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Investigation of Lift Coefficient Characteristics for an Airfoil with High-Lift Devices Via Ansys Fluent

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Abstract- This paper presents the results of a survey on the change in the lift coefficient of the wing profile when using flaps on the Ansys Fluent application platform. The use of these flaps is extremely important. They not only ensure safe and efficient takeoff and landing but also enable rapid takeoff to approach and destroy targets even under runway damage. The paper investigates the change in the lift coefficient of the wing with flaps using Ansys Fluent software. Using this method, it is possible to determine the parameters corresponding to each type of flap, calculate the lift coefficient in each case, and identify the causes of these parameter changes.

Keywords- Aerodynamic Lift Coefficient; High-Lift Devices; Trailing-Edge Flaps; Leading-Edge Slats; Computational Fluid Dynamics (CFD); ANSYS Fluent.

I. INTRODUCTION

The take-off and landing process is a crucial stage that determines the safety of each flight. Improving aircraft take-off and landing performance, such as reducing lift-off speed, landing speed, approach distance, and braking time, through the use of flaps, plays a vital role. It not only ensures safe and efficient take-off and landing but also allows for rapid take-off to approach and engage targets even under runway damage. In the continuous development of aviation technology, many types of flaps have been applied and proven highly effective in performing various tasks. Therefore, understanding the types of flaps used on aircraft and their impact on take-off and landing performance is essential. This forms the basis for testing models with specific parameters before proceeding with actual aircraft manufacturing and testing.

II. METHODOLOGY

The choice of survey calculation method for a specific problem depends on the required accuracy, simplicity and consistency of the method, economic requirements, available resources, and controllability. Verification of the results is also important.

We chose the wing model survey method using Ansys Fluent software. This is a powerful software that can easily build many different models, provides quick calculation results, and allows for easy parameter changes to conduct surveys while still meeting accuracy requirements.

In practice, wing flaps are very commonly used in modern aircraft. Wing flaps can be: front flaps, rear flaps; rear flaps may or may not have gaps.

To study the influence of flap use on the lift coefficient of the wing profile, we chose to build models to calculate the lift coefficient in characteristic cases such as:

- Wing profile without flaps;
- Wing profile with rear flap without gap;
- Wing profile with rear flap with gap;
- Wing profile with forewing and aft flaps.

These models need to have identical dimensions, differing only in component details such as: forewing, aft flaps, etc.

For the wing profile without flaps, the author chose a profile with a 1m long chord according to the NACA 2112 model, with the upper and lower surfaces determined according to Table 1:

Table 1: Coordinates defining the wing profile

X	0	0.0125	0.025	0.05	0.075	0.1	0.125
YU	0	0.0215	0.0299	0.0413	0.0496	0.0563	0.0613
Yd	0	-0.0165	-0.0227	-0.0301	-0.0346	-0.0375	-0.0393

X	0.15	0.2	0.25	0.3	0.4	0.5	0.6
Y_U	0.0661	0.0726	0.0767	0.0788	0.078	0.0724	0.0636
Y_d	-0.041	-0.0423	-0.0422	-0.0412	-0.038	-0.0334	-0.0276

X	0.7	0.72	0.8	0.9	0.95	1
Y_U	0.0518	0.0495	0.0375	0.0208	0.0114	0.0013
Y_d	-0.0214	-0.002	-0.0015	-0.0082	-0.0048	-0.0013

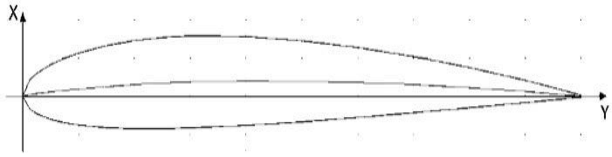

Figure 2: Wing profile without flaps

A wing profile with a rear flap without a gap is a profile with the rear flap extended at 25° .

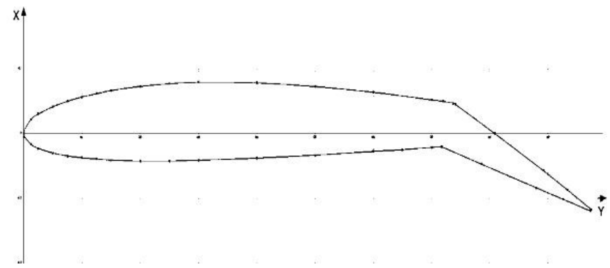

Figure 3: Wing profile with aft flap without gap

A wing profile with a gap at the rear flap is a profile where the rear flap extends 25° degrees and, when extended, creates a gap with the front flap.

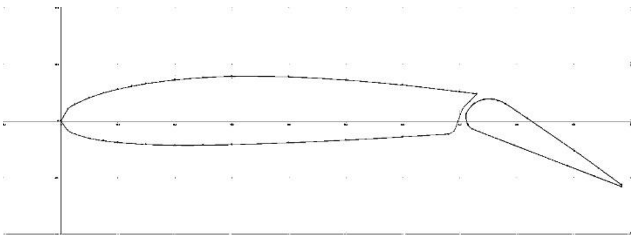

Figure 4: Wing profile with aft flap having a gap.

The wing profile, with its forewing and aft flaps, is a profile where the aft flap extends 25°, creating a gap with the front flap when extended, and the nose flap is extended and tilted downwards at an angle of 15°.

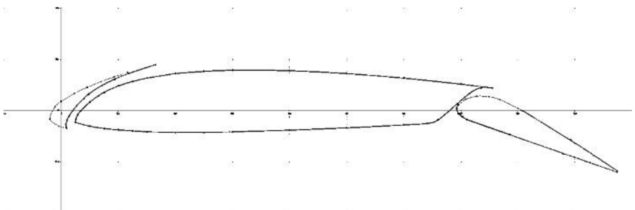

Figure 5: Wing profile with forewing and hindwings having gaps

After obtaining the geometric models of the wing profiles and flaps, the element models were created using ANSYS Fluent to construct the wing elements with different angular positions and to mesh the elements under study and the surrounding space.

For simulating profiles in low-velocity flows, the author chose an automatic meshing method with a Triangles mesh structure, and set the size of the mesh elements in Edge Sizing, selecting a size of 0.005 m for each element in Element Size.

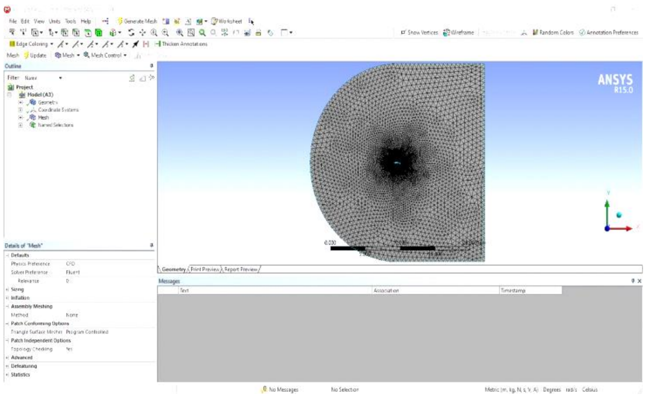

Figure 6: Building the survey element model

III. RESULTS AND DISCUSSION

After constructing the computational models, we proceed to examine them. For each model, we vary the angle of attack values of the profile from low to high, then run experiments to determine the value of the lift coefficient in each case, while observing the changes in flow and pressure corresponding to each angle of attack value.

The software calculations have determined the lift coefficient of the wing profile corresponding to different angles of attack in all cases according to the selected models:

- The wing profile does not use wing flaps;
- The wing profile and aft flap have no gaps;
- Wing profile with a gap between the aft flaps;
- Wing profile with forewing and hindwing.

From the results obtained, we can easily construct a graph showing the dependence of the lift coefficient of the wing profile on its angle of attack (Figure 7).

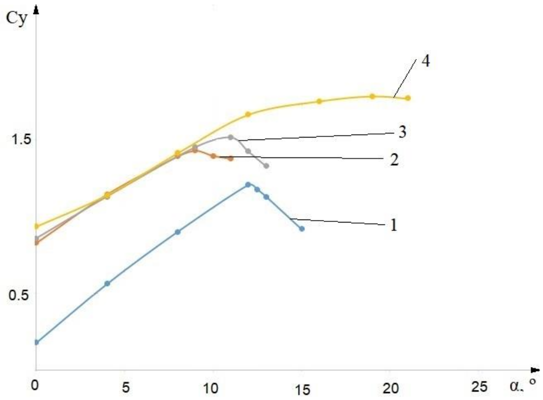

Figure 7: Graph of the results obtained
1 - Wing without flaps; 2 - Wing profile with rear flaps without gaps; 3 - Wing profile with rear flaps with gaps; 4 - Wing profile with both forewing and rear flaps

At the same time, we also obtain images of the movement of the airflow, changes in flow velocity, and pressure within the surveyed area.

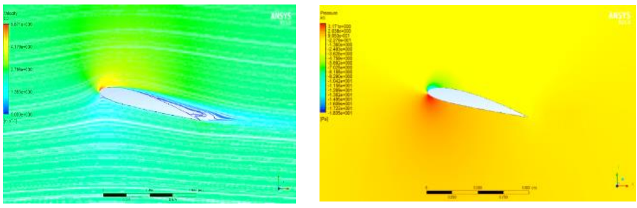

Figure 8: Change in airflow parameters around the wing profile without flaps.

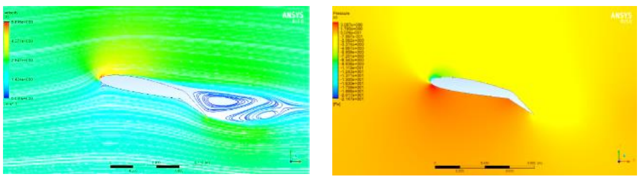

Figure 9: Variation of airflow parameters around the wing profile using a gapless trailing flap.

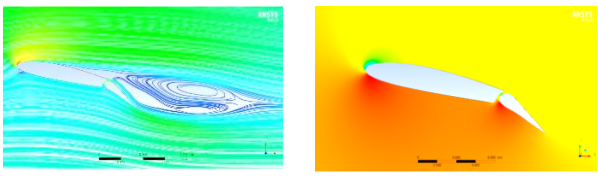

Figure 10: Change in airflow parameters around the wing profile using a split-slot rear flap

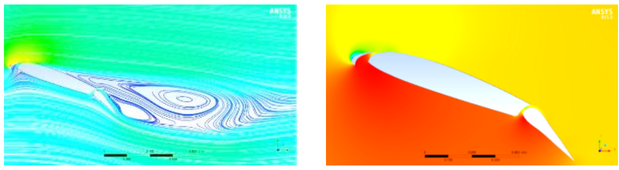

Figure 11: Variation of airflow parameters around the wing profile using a leading and trailing flaps with a gap.

Based on the calculation results (Figure 7), we can see that:

- For each survey model, the lift coefficient of the wing profile will increase with increasing angle of attack α. This increase in lift coefficient continues until α reaches a sufficiently large value, at which point the lift coefficient will increase more slowly, and at a certain angle of attack, the lift coefficient will reach its maximum value.
- When using a gapless aft flap, the increased curvature of the flap profile enhances the flow damping process at the underside of the flap, thereby increasing the lift coefficient. However, due to the increased curvature of the flap profile, flow separation occurs earlier, thus the lift coefficient reaches its maximum value sooner than in the case without a flap.
- When using a rear flap with a gap, the airflow through the gap is similar to blowing the boundary layer of air at the top of the flap, thereby slowing down the separation of the boundary layer and resulting in a higher maximum lift coefficient value at a correspondingly higher angle of attack compared to the case of using a flap without a gap.
- When using additional leading edge flaps, the airflow passes through the gap in the leading edge flaps, creating a boundary air layer on the upper surface of the flap. This causes the boundary layer separation to occur later, resulting in a higher lift coefficient compared to a system without leading edge flaps.

Significance

- Through surveying the change in the lift coefficient when using flaps, it was found that:
- The survey results obtained are entirely consistent with the theoretical content.
- The survey determined specific lift coefficient values corresponding to specific angles of attack values;

- The survey results also provide images of the movement of the airflow, the change in airflow velocity within the surveyed area, and the distribution of pressure around the profiles. This creates visual representations of the airflow process, making it easier to observe and understand the nature of the process;
- The survey results of this project can be used in the learning process of students at the school;
- The survey methods used in this study can be used to further investigate the aerodynamic characteristics of other aircraft components.

IV. CONCLUSION

From the model's calculation results, we have determined the changes in aircraft wing profile parameters at different angles of attack when using different types of flaps. The survey results show that using different types of flaps increases the lift coefficient of the wing. This increase in lift allows for a reduction in takeoff and landing speeds while maintaining lift equal to the aircraft's weight. This makes takeoff and landing smoother, easier, and safer.

The survey also helps to thoroughly analyze the reasons for the changes in parameters when using these types of flaps. The phenomenon of boundary layer separation occurring at different angles of attack when using different types of flaps, leading to corresponding changes in the lift coefficient of the wing, is clearly shown in the specific images. These images can be used in the teaching process for students, helping them to visually understand the nature of the phenomena occurring on aircraft wings.

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