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Multifunctional Additives for Biodiesel Blends Application in Diesel Generator

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Abstract. The use of a 30 percent biodiesel blend in diesel fuel (B30) has been tested in various diesel engines, including a generator. It shows certain benefits, but on the other hand, there are still several technical problems. The most apparent reported issues are energy loss, increased fuel consumption, CO, UHC, PM, and NOx emissions. Using an additive is an advisable and straightforward way to solve these problems. In this study, the commercial additives 2-Ethylhexyl Nitrate (EHN) and Methyl tert-Butyl Ether (MTBE) were mixed into a combination and multifunctional additive for B30 application. Fuel with additives in various compositions and concentrations were then tested on a generator (Vanco DF-2400E). It was operated for 180 minutes with a constant load. This study shows that the generation of electric voltage is more stable through the addition of additives. The most stable electrical conversion is shown by using a combination of additive H3 (MTBE: 2-EHN=70%: 30%v). The introduction of additives has also reduced the Specific Fuel Consumption, where the combination of H1 (MTBE: 2-EHN=50%: 50%v) showed the highest decrease up to 11.9%. This study concludes that the ratio of additives to fuel does not linearly affect generator performance. Low additive concentrations (2%) are still performing better combustion quality in the generator with B30. However, the arrangement of the combustion chamber and air intake control features are required to achieve optimum performance.

INTRODUCTION

In Indonesia, the program to utilize a blend of 30% biodiesel in diesel fuel (B30) has been implemented and continues to develop. The Indonesian government has issued a mandatory biodiesel blend in diesel engines in all sectors. This program is temporarily claimed to be successful, especially in automotive engines. The use of biodiesel has a positive impact on emissions reduction. Moreover, biodiesel may displace the need to import diesel fuel and economically supports the development and use of Indonesian palm oil products.

Generators are commonly used in industrial, household and commercial applications. The working principle of the generator is transforming kinetic energy into electricity. The system of this engine is relatively simple compared with automotive engines. It means that if the application of B30 on a vehicle engine is considered to have a minimum of issues, then the application on a generator should have a similar effect. However, there are still limited comprehensive test results on using higher blend biodiesel in generators or typical diesel engines. Some believe that biodiesel has a good effect on emissions, but there are still concerns about engine performance and durability. Several potential problems that require frequent engine maintenance are a concern for engine users. Failure of engine operation is greatly avoided because it is economically very detrimental.

The effect arises due to biodiesel in generators generally being the same as the reported effect of tests on typical static diesel engines. It is reported that there are tendencies to increase fuel consumption [1–5], a decrease in engine

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power [4,6,7], the increase of NOx and unburnt hydrocarbon or particulates [8,9], and problems related to electricity production stability [10,11] the existence of knocking [10,12,13], filter clogging [14–16], and others.

One practical way to prevent engine performance degradation and operation failure in diesel engines is to use fuel additives. Fuel additives have played a very broad role and continue to grow. The role of additives is to overcome the specific engine operational problem or potential performance degradation affected by the fuel and the type and dosage of additives for diesel fuel depending on the level of the specific problems and the engine requirements.

As so many fuel performance parameters need to be maintained and enhanced, the development of multifunctional additives is urgent. Besides optimum performance and economic considerations, the side effects of using additives should be avoided. The use of additives is intended to achieve the smallest possible dose. In the case of the use of biodiesel, it is necessary to have multifunctional additives that enhance fuel economy while minimizing emissions. Combined packages of several selected additive components can be assembled to provide a customized performance for biodiesel application in generators.

Various tests of biodiesel applications and the role of additives in generators have been reported by several authors [1,6,16–19]. Almost all of them demonstrate that specific engine problems are resolved and overcome with the use of additives.

Previous studies have shown that fuel consumption tends to be higher, and electricity production is unstable due to biodiesel blends as fuel in generators. In this study, two commercial additives will be combined, namely 2-Ethylhexyl Nitrate (EHN) and Methyl tert-butyl ether (MTBE). Both are commonly used for diesel fuel. 2-EHN is more commonly known as a cetane enhancer, while MTBE is an oxygenated additive.

The efficacy of the combination of both additives has been tested at a variety of dosages. Furthermore, it is examined in terms of generator performance, emissions, and the production of electrical voltage during operation. The objective of this study was to guide the use of highly mixed biodiesel in diesel generators. Moreover, the choice of type, composition and dosage of the most appropriate additives for B30 applications will be known. Consequently, potential technical problems can be avoided, and the mandatory biodiesel program will effectively be applied to all types of machinery in various user sectors.

MATERIALS AND METHODS

The generator used for this work is a diesel generator Vanco DF-2400E with elements shown in Fig. 1. This generator is a common type for small industrial sectors and households designed for diesel fuel. Table 1 provides the technical information of the generator. The fuel used is a mixture of palm-based biodiesel from the oleochemical industry and diesel from the petrol station.

a. Dynamo starter
b. Cooling system
c. Alternator
d. Accumulator
e. Intake air
f. Fuel injector
g. Exhaust gas port
h. Fuel injection pump
i. Fuel tank
j. Governor
k. Fuel tank cap
l. Fuel level indicator

FIGURE 1. Components in Generator Set Vanco DF-2400E

TABLE 1. Specifications of the Diesel Generator

Model	**Horizontal, Air-cooled, 4-stroke**
Combustion System	Swirl combustion chamber
Total Cylinder/Dispacement (L)	1/ 331 (L)
Bore x Stroke (mm)	75 x 75
Compression Ratio	21±1
Rated power (kW)	3.68
Rated speed (r/min)	2600
Cooling System	Air-cooled
Lubricants System	Combined pressure and splashing
Starting Method	Hand cranking
Net Weight (kg)	≤50

The two basic additives selected in this work is Methyl Tert-Butyl Ether (MTBE) and 2- Ethylhexyl Nitrate (2-EHN). The specifications are presented in Table 2. Mixing is done simply without stirring because each additive is miscible. Before being inserted in the fuel tank on the generator, additives are mixed in B30 with a variation in the fuel ratio, which is 2; 3; 4 and 5%-v. The combined (multifunctional) additives are manufactured in three types according to the composition of the MTBE and 2-EHN mixtures, as shown in Table 3.

TABLE 2. The properties of fuel additives

	2-Ethylhexyl Nitrate	**Methyl tert-butyl ether (MTBE)**
Formula	$C_8H_{17}NO_3$	$(CH_3)_3COCH_3$
Major function	Cetane Number Improver	Oxygenated additives
Appearance	Liquid, Colourless to Yellow	a colourless liquid, flammable, a distinctive anaesthetic-like odour
Density	0.963 g/mL at 25 °C (lit.)	0.74 g/mL at 25 °C (lit.)
Boiling point	210.90° C at 760 mmHg	55.2 °C
Flashpoint	70°C	−33.0 °C
Kinematic viscosity	2.76e-3 inch2/s (1.78 mm2/s)	0.36 cP at 25 °C
Molecular weight	175.23 g/mol	88.15 g/mol

For each test of the study, the diesel generator was operated at least for 180 minutes. The observation is started when the engine is turned on. The experimental parameters include engine knocking, smoke opacity, CO emissions, O2 concentration, exhaust gas temperature and electrical voltage.

The electrical voltage was measured using the digital multimeter clamp. The gas analyzer is used to observe CO emission, residual O_2 concentration and exhaust gas temperature. The smoke observed from the generator was measured using the Ringlemann Smoke Chart.

TABLE 3. Variations of combined additives

Ratio (%-vol)	**H1**	**H2**	**H3**
MTBE : 2-EHN	50: 50	70 : 30	30 : 70

RESULTS AND DISCUSSION

Effects on Combustion

The combustion efficiency of generators in the study was indicated by smoke, CO emissions and residual oxygen in the exhaust gasses. The smoke generated from the operation of the B30-fueled generator set (without additive additions) showed levels 1-3 on the Ringlemann Smoke Chart scale. It means smoke opacity in the range of 20-60%. In the first 15 minutes of the engine, the smoke colour is grey, but over time, the concentration of smoke thins, and the colour turns to light grey. Adding additives to B30 fuel (H1, H2 and H3) causes the smoke opacity to meet a scale range of 0-1 or opacity <20%. When matched with the Ringleman Chart colour bar, the smoke out of the generator is observed to be light grey to white.

Smoke opacity emissions typically occur in the diffusion combustion phases of the fuel-rich area due to the incomplete or partially burned carbon molecule. They are heavily dependent on the fuel structure [10]. The high oxygen content of the fuel contributes to the complete oxidation of the fuel, even in locally rich areas, thereby reducing the propensity of the fuel to produce gaseous emissions.

Meanwhile, smoke opacity is closely correlated with CO levels. The use of these three types of multifunctional additives at all concentrations lowered average CO emission levels by 36% for H1, 17% for H2 and 52% for H3, respectively, as shown in Fig. 2.

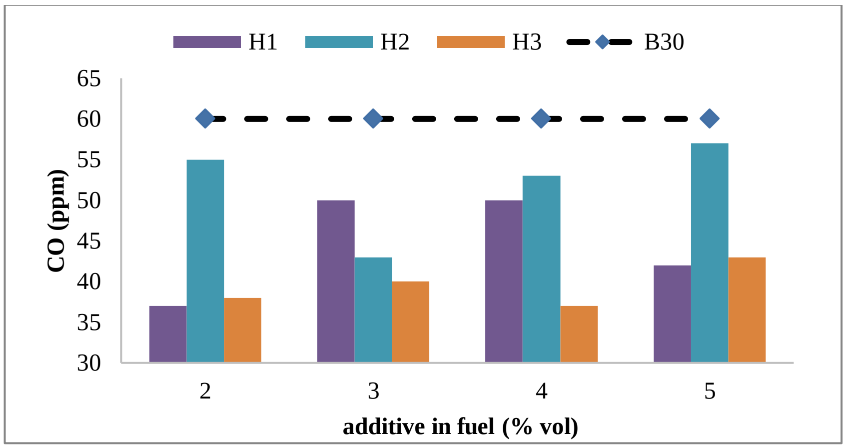


FIGURE 2. Comparison of CO levels in the generator exhaust gas

The combustion performance on B30 generators is getting better with the addition of combination additives at all ratios. The combination of H3 additives contributed to the highest reduction in CO.

The temperature of the exhaust gases indicates the temperature of the combustion process in the cylinders, which is generally directly related to the air/fuel ratio. In Figure 3, biodiesel (B30) generators tend to have lower exhaust gas temperatures than B20 and conventional diesel. The addition of additives further decreases the temperature of the exhaust gases. This condition indicates that some emission parameters will be significantly reduced, but the air-to-fuel ratio will perform low. This condition results in low exhaust gas temperature, which occurs simultaneously with heat loss and reduced engine power.

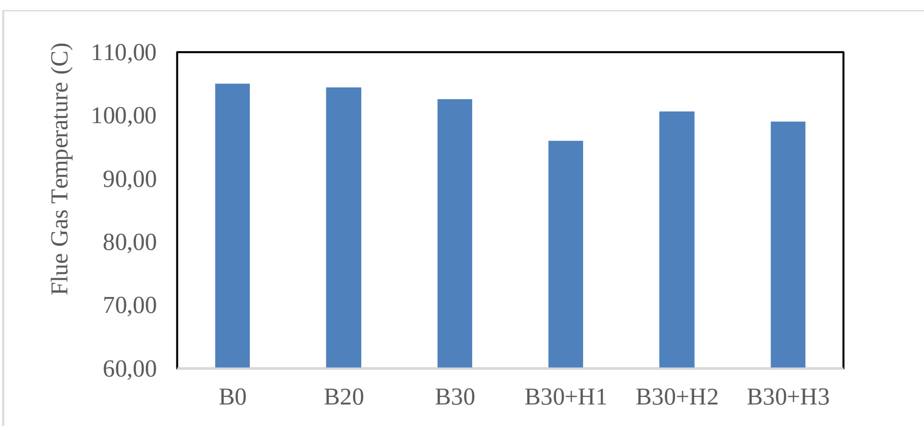


FIGURE 3. Comparison of generator's average exhaust temperature

As known, diesel engine exhaust gases vary with speed and load. The low exhaust gas temperature indicates that combustion in the cylinder also takes place at low temperature. For generators with a rated power of 3.68 kW, the engine load is ideally powered by 4.9 HP, only half or medium load.

The generator technology used in this study was originally designed for diesel petroleum fuel, so the air supply to the combustion chamber has not been specifically for fuel combustion with biodiesel. The existing air intake works automatically as the initial design, so for the new fuel properties, the exact amount of oxygen required for combustion is difficult to estimate. In addition, the incoming airflow system on the generator may involve filter water that is clogged due to previous use.

Effect on electrical voltage stability

In this study, the amount of very excess combustion air was shown by lower combustion temperature so that absorbing heat is useful in exhaust gases. It causes the effect of decreased engine power or disruption of the stability of electrical production.

As seen in Fig. 4, over 180 minutes of operating, generators with petrodiesel fuel (B0) and biodiesel with a mixture of 20% (B20) tend to produce stable electricity. Meanwhile, the generator with B30 generates electricity with a voltage that tends to fluctuate—adding additives to B30 fuels in various combinations and ratios achieved to make generator operation more stable. Good combustion quality leads to more stable electricity output, as shown in Fig. 5.

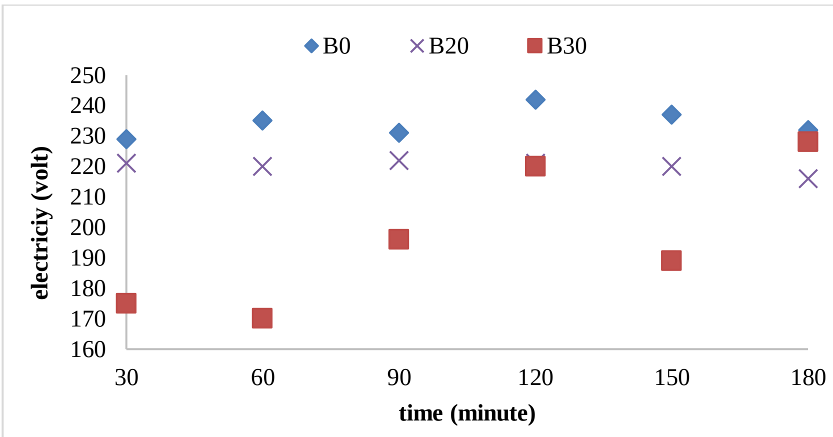
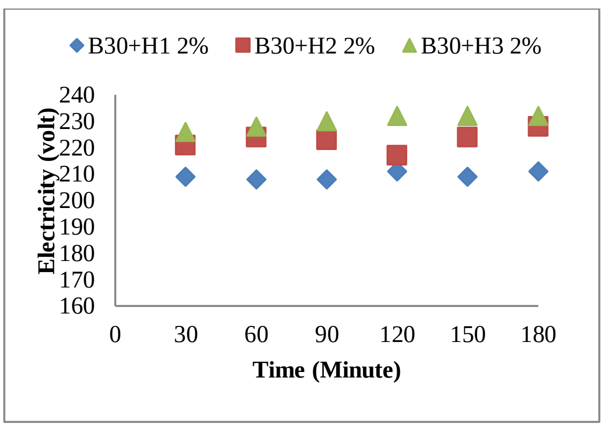
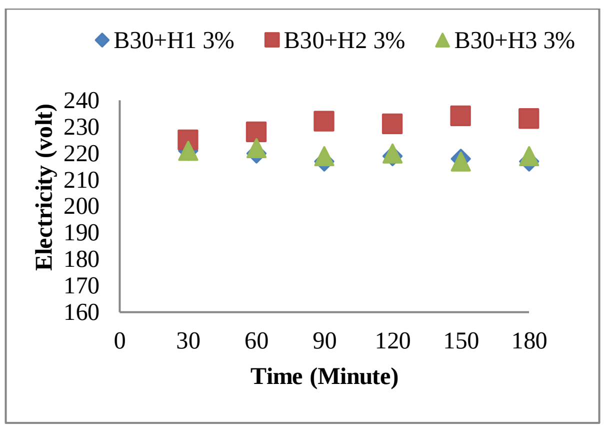


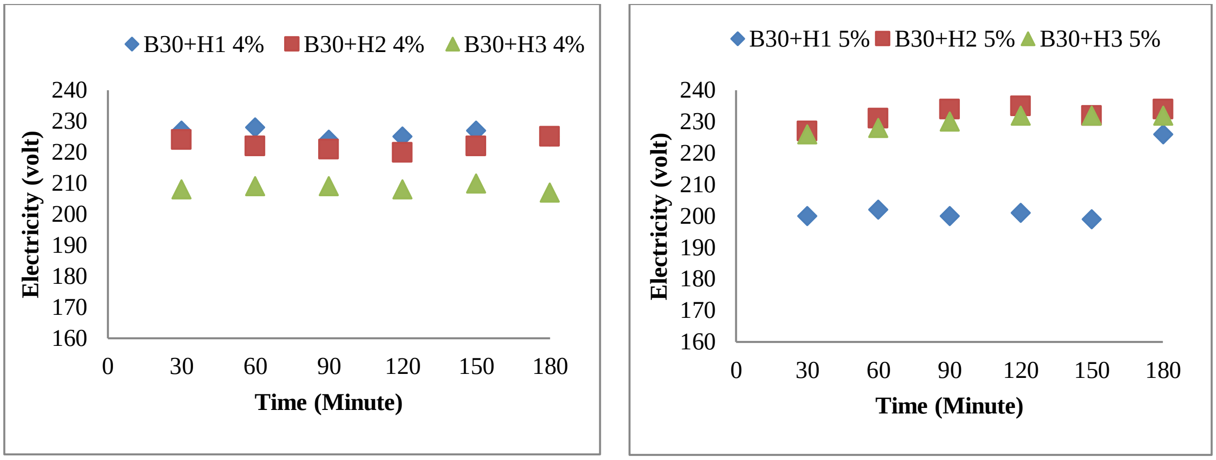
FIGURE 4. Comparison of Generator with biodiesel dan diesel oil in electricity production



(a)



(b)



(c) (d)

FIGURE 5. Electricity Production from B30-fueled generators with variations in additive concentrations: (a) B30+H1 2%, B30+H2 3%, and B30+H3 2%; (b) B30+H1 3%, B30+H2 3%, and B30+H3 3%; (c) B30+H1 4%, B30+H2 4%, and B30+H3 4%; and (d) B30+H1 5%, B30+H2 5%, and B30+H3 5%

Effects on Fuel Consumption

Specific Fuel Consumption (SFC) is the ratio of the total fuel consumption to the electrical power generated in a power generation system. The SFC value also indicates the efficiency of the generator and the calorific value of the fuel used for combustion. In this study, to produce the same output, the use of B30 showed an average fuel consumption of 5% higher than petroleum diesel fuel.

The addition of multifunctional additives allows for an efficient reduction in fuel consumption. As shown in Fig. 6, the lowest fuel consumption rate was contributed addition of H1, which was added at a ratio of 5%-vol. However, the additives composition in the mixture and the high ratio of additives to fuel do not assure a decrease in fuel consumption. It means that at a low ratio (2%), the addition of this additive can be used to reduce fuel consumption while contributing to other efficiency parameters of the generator.

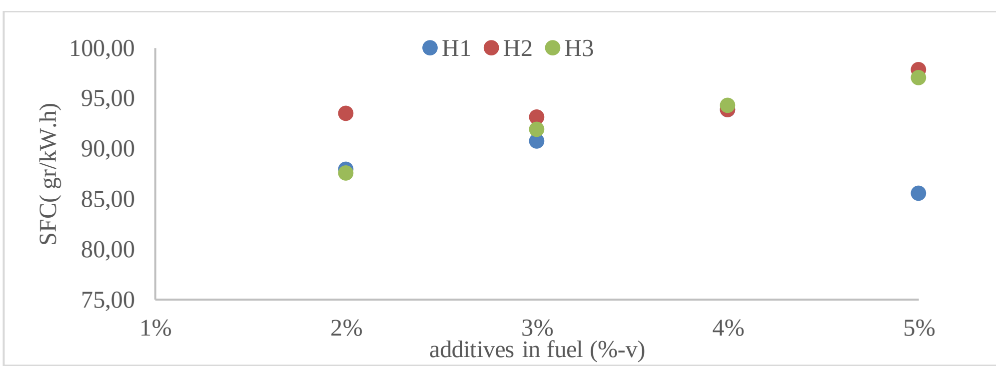


FIGURE 6. Specific Fuel Consumption of B30 with additives in various concentrations

CONCLUSION

The application of B30 on diesel generators has been tested in this study. The use of multifunctional additives with a combination of MTBE and 2-EHN has succeeded in making a significant contribution to the combustion quality of B30, as evidenced by the reduction in exhaust emissions, smoke opacity, and controlled exhaust gas temperature. Even at low concentrations (2%), these two additives improve the diffusion combustion, resulting in intensive oxidation of fuel elements. It is furthermore effective in reducing gaseous emissions. Voltage stability can be achieved by using B30 with the addition of additives, especially the combination of H3 (MTBE:2-EHN=70:30,

%v). This improved combustion quality immediately succeeded in causing a decrease in Specific Fuel Consumption. The introduction of H1 additives (MTBE:2-EHN=50:50, %v) reduced fuel consumption by an average of 11.9%.

The internal combustion engine, alternator and fuel system are the key components in the generator system. Changes in work patterns on one of the key elements will certainly cause the work output of the generator to change, including the voltage generated by the electric current. Adjustments to the combustion cylinder arrangement, intake air volume, and fuel flow system are required.

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