Faculty of Mechanical Engineering

EXPERIMENTAL INVESTIGATION OF ENGINE PERFORMANCE AND EMISSION OF WASTE BIOCOMPOSE BASED BIODIESEL

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EXPERIMENTAL INVESTIGATION OF ENGINE PERFORMANCE AND EMISSION OF WASTE BIOCOMPOSE BASED BIODIESEL

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A thesis submitted
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DECLARATION

I declare that this thesis entitled "Experimental Investigation of Engine Performance and Emission of Waste Biocompose Based Biodiesel" 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.

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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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Supervisor Name : Professor Ts. Dr. Noreffendy Bin Tamaldin

Date : ……..

DEDICATION

To my beloved mother, father and family.

ABSTRACT

Decanter cake, spent bleaching clay and waste cooking oil which were oil palm derivatives had the potential to be mass produced into biodiesel. using the conventional biodiesel production method. Biodiesel of these feedstocks were evaluated in terms of physical properties characterisation, engine performance and engine emission at various blending ratio referenced to palm oil feedstock. The physical properties characterisations were conducted according to ASTM standard while engine performance and emission test were conducted using steady state test method. The production of biodiesel from both decanter cake and spent bleaching clay feedstocks using the conventional biodiesel production method was unsuccessful while the production of biodiesel from waste cooking oil feedstock was successful with high yield. The successful production of biodiesel from palm oil and waste cooking oil feedstocks had the yield of 91% and 88% respectively. From physical properties characterisation, it was found that density, kinematic viscosity, flash point and total acid number increased with increasing biodiesel content. Biodiesel blend of waste cooking oil showing higher properties increase than biodiesel blend of palm oil feedstock. The lower heating value of biodiesel blend diesel fuel on the other hand decreased with increasing biodiesel content. Biodiesel blend from both palm oil and waste cooking oil showing similar decrease. In terms of engine performance, brake torque and brake power increased up to 3.2% with increasing biodiesel content up to 7% volume. Biodiesel blend of palm oil showed better engine performance than biodiesel blend from waste cooking oil feedstock. The fuel consumption of biodiesel blend increased up to 42% with increasing biodiesel content up to 10%. Mechanical efficiency on the other hand showed no significant change despite the differences in feedstocks and biodiesel content. In terms of engine emission, carbon dioxide (CO_2), carbon monoxide (CO) and unburned hydrocarbon (HC) decreased with increasing biodiesel content up to 10% volume for biodiesel blend from palm oil and up to 7% volume for biodiesel blend from waste cooking oil with the trade-off of increased oxygen (O_2) and oxides of nitrogen (NO_x) emissions. Biodiesel blend from palm oil feedstock showed higher reduction in carbon dioxide (CO_2), carbon monoxide (CO) and unburned hydrocarbon (HC) than biodiesel blend from waste cooking oil with the trade-off of higher oxygen (O_2) and oxides of nitrogen (NO_x). In other words, biodiesel blend from both palm oil and waste cooking oil showed significant engine performance increase up to 7% biodiesel content for both palm oil and waste cooking oil. Biodiesel blend showed significant engine emission reduction up to 10% biodiesel content for palm oil and 7% biodiesel content for waste cooking oil. Further studies should be conducted using a modern diesel engine equipped with programmable engine management system instead of using conventional diesel engine in this study. Since traditional diesel engine operation was affected by biodiesel blend diesel fuel properties, this study proposed the use of programmable electronic control unit. The programmable electronic control unit can control diesel engine operation regardless of properties of diesel fuel used.

ABSTRAK

Sisa pepejal kelapa sawit serta tanah liat pelunturan terpakai mempunyai potensi untuk dihasilkan sebagai biodiesel, menggunakan kaedah penghasilan biodiesel konvensional. Biodiesel yang dihasilkan dinilai dari segi pencirian fizikal, pretasi enjin serta pelepasan gas pada pelbagai nisbah campuran dan dibandingkan dengan biodiesel minyak kelapa sawit. Pencirian fizikal dibuat menggunakan kaedah piawaian ASTM manakala ujian pretasi enjin dan pelepasan gas dibuat menggunakan kaedah keadaan stabil. Berdasarkan kajian ini, penghasilan biodiesel daripada sumber sisa pepejal kelapa sawit serta tanah liat pelunturan terpakai dengan menggunakan kaedah penghasilan biodiesel konvensional tidak berjaya. Penghasilan biodiesel minyak kelapa sawit serta minyak masak terpakai berjaya dan biodiesel tersebut mempunyai ketulenan sebanyak 91% dan 88% masing-masing. Daripada pencirian fizikal dibuat, ketumpatan, kelikatan kinematic, titik kilat dan jumlah asid meningkat dengan peningkatan kandungan biodiesel dalam campuran biodiesel. Campuran biodiesel minyak masak terpakai mencatat lebih kenaikan dari segi ciri-ciri fizikal tersebut berbanding campuran biodiesel minyak kelapa sawit. Kandungan tenaga dalam campuran biodiesel mencatat penurunan dengan peningkatan kandungan biodiesel dalam campuran biodiesel. Campuran biodiesel minyak kelapa sawit dan minyak masak terpakai mencatat penurunan yang sama. Dari segi pretasi enjin, daya kilas brek serta kuasa brek meningkat sehingga 3.2% dengan peningkatan kandungan biodiesel sehingga 7% isipadu bagi kedua-dua jenis minyak. Penggunaan bahan api meningkat sehingga 42% dengan peningkatan kandungan biodiesel sehingga 10%. Kecekapan mekanikal tidak mencatat sebarang perubahan ketara walaupun dengan perbezaan jenis minyak dan nisbah campuran biodiesel. Campuran biodiesel minyak kelapa sawit mencatat pretasi enjin lebih unggul daripada campuran biodiesel minyak masak terpakai. Dari segi pelepasan gas, pelepasan karbon dioksida (CO_2), karbon monoksida (CO) serta hidrokarbon tidak terbakar (HC) mencatat penurunan dengan peningkatan kandungan biodiesel sehingga 10% isipadu bagi campuran biodiesel minyak kelapa sawit dan 7% isipadu bagi campuran biodiesel minyak masak terpakai dengan peningkatan pelepasan oksigen (O_2) serta oksida nitrogen (NO_x) Campuran biodiesel minyak kelapa sawit mencatat lebih pelepasan karbon dioksida (CO_2), karbon monoksida (CO) serta hidrokarbon tidak terbakar (HC) daripada campuran biodiesel daripada minyak masak terpakai dan mencatat lebih peningkatan pelepasan oksigen (O_2) serta oksida nitrogen (NO_x) daripada campuran biodiesel daripada minyak masak terpakai. Dalam erti kata lain, campuran biodiesel kedua-dua minyak meningkatkan pretasi enjin sehingga 7% isipadu bagi kedua-dua jenis minyak dan menurunkan pelepasan gas sehingga 10% isipadu bagi minyak kelapa sawit dan 7% isipadu bagi minyak masak terpakai. Kajian lanjutan harus dibuat menggunakan enjin diesel moden dengan sistem pengurusan enjin boleh program daripada enjin diesel biasa. Kajian ini mencadangkan penggunaan unit kawalan elektronik untuk mengawal operasi enjin diesel tanpa kesan ciri-ciri bahan api diesel sepertimana dapat dilihat pada enjin diesel tradisional.

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LIST OF ABBREVIATIONS

BX	-	Biodiesel of X% volume content
$CO(\%)$	-	Percentage of Carbon Monoxide Concentration
$CO_2(\%)$	-	Percentage of Carbon Dioxide Concentration
$EEO_{BiodieselBlend}$	-	Engine Emission Output using Biodiesel Blend Diesel Fuel
$EEO_{PetroleumDiesel}$	-	Engine Emission Output using Petroleum Diesel Fuel
$EEOI(\%)$	-	Engine Emission Output Increase
$EPO_{BiodieselBlend}$	-	Engine Performance Output using Biodiesel Blend Diesel Fuel
$EPO_{PetroleumDiesel}$	-	Engine Performance Output using Petroleum Diesel Fuel
$EPOI(\%)$	-	Engine Performance Output Increase
H/C	-	Ratio of Hydrogen Atoms to Carbon Atoms
$NO(\%)$	-	Percentage of Nitrogen Monoxide Concentration
$O_2(\%)$	-	Percentage of Oxygen Concentration
O/C	-	Ratio of Oxygen Atoms to Carbon Atoms
PO	-	Palm Oil
TAN	-	Total Acid Number
WCO	-	Waste Cooking Oil

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Journal

1. Lee, S.C., Tamaldin, N., and Abdollah, M.F.B., 2017. Tribological performance of low blend decanter cake biodiesel. *Industrial Lubrication and Tribology*, 69(3), pp.425-432.

Conference

1. Lee, S.C., Tamaldin, N., and Abdollah, M.F.B., 2015. Tribological Performance of Low Blend (B5 to B10) Waste Feedstock Biodiesel. *International Conference on Engineering, Technology, and Applied Science (ICETA)*, pp. 1-6.

CHAPTER 1

INTRODUCTION

1.1 Background

Despite the popularity of petroleum diesel fuel, petroleum diesel fuel was notoriously known to produce harmful emission and air pollution. However since there was no concern in protecting the environment during that time, the petroleum diesel usage was continued. Its continuous usage had caused serious air pollution and global warming problem due to carbon dioxide emission. Besides that, the continuous usage of petroleum diesel fuel caused crude petroleum reserve to deplete quicker and caused a price surge of petroleum diesel fuel. In order to conserve the environment and stop the diminishing crude petroleum reserves, vegetable oil rised to popularity again. Vegetable oil was cheaper than petroleum diesel fuel and renewable since the vegetable oil can be produced continuously through agriculture. However from Rudolf Diesel's past mistake, vegetable oil cannot be used directly into the diesel engine and its properties needed to be modified to bring its properties closer to petroleum diesel fuel and suit the diesel engine. Several methods of modifying the vegetable oil close to petroleum diesel fuel had been used which were micro-emulsion, thermal cracking and transesterification. Micro-emulsion method used cosolvent to dilute the vegetable oil while thermal cracking used heat to break the long fatty chain of the vegetable oil into shorter chain of fatty acid. Both micro-emulsion and thermal cracking methods were expensive to be used, thus the transesterification method was the preferred method since it was a cheap process in modifying the properties of vegetable oil. Transesterification method uses alcohol to break the bond of the long fatty

acid chain attached to the glycerol molecule and the long fatty acid chain reacts with it to form ester which was biodiesel (Agarwal and Das, 2001; Agarwal, 2007).

In Malaysia, the common vegetable oil produced was the palm oil. In 2006, the Malaysian government produced 15 million tonnes of palm oil and 90% of the palm oil production was exported (Sumathi et al., 2008). From the 10% of the produced palm oil which was not exported, the Malaysian government allocated 40% of its palm oil production which was 600000 tonnes for biodiesel production (Mofijur et al., 2013). The remaining 900000 tonnes of palm oil was distributed to the local people for consumption and the palm oil was commonly used in cooking or frying. After cooking or frying, those oil was discarded improperly especially discarded to the drainage system by either household or business premises. The waste palm oil discarded to the drainage system will seep into the soil and contaminate the underground water sources. Besides that, the palm oil production produced waste as well.

During the crude palm oil production, the fresh palm fruit was crushed by using screw press and the oil mash produced was centrifuged to obtain the crude palm oil. The leftover press cake which its oil was removed through centrifuge process was called decanter cake. The waste produced was the decanter cake which accounted 17 percent by weight of the crude palm oil production (Pleanjai et al., 2007). The decanter cake obtained was wet and contained residual palm oil. The decanter cake was used as either fertilizer for the palm tree or fuel for the boiler in the palm oil production industries. The entire crude palm oil production process is shown in a process flow chart in Figure 1.1.

Other than the decanter cake, the palm oil production produced spent bleaching clay during the crude palm oil refining process. During the crude palm oil refining process, bleaching clay powder was poured into the reactor containing crude palm oil to remove impurities. After the impurities were removed, the bleaching clay was spent, thus it was

called spent bleaching clay. The spent bleaching clay accounted 24% to 27% by weight of the crude palm oil production (Boey et al., 2011). The whole crude palm oil refining process is shown in a process flow chart in Figure 2.1.

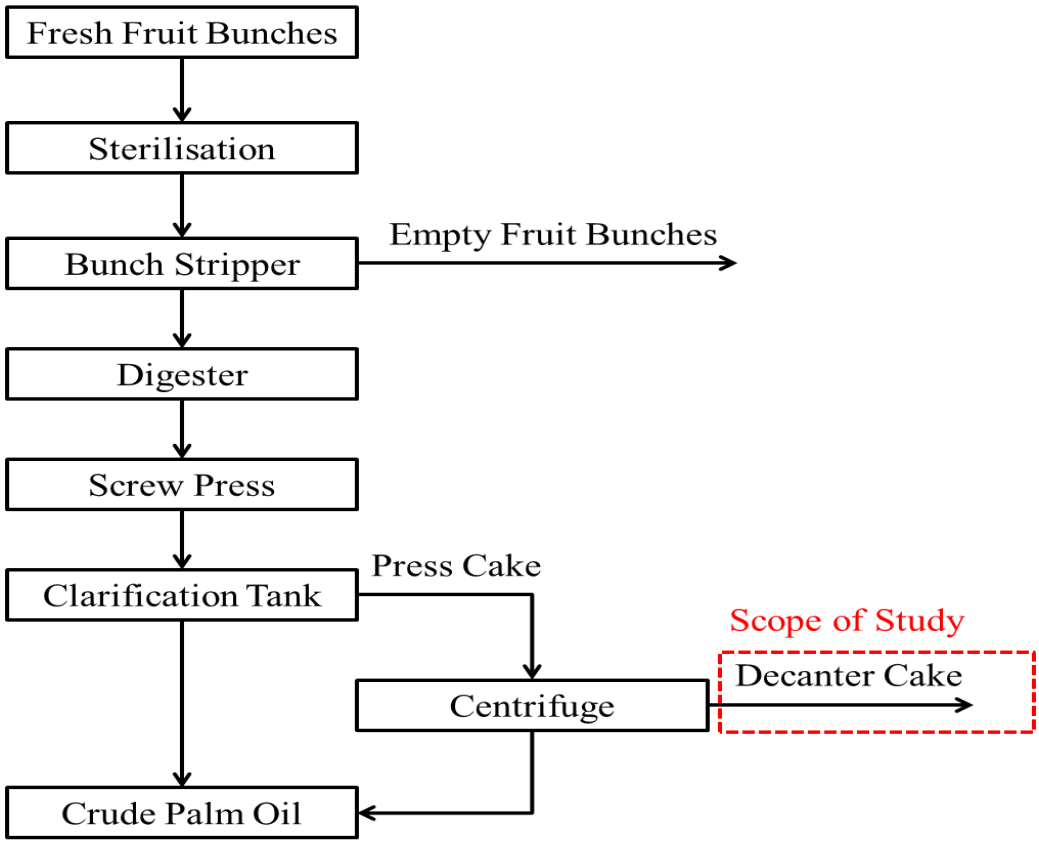

Figure 1.1: Crude palm oil production process flow chart

While there were many studies showed that the waste cooking oil can be made into biodiesel, a study was made recently and proved that decanter cake retained residual oil and with the residual oil extracted, it had the potential to be made into biodiesel and subsequent studies were made to further optimise the yield of the decanter cake biodiesel (Maniam et al., 2013; Nurfitri et al., 2013). Besides that, the residual oil extracted from the spent bleaching clay had the potential to be made into biodiesel as well and subsequent studies were made to optimise the yield of the spent bleaching clay biodiesel (Boey et al.,