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EFFECT OF BIOETHANOL ON ENGINE PERFORMANCE AND EXHAUST EMISSIONS OF A DIESEL FUEL ENGINE

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ABSTRACT

Bioethanol is a renewable and oxygenated bio-based resource with the potential to reduce particulate emissions in direct fuel injection diesel engines. This study aims to further diminish the outflow of a Diesel Fuel Engine motor fueled by diesel-bioethanol by identifying the most suitable blend by applying various blends of diesel-bioethanol, namely E10, E20, E50, and E80 blends. The Diesel engine had been tested using solely diesel fuel and then with bioethanol blends for comparison purposes. The results show that bioethanol fuel can provide a lower torque for the Diesel engine, but a similar engine performance occurs in terms of Horse Power. However, the presence of bioethanol inside the blended fuels increases the emissions of Unburned Hydrocarbon, (HC), CO, CO_2, and NOx compared to engines that use only Pure Diesel. E10 has been found as the most ideal blend from all the fuels tested. Further research is required to distinguish the E80 fuel blend, as it is unable to be tested on a 6-cylinder engine, since the standard running Diesel engine suitable for the E80 blend fuel is a single cylinder.

Keywords: Bioethanol; Engine performed; Exhaust emissions; Diesel fuel emission

1. INTRODUCTION

The world is in need of a cleaner and more efficient fuel as an alternative to achieve energy conservation. All things considered, it is an unquestionable actuality that man still vigorously relies on fossil fuels for electricity generation, transportation, and development. Moreover, misuse of fossil fuels has raised serious natural issues, which bring about negative effects on the earth. In this manner, the pursuit of renewable energy sources has risen as one of the key difficulties in this century to secure Nature, thus making the world sustainable in the future. Due to its cleaner burning, the introduction of biodiesel, as an alternative to diesel fuel, promises more benefits for users, besides conserving the environment Biodiesel has been proven to emit lower greenhouse gas emissions, and this directly reflects its unique benefits (Basha et al., 2009). Biodiesel is easily produced and it can be made domestically from vegetable oils, animal fats, or any other natural resources. Soybean, rapeseed, sunflower, and palm oils are among the common vegetable oils used in biodiesel production. Furthermore, biodiesel is a nontoxic alternative fuel and easily biodegradable in freshwater and soil, making it undeniably good for the environment (Pasqualino et al., 2006). Right now, the demand for liquid fuels comprises more than 40% of the total energy utilization in the world. Along with this, renewable energy sources, such as solar, wind, and hydrothermal are also promising for harvesting to produce electricity or thermal energy. In comparison, biodiesel is better than other

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renewable energy sources as it suits the interest in liquid fuels in the world market, especially in the transportation division. Regarding application, biodiesel and diesel have comparative physic-synthetic properties, implying that no adjustment to an existing diesel motor is needed. Besides, biodiesel and diesel can be mixed and industrially utilized as transportation fuel. All in all, biodiesel can be ecologically compatible and it is possible to replace fossil fuels as the primary source of energy. Beside biodiesel, bioethanol is also compatible with diesel engines, as it is able to meet the fuel specification given in the standards and therefore it can be used as a substitute for petroleum diesel in the future (Hansen et al., 2005). Addition of bioethanol will enhance the physiochemical properties of the fuel (Yilmaz et al., 2014). Zhu et al. (2011) reported that bioethanol-diesel blends improve the engine horse power of four-cylinder DI diesel engines.

Tremendous amounts of carbon dioxide (CO_2) emissions make up the majority of greenhouse gas emissions, which damage the environment and cause climate change. Carbon dixoide comprises 65% of the total greenhouse gas emissions (IPCC, 2014). The colossal emanation of carbon dioxide is because of anthropogenic processes from human activities. Transportation is the one of the major contributors, in which 16% are man-made CO_2 emissions, followed by manufacturing and electricity generation (Ali & Tay, 2013). A previous study on the impact of anthropogenic exercises additionally demonstrated that in the coming decade, the transportation sector will be a significant source of global warming (Barnwal & Sharma, 2005).

The Malaysian government admits that a large portion of the reduced GHG will originate from the execution of required mixing of B5 biodiesel (mixing of 5% biodiesel and 95% mineral diesel), which was started in June 2011. Other than that, in 2005, the National Biofuel Policy was propelled as an indicator of readiness to promote biofuel in Malaysia. The execution of national biofuel approach policy in the short term was to create a Malaysian standard in particular for B5 diesel, participation in B5 diesel trials by selected government departments with their fleets of diesel vehicles, and to establish B5 diesel pumps for the society at chosen stations. In the meantime, it served as a medium-term solution to pass and authorize enactment to mandate the utilization of B5 diesel and make the Malaysian standard in particular for palm oil-based biofuel for household utilization and export. Nonetheless, the efforts of the Malaysiam government to push forward the commencement of renewable energy in the transportation industry still face a lot of vulnerability. Right now, the utilization of biofuel for local utilization in domestic consumption is only 0.1% (Neto da Silva et al., 2003).

Bioethanol creation from fermentable sugars has been turned into a range of recognized research projects because of the social and environmental implications of global warming, deficiency of fossil fuels reserves, and the fluctuating price of oil. Many scientists have tested different methods for efficient bioethanol production from varying biomass sources, including agricultural and industrial waste, woody biomass, and algae (Kin et al., 2005). Bioethanol is produced largely by fermentation and by chemical processes of reacting ethylene with steam (Ndimba et al., 2013; Kusrini et al., 2015). The fundamental source of sugar to produce ethanol originates from fuel or crop vitality. These fuel products are typically for energy utilization, incorporating maize, corn and wheat crops, waste straw, willow, sawdust, reed canary grass, rope grasses and sorghum plants. There is also progressively innovative work into the use of municipal solid wastes to produce ethanol fuel (Sarkar et al., 2012). The world bioethanol production in 2001 was recorded at around 31 billion liters, which shows the intensity and growing belief in replacing fossil fuels (Ogawa & Yoshida, 2005).

Bioethanol is an attractive alternative fuel because it is a renewable bio-based resource and it is oxygenated, thereby offerring the potential to reduce particulate emissions in compression-ignition engines. Drawbacks of bioethanol are lower energy density than gasoline (bioethanol has 66% of the energy that gasoline has), its corrosive properties, low flame luminosity, lower vapor pressure (making cold starts difficult), miscibility with water, and toxicity and adverse effects in biological systems (Shigechi et al., 2002). Some properties of alcohol fuels are shown in Table 1 (Kin et al., 2005).

Table 1 Properties of alcohol fuel

Fuel property	Methanol	Ethanol
Cetane Number	5	8
Octane Number	112	107
Auto-ignition Temperature (K)	737	606
Latent Heat of Vaporization (MJ/Kg)	1.18	0.91
Lower Heating Value (MJ/Kg)	19.9	26.7

Ethanol is an oxygenated fuel that contains 35% oxygen, which reduces particulate and nitrogen oxide (NO_x) discharges from combustion (Posada & Cardona, 2010). Ethanol has a higher octane number (108), more extensive combustibility limits, higher flame velocities and a higher heat of vaporization. These properties allow for a higher compression ratio and shorter burn time, which prompt more hypothetical effectiveness points of interest over gasoline in an internal combustion engine (ICE). The octane number is a measure of the gasoline quality, and refers to the counteractive effects of early ignition, which prompt cylinder knocks. Higher octane numbers are favored in internal combustion engines. An oxygenated fuel, such as bioethanol gives a sensible anti-knock quality. Likewise, as it contains oxygen, fuel ignition is more effective, diminishing hydrocarbons and particulates in exhaust gases. Complete burning of fuel requires the presence of stoichiometric oxygen. On the other hand, the measure of stoichiometric combustion results in insufficient oxygen for complete combustion. The oxygen content of a fuel determines its combustion efficiency. Combustion effectiveness and the octane number of bioethanol are higher than those of gasoline, thanks to the presence of oxygen in bioethanol, which enhances combustion and subsequently diminishes hydrocarbons (HC), carbon monoxide (CO), and particulate emanations; nevertheless, oxygenated fuels likewise have a tendency to build nitrogen oxide (NO_x) outflows.

Therefore, the objective of the present investigation is to find the effect of bioethanol blending with diesel towards the most effective engine emissions and performance. The existing Diesel Fuel engine running on solely diesel fuel has been identified to produce high emissions of gases, which affect the environment negatively, by emitting NO_x, CO, CO_2, and HC (Lapuerta et al., 2008; Susila et al., 2012). In this study, bioethanol is mixed with diesel fuel to compare emissions and performance. A number of nations have conducted various biofuel projects, including the incentive structure for bioethanol-gasoline blend programs. Table 2 shows the blends of bioethanol-diesel in selected countries (Balat et al., 2008).

2. EXPERIMENTAL

2.1. Engine Test Bed

An inline-6 cylinder, direct fuel injection diesel engine has been used to carry out the experiments. Specifications of the HINO H07C engine are as shown in Table 3. For certain reasons and requirements, some modifications were made to the engine to ensure the engine operated under desired conditions. Modifications had been made to the fuel piping, bubble remover system, and transparent fuel tubes.

Table 2 Countries with their bioethanol-gasoline blend programs

Country	Bioethanol Blends
United States	E10
Canada	E10
Sweden	E5
India	E5
Australia	E10
Thailand	E10
China	E1
Columbia	E10
Peru	E10
Paraguay	E7
Brazil	E20, E25

Table 3 HINO H07C engine specifications

Model	HINO H07C 6-Cylinder 6728cc
Type	Water cooled, 4 cycle, overhead valve, inline-6 cylinder, direct fuel injection
No. of Cylinder x Bore x Stroke	6×110 mm×118 mm
Compression Ratio	17.5:1
Rated Output	180 PS/2100 rpm (132.7 kW/2100 rpm)
Maximum Torque	67kgf-m/1600 rpm (657 N-m/1600 rpm)
Fuel Consumption Rate	174 g/ps.hr (235 / kW.hr)

2.2. Experimental Procedure

Five bioethanol-diesel blends were prepared and labeled as E10, E20, E50, and E80, respectively. After the creation of the bioethanol-diesel blends, the engine system was set up and tuned before the starting operation. The final general setting was on a dynamometer and a discharge analyzer.

As the control, pure Diesel fuel was used, and the parameters of the engine performance (Engine Power and Engine Torque) and discharges (NO_x, CO, CO_2, HC) were recorded likewise (Mohsin et al., 2014). After all the parameters, had been tested and measured, the engine was switched off and cooled to ambient temperature. The pure Diesel fuel was then flushed from the engine and fuel tank. The entire steps were repeated again by mixing pure Diesel with bioethanol blends of E10, E20, E50 and E80. All the information for each blends' emissions had been properly recorded. Each bioethanol-diesel blend was also tested for engine runs at 1400 rpm, 1800 rpm, 2200 rpm, and 2600 rpm, respectively. The overall methodology is shown in Figure 1 and the arrangement of experimental set-up is in Figure 2.

2.3. Emissions Instrumentation

The measured parameters from the exhaust emissions were carbon monoxide (CO), carbon dioxide (CO_2), nitrogen oxide (NO_x) and unburned hydrocarbon (HC). The measurements were performed using an emissions analyzer (Aleiferis et al., 2010). Figure 3 shows the emissions analyzer used to measure the exhaust emissions of CO_2, CO, NO_x and UHC, while Figure 4 shows the control panel set to record and display the input data parameters of the results obtained.

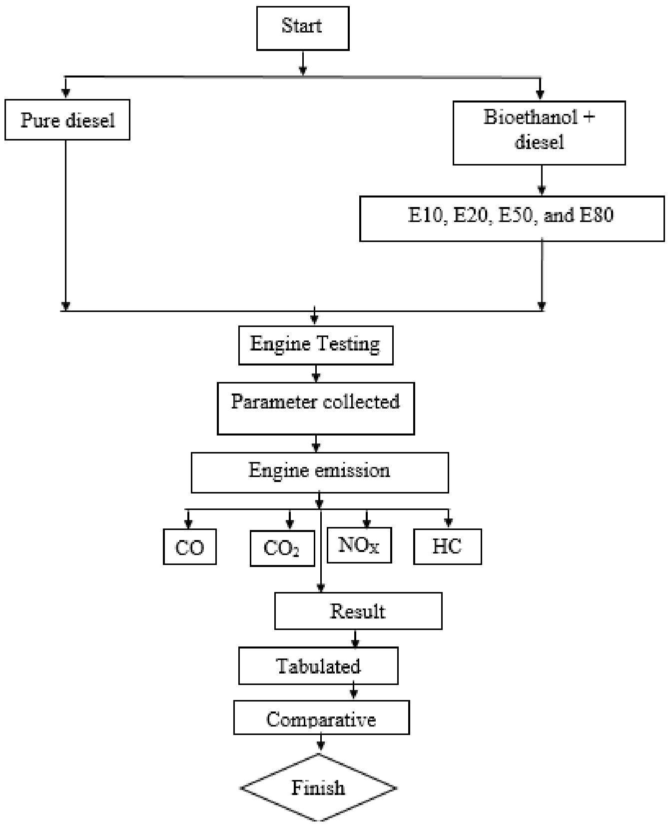

Figure 1 Overall methodology

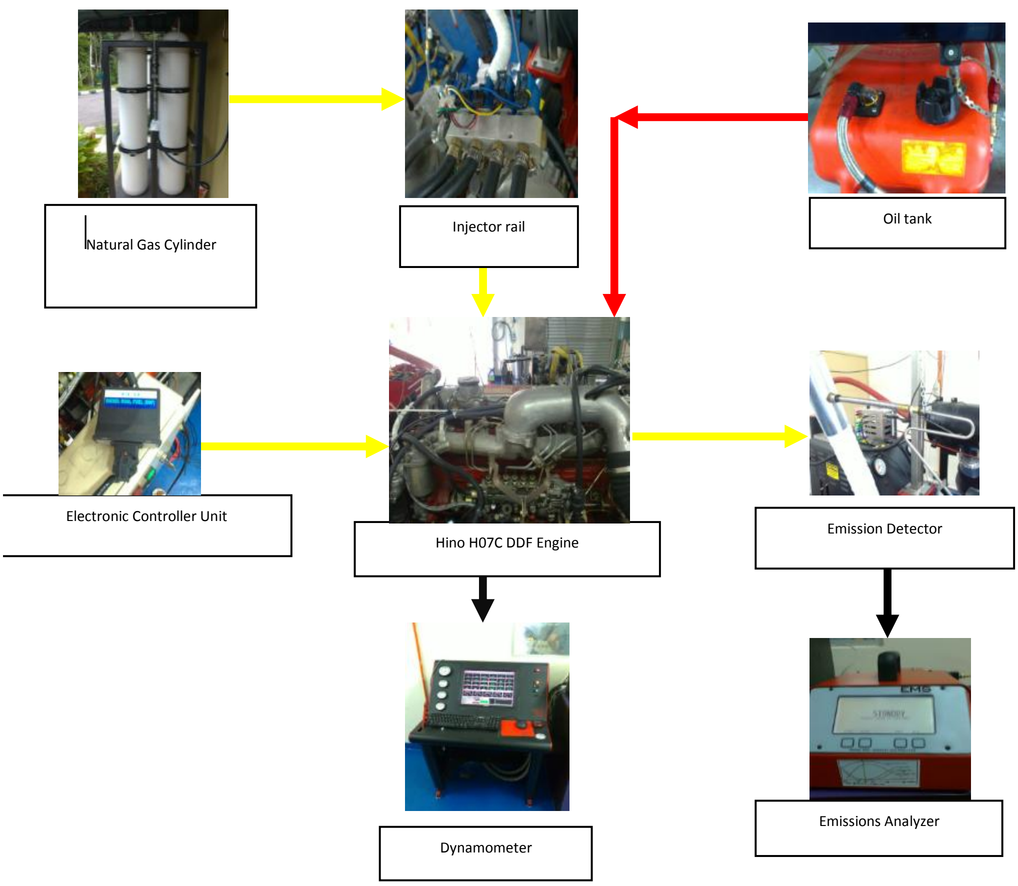

Figure 2 Experimental setup

Figure 3 Emission analyzer

Figure 4 Control panel

3. RESULTS AND DISCUSSION

Results from this experiment were found similar to the research findings from all over the world regarding bioethanol-blend fuel; achieving higher emissions of carbon monoxide (CO), carbon dioxide (CO_2), nitrogen oxide (NO_x) and unburned hydrocarbon (HC), respectively, but lower engine performance in terms of Engine Power and Engine Torque.

3.1. Engine Emissions

According to Shahir et al. (2015), the emissions of CO, CO_2, NO_x, and HC will be increased with the addition of bioethanol into Pure Diesel fuel. This had been observed, which indeed showed a similar trend in our experiment, as from the tested bioethanol fuels, the emissions of HC, and NO_x showed a significant increase, while emissions of CO_2 were observed to be consistent for all the fuels. Apart from that, the CO emissions showed different results, where there were lower emissions in E10 and E50 at the early speed of the engine. However, this trend gradually changed, showing similar outcome as in the previous research, where most bioethanol fuels resulted in more CO emissions. Figures 5 to 8 show the respective emissions levels. Similar results were found by Barabas et al. (2010), Zhu et al. (2011), and Labeckas et al. (2014) where the addition of bioethanol helps to reduce NOx, CO and HC particulates, respectively. The higher oxygen content in the bioethanol lowers the air/fuel stoichiometric ratio, thus reduces the aromatic content of the fuel, which in turn, reduces the carbonaceous soot (Su et al., 2013). Fuel oxygenation increases the auto-ignition delay and combustion pressure in turn reduces the CO emissions (Labeckas et al., 2014).

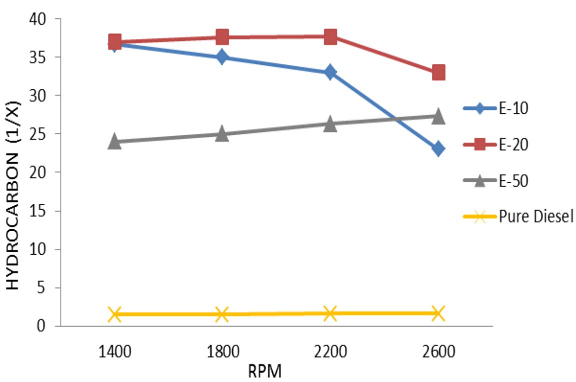

Figure 5 Unburned Hydrocarbon vs RPM

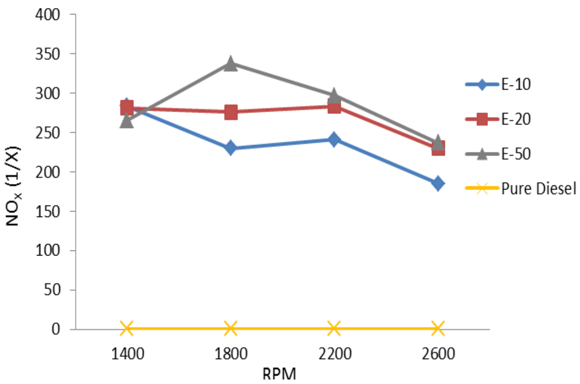

Figure 6 Nitrogen Monoxide (NO_X) vs RPM

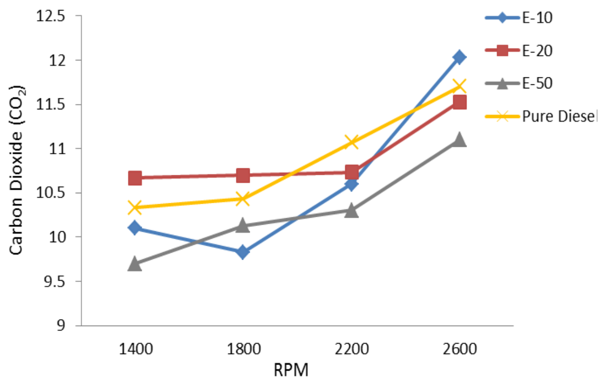

Figure 7 Carbon Dioxide (CO_2) vs RPM

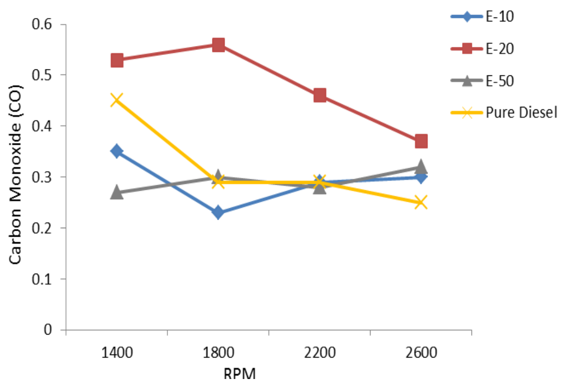

Figure 8 Carbon Monoxide (CO) vs RPM

3.2. Engine Performance

Shahir et al. (2015) also reported that the addition of Bioethanol into Pure Diesel will reduce the engine performance and efficiency in terms of Engine Power and Engine Torque. From the results, the addition of Bioethanol showed almost similar characteristics of performance as the engine tested using Pure Diesel fuel. The E20 fuel blend showed higher engine torque was achieved compared to Pure Diesel and other fuels. Figure 9 and Figure 10 show the results. The engine power and torque reduces as the portion of the bioethanol in the fuel blend increases. This is due to the low cetane number and calorific value and higher ignition delay of the blends, compared to diesel fuel (Can et al., 2004; Lu et al., 2005; Yan et al., 2009; Park et al., 2010). Meanwhile, the ignition delay occurred due to the consumption reaction of the hydroxyl radical (-OH), which retains the heat release (Hashimoto, 2007).

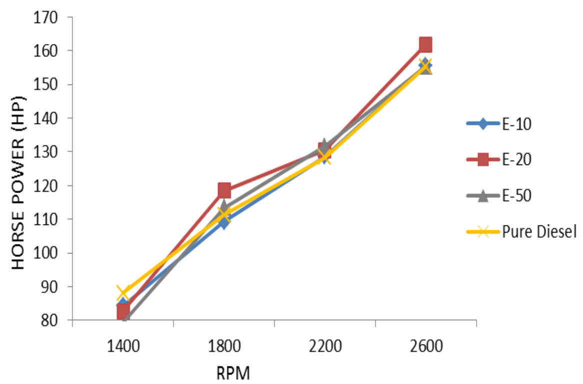

Figure 9 Horse Power vs RPM

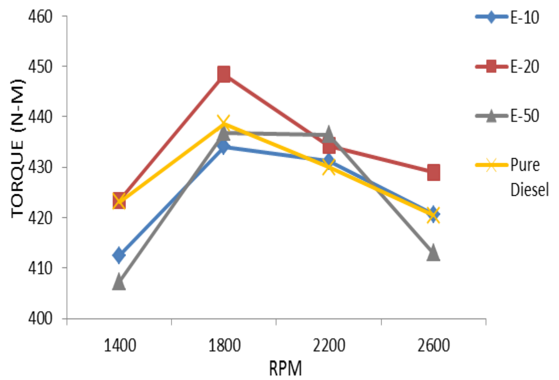

Figure 10 Torque vs RPM

4. CONCLUSION

Exhaust emissions of bioethanol–diesel blends deserve greater attention as the emissions profile may differ from Pure Diesel fuel, which is well-recognized and widely used. Apart from the aim to reduce the emissions of a Diesel engine fuelled by diesel-biodiesel, this research also aims to determine the effect on the engine performance when bioethanol-diesel fuel blends are used. This paper presents the use of five E10, E20, E50, and E80 diesel-bioethanol blends to reduce the emissions of a Diesel engine. However, the results show that there is significant increase in emissions and reduced engine performance when the engine is tested with Bioethanol fuel blends. The most suitable blend for the 6-cylinder Diesel engine is the blend of 10% of bioethanol with 90% of Diesel fuel, as it shows a slightly higher torque, though with similar performance as other Diesel fuels. Apart from that, it shows significant lower emissions of CO, CO_2, NO_x, and HC of about 10%, compared to other fuel blends.

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