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ANALYSIS OF TURBOPROP BLADE UNDER DIFFERENT LOADING CONDITIONS

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ABSTRACT:

This paper's goal is to determine the best material for propeller cutting edges. The method used for this study is to design the NACA 4412 propeller model is analyzed using numerical methods and validated by theoretical methods in order to find maximum stress and distortion area. It shows that the centrifugal stress for titanium is increased 100% than fiber reinforced plastic composites. In the present study static analysis of structure is analyzed using different materials and its stress and deformation values are obtained. This novel concept is used for the entire turbo prop and piston engine propeller to enhance the life time by introducing the new material. Also this concept will be used for existing and upcoming aircrafts.

Keywords: Aerofoil, CATIA, Deformation, Fiber Reinforced Plastic Composites (FRPC), Maximum stress.

1. INTRODUCTION

Nowadays trainer and domestic aircrafts are using the propeller attached engine for safe and efficient operations. Due to the development of domestic airline services all over the world it leads to focus on improve the performance of those aircrafts. In this point of view many researchers are working to enhance the performance of aero plane also improves the life time of the propeller blade to achieve thetarget by changing the design and materials.

H. Roy Lange [1], F. Farassat et al. [2], J.A. Liser et al.[3], P.K. Singh et al.[4] studied the thrust power generation methods and its analysis. Although thrust is normally produced by some application of Newton's Third Law, there are numerous types of drive frameworks that create it in various ways. Praveen and Merugu [5] studied a static analysis of an aeroplane propeller blade was conducted, it was discovered that as the speed of the propeller increased, the stress values increased as well. Carbon fibre experienced lower stress values than E-glass and aluminium alloy. Because carbon epoxy is a composite substance, it is stronger.Jiyuan Tu et al.[6] stated that general goal was to estimate the temperature on propeller surface when the engine is running at full power and aircraft is in static condition by utilizing the

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commercial CFD tool ANSYS Fluent to simulate the flow field around the nacelle and propeller. J. M. Bousquet and P. Gardarein [7] did research on ways to improve high speed propeller unsteady aerodynamics simulations. The use of a numerical solver to compute unsteady effects in the aerodynamic interaction of a high speed propeller is the study of this paper. Young, Y. L., and Motley [8] fluid structural interaction of flexible composite marine propellers is investigated using the coupled BEM-FEM approach. Additionally, the impact of material and loading effects on propellers manufactured of advanced materials was explored. Changduk Kong and Kyungsun Lee [9] conducted the structural and aerodynamic design work for a regional turboprop aircraft's composite propeller blade. High speed turboprop aircraft's thin and wide chord propeller blades need to be strong and rigid enough to support a variety of loads, including strong centrifugal forces and high aerodynamic bending and twisting moments. HN Das et al., [10] showed how the CFD codes may be used to study complex 3D flows to aid in the design of such pump jet propulsions. Hyeonsoo yeo and Wayne Johnson [11] investigated the propeller blade performance, loads, and stability data remained constant after several iterations, the design process was considered finished. J. E. Ffowcs-Williams and D. L. Hawkings [12] demonstrated that, in theory, the noise can be precisely estimated if specific aerodynamic quantities, the theoretical foundation for studying this kind of problem was established. Mahesh Malia et.al [13] studied the methodology and model are satisfactory will be used to perform dynamic analysis considering the flight envelope with propeller rotation. Ross J. Higgins [14] studied the flutter boundary's impact on Mach number and structural damping was the main goal.J.Čerňan et al., [15] reveal the fan, the most significant component of the engine and the source of a significant portion of its tensile force, is the subject of this study. It is a substantially loaded component in this instance as well. Utilizing the finite element approach, a stress and strain analysis was carried out for the purpose of verifying and designing appropriate geometry, and the results demonstrated the suggested solution's resistance to static load conditions.Pankaj Kumar Singh et al., [16] includes a few quick facts on Fiber Reinforced Plastics and the advantages of using composite propellers over traditional metallic ones. This research focuses on the limited component examination-based metal and composite quality assessment of the propeller cutting edge. Ross J. Higgins et.al [17] found the option of refining the operating conditions to provide even larger variations in aerodynamic twisting moment in attempt to trigger greater variations in local, sectional incidence and therefore larger amplitude force oscillations. Gábor Zipszer et al., [18] study the baseline model was modified to have a thorough engine bay. The features of the water and oil cooler units were extracted from explicit CFD simulations and represented as porous zones in the model. Harry S. Wainauski et al., [19] calculated the centre point to the sharp edge's tip, the propeller's diameter can be computed using several different excellent methods. The propeller could detach once more from the circle it is now rotating in.Takestani et al.[20] research was done on the effect of composite materials on ship propeller performance.. Blasques, J. P et.al [21] concluded that more research is needed than ever on composite materials because of their expanding applications.Cho, J., and Lee [22] concluded that Structure analysis is challenging. Numerous academics have used analytical and computational techniques to ascertain how the propeller's fluid-structure interactions.

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The literature concluded that study about the different analysis of propeller blades to identify the flow over the blade and structural analysis. In that very little research work is focus on the study of maximum stress and deformations. The objective of the research work is to analyse the suitable material for minimizing the stress and deformation of turbine blades using titanium and composites materials.

2. Materials and Methods

The study was conducted using the simulation methods. The model is designed by using the CATIA software as shown in fig 1. Later the model is imported into the ANSYS software for further analysis. The length of the propeller is 80 cm and width of the propeller is 12 cm and it is placed with 83^0.The total number of propeller used for the work is three which is placed at 120^o with each other.

Fig 1. Model of Propeller

2.1 Meshing

The model is divided into small elements to attain the good results. In that Triangular mesh was used for this study. The nodes and elements are finalized from the literature survey. The mesh is applied for the blade as well as the hub. It is given the certain naming to provide the boundary conditions at the required locations

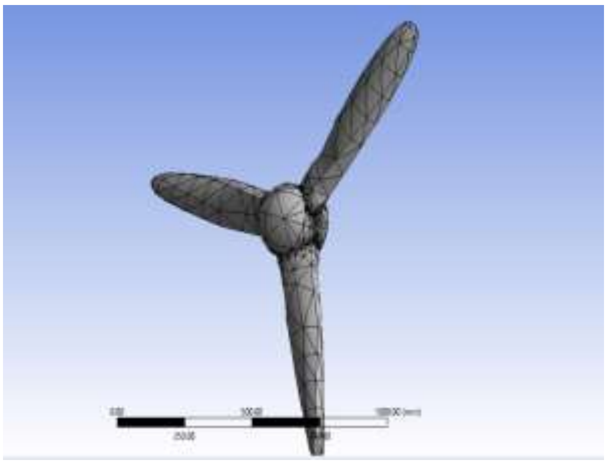

Fig 2. Meshing of the Propeller Model

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2.2 Boundary Conditions

The meshed model is imported into the ANSYS setup file. Numerical analysis of propeller blade is done by using titanium and composites materials. In this regard the boundary conditions for the analysis are given the properties of the same materials. As well as in the design the hub is fixed and propellers are moving with high velocity. The force applied for the work is 0 to 30000 N.

3. Results and Discussions:

The static structural analysis was carried out from the numerical analysis and the stress and strain values are attained for both different materials. The results details are explained below.

3.1 Von misses stress:

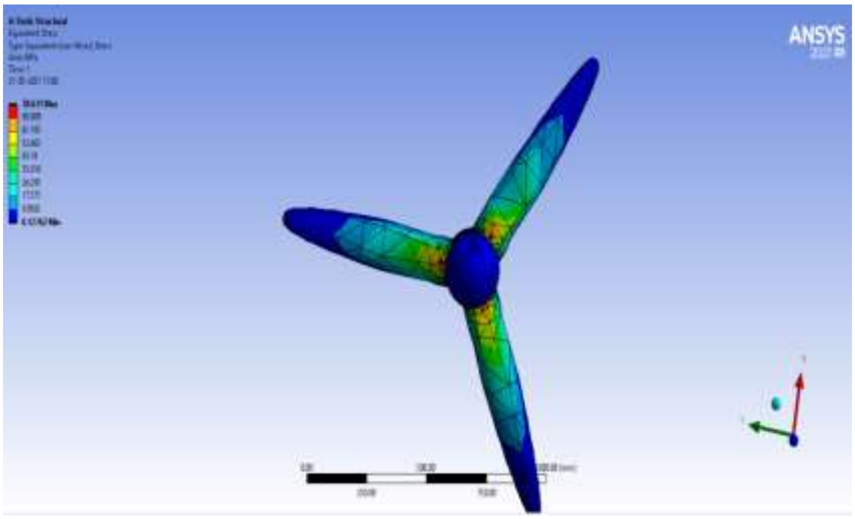

Fig 3. Von misses stress for different materials

Fig 3 shows that the stress acting over a rotating aerofoil with the applied load of 30000N is used to generate the stress of 78.63 Pascal for titanium blade materials. At the same time composites blades are creating 60 Pascal.The reason behind that is the titanium materials weight are high compare to that composite materials. This leads to enhance the stress 30% compare to the composites material blade. In that stress values are increased towards the hub from the leading edge.

3.2 Deformation

The deformation levels also absorbed to analyse the vibration and other characteristics. Fig 4 shows that the deformation level of propeller blade for different materials. It shows that the maximum deflection of titanium material is 0.94 mm and composite material is 0.86mm.It shows that the deformation level is increased from hub to tip for both materials due to the hub is fixed and tip is free to rotate. The overall deformation is reduced by 9% compared to titanium materials

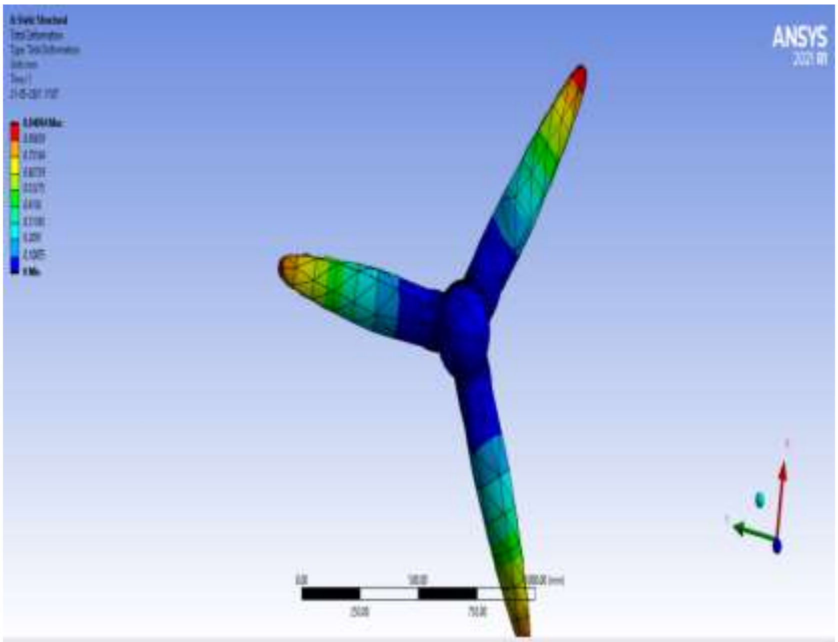

Fig 4. Deformation of Propeller blade

4. Validation of results

The validation of simulation work is achieved by the theoretical study. The theoretical equations used for this work is shown in Equation no 1,2 &3.

Direct stress is calculated by using the equation (1)

$$\sigma_{direct} = \frac{P}{A_{min}} \quad (1)$$

Bending stress is identified by using the equation (2)

$$\sigma_{bending} = \frac{P_e}{I} y \quad (2)$$

The maximum stress acting over the propeller is mentioned in eqn (3)

$$\sigma_{max} = k_t(\sigma_{direct} + \sigma_{bending}) \quad (3)$$

From the above equations the theoretical and simulation results are compared and listed in Table1. It shows that the difference between the simulations and theoretical analysis is less than 5%.It shows that the analysis results are well aligned with theoretical results.

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Table 1: Comparison between theoretical and simulation results

Sr.No	Parameters	Simulation	Theoretical	Difference (%)
1	Maximum stress for titanium	78.3	75.2	4
2	Maximum stress for composites	60.89	58.23	4

5. Conclusion:

The propeller model is designed by using the CATIA software and analyzed by ANSYS brought the maximum stress and deformation values for different propeller blade materials. It brought the following conclusions

- The fiber reinforced plastic composites are producing less stress compared to the titanium materials
- Deformation level is reduced by 9% compared to the titanium materials
- The overall aerodynamic forces produced by the propeller is 79.41KN
- The Centrifugal force developed by the FRPC is 1501.54 KN and Titanium is 3079.54KN which is 100% higher
- Lift force developed by the model is 58.22KN and drag Force is 44.86KN

The overall performance of a propeller blade is enhanced by using the fiber reinforced plastic composites. It can be used for all commercial and trainer aircrafts

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