THE EFFECT OF FLAP TO AERODYNAMICS PERFORMANCE OF AIRFOIL

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This dissertation is submitted to Faculty of Mechanical Engineering in partial fulfilment of the requirements for the degree of Bachelor of Mechanical Engineering (Thermal & Fluids)

Faculty of Mechanical Engineering

UNIVERSITI TEKNIKAL MALAYSIA MELAKA

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DECLARATION

"I admitted that this report is truly mine except the summaries and extractions where both I clearly knew its sources."

Signature :…………………………………………..

Writer :…………………………………………..

Date :…………………………………………..

APPROVAL

"I admitted that I have read this work and from my opinion it is adequately based on the scopes and quality for the degree of Bachelor of Mechanical Engineering"

(Thermal & Fluids)

Signature :……………………………………….

Supervisor Name :……………………………………….

Date :……………………………………….

DEDICATION

I dedicated this Final Year Project to my lovely parent, Mr Zulkefli Bin Hj Yaacob, Mdm Sulyati Binti Abd Kadir and my family because they always keep supporting me and giving me courage in completing this project. Thankful and appreciation I give to Dr. Nazri Bin Md Daud as my supervisor that always guide me in completing this project. Much appreciation I give to my friends that helps me and guide me in completing this project.

ABSTRACT

Airfoil shapes are designed to provide high lift values at low drag for given flight conditions. Lift is the force generated perpendicular to the direction of travel for an object moving through a fluid (gas or liquid) such as an airfoil in a wind tunnel while drag is the force generated parallel and in opposition to the direction of travel for an object moving through a fluid. Conventional aircraft wings often use moving surfaces (flaps and slats) to adapt to different conditions however this study will just focus on the flap of an airfoil. A NACA 0015 symmetrical airfoil was analyzed to determine the lift and drag coefficient. A 3D airfoil was placed in a test section of a low speed wind tunnel to measure the drag force and lift force. The wind tunnel was operated at a nominal 9.5 m/s. The airfoil, with 130 mm chord and 130 mm span, was analyzed at 0, 5, 10 and 15 degree angles of attack. Besides, this experiment was conducted to compare the result between an airfoil with zero angle of flap and airfoil with angle of flap. Angle of flap has been set at two angle which were 30 and 60 degree angle of flap. Two set of airfoils has been printed for this study. The result shows that airfoil have the highest value coefficient of lift at 60 degree of flap which is 0.664. In addition, throughout the previous research and theoretically, an airplane need a higher value of lift coefficient because once the aircraft is on the ground, the flaps may decrease the effectiveness of the brakes, thus increasing stopping distance, particularly in wet or icy conditions.

ABSTRAK

Bentuk sayap pesawat direka untuk menyediakan nilai angkat tinggi pada heret rendah untuk keadaan penerbangan yang diberikan. Angkat adalah daya yang dihasilkan berserenjang dengan arah perjalanan bagi sesuatu objek bergerak melalui cecair (gas atau cecair) seperti lelayang di dalam terowong angin semasa heret adalah daya dijana selari dan bertentangan dengan arah perjalanan untuk objek bergerak melalui bendalir. Sayap pesawat konvensional sering menggunakan permukaan bergerak (kepak dan selat) untuk menyesuaikan diri dengan keadaan yang berbeza bagaimanapun kajian ini hanya akan memberi tumpuan kepada penutup sayap pesawat. Sayap pewasat NACA 0015 simetri dianalisis untuk menentukan angkat dan heret pekali. Sayap pesawat 3D telah diletakkan di dalam ruang ujian terowong angin kelajuan rendah untuk mengukur daya seret dan angkat berkuat kuasa. Terowong angin telah beroperasi pada nominal 9.5 m / s. Sayap pesawat dengan 130 mm kord dan 130 mm span, dianalisis pada 0, 5, 10 dan 15 darjah sudut serangan. Selain itu, eksperimen ini dijalankan untuk membandingkan keputusan di antara sayap pesawat dengan sudut sifar kepak dan sayap pesawat dengan sudut kepak. Sudut penutup telah ditetapkan pada dua sudut antara 30 dan 60 darjah sudut kepak. Dua sayap pesawat yang telah dicetak untuk kajian ini. Hasilnya menunjukkan bahawa sayap pesawat mempunyai nilai pekali lif tertinggi di 60 darjah kepak yang 0.664. Di samping itu, mengikut kajian sebelumnya dan secara teori, kapal terbang perlu nilai pekali lif yang lebih tinggi kerana apabila pesawat itu berada di atas tanah, kepak boleh mengurangkan keberkesanan brek, sekali gus meningkatkan jarak berhenti, terutamanya dalam keadaan basah atau berais.

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LIST OF ABBEREVATIONS

NACA	National Advisory Committee for Aeronautics
CFD	Computational Fluid Dynamics
AoA	Angle of Attack
RANS	Reynolds Average Navier–Stokes
MATLAB	Matrix Laboratory
MPH	Miles per Hour
ABS	Acrylonitrile-Butadiene-Styrene
RPM	Revolutions per minute
UV	Ultraviolet
VRI	Vacuum Resin Infusionor

LIST OF SYMBOLS

α	Angle of Attack
Re	Reynolds Number
Ma	Mach Number
Fr	Froude Number
ε/l	Relative Roughness of the Surface
V	Velocity
C_L	Coefficient of Lift
C_D	Coefficient of Drag
ρ	Density
A_S	Surface Area
l	Span (Airfoil Width)
c	Chord (Airfoil Length)
z	Height
γ	Specific Weight
τ	Surface Shear Stress

CHAPTER 1

INTRODUCTION

1.1 BACKGROUND

Wind turbines use wind energy to transform into electrical energy but wind turbines efficiency is not good. Because of that, a number of scientists are investigated over wind turbines and wind turbines parameters. One of the most important parameter of wind turbines is wing because wind hits to the wings and energy of wind is transformed into the mechanical energy by wings. In the literature, wings profiles are called as airfoils. Airfoil profile is the important parameter for wing design because wing efficiency increases depending on airfoil profile, so there are a lot of studies over the airfoil profile as numerical and experimental in the literature.

A fluid flowing past a body, in this case an airfoil has a force exerted on it. Lift is defined to be the component of this force that is perpendicular to the oncoming flow direction. The drag force is the opposite of lift, which is defined to be the component of the fluid-dynamic force parallel to the flow direction. We will explore how the angle of attack changes the amount of lift the airfoil experiences. The angle of attack (α) is the angle between flow and the chord line. The chord line is a straight line between the most forward point and most aft point of the body. We will also study the effects of velocity on lift, if the angle of attack is kept constant and velocity increased we would expect an increase in lift. We will measure the airfoil lift as a function of velocity.

The drag coefficient (C_D) and lift coefficient (C_L) are functions of dimensionless parameters such as Reynolds number (Re), Mach number (Ma), Froude number (Fr) and relative roughness of the surface (ε/l). The lift and drag coefficients are mostly dependent on the shape of the airfoil, NACA 0015 (Figure 1) is a symmetrical airfoil. The shapes play a huge role on the amount of lift and drag generated and will be seen in this experiment. In order to be able to use equations (1), (2) and (3) the velocity needs to be known.

NOTATION

V : Velocity

C_L : Coefficient of Lift

C_D : Coefficient of Drag

ρ : Density

A_S : Surface Area

l : Span (Airfoil Width)

c : Chord (Airfoil Length)

z : Height

γ : Specific Weight

The lift is a function of dynamic pressure, surface area and lift coefficient as shown in Equation (1).

$$L = \frac{1}{2} \rho V^2 A_S C_L \quad (1)$$

The drag is a function of dynamic pressure, surface area and drag coefficient as shown in Equation (2).

$$D = \frac{1}{2} \rho V^2 A_S C_D \quad (2)$$

Dynamic Pressure is shown in Equation (3).

$$P_d = \frac{1}{2} \rho V^2 \quad (3)$$

Surface Area (As) is a function of the chord and span and is shown in Equation (4).

$$A_S = c\mathrm{l} \quad (4)$$

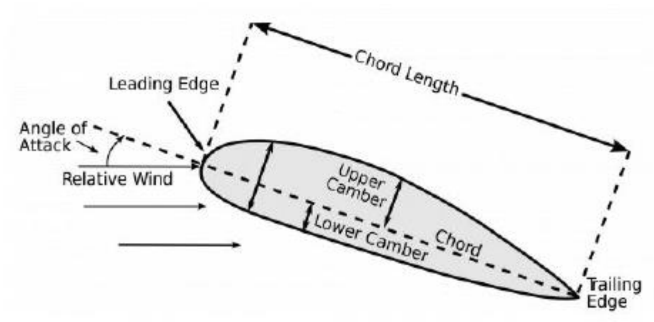

Figure 1 : NACA 0015 Nomenclature

1.2 PROBLEM STATEMENT

Since thin airfoil theory is applicable only to incompressible potential flow, then other means must be used to arrive at the mathematical expression which provide the variation of the airfoil's sectional drag as a function of flap deflection angle. In order to increase the wind capture ability of the wind turbine, many research studies on the lift enhancement method of the wind turbine airfoil have been conducted by scholars at home and abroad. An airfoil with tailing edge flaps has a much higher lift-to-drag ratio than an airfoil without trailing edge flaps.

Among all the lift enhancement methods of trailing edge flaps, the structure of the wind turbine airfoil with discrete trailing edge flaps is simple, the cost of production is low, and it can easily achieve variable angle control. But the aerodynamic performance of the wind turbine airfoil with traditional discrete trailing edge flaps has not been comprehensively studied, and gaps between the flaps and the airfoil main body has an influence on the aerodynamic performance of the airfoil. So it is necessary to optimize the gap structure and study the aerodynamic performance of the discrete trailing edge flaps with different deflection angles. Taking a wind turbine NACA 0015 airfoil as the research object, the structure of the discrete trailing edge flaps was designed, the chord length was set as 130 mm, and the gap between the flap and the main body of airfoil was optimized to make the width of gap an even 1 mm. Then the trailing edge flaps model was established. The flap rotates around the rotate center to form a different flap model at different deflect angles, the deflect angles of the flap varied from 0° - 10°, while the value of angle of attack are at 10° and 20°.

1.3 OBJECTIVE

The objectives of the research are stated below:-

1) To measure the value of drag and lift for NACA 0015 airfoil.
2) To compare both value of drag and lift for base case and actual case.
3) Understand how the angle of attack of an airfoil changes the amount of lift (L vs. α).

1.4 SCOPE OF PROJECT

To fulfill the experimental work, some preparation need to be made:

- A NACA 0015 airfoil with a chord length of 130 mm and span of 130 mm was tested.
- Use fixed value of air velocity.
- To measure C_L and C_D based on a different value angle of attack.
- Study the effect of angle of flap on an airfoil.

1.5 GENERAL METHODOLOGY

The methodology implemented in this research takes the following steps of works:

1.5.1 Fabrication of airfoil

By using a SolidWork software, a NACA 0015 airfoil will be designed referring to its own dimensions with a chord length of 130 mm and span of 130 mm. This experiment was conducted to study the effect of flap to aerodynamics performance of airfoil so that there is a different in drawing this airfoil compared to other design. At the trailing edge of this airfoil, flap is drawn and its length is 20mm from the edge. This helps to change the angle of flap by moving it vertically. The drawing then will be used to perform a 3D printing at a laboratory in faculty of mechanical engineering.

1.5.2 Experimental work

A subsonic wind tunnel was used to determine the lift and drag for the two airfoils at varying angles of attack. The wind tunnel consists of three sections which are nozzle, test section, and exit as shown in Figure 2. Air enters a contraction cone of the nozzle, which is screened by a honeycomb filter to decrease turbulence of the air entering the test section. This contraction cone is followed by the straight test section with the dimensions of 130mm x 130mm (chord x span) in which the airfoil was mounted. The exit consists of an air outflow and a motor-driven fan whose speed is controlled by a frequency drive. A Monarch optical tachometer provides real-time measurements of the fan rotor speed. When the airfoil is already placed, the wind tunnel will run based on a fixed value of air velocity. Angle of attack can be set manually and we only use 2 angle in this experiment. Then the value of lift and drag force are collected to determine the value of C_L and C_D.

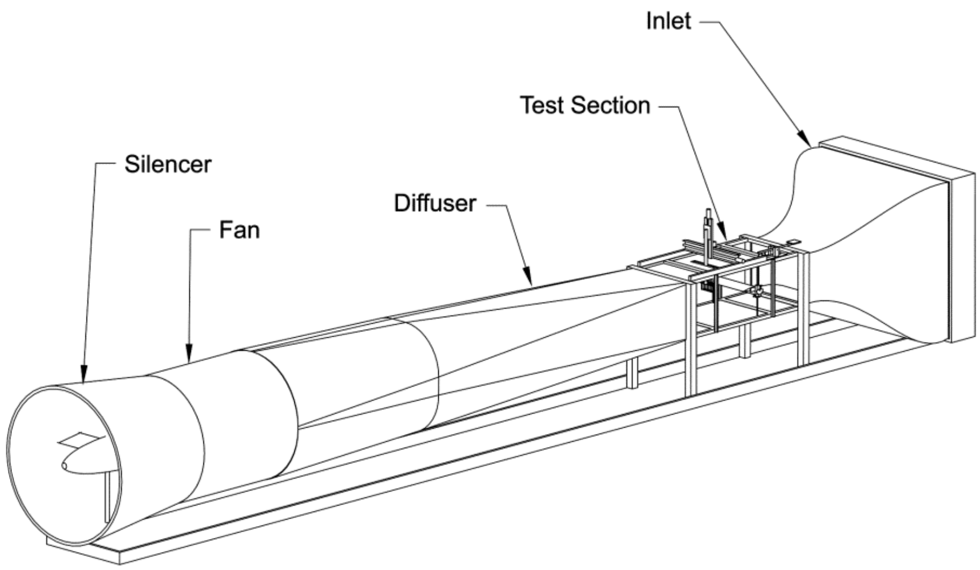

Figure 2 : Wind Tunnel

1.5.3 Flow chart

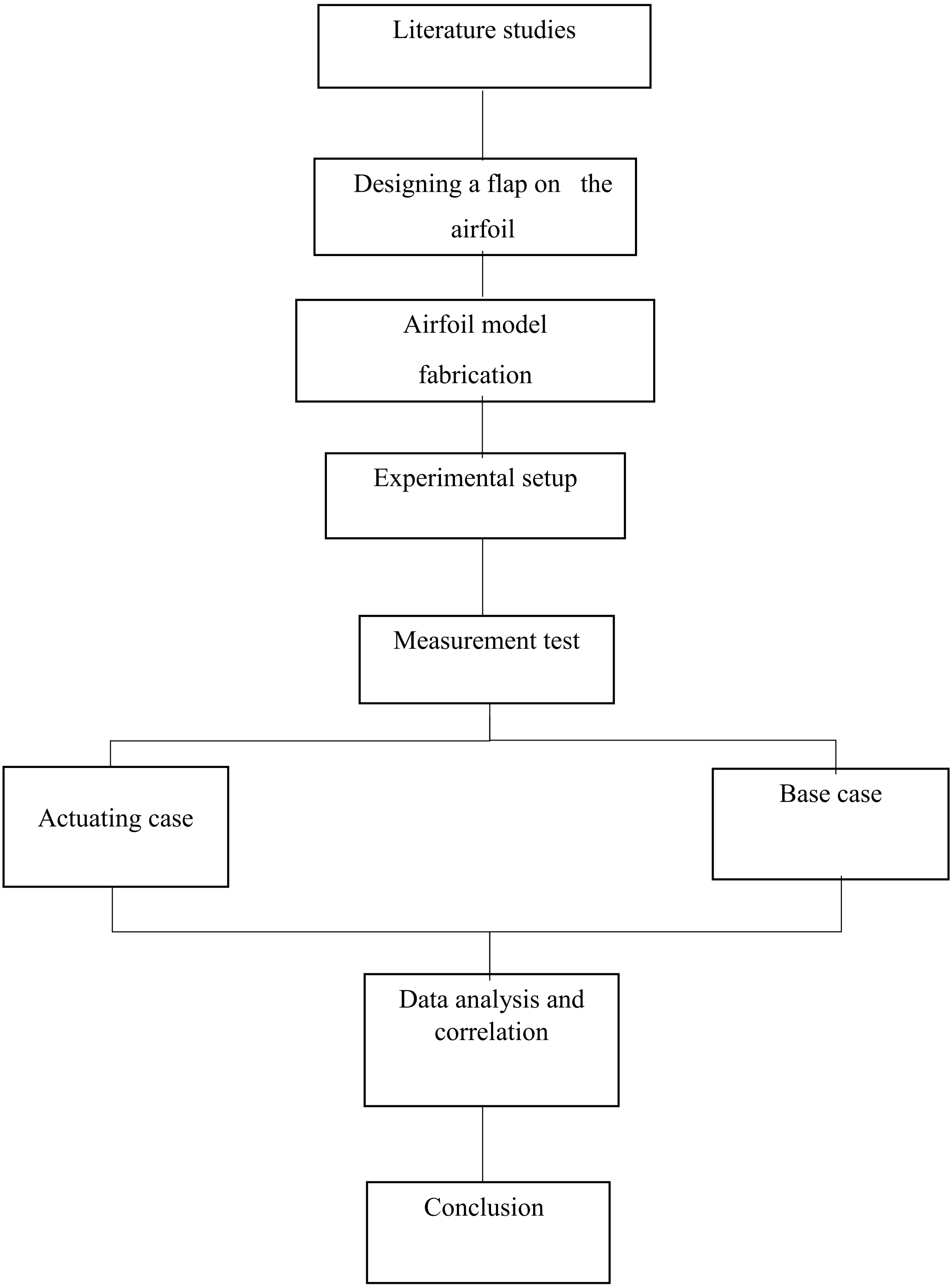

Figure 3 : Flow chart of the experimental step

CHAPTER 2

LITERATURE REVIEW

2.1 OVERVIEW

Literature review is focused on previous study in the related field to obtain knowledge and information for the present study. In this chapter, journals and technical reports from other researchers are selected to be reviewed. The results obtained from the previous study will be compared.

2.2 NUMERICAL AND EXPERIMENTAL INVESTIGATIONS OF LIFT AND DRAG PERFORMANCES OF NACA 0015 WINF TURBINE AIRFOIL BY ADEM ACIR et al. (2015)

In the present work, we studied numerical and experimentally analysis lift and drag performances of NACA 0015 airfoil at different attack angle at low Reynolds numbers (Re) by measuring the forces every two degrees from 0° to 20°. The experiment test was conducted in low speed wind tunnel, and the numerical analysis was performed using CFD