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Design and Analysis of a Propeller Blade Used for Marine Engine

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ABSTRACT

Most of the marine propellers are made of metal material such as bronze or steel. The advantages of replacing metal with CFRP composite materials are that the latter is lighter and corrosion-resistant. Another important advantage is that the deformation of the composite propeller can be controlled to improve its performance. Propellers always rotate at a constant velocity that maximizes the efficiency of the engine. When the ship sails at the designed speed, the inflow angle is close to its pitch angle. When the ship sails at a lower speed, the inflow angle is smaller. Hence, the pressure on the propeller increases as the ship speed decreases. The propulsion efficiency is also low when the inflow angle is far from the pitch angle. If the pitch angle can be reduced when the inflow angle is low, then the efficiency of the propeller can be improved. In addition the load-bearing fibers can be aligned and stacked to reduce fluttering and to improve the hydrodynamic efficiency. Composites can offer the potential benefits of reduced corrosion and cavitations damage, improved fatigue performance, lower noise, improved material damping properties, and reduced lifetime maintenance cost. Traditionally marine propellers are made of manganese-nickel-aluminum-bronze (MAB) or nickel-aluminum-bronze (NAB) for superior corrosion resistance, high-yield strength, reliability, and affordability.

Keywords: Marine engine propeller, composite material, Ansys, ship building.

I. INTRODUCTION

Flexible composite marine propellers, made of fiber-reinforced plastic (FRP) composites, have a number of advantages over conventional rigid metallic propellers. In particular, composite propellers have great potential for performance improvement. Fluid–structure interaction effects are utilized to improve the performance of composite marine propellers under a wide range of operating conditions [1]. Two important mechanisms, namely, the bending twisting coupling effects of anisotropic composites and load-dependent self-adaptation behavior of composite blades are the primary sources for performance improvement of composite marine propellers. Systematically designed self twisting composite propellers are evaluated under both steady and unsteady operating conditions. Finally they showed that the self-twisting propeller leads to significant improvement in energy efficiency over its rigid counterpart [2].In reliability-based design and optimization of adaptive marine structures have objectives to quantify the influence of material and operational uncertainties on the performance of self-adaptive marine rotors, and to develop a reliability-based design and optimization methodology for adaptive marine structures. Using a previously validated 3D fluid–structure interaction model, performance functions are obtained and used to generate characteristic response surfaces. The results demonstrate the viability of the proposed reliability-based design and optimization methodology, and demonstrate that a probabilistic approach is more appropriate than a deterministic approach for the design and optimization of adaptive marine structures that rely on fluid–structure interaction for performance improvement [3]. The strength of a composite propeller blade is evaluated by performing a nonlinear hydro elastic analysis. The strength of the blades with balanced and unbalanced stacking sequences are evaluated and discussed. Five failure modes, fiber tension and compression, matrix tension and compression, and delimitations are considered [4].The aim of hydro elastic analysis and optimization of a composite marine propeller to tailor the laminate to control the deformed shape of the blade and consequently the developed thrust. The development of a hydro-elastic model is presented, and the laminate lay-up which minimizes the fuel consumption for the cruising and maximum speed conditions is simultaneously determined. Results show a reduction of 1.25% in fuel consumption for the combined case corresponding to a decrease of 4.7% in the cruising speed condition. Finally, the strength of the optimal blade is analyzed using the Tsai-Wu strength index. The results suggest that it is possible to design a medium-sized flexible composite marine propeller that will enable a reduction of the fuel consumption while withstanding the imposed loads [5]. The performance of the metallic and composite propellers are compared and discussed in performance-based design and analysis of flexible composite propulsors. The implications of load-dependent deformations of the flexible composite propeller on the operating conditions and the resulting performance with respect to propeller efficiency, power demand, and fluid cavitations are presented for both spatially uniform and varying flows. A global performance-based design and analysis methodology is presented for both rigid and flexible marine propellers. Comparisons of the steady and unsteady performances of the two propellers are shown. The results show that it is critical to consider the full operational space when designing or analyzing adaptive propellers because of the load-dependent blade deformation responses [6].[7] aims to overcome disadvantages of the present machining method of propeller, such as lower machining precision and efficiency, repeated clamping, and limited machining scope, a new machining method, the second order osculating machining method has been presented. The results shown by using the side milling machining method, the propeller can be machined at a single clamping and the set-up time can be reduced. Also, it is very suitable for the machining of propeller with larger area ratio and the machining precision and efficiency could be improved remarkably [7].

A. Carbon Fiber Reinforced Plastic

High-performance marine propeller requires an extra high strength-to-weight ratio material. Fabrication of composite materials satisfies this special requirement. Composite materials are constructed by using several layers of bonding materials (graphite epoxy or boron epoxy). These materials are mechanically fastened to conventional substructures. Another type of composite construction consists of thin graphite epoxy skins bonded to an aluminum honeycomb core. Carbon fiber is extremely strong, thin fiber made by heating synthetic fibers, such as rayon, until charred, and then layering in cross sections.

B. MODELING OF PROPELLER BLADE

CATIA-V5 is the industry's de facto standard 3D mechanical design suit. It is the world's leading **CAD/CAM /CAE** software, gives a broad range of integrated solutions to cover all aspects of product design and manufacturing. Much of its success can be attributed to its technology which spurs its customer's to more quickly and consistently innovate a new robust, parametric, feature based model. Because that CATIA-V5 is unmatched in this field, in all processes, in all countries, in all kind of companies along the supply chains. Catia-v5 is also the perfect solution for the manufacturing enterprise, with associative applications, robust responsiveness and web connectivity that make it the ideal flexible engineering solution to accelerate innovations. Catia-v5 provides easy to use solution tailored to the needs of small medium sized enterprises as well as large industrial corporations in all industries, consumer goods, fabrications and assembly. Electrical and electronics goods, automotive, aerospace, shipbuilding and plant design. It is user friendly solid and surface modeling can be done easily.

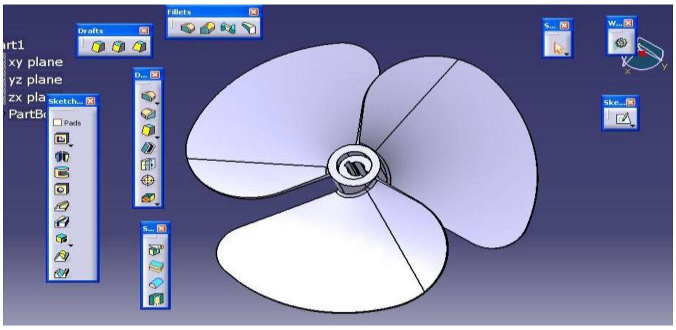


Figure 1.1: Model of a Propeller Blade

II. RESULTS AND DISCUSSION

The results obtained have been analyzed.

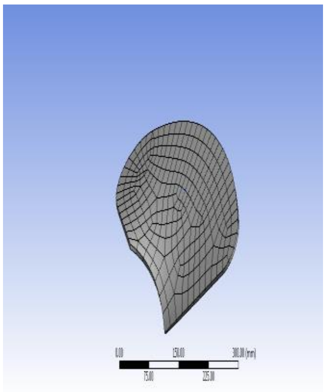


Figure 2.1: FE Model of the Propeller Blade

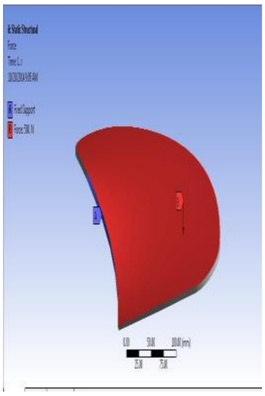


Figure 2.2: FE Model with Boundary conditions

A. Static Structural Results of E-glass Material

Case- 1: 500 N Load.

Case- 2: 1000 N Load.

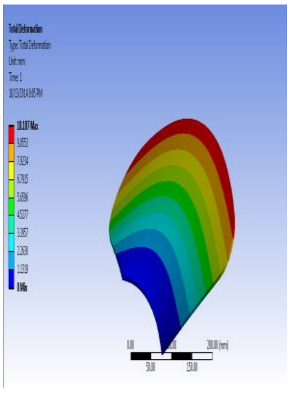


Figure 2.3: Total Deformation of E-Glass.

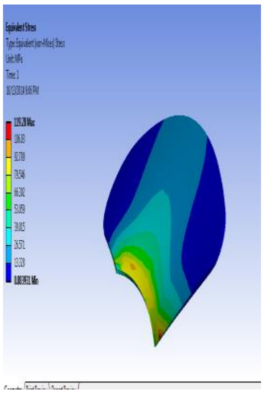


Figure 2.4: Total Deformation of E-Glass.

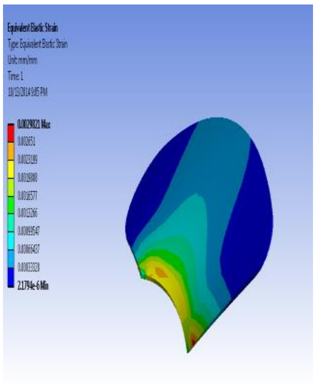


Figure 2.5: Equivalent elastic strain E-Glass.

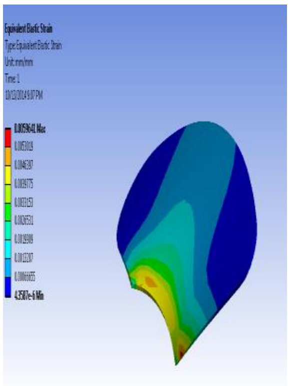


Figure 2.6: Equivalent elastic strain distribution on E-Glass.

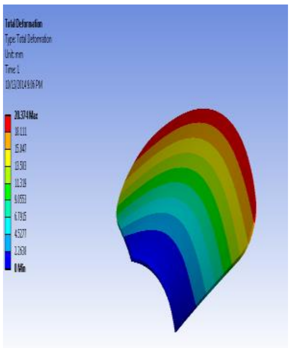


Figure 2.7: Equivalent Stress in E-Glass.

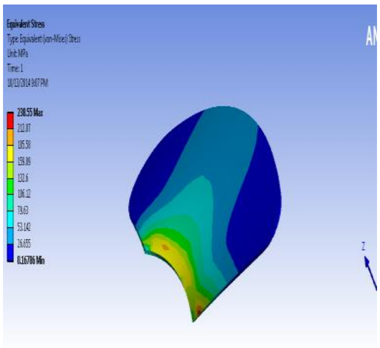


Figure 2.8: Equivalent Stress in E-Glass.

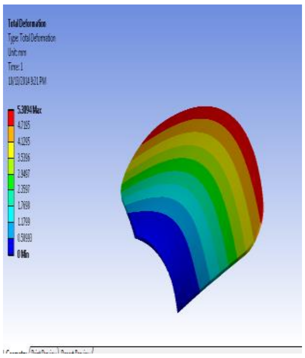


Figure 2.9: Total Deformation in Aluminum.

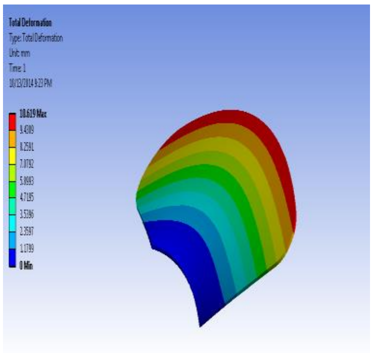


Figure 2.10: Total Deformation in Aluminum

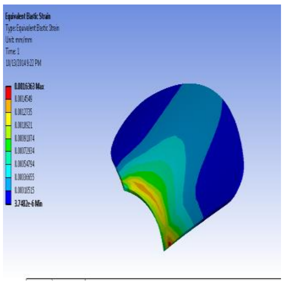


Figure 2.11: Equivalent Elastic Strain Distribution in Aluminum.

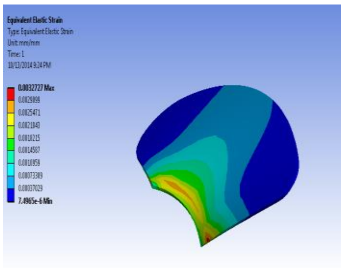


Figure 2.12: Equivalent Elastic Strain Distribution of Aluminum.

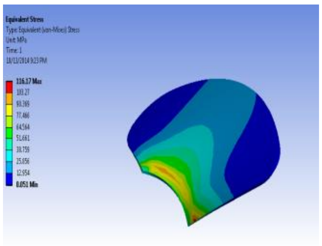


Figure 2.13: Equivalent Stress of Aluminum.

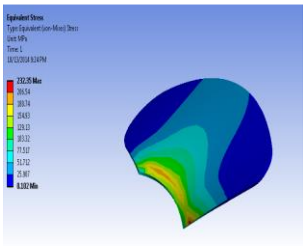


Figure 2.14: Equivalent Stress of Aluminum.

Case-3. 1,500 N

Case-4. 2,000 N Load

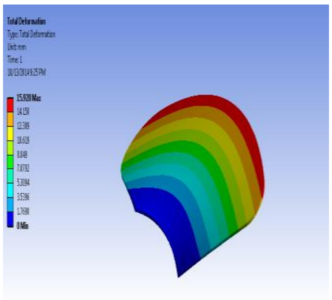


Figure 2.15: Total Deformation of Aluminum.

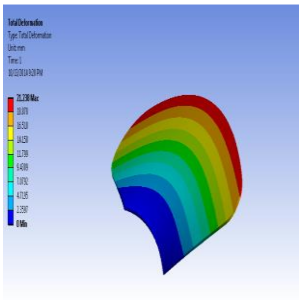


Figure 2.16: Total Deformation of Aluminum

Case-3. 1,500 N

Case-4. 2,000 N Load

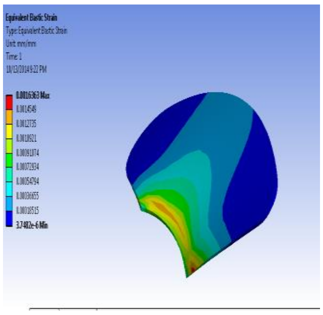


Figure 2.17: Equivalent elastic strain distribution in Aluminum.

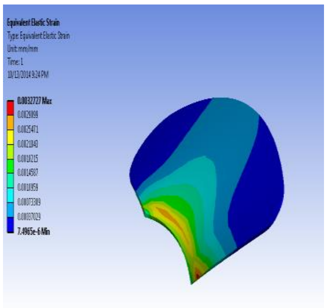


Figure 2.18: Equivalent elastic strain distribution in Aluminum.

Case-3. 1,500 N

Case-4. 2,000 N Load

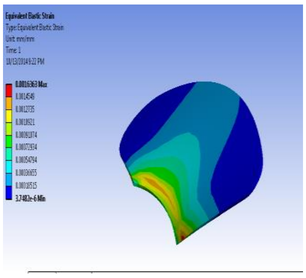


Figure 2.19: Equivalent stress in Aluminum.

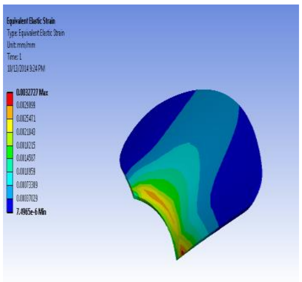


Figure 2.20: Equivalent stress in Aluminum.

B. Static Structural Results of Kevlar Material

Case-1. 500 N

Case-2. 1,000 N Load

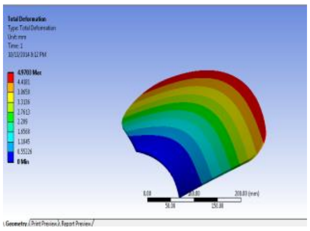


Figure 2.21: Total deformation of Kevlar (CFRP)

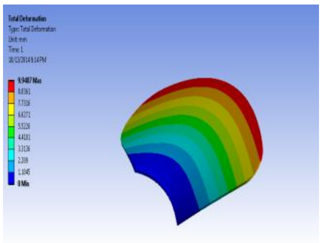


Figure 2.22: Total deformation of Kevlar (CFRP)

Case-1. 500 N

Case-2. 1,000 N Load

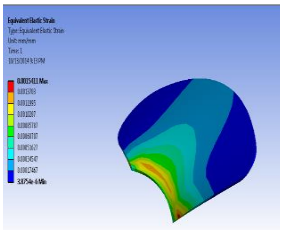


Figure 2.23: Equivalent elastic strain distribution of Kevlar (CFRP).

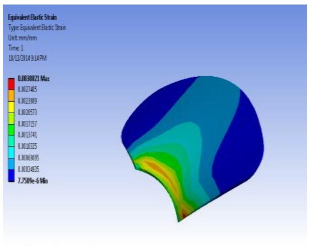


Figure 2.24: Equivalent elastic strain distribution of Kevlar (CFRP).

Case-1. 500 N

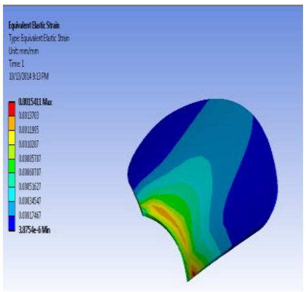


Fig. 2.25: Equivalent stress in Kevlar (CFRP).

Case-2. 1,000 N Load

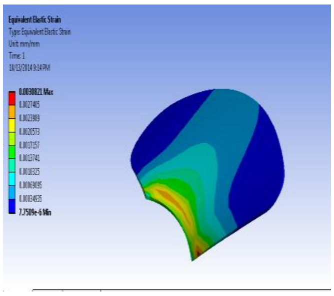


Fig. 2.26: Equivalent stress in Kevlar (CFRP).

Case-3. 1,500 N

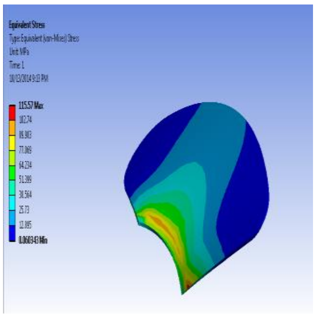


Fig. 2.27: Equivalent stress in Kevlar (CFRP).

Case-4. 2,000 N Load

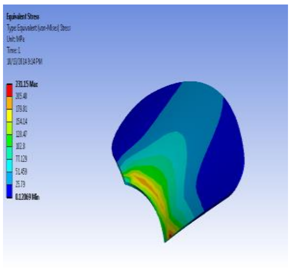


Fig. 2.28: Equivalent stress in Kevlar (CFRP).

Case-3. 1,500 N

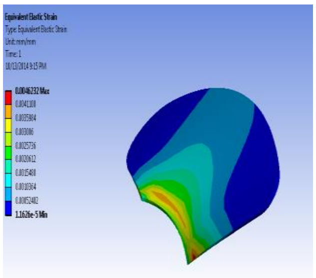


Fig. 2.29: Equivalent elastic strain distribution in Kevlar (CFRP).

Case-4. 2,000 N Load

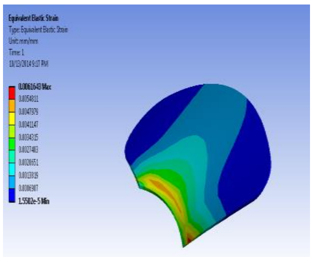


Fig. 2.30: Equivalent elastic strain distribution in Kevlar (CFRP).

Case-3. 1,500 N

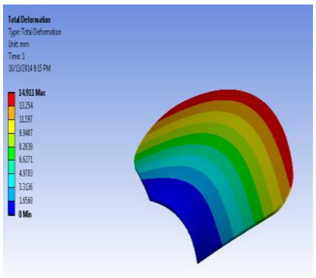


Figure 2.31: Total deformation of Kevlar(CFRP).

Case-4. 2,000 N Load

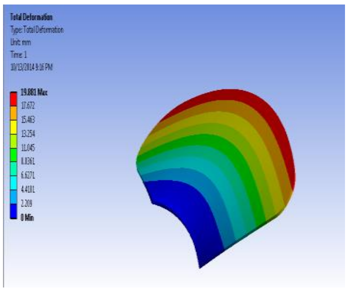


Figure 2.32: Total deformation of Kevlar (CFRP).

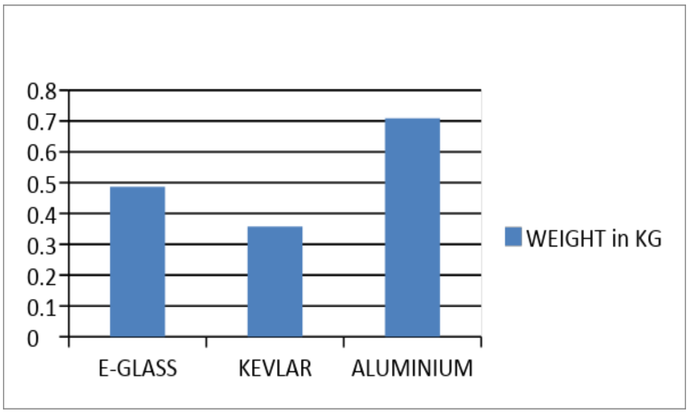


Figure 2.33 : The comparison of weights of the three materials.

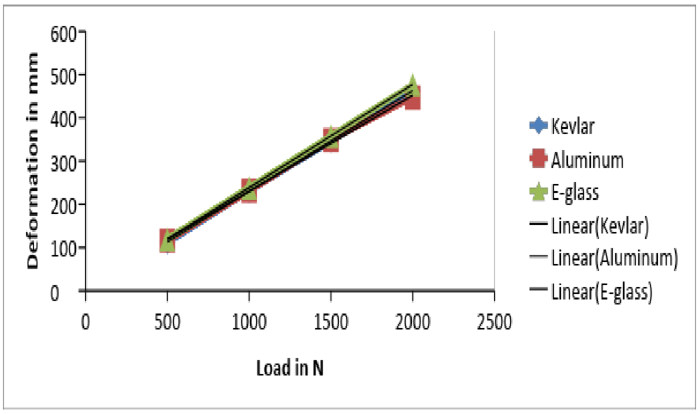
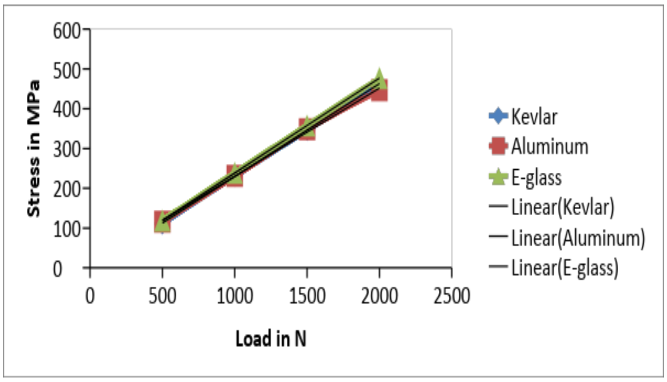
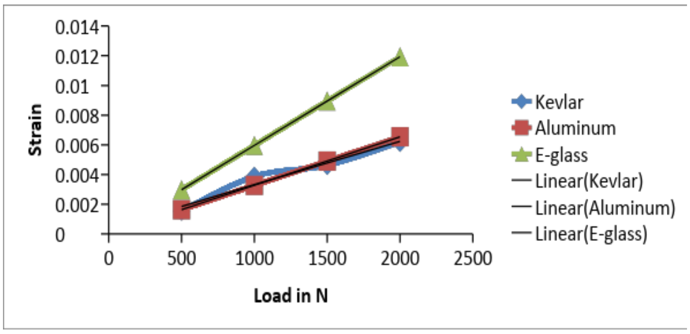


Figure 2.34 : The comparison of weights of the three materials.

From the above Deformation results graph, it is observed that the Kevlar is best for propeller Blade according to rigidity criteria.



From the above Stress distribution graph, it is observed that Kevlar made material is best for propeller blade according to strength criteria. From the above Strain distribution graph Kevlar (CFRP) material made propeller Blade is best material for propeller Blades.



III. CONCLUSION

We conclude that composite propellers have more advantages over the conventional metallic propellers. We concentrated on the metal and composite structural analysis of the propeller blade carried out by using the finite element method Analysis. By comparing the deformation we can say that Kevlar will be having more advantages. Kevlar can with stand more amount of stress when compared with Aluminum, E-glass and by seeing the weight comparison Kevlar is having less weight when observed with E-glass and Aluminum materials.

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