Design and Harmonic Analysis of Helicopter Rotor Blade for Different Materials

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Abstract:

The blades of a helicopter are long, narrow airfoils with a high aspect ratio, a shape that minimizes drag from tip vortices. They for the most part contain a degree of washout that lessens the lift created at the tips, where the airflow is quickest and vortex generation. Rotor blades are made out of different materials, including aluminum, composite structure, and steel or titanium, with scraped area shields along the main edge. The helicopter rotor center point is fueled by the motor, and the rotor blades are appended to the center point. The movement of cutting edge is controlled by the helicopter rotor framework. The main rotor sharp edge is mainly influenced by the wind current for rotation of cutting edge and the impact of streamlined force and centrifugal force applying to edge has been completely considered. The dynamic qualities examination of rotor sharp edge is mainly engaged with the vibration control. The goal is to compute the regular recurrence and working recurrence of rotor cutting edge is adjusting those frequencies and keeping away from reverberation at rotational speed, in this way the vibrations of helicopter may diminish.

In this task, the three-measurement model of helicopter rotor cutting edge is demonstrated in NX-CAD and imported into ANSYS programming to investigate quality and dynamic attributes of rotor sharp edge has been produced. The static quality and the dynamic attributes about rotor edge have been broke down with ANSYS programming for various materials (aluminum combination and composite E-GLASS/EPOXY AND HM CARBON/EPOXY). Amid the investigation of dynamic trademark, the impact of streamlined force and centrifugal force applying to cutting edge has been completely considered.

Keywords:-

INTRODUCTION

HELICOPTER ROTOR BLADE

The wings of the plane make a lift force when they travel through the air. As we known, amid flight, there are four forces following up on the helicopter or plane and those are LIFT, DRAG, THRUST, and WEIGHT. With the end goal to make the wings to travel through the air, obviously, the plane itself needs to move. A helicopter works by having its wings travel through the air while the body remains still. The helicopter's wings are called Main Rotor Blades. The shape and the edge of the blades travel through the air will decide the amount Lift force is made. After the helicopter lifted off the ground, the pilot can tilt the blades, making the helicopter tip forward or in reverse or sideward.

Helicopters come in numerous sizes and shapes, however most offer a similar real parts. These segments incorporate a lodge where the payload and group are conveyed; an airframe, which houses the different segments, or where parts are appended; a power plant or motor; and a transmission, which, in addition to other things, takes the power from the motor and transmits it to the main rotor, which gives the streamlined forces that make the helicopter fly. At that point, to shield the helicopter from swinging because of torque, there must be some sort of against torque framework. At long last there is the arrival outfit, which could be slips, wheels, skis, or buoys. This section is a prologue to these parts.

The Main Rotor System

The rotor framework found on helicopters can comprise of a solitary main rotor or double rotors. With most double rotors, the rotors turn in inverse ways so the torque from one rotor is contradicted by the torque of the other. This drops the turning propensities.

As a rule, a rotor framework can be named either completely explained, semi unbending, or inflexible. There are varieties and blends of these frameworks. A completely verbalized rotor framework more often than not comprises of at least three rotor blades. The blades are permitted to fold, plume, and lead or slack freely of one another. Every rotor sharp edge is appended to the rotor center point by a flat pivot, called the fluttering pivot, which allows the blades to fold here and there. Every edge can climb and down autonomously of the others. The fluttering pivot might be situated at different separations from the rotor center point, and there might be more than one. The position is picked by every producer, basically with respect to security and control. Every rotor cutting edge is additionally appended to the center point by a vertical pivot, called a drag or slack pivot, that allows every sharp edge, autonomously of the others, to move forward and backward in the plane of the rotor circle. Dampers are ordinarily joined in the structure of this sort of rotor framework to anticipate intemperate movement about the drag pivot. The reason for the drag pivot and dampers is to ingest the acceleration and deceleration of the rotor blades. The blades of a completely verbalized rotor can likewise be feathered, or pivoted about their range shrewd hub. To say it all the more essentially, feathering implies the changing of the pitch edge of the rotor blades.

Semi-Rigid Rotor System

A semi unbending rotor framework takes into consideration two distinct developments, fluttering and feathering. This framework is typically involved two blades, which are inflexibly joined to the rotor center point. The center point is then appended to the rotor pole by a trunnion bearing or wavering pivot. This enables the blades to see-saw or fold together. As one sharp edge folds down, alternate folds up. Feathering is practiced by the feathering pivot, which changes the pitch edge of the edge.

Rigid Rotor System

The inflexible rotor framework is mechanically basic, however fundamentally complex on the grounds that working burdens must be invested in bowing instead of through pivots. In this framework, the blades can't fold or lead and slack, yet they can be feathered.

PRINCIPLES OF HELICOPTER AERODYNAMICS

Aerodynamics

Aerodynamics manage the forces following up on items traveling through air and the development of air itself. There are four forces following up on any flying machine, including helicopters. Weight is the force of gravity. Lift is the force of air over the helicopter's rotor blades, countering the force of gravity. Push is the force moving the airplane through the air, made by the main rotor blades. Drag is the force of air obstruction against the air ship as it travels through the air.

Helicopters use more unpredictable aerodynamics than settled wing planes. Helicopters join lift, push and torque in a fragile parity to deliver controllable flight and drifting. Their capacity for vertical, forward and turn around flight, and also static drifting, has created an utility that settled wing airplane can't equal. Helicopters are key to military, modern, protect and law enforcement applications. Adaptability breeds multifaceted nature, be that as it may, and getting and keeping a helicopter noticeable all around effortlessly includes cautious administration of contending streamlined forces.

The vertical force of lift is delivered by the helicopter's rotor blades. Consider them turning wings or even propellers, since they are extremely both. Like the main edge of a plane wing, a helicopter's rotor has an airfoil shape. At the point when an airfoil travels through the air, its shape initiates a zone of lower pneumatic stress above it and higher weight underneath it. This difference produces lift. In a settled wing flying machine, the development of the airfoil through air is given by the forward movement of the plane. In a helicopter, it's caused by the fast turning of the rotor blades. Push produces even flight. In settled wing airplane, push produced by propellers or fly motors advances the flying machine. Push in helicopters is created by tilting the level turning rotor blades the coveted way of flight, which might be forward, in reverse or to either side.

Bernoulli's Principle

The physicist Daniel Bernoulli found this rule by the manner in which water weight is expanded when a pipe is narrowed. Air is influenced by this equivalent standard through helicopter airfoils. Both the main and back rotor blades are airfoils. The bend of the airfoils causes the air heading out over the blade to move more rapidly than the air underneath the blade. This makes a pocket of low weight over the helicopter, making lift, which enables the helicopter to rise. The measure of lift an airfoil makes is subject to five variables: surface zone, shape, speed, air thickness and the point of the airfoil, or the approach.

Torque

Newton's Third Law of Motion expresses that for each activity there is an equivalent however inverse response. At the point when the main rotor of a helicopter turns, it makes a counter-turn in the body of the helicopter. This is called torque. Vast helicopters utilize an even rotor, turning the other way of the primary rotor. Different helicopters have a vertical tail rotor, which utilizes Bernoulli's Principle to neutralize the impact of torque.

For each activity there's a response. The quick turning of the rotor blades creates contradicting torque that demonstrations to turn the body of the helicopter the other way of the blades. This activity is contradicted by the tail rotor, a vertically mounted propeller with customizable pitch that neutralizes the torque forces. The measure of tail rotor pitch is controlled by the pilot's foot pedals.

Directional Control

A helicopter that simply climbed and down would not be exceptionally helpful. Changes in accordance with the pitch of the airfoils give helicopters directional control.

At the point when the airfoils of the main rotor are pitched forward, their lift makes forward movement. A more prominent approach in their pitch implies more forward speed. At the point when the airfoils are pitched in reverse, the helicopter moves backward. At the point when the speed of the auxiliary rotor is expanded or diminished, the helicopter turns left or right.

Air Compressibility

As the airfoil travels through the air, the air is part into two streams which go above and underneath the blade. At low speeds, it requires little vitality to part the air. At quick speeds, notwithstanding, the air striking the edge of the airfoil ends up packed and more hard to part. This compressibility constrains the paces feasible for a helicopter. The impact is like that seen with water. When you gradually given yourself a chance to submerge, there is little obstruction.

BLADE VIBRATIONS

Today, helicopters still experience the ill effects of commotion, vibrations, constrained flight envelope and execution. Current models as of now perform much superior to early sorts. These enhancements are generally because of better rotor aerodynamics, novel arrangement structures and airfoils, propelled tail rotor ideas, composite materials, pivot and bearing less rotors, present day motors and aloof and additionally dynamic vibration damping.

Clamor

Main rotor, tail rotor and motors produce a large portion of the outer helicopter commotion. The acoustic flag of the main rotor comprises of broadband and rash commotion. The broadband sources are limit layer stream consequences for the rotor blades (alleged self commotion) at high frequencies and blade cooperations with turbulences in and around the wakes and tip vortices at medium frequencies. Blade-wake cooperation (BWI) endures over an extensive scope of working conditions. The low recurrence hasty sources are overwhelming particularly in high speed forward flight and in plunge flight, average for landing. In drop flight or low speed moves, the rotor blades experience the tip vortices of going before blades. This blade vortex connection (BVI) causes boisterous slapping clamors, ruling the acoustic flag of a helicopter in these flight conditions. In high speed forward flight, the airflow at the blade tip winds up transonic. The happening stun waves produce an uproarious clamor coordinated in flight bearing (high speed imprudent commotion, HSI). Symphonious and higher consonant stacking clamor are other low recurrence sources at the main rotor.

Vibration

Vibration sources in the helicopter are the main rotor, tail rotor, motors and other pivoting frameworks as water driven siphons and aviation based armed forces following up on the fuselage, e.g. tail shake. Main rotor vibrations emerge particularly in forward flight. The rotor encounters fluctuating liquid speeds and approaches at the progressing and withdrawing blade. Fluctuating range astute appropriations of lift and drag energize the blade's bowing modes. This outcomes in rotating rotor center burdens, particularly vertical forces and sidelong and longitudinal pole minutes. The happening vibration frequencies are regularly a different of the blade number and the insurgency recurrence. Utilizing more rotor blades and a littler fluttering pivot counterbalance can diminish Vibrations .In high speed flight, vibrations can happen if the withdrawing blade experiences solid unique slow down while the propelling blade encounters transonic stream with the inborn stuns. Another wellspring of vibrations is BVI particularly in fair flight. Insufficient blade following can be an extra wellspring of vibrations.

COMPOSITE MATERIALS:

A composite material is made by joining at least two materials – regularly ones that have altogether different properties. The two materials cooperate to give the composite special properties. The greatest preferred standpoint of present day composite materials is that they are light and additionally solid. By picking a fitting mix of lattice and reinforcement material, another material can be made that precisely meets the prerequisites of a specific application. Composites likewise give plan adaptability on the grounds that a significant number of them can be formed into complex shapes. The drawback is regularly the expense. In spite of the fact that the subsequent item is more effective, the crude materials are regularly costly.

Composite material a blend of a network and a reinforcement, which when consolidated gives properties better than the properties of the individual segments. On account of a composite, the reinforcement is the filaments and is utilized to sustain the grid as far as quality and stiffness.The reinforcement strands can be cut, adjusted, put in various approaches to influence the properties of the subsequent composite.The framework, regularly a type of sap, keeps the reinforcement in the coveted introduction. It shields the reinforcement from concoction and ecological assault, and it bonds the reinforcement with the goal that connected burdens can be successfully exchanged.

KIND OF COMPOSITES:

The term 'composite' can be utilized for a huge number of materials. Composites UK utilizes the term composite, or reinforced polymers to envelop:

1. Carbon fiber-reinforced polymers (CFRP)
2. Glass fiber-reinforced polymers (GFRP)
3. Aramid items (e.g. Kevlar)
4. Bio-determined polymers (or biocomposites)

LITERATURE REVIEW

The Dynamic Characteristics Analysis of Rotor Blade Based on ANSYS by **Nian-zhao Jiang, Xiang-lin Ma, Zhi-qing Zhang,** The three-dimension finite element model of helicopter rotor blade has been built with APDL language. Then using this model, the static strength and the dynamic characteristics about rotor blade has been analyzed with ANSYS software package. During the analysis of dynamic characteristic, the influence of aerodynamic force and centrifugal force applying to blade has been totally considered. Furthermore, the resonant chart of rotor blade has been presented in this paper.

Actuator design for the active trailing edge of a helicopter rotor blade by **Christoph K. Maucher1, Boris A. Grohmann1, Peter Jänker1, Andree Altmikus2, Flemming Jensen3, Horst Baier,** Today, helicopters still suffer from their environmental impact regarding external noise, fuel consumption and emissions, their low passenger comfort regarding cabin noise and vibrations and their limited performance regarding flight envelope, speed and range. One of the main sources of noise and vibrations is the main rotor, especially in fast forward and descent flight. Therefore, technologies for advanced rotor control are investigated. Individual blade control (IBC) systems allow to reduce vibration, noise and shaft power consumption. To control each rotor blade individually, on-blade actuation mechanisms based on active materials offer advantages in weight, power consumption and bandwidth compared to systems actuating the rotor blade root.

The most advanced approaches so far are the direct twist concept and the trailing edge flap. The topic of this paper is a new concept for an IBC actuator, the Active Trailing Edge. The Active Trailing Edge concept realizes a morphing cross section for a helicopter rotor blade. The trailing edge of the airfoil is able to deflect upwards and downwards. Similar to the trailing edge flaps, the ATE aims to twist the blade aero elastically using the servo effect, i.e. the change in aerodynamic pitching moment twists the rotor blade.

STRUCTURAL ANALYSIS OF THE MAIN ROTOR BLADE FOR A LIGHT HELICOPTER - CASE OF HOVERING FLIGHT MODE by **Diana CAZANGIU,** in **MAY 2014**, The aerospace industry deals from the beginning with structures with special requirements as extreme lightweight and withstanding to a big number of load cases. Aerodynamics constraints lead to supplementary restrictions, the results being the complex shape to sustain the fuselage, the rotor blades or the wings skin. This paper presents a static structural analysis of the main rotor blade for the light helicopter. To simulate the mechanical behavior of the blade, a finite elements method was used. A case of hovering flight mode was considered.

DESIGN, FABRICATION AND TESTING OF THE HELICOPTER TAIL ROTOR BLADE FROM COMPOSITE LAMINATED MATERIALS by Bosko Rasuo, In this paper the design, fabrication and analysis of behavior by full-scale verification testing for the tail rotor blade of composite laminated materials for a heavy transport helicopter is given. The verification test program for the tail rotor blade encompassed static and dynamic testing. The static tests of the blade involved experimental evaluation of torsion and flexional blade stiffness and its elastic axis position. Dynamic tests involved testing of vibratory characteristics and testing of blade fatigue characteristic. In structural vibration tests natural frequency, vibration modes and damping ratio for the structure were measured. The fatigue analysis of the structure of blade root section was performed after fatigue test cycles for detection of laminate separation, tolerance and distortion of cross sections of structure.

Structural design of composite rotor blades with consideration of manufacturability, durability, and manufacturing uncertainties by **Leihong Li**, A modular structural design methodology for composite blades is developed. This design method can be used to design composite rotor blades with sophisticate geometric cross-sections. This design method hierarchically decomposed the highly coupled interdisciplinary rotor analysis into global and local levels. In the global level, aero elastic response analysis and rotor trim are conduced based on multi-body dynamic models. In the local level, variation asymptotic beam sectional analysis methods are used for the equivalent one-dimensional beam properties.

Performance optimization of helicopter rotor blades by **Joanne L. Walsh** As part of a center-wide activity at NASA Langley Research Center to develop multidisciplinary design procedures by accounting for discipline interactions, a performance design optimization procedure is developed. The procedure optimizes the aerodynamic performance of rotor blades by selecting the point of taper initiation, root chord, taper ratio, and maximum twist which minimize hover horsepower while not degrading forward flight performance. Satisfactory aerodynamic performance is defined by the following requirements which must hold for any flight condition: the required horsepower must be less than the available horsepower; the section drag divergence Mach number on the advancing side of the rotor disc must be avoided, the maximum section lift coefficient on the retreating side of the rotor disc must be avoided, the high nose down pitching moments on either side of the rotor disc must be avoided; and the rotor blade must be trimmed. The procedure uses HOVT (a strip theory momentum analysis) to compute the horsepower required for hover and the comprehensive helicopter analysis program CAMRAD to compute the horsepower required for forward flight and maneuver.

The optimization algorithm consists of the general purpose optimization program CONMIN and approximate analyses. Sensitivity analyses consisting of derivatives of the objective function and constraints are carried out by forward finite differences. The procedure is applied to a test problem which is an analytical model of a wind tunnel model of a utility rotor blade. The hover analysis is performed using non uniform inflow without a wake model. The forward flight analysis is performed with and without wake.

PROBLEM DEFINITION & SOLUTION METHODOLOGY

The main rotor blade mainly influenced by the wind stream for rotation of blade and the impact of streamlined force and centrifugal force applying to blade has been completely considered. The dynamic attributes investigation of rotor blade is mainly engaged with the vibration control. The goal is to figure the normal recurrence and working recurrence of rotor blade is balancing those frequencies and staying away from reverberation at rotational speed, consequently the vibrations of helicopter may lessen.

The static quality and the dynamic attributes about rotor blade have been broke down with ANSYS programming for various materials (aluminum combination and composite materials).

The methodology followed in my project is as follows:

- Create a 3D model of the helicopter rotor blade using NX-CAD software.
- Perform Static analysis using ANSYS software and obtain the deflections and von mises stresses for aluminum material.
- Perform modal analysis of helicopter rotor blade for natural frequency and mode shapes.
- Perform harmonic analysis of helicopter rotor blade for operating frequency and deflections and stress values at critical frequencies.
- Perform static analysis using ANSYS software and obtain the deflections and stresses for composite materials like HM carbon/epoxy material.
- Perform modal analysis of helicopter rotor blade for natural frequency and mode shapes.
- Perform harmonic analysis of helicopter rotor blade for operating frequency and deflections and stress values at critical frequencies.
- Perform static analysis using ANSYS software and obtain the deflections and stresses for composite materials like E-glass/epoxy material.
- Perform modal analysis of helicopter rotor blade for natural frequency and mode shapes.
- Perform harmonic analysis of helicopter rotor blade for operating

frequency and deflections and stress values at critical frequencies.

- From analysis results, best material was proposed.

FINITE ELEMENT ANALYSIS OF HELICOPTER ROTOR BLADE

Finite Element Modeling (FEM) and Finite Element Analysis (FEA) are two most popular mechanical engineering applications offered by existing CAE systems. This is attributed to the fact that the FEM is perhaps the most popular numerical technique for solving engineering problems. The method is general enough to handle any complex shape of geometry (problem domain), any material properties, any boundary conditions and any loading conditions. The generality of the FEM fits the analysis requirements of today's complex engineering systems and designs where closed form solutions are governing equilibrium equations are not available. In addition it is an efficient design tool by which designers can perform parametric design studying various cases (different shapes, material loads etc.) analyzing them and choosing the optimum design.

FINITE ELEMENT METHOD

The FEM is numerical analysis technique for obtaining approximate solutions to wide variety of engineering problems. The method originated in the aerospace industry as a tool to study stresses in complicated airframe structures. It grew out of what was called the matrix analysis method used in aircraft design. The method has gained popularity among both researchers and practitioners and after so many developments codes are developed for wide variety of problems.

STRUCTURAL ANALYSIS

Structural analysis comprises the set of physical laws and mathematics required to study and predicts the behavior of structures. The subjects of structural analysis are engineering artifacts whose integrity is judged largely based upon their ability to withstand loads; they commonly include buildings, bridges, aircraft, and ships. Structural analysis incorporates the fields of mechanics and dynamics as well as the many failure theories. From a theoretical perspective the primary goal of structural analysis is the computation of deformations, internal forces, and stresses. In practice, structural analysis can be viewed more abstractly as a method to drive the engineering design process or prove the soundness of a design without a dependence on directly testing it.

FINITE ELEMENT MODELING:

3D model of the helicopter rotor blade was developed in UNIGRAPHICS from the design calculations done. The model was then converted into a parasolid to import into ANSYS. A Finite Element model was developed with solid elements. The elements that are used for idealizing the helicopter rotor blade were described below. A detailed Finite Element model was built with solid elements to idealize all the components of the helicopter rotor blade .Static and Modal analysis were carried out to find the natural frequencies. Changes were also implemented to shift the fundamental natural frequency. The elements that are used for idealizing the helicopter rotor blade are solid 92. The description of each element

Element Type Used:

Element type: Solid187
No. of nodes: 10
Degrees of freedom: 3 (UX, UY, UZ)

Solid187:

The element is defined by ten nodes having three degrees of freedom at each node translations in the nodal x, y, and z directions. SOLID187 has quadratic

e-ISSN: 2348-6848
p-ISSN: 2348-795X
Volume 05 Issue 22
November 2018

displacement behavior and is well suited to model irregular meshes.

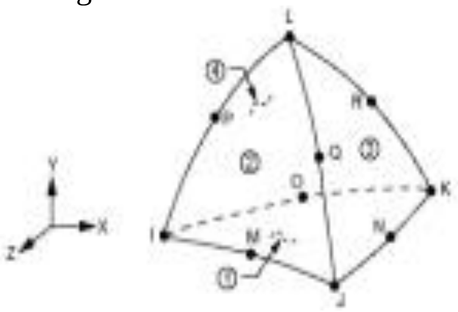


Figure 8: Solid187 geometry

STATIC ANALYSIS OF HELICOPTER ROTOR BLADE USING ALUMINIUM

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 do.

Gravitational force = 9810N

Rotor hub velocity () = 90 m/s

Consider helicopter rotor blade maximum Angular velocity,

Where, Helicopter main rotor blade radios (r) = 6m

Linear velocity (v) = 90m/s

RPS

MATERIAL PROPERTIES:

Aluminum alloys -2014-Mechanical Properties:

Young's modulus = 70Gpa

Yield Strength = 414 Mpa

Poison's ratio = 0.3

Density = 2700 kg/m3

3D model of the helicopter rotor blade was developed in UNIGRAPHICS. The model was converted into a Para solid to import in ANSYS.

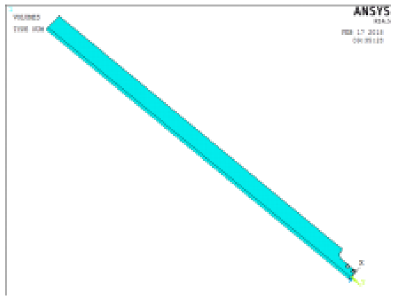


Fig shows the geometrical model of helicopter rotor blade

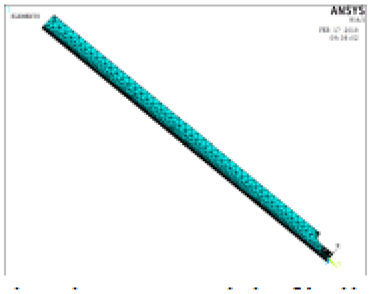


Fig shows the finite element model of helicopter rotor blade

The boundary conditions and loading applied for static analysis are shown below

- Blade is arrested on the bolting locations are fixed in all dof which is connected to hub.
- Angular velocity is applied to helicopter rotor blade.
- Gravitational force(aerodynamic+centrifugal) is applied to helicopter rotor blade in z direction.

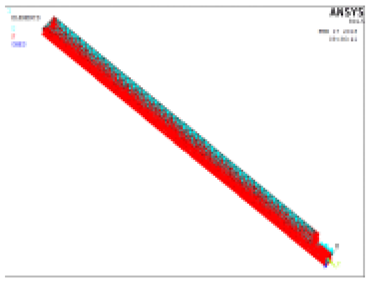


Fig. shows the Boundary conditions and Loading condition for static analysis

RESULTS

International Journal of Research
Available at https://edupediapublications.org/journals
e-ISSN: 2348-6848
p-ISSN: 2348-795X
Volume 05 Issue 22
November 2018

Deflections:

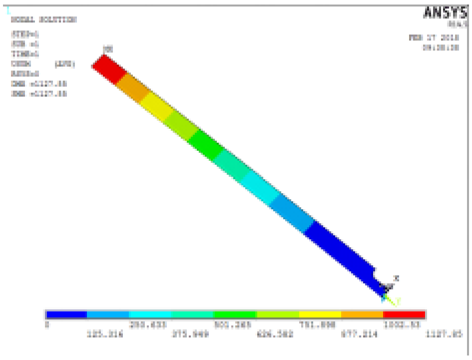


Fig. Total Deflection of helicopter rotor blade

VonMises Stress:

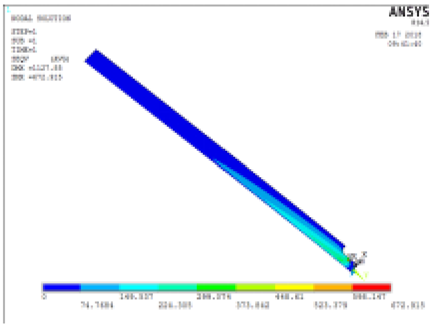


Fig. Von Mises stress of helicopter rotor blade

Table. Shows the max. Deflection and Max. Stress

Deformation(mm)	Von mises stress(MPa)
1127.85	224.35

From the analysis, it is observed that the maximum Von Misses stress observed is 224.35 MPa. The maximum stress is observed on the bolting location. The yield strength of the material is 414 MPa. According to the VonMises Stress Theory, the VonMises stress of helicopter rotor blade is having less stress than the yield strength of the material (aluminum alloy). Hence the design of helicopter rotor blade is safe for the above operating loading conditions.Further modal and harmonic analysis are done to check the dynamic behavior of helicopter rotor blade.

Mode Shapes:

For every natural frequency there is a corresponding vibration mode shape. Most mode shapes can generally be described as being an axial mode, torsional mode, bending mode, or general modes. Like stress analysis models, probably the most challenging part of getting accurate finite element natural frequencies and mode shapes is to get the type and locations of the restraints correct. A crude mesh will give accurate frequency values, but not accurate stress values.

Modal Analysis:

Modal analysis is used to determine the vibration characteristics (natural frequencies and mode shapes) of a structure or a machine component while it is being designed. It can also serve as a starting point for another, more detailed, dynamic analysis, such as a transient dynamic analysis, a harmonic response analysis, or a spectrum analysis.

We can do modal analysis on a pressurised structure, such as a spinning turbine blade. Another useful feature is modal cyclic symmetry, which allows us to review the mode shapes of a cyclically symmetric structure by modelling just a sector of it.

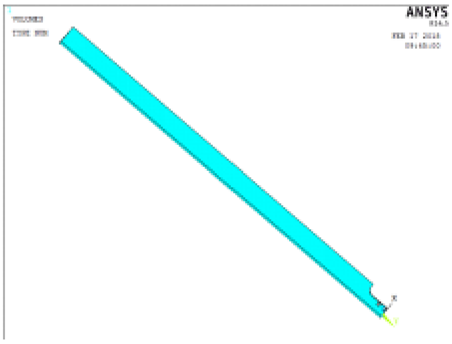
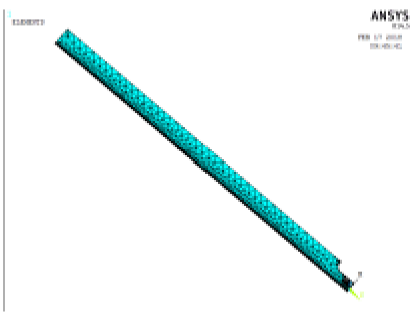


Fig. Imported blade in ansys



e-ISSN: 2348-6848
p-ISSN: 2348-795X
Volume 05 Issue 22
November 2018

Fig. Mesh model

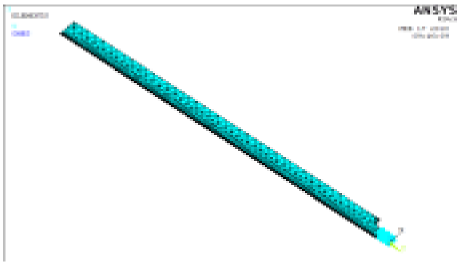
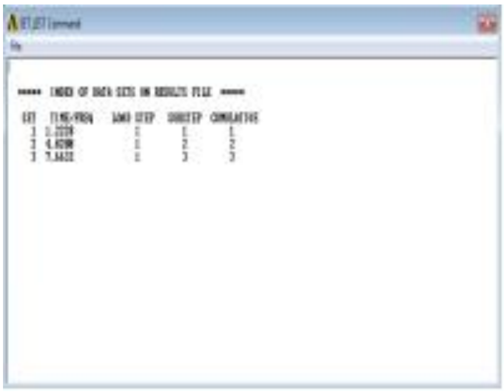


Fig. Applied fixed constraints at bolting region

RESULTS

Natural frequencies

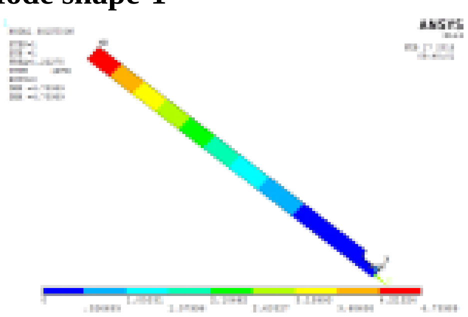


***** INDEX OF DATA SETS ON RESULTS FILE *****

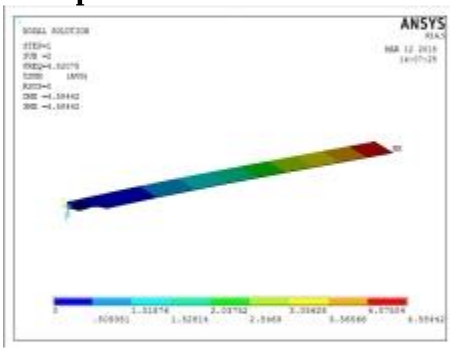
SET	TIME/FREQ	LOAD STEP	SUBSTEP	CUMULATIVE
1	[illegible]	1	1	1
2	[illegible]	1	2	2
3	[illegible]	1	3	3

Modes are inherent properties of a structure, and are determined by the material properties (mass, damping, and stiffness), and boundary conditions of the structure. Each mode is defined by a natural (modal or resonant) frequency, modal damping, and a mode shape (i.e. the so-called "modal parameters"). If either the material properties or the boundary conditions of a structure change, its modes will change

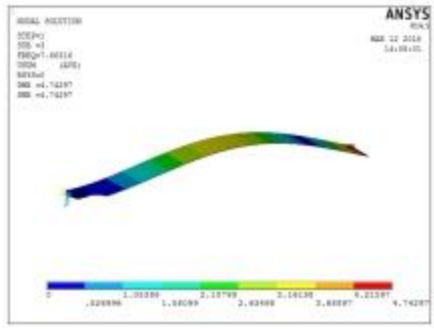
Mode shape-1



Mode shape-2



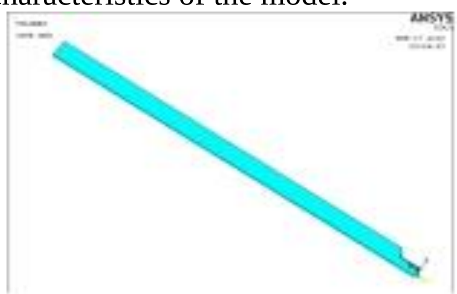
Mode shape-3



5.2.2 HARMONIC ANALYSIS OF HELICOPTER ROTOR BLADE USING ALUMINIUM MATERIAL

A *harmonic analysis* is used to determine the response of the structure under a steady-state sinusoidal (harmonic) loading at a given frequency.

- A harmonic, or frequency-response, analysis considers loading at one frequency only. Loads may be out-of-phase with one another, but the excitation is at a known frequency. This procedure is not used for an arbitrary transient load.
- One should *always* run a free vibration analysis prior to a harmonic analysis to obtain an understanding of the dynamic characteristics of the model.



e-ISSN: 2348-6848
p-ISSN: 2348-795X
Volume 05 Issue 22
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Fig. Imported blade in ansys

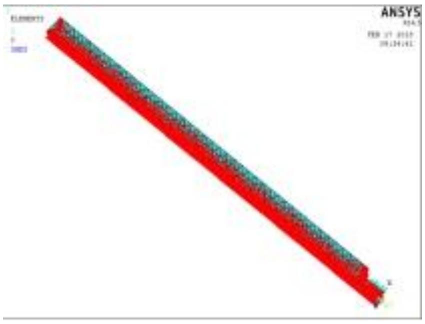
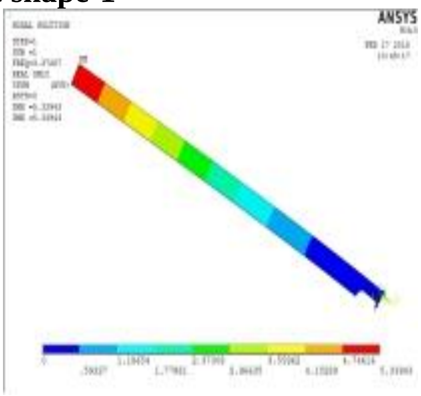
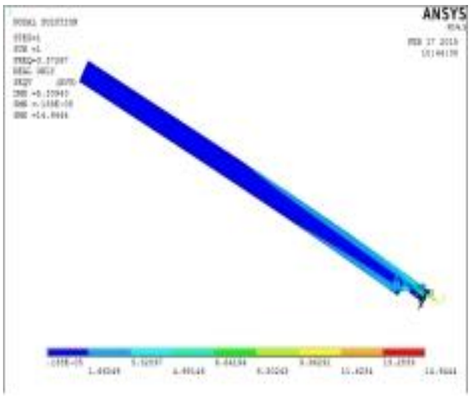


Fig. Applied fixed constraints at bolting region and gravitational force on blade

RESULTS

Mode shape-1





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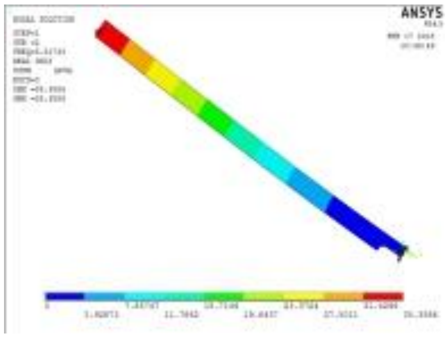
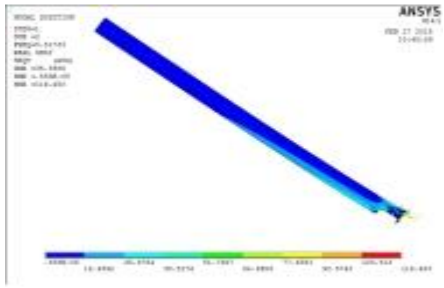
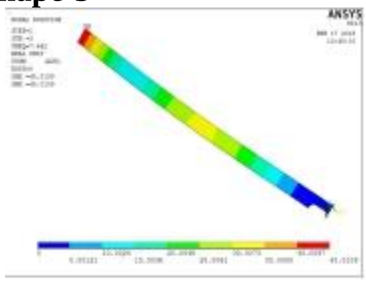
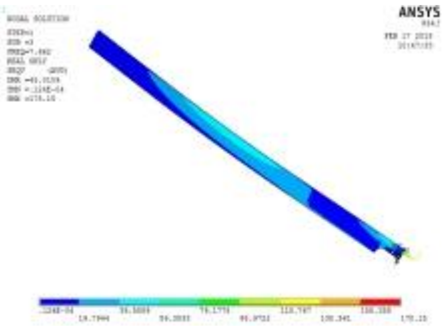




Mode shape-3





STATIC ANALYSIS OF COMPOSITE HELICOPTER ROTOR BLADE USING COMPOSITE HM CARBON/EPOXY

OBJECTIVE:

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

MATERIAL PROPERTIES:

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- **Carbon/Graphite fibers:** its advantages include high specific strength and modulus, low coefficient of thermal expansion, and high fatigue strength. Graphite, when used alone has low impact resistance. Its drawbacks include high cost, low impact resistance, and high electrical conductivity.

Table. Properties of HM Carbon/Epoxy

S. No	Property	Units	HM Carbon/Epoxy
1.	E_{11}	GPa	190.0
2.	E_{22}	GPa	7.7
3.	G_{12}	GPa	4.2
4.	n_{12}	-	0.3
5.	$S^t_1 = S^c_1$	MPa	870.0
6.	$S^t_2 = S^C_2$	MPa	94.0
7.	S_{12}	MPa	30.0
8.	ρ	Kg/m^3	1600.0

3D model of the helicopter rotor blade was developed in UNIGRAPHICS. The model was converted into a Para solid to import in ANSYS.

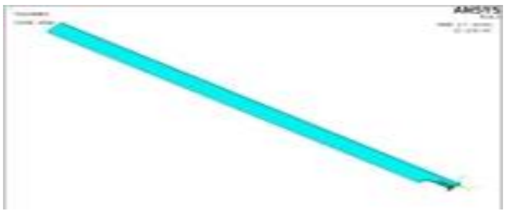

Fig shows the geometrical model of helicopter rotor blade

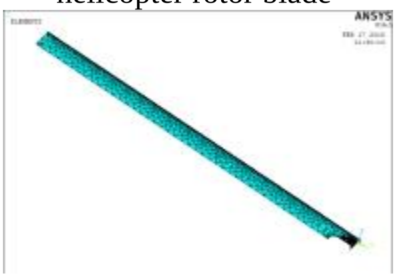

Fig shows the finite element model of helicopter rotor blade

BOUNDARY CONDITIONS:

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 = 9810N
- Angular velocity () = 15

Consider helicopter rotor blade maximum Angular velocity,

Where,

Helicopter main rotor blade radios (r) = 6m

Linear velocity (v) = 90m/s

The boundary conditions and loading applied for static analysis are shown below

- Blade is arrested on the bolting locations are fixed in all dof which is connected to hub.
- Angular velocity is applied to helicopter rotor blade.
- Gravitational force is applied to helicopter rotor blade in z direction.

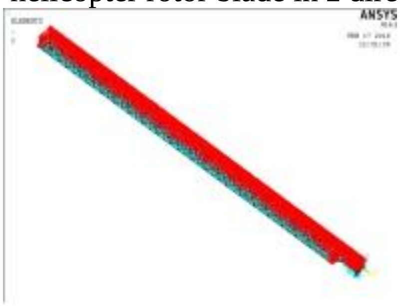

Fig. shows the Boundary conditions and Loading condition for static analysis

Deflections:

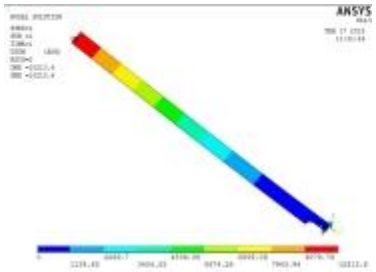

Fig. Total Deflection of helicopter rotor blade

Vonmises Stress:

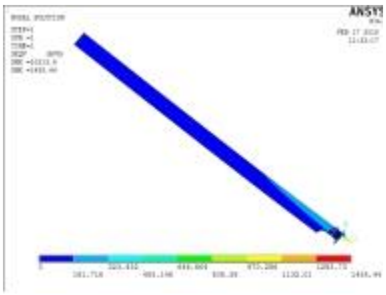

Fig. Von Mises stress of helicopter rotor blade

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MODAL ANALYSIS OF HELICOPTER ROTOR BLADE USING HM CARBON/EPOXY MATERIAL

Methodology:

- Develop a 3D model.
- The 3D model is created using UNIGRAPHICS-NX software.
- The 3D model is converted into parasolid and imported into ANSYS to do modal analysis.
- Calculate natural frequencies and plot their mode shapes.
- **Modal Analysis:**

➢ Modal analysis is used to determine the vibration characteristics (natural frequencies and mode shapes) of a structure or a machine component while it is being designed. It can also serve as a starting point for another, more detailed, dynamic analysis, such as a transient dynamic analysis, a harmonic response analysis, or a spectrum analysis.

We can do modal analysis on a pressurised structure, such as a spinning turbine blade. Another useful feature is modal cyclic symmetry, which allows us to review the mode shapes of a cyclically symmetric structure by modelling just a sector of it.

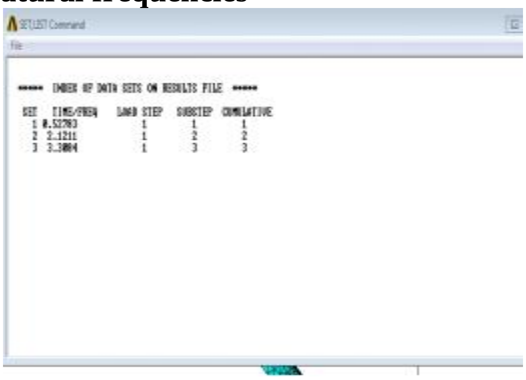
Fig. Imported blade in ansys

Fig. Mesh model

Fig. Applied fixed constraints at bolting region

RESULTS

Natural frequencies



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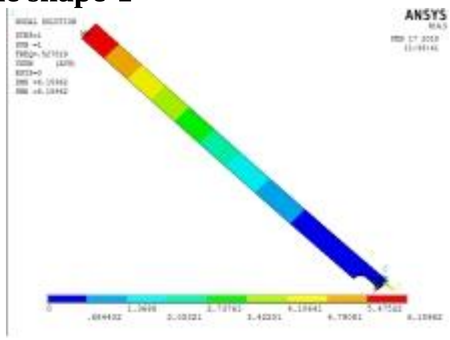

Mode shape-2

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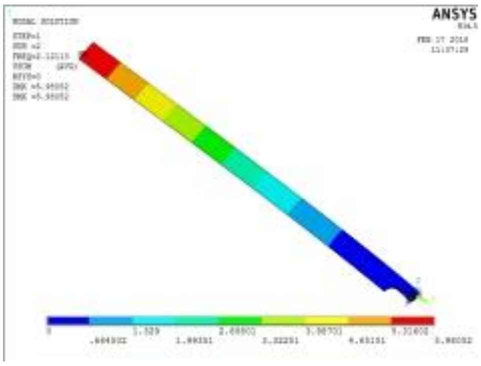
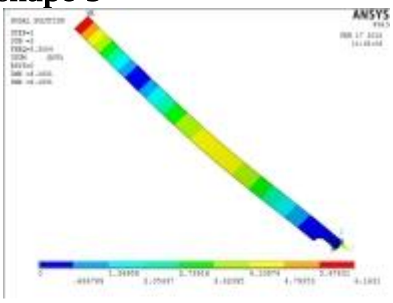


Mode shape-3



5.4.2 HARMONIC ANALYSIS OF HELICOPTER ROTOR BLADE USING E-GLASS/EPOXY MATERIAL

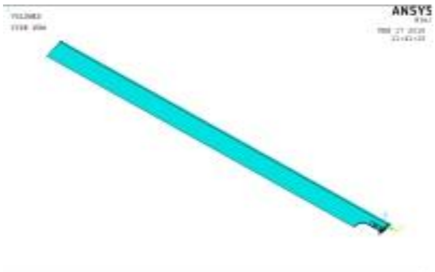


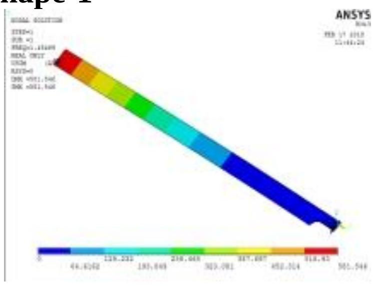
Fig. Imported blade in ansys

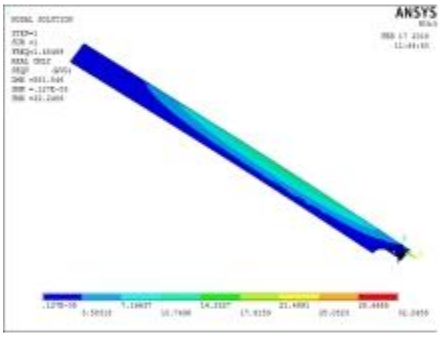
Fig. Mesh model

Fig. Applied fixed constraints at bolting region and gravitational force on blade

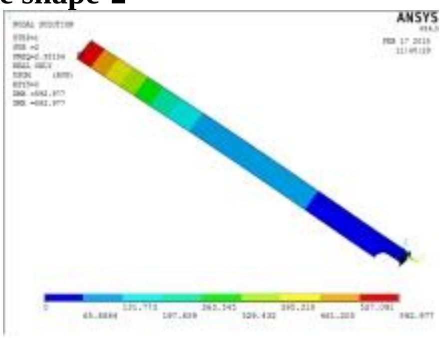
RESULTS

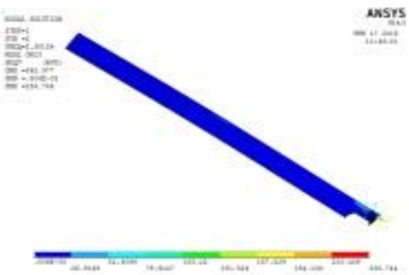
Mode shape-1





Mode shape-2





Mode shape-3

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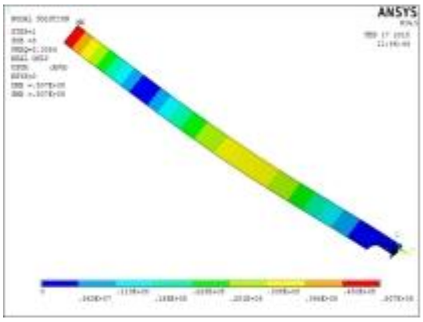

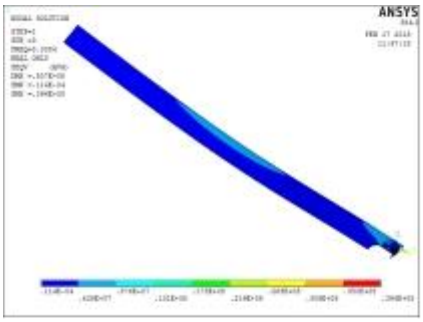

STATIC ANALYSIS OF COMPOSITE E-GLASS/EPOXY HELICOPTER ROTOR BLADE

OBJECTIVE:

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

MATERIAL PROPERTIES:

- **Glass fibers**: Its advantages include its low cost, high strength, high chemical resistance, and good insulating properties. The disadvantages are low elastic modulus, poor adhesion to polymers, low fatigue strength, and high density, which increase shaft size and weight. Also crack detection becomes difficult.

Table. Properties of E-GLASS/Epoxy

S. No	Property	Units	E-Glass/Epoxy
1.	E_{11}	GPa	50.0
2.	E_{22}	GPa	12.0
3.	G_{12}	GPa	5.6
4.	n_{12}	-	0.3
5.	$S^t_1 = S^c_1$	MPa	800.0
6.	$S^t_2 = S^C_2$	MPa	40.0
7.	S_{12}	MPa	72.0
8.	ρ	Kg/m^3	2000.0

3D model of the helicopter rotor blade was developed in UNIGRAPHICS. The model was converted into a Para solid to import in ANSYS.

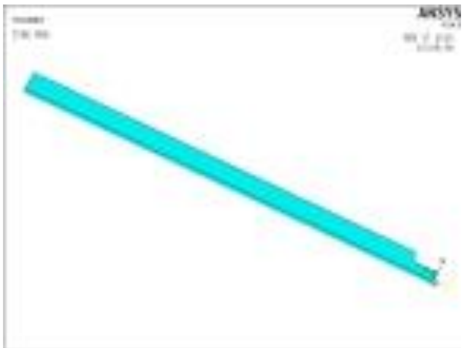

Fig shows the geometrical model of helicopter rotor blade

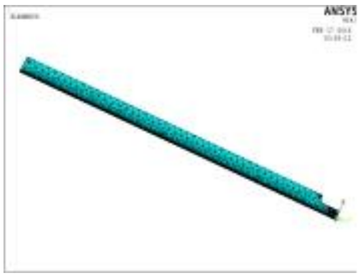

Fig shows the finite element model of helicopter rotor blade

BOUNDARY CONDITIONS:

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 () = 15

Consider helicopter rotor blade maximum Angular velocity,

Where,

Helicopter main rotor blade radios (r) = 6m

Linear velocity (v) = 90m/s

The boundary conditions and loading applied for static analysis are shown below

- Blade is arrested on the bolting locations are fixed in all dof which is connected to hub.
- Angular velocity is applied to helicopter rotor blade.
- Gravitational force is applied to helicopter rotor blade in z direction.

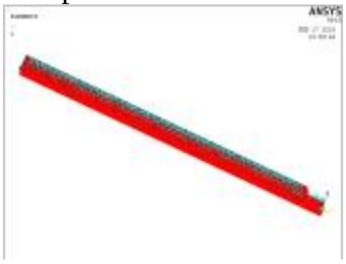

Fig. shows the Boundary conditions and Loading condition for static analysis

RESULTS:

Deflections:

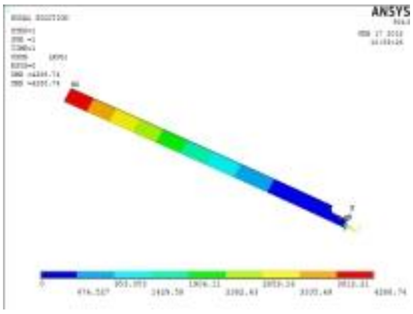

Fig. Total Deflection of helicopter rotor blade

Vonmises Stress:

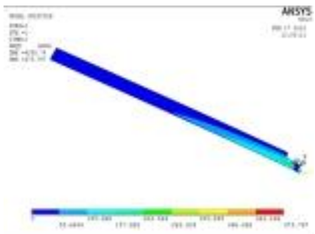

Fig. Von Mises stress of helicopter rotor blade

Modal Analysis:

Modal analysis is used to determine the vibration characteristics (natural frequencies and mode shapes) of a structure or a machine component while it is being designed. It can also serve as a starting point for another, more detailed, dynamic analysis, such as a transient dynamic analysis, a harmonic response analysis, or a spectrum analysis.

We can do modal analysis on a pressurised structure, such as a spinning turbine blade. Another useful feature is modal cyclic symmetry, which allows us to review the mode shapes of a cyclically symmetric structure by modelling just a sector of it.

Fig. Imported blade in ansys

Fig. Mesh model

Fig. Applied fixed constraints at bolting region

RESULTS

Natural frequencies

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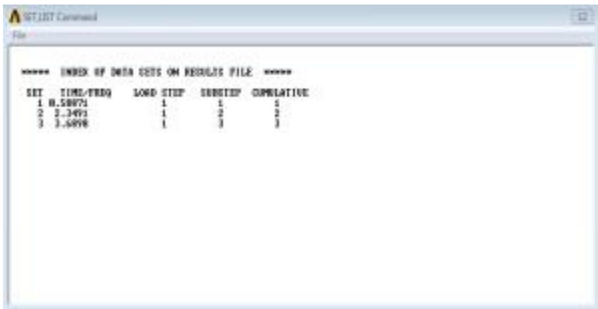

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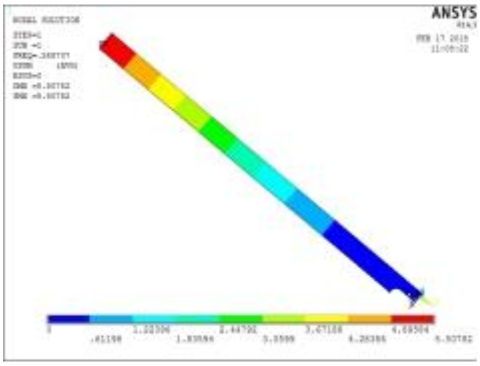
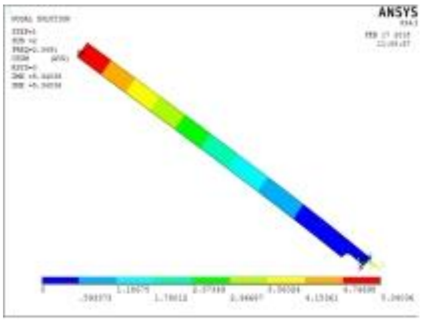
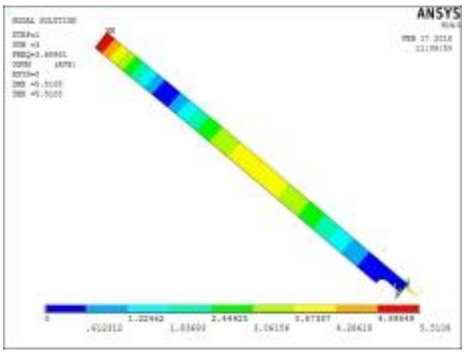


Mode shape-2



Mode shape-3



HARMONIC ANALYSIS OF HELICOPTER ROTOR BLADE USING E-GLASS/EPOXY MATERIAL

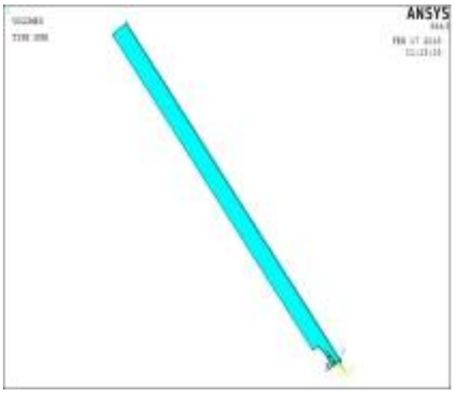


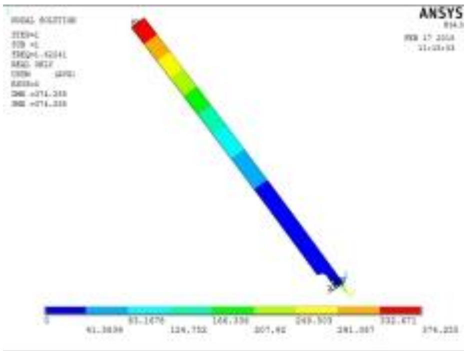
Fig. Imported blade in ansys

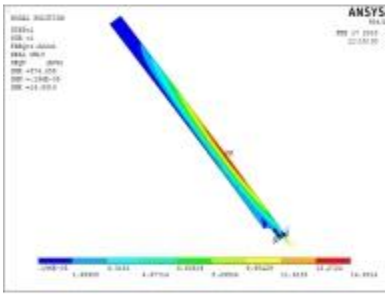
Fig. Mesh model

Fig. Applied fixed constraints at bolting region and gravitational force on blade

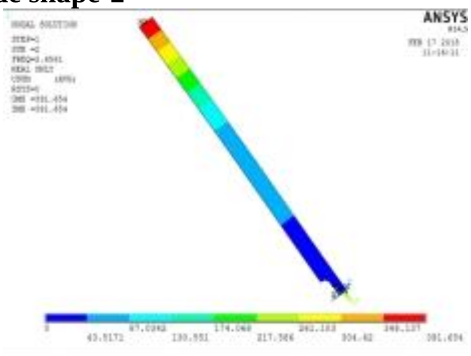
RESULTS

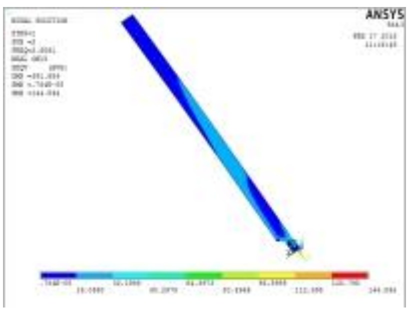
Mode shape-1



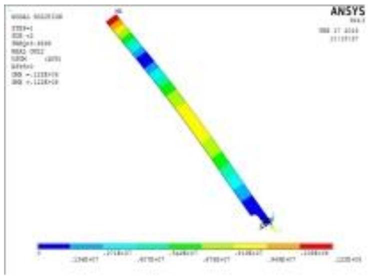


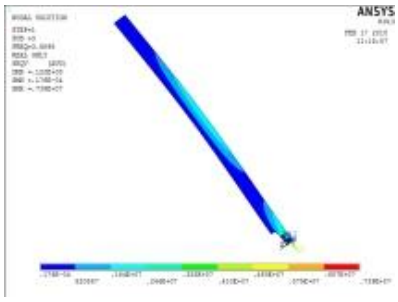
Mode shape-2





Mode shape-3





RESULTS AND DISCUSSIONS

In the present project, the helicopter rotor blade has been studied for structural behavior and optimized 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 224.3 MPa. The maximum stress is observed on the bolting location. The yield strength of the material is 414 MPa. According to the VonMises Stress Theory, the VonMises stress of helicopter rotor blade is having less stress than the yield strength of the material (aluminium alloy).

From modal analysis

From modal analysis results, observed that natural frequency ranges from 1.22Hz to 7.65 Hz.

From Harmonic analysis

From Harmonic analysis, observed that operating frequencies 3.37Hz, 5.51Hz and 7.66 Hz.

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

From static analysis,

From static analysis results for HM Carbon/epoxy, the resultant Von misses stress formed on rotor blade is **161.716MPa.** The ultimate strength of HM Carbon/Epoxy material is **870 MPa**. The Von mises stress of rotor blade was less than the ultimate strength of the material. Hence the rotor blade was safe in design for static conditions.

From modal analysis

From modal analysis results, observed that natural frequency ranges from 0.52Hz to 3.3 Hz.

From Harmonic analysis

From Harmonic analysis, observed that operating frequencies 1.45Hz, 2.38Hz and 3.3 Hz.

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

From static analysis,

From static analysis results for Glass/epoxy, the resultant Von misses stress formed on rotor blade is **210.56MPa.** The ultimate strength of Glass/epoxy material is **870 MPa**. The Von mises stress of rotor blade was less than the ultimate strength of the material. Hence the rotor blade was safe in design for static conditions.

From modal analysis

From modal analysis results, observed that natural frequency ranges from 0.58Hz to 3.6 Hz.

From Harmonic analysis

From Harmonic analysis, observed that operating frequencies 1.62Hz, 2.65Hz and 3.68 Hz.

Comparing all results of three materials, HM Carbon/Epoxy material forms less vonmises stress and natural and operating (forced) frequencies at mentioned loading conditions. So Hm Carbon/Epoxy is a best One for helicopter rotor blade.

CONCLUSION

In the present project, the helicopter rotor blade has been studied for structural behavior and optimized 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 dynamic characteristics of rotor blade has been developed. The static strength and the dynamic characteristics about 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 factor of safety.

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