OPTIMIZATION OF ROTOR HUB FOR DIFFERENT MATERIALS USING ANSYS SOFTWARE

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ABSTRACT- The rotor system is the revolving part of a helicopter which generates lift. This rotor consists of a mast, rotor blades, and hub. The mast is a hollow cylindrical metal shaft which extends in an upward direction from and is driven. Sometimes it is supported by the transmission also. On the top, a mast is the attachment point for the rotor blades (hub). The rotor blades are attached to the hub by different methods. Critical rotor systems are classified according to how they move relative to the main rotor hub and how the main rotor blades are attached. As the rotor starts spinning, each blade responds to inputs from the control system to enable helicopter control. The centre of lift on the whole rotor system proceeds in response to these inputs to impact pitch, roll, and move in upward motion. In this case, the rotor hub must carry aerodynamic forces and the blade weight as rotational speeds. For that of helicopter rotor hub strength will be calculated. In this project, the 3d model of helicopter main rotor hub shall be done in Unigraphics and imported into ansys software to perform static analysis to analyse the strength of rotor hub and optimise by using different materials.

Keywords- Rotor Hub, Von Mises Stresses, Unigraphics, Aerodynamic Forces

I. INTRODUCTION

Helicopters are made in many sizes and shapes, but most share the similar major components. These components include a cabin where the payload and crew are carried. An airframe, which houses the various elements, where components are attached. A power plant or engine and a transmission, which among other things, receives the power from the main engine and transmits it to the central rotor, which supplies the aerodynamic forces that compile the helicopter to fly. Then, to hold the helicopter from overturning due to torque, there must be some anti-torque system. Finally, there is the landing gear, which could be skids, wheels, skis, or floats.

II. LITERATURE REVIEW

1. 'Dynamic Analysis of Helicopter Bearingless Main Rotor With Hub Flex beams Damage Configurations' by Ki C. Kim. This report documents a dynamic analysis of a helicopter bearingless main rotor system with damaged hub flex beam configurations. The analysis was performed using a comprehensive helicopter aeroelastic code based on finite element/blade element theory. The bearingless central rotor (BMR) system, including flex beams, torque tubes, and main rotor blades, is modelled as some elastic beam finite elements, wherein each beam element undergoes flap bending, lag bending, flexible twist, and axial deflections. Aerodynamic forces on rotor blades are calculated using quasi-steady aerodynamic theory with a linear in-flow model. Flex beam ballistic damage is stimulated by changes in the span wise distribution of the mass, bending and tensional stiffness of flex beam element. Results are first calculated for a soft in-plane, five-bladed, bearing fewer rotors, with an undamaged (baseline) configuration. Outcomes are then calculated for this rotor system with damage depiction. The outline of this damage on rotor and helicopter system interpretations are determined regarding blade modal shapes and frequencies, rotor system aeroelastic response and loads variations. Ballistic damage to the hub flex beam can significantly affect the dynamic behaviour of the bearingless rotor system.

2. The design of Nacelle and Rotor Hub for NOWITECH 10MW Reference Turbine by Sandeep Singh Klair Wind turbine development has been formidable in the last years. One of NOWITECH's goal is to research large offshore wind turbines. A bedplate and hub for the NOWITECH 10MW reference turbine have been analysed, according to IEC 61400. The work is based on Ebbe Smith's thesis about bedplate design, and Mohammad Akram Khan's thesis about rotor shaft and rotor hub design. An entirely new bedplate has been designed and analysed with the correct boundary conditions including a yaw bearing with contact surfaces and bolt connections between flanges. The hub received minor modifications and is analysed with a lock link and pitch bearings. The mass of the new bed plate is 99.6 tons, and has peak stress of 217.5MPa which is justified in the discussion. The top stress in the hub is 126MPa.

III. PROBLEM DEFINITION AND METHODOLOGY

As the rotor spins, each particular blade responds to inputs from the control system to allow helicopter control. The centre of lift on the whole rotor system moves in response to these inputs to affect upward motion, pitch, and roll. Here the helicopter rotor hub must bring the blade weight and aerodynamic forces as rotational fastness. In that case, helicopter rotor hub strength will be calculated. The methodology followed in my project is as follows 3D modelling 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 of the helicopter rotor hub and records the deflections and stresses. Execute dynamic analysis to notice 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, aluminium alloy and composite.

IV. 3D MODELLING OF HELICOPTER ROTOR HUB

The 3D model of the helicopter rotor hub is created using the NX-CAD software. NX-CAD is the world's first leading 3D product development solution. This developing software enables engineers and designers to bring better products to the market as fast as possible. It takes care of the entire product definition to serviceability. NX delivers measurable value to manufacturing companies of all sizes and in all industries.

From the below 2D drawings was used to develop a 3D model of helicopter rotor hub.

2D Drawing of helicopter rotor hub

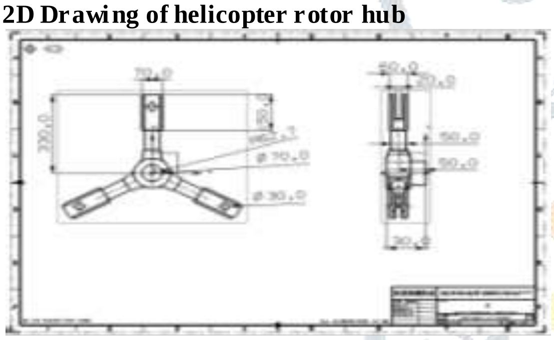


Fig.1: Shows the 2D drawing of helicopter rotor hub

3D Model of helicopter rotor hub

Front view of Helicopter rotor Hub

Fig.2: shows the 3D model of Helicopter rotor Hub (front view)

Top view of Helicopter rotor Hub

Fig.3: shows the 3D model of Helicopter rotor Hub (top view)

Isometric view -1 of Helicopter rotor Hub

Fig.4: shows the 3D model of Helicopter rotor Hub isometric view)

Isometric view -2 of Helicopter rotor Hub

Fig.5: shows the 3D model of Helicopter rotor Hub (isometric view)

V. FINITE ELEMENT ANALYSIS OF HELICOPTER ROTOR HUB

Finite Element Modeling (FEM) and also Finite Element Analysis (FEA) are two best modern mechanical engineering applications offered by existing CAE systems. This is attributed to the fact that the FEM is may be the most popular numerical technique for solving many types of engineering problems. The method is general enough to handle any complicated shape of geometry (problem domain), any of the material properties, any of the boundary conditions and any loading conditions. The universality 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. Also, it is an efficient design tool by which designers can perform parametric design studying various cases (different shapes, material loads etc.) analysing them and choosing the optimum layout.

3D model of the Helicopter rotor Hub is developed in UNIGRAPHICS. The model is converted into a Parasolid to import in ANSYS.

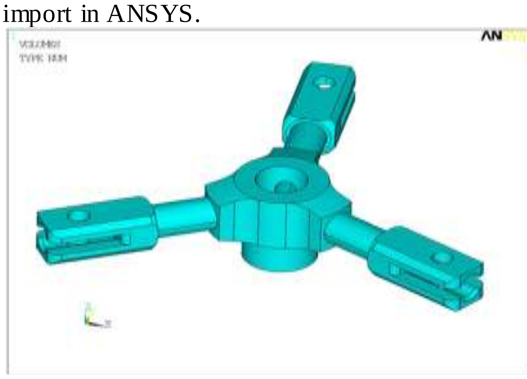


Fig.6: shows the geometric model of the Helicopter rotor Hub

Boundary conditions

- The rotating shaft position is fixed in all dof.
- Rotor blade weight is applied on Helicopter rotor Hub.

- Angular velocity and gravity were applied on Helicopter rotor Hub.

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

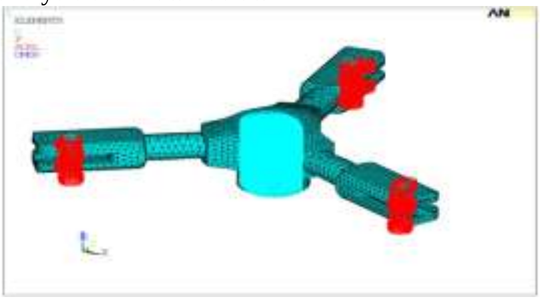


Fig.7: shows the Boundary conditions applied on Helicopter rotor Hub for static analysis

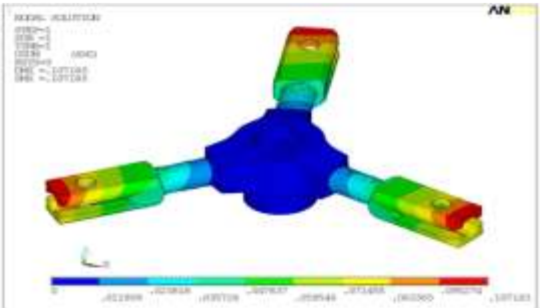


Fig.8: Total Deflection for static analysis

VON MISES STRESS

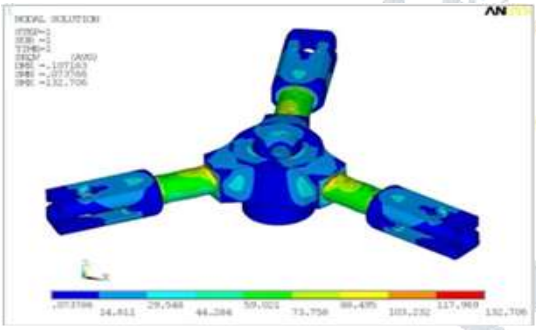


Fig.9: von-mises stress for static analysis

STRUCTURAL ANALYSIS OF HELICOPTER ROTOR HUB

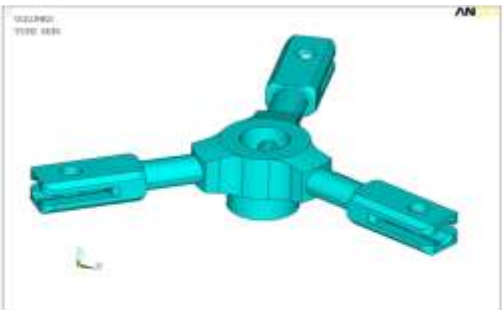


Fig.10: shows the geometric model of the Helicopter rotor Hub

The meshed model is shown in the below figure

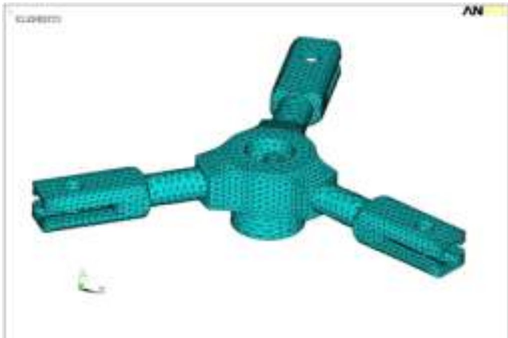


Fig.11: shows the Finite element model of the Helicopter rotor Hub

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

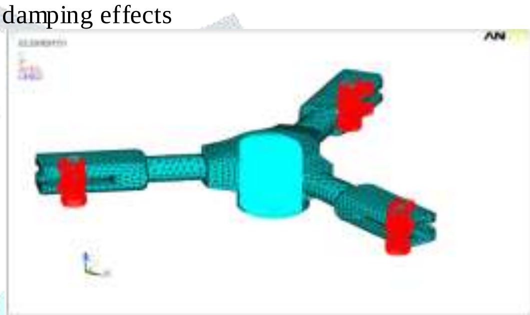


Fig.12: shows the Boundary conditions applied on Helicopter rotor Hub for static analysis

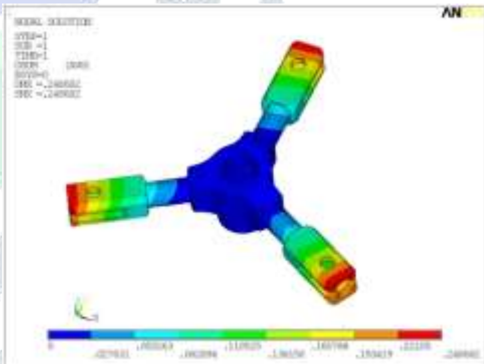
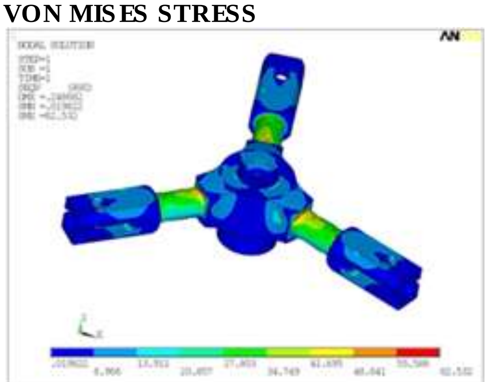


Fig.13: Total Deflection for static analysis

VON MISES STRESS



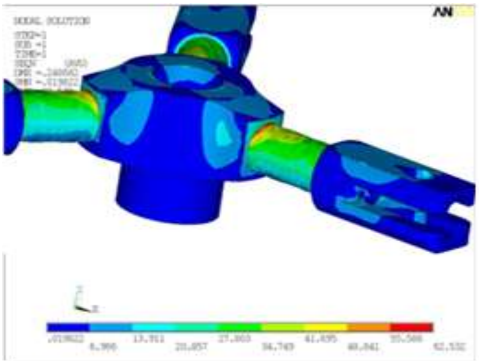


Fig.14: von Mises stress for static analysis

CASE-3

MATERIAL PROPERTIES

Based on the advantages, the E-Glass/Epoxy, materials are selected for composite Helicopter rotor Hub. The Table shows the properties of the E-Glass/Epoxy, materials used for composite Helicopter rotor Hub.

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

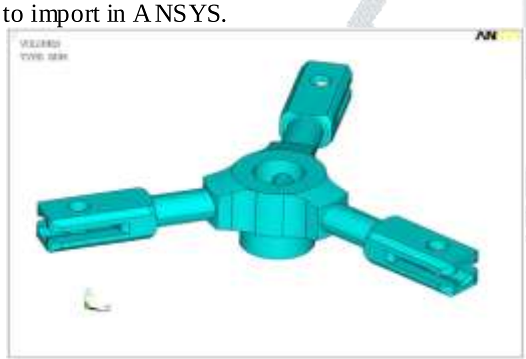


Fig.15: shows the geometric model of the Helicopter rotor Hub

STATIC ANALYSIS OF HELICOPTER ROTOR HUB

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

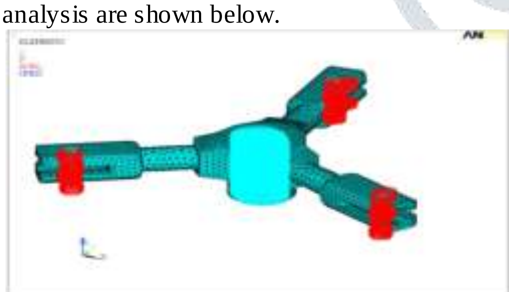


Fig.16: shows the Boundary conditions applied on Helicopter rotor Hub for static analysis

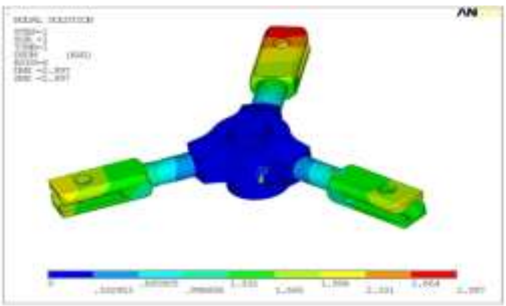


Fig.17: Total Deflection for static analysis

VON MISES STRESS

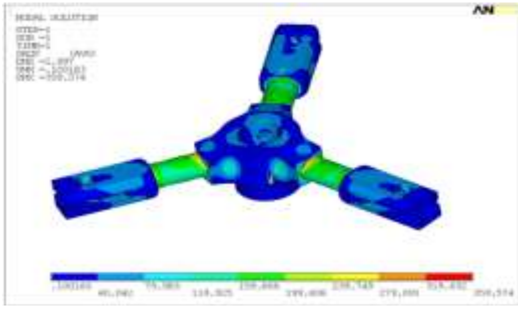


Fig.18: Von Mises stress for static analysis

CASE-4

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

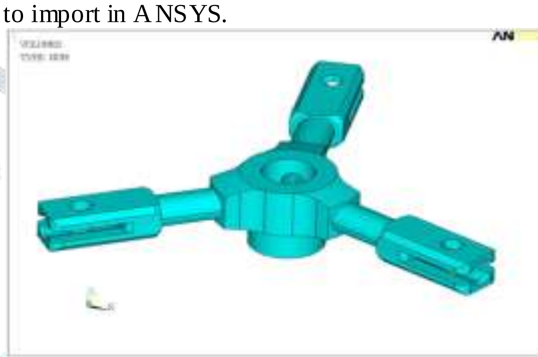


Fig.19: shows the geometric model of the Helicopter rotor Hub

DEFLECTIONS

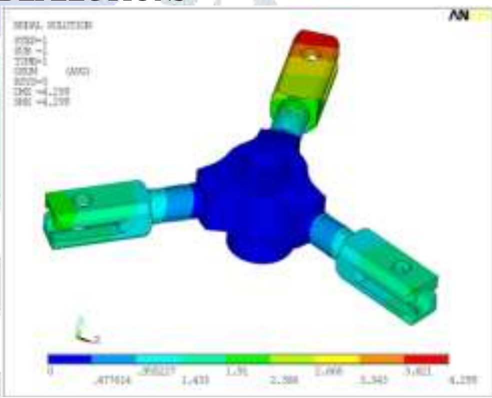


Fig.20: Total Deflection for static analysis

VI. RESULTS

Helicopter rotor Hub structure was studied for structural behaviour for different materials. 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. So the static analyses are performed on helicopter rotor hub for different materials like as steel, aluminium alloy and composites. Structural analysis of helicopter rotor hub with Steel High Strength Alloy material From the Static analysis it is observed that the maximum deformation 0.1mm and Von Mises stress 132MPa observed on Helicopter rotor Hub. The yield strength of the material (Steel, High Strength Alloy) used for Helicopter rotor Hub is 690 MPa. The FOS at most of the locations is 690/132=5.2. Structural analysis of helicopter rotor hub with aluminium alloy material From the Static analysis, it is observed that the maximum deformation 0.2mm and Von Mises stress 62MPa observed on Helicopter rotor Hub. The yield strength of the material (aluminium Alloy) used for Helicopter rotor Hub is 414MPa. The FOS at most of the locations is 414/62=6.6. Structural analysis of helicopter rotor hub with E-Glass/Epoxy composite material From the Static analysis, it is observed that the maximum deformation 2mm and Von Mises stress 359.5MPa observed on Helicopter rotor Hub. The yield strength of the material (E-Glass/Epoxy) used for Helicopter rotor Hub is 800MPa. The FOS at most of the locations is 800/359=2.228. Structural analysis of helicopter rotor hub with HS Carbon/Epoxy composite material From the Static analysis, it is observed that the maximum deformation 4 mm and Von Mises stress 363.5MPa observed on Helicopter rotor Hub. The yield strength of the material (HS Carbon/Epoxy) used for Helicopter rotor Hub is 880MPa. The FOS at most of the locations is 880/363=2.2. The comparison of the results for two materials, steel, aluminium alloy and composites of helicopter rotor hub given in the table below.

Table.1: Comparison of static results for steel, aluminium alloy and composites Helicopter rotor Hub

MATERIAL	VONMISES STRESS (MPA)	WEIGHT (tone)	FOS
Steel	132	21	5.2
Aluminum	62	7.5	6.6
E-Glass Epoxy	359	5.3	2.229
HS Carbon Epoxy	363	4.2	2.21

CONCLUSION

As the rotor spins, each blade responds to inputs from the control system to enable helicopter control. The centre of lift on the whole rotor system moves in response to these inputs to affect pitch, roll, and upward motion. Helicopter rotor Hub structure was studied for structural behaviour for different materials. 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. In this project, the 3D model of Helicopter main rotor Hub was done in UNIGRAPHICS and imported into ANSYS software to perform static analysis to analyse the strength and dynamic characteristics of rotor hub and optimised by using different materials like as steel, aluminium alloy and composites. From the above structural analysis, it is concluded that the Helicopter main rotor Hub has stresses and deflections within the design limits of both the materials used. From the above results, we can conclude that the Helicopter main rotor Hub with HS Carbon/Epoxy composite material model had better FOS and weight reduction than the other material model.

FUTURE SCOPE

In the present design and analysis of Helicopter main rotor Hub, static analysis has been carried out to the analysed strength of Helicopter main rotor Hub for static loads. The modal and harmonic analysis was done to avoid resonance from the range of (0-200 Hz), but in reality Helicopter, central rotor hub is also subjected to huge random vibrations for this case spectrum analysis should be carried out to avoid the structural damage due to random fluctuations in helicopter main rotor hub.

REFERENCES

[1] R.L. Bennett, Application of optimisation methods to rotor design problems, Vertica 7 (3), 201-208 (1983).

[2] P.P. Friedmann and P. Shantakumaran, Optimum design of rotor blades for vibration reduction in forwarding flight, PTOC. of the 39 the Annual Forum of the AHS, St. Louis, MO, May 9-13, 1983, pp. 656-673, American Helicopter Society, Alexandria, VA, (1984).

[3] D.A. Peters, T. Ko, A. Korn and M.P. Rossow, "Design of helicopter rotor blades for desired placements of natural frequencies", Proceedings of the 3gth Annual Forum of the AHS, St. Louis, MO, May 9-13, 1983, pp. 674-689, American Helicopter Society, Alexandria, VA, (1984)

[4] M.W. Davis and W.H. Weller, Application of design optimisation techniques to rotor dynamics problems, Journal of the American Helicopter Society 33 (3), 42-50 (July 1988).

[5] Models shape and harmonic analysis of different structures for helicopter blade by Abdelkader NOUR 1, Mohamed Tahar GHERBI 1, Yon CHEVALIER.

[6] Three-dimensional stress analysis of a helicopter main rotor hub using cyclic symmetry by Richard l.Rotell. jr.

[7] The design of Nacelle and Rotor Hub for NOWITECH 10MW Reference Turbine by Sandeep Singh Klair.

[8] Dynamic Analysis of Helicopter Bearingless Main Rotor With Hub Flex beam Damage Configurations by Ki C. Kim.

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