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Flow Analysis for Pressure Variations on Airfoil for Different Chord Length

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Abstract: Air flow analysis over the airfoil for short and increased length of airfoil profile was investigated. For the modeling with the help of NACA profiles and imported to the ANSYS WORKBENCH for the analysis using FLUENT. Analysis was done for different length of the airfoil. The using standard condition of +14 degree inclination of airfoil for air stream was investigated. Results are obtained using fluent post processer. Pressure distribution over and below surface of the airfoil has been represented in the counters and graphs. Pressure distribution for the sensitive parts like pressure at lead end and trail end has been represented in graphs.

Keywords: CFD, Flow over Airfoil, ANSYS FLUENT, Pressure Distribution.

I. INTRODUCTION

Airfoils are the aerodynamic shapes when they moves through air the air divides and it passes on both sides of it. The wings of upper surface is shaped so that so that the air rushing over the top speeds up and it will spreads out

This decreases the air pressure above the wing. The air flowing below the wing moves in a comparatively straighter line. So that its speed and air pressure remains same.

Since the high air pressure always moves towards the low air pressure. Air below the wing will be pushed upwards towards the air present above the wing of airplane. The wing is in the middle and the entire wing is lifted the faster an airplane moves the lift present is more and when force of lift is greater than the force of gravity/Gravitational force the airplane will fly easily.

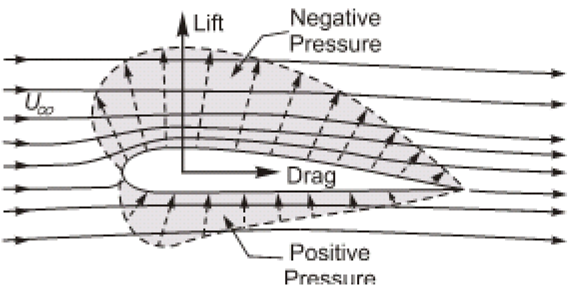

Fig 1: Forces on airfoil

The data reduction equation

Lift force

$$L = \int_A (p_i - p_t)\sin(\theta_i)\,dA \qquad (1)$$

Free stream velocity

$$U_\infty = \sqrt{\frac{2(p_i - p_t)}{\rho}} \qquad (2)$$

Where p_i is the surface pressure measured on the airfoil lower surface, p_t is the surface pressure measured on the airfoil top surface, θ_i is the angle of attach normal to free-stream flow at each of the pressure taps.

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Majority of airfoils used in horizontal axis wind turbines today were originally developed for aircrafts. The design requirements for these airfoils, primarily National Advisory Committee for Aeronautics (NACA) and National aeronautics and space administration (NASA) airfoils are significantly differ from those for the wind-turbine airfoil.

The technique used here is called as computational fluid dynamics technique (CFD). CFD is an art of replacing integrates or the partial derivatives in the equations of fluid flow with decreased algebraic form. Using the CFD technique the complex flow behavior can be clearly visualized which will be helpful for redesigning and to improve the efficiency of the equipment.

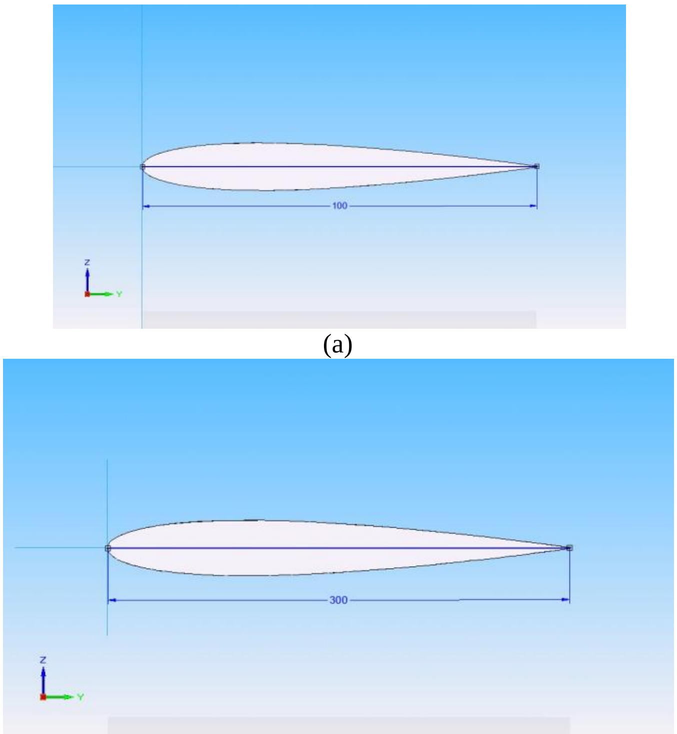
II. OBJECTIVES

The main objective is to analyses the flow characteristic over the air foil of different length of the airfoil. To obtain the pressure distribution on either surface of the airfoil for the increased length. Effect of lift force on increase of length of the airfoil.

III. METHODOLOGY

The total test can be divided into 3 phases.
1) Generating 3D modelling of airfoil
2) Grid independence study
3) Input and boundary condition
4) Results and discussions

1) Generating 3D modelling of airfoil:
Design was made by using the NACA (National Advisory Committee for Aeronautics) profile with the wingspan of 100mm. By considering the real-time profile of airfoil its co-ordinates were formed and they were imported to CAD Software by MACROS importing format.



(a)

(b)

Fig 2: (a)Short Length Airfoil (b) Long Length Airfoil Profile in CAD Software

2) Grid independence study: (Mesh generation):
The domains are often called elements or cells, and the collection of all elements or cells is called a mesh or grid. The discretization of the fluid chamber for the analysis is required. Some region in the fluid chamber requires more importance in analyzing flow parameters. Meshing is process done in CFD analysis for discretizing the fluid flow region into small elements. Analyze the different elements of the mesh.

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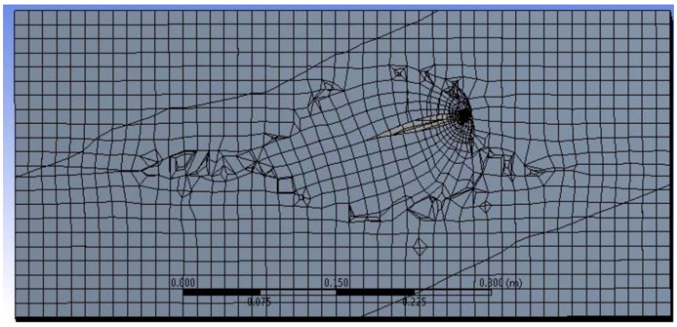
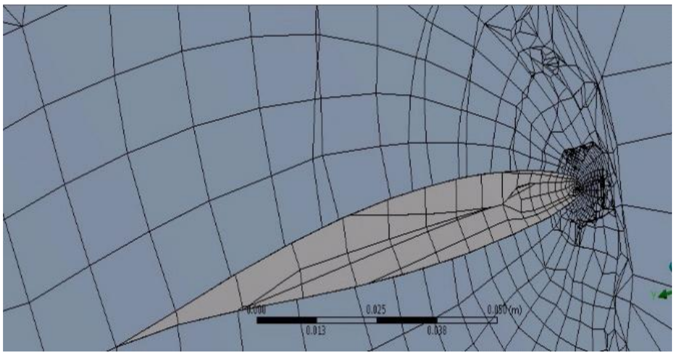


(a)



(b)

Fig 3: (a) Unstructured mesh (b) refinement near stall region

3) Input and boundary condition:

Boundary conditions are the boundary values which need to be pre-defined for the calculation of the partial differentials defining the flow characteristics. Boundaries can take verity of form: Inlet/outlet: velocity, pressure, temperature, are types of boundary conditions specified on fluid boundaries. Along with this can define the properties of materials and type of study required for the analysis.

Table 1: Inlet Boundary Conditions:

Inlet condition	Values
Velocity	51 m/sec
Temperature	300K
Pressure	1 atm
Kinematic Viscosity	1.4×10^{-5} m^2/sec
Density	1.24 Kg/m^3
Fluid	Air (Ideal gas)

IV. RESULTS AND CONCLUSION

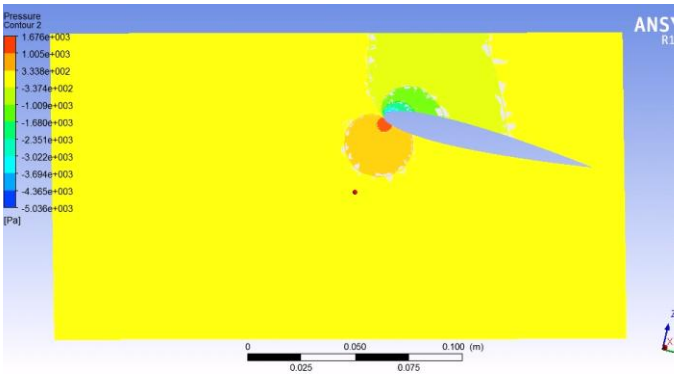


Fig 4: Short Length Airfoil Pressure Counter

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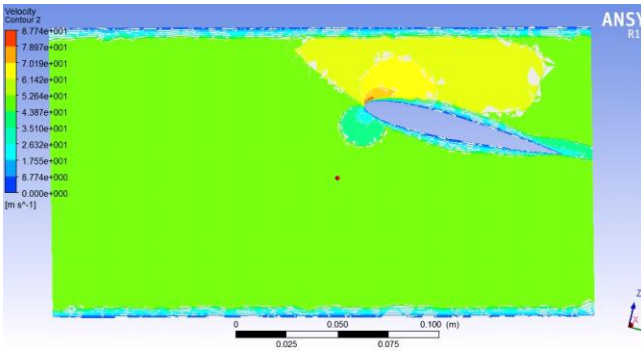


Fig 5: Short Length Airfoil Velocity Counter

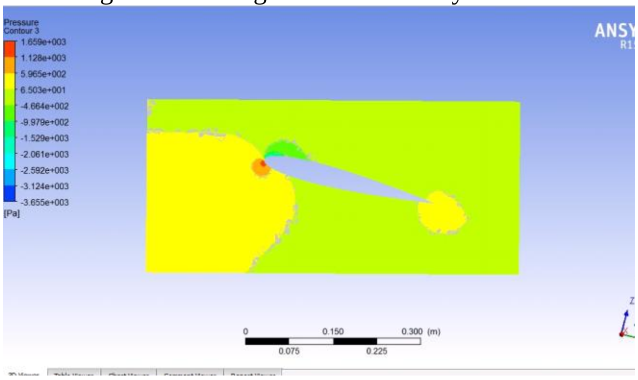


Fig 6: Long Length Airfoil Pressure Counter

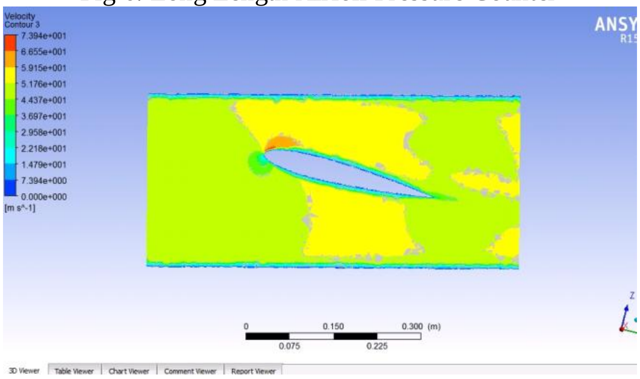
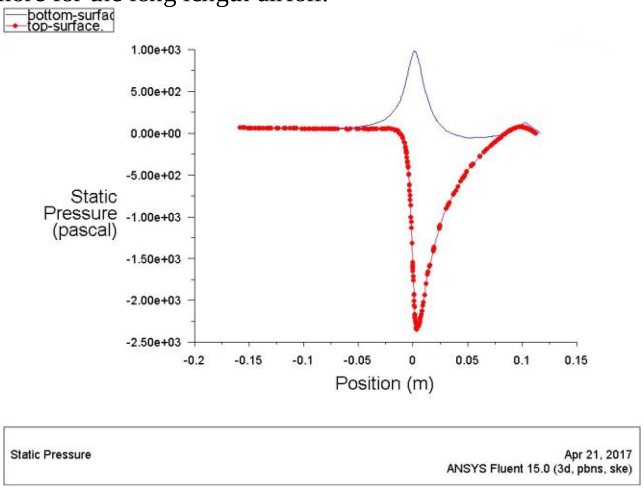


Fig 7: Long Length Airfoil Velocity Counter

According to the lift force equation it's the integral of pressure on above and below surface area of the airfoil thus from graphs it's the pressure difference at the stall region is 3.5kpa in short length airfoil and 2.5kpa for the long length airfoil but the surface area is more for the long length airfoil.



(a)

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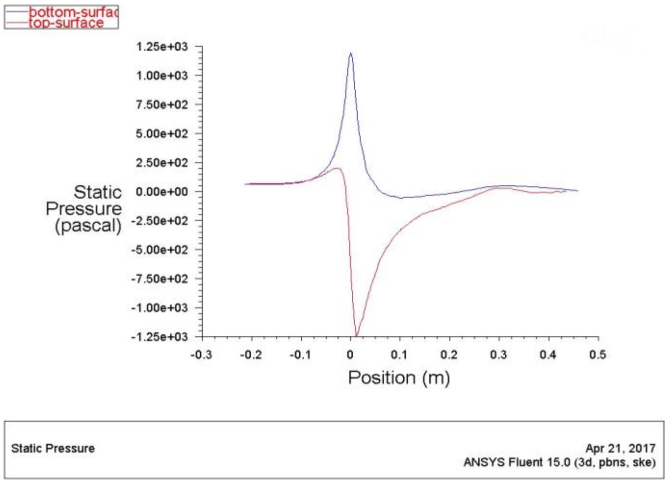
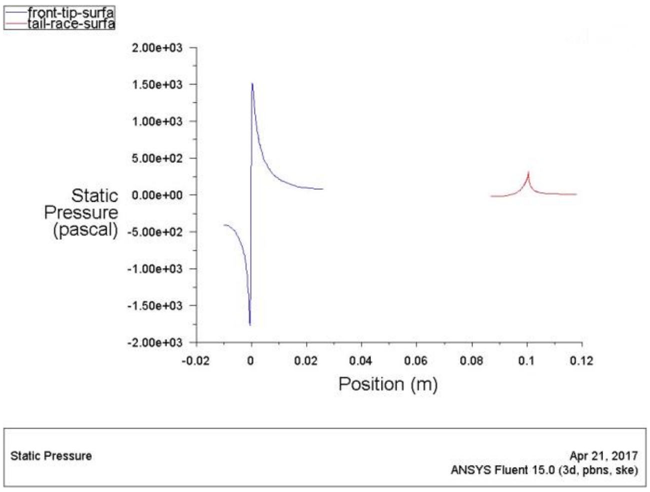


(b)

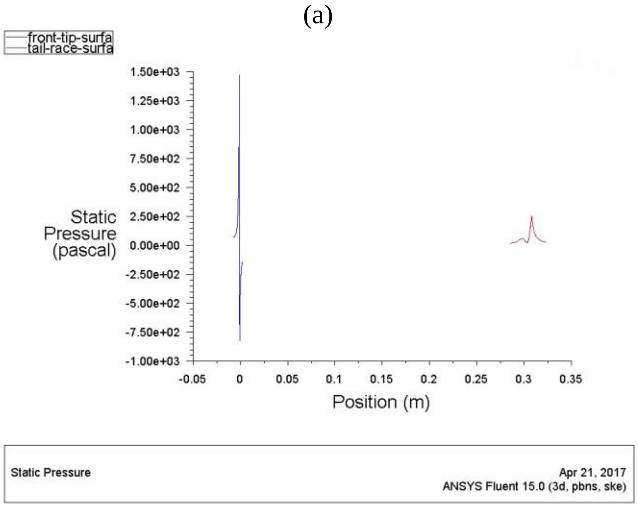
Fig 6: Pressure variation profile on top & bottom surfaces (a) Short length (b) long length

But the area covering between the top surface pressure curve and the bottom surface pressure curve is more in the long length airfoil when compared with the short length airfoil. From this it is observed that more the length of the airfoil more the lift force.

By the analysis it is observed that the pressure on top and bottom surface of the short length airfoil is 1kpa and -2.5kpa thus an uncertainty in the pressure values on top and bottom surface is created this will leads to the airfoil more



(a)



(b)

Fig 7: Pressure variation profile at lead and trail end surfaces (a) Short length (b) long length

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sensitivity to the sudden changes in the flow stream. But whereas on other hand the long length airfoil a same valued but change in sign is obtained this indicates that when we represents in the sinusoidal wave structure this will gives us a same valued amplitude curve thus making the less sensitive to the sudden changes in the flow stream .

On increasing the length of the airfoil, it will not give the laminar exit condition on trailing end of the airfoil. Thus the problem of formation of eddies at the trailing end of the airfoil remains as it is even on increase of the length of the airfoil. So there is a need of analysis of laminar exit condition on the trailing end of the airfoil.

VI. CONCLUSION

According to the analysis, on increasing the airfoil length, airfoil becomes steeper, and gives the balanced pressure distribution on the top and bottom surface of the airfoil. Thus the increase of the airfoil length helps in decrease of the sensitivity of the airfoil to the sudden changes in the flow streams. A high pressure difference in the stall region of the short length sir foil makes it more sensitivity to the changes in the airflow stream. Hence it is prefer to use long length airfoil structure for the application in the moving objects at higher altitude.

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