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Studying the Stability of Fighter Aircraft When Manufacturing at Large Frequency Angles

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A B S T R A C T

Stability is one of the extremely important characteristics of an aircraft, ensuring that the aircraft can restore its original flight status after stopping interference without the need for pilot intervention or automatic intervention. steering motion. However, when maneuvering at high angles of attack, the aircraft often cannot maintain stability due to boundary layer flow separation on the wing surface. The content of the article will use numerical simulation methods to focus on clarifying changes in the stability of the aircraft when maneuvering at high altitudes.

Keywords: Aerodynamic characteristics; large angle of attack; aircraft stability.

1. Introduction

One of the important requirements for modern fighter aircraft today is to ensure high mobility to gain the upper hand in air battles. To achieve such high maneuverability, the aircraft's lift force must be large, and to increase lift force, the angle of attack must be increased. However, when the angle of attack increases, boundary layer flow separation on the wing surface will occur.

Boundary layer flow separation is one of the typical phenomena of flow. When flow separation occurs, it will lead to redistribution of pressure on the surface of the aircraft and change its aerodynamic characteristics. The phenomenon of flow separation will occur when there is a positive pressure gradient in the boundary gas layer along the flow direction. Flow separation depends on many factors such as: angle of attack, flow velocity, shape, blade size,...

One of the aerodynamic characteristics of fighter aircraft when maneuvering at high angles of attack is the asymmetry of the boundary air layers on the wing surface. The cause of this asymmetry is due to boundary layer flow separation and the disruption of the structure of uneven vortex flows on both sides of the aircraft's wings. This phenomenon occurs even when the aircraft flies with zero glide angle. It is this aerodynamic asymmetry that significantly affects the stability and control of the aircraft. The content of the article will focus on clarifying the asymmetry of flow on both sides of the wings when maneuvering at high angles of attack and its impact on the stability and horizontal control of the aircraft.

2. Research objects and methods

2.1 Research subjects

The Yak-130 is a two-seat aircraft used for combat training, helping pilots become familiar with 4th and 5th generation aircraft.

In addition to training purposes, in some cases it is also used as a light fighter aircraft. The content of the article will focus on clarifying aerodynamic changes and their effects on the stability of the aircraft when maneuvering at high angles of attack.

2.2. Research Methods

Using CFD numerical simulation method and specifically using Ansys software.

In CFD numerical simulation, there are many different calculation methods, through analysis and evaluation of the advantages and disadvantages of each method. To solve the problem, the author used the discrete vortex method. This is a combined method between the averaging model (Reynolds-Averaged Navier-Stokes, RANS) and the simulation model of large eddies (Large Eddy Simulation, LES). In flow regions near walls the discrete vortex method works like the RANS model. In areas where flow separation occurs, the discrete vortex method works similarly to the LES model to simulate vortex flows. The advantage of this method is that it gives highly accurate results and saves more time than the LES and DNS models.

The puppet model chosen by the author is Shear Stress Transport (SST). The SST model is the most complete physical model, combining the k-ε model in free flow and the k-ω model near the wall. Where k is the kinetic energy of the turbulence process, and ε is the intensity of turbulence dispersion, that is, the number of k in 1 second, ω is the dissipation rate.

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

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

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

In there:

k - Turbulent kinetic energy

P_k - Export kinetic turbulent energy

ω - Dissipation speed

$\sigma_k, \beta, \beta^*, \sigma_\omega$ - Coefficients

F_1 - Mixing function

2.3. Research process

2.3.1. Model building

To build an aircraft model used in research, the author used Solidworks software, the model size is equal to the actual size of the aircraft. The model is shown in Figure-1.

Figure-1: 3D model of aircraft used in research

2.3.2. Choose the computational space domain and boundary conditions

The size of the computational space (air blowing space) must be large enough compared to the size of the aircraft so that the air flow entering the aircraft is most stable. The computational space is shown in Figure-2.

Boundary conditions

- Inlet velocity vx = 68 m/s (M=0.2) – Velocity inlet;

- Surrounding surfaces correspond to Symmetry conditions,

$$v_y = 0, v_z = 0, \frac{\partial_P}{\partial y} = 0, \frac{\partial_P}{\partial y} = 0 \quad ;$$

- The output will correspond to free flow conditions and 0 residual gas pressure - pressure outlet.

2.3.3. Meshing

To achieve the necessary accuracy and convergence of results in calculations, mesh simulation plays an extremely important role. The smaller the mesh size, the more accurate the results will be, however this will consume more time for meshing, longer solution time and higher requirements for computer hardware. Therefore, choosing a suitable mesh is extremely important for CFD problems.

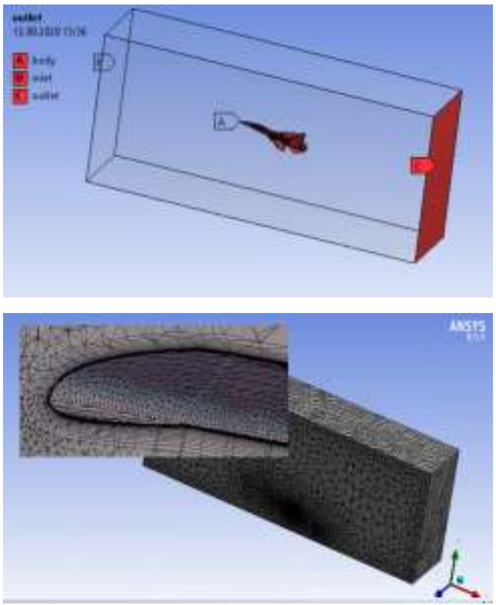


Figure-2: Computational space and grid model

3. Results and Discussion

In Figure-3 is a graph showing the dependence of the longitudinal moment coefficient (mz) on the angle of attack. Comparing the results obtained with the experimen, we see that the error between calculation and experiment is not too large, this shows that the numerical method being used is completely reliable and gives results consistent with experiment.

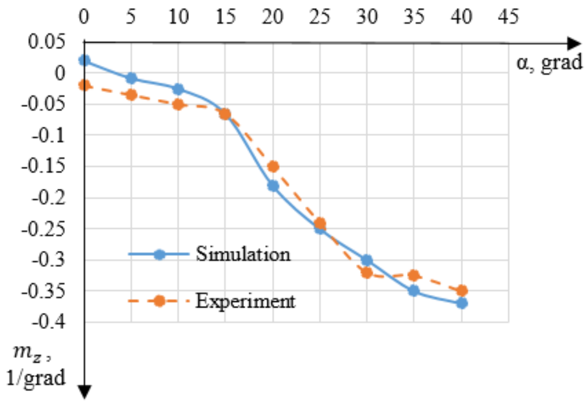


Figure-3: Dependence of the pitch moment coefficient on the angle of attack

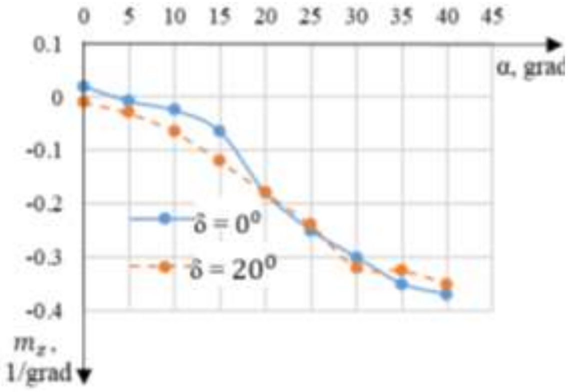
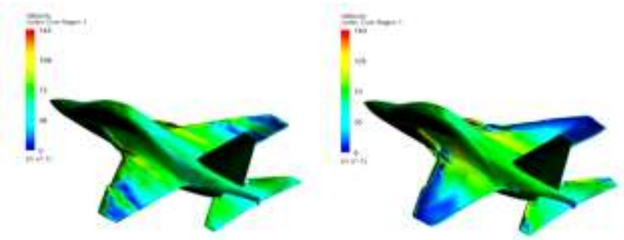


Figure-4: Dependence of the pitch moment coefficient on the angle of attack at different wing tip deflection angles

Analyzing the results obtained from the graph in Figure-3, we see that the dependence of the longitudinal moment coefficient (mz) on the angle of attack (α) at angles of attack 10-15^0 and 30-35^0, the coefficient mz tends to increases (loss of stability along the angle of attack). The reason this phenomenon occurs is because:

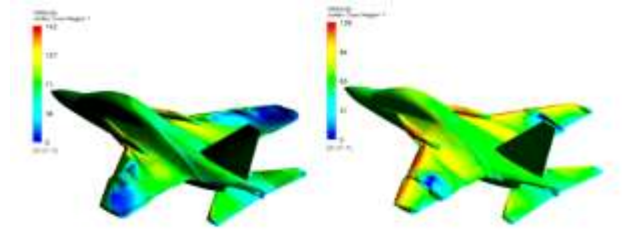
- At angles of attack α = 10-15^0, boundary layer airflow separation occurs at the wing tips (for aircraft with arrow-shaped wings, boundary layer airflow separation will occur first at the wing tips due to the effect of overflow from the wing base to the wing tip). When flow separation occurs at the wing tip, it will shift the aerodynamic focus forward, thereby reducing the pitching moment (reducing longitudinal stability) of the aircraft. As the angle of attack continues to increase, flow separation will occur on most of the wing's surface, so the aerodynamic focus will shift again and stability will be restored (see Figure-5).

The longitudinal instability of the aircraft at these angles of attack can be overcome by rotating the canards (simulation results are shown in figures 4 and 6). Figure-6 depicts the degree of boundary layer flow separation when the canard is rotated at an angle of 20^0 (case b) and without rotating the canard (case a). We see that turning the canard will limit the flow separation phenomenon on the upper surface of the wing and prevent the aerodynamic focus from moving forward, thus ensuring the stability of the aircraft.



a) b)

Figure-5: Boundary layer flow separation on the wing at the angle of attack a) α = 10^0, b) α = 20^0



a) b)

Figure-6: Boundary layer flow separation at angle of attack α = 15^0, a) δ = 0^0, b) δ = -20^0

- The cause of loss of longitudinal stability at angles of attack α = 30-35^0 is because:

+ The up and down rudder is covered by the body and wings, reducing its working efficiency, leading to the aerodynamic focus moving forward.

+ In addition, at these angles of attack, the pressure dilution area created by the vortex is only effective at the tip of the wing, the farther away from the tip the vortex is, the further away it is from the wing surface. Therefore, the aircraft's aerodynamic focus will also shift forward.

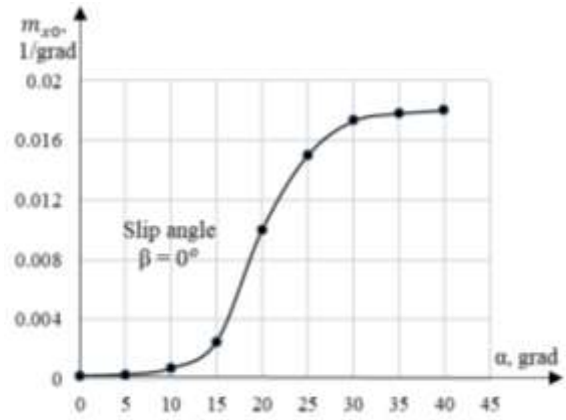


Figure-7: Dependence of the roll moment coefficient on the angle of attack

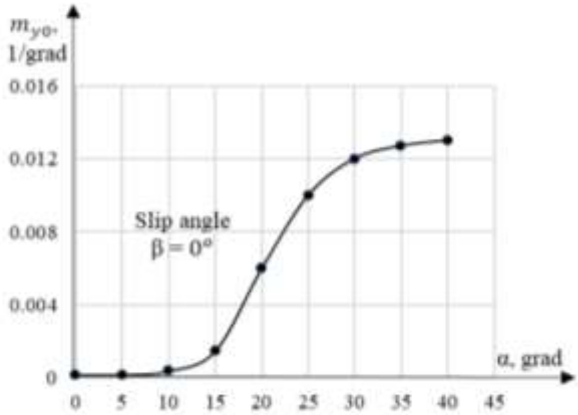


Figure-8: Dependence of yaw moment coefficient on angle of attack

Figures 7 and 8 present graphs showing the dependence of the roll moment coefficient (m_{xo}) and yaw moment coefficient (m_{yo}) on the angle of attack at the side-slip angle $\beta = 0$. Observing the graph, we see that, When increasing the angle of attack to $\alpha < 15°$, the values of the moment coefficients m_{xo} and m_{yo} increase almost insignificantly. However, at large incidence angles ($\alpha > 20°$), the values of the moment coefficients m_{xo} and m_{yo} increase very rapidly. This leads to edge instability and directional instability of the aircraft when maneuvering at high angles of attack. This occurs due to the asymmetric separation of the vortices across the cross-section. This asymmetry occurs instantaneously and unevenly, causing the aircraft to vibrate (Flow asymmetry when maneuvering at high angles of attack is shown in Figure-9).

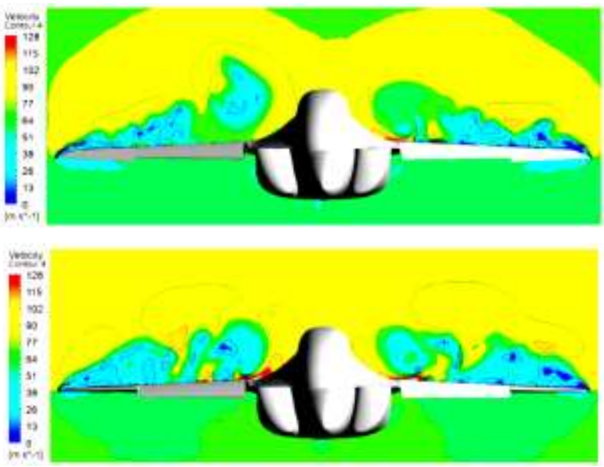


Figure-9: Airflow velocity field surrounding the aircraft when maneuvering at high angles of attack

Conclusion

Thus, the content of the article clarifies the stability of the aircraft when maneuvering at high angles of attack. Due to the disruption of the flow structure, the uneven boundary layer separation between the two wings has changed the pressure distribution on the aircraft surface. This leads to instability of the aircraft when maneuvering at high angles of attack. Research results show that the application of modern simulation software can completely solve aircraft aerodynamics problems with high accuracy. In addition, the above results can also be used as reference. Review and explain the aerodynamics of today's modern aircraft.

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