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Design and Comparative Structural Analysis of Aluminum-Based Hybrid Hollow Drive Shafts using GFRP and CFRP

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Abstract
This paper presents a comparative study of two hybrid hollow drive shaft configurations using Aluminum 2024-T6 as the outer shell material and GFRP or CFRP as the inner core. The goal is to evaluate which composite material provides better mechanical performance under static torsional loading. CAD models were developed using CATIA, and simulations were performed in ANSYS Workbench (Student Version). The results revealed that Al + CFRP shafts exhibit superior stiffness and lower deformation, while Al + GFRP shafts offer better damping at lower cost. This study demonstrates the feasibility of hybrid composite shafts as replacements for conventional steel drive shafts in mechanical systems.

Keywords: Hybrid shaft, CFRP, GFRP, Aluminum 2024-T6, Static analysis, ANSYS, CATIA.

1. INTRODUCTION
Drive shafts are key mechanical elements for transmitting torque in vehicles and machinery. Traditional steel shafts, while strong, are heavy and prone to vibration and fatigue. Composite materials such as GFRP and CFRP offer lightweight alternatives with improved damping and corrosion resistance. This project investigates a hybrid configuration using an Aluminum shell and composite core to optimize strength and weight.

2. METHODOLOGY
Two hybrid shafts were designed in CATIA, both 1000 mm long with outer diameter 60 mm and inner diameter 50 mm. Aluminum 2024-T6 was used as the outer layer, while GFRP and CFRP were analyzed as inner layers in separate models. Static structural analysis was performed in ANSYS Workbench with bonded contact and a torque of 59000 Nm. The mesh was generated using default settings in the student version.

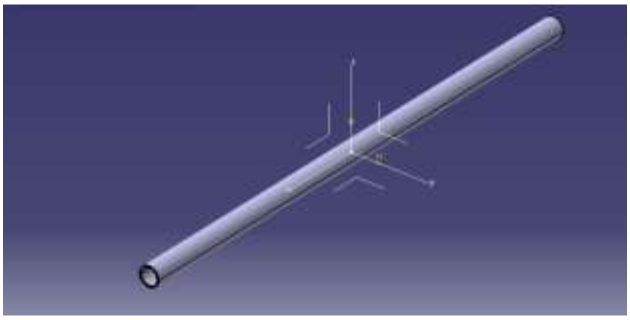

Fig 2.1 CAD Model of the Hybrid Shaft

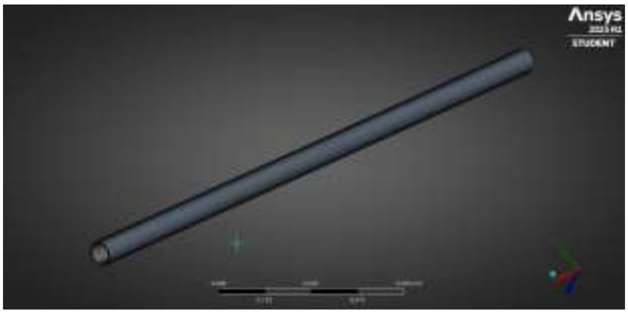

Fig 2.2 Mesh Generated in ANSYS Workbench

Fig 2.3 Applied Boundary Conditions in ANSYS

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3. RESULTS AND DISCUSSION

The Al + CFRP shaft showed less deformation (0.021 m) and higher stiffness, while Al + GFRP had slightly higher deformation (0.028 m) but better damping. Stress values for both remained within material limits, confirming structural safety. The weight advantage of CFRP and cost-effectiveness of GFRP make each suitable for different applications.

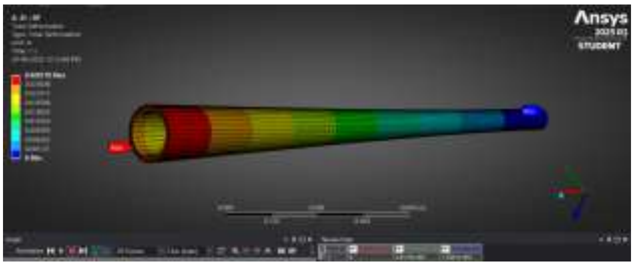

Figure 3.1: Total Deformation Plot – Al + GFRP Shaft

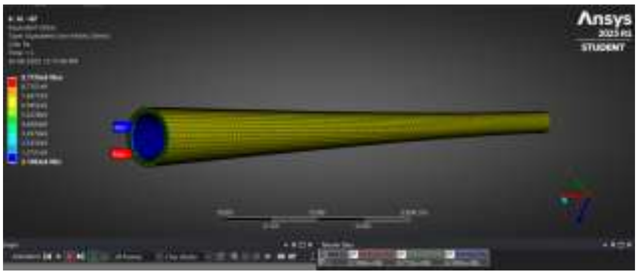

Figure 3.2: Equivalent Stress (Von Mises) – Al + GFRP Shaft

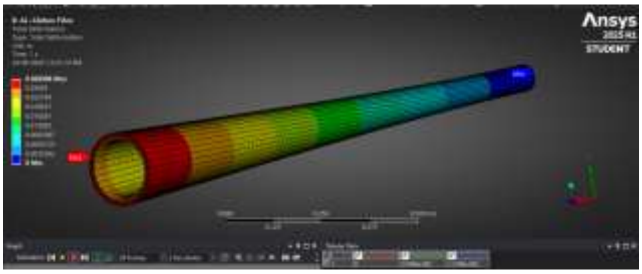

Figure 3.3: Total Deformation Plot – Al + CFRP Shaft

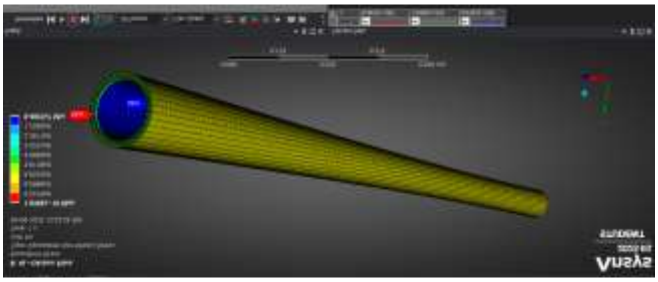

Figure 3.4: Equivalent Stress (Von Mises) – Al + CFRP Shaft

Configuration	Max Deformation (m)	Max Stress (MPa)	Max Strain	Remarks
Al + GFRP	0.028	[illegible]	0.0124	Good damping, moderate weight
Al + CFRP	0.021	11500	0.0098	Highest stiffness, lowest weight

Table 3.5 Result

4. CONCLUSIONS

The comparative analysis revealed that hybrid composite shafts provide better weight efficiency and mechanical performance than conventional steel shafts. The Al + CFRP configuration is suitable for high-performance applications, while Al + GFRP is ideal for cost-sensitive designs requiring moderate strength and good damping.

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