Revolutionising Automotive Performance: The Rise of Composite Drive Shafts

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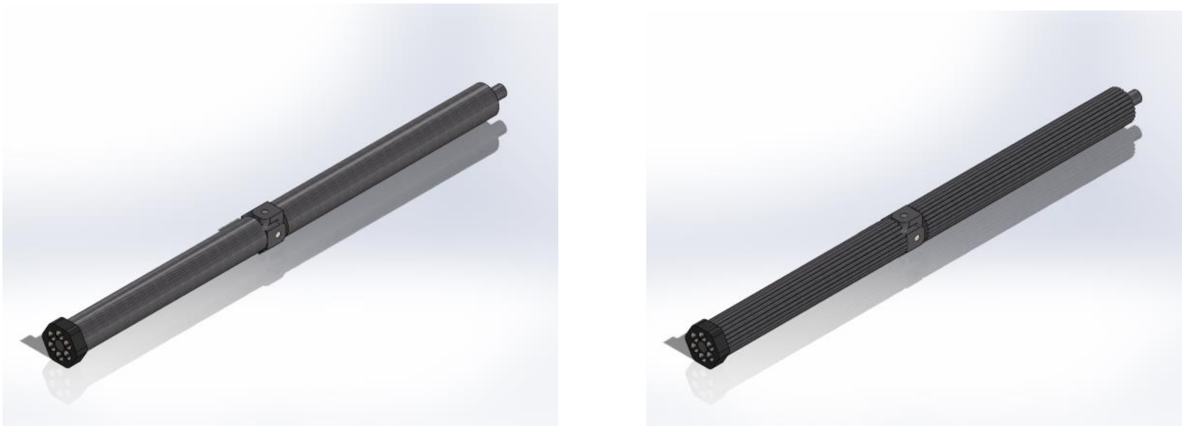
In today's automotive landscape, innovation is driven not only by speed and aesthetics but also by smarter materials, greater efficiency, and sustainable engineering practices. A significant advancement in this evolution is the replacement of traditional heavy steel components with high-performance composite materials. Among these components, the drive shaft—an essential element responsible for transmitting power from the engine to the wheels—is undergoing a major transformation.

This article presents a study focused on the design and simulation of a Carbon Fibre Reinforced Polymer (CFRP) drive shaft, with the goal of achieving substantial weight reduction without compromising structural performance. Using SolidWorks for 3D modelling and ANSYS Workbench for finite element analysis (FEA), the project builds a compelling, data-backed case for transitioning from conventional steel shafts to advanced composite alternatives. In rear-wheel and four-wheel drive vehicles, drive shafts are subjected to complex load conditions including torsional, shear, and bending stresses. While traditional carbon steel shafts are known for their reliability and strength, they are also burdened with significant drawbacks, namely high weight, poor corrosion resistance, and reduced fatigue life over time.

These limitations have become even more critical in the context of performance and electric vehicles, where higher torque outputs and the need for weight reduction are central to design goals. In this regard, composite materials like CFRP offer a highly attractive solution. With exceptional strength-to-weight ratio, superior fatigue resistance, and near-zero thermal expansion, CFRP components promises enhanced efficiency, improved durability, and better overall dynamic performance.

The study began by identifying the inherent limitations of conventional steel drive shafts. While steel provides robust mechanical properties and long service life, it contributes significantly to vehicle mass and is susceptible to corrosion and fatigue failure under cyclical loading. These issues reduce the overall efficiency of the power transmission and lead to higher fuel consumption due to increased rotational inertia. In high-performance and electric vehicle platforms, where managing weight and torque is paramount, the case for a material upgrade is clear. CFRP, with its outstanding mechanical performance and resistance to environmental degradation, emerges as the ideal candidate.

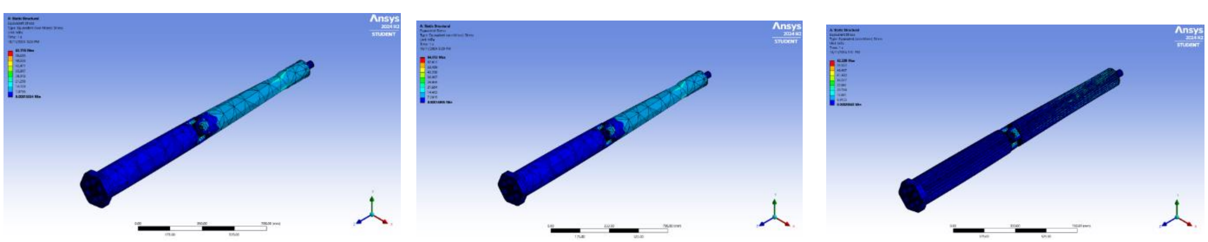
To explore this, the project utilised the geometry of a typical steel driveshaft found in rear-wheel-drive vehicles—specifically, the BMW E92 M3—as a baseline for analysis. Two CFRP design variants were developed for comparison as shown in Figure 1: a standard cylindrical driveshaft and an enhanced version incorporating longitudinal ridges. Both versions shared the same key dimensions—a length of 1680 mm, an outer diameter of 100 mm, and a wall thickness of 10 mm—to ensure consistency in evaluation. The enhanced ridged model introduced a 5 mm surface indentation along its length, a structural feature intended to boost torsional rigidity, improve interfacial bonding, and enhance resistance to localised stress concentrations and buckling.



(a) (b)

Figure 1: (a) Conventional Driveshaft Design using CFRP Material (b) Enhanced Ridged Design Driveshaft.

Using ANSYS Workbench, a series of Finite Element Analyses (FEA) were conducted to evaluate each shaft's performance under stress, strain, deformation, and buckling scenarios. Three configurations were evaluated: a conventional carbon steel driveshaft, a conventional CFRP driveshaft, and an enhanced CFRP design featuring ridges along the shaft. Using Finite Element Analysis (FEA) in ANSYS, several performance parameters—stress, strain, deformation, and buckling—were studied under a torque load of 1500 Nm.



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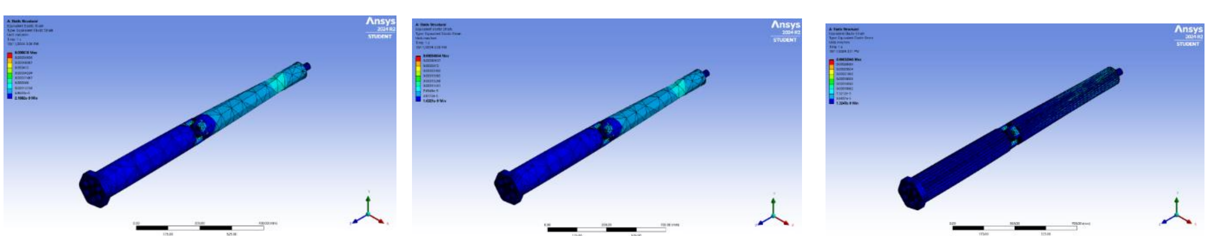

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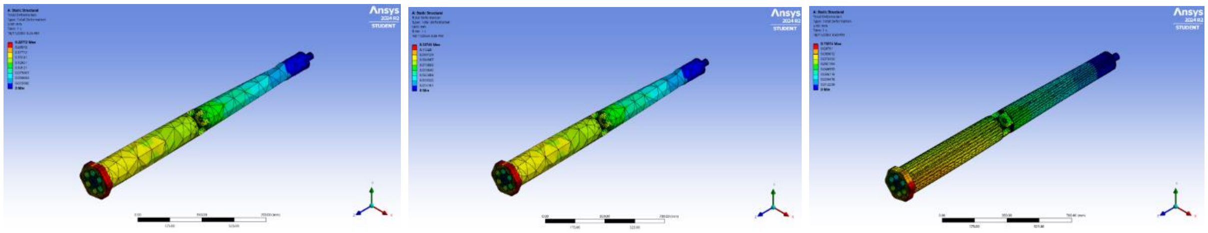

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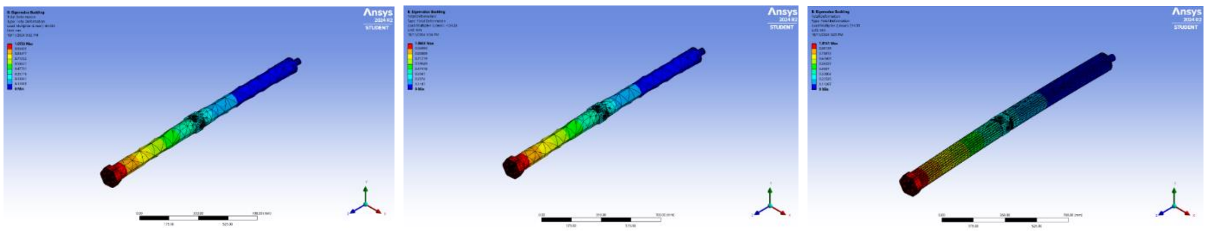

(d)

Figure 2: (a) Stress (b) Strain (c) Deformation (d) Buckling analysis for conventional carbon steel driveshaft, conventional driveshaft design using CFRP material and enhanced ridged design driveshaft.

Table 1 shows the results obtained from the study. In terms of stress analysis, all three shafts showed comparable maximum stress values, with the conventional CFRP driveshaft experiencing the highest stress at 64.812 MPa and the enhanced ridged CFRP showing the lowest at 62.238 MPa. This indicates that the ridged design helped to reduce peak stresses, likely by improving the load distribution along the shaft. For strain, the CFRP designs performed significantly better than carbon steel. The carbon steel shaft showed the highest strain (0.000618 mm/mm), whereas the ridged CFRP design had the lowest (0.000330 mm/mm), showcasing CFRP's superior stiffness and elastic properties.

Table 1: Comparative Performance Results for Driveshaft Designs

Type	Stress (MPa)	Strain (mm/mm)	Deformation (mm)	Buckling Deformation (mm)
Carbon Steel Driveshaft Conventional Design	63.715	0.000618	0.22772	1.0733
CFRP Driveshaft Conventional Design	64.812	0.000344	0.12745	1.0683
CFRP Driveshaft Ridged Design	62.238	0.00033	0.11015	1.0141

The deformation analysis revealed that the CFRP ridged shaft also had the lowest total deformation (0.11015 mm), compared to 0.22772 mm for the carbon steel version. This demonstrates CFRP's enhanced ability to resist twisting and bending, especially when coupled with structural design improvements like ridges. Buckling performance showed similar trends across all three shafts in terms of critical load (506.72 kN), but the ridged CFRP had the least deflection under buckling, further confirming its improved structural integrity.

The outcomes of this project confirm the technical viability and performance superiority of CFRP as a material for automotive driveshaft applications. By integrating optimised geometry and leveraging advanced material characteristics, the proposed composite drive shaft design not only reduces mass and improves efficiency but also enhances mechanical durability under operational loads. The simulations provide robust evidence of improved stress resistance, deformation control, and buckling strength.

In conclusion, CFRP drive shafts offer a highly promising alternative to traditional steel components in automotive applications. They deliver considerable performance improvements across multiple metrics, particularly in reducing vehicle weight and improving dynamic stability. The findings support continued exploration of composite materials and advanced design methodologies for future automotive engineering applications. Further experimental validation and fatigue lifecycle testing are recommended to complement simulation outcomes and to support potential commercial deployment in high-performance and electric vehicles.

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