

Design and Analysis of Non-Conventional Co-Axial Rotor Blade for Multipurpose Drone

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Abstract — Conventional helicopters endure of many disadvantages such as intensified weight and cost, restriction of aero dynamic structure, and displacement of centre of gravity. A co-axial helicopter overcomes most of the disadvantages of a single rotor helicopter with a better dynamic stability. The purposes of the drones have been exemplified by the rising advent of technology. The speed, agility and conformance to purpose have remained the key parameters to design and development of the Aerospace Vehicles. This design utilizes the Co-Axial Rotor with 4 blades each mounted over the fuselage at a distance. The design of the rotor blade with variable twist along the length and a special set of aerofoils with different chord lengths are used. The Co-Axial rotor eliminates the use of rear rotor in conventional helicopters and instead a propeller is used to push the drone to the maximum limit. This project will include selection of suitable aerofoils and design of the blades for the Co-Axial Rotor Drone with the help of CFD, capturing the aerodynamic interaction and calculating the total lift generated.

Index Terms — Co-Axial rotors, helicopters, aero foils, aerodynamics, finite element method, computational fluid dynamics.

I. INTRODUCTION

The recent advent of Quad-copters and other movement controlled Air-Flying-Bodies have opened a window of opportunity to serve the Civilian, Administrative and Defence purposes alike with necessary modifications incorporated in a single design.

This project utilizes the ground-breaking research and technological advancement to make a Co-Axial rotor with an Improved Blade Design so as to increase the Lift, Thrust and

Efficiency of the air screws alongside diminishing the sound of the blades cutting through the atmosphere by a BERP design rotor tip extension inspired by the fins of Blue Whale. A six-blade propeller is attached at the tail boom of the drone thus pushing the drone at the phenomenal speed.

The Axial holder along with the swash plates of the Co-Axial rotor is directly imported from the X-2 Design by the Sikorsky Aircraft Corporation, America Inc. so as to provide extreme agility and maneuverability to the drone in hostile situation and rough climate.

This drone can be easily modified for procurement of goods, emergency services, surveillance and War time usage.

II. OBJECTIVES

The objective is to use Computational Fluid Dynamics (CFD) and conduct a series of trial runs and try to identify the

design for the optimum design of the co-axial rotor drone wings for a drone which weighs approximately 2000kg. We have to design a co-axial rotor that can carry atleast 2000kg of extra load.

1. To study and analyse with help of computational fluid dynamics the aerodynamics parameters such as pressure coefficient, velocity, lift and drag for a co-axial rotor drone.
2. To study the performance of aerofoil of co-axial rotor drone for optimum distance between the two rotors.
3. To study the various parameters considered while designing the helicopter wings.

II. COMPUTATIONAL MODEL AND CFD ANALYSIS

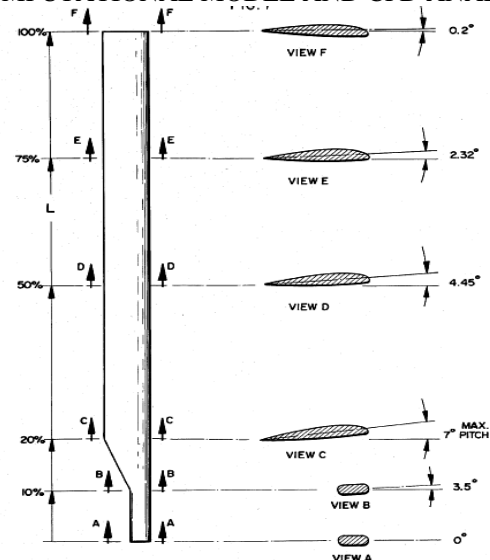


Fig. 1. High Performance Blade for Helicopter Rotor

To optimise lift of the blade without excessively increasing the drag, it is advantageous if the maximum relative thickness of the root profile is atleast equal to 9% and at the most equal to 13% of the length of the chord of said root profile. [1]

Similarly to optimise the drag, the maximum relative thickness of the end profile is atleast equal to 6% and at the most equal to 9% of the length of the chord of the end profile. [1]

The CAD model and the boundary conditions for all the analysis will be the same.

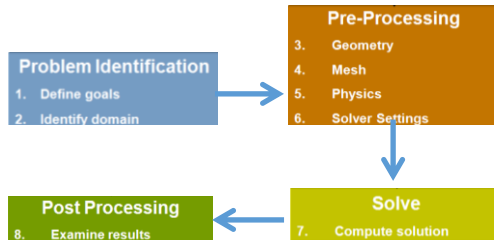


Fig. 2. Methodology

1. Airfoil Selection:

When an aerofoil passes through a fluid, such as air, the fluid exerts a force on the aerofoil that is a function of aerofoil geometry, speed and Angle of Attack. The general characteristics of the forces an aerofoil experiences as it passes through a fluid are fairly well understood. The reader is directed to references such as Hoerner, (1965) or Anderson, (2005) for more insight into this. In the past, aerofoils were designed through a process of trial and error. Data were published for different families of aerofoil (NACA etc). Users would generally choose an aerofoil from a catalogue. These days, aerofoils are generated to suit the given purpose using inverse methods. This allows designers to tailor the aerofoil shape for a given application, and even for a different location along the wing. There are many airfoils available in airfoil database. Graphs were plotted using online tool on www.airfoiltools.com. Airfoil selection criteria is as follows

- Maximum lift coefficient.
- Low drag characteristics.
- High lift at maximum angle of attack.
- Slow stall characteristics.
- Coefficient of pressure (pressure distribution).

After considering all the options we came upto selection of NACA4412 which is a very simple to manufacture airfoil and is widely used in the aerospace industry because of its high Coefficient of Lift and low Coefficient of Drag characteristics.

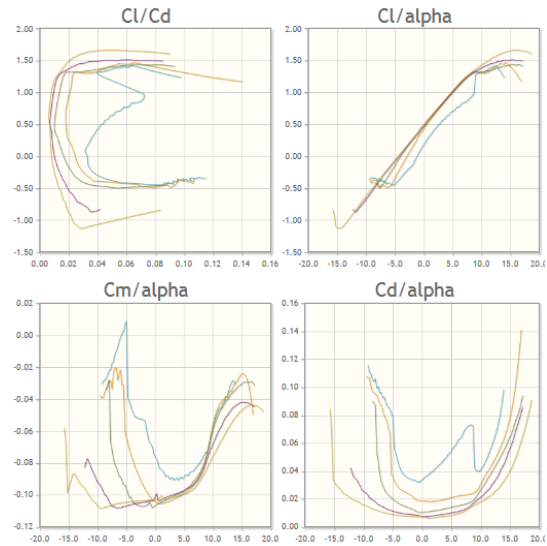


Fig. 3. NACA4412 Cl, Cd, alpha characteristics

2. Boundary Conditions:

- Wing Span = 4000mm
- Rotor Diameter = 600mm
- Wing Span Diameter = 8600mm
- Rotor Speed = 450rpm
- Turbulence intensity = 0.10 %
- Turbulence Length = 0.003 m
- Goals convergence = 1e-6

3. Single Rotor Drone Analysis

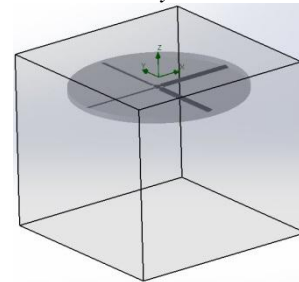


Fig 4. 3D CAD of Wing and Computational Domain

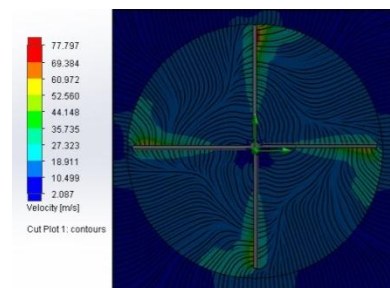


Fig. 5. Velocity Contour of Single Rotor

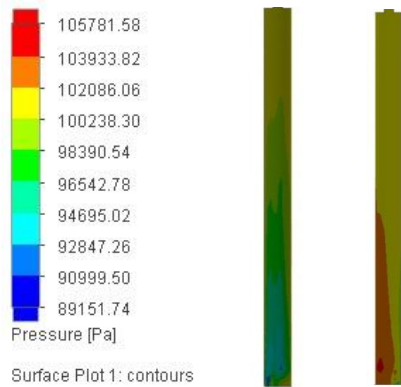


Fig. 6. Pressure Contour on the Top Side & Bottom Side of the Rotor

As seen in the figures above with the help of rotating CFD analysis we have got a thrust of 16888N which is less than the weight of the drone which is 2000kg = 19620N.

To achieve our goal we can either increase the span of the wing with an increase in chord length. But this would create a large amount of drag. So we would rather use the same span and chord length and analyse for co-axial rotors.

4. Co-Axial Rotor Drone Analysis

For the co-axial drone analysis we need to model a similar wing as in Figure 3. at the top which will be rotating in the clockwise direction and a similar wing which would be a mirror image of the above rotating in anticlockwise direction. Both the wings will be moving at the speed of 450rpm. We have to analyse the optimum distance between the two rotors so that they can lift a weight of 2000kg. Which makes the gross weight of the drone as 4000kg or 39420N.

TABLE I

Distance (mm)	Output Values	
	Average Velocity of the model (m/s)	Thrust Generated (N)
200	12.042	24653
300	13.639	36764
400	15.181	48293
500	11.451	34061
600	10.462	30132

As we can see in the table above that a distance of 400mm between the two rotors for the given wings provides us with the best suitable solution. We will see the velocity and pressure contours of the given co-axial rotor.

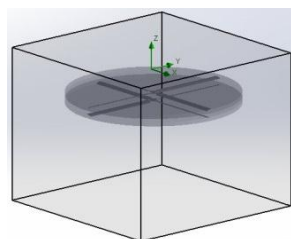


Fig. 7. 3D CAD Model of Co-Axial Rotor

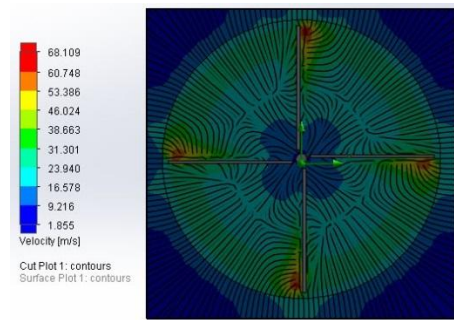


Fig. 8. Velocity Contour of Top Rotor

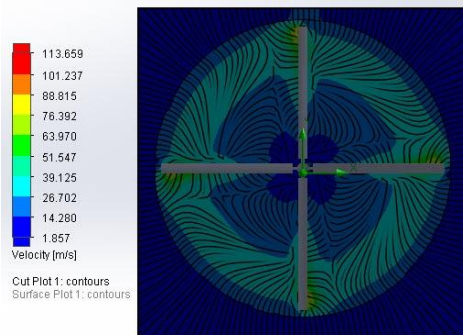


Fig. 9. Velocity Contour of Bottom Rotor

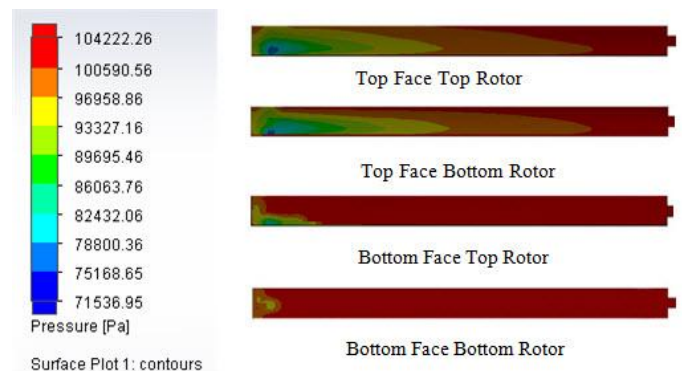


Fig.10. Pressure Contour of all the faces rotors

III. CONCLUSIONS

As we can see in the analysis between the single rotor and co-axial rotor drone it can be said that co-axial design provides increased payload for the same engine power, torque (rotational force) exerted on the helicopter fuselage is no longer a problem. Coaxial rotors avoid the effects of dissymmetry of lift through the use of two rotors turning in opposite directions, causing blades to advance on either side at the same time.

And comparing to the analysis reports we can say that for the given co-axial multipurpose drone which is of the size 8m x 8m x 3m. The rotor distance of 400mm is optimum at 450rpm to provide us with a payload capacity of 3000kg as compared to the the similar single rotor drone.

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