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Aerodynamic Investigation of Flow Field Over NACA 4415 AIRFOIL

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ABSTRACT- The Airfoil NACA 4415 of aerodynamics are mainly used as a wind turbine blades. So the selection of suitable angle of attack for the projected airfoil section involves in this. So the reason of this study is to investigate the behavior of NACA 4415 air foil at different operating condition. In this research CFD analysis has been done over NACA 4415 has been used in fluent 6.3.26. The CFD analysis has been done for angle of attack 12^0, 14^0, 16^0 and 18^0 at Reynolds Numbers 1000000 and 1500000. It was found as the angle of attack enhances, the coefficient of lift also enhances, but after 16^0 coefficient of lift started to reduces due to adverse pressure gradient at the trailing edge.

KEYWORDS: Aerodynamics Airfoil, NACA 4415, Reynolds number, Angle of attack, lift, drag

I. INTRODUCTION

An airfoil is the two dimensional shape of the wings of the aircraft .the shape of the airfoil to be designed in the preliminary phase of aircraft development based on the aircraft performance requirements and technical requirements. Airfoil design is very important for aircraft as the aircraft's performance is determined by the airfoil to a large extent. This is especially true in transonic regime, where in the aircraft speed is limited by drag divergence which is caused by shock wave induced separation. With the assistance of optimization algorithms and computational fluid dynamics (CFD), a new innovative airfoil shape that has minimum drag could be designed with less development cost and fewer man hours.

Flat Bottom - A Flat Bottom Wing is when the lower surface of the wing is primarily flat between the leading and trailing edges. This type of wing has high lift and is common on trainer type aircraft.
Symmetrical -A Symmetrical Wing airfoil is curved on the bottom to the same degree as it is on the top. If a line was drawn from the center of the leading edge to the center of the trailing edge the upper and lower halves of the airfoil would be symmetrical. This is ideal for aerobatic aircraft and most lift is created by the angle of incidence of the wing to the flight path. This type of airfoil commonly used in Supersonic jets, Helicopter blades, Shrouds, Missile/rocket fins

Semi-symmetrical - A Semi-symmetrical Wing airfoil has a curved bottom section but to a lesser degree than a symmetrical section. It is a compromise between the flat bottom and the symmetrical wing. This is a very popular airfoil on sport type aircraft.

Under-camber - An Under-camber airfoil has the lower surface of the wing curved inwardly almost parallel to the upper surface. This type of airfoil produces a great deal of lift but is not common in R/C models

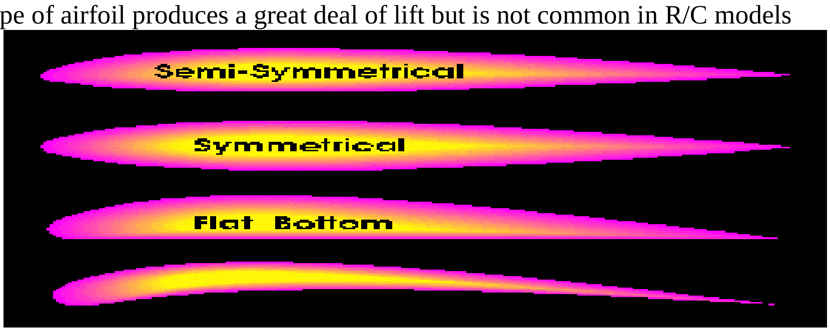

Figure- Types of air foil

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II. PREVIOUS WORK

Kevadiya and Vaidya [1], has done CFD analysis on NACA 4412 air foil of wind turbine blade. **Wadcock and coles [2],** has done Flying hot wire study of flow past an NACA 4412 airfoil at maximum lift. **Agrawal and Saxena [3],** has done analysis of wings using airfoil NACA 4412 at different angle of attack. **Rosario at al. [4]**, has done Evaluation of the radial flow effects on micro HAWTs through the use of a transition CFD 3D model - Part II: Post processing and comparison of the results. **Gulzar at al. [5],** has done simulation on Impact of Variation in Angle of Attack on NACA 7420 Airfoil in Transonic Compressible Flow Using Spalart- Allmaras Turbulence Model

III. METHODOLOGY

A. Mesh Generation

To perform the CFD analysis it is necessary to obtain the mesh file of the airfoil. Depending upon the complexity of airfoil, mesh type may be chosen as described below:

Types of Mesh

1. Structured Meshes
2. Unstructured Meshes
3. Hybrid Meshes

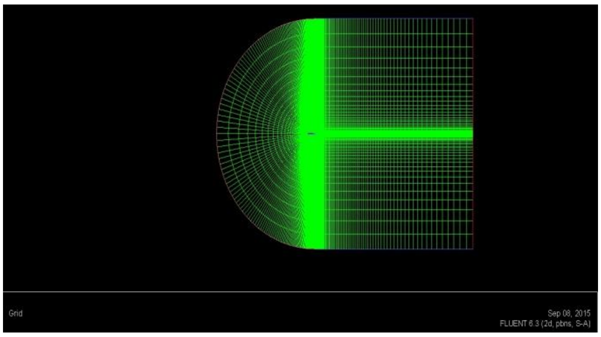

Figure - Upstream side of the airfoil C type topology

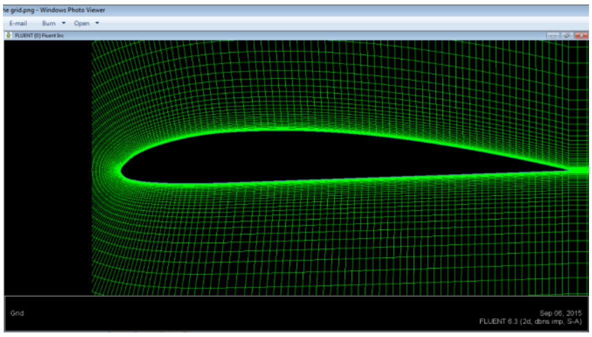

Figure - Full view of Airfoil

B. Boundry Condition

S.No	Zone	Type
1	Farfield 1	Velocity inlet
2	Farfield 2	Velocity inlet
3	Farfield 3	Pressure outlet
4	Airfoil	Wall

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C. Put The Value of Velocity Inlet At Different Angle Of Attack

Reynolds Number = 10,00,000		
Angle	X component (m/s)	Y component (m/s)
12^0	14.288	3.037
14^0	14.176	3.5345
16^0	14.044	4.027
18^0	13.895	4.514

Reynolds Number = 15,00,000		
Angle	Xcomponent (m/s)	Y component (m/s)
12^0	21.439	4.557
14^0	21.267	5.302
16^0	21.069	6.04
18^0	20.844	6.772

D. Select the Material properties

Numbers	Properties	Value
1	Density	1.225 Kg/m³
2	Viscosity	1.7894×10^5 Kg/m-s

IV. RESULT AND DISCUSSION

A. Velocity contour at Different angle of attack and Reynolds number

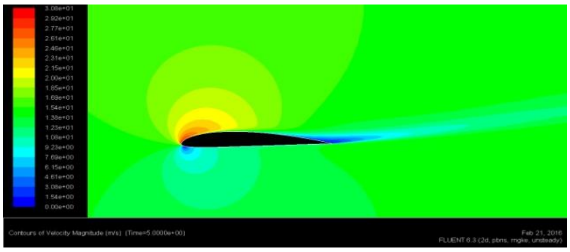

Figure- 12^0 AOA and 1000000 Re

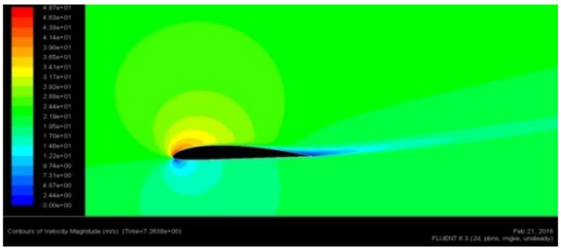

Figure- 12^0AOA and 1500000 Re

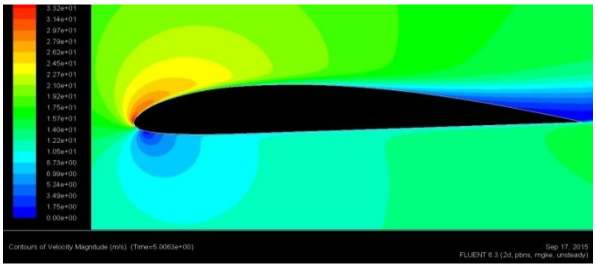

Figure- 14^0 AOA and 1000000 Re

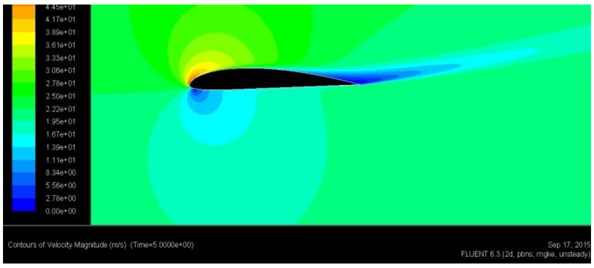

Figure- 14^0AOA and 1500000 Re

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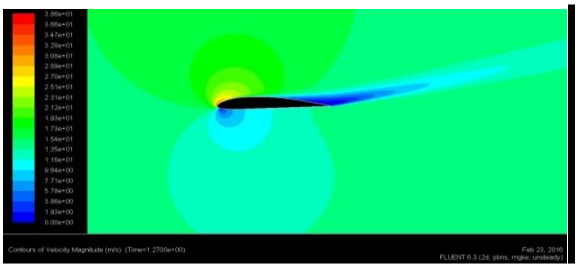

Figure 4.5- 16^0 AOA and 1000000 Re

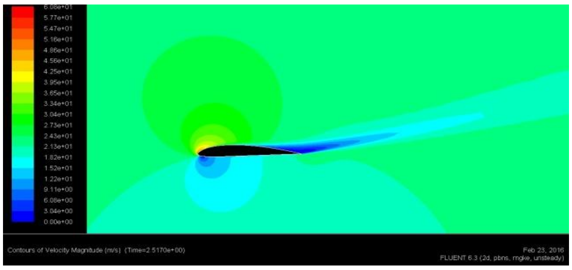

Figure 4.6- 16^{0}AOA and 1500000 Re

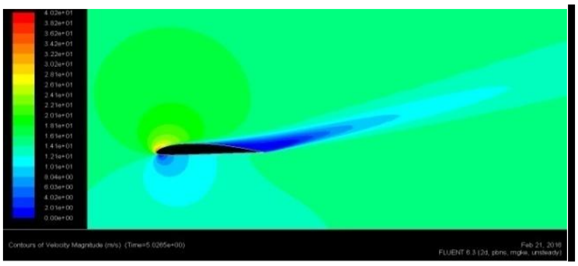

Figure- 18^0 AOA and 1000000 Re

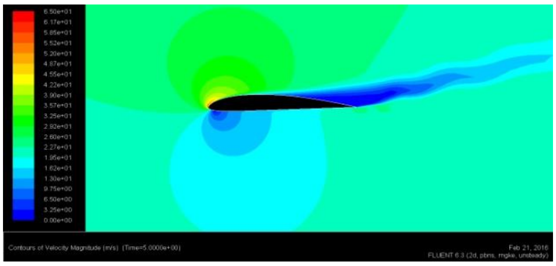

Figure- 18^{0}AOA and 1500000 Re

A. Pressure contour at Different angle of attack and Reynolds number

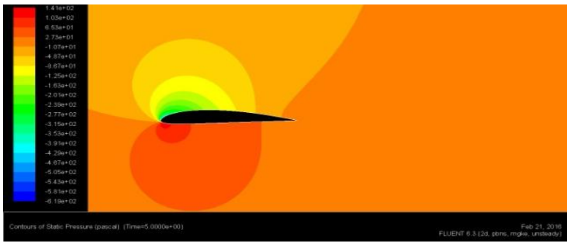

Figure- 12^{0}AOA and 1000000 Re

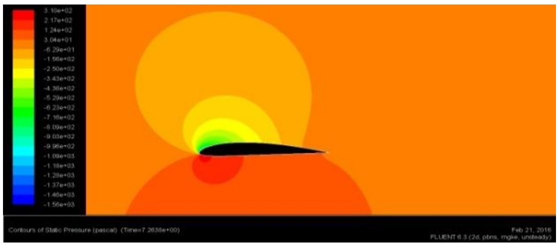

Figure- 12^{0}AOA and 1500000 Re

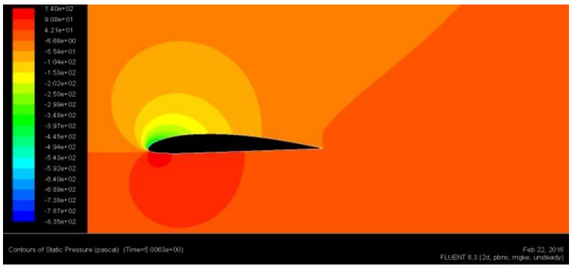

Figure- 14^{0}AOA and 1000000 Re

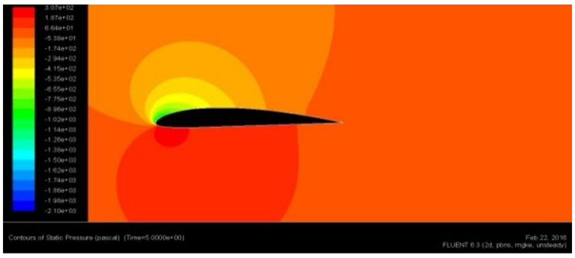

Figure- 14^{0}AOA and 1500000 Re

Figure- 16^{0}AOA and 1000000 Re

Figure- 16^{0}AOA and 1500000 Re

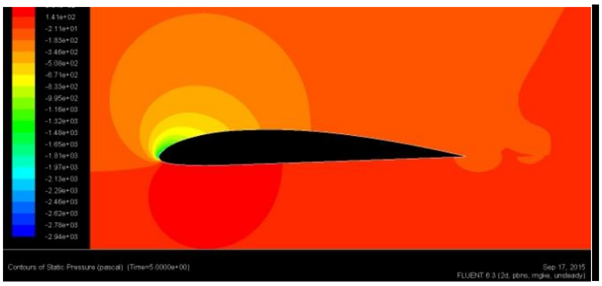

Figure- 18^{0}AOA and 1000000 Re

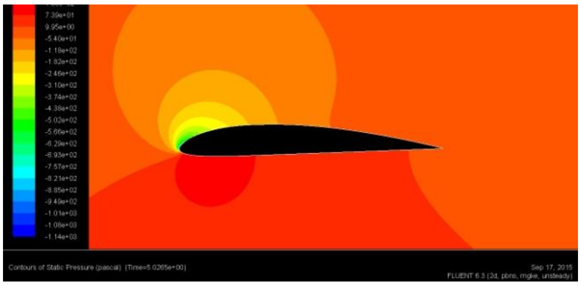

Figure- 18^{0}AOA and 1500000 Re

A. Maximum Lift and Drag Coefficient Vs Angle of Attack

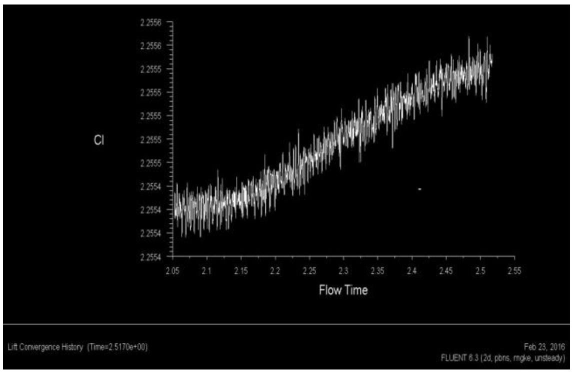

Figure- Maximum C_L Vs AOA at 16^{0}AOA and 1500000 Re

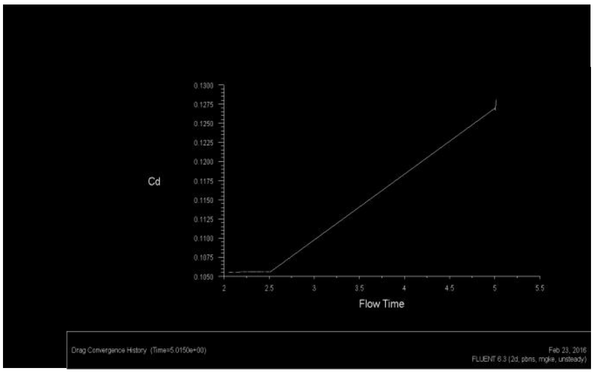

Figure - Maximum C_d Vs AOA at 18^{0} AOA and 1500000

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B. Observation Table

Table - Flow Sepration , Coefficient Of Lift (C_l) And Coefficient Of Drag (C_D)

At Different AOA And 1000000 Reynolds Number

Reynolds Number = 10,00,000				
S.No.	Angle of attack (∝)	Flow separation (x/c)	Coefficient of Lift (C_l)	Coefficient of Drag (C_D)
1	12^0	0.80	0.865	0.038
2	14^0	0.70	0.927	0.045
3	16^0	0.65	0.96	0.059
4	18^0	0.40	0.925	0.065

Table -Flow Sepration , Coefficient Of Lift (C_l) and Coefficient of Drag (C_D)

at Different AOA And 1500000 Reynolds Number

Reynolds Number = 15,00,000				
S.No.	Angle of attack (∝)	Flow separation (x/c)	Coefficient of Lift (C_L)	Coefficient of Drag (C_D)
1	12^0	0.82	2.027	0.071
2	14^0	0.74	2.0275	0.084
3	16^0	0.67	2.255	0.105
4	18^0	0.45	2.25	0.112

From the above table**,** it has been concluded that between angle of attack (α) 12° to 16° the flow separation is also negligible because the flow line above the separation point is capable of suppressing the flow on airfoil surface but the coefficient of lift is not much high hence it is not an optimum condition. From 15° to 18° the flow separation is so severe because of adverse pressure gradient in the trailing edge of the airfoil is increasing with the angle of attack. pressure which increase the drag force. This is stall angle and in our experiment it is found at 16º. At this stall the coefficient of lift is 2.255 which is highest.

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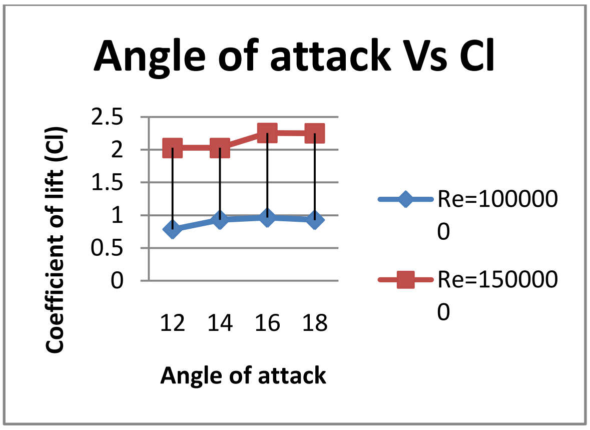
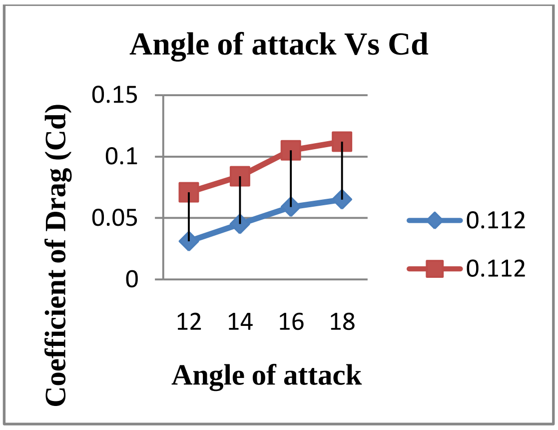
A. Graph Between Coefficient Of Lift And Drag Vs AOA





From above graph that as much as angle of attack is increased the coefficient of lift (Cl) is also increased hence lift is increase. But one condition comes when lift cannot be increased further and goes to reduced continuously. This reduction due to the generation of adverse pressure gradient at the trailing edge.

V.CONCLUSIONS

The point of flow separation was found to decrease from the leading edge as the angle of attack increase from 12^0 to 18^0 and the flow separation point shifted from 0.82 to 0.4 from the leading edge . At Reynolds number 1500000 the reduction in flow separation point from the leading edge was less. Because of the higher initial forces at higher Reynolds number. Which cause to suppress flow separation point. The coefficient of lift was found to increase up to 16^0 after that the reduction in coefficient of lift was observed. The maximum coefficient of lift was found 2.255 at 16^0angle of attack and 1500000 Reynolds number.

REFERENCES

[1] Namgoong H., "Airfoil optimization for Morphing Aircraft" Purdue University, Indiana AA13210757 ,[2005]
[2] http://www.google.co.in/search?q=types+of+airfoil&client cited on February 2016
[3] Halliday, D., and Resnick, R,. " A Text Book on fundamentals of physics" 3rd Edition, John Wiley & Sons,p.378, [2006]
[4] John D. and Anderson, Jr," Fundamentals of aerodynamics" 3rd Edition chapter 4, [2010],
[5] https://en.wikipedia.org/wiki/NACA_airfoil cited on September 2015
[6] Kevadiya, M., and Hemish A. "2D ANALYSIS OF NACA 4412 AIRFOIL" International Journal of Innovative Research in Science, Engineering and Technology Vol. 2, Issue 5, May 2013
[7] Wadcock Alan J. "Flying-Hot-Wire Study of Flow Past an NACA 4412 Airfoil at Maximum Lift" AIAA JOURNAL, VOL. 17, NO. 4, APRIL 1979
[8] Saxena Gaurav and Agrawal Mahendra, "Analysis of wings using Airfoil NACA 4412 at different angle of attack" IJMER, Vol.3, Issue. 3, May.-June. 2013 pp-1467-1469, [2013]
[9] Rosario Lanzafame and Stefano Mauroa, "Evaluation of the radial flow effects on micro HAWTs through the use of a transition CFD 3D model - Part II: Post processing and comparison of the results" Elsevier Ltd., Energy Procedia 82 pg. 164 – 171, [2015]
[10] Islam Md. Rasedul,and Hossain Md. Amzad.], "Experimental Evaluation Of Aero Dynamics Characteristics Of A Baseline Airfoil American Journal of Engineering Research (AJER), vol 17 No. 4, pp. 91-96. , , [2015],