An Experimental research on wake behind airfoil Naca0012 under various angles

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Abstract: The aim of this article is investigation of the wake of an airfoil Naca0012 in the wind tunnel. The measurement has been done at different angles of attach of airfoil α= 0, 5, 10, 15 degrees and locate in test section of wind tunnel a turbulence maker net with intensity of 5% in the entrance of test section. The wind tunnel which is used in this experimental has area section of 1600 mm^2 and 2000 mm length; with minimum free turbulence level less than 0.1% without any net and maximum speed is 30 m/s. For measuring favorite parameters in this test we apply hot wire anemometer, In this paper we focus on wake turbulence behind the airfoil in the angles of 0,5,10,15 degrees and in X/C=0,0.05,0.01,0.15,0.2(that X means distance behind airfoil and C means airfoil thickness). To comparison data wake results in a certain degree for various stations. On the other hand, in certain stations for various degrees, we tried our test in 20m/s velocity. From the diagram at the certain angles can conclude that on the certain angle whatever approach to the farther stations we have increasing on velocity and diagram goes to flatten. We can conclude from diagram at certain stations with increasing in angle the velocity is decrease. Also with increasing in angle the diagram of velocity shifts toward negative and with increasing of airfoil angle from station x/c = 0.5 to the next velocity defect increases.

Keywords: Wake- Experimental- wind tunnel- hot wire- airfoil Naca0012

1 Introduction

It is important to get a suitable angle for airfoil that can be important and essential for lifting force in airplanes. So the appropriate angle for a moment to take off and landing is very important. An airplane must ascend its nose to take off. But in fact the airplanes take off is not as a result of nose ascending. Actually by nose ascending, the attack angle increase that because of this lifting force also increase and opportunity to climb the aircraft has created. Also attack angle can be a criterion to determine the rate of airplanes ascending.

2 Review

Many people have worked on airfoil which includes Yachen Li, Jinjun Wang and Panfeng Zhang [1] that have observed that effects of Gurney flaps on airfoil Naca0012. They verify distribution of pressure and wake profile in wind tunnel and by using that data they find coefficients of lift and drag and torque twist. They concluded that gurney flap increase the maximum coefficient of lift from 1.37 to 1.74.

Dalibar Dvorak [2] made an experiment on airfoil Naca0012 by fluctuates the airfoil. By using experimental measurements; he got the force, moment and field for fluctuated airfoil. He made his experiments in 20000s Reynolds number. In fact he calculated the force in the same Reynolds to theoretical and got same interesting results. He compared the wake behind airfoil, cylinder and fish and he included that the vortex direction is different among these 3 cases.

Andre Luiz Amarante Mesquita [3] tested various airfoils in high attack angles in wind tunnel. The subject of this study was experimental analysis of lift and drag coefficients. The experiments were made in a wind tunnel with 30×30 cm2 areas and the velocity of 11 m/s with low turbulence intensity. The research was done on a Naca0012 airfoil in which the maximum attack angle were got to 40 and the velocity was 8.5 and 11 m/s and the changes of lift and drag coefficients with various attack angles were discussed .the experimental results were not suitable in high attack angle.

Ph. Devinant, T. Laverne and J. Hureau [4] studied aero dynamical feature for an airfoil, used in wind turbines .they tested airfoil in turbulence about 5% to 16% and in attack angle up to 90 degree. The experiments were made in a wind tunnel with 2×2 m2 areas and the maximum velocity of 60 m/s.

Lasse Gilling, Niels N. Sørensen, Lars Davidson [5] studied the effect of resolving inflow turbulence in detached eddy simulations of airfoil flows. They used Synthetic turbulence for inflow boundary condition. The generated turbulence fields are shown to decay according to experimental data as they are convected through the domain with the free stream velocity. The subsonic flow around a NACA 0015 airfoil studied at Reynolds number 1.6 × 106 and at various angles of attack before and after stall. Simulations with turbulent inflow compared to experiments and to simulations without turbulent inflow. Their results showed that the flow is sensitive to the intensity of the resolved turbulence. Especially, when the flow is close to stall; separation can be triggered if the turbulence is resolved. By resolving the inflow turbulence better agreement with experimental data can be achieved.

G. Martinat, M.Braza, Y.Hoarau, G.Harran [6] provided a study of the NACA0012 dynamic stall at Reynolds numbers 105 and 106 by means of two- and three-dimensional numerical simulations. The turbulence effect on the dynamic stall is studied by statistical modelling. The results are compared with experiments concerning each test case. Standard URANS turbulence modeling has shown a quite dissipative character that at attenuates the instabilities and the vortex structures related to the dynamic stall. Emphasis is given to the physical analysis of the three-dimensional dynamic stall structure. Their study has shown that the down stroke phases of the pitching motion are subjected to strong three-dimensional turbulence effects along the span, whereas the flow is practically two-dimensional during the upstroke motion.

Zhou Y, Md. Mahbub Alam, Yang H.X, Guo H, Wood D.H [7] presented the measurements of mean and fluctuating forces on an NACA0012 airfoil over a large

Range of angle (a) of attack (0–90) and low to small chord Reynolds numbers (Rec), 5.3 × 103–5.1 × 104, which is of both fundamental and practical importance. The forces, measured using a load cell, displayed

Good agreement with the estimate from the LDA-measured cross-flow distributions of velocities in the wake based on the momentum conservation. The dependence of the forces on both α and Rec is determined and discussed in detail. They have been found that the stall of an airfoil, characterized by a drop in the lift force and a jump in the drag force, occurs at Rec ≥.05 × 104 but is absent at Rec = 5.3 × 103. A theoretical analysis is developed to predict and explain the observed dependence of the mean lift and drag on α.

J. Soria, T.H. New, T.T. Lim, K. Parker [8] measured the flow field around a NACA 0015 airfoil at a 30_ angle of attack when the flow is accelerated to a constant velocity from a quiescent state by Multigrid cross-correlation digital PIV (MCCDPIV) technique. The experiments were conducted in an acceleration water tunnel using uniform accelerations of 50 and 100 mm/s2. The final uniform velocity was 100 mm/s for both cases, and the Reynolds number based on this velocity and the chord length of the airfoil was about 8000. The MCCDPIV measurements were carried out using a digital 2048 px _ 2048 px CCD camera to record single exposed images of seed particles illuminated with a Nd: YAG laser. Their measurements have revealed a rich and complex unsteady flow structure, during both the acceleration phase and the constant velocity post-acceleration phase.

Propulsive performance of a harmonically heaving and pitching foil is degraded by a breakdown in the angle of attack profile, at high no dimensional frequencies. F.S. Hover, Φ. Haugsdal, M.S. Triantafyllou [9] built upon the method employed by Read et al. (J. Fluid Structure 17 (2003) 163) to invert the key kinematic nonlinearity, and compared directly the performance obtained with four specific angle of attack profiles. Those profiles were: (i) that due to simple harmonic motion in heave and pitch motion, (ii) a square wave, (iii) a symmetric saw tooth wave, and (iv) a cosine function. The cosine angle of attack achieves a significant improvement over the other three cases; in the sense of high thrust values with reasonable efficiency. The highest thrust coefficients have generally found in the saw tooth profile. Flow visualization confirms the partial or complete recovery of a reverse von Karman wake by all three controlled profiles, concurrent with the enhanced force and efficiency at high frequencies.

T. K. Sengupta, S. DE, K. Gupta [10] investigated Unsteady flow past a NACA 0015 aero foil for moderate Reynolds numbers at high angles of attack by solving the full 2-D Navier-Stokes equations with and without the presence of free-stream turbulence (FST). Their investigation focused on the by-pass mode of transition usually encountered in turbomachinery and wind engineering where the flow field around a bluff-body can experience very high levels of FST. Their study was relevant for understanding the implications of reduced order modelling proposed for aero elastic studies. The numerical results showed the solution of the Navier-Stokes equations were not only as the output of a dynamical system in the presence of stochastic noise (FST), but which also produces the intermittency factor in and around the aero foil dominated by differing pressure gradient and unsteady effects. The computed flow field showed that the flow achieves a statistical stationarity even though the overall flow is chaotic and aperiodic.

3 Setup

The wind tunnel ,used in this experiment had an test section with plexus glass kind with a length of 168 cm ,width of 40 cm and the height of 40 cm .the velocity of wind tunnel can be change from 0 to 30 . In this research the fluid flow velocity is 20 m/s. as regards of wind tunnel feature the maximum turbulence of free stream for this device is 0.1%. The rate of turbulence is nominal and the device is suitable to measure the fluids parameters, the hot wire is used. That is able to measure the mean velocity and turbulence. The wind tunnel and the hot wire anemometer device, both are made by Farasanjesh Saba Company. One dimension probe used in these experiments has a sensor with the length of 1.25 mm and diameter of 5 µm.

To move the probe to different points a mechanism with accuracy of 0.01 mm with 3 degree freedom is used. This mechanism is controlled by software and the moment probe status information is to be registered. The above mechanism has been installed on separate frames independent wind tunnel legs to stop the possible turbulence of wind tunnel body. The airfoil for this experiment is Naca0012 and the maximum thickness is 30 mm and the length of airfoil is 30 cm. To create the turbulence in this experiment, a net with the mesh of 39*39 cm2 that the diameter of rod is 1 cm and they are 6 cm far from each other is used. This net is 20 cm far from the airfoil. The schematic view of wind tunnel is shown in figure (1).

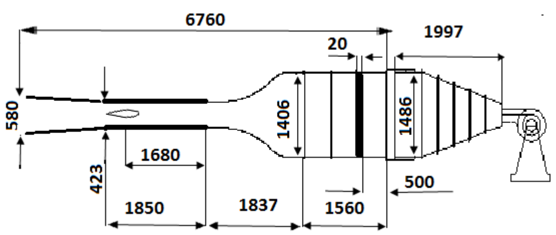

Figure 1. Schematic of wind tunnel and airfoil.

4 Experiment

In this procedure , first we locate a net at the surface of the test section in wind tunnel , in order to turbulence of free stream and then we apply that airfoil that was Naca0012 , at first in 0 degree and then respectively on degrees 5 , 10 , 15 degree and velocity profile for each one of mentioned degrees on stations respectively x/c= 0 , 0.5 , 1 , 1.5 , 2 (that x means distance behind airfoil and c means airfoil thickness) behind airfoil is obtained . In figure (2) mentioned airfoil and position stations behind it that measure mean velocity is shown and then the diagrams were drawn and interesting results were obtained. Velocity defect and half wake were the other parameters that have been discussed and these parameters are shown in figure (3).

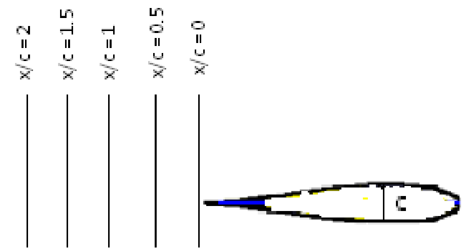

Figure 2. model and different stations for measuring of velocity and turbulence.

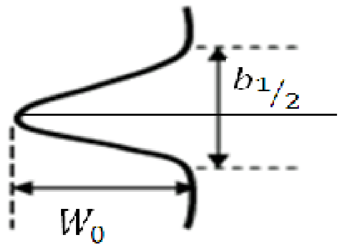

Figure 3. w0 (velocity defect) and b1/2

5 Results analysis

Mean velocity diagram for different degrees is shown in the below. These diagrams explain in a certain angle, velocity profiles for different stations. Figure (4) is mean velocity profile for 0 degree as shown in the figure below, how much we far away from the behind of the airfoil, wake behind of the airfoil diagram reduces from the peak and diagram go to the flatten and this means that wake gradually wastes and as shown in the figure, in the out of shear layer effects (means free stream territories) the potential velocity volume with very good accuracy is continues and there isn't change of pressure in test section in higher x/c. With far away behind the airfoil, velocity goes to the mean velocity. That in figure 4 the volume of U/Uref in peak from 0.00067 in x/c = 0 gets to 0.8441 in x/c= 2 we conclude that volume of peak has reduced.

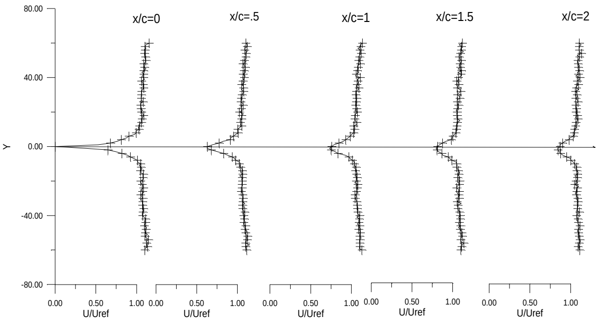

Figure 4. Velocity profile for Naca 0012 airfoil with 0 attack angle in different stations.

Figure (5) is mean velocity profile for angle of 5 degree. As shown in the figure below how much we far away from the behind of the airfoil, wake behind the airfoil diagram reduces from the peak and diagram go to flatten and this means that wake gradually wastes. With investigation on the figure we understand that this curve shifts to the negative y relation to 0 degree and whatever we farther from the behind the airfoil more shifts to the y mines.

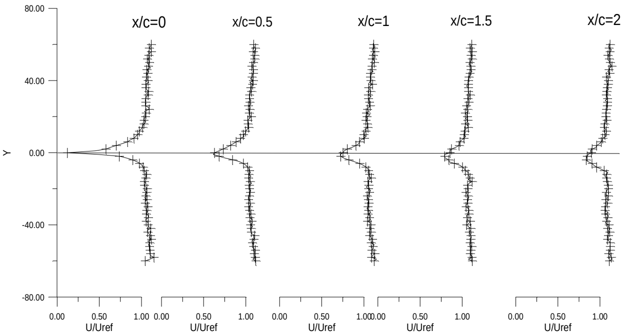

Figure 5. Velocity profile for Naca 0012 airfoil with 5 attack angle in different stations

Figures (6) and (7) are shown in the below in the angle of 10 degree and 15 degree. These diagrams have the same results from diagrams in the angle of 0 degree and 5 degree but with the intensity more than the angle of 5 degree.

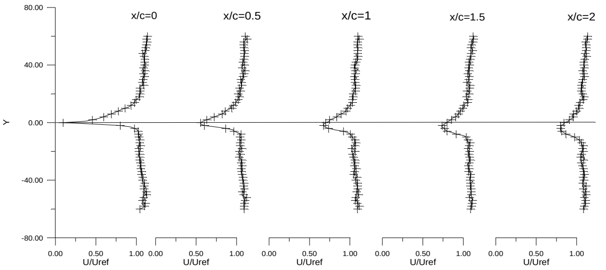

Figure 6. Velocity profile for Naca 0012 airfoil with 10 attack angle in different stations.

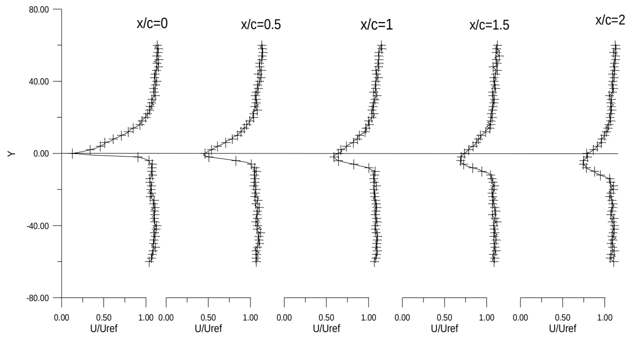

Figure 7. Velocity profile for Naca 0012 airfoil with 15 attack angle in different stations.

Below diagrams are shown velocity profiles for certain station in different angles. Figure (8) is mean velocity for station 1 at behind the airfoil Naca 0012. With increasing airfoil angle the wake asymmetry is increasing and shifts to the +y and velocity defect (w0) decreases and finally the change of b1/2 increases and velocity decreases. With regard to this concept that with reducing in angle, flats the curve.

In figure (8), the first curve is mean velocity curve in 0 degree that U/Uref volume in the peak of this curve is 0.00067 and for the latest curve in this figure that is relate to the 15 degree, U/Uref volume is 0.12745 that is means that the peak of curve reduces.

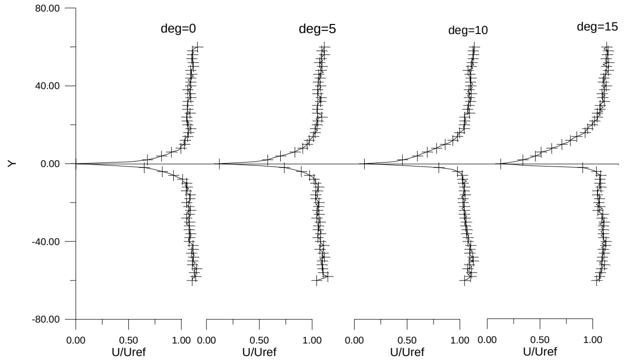

Figure 8. Mean velocity profile for airfoil Naca 0012 on the station x/c = 0 for different attack angle.

Figure (9) is velocity profile behind airfoil in station 2 that is x/c = 0.5. As shown in this section with increasing in degree in this certain station, peak of diagram increases and velocity decreases, consequently in the lower degree curve shifts to flatten. the next curves are the velocity curve on the station x/c = 1 , 1,5 , 2 at the behind of the airfoil that from these we understand, whatever airfoil attack angle increases , it causes the mean velocity behind the airfoil increases ,therefore volume of U/Uref increases and so with increasing the attack angle of airfoil , peak of diagram U/Uref decreases and we can understand that whatever we far away from behind the airfoil , mean velocity of behind the airfoil increases and volume U/Uref is increases, too.

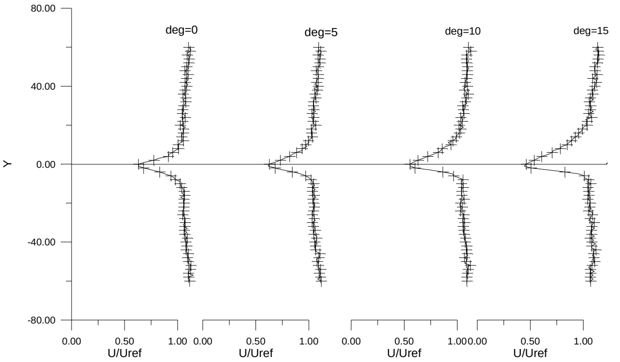

Figure 9. Mean velocity profile for airfoil Naca 0012 on the station x/c = 0.5 for different attack angle.

Figure (10) is the diagram of mean velocity on the station x/c = 1 and different angles of attack. In the first diagram of this figure that is related to 0 degree, minimum of U/Uref is 0.733998 and at the last diagram that related to 15 degree, the volume of U/Uref is 0.588616. That illustrates volume of U/Uref decrease with increasing the degree.

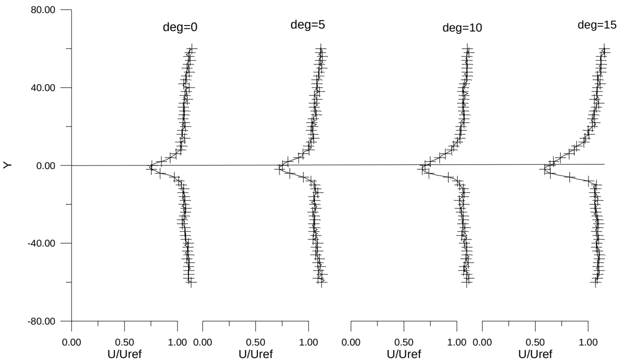

Figure 10. Mean velocity profile for airfoil Naca 0012 on the station x/c = 1 for different attack angle.

Figure (11) is the diagram of mean velocity on the station x/c = 1.5 and different angles of attack. In the first diagram of this figure that is related to 0 degree, minimum of U/Uref is 0.796935 and at the last diagram that related to 15 degree, the volume of U/Uref is 0.689152. That illustrates volume of U/Uref decrease with increasing the degree.

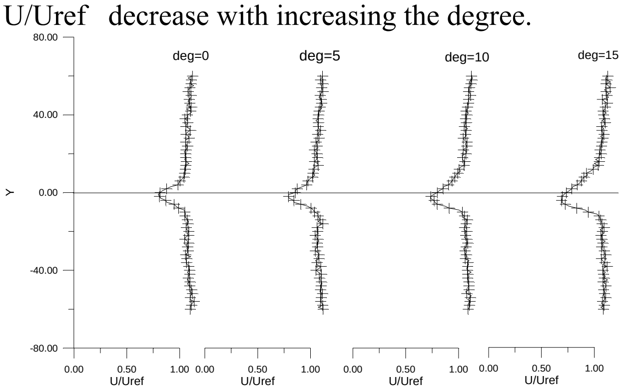

Figure 11. Mean velocity profile for airfoil Naca 0012 on the station x/c = 1.5 for different attack angle.

Figure (12) is the diagram of mean velocity on the station x/c = 2 and different angles of attack. In the first diagram of this figure that is related to 0 degree, minimum of U/Uref is 0.844145 and at the last diagram that related to 15 degree, the volume of U/Uref is 0.742888. That illustrates volume of U/Uref decrease with increasing the degree.

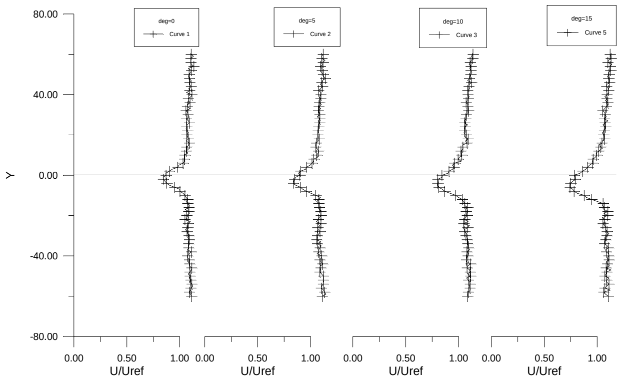

Figure 12. Mean velocity profile for airfoil Naca0012 on the station x/c = 2 for different attack angle.

Another parameter that is estimated in this experiment is velocity defect (W0). In figure (13), the velocity defect curve reduce from 1.152191 to 0.289715 that in fact percent of velocity is 74.85. On the angle of 5 degree percent of velocity defect is 69.95, on the angle of 10 degree percent of velocity defect is 67.57 and on the angle of 15 degree percent of velocity defect is 61.36. Therefore increasing in angle reduce percent of velocity defect and hence with increasing of airfoil angle from station x/c = 0.5 to the next, velocity defect increases.

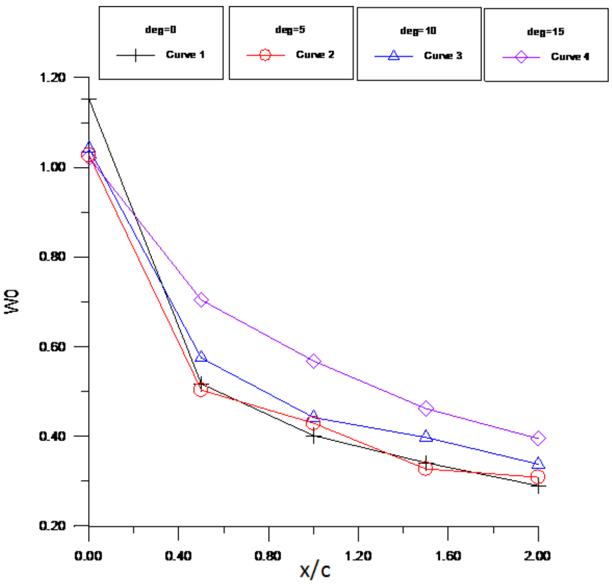

Figure 13. Velocity defect in the scale distance the behind of airfoil in different degrees.

5.1 Satisfy
In figure 14 results have produced by Qiang Zhang and Phillip M. Ligrani [11] have compared with our results. This figure show that our data coincide with their data.

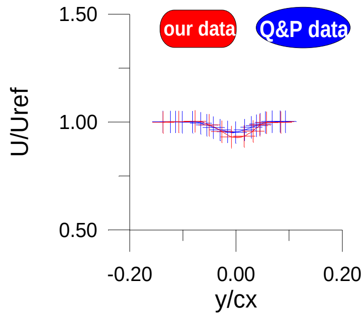

Figure 14. Satisfy of mean velocity profile with Q&P.

6 Conclusions
From the diagram at the certain angles can conclude that on the certain angle whatever approach to the farther stations we have increasing on velocity and diagram goes to flatten. We can conclude from diagram at certain stations with increasing in angle the velocity is decrease. Also with increasing in angle the diagram of velocity shifts toward negative and with increasing of airfoil angle from station x/c= 0.5 to the next velocity defect increases.

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