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Design and Modification of Fixed Wing UAVs for VTOL

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ABSTRACT

This paper attempts to bring out on conceptual design and modification of a fixed wing UAV for vertical take -off and landing that has a wing span of 1.6m and a mass of less than 4Kg, 1Kg is devoted as payload . This UAV under consideration is a class conventional, high wing and V-tail configuration. A selection of a suitable aerofoil for high performance application is indeed an important of design and to install the small rotor within the wing for vertical take-off is also a crucial part of design. The chosen high lift low Reynolds number aerofoil is found to have a minor effect on the aerodynamic parameters with changes in Reynolds Number.

I. Introduction

Many of the extreme unmanned aerial vehicles have come from meeting military objectives and they may vary in their shape and size and configuration, which typically vary in terms of operation of altitude, Take-off and landing distance and range depending on the mission requirement. UAVs come in two varieties: Some of control from the remote location and others by autonomously based on pre-programmed flight path using more complex dynamic automation systems.

One of the considerations that is often a part of every aircraft design is take-off and landing distance. In some cases a short take-off and landing distance may become principle design objective. The principle features of an aircraft that affects take-off and landing distance are Thrust-to-Weight ratio (T/W) and the maximum lift produced by the wings.

The primary objective of this paper is to design a fixed wing UAV that could be able to take-off vertically and would be have a total mass of 4Kg. Main motivation behind this paper comes from the challenges during the war and natural disasters and calamities which are faced by the conventional UAVs. Fixed wing UAVs having vertical take-off will not only be successful during war, but they can be a solution to current security problems.

II. Development of design

In most cases the main lifting surface is single wing. The design of wing consists of selecting the aerofoil cross-section, the average chord length, the maximum thickness to chord ratio (t/c) max , the aspect ratio $AR=b^2/S$, the taper ratio λ, and the sweep angle , which is defined as the leading edge as well as the maximum thickness line.

Another part of the wing design involves enhanced lift devices such as leading and trailing edge flaps.

In this, majority of the information used in the selection of the aerofoil cross section shape comes from experimental results.

A. Aerofoil section shape

Main ultimate goal for the wing design are based on the mission requirement. Low speed aerofoil is best suited for the UAV operations like navigation, surveillance and tracking.

One of the critical parameters that dictate the aerodynamics design of the vehicle is the operating Reynolds number and due to low speed the Reynolds number also decreases as

$$R = \frac{\rho V D}{\mu}$$

The maximum lift to drag ratio $(L/D)_{max}$ is very sensitive to the Reynolds number.

To be more particular a few aerofoils utilized on prevalent RC power aircraft were tried to give a benchmark against which new plan can be thought about. The Selig aerofoil chiefly utilized for sail planes and wind tunnel information as of now exist for a significant number of these aerofoils. Serving as a marker of the conceivable execution change, new aerofoils, the S8036, S7012, S7075, S8052 where planned and tried.

The new outline of aerofoil called S7075 that integrates boundary layer trips into the aerofoil design process. In the idea behind placing the trip so far aft can be explained as follows, When no trip is used the bubble ramp on the upper surface tailored so that the bubble starts far aft at low angles of attack and move forward toward the leading edge until the aerofoils stall. Thus, the entire upper surface serves as a bubble ramp to promote transition in current philosophy, the bubble ramp and the trip assume more as less equal roles in promoting transition. At low angles of attack the trips placed far aft on the aerofoils act to promote transition; whereas, for higher angles of attack the bubble ramp causes transition. Thus, the bubble ramp can be better tailored to operate over a narrower range while the trips promote transition over the remainder of the operating range. These ideas were integrated into S7075 during design process.

The trip was positioned at 57.5% chord to the leading edge. The zigzag trip itself was attached to 0.0034 in thick tape. The lift performance of S7075 at Re=60000 is particularly intriguing. The result of tailoring the bubble ramp for a narrow range of lift coefficients has lead to low drag at Re=60000 for high Cl. This desirable high lift/low Re performance makes the tripped S7075 a perfect aerofoil for UAV.

For cruise speed of 20m/s, Reynolds numbers based on mean aerodynamic chord length of 0.30m will be 397,062 at sea level. The aerodynamic characteristics at Re=200000 and Re= 500000 is computed and shown in the figure 1, 2, 3 and 4.

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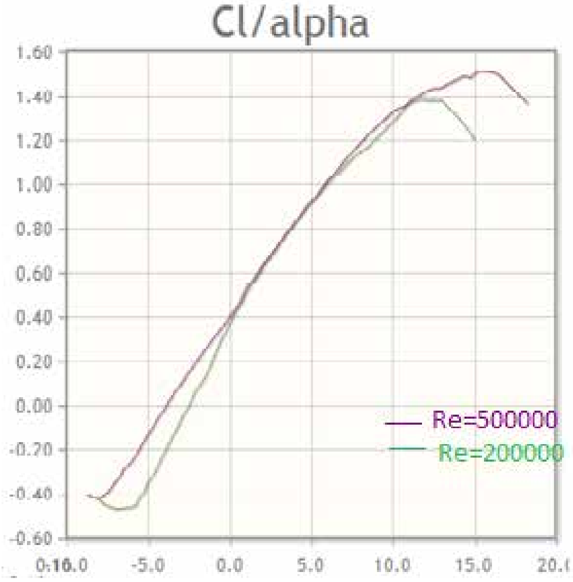

Fig 1: Comparison of Cl with respect to alpha at different Reynolds number.

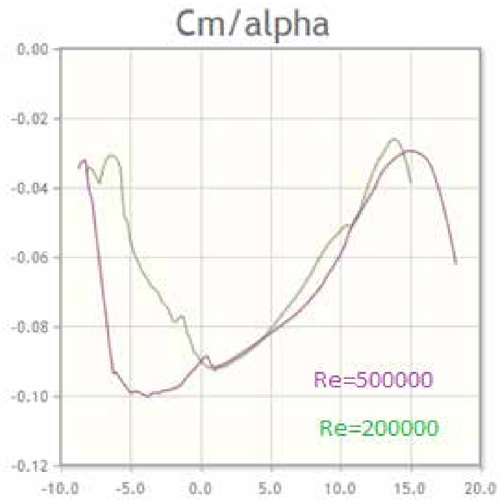

Fig 2: Comparison of Cm with respect to alpha at different Reynolds number.

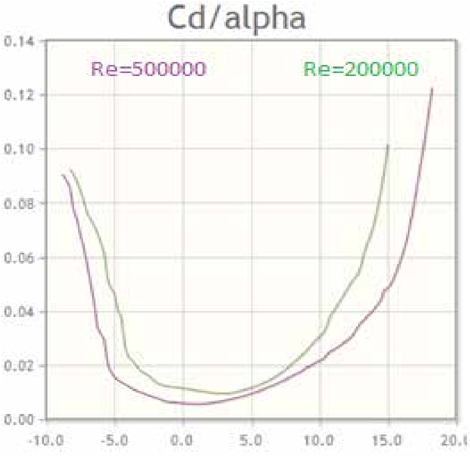

Fig 3: Comparison of Cd with respect to alpha at different Reynolds number.

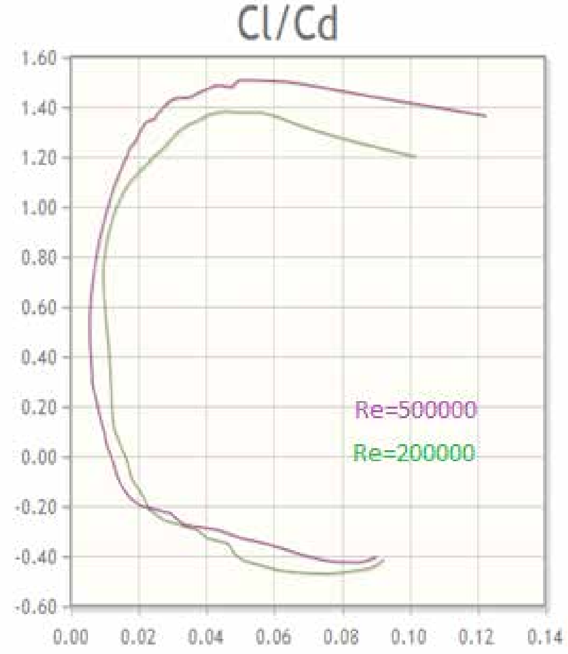

Fig 4: Comparison of Cl with respect to Cd at different Reynolds number.

B. Vertical Take-off and landing

The vertical take-off and landing of fixed wing unmanned aerial vehicles can be achieved with the help of rotors which are attached within the fixed wing i.e. fan-in-wing design. The motor selected for the rotors are brushless motor which produce lift must be slightly greater than the maximum take-off weight of 4kg to accelerate the body in upward direction. The fan-in-wing would be 12-inches in diameter. The propeller-driven fixed-wing aircraft moves forward by pushing the air backwards with its propeller, the equal and opposite reaction forcing the aircraft forward. This UAV has no propeller to provide forward propulsion. Forward motion can be carried out by upward tilt of the rotor disc from the horizontal. When the rotor disc is tilted, the airflow is not only down through the rotor, but slightly backwards as well.

If we now examine the lift vector, we find that instead of being vertical as it was for vertical flight it has been inclined forward slightly. This vector can be resolved into two components representing a vertical force and a horizontal force. Now we can see that the UAV will accelerate in the forward direction.

III. Conclusion

The configuration of a fixed wing unmanned aerial vehicle with a maximum speed of 20m/s and maximum take-off weight of 4kg has been designed and modified for vertical take-off and landing. The design is initiated with a wing aspect ratio of 9 and with 1 kg of payload. After obtaining the preliminary design and geometry of the wing and VTOL technique, we could proceed for designing the whole aircraft through conventional design process and a refined configuration can be further investigated for its static and dynamic stability and its performance is estimated for all flight condition.

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