TAILOR-MADE BIOFUEL-DIESEL BLENDS PROPERTIES VALIDATION AND ENGINE PERFORMANCE

KHAIRUNNISA BINTI MOHIDIN

UNIVERSITI TEKNOLOGI MALAYSIA

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KHAIRUNNISA BINTI MOHIDIN

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To my beloved family

Thanks

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ABSTRACT

Biofuel-diesel blend offers a great opportunity in reducing the usage of petroleum based diesel and improving the pollutant emission. This study is carried out to perform engine performance testing using a set of fuel blends generated through computational work by Narayanasamy et al.(2014), the blends, content mixture of ethanol(E), butanol(B) and butyl levulinate(BL) with B5 diesel as baseline fuel. The basic properties of the fuel blends were measured according to the corresponding ASTM test method. In the previous work mentioned, Kay's mixing rule is used for predicting density, distillation temperature, cetane number and calorific value, while an Arrhenius mixing rule is used for viscosity. The results of prediction are then validated by calculating the absolute average deviations(AAD), with the ASTM test. A high AAD obtained for viscosity (31.15%), showing a poor agreement in the prediction model for this property. The lower AAD value obtained for the other tested properties demonstrating the suitability of the used mixing rules. Engine tests on the fuels were carried out on a HINO H07C diesel engine by varying speed in the range of 1200-2400 rpm. The results shows brake specific fuel consumption(BSFC) of the blends was found to be higher than B5 fuel, while a decreasing trend in horsepower produced was observed with increasing speed. The overall observation of emission analyzed gases of CO_2, CO, NOx and hydrocarbon(HC), the fuel blends showed a good reduction as compared to the B5 fuel baseline. Blend 2 which consists only the mixture of butanol was found significantly high for HC emission compared to the other blends. It is concluded that Blend 1 (0.746%B5- 0.244%B- 0.010%BL) gave better engine performance with lower BSFC for the same power output compared to the other blends. On the other hand, Blend 3 (0.757%B5- 0.123%B- 0.10%E- 0.02%BL) gives the best overall results in emission reduction among all the fuel blends.

ABSTRAK

Campuran bahan api bio-diesel memberi peluang besar bagi mengurangkan penggunaan bahan api berasaskan petroleum dan asap pencemaran. Kajian ini dijalankan bagi melaksanakan ujian prestasi enjin menggunakan set campuran bahan api yang dijana dengan kaedah bantuan komputer oleh Narayanasamy et al. (2014) dimana campuran terdiri daripada etanol, butanol dan butil levulinat dengan menggunakan diesel B5 sebagai asas rujukan. Sifat-sifat asas campuran diukur mengikut ujikaji kaedah ASTM. Menurut kajian terdahulu yang disebut di atas, kaedah campuran Kay digunakan untuk meramal sifat ketumpatan, suhu penyulingan, nombor setana dan nilai kuantiti tenaga, manakala kaedah campuran Arrhenius digunakan bagi meramal sifat kelikatan. Nilai ramalan kemudian disahkan dengan pengiraan sisihan purata mutlak (AAD) dengan nilai melalui kajian ujikaji. Peratus AAD tertinggi didapati dari sifat kelikatan (31.15%), menunjukkan kesesuaian kaedah ramalam yang digunakan adalah kurang sesuai. Sebaliknya peratus AAD yang rendah didapati bagi sifat-sifat lain membuktikan kesesuaian penggunaan kaedah campuran. Ujikaji enjin terhadap kesemua bahan bakar campuran dijalankan menggunakan enjin diesel HINO H07C pada kelajuan di antara 1200-2400rpm. Penggunaan bahan bakar khusus brek (BSFC) oleh campuran didapati lebih tinggi daripada bahan api B5, sementara penjanaan kuasa kuda menunjukkan penurunan dengan peningkatan kelajuan enjin. Keseluruhan analisis pelepasan gas CO_2, CO, NOx dan hidrokarbon(HC), kesemua campuran menunjukkan penurunan yang baik berbanding bahan api B5. Campuran kedua yang hanya mempunyai campuran butanol didapati mempunyai pelepasan HC tertinggi berbanding campuran lain. Kesimpulannya, campuran pertama (0.746%B5- 0.244%B- 0.010%BL) menunjukkan prestasi enjin yang lebih baik menerusi BSFC yang lebih rendah bagi penjanaan kuasa yang sama. Sebaliknya campuran ketiga (0.757%B5- 0.123%B- 0.10%E- 0.02%BL) menunjukkan keputusan keseluruhan terbaik bagi pelepasan gas.

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LIST OF ABBREVIATIONS

NOx	-	Nitrogen Oxide
CO_2	-	Carbon Dioxide
CO	-	Carbon Monoxide
LA	-	Levulinic Acid
LE	-	Levulinate Ester
BL	-	Butyl Levulinate
CI	-	Compression Ignition
CN	-	Cetane Number
MPOB	-	Malaysian Palm Oil Board

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CHAPTER 1

INTRODUCTION

1.1 Overview of research

In the past decades, research on renewable energy has become an important alternative source in replacing the conventional energy currently use, which the majority of the world's supply is mainly from petrochemical sources, natural gas and coal. With the exception of hydroelectric and nuclear energy, all of these sources are finite and at the current usage rates will be consumed in the future (Meher et al., 2006). The increase in energy demand and the concern on the environmental problems caused due to the sources from fossil fuel has also prompted on the necessity of developing renewable energy sources.

Malaysia is well endowed with both the conventional and non-conventional sources of energy with the largest conventional (non-renewable) energy actively exploited in the country is from petroleum based sources. As known it is nonrenewable and will deplete throughout the years with the increase in the energy demand. The energy demand in Malaysia indicates a very rapid increase (Figure 1.1) with more than 50% increase from 2010 to 2030, where it is expected to reach 100 Mtoe (million tonne of oil equivalent).

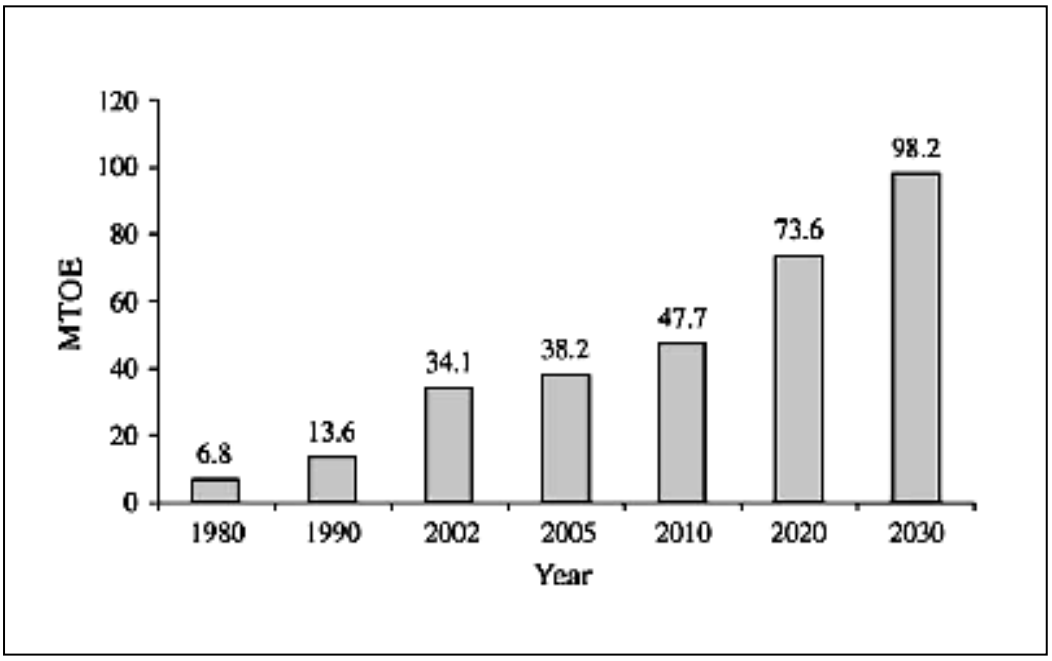

Figure 1.1 : Energy demand in Malaysia (Shuit et al., 2009)

The world total primary energy production, which includes natural fossil fuels and renewable energy consist more than 80% (Figure 1.2) of combine petrochemical sources in the year 2011 (IEA, 2013). In Malaysia for the same year (Figure 1.3) shows the primary energy production dominated by the natural fossil fuel usage (IEA, 2012). Since the petroleum derived energy will eventually deplete in the years to come and not able to meet the energy demand in Malaysia, the development of potential renewable energy technologies is crucial.

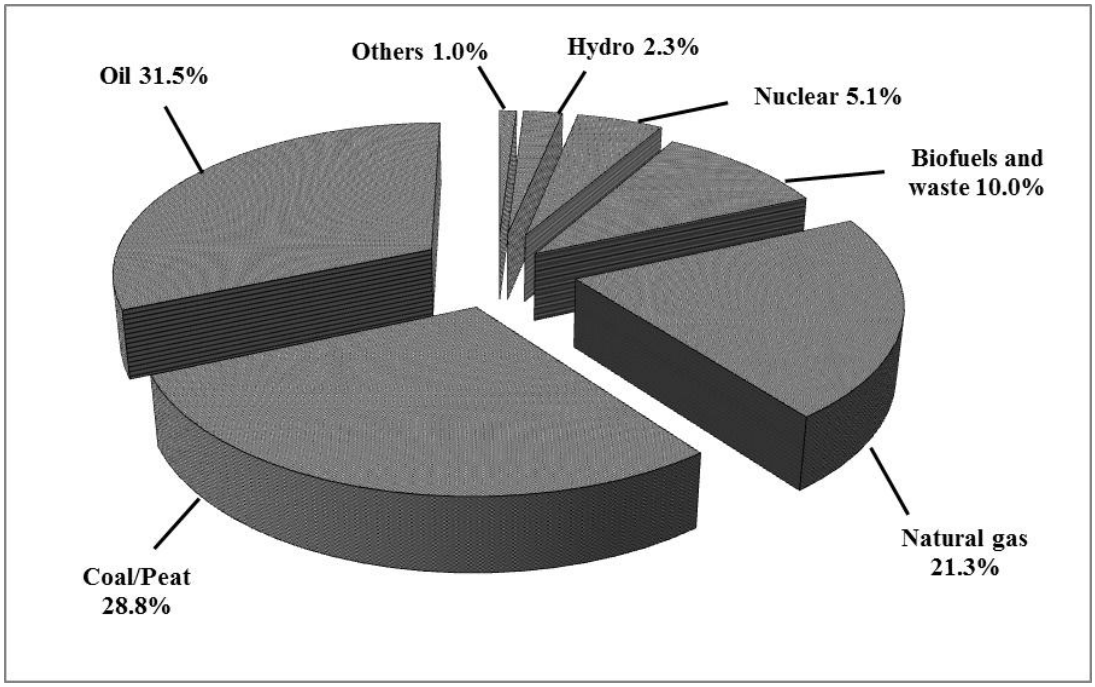

Figure 1.2 : World total primary energy supply in 2011 (IEA, 2013)

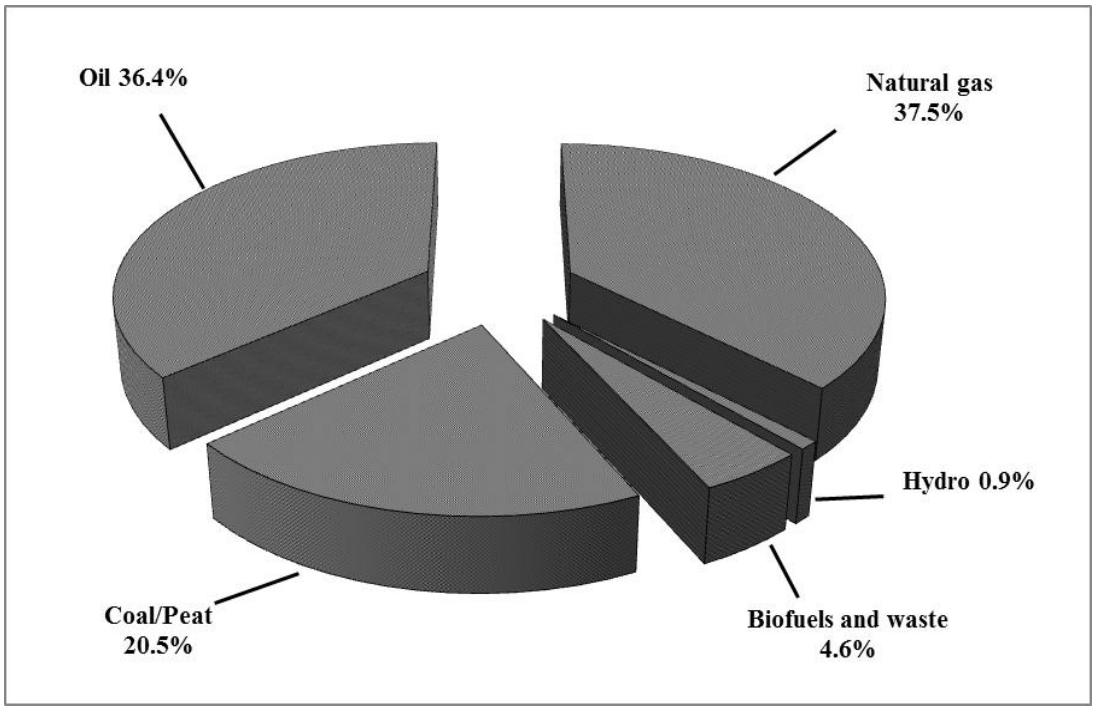

Figure 1.3 : Primary energy supply in Malaysia in 2011 (IEA, 2012)

Another driving force in the importance of developing renewable energy is the environmental concerns. It has been identified that the main cause of the increase in the carbon dioxide (CO_2) concentration was due to the utilization of the electrical power generation activity and transportation fuel. Figure 1.4 shows a tremendous growth of CO_2 emitted each year (from 1990 to 2010) from fuel combustion in Malaysia except the year 2009, based on the International Energy Agency (IEA) statistic. This problem has prompted the government to review the energy policy in the usage of petroleum derived combustion. In 2013, Malaysia government has implemented the use of B5- (5% palm oil diesel) petroleum diesel blend on all personal and private diesel engine vehicles after years of field trial by Malaysian Palm Oil Board (MPOB).

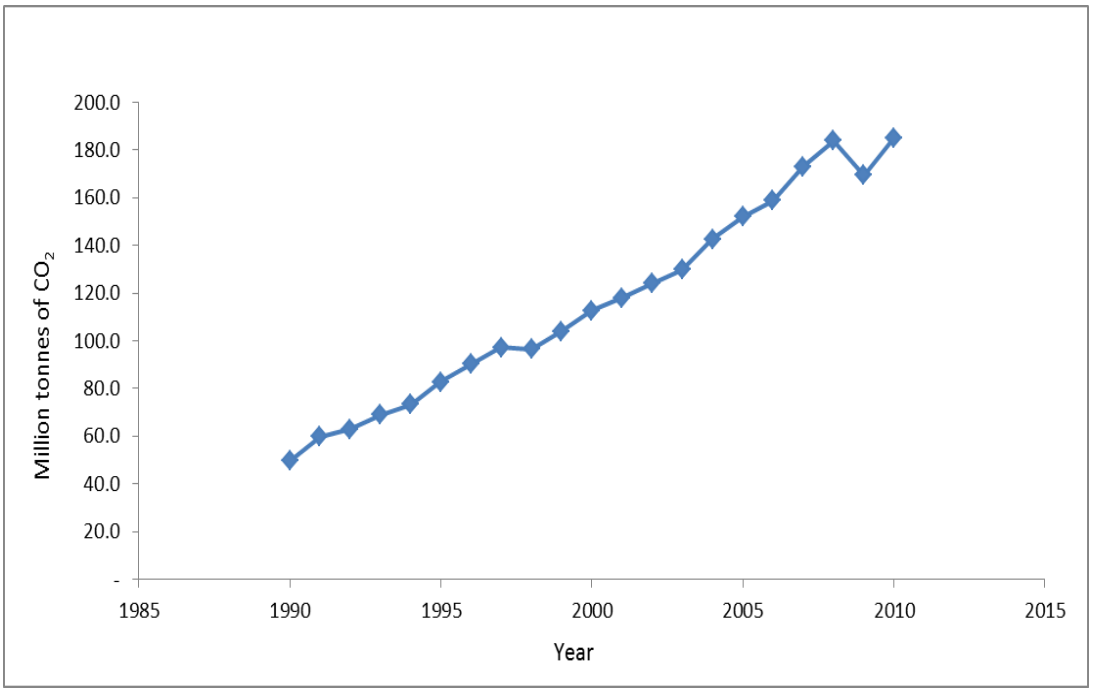

Figure 1.4 : CO_2 emission from fuel combustion in Malaysia (IEA, 2012)

The majority of the countries in the world is still heavily dependent on crude petroleum as an energy source. Lam et al. (2009) suggested the possible solution is in finding a suitable (renewable) and economically feasible alternative energy sources. There are lots of sustainable alternative energy available such as solar, wind and geothermal, but they are not economically feasible. Malaysia is also abundant with renewable energy, mostly from biomass, which fits both of the criteria mentioned.

Biomass derived energy can be converted into chemical and fuel feedstocks. Biofuels have shown great potential in serving as a substitute for petroleum derived fuel, which are readily renewable, economically competitive and environmentally benign. The use of biofuels can be as pure fuel or blends with the petroleum derived fuels injected directly into an engine application without any significant modification. There are many advantages of biofuels compared to petroleum fuel. There are non-toxic and biodegradable, does not emit any new CO_2 gas (Tan et al., 2004), where the carbon balance is close to neutral resulting in reduction of greenhouse gas (GHG) emission. Biofuel has less or negligible harmful emission and the usage of biofuels in the future will reduce the dependence of petroleum fuel (Kousoulidou et al., 2008).

The efficiency of the biofuel as pure or blends fuel are obtained through the engine performance. There are many factors in improvement of engine performance, whether through modification of the engine or fuel modification. The basic concept of internal combustion engines, comprises of burning mixture of air and fuel. The fuel use can be petrol, diesel, methane, etc. Diesel engine as one of the internal combustion engine, occupied a major part of the world's transportation, especially in the agricultural sector. It is more rigid and fuel efficient in comparison to the petrol engine. The concept of the diesel engine is that it uses the heat of compressed air to ignite the fuel. In a compression ignition (CI) engine, the properties of fuel use will effect the characteristics of the combustion occur in the combustion chamber. This will in turn effect the efficiency of the engine performance and the exhaust gas emission. The characteristics of engine performance can be determined through the following methods (Ganesan, 2007);

- Using experimental methods of obtaining through engine test runs and,
- Analytical calculation based on theoretical data

In which the performance is to observe on how well the engine works in relation to the energy input and effectively provides useful energy.

In fuel modification, the physical properties are the most important parameter in determining the quality of the fuel blend. By obtaining the properties of the fuel blends, it will provide an explanation on how the engine will operates in terms of performance, combustion and emission characteristics. In recent years, various computational models have been developed in predicting the performance and properties of the optimum blends using various types of biofuel with diesel fuel. Computer aided techniques can significantly narrow down a number of possible and promising candidates. Due to the limitation of the availability validation of the models, experimentally-based data are needed to verify the generated data to find the best fuel blend composition.

In this study, experimental based method will be conducted to determine the properties of fuel blends to validate the prediction values which were obtained through computational method. Meanwhile, the diesel engine performance testing is conducted to observe the efficiency of the fuel blends generated in terms of the performance i.e. brake specific fuel consumption and horsepower as well as gas emission, in obtaining the most optimum blend.

1.2 Problem Statement

Trial and error of experimental methods were implemented to identify an appropriate or desirable composition of fuel blending ratios. However the experimental methods consume a lot of time and are costly due to the needs to test all types of trials and samples. On the other hand, computer aided techniques are able to solve the problem at the design product stage. This method will narrow down the search target and determine the best selected blend ratios, thus shortlisting the optimum blends for the experimental methods to be conducted. The results generated by simulation can be validated with a real world setting condition.

In this study, experimental test of the engine performance and emission and properties for validation is conducted for a set of fuel blends composition has been identified generated by computational methods, based on mixing rule model (Narayanasamy et al., 2014). American Society for Testing and Materials (ASTM) standard will be used to validate the predicted properties value of the generated blends. This is to verify the agreement between the predicted and experiment properties value, thus proving the suitability of the mixing rule model in predicting fuel blend property. The efficiency of the blends in terms of real setting engine performance is, however, has yet to be tested experimentally. The importance of engine test is to observe the improvement of the blends in comparison to B5 diesel fuel as baseline fuel. A six cylinder with a hydraulic dynamometer, diesel engine will be used for the engine performance and gas emission test. Through the observation of power output and fuel consumption, the optimum blend can be observed in which the blend will produce higher power with lower fuel usage. While the improvement by reduction of the gas emission should be observed from the fuel blends. Exhaust gases tested includes carbon dioxide, carbon monoxide, oxide of nitrogen and hydrocarbon.

1.3 Objectives of the Study

The main objective of this research is to test the engine performance and emission of tailor made biofuel- diesel blend. Feasible fuel blends from several candidates of biofuels was generated from previous literature using computer aided techniques. In which the predicted properties of the blends were based on the Kay's and Arrhenius mixing rules. The engine performance and emission of fuel blends are investigated on an existing HINO H07C diesel test engine at varying speed. The predicted properties are validated with ASTM test method.

1.4 Scope of the Study

The scopes of this research are:

1. To conduct the tests on six test fuels, which consist of ethanol, butanol and butyl levulinate composition (Narayanasamy et al., 2014), generated by computer aided techniques including B5 diesel as the base fuel.
2. Validating the target properties of the fuel blend using the ASTM parameters standard with the predicted values from the mixing rules model. The target properties include, kinematics viscosity, density, cetane number/index, distillation temperature and calorific value.
3. The experimental test of performance and exhaust emission characteristic is conducted on a six cylinder, direct fuel injection, water cooled, 4 stroke HINO H07C diesel engine at speed range of 1200-2400 rpm. Parameters evaluated, including the horsepower, brake specific fuel consumption and the regulated gas emission i.e; CO, NOx, HC including CO_2.

1.5 Research Significance

The increasing of high energy demand and the pollution problem caused by the fossil derived fuel has put biofuels as one of the most promising renewable energy to replace the conventional fuel. Malaysia is one of the largest producers of biofuel from palm oil biomass. With the depleting of fossil derived fuels, biofuels as an alternative energy fuel will be the next asset to the country's economy. In 2006 itself, Malaysia contributed 43% of the world total palm oil product (Shuit et al., 2009). By following the National Biofuel Policy which in line with the European Union (UN), in general Malaysia will be able to improve in terms of the energy supply security, while at the same time reducing the greenhouse gas emission.

The most significant way in assessing an automotive fuel is by its capability to reduce emissions, to increase fuel efficiency and the ability to lessen the dependency on conventional fuel. The fuel must be able to provide the same drivability quality as the existing conventional fuels do and the most important factor is its usability in the currently available engine. Thus the fuel blend is proposed instead of modification of the engine.

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