Biodiesel from Neem Oil and its Effect on Engine Performance and Exhaust Emission

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Abstract. Neem Oil can act as an environmental friendly alternative feedstock for production of biodiesel. The present research work deals with the effect of Neem oil bio-diesel and its blending with pure mineral diesel on diesel engine performance and emission to evaluate break thermal efficiency, specific fuel consumption, brake specific energy consumption and exhaust gas emissions. A four stroke compression ignition double cylinder engine was used to measure different performance and emission parameters. Five different volume concentrations of biodiesel and diesel are used i.e. 20%, 40%, 60%, 80% and 100% of biodiesel. Based on the analysis of performance and emission parameters, the biodiesel blend B40 (40% Neem Oil biodiesel + 60% Mineral Diesel) was found to be optimum for the most efficient operation of the engine by comparing the performance parameters at all load conditions. It shows maximum BTHE with an increase of 9.2% at full load condition and relatively lower specific fuel utilization. The CO and HC emissions were also realized to be less relative to all the blends of biodiesel and pure diesel. The CO emission of B40 is 18.18% lower than pure diesel due to improved combustion process and the HC emission of B40 is 5.94% lower than pure diesel. The 12% NOx emission increase using B20 blend and lower on other blends of neem biodiesel was observed.

Keywords: Neem oil, Neem biodiesel, CI engine, Alternative fuel.

1. INTRODUCTION

In 1911, Rudolph Diesel was the first to utilize a vegetable oil (peanut oil) in a diesel engine. As in current scenario, diesel engines are generally utilized in transportation, agriculture vehicles, power generations, marine application, etc. Therefore, it is important to develop options to diesel fuels which would weigh in to the diminution of dependence on fossil fuels. Presently biodiesel is developing as an replacement fuel as practical option in contrast to petroleum diesel. Among various possible sources of biofuels derived from seeds bearing trees rich in oil, Neem (Azadirachta Indica), Jatropha (Jatropha Curcas), and Karanja (Pongamia Pinnata) are the favorable species as they can be grown almost on all types of terrain all over India. Different methods are used for production of biodiesel conventionally such as transesterification, pyrolysis, dilution, micro emulsification, etc. [1,2,3].

2. NEEM BIODIESEL

Neem trees start bearing harvestable seeds within 3-5 years, and full production may be started in 10 years, and this will continue up to 150-200 years of age. A mature Neem tree may produce 30-50 kg of fruit each year. The fruit is a smooth (glabrous), olive-like drupe which varies in shape from elongate oval to nearly roundish, and when ripe is 1.4–2.8 centimeters (0.55–1.10 in) by 1.0–1.5 centimeters (0.39–0.59 in). The fruit skin (exocarp) is thin and the bitter-sweet pulp (mesocarp) is yellowish-white and very fibrous. The mesocarp is 0.3–0.5 centimeters (0.12–0.20 in) thick. The white, hard inner shell (endocarp) of the fruit encloses one, rarely two, or three, elongated seeds (kernels) having a brown seed coat as shown in figure 1.

Figure 1. Neem Fruits, Neem Kernels, Neem Kernel After Drying and Neem Oil

By rough estimate India has nearly 20 million Neem trees. Indian Neem trees have a potentials to provide one million tons of fruits per year and 0.1 million tons of kernels per years (assuming 10% kernel yield). Neem seeds yield 40-60% oil [4]. Making biodiesel, producing it on a large scale and using it to replace petro diesel is one among the most researched and anticipated developments of today [5].

3. NEEM BIODIESEL PRODUCTION

The most common method for biodiesel production is transesterification as shown in figure 2. It is also called alcoholysis which as the name suggests is the displacement of an alcohol from an ester by another alcohol i.e. basically conversion of one ester into other [6].

In the process of transesterification a mixture of 100ml of Neem oil and 25ml methanol is stirred and heated in the presence of 0.8gm of KOH as catalyst for one and a half hour at a temperature between 50 and 55°C. The obtained mixture of biodiesel and glycerol is kept for 8 to 10 hours to separate biodiesel and glycerol. The biodiesel (upper layer) is then separated from the raw glycerin (lower layer) by decantation. The crude biodiesel layer was needed to purify by washing with warm water. After the washing process, it was required to measure the pH of the biodiesel layer. When the pH of the biodiesel layer reached seven, the washing process was completed [6].

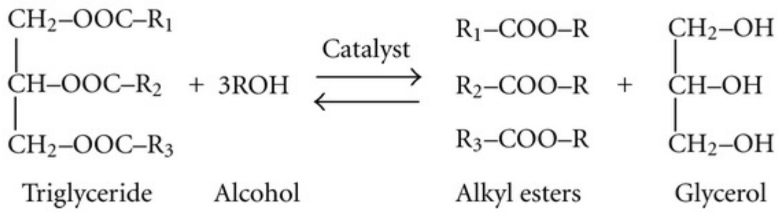

Figure 2. Transesterification Reaction

The different physical and chemical properties of neem oil and neem biodiesel are tested in the chemistry lab of the institute using standard process of testing. The physical and chemical properties of Neem oil, Neem biodiesel, diesel and ASTM biodiesel standards are compared and shown in Table 1.

Table 1: Comparison of various physical and chemical properties of Neem oil and Neem biodiesel with diesel and ASTM standards [7,8]

Properties	ASTM D-6751	Diesel	Neem oil	Neem biodiesel
Density (kg/m^3)	0.862 – 0.9	830	912–965	820–940
Viscosity at 40˚C (cSt)	1.9-6.0	4.7	20.5–48.5	3.2–10.7
Calorific value(MJ/kg)	=/>37.5	42	32–40	39.6–40.2
Flashpoint (˚C)	>130	60	214	120
Cetane number	47 min	45	31–51	48–53

4. METHODOLOGY AND EXPERIMENTATION

The properties of Neem biodiesel and its blends are close to mineral diesel and in the specified limit of ASTM standards of biodiesel. The different blends of biodiesel (B20, B40, B60 and B80) (B20 20% Neem biodiesel and 80% Diesel) was prepared and used as a fuel for testing. The Performance test was conducted on dual cylinder diesel engine. The picture of the engine on which the experiments are carried out is shown figure 3. i.e. of the constant speed compression ignition engine.

Figure 3. Pictorial view of the experimental setup (Dual Cylinder Diesel Engine)

The apparatus consists of two-cylinder vertical diesel engine attached over a strong frame. Many measurements provided enables to calculate the performance of the engine at different loads. **Specifications of the engine (**Make Type: Mahender Ltd., Engine Type: Double Cylinder 4-Stroke, Water Cooled, Compression ratio: 18:1, Rated power: 7.5 kW @1500 R.P.M, Stroke: 110 mm Bore: 102 mm, Loading device: Rope Brake dynamometer, Drum dia. = 0.25m, Rope dia.= 0.012m, Load indicator: Range 0-50 kg, Speed Measurement: Digital with contact type speed Tachometer, Temperature sensor: Thermocouple, Type K (Nickel-Chromium / Nickel-Alumel). Thirdly emission test was performed for the given engine using calibrated AVL Di Gas Analyzer was used for Emission Measurement.

5. RESULTS AND DISCUSSION

With reference to the experiment did on CI engine utilizing different blends of neem biodiesel and unadulterated diesel is studied and compared in the paper. A portion of the significant parameters of CI engine dependent on execution and emission are discussed below [11,12,13]. First the experimentation was performed using diesel as a fuel and three sets of readings were observed and average was calculated. Then the experiment was performed using B20, B40, B60, B80 and B100 and three set of readings were observed and average was calculated for result analysis.

5.1 Brake Thermal Efficiencies (BTHE) Vs. Brake Power (BP).

The figure 4 demonstrates the different of brake thermal efficiencies with BP. The brake thermal efficiency has increased with rise in the BP (i.e. load). The rate of increase was more at lower loads whereas it has decreased with increasing the load further. From the figure it can be seen that the BTHE obtained for B40 blend was maximum at higher loads. It was found 30.47% BTHE by using pure diesel while 33.29% BTHE by using B40 which is 9.2% higher than unadulterated diesel. This trend is due to higher load, the rate of increase of BP decreases whereas the rate of increase of fuel consumption remains almost constant. So the decrease in rate of increase of BP at higher loads leads to decrease in the rate of increase of brake thermal efficiency. It was found 30.47% BTHE by using pure diesel while 27.41% BTHE by using B100 which is 10.04% lower than pure diesel.

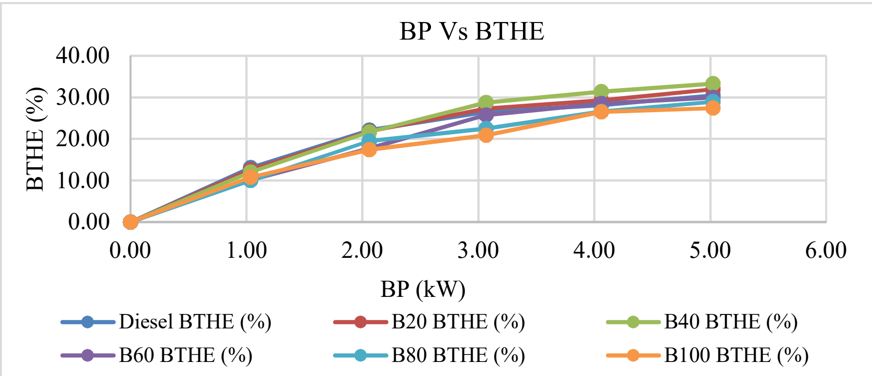

Figure 4. Variation of BTHE Vs BP for diesel and different biodiesel blends

5.2 Brake Specific Fuel Consumption Vs. Brake Power.

The figure 4 demonstrates the variety of BSFC (brake specific fuel consumption) with BP of diesel and various biodiesel blends. As the BP increment in the above figure the BSFC reduces at lower loads and afterward it remains practically steady. As the load increases firstly the rate of increment of BP compared to fuel utilization is more and as the load moves towards full load conditions the rate of increment of BP and fuel consumption remains same so at these loads BSFC remains almost constant. With increase in the biodiesel percentage in the blends, the BSFC values rises because the fuel utilization increases because of the lesser calorific value of biodiesel. It is also seen that B40 has minimum BSFC at all loads. It was found 0.27 kg/kWhr BSFC by using pure diesel while 0.25 kg/kWhr by using B40 which is 7.4% lower than pure diesel. Further, it is recorded that with increase in blend percentage i.e. B100 has maximum BSFC at all loads. It was found 0.27 kg/kWhr BSFC by using pure diesel while 0.31 kg/kWhr by using B100 which is 14.8% higher than pure diesel.

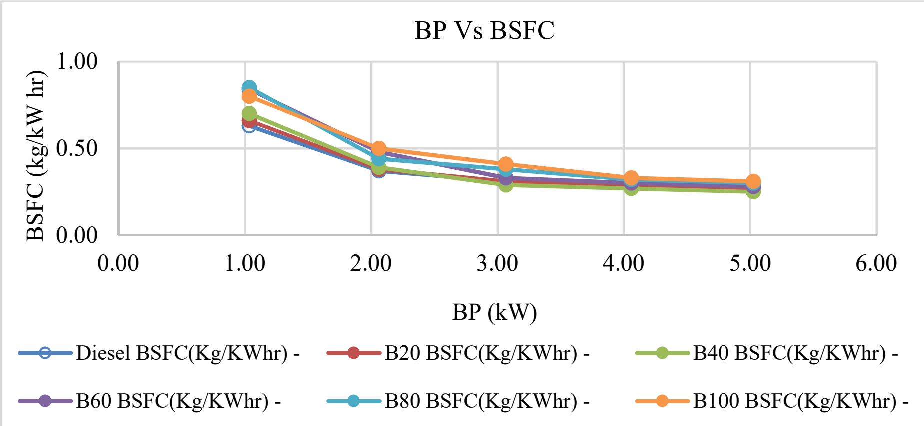

Figure 5. Variation of BSFC vs. BP for diesel and various biodiesel blends

5.3 Brake Specific Energy Consumption vs. Brake Power.

The figure 6 demonstrates the variety of BSEC (Brake Specific Energy Consumption) with BP of diesel and distinctive biodiesel mixture.

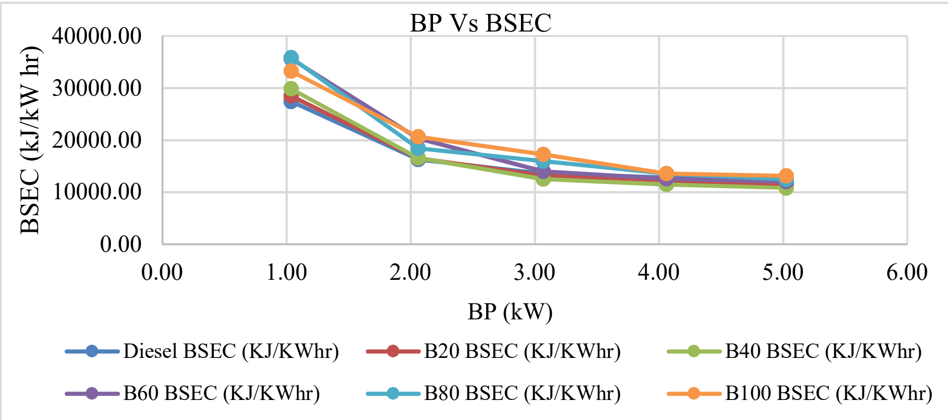

Figure 6. Variation of BSEC Vs BP for diesel and various biodiesel blends

As the BP increments in the figure the BSEC reduces at lower loads and afterward it remains practically steady. It follows the same trend as of BSFC vs. BP. Since, different blends of biodiesel in diesel are having various calorific values. Hence, specific energy utilization is much relevant and correct rather talking about specific fuel consumption because it is used for indicating single type of fuel having single or fixed calorific value. It was found 11815.07 kJ/kWhr BSEC by using pure diesel while 10814.07 kJ/kWhr by using B40 which is 8.47% lower than pure diesel. Further, it is recorded that with increase in blend percentage i.e. B100 has maximum BSEC at all loads. It was found 11815.07 kJ/kWhr BSFC by using pure diesel while 13134.72 kJ/kWhr by using B100 which is 11.16% higher than pure diesel.

5.4 Exhaust Gas Temperature Vs. Brake Power

The figure 7 demonstrates the variety of exhaust gas temperature with load for diesel and different biodiesel mixture. From the figure it is evident that exhaust temperature of gases has shown parabolic increasing trend with increase in the load. As the amount of biodiesel was increased from 20% to 40% the temperature of exhaust gases has also increased at all the load due to improvement in the combustion process as the biodiesel has more cetane number relative to diesel[4]. Cetane number also leads to decrease in ignition delay hence giving availability of more time for combustion process which suggests complete combustion of A/F ratio of fuels hence further giving maximum exhaust temperature[4,6]. As the amount of biodiesel is further increased the effect of lower calorific value became more predominant. On further increase of biodiesel amount i.e. from 60% to 100% the decrease in exhaust temperature was recorded because of lower calorific value of biodiesel which decreases the overall heat content of fuel blend leading low exhaust temperatures.

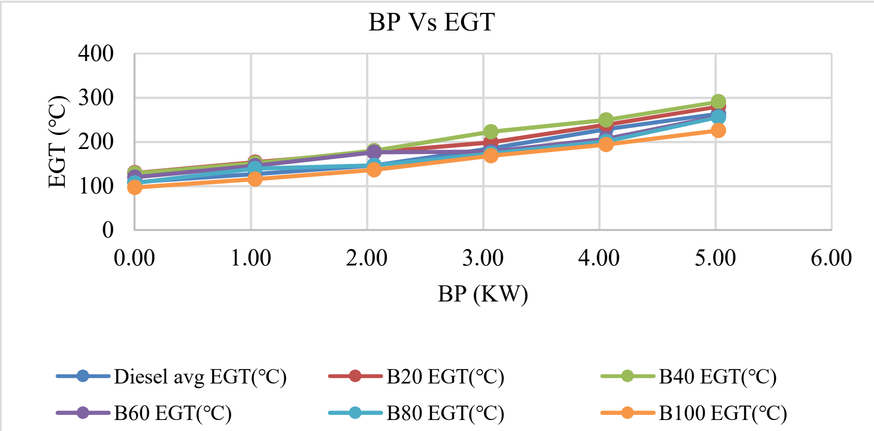

Figure 7. Variation of EGT Vs BP for diesel and various biodiesel blends

5.5 Emission Parameters

The different pollutants coming from the engine was measured using calibrated AVL Di Gas Analyzer and the results obtained are studied in detail and presented in the report.

5.5.1 Carbon Monoxide Emission

CO is formed when due to deficiency of oxygen to convert all carbon molecules into CO_2. CO in diesel engines is formed during the intermediate combustion stages[6].

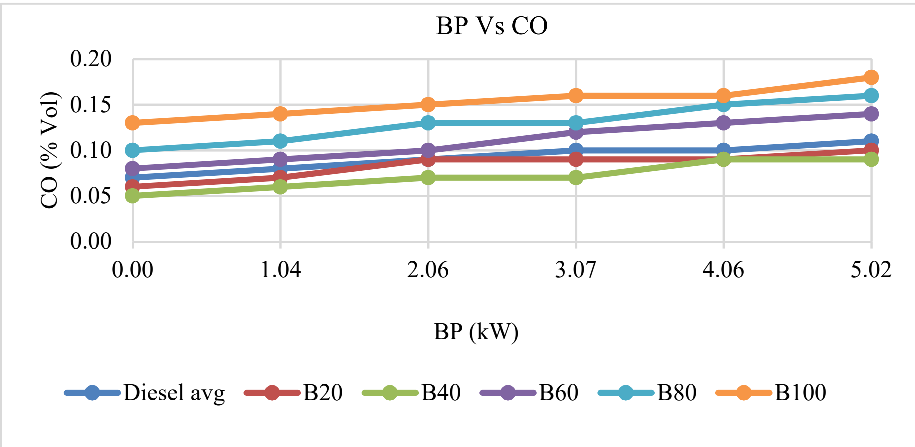

Figure 8. Variation of CO emissions Vs BP for diesel and different biodiesel blend

The variation of carbon monoxide (CO) with regard to BP for diesel and various blends of biodiesel is shown in figure 8. The carbon monoxide decreases with increase in percentage of neem biodiesel within the fuel. This trend is because, the occurrence of oxygen molecules within biodiesel blends, which enables the re-burning of CO produced in the cylinder. The lowest CO emission has been decreased by 18.18% on addition of 40% biodiesel (B40). On further addition of biodiesel i.e. methyl esters the CO emissions has raised because of incomplete combustion caused by improper mixing at higher concentrations of biodiesel. An increase of 63.63% was obtained in CO emissions in comparison to diesel when biodiesel was added at 100% concentration i.e. B100. As on lower concentration i.e. B20 and B40 the oxygen amount was sufficient for combustion of mixture leading to lesser CO emissions.

5.5.2 Carbon Dioxide Emission

Carbon dioxide not just effect as a green-house gas to climate yet in addition make the seas about 30% increasingly acidic influencing wide assortment of ocean life forms. After combustion of the fuel the oxygen present in the air converts into the CO_2[8]. The variation of carbon dioxide (CO_2) with regard to BP for diesel and various blends of biodiesel are shown in figure 9. The highest CO_2 emissions have been increased by 3.5% for 40% concentration of biodiesel blend i.e. B40. This is because of proper combustion of A/F mixture took place which lead to the conversion of C and CO into CO_2. The further increment of biodiesel blend has led to decrease in CO_2 emissions due to improper mixing and combustion due to high viscosity of biodiesel and oxygen deficiency respectively. The decrease of 10.7% was obtained in CO_2 emissions in comparison to diesel when biodiesel was added at 100% concentration i.e. B100. The combustion characters of the fuel are also influenced by the ambient conditions such as humidity, temperature etc. of the air where experiments are being performed.

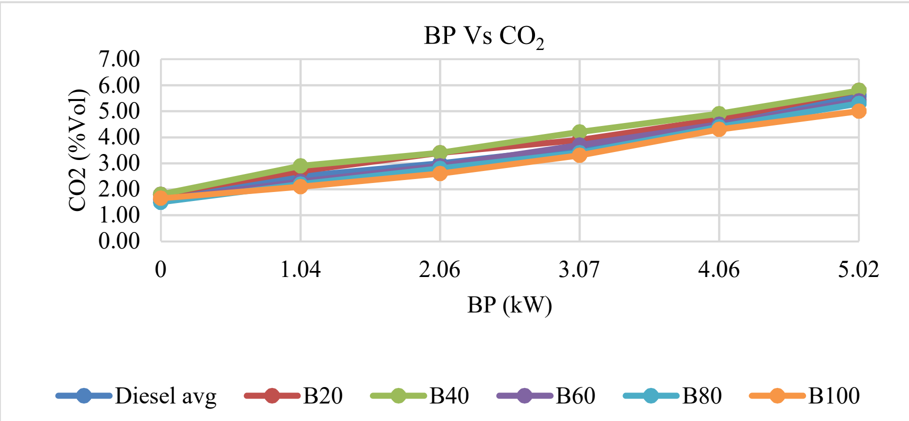

Figure 9. Variation of CO_2 emissions Vs BP for diesel and various biodiesel blend

5.5.3 Hydrocarbon Emission

Hydrocarbons (HCs) are comprised of unburned or incompletely consumed fuel, and are a major supporter of urban exhaust cloud, just as being poisonous. HC emission is almost always a sign of poor fuel ignition. Hydrocarbons in exhaust are because of incomplete combustion of carbon compounds within the blends[6,8]. The variation of hydrocarbon (HC) with relevance to engine power output for various fuels is shown in figure 10. The values of HC emission reduces with increase in proportion of biodiesel within fuel blends. The emissions of unburnt hydrocarbon for biodiesel exhaust is below of diesel fuel. The HC emissions has decreased by 3.96% and 5.94% on addition of 20% and 40% biodiesel i.e. B20 and B40 respectively.

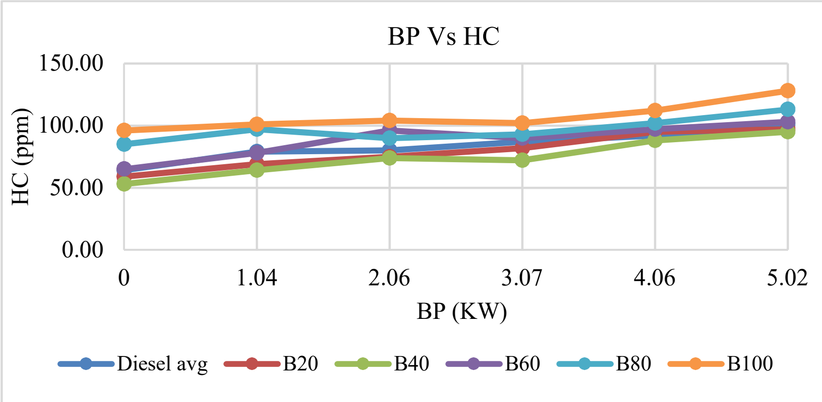

Figure 10. Variation of HC emissions Vs BP for diesel and different biodiesel blend

The attainable reason for reduction in unburnt HC may be greater cetane number and increased gas temperature. The greater cetane number of biodiesel results reduction in HC emission because of shorter ignition delay. Rise in temperature of burnt gases in biodiesel fuel helps in preventing condensation of higher hydrocarbon thus decreasing unburnt HC emissions. On further addition of biodiesel blends in diesel, the effect of lower calorific value became more predominant which lowers the overall heat content of the fuel. Due to this flame speeds could be too low for combustion to be completed throughout the power stroke and these conditions cause high hydrocarbon emissions. The highest increase of 26.73% HC emissions in comparison to diesel when biodiesel was added at 100% concentration i.e. B100.

5.5.4 Oxides of Nitrogen

The formation of NOx is highly dependent on in-cylinder temperature, the oxygen concentration and residence time for reaction to take place. From the experimental investigation as shown in figure 11 it is observed that NOx emission decreases with higher blends due to high viscosity, low calorific value and low volatility which leads to poor combustion as compared to diesel whereas lower blend of biodiesel increases NOx because oxygen present in the blends help in complete combustion of fuel increasing the temperature causing better reaction and more NOx emission.

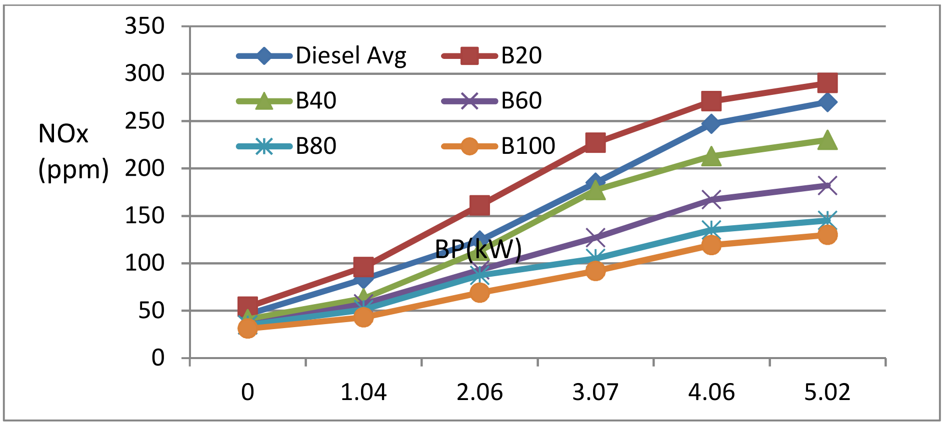

Figure 11. Variation of NOx emissions Vs BP for diesel and different biodiesel blend

From the experimental investigation it can be stated that 12% NOx increases using B20 blend neem biodiesel. On further addition of biodiesel blends in diesel, the effect of lower calorific value became more predominant which lowers the formation of

NOx. The NOx emission found comparable to mineral diesel using B40 and it reduces on increase of the biodiesel in diesel. The lower NOx emissions is influenced by viscosity, density and volatility of fuel.

6. CONCLUSION

After analyzing the performance and emission parameters from results obtained during high load condition, it has been concluded that, B40 (40% Neem biodiesel + 60% diesel) has most suitable performance and emission characteristics which are explained below.

1. Brake thermal efficiency (BTHE) has shown linear increasing trend with load at lower loads, whereas the curve becomes almost flat at higher loads due to the small rise in the brake power at higher loads. BTHE of B40 is 9.2% higher than BTE of refined diesel due to the additional oxygen content.
2. Brake specific fuel consumption (BSFC) has shown decreasing trends with the load also at lower loads decrease in BSFC is more due to higher rate of increase of brake power at lower loads relative to rate of rise in fuel consumption. BSFC of B40 is 7.4% less than pure diesel due to existence of extra quantity of oxygen in it.
3. Brake specific energy consumption (BSEC) reduces at lower loads and then it remains nearly constant. It follows the same trend as of BSFC Vs BP. BSEC of B40 is 8.47% lower than pure diesel.
4. The Exhaust gas temperatures (EGT) have increased with rise in the load because of the use of rich air fuel mixtures at elevated loads. EGT of B40 is 10.22% higher than pure diesel due to improvement in combustion process, thus life of engine components may be affected.
5. The carbon monoxide (CO) and Hydrocarbon Emission (HC) decreases with rise in percentage of neem biodiesel in fuel yet on further addition of biodiesel, the CO and HC emissions has raised because of incomplete combustion caused by the improper mixing at higher concentrations of biodiesel. The CO and HC emission of B40 is 18.18% and 5.94% respectively lower than pure diesel due to proper combustion process.
6. In case of carbon dioxide (CO_2), it increases with the rise in percentage of neem biodiesel in fuel but on further addition of biodiesel, the CO_2 emissions has decreased due to improper mixing and combustion due to high viscosity of biodiesel and oxygen deficiency respectively. The CO_2 emission of B40 is 3.5% higher than pure diesel due to re-burning of CO into CO_2.
7. From the experimental investigation it can be stated that 12% NOx increases using B20 blend neem biodiesel. On further addition of biodiesel blends in diesel, the effect of lower calorific value became more predominant which lowers the formation of NOx.

The present research work exhibits the initial feasibility of Neem biodiesel as a diesel engine fuel. Moreover, the experimental procedure adopted in present research work can be extended to study the performance using different fuel injection pressures, using other diesel engines used in agriculture and transport sector. However, the long term endurance test is also necessary to evaluate the durability of the engine with prolonged operations.

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