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Flow Separation Analysis For Various Angle of Attack on NACA 4412 Aerofoil A Computational Approach

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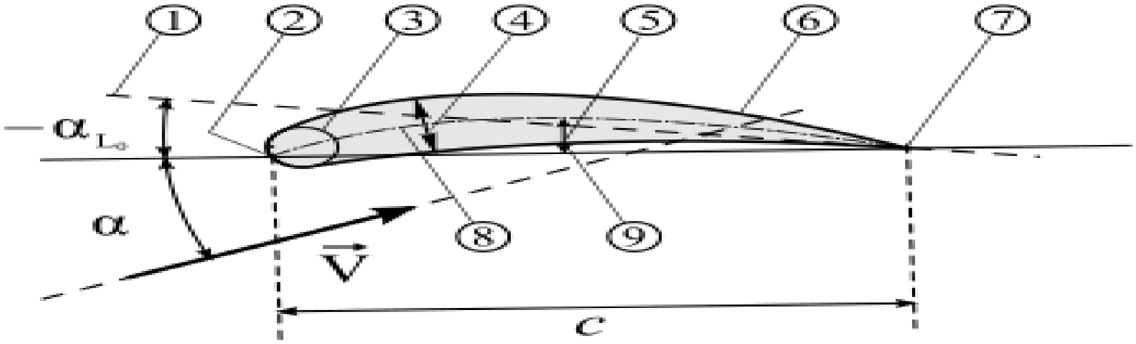
ABSTRACT

This paper has different parameters of an airfoil (NACA 4412). This paper attempts to discuss the changes in flow characteristics which the surface heating would bring in, when flow takes place over a NACA 4412 airfoil. In this numerical study, the surface heating is quantified using the non-dimensional number called the Richardson number, Ri. A positive value for the Ri indicates surface heating and negative value shows surface cooling. The numerical simulation is done using the commercial CFD package ANSYS Fluent. The investigation is performed for the Richardson number (Ri) ranging -0.5 to 0.7 and at standard sea level conditions. We have considered a single representative Reynolds number of $1x10^3$ at zero angle of attack of the airfoil. It is observed that both surface heating and cooling imparts asymmetry in the flow structure around the airfoil when flow takes place over it. And the surface temperature of the NACA 4412 airfoil has greater influence in the aerodynamic coefficients Cl and Cd.The NACA 4412 airfoil have a higher efficiency at Tip speed ratios of 7. The study of flow over NACA 4412 airfoil is done for the Reynolds number (Re) of 10^3 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.

INTRODUCTION

Airfoil

Generally airfoil is described the cross-section shape of an object with the help of air flowing through it so it producing aerodynamic force and also its able to produce thrust and lift as well. For different uses were preferred different types of airfoils shapes that’s considering under NACA (National Advisory Committee for Aeronautics) profile. Airfoil is considering in two part which is symmetrical and cambered airfoil.NACA mainly describing the airfoil into 3 major parts NACA 4 digit airfoil,NACA 5 digit airfoil, and NACA 6 digit airfoil.



(1) Zero lift line (2) Leading edge (3) Nose circle (4) Max. thickness (5) Camber (6) Upper surface (7) Trailing edge (8) Camber mean-line (9) Lower surface

NACA profile is used to describe the camber of the mean line of an airfoil and also for the distribution of thickness along the length of an airfoil. Mean line is also known as camber line which state that the line which joins the leading edge to trailing edge with an equal distance from lower surface to upper surface. Whereas the chord line is stating that it's the line which joins from the leading edge to the trailing edge directly.

NACA 4 digit is the first approach which is generally using in different aircraft, helicopters and in rotorcraft also.

In **NACA 4** digit were considering **NACA 4412.**
In this profile we are considering 4 digit where the

- 1st digit is refer to the Maximum camber,
- 2nd digit is the Location of maximum camber is of the chord line and,
- 3rdand 4th is the Maximum thickness.

In **NACA 5** digit we are considering **NACA 23012.**
Its known as the best airfoil in all 5 digit series.

- 1st is coefficient of lift (C_l),
- 2nd and 3rd is showing the position of the maximum camber with respect to the chord when we are diving it by 2 and,
- 4thand 5th is giving the thickness in percentage with respect to the chord.

In **NACA 6** digit we are considering **NACA 63012A**

- maximum thickness is 12% at 35% chord and,
- Maximum camber 0% at 0% chord.

Airfoil consideration performs really hard while we're making new wing and aiming for better outcomes. The consideration is also dependent on the requirement that shows the wing's performance on the platter. The entire performance is dependent on the styles of the airfoil.

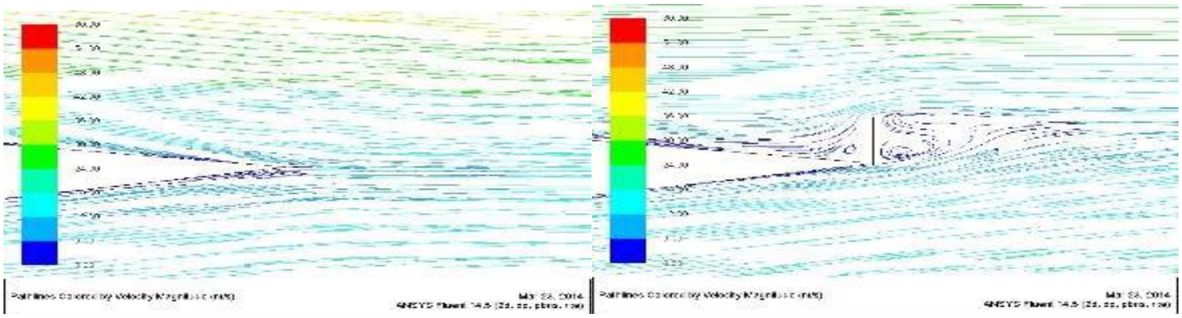
According to the NASA report, NACA 0012 is considered the best4-digit airfoil and NACA 23012 is the best Performing 5-digit airfoil while the 6-digit airfoil operates at a higher level because it shows higher performance so but we use 4 and 5 digits instead of 6-digit airfoil. While considering the airfoil, we should be aware of the uses and some resulting issue of the series that is being consulted under the NACA performance and we also take X foil's help to create a new airfoil as required.

LITERATURE REVIEW

Zhao et al [1] This paper is a validated study or comparison of experimental data of NACA 0012 airfoil at various Angle of attacks. Three types of grid topologies are used for the study firstly Structured O-grid, secondly Structured C-H grid, and thirdly Unstructured T- Rex grid. A grid generation software named Point wise is used to create Grids. The provided NACA0012 airfoil geometry was used, keeping the chord length as 1 meter. Field Boundary is set at approximately 50 chord lengths away from the airfoil. The differences to be minimized between each grid topology; wall spacing is kept at Δ s =1.0e-4; whereas grid point distribution kept at Δ d=0.01 at both its trailing and leading edges. After completion of the grid generations CFD++ Solver generated solutions at different angles of attacks are used. These generated Data and simulations were analyzed on Microsoft Excel. Co-efficient of lift Vs Angle of attack graph is plotted in comparison with experimental data(refer fig 1). Theoretical Co-efficient of lift was calculated using the thin airfoil theory within the same graph to set a comparison which is plotted against Co-efficient of drag. Conclusions were provided as that the structural grids give better results than the unstructured grids if the grid resolutions are good.

Platzer et al [2] This paper is a validation study of the flapping wing concept which shows the advance technology under the category of wing section where as the, it can be use in airplane. According to the paper which consider the flying theory of bird and the main advantage of taking this type of wing is indicating that it can be able to produce the lift as well as thrust at same interval of time. By using this technology we are assure it’s the more reliable, fuel efficient and simple & quieter. there is a concept of aerodynamic characteristics which indicate that the design which make the sustainable flight condition. The flapping replica is sustaining equal time interval of up and down stroke. Also the consideration of Navier Strokes equation in that the flapping angle denoted by which can varies with different interval of time.Conclusion is showing that we can able to increase the aerodynamic stability of the unsteady force and also improve the better performance. It containing light in weight, the thrust performance increase more compared to lift. A best performance is obtained by setting the down-stroke angle greater than the upstroke angle. We can use this concept in the future for better stability, better performance and the lighter weight with producing higher amount of thrust and consuming less fuel so it’s the best things we can consider under the wing design

Ganesan et al [3]This research paper deals with the effect of attached Gurney Flap at the trailing end of an inverted NACA 23012 rear wing. AUTOCAD 2013 was used for the creation and ANSYS Gambit 2.4.6 to check the meshing of the airfoil. Flow Analysis were considered only by placing the rear wing end in the pressure field neglecting the ground effects. Results were plotted considering various heights of gurney flaps keeping down force, drag and down force to (L/D) ratio factors keeping into account. Velocity of 0.1 Mach(33 m/s) was chosen and then the analysis were done at different angles of attacks. Contours of pressure distributions, pressure co-efficient and the flow path lines generated were visualized for varying the flow characteristics within the computational domain. Observations were done that with an increase in angle of attack and the gurney height, down force to L/D ratio increases.



Husain mehdi et al [4] This paper describes about the vibration analysis of a highly folded Dragonfly Wing section at low Reynolds numbers. Dragonfly wings are generally highly corrugated for its light weight and corrugation increases the overall aerodynamic performances and overall strength of the wing. These types of wings are widely applicable for Micro Air Vehicles (MAVs). The primary focus of the paper is to calculate and analyze the natural frequency of a Dragonfly Wing Section. The motive of choosing the Dragonfly insect is that as MAVs and Dragonflies almost work at the same Reynolds numbers (Re 10^2 to 10^4). Moreover the glide up path of a dragonfly without any loss of its altitude is 30 seconds, having a glide speed of 2.3m/sec. This paper focuses on the Numerical study of model Analysis for insects in 2D airfoils at very low Reynolds number in glide modes. This paper further throws some light on the different aerodynamic loading for different Reynolds numbers (100-1000) at different angles of attacks (0° to 15°) using ANSYS-14 Multi Physics Solver. These results displayed by the CFD Solver in forms of lift and drag forces are inputted in the ANSYS and thus model is analyzed.

Eleni et al [5] This paper is a validated study or comparison of experimental data of NACA 0012 airfoil at various Angle of attacks. Three types of grid topologies are used for the study firstly Structured O-grid, secondly Structured C-H grid, and thirdly Unstructured T- Rex grid. A grid generation software named Point wise is used to create Grids. The provided NACA0012 airfoil geometry was used, keeping the chord length as 1 meter. Field Boundary is set at approximately 50 chord lengths away from the airfoil. The differences to be minimized between each grid topology; wall spacing is kept at Δ s =1.0e-4; whereas grid point distribution kept at Δ d=0.01 at both its trailing and leading edges. After completion of the grid generations CFD++ Solver generated solutions at different angles of attacks are used. These generated Data and simulations were analyzed on Microsoft Excel. Co-efficient of lift vs Angle of attack graph is plotted in comparison with experimental data. Theoretical Co-efficient of lift was calculated using the thin airfoil theory within the same graph to set a comparison which is plotted against Co-efficient of drag. Conclusions were provided as that the structural grids give better results than the unstructured grids if the grid resolutions are good.

PARAMETERS FOR FLOW ANALYSIS

Parameters:

Density - 1.225 kg/m^3

Viscosity - 1.7894 kg/m-s

Inlet velocity – 18 m/s

Chord length – 0.1 m

Reynolds number – 1x 10^3

RESULT AND DISCUSSION

Velocity and pressure distribution over an airfoil (NACA4412) with different angle of attack

At 2^o degree Angle of attack

Pressure and velocity contour plotted at above mentioned flow parameters at 2 º angle of attack

Fig:1 Pressure contour at 2º AoA

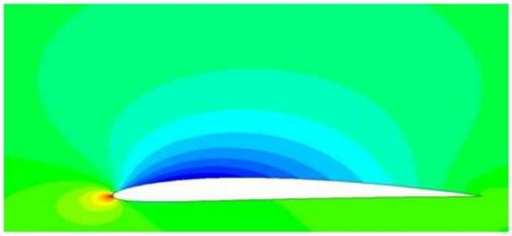


Fig: 2 Velocity contour at 2º AoA

At 6^o degree Angle of attack

Pressure and velocity contour plotted at above mentioned flow parameters at 6 º angle of attack

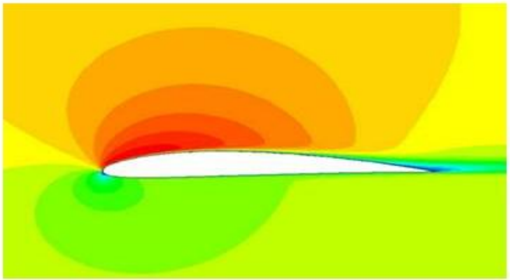


Fig:3 Pressure contour at 6º AoA

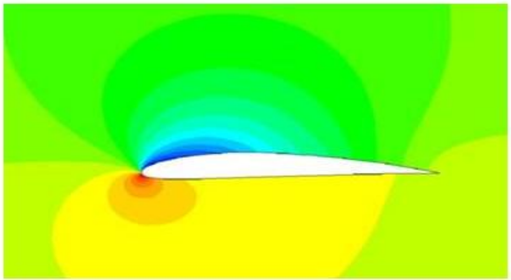


Fig: 4 Velocity contour at 6º AoA

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At 8º degree Angle of attack

Pressure and velocity contour plotted at above mentioned flow parameters at 8º angle of attack

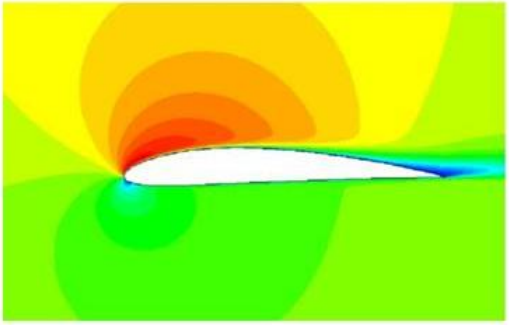


Fig:5 Pressure contour at 8º AoA

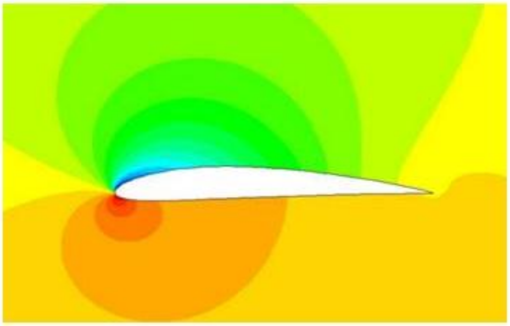


Fig: 6 Velocity contour at 8º AoA

At 10º degree Angle of attack

Pressure and velocity contour plotted at above mentioned flow parameters at 10 º angle of attack

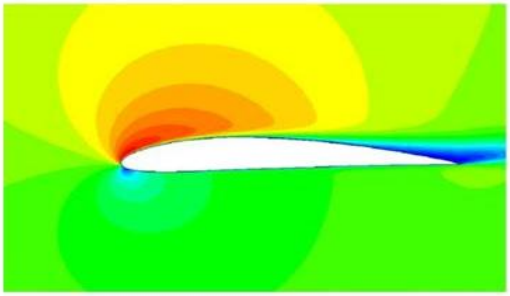


Fig:7 Pressure contour at 10º AoA

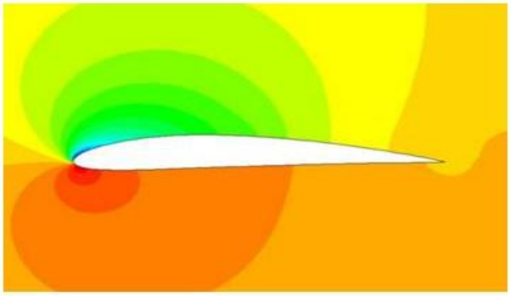


Fig: 8 Velocity contour at 10º AoA

Stream line flow on NACA 4412

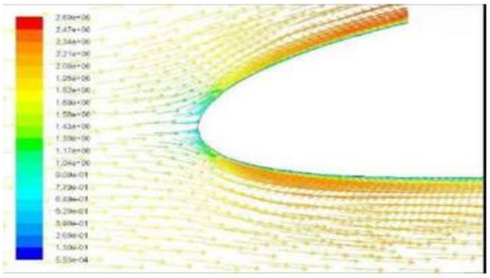


Fig:9 At 0 °degree angle of attack

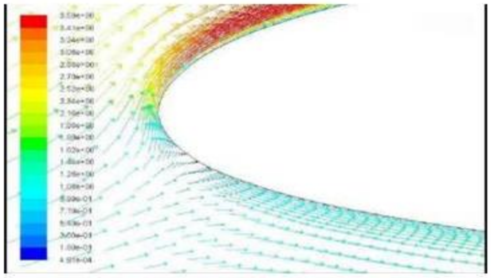
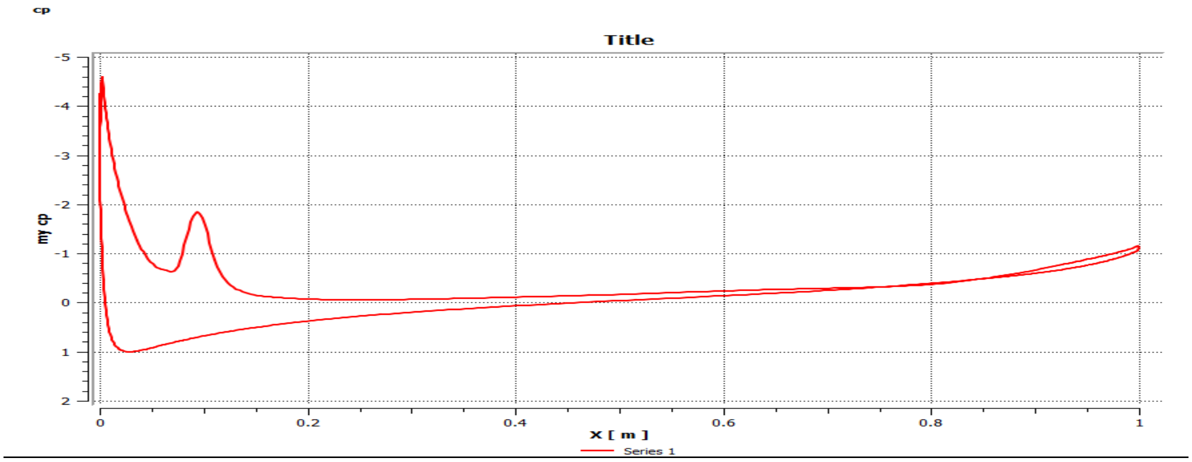


Fig: 10 At 8° degree angle of attack

Comparative study of simulation data to plot coefficient of pressure along x-axis

Angle of attack	U $[m/s^2]$	V $[m/s^2]$	FORCE VECTOR DRAG		FORCE VECTOR LIFT		Cl	Cd
			X	y	X	Y		
2	51.32	3.58897	0.99576	0.06976	-0.06976	0.99576	0.3301	0.008909
6	51.168	5.377	0.99452	0.1045	-0.1045	0.99452	0.646	0.01089
8	50.668	8.934	0.9848	0.1736	-0.1736	0.9848	0.8815	0.4046
10	49.69	13.31	0.9659	0.2588	-0.2588	0.9659	1.4913	0.310
12	49.456	14.81	0.96126	0.2756	-0.2756	0.9126	1.202	0.05816

Plotting of pressure coefficient along the x axis of the airfoil



CONCLUSION

Extended data is available on NACA 4412 from the literature review we found NACA 4412 is considered as one of the best airfoils after 5 digit profile and being considered mainly for research purposes, pressure plotting and velocity distribution on the airfoil surface was plotted and we find from the data that the flow pattern and streamline distribution is well oriented and even at higher angle of attach flow and stream lines pretty much adhere to the surface which in turn will enhance the lift production and considerably allowing more lift at stalling angles. However this type of flow analysis has to be extended at different mission profile so that one could get fair idea about the variation of different parameter at various Reynolds number and at different altitudes where the flow parameters changes drastically, so will be the performance and further simulation data and research is required to completely understand the characteristic of NACA 4412 airfoil and compare it with existing data**.**

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