Design and Performance Analysis of Airfoil by Low Reynolds Number Method using CFD

Mr. Santosh Kansal[1] Dilip Muchhala[2]
[1]Assistant Professor [2]Student
[1,2]Department of Mechanical Engineering
[1,2]Institute of Engineering and Technology, DAVV Indore

Abstract— The present work deal with the design and performance analysis of NACA0018 airfoil with the use of viscous laminar model of FLUENT and also comparative analysis with standard experimental results. It also comprises the various angle of attack (00,40, 80) with respective variation in coefficient of lift (CL) and coefficient of drag (CD). In this numerical study we use low Reynolds number Airfoil design method.

Key words: NACA0018, CFD FLUENT, Attack angle, Pressure difference, Shape Design, Analysis of Airfoil

I. INTRODUCTION

As we know that a moving body in air having four forces. Out of four two are most important one in lift force and other one is Drag force they depend on the wing structure. Airfoil is a shape in which two edges one is leading and other trailing edge when air moves through airfoil, air split into and passes above and below the wings the upper surface is the shaped so the air speed is high as compare to lower surface due to this pressure gradient a lift force induced upward direction. This is the basic principal of generation of lift force .the value of lift force increasing with respective increasing of aircraft[1] .in this study we mainly focus on the analysis of NACA0018(National Advisory Committee for Aeronautics) airfoil at various angle of attack .also we use low Reynolds number method for design of airfoil. airflow over the wing we take it as like flow over a flat plat case thats why Reynolds number for laminar flow is less than $3x10^5$ flow near the boundary are laminar. We use FLUENT program for design and performance analysis. NACA four digit airfoil coordinate calculate by empirical relation [7]

$$Yc = \frac{m}{p^2}[(1-2p)+2px-x2] \qquad (1.1)$$

from x=0 to x=p

$$Yc = \frac{m}{(1-p)^2}[(1-2p)+2px-x2] \qquad (1.2)$$

from x=p to x=c

Where x= coordinates along the length of the airfoil from 0 to c (which stands for chord length)

$$\pm Yt = \left(\frac{t}{0.2}\right)[0.2969\,x0.5\ -0.1260\,x2-0.3516\,x2\ +0.2843\,x3-0.101\,x4\,] \quad (1.3)$$

Determine the final Coordinate for the airfoil upper surface (X_u, Y_u)&lower surface (X_L,Y_u) using the following relationships

$$X_u = X- Y_t \sin ø \qquad (1.4)$$
$$Y_u= Y_c-Y_t \cos ø \qquad (1.5)$$
$$X_L= X+Y_t \sin ø \qquad (1.6)$$
$$Y_L= Y_c–Y_t \cos ø \qquad (1.7)$$
$$ø = \boldsymbol{arc\ tan}\left(\frac{dY_c}{dX}\right)$$

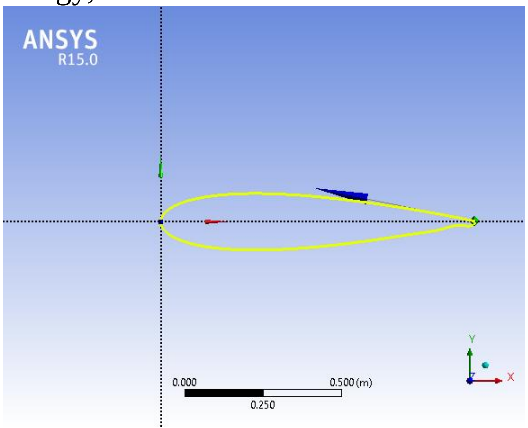

Fig. 1: NACA0018 2D model

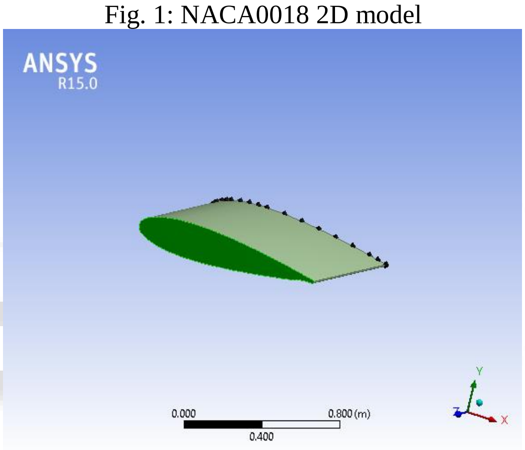

Fig. 2: NACA0018 3D model

II. GOVERING EQUTION

The governing equation are RANS (Reynolds Averaged Navier Stokes) [1] and continuity equation without the gravity and the body force item in Cartesian tensor from

$$\frac{\partial \rho}{\partial t}+\frac{\partial(\rho u_i)}{\partial x_i}=0 \qquad (2.1)$$

$$\frac{\partial(\rho u_i)}{\partial t}+\frac{\partial(\rho u_i u_j)}{\partial x_j}=-\frac{\partial P}{\partial x_i}+\frac{\partial}{\partial x_j}\left(\mu\frac{\partial u_i}{\partial x_j}-\rho u_i' u_j'\right)+S_i \quad (2.2)$$

Where ρ is the density u_i the velocity component of i direction p pressure, μ dynamic viscosity of the fluid , $\rho u_i' u_j'$ the Reynolds stress and S_i the generalised source term.

III. MESH GENERATION

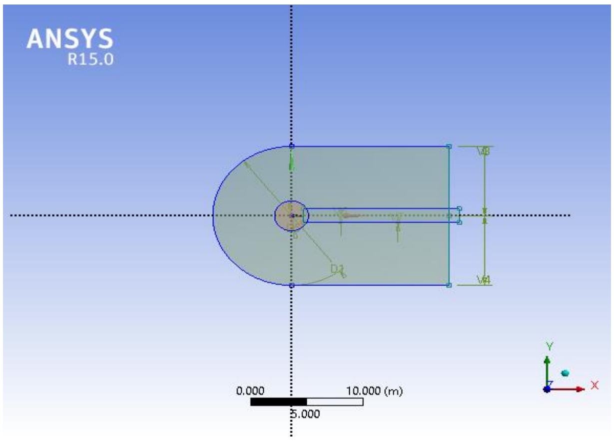

Fig. 3: C-type grid

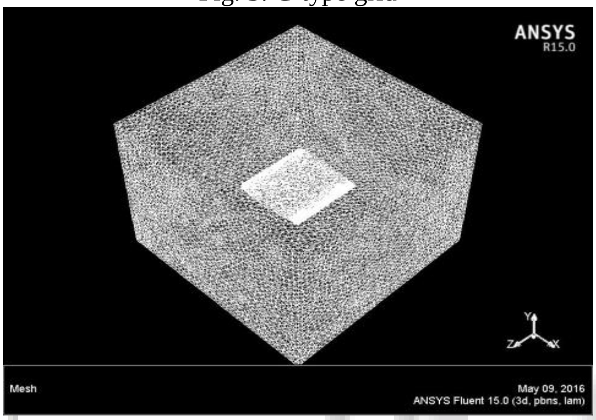

Fig. 4: Highly Dense Mesh Near Airfoil

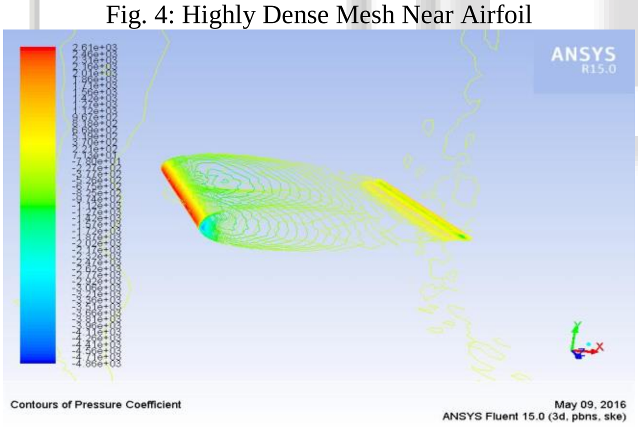

Fig. 5: contours of pressure coefficient

A. Low Reynolds Number

The most obvious effect of operation at very low Reynolds number (Re) [1] is a very large increase in the section drag coefficient. In the Re 10^3 operating range the drag increase a full order of magnitude. There high drag values are in line with theoretical laminar plate drag. Which is inversely proportional to square root of the Reynolds Number the increase in drag is unfortunate not reciprocated in lift. Lift coefficient remain of order one resulting in a large reduction in the L/D ratios. The definition of boundary layer thickness becomes more and more pronounced .the definition of boundary layer at such low Re in a fully viscous fluid field is an in exact notion.

B. Angle of Attack

Angle of attack (AOA) [3] is the angle between the oncoming air or relative wind and a reference line on the airfoil.the reference line is a line connecting the leading edge and trailing edge at some average point on a wing.

Empirical Relation [6] show the relation between variation of AOA with coefficient of lift C_l

$$Cl = \frac{dCl}{d\alpha} = 1.8\pi(1 + 0.8\frac{tmax}{c}) \quad (3.1)$$

Where $\frac{tmax}{c}$ is the maximum thickness to chord ratio of airfoil.

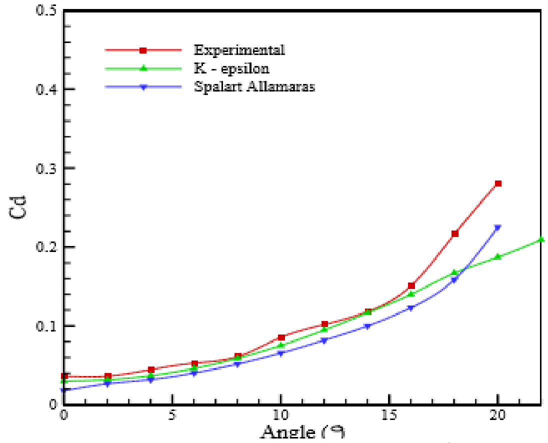

Fig. 6: C_d variation with AOA (α^0)

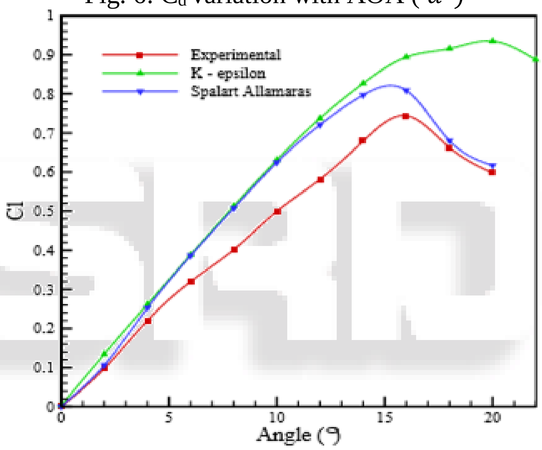

Fig.6 C_l variation with AOA (α^0)

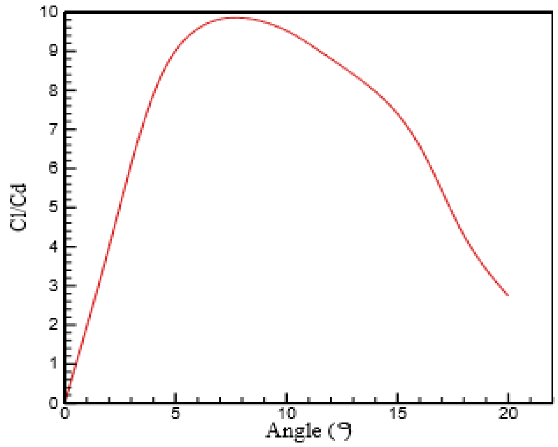

Fig. 6: C_l/C_d variation with AOA (α^0)

IV. CONCLUSION

This work deals with the aerodynamic behaviour of NACA0018 airfoil at different angle of attack. low Reynolds number flow is unsteady and is not easy to be researched in quantitative experiments numerical simulation can calculate the aerodynamic characteristics with an desirable accuracy[5]. A symmetric pressure distribution was obtained along the section of airfoil at zero angle of attack and maximum pressure is obtained at 4%of chord length and also pressure difference is higher when AOA is 8^0. After CFD analysis of NACA0018[4] airfoil based on results we can conclude that the zero angle of attack there is no lift force generated the value of AOA[3] increases with respective increase the value of lift force amount of drag force also be increase but the value of drag coefficient is quite lower compare to lift force.

REFERENCES

[1] Ma Dongli, Zhao Yanping, Qiao Yutang Li Guanxiang Effects of Relative Thickness on Aerodynamic characteristics of airfoil at a low Reynolds number. CSAA; 2015 school of Aeronautics Science and Engineering Beijing University Beijing 1001191 china
[2] Hardik S. Patel, An analysis of Pressure Difference on Airfoil by Changing angle of Attack and flap Height Vol. 4 April-2015 ISSN No.2277-8160
[3] Mr. Arvind, Design and CFD analysis of airfoil with variation of attack angle .International Journal for Scientific Research and development Vol.4 2010 ISSN; 2320-0310
[4] Mr. Kaushik Devmurari, Mr. Tapan Barot, Prof. Dr. Shah A Review on Design and Aerodynamic Behavior of Airfoil. International Journal for science and Development Vol. 3 2015 ISSN No.2321-0613
[5] Selig MS, Guglielmo JJ ,Broern AP, Giguere P. Experiments on airfoils at low Reynolds numbers. Reston: AIAA; 1996. Report No.AIAA-1996-0062.
[6] Carmichael BH. Low Reynolds number airfoil survey, volume I. Washington, D.C.: NASA Langley Research Centre; 1982. Report No.: NASA-CR-165803-Vol-1.
[7] E.N. Jacobs, K.E. Ward, R.M. Pinkerton, The Characteristics of 78 Related Airfoil Tests in the National Advisory Committee for Aeronautics, 1933.

