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Research Paper

PERFORMANCE AND EMISSION ANALYSIS OF PONGAMIA, JATROPHA AND NEEM METHYL ESTERS AS BIODIESEL IN A C.I ENGINE

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In the present investigation, experimental work has been carried out to analyze the emission and performance characteristics of a single cylinder 3.7 kW, compression ignition engine fuelled with mineral diesel and biodiesel blends at an injection pressure of 200 bar. Methyl ester of Pongamia (PME), Jatropha (JME) and Neem (NME) were derived through transesterification process. Experimental investigations have been carried out to examine Properties, Performance and Emissions of different blends (B10, B20, B40 and B100) of PME, JME and NME in comparison to diesel. Results indicated that B20 have closer performance to diesel and B100 had lower brake thermal efficiency mainly due to its high viscosity compared to diesel. However, its diesel blends showed reasonable efficiencies, lower smoke, CO, HC and higher NOx emissions. Pongamia methyl ester gave better performance compared to Jatropha and Neem methyl esters.

Keywords: Non edible oils, Biodiesel, Transesterification, Methyl esters, Pongamia, Jatropha, Neem

INTRODUCTION

The ever increasing number of automobiles has lead to increase in demand of fossil fuels (petroleum). The increasing cost of petroleum is another concern for developing countries as it will increase their import bill. The world is also presently confronted with the twin crisis of fossil fuel depletion and environmental degradation. Fossil fuels have limited life and the ever increasing cost of these fuels has led to the search of alternative renewable fuels for ensuring energy security and environmental Protection. Fuels derived from renewable biological resources for use in diesel engines are known as biodiesel. Biodiesel is environmentally friendly liquid fuel similar to petro-diesel in combustion properties. Increasing environmental concern, diminishing petroleum reserves and agriculture based economy of our country are the driving forces

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to promote biodiesel as an alternate fuel. Biodiesel derived from vegetable oil and animal fats is being used in USA and Europe to reduce air pollution, to reduce dependence on fossil fuel. In USA and Europe, their surplus edible oils like soybean oil, sunflower oil and rapeseed oil are being used as feed stock for the production of biodiesel (Ramadhas *et al.*, 2004; and Rakesh and Meeta, 2007).

Since India is net importer of vegetable oils, edible oils cannot be used for production of biodiesel. India has the potential to be a leading world producer of biodiesel, as biodiesel can be harvested and sourced from non-edible oils like Jatropha Curcus, Pongamia Pinnata, Neem (Azadirachta indica), Mahua, castor, linseed, Kusum (Schlechera trijuga), etc. Some of these oils produced even now are not being properly utilized. Out of these plants, India is focusing on Jatropha Curcas and Pongamia Pinnata, which can grow in arid and wastelands. Oil content in the Jatropha and Pongamia seed is around 30-40%. India has about 80-100 million hectares of wasteland, which can be used for Jatropha and Pongamia plantation. India is one of the largest producer Neem oil and its seed contains 30% oil content. It is an untapped source in India (Barnwal and Sharma, 2005; and Deepak *et al.*, 2007).

Implementation of biodiesel in India will lead to many advantages like green cover to wasteland, support to agriculture and rural economy and reduction in dependence on imported crude oil and reduction in air pollution (Deepak *et al.*, 2007).

Pryde *et al.* (1982) reviewed the reported successes and shortcomings for alternative fuel research. However, long-term engine test results showed that durability problems were encountered with vegetable oils because of deposit formation, carbon buildup and lubricating oil contamination. Thus, it was concluded that vegetable oils must either be chemically altered or blended with diesel fuel to prevent premature engine failure.

Blending, cracking/pyrolysis, emulsification or tranesterifcation of vegetable oils may overcome these problems. Heating and blending of vegetable oils may reduce the viscosity and improve volatility of vegetable oils but its molecular structure remains unchanged. Hence, polyunsaturated character remains. Blending of vegetable oils with diesel, however, reduces the viscosity drastically and the fuel handling system of the engine can handle vegetable oil-diesel blends without any problems. On the basis of experimental investigations, it is found that converting vegetable oils into simple esters is an effective way to overcome all the problems associated with the vegetable oils. Most of the conventional production methods for biodiesel use basic or acidic catalysist. A reaction time of 45 min to 1 h and reaction temperature of 55-65 °C are required for completion of reaction and formation of respective esters (Pryde, 1982; Fangrui and Hanna, 1999; and Srivastava and Prasad, 2004).

Biodiesel consists of alkyl esters of fatty acids produced by the tranesterification of vegetable oils. The use of biodiesel in diesel engines requires no hardware modification. In addition, biodiesel is a superior fuel than diesel because of lower sulpher content, higher flash point and lower aromatic content. Biodiesel fuelled engine emits fewer pollutants. Biodiesel can be used in its pure form or as a blend of diesel. It can also be used as a diesel fuel additive to improve its properties.

Deepak *et al.* (2007) observed significant improvement in engine performance and emission characteristics for the biodiesel fuelled engine compared to diesel fuelled engine. Thermal efficiency of the engine improved, brake specific fuel consumption reduced and a considerable reduction in the exhaust smoke opacity was observed.

TRANESTERIFICATION

The formation of methyl esters by transesterfication of vegetable oil requires raw oil, 15% of methanol and 5% of sodium hydroxide on mass basis. However, transesterification is an equilibrium reaction in which excess alcohol is required to drive the reaction very close to completion. The vegetable oil was chemically reacted with an alcohol in presence of a catalyst to produce methyl esters. Glycerol was produced as a by-product of tranesterification reaction.

CH-COOR1		CH2-OH	R1COOR
I	+ 3ROH catalyst	I	+
CH-COOR2	⇄	CH-OH +	R2ICOOR
I		I	+
CH3-COOR3		CH2-OH	R3COOR

Triglyceride + Methanol → Glycerol + BIODIESEL

where R1, R2, and R3 are long chain hydrocarbons.

The mixture was stirred continuously and then allowed to settle under gravity in a separating funnel. Two distinct layers form after gravity settling for 24 h. The upper layer was of ester and lower layer was of glycerol. The lower layer was separated out. The separated ester was mixed with some warm water (around 10% volume of ester) to remove the catalyst present in ester and allowed to settle under gravity for another 24 h. The catalyst got dissolved in water, which was separated and removed the moisture. The methyl ester was then blended with mineral diesel in various concentrations for preparing biodiesel blends to be used in CI engine for conducting various engine tests (Fangrui and Hanna, 1999; and Deepak *et al.*, 2007)

EXPERIMENTAL SETUP

A typical 3.75 kW single cylinder, 4-stroke, constant speed (1500 rpm) diesel engine used for agricultural applications in rural India was selected for investigation to study the performance and emissions. The Present study was carried out to investigate the performance and emission characteristics of Jatropha, Pongamia and Neem methyl esters in a stationary single cylinder diesel engine and to compare it with diesel duel. Technical specifications of the engine are given in Table 1. The engine was coupled to a rope brake dynamometer. The major pollutants in the exhaust of a diesel engine are smoke. AVL 437 smoke meter was used to measure the smoke density of the exhaust from diesel

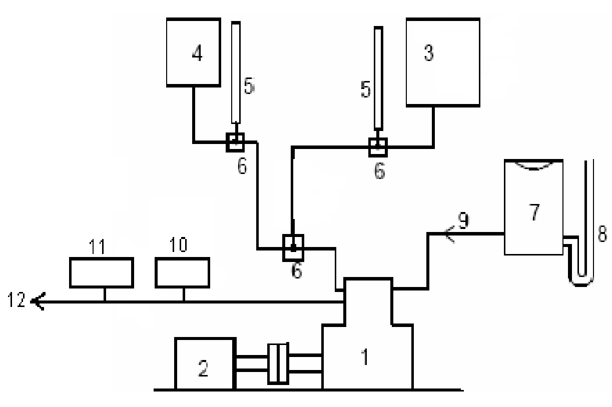
Table 1: Engine Specifications

Type	Kirloskar
Details	Single Cylinder, Four Stroke, DI, Water Cooled
Bore and Stroke	80 × 110 mm
Compression Ratio	16.5 :1
Rated Power	3.7 KW at 1500 rpm
Injector Opening Pressure	210 bar

engine. HORIBA-MEXA-324 FB was used for the measurement of CO and HC emissions.

The engine was operated on diesel first and then on methyl esters of Jatropha, Pongamia, Neem and their blends. The different fuel blends and mineral diesel were subjected to performance and emission tests on the engine. The performance data were then analyzed from the graphs regarding thermal efficiency, brake-specific fuel consumption and smoke density of all fuels. The brake-specific fuel consumption is not a very reliable parameter to compare different fuels, as the calorific values and the densities are different.

Figure 1: Experimental Setup



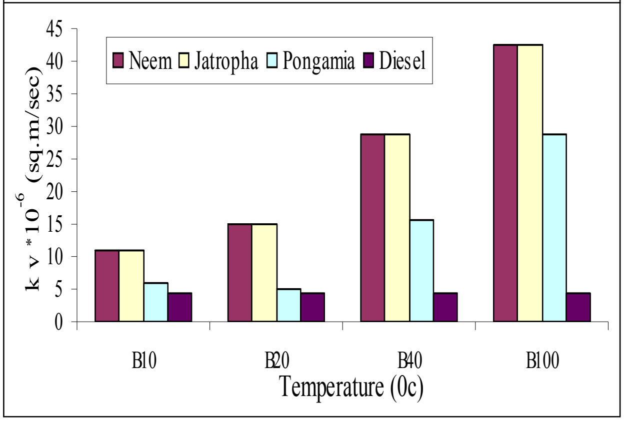
Note: 1) Engine, 2) Dynamometer, 3) Fuel tank (Bio-diesel), 4) Diesel tank, 5) Burettes, 6) Three way valve, 7) Air box, 8) Manometer, 9) Air flow direction, 10) Exhaust analyzer (CO and HC), 11) Smoke meter and 12) Exhaust flow.

RESULTS AND DISCUSSION

The experimental investigation was carried out for different blends of Pongamia, Jatropha and Neem methyl esters (biodiesels) and the performance was evaluated and compared with diesel.

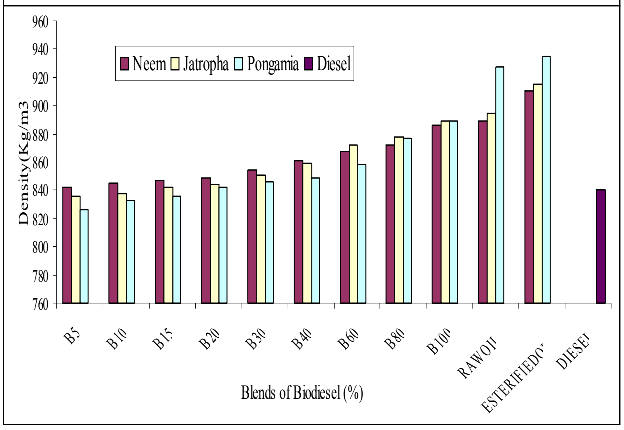
In Figure 2, the Kinematic Viscosity (at room temperature of 35 °C) of different blends of methyl esters B10, B20, B40 and B100 are higher than the viscosity of diesel. But up to B20 the viscosity of biodiesel is very close to the viscosity of diesel. So that the biodiesels of B5, B10, B15 and B20 blends can be used with out any heating arrangement.

Figure 2: Kinematic Viscosity vs. Temperature



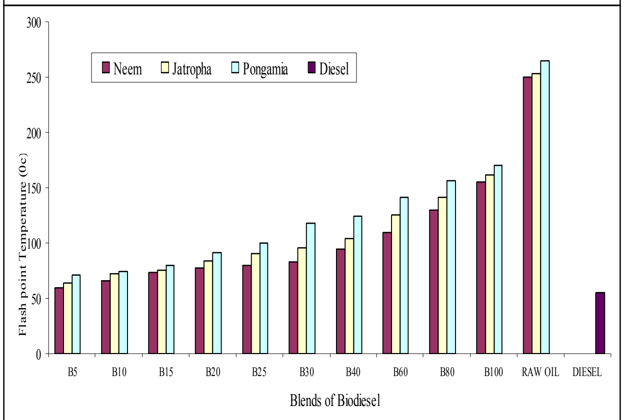
The density of different blends of methyl esters are increased with increase in blend percentage as shown in Figure 3. The blends of B5, B10, B15 and B20 of Pongamia, Jatropha and Neem methyl esters are closer to the density of diesel, because of which Pongamia, Jatropha and Neem methyl esters are an alternative fuels for diesel. The high density of methyl esters (B25, B30, B60, etc.), can be reduced by heating of fuel.

Figure 3: Different Blends of Biodiesel vs. Density of Oils



The flash points of different blends of methyl esters are increased with increase in methyl ester percentage as shown in Figure 4. It is also observed that the flash points of raw and esterified oils are more compared to diesel. Thus, it can be used as a fuel without any fire accidents.

Figure 4: Blends of Biodiesel vs. Flash Point Temperatures



In Figures 5 to 8, a slight drop in efficiency was found with methyl esters (biodiesel) when compared with diesel. This drop in thermal efficiency must be attributed to the poor combustion characteristics of methyl esters due to high viscosity. It was observed that the brake thermal efficiency of B10, and B20 are

Figure 5: Brake Power vs. Brake Thermal Efficiency for B10 Blends

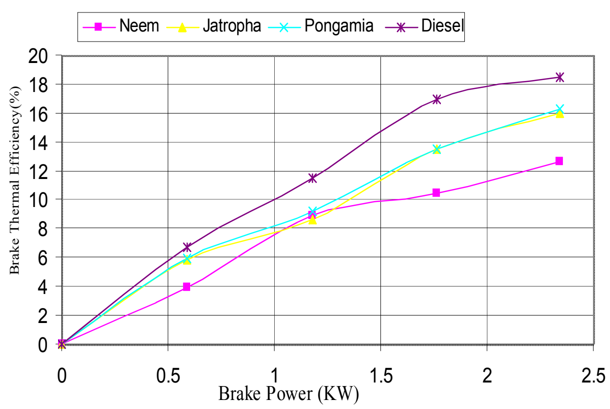


Figure 6: Brake Power vs. Brake Thermal Efficiency for B20 Blends

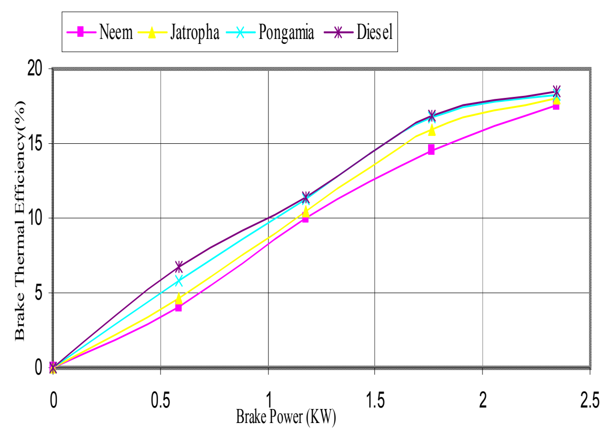


Figure 7: Brake Power vs. Brake Thermal Efficiency for B40 Blends

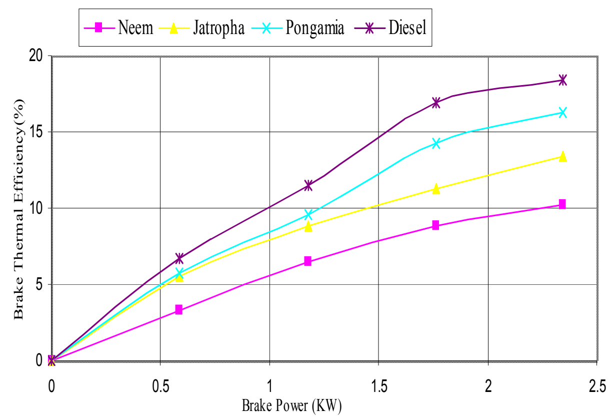
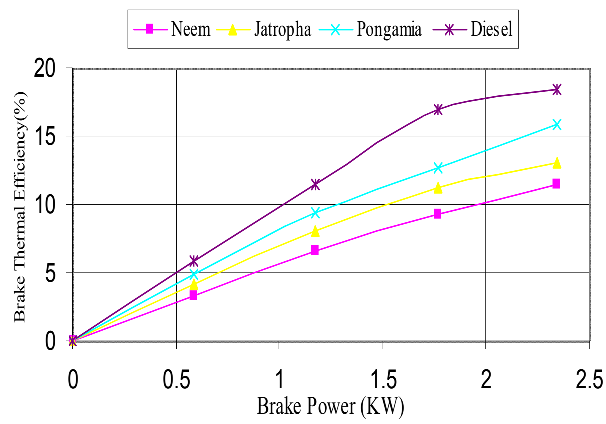


Figure 8: Brake Power vs. Brake Thermal Efficiency for B100 Blends



very close to brake thermal efficiency of Diesel. B20 methyl ester had equal efficiency with diesel. Pongamia Methyl Ester (PME) had better brake thermal efficiency than compared with the methyl esters of Jatropha and Neem. So B20 can be suggested as best blend for biodiesel preparation with Pongamia oil.

Smoke density was calculated by Opacity test for various blends of biodiesel and diesel. Biodiesel gives less smoke density compared to petroleum diesel. When percentage of blend of biodiesel increases, smoke density decreases as shown in Figures 9 to 12, but smoke density increases for B80 and B100

Figure 9: Brake Power vs. Smoke Density(K) for B10 Blends

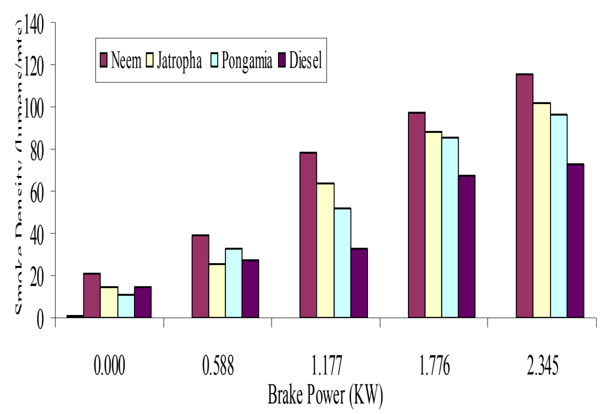


Figure 10: Brake Power vs. Smoke Density(K) for B20 Blends

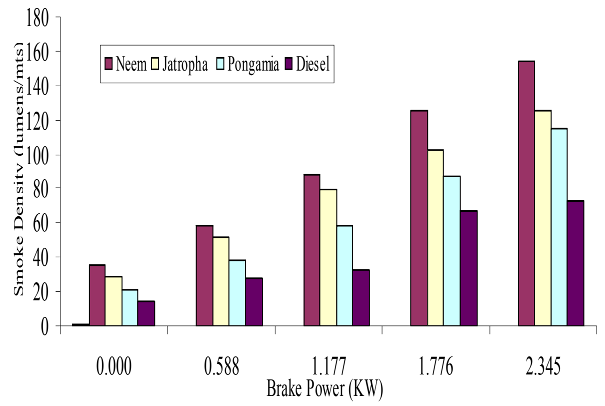


Figure 11: Brake Power vs. Smoke Density(K) for B40 Blends

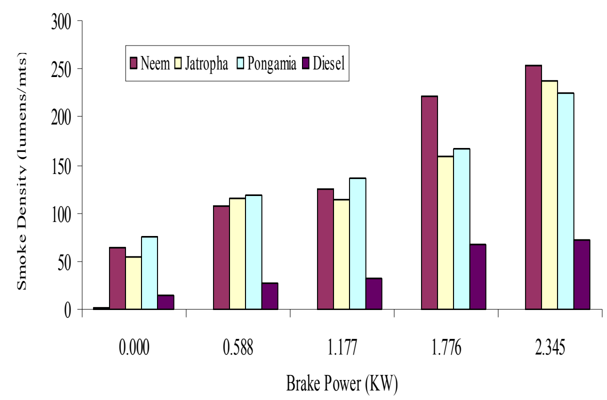
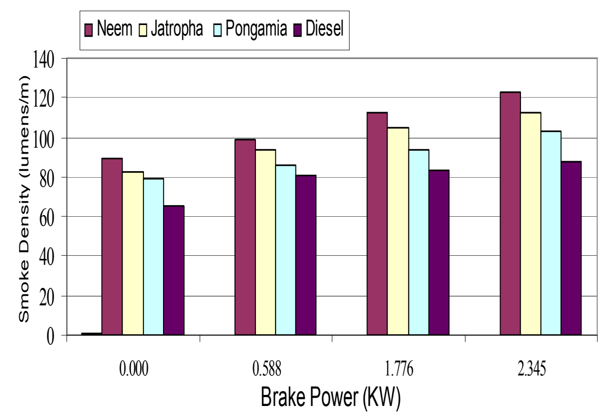


Figure 12: Brake Power vs. Smoke Density(K) for B100 Blends



due to insufficient combustion. It requires changes in injection pressure and combustion chamber design. Smoke density also decreases when load increases.

Carbon monoxide emissions for all blends of Pongamia, Jatropha and Neem are measured to be lower in comparision with diesel. The emissions of carbon monoxide of different blends are found to be increasing with increase in load and decrease with increase in percentage of blend of biodiesel. Pongamia methyl ester gives less carbon monoxide emissions than other methyl esters. The main difference between ester-based fuel and

Figure 13: Carbon Monoxide vs. Brake Power for B10 Blends

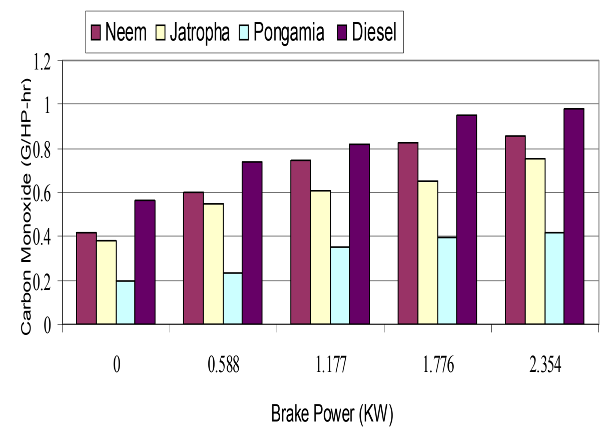


Figure 14: Carbon Monoxide vs. Brake Power for B20 Blends

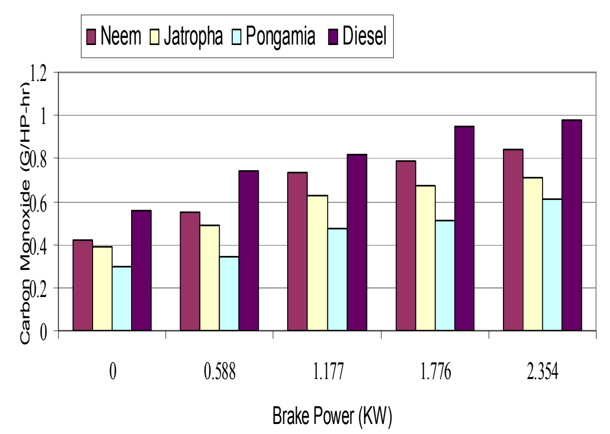


Figure 15: Carbon Monoxide vs. Brake Power for B40 Blends

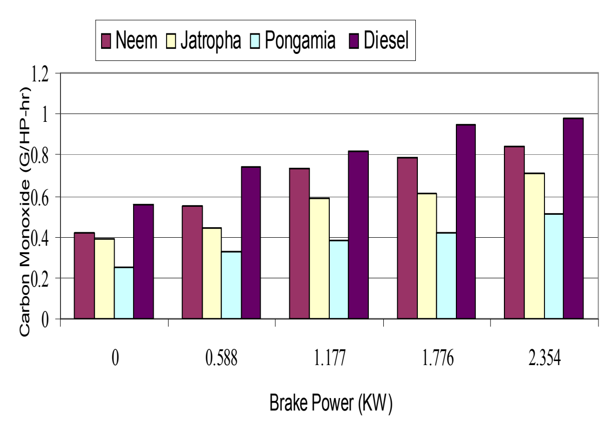
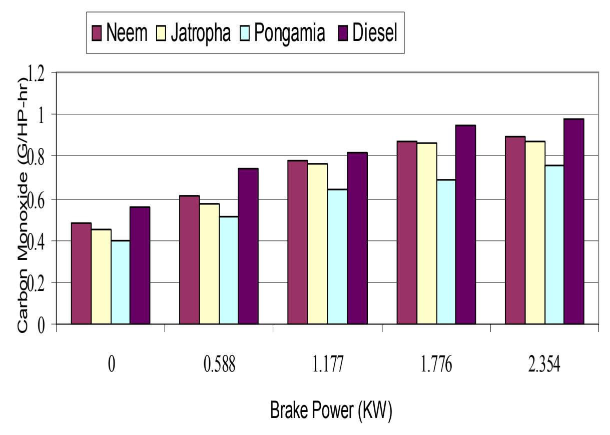


Figure 16: Carbon Monoxide vs. Brake Power for B100 Blends



diesel is the oxygen content, heating value and cetane number. The ester-based fuel generally contains approximately 10-12% of excess oxygen. During combustion process, this bounded oxygen may be available locally to enhance the burning process by which most of the carbon available in the fuel may oxidize to CO_2 leaving very less CO as intermediate products. Hence carbon monoxide, which is present in the exhaust due to incomplete combustion, reduces drastically (Figures 13 to 16).

Hydrocarbons were calculated by Emission test for various blends of biodiesel and diesel. In Figures 17 to 20, Biodiesel gives fewer Hydrocarbons than compared to petroleum diesel. When percentage of blend of biodiesel increases Hydrocarbons decreases. But Hydrocarbons increase for B60, B80 and B100 due to insufficient combustion. It requires changes in injection pressure and combustion chamber design. Hydrocarbons also increase when load increases.

The variations of NOx emissions with brake power for methyl esters and their blends are

Figure 17: Hydrocarbons vs. Brake Power for B10 Blends

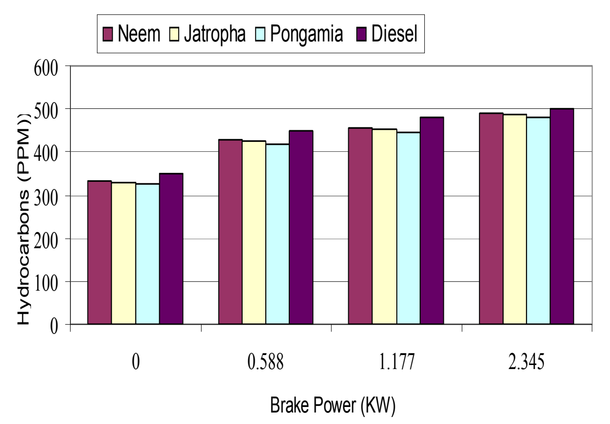


Figure 18: Hydrocarbons vs. Brake Power for B20 Blends

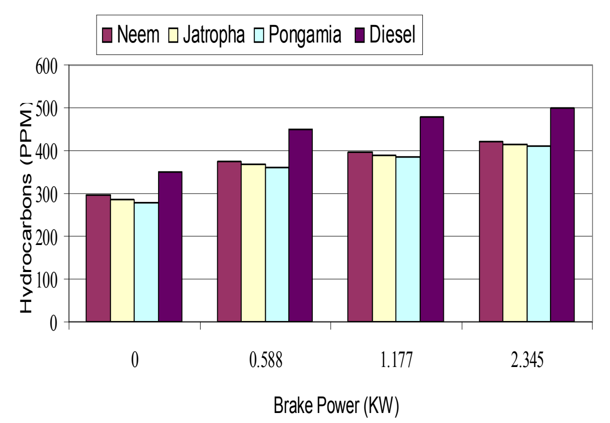


Figure 19: Hydrocarbons vs. Brake Power for B40 Blends

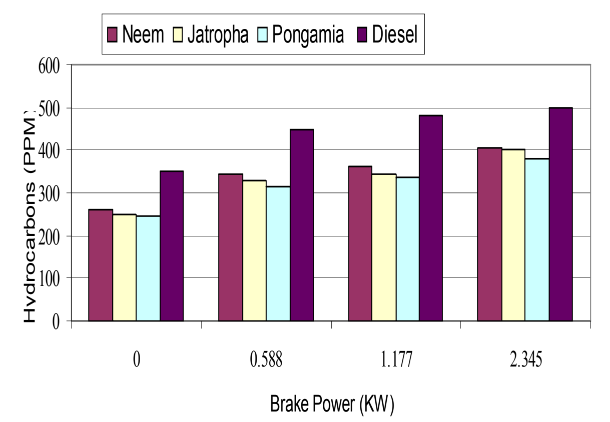
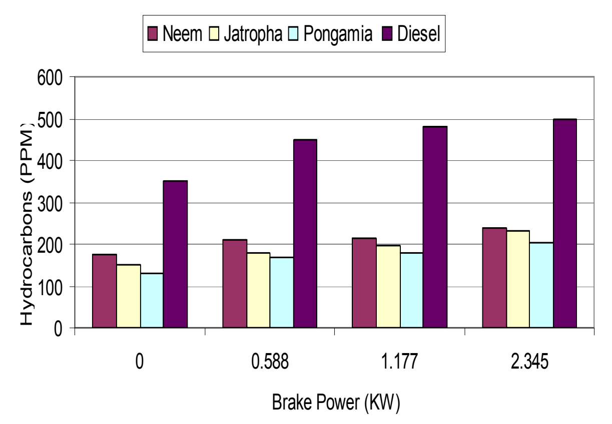


Figure 20: Hydrocarbons vs. Brake Power for B100 Blends



compared with those of diesel in Figures 21 to 23. It is observed that the NOx emissions increase with increase in power for all the biodiesel blends of B20, B40. This is due to increase in the amount of fuel burnt with load, which results in increase in combustion temperature. At any brake power a gradual increase in the emission of nitrogen oxides (NOx) with increase in percentage of methyl ester in the fuel is observed. Methyl esters with their lower stoichiometric air-fuel ratio relative to diesel can burn with less air requirement for combustion. This results in higher combustion

Figure 21: Variation of NOx for Various B20 Blends

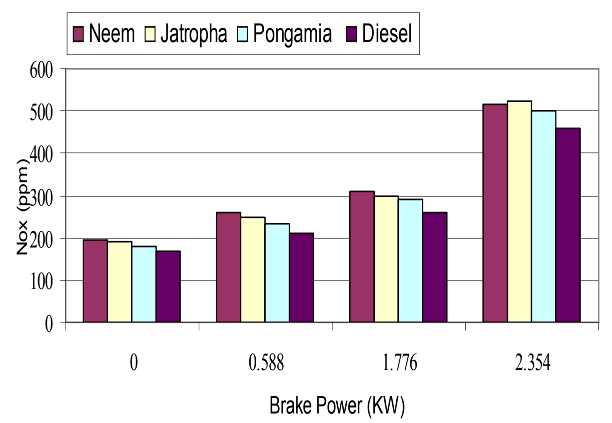


Figure 22: Variation of NOx for Various B40 Blends

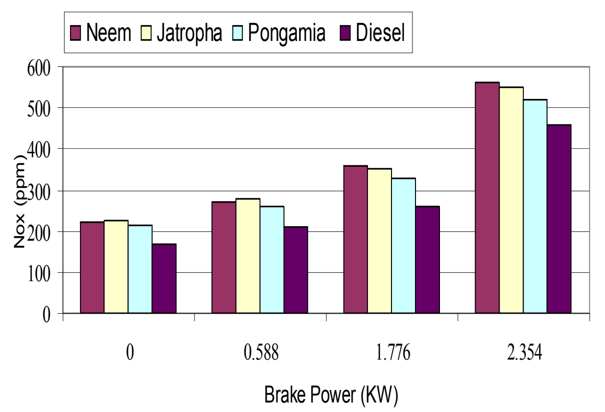
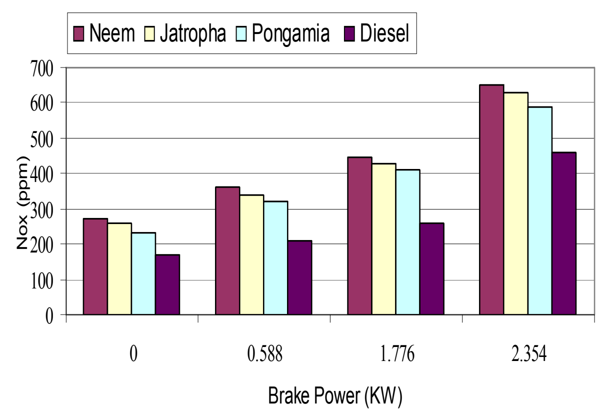


Figure 23: Variation of NOx for Various B100 Blends



temperatures. As methyl esters are oxygenated fuels more oxygen is available for the formation of NOx compared to diesel. Hence the NOx emissions are found to be increasing with increase in percentage of methyl esters in the blend. Among the three fuels NOx emissions with Pongamia is noticed to be the lowest.

CONCLUSION

Based on the experimental results obtained while operating single cylinder diesel engine fuelled with biodiesel from Pongamia, Jatropha and Neem seed oils and their diesel blends, the following conclusions are drawn.

- Pongamia, Jatropha and Neem based methyl esters (biodiesels) can be directly used in diesel engines without any engine modifications.
- Brake thermal efficiency of B10, B20 and B40 blends are better than B100 but still inferior to diesel.
- Properties of different blends of biodiesel are very close to the diesel and B20 is giving good results.
- It is not advisable to use B100 in CI engines.
- Smoke, HC, CO emissions at different loads were found to be higher for diesel, compared to B10, B20, B40 and B100 blends.
- NOx emissions for biodiesel were found higher than diesel. Among the three fuels NOx emissions with Pongamia is noticed to be the lowest.

Good mixture formation and lower smoke emission are the key factors for good CI engine performance. These factors are highly influenced by viscosity, density, and volatility of the fuel. For Biodiesels, these factors are mainly decided by the effectiveness of the transesterification process. With properties close to diesel fuel, Biodiesel from Jatropha, pongamia and Neem seed oil can provide a useful substitute for diesel thereby promoting our economy.

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