JJMIE

Volume 2, Number 2, Jun. 2008
ISSN 1995-6665
Pages 117 - 122

Jordan Journal of Mechanical and Industrial Engineering

Experimental Investigation of Pongamia, Jatropha and Neem Methyl Esters as Biodiesel on C.I. Engine

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Abstract

The methyl esters of vegetable oils, known as biodiesel are becoming increasingly popular because of their low environmental impact and potential as a green alternative fuel for diesel engine and they would not require significant modification of existing engine hardware. Methyl ester of Pongamia (PME), Jatropha (JME) and Neem (NME) are derived through transesterification process. Experimental investigations have been carried out to examine properties, performance and emissions of different blends (B10, B20, and B40) 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 and HC. Pongamia methyl ester gives better performance compared to Jatropha and Neem methyl esters.

Keywords: Bio-diesel; Non edible oils; Transesterification; Methyl Esters;

1. Introduction

Fuels derived from renewable biological resources for use in diesel engines are known as biodiesel. Biodiesel is environmentally friendly liquid fuel similar to petrol-diesel in combustion properties. Increasing environmental concern, diminishing petroleum reserves and agriculture based economy of our country are the driving forces 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. [1, 4]

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. [2, 3]

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. [3]

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 transesterification 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

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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 45min to 1h and reaction temperature of 55-65° C are required for completion of reaction and formation of respective esters. [5, 6, 7]

Biodiesel consists of alkyl esters of fatty acids produced by the tranesterification of vegetable oils. The use of biodiesel in diesel engines require 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.

Agarwal [3] 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.

2. Tranesterification:

The formation of methyl esters by transesterification of vegetable oil requires raw oil, 15% of methanol & 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 transesterification reaction.

CH-COOR1				CH_2-OH		R1COOR
|				|		+
CH-COOR2	+	3ROH	$\xrightarrow{\text{Catalyst}}$	CH-OH	+	R2COOR
|				|		+
CH-COOR3				CH_2-OH		R3COOR
Triglyceride	+	Methanol	$\xrightarrow{\text{Catalyst}}$	Glycerol	+	Biodiesel

Where R1, R2, & R3are 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. [3, 6, 15]

3. Experimental setup:

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 437smoke meter was used to measure the smoke density of the exhaust from diesel 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.

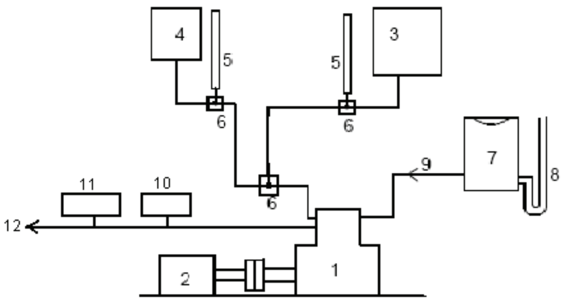

Figure 1: Experimental Setup

1) Engine	7) Air box
2) Dynamometer	8) Manometer
3) Fuel Tank (Bio-diesel)	9) Air flow direction
4) Diesel Tank	10) Exhaust Analyzer (CO & HC)
5) Burettes	11) Smoke meter
6) Three way valve	12) Exhaust flow

Table 1: Engine Specifications

Type	Kirloskar
Details	Single cylinder, Four stroke, DI, Water cooled
Bore & Stroke	80 × 110 mm
Compression ratio	16.5 :1
Rated Power	3.7 KW at 1500 rpm
Injector Opening Pressure	210 bar

4. Results and Discussions:

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

1. In Fig. 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 biodiesel of B5, B10, B15 and B20 blends can be used with out any heating arrangement.

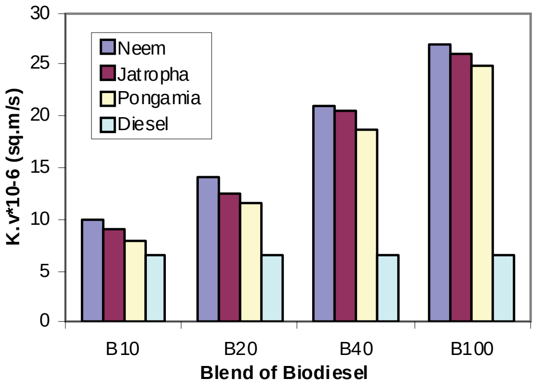

Fig. 2: Kinematic Viscosity Vs Blends

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

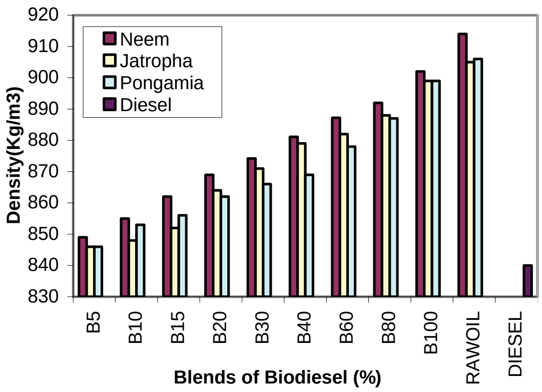

Fig. 3: Different blends of biodiesel Vs Density

3. The flash points of different blends of methyl esters are increased with increase in methyl ester percentage as shown in Fig.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.

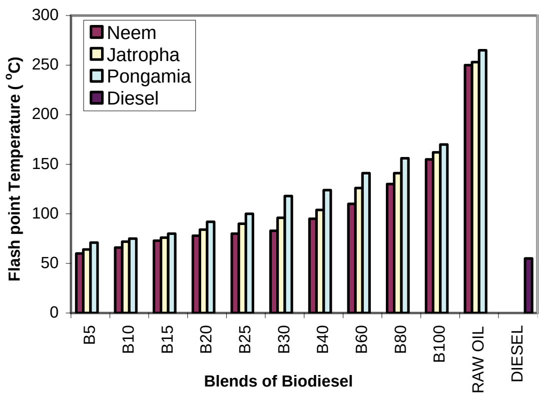

Fig. 4: Blends of Biodiesel Vs Flash Point Temeratures

4. In Fig. 5 to 7, 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 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.

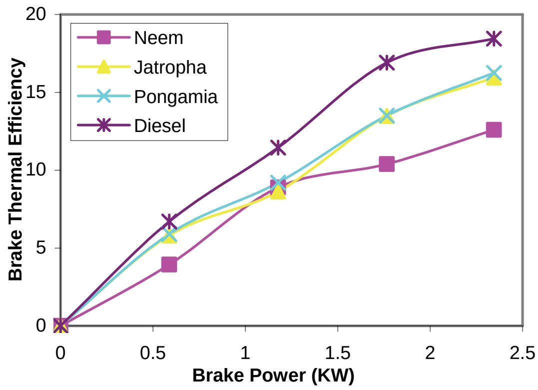

Fig. 5: Brake Power Vs Brake Thermal Efficiency for B10 Blends

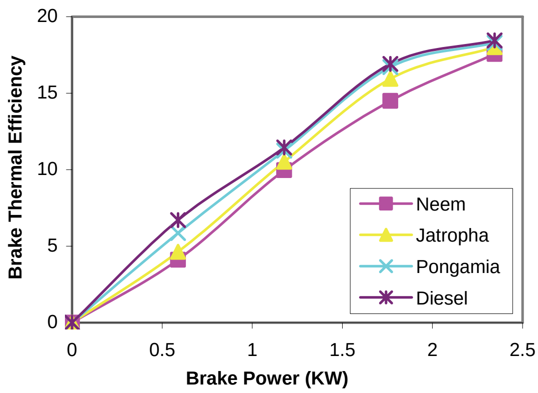

Fig. 6: Brake Power Vs Brake Thermal Efficiency for B20 lends

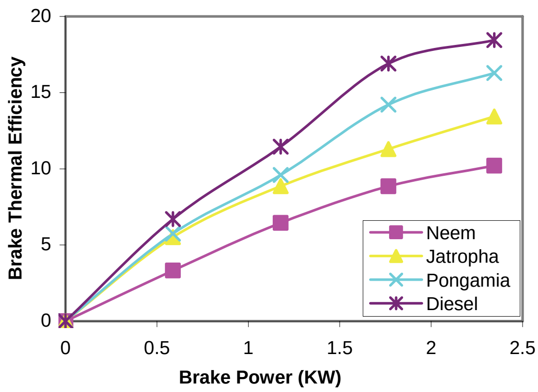

Fig. 7: Brake Power Vs Brake Thermal Efficiency for B40 Blends

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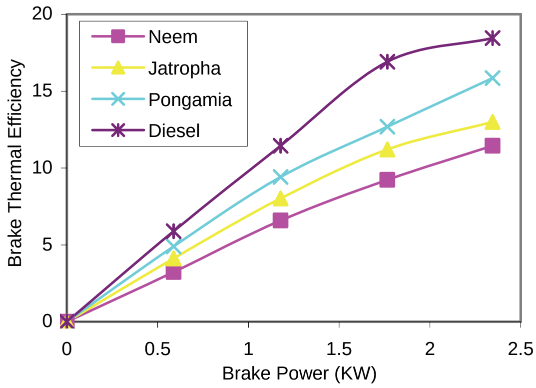

Fig. 8: Brake Power Vs Brake Thermal Efficiency for B100 Blends

5. 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 Fig.9 to 11, but smoke density increases for B80 and B100 due to insufficient combustion. It requires changes in injection pressure and combustion chamber design. Smoke density also decreases when load increases.

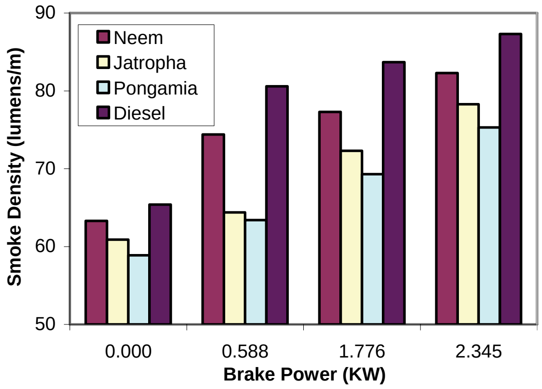

Fig. 9: Brake Power Vs Smoke Density (K) for B10 Blends

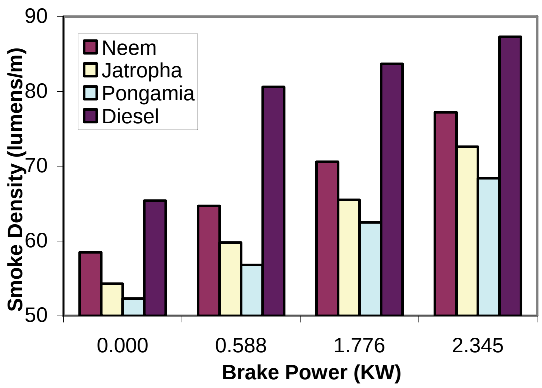

Fig. 10: Brake Power Vs Smoke Density (K) of B20 Blends

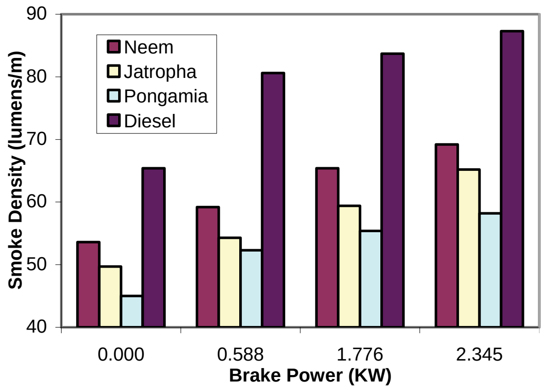

Fig. 11: Brake Power Vs Smoke Density (K) of B40 Blends

6. Carbon monoxide was calculated by Emission test for various blends of biodiesel and diesel. Biodiesel gives less Carbon monoxide than compared to petroleum diesel. When percentage of blend of biodiesel increases, Carbon monoxide decreases. But Carbon monoxide increases for B60, B80 and B100 due to insufficient combustion. It requires changes in injection pressure and combustion chamber design.

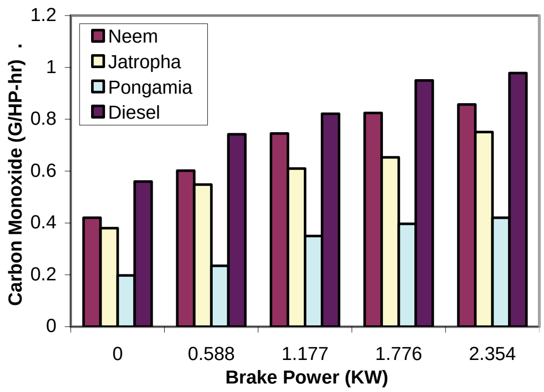

Fig. 12: Brake Power Vs Carbon monoxide for B10 Blends

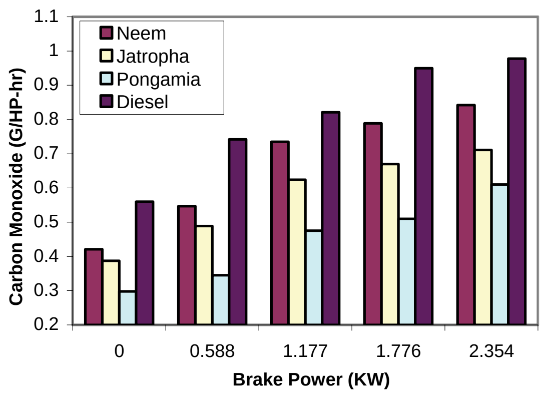

Fig. 13: Brake Power Vs Carbon monoxide for B20 Blends

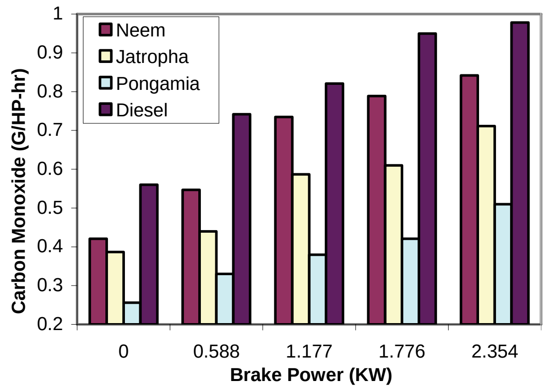

Fig. 14: Brake Power Vs Carbon monoxide for B40 blends

7. Hydrocarbons were calculated by Emission test for various blends of biodiesel and diesel. In Fig. 15 to 17, 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.

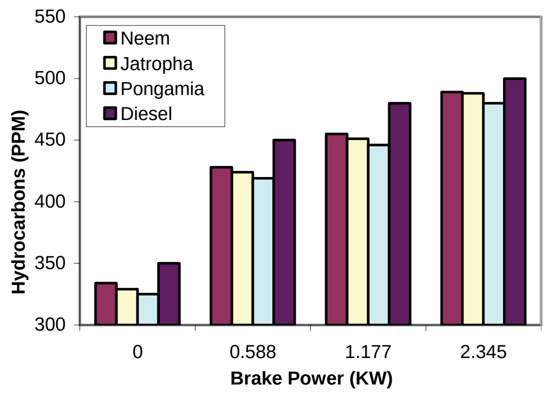

Fig. 15: Brake Power Vs Hydrocarbons for B10 Blends

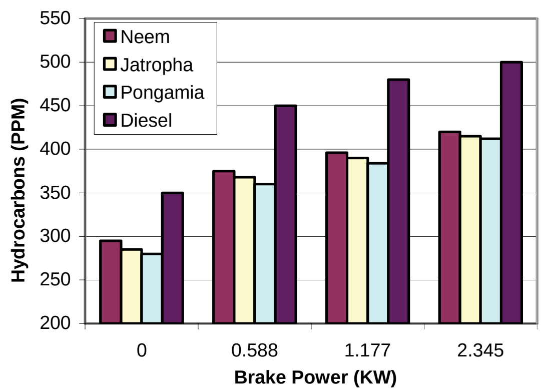

Fig. 16: Brake Power Vs Hydrocarbons for B20 Blends

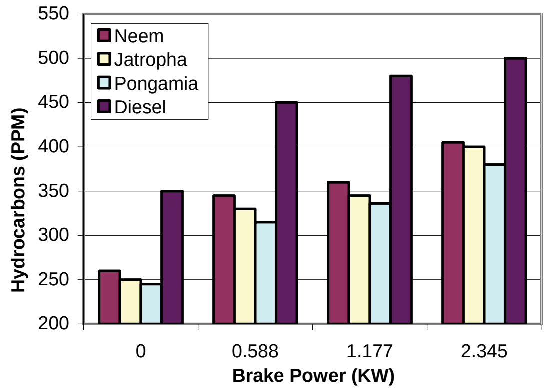

Fig. 17: Brake Power Vs Hydrocarbons for B40 Blends

5. Conclusions:

Following are the conclusions 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.

- Pongamia, Jatropha and Neem based methyl esters (biodiesel) 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 unless its properties are comparable with diesel fuel.
- Smoke, HC, CO emissions at different loads were found to be higher for diesel, compared to B10, B20, B40 blends.

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 bio-diesels, these factors are mainly decided by the effectiveness of the transesterification process. With properties close to diesel fuel, bio-diesel from Jatropha, pongamia pinnata and Neem seed oil can provide a useful substitute for diesel thereby promoting our economy.

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