxy	-1.67E-02	1.70E-02
Boron/Epoxy	-1.59E-03	1.62E-03

From above table it can be observed that the directional deformation because of the applied boundary conditions is much less in composite material as compared to steel and the stress value obtain in carbon epoxy is least.

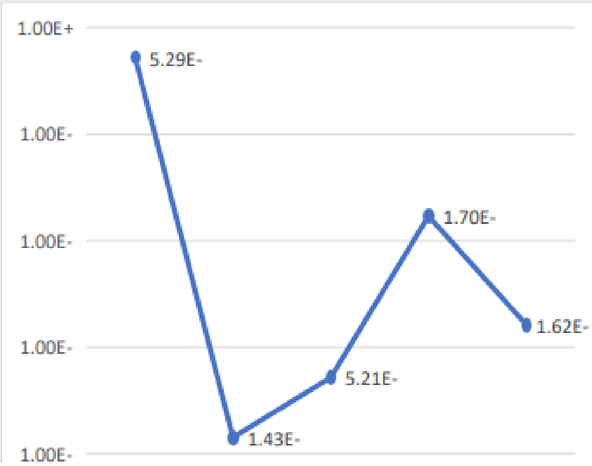

Chart -3: Directional Deformation of Materials

Table 3: Results of Equivalent Elastic Strain

	Minimum (mm/mm)	Maximum (mm/mm)
Steel	1.54E-05	5.66E-01
Carbon/Epoxy	2.46E-06	3.65E-04
Glass/Epoxy	9.21E-06	1.37E-03
Kevlar/Epoxy	3.65E-06	1.47E-03
Boron/Epoxy	8.12E-07	3.50E-04

From the above table it can be observed that the equivalent elastic strain because of the applied boundary conditions is much less in composite material as compared to steel and the stress value obtained in carbon epoxy is least.

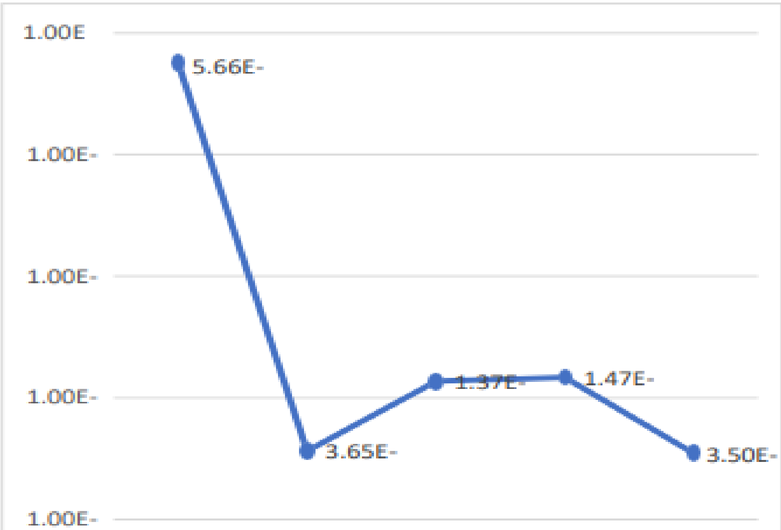

Chart - 4: Equivalent Elastic Strain of Materials

Table 4: Results of Equivalent (von-Mises) Stress

	Minimum (MPa)	Maximum (MPa)
Steel	3.08E-03	
Carbon/Epoxy	0.34815	65.784
Glass/Epoxy	0.35079	66.01
Kevlar/Epoxy	9.52E-02	223.79
Boron/Epoxy	9.61E-02	71.411

Stress in carbon/epoxy is the least compared to other composite material, also the stresses in composite material are much less the steel except for Kevlar/epoxy.

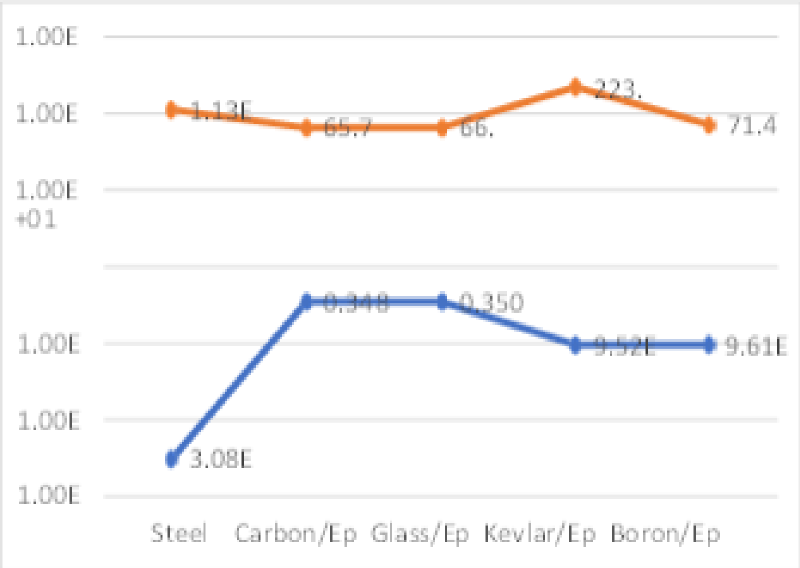

Chart -5: Equivalent Shear of Materials

The steel plays a part in the E-glass/epoxy as in transmitting the necessary torque, and the E-Glass epoxy composite raises the bending natural frequency. The static torsion capacity was the subject of an experimental investigation. Steel tubes were used in four studies, each of which included wounding the tubes with a composite substance.

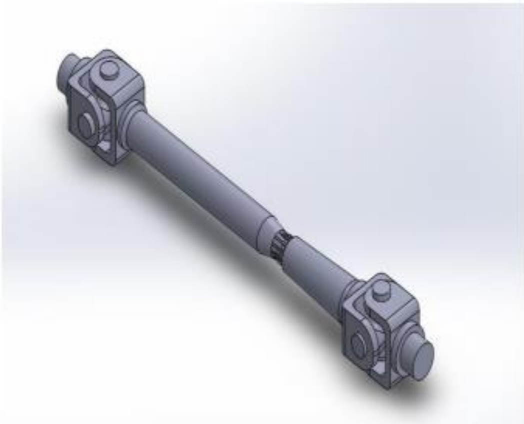

Figure 8: Model of propeller shaft with universal joints

UNIVERSAL COUPLING PROPELLER SHAFT ANALYSIS FOR STRUCTURAL STEEL

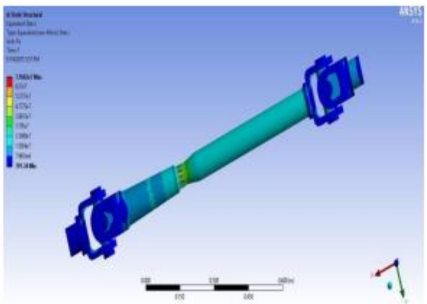

Figure 9: stress analysis

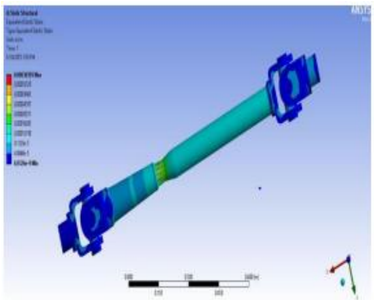

Figure 10: Stress analysis

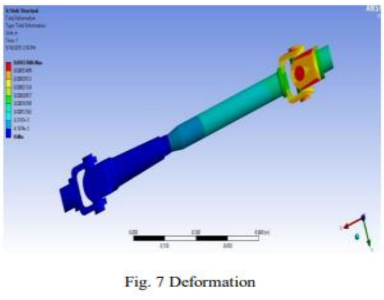

Figure 11: Deformation

Table 5: Result for structural steel

Descriptions	Steel
Max. Stress	5.7087e7
Min. Stress	1096
Max. Strain	0.00029716
Min. Strain	1.3661e-8
Deformation	0.00033251

E-GLASS RESIN PROPELLER SHAFT ANALYSIS USING A UNIVERSAL COUPLING

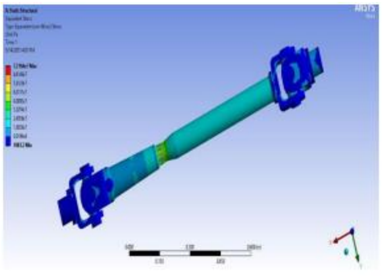

Figure 12: stress analysis

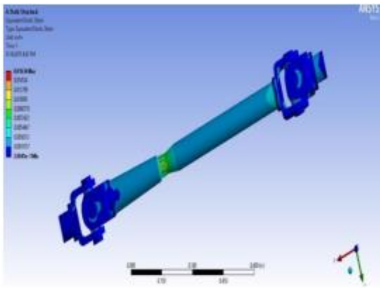

Figure 13: Stress analysis

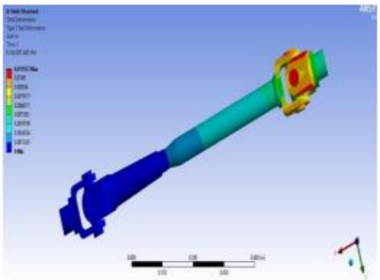

Figure 14: Deformation

Table 6: Result for E-glass resin

Description	E-Glass
Max. Stress	7.1684e7
Min. Stress	791.37
Max. Strain	0.0044705
Min. Strain	609379e-9
Deformation	0.00053946

A maximum static torsion about 66% larger than the pure aluminum and a mass reduction of 42% compared with the steel drive shaft may be inferred from the results of this study by increasing the number of layers. We performed a theoretical study of a complete hybrid composite drive shaft using Finite Element study software and compared the findings to those obtained with a conventional steel drive shaft.

III. CONCLUSION

The study of the design and analysis of composite drive shafts for automotive applications holds great potential for revolutionizing the automotive industry. Composite drive shafts offer numerous advantages, including reduced weight, improved performance, and increased fuel efficiency. Material selection, finite element analysis, and precise manufacturing processes are vital in optimizing their performance. Challenges include cost considerations and long-term durability. Further research is required to advance design, manufacturing techniques, and cost-effectiveness, ultimately leading to the development of lighter and more efficient vehicles.

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