THE EFFECT OF DIELECTRIC BARRIER DISCHARGE (DBD) PLASMA ACTUATOR ON THE LEADING EDGE OF AN AIRFOIL

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DECLARATION

I declare that this project report entitled "Effect of Dielectric Barrier Discharge (DBD) plasma actuator on the leading edge of an airfoil" is the result of my own work except as cited in references.

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Date :…………11/5/2018 ……………

APPROVAL

I hereby declare that I have read this project report and in my opinion this report is sufficient in terms of scope and quality for the award of the degree of Bachelor of Mechanical Engineering (Hons).

Signature :…………………………

Name of Supervisor :………………………….

Date :………………………..

DEDICATION

To those who have been supporting me throughout my 4 years of study.

Thank you.

ABSTRACT

Dielectric Barrier Discharge (DBD) plasma actuator has been found to be very useful in a wide area of applications. The various types and position of DBD plasma actuator can be applied for specific tasks. For instance, the used of DBD plasma actuator have been implemented on the surface of vehicles such as car and on the wing of aircraft. The DBD plasma actuator used in delay the flow separation occurs toward the surface of vehicles. By applying this method, a higher amount of lift force can be obtained at the critical angle of attack apply towards an airfoil and overcome the increasing drag force. Recently, the aerodynamics performances are frequently being studied for airflow control. The DBD plasma actuator 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 DBD plasma actuator. DBD plasma actuator is introduced in the beginning a detailed review and designs is presented. Furthermore, for the outstanding findings for this thesis are, actuation case have better aerodynamics performance compared with baseline case and it achieved the functional application of DBD plasma actuator which are used to delay flow separation occurs on the surface of airfoil and prevent stall at higher angle of attack applied. Last but not least this thesis had fulfilled its objectives to investigate the effect of Dielectric Barrier Discharge (DBD) plasma actuator on the leading edge of airfoil and to compare the airfoil aerodynamic performance between base case and actuation case**.** The angle of attack used in the experiment range from 0^{o} to 24^{o}. The power supply used is 6 KV. The lift coefficient is increase as the angle of attack increases for both cases. The drag coefficient is decreases for actuation case. The experiment is conducted with velocity 15 m/s and 20 m/s. The finding of the study shows that by applying DBD plasma actuator, the value of lift coefficient of an airfoil shows an increment in range of 0.63% to 7.79% with different angle of attack for velocity of 15 m/s. However, the value of drag coefficient of an airfoil shows a declination in range of 3.25% to 100% with different angle of attack for velocity of 15 m/s. For velocity of 20 m/s, the value lift coefficient of an airfoil shows an increment in range of 0.51% to 3.3% and the value of drag coefficient shows a declination in range of 4.9% to 24.4% with different angle of attack. The aerodynamic performance can be improved by applying DBD plasma actuator as the lift coefficient is increase and drag coefficient is decrease based on the result of this study.

ABSTRAK

Penggerak plasma (DBD) amatlah berguna dalam pelbagai aplikasi. Jenis-jenis dan kedudukan penjana vorteks boleh digunakan untuk tugas-tugas tertentu. Antara contoh-contoh pengunaan penggerak plasma DBD adalah diterapkan dipermukaan kenderaan seperti kereta dan di bahagian sayap pesawat. Fungsi penggerak plasma DBD 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 penggerak plasma DBD 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 penggerak plasma DBD. Bab dimulakan dengan introduksi kepada reka bentuk dan penerangan mendalam mengenai penggerak plasma DBD. Sehubungan dengan itu, penemuan ketara pada tesis ini adalah kes penggerak plasma DBD mempunyai kecekapan aerodinamik yg lebih tinggi berbanding kes yang lain (baseline) dalam kajian ini dan ia mematuhi objektifnya iaitu menyelidik kesan penggerak plasma DBD terhadap permukaan awal di aerofoil dan membezakan prestasi aerodinamik oleh aerofoil antara es baseline ataupon kes actuation. Sudut serangan yang digunakan dalam julat eksperimen dari 0^o ke 24^o. Bekalan kuasa yang digunakan ialah 6 KV. Koefisien angkat meningkat apabila sudut serangan meningkat untuk kedua-dua kes. Pekali seret adalah berkurangan untuk kes keganasan. Eksperimen dijalankan dengan halaju 15 m / s dan 20 m / s. Dapatan kajian menunjukkan bahawa dengan menggunakan penggerak plasma DBD, nilai pekali angkat an airfoil menunjukkan kenaikan di antara 0.63% hingga 7.79% dengan sudut serangan yang berbeza untuk halaju 15 m / s. Walau bagaimanapun, nilai pekali seretan lelayang lelayang menunjukkan penurunan sebanyak 3.25% hingga 100% dengan sudut serangan yang berbeza untuk halaju 15 m / s. Untuk halaju 20 m / s, pekali angkat nilai a airfoil menunjukkan kenaikan dalam kisaran 0.51% hingga 3.3% dan nilai pekali seretan menunjukkan penurunan sebanyak 4.9% kepada 24.4% dengan sudut serangan yang berlainan. Prestasi aerodinamik dapat ditingkatkan dengan menggunakan penggerak plasma DBD kerana koefisien angkat meningkat dan koefisien seretan menurun berdasarkan hasil kajian ini.

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DBD	Dielectric Barrier Discharge
NACA	National Advisory Committee for Aeronautics
AR	Aspect Ratio
SJA	Synthetic Jet Actuator
STOL	Short Take OFF and Landing
UAV	Unmanned Aerial Vehicles
MAV	Micro Aerial Vehicles
CFD	Computational Fluid Dynamics
3D	Three Dimension

LIST OF SYMBOL

α	Angle of attack
C_L	Lift Coefficient
C_D	Drag Coefficient

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CHAPTER 1

INTRODUCTION

1.1 BACKGROUND

Airplanes have made great contribution to the growth of modern society by satisfying many of it needs for mobility in daily life. However, the airplanes should be improved in terms of aerodynamic and any problems that can affect its efficiency can be avoided. One of the alternative way to improve aerodynamic for an aircraft is by applying the Dielectric Barrier Discharge (DBD) plasma actuator on the airfoil. Plasma actuators are electrical devices that create a divider limited stream without the usage of any moving parts. For aerodynamic applications, the actuators can be utilized as stream control devices to postpone division and enlarge lift on a wing. The standard plasma actuator comprises of a solitary embodied (ground) cathode (Rasool Erfani, Craig Hale & Konstantinos Kontis, 2014).

Previously, the plasma actuators already appeared to be fit for controlling airflow by delivering an electric wind in the limit layer. It used for aerodynamic application for both low and high speeds Numerous analysts have researched the benefits of this device. As of late, numerous analysts have been learning about flow partition control with unsteady incitation. Be that as it may, the pulse-modulated drive is as yet not obviously depicted when approach is high. Accordingly, an examination on the flow is contemplated when a plasma surface release is driven with pulse modulation both at the slow down control condition and at high angle of incidence condition (Mehul P. Patel, 2008).

The actuator itself is exceptionally basic, comprising of just 2 materials that layered over any surface. As of now, the actuators themselves are lightweight and provided with control from a transformer system that would itself be able to be substantial. As the innovation develops it is normal that the framework weight will diminish, getting to be plainly lighter than that of conventional flow control techniques. The actuator is adaptable and ready to flow the curvature of the surface it is connected to and simple to repair. The actuator can be influenced dynamic or inactive at the flick of a change, to can be actuated at a wide range of balance frequencies and has a high recurrence reaction. The whole framework is all electric and fits in well with the present ethos of airplane makers to deliver every single electric airplane. The current and perhaps the biggest boundary to the usage of this actuators is the impotence to produce momentum that can equal that of ordinary pneumatic systems and be utilized on full scale airplane

1.2 PROBLEM STATEMENT

The airplanes motion is affected by the airfoil's shape. Aerodynamics is associated to airfoil as it is the learning of forces and the subsequent movement of objects through the air. It can affect the efficiency and stability of the airplanes movement. Too many drag forces on the airplanes body could cause high waste in engine energy consumption while too many lift force could cause the airplanes lacks in stability and dangerous. The uses of slat, flap and plasma actuator on an airfoil can improve aerodynamic performance. Slat is a device that install ahead of the wing so air can flow at high angle of attack while flap's location is at the leading edge of airfoil to increase the camber of wing. Vortex generator use to energize the airflow in order to delay the separation of air during high angle of attack.

Besides, the usage of this Dielectric Barrier Discharge (DBD) plasma actuator can contribute in improving performance of aerodynamic. It can be used for many type of vehicles or transportation such as airplanes, car and truck. It usually be applied at the airfoil and blades of airplanes. The working of the actuators relies upon the development of a low-temperature plasma between a couple of unbalanced electrodes by utilization of a high-voltage AC signal over the electrodes. Subsequently, air molecules that surround the electrodes are ionized, and are quickened through the electric field.

This DBD plasma actuator improve aerodynamics as it can increase lift force which enable an airplane to overcome gravity and decreasing the drag force which another aerodynamic force that act as a resistance for an airplane as it moves through air. Lift is a force which opposes the gravity that depends on weight. It produced by dynamic impact of air acting on the wings or airfoil. Lift is affected by the size and airfoil, the angle of attack, and air's density. Lift force produced by a wing is affected by all of them. Force is increase when the air (liquid) moving of the highest part of the wing experiences a hindrance that it must go around and hence its speed increases and its pressure drops. The distinction in pressure between the bottom and upper of the wing brings about more pressure at the bottom, hence pushing the wing upward into the sky.

This actuator is suitable for airfoil in terms of aerodynamic performance. It usually is applied at the leading edge of an airfoil. It can also be used to delay stall which is rapid decreases of lift. When an airfoil exerted air at high angle of attack that exceeds a critical point, a stall is occurred as it is unable to sustain lift. Airflow on the airfoil separates resulting an end of lift. Besides, less number of research on DBD plasma actuator in high angle of attack have been done. Therefore, this research are implement to investigate the effect of DBD plasma actuator on the leading edge of airfoil and compare the airfoil with plasma actuator and without plasma actuator in terms of aerodynamic performance

1.3 OBJECTIVE

The objectives of this research project are:

1. To investigate the effect of Dielectric Barrier Discharge (DBD) plasma actuator on the leading edge of airfoil.

2. To compare the airfoil aerodynamic performance between base case and actuation case.

1.4 SCOPE

The scopes of this project are:

1. This project focuses on investigation of the effect of applying of Dielectric Barrier Discharge (DBD) plasma actuator by using on the leading edge of airfoil model NACA 0015. This airfoil model NACA 0015 has 6 KV of power and 8 kHz of frequency.This plasma actuator is applied to study the drag force and lift force act on the airfoil. Both forces will influence the performance of aerodynamic for an object.

2. The experimental of wind tunnel with velocity of 15 m/s and 20 m/s on the airfoil. In order to test an aerodynamic for an object, this experiment should be conducted on an

object as it is device for creating a controlled air flow to investigate the movement effects through air and resistance that act on models of aircraft and others object. The object is fabricate in standard design and smaller scale. By conducting this experiment, the result is obtained to know the effectiveness of the object in terms of aerodynamic.

1.5 GENERAL METHODOLOGY

The actions that need to be conducted to achieve the aims in the research are listed below:

1. Suitable Objective, Scope and Problem Statement

   Study the objective, scope and problem statement of the project.

2. Literature review

   Journals, articles or any sources regarding the research will be reviewed.

3. Study the DBD plasma actuator application on airfoil and basic principle DBD.

   The theory regarding of DBD plasma actuator application on airfoil and basic principle DBD is learned and well understood.

4. Experiment of Wind Tunnel

   The wind tunnel test will be conducted on fabricated airfoil to study the effect of DBD plasma actuator in terms of aerodynamic performance

5. Analysis and proposed solution

   Analysis will be done to know the efficiency of the DBD plasma actuator applied on the leading edge of airfoil.

6. Report writing

   This research will be written in a report at the end of this study.

The methodology of this study is summarized in the flow chart as shown in Figure 1.1.

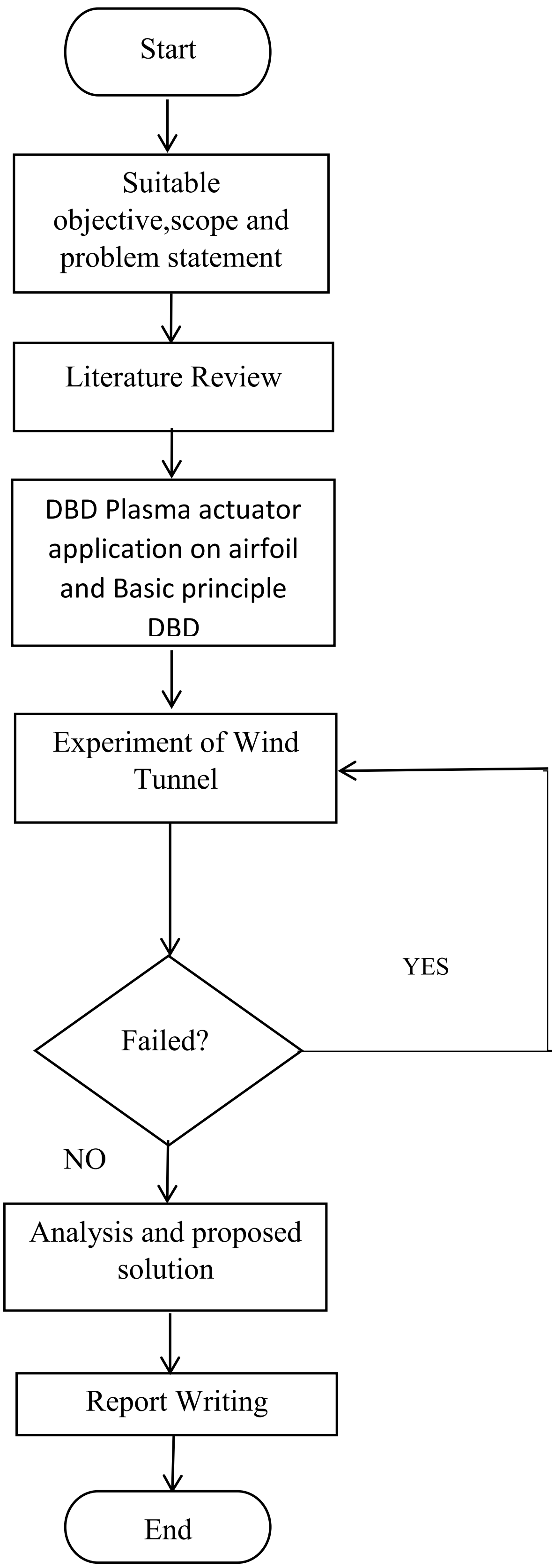

Figure 1.1: Flowchart for general methodology

CHAPTER 2

LITERATURE REVIEW

2.1 INTRODUCTION

For the literature review, the structuring of the chapter includes the Dielectric Barrier Discharge(DBD) plasma actuator which cover the literature regarding aerodynamic application and how it works in aircraft. The drag and lift forces concepts are also included in this chapter. Other than that, this chapter also includes DBD plasma actuator background which describes about the history of this plasma actuator. Next, it also includes effect of DBD plasma actuator for vehicle which describe the usage of DBD plasma actuator for vehicle. Besides, efficiency of DBD plasma actuator, component and how it works also will be included in this chapter.

2.2 AERODYNAMIC APPLICATION

The research regarding the interaction of gases among moving bodies is known as aerodynamics. Since the gas that we experience most is air, aerodynamics is essentially concerned about lift and drag forces. The airflow will pass over and around solid bodies. The principles of aerodynamics is applied by engineers to design of a wide range of things, including structures and bridge but mainly used for vehicles such as aircraft and automobiles. The design of vehicles is very prominent as it can affect the aerodynamics because it associated to the forces (lift and drag)..