

# Performance Analysis of 4 Stroke Ci Engine Using Renewable Fuel Neem Oil Blend with Diesel

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## Abstract

The increasing demand for petroleum fuels and growing environmental concerns have encouraged the exploration of renewable and sustainable alternative fuels for diesel engines. In this study, the performance characteristics of a four-stroke compression ignition (CI) engine fueled with Neem oil biodiesel–diesel blends were experimentally investigated. Neem oil, a non-edible and renewable feedstock, was converted into biodiesel through the trans esterification process and blended with conventional diesel in different proportions.

The experiments were conducted under varying engine load conditions to evaluate key performance parameters such as brake thermal efficiency (BTE), brake specific fuel consumption (BSFC), and exhaust gas temperature (EGT). The results obtained from the Neem biodiesel blends were compared with those of neat diesel fuel. The study revealed that the biodiesel blends exhibited satisfactory engine performance with only minor variations in efficiency and fuel consumption. The oxygenated nature of Neem biodiesel promoted improved combustion, contributing to enhanced thermal efficiency and reduced emissions.

In this work, the performances of the engine and emission produce during combustion of Neem Bio-diesel are optimize. The objective of this research is to investigate effect of Neem bio-diesel blending with fuel preheating on performance and emission of multi cylinder, four stroke, water cooled, direct injection, CI engine by Determining the relationship between diesel engine performance and the percentage of Neem bio-diesel in fuel blends this Experiments are carried out at constant engine speed of 1500 RPM Load is varied by changing excitation of hydraulic dynamometer. Starting from no load observations are taken for each fuel at six different loads Using measured data, brake power, brake thermal efficiency, brake specific energy consumption are calculated for each test fuel including diesel. For this work freely available resources can be used. The blends of Neem methyl ester and Diesel were prepared analyzed and their performance compared with performance of diesel oil. In this work, the emission characteristics of Neem oil have been tested. The blends of varying proportions of Neem oil are Blend 20%, 40%, 60% at different preheated temperature 25°C, 50°C, 75°C, 100°C and 125°C Diesel were prepared analyzed and their emission compared with emission of diesel fuel. The basic engine emissions are CO, CO<sub>2</sub>, HC, and NO<sub>x</sub> have been obtained from different blends and results are compared with pure diesel. The goal of this study is to verify the affiliation between engine performances and emission by means of diesel.

**Keywords:** Neem oil, Neem bio-diesel, Diesel oil, Emission, fossil fuel, blending, performance parameters.

## INTRODUCTION

The journey idea of using alternative fuels for compression-ignition (CI) engines dates back to the late 19th century, when Rudolf Diesel, the inventor of the diesel engine, demonstrated engine operation using peanut oil at the 1900 Paris Exposition, asserting that vegetable oils could become future fuels. This early experiment laid the philosophical foundation for bio-based fuel utilization in IC engines. However, the discovery of abundant and inexpensive petroleum reserves shifted global focus toward conventional diesel for several decades.

The oil crisis of 1973 and 1979 rekindled research interest in non-petroleum fuels. Scientists worldwide began investigating straight vegetable oils (SVO), alcohols, and early biodiesel derivatives. Initial studies revealed that raw

vegetable oils could operate IC engines, but limitations such as high viscosity, poor atomization, injector coking, carbon deposits, and cold flow issues prevented large-scale adoption. These challenges motivated researchers to explore fuel modification techniques including transesterification (biodiesel production), micro-emulsification, pre-heating, and blending with diesel.

During the 1990s and early 2000s, biodiesel emerged as the most commercially viable vegetable oil derivative, particularly in Europe and the United States, where regulatory support and emission mandates accelerated its use. In parallel, research in Asia, Africa, and South America expanded toward region-specific non-edible feed stocks to ignore conflict with supply chains of food. This phase marked the transition from experimental feasibility to performance and emission characterization. India, with its large agrarian economy and biodiversity, became an active contributor to biofuel research, exploring feedstocks such as jatropha, karanja, mahua, castor, rice bran, rubber seed, and neem oil. Among these, neem (*Azadirachta indica*) oil gained attention due to its non-edible nature, wide availability, high oil yield, natural antioxidant properties, and socio-economic relevance, especially in rural regions. Early Indian studies primarily focused on fuel property evaluation and small-scale engine trials, revealing that neem oil could be blended with diesel, but required optimization to mitigate combustion inefficiencies.

In recent years (post-2020), renewable fuel research has further evolved toward sustainability-aligned performance benchmarking, life-cycle assessment, engine tribology, combustion modeling, artificial intelligence-based optimization, and multi-criteria impact analysis, emphasizing carbon neutrality and energy security. Experimental investigations now integrate in-cylinder pressure analysis, heat release rate (HRR), ignition delay (ID), peak pressure rise rate (PPRR), and fuel-air mixing dynamics to establish deeper combustion insights.

## Bio-Diesel in India

Around 400 native plant species in India are known to yield non-edible oils that can be processed into bio-diesel [8]. A key aspect of India's bio-fuel initiative is the exclusive use of wastelands, degraded forests, and non-agricultural areas for cultivating oil-bearing crops. Out of nearly 55 million hectares of wasteland available in the country, approximately 32 million hectares have been identified as potentially suitable for bio-diesel production [8]. This suitability is based mainly on physical characteristics; however, actual utilization depends on several factors such as climate, soil quality, availability of infrastructure like roads and electricity, and land ownership patterns. Since existing data on wasteland suitability for oilseed cultivation is limited, comprehensive land-mapping studies are essential before implementing large-scale bio-diesel development programs in India.

**Table 1.2 Estimated Bio-diesel Requirements for blending with Diesel <sup>[4]</sup>**

|         | Diesel | Bio-      | Area | Bio-       | Area | Bio-      | Area  |
|---------|--------|-----------|------|------------|------|-----------|-------|
| Year    | Demand | diesel@5% | @5%  | diesel@10% | @10% | diesel@20 | @20%  |
|         | MMT    | MMT       | Mha  | MMT        | Mha  | MMT       | Mha   |
| 2001-02 | 39.81  | 1.99      | -    | 3.98       | -    | 7.96      | -     |
| 2006-07 | 52.33  | 2.62      | 2.19 | 5.23       | 4.38 | 10.47     | 8.76  |
| 2011-12 | 66.90  | 3.35      | 2.79 | 6.69       | 5.58 | 13.38     | 11.19 |

## 2 NEEM OIL

Neem oil is a natural vegetable Oil extracted from the seeds of the neem tree (*Azadirachta indica*), widely used found in India and other tropical regions. It is known for its excellent medicinal, agricultural, and industrial properties by the presence of bioactive compounds such as azadirachtin, nimbin, and salannin. Neem oil is extensively used as a natural pesticide and insect repellent because it is eco-friendly and biodegradable. In recent years, neem oil has gained significant attention as a renewable biofuel source, as it can be developed into biodiesel and used in compression ignition (CI) engines with diesel blends. Neem oil-based fuels help reduce dependence on fossil fuels and contribute to lower exhaust emissions, making it an important alternative source of energy for sustainable development.

## REVIEW OF LITERATURE

**Vara Prasad Anumukonda et al. (2023)** Because the world's fossil fuel reserves are depleting at an alarming rate as a result of increased consumption, biodiesel is a useful alternative to fossil fuels in many scenarios. Since biodiesel emits fewer harmful emissions, it's an environmentally friendly fuel. Biodiesel can be produced at a lower cost and can be used without any modifications in the engine. The most acceptable process for biodiesel production is base-catalysed transesterification. In this present research work we prepared and compared the characteristics of the biodiesel with conventional diesel fuel. Waste fry oil taken from potato chip industry and Jatropha from Jatropha seeds methyl ester-based biodiesel was prepared using transesterification process. The pure bio-diesel was blended with diesel in some proportions making it as B20, B30, B40, B50 blends and tested in a four-stroke, fourcylinder, diesel ignition engine running at five different engine speeds 1600, 1800, 2000, 2200, 2400 respectively.

**Duraisamy Sakthivadivel et al. (2022)** In this paper, an effort has been made to produce biodiesel from Neem oil (*Azadirachta Indica*) and to perform a comparative analysis on various blends with diethyl ether (DEE) and alumina nanomaterials at different volume fractions. The fraction of alumina oxide ( $Al_2O_3$ ) nanomaterials with the blend (Pure Diesel 40% + Neem BD 40% + Ethanol) is varied in the range of 25, and 50 ppm. Experimental outcomes displayed that the physical and chemical properties of the biodiesel enhanced with the dispersion of alumina nanomaterials. The performance characteristics of the biodiesel blend such as brake thermal efficiency were increased up to 7.2% and brake specific fuel consumption was reduced up to 6.7% by adding the adding nanomaterial at 25 ppm of alumina nanomaterials compared with the pure diesel fuel.

**M. Mathiyazhagan, et al. (2022)** Biodiesel made from edible and non-edible vegetable oils, waste cooking oils, and animal fats is gaining popularity these days due to its renewable nature and environmental friendliness. As a result, several nations are switching to biodiesel production from plant oils such as maize, soy bean, canola, sunflower, palm, and others. However, these oils are out of reach for developing nations like India, since they may result in a lack of food-grade oil as well as a significant increase in gasoline prices. In this study,

**Md Modassir Khan et al. (2023)** Diesel emissions have resulted in air pollution, which is harmful to the sustaining of life. The concerns of energy security and poor air quality have propelled researchers to seek alternate and environment-friendly fuels for the transport sector, keeping diesel engines at the core. Thus, a quaternary blend (diesel-biodiesel-vegetable oil-alcohol) proves to be a promising key to address the above problems. This experimental work focuses aims on investigating the performance and emissions of a diesel engine powered with quaternary blends by changing the fuel injection pressure. The quaternary blend comprised of diesel, neem biodiesel, pure neem oil, and decanol was used to prepare quaternary blends of varied volumetric proportions.

**B. Prbakaran \*, Dinoop Viswanathan (2016)** The study presents the experimental evaluations of performance, combustion and emission characteristics of blends containing non-edible cotton seed oil methyl ester and anhydrous ethanol in a diesel engine at various loads. Blends are made from bio-diesel from cotton seed oil by transesterification and anhydrous ethanol (200 proof) in various proportions ranging from 10% to 50%. The results of the investigation are compared with diesel as base fuel. It is observed from the results that the brake thermal efficiency of the blends is similar to that of diesel.

**S V Channapattanaa\*, Kantharaj Cb,(2015)** The present work investigates the emission and thermal performance of DI CI variable compression ratio engine using blends of biodiesel and standard diesel as a fuel at compression ratios of 15,16,17 and 18. The biodiesel derived from non edible *Calophyllum Inophyllum* linn oil is used on the engine. The blends of biodiesel and diesel used were B20, B40, B60, B80 and 100% biodiesel. At 18 CR the brake thermal efficiency of the engine operated with 100% biodiesel is 8.9% less than Diesel and the brake specific fuel consumption for biodiesel found to be more than that of diesel. There is major reduction in Carbon monoxide and Hydrocarbon emissions with 100% biodiesel as a fuel compared to diesel at compression ratio of 18. The change in CR does not have much effect on the HGas of the engine. However, at most of the CRs it is less for Honne biodiesel than Diesel. The performance study reveals that the blend B20 operates very close to Diesel with respect to thermal performance.

**Al\_Dawodya\*, S.K. Bhattib (2014)** In this work experimental and theoretical investigations were carried out on a single cylinder, direct injection diesel engine operating on different blends of a soybean methyl ester (SME) with diesel fuel. The effect of blending on the cylinder pressure, heat release rate, carbon monoxide (CO), unburned hydrocarbon (UHC), nitrogen oxides (NOx), and smoke opacity were measured. The results indicate that the use of biodiesel produces lower smoke opacity up to 48.23% with 14.65% higher brake specific fuel consumption (BSFC) compared to diesel fuel. The measured CO emissions of B20% SME and B100%SME were found to be 11.36% and 41.7% lower than that of diesel fuel respectively.

**S. M. Ameer Uddina\*, A. K. Azadb,(2015)** Increasing oil prices and global warming activates the research and development of substitute energy resources to maintain economic development. The methyl esters of vegetable oil, known as biodiesel are becoming popular because of their low ecological effect and potential as a green substitute for compression ignition engine. Diesel engines are more efficient and cost effective than other engines. Vegetable oils can be used in the diesel engine by pure form or by trans-esterified form. In this paper pure mustard oil blending with kerosene at different proportion like m20, m30, m40, m50 and M100 (pure mustard) has been used in different load condition in 4 stroke single cylinder diesel engine mounted on a hydraulic dynamometer bed. Physical properties of different blend like heating value, density, viscosity, flash point and fire point has been determined before engine testing.

**T. Pushparaja\*, S. Ramabalanb,(2013)** Vegetable oils are a potential alternative to the partial or total substitution of diesel fuels. An experimental investigation is conducted to evaluate the effects of using ethanol and diethyl ether as additives to biodiesel/diesel blends on the emission and performance of direct injection unmodified diesel engine. Biodiesel was made by pyrolysis process. Cashew nut shell liquid (CNSL) was selected for biodiesel production. The fuel containing 20% biodiesel and 80% Number 2 diesel fuel, is called here as B20, 90% B20 and 10% ethanol by volume is called B20+E10 and 90% B20 and 10% diethyl ether by volume is called B20+D10. The effect of test fuels on engine torque, power, brake specific fuel consumption, brake thermal efficiency, exhaust gas temperature, were ascertained by performance tests. The influence of blends on CO, CO<sub>2</sub>, HC, NO and smoke opacity were investigated by emission tests.

**Gaurav Dwivedi \*, Mahendra Pal Sharma (2015)** Biodiesel from Pongamia oil is one of the promising non edible sources in India. But the main problem of using Pongamia biodiesel as fuel is its poor stability characteristics. Poor stability leads to gum formation which further leads to a storage problem of these fuels for a longer period of time. This paper investigates the methodology of improving the stability characteristics of Pongamia biodiesel by blending with diesel and use of the antioxidant Pyrogallol. The experimental investigation shows that blending with diesel and using of antioxidant Pyrogallol improves the stability characteristics of Pongamia biodiesel significantly. Results of the study show that the optimum amount of antioxidant (PY) for pure PB20 is 300 ppm to maintain the oxidation stability specification and blending of diesel with Pongamia shows that PB10 requires no additive to maintain its stability characteristics. Oxidation stability is the main problem of using biodiesel as an alternative fuel. Pongamia biodiesel has poor oxidation stability which will lead to gum formation and the biodiesel cannot be stored for longer periods of time.

## RESEARCH GAP

Biodiesel obtained from vegetable oils are known to be environmentally friendly and abundantly available. However, their combustion properties are often found to be inferior to diesel. This calls for improvement of the base oil by blending it with another oil with better properties to obtain a blend that has properties intermediate of the parent oils.

## OBJECTIVES OF STUDY

The objective of this research is to investigate effect of Neem bio-diesel blending with fuel preheating on performance and emission of multi cylinder, four stroke, water cooled, direct injection, CI engine by:

- Compare the Performance of diesel engine With the Neem bio-diesel in fuel blends engine.
- Optimize the percentage of Neem bio-diesel in fuel blends.
- Identify and established a relationship between pollutant concentrations in diesel engine exhaust and the percentage of Neem bio-diesel in fuel blends.

- Optimize the percentage of Neem bio-diesel in fuel blends with using different preheating blend.
- Identify and established a relationship between pollutant concentrations in diesel engine exhaust and the percentage of Neem bio-diesel in fuel blends with using different preheating blend.

## METHODOLOGY

The present research work aims to analyze that how compatible of neem oil–diesel blends as an alternative renewable fuel for a conventional 4-stroke compression ignition (CI) engine. The methodology involves fuel preparation, characterization of fuel properties, experimental analysis on a single-cylinder IC engine, testing the performance under load variation conditions, and comparison with neat diesel operation. The entire experimental procedure is carried out under controlled operating conditions to ensure repeatability and accuracy of results.

### Experimental Procedure

The experimental procedure is conducted in the following steps:

1. The engine is initially operated with neat diesel to achieve steady-state conditions.
2. The engine speed is maintained constant throughout the experiment.
3. Load is applied gradually using the dynamometer.
4. For each load condition, all required parameters are recorded.
5. After completing diesel testing, the engine is allowed to cool.
6. The fuel system is flushed before introducing the next neem oil blend.
7. The same procedure is repeated for all fuel blends (B20, B40, B60).

Each test is repeated to ensure reliability of data.

All tests are conducted at a fixed speed of the engine is 1500 rpm. The engine load is adjusted by regulating the excitation current of the hydraulic dynamometer. Beginning from the no-load condition, Measurements are considered for each fuel under six different loading conditions. The observations are recorded only after the exhaust gas temperature reaches a steady state. At every load level, the engine's Performance and emission parameters are evaluated for all fuel samples. Based on the experimental data obtained, key performance indicators—such as brake power (BP), brake thermal efficiency (BTE), and brake specific energy consumption (BSEC) are determined and analyzed are determined for each fuel, including diesel.

- Time taken for 25ml fuel consumption.
- Exhaust Gas Temperature.
- Load on Dynamometer
- Carbon
- Monoxide
- Hydrocarbon.

Initially, the engine performance is evaluated using conventional diesel fuel. Subsequently, tests are conducted with blended fuels B20, B40, and B60 under identical operating conditions. Advance Procedure will be done with the same blends at various preheating temperatures of 25°C, 50°C, 75°C, 100°C, and 125°C, following the previously described preheating procedure. The recorded and computed finding results are then analyzed and ...compared to the values determined for mineral diesel. Calculation examples are presented to determine brake output, thermal braking efficiency, and specific energy consumption (related to brake output)

### Engine Performance Parameters

Figures 5.1, 5.2, and 5.3 present a comparative analysis of Brake thermal efficiency (BTE), brake specific energy consumption (BSEC), and exhaust gas temperature of diesel engines, neem biodiesel, and their various blended combinations as fuels under different brake power conditions.

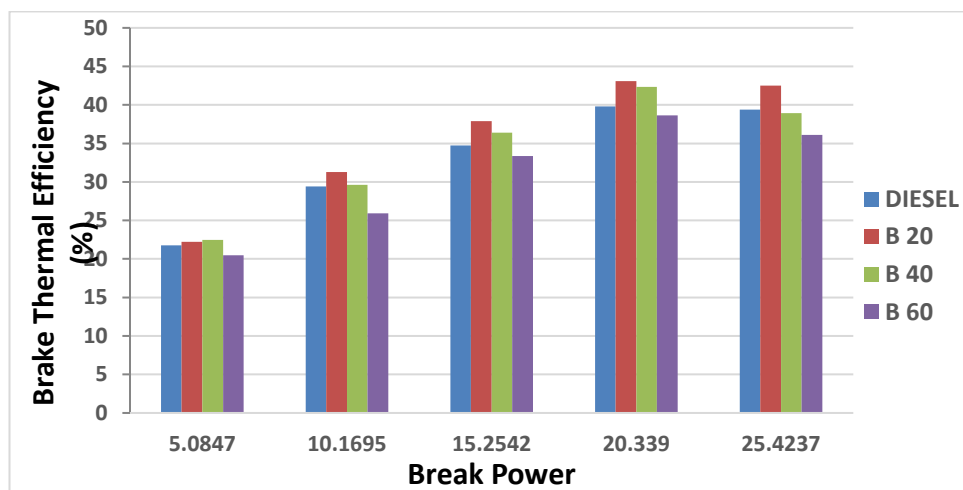


Figure 5.1 Variations in BTE with BP and Bio-diesel Percentage in blend

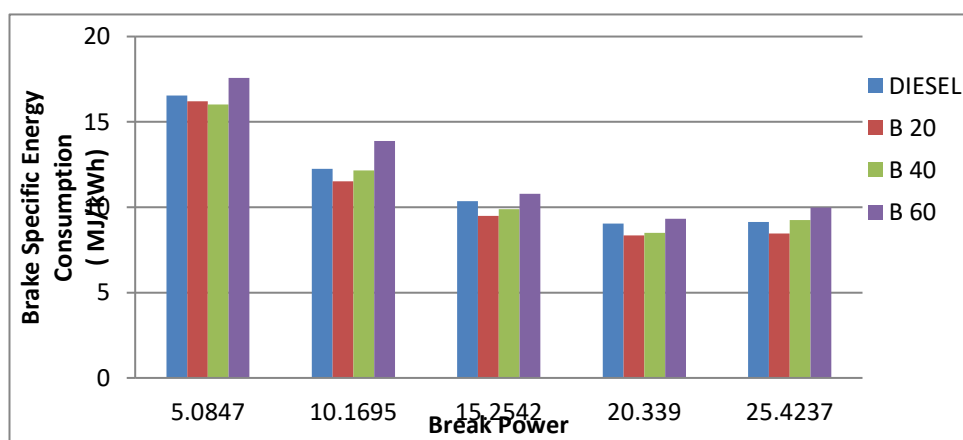


Figure 5.2 Variations in BSEC with BP and Bio-diesel Percentage in blend

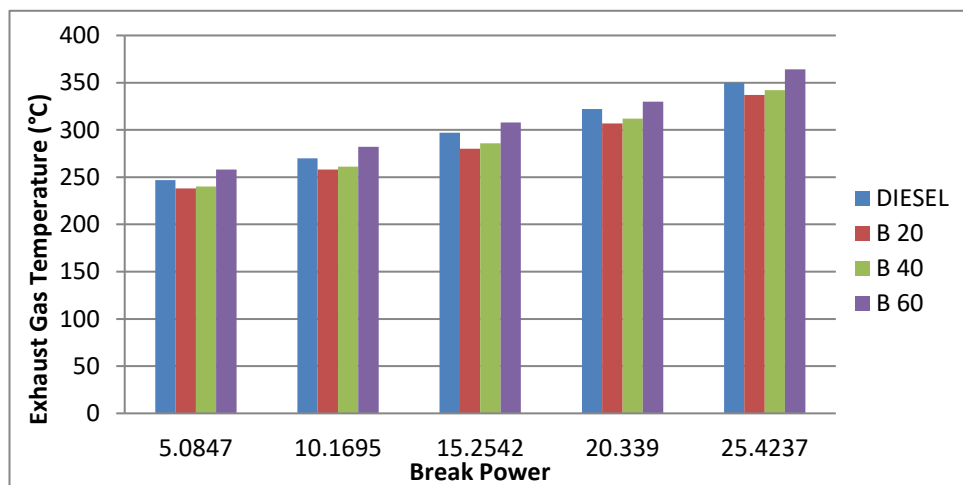


Figure 5.3 Variations in EGT with BP and Bio-diesel Percentage in blend

### Engine Emission Parameters

Figures 5.4 and 5.5 compare emissions of Carbon Monoxide and Hydrocarbon Emission using diesel, B20, B40 and B60 as fuels.

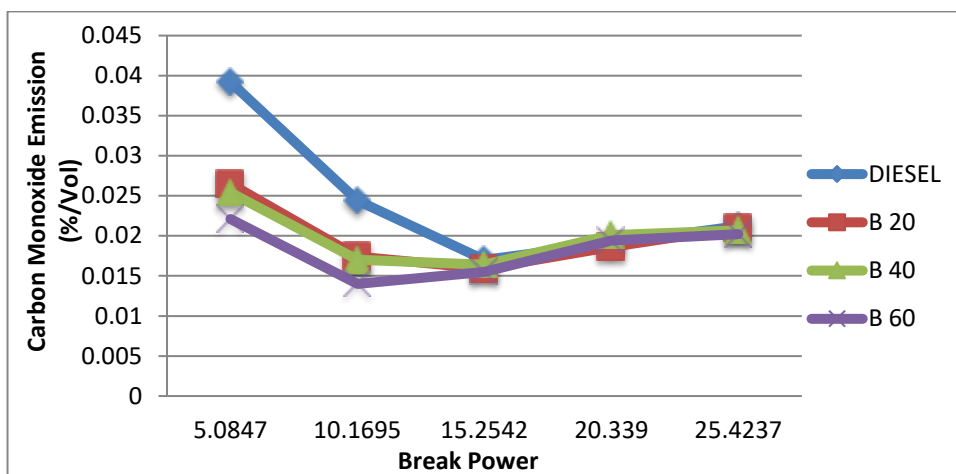


Figure 5.4 Variations in Carbon Monoxide iEmission with Brake Power and Bio-diesel Percentage in blend

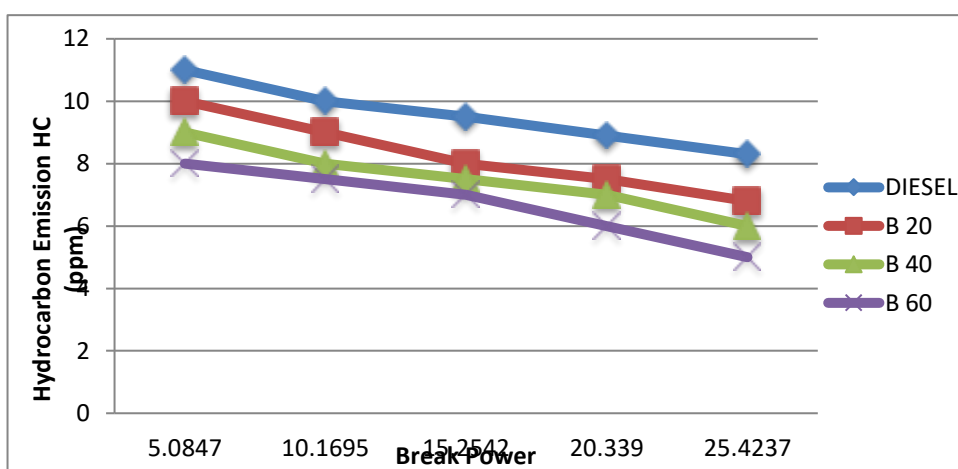


Figure 5.5 Variations in Hydrocarbon Emission with Brake Power and Bio-diesel Percentage in blend

### Effect of Bio-diesel blending with Preheating on IC engine

#### Engine Performance Parameters

Figures 5.9 and 5.10 shows variations in brake thermal efficiency with brake power, Neem bio-diesel blending with different preheating

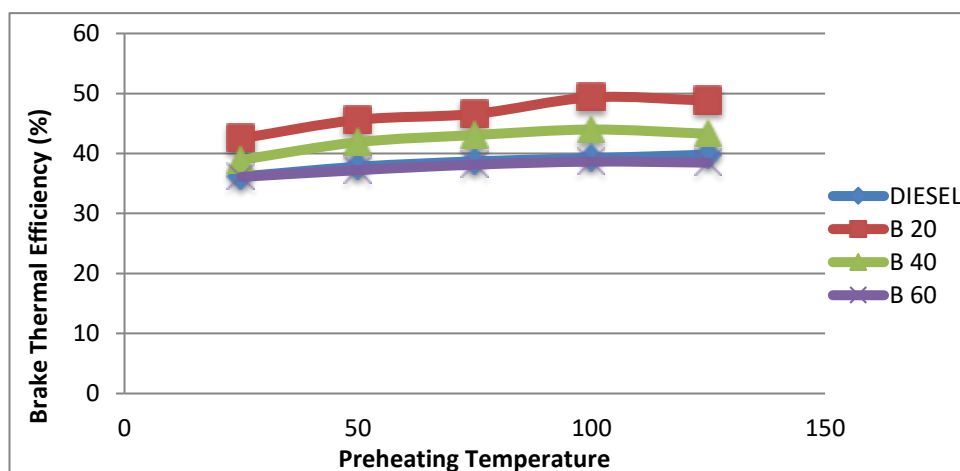


Figure 5.6 Variations in BTE with Brake Power and Preheating at different temperature.

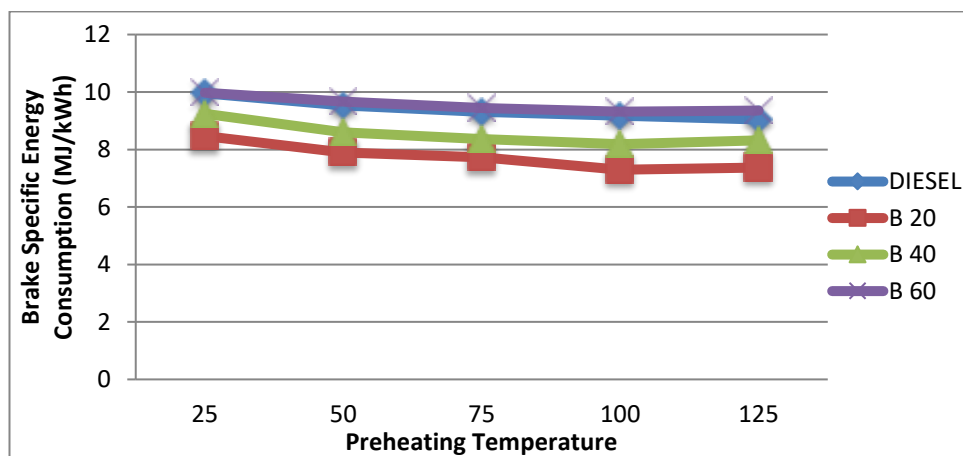


Figure 5.7 Variations in BSEC with BP Preheating at different temperature

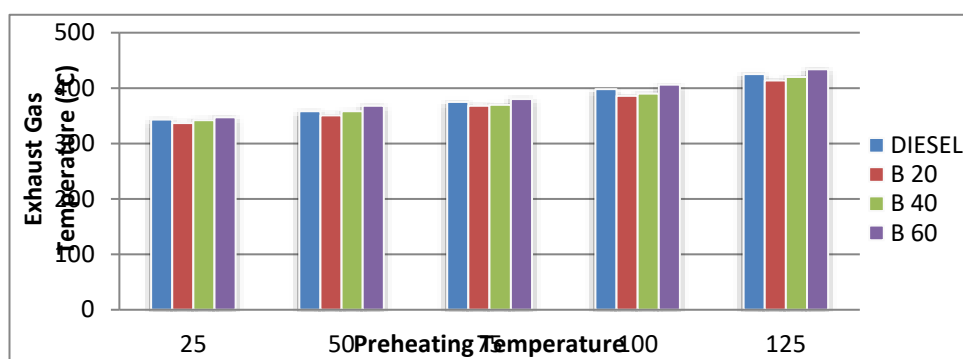


Figure 5.8 Variations in EGT with Brake Power and Preheating at different temperature.

### Engine Emission Parameters

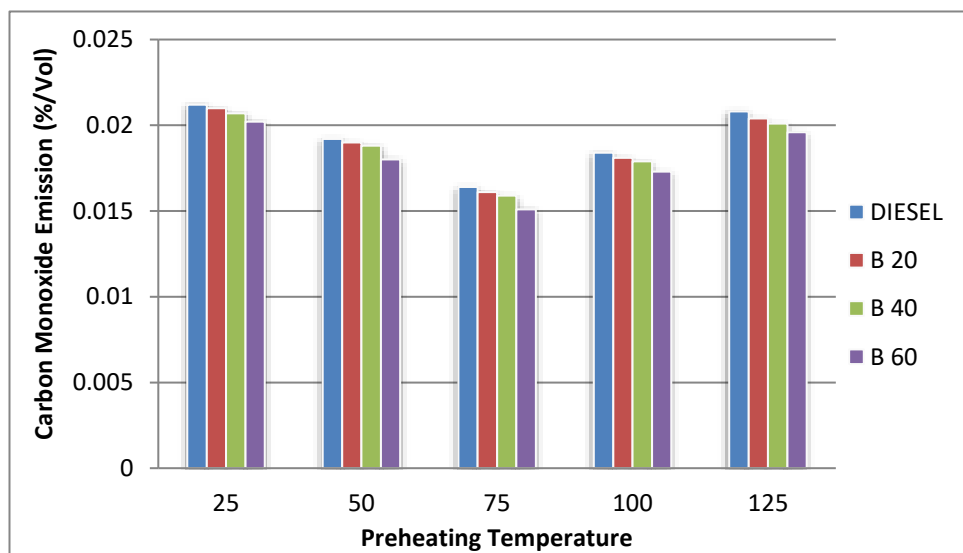


Figure 5.9 Variations in CO Emission with BP and Preheating at different temperature.

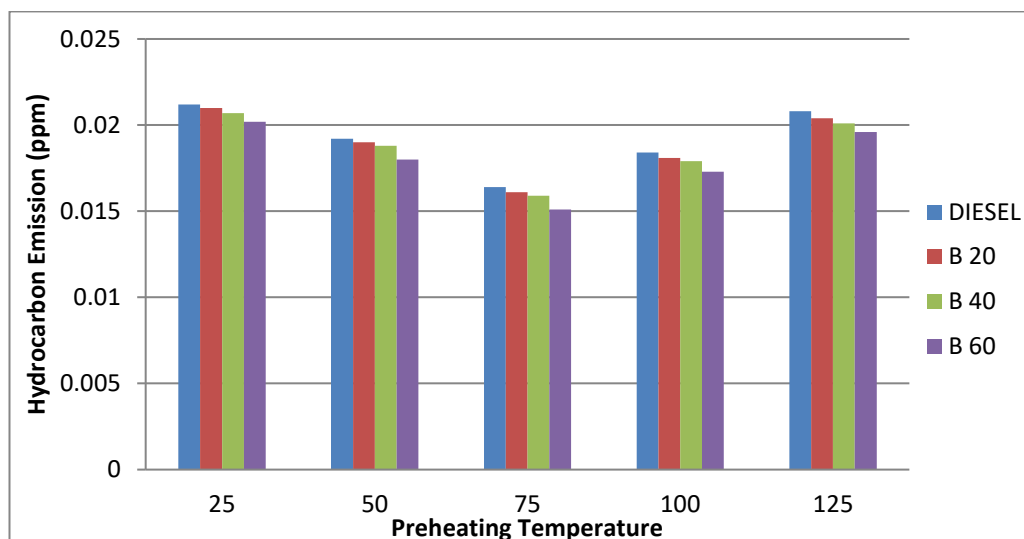


**Figure 5.10 Variations in Hydrocarbon Emission with Brake Power and Preheating at different temperature**

## CONCLUSIONS

On the bases of the experimental study performed on a four-cylinder, four-stroke, direct-injection diesel engine fueled with Neem biodiesel–diesel blends, both in the presence and absence of fuel additives, several important conclusions were obtained. The engine's performance and exhaust emission characteristics were systematically analyzed and compared against those recorded for standard diesel fuel under similar operating conditions.

❖ Neem biodiesel exhibits properties that are generally similar to those of conventional diesel fuel, although its heating value is approximately 10.17% lower. Due to this lower energy content, the peak power produced by pure Neem biodiesel is marginally less than that achieved with mineral diesel. In addition, the kinematic viscosity of Neem biodiesel is nearly 180% greater than that of diesel, resulting in the generation of larger fuel droplets during the injection process. Consequently, an increased fuel injection pressure is required to improve atomization and ensure efficient combustion within the engine cylinder is required to achieve finer atomization and improved combustion.

❖ The brake thermal efficiency (BTE) recorded for B20 and B40 blends is 49.34% and 43.98%, respectively, which is higher than the 39.78% observed for diesel. In contrast, the maximum BTE for B60 is 38.63%, slightly below that of diesel. The comparatively high viscosity of B60 results in larger droplet size and inferior atomization, thereby reducing combustion efficiency. The highest BTE achieved during the tests was 42.36% at a brake power of 20.34 kW, representing an improvement of 6.45% over diesel.

❖ The minimum brake specific energy consumption (BSEC) values for diesel, B20, and B40 were 9.04811 MJ/kWh, 8.35475 MJ/kWh, and 8.499496 MJ/kWh, respectively. Among these, B20 demonstrated the lowest BSEC, followed by B40 and diesel. Increased viscosity of higher blends, without modifying injection pressure, causes larger droplet formation and altered spray characteristics compared to diesel.

❖ The reduced BSEC observed for B20 and B40 can be attributed to their inherent oxygen content, higher cetane number, moderate viscosity, and shorter combustion duration relative to diesel. The lowest BSEC for B60 was 9.31528 MJ/kWh, which is about 3% higher than the minimum value obtained with diesel.

❖ The high exhaust gas temperature (EGT) recorded was 364°C for B60 at a brake power of 25.42 kW, while the minimum EGT of 238°C was observed for B20 at 5.08 kW. Compared to B60, B20 showed nearly a 34% reduction in EGT. At 25.42 kW, diesel and B40 produced maximum EGT values of 350°C and 342°C, respectively. Except for B20, all other blends exhibited higher EGT than diesel. Elevated EGT generally indicates increased heat carried away by exhaust gases and may correspond to reduced thermal efficiency. A compact combustion chamber design may also limit heat transfer to cylinder walls, contributing to higher exhaust temperatures.

❖ Carbon monoxide (CO) emissions at 25.42 kW were 0.0212% (Vol.) for diesel, 0.02098% for B20, 0.02066% for B40, and 0.02024% for B60. Diesel produced the highest CO emissions at this load. As the proportion of Neem biodiesel increased in the blend, CO emissions decreased, primarily Thanks to the oxygen content of biodiesel, which promotes more complete combustion, lower CO emissions are achieved for diesel, B20, B40, and B60 were 0.01696%, 0.0159%, 0.01643%, and 0.01402% (Vol.), respectively, at 15.25 kW.

❖ Hydrocarbon (HC) emissions were highest at idle and decreased continuously as braking performance improved for all fuels. Blending neem biodiesel with diesel reduced HC emissions across the entire load range, and a higher biodiesel content further lowered HC levels. Among all fuels, B60 exhibited the lowest HC emissions. The maximum HC emissions at no load were 11 ppm for diesel, 10 ppm for B20, 9 ppm for B40, and 8 ppm for B60. Using B60 reduced HC emissions to nearly half of those observed with diesel, mainly due to the oxygen content in Neem biodiesel, which enhances oxidation of unburned hydrocarbons.

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