UNIVERSITI PUTRA MALAYSIA

PERFORMANCE AND EMISSION OF HOMOGENEOUS CHARGE COMPRESSION IGNITION ENGINE WITH MODIFIED VOLUME OF DISPLACEMENTS USING KEROSENE FUEL

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By

AHSANUL KAISER

Thesis Submitted to the School of Graduate Studies, Universiti Putra Malaysia, in Fulfilment of the Requirements for the Degree of Master of Science

January 2014

DEDICATION

To my all parents and lecturers always whose support and understanding mashallah help to make possible

Abstract of thesis presented to the Senate of Universiti Putra Malaysia in fulfilment of the requirement for the degree of Master of Science

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By

AHSANUL KAISER

June 2014

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Faculty : Engineering

Homogenous Charge Compression Ignition (HCCI) is a promising combustion process which has lower fuel consumption and emits very low nitrogen oxides (NOx). It is one of the few solutions on hand that looks very promising to address the issues on the atmospheric air pollution and depleting fossil fuel resources exacerbated by increasing energy consumption of the world. However, currently there is no established means for increasing the limited power at HCCI mode. In this project, intake air heating with increasing volume of displacement were the chosen parameter that can help the combustion process of the engine to run under HCCI mode. The studies were carried out on a single cylinder air-cooled spark ignition (SI) engine. All the data analysed for the notification of performance and emission characteristics of the engine at SI condition were analysed. An experimental works have been done by fitting an intake air heater to the engine and operate the engine using kerosene fuel in HCCI mode at standard condition. Compressed auto- ignition combustion of homogeneously premixed charge of kerosene was achieved by heating the intake air. Other experiment done was to investigate the effect of volume of displacement changes of the engine cylinder diameter from 5.0cm to 5.15cm. All experiments were repeated at different engine speeds ranging from 800 to 1350 rpm to get the output parameters such as load, torque, power, volumetric efficiency, brake mean effective pressure (BMEP), exhaust gas temperatures and also NOx, carbon monoxide (CO), hydro carbon (HC) were observed at three different throttle positions with fixed speed of 800 rpm. From the study it is found that the power rate for HCCI after modification of volume displacement is 12 % - 76.5% and 1.5% - 5.6% higher than the values of HCCI using standard volume displacement and SI system respectively. Also it is found that the rate of NOx of HCCI after modification of volume displacement is 10%-12% lower than HCCI using standard volume displacement also 85%-86.5% lower than SI system.

Abstrak tesis yang dikemukakan kepada Senat Universiti Putra Malaysia sebagai memenuhi keperluan untuk ijazah Master Sains

PRESTASI DAN KELUARAN ENJIN HCCI DENGAN KESAN ANJAKAN ISIPADU MENGGUNAKAN BAHAN API KEROSIN

Oleh

AHSANUL KAISER

Jun 2014

Pengerusi : Profesor Madya Nuraini bt. Abdul Aziz, PhD
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Pencucuhan mampat bercaj seragam (HCCI) merupakan proses pembakaran yang menjanjikan penggunaan bahan api yang rendah dan mengeluarkan nitrogen oksida (*NOx*) yang sangat rendah. Ia merupakan salah satu daripada beberapa penyelesaian yang dilihat sangat meyakinkan untuk menangani isu pencemaran udara dan penyusutan sumber bahan bakar fosil akibat daripada peningkatan penggunaan tenaga di dunia. Walaubagaimanapun, sehingga kini belum ada cara yang betul-betul mampu untuk meningkatkan daya tenaga menggunakan cara *HCCI*. Dalam projek ini, masukan pemanas udara dengan peningkatan isipadu anjakan dipilih sebagai parameter yang dapat membantu agar proses pembakaran enjin berlaku dalam cara *HCCI*. Kajian ini menggunakan enjin silinder tunggal cucuhan percikan (*SI*) berpendingin udara. Semua data dianalisis untuk mengetahui prestasi dan ciri-ciri keluaran enjin pada kinerja dan karakteristik emisi daripada enjin pada kondisi *SI*. Kerja-kerja ujikaji telah dijalankan dengan memasang alat pemanas udara masuk pada enjin dan menggunakan bahan api kerosin serta enjin beroperasi dalam cara *HCCI* pada keadaan piawai. Pembakaran mampatan cucuhan automatik bagi pracampuran seragam bercaj kerosin dapat dihasilkan dengan cara memanaskan aliran udara masuk. Uji kaji lain yang dijalankan adalah untuk memeriksa kesan perubahan isipadu anjakan silinder enjin dari diameter gerek 5.0 sm ke 5.15sm. Semua uji kaji di ulang pada kelajuan enjin yang berbeza antara julat 800 ke 1350 pusingan seminit (psm) bagi mendapatkan parameter keluaran seperti beban, tork, daya, kecekapan isipadu, tekanan berkesan min brek (*BMEP*), suhu gas ekzos dan juga kadar *NOx*, karbon monoksida (*CO*), hydro karbon (*HC)* dikaji pada tiga posisi pendikit yang berbeza pada kelajuaan tetap iaitu 800 psm. Melalui kajian ini didapati bahawa kadar kuasa bagi *HCCI* selepas pengubahsuaian isipadu anjakan adalah 12% - 76.5% dan 1.5% - 5.6% lebih tinggi dari nilai *HCCI* menggunakan isipadu anjakan piawai dan sistem *SI* masing-masing. Juga didapati bahawa kadar *NOx* bagi *HCCI* selepas pengubahsuaian isipadu anjakan adalah 10% - 12% rendah dari nilai *HCCI* menggunakan isipadu anjakan piawai serta 85%-86.5% lebih rendah dari sistem *SI*.

ACKNOWLEDGEMENTS

I am grateful for all bounties that Allah has showered on me which enable me complete this Master thesis. I would like to express my affectionate thanks to my family members for their endless love, continual understanding, sacrifice, prayers and confidence and selfless support. I would like to thank my friends for their constant support, motivation and help.

Especially I would like to profess my gratitude to Associate Professor Dr. Nuraini bt. Abdul Aziz, my supervisor, who has always been a source of guidance with her immense knowledge and experience. Also my deepest thanks to my co-supervisor Associate Prof. Ir. Dr. Nor Mariah bt. Adam for her encouragement, kindness, information and insightful comments. I would like also to express my deep gratitude to for never-ending moral support and encouragement.

Finally, I would like to express my appreciation to faculty and administration staff of the faculty of Engineering, University Putra Malaysia, UPM, for providing advice and facilities. I would like to express my particular thanks to the School of Graduate Studies for their assistance and support.

This thesis was submitted to the Senate of the Universiti Putra Malaysia and has been accepted as fulfilment of the requirement for the degree of Master of Science. The members of the Supervisory Committee were as follows:

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVIATIONS

BDC	Bottom Dead Centre
BMEP	Brake Mean Effective Pressure
EGR	Exhaust Gas Recirculation
CI	Compressed Ignition
IC	Internal Combustion
HCCI	Homogeneous Charge Compression Ignition
NVO	Negative Valve Overlapping
RPM	Revolution Per Minute
SI	Spark Ignition
PPM	Parts Per Million
VCR	Variable Compression Ratio
VE	Volumetric Efficiency
VVT	Variable Valve Timing
TDC	Top Dead Centre

CHAPTER 1

INTRODUCTION

1.1 Introduction

Homogeneous charge compression ignition (HCCI) combustion process has been implemented because of very high thermal efficiency and lower nitrogen oxide (NOx) and particulate matter emissions (Kawamoto et al., 2004; Kulzer et al., 2006) to meet the demand of fuel economy and greenhouse effect. HCCI includes the best features of both spark ignition (SI or Gasoline) engines and compression ignition (CI or Diesel) engines leading to a promising combustion method in internal combustion (IC) engine. This improves the thermal efficiency and emissions of motor vehicle leading to an environmentally friendly and sustainable society. This system may perhaps be able to produce a better fuel efficiency and cleaner emissions by improving the ignition performance and combustion control as shown in Figure 1.1(Nissan-global, 2011). Because it can provide high efficiencies using most alternative fuels with very low NOx and particulate matter.

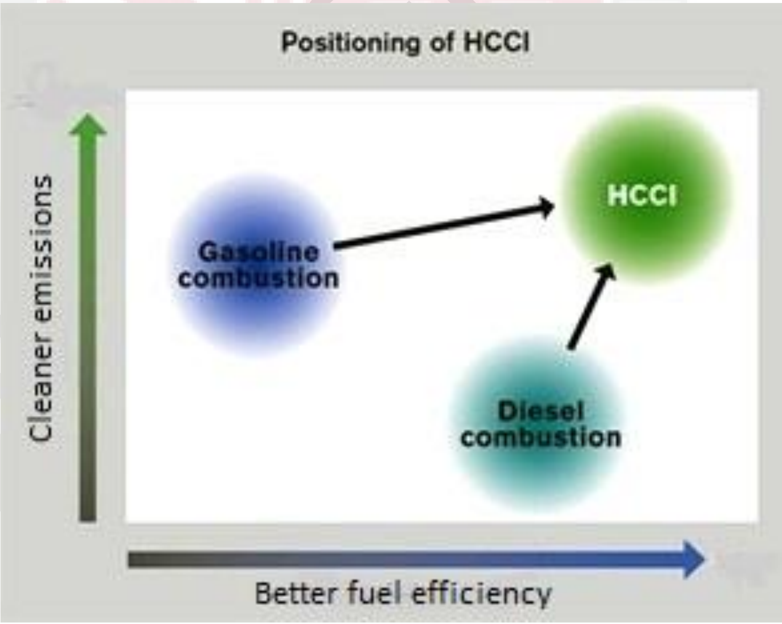

Figure 1.1 : Position of HCCI (Nissan global, 2011)

1.2 Why HCCI?

The demand for alternative fuel, clean and efficient power sources has led researchers to develop and companies to produce cleaner and more fuel-efficient engines. The reduction of exhaust emissions and increase the demand of fuel economy in IC engines is now a very important global issue (Krzysztof and Tadeusz, 2003). Additionally, these pressures have led to the development of alternative transportation power generation devices. Alternatives to traditional IC engines are electrical vehicles, hybrid-system, batteries and fuel cells. These solutions, however, still have obstacles and limitations to overcome, namely energy storage and the development of necessary infrastructure.

By theory these technologies could give more environmentally friendly alternative sources to the IC engine; but issues such as cost, effectiveness and limited output prevent them from replacing IC engines. In order to be demanded by the customer, mobile power generation machines and engines must be accepted by low fuel consumption, better efficiency, reliability, lower weight with affordable price & cost of use (Krzysztof and Tadeusz, 2003).

Solutions that help to improve regulated emissions and economic fuels for I.C. Engines are: cleaning of the burning gas by catalytic converter or NOx trap or plasma reactor or selective catalytic reduction (SCR) system, renewable alternative fuels and modification of combustion strategy. That is why, HCCI combustion engine as a prime mover for transportation and stationary applications that does not displace the entire IC engine but develops the combustion process within the engine as an alternative replacement to the IC engine has been developed within the past 30 years (Flowers et al., 2005). This HCCI combustion system, utilizes and fulfils the demand both of conventional SI and CI engines.

This system can therefore be a promising combustion method in IC engine to improve the thermal efficiency of motor vehicles in order to establish an environmentally friendly and sustainable society (Asmus et al., 2003; Zhao, 2007). In HCCI, homogeneous charge of fuel and air is injected into the combustion chamber. The charge is compressed within the chamber until thermodynamic conditions initiate spatially distributed auto-ignition. The homogeneously pre-mixed fuel and air charge is a characteristic of a SI engines while ignition due to compression is found in CI engines.

The chemical reaction that results does not propagate through the combustion chamber as a normal flame would but releases heat continuously across the whole area (combustion chamber). It is absent in all other IC engines such as sparkplugs (SI engines) or fuel injectors (CI engines) engines.

1.3 Problem Statement

Nitrogen Oxide (NOx) is a general term which includes mainly nitric oxide (NO) and nitrogen dioxide (NO_2). NOx emissions are responsible for the formation of acid rain (Turns, 2000). It is well known to create many respiratory tract inflammations including asthma. NOx also reacts with ammonia, water and many other compounds in the air forming small nitrate particles. These particles directly cause emphysema and bronchitis in human being. This reaction creates ozone, which in turn damages the respiratory tract, leading to numerous health problems (Peter and Derek, 2009). Children and the elderly are more susceptible to the adverse physical effects of NOx in the atmosphere. Since 1974, emissions of particulate matter (PM) and oxides of nitrogen in Europe, Canada and USA have become very stringent (Peter and Derek, 2009).

Nowadays, serious concerns have been discussed regarding the greenhouse effects by the harmful gaseous and particulate emissions generated from the utilization of IC engines. For this reason, governments all around the world have now introduced strict legislations restricting levels of pollutants that may be emitted from engines. Furthermore, concerns about the world's finite fossil fuel reserves and more recently emissions brought about by climate change have led to interests in both making IC engines fuel flexible and more efficient (Peter and Derek, 2009).

The world is facing a critical challenge depending on fossil fuels to satisfy global energy consumption requirements. Over 75% of the world's energy use is based on fossil fuels. Half of that is supplied by oil, which is totally used for transportation purposes. Furthermore, liquid fuels are still leading the transportation sector, with the rate of increase in automotive use in developing countries, this consumption rate will increase up to 60 percentage by the year 2020 (IAGS, 2004). Also another research by Doman (2010), it is calculated that the demand will rise up to about 81% of the total liquid fuel consumption of the world in 2035. Figure 1.3 (Doman, 2010) represent the energy consumption of the world, describes the trend of continuously increasing demand in the energy consumption up to 2035.

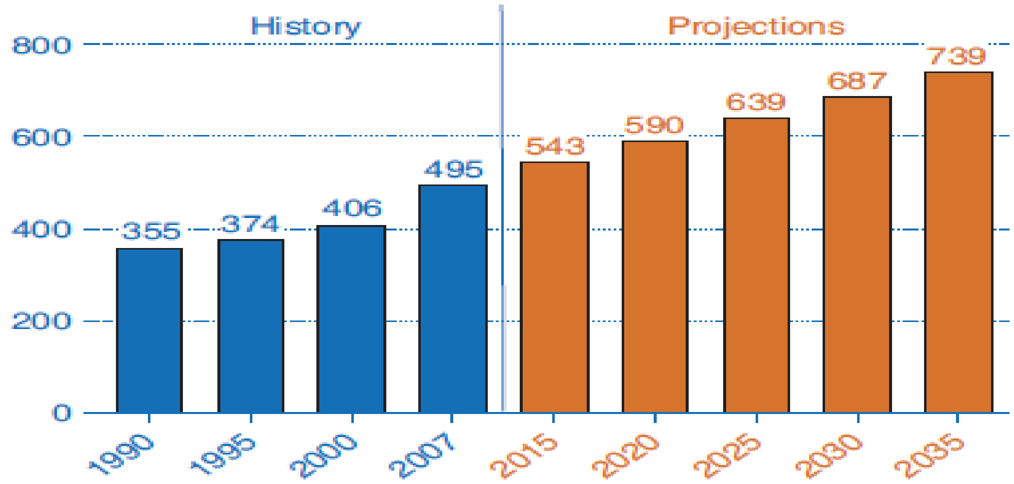

Figure 1.2 : World energy consumption (Quadrillion Btu) [Doman, 2010]

Kerosene is cheaper as alternative fuel in 3rd world counties and motorcycle is one of the main transports/vehicle in south Asian countries. Yuh-Yuh et al., (2010) researched on much bigger volume of displacements 150cc single motorcycle HCCI engine by EGR method. It is described that the world energy consumption would reach at much higher levels in 2035 because of the fluent economic growth developments of the modern world. As a result, there is need to research on smaller 4 stroke single cylinder 113.7cc motorcycle HCCI engine by intake air heating method.

1.4 Scope and Limitation

The scope of this study are focusing on modifications of a small single cylinder gasoline motorcycle engine that can be operated using HCCI method. This engine will run using kerosene fuel. The study is focusing on experimental work. HCCI is near to SI efficiency and has much lower NOx and easy to adopt. There is no need for implementation after treatment technologies (such as catalytic converter) which reduce the cost, noise, vibration and fuel flexibility.

However, the limitations are inability to start in cold conditions, difficult to control combustion directly, limited power, using manual heater, improper cooling and unable to collect the data about specific fuel consumption and thermal efficiency.

1.5 Aims and Objectives

Generally, the aim of this study is to identify and increase the performance of the motorcycle engine using HCCI combustion technique. Specific objectives are:

1. To modify the conventional 4-stroke single cylinder gasoline reciprocating engine to operate in homogeneous charge compression ignition (HCCI) mode at standard volume of displacement and after modified displacement.
2. To determine the engine performance parameters and the emissions of the modified homogeneous charge compression ignition (HCCI) engine using kerosene fuel. To compare among all the operation of two different volume of displacement of the HCCI engine and the conventional spark ignited (SI) engine.

1.6 Outline of the Thesis

Chapter 1 briefly describes the current trends in research in IC engines. A brief description of the problem has studied with its important effects to the automotive industry and vice versa. Chapter 2 review about type of engine, story and evolution of HCCI combustion systems are described with basic characteristics of HCCI method reported by several researchers. Chapter 3 materials and method of the test engine facility with the appropriate modifications carried out to fulfil the objectives of this research is presented in chapter 3 and in addition, the various types of instruments whose are used to measure all the engine parameters and the experimental procedure are presented step by step. The results are discussed and analysed in chapter 4. The conclusion and recommendations for future studies are presented in chapter 5.

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BIODATA OF STUDENT

Ahsanul Kaiser was born in Dhaka, Bangladesh on January 1, 1978. He completed his Secondary School Certificate (S.S.C) and Higher Secondary Certificate (H.S.C) at Motijheel Model High School and Tejgaon College in 1992 and 1994 respectively under the Dhaka Board of Intermediate & Secondary Education scoring First Division in both examinations.

After finishing school he became a cadet and completed Marine Engineering Course in 1998 scoring First Division. In 2002 he graduated with a degree of B.Sc. (Pass) in Marine Engineering from Marine Fisheries Academy under the National University of Bangladesh in First Division.

Also, he was holding the post of Vice President (V.P.) of the UPM International Student Association (UPMISA) in 2013-2014 session of Universiti Putra Malaysia.

He worked for 9 years in different multinational & local companies as Chief Engineer, 2nd Engineer and Mechanical Service Engineer in Bangladesh, Republic Benin and Saudi Arabia. He has varied experience in overhauling different engines with other auxiliary machineries of different ships, vessels and power plants of shore.

He keeps abreast with latest development on marine engineering and mechanical engineering participating in various professional short courses / workshops at home and abroad.

He has the certificate of competency (C.O.C) as a coastal engineer for the coastal voyage ships which is given by the "Government Department of Shipping" of Bangladesh.

He is now pursuing post graduate study M.Sc. in Mechanical Engineering with thesis at University Putra of Malaysia starting September, 2011.

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