International Journal of Research
Available at https://edupediapublications.org/journals

e-ISSN: 2348-6848
p-ISSN: 2348-795X
Volume 04 Issue 09
August 2017

Optimization of Helic, Opter Rotor Blade by Using Ansys Software

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ABSTRACT

The blade of the helicopter was affected by flow of air. The effects or loads caused by both aerodynamic action and centrifugal action are considered for analysis of the blade. The objective is to reduce the weight of the blade to reduce the load caused by aerodynamic load. The weight of the blade can be reduced by choosing of alternative material. Selection of alternative material (i.e. to reduce the weight) is called as optimization. The alternative material should have less weight and high stiffness. The optimization can be done by CAE package.

The objective of the project is to perform the structural analysis on the helicopter blade. Structural analysis involves both static and modal analysis. In static analysis, deflections and stresses are documented for forces due to aerodynamic action of the blade. Then modal analysis is performed to determine the natural frequencies. Based on the natural frequencies, the stiffness of the material can be determined. The structural analysis of the blade is performed for different materials (aluminum alloy and Eglass Epoxy and Carbon Epoxy materials). Based on the analysis results, best material is preferred. NX-CAD software is used to model the blade and ANSYS software is used for analysis of the blade.

INTRODUCTION

During the motion of the airplane or helicopter in the air, lift force was created by wings of the airplane or helicopter. Generally four forces are impacted on the helicopter in the flight of the helicopter. They are LIFT, DRAG, THRUST, and WEIGHT. As we know that, the movement of the helicopter is due movement of wings. In the movement of helicopter, the body of the helicopter is stationary while the wings are moving along with the helicopter. Those helicopter wings are called as Main Rotor Blades. Lift force is determined by the design of the blade. The design of blade incudes design angle of the blades and shape of the blade. The forward or backward or sideward tip of the helicopter is due to tilt of the wings by the pilot after the lift of helicopter from the ground.

Helicopters come in many sizes and shapes, but most share the same major components. These components include a cabin where the payload and crew are carried; an airframe, which houses the various components, or where components are attached; a power plant or engine; and a transmission, which, among other things, takes the power from the engine and transmits it to the main rotor, which provides the aerodynamic forces that make the helicopter fly. Then, to keep the helicopter from turning due to torque, there must be some type of anti-torque system. Finally there is the landing gear, which could be skids, wheels, skis, or floats. This chapter is an introduction to these components.

The Main Rotor System:

The helicopter has rotor system which has either single main rotor or dual rotors. In the dual motors, the rotors rotate in opposite direction. In this system, the turning tendencies are cancelled by opposing the torque of one rotor with other rotor. The rotor system may be fully articulated, semi rigid, or rigid.

SOLUTION METHODOLOGY

- 3D model of the helicopter rotor blade is developed in NX-CAD software.
- The 3d model of the blade was imported to ANSYS software using parasolid file.
- In Ansys software, static analysis is done and deflections, stresses are documented.
- Next, modal analysis is done to plot the natural frequencies of the blade.
- The material for above analysis is aluminum material.

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p-ISSN: 2348-795X
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- Similarly, static and modal analysis is done on the blade by considering Eglass/ Epoxy material and Carbon/Epoxy material.
- The results of three materials are compared.

DESIGNING OF HELICOPTER ROTOR BLADE

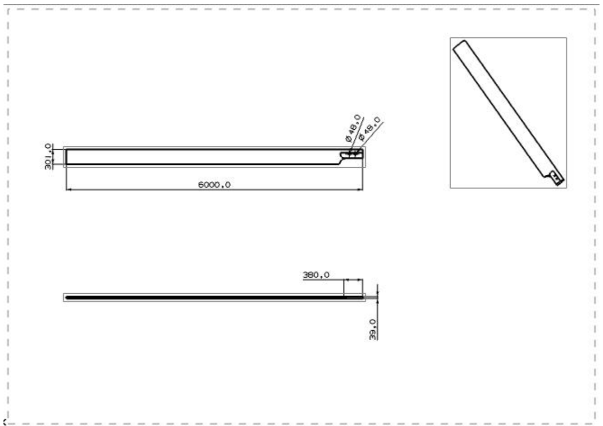

Fig shows the drafting file of the rotor blade

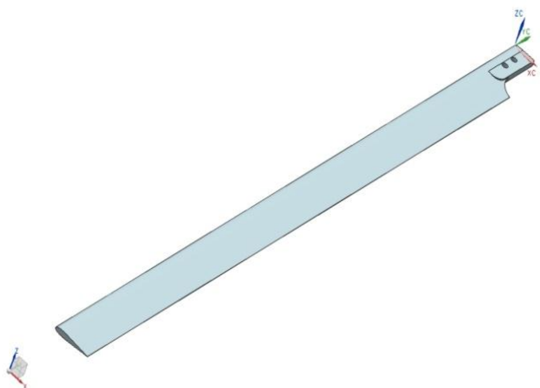

Fig shows the 3D model of rotor blade

STRUCTURAL ANALYSIS OF ROTOR BLADE

Material properties:

Aluminum alloys -2014-Mechanical Properties:

Young’s modulus = 70Gpa
Yield Strength = 414MPa
Poison’s ratio = 0.3
Density = 2700 kg/m3

Element type used is solid92

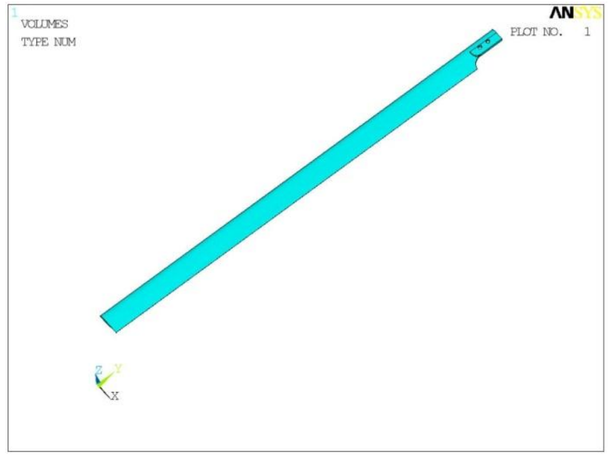

Fig shows the geometrical model of helicopter rotor blade

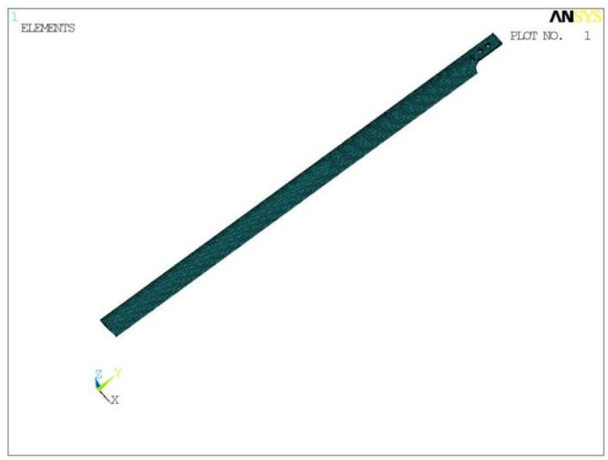

Fig shows the finite element model of helicopter rotor blade

Static analysis of helicopter rotor blade:

Structural static analysis has been performed on the helicopter rotor blade structure by applying the angular velocity and gravity of earth. The bolting locations are fixed in all Dof.

- Gravitational force = 9810mm/s
- Angular velocity (Ꞷ) = 15

Consider helicopter rotor blade maximum Angular velocity,

$$\omega = \frac{v}{r}$$

Where,

e-ISSN: 2348-6848
p-ISSN: 2348-795X
Volume 04 Issue 09
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Helicopter main rotor blade radios (r) = 6m
Linear velocity (v) = 90m/s

$$\omega = \frac{90}{6}$$

$$\omega = 15$$

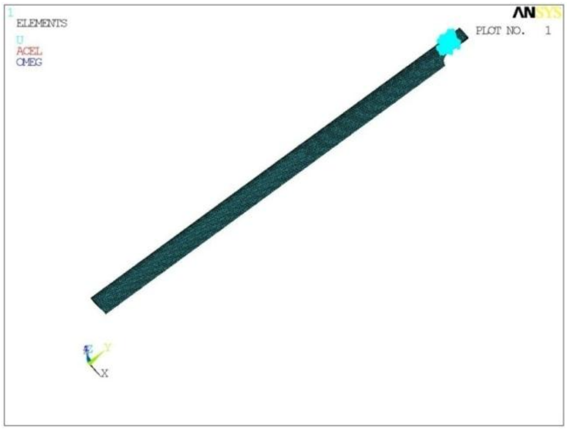

Fig. shows the Boundary conditions and Loading condition for static analysis

RESULTS

Deflections:

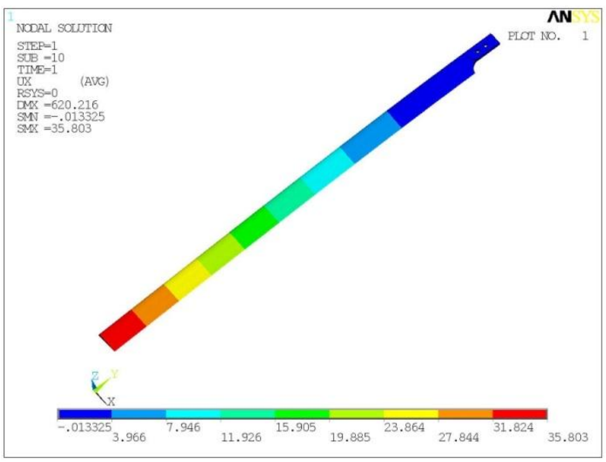

Fig shows Deflection in X-dir. of helicopter rotor blade

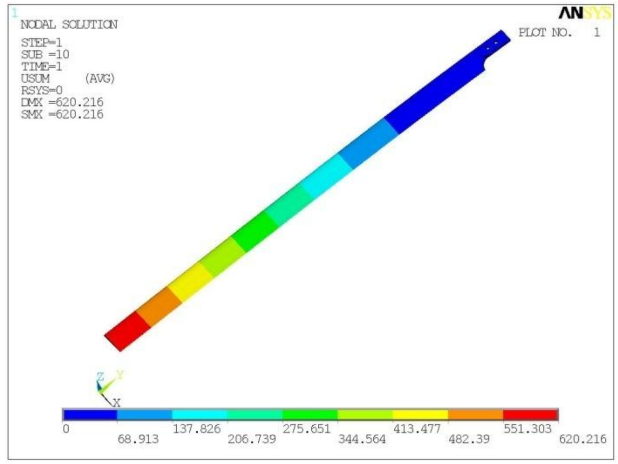

Fig shows Total Deflection of helicopter rotor blade

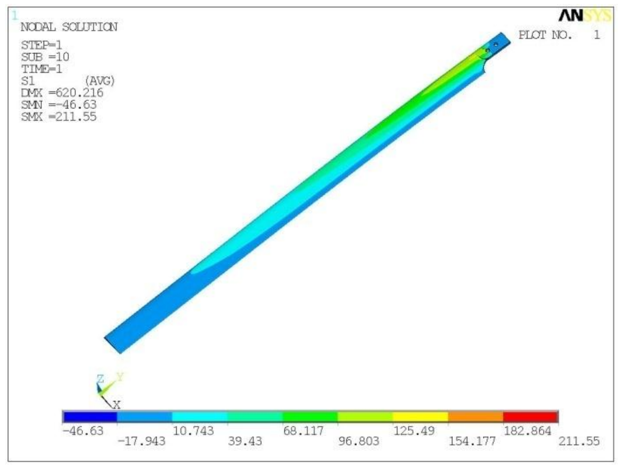

Fig. 1st principal stress of helicopter rotor blade

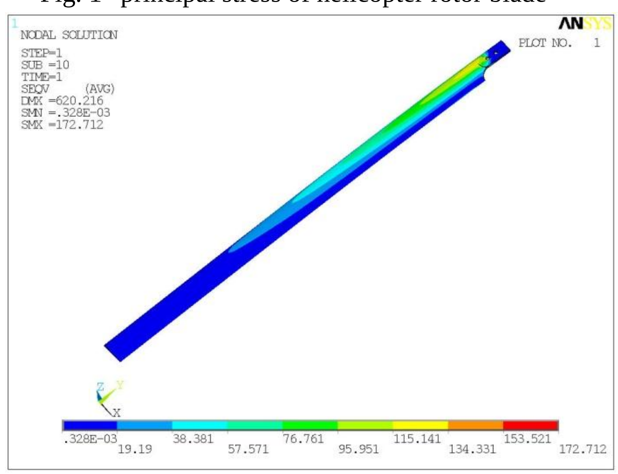

Fig shows Von Mises stress of helicopter rotor blade

According to the VonMises Stress Theory, the VonMises stress of helicopter rotor blade**(i.e. 172.7Mpa)** is having less stress than the yield strength of the material (i.e. **414Mpa** aluminum

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e-ISSN: 2348-6848
p-ISSN: 2348-795X
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alloy). Hence the design of helicopter rotor blade is safe for the above operating loading conditions.

Modal analysis of the rotor blade:

Modal analysis was carried out to determine the natural frequencies and mode shapes of a structure in the frequency range of 0 -12Hz.

Boundary Conditions:

- Blade is arrested on the bolting locations are fixed in all Dof which is connected to hub.

Fig shows the boundary conditions of helicopter rotor blade

Table .frequencies and mass participations for modes in the range of 0- 12 Hz

MODE	FREQUENCY
1	0.787
2	4.93
3	5.44

Mode shape 1@0.787 Hz

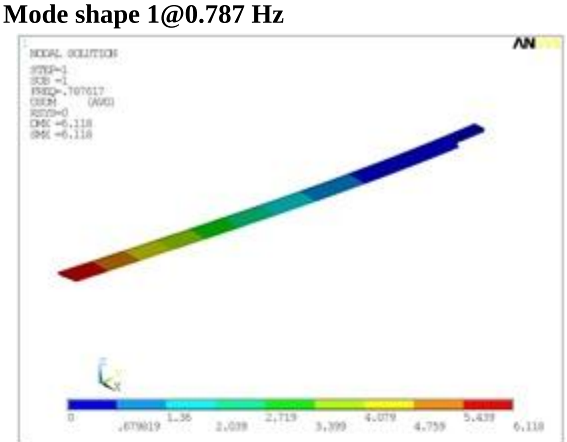

Fig. shows Mode shape 1@0.787 Hz for helicopter rotor blade.

Mode shape 2@4.9 Hz

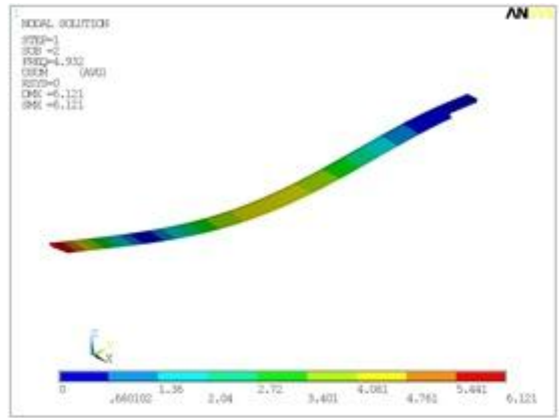

Fig. shows Mode shape 2@4.9 Hz for helicopter rotor blade.

Mode shape 3@5.4 Hz

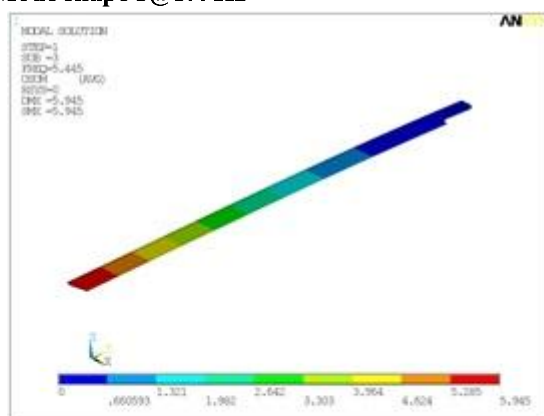

Fig. shows Mode shape 3@5.4 Hz for helicopter rotor blade.

- The helicopter main rotor blade weight observed is111kgs.

STRUCTURAL ANALYSIS OF HELICOPTER ROTOR BLADE FOR CARBON/EPOXY MATERIAL

Static analysis of rotor blade:

Material properties:

Table shows properties of HM carbon/epoxy

Property	Units	HM Carbon/Epoxy
E_{11}	GPa	190.0
E_{22}	GPa	7.7
G_{12}	GPa	4.2
ν_{12}	-	0.3

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$S^t_1 = S^c_1$	MPa	870.0
$S^t_2 = S^C_2$	MPa	94.0
S_{12}	MPa	30.0

Results:

Deflections:

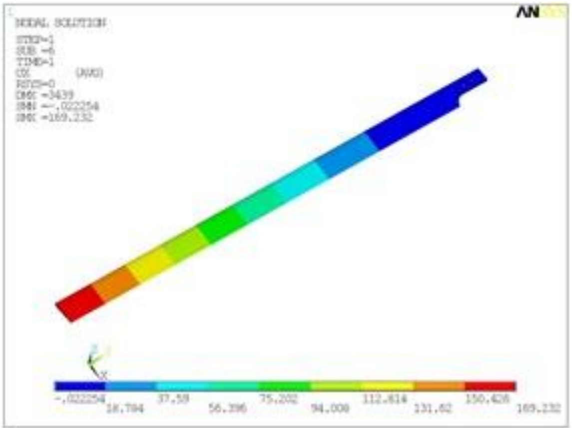

Fig shows Deflection in X-dir of helicopter rotor blade

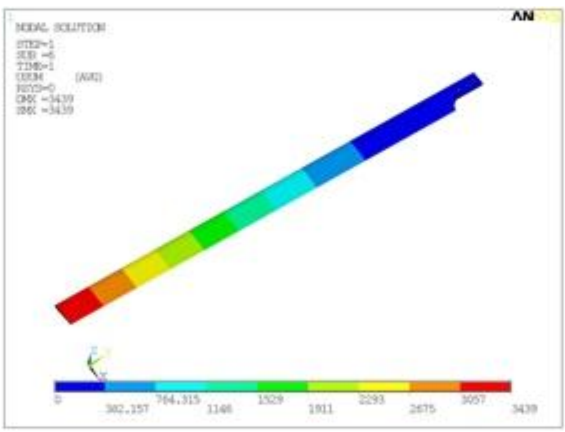

Fig shows Total Deflection of helicopter rotor blade

Stress:

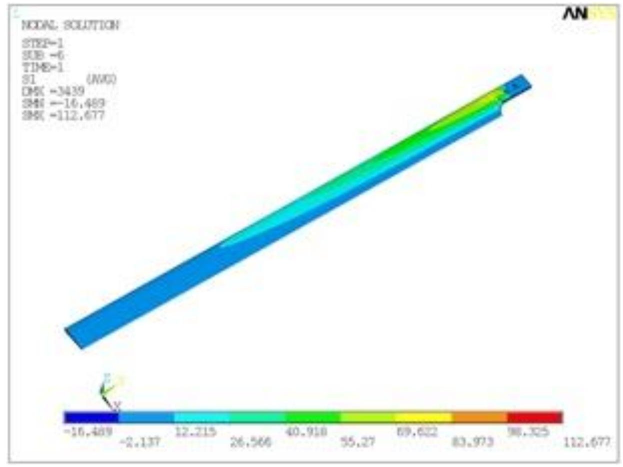

Fig shows 1st principal stress of helicopter rotor blade

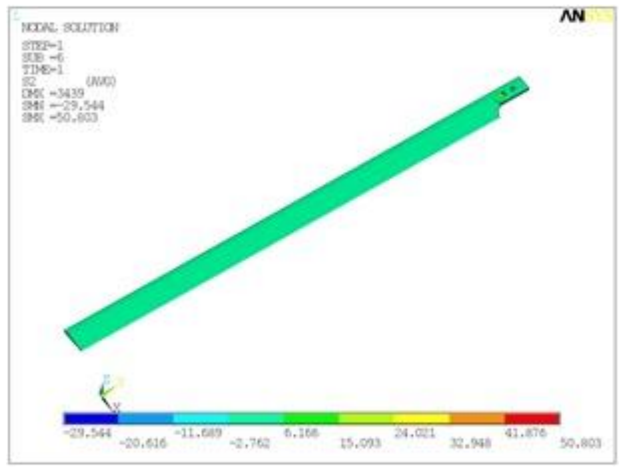

Fig shows 2nd principal stress of helicopter rotor blade

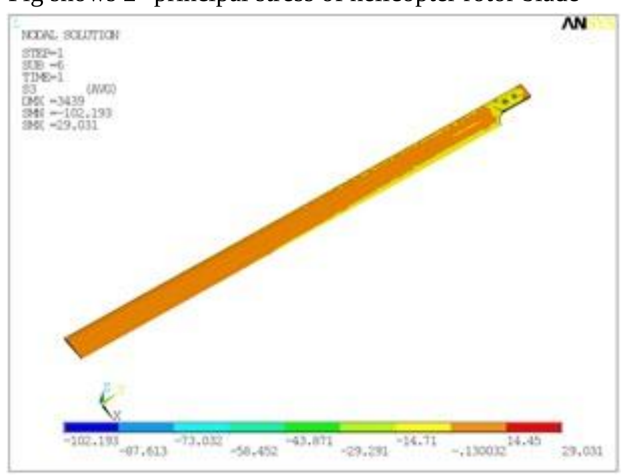

Fig shows 3rd principal stress of helicopter rotor blade

From the above results it is observed that the principal stresses values 112MPa, 50MPa, and

29MPa are less than the principal stresses values of the material 870MPa, 54MPa, and 30MPa with respectively 1st, 2nd and 3rd principal stresses. Hence according to the Maximum Stress Theory, the Composite Helicopter rotor blade design is safe for the above operating loads

Modal analysis of rotor blade:

Modal analysis was carried out to determine the natural frequencies and mode shapes of a structure in the frequency range of 0 -12Hz.

Results:

Table shows frequencies and mass participations for modes in the range of 0- 12 Hz

MODE	FREQUENCY
1	0.33
2	2.1
3	2.3
4	5.8
5	11.4

Mode shape 1@0.33 Hz

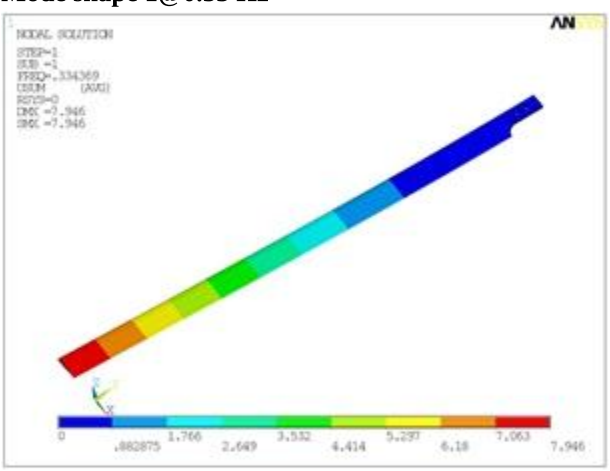

Fig shows Mode shape 1@0.33Hz for helicopter rotor blade

Mode shape 2@2.1 Hz

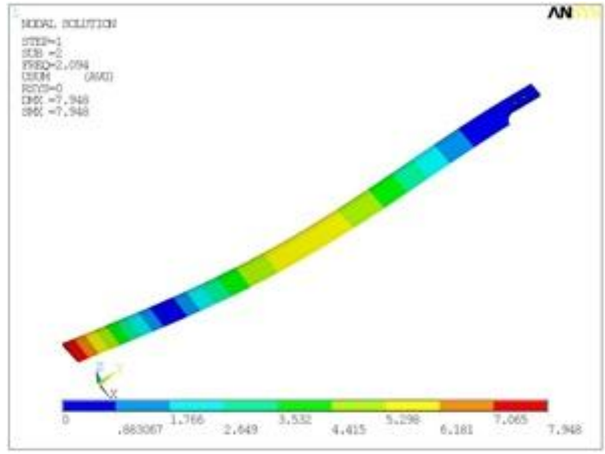

Fig. shows Mode shape 2@2.1 Hz for helicopter rotor blade

Mode shape 3@2.3 Hz

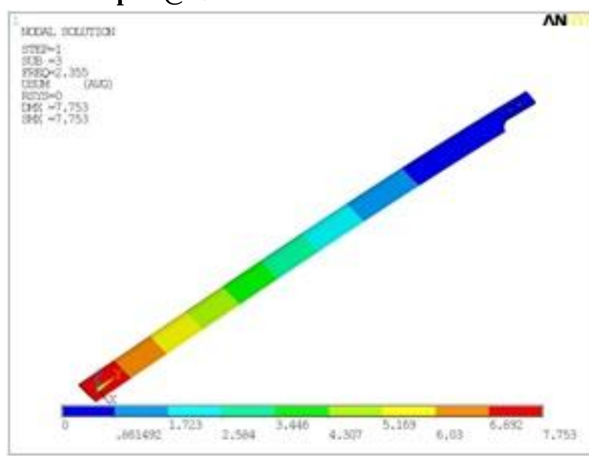

Fig. shows Mode shape 3@2.3 Hz for helicopter rotor blade

Mode shape 4@5.8 Hz

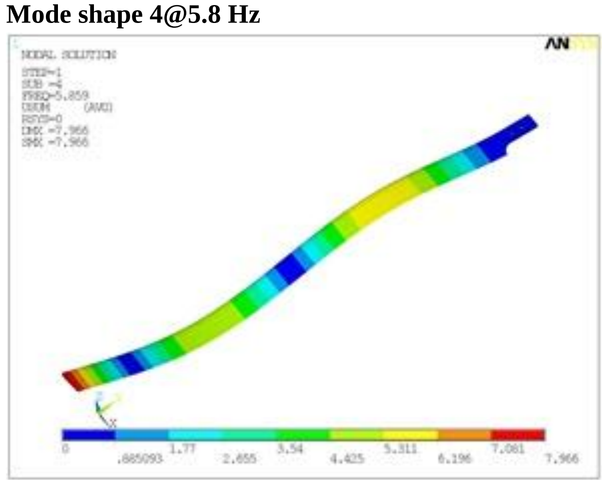

Fig shows Mode shape 4@5.8 Hz for helicopter rotor blade

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e-ISSN: 2348-6848
p-ISSN: 2348-795X
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Mode shape 5@11.4 Hz

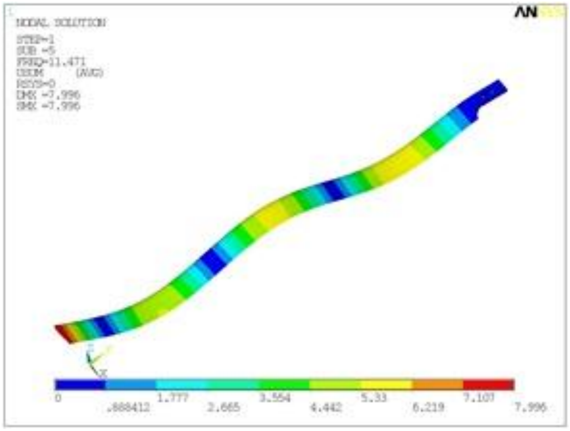

Fig shows Mode shape 5@11.4 Hz for helicopter rotor blade

- Total helicopter main rotor blade weight observed is 66kgs.

STRUCTURAL ANALYSIS OF ROTOR BLADE FOR EGLASS/EPOXY MATERIAL

Material properties:

Table shows Properties of HM Carbon/Epoxy

Property	Units	E-Glass/Epoxy
E_{11}	GPa	50.0
E_{22}	GPa	12.0
G_{12}	GPa	5.6
ν_{12}	-	0.3
$S^t_1 = S^c_1$	MPa	800.0
$S^t_2 = S^C_2$	MPa	40.0
S_{12}	MPa	72.0
ρ	Kg/m^3	2000.0

Static analysis of rotor blade:

Results:

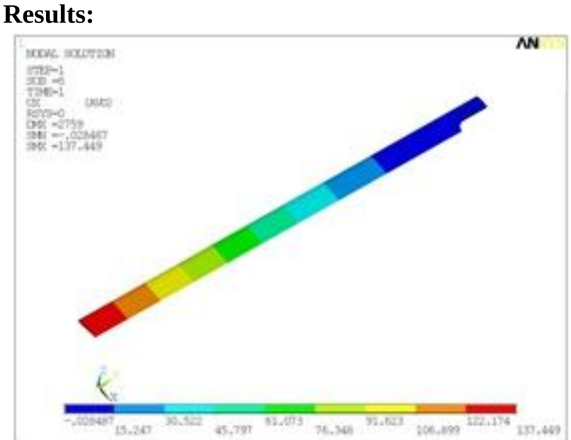

Fig shows Deflection in X-dir of helicopter rotor blade

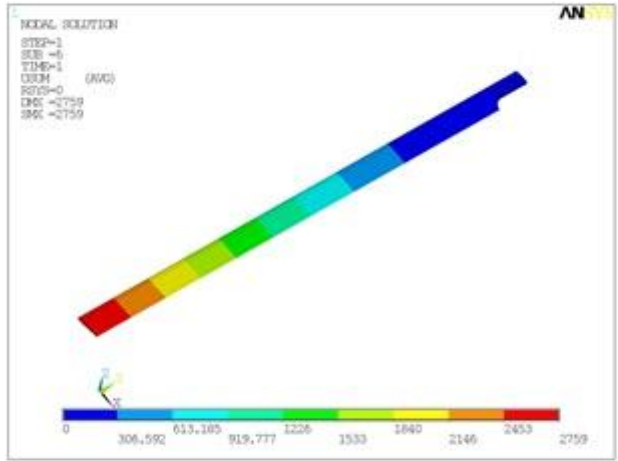

Fig shows Total Deflection of helicopter rotor blade

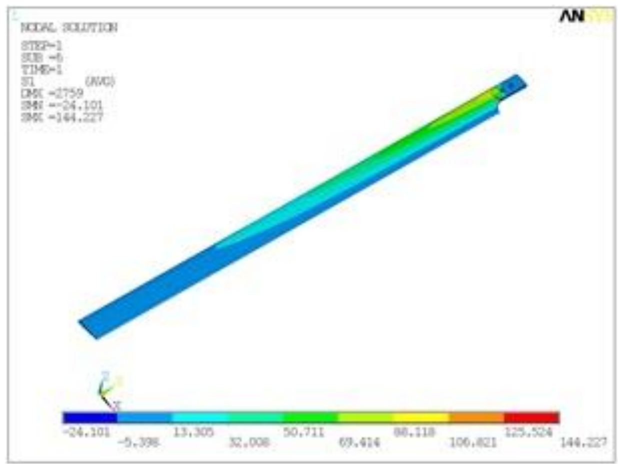

Fig shows 1st principal stress of helicopter rotor blade

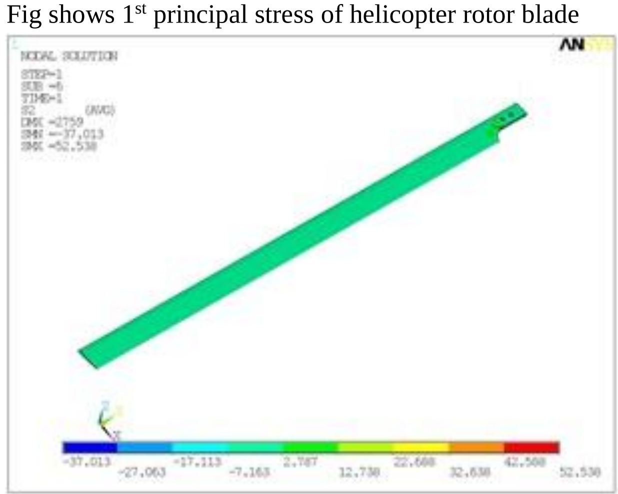

Fig shows 2nd principal stress of helicopter rotor blade

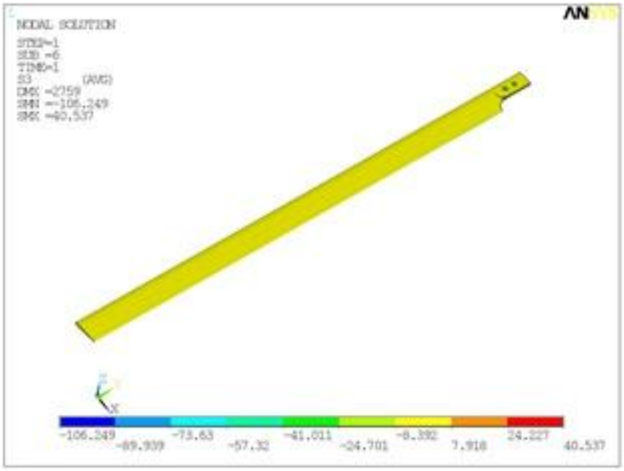

Fig shows 3rd principal stress of helicopter rotor blade

From the above results it is observed that the principal stresses values 144MPa, 52MPa, and 40MPa are less than the principal stresses values of the material 800MPa, 60MPa, and 74MPa with respectively 1st, 2nd and 3rd principal stresses. Hence according to the Maximum Stress Theory, the Composite Helicopter rotor blade design is safe for the above operating loads.

Modal analysis of rotor blade:

Modal analysis was carried out to determine the natural frequencies and mode shapes of a structure in the frequency range of 0 -12Hz.

Results:

Table shows frequencies and mass participations for modes in the range of 0- 12 Hz

MODE	FREQUENCY
1	0.37
2	2.3
3	2.6
4	6.4

Natural frequencies and mode shapes are plotted below:

Mode shape 1@0.37Hz

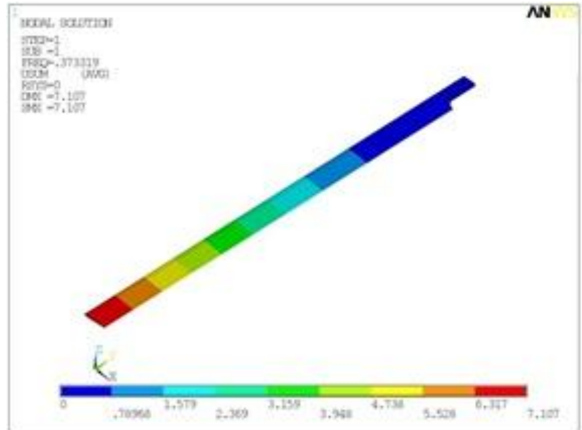

Fig. shows Mode shape 1@0.37Hz for helicopter rotor blade

Mode shape 2@2.3 Hz

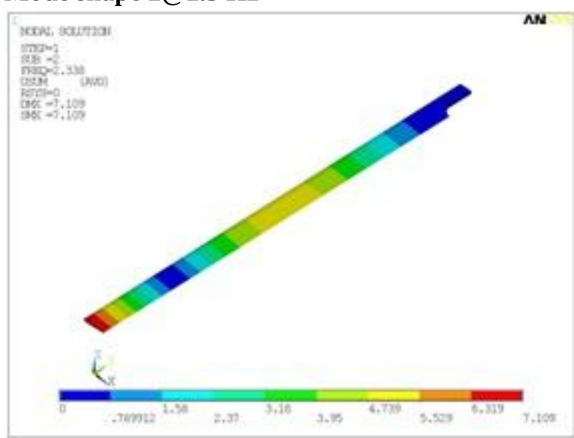

Fig. shows Mode shape 2@2.3 Hz for helicopter rotor blade

Mode shape 3@2.6 Hz

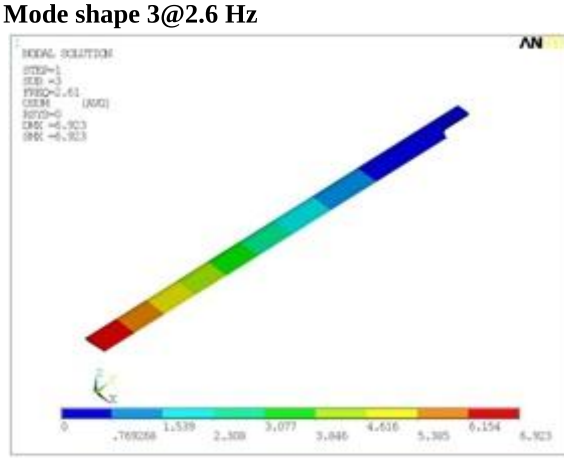

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Fig. shows Mode shape 3@2.6 Hz for helicopter rotor blade

Mode shape 4@6.5 Hz

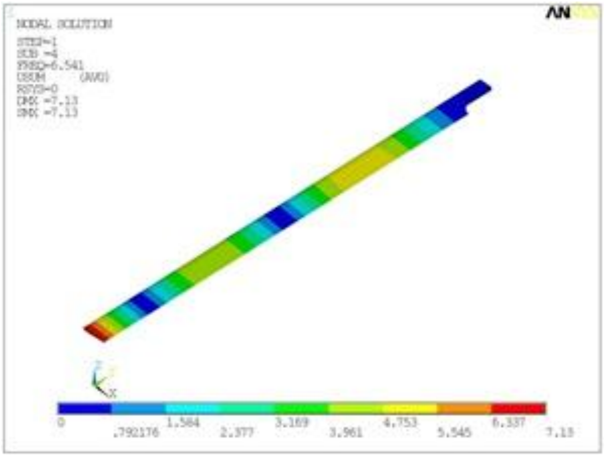

Fig. shows Mode shape 4@6.4 Hz for helicopter rotor blade

- ➢ Total helicopter main rotor blade weight observed is 82kgs.

RESULTS AND CONCLUSION

In the present project, the helicopter rotor blade was studied for structural analysis for different materials (aluminum and composite materials).

The helicopter rotor blade was studied for 3 different materials:

- ➢ Aluminum
- ➢ HM carbon/ epoxy
- ➢ E-glass/ epoxy

CASE-1: Structural analysis of helicopter rotor blade with aluminum material:

From static analysis,

From the static analysis results it is observed that the maximum VonMises stress observed is 172 MPa. The maximum stress is observed on the bolting location. The yield strength of the material is 414 MPa.

From the modal analysis,

From the above modal analysis results it is observed that only 3 natural frequencies exists in the operating range of 0-12 Hz.

- ➢ Total helicopter main rotor blade weight observed is 111kgs.

CASE-2: Structural analysis of helicopter rotor blade with HM carbon/ epoxy material:

From static analysis,

From the results it is observed that the principal stresses values 112MPa, 50MPa, and 29MPa are less than the principal stresses values of the material 870MPa, 54MPa, and 30MPa with respectively 1st, 2nd and 3rd principal stresses.

From the modal analysis,

From the modal analysis results it is observed that only 5 natural frequencies exist in the operating range of 0-12 Hz.

- ➢ Total helicopter main rotor blade weight observed is 66kgs.

CASE-3: Structural analysis of helicopter rotor blade with E-glass/ epoxy material:

From static analysis,

From the results it is observed that the principal stresses values 144MPa, 52MPa, and 40MPa are less than the principal stresses values of the material 800MPa, 60MPa, and 74MPa with respectively 1st, 2nd and 3rd principal stresses.

From the modal analysis,

From the modal analysis results it is observed that only 4 natural frequencies exist in the operating range of 0-12 Hz.

- ➢ The total weight of the rotor blade is 82 kgs.

Comparison of aluminum alloy, HM carbon/Epoxy and E glass/ Epoxy materials

Material	FOS	Weight
Aluminium alloy	414/172=2.4	111
HM carbon/Epoxy	870/167=5.2	66
E glass/ Epoxy	800/144=5.5	82

Hence the design of helicopter rotor blade is safe for the above operating loading conditions in all 3 materials.

Conclusion:

In the present project, the helicopter rotor blade was studied for structural analysis for different materials (aluminum and composite materials).

In this project, the three-dimension model of helicopter rotor blade was modeled in NX-CAD and imported into ANSYS software to analyze strength and stiffness of rotor blade. The strength and stiffness of the rotor blade were analyzed with ANSYS software for different materials (aluminum alloy and composite materials).

From the above analysis it is concluded that the helicopter rotor blade has stresses and deflections within the design limits for the all three materials (aluminum and composite materials). From the results we can conclude that the HM carbon/ epoxy material helicopter blade has less weight and better stiffness and better factor of safety compare to other materials. Hence, it was concluded that the HM Carbon/Epoxy is best material.

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