

A Study of The Performance of Surface Modified NACA 2416 Airfoils at Various Angles of Attach at Re80000

Abhishek T K^{1,*}, H V Srikanth², Ramvishal³, Venugopal M M⁴

Abstract

This study delves into the aerodynamic effects and characteristics of surface-modified NACA 2416 airfoils, placing a greater emphasis on the aerodynamic efficiency of a two-dimensional surface-modified NACA 2416 airfoil under subsonic flow conditions at $Re=80000$ and various angles of attack (AOAs). The surface-modified airfoils were crafted using CATIA V5, and simulations were conducted in ANSYS Fluent for angles of attack ranging from 0° to 12° . The CFD results encompass a broad spectrum of surface modifications, including cuts of 20%, 40%, and 80% on the bottom surface. The analysis covers key aerodynamic characteristics such as the Coefficient of Lift, Coefficient of Drag, and Pressure Distribution. The airfoil featuring an 80% chord cut, positioned near the trailing edge, exhibits a gradual flow acceleration, leading to increased pressure on the lower surface and consequently, a maximum lift coefficient. Flow separation is identified within the range of 0° to 12° AOA for all three airfoils. Notably, airfoils with an 80% chord cut experience earlier stall compared to the other two airfoils.

Keywords: NACA, AOA, Coefficient of lift, Coefficient of drag, Pressure distribution, Flow analysis, ANSYS Fluent, Reynold's number (Re)

INTRODUCTION

People have been constantly working to improve the quality of flow over the aircraft components such as wings, fuselage, and empennage. This project gives an idea of how to improve the overall performance of the wing in terms of lift, and stability characteristics. [2] [3] Any geometry producing more lift and less drag when kept in the flow of air is known as an airfoil. We have been chosen NACA 2416 airfoil over NACA 0012 [5], the differences between the Aerodynamic properties of these airfoils are the NACA0012 airfoil has a symmetric profile, meaning that the upper and lower surfaces are mirror images of each other with respect to the chord line The "0012" in its name indicates that the airfoil has 0% camber (symmetric) and a 12% thickness-to-chord ratio whereas NACA 2416 airfoil has a 2% camber and a 12% thickness-to-chord ratio. The camber means that the airfoil has a curved shape, and the "2412" indicates the specific camber and thickness distribution, The NACA 2412 airfoil, with its camber, generally produces more lift compared to the symmetric NACA 0012 airfoil at moderate angles

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of attack. This can be advantageous for applications where lift is a critical factor, such as in aircraft wings, the NACA 0012 are using in horizontal stabilizers of aircraft or rotor blades in some helicopter designs, the NACA 2412 [7], are commonly used in main wings of aircraft where a higher lift coefficient is needed for takeoff and landing performance, The drag characteristics depend on the specific conditions and the angle of attack, but in general, the NACA 2412 might exhibit slightly higher drag at zero lift compared to the NACA 0012 due to its camber. In this paper, we have designed NACA 2416 with an inward cut of

Chord length at 20%, 40%, and 80% and performed a CFD test in each cut and compared the aerodynamic efficiency. Various researchers have studied the aerodynamic performance characteristics of various airfoils. A few research works have been presented as follows. O. John E. Matsson [1] presented a conference on “Aerodynamic Performance of the NACA 2416 Airfoil at Low Reynolds Number” and explained CFD simulations using ANSYS Fluent software. A. Ram Krishna Prasad [2] published a journal on “Flow Simulation on New Airfoils Design” and here new airfoil shapes were created and designed and analyzed by using CATIA and ANSYS software respectively. The C_L and C_D were calculated for both NACA 2412 and new airfoil shapes. Arvind Prabhakar [4][9] published a journal on “CFD Analysis on MAV NACA 2416 Wing in High Lift Take-Off Configuration for Enhanced Lift Generation” from this we studied the design and analysis processes and airfoil stalling phenomenon at various AOA.

METHODOLOGY

Modelling: The surface modified NACA 2416 airfoils were obtained from CATIA tools. [2] This was simulated by ANSYS. [8] Three surface-modified airfoils were designed from the main NACA 2416 airfoil. We cut the main airfoil vertically inward about 2mm on the lower surface at 20%, 40%, and 80% of chord length as shown in Figures 1, 2, and 3.



Figure 1. 20% chord cut

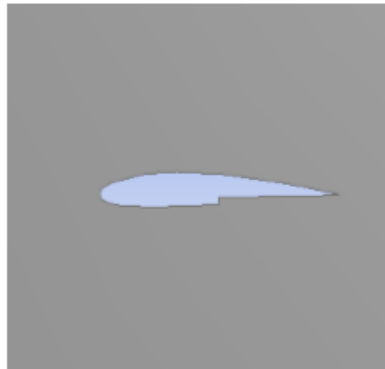


Figure 2. 40% chord cut

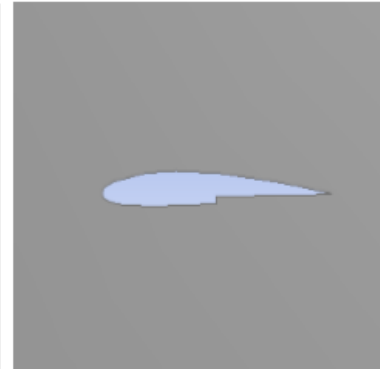


Figure 3. 80% chord cut.

Meshing: All the above designs were analyzed using ANSYS fluent. We used structured mesh elements in the entire far field. [6] For the generation of structured mesh, we used the sizing technique and mapped face methods available in the ANSYS workbench. [2] To obtain more mesh density near the airfoil, we gave a matching spacing pattern along with a few divisions as 60. The spacing pattern given at different elements should match to get structured mesh elements in every part of the far field. We did a trial-and-error method to obtain proper matching of these spacing patterns for different elements. Mesh generations are shown in Figures 4, 5, and 6.



Figure 4. 20% chord cut



Figure 5. 40% chord cut



Figure 6. 80% chord cut

Table 1. Boundary conditions.

Model	K- ω Turbulence model
Fluid	Ideal
Flow Condition	Steady

Inlet	Velocity (Inlet)
Outflow	Pressure (outlet)
Fairfield	Wall
Top and Bottom wall	Free Slip
Solver	FLUENT

COMPUTATIONAL WORK

Velocity and pressure contour: We have taken a Reynolds number of about 80000 and we did a flow test around all three modified NACA 2416 airfoils and obtained velocity and pressure contour at $0^\circ, 4^\circ, 8^\circ, 12^\circ$ AOAs. The results are shown below.

Airfoil: 20% chord cut, Reynolds number: 80000, AOA: $0^\circ, 4^\circ, 8^\circ, 12^\circ$

Pressure contour

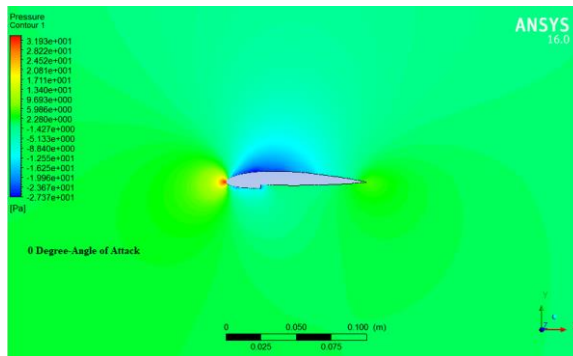


Figure 7. AOA= 0°

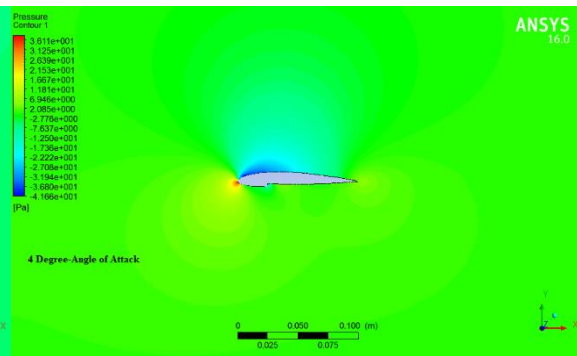


Figure 8. AOA= 4°

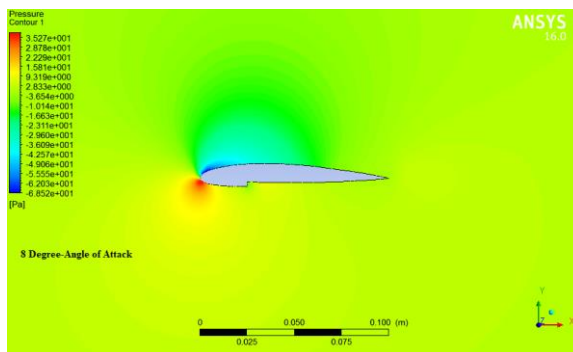


Figure 9. AOA= 8°

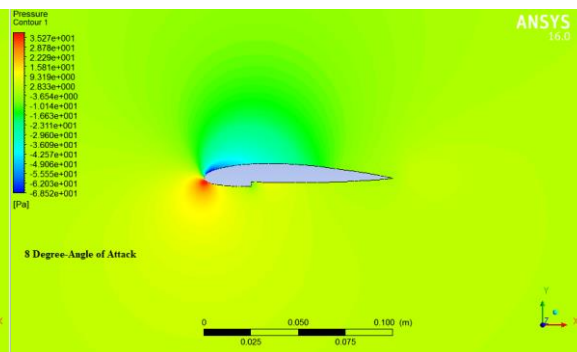


Figure 10. AOA= 12°

Velocity contour

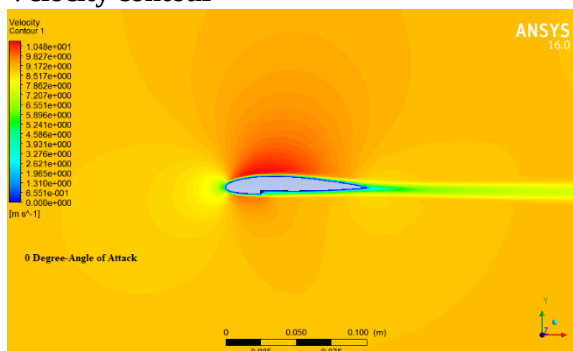


Figure 11. AOA= 0°

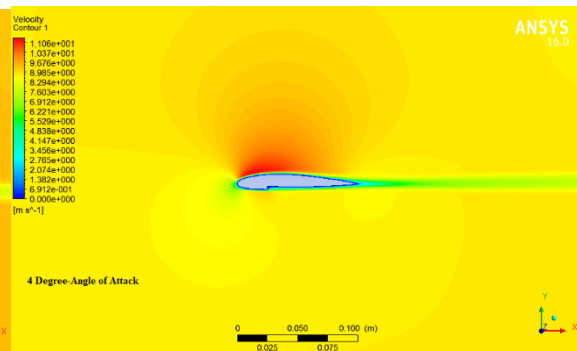


Figure 12. AOA= 4°

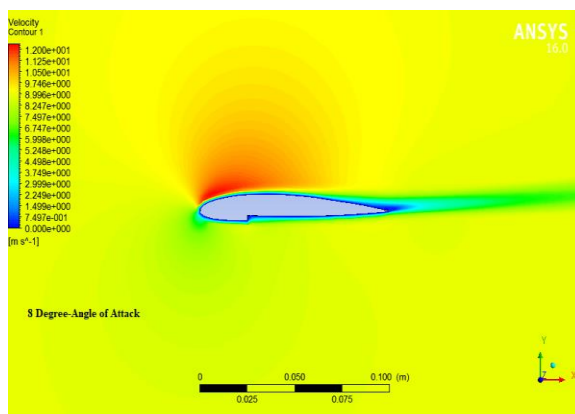


Figure 13. AOA=8°

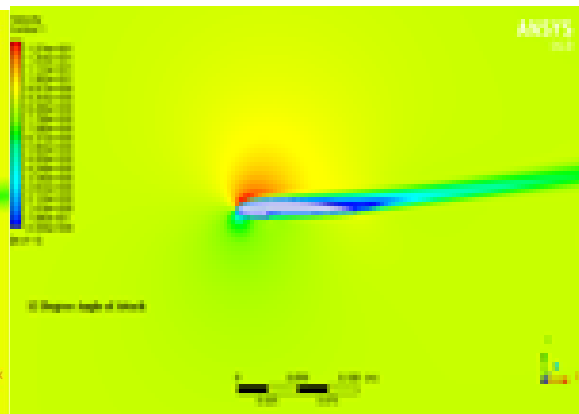


Figure 14. AOA=12°

RESULTS AND DISCUSSION

Pressure distribution over 20% chord cut airfoil for $Re=80000$ at AOA 0° , 4° , 8° , 12°

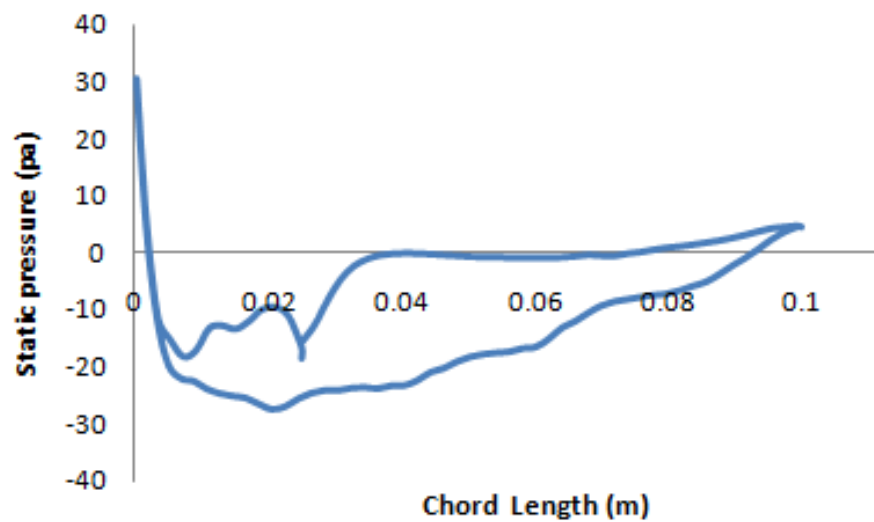


Figure 15. AOA=0°

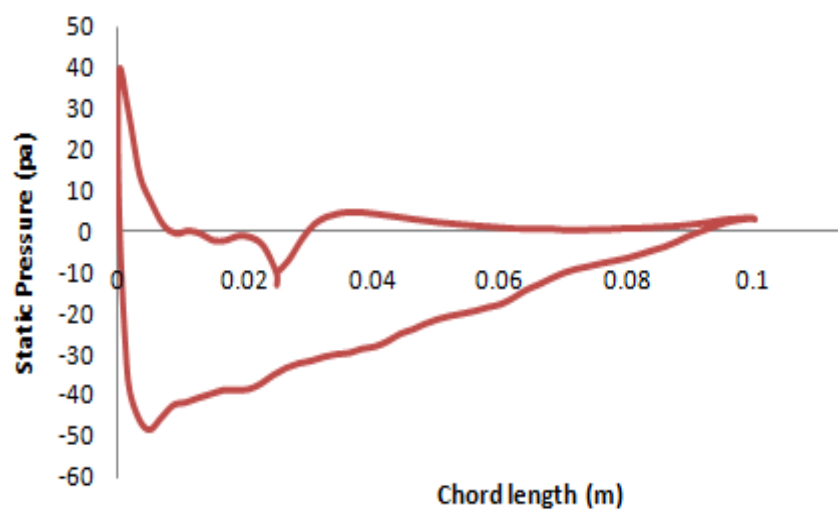


Figure 16. AOA=0°

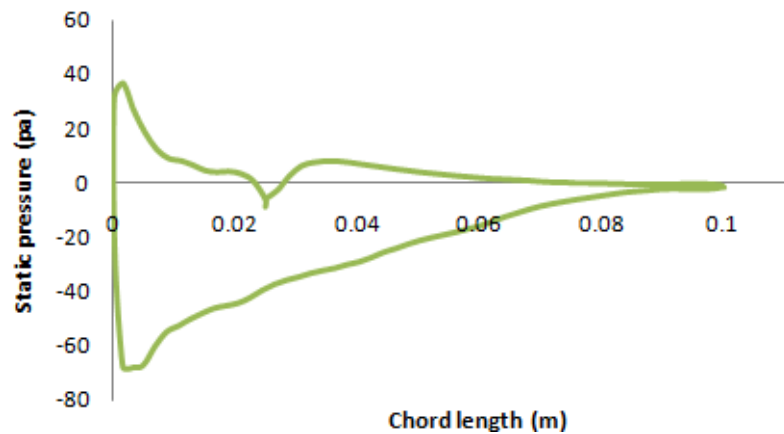


Figure 17. AOA=0°

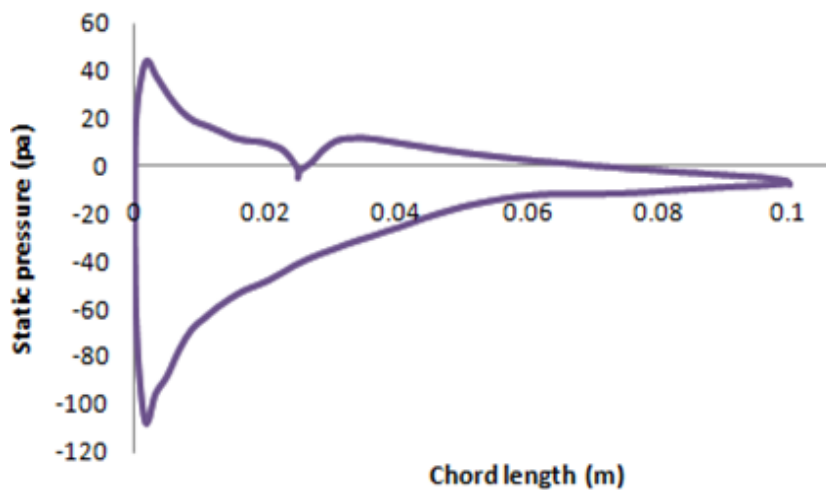


Figure 18. AOA=0°

The above graphs indicate static pressure v/s chord length over an airfoil at 0, 4, 8, and 12-degree angles of attack respectively, for 3 mm 90° inward cuts at 20% of chord length and Reynolds number 80000. The upper line of the graph indicates the lower surface of the airfoil, and the lower line indicates the upper surface of the airfoil.

Table 2. L, D, C_L, C_D for different AOAs for 20% chord cut at Re=80000.

Angle of attack(degree)	Lift	Lift coefficient	Drag	Drag coefficient
0	1.1912	0.0256	0.0765	0.0040
4	2.0949	0.0462	0.0053	0.0015
8	2.9820	0.0667	0.1757	0.0028
12	3.5317	0.0785	0.3318	0.0060

The same procedure was repeated for 40% and 80% of chord cut airfoil and outputs were obtained as shown below:

Table 3. L, D, C_L, C_D for different AOAs for 40% chord cut at Re=80000.

Angle of attack(degree)	Lift	Lift coefficient	Drag	Drag coefficient
0	1.3108	0.0272	0.0866	0.0034
4	2.2611	0.0492	0.0109	0.0054
8	3.3143	0.0693	0.1998	0.0087
12	3.8002	0.0841	0.3684	0.0064

Table 4. L, D, C_L, C_D for different AOAs for 40% chord cut at Re=80000.

Angle of attack(degree)	Lift	Lift coefficient	Drag	Drag coefficient
0	1.4474	0.0341	0.0784	0.0099
4	2.4362	0.0574	0.0391	0.0084
8	3.6401	0.0783	0.2372	0.0075
12	4.3307	0.0979	0.4600	0.0117

Table 5. Comparing the lift coefficient v/s AOA of all test cases.

AOA	20% cut	40%cut	80%cut
0	0.0256	0.0272	0.0341
4	0.0462	0.0492	0.0574
8	0.0667	0.0693	0.0783
12	0.0785	0.0841	0.0979

Comparing all three airfoil lift coefficients, increasing the chord cut from 20% to 80% resulted in an increment of the lift coefficient.

CONCLUSION

All three surface-modified airfoils were analyzed and obtained the result for four different angles of attack that are 0°, 4°, 8°, and 12°. The lift coefficients of all three surface-modified airfoils were compared, and from this result, we can see that change in chord cut from 20% to 80% resulted in an increase in lift co-efficient also there is an increasing lift coefficient, because, the 20% chord cut is near the leading edge of the airfoil so the flow acceleration is more on the lower surface and the pressure decreases resulting in minimum lift coefficient. The airfoil with 80% of chord cut is near the trailing edge so flow accelerates slowly, and pressure increases on the lower surface resulting in maximum lift coefficient. The flow separation is found between 0° and 12° AOA for all three airfoils. Airfoils with 80% chord cut stall earlier compared with the other two airfoils. Hence, it can conclude that the surface modified NACA 2416 airfoil with an 80% chord cut produces the highest lift coefficient.

REFERENCES

1. Matsson JE, Voth JA, McCain CA, McGraw C. Aerodynamic performance of the NACA 2412 airfoil at Low Reynolds Number. In 2016 ASEE Annual Conference & Exposition 2016 Jun 26.
2. Rakesh CM, Hiremath N, Harshith JN, Dhanush DR. A study on performance of surface modified NACA 2412 airfoil at various Reynolds number and angle of attacks. Journal of Mines, Metals and Fuels. 2021 Dec 1:269-75.
3. Prabhakar A, Ohri A. CFD analysis on MAV NACA 2412 wing in high lift take-off configuration for enhanced lift generation. J Aeronaut Aerospace Eng. 2013 Dec;2(125):2.
4. Lindsay SD, Walsh P. Experimental investigation of spoiler deployment on wing stall. Open Journal of Fluid Dynamics. 2018 Sep 20;8(03):308.
5. Sarkar S, Mughal SB. CFD analysis of effect of flow over naca 2412 airfoil through the shear stress transport turbulence model. International Journal of Mechanical and Production Engineering. 2017 Jul;5(7):2320-092.
6. Saxena ES, Kumar MR. Design of NACA 2412 and its Analysis at Different Angle of Attacks, Reynolds Numbers, and a wind tunnel test. International Journal of Engineering Research and General Science. 2015 Mar;3(2):193-200.
7. Chalia S, Bharti M. Design and analysis of vortex generator and dimple over an airfoil surface to improve aircraft performance. IJA-ERA. 2017 Aug;3(4):173.
8. Yogesh Thawrani and Ajith Kumar S Department of Mechanical Engineering, Amrita Vishwa Vidyapeetham, Amritapuri, India "Influence of surface temperature on the flow characteristics of NACA 2412 airfoil" Volume 119 No. 12 2018, 71-75 ISSN: 1314-3395.
9. Islam MT, Arefin AM, Masud MH, Mourshed M. The effect of Reynolds number on the performance of a modified NACA 2412 airfoil. In AIP conference proceedings 2018 Jul 13 (Vol. 1980, No. 1). AIP Publishing.