ANALYSIS OF PRE-COMBUSTION CHAMBER IN SINGLE CYLINDER ENGINE PERFORMANCE WITH NATURAL GAS FUEL

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Faculty of Mechanical Technology and Engineering

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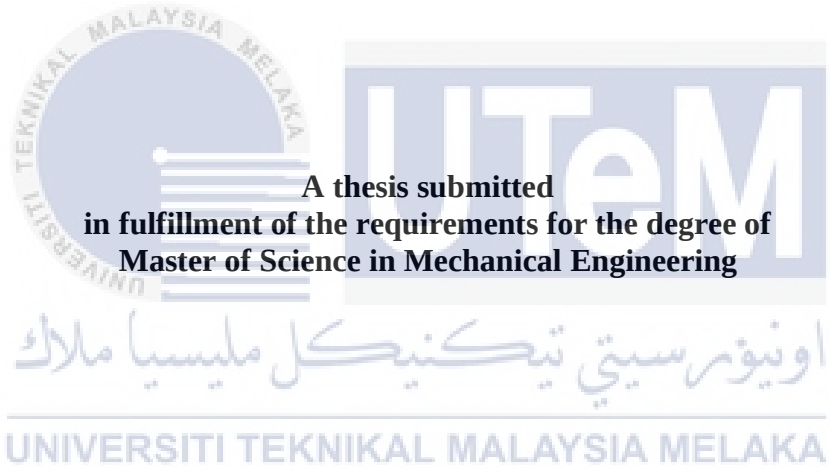

A thesis submitted
in fulfillment of the requirements for the degree of
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DECLARATION

I declare that this thesis entitled “Analysis of Pre-combustion Chamber In Single Cylinder Engine Performance With Natural Gas Fuel” is the result of my own research except as cited in the references. The thesis has not been accepted for any degree and is not concurrently submitted in candidature of any other degree.

Signature : *Amri*

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Date : 22 Mac 2024

APPROVAL

I hereby declare that I have read this thesis and in my opinion this thesis is sufficient in terms of scope and quality for the award of Master of Science in Mechanical Engineering.

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Date	:	22 Mac 2024

DEDICATION

To my beloved mother, father, wife, parents-in-law, siblings and family for their priceless support and generous prayers.

ABSTRACT

Research on alternative fuels has become important due to the increase in the use of gasoline oil resources worldwide and contributed primarily to environmental concerns. Provides solutions for the development of spark ignition (SI) engines using alternative fuels such as compressed natural gas (CNG). The purpose of the research is to explore and understand the combustion phenomena in engines that operate on gas fuel and develop technology as an alternative to today's gas engine technology for heavy duty applications. In this research, CNG had been introduced as an alternative fuel to address environmental problems. However, there was a basic need for mixed formulation studies and spray combustion processes as the type of fuel changes. The pre-combustion chamber design (PCC) had an important influence on engine performance and its knocking properties in engine. The PCC design involves pre-combustion shapes, spark plug locations and inlet and exhaust valves position. To produce higher compression ratio, higher octane number was needed. Therefore, CNG was used to allow incineration without knocking in the engine. The main objective of this investigation is to design, fabricate and included installation of PCC on the SI single cylinder engine that uses natural gas as fuel. In addition, using PCC techniques through experiments to improve engine performance rates and reduce the release of harmful gases while using CNG fuel. Finally, verify all results from simulation and experiments with the same engine specifications. Experiments on single cylinder engine are carried out alongside hydraulic dynamometer as well as some other sensor equipment. The sensors used during the experiment were high pressure sensor, crankshaft angle decoder, gas analyzer, and data analysis acquisition (DAQ). The experiment was conducted based on SAE International standard J1349. The released of HC and CO was better when using CNG than gasoline fuel. The results showed the performance of this single cylinder SI engine when using CNG fuel was reduced against gasoline fuel. However, when PCC was used with CNG fuel, there was an increase in performance output on engine speed. Based on the performance produced by each of these PCCs, PCC 2 has performed better than PCC 1 and PCC 3 for power, torque and work output compared to CNG fuel only. Performance output produced by PCC1, PCC 2 and PCC 3 compared to CNG use without PCC was 5 %, 15 % and 10%. In addition, the results of the ANSYS simulation and experimental results had concluded that the pre-chamber of PCC 2 with CNG use had the best design geometry and higher performance output than PCC 1 and PCC 2. Gas emission levels of O_2, CO_2, CO, NO, SO_2, C_3H_8 and HC from the experimental results measured by MRU gas analyzer. The use of PCC as well as CNG as a fuel in the engine reduced the release of contaminated gases into the surrounding air compared to the used of gasoline fuel.

ANALISIS PRESTASI KEBUK PRA-PEMBAKARAN DENGAN GAS ASLI DI DALAM ENJIN SILINDER TUNGGAL

ABSTRAK

Penyelidikan mengenai bahan api alternatif telah menjadi penting kerana peningkatan dalam penggunaan sumber minyak petrol di seluruh dunia dan juga memberi sumbangan utama terhadap kebimbangan alam sekitar. Menyediakan penyelesaian untuk pembangunan enjin palam pencucuh (SI) yang menggunakan bahan api alternatif yang sedia ada, seperti gas asli termampat (CNG). Tujuan penyelidikan ini adalah untuk meneroka dan memahami fenomena pembakaran dalam enjin yang beroperasi pada bahan api gas, dan mengembangkan teknologi sebagai alternatif kepada teknologi enjin gas sekarang untuk aplikasi tugas berat. Dalam penyelidikan ini, CNG telah diperkenalkan sebagai salah satu bahan api alternatif untuk mengatasi masalah alam sekitar. Walau bagaimanapun, terdapat keperluan asas terhadap kajian pembentukan campuran dan juga proses pembakaran semburan terhadap jenis bahan api yang berubah. Reka bentuk kebuk pra-pembakaran (PCC) mempunyai pengaruh yang penting terhadap prestasi enjin dan juga terhadap sifat ketukannya di dalam enjin. Reka bentuk PCC melibatkan bentuk ruang pra-pembakaran, lokasi palam pencucuh dan juga kedudukan injap masuk dan injap ekzos. Untuk menghasilkan nisbah mampatan yang lebih tinggi, bilangan oktana yang lebih tinggi diperlukan, Oleh itu, CNG telah digunakan untuk membolehkan pembakaran tanpa jadinya ketukan yang kerap di dalam enjin. Objektif utama penyelidikan ini dilakukan adalah untuk mereka bentuk, fabrikasi dan juga pemasangan PCC terhadap enjin satu silinder yang menggunakan gas asli sebagai bahan bakar. Di samping itu, menggunakan teknik PCC melalui eksperimentasi untuk meningkatkan kadar prestasi enjin dan juga mengurangkan pelepasan gas berbahaya semasa menggunakan bahan bakar CNG. Akhir sekali, mengesahkan semua keputusan dari simulasi dan eksperimen dengan spesifikasi enjin yang sama. Eksperimen terhadap enjin silinder tunggal dilakukan bersama dinamometer hidraulik dan juga beberapa peralatan sensor yang lain. Sensor yang digunakan semasa eksperimen adalah sensor tekanan tinggi, engkol sudut pengekod, penganalisis gas, dan juga analisis pembakaran (DAQ). Eksperimen ini dijalankan berdasarkan SAE Antarabangsa J1349. Ciri pelepasan HC dan CO adalah lebih baik daripada CNG berbanding bahan api petrol. Hasilnya menunjukkan prestasi enjin SI silinder tunggal ini rendah apabila menggunakan bahan bakar CNG berbanding penggunaan bahan bakar petrol. Walau bagaimanapun, apabila PCC bersama dengan bahan bakar CNG digunakan, terdapat peningkatan prestasi apabila kelajuan enjin semakin meningkat. Berdasarkan prestasi yang dihasilkan oleh setiap PCC ini, PCC 2 telah melakukan lebih baik daripada PCC 1 dan PCC 3 untuk kuasa, tork dan kerja yang yang dihasilkan berbanding penggunaan bahan bakar CNG sahaja. Peningkatan keluaran prestasi yang dihasilkan oleh PCC 1, PCC 2 dan PCC 3 berbanding penggunaan CNG tanpa PCC adalah sebanyak 5 %, 15 % dan 10 %. Selain itu, keputusan dari hasil simulasi ANSYS dan juga keputusan dari hasil eksperimen telah merumuskan bahawa pra-kebuk PCC 2 bersama penggunaan CNG telah menjadi rekabentuk terbaik malah dapat menghasilkan prestasi yang lebih tinggi

berbanding PCC 1 dan juga PCC 3. Kadar pelepasan gas O_2, CO_2, CO, NO, SO_2, C_3H_8 dan HC dari hasil eksperimentasi tersebut diukur oleh alat penganalisis gas MRU. Penggunaan PCC bersama CNG sebagai bahan bakar di dalam enjin dapat mengurangkan lagi pelepasan gas tercemar ke udara sekeliling berbanding penggunaan bahan bakar petrol.

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LIST OF SYMBOLS

%	-	Percentage
C_3H_8	-	Propane
CH_4	-	Methane
CO_2	-	Carbon dioxide
m^3	-	Metre cubic
NO_2	-	Nitrogen dioxide
O_2	-	Oxygen
SO_2	-	Sulphur dioxide
$\dot{m}$	-	Mass flow rate (g/s)
A/F	-	Air/Fuel
bar	-	100 kilopascals
℃	-	Celcius (temperature)
cc	-	Cubic centimetre
CO	-	Carbon oxide
CR	-	Compression ratio

°F	-	Farenheit (temperature)
g	-	Gram
HC	-	Hydrocarbon
J	-	Work done
kg	-	Kilogram
kHz	-	kilohertz
kPa	-	kilo pascal
kpsi	-	kilo pound per square inch
kW	-	Power
mA	-	milliAmpere
MJ	-	Mega joule
mm	-	millimetre
MPa	-	Mega pascal
N	-	Engine speed
Nm	-	Torque
NO_x	-	Nitrogen oxides
P	-	Pressure
pC	-	pico Coulomb