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Original Article

Experimental Investigation on Diesel Engine Performance Analysis of Ternary Fuel (Diesel - Biodiesel-Magnesium Oxide Nanoparticles) Mixtures

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***Abstract** - In the current scenario, Biodiesel is the best alternative to regular diesel fuel, as demonstrated by several studies. In contrast, Biodiesel led to higher nitric oxide emissions. This experimental research investigates the performance of a single-cylinder four-stroke diesel engine employing 30% Juliflora Methyl Ester (JFME30) with variable percentages of Magnesium Oxide (MgO) tiny additive in levels of 30ppm, 40ppm, and 50ppm. The research findings demonstrated that when compared to standard diesel, the JFME30 + 40 ppm MgO mix considerably decreases hydrocarbon, carbon monoxide, smoke opacity, and NO emissions by 23.8%, 33.3%, 32.5%, and 16%, respectively. The JFME30+40ppm MgO combination also resulted in enhanced combustion characteristics and engine performance. From the final observations, it was found that there is a considerable difference in NO reduction of 16% and smoke opacity of 11.82% at full load. The engine's combustion characteristics improve, and there is a significant trade-off between smoke and NO emissions.*

***Keywords** - Juliflora Methyl Ester, Magnesium Oxide, Diesel Engine, Emission, Combustion, Nanoparticles.*

1. Introduction

The expanding global reliance on petroleum and natural gas, combined with rising supply costs, has spurred research into unconventional energy sources [1, 2]. Wind and solar Energy have grown in importance due to limited petroleum supplies, rising global oil prices, and environmental concerns. Unconventional powers like solar and wind have gained popularity due to finite petroleum reserves, rising global oil prices, and environmental concerns [3, 4]. Oils derived from plants and animals possess properties comparable to those of regular fuel, but have not been recognized for their ecological safety, non-toxicity, and biodegradability, thereby contributing to environmental sustainability [5, 6].

Biodiesel is a viable solution that can be made from algae, animal fats, and edible and non-edible plants. It is suitable for use in diesel engines with few or no modifications. Juliflora biodiesel was chosen for this study because its properties were similar to those of regular diesel. Biodiesel emits fewer hazardous pollutants than traditional diesel, such as Nitrogen Oxides (NOx), Carbon Monoxide (CO), Sulfur Oxides (SOx), and unburned hydrocarbons. Moreover, it is sustainable and renewable. The chemical structure of Biodiesel includes extra oxygen atoms, which supply the oxygen required for better fuel burning. Despite the fuel having numerous advantages, such as decreased heating value, poor cold flow properties, and high viscosity, it also has certain downsides [7]. Different concentrations of regular diesel and Juliflora blends were investigated [8]. According to the results of the blended fuels, they performed comparably to diesel fuel. However, in fully loaded condition, the Juliflora B100 produced 31.11% of BTE, which was comparable to that of regular fuel. While the B100 fuel exhibited higher NOx emissions at full load, it also showed lower CO, hydrocarbon, and smoke emissions compared to standard diesel.

Biodiesel is a biodegradable, renewable fuel with a higher cetane number than diesel. This fuel has no aromatic compounds while providing excellent lubrication performance [9]. Although Biodiesel produces more NOx, it significantly reduces HC and CO emissions [10]. It is worth noting that using pure Biodiesel directly results in incomplete combustion and decreased fuel atomization. As a result, the latest research suggests employing a blended fuel to reap both the fuel benefits while minimizing their harmful consequences [11]

In this scenario, HC and CO emissions would be reduced, and combustion would be complete [12]. The operation of the engine when using diesel fuel against that of diesel-biodiesel

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blends was compared [7]. They also mentioned the good impacts of water content in the emulsion, which resulted in decreased NOx. They stated that increasing water content would increase CO emissions. Although the use of Biodiesel is generally recommended due to its benefits, the greater NOx emission of this fuel remains a significant disadvantage [8]. Recent studies have focused on reducing output NOx using a variety of strategies.

Juliflora biodiesel against conventional fuel with fully loaded settings was tested and showed that the BTE was decreased by about 8.34% and smoke was augmented by 16, 11, and 10.6% [9]. Employing nanoparticles as an additive can enhance biodiesel blends. A technique for improving fuel quality by adding fuel additives is currently under investigation [10, 11].

In a comparison, the results of diesel and propanol plus-diesel blends produced a 5% power loss at all speeds. Significant benefits were obtained by adding PJB and isopropanol to diesel [12], including a more extended delay period, lower NOx and CO2 emissions, and an improved combustion rate [13].

One reliable and effective way to reduce NOx emissions is by Exhaust Gas Recirculation (EGR) [14]. When compared to an uncoated engine, it was [15] revealed that applying cottonseed oil methyl ester in an engine with short heat rejection enhanced emissions (up to 18.0% for CO and 8.0% for smoke density) and performance.

Biodiesel feedstock originating from natural plants, animal fats of animal and rubbish is commonly employed [16]. Pure Biodiesel is difficult to employ in ignition engines due to its low cold start, high density, poor cold flow performance, and delayed fuel atomization. According to research, putting a small quantity of Biodiesel into diesel fuel can help to relieve the concerns described above. Several researchers have supported this notion, Aydin [17]. This study compared the engine performance efficiency of three mixed biodiesels with a 9:1 ratio.

The study discovered that using blended Biodiesel increased performance efficiency substantially. However, the blending process can also cause a worsening of the discharge of emissions, which can be avoided or regulated by using nanoparticles. The reports expressed worry about the use of chemically produced metal nanoparticles may distress the human and the atmosphere [18, 19]. Metal oxide nanoparticles, such as titanium dioxide, have been biologically engineered to improve catalytic performance while reducing environmental impact [20]. Titanium dioxide plays an important function in the fuel blends because of its superior oxidation level, which may enhance engine performance with high dispersion [21].

Over the last decade, biodiesel fuel blends have included more alcohol-based additives to increase the level of oxygen in the combustion chamber, resulting in maximum effective combustion and reduced emissions [22].

Some studies suggest that nano-additives and their effects improve the performance of diesel engines [23]. The disadvantages of Biodiesel in diesel engines can be addressed by employing small amounts of nanoadditives [24]. The outcome of metallic and carbon nano-additives showed an enhancement in the characteristics of the engine and reduced the emissions due to complete burning [25]. When these nanoparticles are included in fuels, they aid in minimizing NOx emissions during combustion [26]. In addition to raising injection pressure and lowering exhaust emissions, adjusting engine characteristics such as injection time, Compression Ratio (CR), and load has been demonstrated to increase combustion and performance.

The nanofuel mix of Dairy Scum Oil Methyl Ester (DSOME-2040) showed enhanced engine characteristics due to the maximum catalytic action. The test was done to determine how MWCNTs and CeO_2 were blended in lemon and orange peel oil mixes for CI engines [28]. B20 + (50 and 100 ppm) and eight different fuel blends resulted in lower Brake Specific Fuel Consumption (BSFC), HC, CO, and NOx emissions while increasing BTE at peak power.

The CI engine characteristics with the influence of ZnO nano additive blends with Biodiesel were studied, and it was discovered that the nanoparticles reduced NOx, HC, and CO emissions [29]. The investigation results of neat palm oil with Ag2O nanoparticles showed that the Ag2O nanoparticles increased BTE while decreasing BSFC and minimizing the levels of other parameters specified above [30].

The tests were conducted using a blended emulsified fuel composed of lemongrass oil and ceria nanoparticles, and the results were obtained. The BTE of LGO-nanoparticle blended fuel was higher than that of neat LGO and LGO-emulsion fuels due to enhanced atomization and a faster evaporation rate due to the enormous surface area to volume ratio of CeO nanoparticles. When compared to neat LGO, LGO-emulsion, and diesel fuel, CO, HC, and NOx emissions were significantly reduced, with a modest decrease in smoke emissions [31-33].

From the extensive literature review, there are only very few studies that have been conducted on the performance behaviors of diesel engines using nanoparticles mixed with Juliflora Methyl Ester (JFME) diesel blends. Hence, the present study primarily focused on the objective parameters, using JFME30 mixed with MgO nanoparticles in three different dosages: 30 ppm, 40 ppm, and 50 ppm. The final values were compared with those of the JFME30 mixtures.

2. Materials and Methods

2.1. Juliflora Tree

The Juliflora tree, also known as Prosopis Juliflora, is a robust and drought-resistant plant that can be found in arid and semi-arid environments worldwide. It grows quickly, fixes nitrogen in the soil, and can withstand dry and salty conditions, making it an excellent choice for environmental restoration. The tree produces elongated seed pods, each holding a large number of small, hard seeds encased in a strong outer covering that naturally limits water absorption. If not properly treated, this seed coat makes germination problematic. Seeds usually germinate within one to three weeks of treatment under ideal conditions. Juliflora produces approximately 2.5 tons of timber, which contains more than 70% cellulose molecules, thereby enhancing the bio-oil quality. It generates an estimated 5000 liters of oil per acre, making it a promising source of bioenergy. The pods are flat, approximately 1 ft. long, 5-15 mm broad, and 3-9 mm thick, and mature from green to a mushy, yellowish-brown color. Each inflorescence bears one to sixteen pods, with seeds weighing between 0.20 and 0.32 grams, and occurs in densities ranging from 20,000 to 32,000 per kilogram. Depending on environmental conditions, a single tree can produce 5 to 10 kilograms of kernels. At a density of 20 kg per tree, the total pod production can be over 2,230 kg per hectare. Figure 1 and 2 depicts Juliflora trees, pods, and seeds, emphasizing their distinguishing features and potential applications.

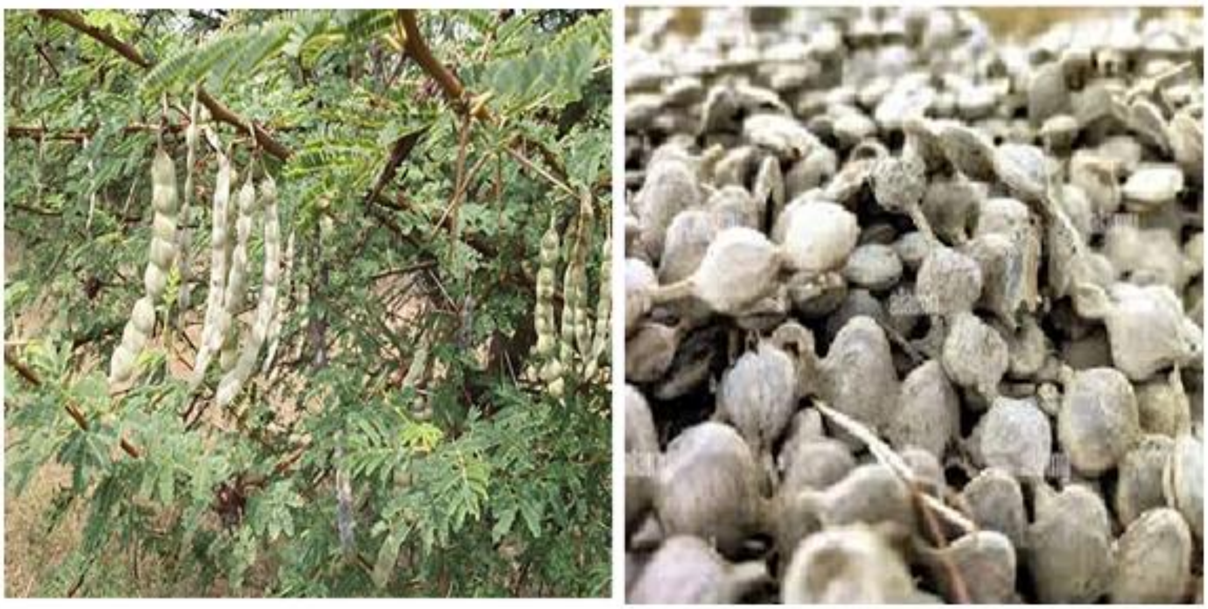

Fig. 1 Juliflora tree and pods

Fig. 2 Juliflora seeds

2.2. Preparation of Juliflora Oil

Prosopis Juliflora is an average-sized tree widespread throughout India. Peru, Sri Lanka, South America, Central America, the Philippines, Mexico, and India have a higher concentration of the tree. The oil content of the seed is approximately 27%-39%. Seeds yield a rich, strong yellowish-orange to brownish oil. Using a mechanical expeller yields a 25% increase in volume. The oil has a bitter flavor and an unpleasant scent; therefore, it is not suitable for consumption. JFO can be extracted using three methods: cold pressing, oil expellers, and solvent extractors. In the oil expeller process, a spinning screw squishes the seed in an even chamber, and the oil gradually proceeds. The cold-squeezed process is utilized to keep up with the highest concentration of nutrients. The crisp-squeezed method is similar to the expeller method, except it must maintain a temperature of less than 45 degrees Celsius. The dissolvable extraction method concentrates oil from the seed at high temperatures in order to make a large amount of money [18, 19].

2.3. Juliflora Methyl Ester (JFME) Preparation

Transesterification was used to produce Biodiesel from Juliflora oil, isolating the glycerin and methyl ester. The basic thermo-physical properties of the biofuel were determined using the standard ASTM testing procedures. The obtained Juliflora biodiesel has a higher density, flash point, cetane number, viscosity, and sulphur content than conventional diesel. There are two mixing methods: volume-based and mass-based. Fuel mixing is the only way to minimize viscosity and thus the heat valve. Magnesium nitrate and urea from identified Biodiesel were used to produce MgO nano additives utilizing the Sol-gel technique under air conditions. Three distinct test fuels were created by combining 30 ppm, 40 ppm, and 50 ppm of MgO with one liter of biodiesel fuel [20]. To obtain the testing fuels with their homogeneous suspension, the mixture is concussed for 30 minutes using an ultrasonicator with a frequency of 24 kHz and a power of 200W. To prevent settling or the formation of sediments, the fuel blends were immediately tested on diesel engines after preparation.

Table 1. Properties of the fuel

Properties	ASTM Std	Diesel	JFME
Density (kg/m^3)	D127	830	878
K. Viscosity @ 40°C (cSt)	D2217	2.83	3.45
Calorific Value (MJ/kg)	D4809	43	39.9
Flash Point (ºC)	D93	56	194
Cetane Number	D6890	46	59.5
Oxygen (%) by wt	D943	-	11.8
Latent Heat (kJ/kg)	D2015	250	-

2.4. Preparation of Magnesium Oxide Nanoparticles

Magnesium oxide nanoparticles can be prepared using a simple chemical precipitation method, as shown in Figure 3(a). First, magnesium nitrate is dissolved in distilled water and stirred well. Then, sodium hydroxide solution is added slowly until the pH reaches around 10–11. This causes a white solid, magnesium hydroxide, to form. The mixture is left to sit for a few hours, then the solid is filtered and washed with water and ethanol to remove impurities. After drying the solid at about 80–100°C, it is heated (calcined) in a furnace at 400–600°C. This heating process turns the magnesium hydroxide into magnesium oxide nanoparticles. The size of the nanoparticles can be controlled by changing the pH, temperature, or amount of chemicals used. This method is straightforward and commonly employed in laboratories to produce MgO nanoparticles for various applications, including medicine, electronics, and environmental uses. The SEM and XRD images of MgO nanoparticles are represented in Figure 3(b).

Fig. 3(a) Preparation of biodiesel-nanoparticle mixing process through Ultrasonicator

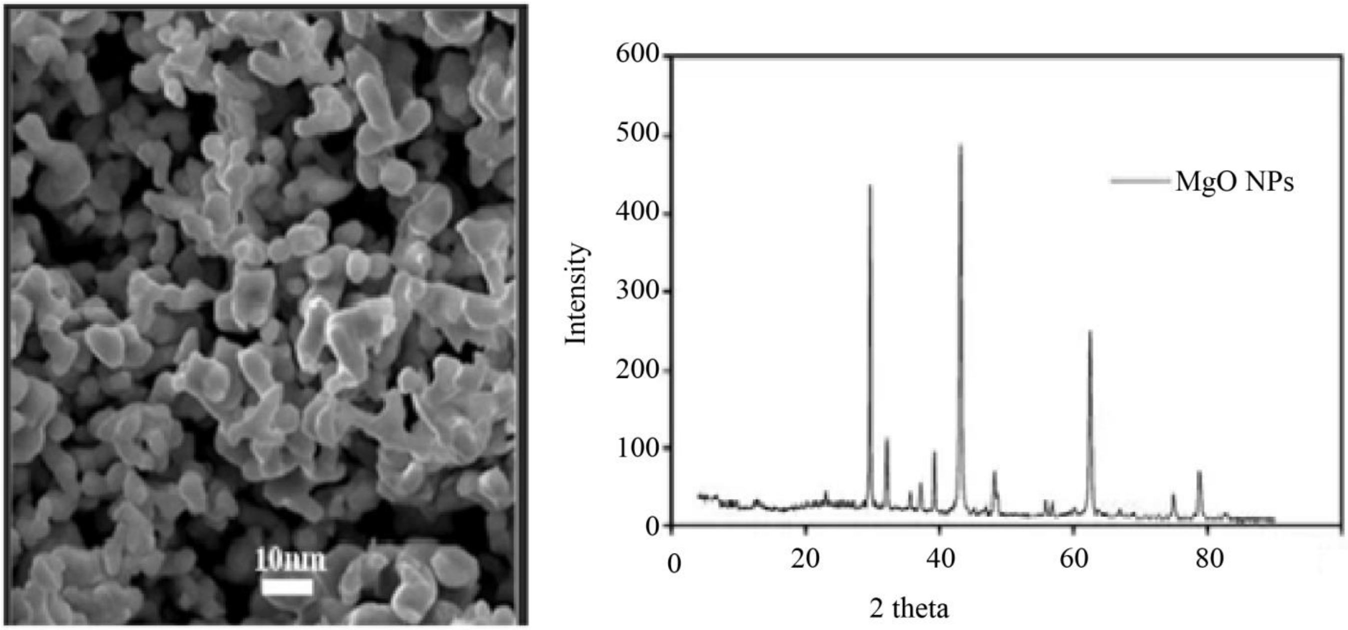

Fig. 3(b) SEM & XRD images of MgO nanoparticles

3. Experimental Setup

The experimental studies were conducted using a 4-stroke mono-cylinder diesel engine of the TAF-1 model that rotated continuously at 1500 rpm. Figure 4 illustrates how the engine arrangement is built. Table 2 presents the general engine specifications. This engine's combustion parameter was recorded on a personal computer using a data acquisition system while it was attached to an eddy current dynamometer. The pressure is measured by the appropriate pressure sensor, and the analyzer, encoder, and amplifier are used to identify the various engine input signals. In addition to the flywheel, an optical sensor was fitted to monitor the engine's 1500 rpm, and a K-type thermocouple was used to measure the exhaust gas temperature. After the AVL five-gas analyzer examined the engine's emissions, runs with diesel were conducted for about 15 minutes by passing the discharges to the clean channel for moving on to the subsequent testing. During this technique, the non-dispersive infrared sensor was fed the emissions, and the smoke emissions were measured using the electrochemical sensor and the AVL 437 C type apparatus. This diesel engine's engine brake power was tested under five load conditions of 0, 25, 50, 75, and 100 percent, with the necessary test fuel blends. Table 3 represents the emission range, accuracy, and uncertainty.

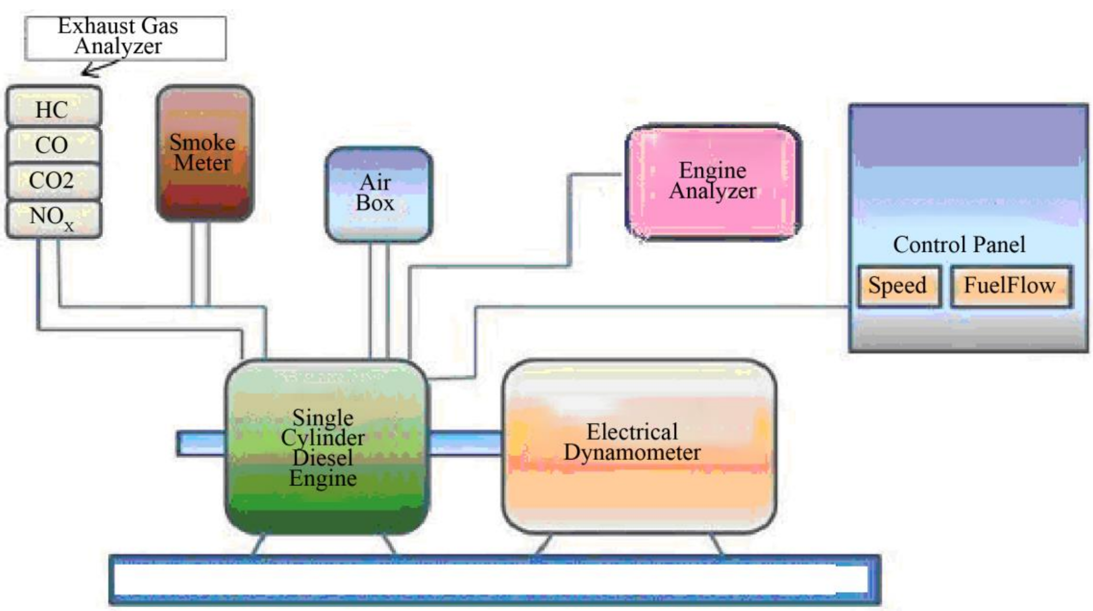

Fig. 4 Experimental engine setup

Table 2. Terms of the testing engine

Make & Model	Kirloskar, Vertical, 4 Stroke, Single cylinder, Air cooled
Power Valued	4.4kW
Bore and Stroke	87.5 and110 mm
Displacement	661cc
Nozzle Initial Pressure	200bar
Timing of Injection	23^{o}bTDC
Ratio of Compression	17.5:1
Gas Analyzer	AVL 444 Di gas analyzer
Smoke Tester	AVL-437C

Table 3. Emission range, accuracy, and uncertainty

Device	Dimension	Level	Precision	Ambiguity
AVL DI Gas 444 Five gas analyzer	CO	0-10%Vol	±0.03%	±0.2%
	CO_2	0-20%Vol	±0.%	±0.15%
	HC	0-20000ppm	±10ppm	±0.2%
	O_2	0-22%Vol	±0.1%	±0.5
	NOx	0-5000ppm	±50ppm	±1
AVL 437 Smoke meter	Opacity (%)	0-100	0.1	±1%
	Absorption (m^{-1})	0-99.9	0.01	±1%

3.1. Uncertainty Analysis

The experimental results showed a number of mistakes caused by calibration, equipment accuracy, climatic circumstances, and observer error, among other things. Ambiguity analysis is used to acquire reliable results. The uncertainties in the engine system were calculated using the propagation of uncertainty method, often known as the RMS method. The uncertainty of the engine characteristics was determined with the following equation.

$$w_R = \left[\left(\frac{\partial R}{\partial x_1} w_1\right)^2 + \left(\frac{\partial R}{\partial x_2} w_2\right)^2 + \cdots + \left(\frac{\partial R}{\partial x_n} w_n\right)^2\right]^{\frac{1}{2}}$$

R is a function that depends on independent variables (x1, x2, x3, …, xn). Holman (2012) defines wR as the total percentage uncertainty of experimental values in outcomes, while w1, w2, and wn represent the uncertainties of independent variables. The proportion of uncertainty for various quantities was calculated and shown in Table 4. The accuracy of the test findings was confirmed using an error analysis performed based on Taylor's theorem. Overall uncertainty is represented by

Overall uncertainty = Square root of [(BTE)^2 + (BSFC)^2+ (CO)^2 + (HC)^2 + (NOx)^2 + (Smoke)^2 + (Pr sensor)^2+(CA encoder)^2

= Square root of [(1.0)^2 + (1.0)^2 + (0.2)^2 + (0.2)^2 + (0.2)^2 + (1.0)^2+ (0.2)^2+ (0.2)^2]

= ± 2.16%

4. Results and Discussion

4.1. Combustion Characteristics

The investigation was carried out on a CI engine with different dosages of MgO and the diesel blends to enhance the engine performance at different load conditions.

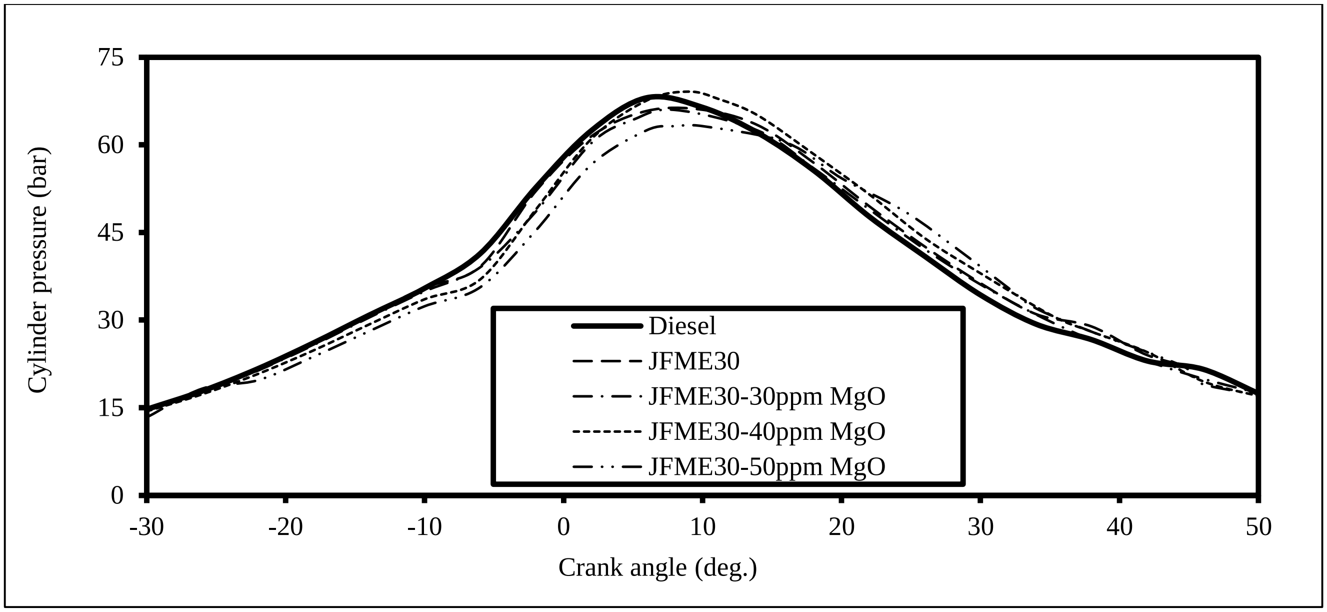

Fig. 5 Variations of cylinder pressure with CA at full load

4.1.1. Cylinder Pressure

The variations of cylinder pressure with different modes are shown in Figure 5. It is observed that the variation of cylinder pressure with crank angle for diesel and JFME30 with varied dosages of MgO nanoparticles mixes. In CI engines, the top pressure of the cylinder is determined by the quality of combustion in the early stages, which is influenced by the amount of fuel used during the delay period. It is noticed that the figure depicts the fluctuation of peak pressure with crank angle for diesel and JFME30 with varied dosages of MgO nanoparticle mixes. JFME30 biodiesel has a lower cylinder pressure than diesel because of its low energy content and high viscosity. At full load, the peak cylinder pressures for diesel and JFME30 are 68bar and 66bar, respectively, due to improved diesel combustion [20]. Because JFME30 with nanoparticles has a lower cetane index than diesel, the ignition delay is prolonged; as a result, the highest cylinder pressure is raised for JFME30 with nanoparticle mixtures when compared to diesel fuel. This can be ascribed to excessive premixed mixture, which causes a more prolonged delay followed by increased cylinder pressure. At full power, the peak pressure for JFME30 with 30ppm, 40ppm, and 50ppm of MgO mixes is 67bar, 69bar, and 63bar, respectively.

4.1.2. Heat Release Rate (HRR)

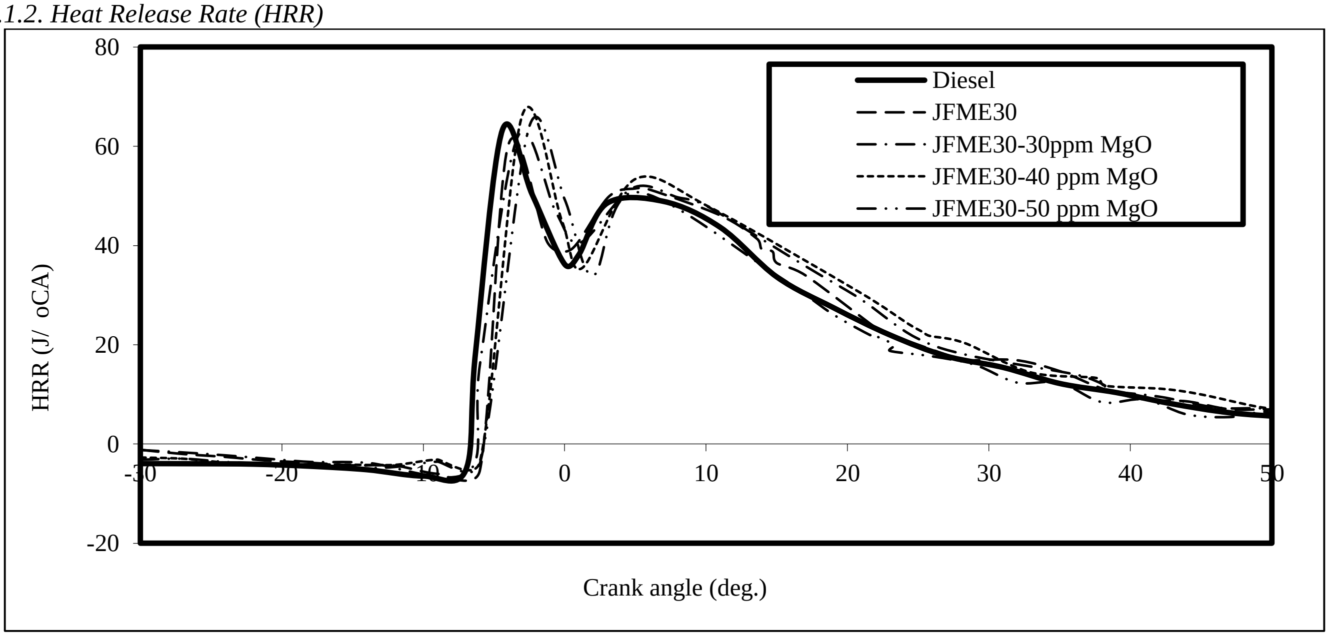

Fig. 6 Variations of the HRR with CA

Figure 6 depicts the variation in HRR with crank angle for diesel and JFME30 with varied dosages of MgO nanoparticle mixes. Because of the longer ignition delay, JFME30 diesel blends have higher premixed combustion phase levels. Premixed combustion is affected by cylinder temperature, fuel-air mixing duration, and fuel characteristics. At later stages of combustion, there is a discernible shift in HRR towards TDC [20]. The HRRs for diesel and JFME30 at full load are 63J/oC and 60J/ºC, respectively. This is owing to diesel's increased calorific value, which results in a higher HRR. In comparison to biodiesel blends, the premixed combustion phase is increased for JFME30 with varying nanoparticle mixture dosages. This could be attributed to the longer ignition delay when compared to JFME30 mixes at full load. This increase in HRR could be attributed to a nanoparticle acting as an additive, hence improving premixed combustion rates [21]. At full load, the maximum HRR achieved by JFME30 with 30ppm, 40ppm, and 50ppm of MgO nanoparticle mixes is 61J/oCA, 65/oCA, and 62J/oCA, respectively.

4.2. Performance Characteristics

4.2.1 Brake Thermal Efficiency

Figure 7 depicts the thermal efficiency of the brakes using BP diesel and Juliflora biodiesel with various MgO blend dosages. BTE measures the efficiency with which chemical Energy from the fuel is converted into usable work in an engine. At full load, the BTEs of diesel and JFME30 are 31.7% and 28.4%, respectively. The BTE is reduced with biodiesel blends due to their low calorific value, greater viscosity, high volatility, and poor spray characteristics [21]. As a result, the percentage difference between the superior BTE JFME30 and diesel is 2.3%. On the other hand, the BTE of modified Juliflora biodiesel blends with varied dosages of MgO nanoparticle combination is obtained for JFME30 with 30ppm, 40ppm, and 50ppm of MgO nano mixes, which are 29.6%, 30.4%, and 30.9% respectively. Compared with the neat diesel-biodiesel fuel blends, the MgO nanoparticle mixtures facilitate complete combustion of the fuel charge, due to the enhanced micro-explosion phenomenon and higher catalytic activity of MgO nanoparticles [18].

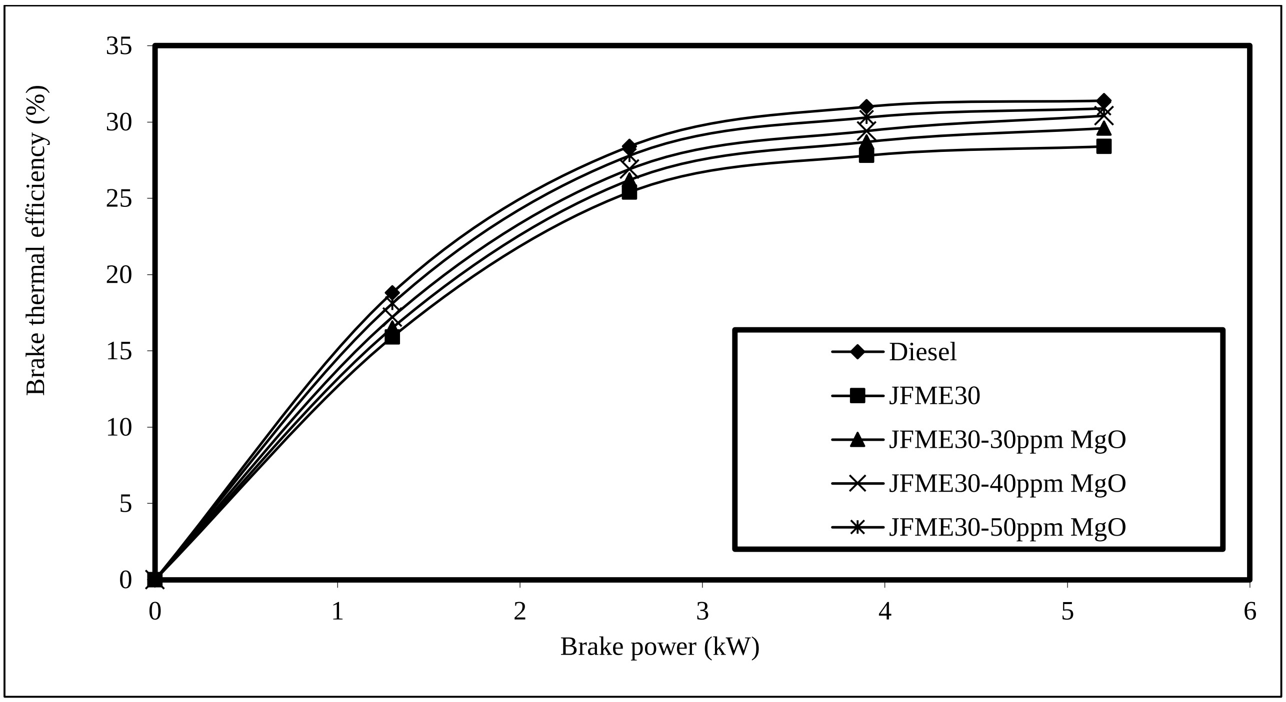

Fig. 7 Variations of BTE with BP

4.2.2. BSFC

Figure 8 depicts the BSFC findings for all fuels tested at various engine loads. The addition of nanoparticles ultimately condenses the emission level to minimize the friction, in turn reducing the intake of fuel. The biodiesel CV and density may define its BSFC rating. Diesel provided the best BSFC on all loads when compared to JFME30. As the density of Biodiesel grows, so does the level of BSFC. Furthermore, because Biodiesel has a lower gross calorific value (energy content) than diesel, it produces less power with the same amount of fuel usage [22]. At standard engine speed, the minimal BSFC value for diesel and JFME30 was 0.29 and 0.33 kJ/kWh, respectively. Furthermore, MgO nanoparticles added with JFME30 reduced the BSFC of all tested fuels, with 0.32 (30ppm of MgO), 0.30 (40ppm of MgO), 0.31 (50ppm of MgO), and JFME30+40ppm of MgO fuels showing lower BSFC due to improved heating values and ternary blends, This decrease in BSFC is brought with the action of the catalytic and the high reactive surface of MgO nano particles.

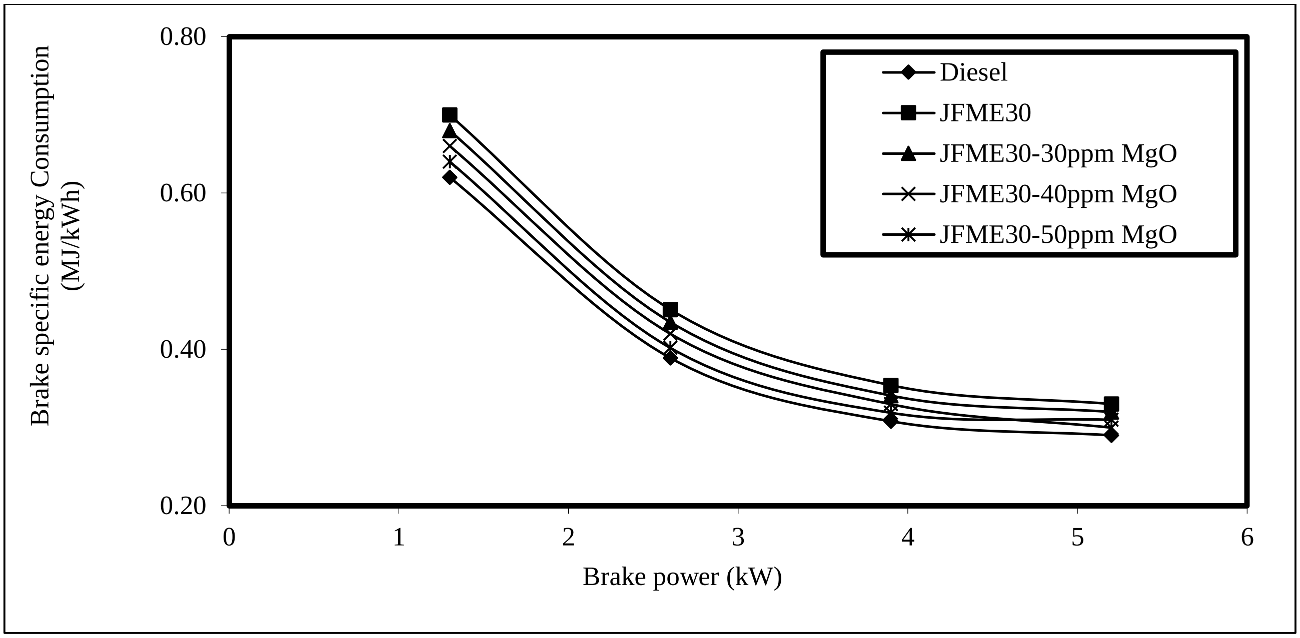

Fig. 8 Variations of BSFC with BP

4.3. Emission Characteristics

4.3.1. CO Emission

Figure 9 compares the CO emission projections derived from diesel and JFME30 with nanoparticle mixtures. From the observed results, it was found that the JFME emits less CO than diesel fuel, which clearly has a greater CO_2 conversion rate. The CO emissions for diesel and JFME30 were 0.14% and 0.12%, respectively. This might be due to oxygen molecules in Biodiesel that accelerate oxidation. In addition, the CO emission for JFME30 with MgO nano particles combination was lower than for diesel and JFME30. It is observed that the CO produced for JFME30 with MgO 30ppm, 40ppm, and 50ppm is 0.1, 0.08, and 0.09% vol., respectively. It may be induced by the presence of a nano material that enhances the quantity of oxygen accessible for combustion. MgO nanoadditive acts as an oxygen-producing catalyst, converting CO into CO_2 [34]. A lower proportion of CO suggests a more effective combustion process, as indicated when nano-additive is used, and ultimately, the oxidation process could be increased [23]. The lower CO concentrations in the combustion mixture indicate a greater conversion rate. Furthermore, when more than 50ppm of MgO nano additives are used, CO levels rise somewhat, resulting in inefficient combustion.

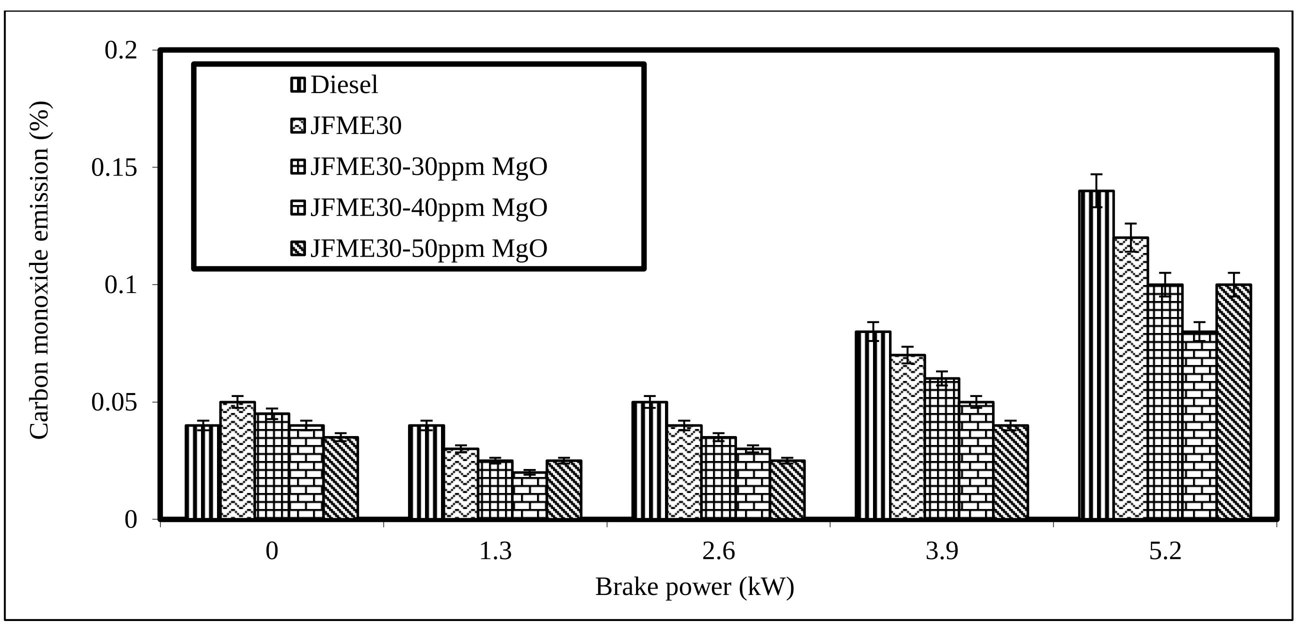

Fig. 9 CO emissions versus BP

4.3.2. Hydrocarbon Emission

Figure 10 depicts the measured hydrocarbon emission patterns for diesel and JFME30 with MgO nanoparticle mixes. Because diesel fuel lacks oxygen, it has a larger range of HC production than JFME30 for all loads. The production of HC leads to inadequate oxygen for the fuel to burn, which is another factor leading to power loss and reduced efficiency. The amount of unburned hydrocarbons released increases as the load grows.

The data also revealed that reductions in HC production in the exhaust were associated with lower nanoparticle concentrations. When compared to diesel, the JFME30 produces higher HC emissions. This consequence might be that the low volatility of the biodiesel mixture precludes the creation of homogeneous mixtures.

Furthermore, the HC for MgO-doped JFME30 has increased due to catalytic breaking of the hydrocarbon chain and nanoparticles' capacity to buffer O2 [24]. It is obvious that an engine's measured HC emission was 36 ppm for diesel, 56 ppm for JFME30, 40 ppm for MgO 30ppm, 36 ppm for MgO 40ppm, and 30 ppm for MgO 50ppm. This is due to MgO's high catalytic activity and large surface area per unit volume, which improves combustion.

4.3.3. Nitrogen Oxides Emission

Figure 11 depicts the variability in NO emission versus BP for all test fuels. These pathways, which mostly occur inside the cylinder for NO production, include the thermal N2O route and fuel-bound nitrogen at high temperatures [24]. JFME30 produced greater NO emissions than diesel. More NO for JFME30 can be due to more fuel-bound oxygen in Biodiesel, which causes higher local peak temperature and therefore higher NO production. Another possible cause of the greater cetane number in Juliflora biodiesel. It is noticed that an engine's measured NO emissions were for diesel, 972ppm and for JFME30, it is 1054ppm respectively. Because of the greater cetane number, the development of burning, the decrease of burning duration, and the premixed portion of the combustion increase when NO is mostly generated. According to the findings, including MgO nanoparticles in the gasoline might significantly cut NOx emissions. Nano additions reduce peak cycle temperature by absorbing more heat from the cylinder and releasing more oxygen. The nano additives convert NO to NO2 by serving as an oxygen-supply catalyst. MgO nano additions have unique oxygen absorption and endowment capabilities, which minimise NOx and soot emissions [22]. Also, the NO emission obtained for JFME30 with MgO 30ppm, 40ppm, and 50ppm are 952ppm, 859ppm, and 789ppm, respectively.

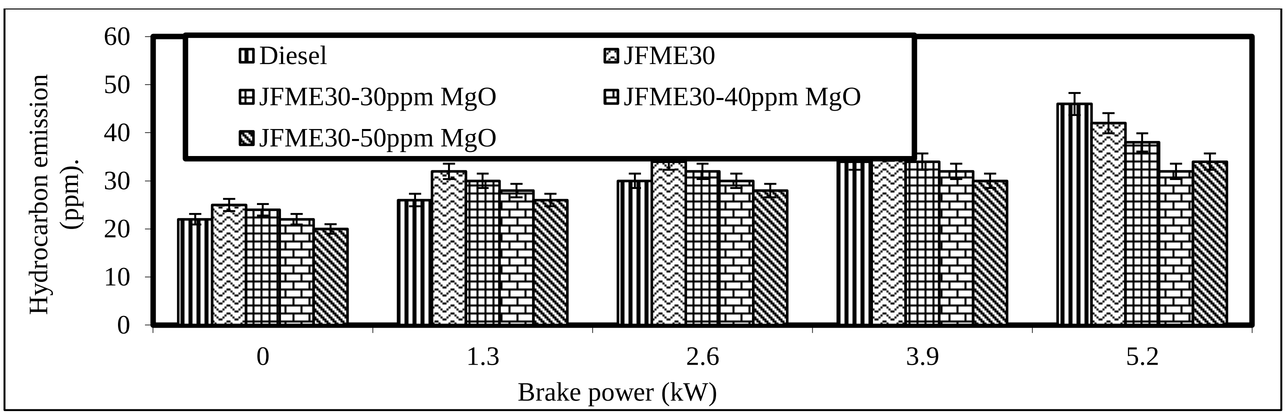

Fig. 10 HC emissions versus BP

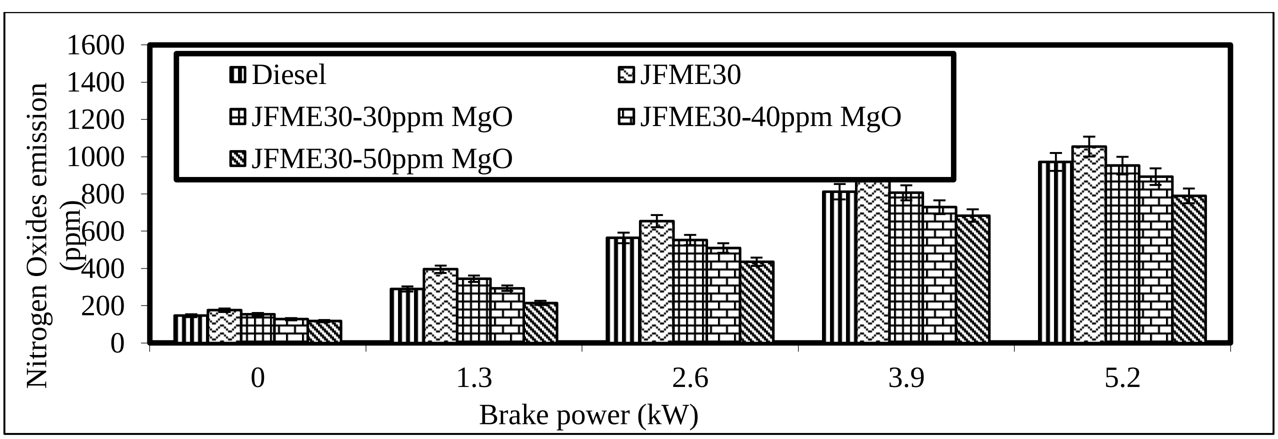

Fig. 11 NO emissions versus BP

4.3.4. Smoke Emission

Figure 12 shows that the fluctuation in smoke opacity at various engine loads for diesel and JBFME30 using different MgO-nano combinations. Smoke forms in engines during the diffusion combustion phase, when all fuel atoms are fragmented into elemental carbon soot particles, which are later oxidized in the reaction zone. Biodiesel emits less smoke than diesel fuel because of its superior oxygen percentage and fewer aromatic chemicals. It is noticed that an engine's measured smoke emissions were for diesel, 40% and for JFME30, it is 34% respectively. This consequence may have led to secondary atomization. The introduction of MgO nano component in the JFME30 mix has significantly decreased smoke emissions. Smoke emissions are significantly decreased by 18% at 30 ppm, 306% at 40 ppm, and 24% at 50 ppm. This conclusion might be attributed to the improved combustion phase and evaporation rate in the premixed mixture, making the nano additive the ideal anti-smoke agent [24]. Also, the smoke emission obtained for JFME30 with MgO 30ppm, 40ppm, and 50ppm is 28%, 24% and 26% respectively.

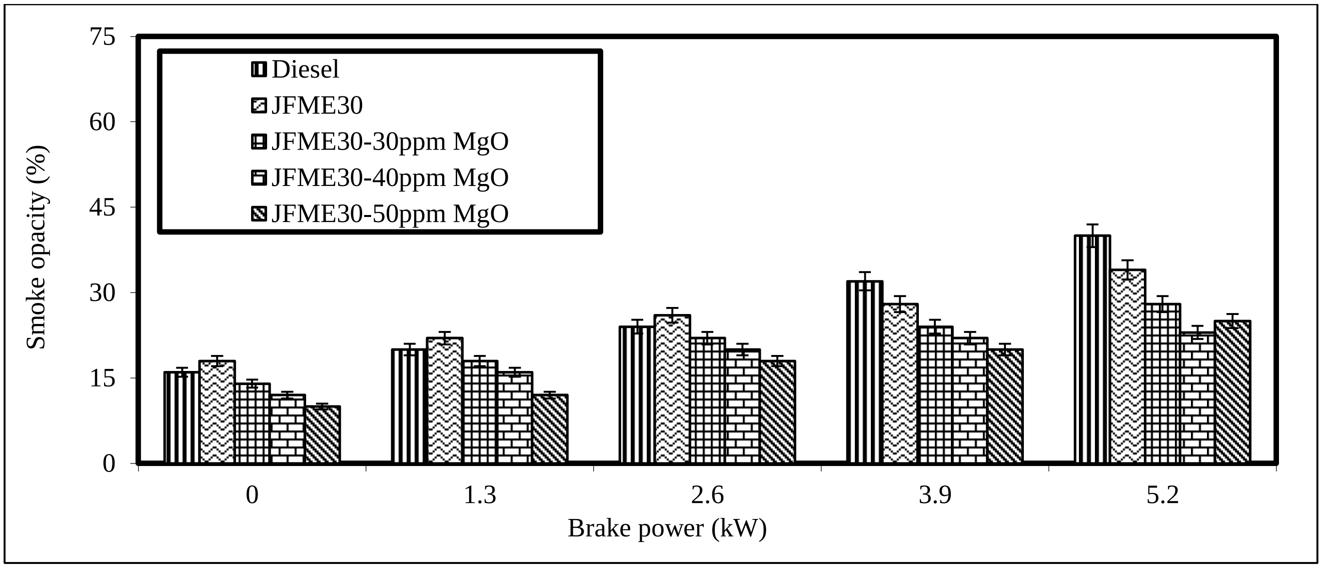

Fig. 12 Smoke versus BP

5. Conclusion

This experimental study examines how the nano additions with JFME30 blends are affecting the engine characteristics. The basic diesel was powered by existing engines that were not modified. JFME30 is a highly efficient and low-emission alternative fuel source. JFME30 was chosen for its capacity to concurrently reduce NOx and smoke. Adding MgO nano additions to JFME30 enhanced its performance and reduced emissions. The research findings demonstrated that when compared to standard diesel, the JFME30 + 40 ppm MgO mix considerably decreases hydrocarbon, carbon monoxide, smoke opacity, and NO emissions by 23.8%, 33.3%, 32.5%, and 16%, respectively. The JFME30+40ppm MgO combination also resulted in enhanced combustion characteristics and engine performance. The JFME30+40ppm MgO mix enhanced combustion properties, particularly CP and HRR, compared to the JFME mixture, due to some potential variables, including lower ignition delay and enhanced mixture qualities. Nevertheless, JFME30 has lower CP and HRR compared to diesel. MgO nano additions increase CP by 4.7% and HRR by 8.3% in the JFME30 + 40 ppm MgO compared to JFME30, highlighting their benefits.

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