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Study on the Effect of Angle of Attack on the Drag Coefficient of the Yak-130 Aircraft Wing

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***Abstract*—The angle of attack is a key parameter that significantly influences the aerodynamic characteristics of an aircraft wing, particularly the drag coefficient (C_x), which directly affects flight performance and fuel consumption. In this study, Computational Fluid Dynamics (CFD) simulations are performed for the YAK-130 aircraft wing over an angle-of-attack range from 0° to 35° in order to investigate the effect of the angle of attack on the drag coefficient. The obtained results provide insight into the aerodynamic mechanisms governing drag variation and contribute to a better understanding of the aerodynamic behavior of the YAK-130 aircraft at both low and high angles of attack.**

Keywords*— *Angle of attack; drag coefficient; YAK-130 aircraft; CFD.

I. INTRODUCTION

The aerodynamic characteristics of an aircraft wing strongly depend on the angle of attack. Among the aerodynamic parameters, the drag coefficient (C_x) plays a crucial role, as it directly influences flight performance, maneuverability, and fuel consumption.

The YAK-130 is a trainer and light combat aircraft capable of operating at high angles of attack. Under such conditions, the airflow over the wing becomes highly complex due to boundary-layer separation and the formation of leading-edge vortices, which lead to a significant increase in aerodynamic drag.

Therefore, this study aims to analyze the effect of the angle of attack on the drag coefficient of the YAK-130 aircraft wing and to clarify the underlying aerodynamic mechanisms responsible for this behavior. The results provide visualized flow-field data and contribute to a deeper understanding of the aerodynamic characteristics of the YAK-130 aircraft, thereby supporting improvements in operational efficiency and aircraft utilization..

II. METHODOLOGY

Various approaches have been developed to determine the aerodynamic characteristics of aircraft wings. These approaches can be classified into four main categories:

- Analytical methods;
- Physical aerodynamic methods;
- Experimental methods;
- Numerical methods.

After evaluating the advantages and limitations of each approach, the numerical method based on Computational Fluid Dynamics (CFD) was selected to address the objectives of this study.

Computational Algorithm

The computational procedure employed in this study is illustrated in Fig. 1.

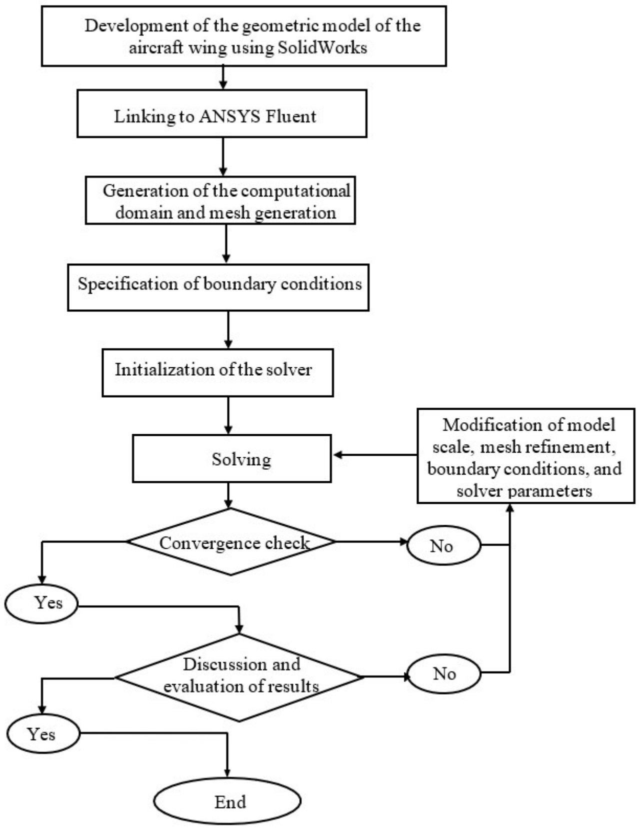

Fig. 1. Computational algorithm flowchart for the simulation problem

The simulation process consists of three main stages:

- **Stage 1:** Developing three-dimensional (3D) model of the aircraft wing;
- **Stage 2:** Numerical simulation and computation at angles of attack ranging from 0° to 35°;
- **Stage 3:** Analysis and interpretation of the results.

Model Development

To construct the YAK-130 aircraft wing model, SolidWorks software was used. The wing geometry was modeled at full scale, corresponding to the actual dimensions of the aircraft.

For the YAK-130 aircraft, when the angle of attack exceeds 10°, the leading-edge flaps are automatically deployed to -20°. When the angle of attack exceeds 24°, the flaps are further deployed to -27°. Accordingly, three 3D wing models were developed corresponding to the following configurations:

- Leading-edge flap at 0°;
- Leading-edge flap at −20°;
- Leading-edge flap at −27°.

The constructed wing models are presented in Fig. 2.

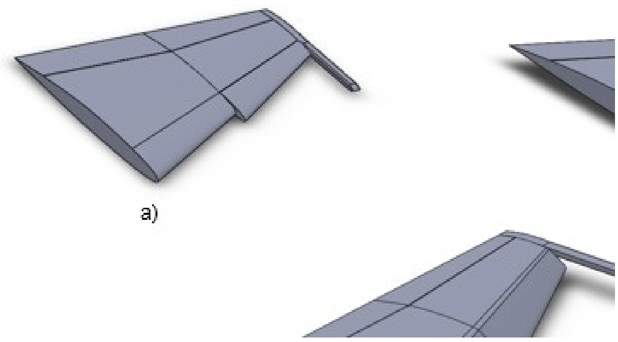

Fig. 2. Wing models used in the study
a) Leading-edge flap at 0°
b) Leading-edge flap at −20°
c) Leading-edge flap at −27°

Computational Mesh Generation

Mesh generation is a critical step in CFD simulations, as the accuracy of the numerical results strongly depends on mesh quality. Although a finer mesh generally improves accuracy, it also increases computational cost and hardware requirements.

Therefore, a mesh optimization study was conducted using different mesh densities to determine an optimal mesh configuration that provides sufficient accuracy while maintaining reasonable computational efficiency.

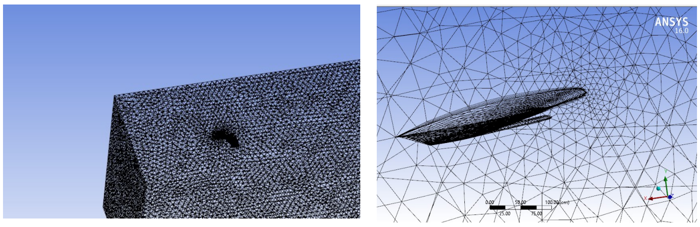

Fig. 3. Computational domain mesh

Boundary Condition Setup

The aerodynamic characteristics of the YAK-130 aircraft wing were computed using ANSYS CFX under the following conditions:

- Laminar flow velocity: $V = 50$ m/s;
- Ambient pressure: $p_0 = 1$ atm $= 101{,}325$ Pa;
- Altitude: $H = 0$ m;
- Temperature: $T = 288$ K.

Simulations were carried out for the three leading-edge flap configurations (0°, -20°, and -27°) at angles of attack ranging from 0° to 35°.

III. Results and Discussion

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Based on the CFD results, the variation of the drag coefficient C_x with the angle of attack α for the YAK-130 aircraft wing is presented in Fig. 4.

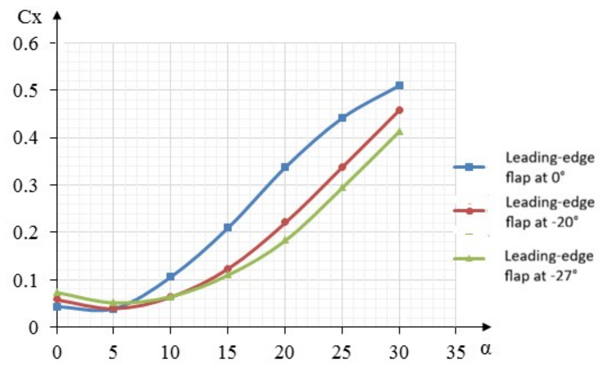

Fig. 4. Variation of the drag coefficient C_x with the angle of attack α

For the configuration with the leading-edge flap at 0°, several observations can be made:

- The drag coefficient C_x remains positive throughout the entire angle-of-attack range.
- At low angles of attack (α < 10°), prior to the onset of flow separation, the drag coefficient exhibits a second-order parabolic trend and increases gradually due to the absence of boundary-layer separation (Fig. 5).

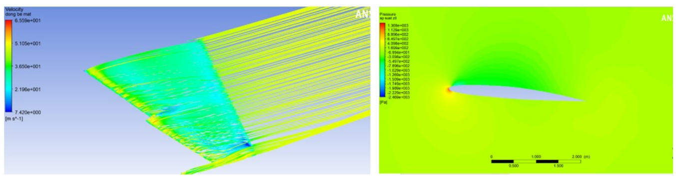

Fig. 5. Streamlines over the YAK-130 wing and pressure field at the Z_0 cross-section for α = 5°

When α > 10°, boundary-layer separation occurs on the wing surface, leading to a rapid increase in viscous drag $C_{x,ms}$. At the same time, pressure drag $C_{x,p}$ also increases, resulting in a sharp rise in the total drag coefficient C_x as the angle of attack increases (Fig. 6).

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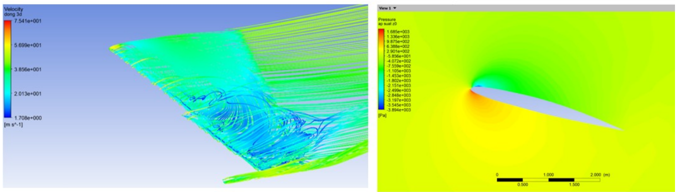
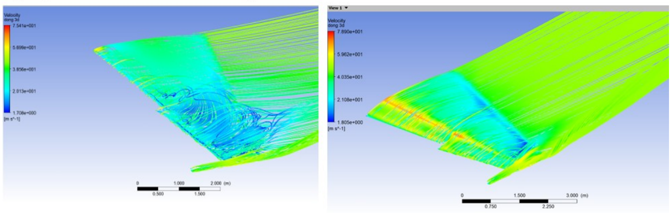


Fig. 6. Streamlines over the YAK-130 wing and pressure field at the Z_0 cross-section for α = 15°

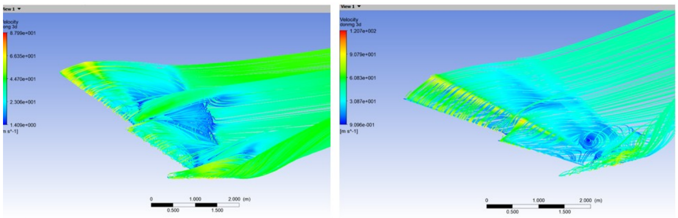
Similar results are observed for the configurations with the leading-edge flaps deployed at -20° and -27°. Further analysis of Fig. 4 shows that, at low angles of attack, the drag coefficient for the configuration without leading-edge flap deployment is lower than that of the configurations with deployed flaps. Conversely, at high angles of attack, deploying the leading-edge flaps significantly reduces the drag coefficient.

This behavior can be explained by the fact that, at high angles of attack, leading-edge flap deployment delays boundary-layer separation on the wing surface, thereby improving the flow structure, as illustrated in Fig.s 7 and 8. Based on these aerodynamic characteristics, the YAK-130 aircraft is equipped with an automatic leading-edge flap control system, which deploys the flaps to -20° when the angle of attack exceeds 10° and further to -27° when it exceeds 24°.



a) Leading-edge flap at 0° b) Leading-edge flap at -20°

Fig. 7. Streamlines at α = 15°



a) Leading-edge flap at -20° b) Leading-edge flap at -27°

Fig. 8. Streamlines at α = 25°

IV. CONCLUSIONS

This study employed Computational Fluid Dynamics (CFD) to investigate the influence of the angle of attack on the drag coefficient of the YAK-130 aircraft wing for different leading-edge flap configurations. The results show that the drag coefficient increases with increasing angle of attack and rises sharply when boundary-layer separation occurs.

At low angles of attack, the configuration without leading-edge flap deployment yields the lowest drag coefficient. In contrast, at high angles of attack, deploying the leading-edge flaps to -20° and -27° significantly reduces the drag coefficient by delaying boundary-layer separation and improving the flow structure.

The findings clarify the primary aerodynamic mechanisms responsible for drag increase, provide aerodynamic justification for the automatic leading-edge flap deployment system of the YAK-130 aircraft, and offer practical value for aerodynamic simulations as well as operational exploitation of the aircraft.

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