PULSE DETONATION ENGINE PERFORMANCE AND THRUST IMPROVEMENT USING EJECTOR

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To my beloved mother, father, wife and daughter

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Assalamualaikum...

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ABSTRAK

Tesis ini adalah berkenaan peningkatan tujahan yang dihasilkan oleh *pulse detonation engine* (PDE) dengan menggunakan pelenting pada hujung tiub. Terdapat dua kaedah untuk meningkatkan tujahan PDE, yang pertama adalah dengan menggunakan komponen-komponen enjin yang berprestasi tinggi, dan yang kedua dengan memperbaiki mekanisma dalam menghasilkan detonasi. Tetapi, langkah ini memerlukan pendekatan yang lebih maju dan kompleks. Terdapat kaedah yang lebih ringkas dan mudah untuk meningkatkan tujahan yang dihasilkan PDE iaitu dengan menggunakan pelenting pada hujung terbuka PDE. Oleh itu, objektif tesis ini adalah untuk meningkatkan prestasi PDE supaya detoansi yang terhasil pada kadar yang stabil dan memuaskan. Dalam kajian ini kesan peningkatan daya tujahan hasil daripada penggunaan pelenting juga diukur. Kajian ini telah dijalankan di High Speed Reacting Flow Laboratory (HiREF), Fakulti Kejuruteraan Mekanikal, Universiti Teknologi Malaysia. PDE telah beroperasi menggunakan gas propana, C_3H_8 sebagai bahan bakar dan oksigen, O_2 sebagai pengoksida pada kadar 5Hz. Empat jenis pelenting yang telah diuji dalam projek ini adalah jenis lurus, menumpu, mencapah dan kombinasi menumpu dan mencapah. Kesemua pelenting tersebut mempunyai panjang 400 mm dan diameter bibir pelenting 130 mm. Peningkatan tujahan maksimum telah diukur dengan menggunakan sel beban. Peningkatan paling tinggi iaitu sebanyak 12.6% telah diperolehi dengan penggunaan pelenting menumpu yang dipasang pada kedudukan hiliran. Eksperimen ini juga menunjukkan pelenting sangat sensitif dengan kedudukan paksi kepada hujung PDE.

ABSTRACT

This thesis is concerning the improvement of thrust by employing ejector at the end tube of pulse detonation engine (PDE). There are two ways of improving the thrust of PDE, one is to choose higher performance engine component and the other is in to improve the mechanism of detonation initiation. But sometimes those steps required more advanced and sometimes more complex mechanism. This thesis suggest a simpler and easier way to improve thrust in PDE by employing ejector of different geometries at the open end of detonation tube. Therefore the objective of this thesis is to improve the performance of the PDE so that stable detonation can be achieved at a reasonable repetitive rate. In this study the improvement on thrust generated by the installation of ejector is quantified. The study is conducted in High Speed Reacting Flow Laboratory (HiREF), Faculty of Mechanical Engineering, Universiti Teknologi Malaysia. The PDE is operated with propane as fuel and oxygen as the oxidiser at the frequency of 5Hz. The four ejectors tested in this study namely straight, convergent, divergent and convergent-divergent ejectors. All ejectors have similar length and inlet diameter which are 400 mm and 130 mm respectively. The maximum augmentations for each ejector were measured using load cell. The highest improvement on thrust generated which is 12.6% higher than the baseline configuration has been achieved with the use of convergent ejector that is installed at downstream position. The study shows that the ejectors are very sensitive with its axial position to the open end of PDE.

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INTRODUCTION

Pulse detonation engines (PDEs) have shown great potential in converting the chemical energy content of combustible mixtures by using detonation process. Detonation is a reactive combustion wave that propagated supersonically. PDE has a simpler and lighter design in comparison to the current conventional propulsion system namely gas turbine.

For a PDE to operate, initially it requires the combustible mixture to be filled completely in the combustion tube. Then the combustible mixtures need to be ignited by using a sufficient energy initiating device. Detonation wave created will generate a sudden high pressure rise. These will be accompanied by strong shock wave that propagates through the tube open end.

A lot of studies in PDE have been conducted by various researchers so that it can be used as the main propulsion system for aircraft. It is believed that PDE produced more thrust than other propulsion system. There are two ways of

improving the thrust of PDE, one is to improve the engine component and the other is in improving the mechanism of the PDE. But sometimes those step required more advance or more complex mechanism. There is simpler and easier way to improve thrust in PDE that is to employ ejector at the outlet of PDE. There are several types of augmentor. Currently nozzles and ejectors are the most common types that are widely studied [15].

Nozzle is a mechanical device attached at the end of the detonation tube. It is used to utilize the combustion energy to augment the thrust generated by the Pulse Detonation Engine. Ejector is a separated device which is placed at the open end of Pulse Detonation Engine to increase the amount of thrust produced. Theoretically, an ejector is a coaxial duct placed at the opened end of Pulse Detonation Engine that performs as a fluidic pump. The surrounding ambient air enters the ejector due to the primary exhaust flow from the Pulse Detonation Engine and causes the increase in the momentum of engine exhaust flow which lead to the increase of thrust generated [1].

In this thesis, the effects of ejectors to the performance of Pulse Detonation Engine will be investigated. The parameters that determine the thrust augmentation of including its inner geometry as well as its position relative to the PDE tube end. In the end of this thesis, the best ejector geometry which produces the optimum thrust augmentation will be proposed.

1.1 Research Background

As mentioned before, Pulse Detonation Engine (PDE) has a big potential to be applied as the main aircraft propulsion system. Base on theoretical calculation, this type of engine will generate more impulsive thrust than other types of conventional engines [6]. In order for this PDE concept to become reality, a significant amount of researches are required

Various researchers have reported on the use of nozzle as augmentor [3, 4, 5, 7 and 8]. Ejectors also have been used to increase the thrust generated from PDE. Even though there were numbers of researches working on this field, there was no work done to investigate the effect of ejector installation on the PDE using propane as a fuel.

Optimization of thrust generation is important in utilizing the energy released by the Pulse Detonation Engine. Therefore, this research will investigate the optimization of the thrust generated from Pulse Detonation Engine using ejectors of several geometries. The PDE in this work was fuelled with propane, C_3H_8 and oxygen as the oxidizer. The PDE in this research was operated at a frequency of 5Hz.

1.2 Objective

There are three objectives listed in this project. The first objective is to improve the operation of Pulse Detonation Engine (PDE). The other is to investigate the effect of ejector on the thrust generated by gaseous fuel PDE. The last objective is to determine the maximum improvement of thrust generated by the installation of ejector on PDE.

1.3 Scopes

There are several scopes listed to be completed in the end of this project. The research is focused mainly on the experimental. Several ejector geometries are fabricated. The ejectors are attached to the end of the Pulse Detonation Engine and the performance is evaluated by measuring the thrust generated using load cell that connected to data acquisition system. Pressure transducer also connected to the PDE to record the pressure profile trend generated by the PDE.

1.4 Problem Statement

PDE are currently being investigated as a potential candidate for the technological development of a new and more efficient aerospace propulsion system. In order to optimize the thrust generated from PDE, several steps of further refinement are required. There are two ways of improving the thrust of PDE, one is to improve the engine component and the other is in improving the mechanism of the PDE. But sometimes those steps required more advanced and sometimes more complex mechanism. There is a simpler and easier way to improve thrust in PDE that is to employ ejector at the outlet of PDE. Therefore the objective of this thesis is to see the effect of ejector on the thrust produced by PDE. The study was conducted in High Speed Reacting Flow Laboratory (HiREF), Faculty of Mechanical Engineering, Universiti Teknologi Malaysia. After a lot of research programs in studying and developing the pulse detonation engine (PDE), there is a need to make a research in optimizing the thrust generated from Pulse Detonation Engine. Previous research works confirmed that Pulse Detonation Engine with ejectors is extremely effective in increasing the thrust. It is due to more efficient energy-transfer process between the primary and secondary flows that result from the dominant effects of the starting vortex ring [1].

Many factors need to be considered in optimizing the thrust. A numbers of parameters which affect the performance of Pulse Detonation Engine need to be identified. Until today, there are no solid theories regarding to the unsteady ejectors. On the other hand, steady ejectors' theories were well-established [10, 13, 20].

Due to this, a research on optimizing the thrust using ejector should be attempted. In this research, the effect of ejector will be investigated by using the pulse detonation engine fuelled with propane C_3H_8 and used oxygen as the oxidizer. There is no work done in this field using this type of fuel. Also, the experiments will be held using low frequency Pulse Detonation Engine of 5 Hz. Previous works were

done using higher frequency rates of Pulse Detonation Engine ranges from 10 Hz to 20 Hz. In the end of this research, the best modification in optimizing the thrust generated will be proposed.

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