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Impact of 1-Hexanol Fumigation on Diesel engine Emissions using Moringa Oleifera Biodiesel

R.Pradeepraj[1, a]*, K.Rajan[2, b], S. Nallusamy[3, c]

[1*] *Research Scholar,*[2, 3] *Professor, Department of Mechanical Engineering,*
Dr. M.G.R. Educational and Research Institute, Chennai - 600 095, Tamil Nadu, India

[a]jarpeedarp@gmail.com, [b]krajanmech@gmail.com, [c] ksnallu@gmail.com

Abstract - *Pollution is one of the big issues in the modern environment all over the world. The greatest contribution in this field is vehicle pollution and industry. Diesel is also one of the key fuels that introduce toxic contaminants to the atmosphere. To meet the strict emission requirements, the polluting components in the fuels need to be drastically reduced. In this research, the aim is to investigate diesel engine performance characteristics utilizing Moringa Oleifera oil Biodiesel blend (MOBD25) with different ratios of 1-hexanol fumigation. Fumigation is a method that increases the combustion of the engine and decreases emissions. Fumigation is the Fuel that is to be fumigated by carburizing, vaporizing the alcohol into the engine's intake manifold.*

Additionally, it requires control systems for the Fuel, fuel tank, and vaporizer. The results showed that for MOBD25, the BTE is improved by 1.1% with 30% 1-hexanol fumigation relative to other proportions of 1-hexanol. At peak power, the NO and smoke opacity of MOBD25 with 30% fumigated hexanol was diminished by about 36% and 38%, respectively, relative to diesel. Finally, it is concluded that MOBD25 with 30% of fumigated 1-hexanol can effectively diminish the NO and Smoke emissions with a decrease in the engine's performance.

Keywords: *Fumigation, Diesel Engine, hexanol, Methyl ester of Moringa Oleifera oil, emissions, performance*.

I. INTRODUCTION

Now a day's automotive vehicles remain a major source of pollution in many cities around the world. For new diesel vehicles, increasingly stringent emissions norms have been imposed to reduce the emissions to protect the environment. Biofuels such as alcohols, vegetable oil, and methyl ester have been proposed to use in engines as an alternative to diesel. In general, vegetable oil and its methyl ester have been given more importance as a fuel substitute. It is biodegradable, non-toxic, and can greatly decrease the emissions and total life cycle emissions of CO2 from the engine. Bio-origin fuels can, therefore, be a viable alternative to fossil fuels [1-3]. Vegetable oil and methyl ester have usually been given greater importance as a fuel alternative. They are biodegradable, non-toxic, and can substantially reduce the emissions and life cycle total carbon emission from the engine[4]. Many researchers used biodiesel and its fuel mixtures in diesel engines and claim that the use of biodiesel in diesel engines reduced the emissions of CO and Smoke, with increasing emissions of NOx [5, 6]. However, biodiesel's main issues are the decreased engine brake power and increased fuel consumption due to its viscosity and the lower heating values of biodiesel. Nitrogen oxide also increases with biodiesel due to its excess oxygen in the structure [7].

Lakshminarayana Rao et al. [8] analyzed diesel engine characteristics using rice bran biodiesel mixtures. They found that biodiesel mixtures emitted lesser emissions of HC, CO, and smoke but increased NOx emissions relative to diesel. Tesafa et al. [9] analyzed an engine's performance using three different biodiesel and showed lesser smoke emissions and higher BSFC than diesel fuel. The engine performance test was conducted using a biodiesel blend with the toroidal combustion chamber and varying injection pressures. It found that the CO, HC, and smoke emission for toroidal combustion chamber with 240 bar injection pressure was lowered. There is a rise in NOx emissions relative to the base engine.

Most researchers have been using diesel-alcohol mixtures with a minimal percentage of ethanol, methanol, and propanol to substitute diesel by a maximum fraction of methanol and propanol in diesel mixtures with the aid of biodiesel and balance biodiesel lubricity with low alcohol lubricity by combining these additives with diesel fuel and reducing the NOx level [10-13]. Lapuerta et al. [13] tested alcohols as biodiesel additives – fuel mixtures in diesel engines. It was noted that up to 20 % of alcohol intake usually does not entail any major change. There is an increase of HC and CO emanations, while these emanations are decreased with 5% additional alcohol with biodiesel [14]. Mixtures of biodiesel-ethanol and biodiesel-methanol have been shown to minimize emissions of NOx and PM by Yilmaz and Vigil[15], while methanol is more effective than ethanol. Some of the researchers investigated biodiesel's effect with DEE blends on the diesel engine's performance. The 15% DEE blends with the B20 blend have confirmed a dramatic drop in NOx emissions while the performance was declined and other emissions were increased [17, 18].

Fumigation is a method that increases the combustion decreases emissions of an engine. In this technique, the Fuel is fumigated by carburizing, vaporizing the Fuel into the inlet airflow to the engine [19]. The fumigation of alcohol has substantially lowered CO_2 and NOx emissions by up to 20% and PM by 57%. Kaulani et al. [20] reported that the 5% and 10% ethanol fumigation drastically diminished the NOx emissions by 24% and 43%. Senthil Kumar and Rajan [21] studied the combustion, performance, and emission of an engine utilizing Dimethyl carbonate fumigations with rubber-seed oil biodiesel. It is stated that the biodiesel mixture has increased BTE and reduced NO and smoke emissions, with 30% of DMC fumigation relative to diesel.

Gowtham et al. [22] examined diesel engine performance using varying amounts of n-butanol fumigation and reported that BTE was improved for 20% fumigation of n-butanol against diesel. NOx emissions were declined by 11.4 %, and other emissions were enhanced by raising n-butanol fumigation ratios. Meisam et al. [23] investigated an engine's performance with biodiesel-ethanol mixtures mode and biodiesel-fumigation mode. The CO and HC emissions were enhanced and diminished the BTE and NOx, while fumigation mode reduces NOx emissions with reducing the efficiency. From the above literature survey, it can be understood that while several studies have been performed on both ethanol and methanol fumigation and very little research has been carried out on higher alcohol (hexanol/octanol) fumigation indirect injection diesel engines. For these motives, influences on engine performance, emission, and combustion using biodiesel mixture with different ratios of 1-hexanol fumigation have been investigated experimentally to provide comprehensive and profound information under various engine operating conditions results are compared with base fuel.

II. BIODIESEL EXTRACTION PROCESS

Moringa Oleifera biodiesel was purchased from Annamalai University using non-edible grade Moringa Oleifera oil (MO). The transesterification technique was applied to extract biodiesel from MO. The solution consisting of 200 ml methanol and 10g sodium hydroxide at a molar ratio of 5:1 has been applied to 1000 ml and heated for two hours at 65°C and constant stirring. After 8 hrs of settling, the ester is isolated in the top layer and glycerol at the bottom layer. Table 1 depicts the properties of diesel, MOBD, and 1-hexanol as per ASTM D6751 standards.

III. ENGINE SETUP

The experiment was performed on a Kirloskar diesel engine and an eddy current dynamometer at an invariable speed of 1500 rpm. The layout of the test engine is illustrated in Fig. 1. Engine details are presented in Table 2. A digital type AVL gas analyzer is used to check the number of exhaust gases emitted from the tailpipe, including NOx, CO, and HC emanations. The smoke is recorded by using an AVL Smoke meter.

Table1: Fuel Properties

Properties	Diesel	MOBD	Hexanol
Specific gravity	0.83	0.88	0.8218
K.Viscosity@40ºC (cSt)	2.7	5.18	3.32 @20ºC
Calorificvalue (MJ/kg)	43	36.4	39.1
Density (kg/m^3)	830	880	821.8
Flash point (ºC)	50	70	59
Fire point (ºC)	60	83	64
Cetane Number	48	52	26
Oxygen content (%) by weight	-	11	15.7
Latent heat of vaporization	<300	<300	603

A Kistler makes piezoelectric pressure. A TDC position sensor was used to recognize the TDC position and calculate the crank angle using an encoder to obtain a combustion pressure history. A high-speed computer-based DAQ system (AVL INDI-MICRA 602-T10602A) was used to obtain the signals from pressure inside the cylinder, CA, and TDC position.

A. Fumigation of hexanol

Fumigation is a mechanism that injects alcohol into the airflow by vapor and injects biodiesel into the engine cylinder through an injector. The schematic diagram of fumigation fuel is depicted in Figure2. A relatively low-pressure hexanol delivery was chosen. Since the airflow rate was relatively high, the developed jet could immediately mix with air before entering the engine cylinder. The hexanol liquid was supplied to the nozzle by an electrically operated air compressor. The nozzle was located approximately 0.5 m above the inlet manifold so that hexanol was thoroughly mixed with the intake air for a reasonable amount of time, which provided uniform mixing with biodiesel.

Table2: Specifications of the Test Engine

Make	Kirloskar diesel engine
Rated Power (kW)	5.2 kW
Bore x Stroke	87.5mmx110mm
Comp. ratio	17.5:1
Swept volume (cc)	661
Nozzle opening pressure	200bar
Nozzle opening timing	23ºbTDC
Rated Speed	1500rpm

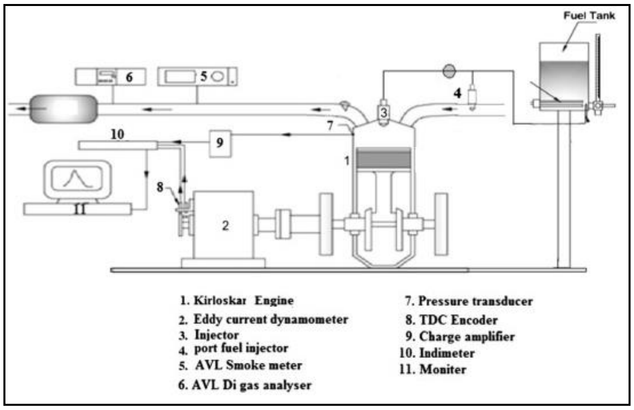

Fig. 1: Schematic View of Test Engine

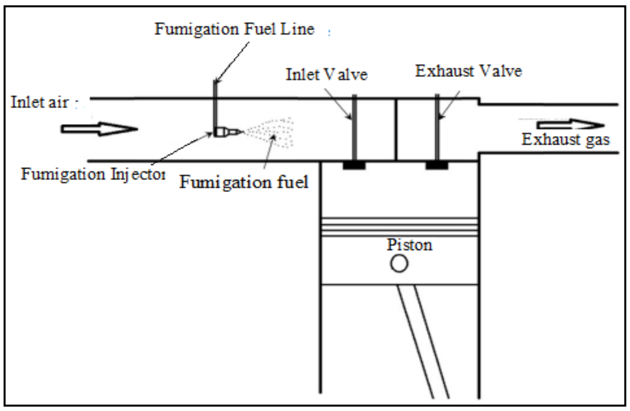

Fig. 2:Fumigation Setup

IV. RESULTS AND DISCUSSION

The diesel engine performance, emanation, and Combustion parameters using MOBD25 with different ratios of 1-hexanol fumigation, and the readings were noted and recorded for each load. The measured parameters were analyzed and compared to base fuels.

A. Cylinder Peak Pressure

Figure 3 illustrates the cylinder peak pressure change with CA for diesel and MOBD25 s with different ratios of 1-hexanol fumigation. It has been found that the peak cylinder pressure for MOBD25 is much lower MOBD25 with an increase in the ratio of fumigated 1-hexanol at all loads. This is due to decreased combustion temperature combined with higher LHV of 1-hexanol (Jamuwa et al., 2016). The maximum cylinder pressure is 67 bar, 66 bar, and 64 bar for MOBD25 with 10, 20%, and 30% hexanol fumigation, respectively, while it has 69 bar and 68 bar for diesel and MOBD25, respectively at maximum power conditions. Higher hexanol quantities, which minimize the cylinder pressures and the temperature-induced by the cooling effect, can also decrease the in-cylinder pressure. This is also because the fuel mixtures' lower energy content contributes to the slow-burning of fuel mixtures at peak loads. Researchers Cheng et al. (2008) reported similar trends of alcohol fumigation results along with biodiesel.

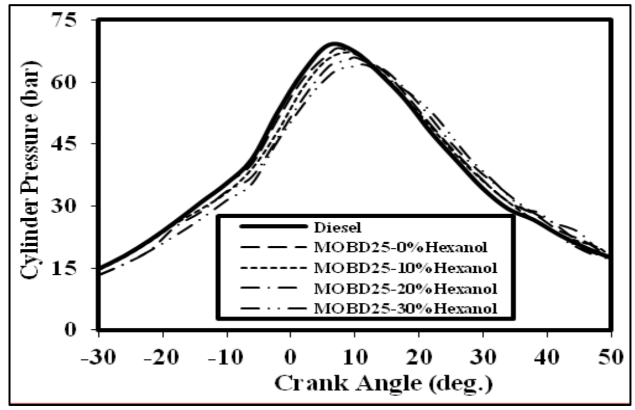

Fig.3: In-Cylinder Pressure Vs. CA

B. Heat Release Rate

The change in HRR with CA at peak load for diesel and MOBD25 a different ratio of fumigated 1-hexanol is depicted in Figure 4. HRR is mainly influenced by fuel properties such as energy content and latent heat and fuel injection parameters. With the increase in the fractions of the 1-hexanol, the amount of heat emitted rises during the premixed combustion phase. The diffusion combustion phase also decreases marginally due to longer ignition delays with an increase in the fumigated 1-hexanol fraction in mixtures (Jamuwa et al., 2016).

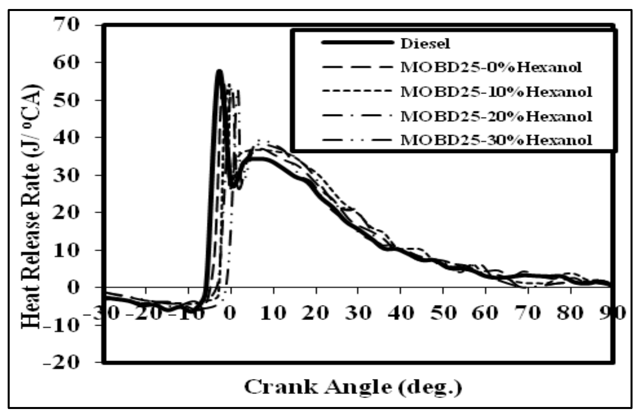

Fig. 4: Heat Release Rate Vs. CA

The MOBD25 heat-release average with 10%, 20%, and 30% hexanol is 54J/oCA, 53/oCA, and 52J/oCA, respectively, while it's 57 J/oCA and 55J/oCA for diesel and MOBD25, respectively. Biodiesel mixture with fumigated 1-hexanol fraction has a lower HRR in contrast to MOBD25 mixtures, as its lower heating value lowers the HRR. Higher fractions of hexanol decreased the HRR, contributing to increased heat absorption during evaporation and reduced the in-cylinder temperature and test fuel pressure. Researchers Cheng et al. (2008) reported similar trends of results in alcohol fumigation along with biodiesel.

C. Brake Thermal Efficiency

Deviation of BTE with BP for diesel and MOBD25 with different ratios of 1-hexanol fumigation is shown in Figure 5. A small rise in BTE with 1-hexanol fumigation is observed from the graph to MOBD25 and other hexanol proportions at peak load. Brake thermal efficiency improvements were due to a more homogenous blend of hexanol fuel and biodiesel, leading to better combustion. At the maximum power, the BTE of MOBD25 with 10%, 20% and 30% fumigated 1-hexanol has 28.2%, 28.6% and 27.2% respectively and 29.7% and 27.8% for diesel and MOBD25 respectively. BTE of MOBD25 with 10% and 20% fumigated hexanol gains 1.8% and 2.8% higher than MOBD25, and for 30% fumigation, it is 2.1% lower than MOBD25 at maximum power conditions. The decrease in BTE with 30% 1-hexanol fumigation owing to the non-homogenous combustion between air and hexanol and the higher LHV of the hexanol fuel, resulting in slow combustion and thus reduces the efficiency. Researchers Cheng et al. (2008) reported similar trends of results in alcohol fumigation along with biodiesel.

D. Brake Specific Energy Consumption

Figure 6 presents BSEC changes with BP for all the test fuels. BSEC is defined as the product of calorific value and specific fuel consumption of the engine. Usually, it is calculated when two different fuels were used having different calorific values.

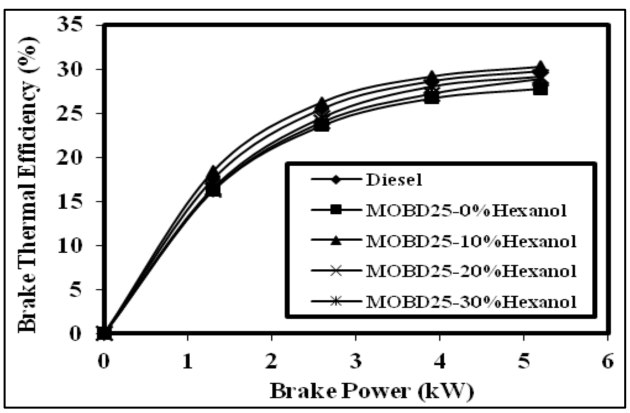

Fig.5: Brake Thermal Efficiency Vs. Brake Power

BSEC decreases as engine load rises and an increase in the ratio of fumigated 1-hexanol relative to diesel. With 10%, 20 %, and 30% fumigated 1-hexanol, the BSEC of MOBD25 produced are 11.8 MJ/kWh, 11.4 MJ/kWh, and 12.6 MJ /kWh at maximum power. The BSEC achieved for diesel and MOBD25 are 10.7 MJ/kWh and 12.1 MJ/kWh, respectively, at maximum power conditions. This is because of the lower energy content of biodiesel and hexanol fuels. It is also responsible for the high latent heat of 1-hexanol, which causes the charge to cool at maximum load compared to diesel and MOBD25, which results in greater fuel requirements needed to generate the same quantity of power (Cheng et al. 2008). The similar trends of curves are matched with the researchers Meisam Ahmadi Ghadikolaei et al. 2019.

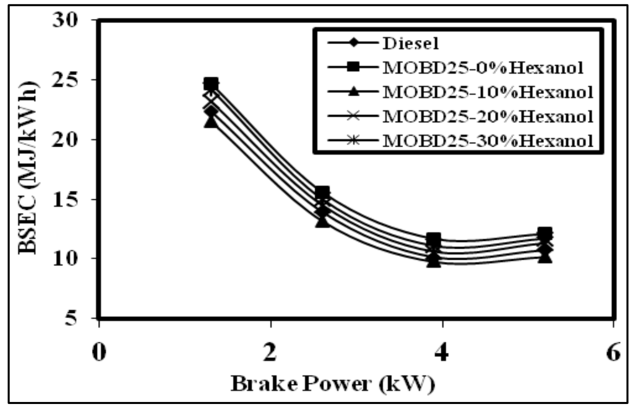

Fig. 6: BSEC Vs. BP

E. Carbon monoxide Emissions

Figure 7 portrays the CO emission changes with BP for diesel and MOBD25 and different hexanol fumigations ratios. CO emissions are formed due to poor Combustion of Fuel, and it is found to be decreased up to a medium-range of power and is improved at maximum power. It is observed that CO emissions for MOBD25 were decreased due to the excess oxygen in biodiesel. Compared to diesel fuel, the CO of MOBD25 was reduced by 24% at maximum power conditions.

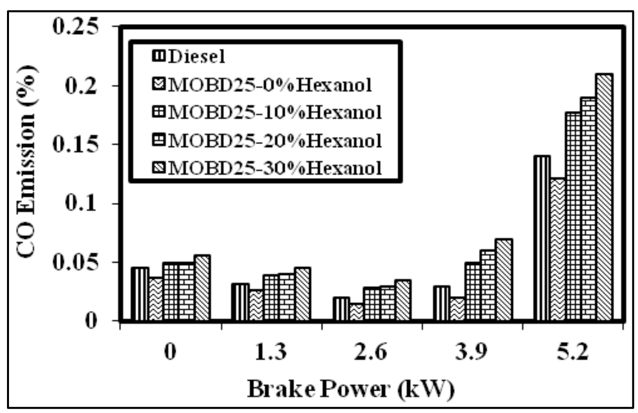

Fig.7: CO Emissions Versus Brake Power

The CO emissions rose to 24% at full load for fumigated 30% 1-hexanol with MOBD25 mixtures. At maximum power, the CO emissions obtained for MOBD 25 are 0.17%, 0.19% and 0.21% respectively for 10%, 20% and 30% fumigated 1-hexanol; while it was 0.16% and 0.12% for diesel and MOBD25 respectively. The rise in CO emissions due to higher LHV of 1-hexanol enables the cylinder temperature and enhances the CO emissions. Researchers Gowtham (2019) reported similar trends of results in alcohol fumigation.

F. Nitrogen Oxide Emissions

The deviation of NO emissions with the brake power for all the fuels is shown in Figure 8. The formation of NO may be formed due to the temperature of in-cylinder gas and atmospheric oxygen available during combustion. It is noted that the emission of NO gradually increases from low load to higher engine loads. It is noticed that the NO emission for MOBD25 is increased by about 13% against diesel. NO emissions obtained for MOBD25 with 10%, 20%, and 30% 1-hexanol fumigation are 866ppm, 695ppm, and 618ppm respectively at peak power, and it is 959ppm and 1086ppm for diesel and MOBD25, respectively. It is noted that for MOBD25, the NO emissions are decreased with fumigated hexanol at all loads. The NO emission for the MOBD25 decreased by 10-36% with fumigated hexanol fuel. This decrease in NO emission is due to the LHV of 1-hexanol, reducing the combustion temperature, which reduces the formation of NO emissions. Similar patterns of the results were achieved by the researchers Gowtham et al. (2019).

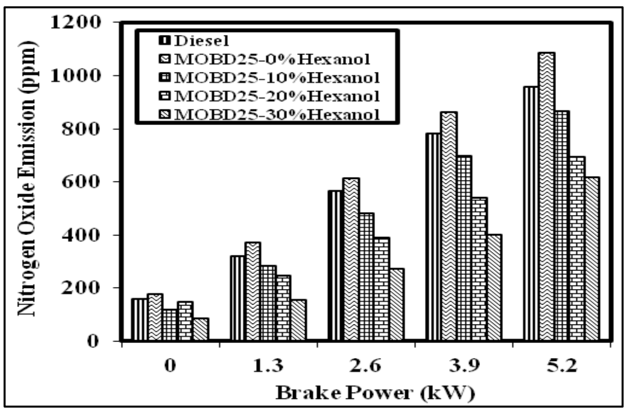

Fig. 8: Nitrogen Oxide Emissions Versus Brake Power

G. Smoke Opacity

The change in smoke emission with BP for the various ratio of 1-hexanol fumigation with MOBD25 is illustrated in Figure 11. The smoke opacity decreased with a rise in the proportion of 1-hexanol fumigation at maximum power. Smoke opacity for MOBD25 with 10%, 20%, and 30% of 1-hexanol fumigation is 28%, 24%, and 22%, and it is 36% and 30% for diesel and MOBD25 respectively at maximum power. The reduction in smoke opacity owes to lower SFC and the increased ratio of 1-hexanol fumigation. Thus, in the diffusion model, biodiesel mixtures burn together with the homogenous 1-hexanol - air mixture, which results from incomplete combustion and diminishes the smoke. Fumigation also enhances the ignition delay that improves the mixing of n-hexanol -air mixture with MOBD25, thereby improving air utilization during the combustion and diminishes the smoke. Similar observations were made by researchers Gowtham et al. (2019).

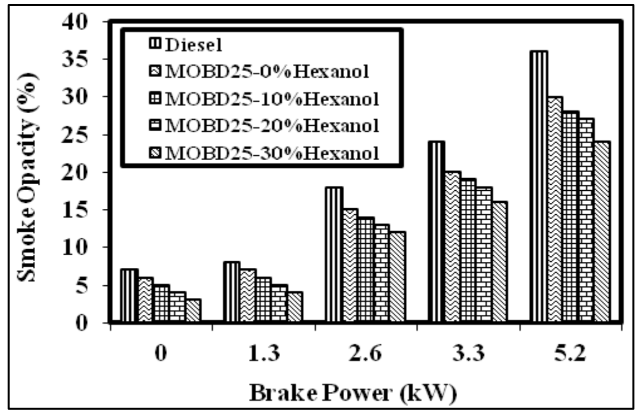

Fig. 9: Smoke Opacity Versus Brake Power

IV. Conclusion

The experimental test aims to examine a diesel engine's performance using a Moringa Oleifera oil biodiesel mixture with different ratios of 1-hexanol fumigation with various loads. Following are the observations of the test results:

On comparing with MOBD25, the BTE of with 30% hexanol fumigation is decreased by 1.1% and decreased by 0.8% compared to diesel; BSEC is substantially higher for all ratios of 1-hexanol fumigation at maximum power conditions. CO emissions for 30% 1-hexanol fumigation were increased by 24% and HC emissions increased by 24% at peak power. At peak power, NO emissions of 30% hexanol fumigation are diminished by 36%. NO emission obtained for MOBD25 with 30% 1- hexanol fumigation is 618ppm, and for without fumigation, it is 1086ppm. Smoke opacity was lowered by 38%, with an improvement in 1-hexanol fumigation ratios due to the rapid Combustion of 1-hexanol Fuel with excess oxygen. In general, it is suggested that 30% 1-hexanol fumigation and MOBD25 mixture can be used to reduce NO and smoke emissions without affecting engine performance.

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