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Diesel engine performance and exhaust emission analysis using diesel-organic germanium fuel blend

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Abstract. Alternative fuels such as biodiesel, bio-alcohol and other biomass sources have been extensively research to find its potential as an alternative sources to fossil fuels. This experiment compared the performance of diesel (D), biodiesel (BD) and diesel-organic germanium blend (BG5) at five different speeds ranging from 1200-2400 rpm. BG5 shows significant combustion performance compared to BD. No significant changes of power observed between BG5 and BD at a low speed (1200 rpm). On the contrary, at higher speeds (1800 rpm and 2400 rpm), BG5 blend fuel shows increased engine power of 12.2 % and 9.2 %, respectively. Similarly, torque shows similar findings as engine power, whereby the improvement could be seen at higher speeds (1800 rpm and 2400 rpm) when torque increased by 7.3 % and 2.3 %, respectively. In addition, the emission results indicated that for all speeds, CO_2, and NO had reduced at an average of 2.1 % and 177 %, respectively. Meanwhile, CO emission had slightly increased compared to BD at low speeds by 0.04 %. However, the amount of CO released had decreased at an average of 0.03 % as the engine speed increased. Finally, measurement of O_2 shows an increment at 16.4 % at all speed range.

1 Introduction

Nowadays, the use of diesel engines in motor vehicles and electric generators has tremendously increased due to its higher efficiency and better performance compared to gasoline engines. Nevertheless, the diesel engine produces major problems associated with combustion characteristics and exhaust emissions such as a high NO_x and smoke emission in spite of yielding lower HC and CO[1, 2]. In order to improve diesel fuel properties and obtain lower exhaust emissions, various investigations on alternative liquid and gas fuels were performed.

Researchers reported that there are several ways of improving the self-ignitability of fuel such as increasing the compress ratio, adding an extra spark plug and redesigning the combustion chamber. On the other hand, another simple and efficient way is by adding a certain amount of cetane improvers to the fuel [3-5]. The function of cetane improvers is to

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shorten the ignition delay period and accelerate the burning rate of the fuel. Normally, the maximum amount of improvers added to diesel fuel is not more than 5% [6]. Meanwhile, the utilization of metal additives is an elective decision aimed towards better engine performance and decreasing pollutants in diesel engines. Metal additives have reactant impact with respect to enhancing the combustion process. These additives function as a combustion catalyst to promote combustion and decrease fuel consumption by reducing pollutant emissions. The metal work used reacts with water vapor to process hydroxyl radicals or specifically responds with carbon atoms as a catalyst, thereby discharging oxidation temperature [7-9]. Consequently, remarkable reductions in smoke and CO emissions were obtained. In order to determine the impact of metal-additive fuel properties and engine performance-emission characteristics, different metal additives such as titanium, manganese, iron, platinum, barium and cerium were investigated in numerous studies [8, 10-13]. The results indicated that metal additives helped fuel consumption in aspects such as viscosity, streak point, pour point, calorific value and cetane value. Furthermore, the characteristics of engine performance and emission improved significantly.

In this experiment, bis-carboxyethyl germanium sesquioxide also known as organic germanium (Ge-132) was blended with pure diesel and biodiesel fuel. Germanium is a chemical with physical properties similar to silicon and has a jewel similar to a crystalline structure. When organic germanium blends into diesel fuel, the blend shows an increase of oxygen content due to the organic germanium function is by attach to the oxygen molecules. Germanium is one of the element inside the carbon group in periodic table with carbon (C), silicon (Si), tin (Sn), lead (Pb) and flerovium (Fl) and it can easily reacts to form complexes with oxygen in nature. In addition, germanium is stable in air and water and also unaffected by alkalis and acids.

The purpose of this research is to evaluate diesel engine performance and exhaust emissions by using organic germanium (Ge-132) blend with pure diesel and biodiesel. The engine performance parameters included power and torque with data collected from experiments on the test engine. The emission parameters measured during the engine performance test were CO_2, CO, O_2 and NO.

2 Experimental setup

Three fuel types were used in the experiments. Organic germanium was blended with biodiesel using a mechanical stirrer at speed of 2000 rpm. The biodiesel–germanium blend was prepared with 5 mg organic germanium concentration by volume basis (BG5) while other test fuels are pure diesel (D) and biodiesel (BD). The data extracted for the blend was then compared with pure diesel and biodiesel. The measurement of the fuel properties was collected which all the biodiesel complied with standard ASTM. The chemical properties for all types of fuel are shown in Table 1:

Table 1. Physicochemical properties of test fuels.

Properties	Diesel	Biodiesel	BG5
Density (g/cm^2)	0.843	0.85	0.83
Cetane number	46.6	52.2	46.4
Kinematic viscosity at 40^o C (cst)	3.718	4.57	4.29
Calorific value (MJ/kg)	42.32	46.1	NA
Cloud point (^{o} C)	-3	-8.3	NA

The experimental test was performed using YANMAR TF120M single–cylinder, direct injection, four-stroke diesel engine. The specifications of the test engine are listed in Table 2. Figure 1 shows the schematic diagram that represents the experimental setup. The fuel control unit consists of two tanks; the diesel fuel tank and the alternative fuel tank. A hydraulic type dynamometer employed to apply load to the engine. All the data were collected and processed using the DAQ by TFX Engineering. The parameters measured and analyzed in this project were engine power, torque and exhaust emissions. Engine speed was in the range of 1200 rpm, 1500 rpm, 1800 rpm, 2100 rpm and 2400 rpm and at 30% load.

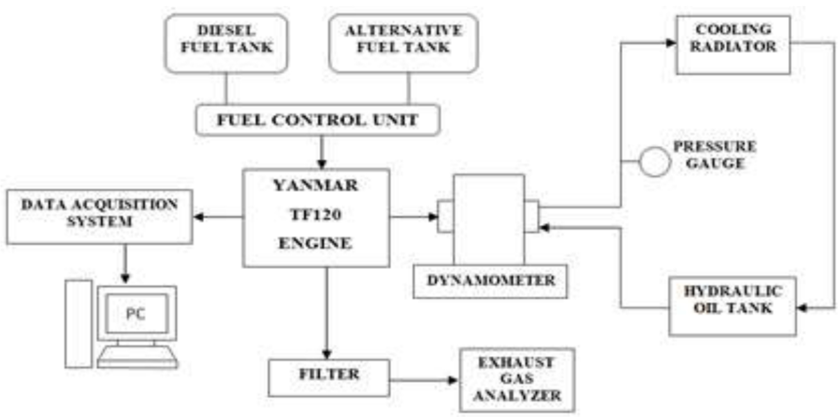


Fig. 1. Schematic diagram of an experiment setup.

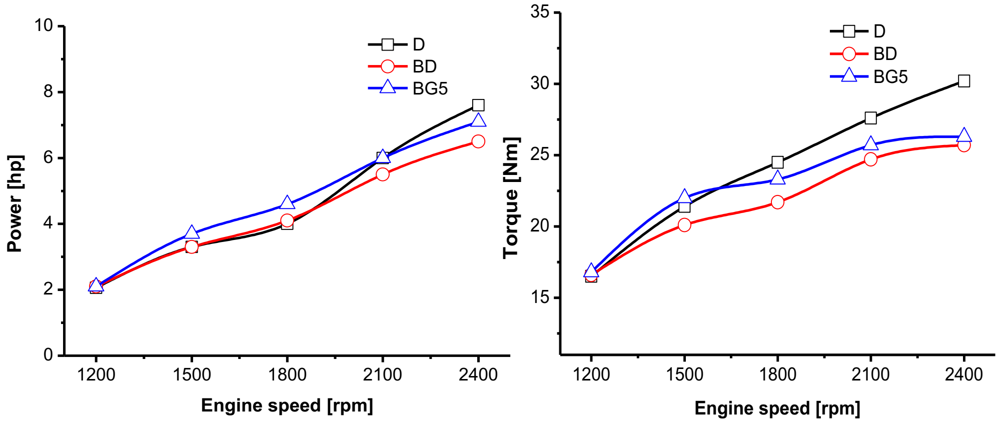
Table 2. Engine specification.

Description	Specification
Engine model	YANMAR TF120M
Engine type	Single cylinder, horizontal, diesel 4 stroke cycle
Combustion system	direct injection
Number of cylinders	1
Bore x stroke (mm)	92 x 96
Displacement (L)	0.638
Injection timing	18° BTDC
Compression ratio	17.7
Continuous output (HP)	10.5 HP at 2400 rpm
Rated output (HP)	12 HP at 2400 rpm

3 Results and discussion

3.1 Power performance

Figure 2(a) shows the graph for engine power at all engine speed for D, BD and BG5. From the observations, BG5 overall power was larger than BD at all speeds. In addition, at low speeds of 1500 rpm, the increase of BG5 compared to D and BD was at 12.1 %. At a medium speed of 1800 rpm, the power increment of BG5 was 15 % and 12.2 % compared to D and BD, respectively. At a high speed of 2400 rpm, BG5 showed a power increase of 9.2 % compared to BD, while a reduction of 6.5 % compared to diesel.



a) b)

Fig. 2. Comparison of (a) engine power and (b) engine torque for all test fuel.

Overall, the engine power is increase proportionally with the increment of engine speed for all test fuels. Additionally, BD high density and viscosity resulted in poor atomization and uneven combustion, therefore producing low levels of power [14]. The high density and kinematic viscosity of BD produce large size droplets during fuel injection into the combustion chamber, affecting the vaporization process and leads to incomplete combustion. Comparatively, the power produced by BG5 was higher than BD, which leads to the conclusion that BG5 is a more effective fuel than BD in terms of the combustion process.

3.2 Torque performance

Referring to Figure 2(b), at low to medium engine speeds of 1200-1500 rpm, BG5 torque was the highest compared to other fuels. The highest torque was measured by BG5 (22 Nm) followed by D (21.4 Nm) and BD (20.1 Nm). However, from 1600-2400 rpm, D torque had overtaken that of other fuels. The largest difference in percentage of D compared to BG5 was 12.9 % at a speed of 2400 rpm. Torque for BG5 was higher than BD at all ranges of speed. BG5 average percentage of BG5 was 4.8% higher than BD. Nevertheless, at higher speeds of 2400 rpm the percentage difference between BG5 and BD got smaller at 2.3 %. D torque showed an increase from a medium speed of 1800 rpm to a high speed of 2400 rpm.

Overall observation shows the torque graph shows that it is directly proportional, which is similar to the power. Pure diesel (D) marked the highest compared to BD and BG5 due to its low kinematic viscosity value among all test fuels. Torque increases because of complete combustion due to the good atomization of fuel, which then produces droplets in low density, calorific value and viscosity that is easier to vaporize. BD showed the lowest values in torque compared to all other fuel types. Again, the high density and high kinematic viscosity of BD resulted in lower velocity of air fuel mixtures, lack of turbulence, and the lack of mixing air and fuel particles in the combustion chamber, which affected combustion efficiency when compared to diesel [15]. On the other hand, BG5 produced good results when compared to BD. Adding germanium into fuel will increase higher combustion temperature thus improve combustion characteristics, leading to the efficient combustion process.

3.3 NO emission

Figure 3(a) shows the variation of NO emissions for the test engine with BG5, in reference to diesel fuel. NO emission decreased as engine speed increased for fuel type. At a low speed of 1200rpm, D shows the lowest emissions compared to other fuels. At low and medium engine speeds, the percentage difference between BG5 compared to D increased by 47.8% and 22.69%, respectively. Meanwhile, NO exhaust from BG5 compared to BD reduced by 8.5% and 25.13%, respectively. Moreover, at high speeds the pattern was similar when compared to low and medium speeds. Trend for NO emissions for all test fuel were declined gradually with the increment of engine speed. Among all the fuels, the highest NO was emitted by BD followed by BG5 and D. The results can be correlated with the value of kinematic viscosity of the fuel. BD has the highest kinematic viscosity at 4.57 cst compared to D at 3.718 cst and BD5 at 4.29 cst. In addition, high density of BD at 0.85 g/cm^2 contributes to the trend. The overall results show that addition of Ge-132 into BD could reduce the NO emission.

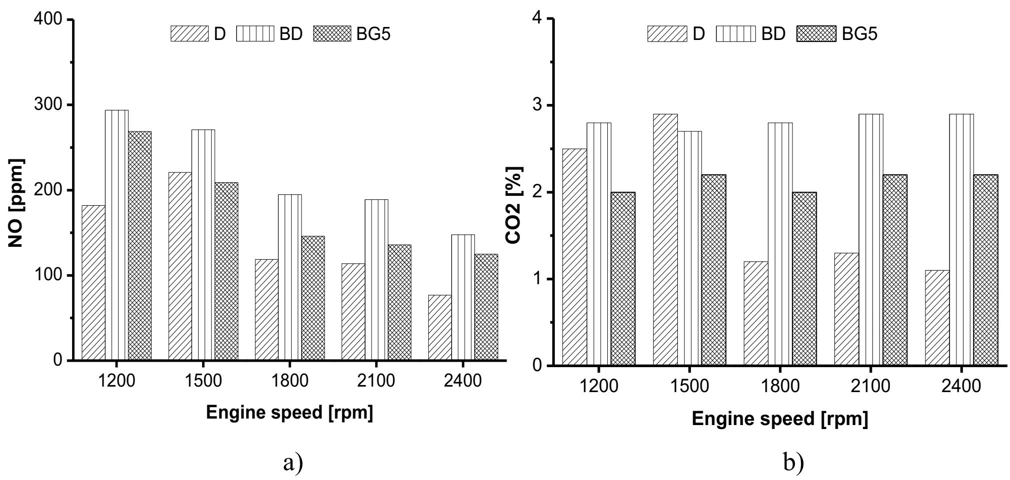


Fig. 3. Effect of test fuel on (a) NO emission and (b) CO_2 emission.

3.4 CO_2 emission

CO_2 emission is generated by the complete burning of fuel and it is a critical part in worldwide warming. Research has shown that carbon discharged during combustion of biodiesel is absorbed by plants through the process of photosynthesis [16-18]. As shown in Figure 3(b), BD has the highest CO emission among all types of fuels. Referring to Table 1, BD had the highest calorific value of 46.1 MJ/kg compared to BG5 and D. Figure 3(b) shows that the CO_2 emission of BD on average was 2.8 %, which was higher than that of diesel at all engine speeds. It is clear that BD marked the highest CO_2 emissions at all engine speeds. Overall, when comparing BG5 to BD for CO_2 emission, there was a decrease of 24.8 %. As compared to D, the overall average reduction was 1.8 % when BD was compared to BG5; there was a reduction of 2.1 %. Similar to BD, BG5 showed constant CO_2 emissions for all engine speeds. On the contrary, D showed an increasing trend of emissions at low engine speeds until 1500 rpm. At higher engine speeds from 1800-2400 rpm CO_2 emissions released by D was reduced by 0.028 %. At a speed of 1800 rpm the CO_2 emissions by BG5 increased to 66.6 % when compared to D. From a medium engine speed to a high engine speed, the percentage of increase by BG5, when compared to D, was by 66.7 % and up to 100 % at 2400 rpm.

3.5 CO emission

For overall CO emissions, Figure 4(a) shows that the trend is similar to CO_2 emissions, where BG5 at low engine speeds had decreased CO emissions while at medium to high engine speeds the trend for BG5 was constant. For D at low engine speeds, the graph showed that there was an increase of CO emission but at medium speed the CO emission for D dropped by 0.04 %. When at high speeds, CO emissions for D became constant with small changes. At low engine speeds, CO emission for BD decreased, while at medium to high engine speeds, the trend of the emissions had increased. When comparing BG5 with D at low engine speeds, the trend graph decreased, while at medium engine speed and the percentage increase by 50 %. At a high speed, there were small changes between BG5 and D. When comparing BG5 with BD, BG5 show an increment by 33.3 % at 1200 rpm but there was no change in value at 1500 rpm. However, at speeds of 1800 rpm, 2100 rpm and 2400 rpm, BG5 when compared to BD had decreased by 25 %, 50 % and 62.5 %, respectively.

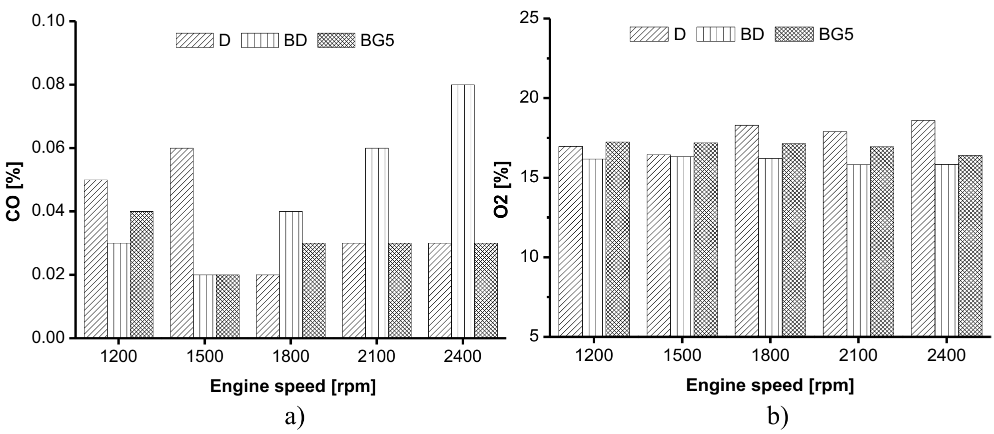


Fig. 4. Effect of test fuel on (a) CO emission and (b) O_2 emission.

3.6 O_2 emission

Figure 4(b) shows O_2 emission emitted by all test fuels. Among all test fuels, D record highest O_2 emission at all engine speed. Meanwhile, BD shows that the trend of O_2 emission from a low engine speed to a high engine speed is constant, although there were small changes. Similar, BG5 also showed a constant according to the graph. Moreover, at low engine speeds, emissions by BG5 increased by 1.6 % compared to D. However, at medium and high engine speeds, emissions by BG5 had reduced by 6.4 % and 11.9 %, respectively. Besides that, when BG5 was compared to BD, the graph showed that emissions by BG5 were the highest from 1800 rpm until 2400 rpm. At low engine speeds, emissions by BG5 increased by 6.6 % while at medium and high engine speeds BG5 showed that emissions increased by 5.7 % and 3.47 % when compared to BD.

4 Conclusions

The research had compared the engine performance in terms of engine power, engine torque and exhaust emission characteristics of diesel (D), biodiesel (BD) and biodiesel (BG5). The findings show that the power and torque characteristics of BG5 blends were almost similar in trend with D and better than BD. BG5 shows highest engine power among all fuel while D shows highest engine torque at all engine speed. BD marked lowest at engine power and torque among all fuel at all engine speed. Moreover, BG5 also showed reduced NO, CO_2 and CO emissions when compared to biodiesel. However, addition of germanium in biodiesel BG5 resulting an increment of O_2 emission compared to BD at all engine speeds. This is due to the addition of organic germanium results an increment of oxygen content inside the fuel blends. In general, the overall results indicate that BG5, as a new additive fuel, could be used as a diesel substitute without any modification to the engine and for long-term use.

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