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44 Performance Improvement of a Diesel Engine Using Additive in Palm Oil Methyl Ester

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Abstract: This paper presents experimental results carried out to evaluate performance and exhaust emissions characteristics of a turbocharged diesel engine when operated on anti-corrosion additive blended palm oil methyl ester. The palm oil methyl ester is also called biodiesel. A total of eight fuels were used including ordinary diesel fuel (OD) which was used for comparison purposes. The performance results such as brake power and specific fuel consumption (SFC) were measured using computer controlled eddy current dynamometer and load cell arrangement respectively. The emissions results such as CO, CO_2, NOx and HC were measured using Bosch and Bacharach exhaust analyzers. The results show that anti-corrosion additive is effective to enhance turbocharged engine brake power and to reduce exhaust emissions including NOx emissions. From the overall test results, fuel B20+1% (20% biodiesel with 1% additive) were found as a promising alternative fuel for diesel engine.
Keywords: Additive, Biodiesel, Emissions, Brake Power and SFC.

1. INTRODUCTION

Diesel engine sector forms a vital part of transportation systems in all the developed and developing countries in the world due to their high fuel efficiency as compared to other conventional fuels. However the increasing price of fossil petroleum fuels together with the environmental concerns has brought a renewed focus on biodiesel fuels.

Pure biodiesel is biodegradable, nontoxic and essentially free of sulfur and aromatics. In Malaysia, biodiesel was made from palm oil as a renewable resource which is grown anew each year. This fuel is called Palm Oil Methyl Ester (POME) or Palm Oil Diesel (POD). It is produced domestically, hence reducing this country's dependence on foreign oil. It requires no engine modifications or changes in the fuel handling and delivery systems. Biodiesel delivers more or less similar torque, horsepower and miles per gallon as compared to conventional fuels. However some vehicle hoses may need to be checked after the first 6 months of operation on biodiesel. Replacement of non-compatible hoses may be necessary, but is not usually difficult or expensive [**1**]. Blends of 20% or less tend to have little effect, even on non-compatible hoses. Biodiesel used in a 20 percent blend with petroleum diesel and a catalytic converter will cut air pollution. Particulate matter is reduced 31 percent, carbon monoxide by 21 percent and total hydrocarbons by 47 percent. Biodiesel used in a blend will also reduce sulfur emissions and aromatics [**2**].

The low performance of engine powered by biodiesel could be improved by using a turbocharger. Turbocharger is believed as a significant additional equipment to increase the engine performance especially power output. Furthermore, the significant side effect of turbocharger usage on diesel engine *running* on biodiesel is rarely reported. On the other hand, emission from diesel engines have been reported were affected by factors such as fuels, lubricant, exhaust after-treatment device and driving conditions [**3, 4**].

This paper presents the experimental results of an Indirect Injection Turbocharged Diesel engine exhaust emissions while running with Palm Oil Methyl Ester (POME) blended anti-corrosion additive as fuels. This investigation focused on the significant effects of additive on POME-Diesel blended fuels. However, the conventional Diesel #2 (OD) fuel was blended with 20% (B20) and 35% (B35) POME by volume. Moreover, the blended fuels were also added with 1-2% anti-corrosion additive in order to upgrade several properties of POME-Diesel blended fuels.

2. Experimental set-up and apparatus

Tests were carried out with conventional diesel fuel powered natural aspirated engine as the baseline study. The similar engine was coupled with turbocharger for the next test stage. At this stage, 20% and 35% biodiesel blended diesel fuels as well as conventional diesel fuel were used to obtain the comparison results.

The tests were conducted at the Heat Engines Laboratory of Mechanical Engineering Department, University of Malaya based on the SAE Recommended Practice. The Isuzu 4FBI four-cylinder diesel engine which is controlled by CP CADET 10 Data Acquisition System was used in this experiment. The engine specification and the details of instrumentation have been fully described by Masjuki *et.al* [**5**]. The engine is operated between 1000 to 4000 rpm. The exhaust emissions were measured by using a HORIBA MEXA 9100-D Gas Analyzer. Meanwhile, the fuel blends were prepared at the laboratory by blending conventional diesel with biodiesel by using a homogenizer dispersion system to achieve a homogeneous fuel blend between diesel fuel and biodiesel. The characteristics of fuels were also obtained using several instruments in accordance with ASTM methods. Table 1 shows some obtained important characteristics.

Table 1. Fuel Characteristics of biodiesel blended fuel and Conventional diesel (OD)

Properties	OD	B20	B35	B100
Calorific value MJ/kg	45.8	44.74	44.26	39.21
Kinematic viscosity (cSt) at 40 ^{o}C	3.60	4.05	4.15	5.85
Cetane index ASTM D976	53	52	50	37
Conradson carbon residue ASTM D198%wt	0.14	0.01	0.03	-
Sulfur content %wt	0.1	0.03	0.04	-

Additive: IRGANOR NPA (Product name) has been used as a corrosion inhibitor for fuels. When it is added to the fuels, the metal protections, limit the formation of ions which catalyse oxidation processes to gum formation.

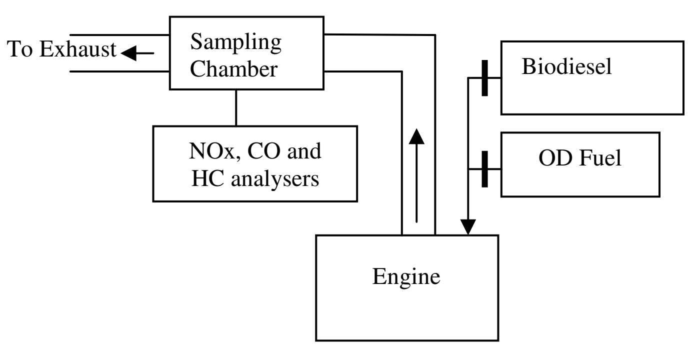

Figure 1: Schematic diagram of experimental set-up

3. RESULTS AND DISCUSSIONS

All the tests and data analysis were performed for different fuels in the Tribology Laboaratory, Department of Mechanical Engineering, University of Malaya. The data were used to evaluate differences in these fuels and to serve as a basis for comparison of the blended fuels.

3.1 Brake power output

The results of brake power output from turbocharged diesel engine for every fuel test with different percentages of additive added biodiesel fuels are shown in Fig.2. It can be seen that fuel “B20+1%” produces higher brake power over the entire speed range in comparison to other fuels. It is found that fuel “B20+1%” produces an average of 11.60 kW brake power over the entire speed range which is 1.70% higher than fuel B20. This can be attributed to the effect of fuel additive in B20 blends which influences the conversion of thermal energy to work or increases the fuel conversion efficiency by improving the fuel ignition and combustion quality (complete combustion). However, for B35 fuel with additive the brake power output shows more or less similar result as conventional diesel fuel. This is due to higher fuel viscosity which affects to the stabilization of fuel penetration into the combustion chamber. This phenomenon will diminish the engine performance especially on engine brake power. Details of brake power results for other fuels can be seen in Fig.2.

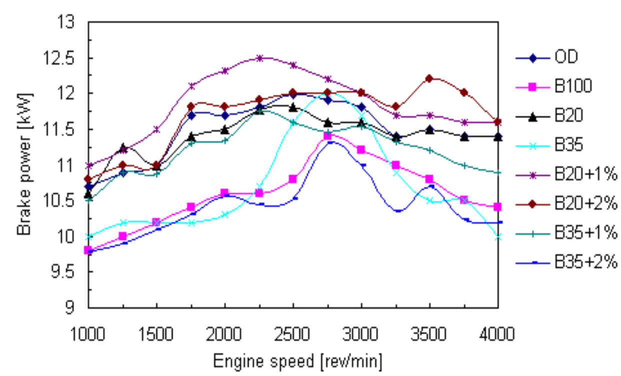

Figure 2: Brake Power Output vs. Engine Speed

3.2 Specific fuel consumption

Fig. 3 shows specific fuel consumption (SFC) for all the fuels. It can be seen that increasing biodiesel in diesel fuel causes fuel consumption to increase. This is mainly due to value (**6**) which produces higher SFC. Meanwhile, it is

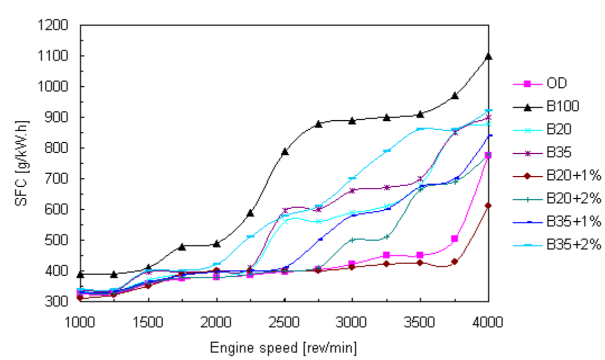

Figure 3: Specific Fuel Consumption vs. Engine Speed

found that B100 consumes an average of 707 g/kW.h fuel with immediate volumetric effect of constant fuel injection rate. Fuel with higher density and viscosity together with lower calorific followed by B35 and B35+2% and so on. It can also be seen that fuel B20 consumes an average of 536 g/kW.h and fuel B20+1% consumes 405 g/kW.h which is the effect of additive in fuel B20. Fuel B20+1% shows lowest level of SFC which is even lower than even OD fuel.

3.3 Oxides of Nitrogen (NO_x) emission

The effect of biodiesel blended additive on Nitrogen Oxide (NOx) concentration is shown in Fig. 4. It is found that the NOx concentration decreases with additive percentage increased in the fuel blends. The result shows that by turbocharging, NOx is reduced especially while engine is running on B20+1% fuel with additive. This phenomenon shows that B20+1% fuel is the optimum composition in order to achieve better fuel quality with less NOx formation. In addition, with the presence of additive, the combustion temperature could be reduced which in turn controls the formation of NOx. Another explanation to the phenomenon of low NO_x formation is that with the presence of additive in B20 fuel the flame temperature during combustion could be maintained. Besides that, the additives also prevent the creation of additional heat inside the cylinder by cylinder wall friction with the piston. This condition causes a decrease in heat loses inside the cylinder which affects to complete fuel combustion process. This condition was also observed by several researchers who conducted some studies in terms of flame and combustion stability of oxygenated and renewable fuels. (**7**,**8**). Over the entire speed range, B20+1% fuel produces an average of 96 ppm and fuel B20 produces 125 ppm. Hence the 29 ppm reduction is due to the effect of 1% additive in B20 fuel.

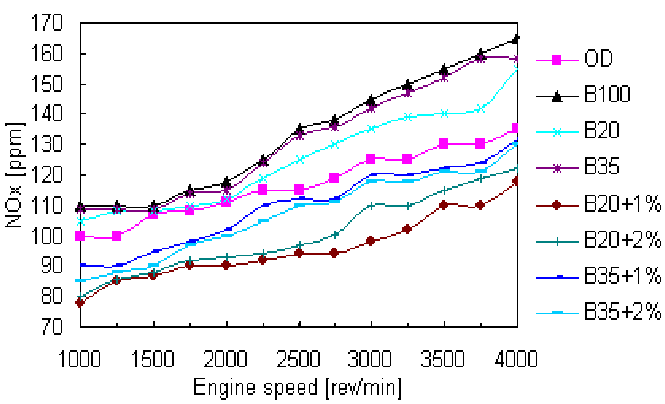

Figure 4: NOx concentration vs Engine Speed

3.4 Carbon Monoxide (CO) emission

Carbon monoxide is formed during the combustion process with rich air-fuel mixtures regions and when there is insufficient oxygen to fully burn all the carbon in the fuel to CO_2. Normally a diesel engine uses more oxygen (excessive air) to burn fuel which has a little effect on CO emissions. However, since the operating conditions are exclusively lean, the CO concentration value for all the fuels is less than 1% as shown in Fig.5. It is found that among all the fuels, fuel B20+1% produce lowest level of CO emissions which is on average of 0.142 %, B20 is 0.212% and OD is 0.295% on average. The difference between B20+1% and B20 shows the effect of additive in Biodiesel fuel especially with B20 fuel. The details results for all the fuels are shown in Fig.5.

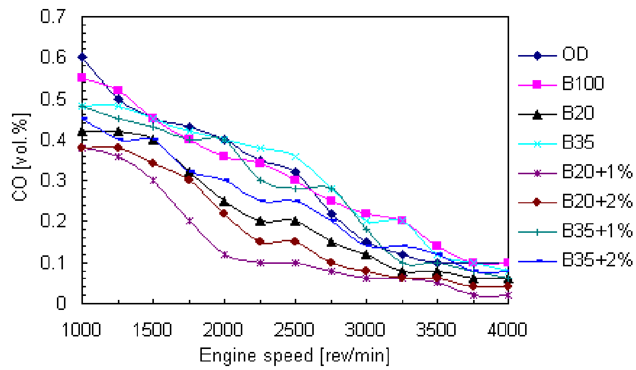

Figure 5: Carbon Monoxide concentration vs. Engine Speed

3.5 Hydrocarbon (HC) Emission

Fig.6 shows HC emissions for all the fuels. It is found that fuel B35+2% produces lower level of HC emission followed by B35+1%, B20+1%, B20+2%, B100, B35 and OD fuels respectively. The maximum level of HC was produced by OD fuel. It can be seen that additive added biodiesel fuel produces comparatively lower level of HC as compared to OD fuel. This is mainly due to complete combustion which occurs with biodiesel-additive mixture.

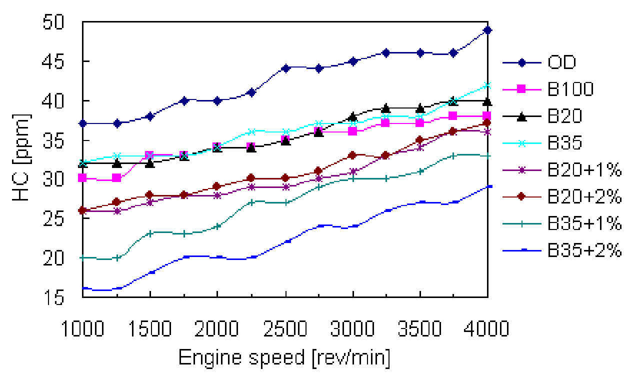

Figure 6: HC concentration vs. Engine Speed

3.6 Exhaust Temperature

Fig. 7 shows the effects of biodiesel blended fuels with and without additive on exhaust temperature of an indirect injection turbocharged-diesel engine. The trends of exhaust temperature shown for all the fuel tests are similar. However, biodiesel blended fuels with additive produces lower exhaust temperatures as compared to OD fuel. The presence of additive maintains combustion temperature by increasing fuel thermal conversion efficiency.

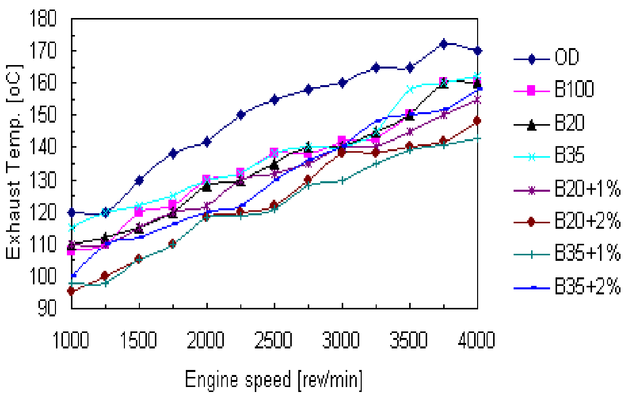

Figure 7: Exhaust Temperature vs. Engine Speed

3.7 Carbon Dioxide (CO_2) emission

Fig. 8 illustrates the variation of carbon dioxide (CO_2) as a function of speed. It is observed that fuel B20+1% reduces CO_2 compared to other blended fuels. The ability of this particular fuel blend to produce low amount of CO_2 is found beneficial to the environment and this fuel might be a promising fuel as compared to other fuels.

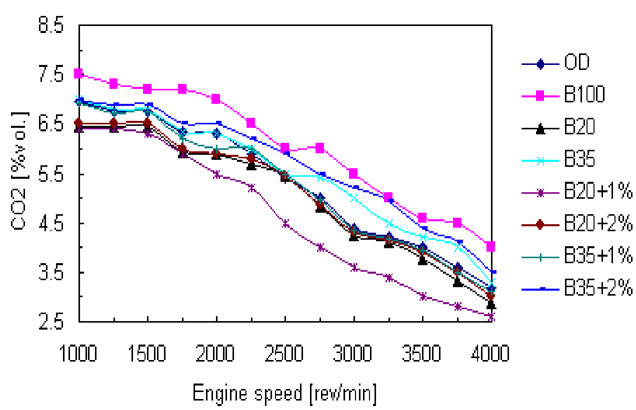

Figure 8: CO_2 concentration vs. Engine Speed

Meanwhile, fuel B100 produces highest level of CO_2. However, the amount is considered negligible taking into account that CO_2 will be returned to the palm tree plantation. Moreover, diesel engine is not a significant contributor of CO_2 formation, because this engine uses excess air during the combustion process.

Diesel engine is also known as a higher efficiency engine compared to spark ignition (SI) engine due to the high pressure of the piston which helps combustion efficiency.

4. CONCLUSIONS

The following conclusions may be drawn from the present investigation:

1. Fuel "B20+1%" produces 1.7% and 8% higher brake power as compared to fuel B20 and OD respectively.
2. Fuel "B20+1%" consumes 25% and 6% lower SFC as compared to fuel B20 and OD respectively.
3. Fuel "B20+1%" reduces CO, NOx and CO_2 emissions as compared to other fuels.
4. Fuel "B35+2%" reduces HC and Fuel "B35+1%" reduces exhaust temperature as compared to other fuels.

Hence, it is found that there is a benefit in addition of additive in biodiesel in terms of better Brake power, SFC and emissions performance.

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