Analysis of Five Bladed Helicopter Main Rotor & Optimisation

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Abstract— The helicopter is a type of rotorcraft in which the lift and thrust are supplied by main rotors. In this an effort has been made to carry out the analysis of helicopter main rotor parts for the identification of possible failure situations; any flaws in the design stage can be identified. The stress developed on the component can be understood and suitably reduce it by carrying out an optimization methods.

Index Terms — Helicopter Main Rotor, Catia V5, Finite Element Analysis, Boundary Conditions, Meshing, Loading, Stress, Optimisation.

1 Introduction

A helicopter is a type of rotorcraft which enables the helicopter to take off and land vertically, to hover, and to fly forwards, backwards, and laterally. These attributes allow helicopters to be used in congested or isolated areas where fixed-wing aircraft would usually not be able to take off or land. The capability to hover efficiently for extended periods of time allows a helicopter to accomplish tasks that fixed-wing aircraft and other forms of vertical takeoff and landing aircraft cannot perform. It is maintained in the air by a variety of forces and controls working in opposition to each other, and if there is any disturbance in this delicate balance, the helicopter stops flying, immediately and disastrously. The helicopter works on Bernoulli's principle. It's the basic principle of pressure differential. The discoverer, Daniel Bernoulli, stated, "As the velocity of a fluid increases, its internal pressure decreases." Air is considered a fluid and therefore falls within the Bernoulli Principle. As the air velocity increases the pressure decreases and as the velocity decreases the pressure increases.
when an airfoil starts moving through the air it divides the mass of air molecules at its leading edge. The leading edge is an edge which actually first comes in contact with an air. The distance across the curved top surface is greater than that across the relatively flat bottom surface.

Air molecules that pass over the top must therefore move faster than those passing under the bottom in order to meet at the same time along the trailing edge. The faster airflow across the top surface creates a low-pressure area above the airfoil. Air pressure below the airfoil is greater than the pressure above it and tends to push the airfoil up into the area of lower pressure. As long as air passes over the airfoil, this condition will exist. The resulting pressure differential between the surfaces causes an upward force called as lift .When air movement is fast enough over a wing or rotor blade, the lift produced matches the weight of the airfoil and its attached parts. This lift is able to support the entire aircraft. As airspeed across the wing or rotor increases further, the lift exceeds the weight of the aircraft and the aircraft rises. Not all of the air met by an airfoil is used in lift. Some of it creates resistance, or drag, that hinders forward motion. Lift and drag increase and decrease together. They are therefore affected by the airfoil's angle of attack into the air, the speed of airflow, the air density, and the shape of the airfoil or wing. During the flight of helicopter, there are four forces working on the helicopter such as lift, drag, thrust, weight.

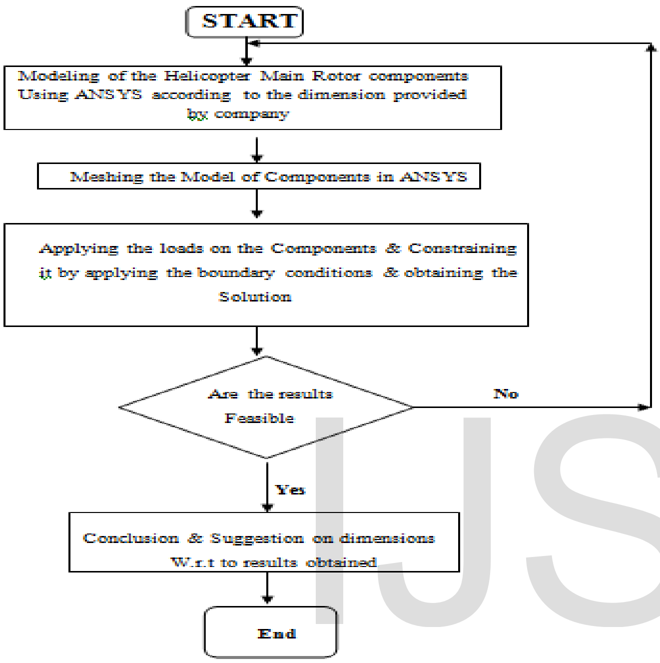
2 Literature Review

K.M. Pandey et al.[1], worked on " Numerical Analysis of the Helicopter Rotor at 400 RPM", with an objective to analyze the flow around three (3) bladed isolated main helicopter rotor at a particular main rotor speed of 400 rpm, and angle of attack of 8 degrees and blades of the helicopter Eurocopter AS350B3 which uses the blade profile of standard ONERA OA209 airfoil during hovering flight conditions. For CFD analysis, the Motion Reference Frame (MRF) method with standard viscous k- turbulent flow model was used on modeling the rotating rotor operating in hovering flight.
The Ansys fluent was used for the purpose of analysis.
From the above analysis, it can be concluded that a main rotor speed of around 400 RPM is suitable for the hovering flight conditions for the helicopter taken into account that is Eurocopter AS350B3.
The computational results for this helicopter show that the safe optimum range for this helicopter is around 380-430 RPM for hovering flight conditions.

3 RESEARCH METHODOLOGY

The methodology and objective followed during this research work is to carry out the analysis of helicopter main rotor for the identification of possible failure situations using Ansys workbench. The stress developed can be understood and suitably reduced by increasing or decreasing the dimensions, using a better material etc. The stress distribution can be understood and the maximum and minimum stress acting on the material can be estimated. An effort has also been made to give suggestions regarding the dimensions of the machine for better results. The helicopter main Rotor assembled model, which mainly consists of Rotor Mast, Blade Gripper, Swash Plates, and Pitch Control Rods Here Structural type of analysis carried out for the helicopter main rotor.

Flow Chart of Research Methodology



4.1 ANALYSIS OF PITCH CONTROL ROD

The figure represents the model of pitch control rod. Elements is solid 45 Element (8 node with 3 DOF/ node) is used to mesh the pitch control rods. The component is free meshed. The component is constrained in all DOF along with boundary conditions and the load is applied with the 25kN at the right end in X-direction.

Fig "a": Pitch Control Rod

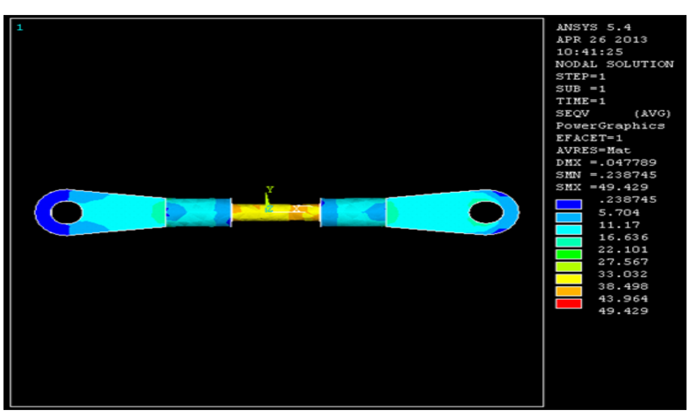
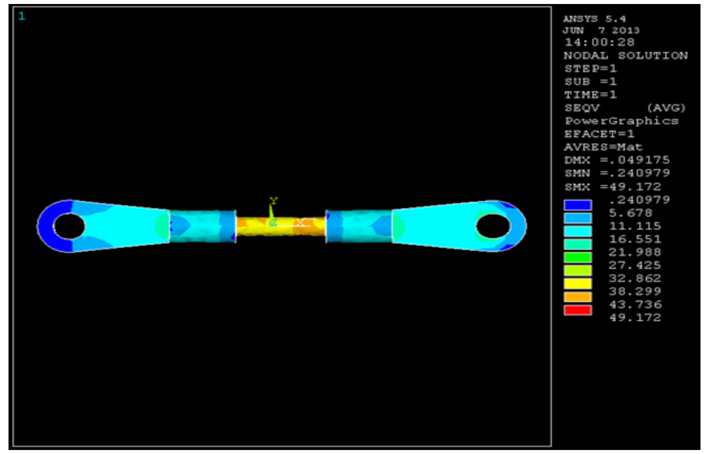


Fig "b", Optimization of Pitch control Rod



The above fig "a" and fig "b" represents before optimisation and optimization.

In this an attempt has been made regarding the optimization of the material for the helicopter main rotor. Due to the complexity involved in design and operation of the helicopter main rotor assembly, the optimization of the volume of the material are not feasible because there encounters the problem of fit during assembly of one component with another. Hence the material optimization is carried out by using different material along with their suitable physical, mechanical properties & with a main intention to reduce the process time and process cost.

TABLE – 1 Properties of 4340 Alloy Steel & Ferrium S53

Sl.No	Properties	4340 Alloy Steel	FerriumS53
1	Density	7850 Kg/m³	7920 Kg/m³
2	Poisson's Ratio	0.27	0.3
3	Ultimate Strength	1550 MPa	1986 MPa
4	Elastic Modulus	210 GPa	204 GPa
5	Yield Strength	1240 MPa	1551 MPa

TABLE – 2 Results of Pitch control rod

SL. No	Parameters	Before optimization	After optimization
1	Stress developed (MPa)	49.42	49.17
2	Max.Deflection (mm)	0.047	0.043

The below following results were obtained for the pitch control rod and has been compared in the above.

4.2 ANALYSIS OF BLADE GRIPPER

The figure represents the model of blade gripper. The material 4340 alloy steel has been adopted before optimization and ferrium S43 for optimization has been used. The Ferrium S53 has a certain advantages as less sensitive to overheating; the material appears to be more damage-tolerant, excellent resistance to fatigue. The alloy has good fracture toughness, indicating ductile performance and strong resistance to crack propagation.

The Ferrium S53 Ultra High Strength Steel has a wide application throughout the Aerospace Industry. Although this alloy was developed specifically for Aircraft, drive shaft, hydraulic actuators and rotary gear actuators, as many smaller items such as hinges and brackets are used throughout the aircraft.

Fig "a": Blade Gripper

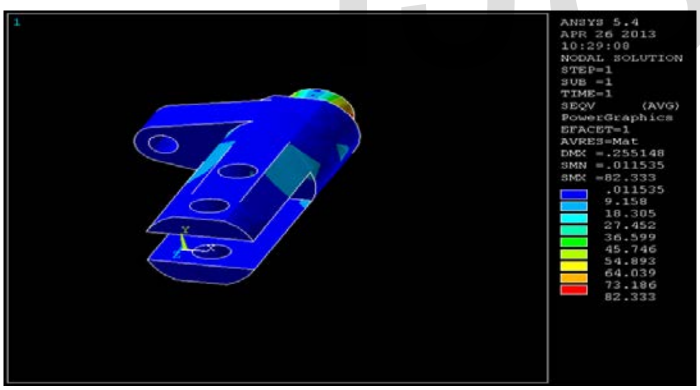


Fig "b": Optimisation of Blade Gripper

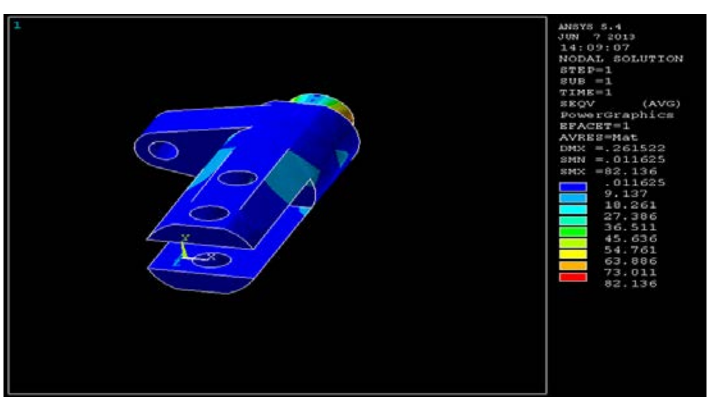


TABLE – 3 Results of Blade Gripper

The below following results were obtained for the blade

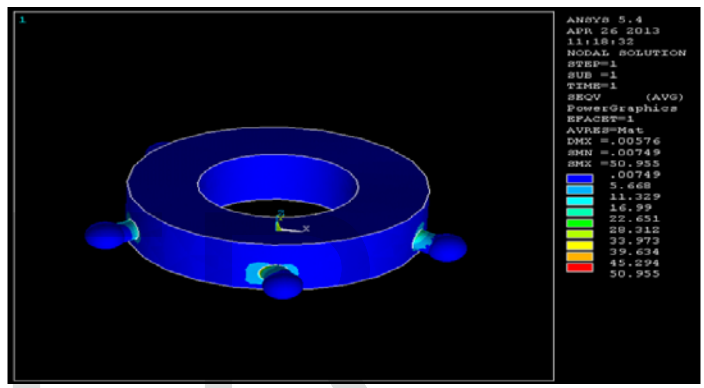
SL. No	Parameters	Before optimization	After optimization
1	Stress developed (MPa)	82.33	82.13
2	Max.Deflection (mm)	0.255	0.251

gripper and has been compared.

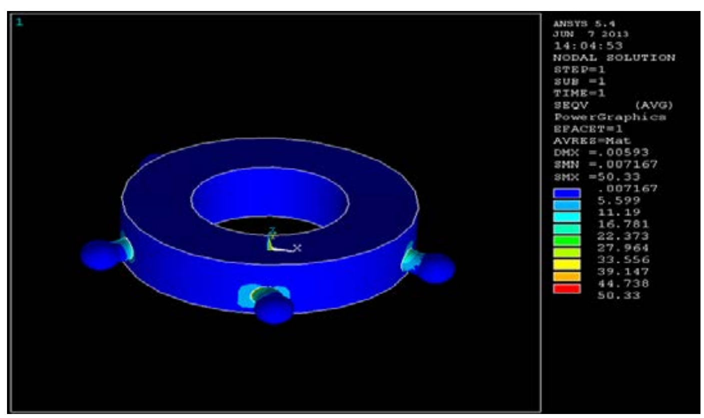
4.3 ANALYSIS OF SWASH PLATE

The figure represents the model of swash plate, which connect to the blade gripper through control rods.

Fig "a": Swash Plate



Fig"b": Optimisation of Swash Plate



The swash plate enables in the angular twist of the heliconpter blades through the pitch control rods upto a certain degree, which depends upon a direction of movement of the heliconpter, direction of the wind flowing across and over the blades of the helicopter. Elements is solid 45 Element (8 node with 3 DOF/ node) is used to mesh the pitch control rods. The component is free meshed. The component is constrained in all DOF along with boundary conditions.

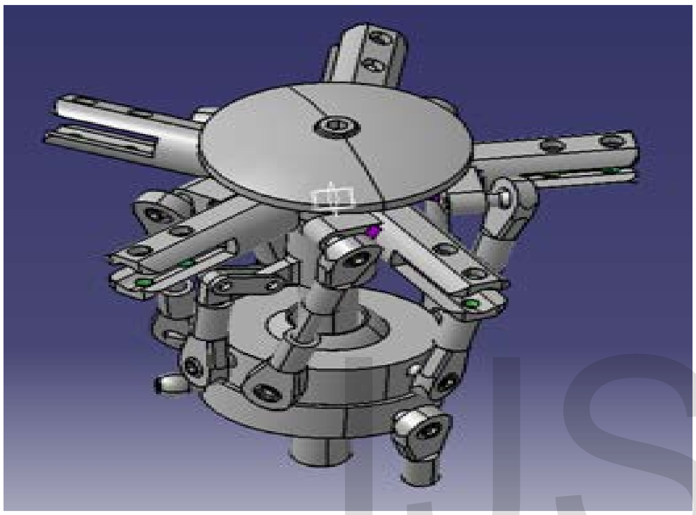
TABLE – 4 Results of Swash Plate

The Assembled model of helicopter main rotor assembly per-

SL. No	Parameters	Before optimisation	After optimisation
1	Stress developed (MPa)	50.95	50.33
2	Max.Deflection (mm)	0.0057	0.0054

formed through CATIA V5, which includes main components such as Pitch control rod, Blade gripper, Swash plate.

Fig : Model of Helicopter Main Rotor



5. Comparision & Discussion on Material Properties of Ferrium S53 over 4340 Alloy Steel.

1. The material 4340 Alloy steel which has been used for analysis before optimization has a density of 7.85gm/cm3 is then compared with ferrium S53 which has a density 7.92gm/cm3 almost same as 4340 alloy steel. When it deals with mechanical properties the strength of the ferrium S53 is greater than 4340 alloy steel and is highly desirous in Aerospace components.

2. The material cost of ferrium S53 is almost same as when compared with 4340 alloy steel. The major unique feature with the use of ferrium S53 is, it eliminates the need for toxic cadmium plating for corrosion resistance after the manufacture of the component but where in other material it needs to be plated. This completely prevents the environmental pollution and occurrences of health Hazards. Thus it saves the specific manufacturing costs.

3. As the ferrium S53 does not need corrosion resistant plating and the subsequent accompanying process, the following cost saving benefits are mentioned below:

a) Reduces the cost of material handling.
b) It completely saves the cost of coating process.
c) Less inventory needed.
d) It saves the total maintenance & production time.
e) Reduces labor costs.
f) Reduce general corrosion and related expenses for part condemnation and equipment/system failure.

The Ferrium S53 has a certain material performance advantages like Resistant to stress corrosion cracking, less sensitive to overheating and grind burning, the material appears to be more damage-tolerant, excellent resistance to fatigue and to corrosion fatigue. The alloy has good fracture toughness, indicating ductile performance and strong resistance to crack propagation.

6. CONCLUSION

An attempt has been made to analyze and optimize the five bladed helicopter main rotor using Ansys software. The project work carried out is successfully analyzed to meet the requirements as per the constraints. The project is analysed & is further carried out with the material optimization due complexity involved in design and operation of helicopter main rotor. In this project the material selected for optimization (ferrium S53) with the main intention to have high strength of components and to eliminate the need of corrosion resistant plating on the components and its subsequent process. The elimination of corrosion resistant plating process which inturn saves the cost of plating process, cost of material handling for process, labour cost, less inventory, process time etc.

The use of ferrium S53 completely prevents the environmental pollution and occurrences of health Hazards due to the presence of toxic in plating.

There is a scope for future study on five bladed helicopter main rotor. The project can be further carried out with the dynamic analysis and mapped meshing of assembly model, which can give comparatively better results than free meshing. The project can be further carried out with some smart and advanced materials like Titanium alloys – Ti 6Al-4V which is strong , light weight , less density which may be critical to the aerospace industries, when the cost of the material is not important.

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