Computational Analysis of Wind Turbine Blade with NACA 0021 Profile Under High Reynolds Number using ANSYS

Shailendra Shukla
PG Student
Rewa Institute of Technology
Rewa, India

Pushparaj Singh
HOD Mechanical Engineering
Dept Rewa Institute of Technology
Rewa, India

Abstract- **Lift and Drag forces plays a very important role in defining the performance of wind turbine blade. In this work Lift and Drag forces are calculated NACA 0021 profile with different angle of attack from 0^0 to 80^0 and different Reynolds number namely 10000, 40,000, 160,000, 360000 and 800000 respectively. Values of C_L and C_D are calculated in above conditions and found to play a very important role performance of wind turbine blade at higher Reynolds Number. It was observed that Lift and Drag forces are inversely proportional to Reynolds number and in direct proportion with Chord Length.**

Keywords — Lift coefficient, Drag coefficient, angel of attack, NACA Blade profile, Chord length

I. INTRODUCTION:

Wind energy is the purest, safest and least expensive form of renewable energy for producing electricity. In the regions geographically suited for harnessing the wind energy this clean form of energy can be used efficiently for producing electricity without any emissions. Wind turbine blades are subjected to various types of loads it has to be designed effectively to prevent it from fatigue so that it may perform its function properly for sufficient period of time. Wind turbine blades generate lift due to their shape. The more curved side creates low air pressures while high pressure air goes on the other side of the blade. This produces a lift force perpendicular to the direction of flow of the air. The lift force increases when the blade is presented at a higher angle to the wind, called angle of attack. At very higher values of angles of attack, blade "stalls" and thus, lift decreases again. So, an optimum value of angle of attack is there to generate the maximum lift. Liu et al. [1] used Blade element theory and CAD model for optimizing the angle of attack for a large-scale wind turbine blade. Numerical studies, for analysis as well as for design and experimental validations of airfoils at ultralow Reynolds number are presented in Kroo et al. [2, 3]. The effects of aerofoil profile modification on a vertical axis wind turbine performance are studied by Ismail et al. [4]. Rainbird et al. [5] studied the effect of Blockage-tolerant wind tunnel measurements for a NACA 0012 at high angles attack. From literature survey, it is observed that study of lift and drag forces on aerofoil for very high Reynolds number at angle of attack is not explored much. So, in present work an attempt is made to study the Lift and Drag forces on a wind turbine blade for very high Reynolds number and different angle of attack. Wind turbine blade is considered with NACA 0021 profile with different angle of attack varying from 0^o to 80^o for five different Reynolds number from 10,000, 40000, 160000,360000 and 800000 for three different chord lengths to estimate its lift and drag forces using ANSYS FLUENT.

II. METHODOLOGY:

In order to perform CFD analysis on a wind turbine blade firstly a model is prepared which is then meshed into smaller elements and further boundary conditions are applied. In present analysis, a wind turbine blade profile is created inside a C type mesh with two way velocity inlet method. The pressure based implicit steady solver with Standard k-ε model turbulence model with PRESTO second order upwind scheme is used for analysis. All the parameters and the blade profile along with the boundary conditions is presented in fig.1.

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 6 Issue 12, December - 2017

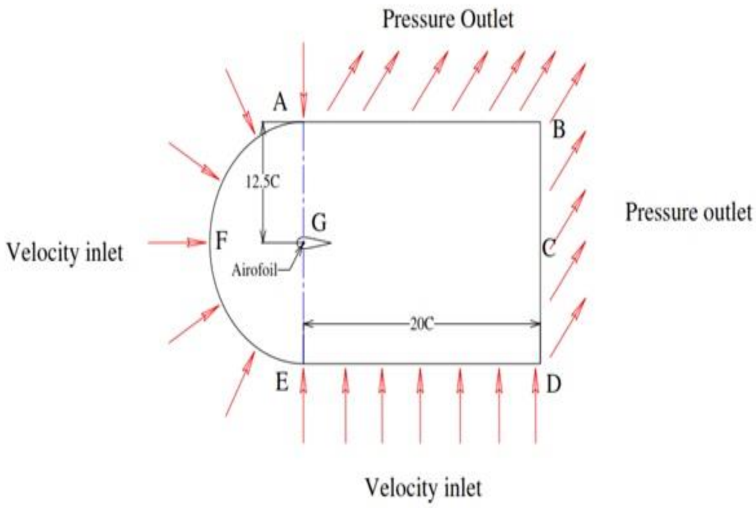

Fig.1. Geometry with boundary conditions

Before performing the analysis a grid independence test is performed for finding the least resolution or number of cells required to obtain accurate solutions. It saves time and memory space in working out a numerical simulation. In this method one or parameters are obtained at various resolutions, starting from lower to higher. As the number of cells increases the parameter converges to an asymptotical value indicating the accuracy of solutions and minimum cells required for it. By doing the Grid Independence Test we will be able to save the computational time. The Grid Independence Test is performed for an airfoil at 10 degree angle of attack with the above Boundary conditions by using all the turbulence models. The k-ε turbulence model converges needs more number of iterations as compared to the other two models. Hence the results shown below are plotted for the different element size. The element size of 14040 is selected as the best element size from all element sizes taken.

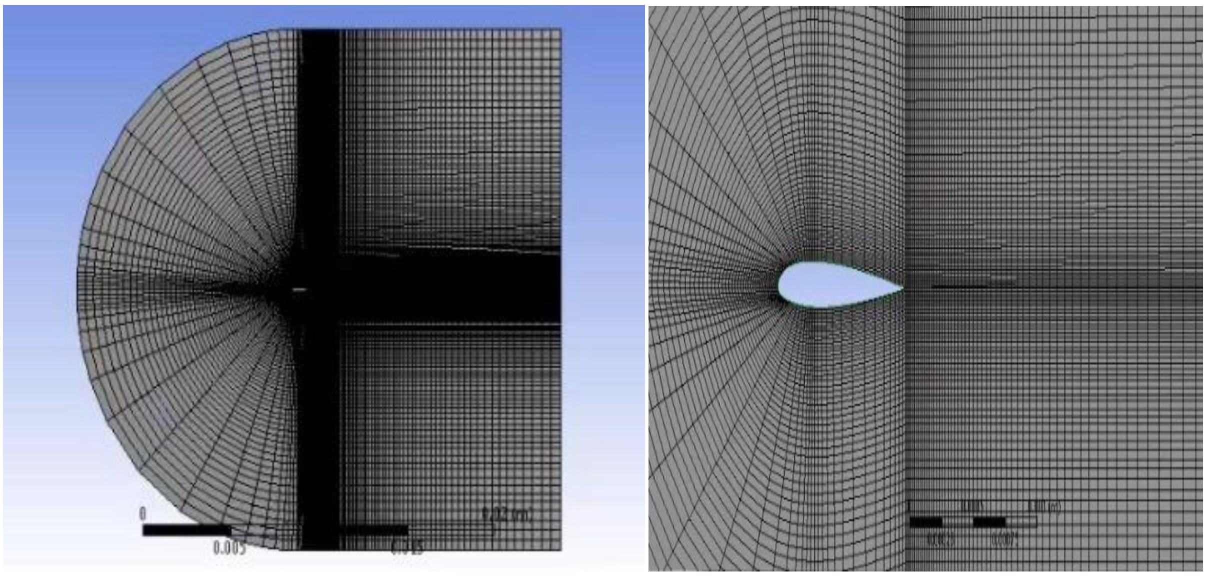

Fig. 2. Close view of C type mesh

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 6 Issue 12, December - 2017

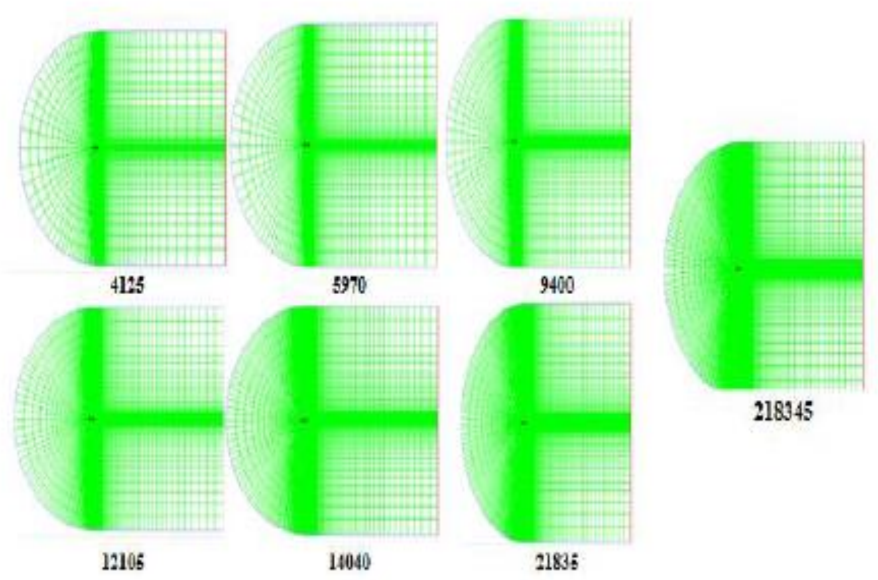

Fig.3. Grid independence study mesh

III. RESULTS AND DISCUSSION:

CFD analysis is carried out for NACA0021 and three different chord length 5cm ,10 cm ,15 cm and for five different Reynolds number = 10,000,40000, 160000,360000, 800000. All the analysis is also performed with varying the input angle of attack as 10º, 40º and 70º respectively on velocity contour around aerofoil. The flow patterns and flow velocity changes in different position is represented in fig 4 to fig 6. The results obtained by simulation is shown in following figures for representing variation of lift coefficient with reference to angle of attack for various Reynolds number. The Reynolds number is varied by changing free stream velocity at inlet.

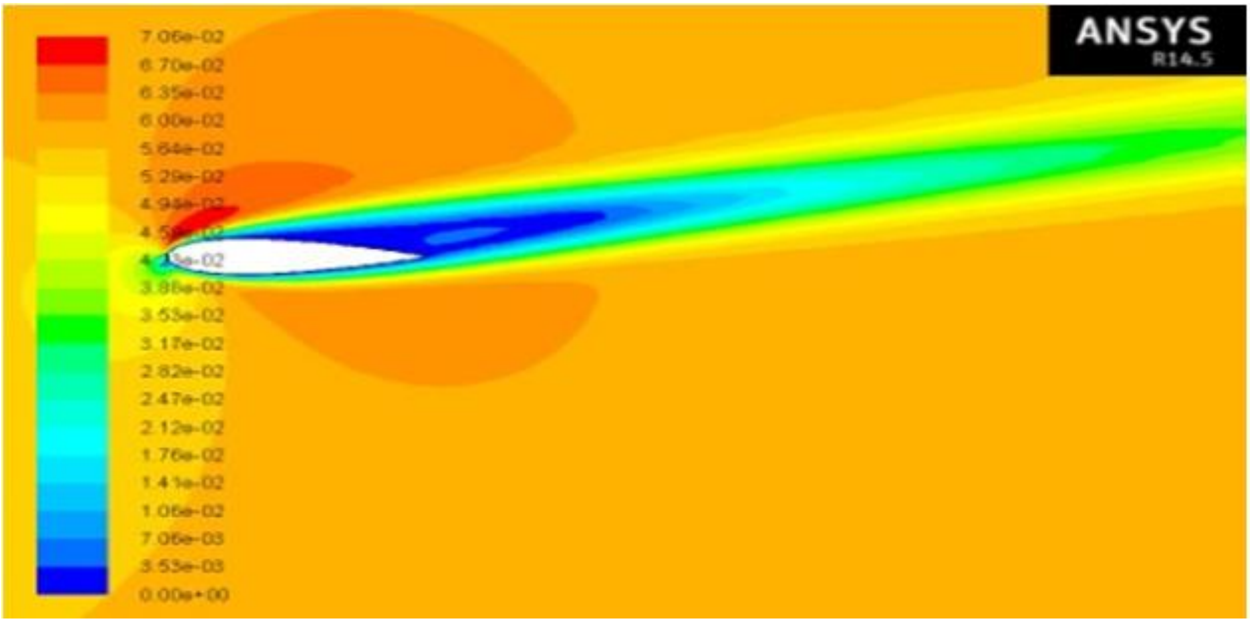

Fig.4. Velocity contour for angle of attack 10^0

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 6 Issue 12, December - 2017

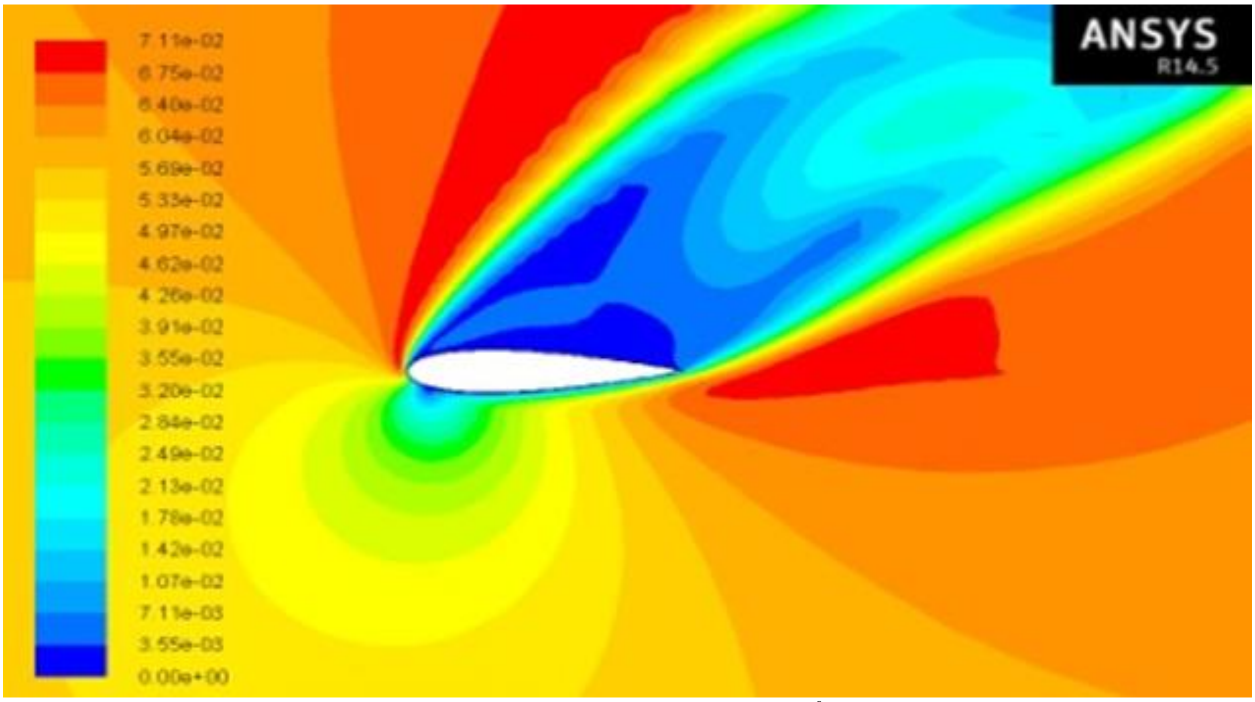

Fig.5. Velocity contour for angle of attack 40^0

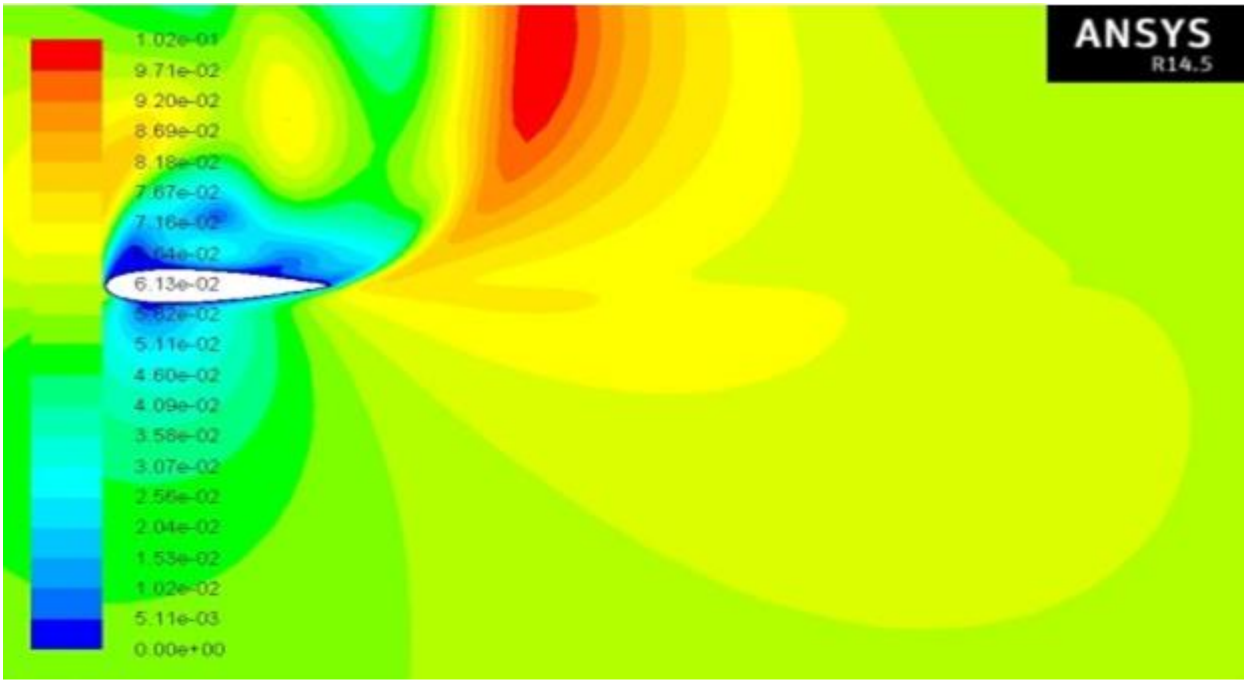

Fig.6. Velocity contour for angle of attack 70^0

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 6 Issue 12, December - 2017

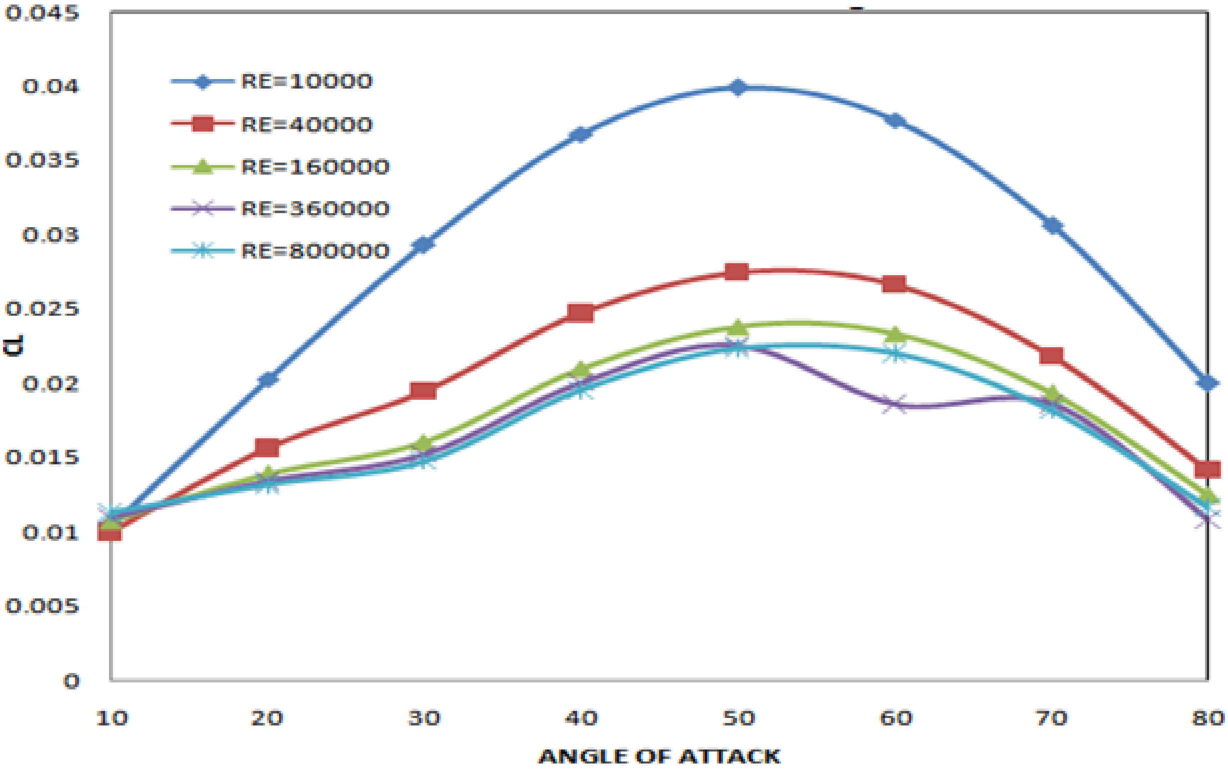

Fig. 7. Graph of C_L Vs AOA For Comparison Of Re For Naca0021 -5 Cm Chord Length

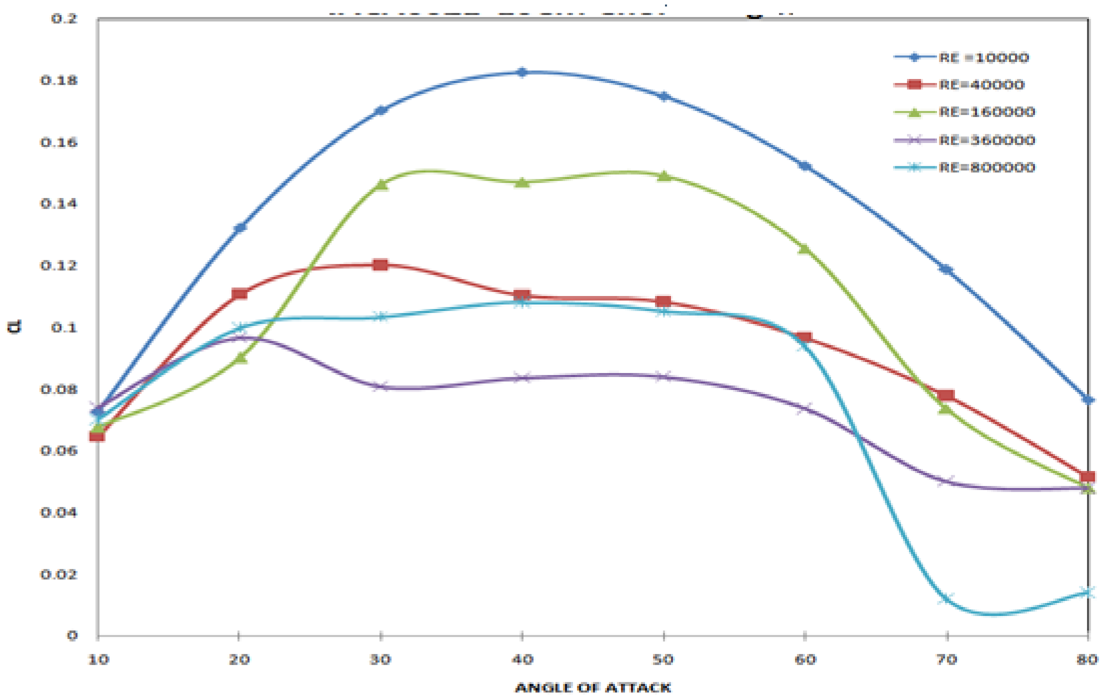

Fig. 8. Graph of C_L Vs AOA For Comparison Of Re For Naca0021 -10 Cm Chord Length

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 6 Issue 12, December - 2017

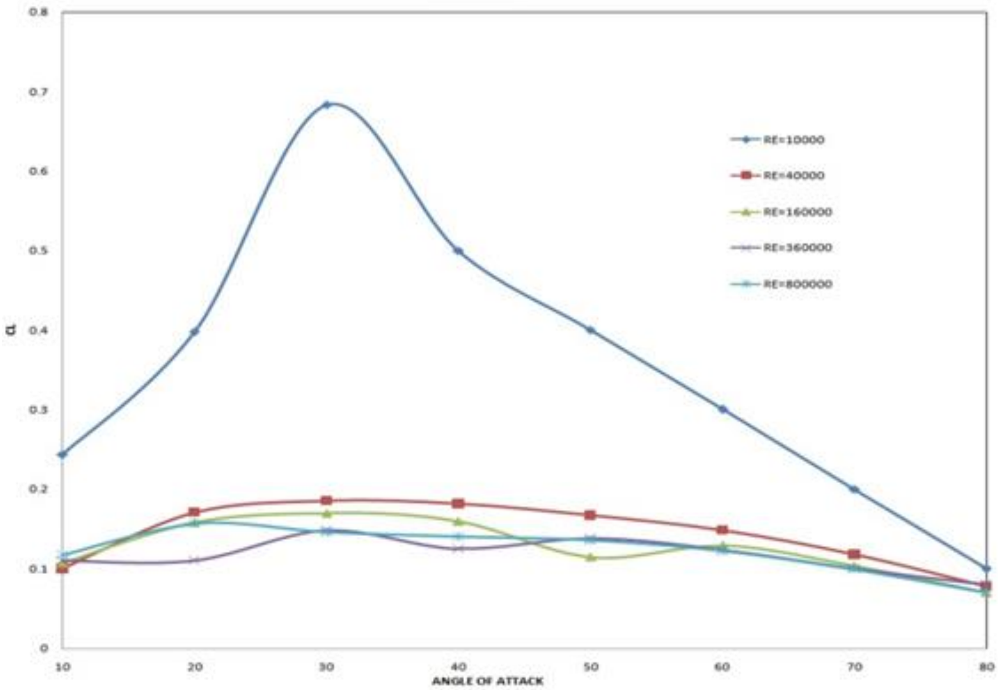

Fig. 9. Graph of C_L Vs AOA For Comparison Of Re For Naca0021 -15 Cm Chord Length

Comparison graph is plotted between coefficient of lift and angle of attack based on the simulations for various Reynolds number and different chord length. It is observed from the graphs that increase in Reynolds number leads to reduction in coefficient of lift as along the increase in angle of attack. This phenomenon is mainly due to shifting of the separation flow points into earlier phases and early start of separation. It is also seen that coefficient of lift increases with increase in angle of attack reaches maximum value and suddenly it falls down when Reynolds number and Chord length remains same. The above phenomena called as stalling. . It is observed that for same chord length Reynolds number 10000 gives maximum lift and drag coefficient value, and Reynolds number 8000000 show minimum lift and drag coefficient value. Form all above comparisons NACA0021 and chord length 15 cm shows highest lift coefficient up to 0.07.

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 6 Issue 12, December - 2017

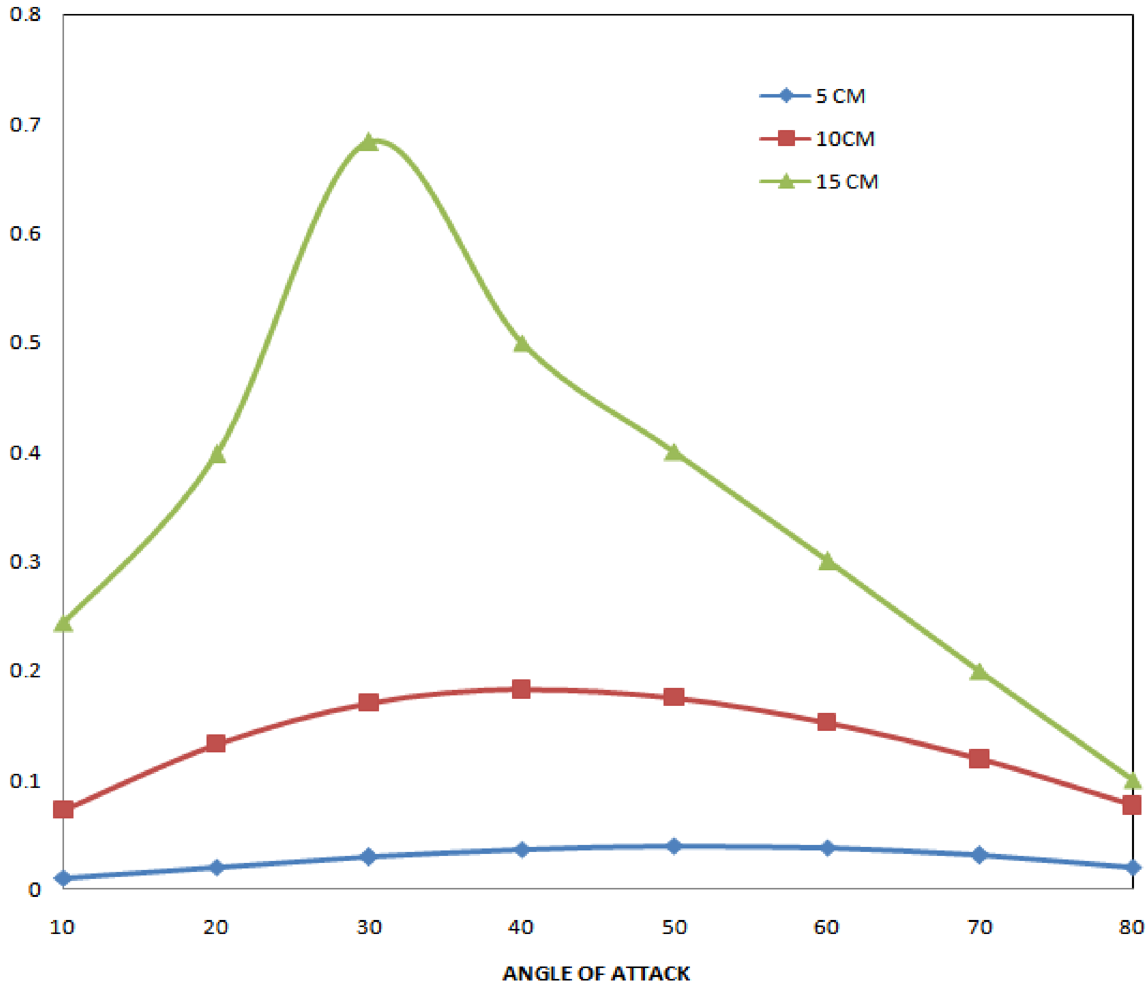

Fig.10. Graph Of C_L Vs AOA For Comparison Of Chord length for Naca0021 -for RE=10000

It is observed that coefficient of lift and drag is directly proportional to chord length when the Reynolds number remains constant throughout the flow. It was also seen that turbine blade with 15 cm chord length has maximum coefficient of lift on comparison with 10 cm and 5 cm chord length blades.

IV. CONCLUSION:

- CFD analysis is carried out in wind turbine blade with NACA 0021 profile with varying conditions like change in Reynolds number and varying chord length and angle of attack to evaluate coefficient of lift and drag.
- It is observed that coefficient of lift and drag is directly proportional to chord length when the Reynolds number remains constant throughout the flow.
- It is observed from the graphs that increase in Reynolds number leads to reduction in coefficient of lift as along the increase in angle of attack. This phenomenon is mainly due to shifting of the separation flow points into earlier phases and early start of separation.
- It is also seen that coefficient of lift increases with increase in angle of attack reaches maximum value and suddenly it falls down when Reynolds number and Chord length remains same. The above phenomena called as stalling. .

REFERENCES

[1] Kroo I., Kunz P. J., (2000) Meso-scale ight and miniature rotorcraft development, Proceedings of the Conference on Fised, Flapping and Rotary ,Vehicles at very Low Reynolds Numbers, Univ. of Notre Dame, Notre Dame, IN, 184-196.

[2] Kunz P. J., Kroo I., (2000) Analysis, design and testing of airfoils for use at ultra-low Reynolds numbers. Proceedings of the Conference on Fised, Flapping and Rotary Vehicles at very Low Reynolds Numbers, Univ. of Notre Dame, Notre Dame, IN, 349-372.

[3] Schmitz F. W. (1967 Aerodynamics of the model airplane. Part I. Airfoil measurements, NACA TM X-60976.

[4] Sheldahl R. E., Klimas P. C. Aerodynamic characteristics of seven symmetrical airfoil sections through 180-degree angle of attack for use in aerodynamic analysis of vertical axis wind turbines, Sandia national laboratories energy Report, SAND80-2114.

[5] Sunada S., Sakaguchi A., Kawachi K. (1997). Airfoil section characteristics at a low Reynolds number. Journal of Fluids Engineering, 119, 129-135.

[6] Sunada S., Yasuda T., Yasuda K., Kawachi K., (2002) Comparison of wing characteristics at an ultralow Reynolds number. Journal of Aircraft, 39, 331-338.

[7] Nazmul Haque, Mohammad Ali, Ismat Ara, "Experimental investigation on the performance of NACA 4412 aerofoil with curved leading edge planform", Procedia Engineering 105 (2015) 232 – 240, Elsevier.

[8] Md Farhad Ismail, Krishna Vijayaraghavan, "The effects of aerofoil profile modification on a vertical axis wind turbine performance", Energy 80 (2015) 20e31, Elsevier.

[9] J.M. Rainbird, J. Peiró, J.M.R. Graham, "Blockage-tolerant wind tunnel measurements for a NACA 0012 at high angles of attack", J. Wind Eng. Ind. Aerodyn. 145 (2015) 209–218,