

The Effect of Airport Distance on Wing Aerodynamic Characteristics for Ultra-Light Airplane

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Abstract - The airport surface effect on aerodynamic characteristics of an airfoil NACA 0012 at different height was investigated. The lift, drag and moment coefficients are numerically calculated using singularity method for Mach number $M = 0.3$ and different angles of attack. The runway surface was represented by the wind tunnel wall and the wall distance control (h/c) from the wing. This paper showed that this airfoil, in order to work with good aerodynamic characteristics in take-off and landing, must be at height $h/c > 0.75$ and fixed at an angle more than 0° with the center line of aircraft body. At height ($h/c < 0.75$), the action of the wing is inverted, so negative forces are generated for all angles of attack. There is good agreement in this paper with the work of other researchers.

Keywords: height to chord ratio (h/c), Lift, Drag, run way surface.

I. INTRODUCTION

As it is known, sufficient aerodynamic characteristics must be available to help the aircraft take off and land safely. Therefore, the impact of the runway surface on the wing of the aircraft must be taken into consideration in this case. So, it must be ensured that a high wing lift is possible, and that the impact of the runway surface on the wing characteristics is positive by choosing the appropriate height of the wing from the ground surface.

Numerous studies on the effect of the Earth's surface on the aerodynamic characteristics of the wing.[1]In their experimental study, they demonstrated that lift increases with decreasing the distance between the surface of the wing and the ground to a certain extent.[2] Studied the performance of the airfoil numerically. [3], they experimentally found that the lift increases by 36% and the drag decreases by 21% with approach to the ground surface by 20% of the chord length.[4]found an 80% increase in Cl/Cd ratio for seabirds at 20% chord above the ground surface.

[5] Study ground effects computationally using both the panel and finite volume methods. Their study showed that the results of both methods are consistent with the experimental results.[6], Their study aimed to reveal the dependence of the forces acting on different wing configurations on ground

distance. They were also interested in understanding the effect of ground on the aerodynamic properties by experimental examination of the flow around a symmetric airfoil of NACA 0015 with different angles. When an aircraft is hovered over the runway surface, the interaction occurs between the air around the airfoil and the ground surface resulting in a change of the lift-to-drag ratio L/D [7]–[9].The behavior of the air flow from the leading edge to the trailing edge can be observed by the study by [10],[11], [12][13] demonstrated the ground effect of creating a clean wing. They conducted experiments and carried out numerical studies on the single-element symmetric inverted and cambered airfoil, and found that the lift force reaches its maximum at a ground clearance of about $0.08C$, subsequently, the lift reduces sharply close to the ground surface.

In this paper, the aerodynamic characteristics of the airfoil NACA 0012 were calculated at different heights and angles of attack, with constant velocity. It was shown that the low height, especially $h/c=0.25$ to 0.75 , and for different angles, the lift force generated is negative. Therefore, the wing must be installed at a height of more than $h/c=0.75$ and angle more than 2° with the aircraft body center line to obtain aerodynamic characteristics suitable for take-off and landing.

II. GOVERNING EQUATIONS

The flow is in viscid and irrotational around airfoil, therefore Navier-Stokes equations replaces by potential flow equation:

$$\theta^2 \frac{\partial^2 \hat{\phi}}{\partial \hat{x}^2} + \frac{\partial^2 \hat{\phi}}{\partial \hat{y}^2} = 0 \quad (1)$$

Correction parameter for compressibility is defined as:

$$\theta = \sqrt{1 - M^2} \quad (2)$$

Where M is Mach number for free stream, and $\hat{\phi}$ is the velocity potential.

The equations for linear vortex strength are:

$$u = \frac{1}{2\pi} \int_{x_1}^{x_2} \gamma(x_0) \frac{x_0 y}{(x - x_0)^2 + y^2} dx_0 \quad (3)$$

$$v = \frac{1}{2\pi} \int_{x_1}^{x_2} \gamma(x_0) \frac{x_0(x - x_0)}{(x - x_0)^2 + y^2} dx_0 \quad (4)$$

Where u, v is velocity potential[14]for any arbitrary point with coordinate (x, y).

γ - is a vortex strength at position x_0 on the panel with the ends (x_1, x_2).

$$\text{Lift coefficient } C_l = \frac{F_l}{qA} \quad (5)$$

$$\text{Drag coefficient } C_d = \frac{F_d}{qA} \quad (6)$$

$$\text{Moment coefficient } C_m = \frac{M}{qAl} \quad (7)$$

$$\text{Pressure coefficient } C_p = \frac{p - p_\infty}{q} \quad (8)$$

Where F_l, F_d, M is Lift force, drag force and moment respectively.

q - Dynamic pressure, A - wing area, l -chord, P - static pressure, p_∞ - static pressure for free stream.

III. RESULT AND DISCUSSION

In the Fig.1 the pressure distribution considered for angles $0^\circ, 2^\circ, 6^\circ$ and 10° at $M = 0.3$, for NACA 0012 with height $h/c = 0.25$. For zero angle, a large drop in pressure occurs on the lower surface of the wing due to the increase in the air flow under the wing as a result of formation of a nozzle channel between the surface of the wing and the surface of the runway, this pressure drop starts from the wing leading edge to the trailing edge, and as a result, the direction of the lift force will be downward, this is clear in Figure 1, where a jump of the pressure line of the lower wing surface is observed in the direction of the negative pressure axis.

For angle 2° , curve behavior of pressure coefficient shows that the flow began to accelerate a little past the leading edge, generating a negative lift force as well.

The similar behavior as for angle 2° occurs at angle 6° the curve for lower surface indicate that the negative pressure starts to increase from leading edge up to $x/c = 0.45$ then begin to decrease, the negative pressure zone starts form $x/c=0.15$ to trailing edge. This behavior can be interpreted as a

consequence as a result of a change in the cross-sectional area of the inlet and outlet of the nozzle formed under the surface of the wing, which led to a slowdown in the air flow in the beginning of the nozzle and then accelerate toward the exit. The negative pressure generated less than that in case angles 2° and 0° i.e. A very small positive lifting force was generated on the surface of the wing.

For angle 10° the negative pressure begins at $x/c = 0.35$, and there is a match in the pressure line for the lower surface with the upper of the wing, so half of the wing will be ineffective to generate the lifting force. Positive lift force was generated in this case.

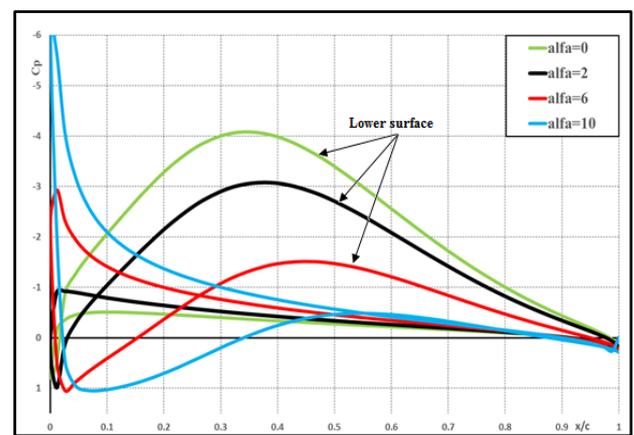


Figure 1: Pressure distribution for $h/c=0.25$

In the Fig.2 at $h/c=0.5$, the behavior of the pressure lines of the lower surface in the negative direction are less disturbed than in Figure 1, the reason is that the nozzle formed with large dimensions reduced the velocity of air flow under the wing. The pressure line for lower surface jump toward negative pressure axis for 0° and 2° angles. The lift force generated for zero angles is very small and negative direction; also there is very small positive force for 2° . It is noticeable for the same figure 2 that the remaining two angles 6° and 10° behave completely differently, as the positive lift appears.

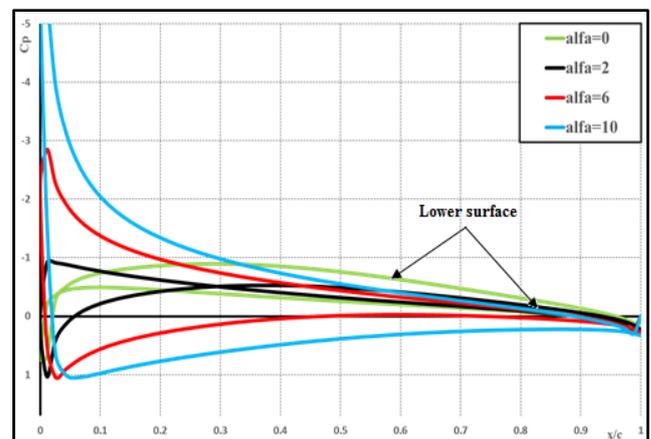


Figure 2: Pressure distribution for $h/c=0.5$

The lift coefficient behavior for different height shown in the Fig. 3 For $h/c = 0.25$, the lift curve starts from minus value at angle 0° and increases with increasing angles, the lift becomes positive at an angle of 6° and it continues positive until angle 12° .

For $h/c = 0.5$, there will be a slight improvement in the lift line, but it remains negative at the zero angle, then it is positive at 2° and continues to increase until the angle 12° .

With the increase in height at $h/c = 1.0$, a clear change occurs in the line of lift, and it starts almost from zero at the zero angle and begins to increase with the increase in the angles of attack.

At heights, $h/c = 2, 3$ and free stream, the difference between the lift lines will be very small i.e. these lines close to free stream line, this means that the effect of the ground surface on the wing characteristics has become neglected.

becomes zero at 6° angle, then begins to close with other lines after the 8° angle. For $h/c = 0.5$, the lift to drag line stars from high value and close to other lines after 6° angle. The line for $h/c = 1$ close to other lines after angle 3° while the other heights close to the free stream line.

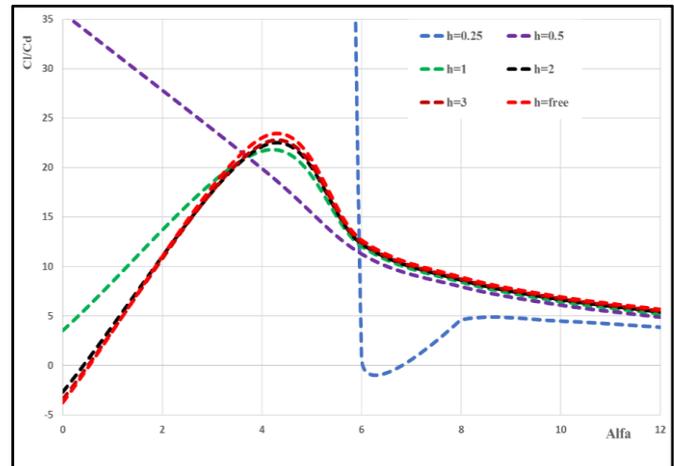


Figure 5: Lift to drag coefficients

In the Fig. 6, the increase in the nose down C_m is obvious, especially at height $h/c = 0.25$, the slop of the moment line is sharp.

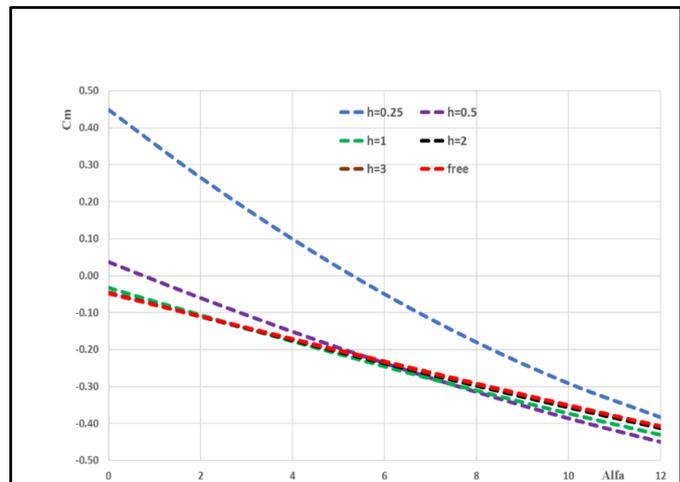


Figure 6: Moment coefficient

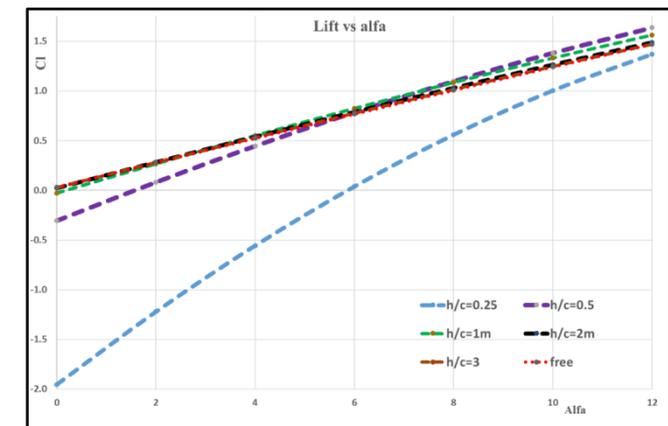


Figure 3: Lift coefficient

In Fig. 4, all the drag lines start with a negative value at angle zero and change to positive axis at angle 2° except for the height $h/c = 0.25$, the positive value starts after angle 4° .

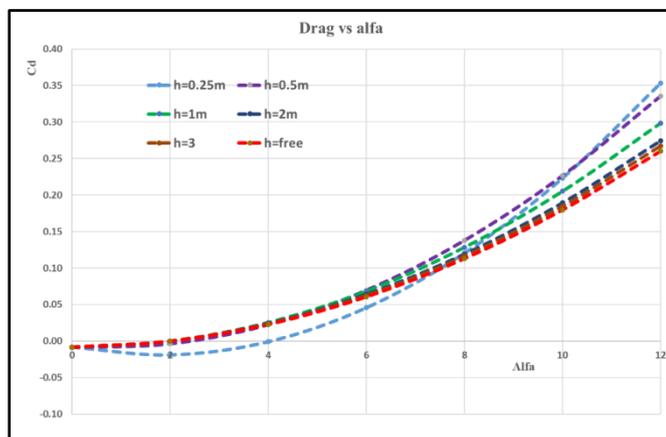


Figure 4: Drag coefficient

In the Fig. 5, the behavior of cl/cd line at $h/c = 0.25$ seems strange and starts from a very high value, then its value

In Fig.7, at zero angle of attack and $h/c = 0.25$, a sharp negative lift is generated as a result of the formation of the nozzle, which leads to a large acceleration in the flow under the wing, forcing the wing to work in reverse. At angles $2^\circ, 4^\circ$ and $h/c = 0.25$, a negative lift is generated, which disappears with the increase in height, and then the lift begins to stabilize after a height $h/c = 0.75$ i.e. the effect of the surface of the earth on the wing begins to decay after this height.

The lift formed at an angle 6° and more is positive, and its increase is sharp from $h/c = 0.25$ to height $h/c = 0.5$, and then begins to stabilize after $h/c = 0.75$.

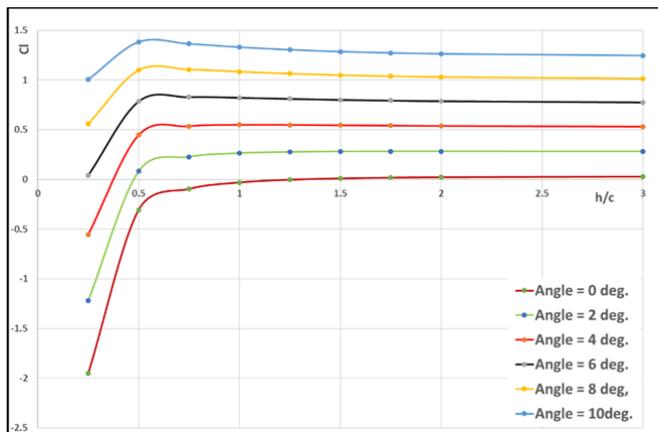


Figure 7: Lift vs height

IV. CONCLUSION

The effect of the surface of the runway on the clean airfoil NACA0012 was taken into account and the study showed the following:

1. At height $h/c = 0.25$, with 0° , 2° , 4° angles, the generated lift is negative, so it is impossible to install the wing on the body of the aircraft at this height or at angles more than 6° with the body center line.
2. At height $h/c = 0.5$ with zero angle the lift generated is negative and very small at 2° , then it starts to increase as the angles of attack increase, therefore, this height is not considered safe to generate sufficient lifting forces for take-off and landing.
3. At the height $h/c = 1$ and the angle of zero, the lift is negative and increases with the increase in the angles of attack. The lift line begins to close with the line of free stream lift in the few angles and is greater at the high angles, and this indicates the positive effect of the runway surface on the characteristics of the wing.
4. For heights $h/c = 2, 3$, the lift lines close completely to the free stream lift line, so we conclude that the height more than $h/c = 1$, the effect of the runway surface on the wing specifications recedes.

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