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Performance and emission analysis of dual biodiesel (April 2017)

V. Gurumanikkanayakam , C. T. Muthaiah , P. T. Dinesh kumar

Abstract **Gasoline and diesel fuels have been considered as primary fuels for automotive, farm and recreational vehicles applications. Transportation sector is mainly depends on crude oil. Biodiesel has obtained from vegetable oils that have been considered as a promising alternate fuel. India happens to be the world's fourth largest energy consumer and a consumer of crude and petroleum products after the United States, China, and Japan. Very few works have been done with the combination of two different biodiesel blends with diesel and left a lot of scope in this area. The project brings out an experiment of two biodiesels from pongamia pinnata oil and mustard oil and they are blended with diesel at various mixing ratios. Various physical and thermal properties of dual biodiesels of pongamia pinnata oil and mustard oil and its blends were evaluated. The performance of the engine was evaluated using several parameters such as thermal efficiency, specific fuel consumption and exhaust gas temperature. The dual biofuel performance of the engine is calculated and compared with diesel. The maximum brake thermal efficiency of combination of pongamia pinnata methyl ester and mustard methyl ester at full load is 36.33%, which is 3.68% higher than that of diesel and also 22.12% of carbon monoxide emission, 37.5% of hydrocarbon emission was reduced.**

Index Terms— **Introduction, dual biodiesel, alternate fuel, performance Analysis.**

1.INTRODUCTION

Large proportion of crude oil is imported from foreign countries and mainly obtained from Persian Gulf (this region provides one-fourth of the world's current consumption of oil and nearly two thirds of the world's oil reserves). Due to the decrease in oil availability and distribution instability, reliance on these fossil fuels must end. Crude oil is a finite resource, which means that its supply is limited and cannot be reproduced. It took millions of years for these oil reserves to accumulate and we have used them up in the last two hundred years. It is estimated that the current available reserves of oil on the earth will only be able to supply total world demand for the next 40 years. When these reserves are completely exhausted we will have to use alternative fuel sources. In the short-term future, there are many alternative energy sources available that can be utilized properly in place of crude oil.

A lot of research work pointed out that biodiesel has received a significant attention and it is a possible alternative fuel. Biodiesel and its blends with diesel were employed as a fuel for diesel engine without any modifications in the existing engine.

Kumar et al (2003) conducted the experiments using pure jatropha oil, jatropha methyl ester, blends of jatropha and methanol and dual fuel operation (0–80% methanol by volume is inducted and jatropha acts as pilot fuel).The authorsreported that, brake thermal efficiency for jatropha esters, dual fuel operation and diesel was 29%. 8.7% and 30.2% respectively.

Nwafor (2004) studied the potential of rapeseed methyl ester and its blends with diesel fuel as alternative substitute for diesel fuel. The author described that, the fuel consumption of rapeseed methyl ester was little higher than diesel fuel operation.

Rakopoulos et al. (2006) evaluated the performance and emission characteristics of a direct injection diesel engine fuelled with blends of soyabean, rapeseed, sunflower oil methyl ester and diesel. The smoke density was significantly reduced with the use of bio-diesel blends of various origins with respect to that of the neat diesel fuel. The biodiesel showing higher specific fuel consumption for the high load and a minimum of it at the 10/90 blends for the medium load.

Wang et al (2006) confirmed that, the vegetable oils possess almost the same heat values as that of diesel fuel. The engine power output and the fuel consumption of the vegetable oil and its blends are almost the same when the engine is fueled with diesel.

Srivastava and Verma (2008) carried out the experiments using methyl ester of karanja oil. The authors reported that, the maximum thermal efficiency with methyl ester of karanja oil was about 24.9%, whereas that of the diesel was 30.6% at maximum power output. The authors concluded that, the methyl ester of karanja oil is a suitable substitute of diesel.

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Ramadhas et al (2008) studied the dual fuel mode operation using coir-pith derived producer gas and rubber seed oil as pilot fuel. The authors reported that, non-edible oils can be used as pilot fuel, which eliminates the use of petroleum diesel

ABBREVIATIONS

PPME	- Pongamia pinnata methyl ester
MME	- Mustard methyl ester
PPO	- Pongamia pinnata oil
MO	- Mustard oil
SFC	- Specific fuel consumption
BSEC	- Brake specific energy consumption
TFC	- Total fuel consumption
HC	- Hydro carbon
NO_X	- Nitrogen oxide
CO	- Carbon monoxide
CO_2	- Carbon dioxide
FFA	- Free fatty acid
Blend A	- PPME5%+M5%
Blend B	- PPME10%+MME10%
Blend C	- PPME15%+MME15%

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Rahimi et al (2009) used Diesterol (combination of diesel fuel, bioethanol and sunflower methyl ester as a fuel for diesel engines. The authors revealed that, as the percentage of bioethanol in the blends is increased, the percentage of CO concentration in the emission is reduced. This trend is due to the fact that bioethanol has less carbon than diesel.

Mani et al (2009) investigated the diesel engine runs with waste plastic oil as fuel. The authors concluded that, the smoke was reduced by 40% than diesel.

K. Anbumani and Ajit Pal Singh (2010) studied that the performance of mustard and neem oil blends fueled with diesel engine. Results have indicated that engine run at 20% blend of oils showed a closer performance to pure diesel. However, mustard oil at 20% blend with diesel gave best performance as compared to neem oil blends in terms of low smoke intensity, emission of HC and NO_X.

Hanbey Hazar et al. (2010) has studied that the performance and emission analysis of diesel engine fuelled with corn oil methyl ester and its diesel blends. Tests were performed on the uncoated engine, and then repeated on the coated engine and the results were compared. A decrease in engine power and specific fuel consumption, as well as significant improvements in exhaust gas emissions (except NO_X), were observed for all test fuels used in the coated engine compared with that of the uncoated engine.

Lawrence et al. (2011) revealed that prickly poppy methyl ester (PPME) blended with diesel could be conveniently used as a diesel substitute in a diesel engine. The test further showed that there was an increase in break thermal efficiency, brake power and reduction of specific fuel consumption for PPME and its blends with diesel.

Satyanarayana et al. (2011) evaluated the permission and emission characteristics of a single cylinder, four stroke diesel engine fueled with a coconut oil methyl ester (COME). It was observed that the COME shows poor performance and slightly less emission as compared to diesel fuel. The HC and CO emissions are decreased by the value of 16.66 % and 60 % at full load operation. NO emission increases by the value of 20 % as compared diesel fuel.

Deepanraj et al. (2011) described that the lower blends of biodiesel increased the brake thermal efficiency and reduced the fuel consumption. In addition to this, biodiesel blends produce lower engine emissions than diesel.

Muralidharan and Govindarajan (2011) prepared biodiesel from non-edible pongamia pinnata oil by transesterification and used as a fuel in C.I engine. The authors reported that blend B5 exhibits lower engine emissions of unburnt hydrocarbon, carbon monoxide, oxides of nitrogen and carbon dioxide at full load.

Venkatraman and Devaradjane (2011) performed the experiments in a single cylinder DI diesel engine fueled with a blend of pungamia methyl ester for the proportion of PME10, PME20 and PME30 by volume with diesel fuel for validation of simulated results. The authors observed that there is a good agreement between simulated and experimental results.

S.M.Ameer uddin , A.K .Azad (2015), has studied the combination of mustard and kerosene, gives viscosity values very close to diesel fuel that required by the diesel engine. Therefore, 20% to 30% mustard oil can be blended with kerosene as While Mustard is blended with kerosene found that the bsfc of m20 and m30 are 257.94 gm/kw-hr at12.5kg load & 269.67 gm/kw-hr at the same load condition which are close to standard consumption of diesel fuel (233.51 gm/kw-hr) in this engine. Hence, m20 and m30 can be considered as suitable fuel for the diesel engine.The bsfc and brake thermal efficiency of the other blends m40 & m50 are also close to m20 but the viscosity and density are higher which is problem for smooth engine running.

From the review of literatures, numerous works in the utilization of biodiesel as well as its blends in engines have been done. However, most of the literatures focused on single biodiesel and its blends. From previous studies, it is evident that single biodiesel offers acceptable engine performance and emissions for diesel engine operation. Very few experiments have been conducted with the combination of dual biodiesel and diesel as a fuel. Most of the literatures suggested that pongamia pinnata oil (also called as karanja oil) is a suitable substitute of diesel and a few research works have also been carried out with mustard oil. Both the pure biodiesel and higher blends are not gives higher efficiency and there is increase in emission. So, the lower blends of pongamia pinnata oil methyl ester and mustard oil methyl ester were selected for this current study which is easily and locally available. In the second level performance and emission characteristics of diesel engine and the blends of dual biodiesel and compared with the diesel.

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2. Material and method

The pongamia pinnata methyl ester and mustard methyl ester are prepared from transestification process. The dual is mixed with various proportion with diesel and the performance and emission characteristics are compared with diesel.The various properties like kinematic viscosity, specific gravity, calorific value, flash point temperature and fire point temperature of two biodiesel blend were determined by using ASTM methods and com- pared with diesel properties. The experiments were conducted on a stationary single cylinder four stroke air cooled diesel engine with electrical loading and the performance and emission characteristics were compared with baseline data of diesel fuel. Tests were conducted at a constant speed and at varying loads for all dual biodiesel blends. Engine speed was maintained at 1500 rpm (rated speed) during all experiments. Three experiments for each load were carried out for accuracy. Fuel consumption and exhaust gas temperatures were also measured. The smoke opacity of the exhaust gases was measured by the AVL make smoke meter. The exhaust emissions were measured by the Indus make five gas analyzer. The experimental set up is shown in Fig. 1 and the detailed engine specifications are also given in Table 1.

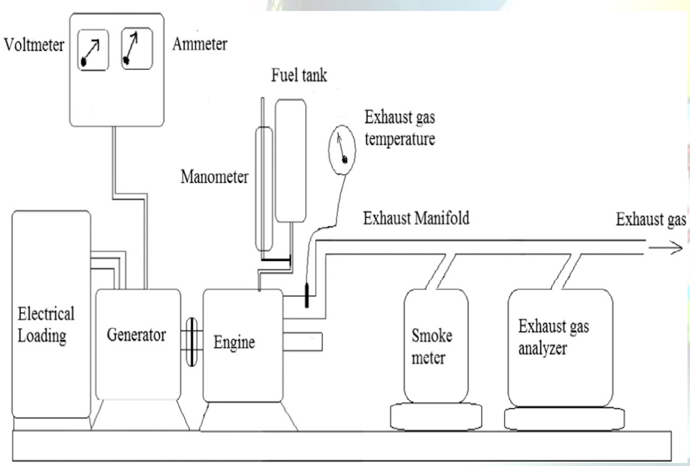

Figure 1 Test engine setup

Table 1 Test engine specification

Item	Specification
Model	Kirloskar
Type	Single cylinder
Bore	87.5 mm
Stroke	110 mm
Compression ratio	17.5:1
Type of cooling	Water cooling
BHP	5.25 KW
Speed	1500 rpm

3.Result and Discussion

Various physical and thermal properties of dual biodiesels of pongamia pinnata oil and mustard oil blends were evaluated. The performance of the engine was evaluated using several parameters such as thermal efficiency, specific fuel consumption and exhaust gas temperature.

3.1. Calorific value of the fuel

The digital bomb calorimeter is used to find out the calorific value of fuels. ASTM D420 procedure is followed to analyze the calorific value of different test fuels. The raw vegetable oil has lower calorific value than diesel. After transesterification process, the biodiesels have slightly higher calorific value than raw oil. The pongamia pinnata methyl ester has higher calorific value than mustard oil methyl ester. By blending the dual biodiesels with diesel, the calorific values of Blend B and Blend C are close to diesel which is more than single biodiesel blends. The calorific values of Blend A are almost equal to the single biodiesel blends. Hence, dual biodiesel lower blends are utilized to analyze the performance and emission analysis experimentally.

3.2. Specific gravity of fuel

Specific gravity of different dual blends is measured using a precision hydrometer. The specific gravity of dual biodiesel Blend A, Blend B and Blend C is 0.812, 0.824, 0.83 where as diesel 0.814.

3.3.Viscosity of fuel

Calibrated Redwood viscometer used for determining the kinematic viscosity. ASTM - D0445 procedure is followed to analyze the viscosity of fuels. The viscosity of the blends increases with the blend ratio and the viscosities of dual biodiesel blends and they are higher than diesel fuel. The viscosity of the raw pongamia pinnata oil and the mustard oil is very high compared to diesel. However, the high viscosities of raw oils are reduced by the transesterification process. Viscosity of dual biodiesel Blend A, Blend B and Blend B is nearer to diesel. The viscosity of diesel is 3.9 Cs whereas for the Blend A, B and Blend C is 4.15, 4.21 Cs and 4.29 Cs respectively.

3.4. Performance analysis

Figure 2 shows the variation of brake thermal efficiency for diesel, combination of PPME and MME blends. It can be observed that the brake thermal efficiency of the tested fuels increase, with increase in the load. It is due to reduction in heat loss and increase in power developed with increase in load [12]. The trends of the brake thermal efficiency of combination of PPME and MME blends are higher than that

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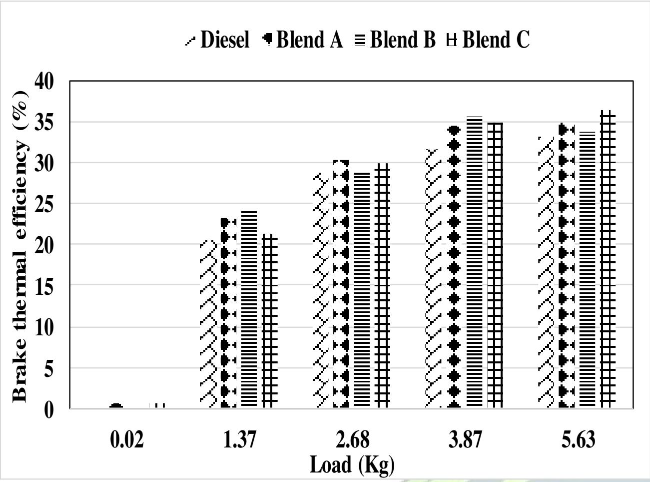
diesel, due to presence of increased amount of oxygen in PPME and MME blends, and additional



lubricity [6].

Figure 2 Variation of brake thermal efficiency with different blends

The maximum brake thermal efficiency for Blend C at full load is 36.33%, which is 3.68% higher than that of diesel. The brake thermal efficiency of diesel and its blends full load is comparable with diesel. The brake thermal efficiency diesel and its blends are 33.21%, 34.8%, 33.68%, 36.33%. The brake thermal efficiency of dual biodiesel (combination of PPME and MME) gives higher brake thermal efficiency compared with single biodiesel blended with diesel [7].

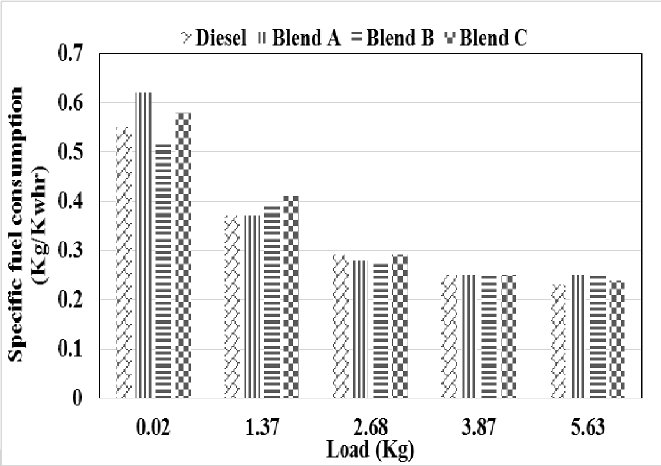


Figure 3 Variation of Specific fuel consumption with variable blend

The variation specific fuel consumption with different blends shows in Figure 3. It is obvious from the figure that the BSFC of the engine gradually decreases with increase in load. The main reason may be that the percent increase in fuel required to operate the engine is lesser than the percent increase in brake power due to relatively less portion of the heat losses at higher loads. The SFC of the Blend C at full load is 0.2405 kg/kWh, whereas for diesel it is 0.2315 kg/kWh. The specific fuel consumption for combination of PPME and MME blends are higher than that of diesel fuel. This is due to the fact that ester has lower heating value compared to diesel; so more fuel is needed to maintain constant power output [4].

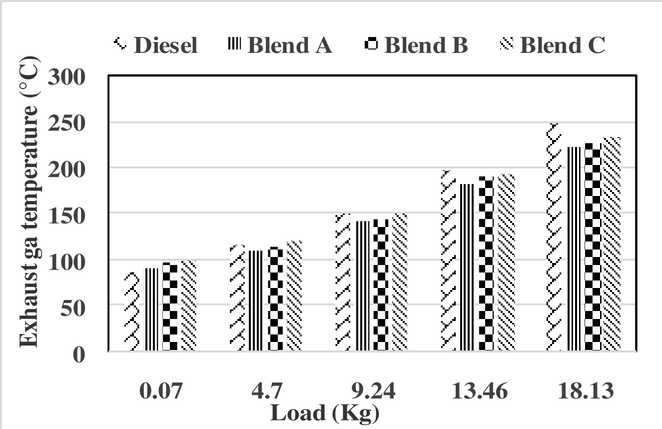


Figure 4 Variation of exhaust gas temperature with different blend

The variation of exhaust gas temperature for diesel, combination of PPME and MME blends is shown in figure 4. Exhaust gas temperature is affected by change in ignition delay. Shorter ignition delay results in a delayed combustion and lower exhaust temperature [14]. For PPME and MME blends is lower compared to that of diesel fuel. This may be due to shorter ignition after burning stage [4]. The blend B records 191.47°C whereas, diesel records 195.5°C. The maximum temperature is noticed with combination of PPME and MME blend is 246 °C.

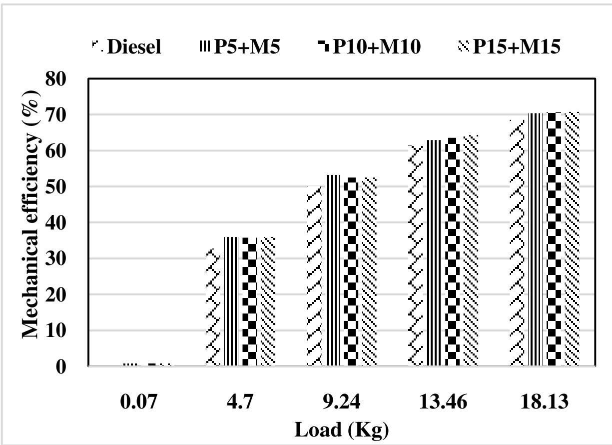


Figure 5 Variation of mechanical efficiency with different blend

The effect of load on mechanical efficiency is shown in figure 5. Indicated power and engine friction are essential for calculating the mechanical efficiency of the engine. Efficiency is measured as a ratio of the measured performance to the performance of an ideal machine. Mechanical efficiency measures the effectiveness of a machine in transforming the energy and power that is given as an input to the device into an output force and movement. Hence, mechanical efficiency indicates how good an engine is, in converting the indicated power to useful power. The Blend C gives the mechanical efficiency of 64.8%, whereas diesel is 61.41%. The maximum mechanical efficiency of Blend C (POME15%+MME15%) is 70.3% at full load condition.

3.5. Emission analysis

The variation of carbon monoxide emissions for diesel, combination of PPME and MME blends is shown in Figure 6. An emission of CO from a direct injection diesel engine is mainly depends on the physical and chemical properties of the fuel. From the figure, it can be observed that the CO emissions are lower for PPME and MME blends as compared to that of diesel fuel. The percentage variation of emissions is shown in Figure 6. Lower CO emissions form biodiesel fuelled engine may be due to their more complete oxidation compared to that of diesel. Some of the CO produced during combustion of biodiesel might have converted into CO_2 by taking up the extra oxygen molecule present in the biodiesel chain and thus reduced CO formation [4].

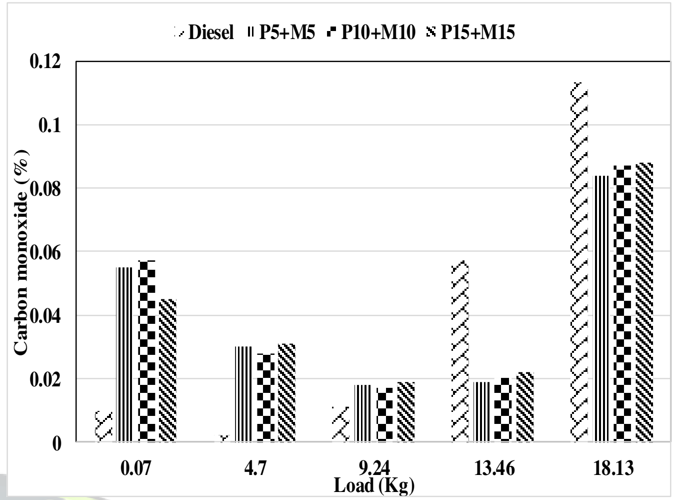
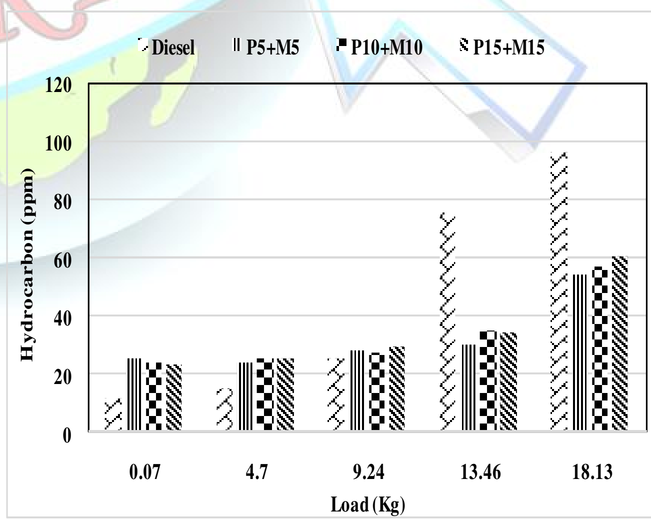


Figure 6 Variation of carbon monoxide emission with variable blends

Another reason may be due to lower C/H ratio of biodiesel than that of diesel fuel [7]. There is similar changes is obtained upto 50% of loading condition.The blend C gives less than 22.12% of carbon monoxide emission when compared with diesel at full load condition. HC is also an important parameter for determining the emission behaviour of the engines. Figure 7 shows that the variation of unburned hydrocarbon of different tested fuels. It can be observed that the HC emissions are lower for combination PPME and MME blends as compared to that of diesel fuel. Blend C gives less than 37.5% of hydrocarbon emission when compared to diesel at full load condition.

Figure 7 Variation of unburnt hydrocarbon with different blend



The figure 8 shows the carbon dioxide emission with different blends. All the dual biodiesel (combination of PPME and MME) blends are give lower CO_2 than diesel and PPME and MME at all loading condition [6]. This is due to the oxygen contents in the biodiesel which makes easy burning at higher temperature in the cylinder. When the blend ratio was

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increased, the CO2 emission was reduced because of higher viscosity and the air-fuel mixing process is affected by the difficulty in atomization and vaporization of dual biodiesels. Oxygen should not be either too high or too low which will lead to less combustion. Whenever there is too lean or too rich mixture of air and fuel, incomplete combustion occur [5].

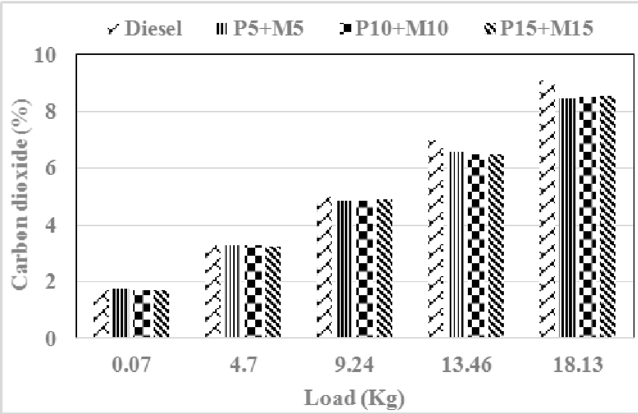

Figure 8 Variation of carbon dioxide emission with different blend

Figure 9 illustrates the variations of nitrogen oxide (NO) emissions for diesel, combination of PPME and MME blends. For all loads the NO emission for dual biodiesel (PPME and MME) blends is higher than that of diesel fuel. The nitrogen oxides (NO_X) increased by increasing the load for each blend. For the maximum load. It is well known that the vegetable based fuel contains a small amount of nitrogen. This contributes towards more NO_X production [15].

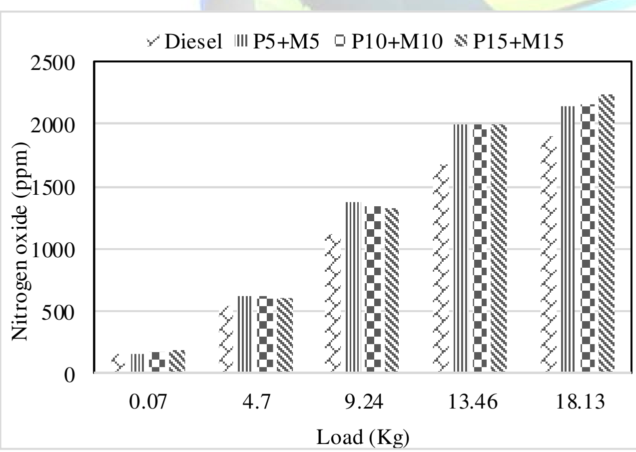

Figure 9 Variation of Nitrogen oxide emission with different blends

The reason for higher NO_x emission for dual biodiesel and blends is due to higher cylinder temperature. Another reason may be due to oxygen content present in biodiesel and its blends [5]. The NO_x emissions level was found to be directly related to the exhaust gas temperature while it was inversely related to the smoke and CO values.

4. Conclusion

An experimental investigation was carried out to appraise and evaluate the combustion, performance and exhaust emission levels of PPME and MME blends in a fully instrumented single cylinder, four stroke, air cooled, direct injection diesel engine. The conclusions are summarized as follows:

- The specific fuel consumption increases with increase in percentage of PPME and MME blends due to lower calorific value of all tested fuels. Brake thermal efficiency of the blends increases with increase in applied load. The maximum brake thermal efficiency for 30% blend (PPME15%+MME15%) at full load is 36.33%, which is 8.68% higher than that of diesel.
- From the analysis of exhaust emission of the PPME and MME blends, it is found that the NO_X emission increases with increase load. Increase in oxygen content in the PPME and MME blends as compared to diesel results better combustion and increases in the combustion chamber temperature, which leads to increase NO_X emission. The other emissions, such as CO, HC and smoke are lower than single biodiesel and standard diesel fuel for all tested fuels.

From the above results, it has been found that the 30% blend (PPME 15%+MME 15%) is superior when compared with the standard diesel fuel at full load for performance and emission analysis. The experimental result also proves that the lower blends of combination of pongamia pinnata methyl ester and mustard methyl ester are potentially good alternate fuel for diesel engine.

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