EXPERIMENTAL STUDY ON THE EFFECT OF VORTEX GENERATOR TO AERODYNAMICS PERFORMANCE OF AEROFOIL

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Report
Projek Sarjana Muda II

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DECLARATION

I declare that this project report entitled “Experimental study on the effect of vortex generator to aerodynamics performance of areofoil” is the result of my own work except as cited in references.

Signature :..

Name :...AZUWAR BIN AZMI...

Date :.....24/5/2017......................

SUPERVISOR'S DECLARATION

I hereby declare that I have read this project report and in my opinion this report is sufficient in term of scope and quality for the award of degree of Bachelor of Mechanical Engineering (Thermal-Fluid)

Signature :...

Name of Supervisor :..DR. NAZRI BIN MD DAUD..

Date :................24/5/2017..................

DEDICATION

For my beloved family members

ABSTRACT

Vortex Generator has been found to be very useful in a wide area of applications. The various types and position of vortex generator can be applied for specific tasks. For instance, the used of vortex generators have been implemented on the surface of vehicles such as BMW and on the wing of aircraft. The vortex generators used in delay the flow separation occurs toward the surface of vehicles. By applying this method, a higher amount of lift force can be obtain at the critical angle of attack apply towards an aerofoil and overcome the increasing drag force. Recently, the aerodynamics performances are frequently being studied for airflow control. The vortex generator has the ability to control airflow on wing profiles by maintaining the streamline of the boundary layer. This report attempts to define the principle and application of the vortex generator. Vortex generator is introduced in the beginning a detailed review and designs is presented. Furthermore, for the outstanding findings for this thesis are, VGs with fin shape have better aerodynamics performance compared with other cases and it achieved the functional application of VGs which are used to delay flow separation occurs on the surface of aerofoil and prevent stall at higher angle of attack applied. Last but not least this thesis had fulfil its objectives to obtain C_L and C_D for all the cases and make a comparison between the aerodynamics performances.

ABSTRAK

Penjana vorteks amatlah berguna dalam pelbagai aplikasi. Jenis-jenis dan kedudukan penjana vorteks boleh digunakan untuk tugas-tugas tertentu. Antara contoh-contoh pengunaan penjana vorteks adalah diterapkan dipermukaan kereta seperti BMW dan di bahagian sayap pesawat. Fungsi penjana vorteks ini adalah untuk melengahkan lagi pembahagian aliran bendalir di permukaan kenderaan. Dengan kaedah ini, daya angkatan dapat di naikkan pada sudut maxima yang ditujukan terhadap aerofoil serta mengatasi daya seretan dihadapi. Sejak kebelakangan ini, prestasi aerodinamik giat dikaji untuk mengawal keberkesanan prestasi aliran udara dan penjana vortex ini mempunyai kemampuan untuk mengawal aliran udara pada profil sayap dengan kaedah mengekalkan corak aliran bendalir pada lapisan sempadan (Boundary Layer). Laporan ini bertujuan mentakrifkan dasar dan aplikasi penjana vorteks. Bab dimulakan dengan introduksi kepada reka bentuk dan penerangan mendalam mengenai penjana vorteks. Sehubungan dengan itu, penemuan ketara pada tesis ini adalah penjana vorteks berbentuk sirip mempunyai kecekapan aerodinamik yg lebih tinggi berbanding kes-kes yang lain dalam kajian ini dan ia mematuhi fungsi penjana vorteks iaitu dengan menghalang pembahagian aliran pada permukaan aerofoil dan menghalang kesan "stall" berlaku pada sudut tuju yang lebih tinggi. Secara konlusinya, C_L dan C_D dapat ditentukan untuk semua kes dan perbandigan dibuat untuk setap kajian.

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C_D	Coefficient of Drag
C_L	Coefficient of Lift
β	Skew Angle (Degree◦)
α	Pitch Angle/Angle of Attack (Degree◦)
D	Distance Link Adjacent
d	Distance Between Tow
c^1	Chord
h	Height
δ	Boundary Layer Thickness
Re	Reynolds Number
l	Chord Length (m)
C_p/P	Coefficient Pressure Distribution
ρ	Density (kg/m^3)
U_{stag}	Stagnation Point
L	Lift Force (N)
v	Velocity (m/s)
A	Frontal Area (m^3)
D	Drag Force (N)
m	Metre
s	Second
W	Watt
V	Volt
Hz	Hertz
lPh	Liquid Pound per Hour
A	Ampere
µ	Dynamic Viscosity [kg/(s.m)]
c	Symmetrical Chord of Length

θ	Angle
p_o	Pressure at Some Distance Upstream from the Section
p	Pressure at Any Point on the Vane Surface
ΔP	Dynamic pressure or P_{dyn} (N/m^2)
N	Weight (kg x $\frac{m}{s^2}$)
X_A	Actual Distance
X_S	Standard Distance
L_O	Indicated Lift
D_O	Indicated Drag
T	Temperature (°C)
%	Percentage

LIST OF ABBEREVATIONS

VGs	Vortex Generators
VGJs	Vortex Generator Jets
VVGs	Vane Vortex Generators
UVGJ	Velocity Vortex Generator Jets
ΦVGJ	Exit Diameter Vortex Generator Jet
CFD	Computational Fluid Dynamics
PIV	Particle Image Velocimetry
NACA	National Advisory Committee for Aeronautics
AR	Aspect Ratio
T.I	Turbulence Intensity
SC	Stall Cell
ZZ	Zigzag
VAWT	Vertical Axis Wind Tunnel
3D	Three Dimension
STL	STereoLithography
PLA	PolyLactic Acid
PVA	Polyvinyl alcohol
ABS	Acrylonitrile butadiene styrene
2D	Two Dimension
etc	et cetera
DBD	Dielectric Barrier Discharge

CHAPTER 1

INTRODUCTION

1.1 Background

Generally, vortex generator is a small angled vane in any kind of shapes and dimensions that being installed on an outer surface of an aerodynamic body. For this case of study, small angled vane with shapes of square and fin is being install on the surface on an aerofoil. The specific position for this investigation is focus on the leading edge and trailing edge of an aerofoil. The experimental test conducted in a vertical axis wind tunnel with specific parameter of air velocity supply and tilt angle of the aerofoil. Continuously related about the vortex generator, the angle of the vane will causes the air to swirl, generating a vortex behind it. This result allow the air flow to stay "attached" to the surface even at points where the flow without a vortex would separate from the surface.

One of the most common uses of vortex generators is on aircraft wings forward of an ailerons. When the aircraft wing stalls, the flow detaches from the wings. This means that the flow will detach before it reaches the ailerons, making them ineffective. The use of vortex generators helps the ailerons to provide control even if the rest of the wing is stalled.

Related with the earlier explanation, vortex generator is normally taking the shape of a vane and also influence by the size and angle of position and it generate a small vortex. This vortex is essentially a region where the flow is rotating around its axis. Basically this plate extracts energy from the flow generating this rotation on the flow.

Next, the rotational flow has gain the energy and accurately oriented interacts with the boundary layer over the wing, it can provide higher energy towards it. With the extra energy gain, it cause the boundary layer become unaffected to separation. Due to the phenomena, angle of attack can be increase and higher lift coefficient can be obtain for the aerofoil that being installed with vortex generator.

Furthermore, vortex generator will increase the amount of drag force due to oppose motion against the air and higher angle of attack. According to (Masaru Koike, Tsunehisa Nagayoshi and Naoki Hamamoto, 2004), by installing vortex generator, it can help in reducing the drag force by preventing flow separation at downstream besides delay flow separation.

At certain point, the aerofoil reaches a condition of stalling effect, both the pressure distribution on the bottom and top surface of the aerofoil is equivalent. This effect happens because of the critical angle of attack of the aerofoil is exceed.

1.2 Problem Statement

- Since, there is a lack of study in comparing baseline case and modify case (vortex generator) of aerofoil.
- To determine coefficient of drag (C_D) and lift (C_L) for baseline case and modify (vortex generator) case.
- Compare the C_D and C_L Of the modify case at the leading and trailing edge of the aerofoil.

For the vortex generator investigation, it is important to get precise configuration of apparatus and materials to determine an accurate reading of data as shown as Figure 1.1(a). The main problem in this case is to determine and study about the drag and lift coefficient of the baseline case and modify case of an aerofoil (NACA 0015). The optimum position/distance (x) of vortex generator need to be determine on the leading and trailing edge to achieve the maximum efficiency of the C_D and C_L. This method can be apply to study the aerodynamic air flow of aerofoil or vehicle. The experiment conducted in a wind tunnel with by supplying specific parameter of air velocity towards the aerofoil. Figure 1.1(b) shows and indicates the pattern of airflow before and after installing the vortex generator on the surface of an aerofoil with three different angles of attack.

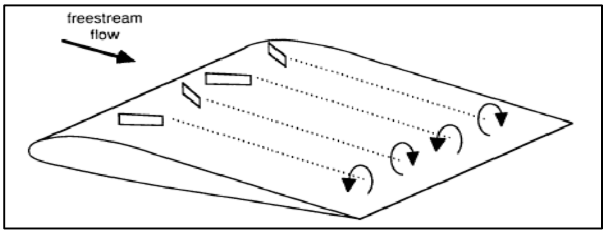

Figure 1.1(a): Rough Setup of Vortex Generator on Aerofoil.
(https://www.researchgate.net/figure/283504299_fig1_Figure-1-contra-rotating-vortex-generator-configuration)

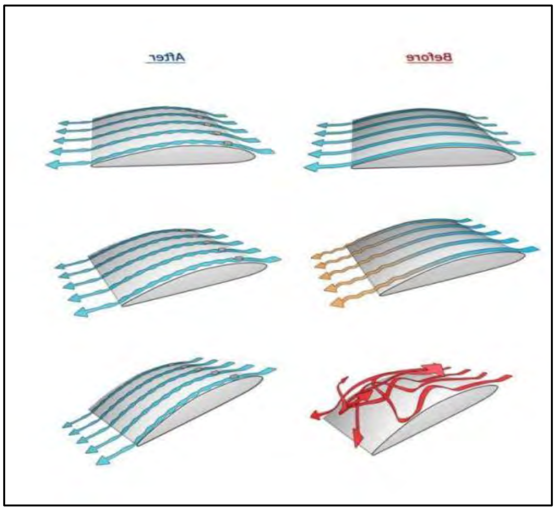

Figure 1.1(b): Vortex Generator Installment After and Before with Different Angle of Attack. (http://www.vortex-generators.com/vortex-generators.html)

1.3 Objective

The objectives of this project are as follows:

1. To determine the C_D and C_L for the baseline case of aerofoil.
2. To determine the C_D and C_L for the modify case of aerofoil by installing vortex generator.
3. Compare both C_D and C_L for the base and modify case of aerofoil.

1.4 Scope of Project

The actions that need to be carried out to achieve the objectives in this project are listed below.

The scope for this project are:

1. Type of aerofoil being use:
2. Fix air velocity measurement:
3. Measure C_D and $C_{L.}$

Only vortex generator findings are presented in this report. The result of the airflow, C_D and C_L can be obtained during the experiment conduct with the helps from technician and supervisor.

In order to manipulate C_D and C_L, these three main fields of flow control can be investigated:

a) Angle of attack of the aerofoil.
b) Position of the vortex generator being install.
c) Shape of the vortex generator.

1.5 General Methodology

The actions that need to be carried out to achieve the objectives in this project are listed below.

1. Literature review

   Journals, articles or any materials regarding the project will be reviewed.

2. Inspection

   The C_D and C_L will be determined and discuss with the supervisor between the relationship of angle of attack and vortex form at surface of the aerofoil.

3. Measurement

   The measurement will be conducted at Turbo Machinery Lab. For aerofoil test will be conducted inside a wind tunnel. Measurement data of C_D and C_L will be collected and compare between two different cases.

4. Analysis and proposed solution

   Analysis will be presented on how mathematical calculation to determine C_D, C_L and the angle of attack will help in creating vortex near the surface of the aerofoil as well as the optimum position/distance (x) of vortex generator to be determine to achieve the maximum velocity profile. Solutions will be proposed based on the analysis.