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Research the Effect of Ground Effect on the Aerodynamic Characteristics of Aircraft

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A B S T R A C T

The landing process of the aircraft includes: descent, roundout and flare. In the flare process, altitude of the aircraft is from 0.5 to 1m. Such a process of near-ground movement will produce a boundary layer between the aircraft and the runway, leading to the changes of the airflow around the aircraft. This phenomenon is called ground effect. In this research, the authors use the Fluent module of Ansys software to study the pressure distribution, speed around the surface of flying objects, drag coefficient, lift coefficient of the aircraft according to altitude and angle of attack.

Keywords: Uhs: Plane ground effect; Aerodynamic characteristics of Su-27; Landing process.

1. Introduction

Ground effect is a phenomenon that occurs when an aircraft is moving close to the runway surface (ground, water) at a very small distance. This distance is usually determined from the average aerodynamic bowstring length of the wing. When the aircraft is moving near the runway surface, the air between the aircraft and the runway will be compressed, increasing pressure under the wing and overflowing at the tip of the wing. This changes the distribution of the pressure field, the air velocity around the aircraft, leading to changes in the aerodynamic characteristics of the aircraft.

The content of the article will focus on clarifying the effect of this effect on the aircraft's aerodynamic characteristics, thereby giving recommendations to pilots to improve the efficiency of aircraft operation and use. In this study, the authors used the Su-27 aircraft model and Ansys Fluent software to simulate and calculate to clarify the nature and effects of ground effects on the aerodynamic characteristics of the aircraft. plane.

2. Methodology

2.1. Build an airplane model

To simulate the aerodynamic characteristics of the Su-27 fighter during landing, the author built a 3D model of the aircraft using Solidworks software. The geometric dimensions of the model are equal to the actual size of the aircraft with a fuselage length of 21.9m, a wingspan of 14.7m. The model is shown in Figure 1.

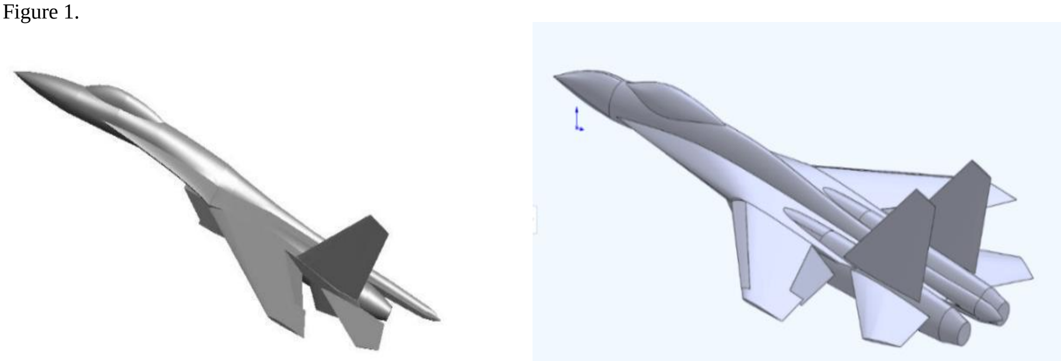


Figure 1. 3D model of aircraft used in the research

2.2. Carry out calculations and simulations

In numerical simulation CFDs exist many different calculation methods of which three are common:

- Direct Numerical Simulation (DNS) method, which solves the Navier-Stokes equation directly, the advantage of the method is that it gives accurate results, the most realistic simulation of phenomena, but the disadvantage is that is to use large resources and long computation time.

- The Reynolds-averaged Navier-Stokes (RANS) method works on the principle of averaging the parameters of the flow. The advantage of the method is that the calculation time is fast, but because of the averaging, for flows with large disturbances, the method gives not really accurate results.

- The method of simulating large vortices (Large Eddy Simulation, LES) This method directly calculates large vortices and simulates small vortices, suitable for simulating boundary layer separation, but the method requires the use of use large resources, so it is rarely used in calculations.

Through analyzing and evaluating the advantages and disadvantages of each method, to solve the problem, the author has used the discrete vortex method, the discrete vortex method is a combination method between the averaging model (Reynolds-averaged Navier-Stokes, RANS) and simulation model of large vortices (Large Eddy Simulation, LES). In the flow areas near the wall, the discrete vortex method works like the RANS model, and in the areas where the separation occurs, the discrete vortex method works similar to the LES model to simulate the eddy currents, the advantage of the method. The solution is to give highly accurate results and save more time than the LES and DNS models.

2.2.1. Choice of turbulence model

In general CFX problems, there are many puppet models that can be used for different specific cases. Through studying documents and referring to different puppet models, to solve this problem, the author decided to choose the Shear Stress Transport (SST) puppet model. The SST model is the most complete physical model, having a combination of the k-ε model in the free-flow and the k-ω model near the wall. Where k is the kinetic energy of the entanglement, and ε is the intensity of the turbulence dispersion, i.e. the number of k in 1 second, and ω is the dissipation rate.

The state equation of the entangled model SST is described by the equations:

$$\frac{D(\rho k)}{Dt} = \nabla.[(\mu + \sigma_k \mu_T)\nabla k] + P_k - \beta^* \rho \omega k \quad (1)$$

$$\frac{D(\rho \omega)}{Dt} = \nabla.[(\mu + \sigma_\omega \mu_T)\nabla \omega] + \gamma \frac{\rho}{\mu_T} P_k - \beta \rho \omega^2 + (1 - F_1) D_{k\omega} \quad (2)$$

where:

k - Kinetic turbulence

P_k - Output kinetic turbulent energy

ω - Dissipation speed

$\sigma_k, \beta, \beta^*, \sigma_\omega$ - The coefficients

F_1 - Mix function

2.2.2. Set the boundary condition

The size of the calculated space domain (inflatable space domain) must be large enough compared to the size of the aircraft for the most stable flow of air entering the aircraft, minus the distance from the belly of the aircraft to the underside of the domain. The computational spatial domain is shown in Figure 2.

- Inlet velocity vx = 68 m/s (M=0,2) – Velocity inlet;

- The surrounding faces correspond to the Symmetry condition, $v_y = 0, v_z = 0, \frac{\partial P}{\partial y} = 0, \frac{\partial P}{\partial y} = 0$

- Output will correspond to free flow condition and zero residual gas pressure – pressure outlet.

- The bottom side is the screen - wall.

2.2.3. Meshing the model

To achieve the required accuracy and convergence of results in calculations, meshing simulation plays an extremely important role. The smaller the mesh size, the more accurate the results will be, but this will make the problem take longer to solve and when the grid has converged, reducing the resulting grid size will not change significantly. The altitude of the aircraft above the ground will be changed from $\bar{h}$ = 0.2 to $\bar{h}$ = 3, where: h is the relative altitude of the aircraft above the ground and is determined by the formula:

$\bar{h} = \frac{h}{b_A}$ Where: h - Altitude of the aircraft above the ground,

b_A - Mean aerodynamic chord.

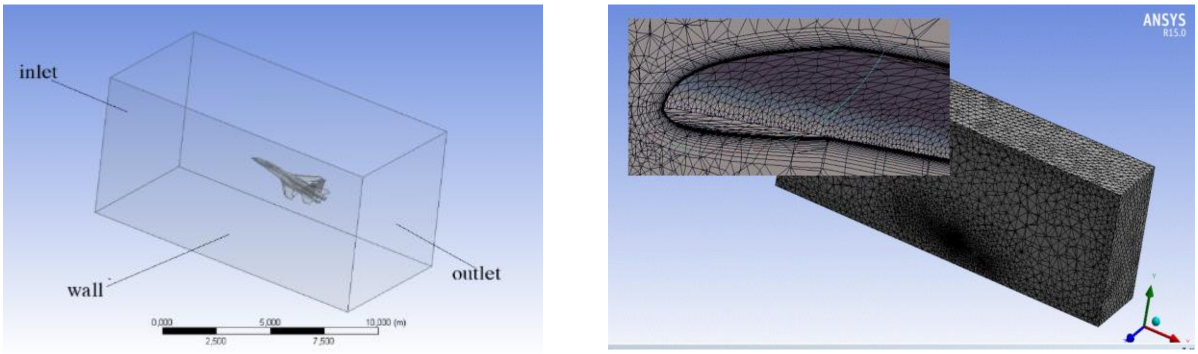
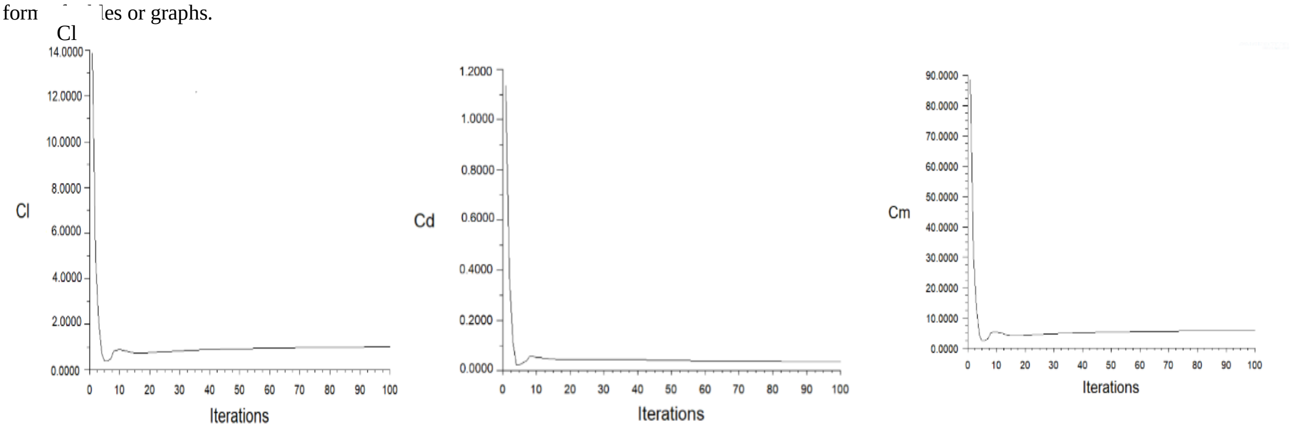


Figure 2. ***Meshing the model***

2.3. Initialize the calculation

After completing the meshing and setting the boundary conditions, we proceed to initialize the calculation. The computer will automatically calculate and output the coefficient of drag (Cd), coefficient of lift (Cl) and coefficient of moment (Cm) of the aircraft. Calculation results can be presented in the form of tables or graphs.



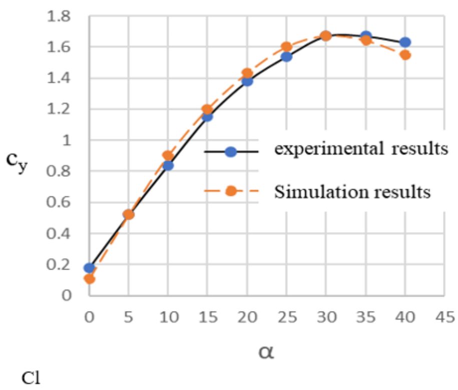
a) *b)* *c)*

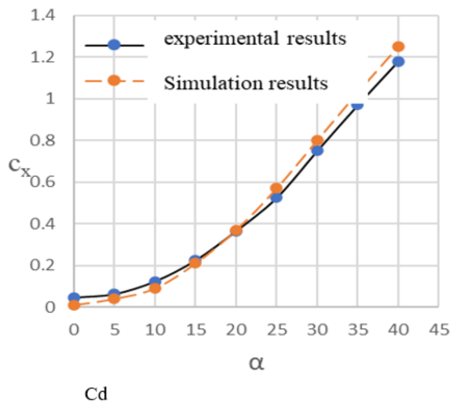
Figure 3. Calculation results of aerodynamic coefficients a) Coefficient of lift, b) Coefficient of drag, c) Coefficient of moment

From the obtained results, we can build graphs showing the dependence of drag coefficient, lift coefficient on flight altitude at different angles of attack. In addition, the software also allows to output images showing the distribution of pressure field, velocity field around the aircraft.

3. Results and Discussion

Based on the graphs obtained above in Figure 3, we can easily determine the values of drag coefficients, lift coefficients and longitudinal moment coefficients at different angles of attack and heights. of the aircraft relative to the runway surface. From there build graphs showing the relationships between them.

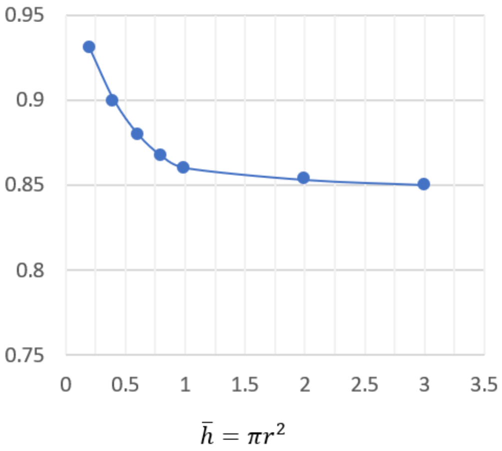


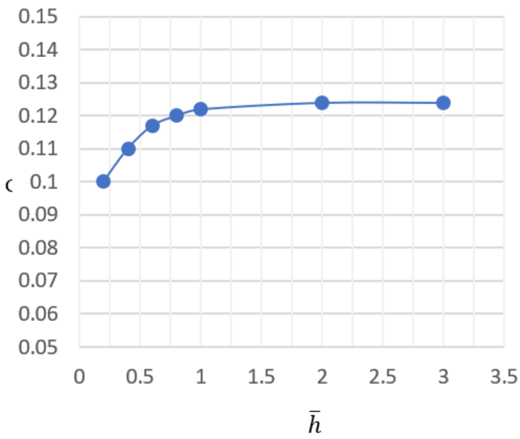


Droop nose wing angle: φ = 18o; Wing flap angle: φ = -23o

Figure 4. The dependence of the lift coefficient on the angle of attack **Figure 5. The dependence of the drag coefficient on the angle of attack**

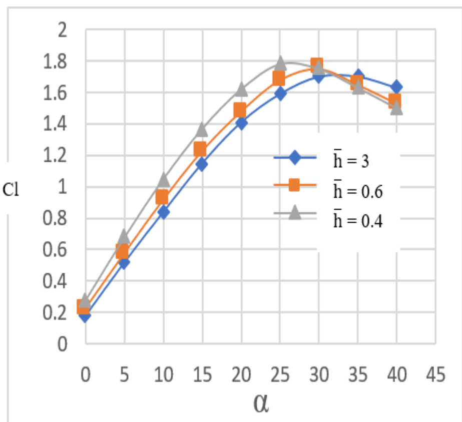
Figures 4 and 5 are graphs showing the dependence of the drag coefficient and lift coefficient of the aircraft on the angle of attack. Based on the graph, it is easy to see that the error between the results obtained from the simulation and the experiment is not significant (the error ranges from 5% - 10%). The above results show that the research method is completely reliable, has high accuracy and can be applied to further research for other cases.

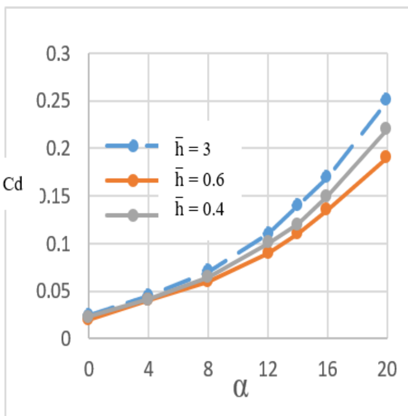




Angle of attack: α = 10o; Droop nose wing angle: φ = 18o; Wing flap angle: φ = -23o

Figure 6. The dependence of the lift coefficient on the height **Figure 7. The dependence of the drag coefficient on the height**





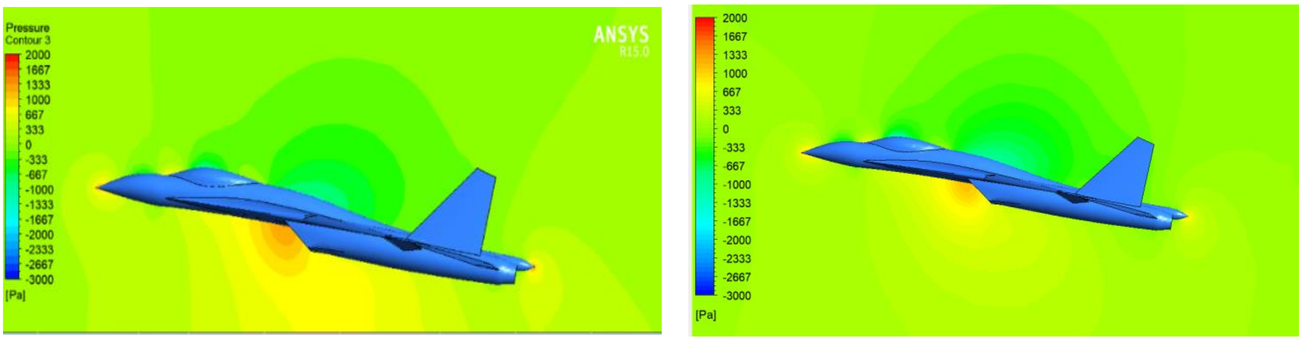
Angle of attack: α = 10o; Droop nose wing angle: φ = 18o; Flaperon deflection angle: φ = -23o

Figure 8. The dependence of the lift coefficient on the angle of attack Figure 9. The dependence of the longitudinal moment coefficient on the height

From the results obtained in Figures 6, 7 ,8 and Figure 9 we see that when the altitude is gradually reduced to $\bar{h}$ = 1 and fixed other parameters such as angle of attack, velocity, the aerodynamic characteristics of the aircraft begin to change. The initial changes such as: The lift coefficient will increase, the drag coefficient will decrease, and the critical angle of attack of the aircraft will also be gradually reduced.

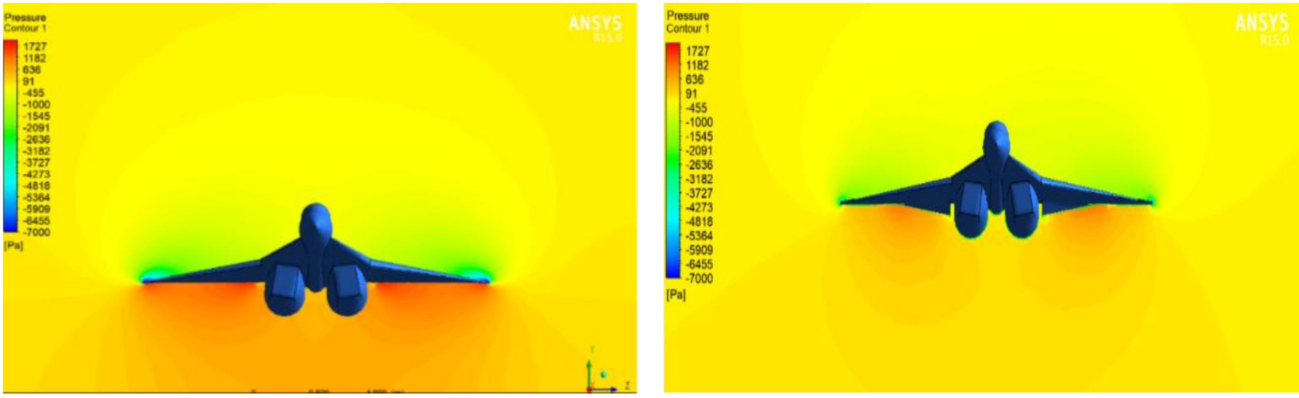
To explain the change in the aerodynamic characteristics of the aircraft due to the influence of the ground effect, we take two typical cases for comparison. One is that at an altitude of $\bar{h}$ = 0.4 at this height the ground effect is already evident. The second case is at altitude $\bar{h}$ = 3 shown when the aircraft is moving away from the ground (not taking into account the influence of the ground).

At other altitudes and angles of attack, the velocity and line pressure distributions are similar, with the same regularity, differing only in magnitude and value. Due to the nature of the phenomenon of ground effect is the phenomenon of air compression in the space between the aircraft and the ground. Therefore, to explain the changes in the aerodynamics of the aircraft when flying close to the ground, we will start with the analysis from the pressure distribution along the fuselage and wingspan. Also analyze the effect of pressure distribution changes on the air velocity field surrounding the aircraft.



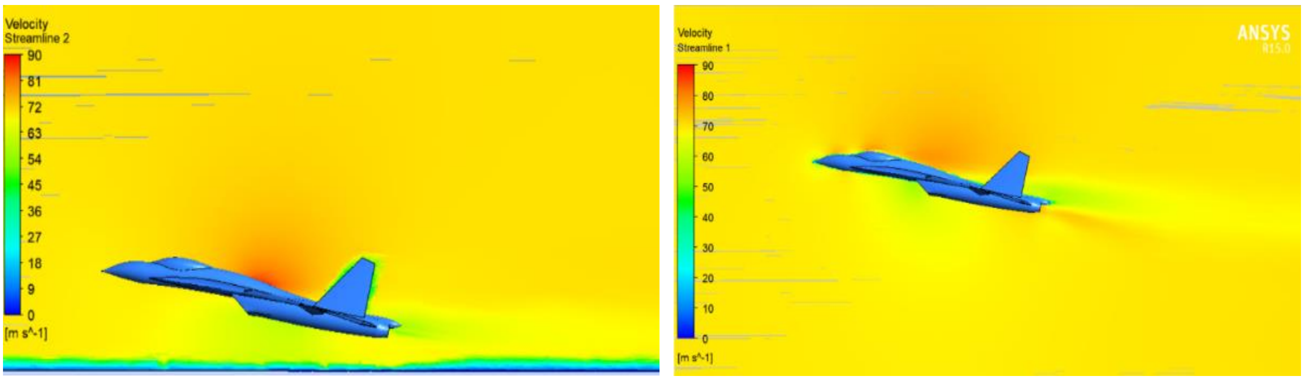
a) $\bar{h} = 0.4$; $\alpha = 10^o$ b) $\bar{h} = 3$; $\alpha = 10^o$

Figure 10. Pressure distribution along the fuselage



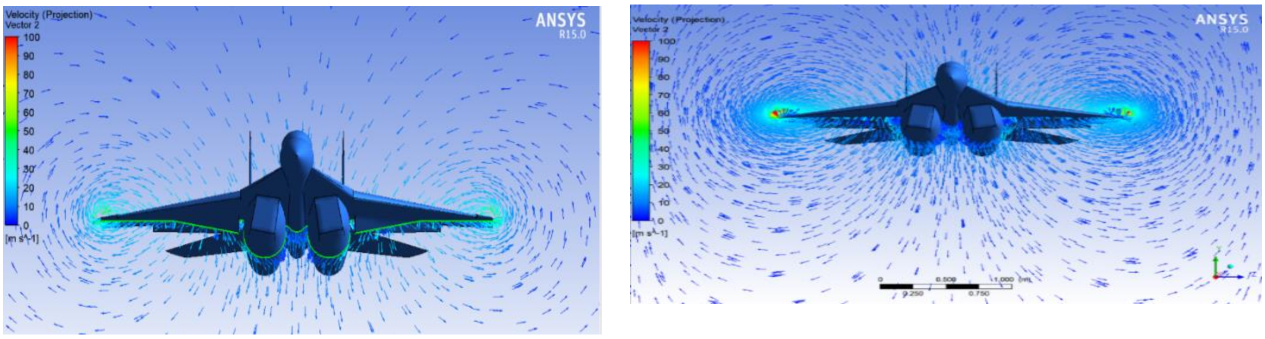
a) $\bar{h} = 0.4$; $\alpha = 10^o$ b) $\bar{h} = 3$; $\alpha = 10^o$

Figure 11. Pressure distribution over the span of an aircraft



a) $\bar{h} = 0.4$; $\alpha = 10^o$ b) $\bar{h} = 3$; $\alpha = 10^o$

Figure 12. Velocity distribution along the fuselage



b) $\bar{h} = 3$; α = *10º*

a) $\bar{h} = 0.4$; α = *10º*

Figure 13. Velocity field of eddy currents through the two tips of the wings

The simulation results Figure 10, 11 show that the ground effect causes the pressure in the belly of the aircraft to increase, causing a part of the air in the lower wing to flow upward on the back of the wing. This leads to an increase in velocity and a decrease in pressure in the back of the wing (see Figure 12). From the above analysis, we can conclude that, when moving near the ground, the lift of the aircraft increases.

From the results of the eddy current velocity field through the two tips of the wing, it is shown that the ground effect reduces the overflow intensity of the gas flow through the two ends of the wing. This results in a decrease in vertical velocity (V_y) and a reduced drift of the aft air stream. The result is a reduction in the induced drag of the aircraft.

Due to the larger ventral pressure in the case of the larger ground effect, the overflow of the fore wing air from the wing belly to the back of the wing is increased. This causes the back pressure to decrease resulting in an increase in the wing topside pressure gradient, so the flow break will occur sooner, causing the critical angle of attack to be reduced (see Figure 8.a).

CONCLUSION

Based on the calculation, analysis and comparison of the obtained results, we can draw the following conclusions:

- Ground effect increases the lift and reduces the drag of the aircraft.

- To make the operation and use of flying devices safe and effective. The research team made some recommendations as follows:

+ In order for the landing process to be soft and shorten the distance of braking, during the landing process. Before landing, the aircraft needs to fly at an altitude of about 0.5 to 1 meter in order to make the most of the ground effect to increase the lift coefficient, helping to reduce the aircraft's landing speed. At the same time, it helps to reduce the load acting on the fuselage and fuselage.

+ When the aircraft has landed, the reducer plate installed on the back is used to increase the frontal drag, eliminate the lift force so that the aircraft can grip the ground well, improving the performance of the take-off and landing system.

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