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Effect of T-tail on the Aerodynamic Characteristics and Static Stability of an Aircraft – A Computational Analysis

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Abstract

It is the purpose of this paper to find out the effect of T-tail on Aerodynamic characteristics and static stability of an aircraft. A T-tail aircraft with a configuration of tail with the horizontal stabilizer placed above the vertical stabilizer. Typically, a tail configuration in T shape. T- tail configuration is proposed with a goal of enhancing stability and controllability during high angle of attack and low speeds. Data is presented from a series of XFLR5 analysis to qualify the aerodynamic effect of T-tail over a range of angle of attack from -15^0 to $+15^0$. Various graphs were obtained during this analysis which indicates that the T-tail configuration can perform better at low speeds.

Keywords: T-tail, high angle of attack, Stability, horizontal stabilizer

1. INTRODUCTION:

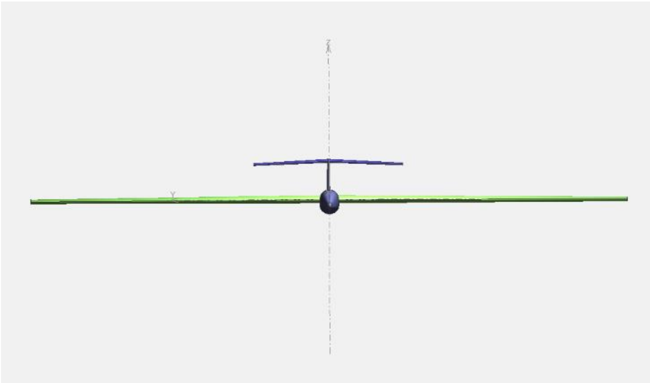
The empennage (tail) of an aircraft includes majorly two parts namely horizontal and vertical stabilizer. The main function of the stabilizers is to provide stability for the aircraft to keep it flying straight. The horizontal stabilizer in the tail is used to maintain longitudinal balance of aircraft or to trim the aircraft. The main wing of an aircraft produces lift but also this force generates some moment when disturbed. So the horizontal stabilizer exerts force in vertical direction at some distance which counters this moment so that the net pitching moment about the center of gravity is zero. One more very important role of horizontal stabilizer in aircraft is to provide longitudinal static stability which refers to the tendency of aircraft to maintain trim condition when disturbed. To ensure the longitudinal static stability it requires the aircraft's center of gravity should be ahead of center of pressure. The control surface at horizontal stabilizer is elevator which serves to control the Pitch of aircraft.

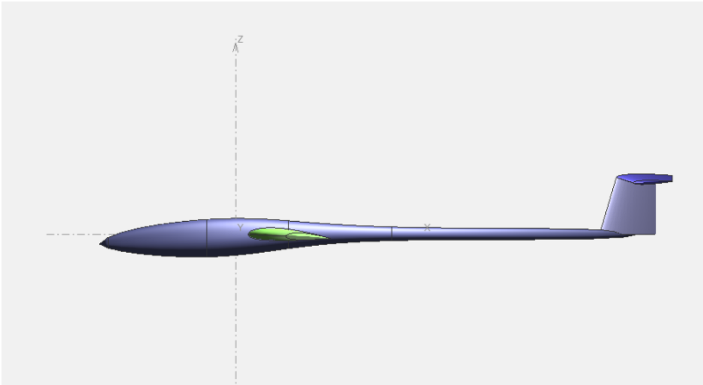
The vertical stabilizer in the tail is used to maintain the lateral balance of an aircraft or to trim the aircraft that is disturbed by the side forces. The side force disturbs the steady flight, so to counter that forces the vertical stabilizer is used. This vertical stabilizer makes the net yawing moment and the rolling moment about the center of gravity zero. The important role of vertical stabilizer in an aircraft is to provide lateral-directional static stability which refers to the initial tendency of an aircraft to maintain in steady state flight when it disturbed by the side forces. The control surface at vertical stabilizer is rudder which serves to control the Roll and Yaw of an aircraft.

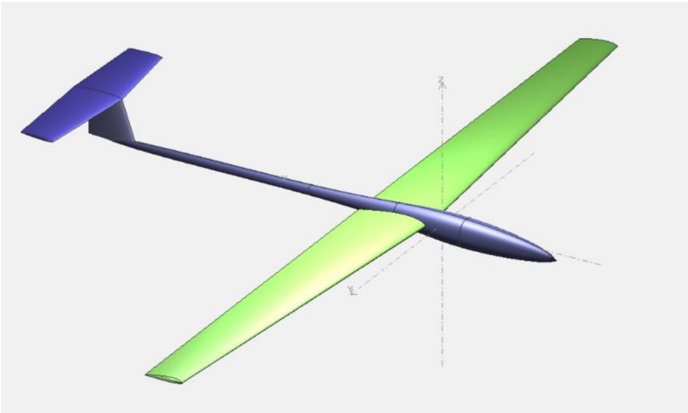
The T-tail is very common on aircraft with engines mounted in nacelles on a high-winged aircraft or on aircraft with the engines mounted on the rear of the fuselage, as it keeps the tail clear of the jet exhaust. These layouts are often found in military transport aircraft - such as the Ilyushin Il-76, Airbus A400M and the Boeing C-17 Globe master III - and regional airliners and business jets such as the Pilatus PC-12, Beech craft Super King Air, Embracer ERJ, British Aerospace 146, and Learjet and Gulfstream families. It is rarely seen in combat aircraft, although the Glister Javelin, McDonnell F-101 Voodoo, and Lockheed F-104 Star fighter interceptors all sported T-tails, as did the Blackburn Buccaneer attack aircraft

2. METHODS AND MATERIALS

2.1 Design







2.2 Specifications

The prototype was designed in XFLR.

Wing span = 160 cm

Wing area = 0.184 m

Plane mass = 0.775 kg

Wing load = 40212 kg/m

Tail volume = 1.006

Root chord = 15 cm

Aspect ratio = 11.85 cm

Taper ratio = 1.875

Root tip sweep = 3.775

The aircraft model is designed in XFLR5 software. Using NACA airfoil NACA2415 for the wing and NACA0010 for the horizontal stabilizer and vertical stabilizer. Taking wing span of 1600mm and the chord length as 150mm. Taking span for the horizontal stabilizer as 200mm and the chord length as 100mm and for the vertical stabilizer the span is 100mm and chord length is 100mm.

During each test, servo commands were given to change the angle of attack from -15 to+15 with a wind velocity of 15m/s. The model was designed by using a T-tail with the horizontal stabilizer placed above the vertical stabilizer.

2.3 Literature study

2.3.1 Aerodynamic coefficients

To gain insight into the aerodynamics of the T-tail aircraft configuration we made an aircraft design in XFLR and ran few analysis to get some aerodynamic data related to T-tail aircraft configuration.
The aerodynamic coefficients were calculated from standard definitions

$$C_L = \frac{2F_z}{\rho S v^2},$$

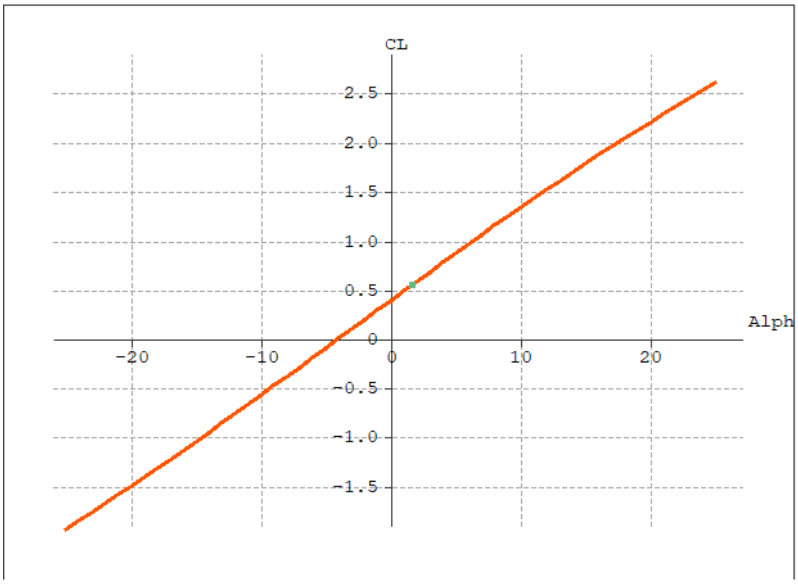
$$C_D = \frac{2F_x}{\rho S v^2},$$

$$C_M = \frac{2\tau_y}{\rho S c v^2},$$

where ρ is the air density, S is the plan form area of the model, c is the mean chord of the wing, and v is the wind velocity.

2.3.2 Graphs:

Below graph shows the Cl vs alpha graph with positive slope indicating incease in lift with increse in angle of attack.



2.4 Analysis:

The analysis of this T-tail aircraft was done on XFLR5 at different angle of attacks to study the flow field and aerodynamic coefficients.
XFLR5 is an analysis tool for aerofoils, wings and planes operating at low Reynolds numbers.
It includes:

- X-Foil's Direct and inverse analysis capabilities
- Wing design and analysis capabilities based on the lifting line theory, on the vortex lattice method and on 3D panel method

The specifications of the design are mentioned above.

3. Results and Calculation:

This shows the potential of the T-tail aircraft in enhancing the agility and performance . Perching remains an extremely difficult challenge for autonomous aircraft and an area where birds can offer inspiration and, perhaps, some design guidance. As suggested by avian behaviour, our preliminary modelling and control work indicates that a T-tail may provide better performance than a conventional tail in stability at low speeds.

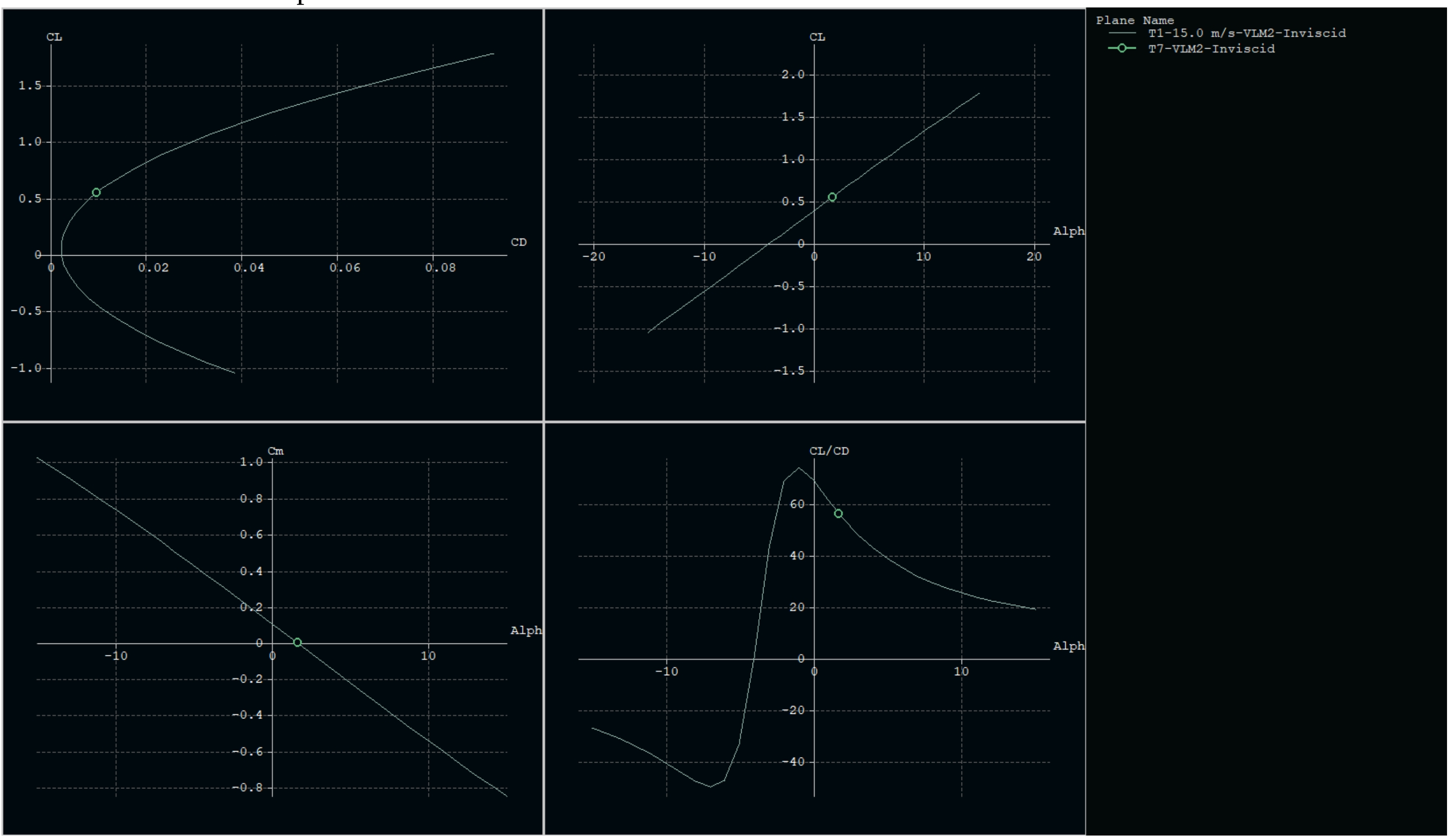


Figure 2: represents the graph obtained after analysis was run with wind speed 15m/s

First graph of the figure represents Cl vs Cd graph: This graph clearly indicates the increse in induced drag as the lift of aircraft increses.

Second graph shows the Cl vs alpha graph with positive slope indicating incease in lift with increse in angle of attack.

Third graph indicates the Cm vs alpha graph: we can clearly see the Cm0 is positive with negative slope of the curve indicating the stability of aircraft. By this we can clearly conclude the T-tail is a stable configuration for aircraft with stability.

The fourth graph represents Cl/Cd vs aplha graph.

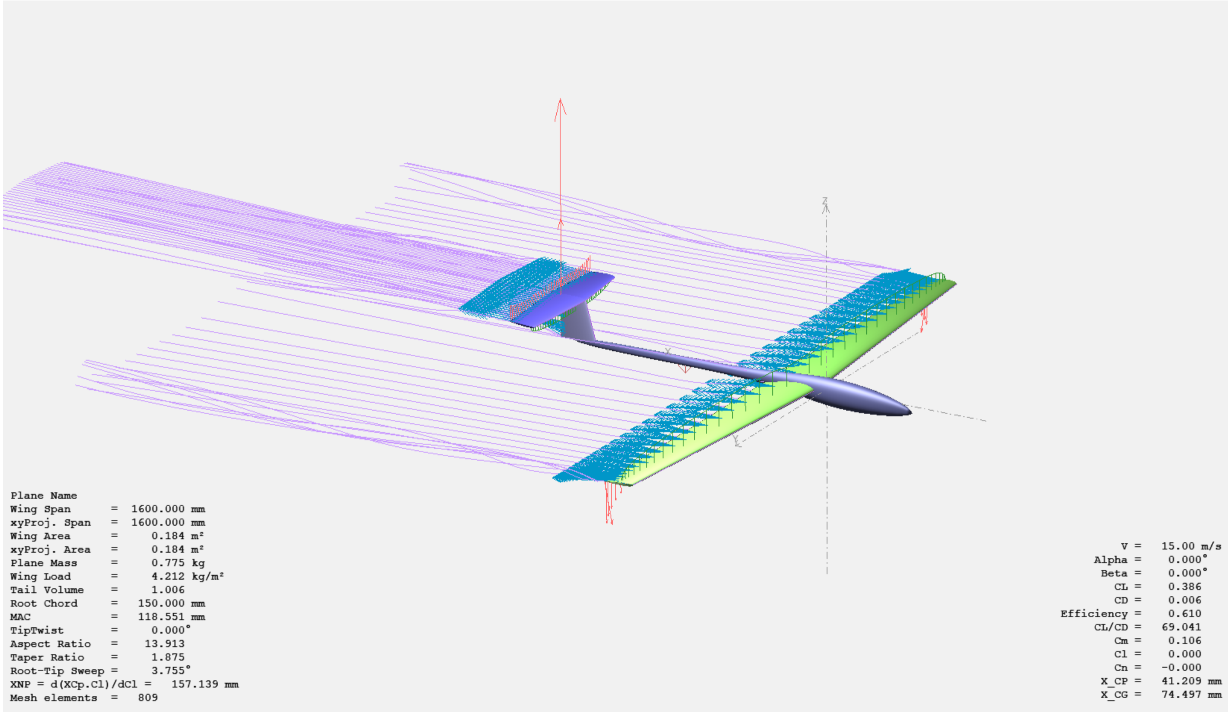


Figure 3. Aerodynamics of aircraft at 0^0 angle of attack

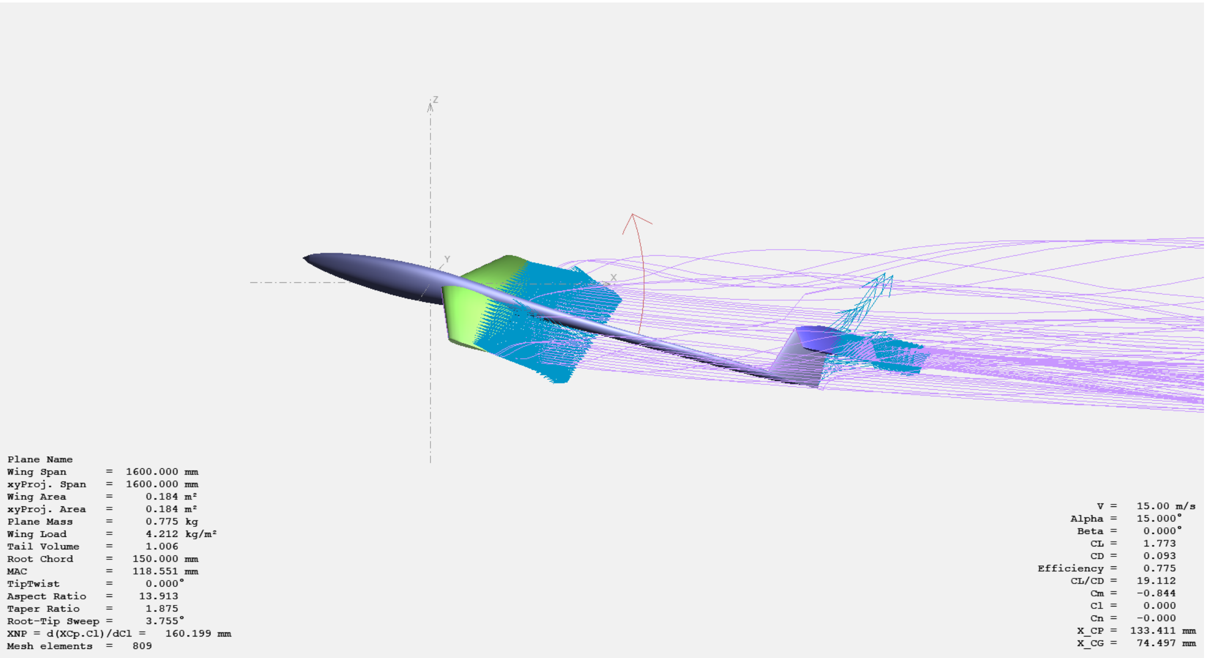


Figure 4. Aerodynamics of aircraft at 15^0 angle of attack

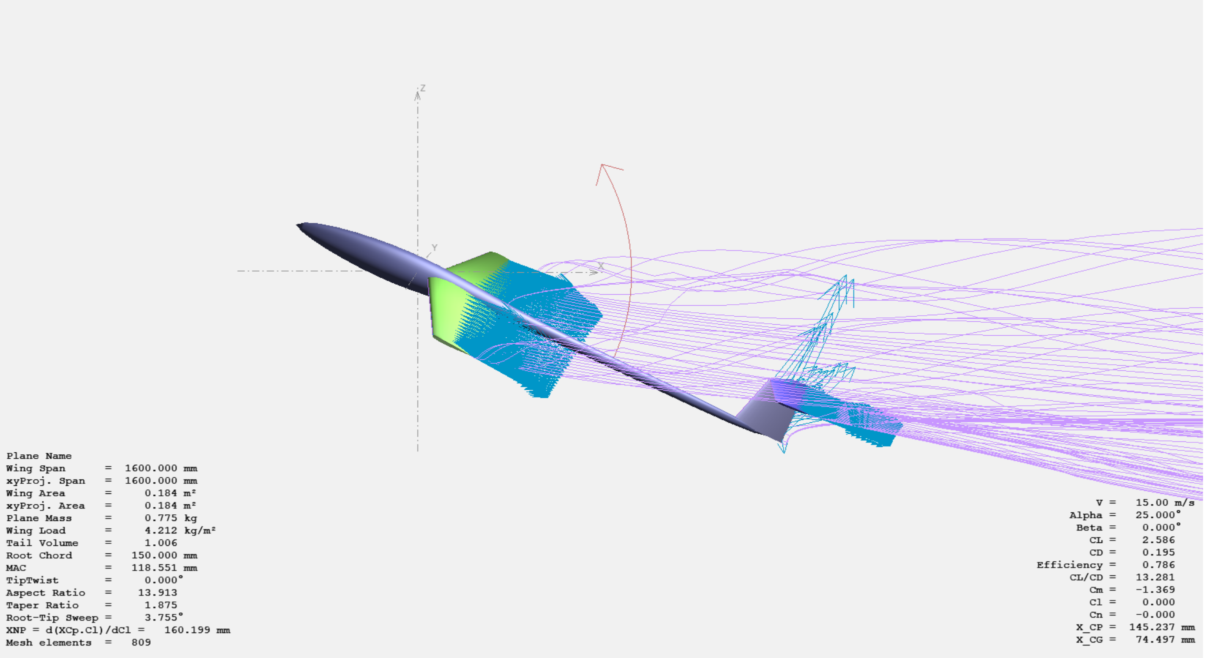


Figure 5. Aerodynamics of aircraft at 25^0 angle of attack

4. Conclusion:

The T-tail concept in this research shows potential for enhancing the agility and performance of small size air vehicles, how even at high angle of attack it generates lift and have good deep stall characteristics. In a T-tail design, the arm of the CG is made smaller. A smaller elevator and stabilizer results in less drag.

It is effective for aircraft flying at low speeds because having a responsive pitch control enables the aircraft to effectively rotate on landing. It is easy to recover from a spin with this type of design because the elevator is located above the rudder. This ensures no dead air zone above the elevator-tail design gives you a better rudder authority when flying at a very high AOA and stalls thus preventing a spin. It results in high performance of aerodynamics and also ensures there is an excellent glide ratio since the empennage is not affected by the wing slip steam. T-tail design ensures the elevator and the aircraft stabilizer are out of the way of FOD kicked up by the engines and gears. A T-tail ensures the tail plane surfaces behind the wings are out of the airflow. This ensures smooth flow and better pitch control of the aircraft. Planes operating at low speeds need clean airflow for control. A T-Tail surface makes it easy to increase the distance between the wing and the tail plane without affecting the weight of the aircraft. This distance gives the plane leverage and enables the tail plane to control the aircraft’s pitch attitude.

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