DRAG REDUCTION USING DIELECTRIC BARRIER DISHARGE PLASMA ACTUTOR ON TRUCK

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DECLARATION

I declare that this study entitled "Drag Reduction using Dielectric Barrier Discharge Plasma Actuator on truck" is the result of my own research except as cited in the references. The study has not been accepted for any degree and is not concurrently submitted in candidature of any other degree.

Signature : ....

Name : ....

Date : ....

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 .

Signature : ....

Name of Supervisor : ....

Date : ....

DEDICATION

A very special dedication to my beloved parents

and to my respected supervisor Dr Nazri Bin Md Daud.

ABSTRACT

An experimental investigation has been undertaken in a wind tunnel to study the drag reduction capability of Dielectric Barrier Discharge plasma actuator on truck. Plasma is the fourth state of matter whereby a medium, such as air, is ionized creating a system of electrons, ions and neutral particles. Dielectric Barrier Discharge plasma actuator have recently become a topic for flow control due to their ability to exert a body force near the wall of an aerodynamic object which can create or alter a flow. The ultimate goal of this research is to study about DBD plasma actuator and evaluate the drag reduction as well as the performance of plasma actuator when placed on few different positions around the truck. To be specific, three objectives were determined to be achieved by the end of this study. Particularly, the study presented strives to prove the drag force acting on the trailing edge of the truck is the highest among the few positions that were tested. On the whole, this study shows the significant improvement done by Dielectric Barrier Discharge plasma actuator on the overall drag force acting at few locations around the truck. Other than that, the reduction of drag coefficient when there is Dielectric Barrier Discharge plasma actuator fixed on a particular position around a truck is also discussed throughout this paper. All the gathered experimental results and mathematically calculated experimental data were presented well in the fourth chapter. Generally, the results obtained from this experimental investigation should correlate with the theoretical understanding gained from all the relevant previous studies.

ABSTRAK

Siasatan ujikaji telah dilakukan dalam terowong angin untuk mempelajari kemampuan pengurangan seretan penggerak plasma pelepasan dielektrik halangan pada trak. Plasma adalah keadaan keempat perkara di mana satu medium, seperti udara, diionisasikan mewujudkan sistem elektron, ion dan zarah neutral. Pada zaman teknologi tinggi ini, penggerak plasma pelepasan dielektrik halangan baru-baru ini menjadi topik untuk kawalan aliran angin kerana keupayaan mereka untuk mengenakan daya badan berdekatan dinding objek aerodinamik yang boleh mencipta atau mengubah aliran. Matlamat utama penyelidikan ini adalah untuk mengkaji penggerak plasma pelepasan dielektrik halangan dan menilai pengurangan seretan serta prestasi penggerak plasma apabila diletakkan pada kedudukan yang berbeza di sekitar trak. Untuk memudahkan process penyelidikan, tiga objektif telah ditentukan untuk dicipai sebelum eksperimen berakhir.Khususnya, kajian yang dipersembahkan berusaha untuk membuktikan daya seretan yang bertindak di bahagian belakang trak adalah yang paling tinggi dalam kalangan beberapa kedudukan penggerak plasma yang telah diuji. Keseluruhannya, penyelidikan ini menunjukkan peningkatan yang ketara yang dilakukan oleh penggerak plasma pelepasan dielektrik halangan ke atas daya seretan keseluruhan yang bertindak di beberapa lokasi di sekitar trak. Selain daripada itu, pengurangan pekali seret apabila terdapat penggerak plasma pelepasan dielektrik halangan yang dipasangkan pada kedudukan tertentu di sekitar trak juga dibincangkan di sepanjang tesis ini. Segala hasil eksperimen yang dikumpul dan data eksperimen yang dikira menggunakan rumus matematik telah dibentangkan dengan baik dalam bab keempat. Umumnya, hasil yang diperolehi daripada penyiasatan eksperimen ini harus dikaitkan dengan pemahaman teori yang didapati daripada beberapa kajian lama yang berkaitan.

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LIST OF SYMBOLS AND ABBREVIATIONS

D_o	-	Indicated Drag Force
D	-	Actual Drag Force
A	-	Frontal Area
ρ	-	Density of air
V	-	Wind Velocity
X_S	-	Distance from base to joint 2
X_A	-	Distance from base to centre of the truck
C_D	-	Coefficient of Drag
DBD	-	Dielectric Barrier Discharge

CHAPTER 1

INTRODUCTION

1.1 Background

Numerous studies demonstrate the ability of plasma actuators in active flow control for more than a decade. Basically, plasma actuators can be divided into two major group which are thermal actuator and non-thermal actuator [1]. In this case, dielectric barrier discharge which is a type of non-thermal actuator will be used to study the aerodynamics drag around a truck . Dielectric barrier discharge (DBD),is based on the generation of a non-equilibrium surface discharge, which induces a body force parallel to the wall inside the boundary layer [1]. This kind of actuator has been widely characterized in quiescent air for different ambient conditions and are well-known for their ability to control airflows around different kinds of bodies.

This study focuses on the drag force acting around a truck mainly. In fluid dynamics, drag is a force acting opposite to the relative motion of any object moving with respect to a surrounding fluid. This can exist between two fluid or solid layers or a fluid and a solid surface. Drag is generally a result of three components which are form or pressure drag resulting from the difference in pressure between the wake of an object and the upstream [3]. Skin-friction drag is resulted from the action of fluid shear at the interface between a solid and fluid. Pressure and wave drag can be reduced by careful design of the body shape [3]. This is how the flow separation is postponed or eliminated and shock wave effects are minimized. Skin-friction drag is traditionally minimized by improving the surface finish of the aerodynamic body [3]. However, in many applications, we have reached the limits of the amount of drag that can be reduced by careful streamlining and using smooth surfaces.

Plasma aerodynamics has recently become a topic for flow control due to technological advancements that allow weakly-ionized plasma to be generated over large surfaces [6]. Surface plasma actuators show a curious effect of creating a force on the ambient gas that can be used to either drive a flow or alter an existing flow to achieve global effects such as delaying airfoil stall, delaying or promoting transition and moving or eliminating shock waves [1]. Plasma offers many advantages over conventional actuators. Solely, it has high bandwidth, is purely electrical and can be of low power.

The truck industry has made big efforts to make their trucks cleaner and safer. Despite that, is the air flow around the truck properly streamlined ? As a truck travels down the road, it moves through a fluid. While in motion, the truck's surface contacts air molecules [2]. Because there is relative motion between the truck and air molecules, indirectly friction occurs. Fluid friction contributes to aerodynamic drag, which is a resistance to the forward motion of a body through air. The faster you go, the greater the drag. Furthermore, the shape of the forward moving object influences the amount of resistance or drag [2]. The less aerodynamic the shape the greater is the drag. For an example, a bullet creates less drag than a box. Research proves that slowly the design of trucks are getting more bullet shaped than box shaped.

1.2 Problem Statement

A truck will never really be thin or bullet shaped, even if they were to go on diets. A design of a truck plays a huge role for the air movement around the truck. Air can be "tricked" and "manipulated" to move where you want and in any shape you want. Because of this trucks nowadays began to change shape and more importantly the air flow around the truck was being shaped and tricked. This is mainly done because improper air flow leads to unwanted drag force creation acting towards the truck. This doesn't mean drag only acts in single direction. There are few other factors that causes drag around the truck. Figure 1 shows a brief diagram about the drag acting areas around a truck. This diagram proves that drag doesn't act only at the front part of the truck. In fact, the majority of drag acts at the trailing edge of a truck. Clearly, Figure 1 shows that the trailer of a truck is the main part where the drag acts on. Eventually, this also causes massive amount of fuel consumption.

Figure 1.1 : Drag acting areas on truck

1.3 Objectives

The objective of this project is as follow :

1. To compare the drag force acting on few location around the truck.
2. To prove trailing edge of the truck has the highest amount of drag force.
3. To study the effect of DBD plasma actuator on the drag coefficient.

1.4 SCOPE OF PROJECT

The scopes of this project are :

1. Concentrate only on drag reduction on few location of a truck in this report.
2. The Dielectric Barrier Discharge (DBD) plasma actuator used in this project is limited only for 6 kV usage.
3. The frequency of DBD plasma actuator is 8 kHz maximum.
4. Only drag force caused by friction are considered in this study.

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 this project will be reviewed.
2. Preliminary testing
   - This testing is performed before installing the DBD plasma actuator on the trailing edge of the truck.
3. Real Drag Reduction testing
   - This testing is performed after the installation of DBD plasma actuator on the truck. This is the process which leads to the drag measurement.
4. Prototype
   - A lab scale prototype will be developed for few more testing especially wind tunnel testing. This prototyped is also will be used for presentation purposes.

5. Analysis

- Comparing drag reduction at the trailing edge of the truck with drag reduction at the front part of the truck. Analysing the data collected and determining the drag coefficients.

6. Report

- A report on this study will be written at the end of the project.

The flowchart below presents the general methodology of the whole project.

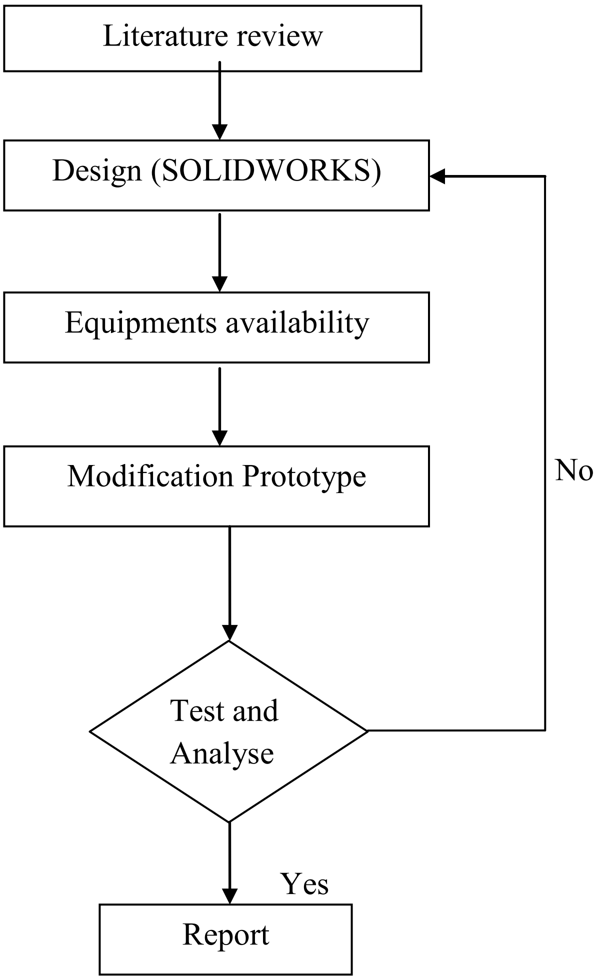

Figure 1.2 : Flowchart of methodology

CHAPTER 2

LITERATURE REVIEW

2.1 Overview

In this chapter, we are going to focus on the previous studies related to the topic to obtain useful knowledge and information for the study. Few journals , reports and articles are been analyzed. With that in mind , several important key points of the study will be deeply looked into.

2.2 Dielectric Barrier Discharge (DBD)

Based on the research, dielectric barrier discharge (DBD) are self-sustaining electrical discharges in electrode configurations containing an insulating material in the discharge path. Dielectric barrier is responsible for a self-pulsing plasma operation . Since this study requires non-thermal plasma actuator, additional information were gained about it. In most studies and applications, DBD are operated with AC high voltage in the kHz-range. In any case, the DBD arrangement has to be interpreted as a capacitive element. Thus, the displacement current is determined by the total capacity of the DBD arrangement as well as the time derivative of the applied voltage. Furthermore, the total capacity is given by the dielectric constant and the thickness of the barrier as well as the geometry of the DBD arrangement.[1][10]

In short, dielectric barrier discharge is formed by a particular configuration of electrodes. In this configuration, two flat electrodes, one larger than the other, are separated by an insulating dielectric layer. This is what referred as the “plasma actuator”. The figure below shows a sketch of single dielectric barrier discharge (SDBD). [5]

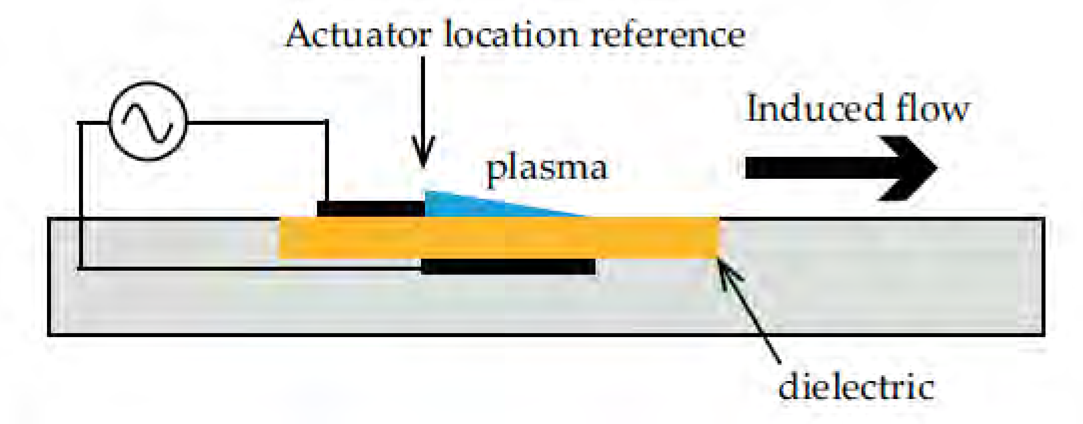

Figure 2.1 : Single Dielectric Barrier Discharge [12]

As shown above, single dielectric barrier discharge plasma actuator is composed by of two plate electrodes asymmetrically mounted on both sides of a dielectric and supplied by an ac voltage. Other than single dielectric barrier discharge, there are several other types of dielectric barrier discharge plasma actuator as well such as multi-electrode dielectric barrier discharge actuators and dielectric barrier discharge (DBD) vortex generators.[11]

2.3 Aerodynamics of vehicles

Ultimately, it is known that aerodynamics is usually used in aircraft or airplane field. However, aerodynamics has equal importance in all the other vehicle manufacturing industry. Aerodynamics design plays a fundamental part in the overall performance of the vehicle. It is important to realize that vehicles such as cars , trucks and motors will be not stable and burns a lot more fuel if they are not well designed aerodynamically. A fact says that aerodynamics of a car starts to significantly affect the total resistance of a car movement from 16 km/hr and completely dominate by 56 km/hr. To point out, a fast cars won't be as fast as expected without good aerodynamics design.[9]

In other words, aerodynamics is a study of flow of air over bodies. Aerodynamics plays an important role in anything which moves in air or air moves past them. As this study focuses on truck, truck aerodynamics were studied a bit more for an additional knowledge and exposure about the particular issue. According to previous study, moving through air requires force and energy to overcome the resistance to movement for objects. This resistance to movement is called drag. Indirectly, this creates fuel consumption issues for large objects travelling through it at speed. [4][17]

However, study proves that this unconvincing situation can be overcome with number of aerodynamic devices. Moreover, aerodynamic products that manipulate , redirect and reshape the air can be also used to reduce drag and make the vehicle more fuel efficient. In this particular study[10], vortex generators were used to control the air flow and also reduce the drag of the truck. I believe the concept of this previous study is almost related to this current project. The only difference is the type aerodynamic device that we going to use which is dielectric barrier discharge (DBD) plasma actuator rather than vortex generator.[10]

Figure 2.2 : Dielectric Barrier Discharge Vortex Generator[11]

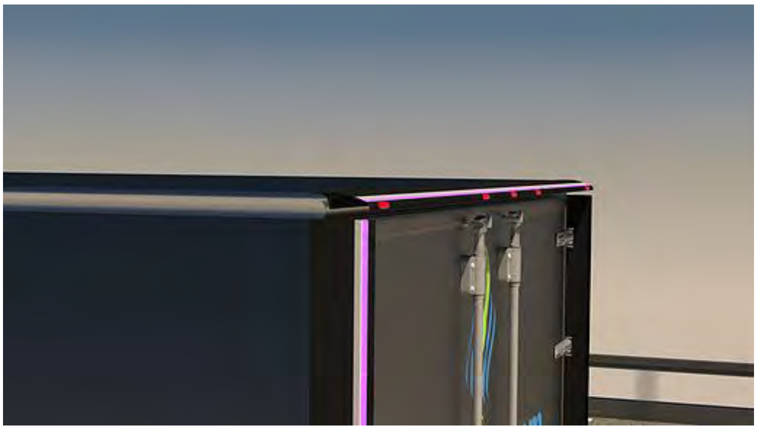

Figure 2.3 : Dielectric Barrier Discharge Plasma Actuator[8]

2.4 Significant Drag acting areas around truck

According to research [aerodynamics], there are few common drag acting areas around truck which are as following :

- Leading edge of the truck