Analysis of Aerodynamic Characteristics on Surface Modification of Airfoil

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Abstract- *This project augments the performances of the existing airfoil by reducing the aerodynamic drag associated with the shape of the airfoil before undergoing modulations.This is achieved by the physical(surface) modifications of the existing popular NACA(National Advisory Committee for Aeronautics) series airfoils and thus the name of the project "ANALYSIS OF AERODYNAMIC CHARACTERISTICS ON SURFACE MODIFICATION OF AIRFOIL".Some scientist developed various types of airfoil series and this kind of approach has an endless effort and having huge scope for development so it is still used. Computational Fluid Dynamics is the technique for analysing and simulation where fluid flow involved. This technique has multiple uses in Industrial and Non industrial application areas.*

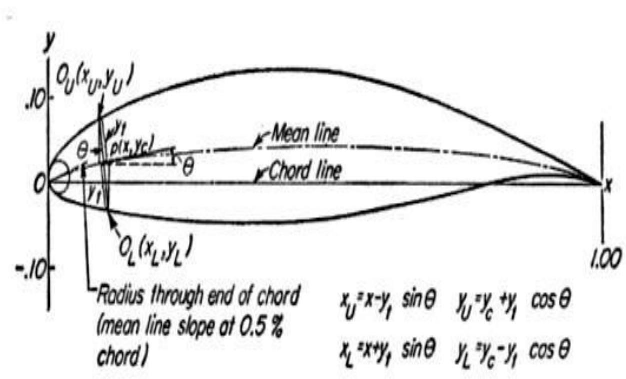
I. INTRODUCTION

Engines power have limitation to work under different critical conditions so it has to forget the early day's technique and an additional effort is required to reduce the drag and to increase the lift with a specified velocity of the aeroplane. Bird's wing inspired to generate an aeroplane that has modified airfoil to see its aerodynamic behaviour. Since the birds have limited power than the engine of aircraft but the design and shape of the wing of the bird motivate to change or modify the shape of the airfoil of the aircraft. Some scientist developed various types of airfoil series and this kind of approach has an endless effort and having huge scope for development so it is still used. Computational Fluid Dynamics is the technique for analysing and simulation where fluid flow involved. This technique has multiple uses in Industrial and Non industrial application areas. This technique reduces the cost of working and gives good agreement with practical results. The CFD contains three main elements which are Pre processor, Solver and Post Processor. (Versteeg & Malalasekera, 2012) .

As we know that Reynolds number is inversely proportional to the total viscosity. Frictions Drag also depends on the surface area. In case of laminar flow friction drag is independent of the roughness of the surface but in turbulent flow it plays a chief role Various terms are here defined and explained to understand the concepts of the airfoil and its aerodynamic behavior like flow separation, separation bubble, CFD, lift and drag etc. Throughout the flight, raises or reduces in lift will cause progressive starting or even be preventing vortices, usually with the result of maintaining the smooth similar flow on the trailing side. At a lower angle associated with the attack, the trunk surfaces come with an adverse stress gradient, however, not enough in order to cause substantial boundary layer splitting up. As the position of assault is improved, the upper-surface adverse obliquity becomes more powerful, and generally, any separation real estate begins to slide forward within the upper surface area.known as the leading edge and what is at the end is known as the trailing edge. If a straight line is drawn between the leading edge and the trailing edge then it is called the chord line. The length of this line is called chord length. The line which divides the airfoil into two equal parts is called the mean camber line. Mean upper part of the camber line is called upper camber and bottom part is called the lower camber.

$$C_L = f(\alpha, Re_c)_{\text{OR}} \qquad C_D = f(\alpha, Re_c)$$

Where Re =VC/*v* The Reynolds numbers are common in the turbulent boundary layer range and have a modest effect.



NACA airfoil geometrical construction.

II. LITERATURESURVEY

It is significant to find out the optimum quality of meshing and best turbulent model to get the accuracy of CFD simulation software. Eleni used NACA0012 noncambered airfoil and simulated this with different turbulent models i.e. Spalart-Allmaras, Realizable k-ε and k-ω shear stress transport (SST). For testing the meshing Eleni continuously increased the number of cells until the results became constant.In this near the 80000 cells, there was a huge chance to achieve much more accurate results. Using hit & trial method transition point was generated because it decides a point where the flow starts separating. During analysis, k-ω and k-ε turbulence models gave much more accurate results. Validation was done with practical data. During analysis, the fluid started separating at an angle of $15^{o.}$ In the small AOA, it remained stick to the upper side of the surface. Eleni divides the airfoil to get transition point by separating into two parts laminar region and turbulent region. The transition point helps to find accurate results while simulated.

(Logsdon, 2006) 2D & 3D models of airfoil with farfield was created in GAMBIT and analysed using FLUENT. 3D model consumes much amount of time and requires high memory computer while 2D model gives the identical results. Author tested NACA0012 airfoil at different Reynolds Number on 2D and 3D models of airfoil. Accuracy of FLUENT was not up to the mark for values of above 10o angle of attack. Simulation was done with Invisid and Spalart Allmaras turbulent models.

(KULUNK & YILMAZ, 2009)Blade Element Momentum Theory (BEM) can be used to explore the Horizontal Axis Wind Turbine Blades. Here S-809 Blade was used.

(Potter, Barnet, Fisher, & Costas, 1986) Breakaway at a point on the surface is known as separation point & such phenomenon is called separation. In this report author found that detachment location is significantly independent on turbulent intensity & vibration but it is dependent on pressure distribution.

(Agrawal & Saxena, 2013)There are many turbulent Models available but these three Models were used. (Realizable and RNG k-Reynolds and Reynolds Stress Model (RSM)) Here aerodynamic behaviour of the airfoil with different turbulent models has been studied.

III. PROBLEMSTATEMENT

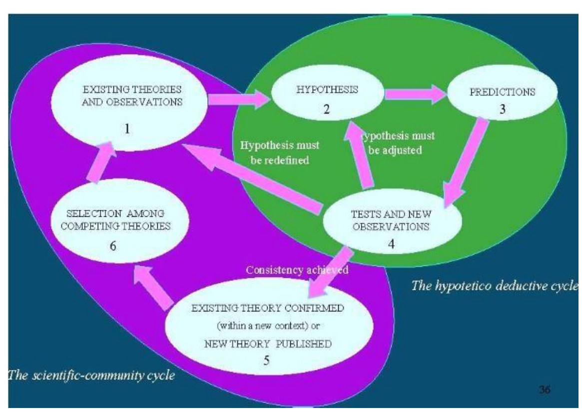
Two different type modifications were taken and analyzed separately and finally combined the same two. Such kind of modification is still not done. A gap was found in previous work that the combined modification was not done yet to investigate the aerodynamic behaviour. In this work, the NACA0012 airfoil surface was modified providing Dimples, Roughness, and Bumps on the surface. These three conditions were analysed separately and found suitable. A combined modification was not done so here a combined modification of roughness and the bumpy surface was done and analysed to find out aerodynamic behaviour.

IV. PROPOSEDSOLUTION

Running an aircraft or equipment having an airfoil, running cost does matter so there were many methods to reduce this cost. Some authors tried to reduce this cost by scheduling and ultimately improved efficiency. The small arrangement can increase 1% efficiency using cost indices . Other many methods have been carried out by and also find out a various solution for fuel saving. Powerful engines consume much amount of fuel so the shape of the airfoil can be used to improve efficiency and can save fuel and cost. Airfoil is widely used in various industries and application of this is in the field of the turbine, aeroplanes, fighter planes, helicopter etc. So this work is very important to increase lift and improve the efficiency of the foil as well as to reduce fuel cost.

V. METHODOLOGY

Methodically study and explanation of the research problem with the use of science are called methodology of the research. Whole steps are decided in the methodology with particular reasoning and arguments. After studying the complete review, gaps, hypothesis and objective of the work a plan was forged for each step/technique with keeping in mind all the if and buts. Research has to know why the work is being done and what the application areas of it for development are. Methods are just a procedure to collect data but the methodology is the design and justification of different plan in a scientific way. In engineering it is not necessary that the following methodology is used throughout, there are many other ways by which a researcher can solve the problem.



Scientific Method of Research

Research Methodology contains some steps out of the first of all the problem is formulated, and then it is very compulsory to understand that problem . Some issues may be rise during the research problem those have to be justified and finally, a problem is defined. Now the conceptual structure is decided on solving the problem.

The approach contains some steps in the completion of this work has been finalized so that the work can be completed within a time limit. During work, first of all, it is very important to import the right coordinate of NACA0012 airfoil so that making geometry become ease. Remaining steps are as per follow construction of geometry, Grid /Mesh generation, Grid Independence testing, Finalization of turbulent Model, Modification in the surface as per desired, simulation of the problem and finally to find out outcomes of the problem.

VI. CONCLUSION

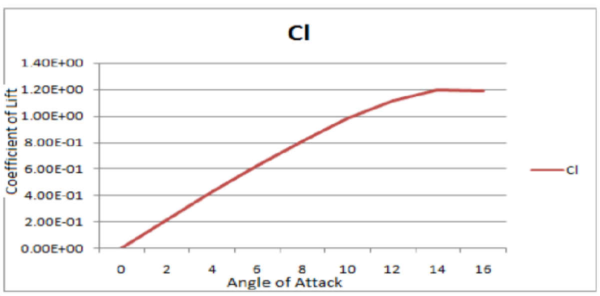


Fig6.18: Coefficient of Lift with k-ε STD Turbulent Model

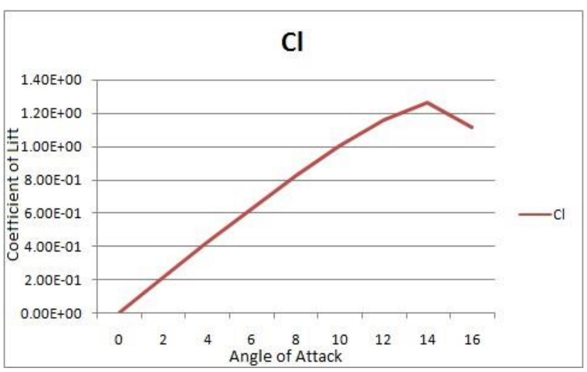


Fig6.19: Coefficient of Lift with k-ε RNG Turbulent Model

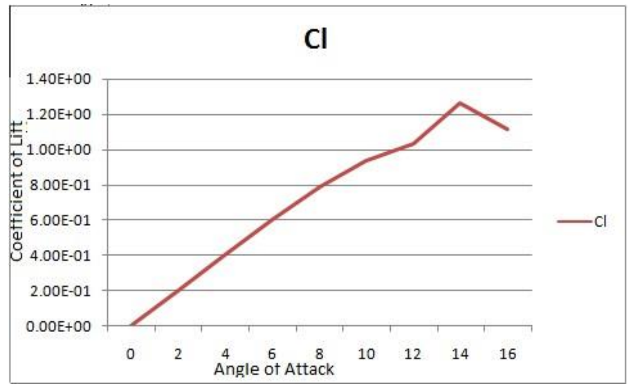


Fig6.20: Coefficient of Lift with k-w SST Turbulent Model

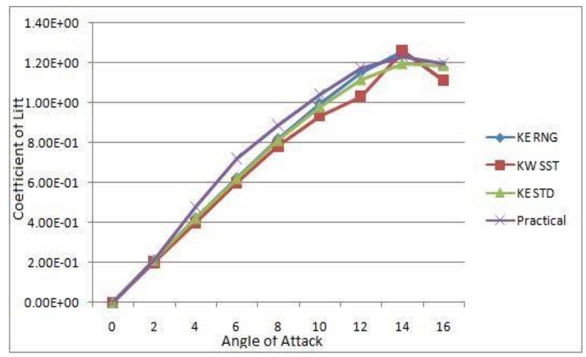


Fig6.21: Comparison of Various Turbulent Models

It was noticed that all the graphs shows similar results but while compared with practical data (airfoiltools.com, 2016) it shows that there is some deviation among all the graphs. From the figures of the graph it is seen that k-ε standard model and k-ε RNG give a good approximation. Though k-ω SST turbulent model is also a good model but here it is not as good as the others. All the models show similar result at lower angle of attack but near angle of stall the deviation in graphs starts showing.

Scope of improvement:

This work is not the limitation of working in the area of the same field; still, much more opportunities are available considering a large number of variables. Following are some work can be done in future.

Effect of changed Reynolds number can be investigated on the same profile.

Other series of the airfoil can be simulated to find the turbulent model as well as the effect of modifications.

Location of the bumps can be analysed in the future as well as the size of the bumps with respect to the size of foil can be analysed.

Two modifications were combined here. It is possible to combine three or more modifications.

In this work, a two-dimensional analysis was done on the foil with the surface modifications i.e. dimples, roughness, bumps and combination of bump and roughness.

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