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EM PARCERIA COM:

Shaft optimization for nautimodels: Comparative analysis between carbon fiber and stainless steel

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ABSTRACT

This article investigates the feasibility of replacing stainless steel shafts with carbon fiber shafts in nautimodels, using simulations in ANSYS software. The results indicate that carbon fiber shafts require larger diameters to achieve similar mechanical strength, which can compromise the hydrodynamic performance and assembly of the model. In addition, issues such as manufacturing difficulty, risk of delamination and high cost make carbon fiber less viable, despite its lightness.

Keywords: Carbon fiber, Stainless steel, ANSYS simulation, Nautimodel.

INTRODUCTION

This article analyzes the feasibility of using carbon fiber shafts in a model nauti, comparing them with traditional stainless steel shafts. Using ANSYS software, simulations were performed to determine the mechanical properties and structural suitability of carbon fiber shafts in different diameters, comparing the results with a 10 mm diameter stainless steel shaft. The simulations showed that, in order to achieve the same mechanical strength as the stainless steel shaft, the carbon fiber shaft would need a much larger diameter, which would compromise the fit of other components and the hydrodynamic performance of the model. In addition, the greater difficulty of manufacturing, the risk of delamination, and the high cost make the use of carbon fiber shafts less feasible, despite the marginal benefits of weight reduction.

The search for high-performance materials that combine mechanical strength and low weight is a constant in several areas of engineering, including the nautical industry. In marine models, the efficiency and reliability of the components are crucial for optimal performance. Traditionally, stainless steel shafts have been widely used due to their excellent mechanical properties and corrosion resistance. However, carbon fiber has been gaining prominence as an alternative material, mainly due to its high strength-to-weight ratio.

Stainless Steel: Stainless steel is a material that is widely used in applications where high mechanical strength and corrosion resistance are required. Its properties include:

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- High tensile and fatigue strength.
- Good corrosion resistance, especially in marine environments.
- Relative ease of manufacture and availability.

Carbon Fiber: Carbon fiber is known for its exceptional mechanical properties, being used in cutting-edge industries such as aeronautics and automotive. Its features include:

- High tensile strength.
- Low specific weight, providing a high strength-to-weight ratio.
- Good corrosion resistance, although less resistant to impact and susceptible to delamination.

RATIONALE FOR THE STUDY

Replacing stainless steel axles with carbon fiber axles in nautimodels could theoretically provide a significant reduction in weight, improving the efficiency and performance of the model. However, it is critical to assess whether carbon fiber can offer the same mechanical strength and reliability as stainless steel, without compromising the structural and functional integrity of the model.

This study aims to compare the two materials through simulations performed in ANSYS software. The analysis will focus on determining the required diameters of carbon fiber shafts to achieve mechanical strength comparable to stainless steel shafts, also considering the effects on the assembly and overall performance of the nautimodel.

OBJECTIVE

To analyze the feasibility of using carbon fiber shafts in a model nauti, comparing them with traditional stainless steel shafts through simulation using ANSYS software.

METHODOLOGY

AXIS CONFIGURATION

The tested axles have the following characteristics:

- **Material:** Carbon fiber with 350 GPa modulus of elasticity.
- **Diameters:** 10 mm, 15 mm and 20 mm.
- **Length:** 500 mm.

CALCULATION OF MOMENT AND TORQUE

To determine the moment and torque applied to the axles, the following parameters of the Imobras 101410212 engine were used:

- **Power (P):** 240 W.
- **Rotational speed (n):** 2900 rpm.
- **Radius (r):** 0.005 m for 10 mm diameter shaft.

CONVERT ROTATION TO ANGULAR VELOCITY

- The engine speed is 2900 rpm (revolutions per minute).
- We convert rpm to rad/s using the formula:

$$\omega = \frac{2\pi \cdot rpm}{60}$$

Replacing:

$$\omega = \frac{2\pi \cdot 2900}{60} \approx 303{,}93\ rad/s$$

CALCULATE TORQUE

- Use the power formula

$$P = T \cdot \omega$$

- Rearranging to meet torque:

$$T = \frac{P}{\omega}$$

- Replacing the values:

$$T = \frac{240}{303{,}93} \approx 0{,}79\ Nm$$

SIMULATION PROCEDURE IN ANSYS MECHANICAL

Axis Modeling

The CAD models of the shafts were created with the specified diameters and imported into ANSYS Mechanical.

Material Definition

The assigned material was carbon fiber, with a modulus of elasticity of 350 GPa.

Mesh Generation

An appropriate mesh was generated for each axle model, ensuring accuracy in the results.

Application of Boundary Conditions

Fixed End: One end of the shaft has been completely fixed to simulate rigid clamping.

Moment Application: At the opposite end, the calculated moment of 0.79 nm was applied.

Performing Static Analysis

The solver was configured to perform the static analysis and calculate the stresses and strains in the shafts.

Results

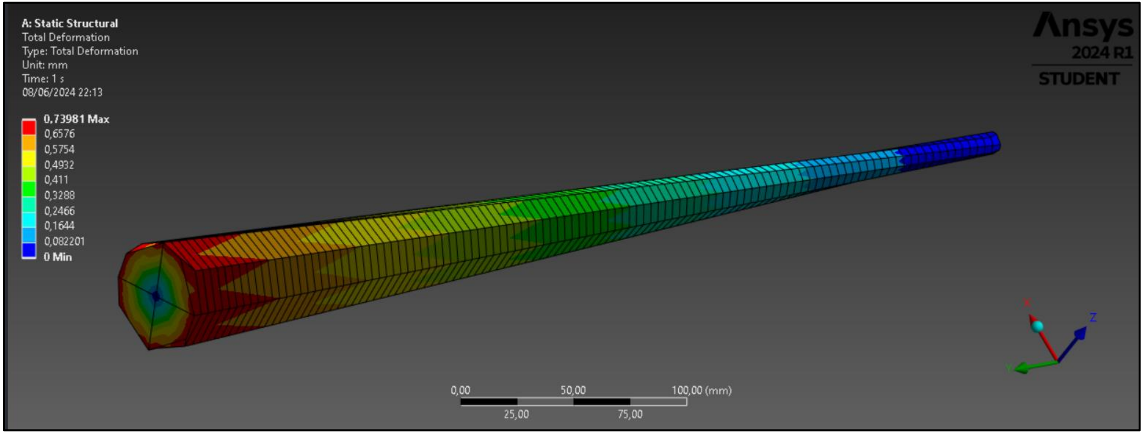
The parameters of Total Deformation, Specific Deformation (Strain) and Stress (Stress) were analyzed for each shaft diameter.

DEVELOPMENT

The results of the simulations for the carbon fiber and stainless steel axles are presented below:

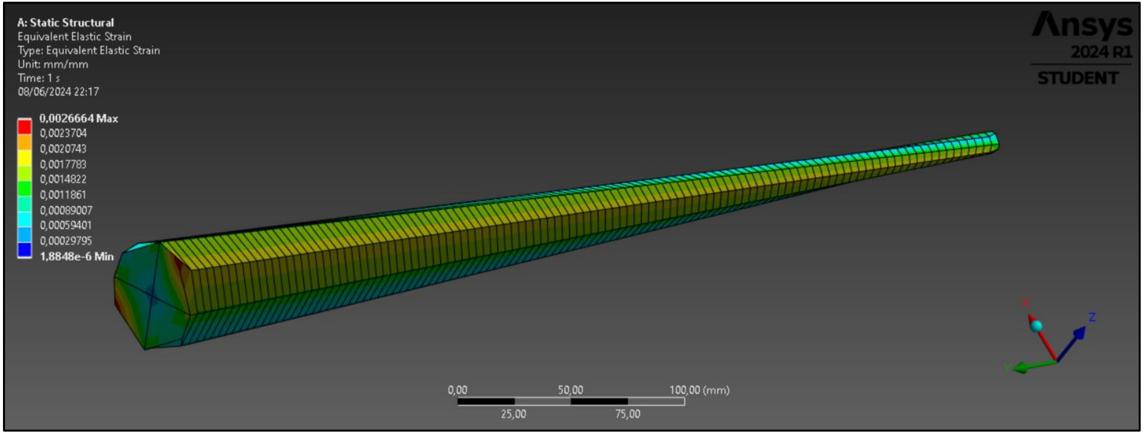
SIMULATION FOR CARBON FIBER MATERIAL WITH SHAFT DIAMETER EQUAL TO 10 MM

Figure 1: D 10mm carbon fiber shaft formation



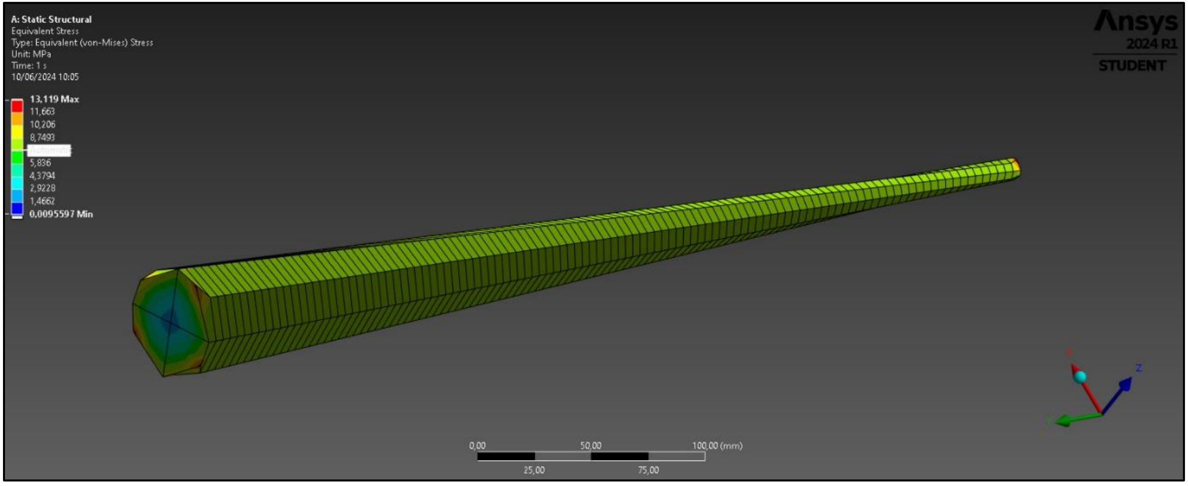
Source: Authors, 2024

Figure 2: Strain of the 10mm carbon fiber shaft



Source: Authors, 2024

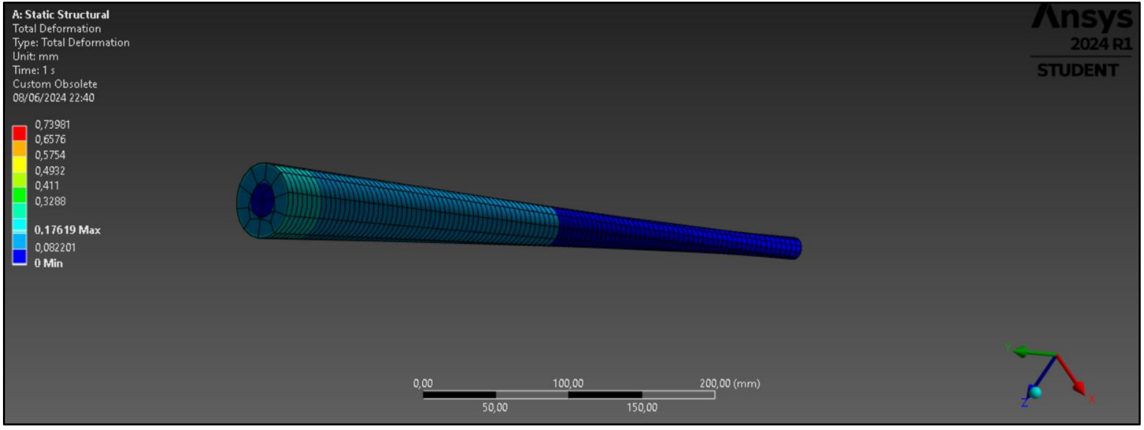
Figure 3: 10mm carbon fiber shaft stress



Source: Authors, 2024

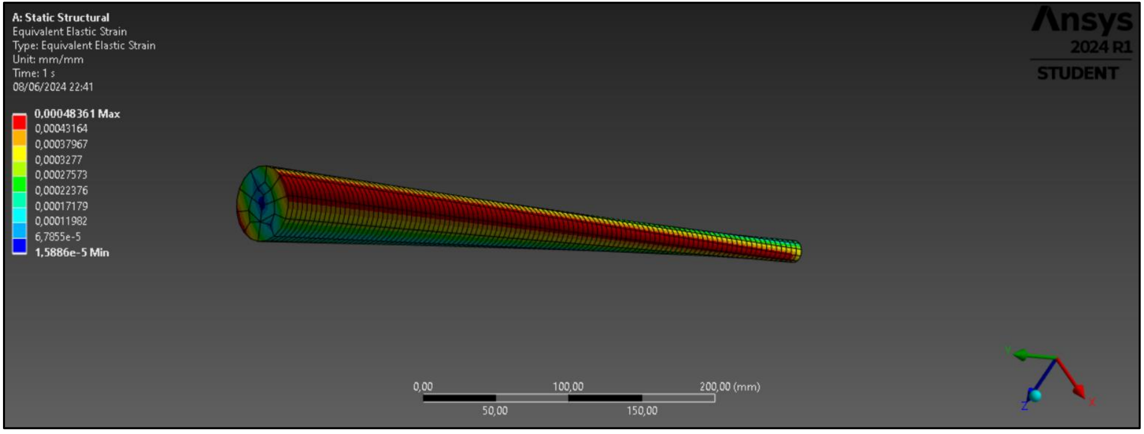
SIMULATION FOR CARBON FIBER MATERIAL WITH SHAFT DIAMETER EQUAL TO 15 MM

Figure 4: D 15mm carbon fiber shaft formation



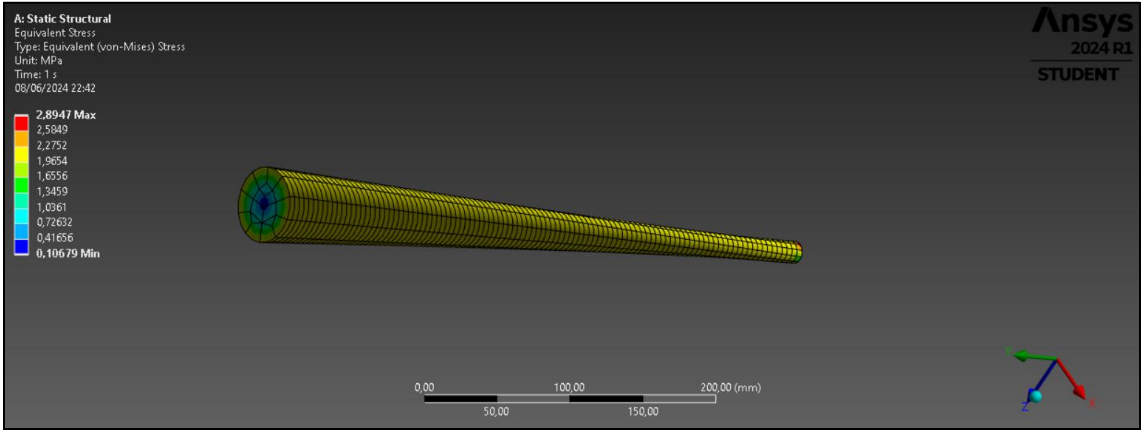
Source: Authors, 2024

Figure 5: Strain of the 15mm carbon fiber shaft



Source: Authors, 2024

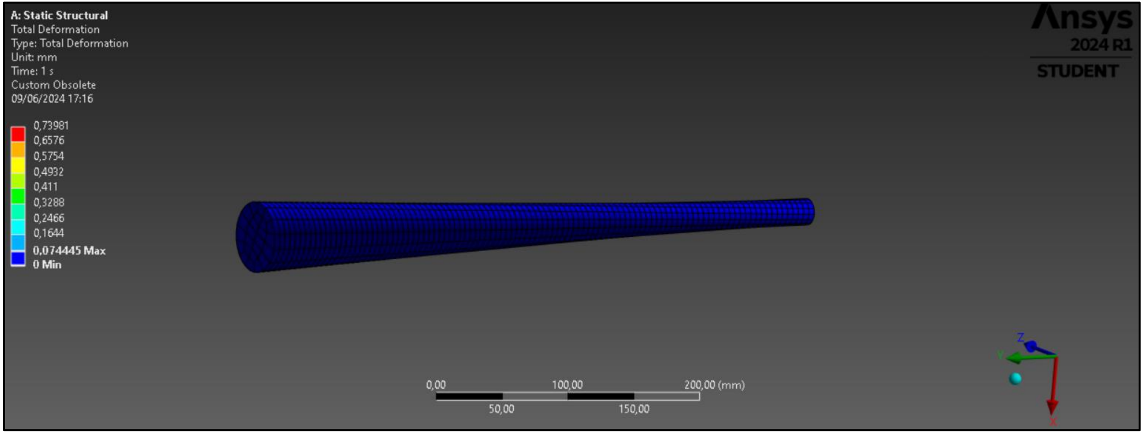
Figure 6: 15mm Carbon Fiber Shaft Stress



Source: Authors, 2024

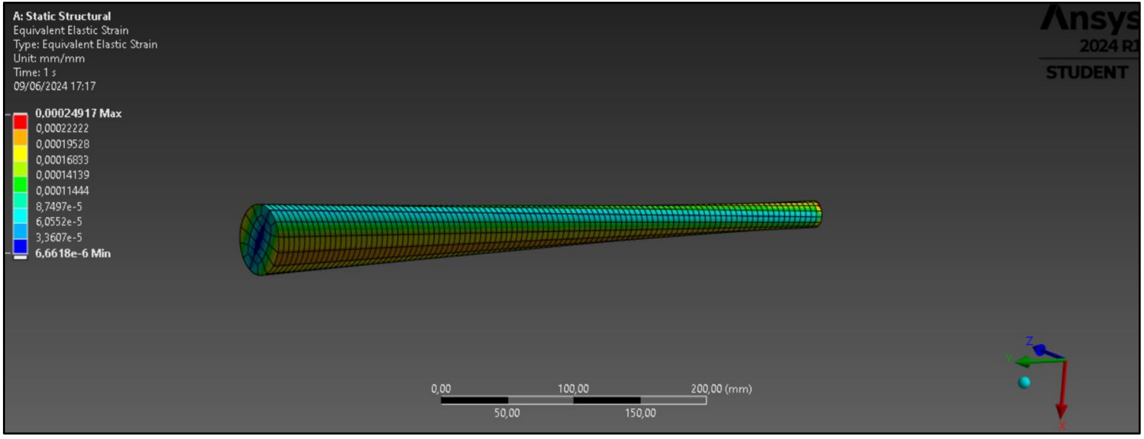
SIMULATION FOR CARBON FIBER MATERIAL WITH SHAFT DIAMETER EQUAL TO 20 MM

Figure 7: Total deformation of the 20mm carbon fiber shaft



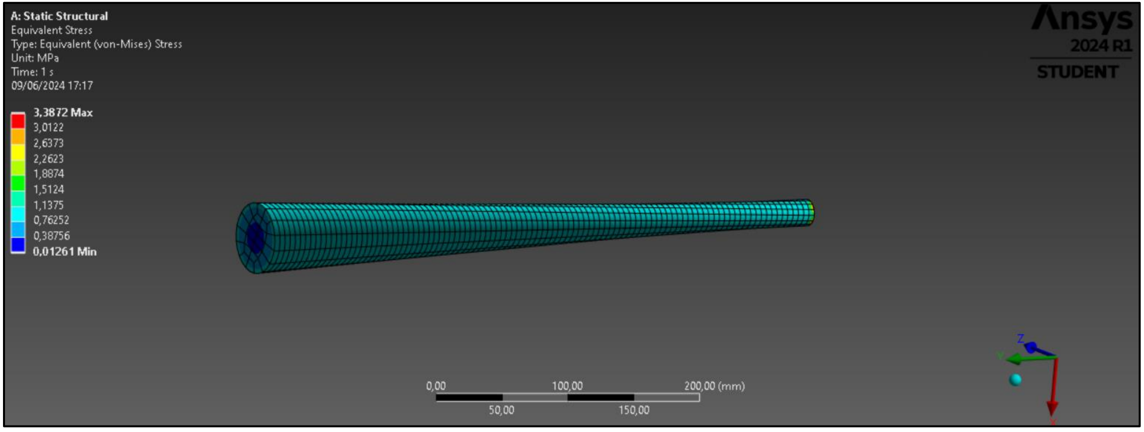
Source: Authors, 2024

Figure 8: 20mm Carbon Fiber Shaft Strain



Source: Authors, 2024

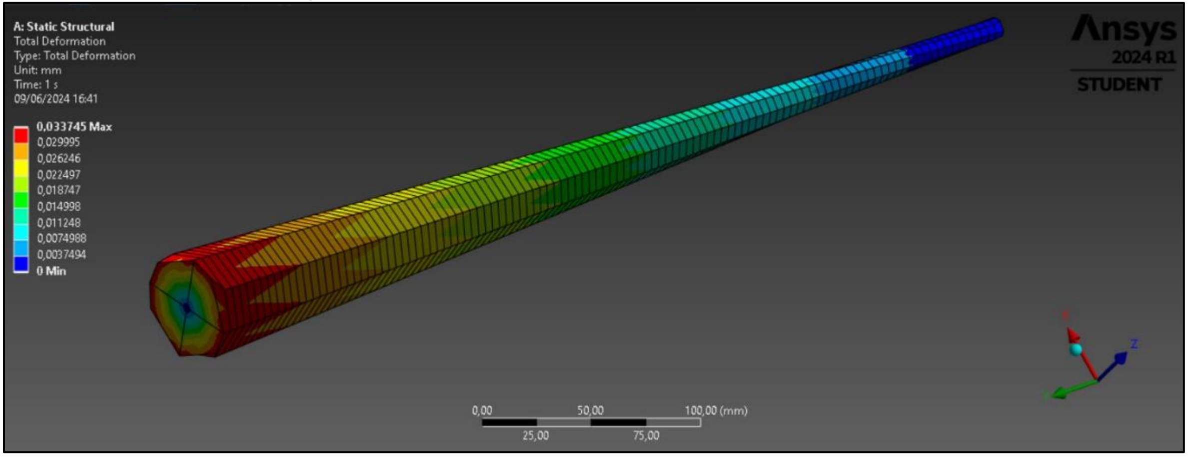
Figure 9: Stress of 20mm carbon fiber shaft



Source: Authors, 2024

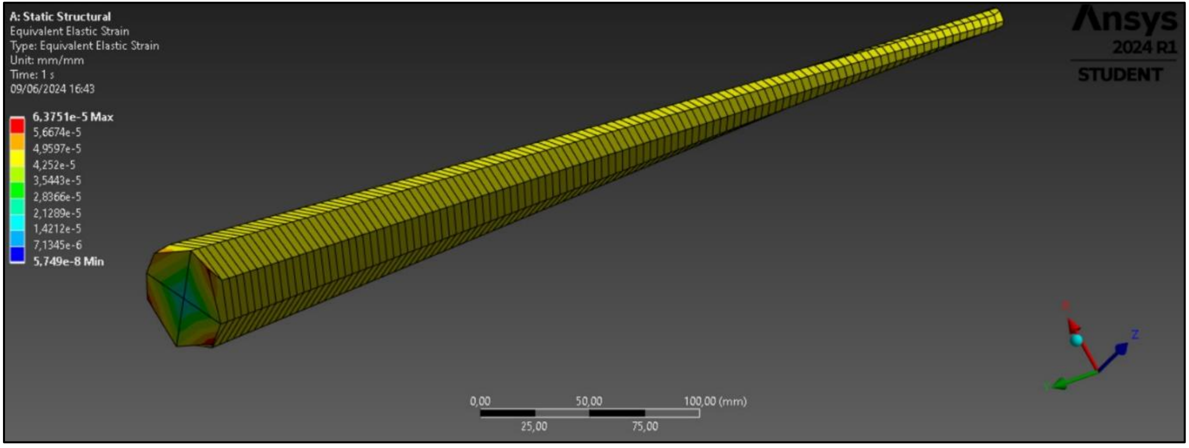
SIMULATION FOR STAINLESS STEEL MATERIAL WITH SHAFT DIAMETER EQUAL TO 10 MM

Figure 10: Total deformation of 10mm stainless steel shaft



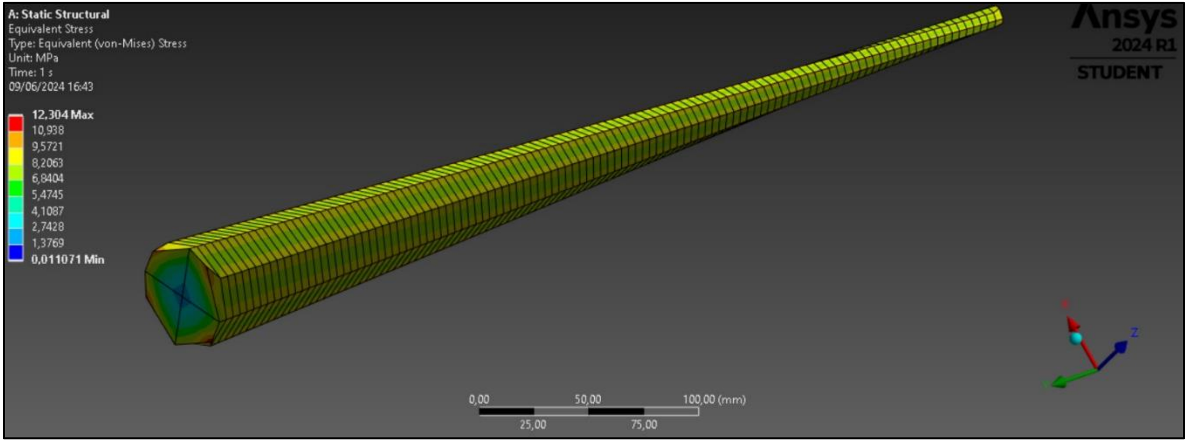
Source: Authors, 2024

Figure 11: Strain of 10mm stainless steel shaft



Source: Authors, 2024

Figure 12: Stress of 10mm stainless steel shaft



Source: Authors, 2024

DISCUSSION

The results indicate that for carbon fiber to achieve the same mechanical strength as stainless steel, the diameter of the carbon fiber shaft would need to be significantly larger. This increase in diameter compromises the fit of other components and the fluid dynamic efficiency of the nautimodel. In addition, factors such as greater difficulty in manufacturing, risk of delamination, and high cost reduce the feasibility of using carbon fiber, despite the weight reduction.

The comparative results are shown in the table below

Table 1: Comparison between the results of the simulations.

Material	Diameter (mm)	Total Deformation (mm)	Strain (mm/mm)	Stress (Mpa)
Carbon Fiber	10	0,73981	0,00267	13,119
	15	0,17619	0,00048	2,8947
	20	0,07445	0,00025	3,3872
Stainless Steel	10	0,03375	0,00006	12,304

Source: Authors, 2024

FINAL THOUGHTS

The analysis showed that the marginal gains in terms of weight reduction when using carbon fibre axles do not outweigh the associated negatives. The need to increase shaft diameter to achieve strength comparable to stainless steel, along with manufacturing difficulties and high costs, make carbon fiber shafts less attractive for model applications.

It would be more useful to continue the studies with variable geometries of the axes and diameters to finally arrive at definitive considerations.

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