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# Modular Analysis of Main Rotor Blade of Light Helicopter using FEM

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***Abstract:*** **The avionic business bargains from the earliest starting point with structures with uncommon necessities as amazing light weight and withstanding to a major number of burden cases. Aerodynamics constraints limitations lead to supplementary confinements, the outcomes being the intricate shape to support the fuselage, the rotor cutting edges or the wings skin . Rotor sharpened steel of the helicopter is one of the urgent parts which focus the execution of the helicopter. The orderly and fitting investigation of the helicopter rotor edge is of prime significance because of its commitment towards the proficiency of the entire helicopter .**

**Basic vibration issues displays a noteworthy Design restriction for an extensive variety of designing item. The principle point of investigation of the vibration phenomenon incorporates deciding the nature and degree of vibration reaction level.**

**Considering the above said truths this task presents an auxiliary vibration examination of the primary main rotor blade of light utility helicopter. To simulate the mechanical the mechanical behavior of the blade, a limited component investigation system was utilized. The examination incorporates figuring out the distinctive Modes of helicopter rotor razor sharp edge and think about them for diverse material, for example, Aluminum Alloy and CFRP material.**

**software used is HYPERMESH and ABAQUS**

***Keywords — Rotor Blade, Hovering Flight Mode, Structural Modular analysis.***

## 1. INTRODUCTION

The Helicopter tail and main rotor blade are the key structural element, which affect the helicopter performance and it's good characteristics from the aspect of reliability and safe operation. The design of helicopter main rotor blade requires dynamic, aerodynamic, mechanical and structural consideration and manufacturing methodology.

Unidirectional carbon fiber and plastic have significant advantage over metals for a blade construction. These composite materials have high static strength and high fatigue strain capability. These characteristics can be used to design blade with long service life and unlimited fatigue lives with little maintenance.

This paper shows Free-Free analysis of main rotor blade for different material to chuck the different modes and natural frequency of Aluminum alloy and CFRP material rotor blade.

To conduct Free- Free analysis first we have to design rotor blade, before designing rotor blade select standard airfoil. The wrought man unsymmetrical rotor blade airfoil are selected. with the help of CATIA V5 rotor blade has to be modeled, after modeling of rotor blade preprocessing are done by using HYPERMESH software in pre-processing, first convert infinite degree of freedom into finite degree of freedom (meshing). After meshing material property has to be updated to the model. After preprocessing the problem as to be solved by using ABAQUS solver.

The result are chucked by using post processing software (hyperview) compare the different modes and natural frequency of different material.

## 2. PROCESS METHODOLOGY

Below figure 1 shows the process methodology of helicopter rotor blade.

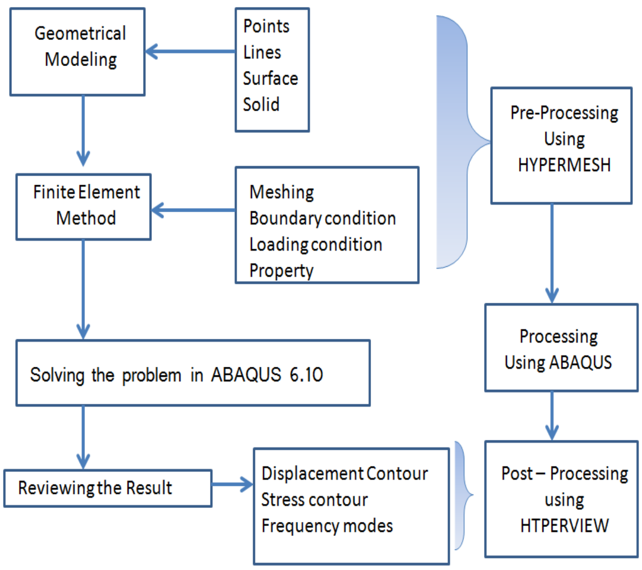



Figure 1 : Step Involved In FEM

3D model of Main rotor blade is imported into the HyperMesh for preprocessing. Preprocessing of model consist of meshing, selection of material properties, creation of load collectors and apply boundary conditions on model. Then model is exported to ABAQUS for solving problem. Results of solution plotted in HyperView which is well known postprocessor of HyperWorks software.

### *2.1 Geometric Modeling*

For the case of the helicopter blade, the 3D modeling was done with the help of the specialized designing software, CATIA, using the real geometrical data from the technical standards and taking into account the practical recommendations from Fig. 2 illustrates the geometry and the main dimensions of the rotor blade.

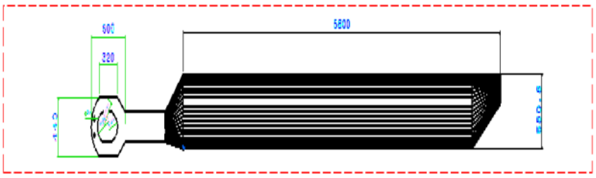


Figure 2 : Rotor Blade
Note : All dimension are in MM

The above figure shows 3D model of helicopter rotor blade.

Figure 3

Figure 4

The figure 3 and figure 4 shows the Meshing of main rotor blade.

For proper Analysis we have to maintain some quality of the elements. The below table 1 shows the quality of the rotor blade.

The rotor has to be satisfied below quality criteria.

| TYPE | VALUE |
|---|---|
| Warpage | 20 |
| Aspect | 5 |
| Jacobian | 0.6 |
| Minimum angle of quad face | 45 |
| Maximum angle of quad face | 135 |
| Minimum angle of tria face | 20 |
| Maximum angle of tria face | 120 |

Table 1

*2.2 Material Selection & Property*

The aerospace industry deals from the beginning with structures with special requirements as extreme light weight and withstanding to a big number of load cases. We chose Aluminum Alloy and CFRP material to reduce the whole weight of the rotor blade and also increase the stiffness of the rotor blade.

| | |
|---|---|
| Young's Modulus ( E ) | 0.75 N / $M^2$ |
| Poisons Ratio ( μ ) | 0.33 |
| Density Of The Material ( $\rho$ ) | 1.278 kg / $M^2$ |

**Table 2**

The table 2 shows the material property of Aluminum Alloy.

| | |
|---|---|
| **Density ($\rho$)** | **1600 $kg/m^3$** |
| $E_{11}$ | **181 GPa** |
| $E_{22}$ | **10.3 GPa** |
| $E_{33}$ | **10.3 GPa** |
| $G_{12}$ | **7.17 GPa** |
| $G_{13}$ | **7.17 GPa** |
| $G_{23}$ | **7.17E8 Pa** |
| $\mu_{12}$ | **0.28** |
| $\mu_{13}$ | **0.28** |
| $\mu_{23}$ | **0.33** |

**Table 3**

The Table 3 shows the material property of CFRP material

## 3. DYNAMIC ANALYSIS

Dynamic Analysis means the analysis is carried out with respect to Time.

The reason to compute Dynamic analysis (Modal Analysis )

- ➢ To chuck the First Natural frequency , because the first natural frequency is very important to improve the component.

- To chuck the Resonance means chuck the working frequency is exactly equal to the any one of our natural frequency with in a specified range.
- It helps us to guide the sensor position.

*3.1 Dynamic Analysis Versus Static Analysis*

A static structural examination decides the displacement, stress, strains, and strengths in structures brought on by burdens that don't instigate significant inertia and damping impacts. Unfaltering stacking and reaction conditions are accepted that is, the loads and the structure's reaction are expected to shift gradually as for time.

The sorts of stacking that can be connected in a static analysis include:

1. Remotely connected strengths and weights.
2. Enduring state inertial strengths, for example, gravity. Temperatures for warm strain.

Two essential parts of element examination vary from static investigation.

1. Element burdens are connected as a component of time or recurrence.
2. Time or Frequency-fluctuating burden application actuates time or recurrence differing reaction removals, speeds, increasing velocities, strengths, and burdens.

*3.2 Free Vibration Analysis:*

Due to inerrant properties stiffness and mass of body tends to vibrate is called free vibration.

The equation of un damped vibration reduce to

$$m\ddot{u}(t) + ku(t) = 0$$

*3.3 Circular Natural Frequency:*

One property of the framework is termed the circular natural frequency of the structure $\omega_n$. The subscript n shows the " natural " for the SDOF framework. In frameworks having one mass degree of freedom and more than one natural frequency,, the subscript may show a recurrence number. For a SDOF framework, the roundabout common recurrence is given by

$$\omega_n = \sqrt{\frac{k}{m}}$$

*3.4 Natural Frequency:*

The frequency of free vibration is called natural frequency. The natural frequency $f_n$ is defined by

$$f_n = \omega_n/2\pi$$

The natural frequency is often specified in terms of cycles per unit time, commonly cycles per second (cps), which is more commonly known as Hertz (Hz).

*3.5 Free - Free Analysis Of Helicopter Rotor Blade*

After Meshing material property will be updated and prepare DECK for Free - Free analysis.

For preparing DECK for Free - Free analysis the Boundary condition and Loading Condition has not to be considered. Here we cannot give Frequency range, we can give only number of Modes.

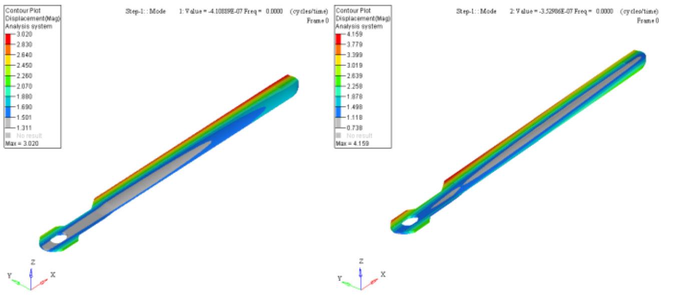
In this Free - Free Analysis the first 6 Modes are rigid modes, The value of the Frequency should be zero. If the Modal is well connected the seventh mode onwards we get positive frequency, It means Modal is well connected.

There are 5 Types of Modes are their in Dynamic Analysis they are

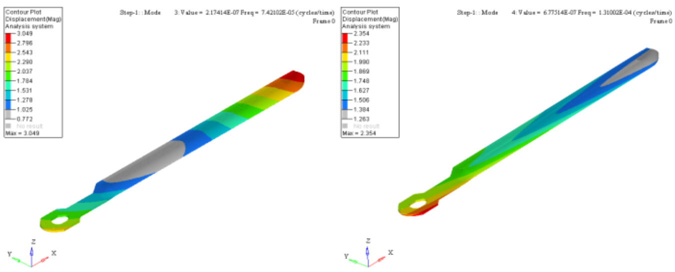
- Linear Mode
- Lateral Mode
- Bending Mode
- Torsion Mode
- Mixed Mode

## 4 . RESULTS AND DISCUSSION

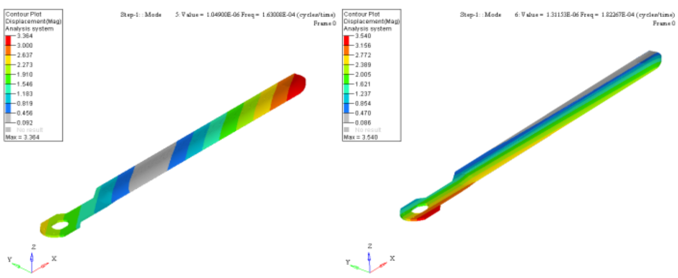
The below figures shows different mode shape of Aluminum Rotor blade.



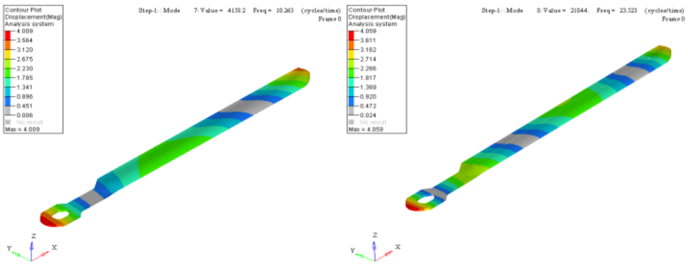
Mode 1 and Mode 2



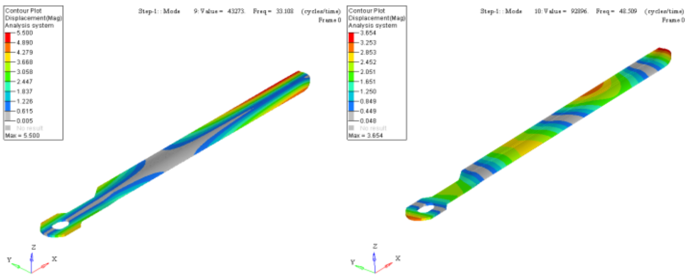
Mode 3 and Mode 4



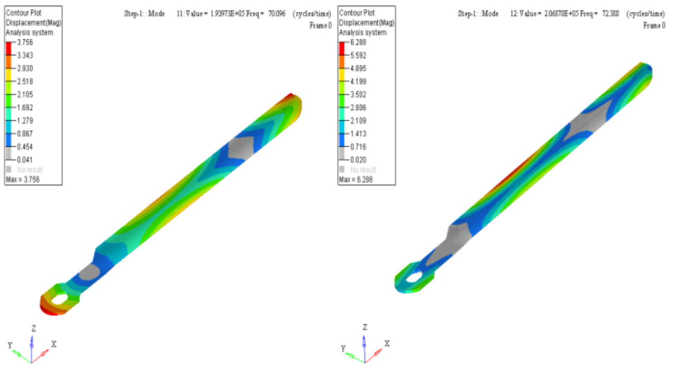
Mode 5 and Mode 6



Mode 7 and Mode 8



Mode 9 and Mode 10



Mode 11 and Mode 12

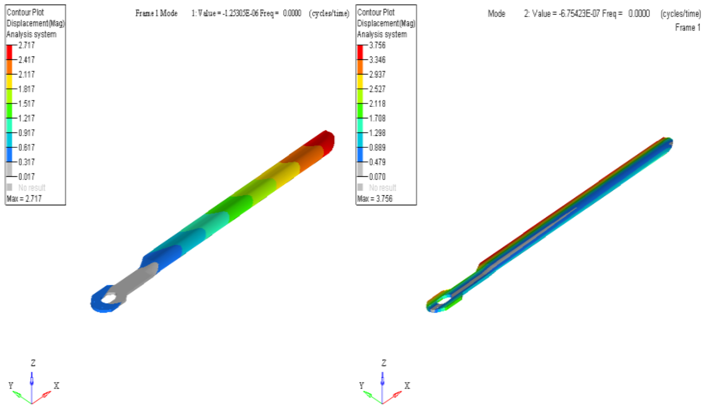
The below table shows the frequency range values of different Modes of Aluminum material.

| MODES | Mode Value | Frequency in Cycle / Time |
|---|---|---|
| 1 | -4.10E-7 | 0 |
| 2 | -3.52E-7 | 0 |
| 3 | 2.17E-7 | 7.42E-5 |
| 4 | 6.77E-7 | 1.31E-4 |
| 5 | 1.05E-6 | 1.63E-4 |
| 6 | 1.31E-6 | 1.82E-4 |
| 7 | 4158.2 | 10.26 |
| 8 | 21844 | 23.52 |
| 9 | 43273 | 33.108 |
| 10 | 92896 | 48.509 |
| 11 | 1.93E5 | 70.09 |
| 12 | 2.06E5 | 72.38 |

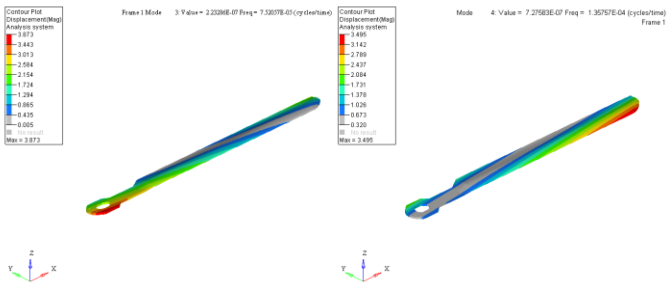
Table 4

The above table 4 shows the values of frequency of different modes. The above values are conclude that the first 6 Modes are rigid modes ( zero Frequency) after seventh onwards we get Positive values, so our model is well connected .

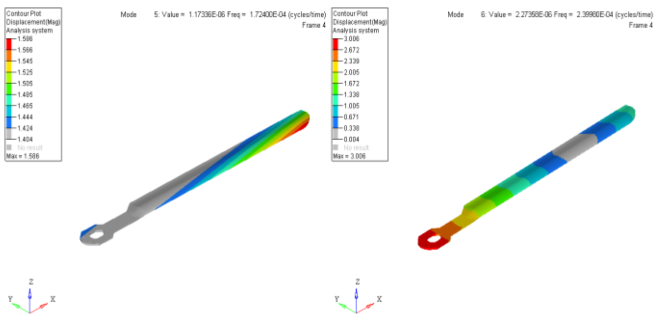
The below figures shows different mode shape of CFRP Rotor blade.



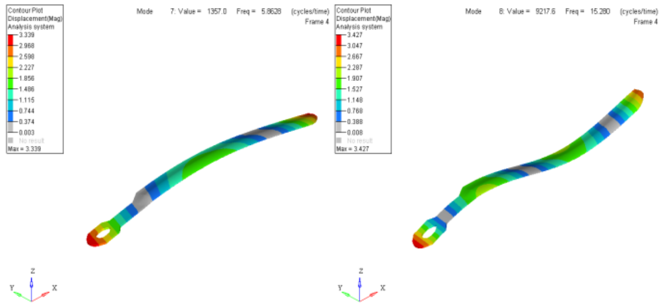
Mode 1 and Mode 2



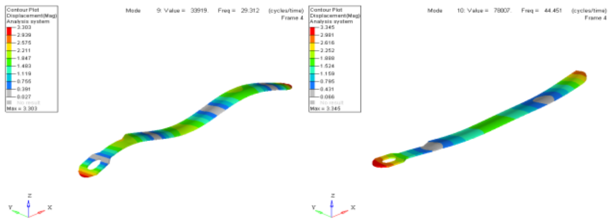
Mode 3 and Mode 4



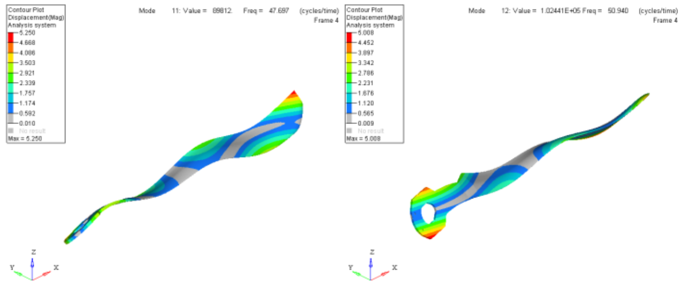
Mode 5 and Mode 6



Mode 7 and Mode 8



Mode 9 and Mode 10



Mode 11 and Mode 12

The below table shows the frequency range values of different Modes of CFRP material.

| MODES | Mode Value | Frequency in Cycle / Time |
|---|---|---|
| 1 | -1.25E-6 | 0 |
| 2 | -6.75E-7 | 0 |
| 3 | 2.23E-7 | 7.52E-5 |
| 4 | 7.27E-7 | 1.35E-4 |
| 5 | 1.17E-6 | 1.72E-4 |
| 6 | 2.27E-6 | 2.39E-4 |
| 7 | 1357 | 5.86 |
| 8 | 9217.6 | 15.28 |
| 9 | 33919 | 29.31 |
| 10 | 78007 | 44.45 |
| 11 | 89812 | 47.69 |
| 12 | 1.02E5 | 50.94 |

Table 5

The above table 5 shows the values of frequency of different modes. The above values are conclude that the first 6 Modes are rigid modes (zero Frequency) after seventh onwards we get Positive values, so our model is well connected .

## 5 CONCLUSION

The above table 4 and table 5 shows the value of natural frequency of Aluminum Alloy and CFRP material. In free – free analysis we won't consider first 6 modes that all are rigid modes i.e zero frequency mode. We consider only $7^{th}$ mode, The value of $7^{th}$ mode is the first natural frequency.
The table 4 shows Aluminum material values, The $1^{st}$ Natural frequency i.e $7^{th}$ mode value is 10.26 Cycle / Time.
The table 5 shows CFRP material values, The $1^{st}$ Natural frequency i.e $7^{th}$ mode value is 5.86 Cycle / Time.
The above results has been shown that the comparative study of Free – Free analysis of two different material (Aluminum and CFRP) of Helicopter main rotor blade. In above table result conclude that the $1^{st}$ Natural frequency of CFRP material (5.86 Cycle / Time) is lesser than $1^{st}$ Natural frequency of Aluminum Alloy material (10.26 Cycle / Time). Which conclusively suggest use of composite material has the better option for the helicopter main rotor blade.

## 6. REFERENCES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