AERODYNAMIC CHARACTERISTIC STUDY FOR UNMANNED AIR VEHICLES(UAVs) FX63-137

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ABSTRACT

Unmanned Air Vehicles are getting a great deal of attention from the research perspective recently. Unmanned Air Vehicles (UAVs) are catching more and more attention for their applications in civilian and military fields. The relatively low speed and the small aspect ratio of wings of these vehicles cause a particular flow regime that is still not well understood. Since the theories on the aerodynamics of low Reynolds number flows are yet to mature and wind tunnel experiments cost long periods and great costs, the mathematical simulation based on computational fluid dynamics (CFD) is a good methodology to adopt. Flow characteristic could be visualized on airfoil using commercial software ANSYS. Reynolds Navier-Stokes (RANS) been used to investigate the characteristics of pneumatic airfoil at different angles of attack. However, CFD typically has difficulty in predicting the location and size of the laminar separation bubble which in turn may result in poor quantitative predictions for lift, drag, and moment. Because of the problems inherent in modeling layers thicker border, where the flow may transition from laminar to turbulent flows at low Reynolds number are not well understood may lead to poor aerodynamic prediction in the results. While CFD methods have been validated for a quantity of airfoils, reliance solely on computational results is ill-advised at this point. The classic FX 63-137 was chosen for its superior low Reynolds number characteristics. It has been publicized to produce a maximum lift coefficient higher than 1.5, whereas conventional airfoils are known to degrade well below this level at low Reynolds numbers.

الخلاصة

تجدب الطائرات بدون طيار انتباهاً اكثر لتطبيقاتها فى المجالات المدنية والعسكرية,السرعة المنخفضه وصغر الجناح يولدان تدفق هوائى معين لايزال غير مفهوم جيداً, بمعنى النظريات الديناميكية الهوائية فى تدفق Re القليل مازالت تبتكروتطور الى حد الان.

التطبيقات العملية بأستخدام النفق الهوائى تكلف نفقات كبيرة وفترات زمنية طويلة ولهذا المحاكاة باستخدام حساب الديناميكا الهوائية C.F.Dجيدة للعمل بها واكثر تقدماً لاختيار الاجنحة المناسبة وخاصاً التى تعمل فى اعداد Re منخفضة .

اختير الجناح FX63-137 نظراً لمعامل الرفع العالى الذى يصل الى 1.5فى اعداد Re منخفضة وهذه ميزة لاتوجد فى باقى الاجنحة وفى هذه الاعداد من Reالمنخفضة.

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LIST OF SYMBOLS

Roman Letters

V	Air Velocity m/s
Re	Reynolds number
T	Air temperature k
A	Aspect ratio
C_L	lift coefficient
C_D	Drag coefficient
A	Angle of attack
L	Lift
D	Drag

Greek Letters

ρ	Kg/m^3
μ	Kg/m.s

CHAPTER 1

INTRODUCTION

1.1 Project Background

Manufacture unmanned aerial vehicles (UAV) of various sizes are by hand-held Micro air vehicle (MAV) to the large-scale of UAV. This has been attracting a lot of attention in the industries of the military and civil aviation over the past decade to the performance of its operations for a long time. Therefore, it becomes important in the military industries and civil aviation over the past decade for the performance of its operations for a long time. It was starting to develop unmanned aircraft broad with different sizes. Since 1980s, a lot of research has been approved in terms of security values, communication and management of the battle. Because of their low cost process, the field of applicable UAV could be changed from military purposes only to one civilian, many development programs have begun all over the world [1].

Remotely piloted refers to the command from people who control the movements aircraft using a radio control system. The human has full control on small aircraft remotely piloted vehicle (RPV). RPV or commonly known as Unmanned Aerial Vehicle (UAV) has a direct continuous link to ground control unit. It can be launched either from ground, vehicle or airplane There are two types of UAV, lethal and non-lethal. Lethal UAVs are missile, 'smart weapon', anti-radiation and 'fire and forget' missile with a smart guidance system. Non-lethal UAVs are mostly spreads for civil task, border patrol, some countries use it for agricultural purposes, traffic controller, and weather inspector. [2] RPVs are used to search and rescue people, aerial inspection of the housing regions, fire detection, traffic control, surveillance of borders and coast. UAVs are used widely much more in military as a smart target, reconnaissance vehicle and 'spy-in–the-sky'. For non-military, many states are now interested in RPV development, exploiting its full capacity and have developed their own UAV programs [3]. A small Unmanned Aerial Vehicle (UAV) is perfectly suited for tasks that are considered a threat to perform with human pilots or inconvenient to carry out with larger UAV's. To perform high-risk missions like monitoring radioactive fallout due to nuclear accidents, UAV was designed. Moreover, it is used for finding people lost in hostile environments (fires, mountains, oceans etc.) and surveillance of borders, and power lines. Several types of responsibilities and a reliable aircraft with a high performance flight computer and advanced payloads/sensors. [4]

A normal mission layout is to takeoff, climb to mission altitude, navigate to the target area, perform the assigned task, and return home. It has a limited range and payload capacity but it is a low cost system and does not need a specially trained air force pilot and extensive logistics. [5].

1.2 Problem Statements

The design of an airfoil structure with the curved surface is to give the most favourable ratio of lift and drag. Many research, experiments, and simulations have occurred on the most specific characteristics of the airfoil, with the objectives of better lift, higher performance, and higher endurance. The most optimal characteristics of the airfoil will be calculated using simulations on XFOIL and CFD, and then compared the results with a practical experiment, these comparisons can be used to check how accurate the simulations are and how these characteristics can contribute to better lift and endurance.

1.3 Research Methodology:

The methodology is a qualitative based approach to calculate the airfoils characteristics using XFOIL and creating a simulation in CFD software to find optimal characteristics of the airfoil which will increase the lift and endurance of the airplane. The results of the simulation are then compared with the results from a practical experiment. After comparing the results, the accuracy of the simulations can be estimated. The main steps of the project are:

a) Analyze data on the airfoil of the airplane wing and draw to a text file with a .DAT extension.
b) This DAT file containing the data will be input into XFOIL software to calculate characteristics about the airfoil.
c) Next, the airplane airfoil is drawn using Solidworks Computer Aided Design Software.
d) The boundary condition is drawn using Solidworks Computer Aided Design Software.
e) A simulation will be done using CFD software.
f) A practical experiment will be done by creating the airplane airfoil and calculating results using wind tunnel.
g) Conclusions can be drawn from comparing results.

The airfoil plays a critical part of the aircraft's performance, and it generates more than 85% of the lift of the airplane, and the airfoil also affects the endurance of the airplane. There are many experiments and simulations to analyse especially on aerodynamic characteristic for an airfoil. The results will be compared and obtained using XFOIL simulation software and experiment, as well as comparing these results with the simulation results using the CFD software.

1.4 History of Unmanned Aerial Vehicles:

The history of Unmanned Aerial Vehicles, (UAV's) started in 1883 when Douglas Archibald attached an anemometer to the line of a kite.

To get differential events of wind velocity at altitudes reach to 1200 ft. Five years later Arthur Bat installed a camera on a kite and made the first aerial photo on 20th June 1888 in France. Charles Kettering designed the first UAV, the Kettering Aerial Torpedo. The airplane was guided to the target by a system of present pneumatic and electrical controls. After a predetermined length of time, an electrical circuit would close and shut down the engine. The wings would then be released, and the fuselage and warhead would fall on the target. The RP-1 was the first radio-controlled aircraft or Remote Piloted Vehicle (RPV). It was designed and tested by Reginald Denny in 1935. Several modified versions followed and 14.891 were built during World WarII.

In 1962, the American company, Ryan Aeronautical started to modify BQM-34 target drones into AQM-34 reconnaissance aircraft. The AQM-34 'Lightning Bug' performed 3,435 missions in Southeast Asia during the Vietnam War. Israel received several improved AQM-34's from the U.S Air Force and used them in the Yom Kippur War in 1973. The Mastiff UAV was developed by Alvin Ellis and it was presented in Israel 1974. The design of the prototype was comparable to a large RC airplane but the Mastiff had altered configuration and featured the pusher-propeller twin-boom setup that is common for combat surveillance UAV's. The Scout system was introduced in 1980 and these systems performed target acquisition missions during the war in Lebanon in 1982.[6]

1.5 Examples of UAV:

In recent years, the UAV's outstanding performance in the Gulf War, The Afghan War and other wars buy the attention of more and more countries. UAV's will become a very important development direction of the air vehicle [5].

The first example of UAV is the IAI Malat Scout, shown in Figure 1.1 and it is specifications are listed in Table 1.1. This UAV was designed more than 25 years ago by Israel, and it is regarded as the predecessor to the American Pioneer and the Israeli Searcher.

Table 1.1 Some UAV Specifications, in Ref [7][8].

Specification	IAI Malat Scout	Aerosonde Mk3
Span	4.96 m	2.9 m
Length	3.68 m	---
Height	0.94 m	---
Payload weight	38 kg	2 kg
Empty Weight	96 kg	14 kg
Launch Weight	159 kg	---

Maximum Speed	176 km/h	115 km/h
Service Ceiling	4500 m	6000 m
Endurance	7 h	30+ h
Launch Scheme	Runway / Catapult	Car roof rack
Recovery Scheme	Runway / Parachute / Net	Land on belly
Payload	Day / Night imager	Camera, sondes,IRsensor
Guidance System	Autopilot / Radio Control	---

The other example of UAV is the Australian Aerosonde, shown in Figure 1.2 and it is specifications are listed in Table 1.1. It was the first UAV to cross the Atlantic in 1998.

Fig. 1.1 IAI Malat Scout UAV. [8]

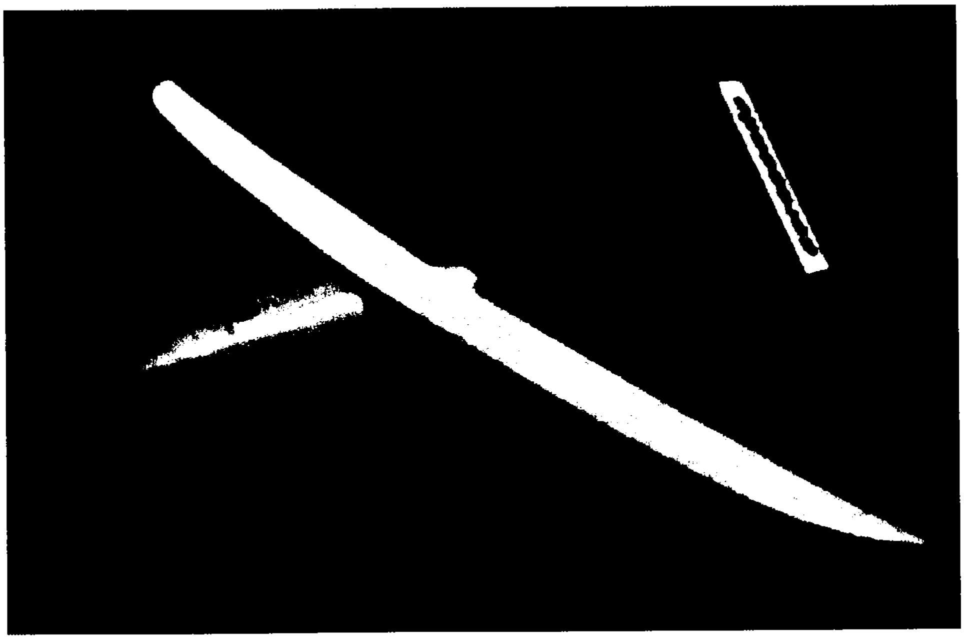


Fig. 1.2: Aerosonde Mk3 UAV. [8]

The Germans developed the UAV and also developed by the Allied Forces the concept of pilotless vehicle, it is a simple unmanned aircraft with a wingspan of about 19 ft and overall length of 26 ft .The UAVs were seen as a potential reconnaissance platform which was done in Vietnam War. Where they were used for taking photo reconnaissance task. It was used for damage-assessment mission where use the modified Teledyne-Ryan AQM-34 Fire bee jet powered target was used. [9].

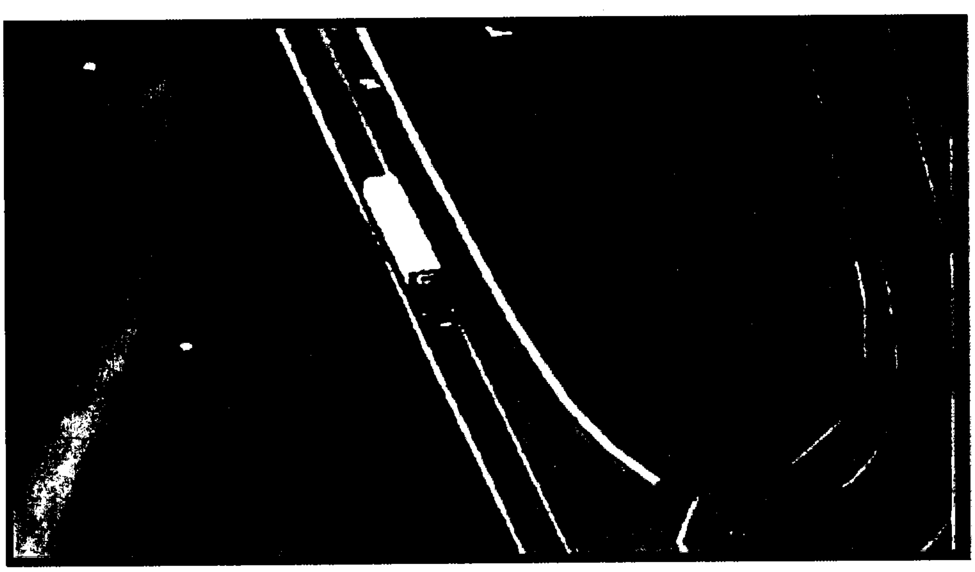


Fig. 1.3 Picture taken by UAV. [9]

UAVs have been used in all major conflicts including those in Kosovo, Afghanistan and Iraq. More recently, the use of UAV and RPV are observed in the military field much more than the civil fields. It was recorded pioneer aerial vehicle at 1011 hours during 307 flights in Operation Desert Storm [Howard et.al, 1996].The Pioneer, remotely piloted vehicle, has served in fleet and ground operation since 1987, this was a record of success in UAV in the Persian Gulf it indicates usefulness obtaining timely intelligence during modern military conflicts. Most of the UAVs are deployed for surveillance and reconnaissance, observation and targeting.

Nowadays, many aircrafts, which are based on the UAV system, exists in the market. Micro Aerial Vehicle (MAV) is the smallest aircraft. And despite its small size, but has the advantage of ability to fly unnoticed in battlefield. The RPVs are capable to carry camera, sensors, missiles, air particle sampler and chemical agent detector depending on the mission. The RPV is designed to operate at radius reach up to 500km with about 7 hours endurance while endurance UAV is designed to exceeding 24 hours operate at a high altitude. So seeking research centers and universities to the large-scale development RPV and performance due to limited information about the UAV designs and performance of the various shapes of the RPV. This represents an attention in aerodynamic performance and design of the RPV and launch and recovery at low Reynolds number flying condition.

"MAVs may need more unconventional configurations and approaches ranging from rotary wings to low aspect-ratio fixed wings. There are one of significant advantages of using these MAV's is that they can sustain large applied loads without loss of structural integrity, the MAV can remain in the flight for up to 60 minutes and carry a payload of 20 grams for up to 10 km. There are some of the popular MAV designs including the Zimmermann, Rectangular, and Elliptical. The names are directly related to the shape of the wing itself. [5].

1.6 The Aerodynamics of UAV

In the aeronautical field when the new design or modification must take into account the aerodynamic, such as lift, drag and moments force, and is considered one of the most important studies in fluid flow and the interaction of the atmosphere around the objects. Many studies in aerodynamics on how to make any flying object to get the maximum capacity in speed and performance, and the ability of any maneuver and prediction of forces and moment.

In UAV design, the placement of the wing, tail is somehow, not the same as in the conventional airplane. The design considered in UAV is one of the most challenging tasks in aerodynamic studies. To obtain safely take off, loiter and land in UAVs needs a lot of aerodynamic skills and knowledge.

There are numbers of CFD software in the market today which will help aerodynamicists and designers working on their fields efficiently. FLUENT, VSAERO, CFX, PORFLOW, FIDAP and AEROSOFT are examples of CFD codes used by researchers for their numerical simulation works. To date, most of the aerodynamic data collected is based on computational methods such as CFD and wind tunnel. [5].

1.7 Scope of the Study

The scope of present project focuses mainly on drawing the airfoil and obtaining the key data on aerodynamic characteristics during steady flight of the FX 63-137 airfoil. There are four basic forces subjected on the aircraft. These forces are lift, drag, thrust, and weight. The parameters drag coefficient (CD),lift coefficient (CL) and moment coefficient (CM) are used to describe aerodynamic characteristics of an airplane. These parameters are dependent on the angle of attack, (α) and Reynolds number, (Re).

With a view to getting the required aerodynamic data, testing was conducted out on the airfoil in wind tunnel at 20, 30 m/s because the maximum speed in this type of wind tunnel (in University Technology Malaysia UTM) is 30 m/s, band this is also complemented by using computational simulation in CFD. Computational simulation with using CFD and experimental tests with using wind tunnel are done at different values of the angles of attack and Reynolds numbers. Through these results, we can get better design and also obtain the maximum altitude and maximum endurance.

1.8 The Objective of Study

Aerodynamic performances are important factors in the design of RPV because there are many different forms of the fuselage and wings for design, launch and recovery at low Reynolds number flying condition [10].

The main objective of the present study is:-

1) Draw the airfoil using Solidwork Computer Aided Design Software.
2) To obtain the lift and drag coefficients of the airfoil FX 63-137.
3) To make an experiment using a wind tunnel subsonic simulation was carried out using ANSYS CFD code.
4) Airfoil used as the wing section in the Wortmann FX63-137. The airfoil was designed for low-speed small aircraft.

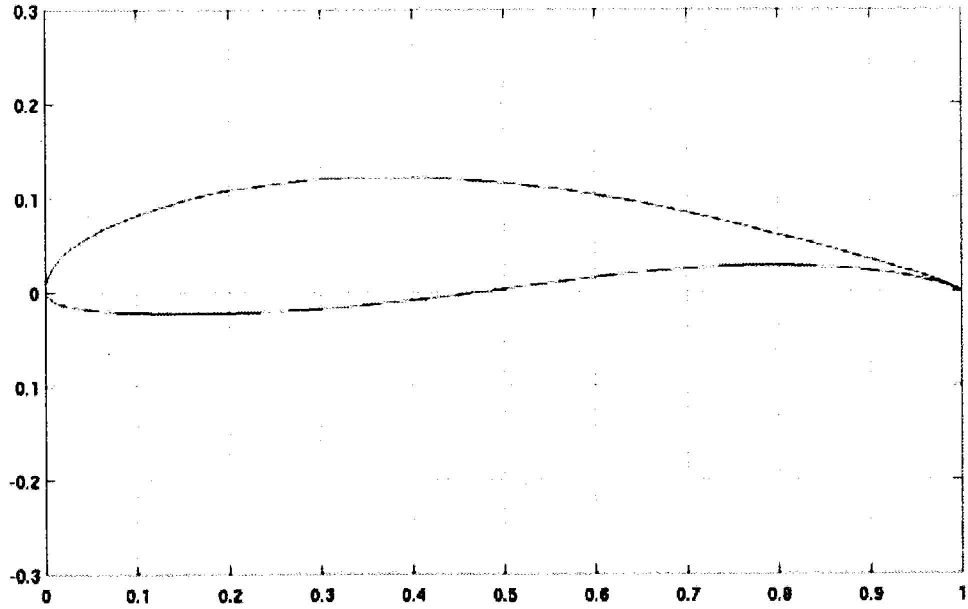


Fig. 1.4 Wortmann FX63-137 Aerofoil. [10]

Table 1.2 The specifications of the Wortmann FX 63-137. in Ref [11].

Thickness	13.68 %
Chord length	200mm
Maximum camber	5.83 %
Leading edge radius	1.81 %
Trailing edge angle	371.842°
Cl_{max}	1.623 (at Re~ 3 x 10^5)
Cd_{min}	0.014 (at Re~ 3 x 10^5)
α_{max}	13.44° (at Re~ 3 x 10^5)

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

In this chapter will be describe the aerodynamic features of an airfoil at low Reynolds number. Literature survey related to wind tunnel that is used for airfoil testing is also discussed and computational simulation using CFD. and will previous research relating to the aerodynamic characteristics of the airfoil are described in feature.

Refers the UAV to Unmanned Aerial Vehicle, which is an aircraft with no pilot on body aircraft. can be controlled UAV aircraft remotely by pilot at a ground control station .And can be also controlled in UAV remotely program is more complicated is named the dynamic automation systems, that can fly autonomously based on pre-programmed flight plans. UAVs are at the moment used for a number of missions, including attack roles and reconnaissance. a UAV is defined as being able to of controlled, sustained level flight by a jet or reciprocating engine. And has adopted the acronym UAS (Unmanned Aircraft System) in The FAA to reflect the fact that these complex systems include ground stations and other elements besides the actual air vehicles.

Officially, the term 'Unmanned Aerial Vehicle' was changed to 'Unmanned Aircraft System' to reflect the fact that these complex systems include ground stations and other elements besides the actual air vehicles. The term UAS, however, is not widely used as the term UAV has become part of the modern lexicon. [12].

For UAV has a good growth rate where it recorded more than 100,000 flight hours for Operation Iraqi Freedom (OIF) and support of Operation Enduring Freedom (OEF). The use of UAS in combat is so new. As the capabilities grow for all types of UAV, nations continue to subsidize their research and development leading to more advances enabling them to perform a many of missions. UAV no longer only perform surveillance, and reconnaissance missions, intelligence, although this still. Remains their predominant type. These UAV has different size and range in cost from a few thousand dollars to tens of millions of dollars, It can also for UAV the roles performance of including electronic attack (EA), strike missions, suppression and/or destruction of enemy air defense. Finally, a review of XFOIL code will be presented. This code will be used to calculate the aerodynamic characteristics of the aerofoil for the purpose of validating the data obtained from last study. XFOIL is very distinguished energy research institutions, such as NERL and RISOE, have benefited from XFOIL in their research and studies. XFOIL is used in most of the top research institutions for simulations [13].

As aircraft become more efficient and reliable, they are also becoming more complicated. This can be seen when calculating the airfoil characteristics for a certain airplane, for example. Integrated systems design now takes the focus in any new aircraft development project. Complex systems modeling require accurate knowledge of subsystem and component performance. Although engineers can manage to get component performance predictions using practical experiments, these test programs can be very expensive. The range of this operating system, characterized by the range of operating conditions (which include inlet pressures, flow rates, altitude and many others), continues to increase as companies extend the use of each aircraft component. [14]

ANSYS CFD software is primarily used to analyze and evaluate the design of components within a system, thereby reducing development time and cost as well as risk. This makes ANSYS CFD software critical for our project, especially when calculating the characteristics of the airfoil. ANSYS CFD plays an important and primary role in our project, and the output of the software is important when comparing our calculations to the practical experiment [14].

2.2 Basic Definitions:

First of all, let's define some of the terms that we will use throughout the course of this research:

- An airfoil is a two-dimensional vertical cut through a wing, parallel to the direction of flow (or of flight for the aircraft).
- The leading edge of an airfoil is the front-most point. The leading edge is nearly always rounded.
- The trailing edge of an airfoil is the aft-most point. The trailing edge is nearly always a sharp corner.
- Chord, c, is the length of the airfoil from leading edge to trailing edge, measured along a straight line, called the chord line.
- Wing span, b, is the distance from one wing tip to the other.
- Planform area, S, is the projected area of a wing when viewed from above, perpendicular to flow direction. For a rectangular wing, such as one might see on a small aircraft, S=bc. For the two-dimensional airfoils we will study in this lab.
- Mean line of an airfoil lies halfway between the upper and lower surfaces.

- Camber is a measure of the deviation of the mean line from a straight line between the leading and trailing edges.
- Angle of attack, α, is the angle between the freestream velocity and the chord line.
- Pressure coefficient, Cp. The pressure coefficient is a non-dimensional way of measuring pressure. The pressure coefficient is always plotted upside down (negative numbers up on the y-axis).
- Lift and lift coefficient. The lift of an airfoil is the total force exerted on the airfoil by the flow in the direction perpendicular to the free stream flow. The lift coefficient is the non-dimensional version of the lift.
- Pitching moment and moment coefficient. The pitching moment of an airfoil is the net moment exerted on the airfoil by the flow. This is generally measured around the quarter-chord (25% of chord behind the leading edge) and is positive if the moment tends to bring the leading edge of the airfoil up. The moment coefficient is the non-dimensional version of the pitching moment. [13]

2.3 Aerodynamic forces on aircraft

As shown in Figure 2.1 there four forces acting on aircraft this forces are lift, thrust, drag weight. These forces are produced by the interaction between the aircraft and the motion of the wind. These forces contribute to the performance of the aircraft whereby it influences the aircraft in speed flight, and endurance. This forces resulting from interaction between the motion of the wind and aircraft. The lift, drag and moment are functions of attitude and configuration geometry.

Of the key factors affecting the endurance is the lift force in the plane of symmetry in the direction perpendicular to the flight line. Lift force has to be balanced by the aircraft weight for steady level flight and must has to be balanced with the aircraft weight the lift is stated as follows

$$L = \frac{1}{2}\rho V^2 S C_L \tag{2.1}$$

Where L is the lift force, ρ is the air density, V is the air velocity, S is the reference area and CL is the lift coefficient. In Ref [15].

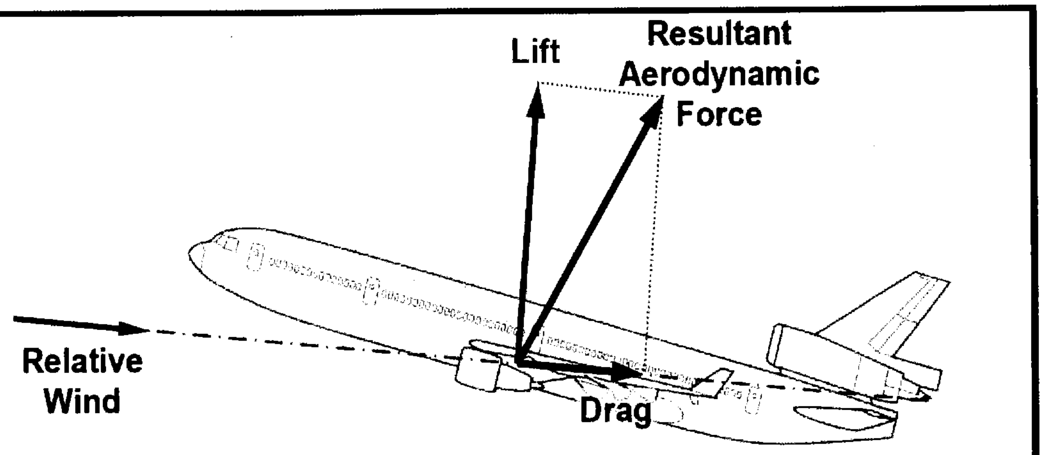


Figure 1 Aerodynamic forces acting on an aircraft.

Fig. 2.1 Aerodynamic forces acting on an aircraft. [15]

The dominant factor on conventional aircraft is the lift coefficient that was created from the wing. Tail and fuselage also contributes to the lift generation but in a few percentages, but vertical and horizontal tail functions control stability and will provide a negative lift or down force.

The generation of lift is achieved by producing a greater pressure at the lower surface than upper surface of the body. The difference of the pressure is achieved when the airspeed at the upper surface is higher compared to the lower surface. Inclination of the body relative to the air flow, also contributes to the lift. Lift coefficient measures how efficiently the wing is changing velocity into lift. The higher lift coefficient indicates an efficient airfoil design. The formula of lift coefficient is:

$$C_L = \frac{L}{\frac{1}{2}\rho V^2 S} \qquad (2.2)$$

In general, drag is a force that causes a resistance in motion. It is the force developed parallel to the relative wind, and is defined as:

$$D = \frac{1}{2}\rho V^2 S C_D \qquad (2.3)$$

Where D is the drag force, ρ is the air density, V is the air velocity, S is the reference area and CD is the drag coefficient. The aerodynamic drag can be defines as the sum of the tangential or skin friction force and the normal or pressure forces parallel to but in the opposite direction of the vehicle's velocity vector.

Drag is one of the important factors that affect the plane with extended region of separated flow. when the vehicle produces a lift there are drag is called induced drag. The total of form drag and skin friction is called viscous or profile drag. The drag coefficient is expressed as:

$$C_D = \frac{D}{\frac{1}{2}\rho V^2 S} \qquad (2.4)$$

Aircraft performance depends on the effectiveness of the wing, which is measured by lift to drag ratio. the lift to drag ratio for all aircraft not associated with wing drag only but includes also drag contributed by the rest of the aircraft.

The centre of pressure coefficient (CP) is the point at which they affect all air forces. chord length is the distance from leading edge to trailing edge. (CP) Is the point at which they affect all aerodynamic forces, where is measured by ratio of the distance of the Cp from the leading edge to the chord length. CP is essential important in aircraft stability, where moves backward whenever decreased angle of attack and moves forward whenever angle of attack increase.[16].

2.4 Airflow around the airfoil

At a small angle of attack, stagnation point is the point at which the particles of air slowing down and which they is divided into two is the point at which they slowdown in air particles, which are divided into two parts of surface. Figure 2.2 shows the streamline division produces from increase in velocity at the upper surface while at the lower surface the velocity will decrease.

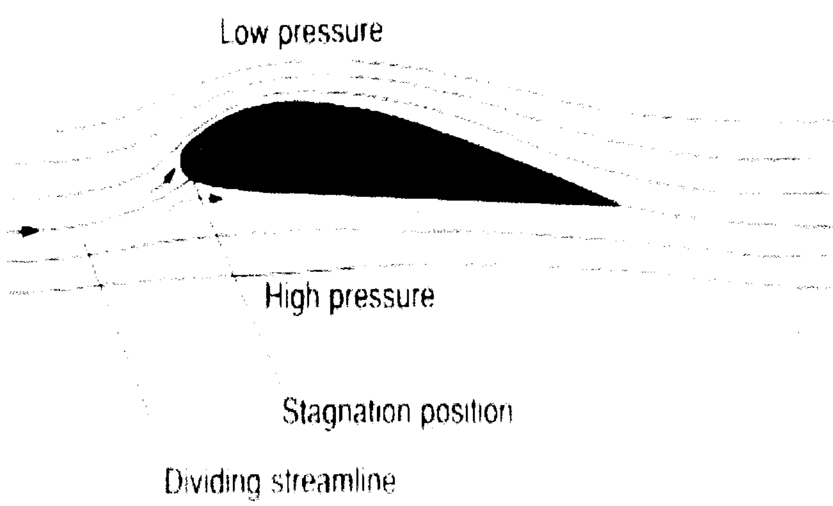


Fig. 2.2 Streamlines around 2D airfoil. [15]

The flow separation produced due to the friction. At the leading edge the flow accelerates to the upper surface and decreased at lower surface this will be higher pressure at upper surface more than lower surface .the pressure is decreased to a minimum value, which is below the static pressure. As the flow is near the trailing edge.

The rate of increase in pressure is rapid occur when the flow moves near the trailing edge. When increases the angle of attack at the leading edge the pressure drops to a value far below the free stream static pressure. The cause stalling occurred when the flow field tends to separate from the surface. [3].

2.5 Reynolds Number

In 1883, Osborne Reynolds introduced a dimensionless parameter knowing as Reynolds number which gave a quantitative indication of the laminar to turbulent flow. It depends on the chord length, velocity and properties of fluid at different altitudes. High Reynolds number is achieved with large chord length, high velocity and low kinematics viscosity. When aircraft design take in your mind scale effect and as an index to predict various types of flows from during calculate Reynolds number. The formula of Reynolds number as:

$$Re = \frac{\rho V l}{\mu} \qquad (2.5)$$

Where ρ is the density of air, V is the mean velocity of air, l is the characteristics length, and μ is the coefficient of viscosity.

2.6 Wing Optimization

Is considered the micro-air vehicle from SMALLEST aircraft size it has a maximum goal weight of 12 lb , Wing design is considered an important factor in the manufacture of this type of aircraft. so this type of aircraft need high coefficient of lift because needs to take off within 100 feet. Therefore, we will test this airfoil with minimal drag on at speed about 30 m/s. in this case we need to low Re, that can be achieved is by using a short wing span.

Through previous studies found that the lift coefficient of approximately 1.6. To get a successful design and with good effectiveness must be a high coefficient of lift and low drag coefficient. Usually be evaluated airfoil at about Re=300,000.

2.7 Wing design

The Airfoil data at low Reynolds number from seldom get it. However would be found airfoil performance at low Reynolds numbers for airfoil (FX 63-137). For maximum endurance must obtain the best design for the wing because he is one of the fundamental factors and the essential for that. [16]

We chose FX 63-137 because it is superior in aerodynamics characteristics at low Reynolds number and at Low Speed. This airfoil has characteristic high lift coefficient where reach about 1.6, this property not found in other airfoils. Figure 2.4 shows the FX 63-137 airfoil. [17].

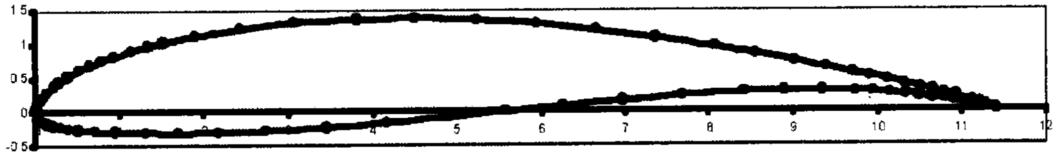
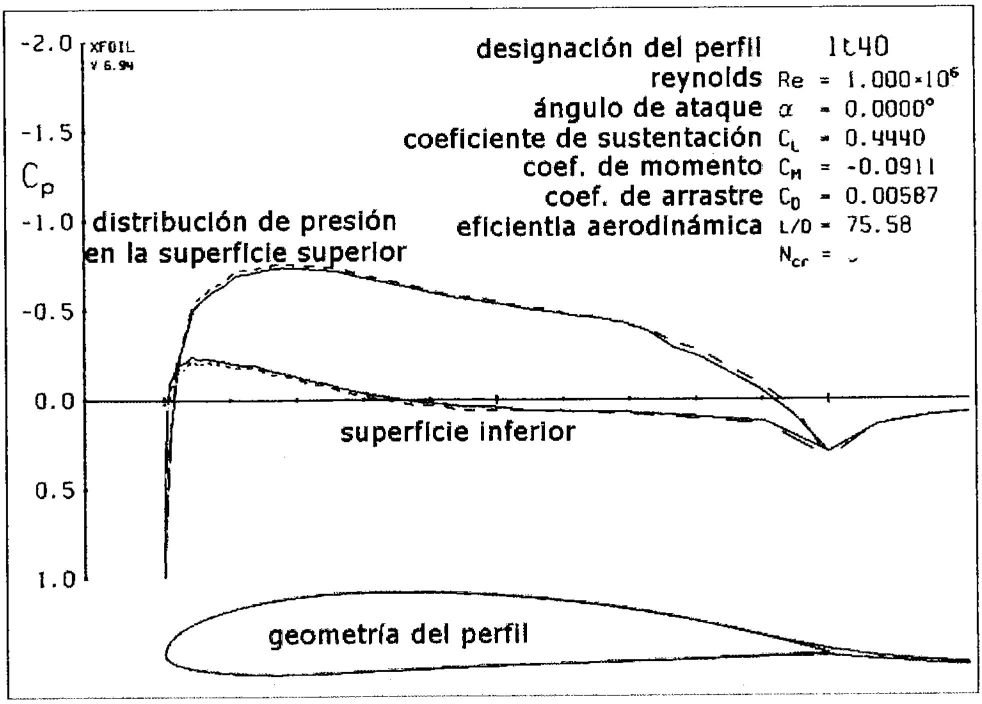


Fig. 2.4 FX63-137 Low-speed Aerofoil. [17]

2.8 XFOIL source code

The XFOIL code combines a conformal-mapping method for the design of airfoils with prescribed pressure distributions, in this study we will using The latest version of the code, XFOIL, where this code used panel method for the analysis of the potential flow about airfoil and is also used an integral boundary-layer method.[18]

The XFOIL is a well known and widely accepted open source code for computation of the aerodynamic characteristics of aerofoil in case of two dimensional flows. XFOIL uses the potential theory vortex panel method, combined with a higher order boundary layer method that allows for prediction of transition and separation effects even under low Re conditions. This makes the program especially suitable for UAV applications that operates at low Reynolds numbers (low speed and/or small dimension). The code includes compressible effects, applying Prandtl-Glauert correction to the calculation results. The program allows for certain geometry modification in order to include a plain flap for example or to enhance trailing edge thickness.



a) airfoil geometry

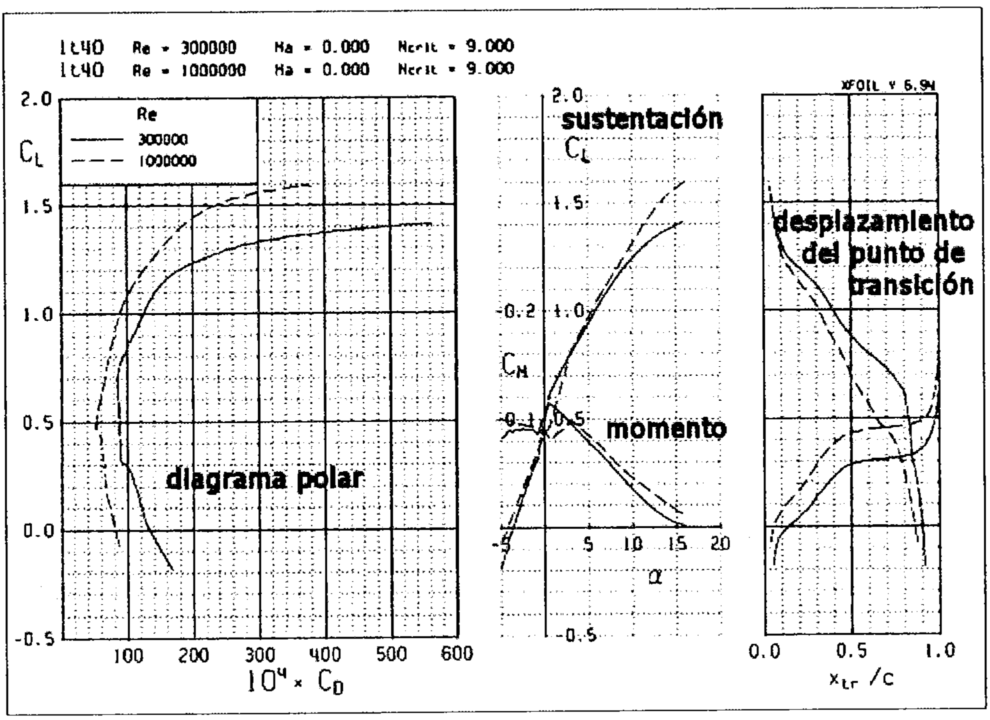


Fig. 2.5: b) Relation between α,C_L, C_D, and C_M

Pressure distribution and its resulting forces and moment are calculated for different angles of attack and can be plotted as a polar diagram Fig 2.5[a&b]. The calculation includes viscous effects and simulates the development of the boundary layer along the airfoil. The transition point is determined by the en method which allows for reliable prediction of viscous effects as laminar separation bubbles, transition, boundary layer separation and friction

The calculation can be adapted to real condition by multiple parameters as for example Reynolds number, Mach number, angle of attack (AOA), free stream turbulence level. The code will be used to calculate the aerodynamic characteristics of the FX63-137 aerofoil for the purpose of validating the data obtained from the experimental testing of the aerofoil. [19]

CHAPTER 3

COMPUTATIONAL METHODS

3.1 INTRODUCTION

CFD is an abbreviation for Computational fluid dynamics, this technique is very powerful in industrial and non-industrial applications, this simulation is based mainly on the computer to analysis fluid flow and associated phenomena heat transfer. These are examples of some of the uses of this technique:

- Aerodynamics of aircraft and vehicles: lift and drag.
- Hydrodynamics of ships.
- Power plant: combustion in IC engines and gas turbines.
- Turbomachinery: flows inside rotating passages, diffusers etc.
- Electrical and electronic engineering: cooling of equipment including micro-circuits.
- Chemical process engineering: mixing and separation, polymer moulding.
- External and internal environment of building: wind loading and heating ventilation.
- Marine engineering: loads on off-shore structures.
- Environmental engineering; distribution of pollutants and effluents.
- Hydrology and oceanography: flows in rivers, estuaries, oceans.
- Meteorology: weather prediction.

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