Aerodynamic analysis of NACA 4412 airfoil using CFD

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ABSTRACT

This project work presents computational study of flow separation over NACA 4412 at different angle of attack (10º,12.5º,15,16º,17º,17.5º,20º and 22.5º) using CFD (Computational fluid dynamics) simulation.

It is found that no flow separation is seen at 10º and 12.5º angle of attack, but flow separation started at angle of attack 15º and it increased as angle of attack increasing i.e. 17.5º, 20º, and 22.5º.

The purpose of this report is to familiarize the reader with the basic aerodynamic theory of wings and to provide an introduction to wind tunnel testing of a NACA 4412 wings and the data of this analysis has been used for further studies using computational fluid dynamic.

Here, NACA 4412 airfoil profile is considered for analysis of wind turbine blade. Geometry of airfoil is created using GAMBIT 2.4.6 and CFD analysis is carried out using FLUENT 6.3.26 at various angle of attack from 10º to 22.5º. variation of flow separation are plotted in form of contour for 0.36×10^{6} Reynolds number.

Key words: CFD simulation, air foil, angle of attack, flow separation

INTRODUCTION

Turbulent boundary layer separation from a surface from airfoil is an important problem because of it we set the upper limit to the performance of aerodynamic device. Here we will try to find out at which angle of attack maximum performance occurs. Although this is old topic, but there has been only limited progress made to predict the separation flow behavior adequately. A central reason holding back development of separating flow is that until recently the data had high uncertainties.

Here Two- equation turbulence models are tested for the ability to predict boundary layer separation on NACA 4412 airfoil at different position of angle of attack. The two equation model is RNG k-€.

Various experimental and theoretical studies have been published relating to the trailing edge flows. The most detailed data in separated flow region over airfoils were measured by Seetharam and wentz (1997), Adair and Horne (1989), Johnston and Horton (1986), Nakayama(1985), Burns and Mueller (1982).

The aerodynamic properties of NACA 4412 airfoil section have been investigated in a number of previous studies, such as Badran and Bruun (2003), Badran (1993), Kayiem and Bruun (1991), Nakayama (1985), Wadcock (1978).

Flying hot – wire techniques has been used by Maddah and Bruun (2002), Badran (1993), Adair(1987), Thompson and Whitelaw (1984).

Flow visualization study has been performed by many workers, Al-Kayem and Bruun (1991), and Badran (1993). Results from these studies indicated that visual techniques can be used to increase the understanding of separated flow phenomenon by visualizing the free shear layer region and the reattachment location of the separated flows.

VALIDATION OF EXPERIMENTAL RESULTS BY CFD SIMULATION

In this section we will verify the experimental results which is found from wind tunnel experimental when airfoil NACA 4412 put at angle of attack 15º and velocity of wind is 18.4 m/s.

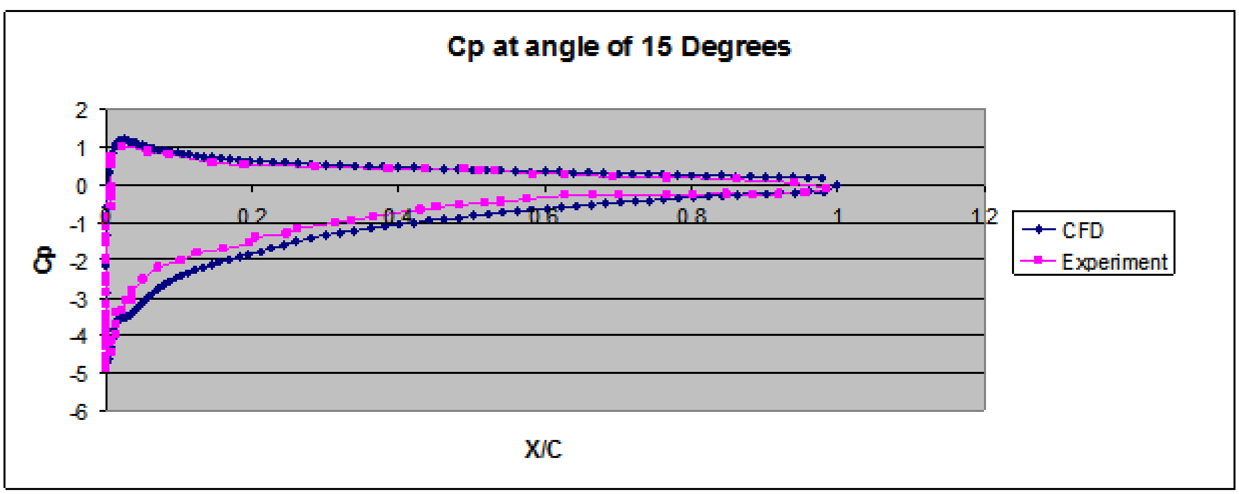

Figure 1: Resultant graph between Cp and X/C

This is the graph which is plotted between Cp and X/C. From this figure this is clear that experimental results at 15º angle of attack are matching with CFD simulation results. So our validation is completed.

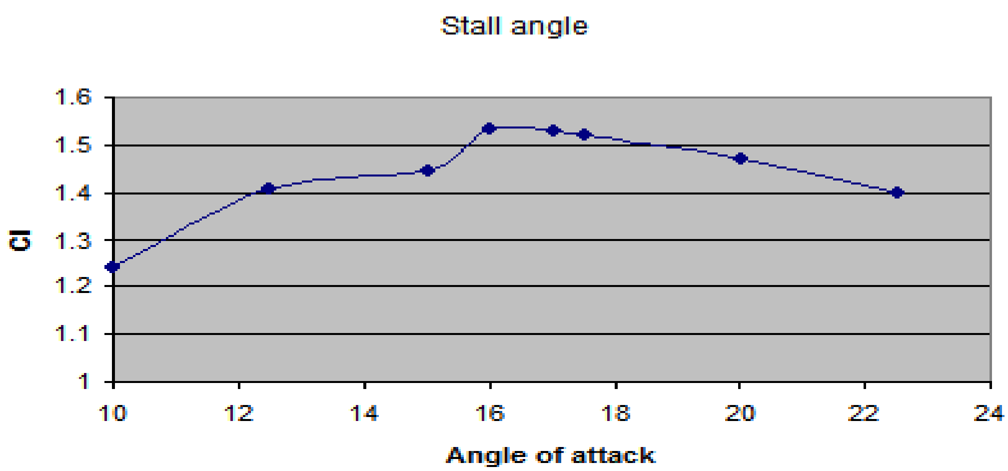

Figure 2:Resultant graph between Cl and angle of attack

From this graph it is clear that coefficient of lift is highest at 16º angle of attack. So stall angle is 16º. Hence lift of NACA 4412 is highest at this angle.

EXPERIMENTAL METHOD

The inlet velocity U∞ is set to 18.4 m/s for the RNG k-€ model for direct comparison with the flying hot- wire measurements. The corresponding Reynolds number is 0.36×10^6 based on the chord c of the airfoil (250 mm). A computational grid of 150×150 was fixed for model.

We are selecting this model because it is most widely used in aerodynamic industry they have well documented strength. Flow conditions around the airfoil were built up by finite element analysis using FLUINT 6.3.26 by fluent Inc.

RESULTS AND DISCUSSION

Turbulent separation has been concern of many experimental and theoretical studies. To provide physical explanation of the flow, the flow behavior is required in the regions of the turbulent separation region and in the wake for the seek of predicting the performance of airfoil.

In the present research, the near wall effect is not consider in this study, because the flying hot wire anemometry could not reach less than 5 mm from the airfoil upper surface.

With the help of velocity contour diagram, we can reach to the conclusion that as much as angle of attack is increased the flow separation is also increased with strong adverse pressure. While at lower angle of attack the pressure gradient is not strong enough to cause large separation region.

The test flows cover a significant range of flow situations typically encountered in aerodynamic computational and are believed to allow some conclusions about model ability to perform engineering applications.

.Figure 3: velocity contour for 10º angle of attack

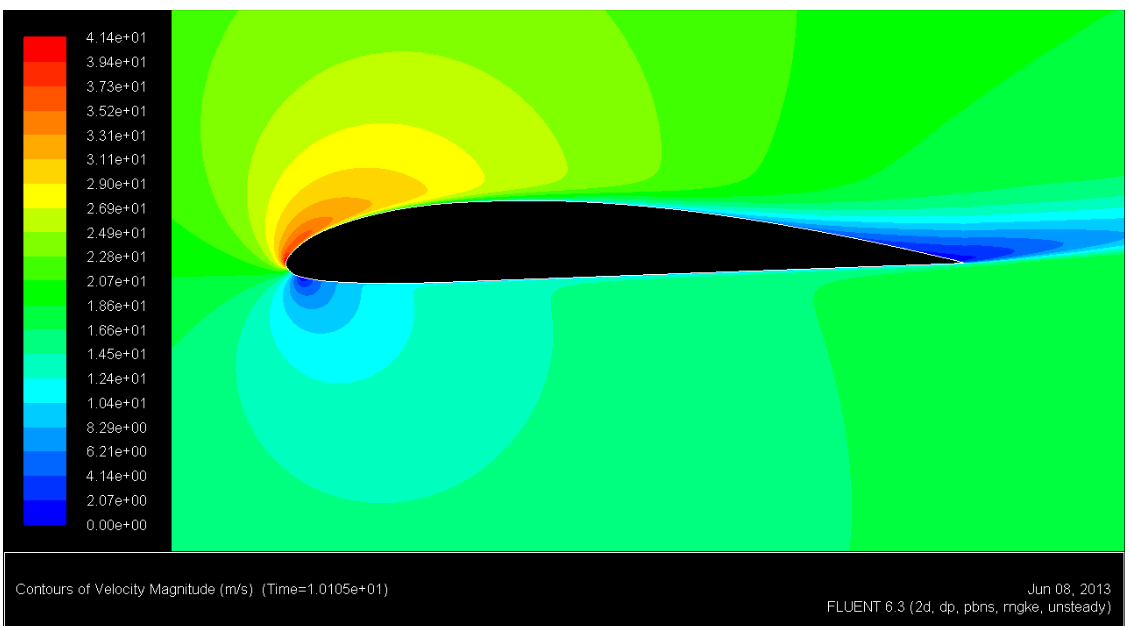

Figure 4: velocity contour for 12.5º angle of attack

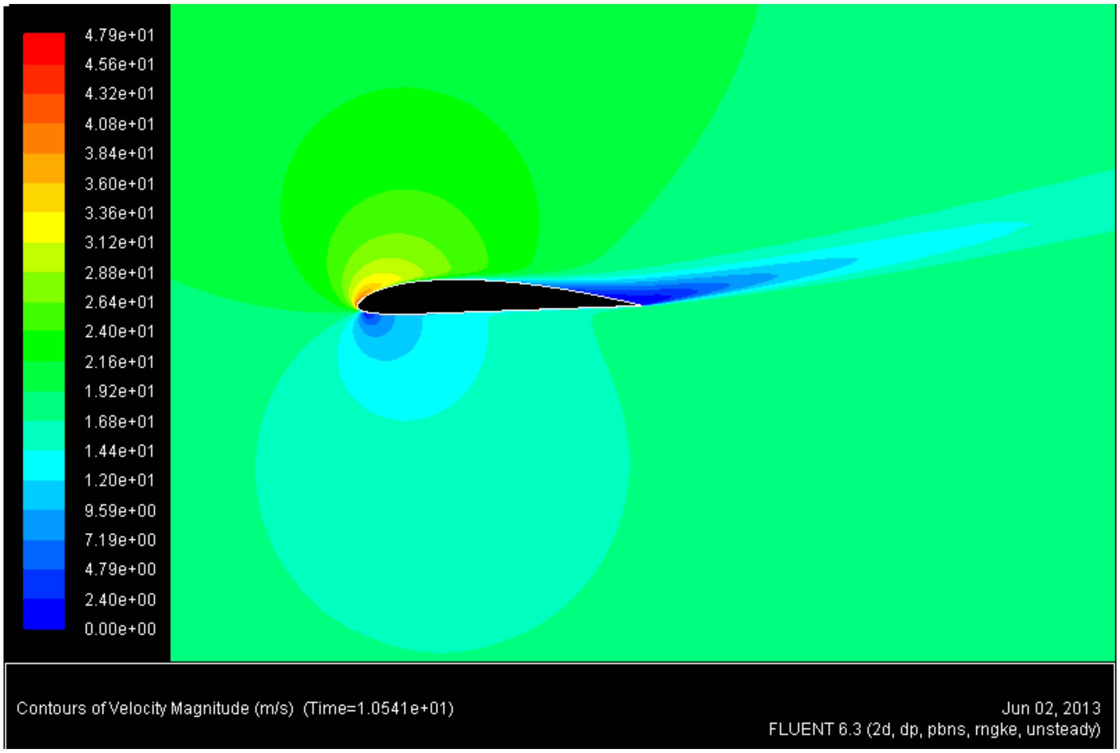

Figure 5: velocity contour at 15º angle of attack

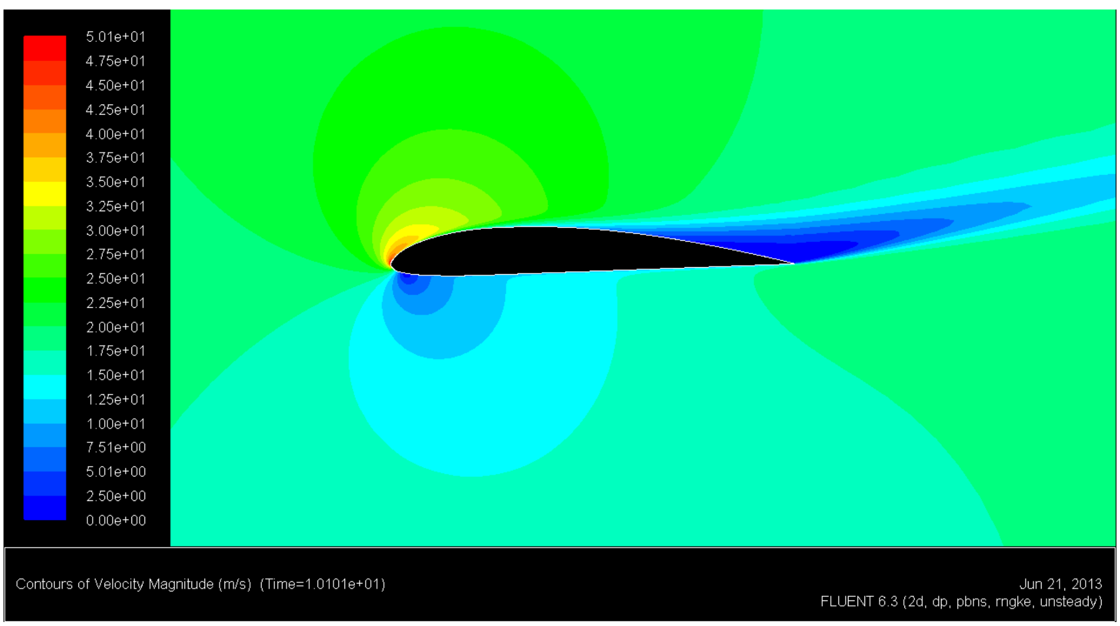

Figure 6: velocity contour at 16º angle of attack

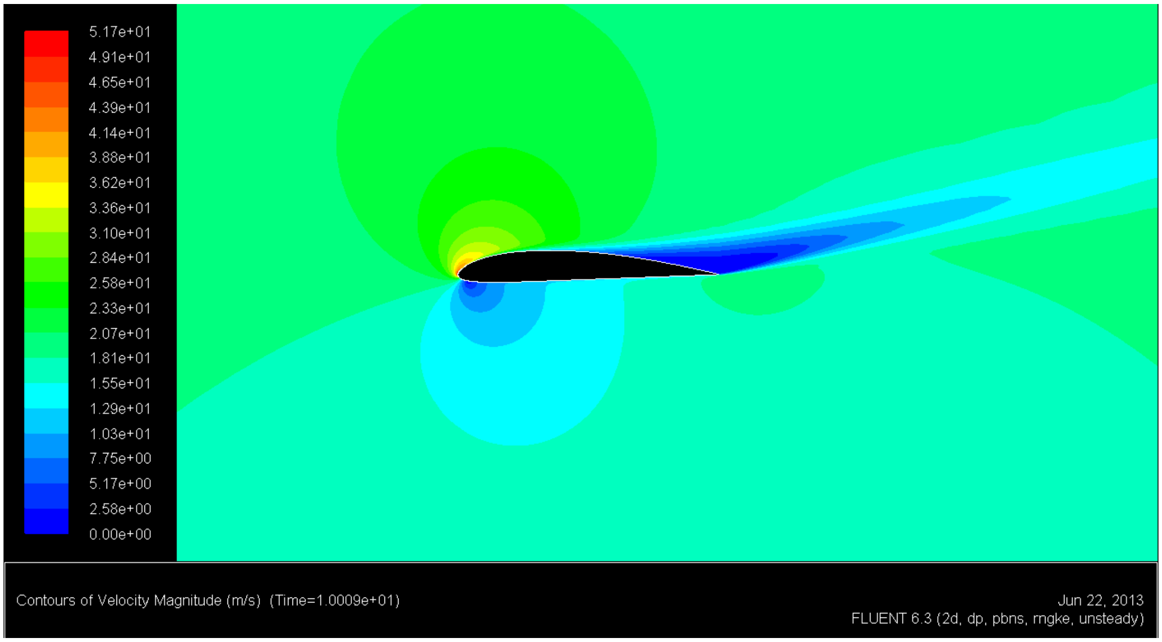

Figure 7: velocity contour at 17º angle of attack

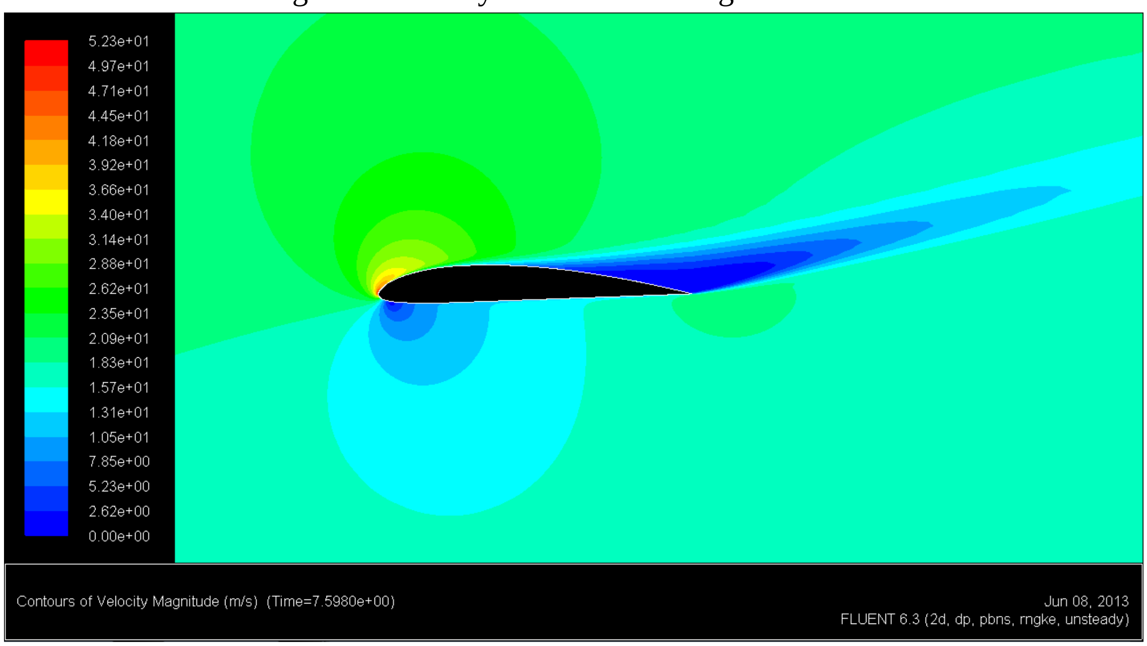

Figure 8: velocity contour at 17.5º angle of attack

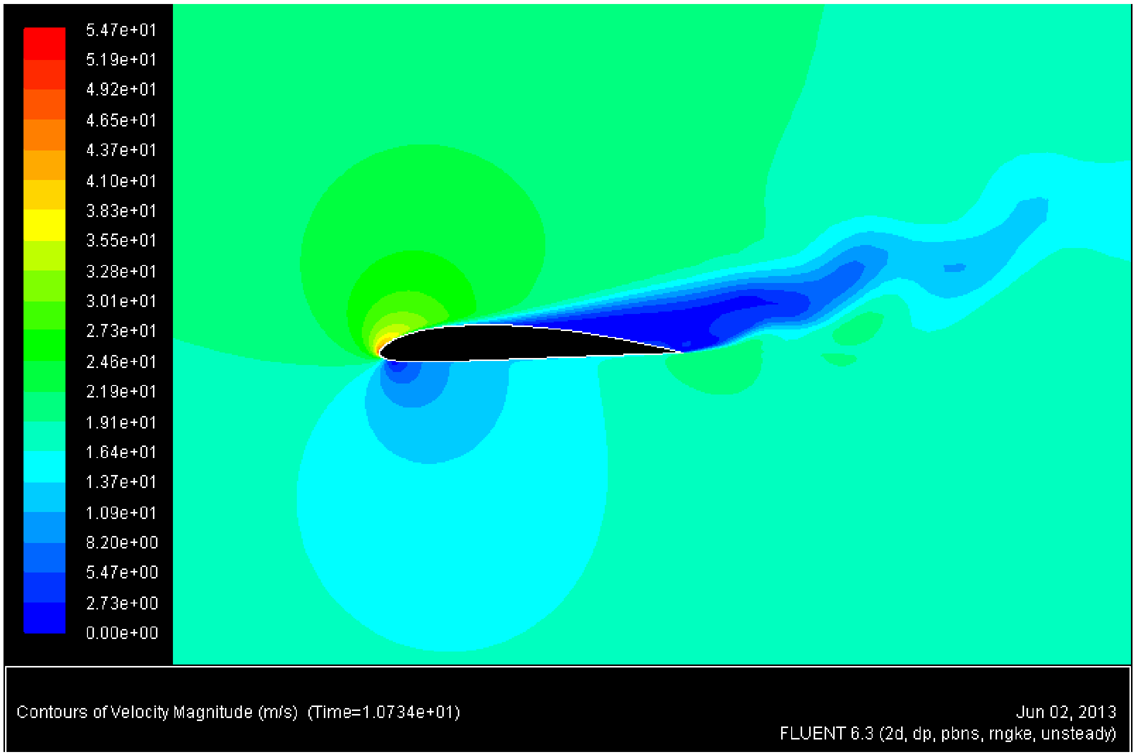

Figure 9: velocity contour at 20º angle of attack

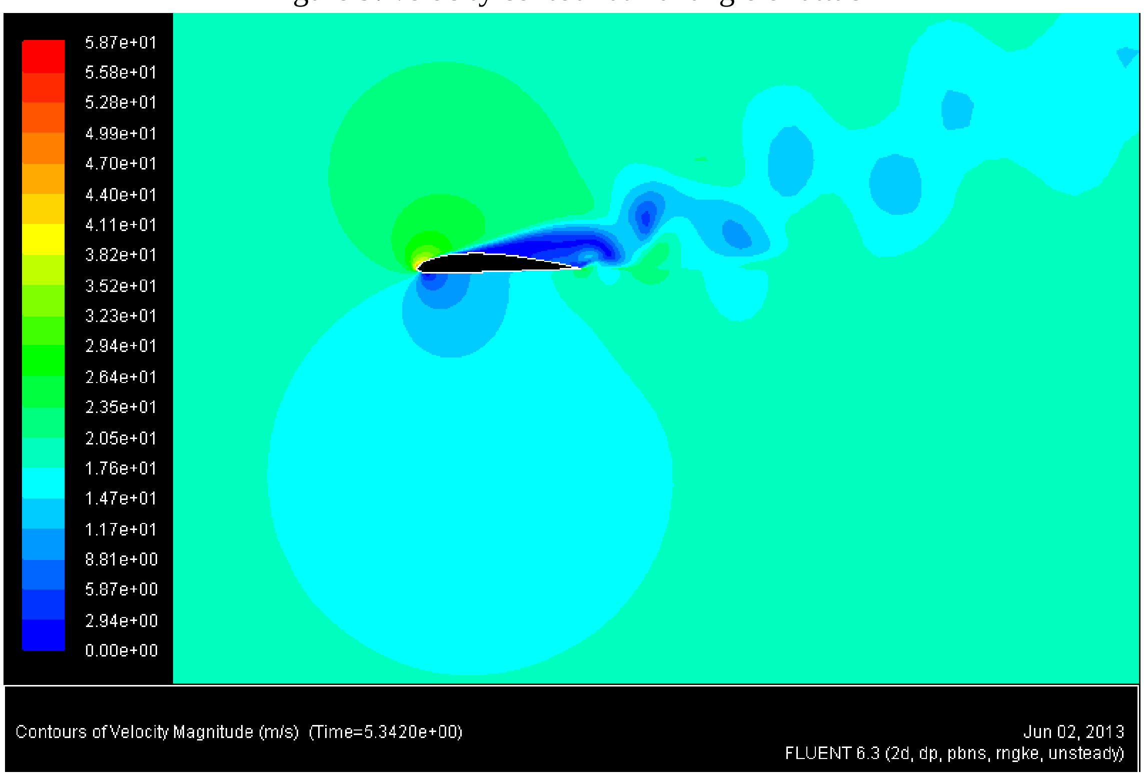

Figure 10: velocity contour at 22.5º angle of attack

CONCLUSION

From above results and discussion we reach on the conclusion that as much as angle of attack is increased the coefficient of lift (Cl) is also increased hence lift is increase. But one condition comes when lift can not be increased further and goes to reduced continuously. This reduction due to the generation of adverse pressure which increase the drag force. This is stall angle and in our experiment it is found at 16º. At this stall the coefficient of lift is 1.55 which is highest.

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