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# "Design and Analysis of Helicopter Rotor Hub for Structural Loads"

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## ABSTRACT:

The rotor system is the rotating part of a helicopter which generates lift. The rotor consists of a mast, hub, and rotor blades. The mast is a hollow cylindrical metal shaft which extends upwards from and is driven and sometimes supported by the transmission. At the top of the mast is the attachment point for the rotor blades called the hub. The rotor blades are then attached to the hub by any number of different methods. Main rotor systems are classified according to how the main rotor blades are attached and move relative to the main rotor hub. As the rotor spins, each blade responds to inputs from the control system to enable helicopter control. The center of lift on the whole rotor system moves in response to these inputs to effect pitch, roll, and upward motion. Here the helicopter rotor hub must carry the blade weight and aerodynamic forces as rotational speeds. For that case, of helicopter rotor hub strength will be calculated. The dynamic characteristics analysis of rotor hub is mainly involved in the calculation about natural frequency and operating frequencies. The objective is to calculate the natural frequency and operating frequencies of rotor hub is modulating those frequencies and avoiding resonance at rotational speeds and blade weights, thus the vibrations of helicopter may reduce. In this project, the 3D model of helicopter main rotor hub shall be done in UNIGRAPHICS and imported into ANSYS software to perform static and dynamic analysis to analyze strength and dynamic characteristics of rotor hub and optimize by using different materials for weight reduction.

## INTRODUCTION:

Helicopters are 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 helicopter's wings are called Main Rotor Blades. The shape and the angle of the blades move through the air will determine how much Lift force is created. After the helicopter lifted off the ground, the pilot can tilt the blades, causing the helicopter to tip forward or backward or sideward.

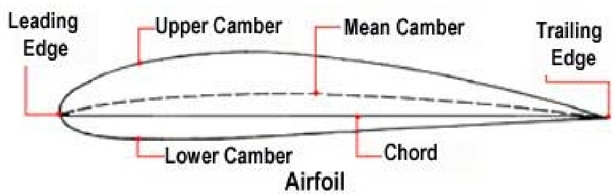


Fig.1. Rotor blade Airfoil shape

Basically the wings of the airplane create a lift force when they move through the air. As we known, during flight, there are four forces acting on the helicopter or airplane and those are LIFT, DRAG, THRUST, and WEIGHT. In order to make the wings to move through the air, of course, the plane itself has to move. A helicopter works by having its wings move through the air while the body stays still.

Fig.2 Rotor Head Assembly- VH-OHA.

## LITERATURE SURVEY:

1. Three dimensional stress analysis of a helicopter main rotor hub using cyclic symmetry by Richard l.Rotelli,jr, a three dimensional stress analysis of the new main rotor hub design fo the SH-2F helicopter was performed using the cycle symmetry feature of MSC/NASTAN. The FEMGEN interaction graphics mesh generator was used to create the one – eighth symmetry finite element model. The structural response of the rotor hub to several different loading conditions, as predicted by MSC/NASTAN, was displayed graphically by the FEMGEN interactive results viewing program. Presented in this way, the resulta of the NASTRAN analysis had a positive impact on the new design of the main rotor hub.

2. Modes shape and harmonic analysis of different structures for helicopter blade byAbdelkader NOUR 1, Mohamed Tahar GHERBI 1, Yon CHEVALIER, This study concerns the dynamic behavior of a helicopter blade. The objective is to simulate by the finite elements method, the behavior of a blade of different materials under an aerodynamic load. This study was conducted to evaluate the aerodynamic loads applied and evaluated by a numerical simulation the frequencies and Eigen modes and calculate the stresses acting on the structure for different modes. The study of the transient behavior has allowed the determination of the vibration responses due to unbalance and different excitation modes.

3. Flow Characteristics of a Five-Bladed Rotor Head by Moritz Grawunder, Roman Reß, Victor Stein, Christian Breitsamter, and Nikolaus A. Adams, This work presents the analysis of the flow characteristics of a rotating five-bladed rotor head including cyclic pitch. The main objective is identifying potential for efficiency gains. The results are obtained through numerical simulations based on the incompressible unsteady Reynolds averaged Navier Stokes equations. Cyclic pitch motion is modeled through mesh deformation. It is shown that the pitch control mechanism contributes considerably to the parasite drag. Thus improving the aerodynamic fairing of these components provides potential for drag reduction. Furthermore, it is shown that the cyclic pitch motion of the blade cuffs has a relevant impact on the aerodynamic characteristics.

## PROBLEM DEFINITION AND METHODOLOGY:

As the rotor spins, each blade responds to inputs from the control system to enable helicopter control. The center of lift on the whole rotor system moves in response to these inputs to effect pitch, roll, and upward motion.

Here the helicopter rotor hub must carry the blade weight and aerodynamic forces as rotational speeds. For that case, of helicopter rotor hub strength will be calculated.

The methodology followed in my project is as follows:

» 3D modeling of helicopter rotor hub shall be done by using NX-CAD software and it is imported into ANSYS software to do finite element analysis.

» Perform static analysis on the helicopter rotor hub and documents the deflections and stresses.

» Perform dynamic analysis to find natural frequencies and operating frequencies on the helicopter rotor hub.

» Perform static and dynamic analysis on helicopter rotor hub for different materials like as steel, aluminum alloy and composite.

## FINITE ELEMENT ANALYSIS OF HELICOPTER ROTOR HUB

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 of helicopter rotor hub

Structural analysis comprises the set of physical laws and mathematics required to study and predict 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.

## Methods of performing structural analysis

To perform an accurate analysis a structural engineer must determine such information as structural loads, geometry, support conditions, and materials properties. The results of such an analysis typically include support reactions, stresses and displacements. This information is then compared to criteria that indicate the conditions of failure. Advanced structural analysis may examine dynamic response, stability and non-linear behavior.

## Description

ANSYS is a Finite Element Analysis (FEA) code widely used in the Computer Aided Engineering (CAE) field. ANSYS software allow to construct computer models of structures, machine components or systems, apply operating loads and other design criteria and study physical responses, such as stress levels, temperature distributions, pressure, etc. The ANSYS program has a variety of design analysis applications, ranging from automobiles to such highly sophisticated systems as aircraft, nuclear reactor containment buildings and bridges. There are 250+ elements derived for various applications in ANSYS. In the present application shell, beam and mass elements that have structural static and dynamic analysis capabilities were considered.

## Finite element modeling

3D model of the Helicopter rotor Hub 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 Hub were described below. A detailed Finite Element model was built with solid elements to idealize all the components of the Helicopter rotor Hub. 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 Hub are solid 92.The description of each element is given below.

## Material properties

All the components of the Helicopter rotor Hub is made using Steel, High Strength Alloy ASTM A-514. All the components of the Helicopter rotor Hub are assigned as per the below material properties.

## Steel, High Strength Alloy ASTM A-514 Mechanical Properties:

Young's modulus = 210GPa
Yield Strength = 690 Mpa
Tensile Strength = 760 Mpa
Density = 7850e kg/m3
Poison ratio = 0.3

## Element Type Used:

Element type: Solid92
No. of nodes: 10
Degrees of freedom: 3 (UX, UY, UZ)

## Solid92:

The element is defined by ten nodes having three degrees of freedom at each node: translations in the nodal x, y, and z directions. SOLID92 has quadratic displacement behavior and is well suited to model irregular meshes.

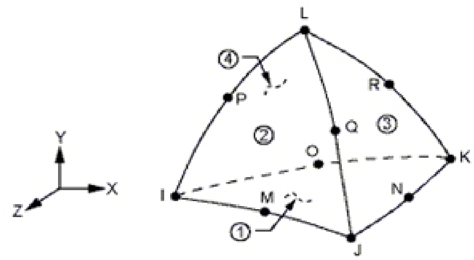


Fig.3. Solid92 geometry

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

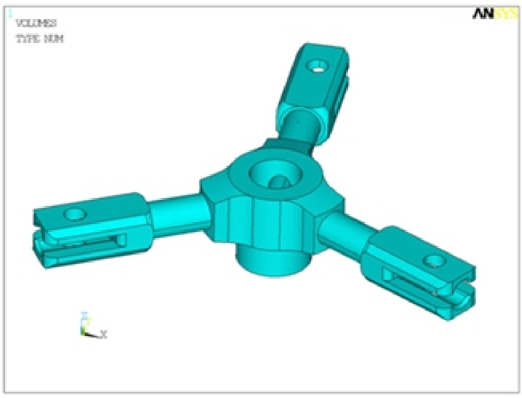

Fig.4 shows the geometric model of the Helicopter rotor Hub

The Helicopter rotor Hub model was meshed with solid 92 element type. A total number of 23115 element and 40019 nodes were created. The meshed model is shown in the below figure.

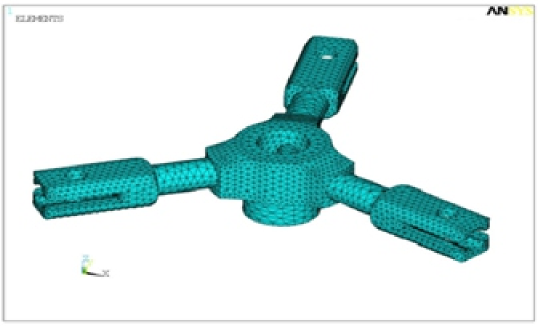

**Fig.5 shows the Finite element model of the Helicopter rotor Hub**

## Static analysis of helicopter rotor hub

Static analysis is used to determine the displacements, stresses, strains and forces in structures or components caused by loads that do not induce significant inertia and damping effects.

## Objective

To Objective of this analysis is to check the High stressed locations and deflections on the Helicopter rotor Hub for the applied loads.

## Boundary conditions

» The rotating shaft location is fixed in all dof.
» Rotor blade weight is applied on Helicopter rotor Hub.
» Angular velocity and gravity was applied on Helicopter rotor Hub.

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

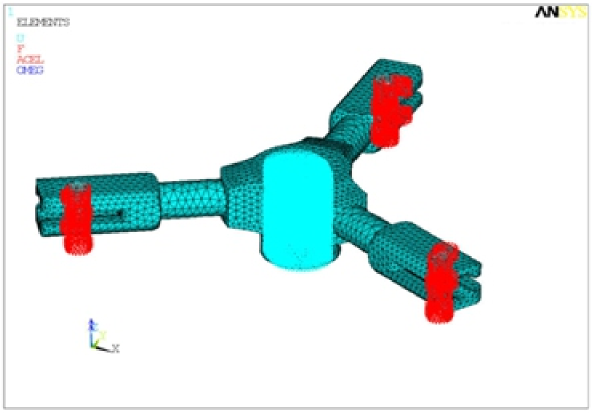

**Fig.6 shows the Boundary conditions applied on Helicopter rotor Hub for static analysis**

## Deflections:

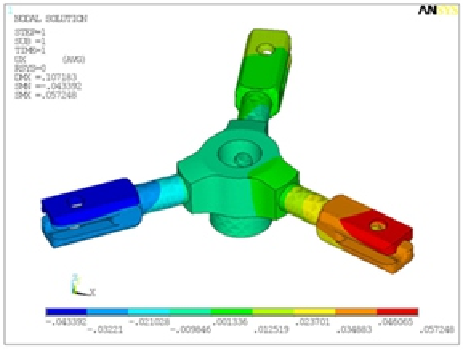

**Fig.7 Deflection in X-dir for static analysis**

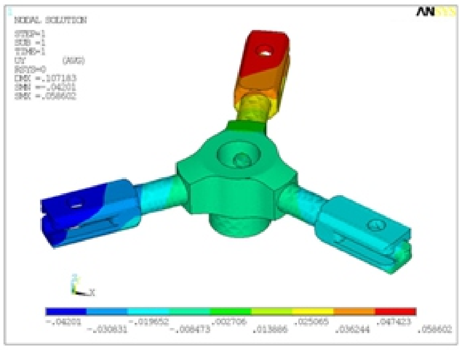

**Fig.8 Deflection in Y-dir for static analysis**

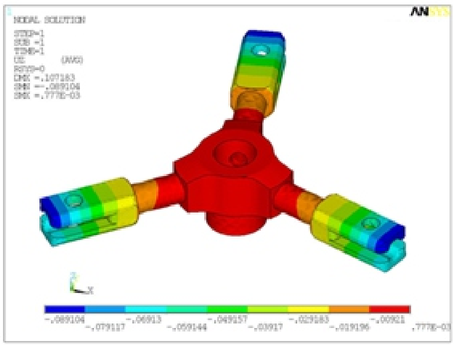

**Fig.9 Deflection in Z-dir for static analysis**

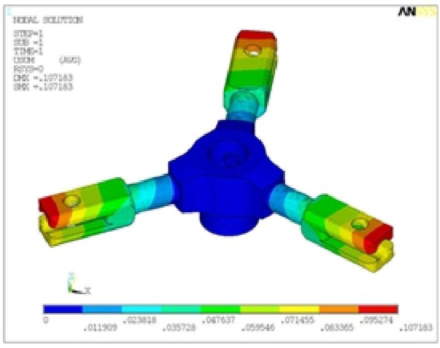

**Fig.10 Total Deflection for static analysis**

**Observations**

From the above analysis results of the Helicopter rotor Hub, following observations are made:
» Six natural frequencies exist in the range of 0-200 Hz.
» The total weight of the Helicopter rotor Hub observed for the analysis is 7.5kgs

To check the magnitude values of deflections and stresses at the above mentioned frequencies due to the operating loads, harmonic analysis is carried out on the Helicopter rotor Hub.

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6. Three dimensional stress analysis of a helicopter main rotor hub using cyclic symmetry by Richard l.Rotelli,jr.

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9. Flow Characteristics of a Five-Bladed Rotor Head by Moritz Grawunder, Roman Reß, Victor Stein, Christian Breitsamter, and Nikolaus A. Adams.