FUEL CHARACTERISTICS OF BIODIESEL FROM WASTE VEGETABLES OIL USING ALKALINE BASED CATALYSTS

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This report is submitted to the Faculty of Mechanical Engineering in partial to fulfill the requirement for Bachelor Mechanical Engineering (Thermal-Fluid) with Honours

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DECLARATION

“I hereby declare that the work in this report is my own except for summaries and quotations which have been duly acknowledged.”

Signature :.....

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"Dedicated to my lovely parent, family, friends and lecturers for giving me encouragement and really support me in my wonderful life"

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ABSTRAK

Kebergantungan yang tinggi terhadap bahan api fosil telah mula menunjukkan kesan sampingan yang serius kepada pemanasan global dan pencemaran alam sekitar. Biofuel sebagai bahan api yang bersih dan mesra alam adalah bertepatan dengan prinsip pembangunan lestari yang menjadi matlamat utama penyelidik di dalam penghasilan sumber tenaga baru. Biodiesel adalah sebahagian dari biofuel yang berpotensi untuk muncul sebagai bahan api versi baru kerana kaya dari segi sumber aslinya iaitu minyak sayuran dan juga dari lemak haiwan. Biodiesel juga boleh di proses daripada sumber-sumber yang tidak boleh dimakan seperti Jatropha dan juga dari minyak sayuran terpakai (WVO). Proses transesterifikasi biasanya dipilih di dalam penghasilan biodiesel disebabkan beberapa kelebihan di dalam pembuatan mahupun biodiesel yang dihasilkan. Di dalam kajian ini, ciri-ciri minyak biodiesel yang dihasilkan iaitu biodiesel tulen (B100) serta campuran biodiesel dan diesel (B10 dan B20) ditentukan. Ciri-ciri ini dipilih berdasarkan kepada pengaruh dan kesan nya terhadap prestasi enjin. Semua ujian yang telah dilakukan adalah di bawah spesifikasi dan kaedah ujian yang termaktub di dalam ASTM (American Society of Testing and Materials) Standard untuk biodiesel dan campuran diesel-biodiesel. Berdasarkan keputusan yang diperolehi, campuran biodiesel-diesel sehingga B20 terbukti mampu untuk memenuhi piawaian ASTM dan boleh digunakan untuk enjin diesel.

ABSTRACT

Central dependency on fossil fuel has finally shown its deterioration towards global warming and pollution. Depletion of fossil fuel and violent swing of price for petroleum products further accelerates the need to find for alternative fuel. Biofuel produces clean and environmental friendly emission which fits perfectly for sustainable development. Biodiesel among the group of biofuels holds enormous potential as the next generation fuel due to its wide variation of sources from animal fats to vegetable oils. Biodiesel could also be made from non-edible sources like Jatropha as well waste vegetable oil (WVO). Transesterification process selected for biodiesel production due to several advantages it holds. The fuel properties of neat biodiesel (B100) as well as blend biodiesel (B10 and B20) were determined in this research. The properties selected were due to its importance towards engine performance. All the testing was done under the specification and testing method of ASTM (American Society of Testing and Materials) standards for biodiesel and blend of petroleum diesel. Results showed that biodiesel blend up to B20 was proved to meet the ASTM standard to be used for standard diesel engine.

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LIST OF SYMBOLS AND ABBREVIATIONS

^{o}C	=	Degree Celsius
ν	=	Kinematic Viscosity (m^2/s)
ASTM	=	American Society of Testing and Materials
EN	=	European Nation
ISO	=	International Organization for Standardization
WVO	=	Waste Vegetable Oil
WFO	=	Waste Frying Oil
FFA	=	Free Fatty Acid
B100	=	100% of Biodiesel, 0% of Petroleum Based Diesel
B20	=	80% of Biodiesel, 20% of Petroleum Based Diesel
B10	=	90% of Biodiesel, 10% of Petroleum Based Diesel
NaOH	=	Sodium Hydroxide
KOH	=	Potassium Hydroxide
BP	=	British Petroleum
FAME	=	Fatty Acid Methyl Ester
EMA	=	Engine Manufacturers Association
BSFC	=	Brake Specific Fuel Consumption
BSCO	=	Brake Specific Carbon Monoxide
BSPM	=	Brake Specific Particulate Matter
$BSNO_x$	=	Brake Specific Oxides Nitrogen
MPOB	=	Malaysian Palm Oil Board

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CHAPTER 1

INTRODUCTION

1.1 RESEARCH BACKGROUND

Energy has become an important resource for mankind in order to maintain living standard and also to drive the economic growth. Current world's energy production relies so much on fossil fuel as the main source. Fossil fuels supply a staggering 80% of world's energy followed by nuclear energy at 6% and 5% for hydroelectricity. The energy growth approximately 2.5% in 2011 based on British Petroleum (BP) on its BP Statistical Review (June 2012). Over dependence on fossil fuel has led to global warming and air pollution around the world today. Sediments and fossil from million years ago are what being used today as fuel source. It is not renewable and led to global degradation towards the environment. In international level, it creates political instability and arguments between nations while only lasts approximately 65 more years as mentioned by Huang et al., in 2012.

In 20 years to come, with new technologies and method discovered, non-fossil fuels contribution will be far bigger than it is now. Non-fossil fuel, comprise of renewable energy, hydro and nuclear, progression will surpasses each of fossil fuel source (coal, gas and oil). Even though its total will remain the same, but there is no dominant supplier of world's energy as the convergence of coal, gas and oil takes place as can be seen in forecast report by BP Energy Outlook 2030 (2012). With this, renewable energy source like biofuel is expected to be produced in big scale. This is to ensure that biofuel can fill the void of energy needed. This will definitely be a big step towards sustainable future and clean environment in years to come.

Study done by Demirbas, A. in 2009 revealed many advantages and benefits offered by biofuels as the replacement of fossil fuel in years to come. The main advantage of using biofuel is the environmental benefit it brings towards the globe. This is the main concerns for researchers and engineers in order to develop new and promising fuel which supports green technology. Biofuels also can be found throughout the whole world in different kinds of sources. With this, political instability and tension between nations could be eased and even be the solution for conflict arise. The most common biofuels are ethanol and biodiesel. Ethanol normally comes from corn, sugar cane and potato.

Biodiesel is a new and renewable fuel for diesel engine. It is a vegetable oil or animal fat based with alkyl esters as it chemical chain. Therefore, it is produced from agricultural based products like palm oil, soy bean, sunflower and animal fats. All these sources of biodiesel will produce biofuel-another name for biodiesel. Biodiesel is produced by chemically changing the molecular structures of its based by means of alcohol and catalysts. Biodiesel made using these two combinations are known chemically as FAME (fatty acid methyl ester). Biodiesel is normally made from transesterification process. There are several other methods that can be used to carry out this process which are supercritical process and ultrasonic process. Transesterification process is used to separate glycerine from the vegetable oil or animal fats. This process will produce methyl-esters which are the desired biodiesel and glycerine is normally used for soap making and other products. Biodiesel can be produced in small scale or big scale plant. The largest plant just started its operation in Singapore and owned by Neste Oil with 800 000 tons annual production as stated in Renewable Energy Policy Network, REN21 (2011).

There are two ways of using biodiesel in diesel engine. One is using neat and pure biodiesel noted as B100 (100% biodiesel) while the other is mixing biodiesel with conventional petroleum based diesel. Mixed biodiesel is called blend biodiesel. For example, B10 normally consists of 10% biodiesel and 90% petroleum diesel. Pandey, A (2008) mentioned in his handbook that at the moment, only biodiesel blend up to B20 can be used without any modification needed for the engine. EMA (Engine Manufacturers Association) has developed specifications and suggested standards to be used in the engine. The standards used as guidelines for biodiesel

producers regarding the quality of biodiesel produced. The main standards used are EN 14214 (European Standard) and ASTM D6751 (American Society of Testing and Materials). Manufacturers must produce their biodiesel and meet one of the standards before selling their products to user in order to maintain the engine as suggested by EMA.

Biodiesel also has been some of government policies due to several critical reasons it offers. With global energy crisis just around the corner, biodiesel offers stability and security towards the countries energy sources. With this, biodiesel is anticipated to give extra dimension regarding alternative fuel when the turning point of energy crisis comes. Lin et al., in their journal in 2011 make known that the emission of greenhouse gas will be reduced significantly when biodiesel is used as the main fuel especially in transportation and power generation. Referring to Sharma et al., in 2008, there are many types of plant species which can also produce and be the source of biodiesel. Their potential is stay put and not enough research has been carried out on the plant even though there have the potential to produce biodiesel. Developing countries throughout the world on the average did not have adequate supply of edible oil. So that, they need to lay emphasis on non-edible oils and work their way through the several of non-edible plants.

The increasing trend of converting crops into biodiesel has accumulated another issue-sustainability. First generation of biodiesel (crops to biodiesel) will affect the price of the crop and also the land used for crop to be grown. With these problems, biodiesel will face sustainability issues where the side effects of biodiesel production will create another problem like competing land for food production. In order to counter the problem, new biodiesel crop been farm in big scale production. Jatropha curcas, dwarf glasswort, switchgrass are some of new energy plants cultivated in order to produce biodiesel. These plants will be planted at marginal land thus avoiding any conflict with food production land. Another way to counter the problem is to use WVO (Waste Vegetable Oil) or some researchers noted as WFO (Waste Frying Oil) as the source of biodiesel. Over abundant of WVO from restaurants and hotels is a huge opportunity to produce biodiesel while keeping up the food supply and also protecting the environment. Even though the technology is

still new and not been published enough, the potential it holds should be given extra attention for the researchers to come up with better schemes and technologies.

In this study, focus would be put on the characterizing biodiesel from WVO originally produced from palm oil. The process would involve transesterification process with the help of methanol and potassium hydroxide (KOH). At the same time, the intention to investigate the properties of produced biodiesel when being blended with conventional diesel used and sold in Malaysia. The blends proposed were B5, B10, B20 and B100. The properties of biodiesel-diesel blend will be measured appropriately in accordance of ASTM standards specification under fuel testing for biodiesel blend.

1.2 PROBLEM STATEMENT

Biodiesel has the potential to be the solution from current pollution problem. It offers renewable, clean and biodegradability alternative fuel for diesel engines. Biodiesel has different fuel properties compared to petroleum based diesel. Blend biodiesel with different amount of diesel gives different fuel properties. Its properties needed to be determined before using it in diesel engine. This can be done using specific testing and procedure as listed under ASTM standard test method for blend biodiesel.

1.3 OBJECTIVES

The objectives of this study are:

i. To determine the quality of biodiesel produce from the alkaline based-catalyst.
ii. To study the biodiesel fuel properties element and its effect on the properties for different blend ratio.

1.4 SCOPE OF STUDY

The scopes of this study are:

i. To perform review study on the engine fuel testing.
ii. To run the fuel testing in order to compare the effect of fuel characteristic performance from each biodiesel sample.

CHAPTER 2

LITERATURE REVIEW

2.1 BIODIESEL

Biodiesel is defined as fuel with mixture of mono-alkyl esters of long chain fatty acids. It is usually derived from renewable sources for example vegetable oils or animal fats. Direct use of vegetable oils is not advisable as it will affect the engine performance as well as initiate more problems to the engine. All these setbacks are caused by the high viscosity of vegetable oils. To overcome the problems, transesterification process is used in order to reduce the viscosity of the vegetable oils as well as animal fats into the desired level (Demirbas, A. (2005)). Transesterification in addition can be classified into several approaches like alkaline catalyzed transesterification, acid catalyzed transesterification, heterogeneous catalyst transesterification process, acid–alkaline catalyzed (two stage) and enzyme catalyzed as has been studied by Math et al., in 2010. Biodiesel or also known as FAME (fatty acid methyl ester) is acknowledged to be biodegradable, zero toxic level and also produce little emission when being used in engines. The name of biodiesel was first started by National Soy Diesel Development Board or known as National Bio-diesel Board in 1992 corresponding to Ramadhas et al., paper in 2004.

Biodiesel is free from any petroleum products but can be used in conventional diesel engines or blend it with fossil based diesel. This is due to the fact that its properties are almost similar or identical with conventional diesel. Biodiesel has slightly different physical properties compared to fossil fuel diesel. The sulphur content, flash point and aromatic content all are better than diesel even though the

energy produce is lower than conventional diesel. Biodiesel do not has any sulphur while having zero aromatic scent and higher cetane number. With this, it is expected to help in reducing pollution caused by emission from transportation as can be seen from paper of Adaileh & AlQdah in 2012.

Nonetheless, the price of vegetable oils restricts the widespread use of biodiesel. Limited availability as well as restricted land for growing oilseeds has been major issues in biodiesel production. As been cited in paper by Anh et al., in 2008, the current price of virgin vegetable oils, the price of biodiesel would be 1.5 times higher than current price of retail diesel fuel. By using waste vegetable oils, the cost of biodiesel production would drop about 60-70% because the price of vegetables oils covered almost 95% of total cost of biodiesel production.

Math et al., 2010 emphasized that there is huge amount of waste vegetable oil (WVO) generated daily by restaurants, fast food restaurants and food processing industries all around the world. A little amount of the WVO is used for goods like soap processing and as an additive in fodder making. Nevertheless, vast amount of it is unloaded onto landfills or being dumped illicitly into rivers and sea. This definitely has its consequence in the long term towards the sustainable environment as well as its effect on human. As an alternative, the WVO could be recycled to produce biodiesel and use it for better purpose. Despite the potential it has, WVO contains a large amount of Free Fatty Acid (FFA) which is undesirable in transesterification reaction process. Together with this, biodiesel production from WVO will be more challenging and the biodiesel properties need to be determined and analyse carefully before being used in any engine.

EMA (Engine Manufacturers Association) in its technical statement, EMA (2006), has developed specifications for biodiesel. This is done for the purpose of usage and evaluation especially for blend fuel of biodiesel (biodiesel blend with fossil-based diesel). This action is important to ensure that its member and their customers will be using uniform and standardized properties of biodiesel. This is an important step to ensure that the engine preserve its performance especially when the biodiesel being dispensed at the pump. The biodiesel should also be examined if any degradation of its properties takes place when in storage. EMA also has limited

knowledge on how the biodiesel would perform on the current engines technologies as well as the secondary effect of its usage for a period of time. Neat biodiesel (100% biodiesel) would in general to pass the ASTM D975 while blend biodiesel would need to meet the requirement as in ASTM D6751 or EN 14214

2.2 BIODIESEL PRODUCTION

There are many biodiesel production technologies that have been developed for the past few years. However, there are four major ways to produce biodiesel which are direct use and blending of raw oils, micro-emulsions, thermal cracking and transesterification. Transesterification process is the most favourable methods as it produces biodiesel with the highest Cetane number, low emission when used in engine and has better efficiency regarding the combustion of the fuel based (Leung et al., in 2010). Lin et al., in their paper in 2011 also stated that transesterification is the best solution to high viscosity problem.

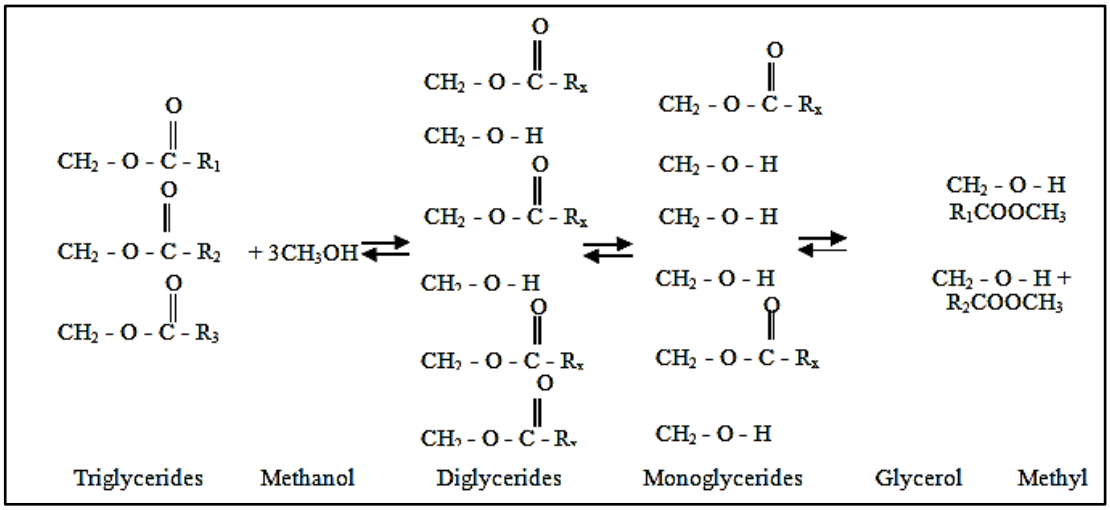

Figure 2.1: Transesterification reaction process used in biodiesel production (Source: Felizardo et al., 2006)

This process also has high efficiency to convert vegetable oils into biodiesel while running at low cost. Transesterification also been known as alcoholysis. Transesterification can be classified into several more categories like alkaline catalysed, acid-catalysed esterification, acid–alkaline catalysed (two stage) and non-

catalysed super critical methanol, enzyme catalysed, and heterogeneous catalyst transesterification process. In the process, every triglycerides reacts stoichiometrically with 3 moles of methanol (alcohol). This will break free the fatty acids from their glycerol backbone to form FAME and free glycerol. Diglycerides and monoglycerides are the transitional products when reaction process takes place. The process can be seen in Figure 2.1.

Methanol and ethanol are normally used commercially due to the fact that both of the alcohols are cheaper and low cost. They also exhibit chemical and physical advantages over other types of alcohol. These two could immediately react with the tri-glycerides and catalysts as founded by Ramadhas et al., in 2004. Sodium hydroxide (NaOH) and potassium hydroxide (KOH) are two types of the catalysts normally used during transesterification process (Math et al., 2010). This also been supported by Alptekin and Canakci (2009) and also Ramadhas et al., (2004). Alkaline catalyzed transesterification has been proved to be most preferable method in producing biodiesel with FFA less than 1^{o} (Helwani et al., 2009). This process would only require reasonable temperature under low pressure while producing astonishing 98% conversion efficiency. In addition to that, it would only need short period of time while the biodiesel is converted directly without any extra process. The alkaline-catalysed transesterification process can best be understood in flowchart in Figure 2.2.