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Research Article

AN INVESTIGATION ON THE AERODYNAMICS OF SYMMETRICAL AIRFOIL

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ABSTRACT

In the present work an aerodynamic investigation was done over a symmetrical airfoil NACA 0014. Experiments were carried out in a low speed wind tunnel and the experimental data was collected at different Reynolds number. The main objective of this experiment is to determine the aerodynamic characteristics of airfoil under the influence of Reynolds number and angle of attack. Airfoil has been tested from 0^o to 18^o angle of attack with 3^o steps and Reynolds number from $1.49x10^5$ to $2.98x10^5$. The coefficients of pressure on both the surfaces were obtained and lift and drag coefficient were calculated. Stall condition were observed at 15-16^o angle of attack.

INTRODUCTION

The aerodynamic is the science which concentrates on air as the working media when it passes through any object. The area of cross section of the wing is known as the airfoil. The airfoil is the centre of investigation in the field of aerodynamic since 18th century, but still lots of researches are going on. National Advisory Committee of Aeronautics (NACA) contributes a lot in this field. Sir Isaac Newton was considered as the first aero dynamist of modern world because of his famous publication Principia. Sir George Cayley gave four fundamental of flight of any object i.e. lift, weight, drag and thrust. Wright brothers got success in their experiments and made first flight for human race (Anderson, 1991). Now a day low Reynolds number applications are widely used in aerodynamics which has wide application in the field of aerospace, civil and military engineering (Juanmian *et al*, 2013). Aerofoil when travels through the air have to handle the aerodynamic forces (Lift and Drag). In recent years many experiments has been done to enhance the performance of aerofoil that means to enhance the lift force and to reduce the drag force. Aerofoil characteristics are mainly dependent on three factors, first is angle of attack second is Reynolds number and third is its geometry. (Sukhri *et al*, 2014).

(Yeminici, 2013) has done her investigation for the aerodynamic characteristics of the symmetrical airfoil NACA 0012. Reynolds number which is based on chord length varied from $9.7x10^4$ to $1.9x10^5$ & angle of attack was varied from 0^0-14^0. It was conclude that initially the pressure coefficient at the suction side increased at the leading edge and get diminished at the trailing edge at all angle of attack. It was also concluded that both lift and pressure coefficient are highly dependent on angle of attack and Reynolds number.

(Rathod, 2014) has done his experiments with the help of sub sonic wind tunnel with variable wind velocity. Symmetric aerofoil NACA 0017 was used in this experiment. Characteristics curves were drawn at different angle of attack with different Reynolds number. In this experiment result comes that the stalling condition was found nearly to the 16^0 angle of attack. It is also conclude that with increase in velocity drag reduced up to a certain limit and after that it is considerably high. Coefficient of lift increases linearly with angle of attack up to stall condition comes and with further increase of angle of attack its value gets diminished. From pressure variation graph it was conclude that pressure over the upper surface decrease with increase in Reynolds number.

(Gerakopulos *et al*, 2010) has analyzed symmetrical airfoil NACA 0018 in his experiments. Pressure distribution at the surfaces was measured and calculation has been done to figure out the relationship between the performance of aerofoil and the development of separated flow region. The variation in angle of attack is from 0^0 to 18^0 and in Reynolds number is from 80×10^3 to 200×10^3. With the help of measured data two distinct regions have been identified, first is of rapid and linear

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growth of coefficient of lift at low angle of attack and second is of more gradual and linear growth of at the high pre- stall condition.

(Islam and Hossain, 2015) had done analysis through their experimental investigation in a sub sonic wind tunnel on a base line airfoil NACA 0015 model. Experiments have been done over a wide range of angle of attack from 0^0 to 20^0 with fixed stream velocity of 12m/s. and with the Reynolds number 1.89×10^5. Pressure distribution measurement has been done on both upper and lower surface of the airfoil and after analysis it has been found that C_l & C_D are 1.3 and 0.31 respectively.

(Uddin and Hossain, 2015) has carried out their experimental investigation to measure the drag and lift coefficient for multiple wings. For the investigation a model of multiple wing was constructed and experiments was conducted through it in a subsonic wind tunnel. Symmetrical airfoils NACA 0012 of chord length 21 cm was used for tri-plane configuration. Angle of attack was varied from 0^0 to 20^0 with 5^0 steps.

MATERIALS AND METHODS

Experimental set-up

The present experimental work has done with the help of an open circuit, suction type, sub sonic wind tunnel which has maximum velocity of 35 m/s. The flow of air is generated by a single stage axial flow fan which has suitable mechanism to make variation in the velocity of air. Wind tunnel has test section of dimension (LBH) 900mm x 300mm x 300mm. Test section has suitable mechanism to hold the test specimen (airfoil). Wind tunnel has honey comb structure with MS screen to correcting the flow of air. Honey-comb structure is used to generate laminar flow. Contraction zone is provided in the wind tunnel after honey-comb structure to accelerate the flow. Flow of air is discharged in the test section through this contraction zone. Strain guage meter is provided in the test section which has digital meter to show the coefficient of drag. Wind tunnel which is used for this purpose is shown in figure below.

Fig. 1 Wind tunnel where tests were conducted

Test model (Airfoil)

An airfoil is used for present work which is symmetrical and has maximum thickness of 14 percent of its chord length (NACA 0014). The airfoil is of wooden material having chord length 145mm and span length of 200 mm. To measure the pressure distribution over the surface of airfoil, pressure tapping is provided on upper and lower surface of the airfoil. A round protractor is provided to set the desired angle of attack for the airfoil.

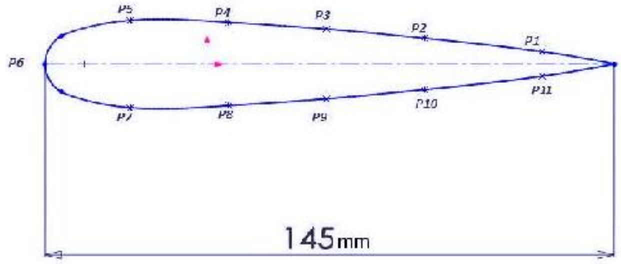

Fig. 2 Location of pressure tapping on airfoil

Pressure distribution measurement on the surface of airfoil was done with the help of pressure tapping as shown in figure. These pressure tapping were connected with the U- tube manometer where pressure on the desired point can be calculate.

Experimental procedure

Firstly the test model was held on the mechanism in the test section at 0^o angle of attack. The required velocity was set with the help of suction fan and pitot tube. Now at desired angle of attack the airfoil was held and the readings on the U- tube manometers were collected. Experimental investigation was performed from 0^o to 18^o angle of attack. Coefficient of pressure C_p was calculated with help of expression $C_p=(P-P_\infty)/0.5\rho V^2_\infty$, where P is static pressure measured at tapping, P_∞ is the static pressure of free stream, ρ is density and V_∞ is free stream velocity. Coefficient of lift was calculated with help of Coefficient of pressure at lower surface (C_{pls}) and Coefficient of pressure at upper surface (C_{pus}) in the expression as given below

$$C_L = \frac{1}{c}\int_0^1 (\text{Cpls} - \text{Cpus})\, dx$$

Drag coefficient observed with the help of strain guage meter which shows value on digital meter.

RESULTS

Surface pressure distribution

Results which are obtained are discussed in this section. Calculations for C_P with respect to x/c (where x is distance from leading edge along the chord) were done and the related graphs are shown in this section. Fig. 3, 4, 5 and 6 shows the upper surface pressure distribution and Fig. 7, 8, 9 and 10 shows the lower surface pressure distribution.

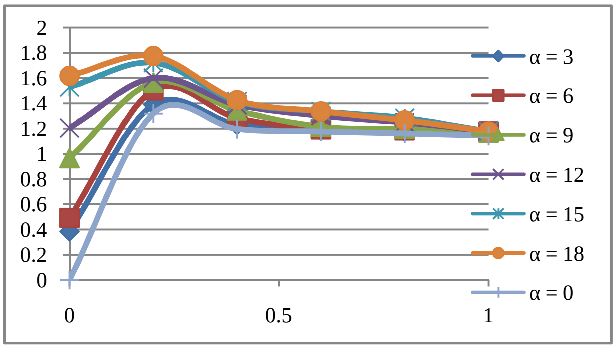

Fig.3 Pressure coefficient at RE = to 2.98×10^5

Surface pressure distribution at the upper surface of airfoil is shown as-

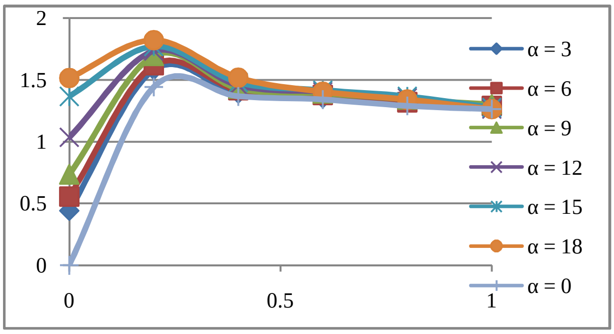

Fig.4 Pressure coefficient at RE = to 2.48×10^5

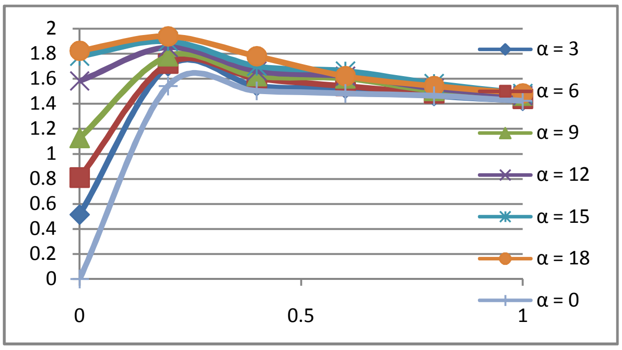

Fig. 5 Pressure coefficient at RE = to 1.98×10^5

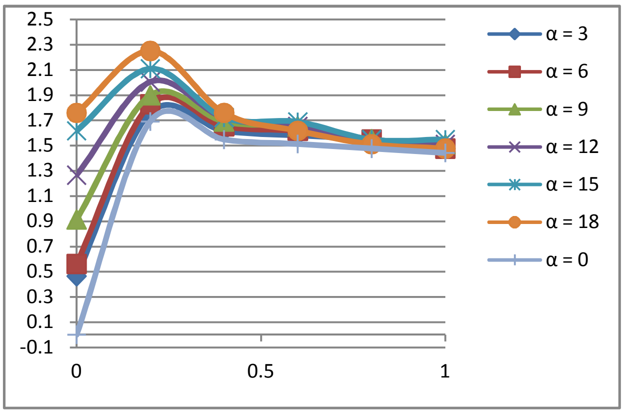

Fig. 6 Pressure coefficient at RE = to 1.49×10^5

Surface pressure distribution at the lower surface of airfoil is shown as-

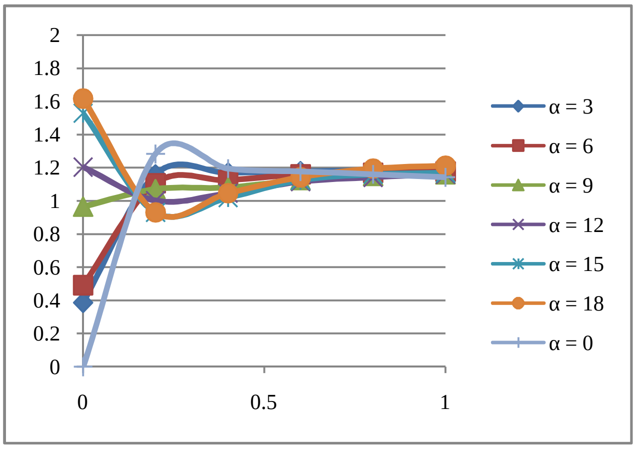

Fig.7 Pressure coefficient at RE = to 2.98×10^5

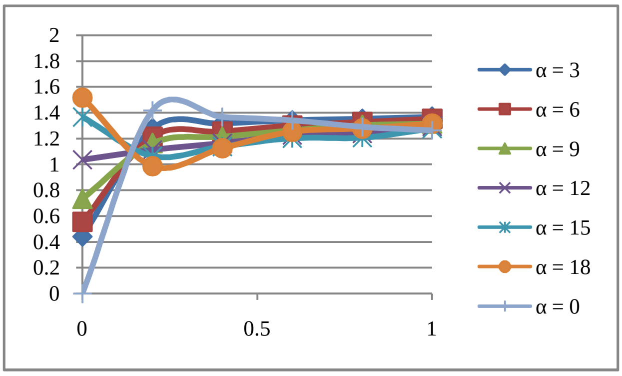

Fig.8 Pressure coefficient at RE = to 2.48×10^5

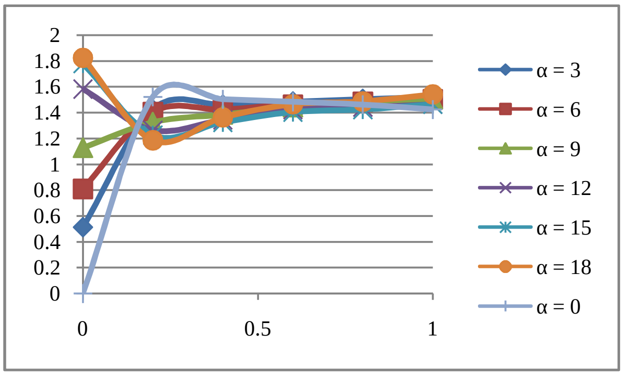

Fig. 9 Pressure coefficient at RE = to 1.98×10^5

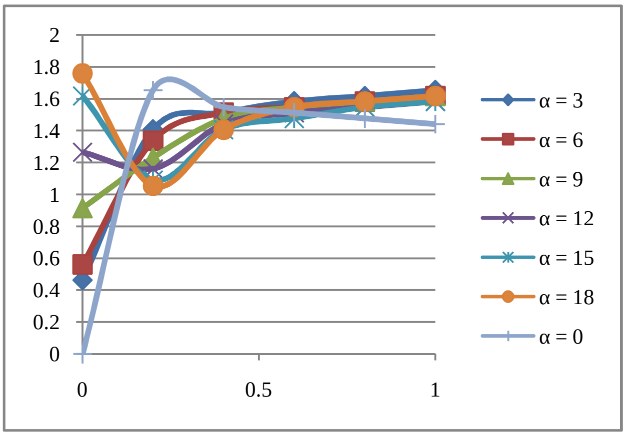

Fig. 10 Pressure coefficient at RE = to 1.49×10^5

Lift and Drag coefficient

Fig. 11 and 12 shows the lift and drag coefficient from different angles of attack.

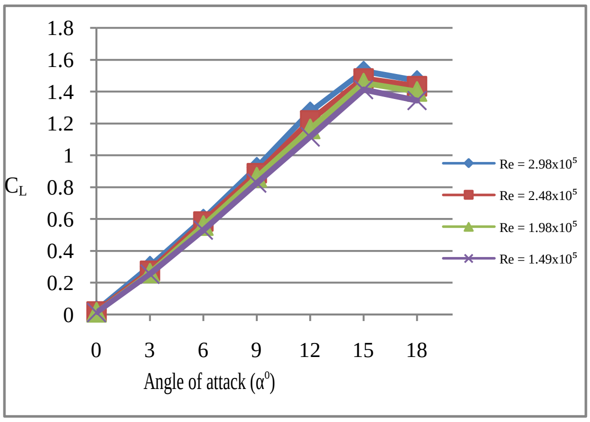

Fig.11 Coefficient of lift at different Reynolds number

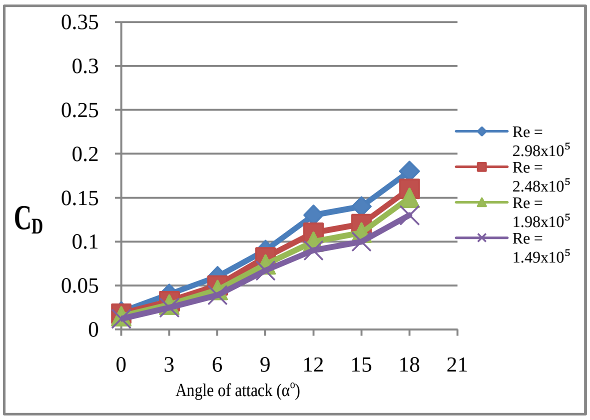

Fig.12 Coefficient of drag at different Reynolds number

DISCUSSION

The aerodynamic characteristics of Symmetrical airfoil NACA 0014 are calculated at four different Reynolds number from 1.49×10^5 to 2.98×10^5 and angle of attack varied from 0^o to 18^o. Coefficient of lift and drag are plotted in reference to angle of attack. Coefficient of lift is increased up to a certain point with increasing of Reynolds number and angle of attack. When airfoil reached to stall condition lift coefficient starts decreasing with increasing of angle of attack. Coefficient of drag is increased gradually up to 12^o angle of attack and falls a little bit at maximum lift coefficient point and after that it increased rapidly. It is found that experimental values of lift coefficient is some lesser than that of theoretical values.

CONCLUSION

The symmetrical airfoil NACA 0014 was analyzed in this experimental work. A subsonic wind tunnel was used for conducting the experiments. From the study it is concluded that the maximum value of lift coefficient is 1.53 at 15^oangle of attack and maximum value of drag coefficient is 0.18. Lift coefficient is nearly zero at 0^o angle of attack and it increases with increasing the angle of attack. The value of drag coefficient increased gradually with increasing of Reynolds number and angle of attack. The separation of boundary layer could not find out by the pressure measurement technique. Stall condition was observed at $15\text{-}16^o$ angle of attack.

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