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Wing Simulation Using Naca 2412 and 2415 Airfoils with Variations in Angle of Attack for Lift and Drag

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ABSTRACT

The geometry of an airfoil plays a critical role in shaping an aircraft's performance, especially during maneuvering. This study emphasizes the necessity of conducting a comprehensive geometric analysis to better understand the effects of airfoil design. In pursuit of optimizing airfoil performance, we conducted extensive tests on NACA 2412 and 2415 series airfoil geometries using the ANSYS Fluent software. The tests employed Aluminum Alloy 1067 material and a wind speed of 300 m/s, encompassing a range of angle of attack variations from 0 to 180 degrees. The simulation results provided valuable insights into the velocity and pressure distributions surrounding the airfoil. Of particular interest, at an angle of 15 degrees, the NACA 2412 airfoil exhibited a maximum drag force of 69.670 N and a maximum lift force of 550.300 N. The corresponding drag and lift coefficients were 0,1516378 N and 1,1977364 N. For the NACA 2415 airfoil, the maximum drag and lift forces were 71.470 N and 564.500 N, respectively, with corresponding drag and lift coefficients of 0,1541963 N and 1,2179072 N.

Keywords: NACA Airfoil, Angle of Attack, ANSYS Fluent

INTRODUCTION

The geometry of an airfoil on an aircraft's wing plays a pivotal role in shaping its aerodynamic performance during various flight maneuvers [1][2]. Among the myriad airfoil shapes, one prominent design is the NACA airfoil, developed by the National Advisory Committee for Aeronautics (NACA) [3][4][5].

The NACA airfoil represents a geometric configuration that, when subjected to airflow, generates both lift and drag forces [6][7]. This phenomenon is fundamental in aviation, where the lift force surpasses the drag force, enabling flight [8][9].

The interaction of a fluid with an airfoil influences multiple variables, including speed, mass density, pressure, and temperature [10][11]. This dynamic interplay forms the bedrock of aerodynamics, influencing the advancement of aviation technology and numerous other engineering domains [12]. The lift force generated during flight results from the aerodynamic pressure differential created as the fluid flows over and under the wings of an aircraft operating at high altitudes [13][14][15].

Aerodynamic research in airfoil modeling has seen extensive exploration through analytical methods, aerodynamic formulas, wind tunnel experiments, and more recently, the adoption of Computational Fluid Dynamics (CFD) using tools like ANSYS, but first designed in SolidWorks software [16].

SolidWorks is a software called solid "parametric modeling" which is intended for drawing designs with 3-Dimensional design modeling [17][18]. SolidWorks itself is a 3D CAD (computer-aided design) mechanical program software used on Microsoft Windows. SolidWorks file storage uses structured Microsoft format file storage [19][20].

ANSYS is software based on finite element analysis (FEA). The use of ANSYS is quite extensive, including structural, thermal, fluid dynamics, acoustics, and electromagnetic simulations. ANSYS is computer-aided engineering (CAE) software developed by ANSYS, Inc [21].

As a reference, this research was conducted to contribute references regarding the aerodynamics of aircraft wings that use the NACA 2412 and 2415 airfoil geometry in the future. Apart from that, this research model can also be used as a reference in designing wind turbine blades [22][23].

In this study, we focus on two specific 4-digit series NACA airfoil models: NACA 2412 and NACA 2515 [24][25]. Our research endeavors to unveil the impact of the angle of attack on various aerodynamic parameters, including the distribution of speed, pressure, lift coefficient, and thrust coefficient. The angles of attack examined encompass 0, 3, 6, 9, 12, 15, and 18 degrees. Furthermore, this study aims to shed light on the variations in lift and drag distribution across the airfoil.

RESEARCH METHOD

The research method carried out in this research is a computational analysis technique or Computational Fluid Dynamic (CFD) using ANSYS R.18 software [16]. The analysis stage is shown in Figure 1.

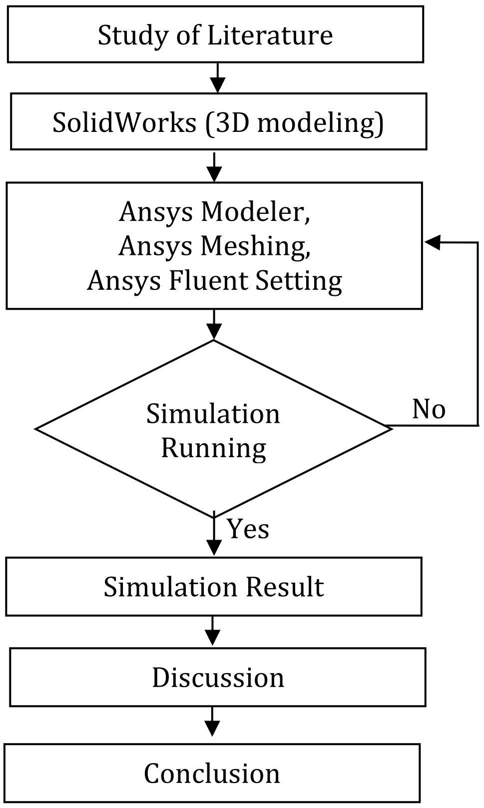

Figure 1. Flowchart of research

The geometry of the NACA 2412 and 2415 airfoils was obtained from the National Advisory Committee for Aeronautics (NACA) website [24][25]. The geometry of the two NACA airfoils taken from the NACA website in the form of x and y axis coordinates is shown in Figure 2.

The overall x and y-axis coordinates are scaled from Chord length 1 to 100 mm without changing the shape of the original coordinates saved in the .igs file. This file is then imported into Solidworks which is then extruded to become a 3-dimensional model. The geometry of NACA 2412 and 2415 was designed in SolidWorks software as shown in Figure 3.

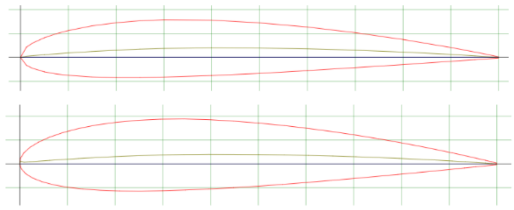

Figure 2. Geometry of NACA 2412 and 2415

Solidworks imports the material chosen, Aluminum Alloy 1060 so that the weight of the model is obtained [26][27]. Apart from that, when the extruded model is carried out, the surface area and volume of the model are also obtained based on the Solidworks software evaluation [28][29].

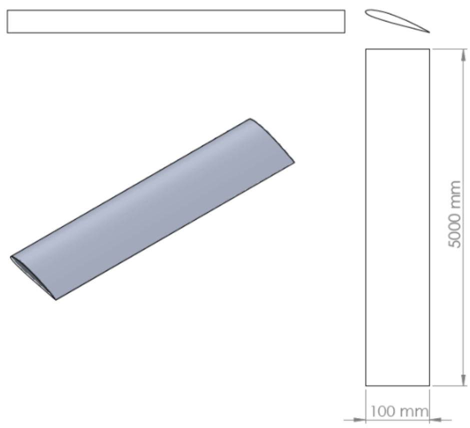

Figure 3. NACA airfoil wing design using solid works software

Before carrying out a simulation, the parameters used are first determined. These parameters are the initial research data shown in Table 1.

Table 1. Initial research data

Variable	NACA 2412	NACA 2415
Mass	1110.2 gr	1388.8 gr
Volume	0.4112 m^3	0.5143 m^3
Density	2700 kg/m^3	2700 kg/m^3
Material	Alluminium Alloy 1060	Alluminium Alloy 1060
Velocity inlet	300 m/s	300 m/s
Model	Laminar K-epsilon	Laminar K-epsilon
Angle of Attack	0, 3, 6, 9, 12, 15, 18 deg	0, 3, 6, 9, 12, 15, 18 deg

Before running the simulation, the design drawing from SolidWorks is imported into ANSYS Modeler and then the domain settings are carried out. The next step is Mesh, mesh is the process of dividing the components to be analyzed into small or discrete elements where the better the quality of the mesh, the higher the level of convergence [30][31], so we will get higher quality data. The final step before running the simulation is setting fixed parameters such as aircraft speed, model, parameters to be exported, and others.

RESULT AND DISCUSSION

Based on the results of simulations carried out on variations in the angle of attack of the NACA 2412 and 2415 airfoils, the velocity and pressure contours around the airfoil geometry were obtained. The pressure and velocity contours on NACA 2412 are shown in Figure 4 to Figure 9. The pressure and velocity contours on NACA 2415 are shown in Figure 10 to Figure 15. Meanwhile, the results of the lift force and drag force from the simulation results are shown in Table 2.

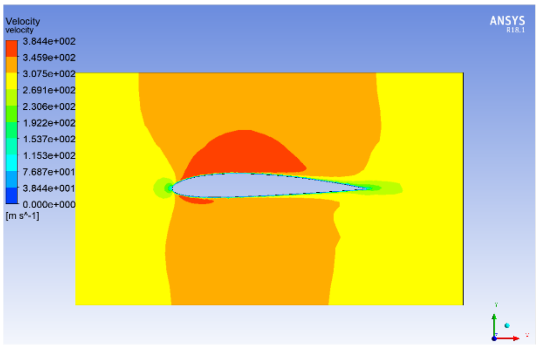

Figure 4. NACA 2412 simulated velocity contours at an angle of attack of 0 degree

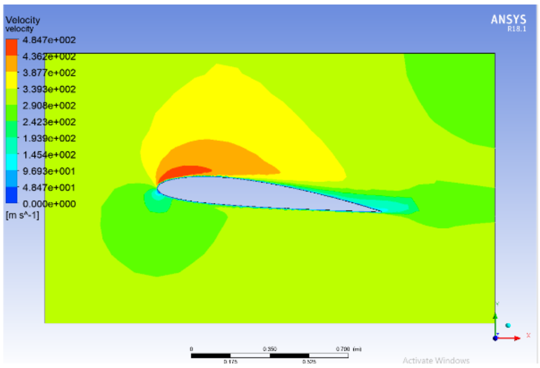

Figure 5. NACA 2412 simulated velocity contours at an angle of attack of 6 degree

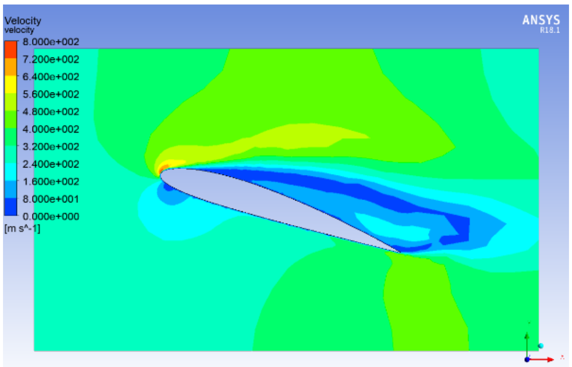

Figure 6. NACA 2412 simulated velocity contours at an angle of attack of 18 degree

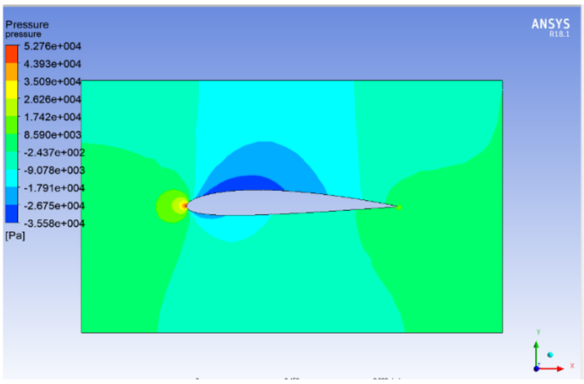

Figure 7. NACA 2412 simulated pressure contours at an angle of attack of 0 degree

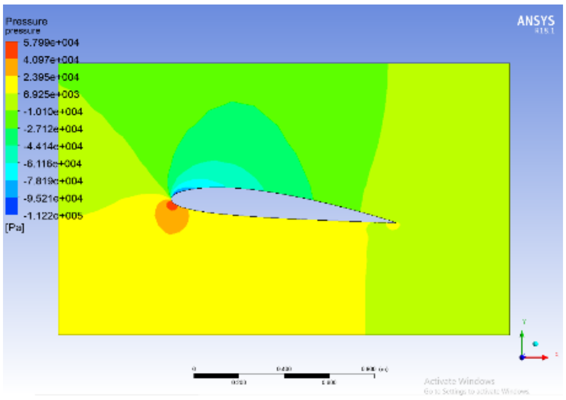

Figure 8. NACA 2412 simulated pressure contours at an angle of attack of 6 degree

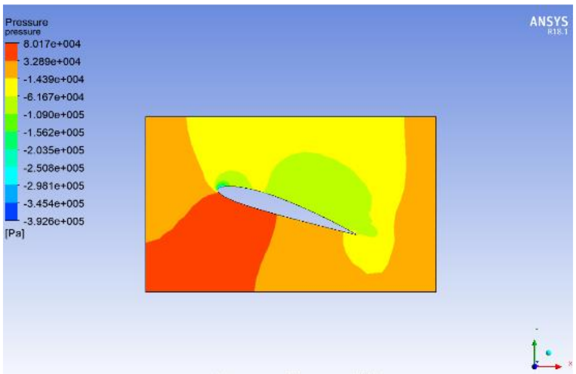

Figure 9. NACA 2412 simulated pressure contours at an angle of attack of 18 degree

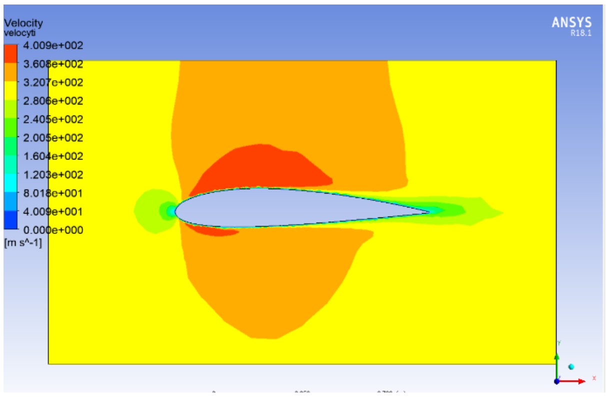

Figure 10. NACA 2415 simulated velocity contours at an angle of attack of 0 degree

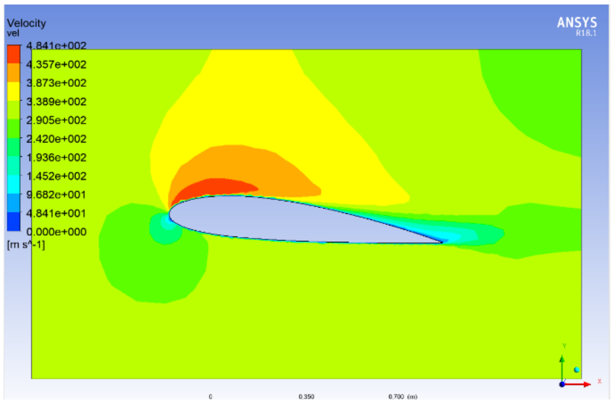

Figure 11. NACA 2415 simulated velocity contours at an angle of attack of 6 degree

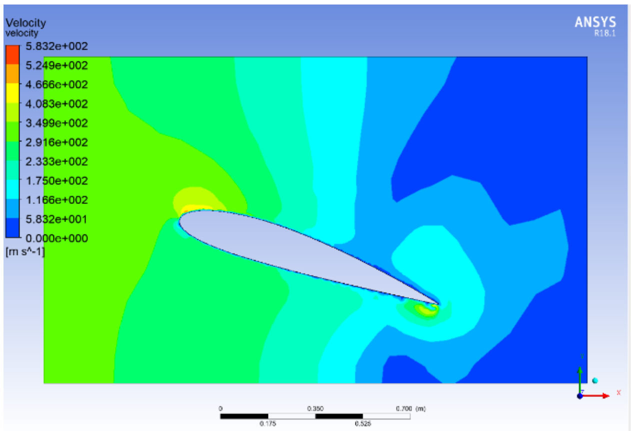

Figure 12. NACA 2415 simulated velocity contours at an angle of attack of 18 degree

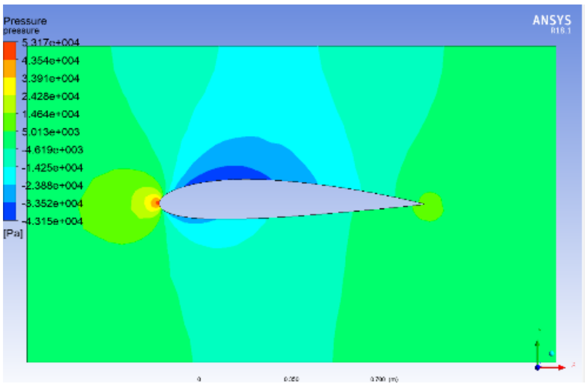

Figure 13. NACA 2415 simulated pressure contours at an angle of attack of 0 degree

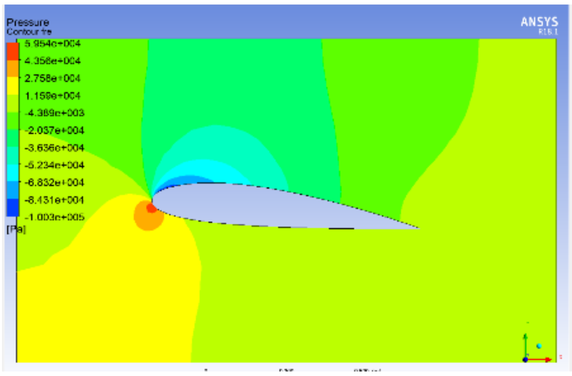

Figure 14. NACA 2415 simulated pressure contours at an angle of attack of 6 degree

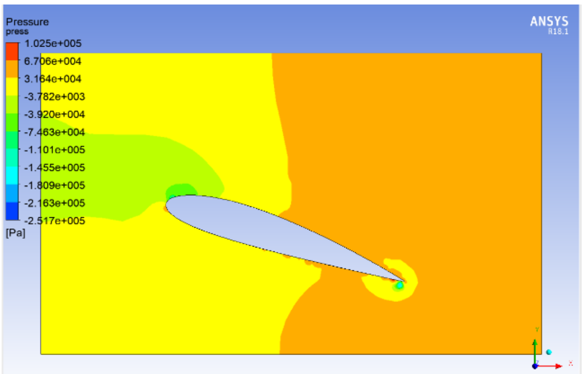

Figure 15. NACA 2415 simulated pressure contours at an angle of attack of 18 degree

Figure 4 to Figure 15 shows the contours of pressure differences and differences in velocity distribution. In the picture, we can see a description of the pressure and speed variables, where the highest pressure or speed spread around the airfoil is in red to the lowest in blue.

From the simulation results that have been carried out, there is a result feature that can be exported in the form of a data sheet or test results data, if you carry out all the steps correctly. The test result data is shown in table 2.

Table 2. Simulation results of NACA 2412 and 2515 with varying angles of attack

Angle of attack (deg)	Lift force (N)	Drag force (N)
NACA 2412		
0	64.820	3.290
3	161.300	5.404
6	259.600	10.250
9	336.000	17.830
12	449.800	33.320
15	550.300	69.670
18	522.400	55.220
NACA 2415		
0	60.420	3.654
3	156.700	5.914
6	243.200	9.585
9	303.400	16.450
12	344.300	17.040
15	564.500	71.470
18	64.230	24.310

Table 2 shows the magnitude of the drag force and lift force on NACA 2412 and 2415 with varying angles of attack so that the calculation of the lift force coefficient can be calculated using the formula $C_l = \frac{F_l}{0.5 \times V^2 \times A}$ and the drag force coefficient is calculated using the formula $C_d = \frac{F_d}{0.5 \times V^2 \times A}$ where A is the area of the model, V is the fluid velocity, F_l is lift force, F_d is drag force, C_l is lifted force coefficient, C_d is drag force coefficient [17][18]. The lift and thrust coefficients can be seen in Tables 3 and 4.

Table 3. Lift and drag coefficients of NACA 2412

Angle of attack (deg)	Coefficent drag (N)	Coefficent lift (N)
0	0,0071607	0,1410817
3	0,0117619	0,3510719
6	0,0223093	0,5650234
9	0,0388073	0,7313092
12	0,0725215	0,9789966
15	0,1516378	1,1977364
18	0,1201219	1,1370116

Table 4. Lift and drag coefficients of NACA 2415

Angle of attack	Coefficent drag (N)	Coefficent lift (N)
0	0,0078835	0,1303128
3	0,0127594	0,3380798
6	0,0206796	0,5247033
9	0,0354908	0,6545847
12	0,0367638	0,7428263
15	0,1541963	1,2179072
18	0,0524488	0,1385761

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 16 and Figure 17.

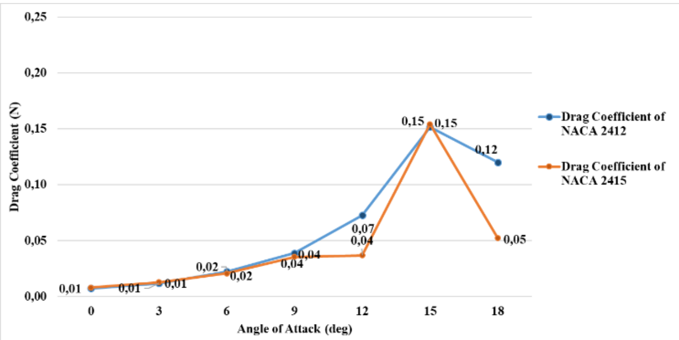

Figure 16. Graph of variation of angle of attack with drag coefficient

Figures 16 and Figure 17 show the coefficients of drag and lift based on variations in the angle of attack. From the picture, it can be seen that the largest dragging force and lifting force are at an angle of attack of 15^0.

This large lifting force coefficient is needed so that the force can overcome the weight force due to the earth's gravitational pull or the lifting force must be able to oppose the earth's gravitational pull so that the object can be lifted and maintain its position in the sky.

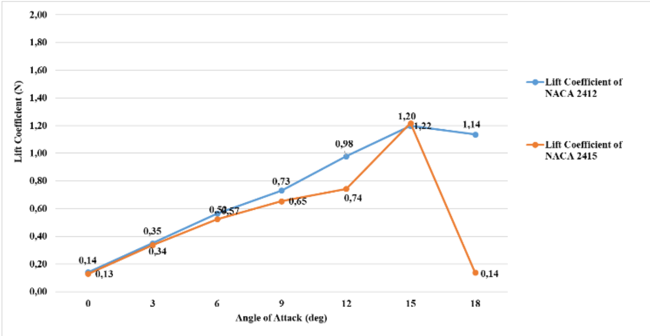

Figure 17. Graph of variation of angle of attack with lift coefficient

The lift force coefficient value in Figures 16 and 17 is higher than the drag force 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 [8][9].

CONCLUSION

Based on the simulation results at a fluid speed of 300 m/s, it was found that the highest lift force for the NACA 2412 and 2415 Airfoils was at an angle of attack of 15 degree is 550.300 N and 564.500 N, while the highest drag force was at an angle of attack of 15 degree is 69.670 N and 7.1470 N. The highest lift coefficient for the NACA 2412 and 2415 Airfoils is at 1,19 N and 1,21 N, and the highest drag coefficient is at an angle of attack of 15^0

is 0,1516 N and 0,1541 N. From the results of simulations and calculations on these two NACAs, it can be seen that the lift and drag forces of NACA 2415 are slightly greater than NACA 2412, so NACA 2415 is better able to overcome the heavy forces due to the earth's gravitational pull and drag forces so that objects can be lifted and maintain their position in space.

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