UNIVERSITI TEKNIKAL MALAYSIA MELAKA

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EXPERIMENTAL INVESTIGATION OF TOP COMPRESSION PISTON RING MORPHOLOGY FOR HYDROGEN ENRICHMENT DIESEL ENGINE

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EXPERIMENTAL INVESTIGATION OF TOP COMPRESSION PISTON RING MORPHOLOGY FOR HYDROGEN ENRICHMENT DIESEL ENGINE

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DECLARATION

I declare that this report entitled "Experimental Investigation of Top Compression Piston Ring Morphology for Hydrogen Enrichments Diesel Engines" is the results of my own research except 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 :

Name : Mohd Rozaini Bin Md Nafiah

Date : 26/10/2016

APPROVAL

I hereby declare that I have read this report and in my opinion this thesis is sufficient in term of scope and quality for the award of Master in Mechanical (Automotive) Engineering.

Signature :

Supervisor Name : Prof. Madya Dr. Noreffendy b. Tamaldin

Date : NOV 22, 2016

DEDICATION

To my beloved mother and father

ABSTRACT

Many researchers believe hydrogen-diesel engine will have an expanded role in the future. Hydrogen-diesel engine generally have reduced vehicle emissions which contribute to smog, air pollution and global warming. Besides that hydrogen-diesel engine also can improve diesel engine thermal efficiency. Hydrogen was produced by electrolysis process and supplied via natural aspirated air flow to the combustion chamber. However hydrogen-diesel combustion causes severe effects to engine components longevity. The component such as piston ring was exposed to high flame combustion under hydrogen enrichments which cause its mechanical material properties to changes. The paper presents an experimental investigation of the morphological effects on top compression piston ring of single cylinder diesel engine under hydrogen enrichments combustion. Scanning Electron Microscopy (SEM) and Energy Dispersive Spectrometer (EDS) test was performed to observe the microstructure changes on the coating surface of compression piston ring before and after hydrogen enrichment combustion. Another technique of imaging used was Focus Ion Beam (FIB) Dual Beam machine to observe the hydrogen embrittlement affect up to 30 μm depth inside the samples coating. Finally, three point bending test using Universal Tensile Test (UTS) machine was performed to get comparative flexural bending strength and flexural modulus for sample before, under normal diesel engine condition, after hydrogen enrichment diesel combustion, nano homogeneus and none-homogeneus engine oil. The results from experiments showed that hydrogen embrittlement caused the coating surface peeled off seriously and also induced a lot of microstructure crack inside the coating layer of top compression piston ring. As the results, top compression piston ring flexural strength and ductility have reduced drastically. The piston ring failure will increased the friction with cylinder wall and this problem can cause catastrophic damage on the engine such as overheating. Surface treatment or special coating is needed to improve the piston ring capability to overcome the hydrogen enrichment diesel combustion.

ABSTRAK

Ramai penyelidik percaya enjin hidrogen-diesel akan berkembang bagi kenderaan pada masa hadapan. Enjin hidrogen-diesel secara amnya telah mengurangkan pengeluaran asap kenderaan yang menyumbang kepada jerebu, pencemaran udara dan pemanasan global. Selain itu enjin hidrogen-diesel juga boleh meningkatkan kecekapan haba untuk enjin diesel. Gas hidrogen dihasilkan melalui proses elektrolisis dan dibekalkan melalui aliran udara beraspirasi ke kebuk pembakaran. Walau bagaimanapun pembakaran hidrogen-diesel boleh menyebabkan kesan yang buruk kepada hayat komponen enjin. Komponen seperti piston akan terdedah kepada pembakaran pada suhu yang tinggi di bawah pengayaan gas hidrogen yang boleh menyebabkan perubahan pada sifat mekanikal asal bahan. Kajian ini membentangkan siasatan serta ujikaji terhadap perubahan morfologi bagi piston ring bagi enjin diesel silinder tunggal di bawah pembakaran pengayaan hidrogen. Scanning Electron Microscopy (SEM) dan Electron Dispersive Spectroscopy (EDS) adalah antara ujian yang dilakukan untuk melihat perubahan mikrostruktur pada permukaan lapisan piston ring sebelum dan selepas pembakaran dengan pengayaan hidrogen. Satu lagi teknik pengimejan adalah dengan menggunakan mesin Dual Beam Focus Ion Beam (FIB) untuk melihat kesan kerapuhan hidrogen sehingga 30 mikrometer ke dalam lapisan coating sampel. Akhir sekali, ujian three points bending dengan menggunakan mesin Universal Tensile Stress (UTS) dilakukan untuk mendapatkan perbandingan kekuatan lenturan dan modulus lenturan bagi sampel bawah keadaan enjin diesel biasa, selepas pembakaran pengayaan hydrogen-diesel, minyak enjin nano homogeneus dan minyak enjin nano tiada-homogeneus. Hasil daripada eksperimen menunjukkan bahawa kerapuhan hidrogen menyebabkan permukaan lapisan atas telah terkupas dengan serius dan juga terdapat banyak mikrostruktur retak di dalam lapisan utama cincin mampatan omboh. Sebagai hasil, omboh kekuatan cincin mampatan atas telah mengalami pengurangan kelenturan dan kemuluran secara drastik. Kegagalan piston ring akan meningkat geseran dengan dinding silinder dan masalah ini boleh menyebabkan kerosakan bencana pada enjin seperti enjin terlampau panas.Rawatan pada permukaan atau coating yang khas adalah diperlukan untuk meningkatkan kemampuan piston ring menghadapi pembakaran diesel dengan pengayaan hidrogen.

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LIST OF ABBREVIATION AND SYMBOL

A/F	Air Fuel
AHSS	Advanced High Strength Steel
AISI	American Iron and Steel Institute
ASTM	American Society for Testing and Materials
IC	Internal Combustion
TDC	Top Dead Center
CI	Compression Ignition
CO	Carbon Monoxide
EEA	European Economic Area
EU	European Union
EURO	European Emission Standard
FIB	Focused ion Beam
HHO	Hydrogen Hydrogen Oxygen system
ISO	International Standardization Organization
LPG	Liquid Pressure Gas
NOx	Nitrogen Oxide
PM	Particulate Matter
PPM	Part Per Million
RPM	Revolution Per Minutes
SEM	Scanning Electron Microscopy
UTS	Universal Tensile Strength

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3. RESEARCH METHODOLOGY

CHAPTER 1

INTRODUCTION

1.0 Background of air pollution study.

Diesel engines todays play an important role in for human activities around the world. Diesel engines have higher brake thermal efficiency, stable combustion characteristics, durability and reliability compared with gasoline engines. However, diesel engine significantly gives harmful effects on exhaust gas emissions for environment and human health. A. Abu-Jrai et al. (2008) observed that engine manufacturer have been developing new technologies such as new modes of combustion to achieve the requirements of the upcoming automotive emissions regulations to reduce nitrogen oxides (NOx) and particulate matter (PM). Meanwhile, S.S. Gill et al. (2010) concluded that NOx and PM emissions from diesel engine will reduce drastically in the future in order to follow emission regulation allowed by government.

Because of this limitation, urgent needs to improve diesel combustion with alternative fuel became more challenging with motivation to get higher fuel economy and lower exhaust emission. M.Talibi et al. (2014) observed that due to the issues in environmental and fuel supply, fossil fuels usage need to be reduced. Many researches start to investigate higher efficient fuel to solve environmental issues. Renewable fuel such as hydrogen can very well combined with diesel to solve the problems without much modification on the engine and the cost of production is considerably low.

According to R.S. Hosmath et al. (2015) some researchers used natural gas, Liquefied Petroleum Gas (LPG) and hydrogen as fuels in diesel engines. The application of hydrogen and diesel as fuel in duel fuel engine operation is the effective methods to reduce the formation of NOx in diesel combustion engines. This is the best method in order to meet EURO 6 diesel emission regulation.

1.1.1 Diesel Emission Regulation

Concern over environmental and air qualities issues come from diesel engines became big issues around the world. A European emission standard, (EURO) was set a specific standard of emission regulation to control the vehicle emission around the globe. EURO 6 standard such as example was the latest emission standard that emphasizes for more significant reduction in NOx emissions from diesel engines.

According to Table 1.1, for light commercial diesels vehicles, the maximum NOx emitted dramatically drop to 80 mg/km compared to the 180 mg/km level that was required to follow Euro 5 emissions standards. It is about a 50 % of NOx reduction compared to Euro 5. This reduction is very high and only achievable with continues research on optimization of fuel such as alternative fuel combustion which results lean combustions.

Table 1.1 : EURO 6 Emission Regulations for Light and Commercial Vehicle.

Source: (S.S. Gill et al., 2010)

Euro 6 emission regulations for light passenger and commercial vehicles (after [11]).

Vehicle Type		Category	Class	Compression ignition (CI) limit values				
				Mass of carbon monoxide (CO) (mg/km)	Mass of oxides of nitrogen (NO_x) (mg/km)	Combined mass of hydrocarbons and oxides of nitrogen ($THC + NO_x$) (mg/km)	Mass of particulate matter (PM) (mg/km)	Number of particles (P) (#/km)
Passenger cars	All	M	–	500	80	170	5.0/4.5	6.0×10^{11}
Light commercial vehicles	≤1305 kg	N_1	I	500	80	170	5.0/4.5	6.0×10^{11}
	1305–1760 kg		II	630	105	195	5.0/4.5	6.0×10^{11}
	>1760 kg (Max 3500 kg)		III	740	125	215	5.0/4.5	6.0×10^{11}

1.1.2 Diesel Combustion

Combustion of compression ignition (CI) engine occurs when diesel was sprayed into the diesel engine cylinder during high pressure exerted at the end compression stroke. High velocity of the diesel sprays through small holes of fuel injector. Fuels will atomize into small vapour and burned via high temperature due to compression.

Figure 1.1 shows the pressure vs degrees of crank angle for diesel engine. Firing pressure rise drastically a few degrees before TDC as the diesel start to burned.

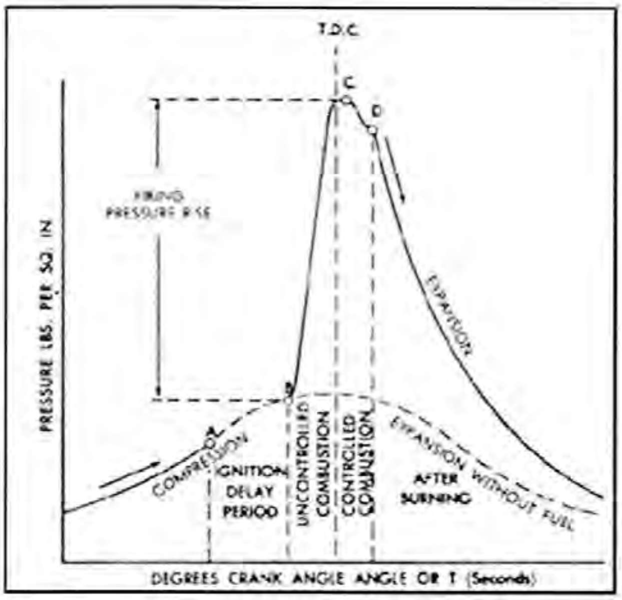

Figure 1.1 : Pressure vs Degrees of Crank Angle for Diesel Engine.

Source: (maritime.org, 2016)

1.1.3 Advantages of Hydrogen as Fuel

Many researchers believe hydrogen will have an expanded role in the vehicle's fuel in the future. Air pollution is one of the main driving forces for alternative fuel such as hydrogen due to lower particulate matter mass emissions, lower smoke emissions, lower CO and lower unburnt hydrocarbons.

P. K. Bose et al. (2013) states that the hydrogen was basic earth element and has abundant quantity. It is very convenience to separate hydrogen gas from its companion substances such as water through electrolysis process. While that may be the case, the results produce a powerful clean energy source. Hydrogen is renewable sources of energy. This means that with hydrogen, high fuel price and limited fuel sources could be solved in the future.

1.1.4 Dual Fuel System

Hydrogen–diesel dual fuel mode is the best method to use hydrogen in diesel engine as hydrogen cannot be use alone in diesel combustion. M.T. Chaichan et al. (2014) states that diesel will act as pilot fuel to ignite hydrogen during auto ignition combustion occurs. Cetane number for hydrogen is lower than diesel fuel and cannot ignite by compression of diesel engine. Therefore, it requires ignition from auto-ignition of diesel to ignite the hydrogen.

Furthermore, M.Talibi, et al. (2014) concluded that duel fuel system is possible for hydrogen and diesel combustion because of the self- ignition of hydrogen is higher than diesel.

In addition, N. Saravanan et al. (2007) observed that duel fuel system such as and diesel and hydrogen combustion can improve combustion efficiency. This due to shorter combustion time and less heat transferred to surrounding.

Meanwhile, P. K. Bose et al. (2013) conclude that hydrogen and combustion combustion will reduce diesel consumption due to enriched hydrogen combustion will results increased brake thermal efficiency.