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The study the angle of attack and lift magnitude of a wing using COMSOL software

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Abstract. Angle of attack (A.O.A.) is defined as the angle at which the chord of an aircraft's wing meets the relative wind. At low angles of attack, the wing could just create a small amount of lift, and it also experience a small amount of drag. As the A.O.A. increases, both lift and drag will increase. However, when the wing reaches a critical angle of attack, the lift it could produce will quickly decrease, since the separation of the air flow and the wing surface. The objective of this study is to find the relationship between the angle of attack and the lift coefficient(which is proportional to the lift it could produce) of the wing. And as a conclusion, we find that the A.O.A. increase, the lift coefficient will also increase, and if the inlet velocity, the wing's surface area and the velocity remains constant, when the lift coefficient increase, the lift will also increase.

Keywords: angle of attack, lift and drag, stall.

1. Introduction

Aircraft wings are an essential component of any airplane, providing the necessary lift to overcome gravity and enable flight. Understanding the relationship between the angle of attack (A.O.A.) [1] and the lift coefficient [2] is critical for designing efficient and safe aircraft. The lift coefficient is a dimensionless quantity that represents the ratio of the lift force to the dynamic pressure and the wing's planform area. The angle of attack, on the other hand, is the angle between the chord line of the wing and the relative airflow. The lift coefficient is influenced by various factors such as wing shape, airspeed, and air density. Additionally, the angle of attack affects the lift coefficient, stall behaviour, and other aerodynamic characteristics of the wing. In this research report, we present a detailed analysis of the lift coefficient versus angle of attack characteristics of an aircraft wing using COMSOL software. COMSOL is a powerful software tool that enables the simulation of complex physical phenomena, including aerodynamics.The objective of this research is to investigate the effects of angle of attack (A.O.A) on the lift coefficient of an aircraft wing. We have used the COMSOL software to create a 2D cross-section model of the aircraft wing and to simulate its aerodynamic performance.

The findings of this research report will provide some insights into the aerodynamic behavior of aircraft wings and the design considerations for optimizing lift performance. The information obtained

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from this study could be useful in the development of new aircraft designs or improving existing ones, especially for applications where high lift efficiency is crucial, such as in commercial aviation.

2. Methodology

In this analysis, we will use a software called COMSOL. COMSOL software is a powerful simulation tool used for modeling and analyzing various physical phenomena. It is designed to solve complex engineering problems across a wide range of disciplines such as electrical, mechanical, chemical, and bio medical engineering, among others. It use the finite element method to solve mathematical equations and simulate the behavior of physical systems under different conditions.

To get familiar with this software, we firstly follow the online tutorial video [3] performed a flow around a circular cylinder simulation, and then we followed an COMSOL official tutorial document [4] to perform the lift coefficient vs. Angle of Attack simulation.

3. Results and discussion

The result of the flow around a circular cylinder is shown in Figure 1 below.

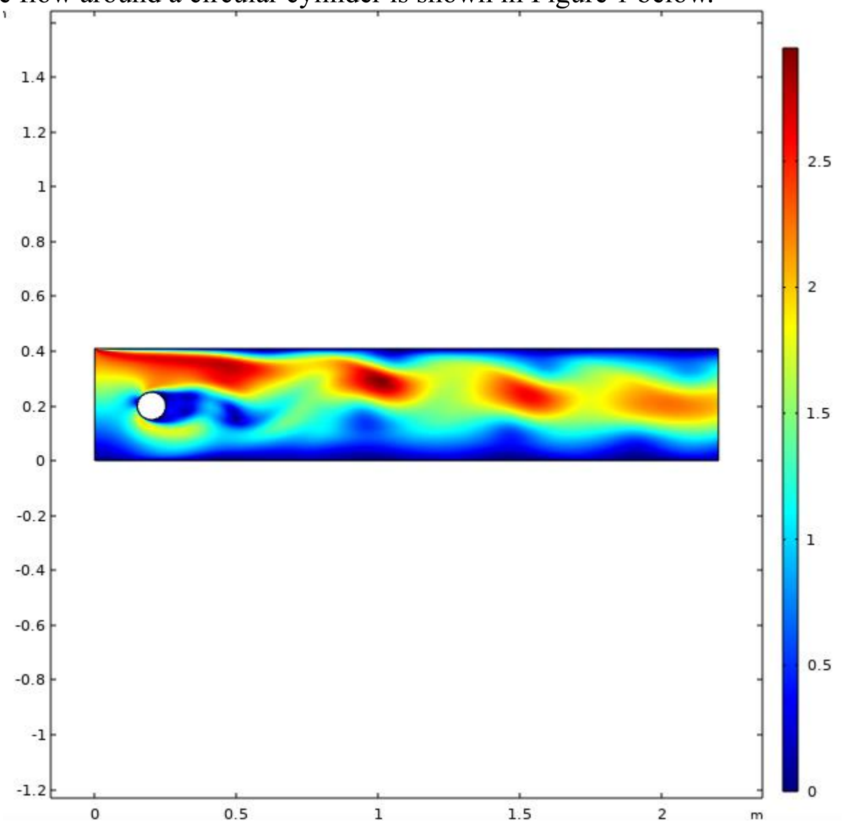

Figure 1. The velocity distribution diagram of the flow around cylinder simulation.

In the above diagram, the different color (from dark blue to dark red) represents different velocity (from low to high) of the flow. We could see that on the top part of the tube, the velocity of the fluid is high compare to the lower part. According to Bernoulli Principle, this would create a pressure difference between these two surface and then create a lift force.

The next step is to change this cylinder shape to aircraft wing shape. Here we use Naca 0012 model from the COMSOL software model library. We set the inlet velocity to be 50m/s, and the density of the fluid to be 1.2043kg/m^3(Air) and the dynamic viscosity to be 1.81397e-5kg/(m·s) The following table(Table 1) shows the parameter set in this simulation.

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Table 1. Parameter set.

Description	Value
Chord Length	1.8[m]
Domain Reference Length	180[m]
Free stream density	1.2043[kg*(m^-3)]
Free stream dynamic viscosity	1.81397e-5[kg*m^-1*s^-1]
Free stream specific dissipation rate	2.778 [1/s]
Free-stream turbulent kinetic energy	4.184E-7 [(m^2)/(s^2)]
Free-stream velocity	50[m/s]

After simulate through the software, we could get the plot of the relationship between Angle of attack vs lift coefficient diagram(Figure 2). We could see that as the A.O.A. increase, the lift coefficient(which directly related to lift) will also increase.

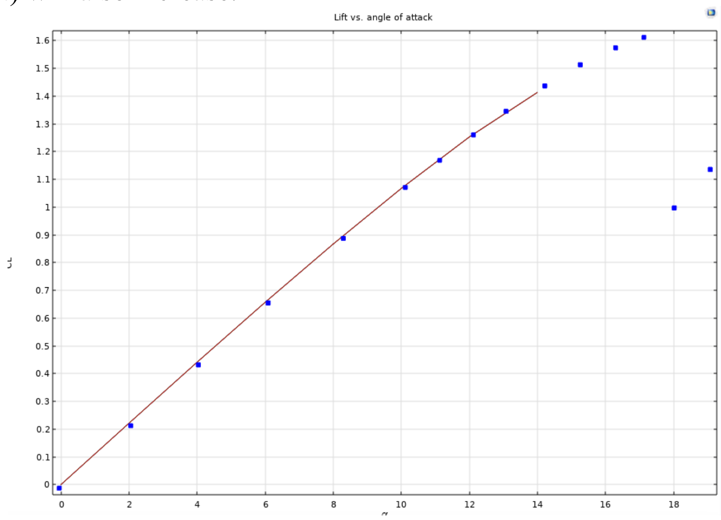

Figure 2. The diagram between AOA and life coefficient.

To corroborate the correctness of our simulation results, we consulted the references in the Pilot Handbook of Aeronautical Knowledge (PHAK) [5] published by the Federal Aviation Administration (FAA). In Chapter 5, it provides detailed explanations on the relationship between lift and angle of attack, which further supports the accuracy of our simulation results! The following figure (Figure 3) is the diagram of the relationship between lift coefficient and angle of attack shown in the PHAK.

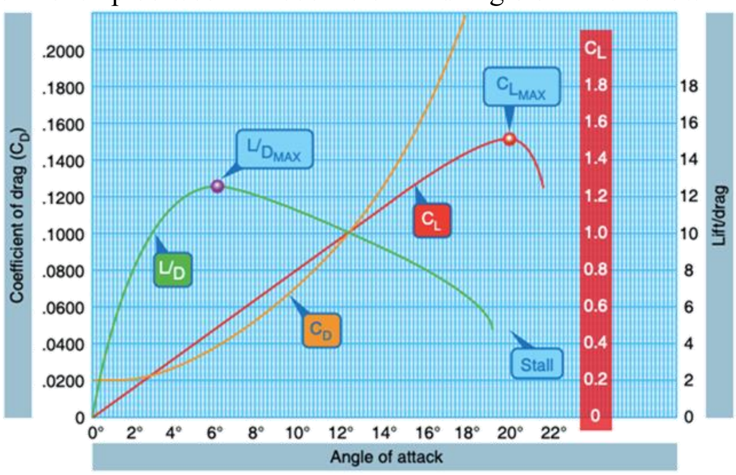

Figure 3. The lift coefficient vs. A.O.A. graph from PHAK [5].

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4. Conclusion remark

In this research report, we conducted an analysis of the lift coefficient versus angle of attack characteristics of an aircraft wing using the COMSOL software. By simulating the aerodynamic performance of the wing, we were able to gain valuable insights into the relationship between the angle of attack and the lift coefficient.

Our findings demonstrate that as the angle of attack increases, the lift coefficient, and therefore the lift generated by the wing, also increases. This confirms the well-known relationship between angle of attack and lift in aerodynamics. The results obtained from our simulations align with the information provided in the Pilot Handbook of Aeronautical Knowledge (PHAK), which further validates the accuracy of our findings.

The information obtained from this study is of great importance for the design and optimization of aircraft wings. By understanding the effects of the angle of attack on the lift coefficient, engineers can make informed decisions when developing new aircraft designs or improving existing ones. This knowledge is particularly crucial in applications where high lift efficiency is essential, such as in commercial aviation.

Overall, our research contributes to the field of aerodynamics by providing valuable insights into the behavior of aircraft wings and their relationship with the angle of attack. Further studies can build upon this research to explore additional factors that influence the lift coefficient and to refine the design considerations for optimal lift performance in various aviation applications.

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