Structural Analysis on Composite Tail Rotor Blade of Helicopter

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ABSTRACT -**The main objective of this work is to determine the dynamic properties in the frequency domain of aircraft structural elements is a very important aspect taken into account nowadays by aircraft manufacturers. One of the helicopters most exposed element to structural vibrations is the rotor blade, thus making its construction and the material choice a very important decision. Finite element methods can be used to assess the dynamic structural properties of such elements, in order to prove their airworthiness. The main objective of the project is to study how the use of different materials affects the structural behaviour of the helicopter tail rotor blade, with regard to the frequencies at which these structures are prone to vibrate. The blade profile is the NACA0012 symmetric aerofoil used on the IAR330 helicopter tail rotor blade and the main objective is to identify the best inner core material, while highlighting the importance of composite materials and the structural analysis of material by which the blade is to be made up.**

Keywords–Design, Structural Analysis, Helicopter tail Rotor Blade.

I. INTRODUCTION

The structural analysis of the helicopter tail rotor blade is one of the most important procedures that such a structure must undergo in order to be certified as airworthy and to be released into production. Thanks to the use of modern finite element simulation programs such as Ansys, the design and fabrication of these aero elastic structures improved significantly. The objective of modal analysis is to determine the dynamic characteristics of a structure, thus allowing researchers to study the natural frequencies and modal shape results. Understanding of the structural behaviour of the helicopter tail rotor blade when exposed its eigenfrequencies is important in order to help maintain aircraft safety requirements at a high standard. Mass and rigidity are the two key parameters involved in the vibration analysis which can be varied within certain limits in order to achieve or avoid the appearance of resonance during flight conditions. The main disadvantage of high vibration levels is the reduction of the fatigue life of certain structures, and when referring to the helicopter tail rotor blade, this can be a major issue because it is an essential element in ensuring the directional yaw control of the helicopter. such as the appearance of flutter (a dynamic instability of an aero elastic structure which can develop uncontrollably and cause serious damage or even material failure) and the blade divergence (characterized by the surface deflection of the lifting surface under aerodynamic load in a direction which further increases lift in a positive feedback loop). It describes a method of realizing a modal analysis by considering an aircraft wing with a similar NACA aerofoil as the tail rotor blade, as a cantilever beam, while ignoring the forces acting on the aircraft (except gravity). The results showed that the modal analysis validated the theoretical calculations in a certain amount, but unfortunately,they were not validated experimentally. The methodology is promising and could be applied in the same matter on the helicopter tail rotor blade of the IAR330 helicopter, taking into account that the blade has a constant profile along it's length and is not geometrically twisted.

The mechanical response of different types of helicopter blades and the possibility of replacement of the metal components with composite materials in their construction is currently the subject of extensive scientific research, with both numerical analyses and experimental tests being undertaken in recent years As discussed in abstract of this project, the material by which we made the helicopter tail rotor blade is with composite material that have many benefits as compared to metal assembly or metal part. Composite materials undoubtedly represent the future of aircraft manufacturing. This tendency has increased over the past decade, with modern aircraft containing high percentages of fibre-reinforced plastics and lightweight cores coming out of the production lines. Although the benefits are clearly visible, the high cost of transition to a modern aircraft can be diminished by replacing certain metallic components of aeroplanes or helicopters of older generations with composite ones, thus enhancing the overall performance and increasing the lifetime of the whole structure. The main advantages of composites, as opposed to metallic components, include the following: a high strength-to-weight ratio (the mass density of carbon fibre is about 24% of one of steel and about 70% of an aluminium one) , proven durability expressed by reduced maintenance costs and long-term stability, new design possibilities (a composite component can replace an entire metal assembly).

The currently used aluminium tail rotor blade of an IAR330 helicopter has a length of 1244.3 mm, being characterized by an NACA0012 symmetric airfoil and no blade twist along the length of the blade. The chord measures 186.5 mm, and the total mass is approximately 2.68 kg. A model of the aluminium blade during aerodynamic analysis inside a subsonic wind tunnel is presented. The components of the current version of the tail rotor blade are manufactured from three aluminium alloys with different physical and mechanical properties, capable of withstanding in-flight loads. The shape of the newly proposed blade has not been the subject of any adaptation since it is designed to equip the same helicopter as the metal blade, with the enhanced performances being only the result of material upgrades.

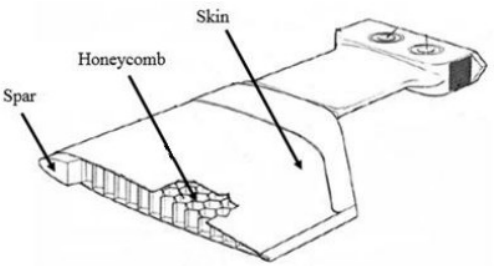


Figure 1:IAR330 helicopter tail rotor blade.

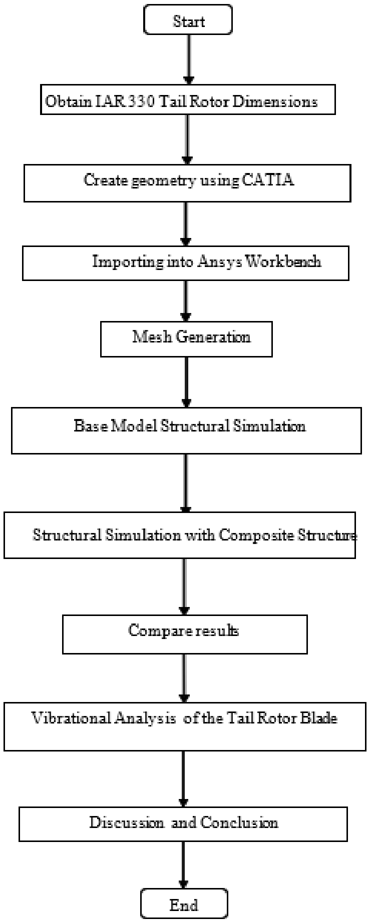
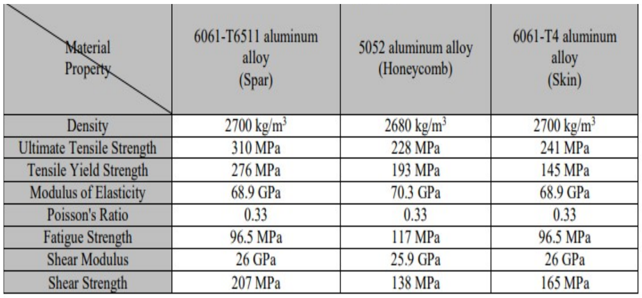
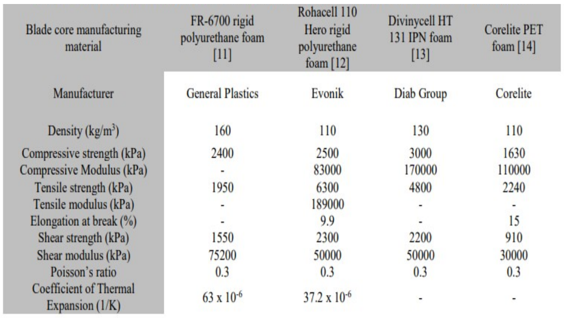


Figure 2: Methodology



Material Property	6061-T6511 aluminum alloy (Spar)	5052 aluminum alloy (Honeycomb)	6061-T4 aluminum alloy (Skin)
Density	2700 kg/m^3	2680 kg/m^3	2700 kg/m^3
Ultimate Tensile Strength	310 MPa	228 MPa	241 MPa
Tensile Yield Strength	276 MPa	193 MPa	145 MPa
Modulus of Elasticity	68.9 GPa	70.3 GPa	68.9 GPa
Poisson's Ratio	0.33	0.33	0.33
Fatigue Strength	96.5 MPa	117 MPa	96.5 MPa
Shear Modulus	26 GPa	25.9 GPa	26 GPa
Shear Strength	207 MPa	138 MPa	165 MPa

Table 1: Material properties of the aluminium alloys used for the IAR330 tail rotor blade



Blade core manufacturing material	FR-6700 rigid polyurethane foam [11]	Rohacell 110 Hero rigid polyurethane foam [12]	Divinycell HT 131 IPN foam [13]	Corelite PET foam [14]
Manufacturer	General Plastics	Evonik	Diab Group	Corelite
Density (kg/m^3)	160	110	130	110
Compressive strength (kPa)	2400	2500	3000	1630
Compressive Modulus (kPa)	-	83000	170000	110000
Tensile strength (kPa)	1950	6300	4800	2240
Tensile modulus (kPa)	-	189000	-	-
Elongation at break (%)	-	9.9	-	15
Shear strength (kPa)	1550	2300	2200	910
Shear modulus (kPa)	75200	50000	50000	30000
Poisson's ratio	0.3	0.3	0.3	0.3
Coefficient of Thermal Expansion (1/K)	63 x 10^{-6}	37.2 x 10^{-6}	-	-

Table 2: Material properties of polymer foams used for aerospace applications.

II. DESIGN OF HELICOPTER TAIL ROTOR BLADE

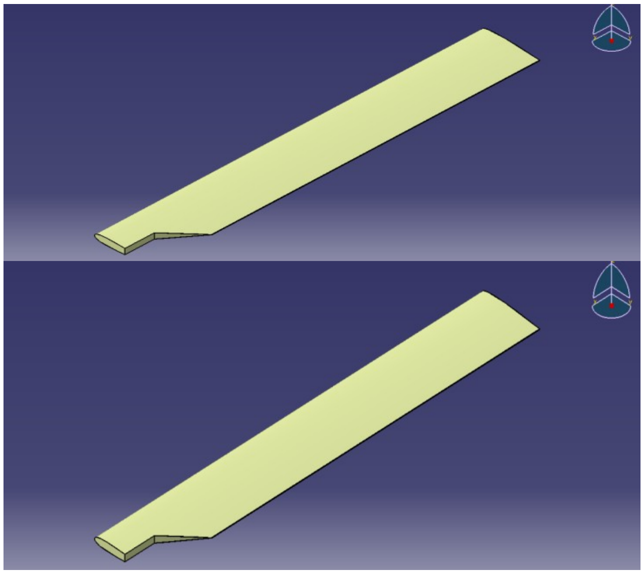


Figure 3: Design of Tail Rotor Blade

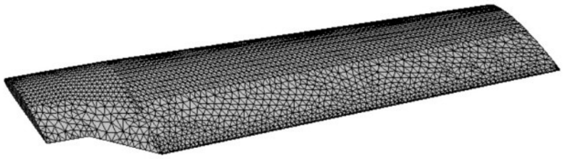


Figure 4: Meshing of Tail Rotor Blade

III. STRUCTURAL ANALYSIS RESULTS

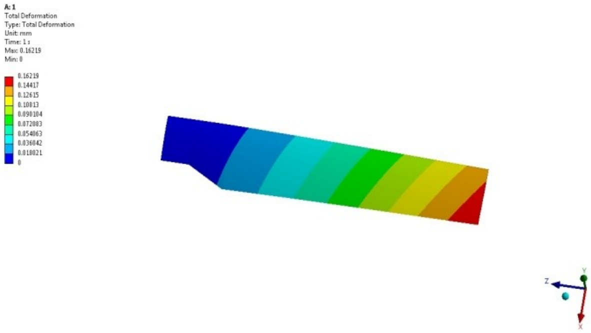


Figure 5: Total Deformation Contour for baseline Tail Rotor Blade

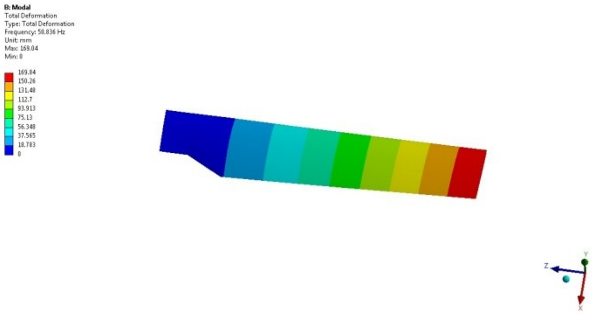


Figure 6: Modal Analysis Contour for baseline Tail Rotor Blade

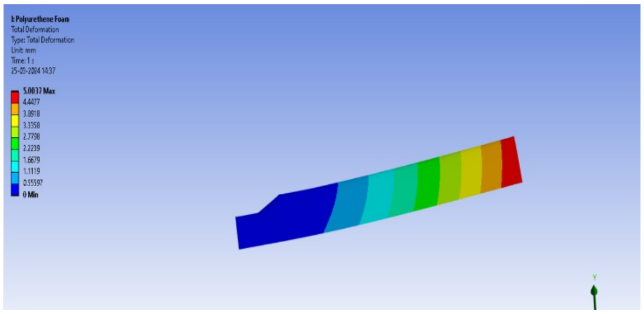


Figure 7: Total Deformation Contour for baseline Tail Rotor Blade with Polyurethane Foam Core

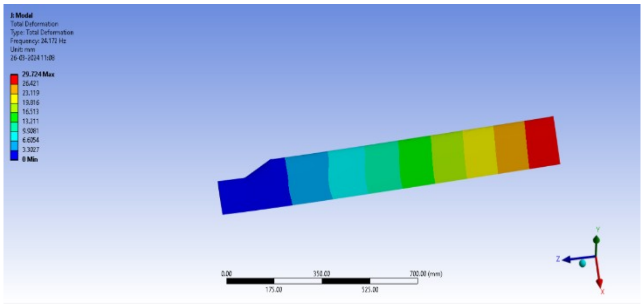


Figure 8: Modal Analysis Contour for baseline Tail Rotor Blade with Polyurethane Foam Core

V.CONCLUSION

- The numerical analysis results suggest, in terms of increasing the natural frequencies, that the polyurethane foam offers the optimal solution with the cost of an increase in the amplitude of the maximum total deformation. Also, taking into account that it has the lowest density, along with the polyurethane foam, implementing it in the tail rotor blade structure which offers a significant mass reduction of approximately 36.5% in comparison to the initial metal blade.
- Also, the stiffening effect generated by the blade rotation has been discussed and the results indicated than the presence of the centrifugal

force on the rotating blade is responsible for a mean frequency reduction of approximately 17% for all previously discussed materials, in comparison with the natural frequencies of the blade without pre-stress. In conclusion, the polymer foam structure of the tail rotor blade offers a higher degree of rigidity and if practically realized, enhances the performance of the entire IAR330 helicopter.

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