Performance of CI Engine using Mahua Biodiesel and its Blend in Different Proportion

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Abstract

This paper deals with performance and emission characteristics of biodiesel obtained from mahua oil and its blend with diesel in different proportion as fuel for four stroke single cylinder CI engine. The engine performance parameter like specific fuel consumption and brake thermal efficiency were investigated. Also engine emissions of CO_2, CO, HC and NO_x were analyzed and discussed. All experiments were carried out for different proportion biodiesel that are MB0, MB20, MB40, MB60, MB80 and MB100 at various brake power. The obtained results have shows that, the blend MB20 gave the best performance and is closest to diesel fuel. Also reduction in exhaust emission has been reported. Further, based on the experimental results the brake thermal efficiency of the blend MB20 was found to be 2.79% lesser than diesel fuel. Also, the emission characteristics of MB20 are such as HC at full load conditions was 8.56% lesser than diesel and CO was 15.66% lesser at 3KW brake power, while it has been observed that on further loading CO emission get enhanced . On the other hand, the NO_x emission was obtained slightly higher than the diesel fuel by 3.77%. The outcomes of this paper corroborate that, without any modification in engine, the blend MB20 can be used as an alternate fuel for the diesel.

1. Introduction

The growing concern due to environmental pollution caused by the conventional fossil fuels and the realization that they are non-renewable have led to search for more environment friendly and renewable fuels. Among various options investigated for diesel fuel, biodiesel obtained from vegetable oils has been recognized world over as one of the strong contenders for reductions in exhaust emissions. Several countries including India have already begun substituting the conventional diesel by a certain amount of biodiesel. Worldwide biodiesel production is mainly from edible oils such as soybean, sunflower and canola oils. Since, India is not self sufficient in edible oil production, hence, some non-edible oil seeds available in the country are required to be tapped for biodiesel production. With abundance of forest and plant based non-edible oils being available in our country such as Pongamia pinnata (karanja), Jatropha curcas (jatropha), Madhuca indica (mahua), Shorea robusta (Sal), Azadirachta indica A Juss (neem) and Hevea braziliensis (rubber), no much attempt has been made to use esters of these non-edible oils as substitute for diesel except jatropha and karanja. Moreover, there are plenty of wastelands available in India, which can be utilized for growing such oil seed crops. Few investigators have already obtained biodiesel from some of these oils [1–5]. However, as compared to other non-edible oils, not much work has been reported on biodiesel production from mahua oil, which has an estimated annual production potential of 181 thousand tons in India [6]. In the light of the above facts, present study was undertaken at Radharaman Institute of Technology & Science, Bhopal to determine the suitability of mahua biodiesel as a substitute for diesel.

2. Literature Survey

Pramod Kumar P et al. [7] had analyzed the performance and emission parameters of DI CI engine fuelled with neem biodiesel and n-octanol additives**.** In this test octanol (Oct) is added to neem biodiesel (NBD) and diesel (D) as an additive to create the fuel blends and its impact upon performance and emission characteristics are evaluated. The fuel properties are found be improved on using higher alcohol additives such as octanol which is having high energy content as well as high cetane number and are also easily miscible in biodiesel and diesel. From the experiment conducted on diesel engine using both diesel as well as with prepared blends, significant decrease for all emission associated with neem biodiesel, diesel and octanol blends was found without any substantial loss of performance compared with results while using neat diesel. The results indicate that blending octanol with biodiesel blends isa viable option as alternative fuel source for CI engines.

Rakesh Kumar et al. [8] had experimental analyzed the performance and emission characteristics of DI CI engine with dual biodiesel blends of mexicana argemone and mahua**.** In this study, the effects of engine load and amount of biodiesel percentage on the performance and emission characteristics of single cylinder, 4 stroke diesel engine has been investigated and presented. The dual biodiesel blends of Argemone Mexicana and Mahua (Madhuca indica) were used in the present study. The results for biodiesel blend D60A20M20 (i.e 60% diesel, 20% Argemone and 20% Mahua) with diesel showed slight increase in brake power. There was average 0.06kg/kW h increase in specific fuel consumption for the biodiesel blends at full load. The carbon monoxide (CO) and hydrocarbons (HC) emissions reduced for the biodiesel blend, while NO_x emission was higher as compared to diesel.

Yuvarajan Devarajan [9] had experimentally evaluated the combustion, emission and performance of research diesel engine fuelled di-methyl-carbonate and biodiesel blends. In this study details an outcome of the Di-methyl-carbonate (DMC) as a cetane improver on neat Almond biodiesel (BD100) to evaluate the emission and performance engine characteristics. Four fuels namely diesel, biodiesel (Almond Methyl Ester), a blend of B100-10% and 20% by volume of DMC (BD90DMC10 and BD80DMC20) are prepared and tested on a stationary research diesel engine. The experimental parameters for BD80DMC20 showed a 1.6% increase in thermal efficiency thereby reducing 4.1% of fuel consumption than the neat biodiesel at peak conditions. Experimental outcomes revealed that 20% of DMC reduces 7.4% CO, 5.2% HC and 4.7% NOx and 3.6% smoke emissions of BD100. Further, The DMC inclusion at 10% volume significantly reduces the peak pressure and increases the net Heat Release rate values and its corresponding CA. An inclusion of 20% DMC in BD100 reduces the In-Cylinder Pressure and increases the Net Heat Release Rate values by 2.2% and 4.7% respectively than BD100. From this study, it is inferred that BD80DMC20 blend could be utilized as a substitute fuel for CI engine.

M.Vijay Kumar et al. [10] Experimental investigated the effects of diesel and mahua biodiesel blended fuel in direct injection diesel engine modified by nozzle orifice diameters. In this paper, Mahua seed oil was transesterified with methanol using acid and alkaline catalyst process to obtain Mahua Methyl Ester. The chemical composition and physical properties of MME were tested. Experimental tests were investigated to study the performance, combustion and emission on computerized single cylinder CI diesel engine fueled with diesel and B20 (20% (vol.) of

MME biodiesel + 80% (vol.) of diesel) along with each of the three nozzles has 3 injection holes, with the aperture of Ø = 0.20 mm (modified), Ø = 0.28 mm (base), and Ø = 0.31 mm (modified). The engine performance, combustion and emission is examined by measuring BSFC, BTE, In-cylinder pressure, MGT, HRR, CO, HC, NO_x and smoke opacity. The authentic results were observed by using B20 and smaller orifice NHD. It is observed that smaller orifice NHD improves the air-fuel mixing, atomization, and vaporization which leads to shorter combustion duration. The B20 fuel showed better results such as performance at lower side of partial loads, combustion and emissions than the baseline diesel. The combination of B20 with smaller orifice NHD has shown appreciable results in performance, combustion and emissions. But, the only drawback was NO_x is found to be increased.

M.ArunKumar et al. [11] investigated the performance and emission analysis of a variable compression multi fuel engine filled with karanja bio diesel-diesel blend. The emission and performance and emission of a single cylinder with four stroke variable compression of multi fuel engines when it is fueled with 20%, 25% and 30% of karanja blended with diesel is to be investigated and compared with the standard diesel. The experiment has been conducted at a compression ratio of 15:1, 16:1, 17:1 and 18:1. The impact of break thermal efficiency, compression ratio on fuel consumption and exhaust gas emissions has been investigated and presented. The performance and the experimental analysis of biodiesel over the diesel was evaluated by the response of surface methodology to find out the optimized working condition. Then the overall optimum is found to be 25% biodiesel–diesel blended with a compression ratio of 18.

Arulprakasajothi mahalingam et al. [12] had investigated the emissions analysis on mahua oil biodiesel and higher alcohol blends in diesel engine**.** Author observed high cetane number and energy content of octanol can be an excellent alternative fuels for existing diesel engines. It is necessary to have an extensive analysis on octanol as an additive in diesel engines. In this study neat mahua oil biodiesel is blended with different proportion of octanol in stationary diesel engine to observe its emission characteristics. Mahua oil biodiesel is prepared by conventional transesterification. The main aim of this study is to reduce various emissions of mahua oil biodiesel by appending octanol. This study discovered a significant reduction in all the emissions associated with mahua oil biodiesel by appending octanol at different proportions.

C. Syed Aalam et al. [13] had studied effects of nano metal oxide blended mahua biodiesel on crdi diesel engine. In this paper, aluminium oxide nanoparticles (ANPs) were added to Mahua biodiesel blend (MME20) in different proportions to investigate the effects on a four stroke, single cylinder, common rail direct injection (CRDI) diesel engine. The ANPs were doped in different proportions with the Mahua biodiesel blend (MME20) using an ultrasonicator and a homogenizer with cetyl trimethyl ammonium bromide (CTAB) as the cationic surfactant. The experiments were conducted in a CRDI diesel engine at a constant speed of 1500 rpm using different ANP-blended biodiesel fuel (MME20 + ANP50 and MME20 + ANP100) and the results were compared with those of neat diesel and Mahua biodiesel blend (MME20). The experimental results exposed a substantial enhancement in the brake thermal efficiency and a marginal reduction in the harmful pollutants (such as CO, HC and smoke) for the nano particles blended biodiesel.

3. Experimental Procedure

The tests were conducted on a single cylinder four-stroke naturally aspirated water cooled diesel engine loaded with a rope brake dynamometer. The technical specification of the engine used for the investigation are given in table 3.1

3.1 Test Setup Specification

A single cylinder 4-stroke water-cooled direct injection diesel engine is used for investigation.

Table 3.1 Engine Specification

Engine parameter	**Specifications**
Engine	4-Stroke Single cylinder (Diesel Engine)
Rated Power	5 BHP
Speed	1500 rpm
Bore	87.5 mm
Stroke	110 mm
Volume	661 cc
Nozzle Type	Single hole
Cooling system	Water cooled

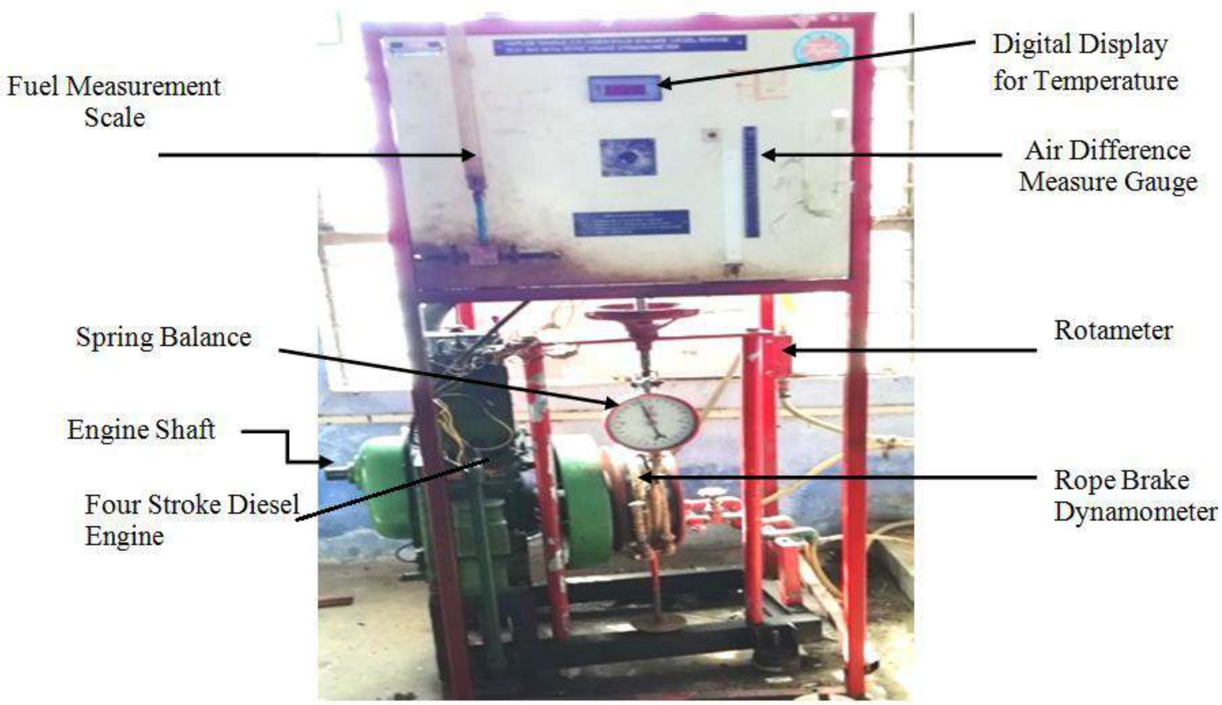

Fig.2 Actual view of experimental setup

The actual view of experimental setup is shown in Fig.2. The setup consists of single cylinder engine coupled with rope brake dynamometer. The dynamometer is used to load and unload the engine as per experiment requirement. In order to measure revolution of the engine shaft a sensor is coupled with the shaft to count the rpm of the shaft, and for measuring various exhaust the test engine is connected with a exhaust sensor. A sensor is coupled with the exhaust pipe outlet to sense various contents of exhaust gas and sent the result to CPU which in turn shows the results on the monitor screen. For cooling external jacket of the engine is coupled with water source. And the fuel tank is coupled with engine to supply the fuel to the cylinder. Experiments were conducted with mahua biodiesel and diesel blends having 0%, 20%, 40%, 60%, 80% and 100% mahua biodiesel on volume basis at different load levels. Tests of engine performance on pure diesel were also conducted as a basis for comparison. The percentage of blend and load, were varied and engine performance measurements such as specific fuel consumption, brake thermal efficiency and emissions were measured to evaluate and compute the behavior of the diesel engine. Each time the engine was run at least for few minutes to attain steady state before the measurements were made. The experiments were repeated thrice and the average values were taken for performance and emission measurements.

4. Results and Discussions

The experiment was conducted on five types of mahua biodiesel blending ratio (mahua biodiesel blended with diesel) that are MB0, MB20, MB40, MB60, MB80 and MB100 tested on diesel engine. The experiment was carried at Internal Combustion Engine Laboratory of Radharaman Institute of Technology & Science, Bhopal.

The parameters that have been tested for comparing six types of mahua biodiesel blending ratio are performance and emission tests. For the performance test, the terms that were considered are specific fuel consumption and brake thermal efficiency at different load. Also, for the emission test carbon dioxide (CO_2), carbon monoxide (CO), hydrocarbon (HC) & oxides of nitrogen emission (NO_x) were considered at different load. The performance and emissions test for the six types of fuel were analysed and results obtained are graphically presented.

4.1. Variation of specific fuel consumption and brake power for different blending ratios

The variation of specific fuel consumption and brake power for different blending ratios i.e. MB0, MB20, MB40, MB60, MB80 & MB100 is shown in Fig. 4.1

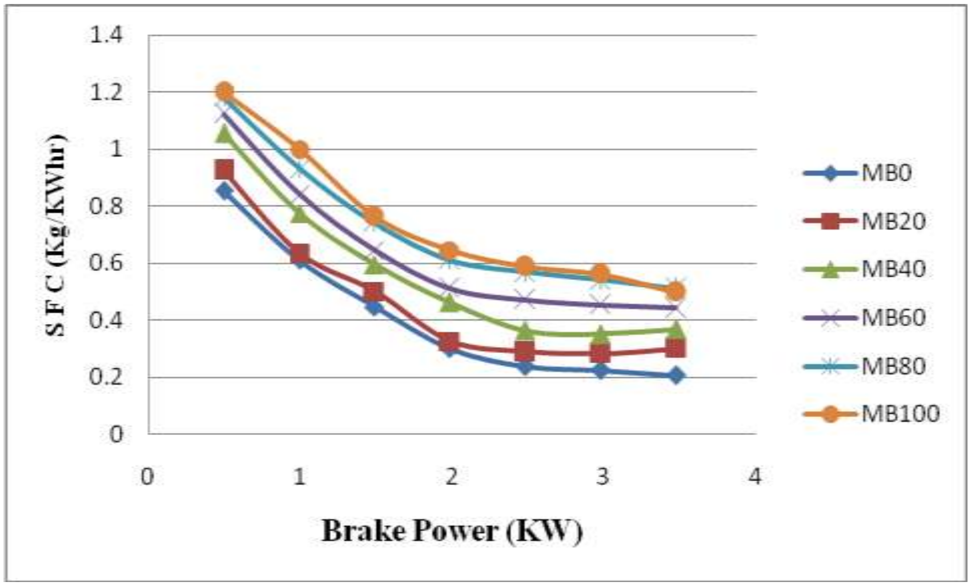

Fig. 4.1 Variation of specific fuel consumption and brake power for different blending ratios

It shows that the specific fuel consumption decreased with an increase in brake power for different blending ratios. It was also observed that specific fuel consumption is slightly higher than diesel for different blending ratio. The main reason for this could be that percent increase in fuel required to operate the engine is less than the percent increase in brake power due to relatively less portion of the heat losses at higher loads [15].

It is found that the specific fuel consumption for the MB20 blend is close to diesel. This is mainly due to the lower heating value of the blend than diesel. Similarly, the blends also have higher viscosity and higher oxygen content when compared to diesel [16]. The higher densities of biodiesel blends caused higher mass injection for the same volume at the same injection pressure [15].

4.2 Variation of brake thermal efficiency and brake power for different blending ratios

The variation of brake thermal efficiency and brake power for different blending ratios i.e. MB0, MB20, MB40, MB60, MB80 & MB100 is shown in Fig. 4.2

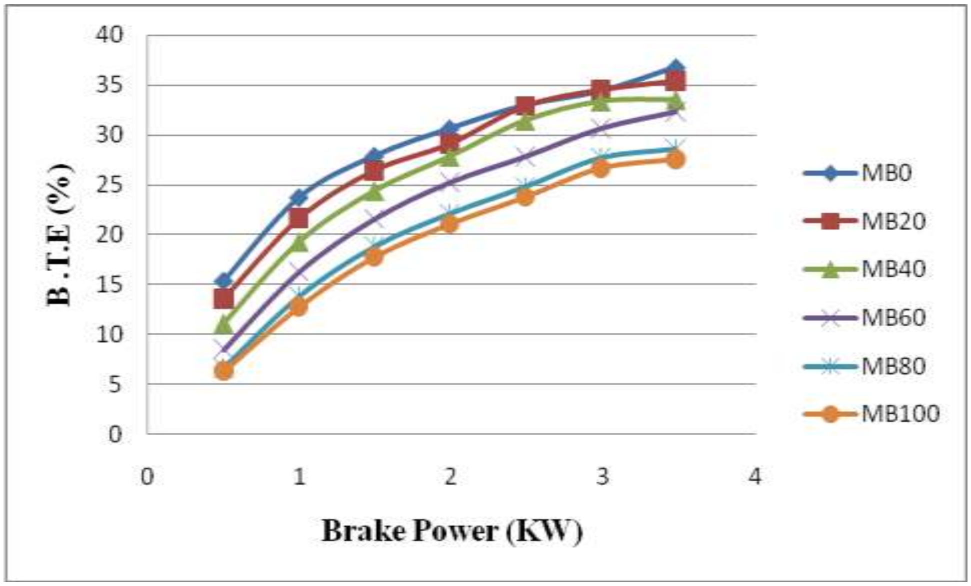

Fig. 4.2 Variation of brake thermal efficiency and brake power for different blending ratios

From the experimental investigation it was observed that brake thermal efficiency increased with increase in brake power. Also, it was found that brake thermal efficiency has decreased as the blending ratio increased.

It was observed that brake thermal efficiencies of all the blends were found to be lower at all load levels. Among the blends MB20 is found to have the maximum thermal efficiency of 34.53% at a brake power of 2.97 kW which is very close to diesel. It was observed that as the proportion of mahua biodiesel in the blends increases the brake thermal efficiency decreases. The decrease in brake thermal efficiency with increase in mahua biodiesel concentration is because of its lower calorific value and higher viscosity [16]. So, with an increase in blending there is a decrease in the calorific value and hence, decrease in brake thermal efficiency [14]. The variations in brake thermal efficiency between various blends at full load conditions was less than those at part loads due to the increased temperatures inside the cylinder as more amount fuel burnt at higher loads [15].

4.3 Variation of carbon dioxide and brake power for different blending ratios

The variation of carbon dioxide and brake power for different blending ratios i.e. MB0, MB20, MB40, MB60, MB80 & MB100 is shown in Fig.4.3

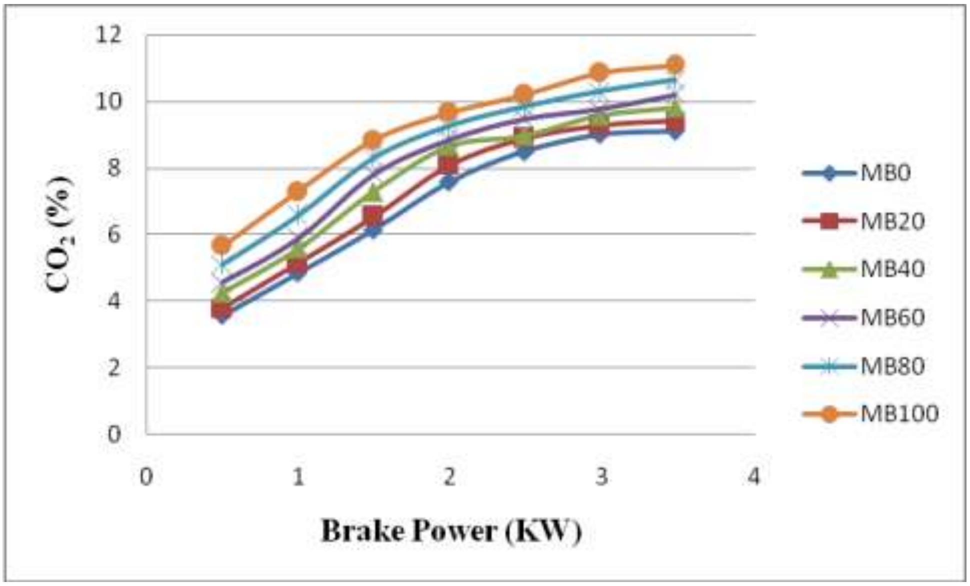

Fig. 4.3 Variation of carbon dioxide and brake power for different blending ratios

Test measurements reveal that the CO_2 emission for all blends were higher as compared to diesel at all loads. The rising trend of CO_2 emission with load is due to the higher fuel entry as the load increases. At full-load condition, 9.11 vol% of CO_2 is formed in MB0 combustion, 9.41 vol%, 9.82 vol %, 10.21 vol%, 10.65 and 11.09 vol% of CO_2 is formed in MB20, MB40, MB60, MB80 and MB100, respectively. This is because oxygen content is more in biodiesel as a result of which an increase in the biodiesel ratio increased the CO_2 formation [14].

It was also found that CO_2 emission for MB20 blend is very close to diesel.

4.4 Variation of carbon monoxide and brake power for different blending ratios

Presence of carbon monoxide indicates incomplete combustion and lack of oxygen for combustion [14]. The variation of carbon monoxide and brake power for different blending ratios i.e. MB0, MB20, MB40, MB60, MB80 & MB100 is shown in Fig. 4.4

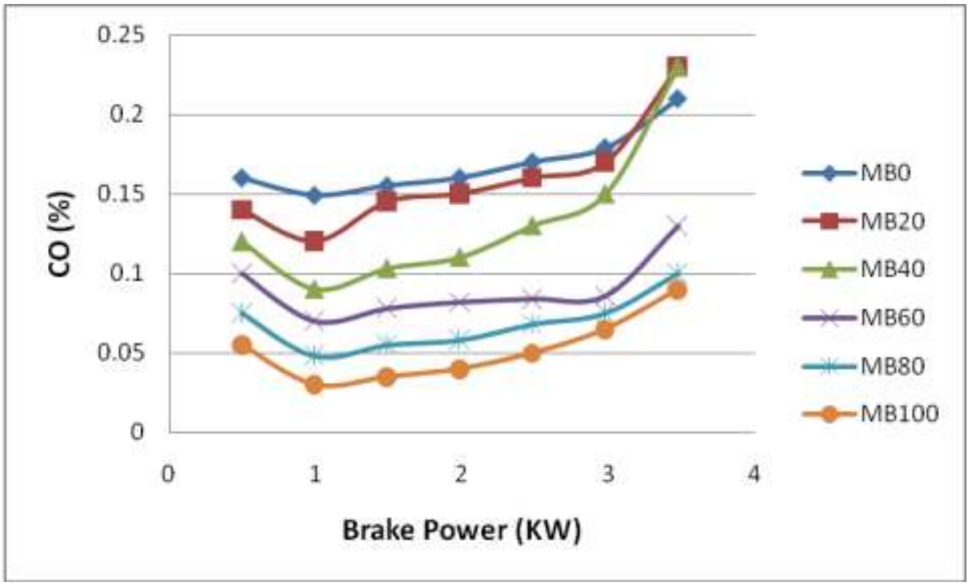

Fig. 4.4 Variation of carbon monoxide and brake power for different blending ratios

The minimum and maximum CO produced were 0.02–0.2% resulting in a reduction of 81 and 12%, respectively, as compared to diesel. These lower CO emissions of biodiesel blends may be due to their more complete oxidation as compared to 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. It can be observed from Fig. 4.4 that the CO initially decreased with load and later increased sharply up to full load. This trend was observed for all the fuel blends tested. Initially, at no load condition, cylinder temperatures might be too low, which increased with loading due to more fuel injected inside the cylinder. At elevated temperature, performance of the engine improved with relatively better burning of the fuel resulting in decreased CO. However, on further loading, the excess fuel required led to formation of more smoke, which might have prevented oxidation of CO into CO_2, consequently increasing the CO emissions sharply. Similar findings were also reported by researchers [7, 9, 10 & 15] while testing different biodiesels.

4.5 Variation of Hydro carbon and brake power for different blending ratios

A Hydro carbon emission results from the part of the fuel that does not take part in the combustion, that is, complete combustion does not take place [14].

Variation of hydro carbon and brake power for different blending ratios i.e. MB0, MB20, MB40, MB60, MB80 & MB100 is shown in Fig. 4.5

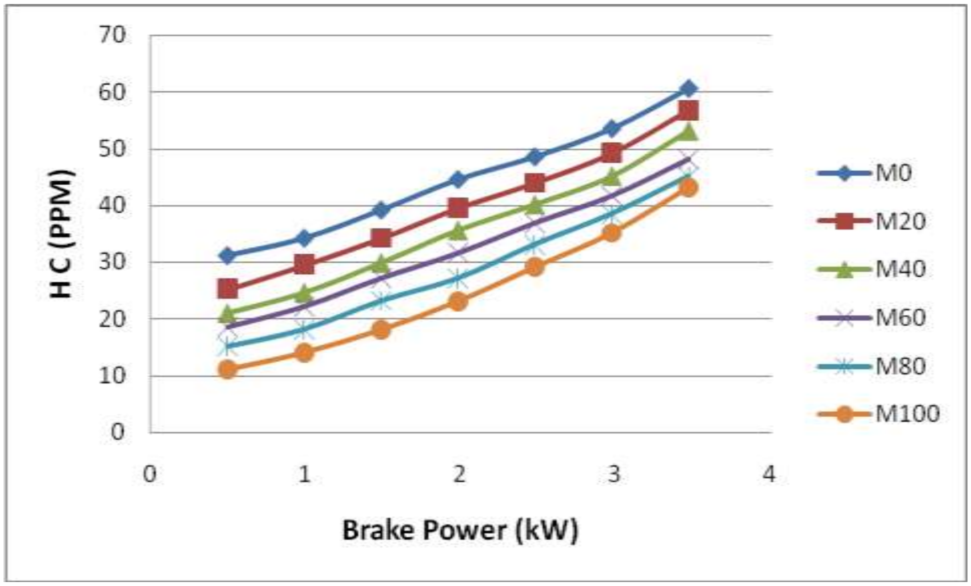

Fig. 4.5 Variation of hydro carbon and brake power for different blending ratios

There is significant reduction in hydrocarbons using biodiesel blends. It was observed that there is increase in hydrocarbon emission with increase in load and decrease with increase in amount of biodiesel in blend. The higher oxygen content in biodiesel and its blends is the reason for which their combustion is relatively more efficient when compared with pure diesel [14]. Complete combustion takes place results in reduction of unburnt hydrocarbon due to rich oxygenated fuel. The trend is similar as for the earlier studies [17].

4.6 Variation of oxides of nitrogen and brake power for different blending ratios

An oxide of nitrogen emission is harmful emission which is produced during the uncontrolled combustion phase. The NO_x formation depends upon the availability of oxygen content and the in-cylinder temperature [14].

The variation of oxides of nitrogen and brake power for different blending ratios i.e. MB0, MB20, MB40, MB60, MB80 & MB100 is shown in Fig. 4.6

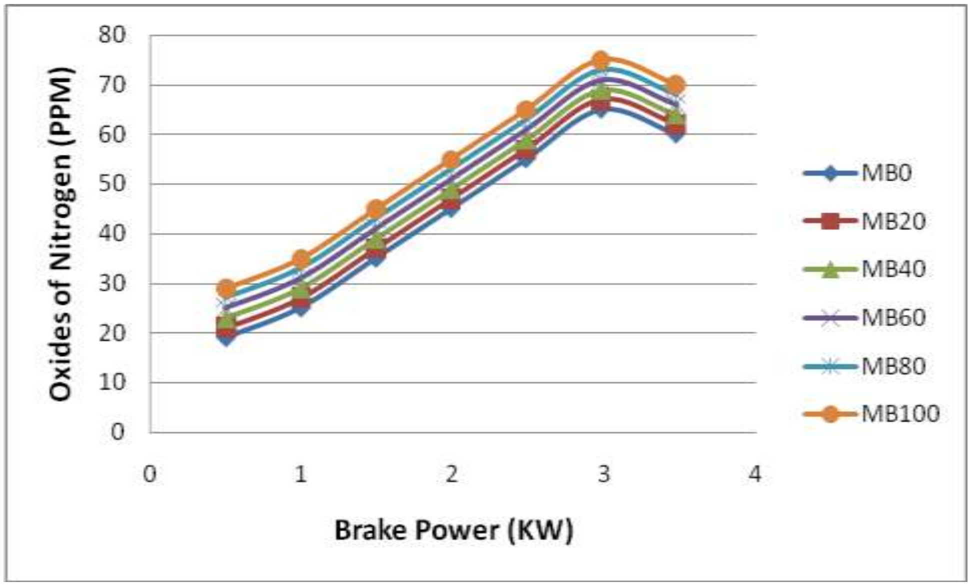

Fig. 4.6 Variation of oxides of nitrogen and brake power for different blending ratios

It shows that NO_x emission for diesel and all the biodiesel blends increases with increase in brake power. However, it was found that higher NO_x was emitted by all biodiesel blend as compared diesel. This could be attributed to the increased exhaust gas temperatures and the fact that biodiesel had some oxygen content in it which facilitated NO_x formation. In general, the NO_x concentration varies linearly with the load of the engine. As the load increases, the overall fuel–air ratio increases resulting in an increase in the average gas temperature in the combustion chamber and hence NO_x formation, which is sensitive to temperature increase [15]. The in-cylinder temperature is comparatively higher due to higher heating and thus NO_x emissions increase [14]. It can be observed from Fig. 4.6 that the peak occurred just before reaching the full load conditions. Similar trend was observed in case of all the fuel blends tested. This might be due to a very high fuel–air ratio at full load conditions where the additional fuel might have cooled the charge, thus lowering the localized peak temperatures and resulting drop in NO_x concentration [15].

4 Conclusion

1. The specific fuel consumption increased and brake thermal efficiency decreased with increase in the proportion of biodiesel in the blends.

2. With increase in brake power the emission of CO_2, CO and HC increases for all blends of biodiesel.

3. The CO_2 increased while the CO and HC emission decreased with increase in the proportion of biodiesel in the blends.

4. The smoke level and CO in exhaust emissions reduced, whereas NOx increased with increase in percentage of mahua biodiesel in the blends. However, the level of emissions increased with increase in engine load for all fuels tested.

5. It was found that higher NO_x was emitted by all biodiesel blend as compared diesel. This could be attributed to the increased exhaust gas temperatures.

6. Mahua oil biodiesel produced from renewable biomass resources are easily available in market.

7. From the above findings, it is concluded that mahua biodiesel could be safely blended with HSD up to 20% without significantly affecting the engine performance (SFC & BTE) and emissions (CO_2 CO, HC and NOx) and thus could be a suitable alternative fuel for diesel.

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