THE EFFECT OF SLAT AND FLAP TO THE AERODYNAMICS PERFORMANCE OF AN AIRFOIL

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Report
Projek Sarjana Muda 2

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2017

DECLARATION

I declare that this project entitled “The effect of slat and flap to the aerodynamic performance of an airfoil” is the result of my own work except as cited in the references.

Signature : ……………………………………...
Name : MOHD SOFIAN BIN ABD HAMID
Date : 24 MAY 2017

APPROVAL

I have checked this report and the report can now be submitted to JK-PSM to be delivered back to supervisor and to the second examiner. DR NAZRI BIN MD DAUD

Signature : ....

Name of Supervisor : DR NAZRI BIN MD DAUD

Date : 24 MAY 2017

DEDICATION

I dedicate this project to my beloved parents.

ABSTRACT

This study was dealing with the effect of the application of the leading edge slat and trailing edge flap on the NACA 0015 airfoil. The lift and drag coefficient were determined after some experiments and further calculation based on the theoretical formula. Generally it is about to see the difference of the airfoil characteristic when it is not equipped with the slat and flap and when the airfoil is being equipped with the slat and flap. The experiment took place in a subsonic high velocity wind tunnel. The airfoil was set up at the angle of attack from 0 to 20 with the 5 of interval. The wind tunnel was set with a constant air velocity of 9.5m/s. The indicator panel on the wind tunnel will show the value of lift force and drag force. The data was recorded and the n the experiment is proceed with the replacement of the airfoil with the modified airfoil with the slat and flap. Several configuration of the slat and flap with variety combination of angle of attack was set and tested. The data was recorded. From the test it was found the best angle of attack combination of the slat and flap that is the best for the airfoil. Slat with the angle of 30 with the flap with the angle of 0 gives the best lift force on the airfoil with the value of the lift coefficient of 1.006. hence it can be conclude that the leading edge slat and trailing edge flap can affect the aerodynamic performance of an airfoil.

ABSTRAK

Kajian ini berkaitan dengan kesan penggunaan flap pinggir hadapan dan belakang pada aerofoil NACA 0015. Daya ngkat dan seret ditentukan selepas beberapa eksperimen dan berdasarkan formula teori. Secara umumnya ia adalah kira-kira untuk melihat perbezaan ciri aerofoil apabila ia tidak dilengkapi dengan bertampar dan flap dan apabila aerofoil sedang dilengkapi dengan bertampar dan flap. percubaan itu berlaku di dalam terowong angin halaju tinggi subsonik. aerofoil ditubuhkan pada sudut serang 0-20 dengan 5 selang. Terowong angin telah ditubuhkan dengan halaju udara yang berterusan daripada 9.5m / s. Panel penunjuk pada terowong angin akan menunjukkan nilai daya angkat dan daya seret. data telah dicatat dan n eksperimen adalah meneruskan penggantian aerofoil dengan aerofoil yang diubah suai dengan bertampar dan flap. Beberapa konfigurasi slat dan flap dengan kombinasi pelbagai sudut serang ditubuhkan dan diuji. data telah dicatat. Daripada ujian didapati sudut terbaik kombinasi serangan slat dan flap yang terbaik aerofoil. Bertampar dengan sudut 30 dengan kepak dengan sudut 0 memberikan daya angkat terbaik di atas aerofoil dengan nilai pekali daya angkat daripada 1,006. oleh itu ia boleh membuat kesimpulan bahawa flap pinggir hadapan tepi bertampar dan belakang boleh menjejaskan prestasi aerodinamik aerofoil.

ACKNOWLEDGEMENT

First thing first, I would like to give my whole heartedly thank you to my supervisor for this study, Dr Nazri bin Md Daud. As my research supervisor, he was such a good mentor and without his helps I will not able to finish my research right on time. He guided me from the beginning until the last minutes of this research. He has helped and supported me to complete my research.

Besides that, not being forgotten my parents in Johor. My father Abd Hamid bin Aini. My mother Saropah binti Warjan. These two people is the one who have helped me a lot not only for this research but from the beginning of everything. They always encourage me to always give my best in everything. They are also believe in me and always motivate me to be a better person.

Next, I would like to give thousands of thank to someone special. To my fiancé Noor Syazwani binti Soelastro who were always be here with me supporting me and keep motivate me to finish my research and give my best on this research. She was always be on my side especially when I was having my difficult time and keep encourage me to not give up. Thank you.

And lastly, I would like to acknowledge with much appreciations to friends for their continuous support and encouragement throughout the project period. To all my BMCT friend, my FKM friend and all my UTeM friend.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

LIST OF ABBEREVATIONS

DBD	Dielectric barrier discharge
PVC	Polyvinyl chloride
PMMA	Polymethyl methacrylate
PIV	Particle Image Velocimetry

CHAPTER 1

INTRODUCTION

1.1 Background

Flap was originally being invented and applied to the airfoil purposed to improve the take off and landing aerodynamics process of an airplane. The optimization results show that under takeoff configuration, the variable camber trailing-edge flap can increase lift coefficient by about 8% and lift-to-drag ratio by about 7% compared with the traditional flap at a takeoff angle of 8°. (Weishuang, Yun, & Peiqing, 2017). In these few years back, the more attentions are given to the aerodynamics of deformable wings. The term deformable means that the wings have flap that can be retracted back (Li, Dong, & Liu, 2015).

Leading edge slat and the trailing edge flap are commonly being applied on the airfoil wings in order to obtain high lift force towards the wings. The design of this type of wings are aided by modern numerical modelling that able people to evaluate many value of performance on different geometries (Savory, Toy, Tahouri, & Dalley, 1992).

1.2 Problem statement

The fuel usage efficiency of an aeroplane is normally being affected by many factors such as the distance, the velocity and the drag force. Basically, the drag force acting on the body of the aeroplane especially the wings give the greatest impact to the fuel consumption. The drag force will slow the velocity of the plane down, more power will be used to overcome the drag because they have and estimated time to arrive to be followed. Using extra power on the engine will directly increase the fuel consumption of the plane.

There were many researches done before working on how to solve this problem. For example, in 1990, Mohamed Gad-El-Hak has done a research on control of a low-speed airfoils aerodynamics in order to find solutions for the problem encountered. Some famous research regarding to the problem of the drag force of an aeroplane's wings is about designing an aerodynamic shape of the wings. A different shape will give different measure related to the flow around it. For example, a bluff area will cause greater air resistance compared to the one with aerodynamic shape.

The application of slatted leading edge of an airfoil and the flapped trailing edge of an airfoil is one of the thing that is being study in order to have a better performance of an airplane. With the theory that the application of flap and slat that is able to increase the lift of an airplane, it means that lower velocity is needed for the airplane to take off which also means that less fuel consumption during the take off. The flap is affecting for the take off while the slat is for the cruising ship at constant velocity.

1.3 Objective

The objectives of this project are as follows :

1. To study the effect that can be caused by the application of leading edge slat and trailing edge flap on NACA 00115 airfoil,
2. To evaluate the drag and the lift of the NACA 0015 airfoil.
3. To compare the result of the application of slat and flap to the one with no flap and slat.

1.4 Scope of project

The scopes of this project are as follows:

1. Design and fabricate a NACA 0015 airfoil
2. Testing the normal NACA 0015 airfoil with no slat and flap in a high velocity wind tunnel.
3. Testing the modified NACA 0015 airfoil with slat on the leading edge and flap on the trailing edge in a high velocity wind tunnel.

1.5 General methodology

The actions that is needed to be carried out in order to achieve the objectives of this project are listed below:

1. Literature review

   Journals, articles, or any materials regarding to this project will be reviewed to find extra information related to the effect of the plasma actuator to the airfoil.

2. Experimentation

   Experiments will be conducted to test the effect of the application of slat on the leading edge of the airfoil and flap on the trailing edge of the airfoil. The cross sectional drawing of this airfoil with slat and flap can be seen as in Figure 1.5.1. The general overview of this project can be seen through the flowchart of this study (Figure 1.5.2)

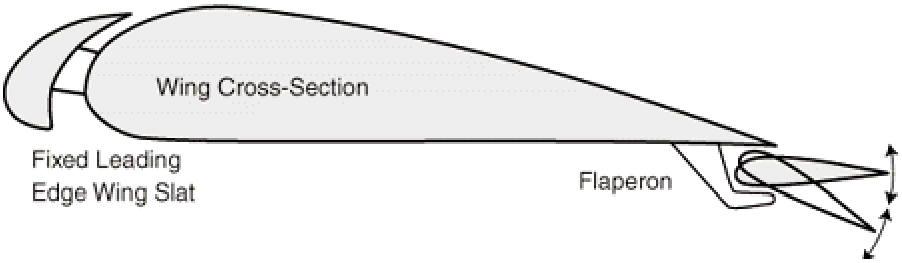


Figure 1.5.1 The cross sectional diagram of the setup of the NACA 0015 airfoil with the lading edge slat and trailing edge flap (Weishuang et al., 2017)

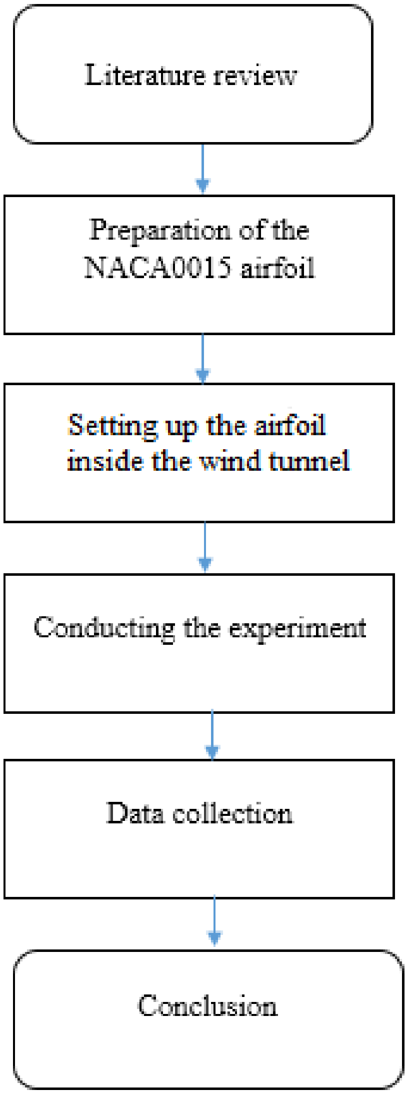


Figure 1.5.2 The overall flowchart of this research

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

In this chapter, a few previous studies done related to the effect of application of the leading edge slat and the trailing edge flap will be reviewed here to gather as much as information that can be very helpful in the future.

2.2 Leading edge slat and trailing edge flap

Trailing-edge flap is traditionally used to improve the takeoff and landing aerodynamic performance of aircraft. In order to improve flight efficiency during takeoff, cruise and landing states, the flexible variable camber trailing-edge flap is introduced, capable of changing its shape smoothly from 50% flap chord to the rear of the flap (Weishuang et al., 2017) Flapping-wing offers unique force-producing mechanisms over conventional flight methods for designing micro air vehicles, especially in the low Reynolds number (Re) regime. (Dickinson et al., 1999)

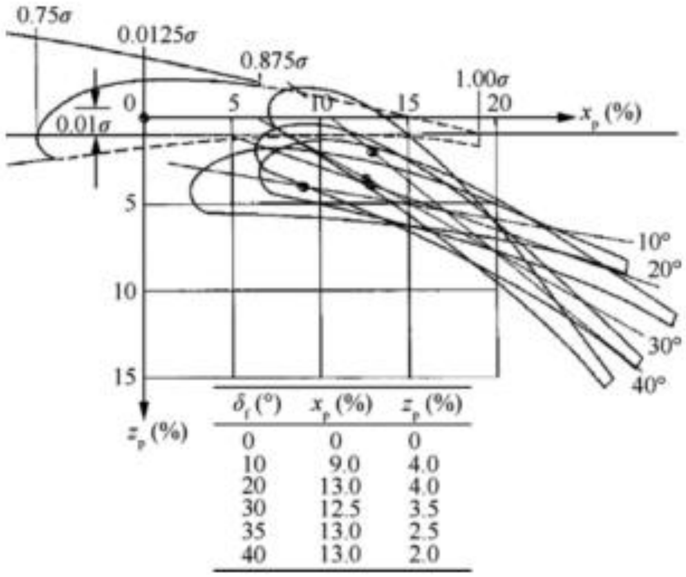
Figure 2.2.1 An A-300 series airfoil profile with leading edge slat and trailing edge flap

(Savory et al., 1992)

Aircraft wing design generally takes the efficiency of the cruise flight and the high-lift performance at takeoff and landing into consideration and the trailing-edge high-lift devices have been widely used on many kinds of aircraft previously (Li et al., 2015)

2.3 Experimental design and set up

In his current study, Lu Weishiang used the GA (W)-2 airfoil is as an analytical model; this is an advanced airfoil for general aviation with a maximum thickness of about 13% of its chord, c. The configuration for the take off and landing mechanism for this airfoil are as in Figure 2.3.1 below where d df is the deflection angle of the flap, xp is the translation amount in the horizontal direction and zp is the translation amount in the vertical direction



δ_f (°)	x_p (%)	z_p (%)
0	0	0
10	9.0	4.0
20	13.0	4.0
30	12.5	3.5
35	13.0	2.5
40	13.0	2.0

Figure 2.3.1 Configuration for takeoff and landing of a GA (W)-2 airfoil. (Weishuang et al., 2017)

In a different but related paper, the writer W.L Siauw in his paper entitled Transient phenomena in separation control over a NACA 0015 airfoil, NACA 4412 was used as a model in his experiment. The test section was 1.3m high, 1.7mwide and 3.0m long. The contraction ratio was 1:8 and the flow was driven by an eight- blade axial fan. The vertically mounted model spanned the entire working section. The model ends were attached to horizontal turntables placed in the central part of the working section. The lower turntable enabled the manual adjustment of the airfoil angle of attack. Porous plates were installed on both lower and upper turntables, through which suction was applied along the model suction-side and in front of the slat to reduce the effect of the tunnel wall boundary layer.

The main wing, slat, and flap were provided with a total of 270 tappings along the centerline to permit the measurement of comprehensive pressure distributions and the computation of overall drag and lift forces(Savory et al., 1992) The experiments were conducted in a blowdown wind tunnel, with working section dimensions of 1.68 m height × 1.37 m width × 9.0 m length and a free-stream turbulence level of 0.20%. A free-stream velocity of 20 m/s was used, giving a chord Reynolds number of 1.26 × 10 6. Only two configurations have been studied to date: with the high-lift devices with- drawn and with the slat and flap set at their optimum posi- tions (slat angle of 25° and flap angle of 20° to the main wing)

Figure 2.3.2 Schematic view of the 270 pressure tappings distributed along the airfoil chord (Pagani, Souza, & Medeiros, 2017)

The top view of the airfoil arrangement and the angle of attack inside the wind tunnel are as in the Figure 2.3.3

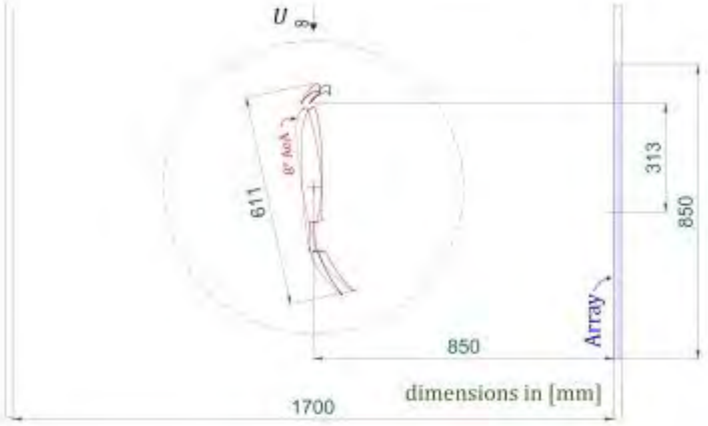


Figure 2.3.3 Top view of the airfoil inside wind tunnel with its angle of attack (Pagani et al., 2017)

Sahin in his paper Numerical and Experimental Investigations of Lift and Drag Performances of NACA 0015 Wind Turbine Airfoil, has conducted an experiment in an open wind tunnel at the University of Gazi, Faculty of Technology. This tunnel test section long is about 0.4m long and flow cross- section is approximately 0.3m×0.3m, interval of wind velocity is from 3.1 to 28 m/s. The airfoil profile used in his experiment was the NACA 0015 airfoil.

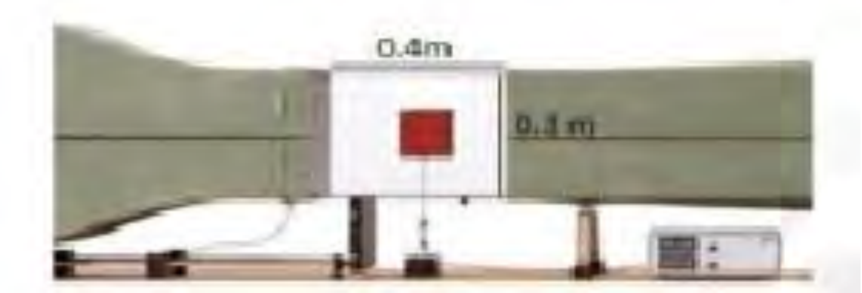


Figure 2.3.4 The wind tunnel (Şahin & Acir, 2015)

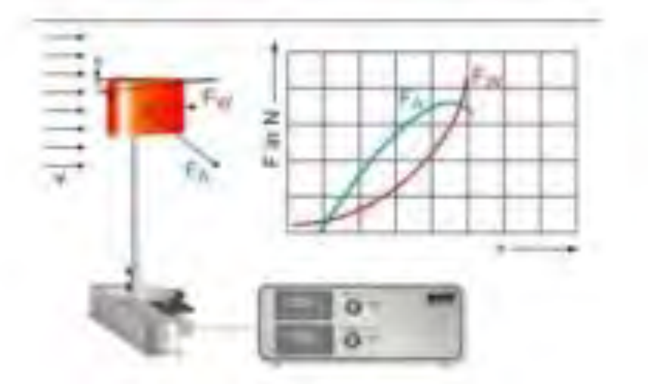


Figure 2.3.5 Wind tunnel test mechanisms (Şahin & Acir, 2015)

The experiments has been conducted at 10 m/s wind velocity (V) in tunnel which is corresponding to 68490 Reynolds number (Re) and the airfoil is forced stationary wind velocity to learn lift and drag coefficient, the airfoil profile is attached to electronic two- component coefficient transducer. The values for drag and lift are displayed digitally on the measurement amplifier (Şahin & Acir, 2015)

2.4 Result and discussion

From the ANSYS FLUENT analysis, Lu Weishuang said that at an attack angle below 19, the total lift coefficient of the airfoil increases with the angle of attack, agreeing well with experimental results. The aerodynamic forces of the leading-edge slat wing and main body and trailing-edge flap are also in good agreement with experiment and then the angle of attack is