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Wing Simulation Using Naca 0018 and 0024 and Aluminum Alloy 7075 T6-SN and 7050-T7451 Materials for Lift and Drag

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Abstract

The analysis of an airplane wing's airfoil shape plays a critical role in determining aerodynamic performance, specifically impacting lift and drag forces. This study investigates two aluminum alloys, Aluminum Alloy 7075-T6 SN and Aluminum Alloy 7050-T7451, to evaluate their effectiveness in enhancing lift and drag on NACA 0018 and NACA 0024 airfoil profiles. Using the ANSYS Fluent software, simulations are conducted at an airflow speed of 200 m/s to analyze pressure contours and velocity contours associated with each material. The results indicate that Aluminum Alloy 7075-T6 SN yields the highest lift and drag coefficients for both airfoil profiles. For NACA 0018, the lift coefficient reaches 6.83 N, while the drag coefficient is 6.89 N. Similarly, for NACA 0024, the lift coefficient is observed at 3.23 N, and the drag coefficient at 4.64 N when using Aluminum Alloy 7075-T6 SN. These findings suggest that Aluminum Alloy 7075-T6 SN offers superior performance in optimizing the aerodynamic forces of lift and drag for these airfoil designs. The study's insights could inform material selection for airfoil design, enhancing efficiency in various aerodynamic applications.

Keywords: NACA Airfoil; Aluminum Alloy; ANSYS Fluent

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INTRODUCTION

An airfoil is a structural design characterized by its specific cross-sectional shape, enabling it to efficiently interact with fluid flow, making it highly applicable in diverse fields, including aircraft wings, wind turbines, compressors, and turbine blades in jet engines [1]. The distinctive shape of an airfoil is essential for creating aerodynamic forces that allow an aircraft to achieve and sustain flight at high altitudes. When air flows over and beneath an airfoil, a difference in pressure is generated, which plays a critical role in lift production [2].

This pressure differential is based on principles of fluid dynamics and aerodynamics. As air moves across the curved surface of the wing, it accelerates, creating a region of lower pressure above the wing compared to the pressure below it. According to Bernoulli's principle, an increase in fluid velocity leads to a decrease in pressure. This principle explains why the pressure above the wing is reduced relative to the higher pressure beneath it, thereby generating the upward lift force necessary for flight [3].

The ability to optimize this aerodynamic effect is crucial not only in aviation but also in energy and mechanical applications where efficient airfoil design can enhance performance. For instance, in wind turbines, well-designed airfoils maximize energy capture from wind, leading to improved energy conversion efficiency. Similarly, in compressors and jet engines, airfoil shapes are optimized to reduce drag while maximizing the force exerted on the blades, thus improving fuel efficiency and performance.

The study of airfoil dynamics continues to be a significant area in engineering research, as advancements in materials and simulation tools enable researchers to develop airfoil profiles that optimize aerodynamic properties, minimize drag, and increase lift. This contributes to innovations in aircraft design, renewable energy technology, and high-performance engineering applications, ultimately pushing the boundaries of efficiency and sustainability in fluid-based systems.

The shape of an airfoil on an airplane wing significantly influences the aerodynamic performance of the aircraft, directly impacting its maneuverability and stability in flight [4]. The National Advisory Committee for Aeronautics (NACA) has been instrumental in advancing airfoil design, developing a series of standardized airfoil profiles that have been widely adopted in aviation engineering. These NACA airfoils serve as foundational models for designing and optimizing aircraft wings to enhance lift, reduce drag, and improve flight efficiency under various operating conditions [5-6]. The diverse range of NACA airfoil shapes allows engineers to tailor wing designs for specific performance requirements, whether for high-speed jets, fuel-efficient commercial planes, or highly maneuverable fighter aircraft. By setting a benchmark in airfoil design, NACA's contributions continue to play a crucial role in modern aeronautical engineering, influencing innovations in both civil and military aviation.

This study focuses on the NACA 4-digit airfoil series, specifically NACA 0018 and NACA 0024, to assess the aerodynamic performance of two materials: Aluminum Alloy 7075-T6 SN and Aluminum Alloy 7050-T7451. The objective is to determine which alloy provides the highest lift force and to analyze lift and drag coefficients, velocity profiles, and pressure distributions across the two airfoil models [7]. Testing will involve simulating airflow conditions to compare the aerodynamic properties of each alloy, which could yield insights into optimal material selection for enhancing lift and reducing drag.

Furthermore, the findings of this research hold potential applications for wind turbine design, particularly vertical axis wind turbines, where minimizing drag can improve rotational torque and overall energy conversion efficiency [8-9]. By exploring material performance in these airfoils, this study contributes valuable data for both aeronautical engineering and renewable energy technology.

The objectives of this research are threefold: first, to evaluate and compare the aerodynamic performance of Aluminum Alloy 7075-T6 SN and Aluminum Alloy 7050-T7451 on NACA 0018 and NACA 0024 airfoils, with a focus on determining which material produces superior lift and drag forces. Second, this study aims to analyze the effects of material selection on the maneuverability and stability of aircraft wings, providing valuable data for improving aeronautical design through optimized lift and drag coefficients. Lastly, the research seeks to extend its findings to potential applications in renewable energy systems, particularly vertical axis wind turbines, by assessing how material choice can enhance rotational torque and energy conversion efficiency. Through these objectives, the study contributes insights into material science and aerodynamic engineering that are essential for advancing performance in both aviation and energy sectors.

METHODOLOGY

This research employs advanced computational analysis techniques, specifically Computational Fluid Dynamics (CFD), using ANSYS R18 software to investigate the aerodynamic properties of selected airfoil geometries. CFD is a powerful tool that allows for the simulation of fluid flow around complex shapes, providing detailed insights into parameters such as lift, drag, pressure distribution, and velocity contours. In this study, the focus is on NACA 4-digit series airfoils, particularly the NACA 0018 and NACA 0024 profiles, chosen for their relevance in aeronautical applications. These airfoils, depicted in Figure 1, have been widely studied and are frequently used in various engineering applications, including aircraft wing and wind turbine blade designs.

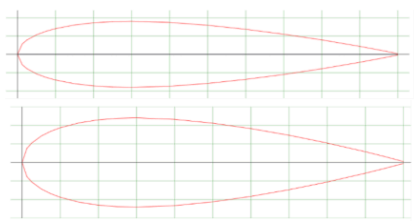

Figure 1. NACA Airfoils 0018 and 0024

Next, the NACA 0018 and 0024 airfoils will be designed using the software Solidworks shown in Figure 2 with an angle of attack of 10°. From this design, initial research data will be obtained in Table 1 and Table 2 which will be used in this research.

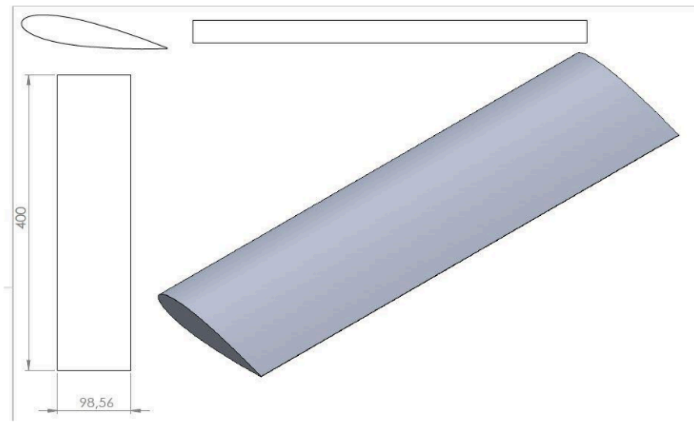

Figure 2. NACA 0018 Airfoil design using Solidworks

Table 1: NACA Airfoil Data 0018

Variable	**Information**
NACA type	NACA 0018 (naca0018-il)
type of material	Aluminum Alloy 7075-T6 SN Aluminum Alloy 7050-T7451
Mass NACA 0018 Al Alloy 7075-T6 SN	1387,98 grams
Mass NACA 0018 Al Alloy 7050-T7451	1397,86 grams
NACA Volume 0018 Al Alloy7075-T6 SN	493944,00 mm^3
NACA Volume 0018 Al Alloy 7050-T7451	493944,00 mm^3
Surface Area NACA 0018 Al Alloy 7075-T6 SN	85678,75 mm^2
Surface Area NACA 0018Al Alloy 7050-T7451	85678,75 mm^2

Table 2: NACA Airfoil Data 0024

Variable	Information
NACA type	NACA 0024 (naca0024-il)
type of material	Aluminum Alloy 7075-T6 SN Aluminum Alloy 7050-T7451
Mass NACA 0018 Al Alloy 7075-T6 SN	1851,12 grams
Mass NACA 0018 Al Alloy 7050-T7451	1864,30 grams
NACA Volume 0018 Al Alloy7075-T6 SN	658763,03 mm^3
NACA Volume 0018 Al Alloy 7050-T7451	658763,03 mm^3
Surface Area NACA 0018 Al Alloy 7075-T6 SN	88349,29 mm^2
Surface Area NACA 0018Al Alloy 7050-T7451	88349,29 mm^2

Followed by Computational Fluid Dynamic (CFD) analysis techniques using ANSYS R 18 software [12]. The model used in ANSYS Fluent is K-Epsilon 2-eqn Standard with an inlet speed of 200 m/s.

RESULT AND DISCUSSION

Based on the material simulation results on the NACA 0018 and 0024 Airfoils, the contour velocity and pressure around the Airfoil are obtained. The velocity and pressure contours for NACA 0018 on Aluminum Alloy 7075-T6 SN and Aluminum Alloy 7050-T7451 materials are shown in Figure 3 to Figure 6 while the velocity and pressure contours for NACA 0024 on two types of material are shown in Figure 7 to figure 10 [13].

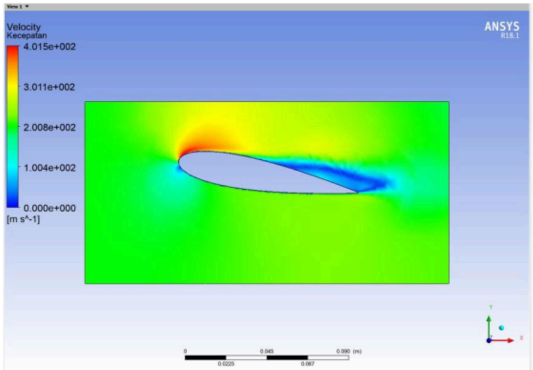

Figure 3: Speed Contour NACA 0018 Alloy 7075-T6 SN

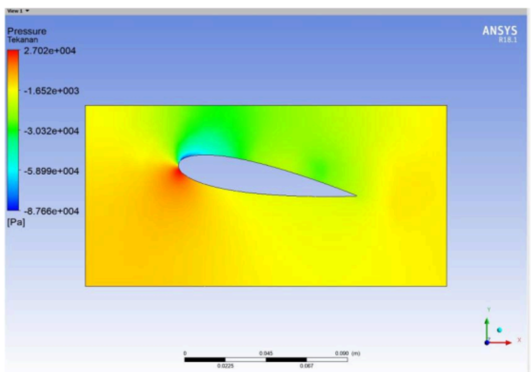

Figure 4: Pressure Contour NACA 0018 Al Alloy 7075-T6 SN

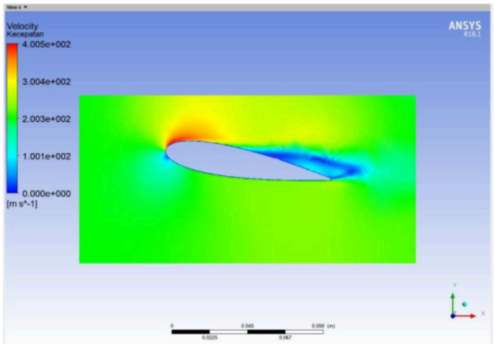

Figure 5: Speed Contour NACA 0018 Alloy 7050-T7451

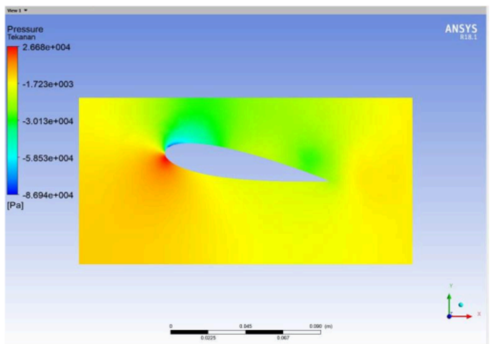

Figure 6: Pressure Contour NACA 0018 Al Alloy 7050-T7451

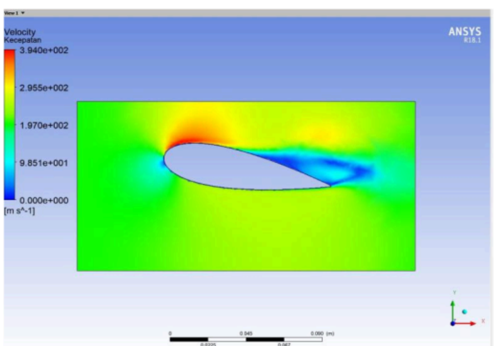

Figure 7: Speed Contour NACA 0024 Al Alloy 7075-T6 SN

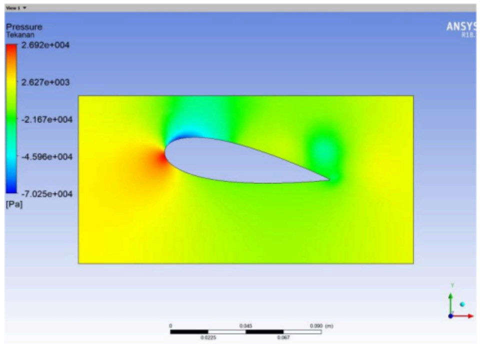

Figure 8: Pressure Contour NACA 0024 Al Alloy 7075-T6 SN

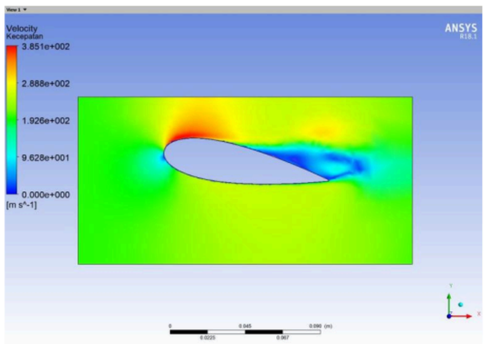

Figure 9: Speed Contour NACA 0024 Alloy 7050-T7451

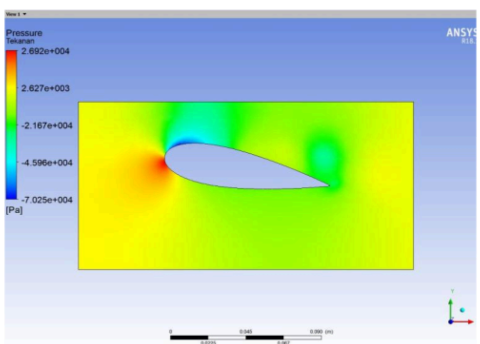

Figure 10: Pressure Contour NACA 0018 Alloy 7050-T7451

Furthermore, the results of the lifting force and drag force of NACA 0018 and 0024 are shown in Table 3 and Table 4.

Table 3: NACA 0018 simulation results with variations in two types of materials

Material	NACA 0018	
	Lift Force (N)	Drag Force (N)
Al Alloy 7075-T6 SN	1,17E+03	1,18E+02
Al Alloy 7050-T7451	1,08E+03	1,13E+02

Table 4: NACA 0024 simulation results with variations in two types of materials

Material	NACA 0024	
	Lift Force (N)	Drag Force (N)
Al Alloy 7075-T6 SN	5,71E+02	8,19E+01
Al Alloy 7050-T7451	4,51E+02	6,49E+01

By obtaining simulation data, the lift coefficient and drag coefficient of Airfoil NACA 0018 and 0024 can be calculated on two types of material. Lift and drag coefficients can be calculated using the formula [14]:

$$Cl = \frac{Fl}{0{,}5 \times V^2 \times A} \quad (1)$$

$$Cd = \frac{Fd}{0{,}5 \times V^2 \times A} \quad (2)$$

Where:

Cl = Lift force coefficient
Cd = Drag force coefficient
Fl = Lift force that occurs
Fd = Drag force that occurs
V = Fluid speed
A = Model area

By using the formula above, the lift and drag coefficients for Airfoil NACA 0018 and 0024 are obtained for the two types of material shown in Table 5 and Table 6.

Table 5: NACA 0018 calculation results with variations in two types of material

Material	NACA 0018			
	Lift Force (N)	Drag Force	Lift Coefficient	Drag Coefficient
Al Alloy 7075-T6 SN	1,17E+03	1,18E+02	6,83E-07	6,89E-08
Al Alloy 7050-T7451	1,08E+03	1,13E+02	6,30E-07	6,59E-08

Table 6: NACA 0018 calculation results with variations in two types of material

Material	NACA 0024			
	Lift Force (N)	Drag Force	Lift Coefficient	Drag Coefficient
Al Alloy 7075-T6 SN	5,71E+02	8,19E+01	3,23E-07	4,64E-08
Al Alloy 7050-T7451	4,51E+02	6,49E+01	2,55E-07	3,67E-08

Seen in Table 5 and Table 6 shows the lift coefficient and drag coefficient for two types of NACA Airfoil with material variations, namely Aluminum Alloy 7075-T6 SN and Aluminum Alloy-T7451. Where the highest lift force and drag force use Aluminum Alloy 7075-T6 SN material.

CONCLUSION

Based on the simulation results, it is concluded that the Aluminum Alloy 7075-T6 SN material exhibits superior aerodynamic performance on both NACA 0018 and NACA 0024 airfoils. This material consistently achieved higher lift and drag forces compared to Aluminum Alloy 7050-T7451, indicating its effectiveness in enhancing the wing's aerodynamic efficiency. Specifically, for the NACA 0018 airfoil, the 7075-T6 SN alloy generated a lift force of 1,170 N and a drag force of 118 N, while the NACA 0024 airfoil produced a lift force of 571 N and a drag force of 81.9 N with the same material. These results suggest that the 7075-T6 SN alloy may offer improved maneuverability and stability, essential for applications requiring optimized lift and drag performance. The findings of this study not only provide valuable insights for material selection in aeronautical engineering but also offer potential applications for wind turbines, where material choice significantly impacts rotational torque and efficiency. This study reinforces the importance of selecting high-performance materials for airfoils to maximize aerodynamic benefits across various engineering fields.

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