UNIVERSITI PUTRA MALAYSIA

NUMERICAL AND EXPERIMENTAL STUDIES OF HOMOGENEOUS CHARGE COMPRESSION IGNITION ENGINE PERFORMANCE

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By

MOHAMMAD IZADI NAJAFABADI

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

February 2014

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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Chairman: **Nuraini Abdul Aziz, PhD**
Faculty: **Engineering**

During the recent decade, an alternative combustion technology, known as Homogeneous Charge Compression Ignition (HCCI), has shown the potential to decrease both emissions and fuel consumption. In spite of its high fuel efficiency and low NO_x emission compared to diesel and SI engines, HCCI combustion has some critical difficulties. The main difficulty of HCCI engine is the absence of any external control of ignition timing. Finding the effects of different parameters on the ignition timing is vital to be able to control HCCI engines. The focus of this study was to carry out a detailed numerical and experimental investigation into the factors affecting HCCI ignition timing in a 2-stroke gasoline engine. As the primary objective of this study, a Computational Fluid Dynamic (CFD) model was developed coupled to a semi-detailed chemical mechanism for the 2-stroke engine to investigate the effects of different variables such as intake temperature, air to fuel ratio, scavenging efficiency, and compression ratio on the ignition timing and emissions. As the second objective, effects of different simulation parameters such as turbulence model, grid density, and time step size were investigated to find the best method for simulation of considered engine. As the final objective, validation of numerical results was carried out using experimental study on the 2-stroke engine that was modified to operate in HCCI mode. Results confirmed that k-ε RNG model was the best turbulence model for simulation of this case study coupled to the time step size of 0.25 crank angle degree and the grid size of around 50,000 cells. Results also demonstrated that decreasing the intake temperature, equivalence ratio, residual gasses, and compression ratio can significantly retard the combustion timing and experimental results confirmed that this ignition retarding can considerably increase the engine power and torque.

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

KAJIAN BERANGKA DAN EKSPERIMEN UNTUK PRESTASI ENJIN PENCUCUHAN MAMPATAN SUAPAN HOMOGEN

Oleh

MOHAMMAD IZADI NAJAFABADI

Februari 2014

Pengerusi: Nuraini Abdul Aziz, PhD
Fakulti: Kejuruteraan

Sepanjang dekad baru-baru ini, satu teknologi pembakaran dikenali sebagai pencucuhan mampat bercaj seragam (HCCI) telah menunjukkan potensi untuk mengurangkan gas pelepasan dan penggunaan bahan api. Walaupun ia mempunyai kecekapan bahan api yang tinggi dan pelepasan gas NOx yang rendah berbanding enjin diesel dan enjin palam pencucuhan, pembakaran secara HCCI mempunyai beberapa masalah kritikal. Masalah yang utama adalah ketiadaan kawalan luaran pemasaan penyalaan. Mencari kesan-kesan daripada parameter enjin yang berbeza terhadap pemasaan penyalaan adalah penting untuk membolehkan mengawal enjin HCCI. Fokus tesis ini adalah untuk menjalankan satu penyiasatan secara pengiraan terperinci dan eksperimen terhadap faktor-faktor yang mempengaruhi pemasaan penyalaan HCCI pada enjin gas dua lejang. Sebagai objektif utama kajian ini, satu model Dinamik Bendalir Komputeran (CFD) dibangunkan dan ditambah kepada satu mekanisma kimia separa terperinci untuk enjin dua lejang bagi menyiasat kesan-kesan pembolehubah lain seperti pengambilan suhu, nisbah udara untuk bahan api, kecekapan menghapus-sisa dan nisbah mampatan pada masa penyalaan dan pelepasan. Sebagai objektif kedua, kesan-kesan berbeza parameter simulasi model pergolakan, grid ketumpatan dan saiz masa langkah disiasat untuk mencari kaedah terbaik untuk simulasi enjin tersebut. Sebagai objektif terakhir, pengesahan keputusan daripada model pengiraan dijalankan menggunakan kajian eksperimen terhadap enjin dua lejang yang diubah untuk beroperasi dalam mod HCCI. Keputusan mengesahkan yang model k-ε RNG merupakan model pergolakan terbaik untuk simulasi kajian ini dengan saiz masa langkah sebanyak 0.25 darjah sudut engkol dan saiz grid sebanyak 50,000 sel. Keputusan juga menunjukkan bahawa pengurangan suhu pengambilan, nisbah setara, sisa gas dan nisbah mampatan boleh melengahkan masa penyalaan dengan ketara dan keputusan eksperimen mengesahkan yang pelengahan masa penyalaan ini boleh meningkatkan kuasa dan tork enjin.

ACKNOWLEDGEMENTS

First of all, I would like to thank my dear spouse, Fahimeh, for her love, warm-heartedness and support she has demonstrated during the past two years it has taken me to finalize this thesis. Furthermore I would also like to thank my parents for their countless affection and support. I am grateful for the endless sacrifices they made for me.

I would like to thank Dr. Nuraini Abdul Aziz who has supported me throughout my thesis with her valuable guidance and knowledge. I could not have imagined having a better supervisor for my Master study. Also special thanks to my supervisory committee member, Associate Professor Ir. Dr. Nor Mariah Adam, for her encouragement and helpful advice.

The author also acknowledges the support of Universiti Putra Malaysia under Research University Grants (RUGS), Project No. 05-05-10-1076RU and Ministry of Higher Education under Exploratory Research Grants Scheme (ERGS), Project Code: ERGS/1/2012/TK01/UPM/02/5 for this research.

I certify that a Thesis Examination Committee has met on 3 February 2014 to conduct the final examination of Mohammad Izadi Najafabadi on his thesis entitled "Numerical And Experimental Studies Of Homogeneous Charge Compression Ignition Engine Performance" in accordance with the Universities and University Colleges Act 1971 and the Constitution of the Universiti Putra Malaysia [P.U.(A) 106] 15 March 1998. The Committee recommends that the student be awarded the Master of Science.

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This thesis was submitted to the Senate of Universiti Putra Malaysia and has been accepted as fulfillment on the requirement for the degree of Master of Science. The members of the supervisory committee were as follows:

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Declaration by graduate student

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Declaration by Members of Supervisory Committee

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Name of Chairman of Supervisory Committee:	Nuraini Abdul Aziz, PhD	Name of Member of Supervisory Committee:	Nor Mariah Adam, PhD

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