UNIVERSITI PUTRA MALAYSIA

COMPUTATIONAL FLUID DYNAMIC ANALYSIS OF KNOCK ON SET IN DIESEL DUAL-FUEL ENGINE

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By

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

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DEDICATION

To my parents whose support and understanding helped make this 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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Chairman: Associate Professor Nor Mariah bt Adam, PhD, PEng

Faculty: Engineering

Energy alternative for the transport sector includes use of natural gas due its large reserves and minimum modifications to the existing diesel engines. The most common diesel dual fuel (DDF) engines use the natural gas as main fuel to provide the engine output power while a low amount of diesel fuel injected to the combustion chamber as the ignition source of the air-gaseous fuel mixture. The DDF engines suffer from low thermal efficiency during part load operations and knock tendency during high load operations compare to the conventional diesel fuel. Improving the DDF engine performance needs the clear understanding of occurring phenomena such as autoignition, injection of diesel fuel and combustion of dual fuel mixture in combustion chamber. Therefore, besides the experimental study, numerical analyses are vital to provide an understanding into the complex process inside the combustion chamber. Hence, the specific objectives of this study are (i) employing the numerical simulation of DDF engine to investigate the effects of different intake mixture temperatures and mixing ratios on the engine performance and knock intensity by using in-cylinder pressure analysis (ii) comparing the accuracy of the chosen turbulence models, k-ε standard and k-ε Re-Normalized Group (RNG), due to the experimental data.

For examining the effect of increased intake mixture (57°C, 70°C and 90°C) and mixing ratio of natural gas and diesel fuel (83%, 85%, 87% and 90%) on performance and knock intensity of DDF engine, a prediction of in-cylinder pressure during engine cycle (340-400 degree of crank angle) using Computational Fluid Dynamics (CFD) technique code, Fluent, was performed and compared the extracted results to the experimental data of the previous researchers as mentioned in literature review chapter on a single cylinder Ricardo Hydra engine. The initial grid was created in Gambit software. CFD codes written for describing the intake and exhaust valve movement were applied to probe the in-cylinder air motion and direct injection of diesel fuel during the intake and compression strokes. The Moving Dynamic Mesh model was performed for the grid generation due to the moving mesh and boundary to provide a more accurate transient condition. A Lagrangian Particle Based approach described the diesel fuel spray and Wave model utilized to represent both the primary breakup (liquid atomization) and the secondary breakup (drop breakup) processes. The combustion process is modeled with the Eddy Dissipation Model of Magnussen and Hjertager for partially premixed reaction with five global reaction schemes. The k-ε standard and k-ε RNG turbulence models were used for the turbulent fluid flows inside the combustion chamber and the predicted results were achieved through the sequential process which ensured accuracy of the computations. The results demonstrated that, the k-ε RNG turbulence model presented more accurate results for predicting the in-cylinder pressure; also the obtained results verified the reliability of applying the CFD method in design process of DDF engines, would lead us to an obvious progress on improving the efficiency of DDF engines.

Abstrak tesis yang dikemukakan kepada senat Universiti Putra Malaysia sebagai memenuhi kepeluan untuk master sains

ANALISIS DINAMIK BENDALIR BEREKOMPUTER PADA PERMULAAN KETUKAN DI DALAM ENJIN DIESEL DWI BAHANAPI

Oleh

MOHAMMADMAHDI GHIJI

Mac 2011

Pengerusi: Profesor Madya Nor Mariah bt Adam, PhD, PEng

Fakulti: Kejuruteraan

Tenaga alternatif untuk sektor pengangkutan termasuk penggunaan gas asli kerana bekalan yang banyak dan juga melibatkan modifikasi minimum untuk enjin diesel yang sedia ada. Enjin diesel dwi bahanapi (DDF) yang paling lazim menggunakan gas asli sebagai bahanapi utama untuk menyediakan kuasa enjin sementara sedikit diesel disuntik ke dalam kebuk kebakaran sebagai punca pencucuhan campuran udara-bahanapi. Enjin DDF mengalami kecekapan termal yang rendah semasa operasi beban tinggi dan bercenderung untuk ketukan semasa beban tinggi berbanding dengan enjin biasa.Untuk meningkatkan prestasi enjin DDF memerlukan pemahaman jelas tentang fenomena yang berlaku seperti pencucuhan auto, suntikan bahanapi diesel dan pembakaran campuran dwi bahanapi di dalam kebuk pembakaran. Oleh itu, khusus selain kajian eksperimen, analisis berangka adalah penting untuk memberi penerangan tentang proses kompleks di dalam kebuk pembakaran. Maka objektif tentu kajian adalah (i) membentangkan simulasi berangka enjin DDF untuk menyiasat kesan suhu campuran yang berbeza dan nisbah campuran terhadap prestasi enjin dan keamatan ketukan dengan menguna analisis tekanan silinder (ii) membuat perbezaan kejituan model gelora yang dipilih k-ε standard dan k-ε RNG, pada data eksperimen.

Untuk meneliti kesan peningkatan suhu masukan campuran (57°C, 70°C and 90°C) dan nisbah percampuran bahanapi gas asli dan diesel (83%, 85%, 87% and 90%) prestasi pengamatan ketukan enjin DDF, ramalan tekanan di dalam silinder semasa kitaran enjin (340-400 darjah sudut engkol) menggunakan teknik Dinamik Bendalir Berkomputeran (CFD). Perisian kod Fluent telah digunakan dan perbandingan keputusan CFD dengan maklumat hasil eksperimen untuk enjin Ricardo Hydra satu silinder daripada sorotan literatur. Grid awalan telah dijana dalam perisian Gambit. Kod CFD yang telah ditulis menerangkan pergerakan injap masukan dan ekzos telah diaplikasi untuk meneroka pergerakan udara di dalam silinder dan suntikan terus bahanapi diesel semasa lejang masukan dan mampatan. Model Mesh Dinamik Bergerak telah dilakukan untuk menjana grid disebabkan sempadan dan mesh bergerak untuk menyediakan keadaan transien yang lebih jitu. Pendekatan Berasaskan Partikel Lagrangian menerangkan semburan bahanapi diesel dan model Wave untuk mewakili proses pecahan primer (pengabusan titis) dan pecahan sekunder (pecahan cecair). Proses pembakan telah dimodelkan mengguna Model Lesapan Pusar Magnussen dan Hjertager untuk reaksi pracampuran separa dengan lima skema reaksi global. Model gelora standard k-ε dan RNG k-ε telah diguna untuk aliran bendalir bergelora di dalam kebuk pembakaran, dan keputusan ramalan telah dicapai melalui proses jujukan yang memastikan kejituan pengiraan. Keputusan menunjukkan bahawa model gelora RNG k-ε menunjukkan hasil yang lebih jitu untuk meramal tekanan di dalam silinder dan hasil yang diperolehi mengesahkan keboleharapan penggunaan kaedah CFD untuk merekabentuk proses enjin DDF, dan seterusnya meningkatkan peningkatan kecekapan enjin DDF.

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I certify that a Thesis Examination Committee has met on 31 March 2011 to conduct the final examination of Mohammadmahdi Ghiji on his thesis entitled " Computational Fluid Dynamic Analysis of Knock Onset in Diesel Dual Fuel Engine" 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 fulfilment of the requirement for the degree of Master of Science. The members of the supervisory committee were as follow:

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DECLARATION

I declare that the thesis is my original work except for quotations and citations which have been duly acknowledged. I also declare that it has not been previously, and is not concurrently, submitted for any other degree at Universiti Putra Malaysia or other institutions.

MOHAMMADMAHDI GHIJI

Date: 31 March 2011

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