Comparative Investigation of Aerodynamic Effects on Geometrically Twisted Wing using CFD

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Abstract - **The main intent of this work is to simulate the aerodynamic effects on different configuration of commercial and delta wing at different angle of twist. This investigation aims to suggest a better aerodynamic configuration for wing to reduce the induced drag formed on wing during flight operation and in-turn improves the efficiency of the UAV. Simulation processes of computational fluid dynamic (CFD) on wing models for medium size high speed UAV, using typical section as NACA 2412 airfoil is been carried out at 1^0 , 2^0 and 4^0 twist angle. The twist is provided to adjust pressure distribution henceforth lift distribution along the wing. ANSYS Fluent is used to analyze the pressure distribution on the surface of wing at speed of 0.6 Mach. The lift and drag forces are also determined which were used for calculating the coefficients of lift and drag. The obtained results were used to establish a comparison between aerodynamic performances of all provided models.**

Keywords- **CFD, Delta Wing, Lift to Drag Ratio, UAV, Wing Twist.**

I. INTRODUCTION

As the easiest means of surveillance and monitoring available, UAV has been getting more and more popular in recent years [1]. This popularity has led to many research aimed develop faster and efficient UAV. Many tools based on CFD analysis [2] and numerical methods have been developed and can prove to be extremely useful for the research about the aerodynamic study on UAV.

Aerodynamic forces [3] acting on flying object are named the lift in the direction normal to the air flow and the drag in direction opposite to the motion of body. These forces depend on the flow velocities ahead of the object and operating condition as well as shown in Fig 1. Broad range of aerodynamic problems is associated with the determination of the interaction between air and a solid body moving in it, such as a wing. Aerodynamic researchers have been interested in the optimal shape of the airfoil [4], so as to provide the highest lift and the lowest drag to wing during flight operation.

Kutta- Joukowski theorem states [5], lifting force for an airfoil with round leading and sharp trailing edge immersed in a uniform flow with an effective angle of attack is proportional to the density of air ρ, the circulation Γ generated by the bound vortex and relative velocity of the airflow U.
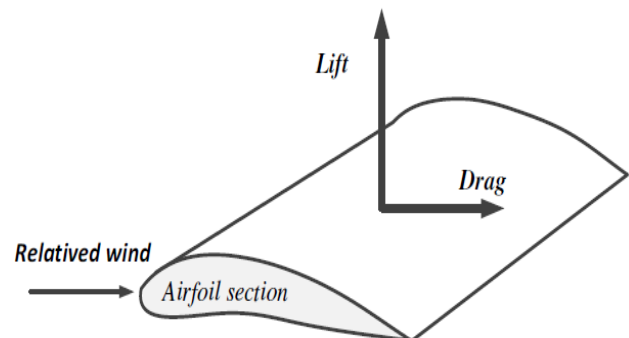

Fig.1. Aerodynamic forces on wing section.

$$L = \rho \Gamma U$$

Also the lift and drag force can be given as,

$$L = 0.5\rho v^2 S C_L$$
$$D = 0.5\rho v^2 S C_D$$

1.Twist

The wing twist distribution must be chosen so that the cruise drag is not excessive. Twist provides extra washout which helps the stalling characteristics of wing and improves the induced drag at higher CL [10]. Twist on sweptback wings also produces a positive pitching moment which has a small effect on production of drag force. Geometric twist shown in Fig 2, is defined as change in the
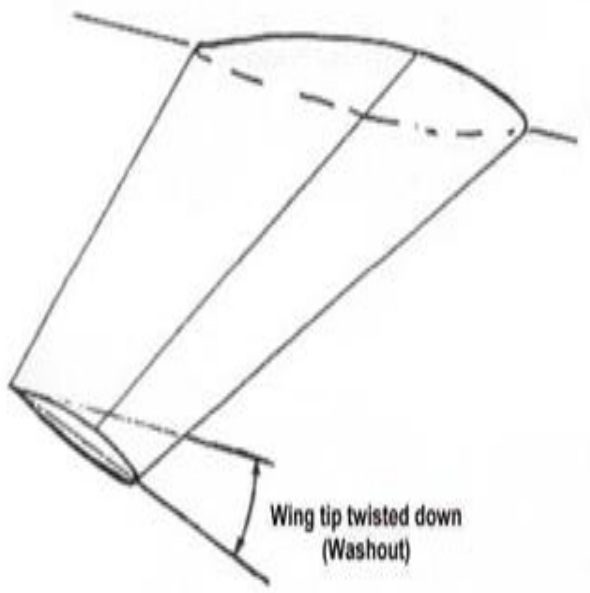
Fig.2. Geometric twist providing washout.

tip airfoil angle of incidence with respect to the root airfoil. Aerodynamic twist is defined as the change in angle between the zero-lift angle of a tip airfoil and the zero-lift angle of root airfoil.

II. METHODOLOGY

1. ANSYS Software
ANSYS offers engineering simulation solution sets in engineering problems that a design and analysis process requires. Various companies and industries use this software. ANSYS uses Fluent and various other programming algorithms for simulating and optimizing various design problems in numerous field. ANSYS has many sub parts out of which ANSYS Fluid Flow is chosen to run the simulations.

2. Design and dimensions
The design of commercial and delta wing was done using NACA 2412 airfoil. The dimensions of wing and boundary condition associated with analysis are tabulated in Table 1 to Table 3.

Table 1 contains the dimension details of commercial wing design, Table 2 is provided with the dimensions of delta wing and Table 3 provides the boundary condition of analysis and flow parameters.

Table I: Dimension of commercial wing.

Terminology	Value	Unit
Sweep angle	30	Degree
Span	2	m
Root chord	0.5	m
Tip chord	0.1	m

Table II: Dimension of delta wing.

Terminology	Value	Unit
Sweep angle	30	Degree
Span	2	m
Root chord	1	m
Tip chord	0.1	m

Table III: Flow parameters.

Property	Value	Unit
Density	1.1768	kg/m^3
Viscosity	1.716e-05	kg/m-s
Pressure	101325	Pa
Flow velocity	0.6	Mach

3. Meshing
In the analysis of wing configuration of high speed UAV, meshing is the next step to be followed after the model is being prepared for the purpose of analysis. The analysis should continue with more refined mesh 169,475 nodes and 94,302 elements and a subsequent comparison until convergence are established.

III. RESULT

In order to estimate the performance of wing by comparing the pressure distribution and aerodynamic coefficient a variety of analysis has been conducted on different wing model. By applying flow velocity of 0.6 Mach the wing models with geometric twist of 0^0, 1^0, 2^0 and 4^0 at an angle of attack of 0^0 are analyzed.
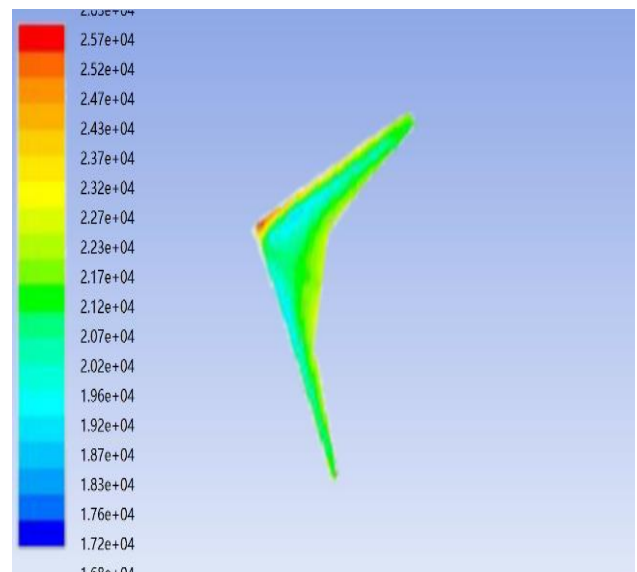

Fig.3. Pressure contours on commercial wing at 0° twist and 0° angle of attack.

As a result, the obtained pressure distribution over a commercial wing is shown in Figure 3 to Figure 6. The obtained values of lift and drag force are used to calculate the coefficient of lift and coefficient of drag respectively. Pressure contours are displayed on commercial wing at 0^0 twist and 0^0 angle of attack in Fig 3 followed by 1^0 twist and 0^0 angle of attack in Fig 4. The analysis is thereby continued with a geometrically twisted wing profile at 2^0 and 4^0 twist shown in Fig 5 and Fig 6 respectively.
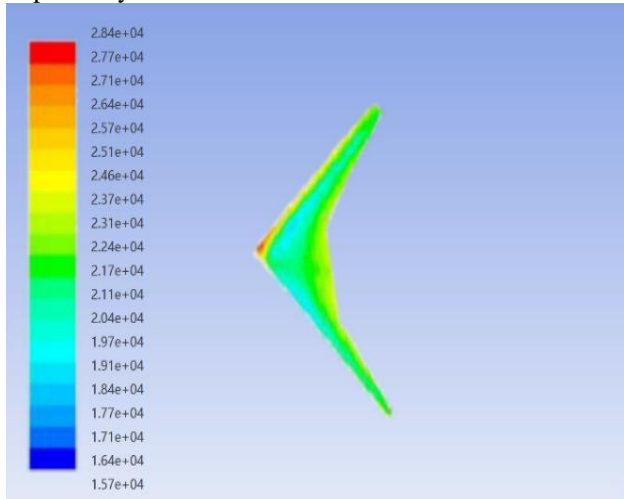

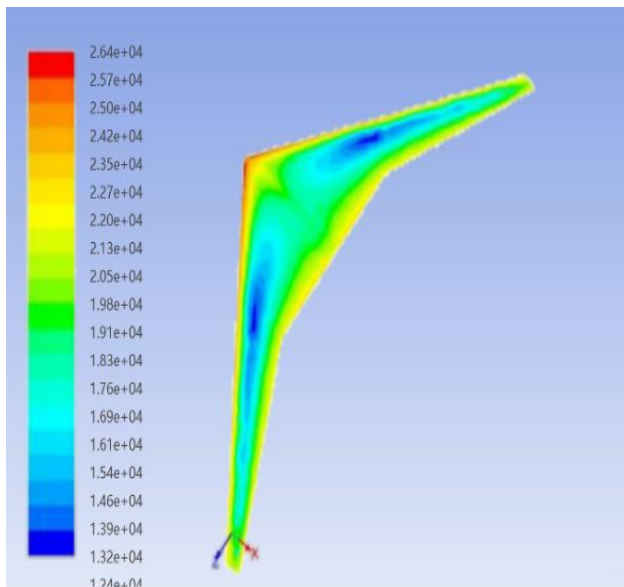Fig.4. Pressure contours on commercial wing at 1^O twist and 0° angle of attack.

Fig.5. Pressure contours on commercial wing at 2^O twist and 0° angle of attack.

The pressure contours obtained on twisted profiles provides more uniform pressure distribution over wing as compared to wing with no twist, also the lift to drag ratio is improved as provided in Table 4.
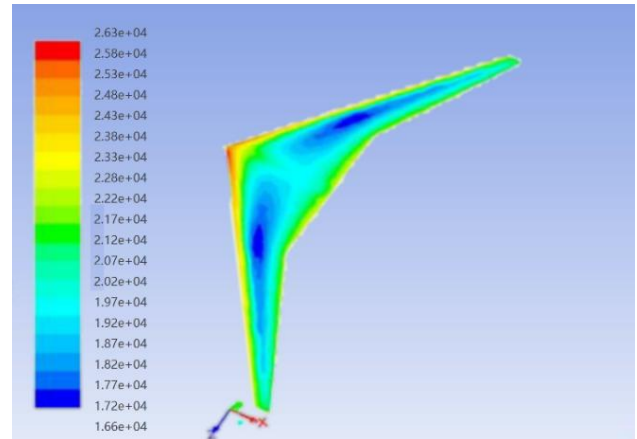

Fig.6. Pressure contours on commercial wing at 4° twist and 0° angle of attack.

From the analysis, obtained values of lift and drag forces acting on wing profile were used to calculate coefficient of lift and coefficient drag. The variation of lift coefficient over various twist angle are plotted and displayed in Fig 7 also the variation of drag coefficient over various twist angle are plotted and displayed in Fig 8.

Table IV: Lift and Drag coefficient on commercial wing at different twist.

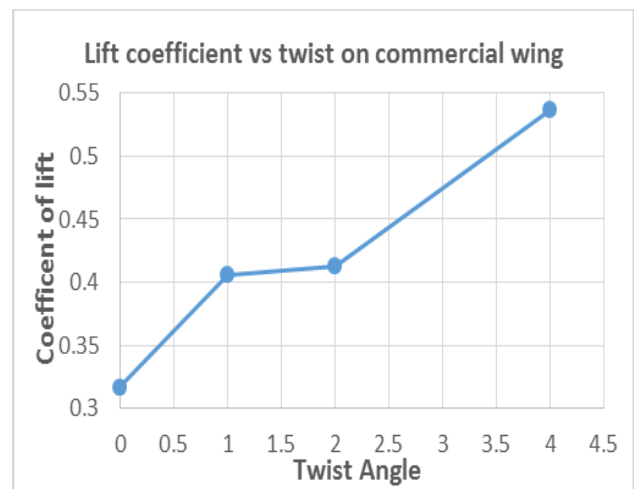| Twist angle	Angle of attack	Lift coefficient C_L	Drag coefficient C_D	Lift to Drag ratio C_L / C_D
0	0	0.317	0.0214	14.813
1	0	0.406	0.0242	16.776
2	0	0.413	0.0239	17.280
4	0	0.537	0.0283	18.975

Fig.7. Variation of lift coefficient over geometrical twist on commercial wing.

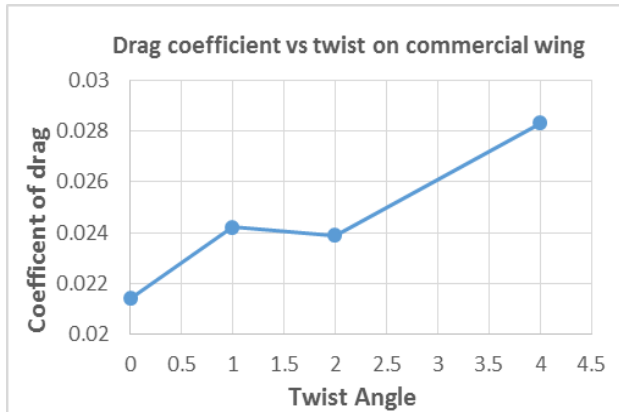Fig.8. Variation of drag coefficient over geometrical twist on commercial wing.

Pressure contours are displayed on delta wing at 2^0 twist and 0^0 angle of attack in Fig 9 followed by 4^0 twist and 0^0 angle of attack in Fig 10. The pressure contours obtained on twisted delta wing profiles shows that the pressure distribution over delta wing has reduced distribution uniformity at high twist angle, whereas the lift to drag ratio is improved as provided in Table 5.
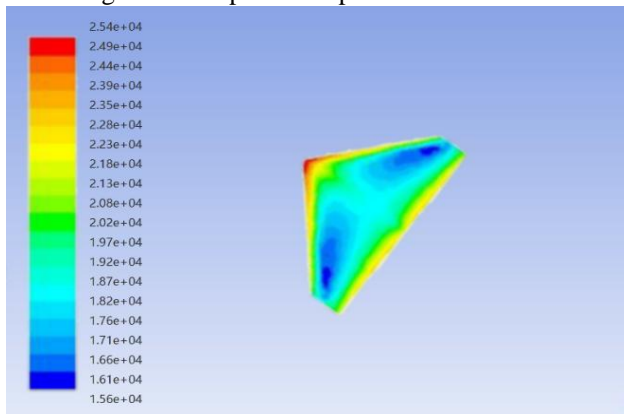

Fig.9. Pressure contours on delta wing at 2^O twist and 0° angle of attack.
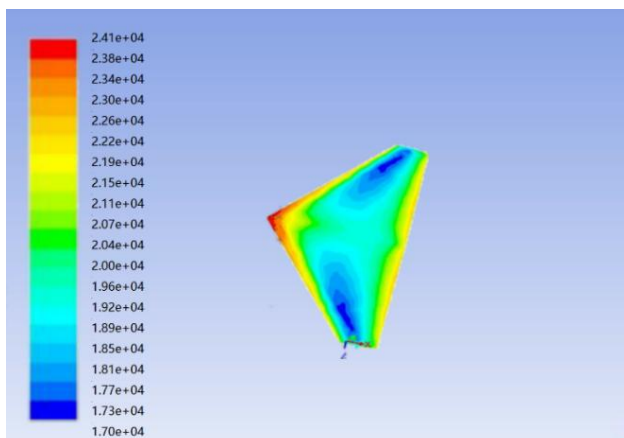

Fig.10. Pressure contours on delta wing at 4° twist and 0° angle of attack.

The pressure contours also describe that twisted wing have some portion in the middle part of camber which has less pressure as that of wing with no twist. This property of twisted wing provides advantage by reducing the structural strength required to sustain the pressure loads.

Table V: Lift and Drag coefficient on delta wing at different twist.

Twist angle	Angle of attack	Lift coefficient C_L	Drag coefficient C_D	Lift to Drag ratio C_L/ C_D
2	0	0.27	0.0278	9.7122
4	0	0.294	0.0293	10.034

IV. CONCLUSION

Based on the computational results the lift and drag coefficient of the geometrically twisted wing has considerable modification as compare with conventional wing with no twist at all. The wing with acceptable twist angle creates a greater decreasing of down-wash velocity due to uniform pressure distribution that leads to a higher augmentation in lift and reduction of drag, as well as an increase of lift to drag ratio for the wing. This work has provided sufficient inputs regarding aerodynamic design aspects of UAV. It is although a rudimentary exercise as far as the design understanding is concern. This has also provided an idea about wing configuration, geometric twist, angle of attack, etc., during the analysis. In future different configuration can be used to provide a better performance for high speed UAV.

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