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Comparative CFD Analysis of NACA 0012 and NACA 4415 Airfoils at Varying Angles of Attack on Aircraft Wings Using ANSYS Fluent

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ABSTRACT

During takeoff and approach to land, all aircraft move at low speed and high lift so that the wing is one of the main components of an airplane that has the basic function of being able to produce good aerodynamic performance characteristics so that objects can be lifted and maintain their position in the sky. In this study, an airfoil geometry with the NACA 0012 and NACA 4415 series was tested using ANSYS Fluent software at a speed of 200 m/s. To obtain maximum performance in this geometry, a variation of the angle of attack from 0° to 20°, was given so that the lift and drag force were obtained from each angle of attack. From the simulation and calculation results, the highest lift coefficient and drag coefficient in the NACA 0012 Airfoil simulation are at an angle of attack of 20°, is 0.5106 and 0.07829. Meanwhile, in the NACA 4415 Airfoil simulation, the highest lift coefficient is at an angle of attack of 20°, is 0.64623 and 0.08238.

Keywords: NACA Airfoil, ANSYS Fluent, CFD

INTRODUCTION

Wings are the main components of an aircraft, which have a basic function to produce good aerodynamic flight performance characteristics in all conditions and flight attitudes, such as takeoff, and landing [1] [2] [3]. These characteristics relate to its behavior towards the wind energy it receives, such as lift and drag at various angles of attack and wind speeds that hit it. In other words, it can be said that the aerodynamic performance characteristics of an aircraft are largely determined by the success of designing the aircraft wing itself [4] [5] [6].

In addition to the wing shape, changes in the angle of attack also affect the shift in the stagnation point or expansion point in the leading edge area of the airfoil body surface, which then affects the overall aerodynamic characteristics [7] [8]. The greater the pressure difference between the upper and lower sides of the airfoil body, the greater the lift force [9] [10].

The lift force on an airplane occurs due to the aerodynamic force produced by the fluid when it passes through the airfoil, causing the pressure under the wing to be higher than the pressure above the wing of an airplane traveling at high altitude (flying) [11] [12].

Aerodynamic characteristics of the wing is calculated by simulation and analysis which is CFD (Computational Fluid Dynamic) software, namely ANSYS Fluent R.18 [13] [14]. This software is expected to be able to solve the calculation and analysis problems related to aerodynamics, in addition to the simulation [15] [16]. Before the simulation is carried out, the 3D model is first drawn using SolidWorks software.

In this study, the NACA 4-digit series airfoil model is 0012 and 4415 against varying angles of attack. This study aims to determine the effect of the airfoil angle of attack on the distribution of speed, pressure, lift coefficient, and drag coefficient [17] [18] [19]. The variations in the angle of attack used are 0°, 5°, 15°, and 20°.

RESEARCH METHOD

In this research, the 4-digit series 0012 and 4415 NACA Airfoil geometry design can be seen in Figure 1.

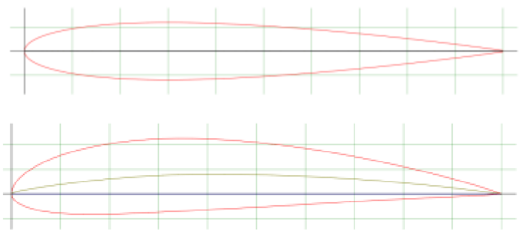

Figure 1. NACA Airfoils 0012 and 4415 [20]

Next, the NACA 0012 and 4415 airfoil 3D model will be designed using the software SolidWorks shown in Figure 2.

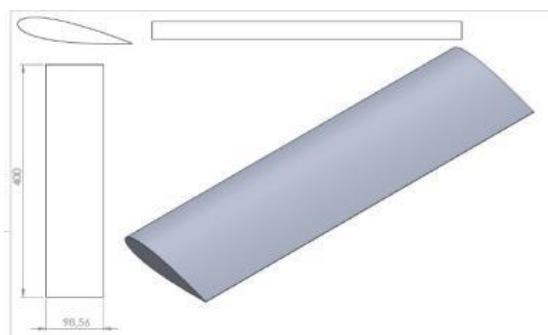

Figure 2. NACA 0012 Airfoil design using Solidworks

Followed by Computational Fluid Dynamic (CFD) analysis techniques using ANSYS R 18 software. The model used in ANSYS Fluent is K-Epsilon 2-eqn Standard with an inlet speed of 200 m/s. K-Epsilon 2-eqn Standard is used because relatively efficient to solve compared to more complex models like Reynolds stress models or large eddy simulations [21] [22] [23].

RESULT AND DISCUSSION

Based on simulation results on the NACA 0012 and 4415 Airfoils, the pressure around and velocity streamline the Airfoil are obtained. The pressure contour for NACA 0012 and 4415 around the wing, in this case, the upper and lower wings are shown in Figure 3 to Figure 6 while the velocity streamline for NACA 0012 and 4415 is shown in Figure 7 to Figure 8.

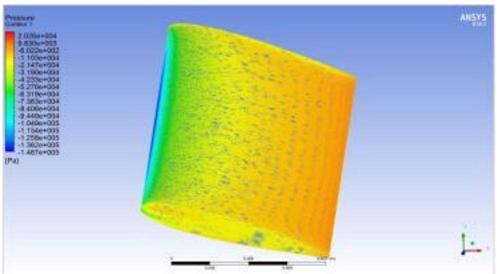

Figure 3. Pressure contour NACA 0012 upper wing area at an angle of 15°

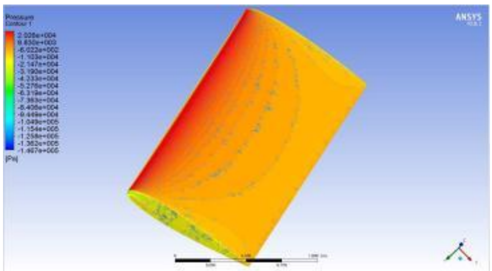

Figure 4. Pressure contour NACA 0012 underwing area at an angle of 15°

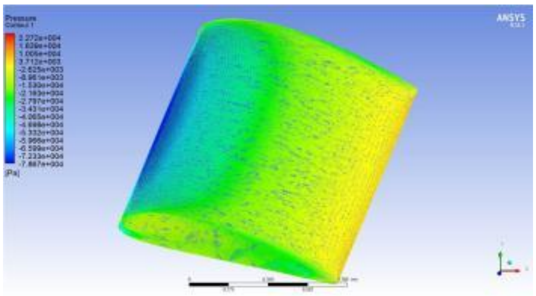

Figure 5. Pressure contour NACA 4415 upper wing area at an angle of 15°

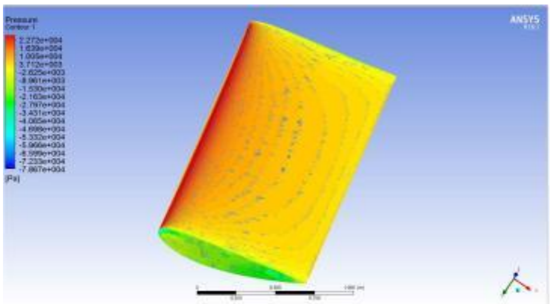

Figure 6. Pressure contour NACA 4415 underwing area at an angle of 15°

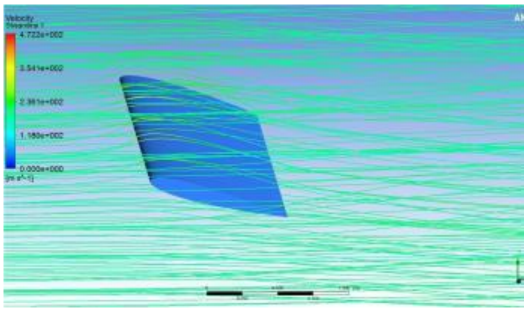

Figure 7. Velocity streamline NACA 0012 at an angle of 15°

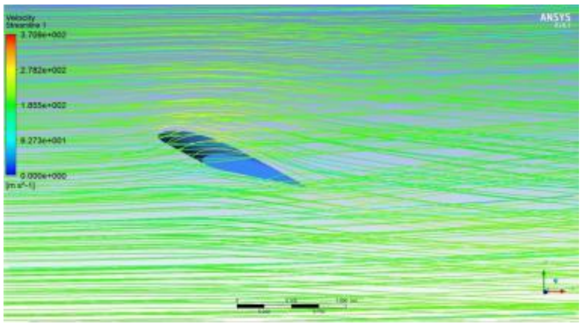

Figure 8. Velocity streamline NACA 415 at an angle of 15°

Figures 3 to 6 show the magnitude of the pressure on the upper and lower sides of the NACA 0012 and 4415. The figure above shows that the pressure on the lower side is higher than on the upper side of the wing.

Meanwhile, the results of the lifting force and drag force of NACA 0012 and 4415 are shown in Table 1 and Table 2.

Table 1. NACA 0012 simulation results with varying angles of attack

Angle of attack	Lift force (N)	Drag force (N)
0°	290	731
5°	41.320	2.060
10°	82.060	6.114
15°	121.100	13.110
20°	158.200	23.180

Table 2. NACA 4415 simulation results with varying angles of attack

Angle of attack	Lift force (N)	Drag force (N)
0°	35.080	1.649
5°	78.080	1.653
10°	118.180	9.984
15°	156.100	17.840
20°	191.700	24.440

By obtaining simulation data, the lift coefficient and drag coefficient of Airfoil NACA 0012 and 4415 can be calculated. Lift and drag coefficients can be calculated using the formula:

$$C_l = \frac{F_l}{0{,}5 \ x \ V^2 \ x \ A}$$

$$C_d = \frac{F_d}{0{,}5 \ x \ V^2 \ x \ A}$$

Where C_l is the lift force coefficient, C_d is the drag force coefficient F_l is the lift force that occurs, F_d is the drag force that occurs, V is fluid speed and A is model area [24] [25] [26]. By using the formula above, the lift and drag coefficients for Airfoil NACA 0012 and 4415 are obtained for the two types of NACA shown in Table 3 and Table 4.

Table 3. NACA 0012 calculation results

Angle of attack	Coefficent drag	Coefficent lift
0°	0,0024850	0,0009870
5°	0,0068080	0,1395690
10°	0,0207600	0,2791390
15°	0,0374450	0,4084960
20°	0,0782950	0,5106200

Table 4. NACA 4415 calculation results

Angle of attack	Coefficent drag	Coefficent lift
0°	0,0053930	0,1179880
5°	0,0155070	0,2629440
10°	0,0333730	0,3708190
15°	0,0573080	0,5056630
20°	0,0823890	0,6462370

Table 3 and Table 4 shows the lift coefficient and drag coefficient for two types of NACA Airfoil 0012 and 4415. Based on the results of the calculations above, variations in the angle of attack on the drag and lift forces can be compared as shown in Figure 9 and Figure 10.

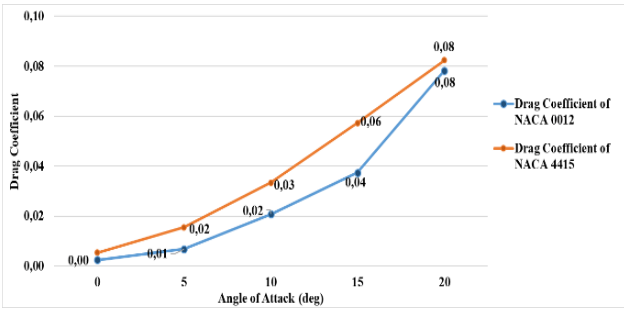

Figure 9. Graph of variation of angle of attack with drag coefficient

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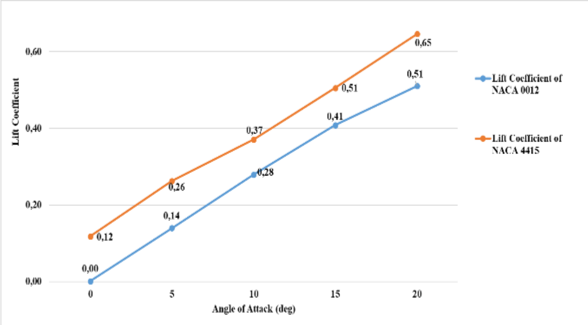

Figure 10. Graph of variation of angle of attack with lift coefficient

Figures 9 and 10 show the magnitude of the drag and lift coefficients based on the variation of the angle of attack. From the figure, the magnitude of the drag and lift is greatest at an angle of attack of 20°. The magnitude of this lift coefficient is needed so that the force can overcome the weight due to the pull of the earth's gravity or the lift force must be greater or equal to weight force so that the object can be lifted and maintain its position [27] [28] [29].

The lift coefficient value in figures 9 and 10 is higher than the drag coefficient value, this is due to the geometric shape of the airfoil which, when placed in a fluid flow, will produce a lift force that is greater than the drag force [30] [31] [32].

CONCLUSION

Based on the simulation results at a fluid velocity of 200 m/s, the highest lift force for the NACA 0012 and 4415 Airfoils is at an angle of attack of 20°, namely 158,200 N and 191,700 N, while the highest drag force is at an angle of attack of 20°, namely 23,180 N and 24,440 N. The highest lift coefficient for the NACA 0012 and 4415 Airfoils is at 0.510620 and 0.64623, and the highest drag coefficient is at an angle of attack of 20°, namely 0.07829 and 0.082389. From the simulation and calculation results on both NACAs, it can be seen that the magnitude of the lift and drag of the NACA 4415 airfoil demonstrated better aerodynamic performance than NACA 0012, generating higher lift at all tested angles. Although it produced slightly more drag, its superior lift makes it more suitable for low-speed, high-lift applications such as takeoff and landing

REFERENCES

[1] K. A. Othman and A. S. M. Al-Obaidi, "Effect of the wing airfoil shape on the aerodynamics and performance of a jet-trainer aircraft – An optimization approach," *J Phys Conf Ser*, vol. 2120, no. 1, p. 012011, Dec. 2021, doi: 10.1088/1742-6596/2120/1/012011.

[2] S. N. V. Neigapula, S. P. Maddula, and V. B. Nukala, "A study of high lift aerodynamic devices on commercial aircrafts," *Aviation*, vol. 24, no. 3, pp. 123–136, Sep. 2020, doi: 10.3846/AVIATION.2020.12815.

[3] N. R. Kluga, "A Study of Flap Management, an Analysis of the Consequences of Flap Management, and a Search for Possible Causes," *Journal of Aviation/Aerospace Education & Research*, vol. 1, no. 3, p. 1, 1991, doi: 10.15394/jaaer.1991.1026.

[4] M. Pane, “Wing Simulation Using Naca 2412 and 2415 Airfoils with Variations in Angle of Attack for Lift and Drag,” *VANOS Journal of Mechanical Engineering Education*, vol. 8, no. 2, pp. 190–199, Nov. 2023, doi: 10.30870/VANOS.V8I2.22321.

[5] T. Batu *et al.*, “Optimal airfoil selection for small horizontal axis wind turbine blades: a multi-criteria approach,” *Advances in Mechanical and Materials Engineering*, vol. Vol. 41, no. nr 1, pp. 57–68, 2024, doi: 10.7862/RM.2024.6.

[6] A. Tokul and U. Kurt, “Comparative performance analysis of NACA 2414 and NACA 6409 airfoils for horizontal axis small wind turbine,” *International Journal of Energy Studies*, vol. 8, no. 4, pp. 879–898, Dec. 2023, doi: 10.58559/IJES.1356955.

[7] C. Lai, B. Ren, and Y. Zhou, “Influence of wing angle of attack and relative position on the aerodynamics of aerotrain,” *Advances in Mechanical Engineering*, vol. 9, no. 8, pp. 1–12, Aug. 2017, doi: 10.1177/1687814017719220/ASSET/DCC1F28C-16F2-4F9D-B2BD-002DA4C2144F/ASSETS/IMAGES/LARGE/10.1177_1687814017719220-FIG23.JPG.

[8] S. Kumar and S. Narayanan, “Airfoil thickness effects on flow and acoustic characteristics,” *Alexandria Engineering Journal*, vol. 61, no. 6, pp. 4679–4699, Jun. 2022, doi: 10.1016/J.AEJ.2021.10.022.

[9] K. E. Swalwell, J. Sheridan, and W. H. Melbourne, “Frequency analysis of surface pressures on an airfoil after stall,” *21st AIAA Applied Aerodynamics Conference*, 2003, doi: 10.2514/6.2003-3416.

[10] Z. Liu, A. Li, X. Xu, and R. Gao, “Computational Fluid Dynamics Simulation of Airflow Patterns and Particle Deposition Characteristics in Children Upper Respiratory Tracts,” *Engineering Applications of Computational Fluid Mechanics*, vol. 6, no. 4, pp. 556–571, 2012, doi: 10.1080/19942060.2012.11015442.

[11] J. Wild, “High-lift aerodynamics,” *High-Lift Aerodynamics*, pp. 1–307, Feb. 2022, doi: 10.1201/9781003220459/HIGH-LIFT-AERODYNAMICS-JOCHEN-WILD/ACCESSIBILITY-INFORMATION.

[12] C. P. van Dam, “The aerodynamic design of multi-element high-lift systems for transport airplanes,” *Progress in Aerospace Sciences*, vol. 38, no. 2, pp. 101–144, Feb. 2002, doi: 10.1016/S0376-0421(02)00002-7.

[13] M. Pane, “Simulasi Sayap Menggunakan Airfoil NACA 0008 dan 0010 dengan Variasi Sudut Serang terhadap Gaya Angkat dan Gaya Dorong,” *J-Proteksion: Jurnal Kajian Ilmiah dan Teknologi*

Teknik Mesin, vol. 8, no. 1, pp. 7–11, Aug. 2023, doi: 10.32528/JP.V8I1.444.

[14] M. Pane, "Wing Simulation Using Naca 0018 and 0024 and Aluminum Alloy 7075 T6-SN and 7050-T7451 Materials for Lift and Drag," *JOURNAL OF MECHANICAL ENGINEERING MANUFACTURES MATERIALS AND ENERGY*, vol. 8, no. 2, pp. 191–200, Nov. 2024, doi: 10.31289/JMEMME.V8I2.13164.

[15] A. Basit, R. Septian Hidayatuloh, and M. Royana, "Aerodynamic analysis and car body optimalization of saving energy 'WARAK' using software Ansys Fluent R15.0," *IOP Conf Ser Mater Sci Eng*, vol. 788, no. 1, p. 012073, Apr. 2020, doi: 10.1088/1757-899X/788/1/012073.

[16] T. Putranto and A. Sulisetyono, "Lift-Drag Coefficient and Form Factor Analyses of Hydrofoil due to The Shape and Angle of Attack," *International Journal of Applied Engineering Research*, vol. 12, pp. 11152–11156, 2017, Accessed: Mar. 12, 2025. [Online]. Available: http://www.ripublication.com

[17] K. S. Nandini, K. N. Subhashini, and V. Somashekar, "Experimental Investigations of Aerodynamic Performances of S9023 Airfoil," *IOP Conf Ser Mater Sci Eng*, vol. 376, no. 1, p. 012060, Jun. 2018, doi: 10.1088/1757-899X/376/1/012060.

[18] M. R. Al Faris, T. Priangkoso, and D. Darmanto, "VISUALISASI PENGARUH SUDUT SERANG DAN KECEPATAN ALIRAN UDARA TERHADAP STALL AIRFOIL NACA 2415 DAN NACA 4424," *JURNAL ILMIAH MOMENTUM*, vol. 16, no. 1, Apr. 2020, doi: 10.36499/MIM.V16I1.3362.

[19] H. Wibowo, "Pengaruh Sudut Serang Aerofoil Terhadap Distribusi Tekanan dan Gaya Angkat," *JURNAL DINAMIKA VOKASIONAL TEKNIK MESIN*, vol. 2, no. 2, p. 148, Oct. 2017, doi: 10.21831/DINAMIKA.V2I2.15999.

[20] "NACA 4 digit Airfoil database search." Accessed: Mar. 12, 2025. [Online]. Available: http://airfoiltools.com/search/index?m%5Bgrp%5D=naca4d&m%5Bsort%5D=1

[21] R. Shaheed, A. Mohammadian, and H. Kheirkhah Gildeh, "A comparison of standard k–ε and realizable k–ε turbulence models in curved and confluent channels," *Environmental Fluid Mechanics*, vol. 19, no. 2, pp. 543–568, Apr. 2019, doi: 10.1007/S10652-018-9637-1/METRICS.

[22] T.-H. Shih, W. W. Liou, A. Shabbir, Z. Yang, and J. Zhu, "A New K-epsilon Eddy Viscosity Model for High Reynolds Number Turbulent Flows: Model Development and Validation," 1994.

[23] M. T. Hamisu, M. M. Jamil, U. S. Umar, and A. Sa'ad, "Numerical Study Of Flow

In Asymmetric 2D Plane Diffusers With Different Inlet Channel Lengths," *CFD Letters*, vol. 11, no. 5, pp. 1–21, 2019, Accessed: May 09, 2025. [Online]. Available: https://akademiabaru.com/submit/index.php/cfdl/article/view/3159

[24] G. S. Samy, S. Thirumalai Kumaran, M. Uthayakumar, M. Sivasubramanian, and K. Bhagavathi Sankar, "Numerical analysis of drag and lift coefficient of a Sport Utility Vehicle (SUV)," *J Phys Conf Ser*, vol. 1276, no. 1, p. 012013, Aug. 2019, doi: 10.1088/1742-6596/1276/1/012013.

[25] D. Eller and S. Heinze, "Approach to Induced Drag Reduction with Experimental Evaluation," *https://doi.org/10.2514/1.11713*, vol. 42, no. 6, pp. 1478–1485, May 2012, doi: 10.2514/1.11713.

[26] A. A. Kharisma, A. Rahman, A. Ramadhan, and B. Amanda, "Pengaruh Variasi Kecepatan Udara Pada Airfoil NACA 2412 Terhadap Distribusi Tekanan Pada Open Circuit Low Subsonic Wind Tunnel," *Jurnal Teknik Mesin Indonesia*, vol. 19, no. 2, pp. 21–31, Sep. 2024, doi: 10.36289/JTMI.V19I02.627.

[27] M. Sandesh, K. Rasal, M. Rohan, and R. Katwate, "Numerical Analysis of Lift & Drag Performance of NACA0012 Wind Turbine Aerofoil," *International Research Journal of Engineering and Technology*, 2017, Accessed: May 09, 2025. [Online]. Available: www.irjet.net

[28] M. Manikandan and R. S. Pant, "Research and advancements in hybrid airships—A review," *Progress in Aerospace Sciences*, vol. 127, Nov. 2021, doi: 10.1016/j.paerosci.2021.100741.

[29] R. D. Novianti, S. Hariyadi, S. Putro, and N. Pambudiyatno, "ANALISIS AERODINAMIKA PENGGUNAAN PLAIN FLAP PADA AIRFOIL NACA 2412," *Approach : Jurnal Teknologi Penerbangan*, vol. 6, no. 1, pp. 12–17, 2022, doi: 10.46491/APPROACH.V6I1.1784.

[30] M. Zhao, H. Cao, and M. Zhang, "Analysis of various NACA airfoil and fabrication of wind tunnel to test the scaled-down model of an airfoil Optimal design of aeroacoustic airfoils with owl-inspired trailing-edge serrations", doi: 10.1088/1757-899X/1130/1/012021.

[31] A. Akbar, "Effect of Angle of Attack on Airfoil NACA 0012 Performance," *R.E.M. (Rekayasa Energi Manufaktur) Jurnal*, vol. 5, no. 1, pp. 35–40, Jun. 2020, doi: 10.21070/R.E.M.V5I1.1235.

[32] H. Zhang *et al.*, "Lift and Drag Coefficient Map of NACA4415 Airfoil," *J Phys Conf Ser*, vol. 2076, no. 1, p. 012066, Nov. 2021, doi: 10.1088/1742-6596/2076/1/012066.