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MODELING AND SIMULATION OF AEROFOIL ELEMENT

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Abstract: There is a need for renewable energy sources to be more feasible. The purpose of this project is to develop a compact device that is able to harvest wind energy to transform it into electrical energy using the concept of vortex shedding. When calibrated correctly, the vortex shedding will induced resonant oscillation. This project deals with harvesting electricity by using wind energy. Wind electricity would be collected from the oscillation using a magnet and coil assembly. It is difficult to do experimental analysis on an aerofoil using wind turbine. Because it is more time taking process requires large area and high cost while in CFD analysis, it is less time taking process and we can get accurate results

***Key Words*: Aerofoil, ANSYS, CFD (Fluent).**

1. INTRODUCTION

In the earliest days, when man was yet living in the lap of nature, the only means of locomotion was his legs. Gradually, we have achieved faster and more luxurious ways of travelling, latest being the air transport. Since, its invention aero planes have been getting more and more popularity as it is the fastest mode of transportation available. It has also gained popularity as a war machine since World War II. This popularity of air transport has led to many new inventions and research to develop faster and more economical planes. This project is such an attempt to determine how we can derive maximum performance out of an aerofoil section.

An aerofoil is a cross-section of wing of the plane. Its main job is to provide lift to an aero plane during takeoff and while in flight. But, it has also a side effect called Drag which opposes the motion of the aero plane. The amount of lift needed by a plane depends on the purpose for which it is to be used. Heavier planes require more lift while lighter planes require less lift than the heavier ones. Thus, depending upon the use of aero plane, aerofoil section is determined. Lift force also determines the vertical acceleration of the plane, which in turns depends on the horizontal velocity of the plane. Thus, determining the coefficient of lift one can calculate the lift force and knowing the lift force and required vertical acceleration one can determine the required horizontal velocity.

1.1 OBJECTIVES

Modeling of symmetric and asymmetric aerofoil in ANSYS.
Modeling of airfoils NACA0012 and NACA4412.
Determination of drag coefficient and lift coefficient of aero foils and study their variation with angle of attack.

1.2 FORCES ACTING ON AEROPLANE

There are four forces acting on an airplane in flight. These are thrust, drag, lift and weight (gravity).

1. Thrust The force exerted by the engine and its propeller(s), which pushes air backward with the object of causing a reaction, or thrust, of the airplane in the forward direction.

2. Drag. The resistance of the airplane to forward motion directly opposed to thrust.

3. Lift. The upward force created by the wings moving through the air, which sustains the airplane in flight.

4. Weight. The downward force due to the weight (gravity) of the airplane and its load, directly opposed to lift.

When thrust and drag are equal and opposite, the airplane is said to be in a state of equilibrium. That is to say, it will continue to move forward at the same uniform speed. (Equilibrium refers to steady motion and not to a state of rest, in this context)

If either of these forces becomes greater than the force opposing it, the state of equilibrium will be lost. If thrust is greater than drag, the airplane will accelerate or gain speed. If drag is greater than thrust, the airplane will decelerate or lose speed and consequently, the airplane will descend.

Similarly, when lift and weight are equal and opposite, the airplane will be in equilibrium. If lift, however, is greater than weight, the airplane will climb. If weight is greater than lift, the airplane will sink.

Figure 1.0 Forces acting on Aero plane

1.3 METHODOLOGY

The first step in my project, after deciding the topic, was to do a literature review of the topic. So, I searched for some previous works done in this topic and got myself familiar with the topic. The second step was to gather the required software for my project which in this case was ANSYS-Analysis Systems and Microsoft excel. The next step was the Data collection. For my project I required coordinates of the three aerofoil i.e. NACA0012 and NACA4412. Then I went through some textual as well as visual manuals to learn ANSYS. Then, I modeled two models of the aerofoil and obtained the coefficient of lift and drag, plotted graph between coefficient of lift, drag and the angle of attack and analyzed the results obtained.

1.4 BASICS OF AERODYNAMICS

Aerodynamics is an extension of science which is concerned with concentrating on the movement of air, especially when associating with a solid object, such as an airfoil. Aerodynamics is a sub-field of fluid progress and gas motion, and numerous parts of aerodynamics hypothesis are regular to these fields. The contrast being that "gas dynamics" applies to the investigation of the movement of all gasses, not constrained to air. Formal aerodynamics think about in the cutting edge sense started in the eighteenth century, despite the fact that perceptions of central ideas, for example, aerodynamic drag have been recorded much prior. The vast majority of the early exertions in aerodynamics worked towards attaining heavier-than-air flight, which was initially exhibited by Wilbur and Orville Wright in 1903. From that point forward, the utilization of aerodynamics through scientific examination, observational estimates, wind tunnel experimentation, and workstation recreations has framed the investigative premise for progressing improvements in heavier- than-air flight and various different advances. Late work in aerodynamics has concentrated on issues identified with compressible stream, turbulence, and limits layers, and has gotten to be progressively computational in nature.

An airfoil (in American English) or aerofoil (in British English) is the state of a wing or edge or cruise as seen in cross-area. An aerofoil-formed body travelled through a fluid handles an aerodynamic energy. The segment of this power perpendicular to the course of movement is called lift. The segment parallel to the bearing of movement is called drag. Subsonic flight aerofoil have a trademark shape with an adjusted heading edge, emulated by a sharp trailing edge, regularly with uneven camber. Foils of comparative capacity composed with water as the working fluid are called hydrofoils

The lift on an airfoil is fundamentally the consequence of its approach and shape. At the point when arranged at a suitable edge, the aerofoil diverts the approaching air, bringing about energy on the aerofoil in the heading inverse to the diversion. This power is known as aerodynamic drive and could be determined into two parts: Lift and drag

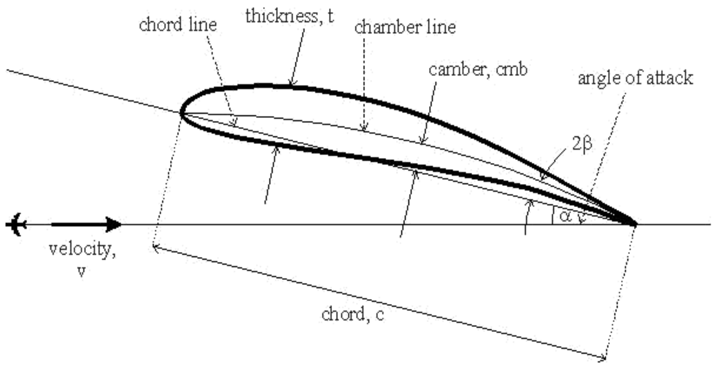


Figure.1.1 General section of an Aerofoil

Some terms related to Aerofoil are:

Leading edge: - It is the edge of the aerofoil facing the direction of motion of plane. It is generally roundish in shape and deflects the air in such a way that the velocity of air on upper surface of the aerofoil is more than velocity on the lower surface.

Trailing edge: - It is the edge of the aerofoil which is pointed in nature. It is located at the back side of the aerofoil.

Chord line: - It is a straight line joining the leading edge to the trailing edge. It bisects the aerofoil into two parts for a symmetric aerofoil but may not do so for an asymmetric aerofoil. It defines another important parameter Angle of attack.

Angle of attack: - It is the angle which the chord line makes with the direction of motion of plane. It is an important parameter which affects the coefficient of lift and drag.

Chamber line: - It is a line joining leading edge and trailing edge and dividing the aerofoil into two symmetrical parts. It may or may not be a straight line.

Lift coefficient: - It is a dimensionless coefficient that relates the lifting force on the body to its velocity, surface area and the density of the fluid in which it is lifting.

Drag coefficient: - It is a dimensionless coefficient that relates the drag force on the body to its velocity, surface area and the density of the fluid in which it is moving.

Stall angle of attack: - It is the angle of attack at which the lift coefficient is maximum and after which the lift coefficient starts to decrease.

.1.5 CLASSIFICATION OF AEROFOILS.

Aerofoils are divided in three types; High lift, General purpose and High speed

High lift: - These sections are normally used for aircraft with short field operations. They have high thickness to chord ratio, a pronounced camber and well rounded edges.

General-purpose: - These aerofoils section employ a lower thickness to chord ratio, less camber and shaper leading edges.

High-speed: - These sections are used for high-speed aircraft. They have very low thickness to chord ratio, no camber, and sharper leading edges.

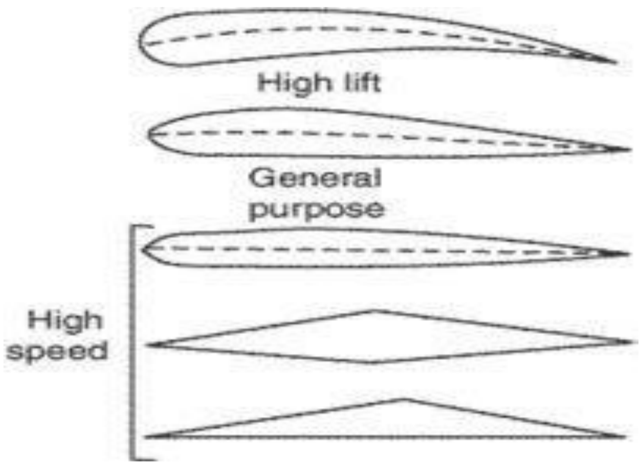


Figure 1.2 Classification of airfoils

1.6 ANSYS:

ANSYS offers engineering simulation solution sets in engineering simulation that a design process requires. Companies in a wide variety of industries use ANSYS software. It uses CFD and FEM and various other programming algorithms for simulating and optimizing various design problems. ANSYS has many sub parts out of which I will use FLUENT.ANSYS Fluent uses CFD for analysis and is mainly used for simulation of fluid mechanics and thermodynamics problems. Data of various fluid and solid materials are already fed into the ANSYS database which we use.

1.7 LITERATURE REVIEW: Mr. Mayurkumar kevadiya (2013)[1] studied the NACA 4412 airfoil profile and recognized its importance for investigation of wind turbine edge. Geometry of the aerofoil is made utilizing GAMBIT 2.4.6. Also CFD investigation is done utilizing FLUENT 6.3.26 at different approaches from 0˚ to 12˚. Mr. Ankan Dash (2016) studied the NACA 0012 Aerofoil profile at various angles of attack and concluded that the CFD simulation results show close agreement with the theoretical results and they suggested CFD analysis as a reliable alternative to experimental methods. Mr. Nazmul Haque , Mr Mohammad Ali , and Mr Ismat Ara published a paper about performance of NACA 4412 and concluded that below 120 angle of attack the drag is decreasing

1.8 MODELLING OF SYMMETRIC AEROFOIL (NACA-0012)

A symmetric aerofoil is the one in which both the camber line and the chord line is the same i.e. a straight line joining the leading edge and the trailing edge bisects the aerofoil into two symmetric sections DETAILS OF NACA-0012: Camber: 0% Chord: 0% Thickness to chord length ratio: 12%

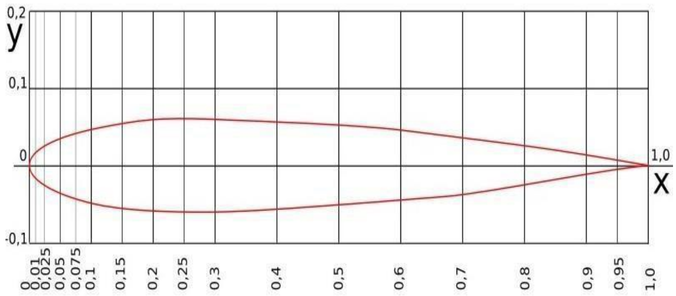


Figure 1.3 NACA-0012 Aerofoil

MODELLING:

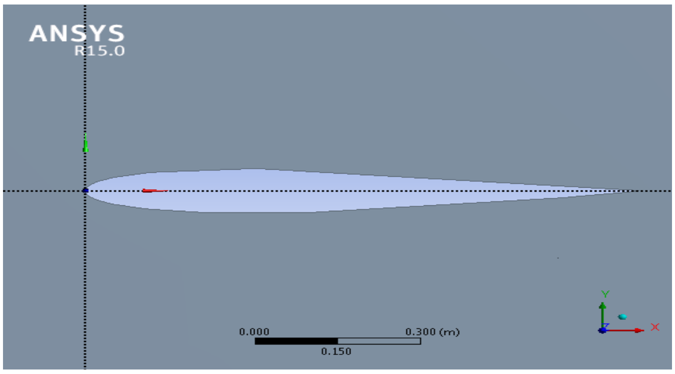


Figure 1.4 Geometry of the symmetrical airfoil section.

MESHING:

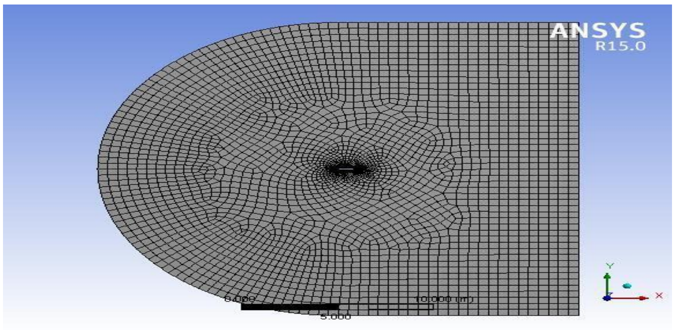


Fig1.5 Meshing of air profile around the symmetrical aerofoil

PROBLEM DESCRIPTION: MODELLING: A symmetric aerofoil is generated with the help of coordinate file using ANSYS-Fluent 15.0.□ □ A "C" shaped domain is sketched and generated over the aerofoil for facilitating the boundary conditions

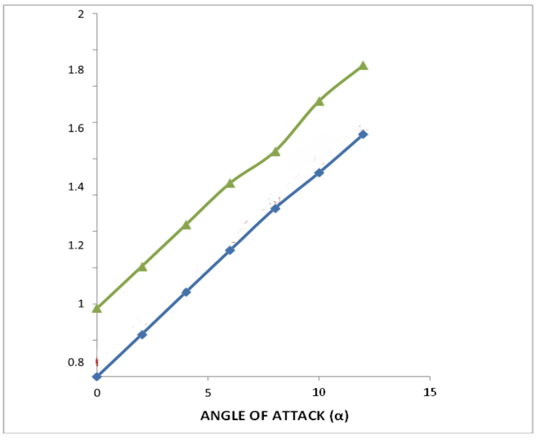
MESHING: A refined mesh is generated over the aerofoil body and the boundaries were specified with their names
BOUNDARY CONDITIONS: Double precision 2-D model. Pressure based. Viscous - inviscid Inlet conditions were specified at different angles of attack (i.e. 0^0, 2^0, 4^0, 6^0, 8^0, 10^0, and 12^0. The aerofoil is taken as wall boundary
SOLUTION: The coefficient of lift (CL) and The coefficient of drag (CD) values were observed at different "Angle of attack"

RESULTS:

Angle of attack (degrees)	**Lift coefficient (CL)**	**Drag coefficient (CD)**
0	-9.9124E-4	4.97E-04
2	0.2319	3.97E-04
4	0.4657	1.59E-03
6	0.6970	6.97E-03
8	0.9265	4.51E-03
10	1.1238	7.60E-03
12	1.535	1.07E-02

Table 1 Variation of lift and drag coefficient with angle of attack.

ANALYSIS OF RESULTS



Graph 1: showing CL Vs α

The above graph showing that coefficient of lift for NACA_4412 is greater than that of other two. The lift is occurring at "00 angle of attack" in the case of asymmetric aero foils (i.e. NACA_4412 and NACA_4418)

CONCLUSIONS

Lift coefficient was found to be higher for Asymmetric airfoil than the Symmetric airfoil for same chord length and maximum camber of the Aerofoil at same angle of attack. Drag force of Asymmetric airfoil was found to be marginally more than that of Symmetric airfoil for same length and camber of airfoil. Out of the two airfoils namely NACA_0012 and NACA_4412, airfoil NACA_4412 was found to have highest "COEFFICIENT OF LIFT".

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