A Computational Case Study on Aerodynamic parameters of NACA symmetrical Aerofoils

Bilji C mathew

1Research scholar , Department of aerospace, Lovely professional university
bilji.20206@lpu.co.in

ABSTRACT

The objective of this research is to determine the velocity and pressure field of NACA-0022 airfoil by solving the governing equation using Ansys fluent and to validate the result data of 10degree angle of attack of an airfoil with the experimental data provided by NASA such as1)Pressure coefficient. 2)Lift and drag coefficient.Also to determine the stalling angle by changing the angle of attack to 4,6,10,15,19 degree. During the research we found that The NACA 4 digit airfoil have a higher efficiency at Tip speed ratios of 7. The study of flow over NACA 4 digit airfoil is done for the Reynolds number (Re) of 105 and Richardson number (Ri) ranging from -0.5 to +0.7 at zero degree angle of attack. It has been found that with the increase in Ri, the Cl decreases almost linearly. On the contrary with the increase in Ri, the Cd increases. We found that the surface heating results in the early flow separation and is attributed to such behavior for Cl and Cd. Early flow separation leads to broaden the wake width and static pressure distribution around the airfoil modifies which eventually resulting in an increase in Cd and decrease in Cl on heating the airfoil surface.

Key words: Aerodynamics , wing , winglets, angle of attack , low speed, Aerofoil's

INTRODUCTION

NACA airfoil is the shape of the aircraft wing which was introduced by National Advisory Committee of Aeronautics. Its series is controlled by 4 digit-(a)The first digit is the maximum camber divided by 100.(b)The second digit is the position of maximum camber divided by 10.(c)The last two digits are the thickness od air foil divided by 100. Below are the fundamental governing equations.

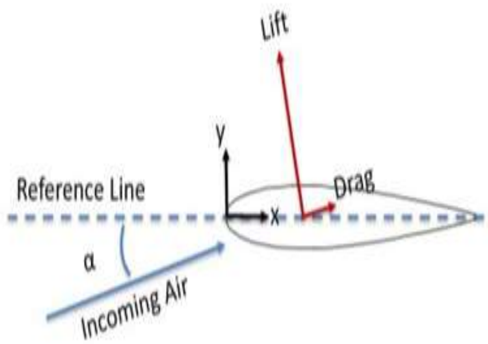
$$\frac{\partial \bar{u}}{\partial x}+\frac{\partial \bar{v}}{\partial y}=0$$

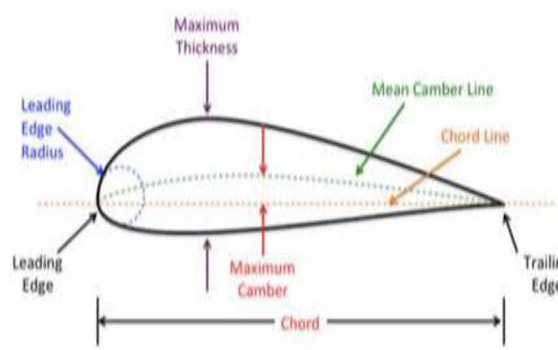
$$\rho\left(\bar{u}\frac{\partial \bar{u}}{\partial x}+\bar{v}\frac{\partial \bar{v}}{\partial y}\right)=-\frac{\partial \bar{p}}{\partial x}+\mu\nabla^2\bar{u}+\bar{f}_{turb,x}$$

$$\frac{\mu_t}{\rho}\approx\frac{C_\mu k^2}{\epsilon}$$

$$C_p=\frac{p-p_\infty}{\frac{1}{2}\rho_\infty V_\infty^2}=\frac{p-p_\infty}{p_0-p_\infty}$$

Assumptions taken 1). Steady flow 2). Two dimensional flow 3). Incompressible flow 4). Average Velocity The governing equation is required to solve the problem of our flow over an airfoil in fluent.assumption to be comsidered





wind tunnel was used to revise lift increase and streamlines patterns using over a NACA 4 digit airfoil replication representation we monitor with the intention of because the angle of attack increase, the value of lift also increases which in turn implies increase in lift coefficient as shown in Figure 15 and 16. Hence, we can conclude that the effect of slot is to energize the sluggish moving boundary layer and prevent separation which reduces the induced drag. This means we can generate same amount of lift with lesser fuel. This design improves the aerodynamic performance and increases structural strength of the aircraft wing compared to other conventional high-lift devices and flow-control devices. This design improves the aerodynamic performance and increases structural strength of the aircraft wing compared to other conventional high-lift devices and flow-control devices. Early flow separation leads to broaden the wake width and static pressure distribution around the airfoil modifies which eventually resulting in an increase in C_D and decrease in C_L on studying the airfoil surface .

REVIEW OF LITERATURE

Firooz et al (2006) [1] Turbulence Boundary layer effect near and far region from the ground has been calculated for different angle of attack. For the validation computational analysis also carry forward in the research. The data shows the variation of the lift co-efficient over the airfoil will vary depends on the angle of the attack, in the same manner drag co-efficient of the following Airfoil also been calculated and validated. Till the buffer layer the Numerical data matches highly with the experimental data's. For the fixed ground condition, due to the escape flux near the ground, pressure drag coefficient increases in suction side, also velocity gradient increases in pressure side resulting friction drag, coefficient increases, so drag coefficient simulated by the fixed ground near the ground, is to some extent larger than that of the fixed one.

Alex et al (2013) [2] The Research shows the effects of different faps in the ground condition has been calculated and the results has been validated with the computational data. The study shows that if the flaps is deflected in the smaller angle and the effect is high comparing to the large deflection. we will get the augmented lift to drag ratio at the point. In the low flap angle the flaps holds high amount of air and creates a low pressure at the top of the aircraft.

Abreu et al (2018) [3] With respect to SPOD and DNS method the airfoil analysis has been carried out for a constant Reynolds number. In that chord wise wave pockets shows that there were more acceleration initiated in that region comparing to the other region. Based on the wave pockets acceleration the value of increment in the result as shown. In the turbulent flow acceleration is maximum at the chord wise manner comparing to span wise manner

Hossain et al (2014) [4] Using Finite element analysis method Two aerofoil's has been analyzed and the variation in the co-efficient of lift and drag value has been calculated with respect to different angle of attack. Lift to Drag ratio and pressure co-efficient value also found and its shown that NACA 4412 is having high amount of practical application comparing to other. Static pressure distribution on these two aerofoils was visualized. It was found that for same angle of attack, NACA 4412 has less negative pressure on the upper surface than NACA 6409

QiulinQu et al (2014) [5] Dynamic ground effects to the NACA 4412 airfoil has been carried out. It shows that when the aircraft altitude changes based on that properties of the lift and drag and other criteria also changes continues and the effects shows the variation the compression work effect becomes very important. At relatively small height, the air below the airfoil does not have sufficient space to escape due to the blockage from the ground as the airfoil moves downwards towards the ground. So the changes in altitude will create the changes in aerodynamically forces of airfoils.

Mustafa et al (2017) [6] For a wind turbine blade design efficiency two NACA serious airfoil has been taken forward. Based on the aerodynamic efficiency of the airfoils the wind turbine efficiency will vary, so to finalize the effective airfoil low analysis has been carried out and the lift and drag co-efficient value has been found out for constant Reynolds number using Ansys.Different angle of attack the upper surface velocity is maximum comparing to lower surface.

Febriyanto et al (2019) [7] To improve the Horizontal axis wind turbine performance the blade aerodynamic efficiency is taken in to account. To improve the efficiency pith angle has been decided for the particular wind turbine for the particular wind speed. In that 4 degree is the best pitch angle for 2m/s is identified using computational analysis and experimental data. For the large wind turbine large blade angle need to be followed. Increment of pith angle will result in low power generation.

Hao Wu et al. (2008) [8] The heat transfer performance over flat surface on 10mm high and 20mm long delta winglet. The height on the wind tunnel is about 30mm and Reynolds number is 6000. The total focus is on angle of attack which is varies from 30 to 60 degree with increment of 15-degree angle. The bottom side of the flat surface is heated stream of 100deg cal. For evaluation of heat exchanger performance, the ratio of heat transfer for the flow is loss which is introduced to take the pressure value which is loss in their consideration. The result shows that the best performance is acted on 30 degree of angle of attack and 15 degree of louver angle

SIMUALTION SET UP

A) Input Parameter

Airfoil chord length=1m
Free stream velocity=51.45 m /sec Density=1.1767Kg/m^3
Coefficient of viscosity = 1.009×10−5kgm^3

NASA Experimental data

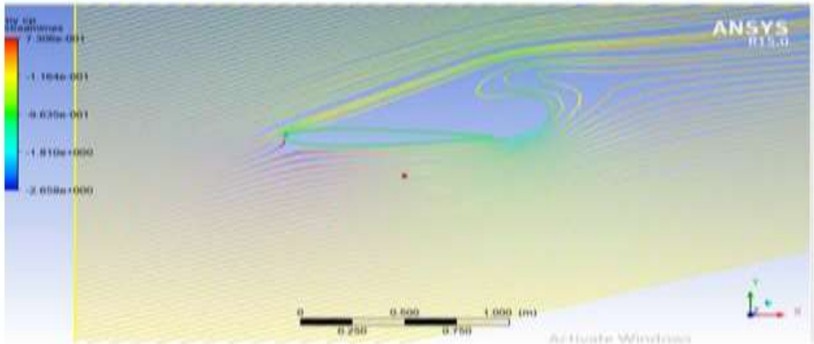
Coefficient of lift (10º)=1.1

Coefficient of drag (10º)=0.012

B) Numerical Model

Meshing nodes and elements

Nodes	67412
Elements	33519



Stream line flow on NACA 0022

SCOPE AND OBJECTIVE OF THE STUDY

The basic scope of studying symmetrical aerofoil is to study the characteristic behavior of aerodynamic parameters at different angle of attack set parameters in Ansys software and plot the curve and see the variation of lift curve at stalling angle.The basic interest here is to compare the result of symmetrical aerofoil at different angle attack and plot the lift and drag curve.

RESULT AND DISCUSSION

Result of NACA 0022 at 4º angle of attack and pressure velocity counter fluent simulation is taken

Pressure contour

From the pressure contour we got a desired result from fluent simulation as pressure variation was generated. Upper region has low pressure and lower region has high pressure as expected.

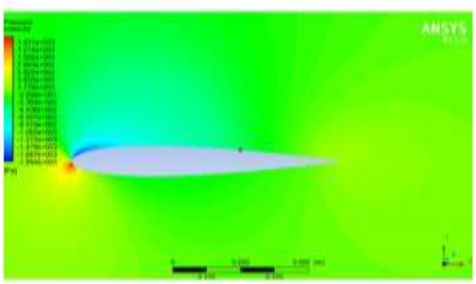


Fig:1 pressure contour at 4º AoA

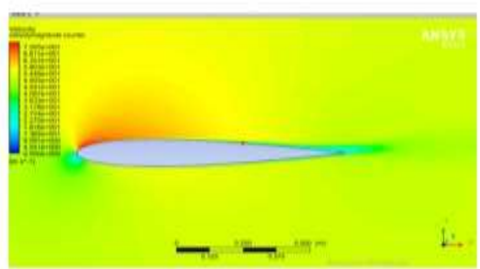


Fig:2 Velocity contour at 4º AoA

Velocity contour

As turbulent flow is generated by the separation of the flow we neglect the fluctuating velocity and calculated on the basis of time average velocity and flow is steady. From the Bernoulli equation which state that with increase in pressure te flow velocity decrease and result from simulation was appeared as expected.

The final value of Cl and Cd converge for NACA-0022 airfoil at 4(degree)is 0.3301 and 0.008909 respectively.

Pressure coefficient Graph

Coefficient of pressure is important factor fo determining the lift and drag value. It also helpful in understanding the high speed and low speed flow. Here is the variation of cp curve along x direction.

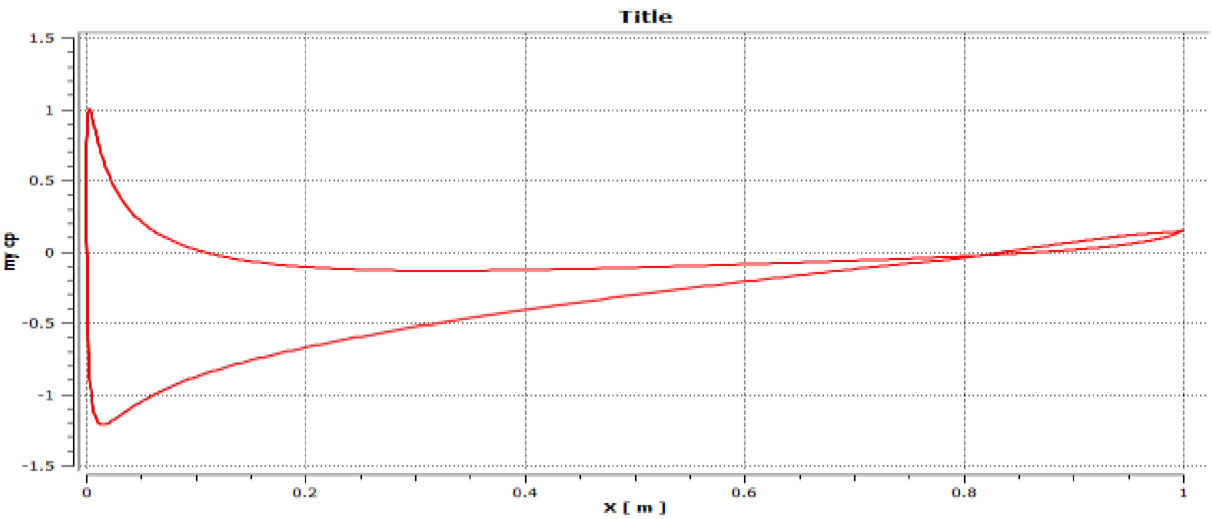


Fig:3 plotting of C_p along x-axis

NACA 0022 at 6º Angle of Attack

Result of NACA 0022 at 6º angle of attack and pressure velocity counter fluent simulation is taken

Pressure contour

From the pressure counter we got a desired result from fluent simulation as pressure variation was generated. Upper region has low pressure and lower region has high pressure as expected. However in the figure a concentrated pressure region can be seen formed at the leading edge of the symmetrical aerofoil.

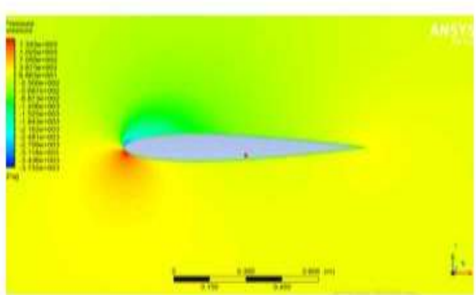


Fig:4 Pressure contour at 6º AoA

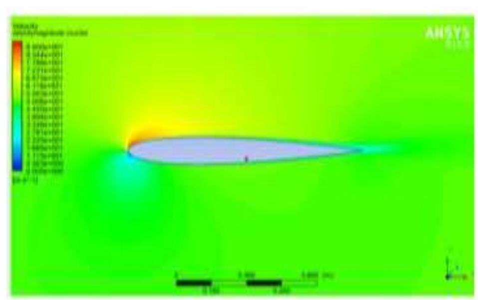


Fig: 5 velocity contour at 6º AoA

Velocity contour

The final value of Cl and Cd converge for NACA-0022 airfoil at 6(degree) is 0.646 and 0.01089 respectively.

Pressure coefficient Graph

Coefficient of pressure at 6º angle of attack is important factor for determining the lift and drag value. It also helpful in understanding the high speed and low speed flow. Here is the variation of cp curve along x direction

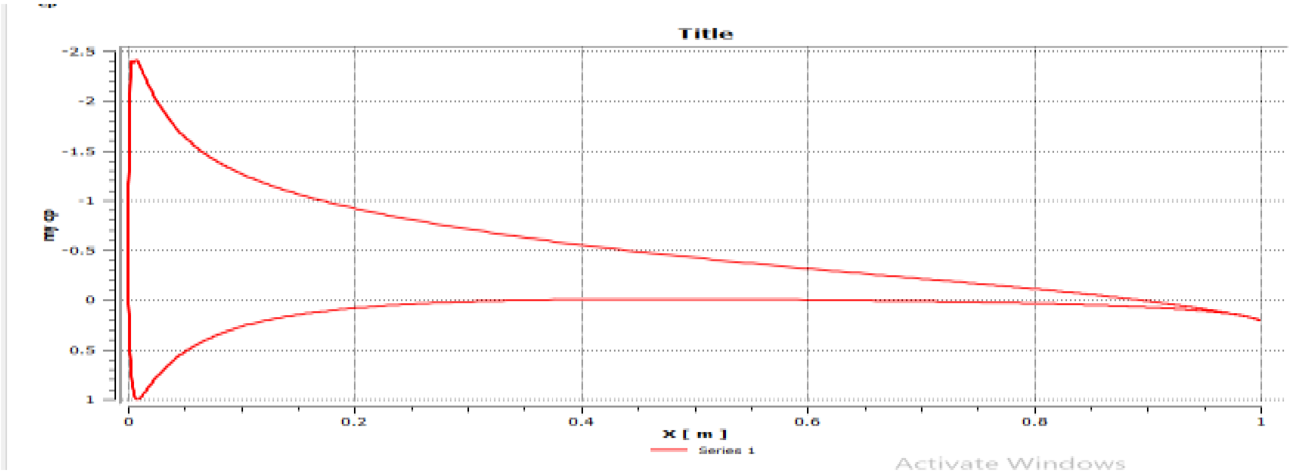


Fig:6 plotting of C_p along x-axis

NACA 0022 at 10º Angle of attack

Result of NACA 0022 at 10º angle of attack and pressure velocity counter fluent simulation is taken.

Pressure Contour

From the pressure contour we got a desired result from fluent simulation as pressure variation was generated. Upper region has low pressure and lower region has high pressure as expected and it can be noted that there is a drastic change in pressure at stagnation point on the leading edge of aerofoil.

Velocity Contour

From the velocity contour diagram we find that there is formation of transient point on the top of symmetrical aerofoil at the trailing edge of aerofoil. In this figure we can notice the origin of flow separation.
The final value of Cl and Cd converge for NACA-0022 airfoil at 10º Angle of attack is 0.8815 and 0.4046 respectively.

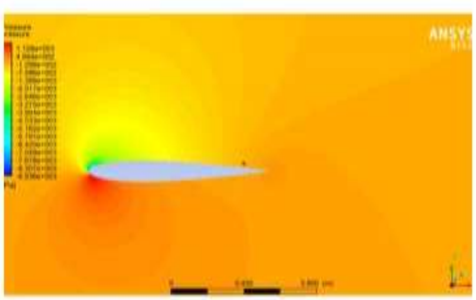


Fig:7 Pressure contour at 10º AoA

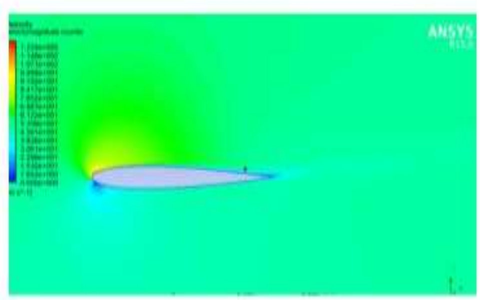


Fig:8 Velocity contour at 10º AoA

Coefficient of pressure

Here we have compared our data with NASA experimental data which signify that our simulation the result was near to that value. A green dot represents NASA experimental data. Red curve line depicts our simulation data.

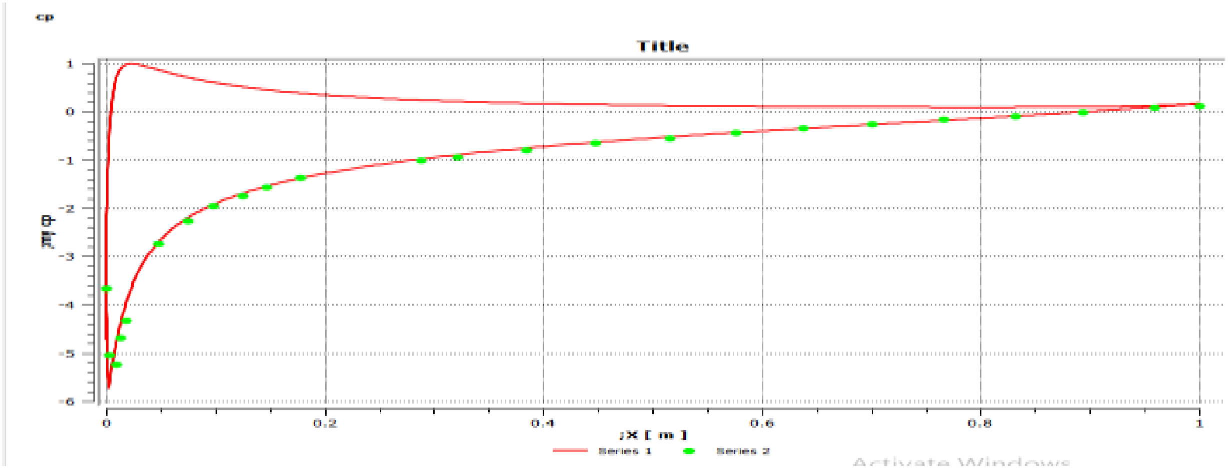


Fig:9 Plotting of C_p along x-axis

NACA 0022 at 15º Angle of attack

Pressure contour

Here we again compared our data with NASA experimental data which signify that our simulation the result was near to that value. A green dot represents NASA experimental data. Red curve line depicts our simulation data.

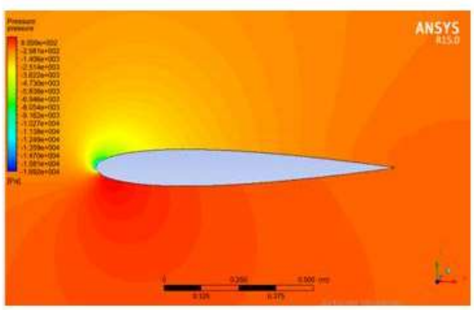


Fig:10 Pressure contour at 15º AoA

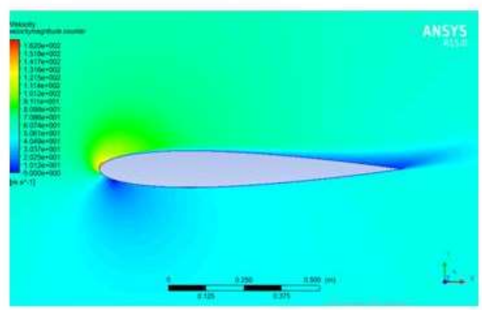


Fig:11 Velocity counter at 15º AoA

Velocity contour

The final value of Cl and Cd converge for NACA-0022 airfoil at 15º Angle of attack is 1.4913 and 0.310 respectively. In the figure flow separation predominates as we near the stalling angle at trailing edge of symmetrical aerofoil.

Coefficient of Pressure

Here we have compared our data with NASA experimental data which signify that our simulation the result was near to that value. A green dot represents NASA experimental data. Red curve line depicts our simulation data

NACA 0022 at 19º Angle of attack

Pressure Contour

At high angle of attack the flow separation predominates and almost all the lift is lost due to increased flow separation and there is least pressure variation on the surface of symmetrical aerofoil.
The final value of Cl and Cd converge for NACA-0022 airfoil at 19º angle of attack is 0.646 and 0.01089 respectively. Here the separation was increased more turbulent was generated as shown in simulation.

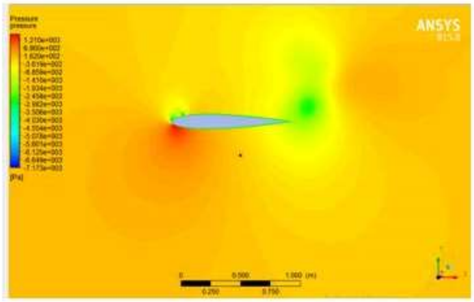


Fig:12 Pressure contour at 19º AoA

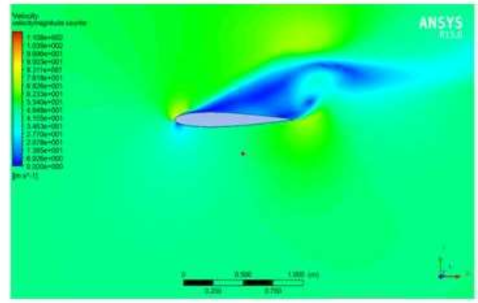


Fig: 13 Velocity contour at 19º AoA

Velocity contour

From the velocity contour diagram we find that there is formation of transient point on the top of symmetrical aerofoil almost at the leading edge of aerofoil. In this figure we can notice the origin of flow separation at the high angle of attack on the symmetrical aerofoil.

Stream line

The figure below shows the formation and separation of stream lines on NACA 0022 symmetrical aerofoil at higher angle of attack and we notice that there is huge variation coefficient of pressure along x axis at 19º angle of attach and the figure is given below for verifying. Here we have compared our data with NASA experimental data which signify that our simulation the result was near to that value. A green dot represents NASA experimental data. Red curve line depicts our simulation data

Conclusion

From the computed data the angle of attack at which the stall occur is 15degree and the corresponding Coefficient of Lift and Drag value is 1.4913 and 0.310 respectively. Also, verification of Cl, Cd and Cp of NACA-0022 airfoil at a 10degree angle of attack was verified form experimental data provided by NASA. Actually, the value of Cl given by NASA for 10degree was 1.1 and Cd was 0.012 but small variation was coming due to course mesh. By improving the mesh the accuracy will further increase and also the need for high computational computer required to get a more accurate value.

References

[1] A. Firooz , M. Gadami Turbulence Flow for NACA 4412 in Unbounded Flow and Ground Effect with Different Turbulence Models and Two Ground Conditions: Fixed and Moving Ground Conditions Int. Conference on Boundary and Interior Layers BAIL 2006.
[2] Alex E, Ocvkfen Aerodynamic characteristics of NACA 4412 airfoil section with flap in extreme ground effects JNAOE 2009
[3] Leandra I. Abreu∗ , André V. G. Cavalieri wavepackets in turbulent flow over a naca 4412 airfoil 31 congress of the international council of the Aeronautical science 2018
[4] Mustafa Yılmaz A comparative CFD analysis of NACA0012 and NACA4412 airfoils Journal of Energy Systems 2017
[5] QiulinQu, XiJia Numerical study of the aerodynamics of a NACA 4412 airfoil in dynamic ground effect Aerospace science and technology 2014
[6] Rusdi Febriyanto1 , Bayu Rudiyanto Study experimental of blade NACA 4412 with pitch angle on horizontal wind turbine Journal of Physics 2019
[7] MD. Safayet Hossain1 , Muhammad Ferdous Raiyan a comparative flow analysis of naca 6409 and naca 4412 aerofoil International Journal of Research in Engineering and Technology 2014
[8] Mohammed Ahmed Rasheed & Ahmed Adnan AL-Qaisy Experimental Investigation of Aerodynamic Characteristics of NACA 23015 under different angles of attack and Comparison with Available Package Eng.&Tech.Journal 2008