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Design and analysis of helicopter rotor

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ABSTRACT

A helicopter's blades are lengthy and are restricted by a secondary perspective proportion. Starting at the tip of the vertices, the blade shapes are such that they reduce drag. They maintain a level of messiness that reduces the lift provided at the corners, where the wind current is fastest and vortex era is greatest. The rotor's huge blades would commit to a variety of materials, including aluminium, composites, and steel. The rotor blades would link to the helicopter rotor centre, which is powered toward the engine. In this project, CATIA is used to create a three-dimensional model of a helicopter rotor with 2, 3, and 4 blades. Analyzing data in ANSYS allows for a near-accurate result to be obtained in less time while avoiding the possibility of errors for future advancement.

Keywords: *Drag, CATIA, ANSYS, Vortex*

1. INTRODUCTION

The rotating portion of a helicopter that provides lift is known as the rotor system. A rotor system can be positioned horizontally, as with main rotors, to produce vertical lift, or vertically, as with a tail rotor, to offer horizontal lift as thrust to offset torque effect. It's also a control system that produces the aerodynamic lift force that sustains the helicopter's weight and the propulsion that counteracts aerodynamic drag in forward flight.

A helicopter's blades are long, narrow airfoils with a high aspect ratio, a design that reduces drag caused by tip vortices. They usually have some washout, which lessens the lift created at the tips, where the airflow is the quickest and vortex production is a major issue. Abrasion shields run the length of the leading edge of the rotor blades, which are built of a variety of materials including aluminium, composite construction, steel, or titanium.

The design and analysis of the helicopter rotor are part of this project. The CATIA V5 software is used for the design phase. Computer Aided Three-Dimensional Interactive Application (CATIA) is an acronym for Computer Aided Three-Dimensional Interactive Application. It is the most capable, powerful, and widely used CAD. This software is used to generate three different rotors with two, three, and four blades. CATIA processes like as part modelling and assembly are carried out. The first draft of the designs are made.

The software Ansys 2021 R1 is used for the analysis. Ansys Mechanical finite element analysis software is used to simulate computer models of structures, electronics, or machine components in order to assess strength, toughness, elasticity, temperature distribution, electromagnetism, fluid flow, and other characteristics.

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The models are then imported into the Ansys software, where they are examined. The software's inbuilt equations are used to calculate various needed parameters such as coefficient of lift, coefficient of drag, lift force, drag force, pressure variation, and velocity variation.

2 METHODOLOGY

2.1 Modelling

CATIA drawing software was used to produce a 1:1 solid model of the primary rotor. CATIA allows you to create 3D parts from 3D designs to sheet metal, composites, molded, forged, or tooling parts, as well as mechanical assemblies. The programme includes powerful mechanical surfacing and BIW technologies. It includes tools for completing product definition, such as functional tolerances and kinematics. CATIA offers a wide range of tooling design applications, including generic tooling and mould and die design. Different tools in CATIA were used to design the model for two, three, and four rotors.Sketch tools such as line, spline, and others were used to create the model's basic figure. CATIA's sketch features make it easy to create 2D figures. The fundamental model is then turned into a three-dimensional model. CATIA provides a large number of 3D tools for creating 3D figures. To create a 3D design from a 2D design, 3D tools such as lap, shaft, and others are used.

2.2 Mesh Generation

The model's drawn IGS file was then imported into the Ansys software as the second phase. The main rotor model that was constructed has over 50 faces, over 200 vortex points, and about 145 edges. After successfully importing the data into Ansys, these values were examined.

An automatic Mesh Generator, by definition, takes some form of border data as an input and automatically generates the inside nodes and components based on it. Because the mesh generator makes few or no assumptions about the domain's structure, these mesh generators can simulate practically any structure. Delaunay-Voronoi methods are used in our calculations. These are the most common kind of automatic mesh generators, and they produce high-quality meshes in both 2D and 3D. Delaunay mesh is the type of mesh they make.

2.3 CFD Simulation

The simulation was then ran in Ansys Fluent software, which was the next and most essential step in this project. The analysis of fluid flows using numerical solution methods is known as computational fluid dynamics (CFD). You can use CFD to solve complicated problems involving fluid-fluid, fluid-solid, or fluid-gas interactions. The mesh must be opened and read in Fluent once it has been created in Ansys software. The mesh was reordered in order to provide a more refined mesh. Models, materials, and boundary conditions were then established. Before conducting the simulations, there was an initial checking step in Fluent for each solving. The simulation version was set to “3ddp” to ensure that the simulation result was extremely accurate for the 3D model that was built.

2.4 Materials

For this simulation, the working fluid was chosen as "air," an ideal gas, and the main rotor was supposed to be operating in ordinary atmospheric circumstances. The standard values were determined to be 101325 Pa and 300 K temperature.
The material given to the simulation process in the ANSYS software is aluminium.

3. RESULTS AND DISCUSSION

3.1 Parameters and Equations

Co-efficient of lift
The co-efficient of lift generated by the blades is related to the fluid density surrounding the body, fluid velocity around the body, and the associated area by the coefficient of lift. A larger lift force is indicated by a higher coefficient of lift.

Lift force
The fluid or air exerts a force on the blades' surface as they revolve through the fluid or air. The component of this force that is perpendicular to the direction of fluid flow is called lift force. It is usually in the upward direction, despite gravity's pull.

$$L = Cl \times \rho \times v^2 \times A/2$$

L = Lift force
Cl = Co-efficient of lift
v = Velocity of fluid
A = Associated area
ρ = Density of fluid

Co-efficient of drag
The drag coefficient is a dimensionless variable that connects or quantifies the drag or resistance that blades face in a fluid environment. The lower the drag coefficient, the less aerodynamic drag the blades will have.

Drag force
The drag force is the force acting in the opposite direction of the blades' relative velocity in relation to the surrounding fluid or air. On the blades, it's also known as fluid resistance or air resistance.

$$D = Cd \times \rho \times v^2 \times A/2$$

D = Drag force
Cd = Co-efficient of drag
v = Velocity of fluid

ρ = Density of fluid

3.2 Solutions for 2-Blade Rotor

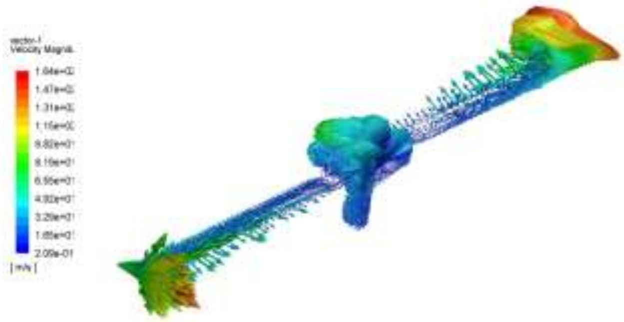


Fig.1 Velocity Variation During Rotation

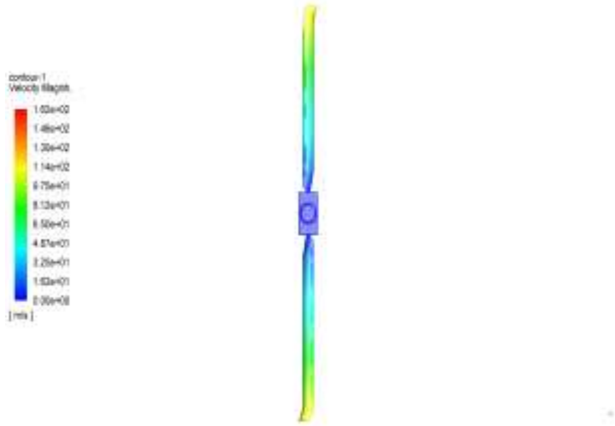


Fig.2 Velocity Variation

From the results obtained, it can be identified that the velocity of the fluid is high at the tips of the rotor blade. As we move towards the center of the rotor the velocity keeps decreasing.

Fig.3 Pressure Variation During Rotation

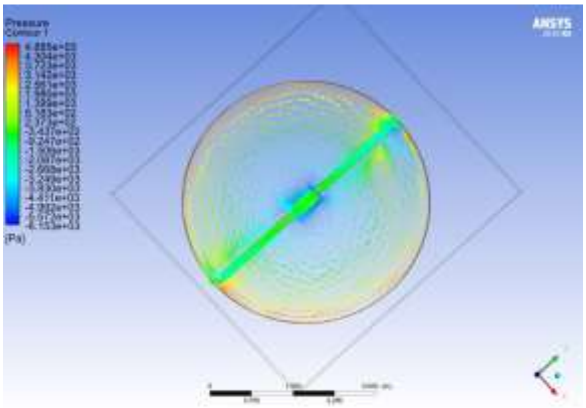


Fig.4 Pressure Variation

For pressure variation, the pressure exerted by the fluid is more at the centre of the rotor when compared to the tips of the rotor blade. Pressure variation is more uneven through out the rotor blade when compared to velocity variation.

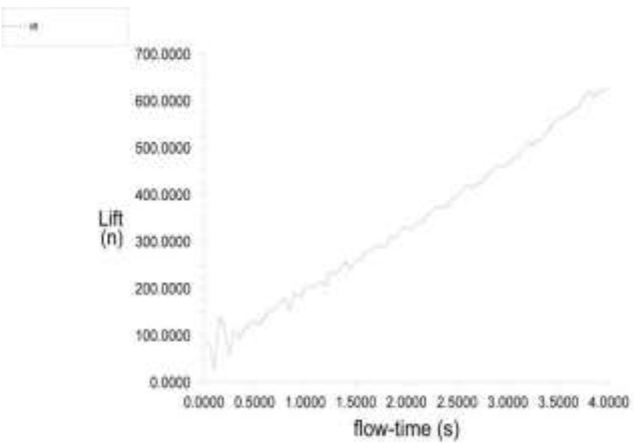


Fig.5 Graph on Lift vs Flow-Time

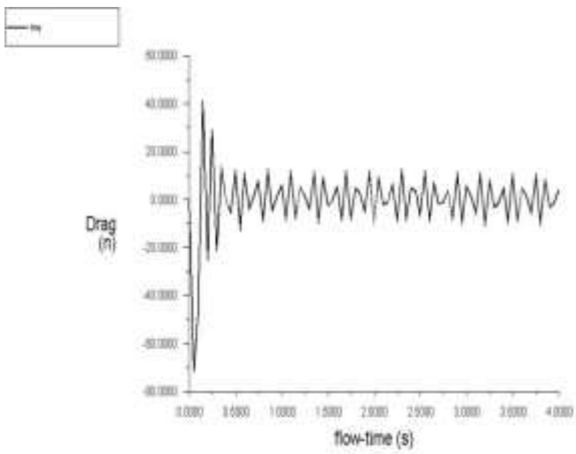


Fig.6 Graph on Drag vs Flow-Time

From Lift vs Flow-time graph of a 2-Blade rotor it can be identified that the lift-force generated is low.It takes more time for a 2-Blade rotor to gain lift-force to carry a helicopter with heavy load.

From Drag vs Flow-time graph of a 2-Blade rotor it can be identified that the drag force fluctuations is less.

3.3 Solutions for 3-Blade Rotor

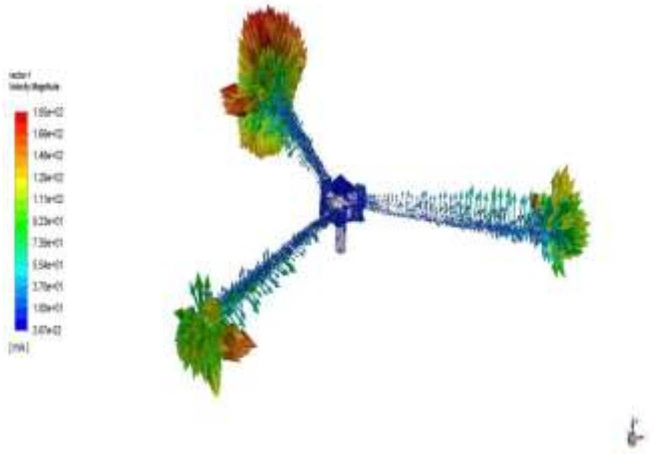


Fig.7 Velocity Variation During Rotation

Fig.8 Velocity Variation

From the results obtained, it can be identified that the velocity of the fluid is high at the tips of the rotor blade. As we move towards the center of the rotor the velocity keeps decreasing.

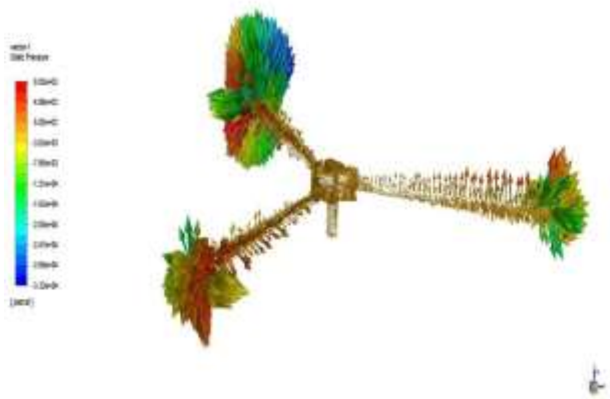


Fig.9 Pressure Variation During Rotation

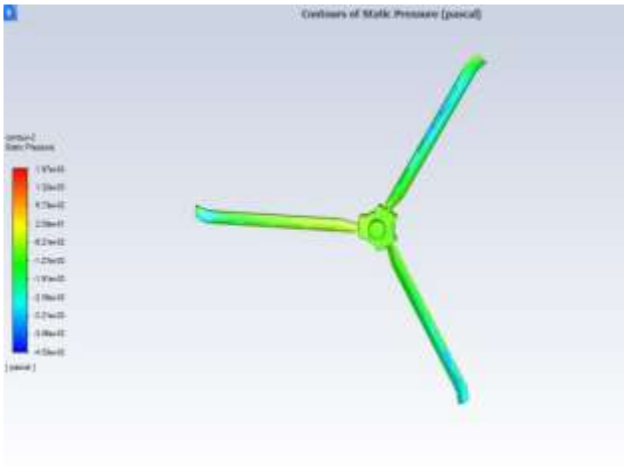


Fig.10 Pressure Variation

For pressure variation, the pressure exerted by the fluid is more at the centre of the rotor when compared to the tips of the rotor blade. Pressure variation is more uneven through out the rotor blade when compared to velocity variation.

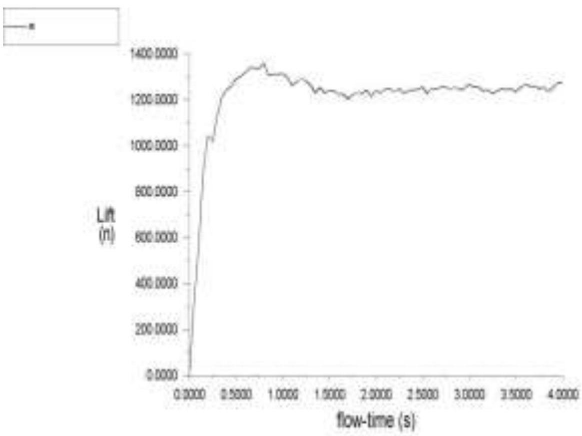


Fig.11 Graph on lift vs Flow-Time

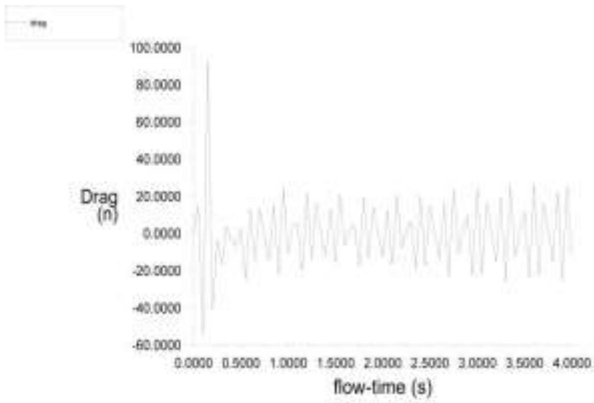
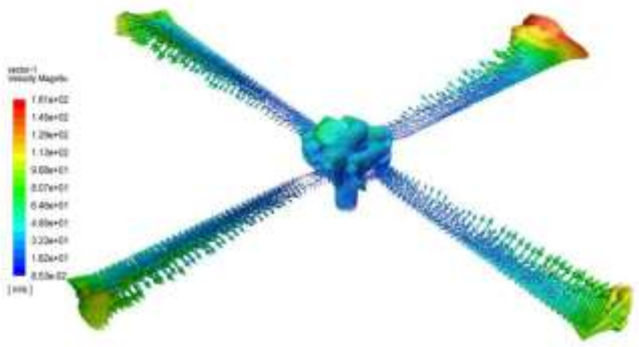


Fig.12 Graph on Drag vs Flow-Time

From Lift vs Flow-time graph of a 3-Blade rotor it can be identified that the lift-force generated is high when compared to a 2-Blade rotor. The time taken for a 3-Blade rotor to gain lift is significantly less when compared to a 2-Blade rotor.

From Drag vs Flow-time graph of a 3-Blade rotor it can be identified that the drag force fluctuations is very high.

3.4 Solutions for 4-Blade Rotor



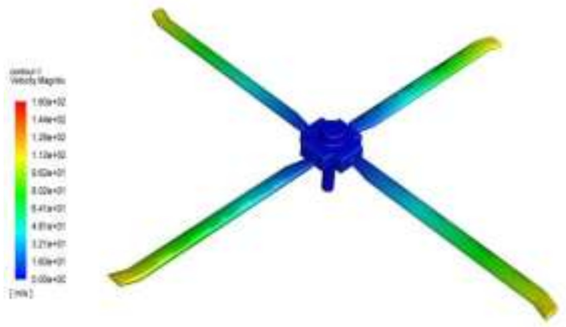


Fig.13 Velocity Variation During Rotation **Fig.14 Velocity Variation**

From the results obtained, it can be identified that the velocity of the fluid is high at the tips of the rotor blade. As we move towards the center of the rotor the velocity keeps decreasing.

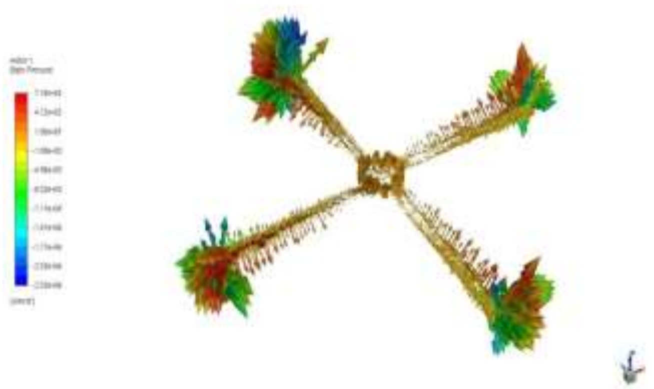
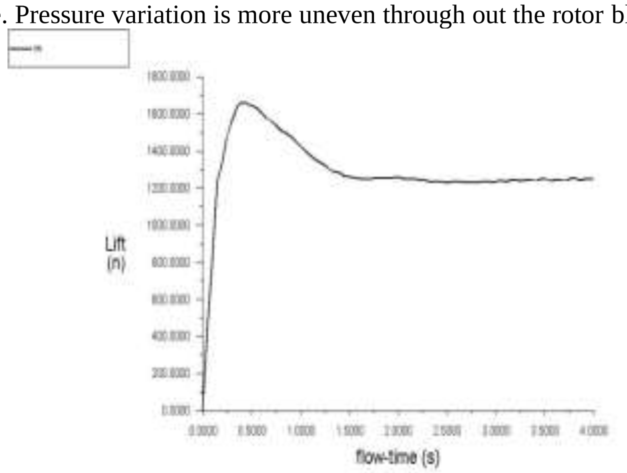


Fig.15 Pressure Variation During Rotation **Fig.16 Pressure Variation**

For pressure variation, the pressure exerted by the fluid is more at the centre of the rotor when compared to the tips of the rotor blade. Pressure variation is more uneven through out the rotor blade when compared to velocity variation.



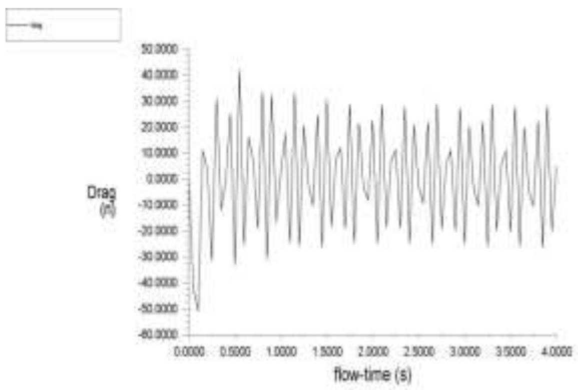


Fig.17 Graph on Lift vs Flow-Time **Fig.18 Graph on Drag vs Flow-Time**

From Lift vs Flow-time graph of a 4-Blade rotor it can be identified that the lift-force generated is very high when compared to the other two rotors. It takes very less time for a 4-Blade rotor to gain lift-force.

From Drag vs Flow-time graph of a 4-Blade rotor it can be identified that the drag force fluctuations is very high.

3.5 Discussions

From the results obtained we can arrive at certain conclusions, 2-Blade rotor produces low lift force when compared to the other two designs. Therefore ,this design is not ideal for helicopters which are required to carry heavy loads. Despite this limitation the 2-Blade rotor has several other benefits. This design helps in keeping the cost low, number of parts used are less, helps to keep the weight of the rotor system down, ensures drag created by the blades is minimal, keeps noise to a minimum and keeps the vibration of the rotor low.

3-Blade rotor produces more lift force than 2-Blade rotor. So it can be used in helicopters which are required to carry moderate load. But it has several limitations when compared with 2-Blade rotor.The noise and vibration generated are more, drag created is increased, number of parts used is increased and the weight of the rotor system get added.

4-Blade rotor produces the most lift force when compared to the other two designs. Therefore, this design is ideal for helicopters which are required to carry significantly more load. But the noise and vibrations created is notably increased which can cause stability issues when flying. The number of parts used is also very high which increases the cost of production of the rotors.

4. CONCLUSION

The ANSYS study for helicopter rotors is based on the standard values, and the findings are within the standard value's constrained preconditions. We can conclude from this research that ANSYS analysis of these rotors is really useful. ANSYS is a time and cost-effective simulation tool that produces good results utilizing a discrete method. This project yielded a graphical representation of the rotors' coefficient of drag, coefficient of lift, pressure variation, and velocity variation.

The study yields the velocity variation, pressure variation, drag, and lift of the three types of rotors. The required type of rotor for the specific application can be determined using these results. There is no magic number for how many rotor blades a helicopter can have, and helicopter designers determine the number of blades each design will have by weighing the trade-offs. Designers can improve the surface area and lift of the total rotor system while keeping the size of each rotor as small as possible by utilizing more blades.

Helicopters have anywhere from two to eight rotors. Here we studied at rotors with 2, 3, and 4 blades. Two-bladed rotors produce less lift, less vibration, and less noise. As a result, they are not suitable for heavy-lift helicopters. In comparison to the other two, the four-blade rotor has more lift. As a result, it's suitable for helicopters that need to carry more cargo. However, the disadvantage of a 4-blade rotor is that it produces more vibration and noise, which can lead to stability concerns. The qualities of a three-bladed rotor are intermediate between those of a four-bladed rotor and those of a two-bladed rotor As a result, it's perfect for helicopters that need to carry a moderate load without compromising their stability.

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