Hindawi
Adsorption Science & Technology
Volume 2022, Article ID 9259173, 8 pages
https://doi.org/10.1155/2022/9259173

Research Article

Reduction of Carbon-Based Emissions using MgO Nanoparticle with Waste Cooking Oil Biodiesel in Diesel Engine

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Received 20 April 2022; Revised 19 May 2022; Accepted 31 May 2022; Published 13 June 2022

Academic Editor: S.K. Khadheer Pasha

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Because biofuels are ecologically beneficial and might possibly lessen global warming, many academics are interested in studying them. Nanoparticles have been added to biodiesel to improve its performance as well as emissions. Diesel engine that operates on waste cooking oil biodiesel is the subject of the present research, which evaluates the impact of MgO nanoadditives on performance and emissions. Transesterification was done to convert waste cooking oil biodiesel into methyl ester. In the present study, SEM (scanning electron microscope), TEM (transmission electron microscope), and EDX spectroscopy are used for investigation of nanoadditives. The sample contained biodiesel blends with and without nanomagnesium oxide, as well as a combination of the two. According to the ASTM (American Society for Testing and Materials), the biodiesel produced from waste cooking oil met all fuel standards. The results of the testing were obtained by running a single-cylinder, 4-stroke diesel engine under a variety of loads. Using SEM analysis, the diameter of nanoparticles is found to be 20 nm to 38 nm. Magnesium oxide nanoparticles have been shown to include the elements oxygen, iron sulphide, silicon dioxide, and sodium. Oxygen accounted for about 50.74 percent of the samples, magnesium accounted for 45.36 percent, silicon dioxide accounted for 3.24 percent, and sodium accounted for 0.66 percent using EDX spectra. Magnesium oxide develops in unique shapes, with diameters varying from 9.24 to 14.94 nm, as seen in the TEM picture. An investigation found that B20 using 100 ppm MgO nanoparticles increases BTE (brake thermal efficiency) by 2.1 percent while simultaneously reducing SFC (specific fuel consumption) which was found to be ranging from 0.54 to 0.38 kg/kWh, respectively. B20 nanoparticles were used to reduce the amount of HC, CO, and smoke emitted by engines.

1. Introduction

The depletion of fossil fuels, increased fuel use, volatile fuel prices, and major environmental issues have motivated us to look into alternative fuels for compression ignition engines [1]. In the future, diesel engines might run on biodiesel instead of petroleum. There are several advantages to using biodiesel as a biodegradable, nontoxic, and ecologically beneficial alternative to gasoline. Research shows that biodiesel is generated from a wide variety of seeds [2]. Transesterification, pyrolysis, microemulsions, and blends have all been proposed for the production of biodiesel. A high conversion rate makes transesterification the most potent biodiesel generation method. Because biodiesel is thicker than diesel, utilizing it in contemporary diesel engines alone will be difficult. A biodiesel/diesel blend is thus preferred in order to achieve the blend qualities needed by current diesel engines. Low heating value, high density, and increased viscosity seem to be major downsides of biodiesel, according to current research. Pressure and temperature are reduced as a result of an influence on fuel atomization in the combustion chamber [3]. As a biodiesel CI engine fuel, nanoparticles have been proposed as an addition that may improve performance and emissions. Because of the increased surface reactivity, their emission and performance characteristics improved. An increase in the catalytic activity during combustion progression is facilitated by metal nanoparticles at the nanoscale [4]. Mahua biodiesel with copper oxide nanoparticles was tested for emission and performance characteristics, and the results were positive for both. BTE was improved by 2.2% as a result of the CuO mixed fuel, although BSFC was somewhat reduced. Hydrocarbon emissions, CO emissions, and smoke emissions are all reduced by more than 5 percent using CuO nanoadditive blended gasoline [5]. The addition of BD100 (silver oxide NPs) boosted BTE while decreasing BSFC in diesel engines, according to the study. Emission reductions of 16.47 percent CO, 14.21 percent NO_x, and 6.66 percent smoke were achieved when the BD100 was replaced with BD100+Ag2O (10 ppm) [6]. Pogamia methyl ester blends containing copper oxide are more environmentally friendly than blends without copper oxide. During the same timeframe, brake thermal efficiency increased by 4.01%, while specific fuel consumption decreased by 1% [7]. A mix of mahua methyl ester and aluminium oxide nanoparticles was tested to see how well it performed and emitted emissions. Brake thermal efficiency is significantly improved by using aluminium oxide nanoparticles in biodiesel, according to the research. It is less harmful to the environment to use [8]. Mahua oil combined with nanoadditives than to use conventional gasoline. Very few studies have been done on single-cylinder CI engines utilizing algae biodiesel with nanoadditives, according to a literature review. Waste cooking oil biodiesel is supplemented with magnesium oxide nanoadditives in varied proportions in this research (50 ppm and 100 ppm). The CI engine was used to compare both performances as well as emission characteristics of the fuel mixes generated.

2. Materials and Method

2.1. Production of Biodiesel. Transesterification, alcoholysis, or supercritical methanol transesterification may all be used to make biodiesel from edible or nonedible oils, animal fats, or waste cooking oil. To produce industrial biodiesel from waste oil, transesterification is the most frequent method of using strong acids or alkalis as a catalyst. A strong alkali catalyst is a common option for transesterification in biodiesel production since it requires less catalyst and reacts faster than a strong acid catalyst.

2.2. Transesterification Process of Waste Cooking Oil Biodiesel. In order to create biodiesel from a wide range of sources, including vegetable oils, animal fats, and even waste cooking oils, the transesterification method is used. When glycerides and alcohols react (typically with in presence of a catalyst), they form fatty acid alkyl esters, which are then converted into fatty acid alkyl esters. Transesterification is seen in Figure 1.

2.3. Biodiesel Preparation Process. Using a 500 ml or bigger beaker, pour the mixture into it and stir it well. A magnetic stirrer heated up 400 milliliters of oil in only a few minutes. Use the magnetic pellet at a speed of less than 500 rpm. Use a thermometer to monitor the oil's temperature on a regular basis. Pour in the methanol after the oil reaches 40°C. The solution should be heated. Use 125 ml of methanol to dissolve 12 sodium hydroxide pellets (NaOH) or 3.5 grams of sodium hydroxide. When the oil temperature hits 56°-58°C, lower the heat. Allow an hour for the dust to settle. The glycerol and methyl ester layers that need to be separated may be seen. Add the accumulated oil to the separator funnel. Glycerine should be poured into a separator and let to evaporate on its own. Now, separate the glycerin and oil. Finally, put the oil back in and refill the funnel. To get rid of soap smells, mix oil and hot water in a separate funnel. For best results, repeat this procedure two or three times. Afterwards, remove the oil from the beaker and discard it. Heating the oil to 90°C may remove the residual water. The waste oil is used for biodiesel production. The chemical reaction in transesterification is shown in Figure 2.

2.4. Characterization of the Nanoparticle. The scanning electron microscope may acquire information on the structure, shape, and composition of solids and other materials. Electrons, X-rays, and secondary electrons are all seen by the SEM detector, which processes them into a signal to provide the final picture. The elemental detection and composition of an unknown material may be determined using one of the conventional analytic surface methods, such as EDX. The SEM equipment is often linked to the EDX procedure. Both transmission electron microscopes as well as scanning transmission electron microscopes may employ EDX in conjunction. The specimen atoms produce X-rays of various wavelengths that are energy-specific and provide information about a single atom. Energy connected with concerned element is shown by the histogram peak's location, and the region underneath the peak indicates how many atoms were affected by the radiation in the area of interest. The crystalline structure, shape of the nanoparticles, and elemental content of MgO were investigated using an EDX analyzer as well as a JEOL-JSM-IT 200 scanning electron microscope. There was a wide range of acceleration from 0.5 kV to 30 kV available. The photos of the nanoparticles were captured using the JEOL JEM-1200EX TEM. The properties of different blends are taken into consideration as per ASTM D6751 [9]. The attributes of various fuel mixes are shown in Table 1. Various fuel mixes' qualities are graphically shown in Figure 3.

2.5. Experimental Setup. Water-cooled CI engine with overhead valve pushrod control (make: Kirloskar, TV1 model) was employed as a test rig for experimental study. A maximum of 5.2 kW of power is generated at 1500 revolutions per minute (rpm) when the engine is fully loaded. To maintain the temperature of the coolant at 80°C, the cylinder had water jackets that circulated coolant. An eddy current

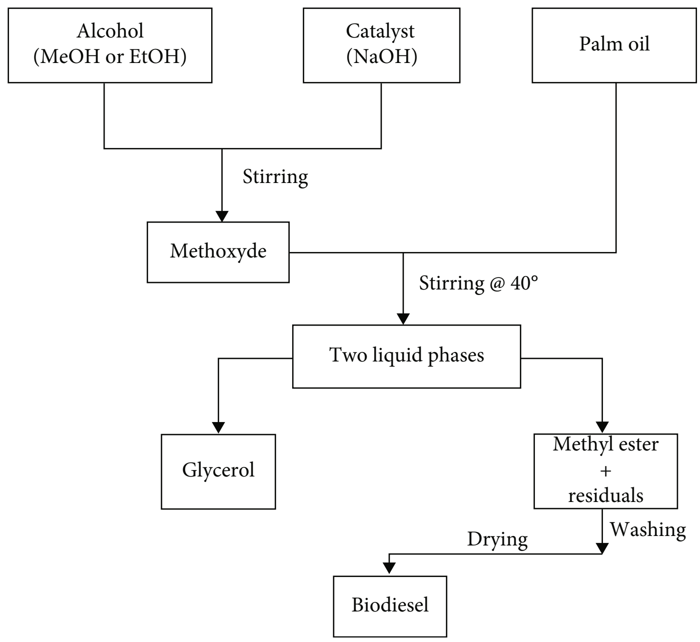

Figure 1: Schematic diagram of transesterification process.

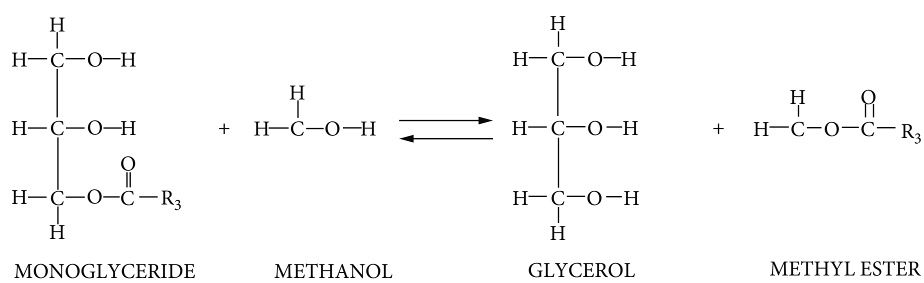

Figure 2: The chemical reaction in transesterification.

Table 1: Fuel properties of different blends.

S. no.	Properties	Waste cooking oil biodiesel (B20)	B20 +MgO 50 ppm	B20 +MgO 100 ppm
1	Kinetic viscosity (St)	481	484	487
2	Density (kg/m^3)	889	893	895
3	Calorific value (MJ/kg)	38.97	37.68	37.12
4	Flash point (°C)	190	193	196
5	Fire point (°C)	261	263	266

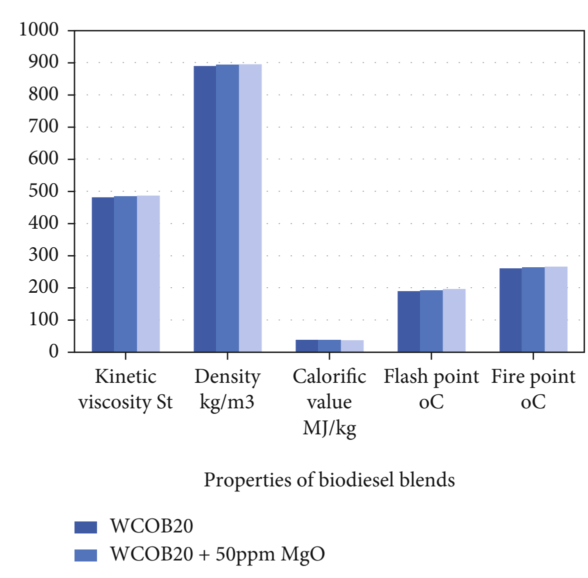

Figure 3: Graphical representation of fuel properties of different blends.

dynamometer was used to measure torque in the engine. Figure 4 depicts the experimental setup in schematic form.

3. Results and Discussion

3.1. Scanning Electron Microscope. Magnesium oxide nanoparticles are seen in SEM picture in Figure 5. Particles having smooth surfaces, according to these results, were about

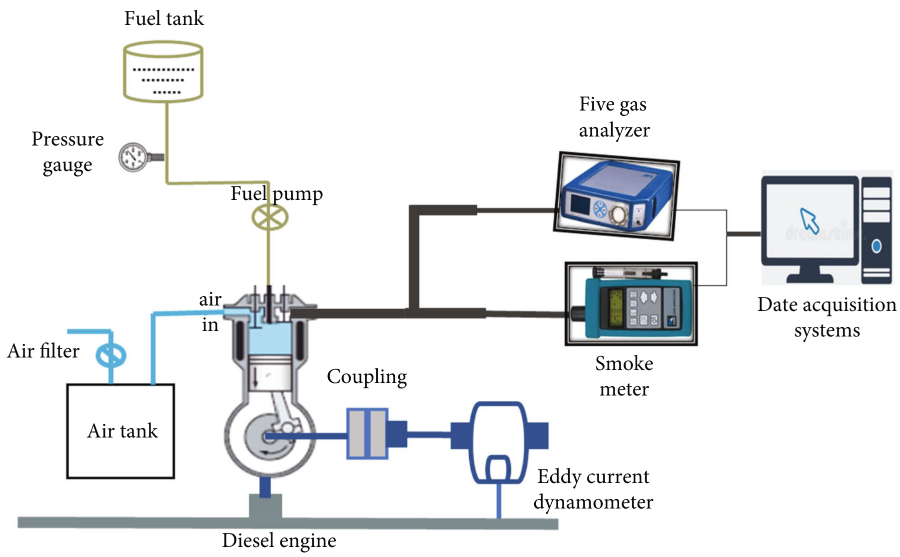

Figure 4: Experimental setup.

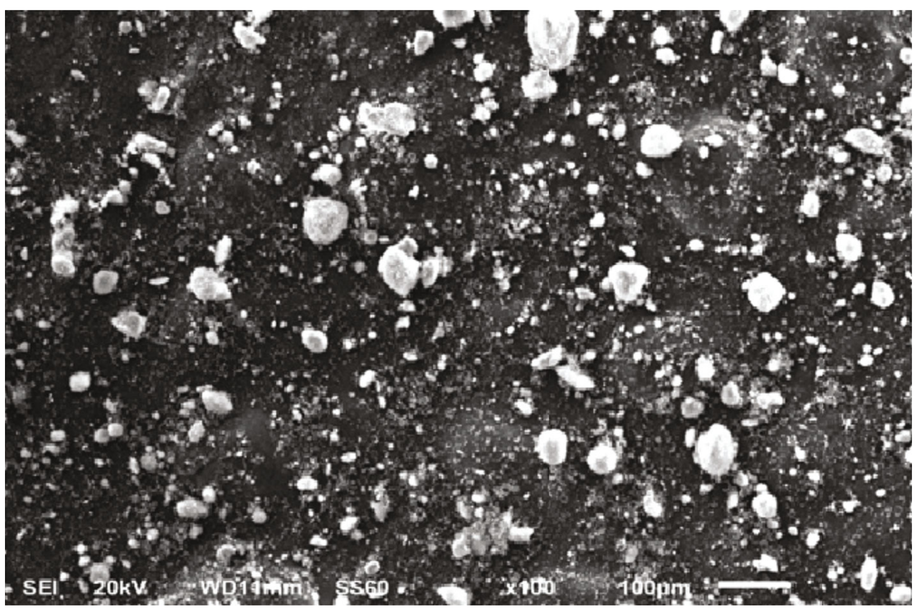

Figure 5: Scanning electron microscope image of MgO.

spherical in shape. In some cases, particles have been found to be uniformly spread, whereas in others, they were concentrated. The carbon in the particles is represented by their black hue, which has a little amount of oxygen dispersed throughout. The particle distribution is observed to be uniform throughout. Using this method, it is shown that nanoparticles with a diameter of 20 nm to 38 nm exist.

3.2. EDX Analyzer. Components were analyzed quantitatively and subjectively using the EDX spectrum. Mg and O were found to have higher concentrations in magnesium oxide nanoparticles than other elements, as seen by Figure 6. Remaining parts have a little impact on the overall structure. Magnesium oxide nanoparticles have been shown to include the elements oxygen, iron sulphide, silicon dioxide, and sodium. Oxygen accounted for about 50.74 percent of the samples, magnesium accounted for 45.36 percent, silicon dioxide accounted for 3.24 percent, and sodium accounted for 0.66 percent.

3.3. Transmission Electron Microscope. Magnesium oxide's size, structure, and composition may all be deduced through the transmission electron microscope examination. Particle size distribution and nanoparticle size can only be determined via TEM. The spectra or images produced on the imaging screen are the result of electrons passing through the nanoparticles and interacting with them. Magnesium oxide develops in unique shapes, with diameters varying from 9.24 to 14.94 nm, as seen in the TEM picture in Figure 7.

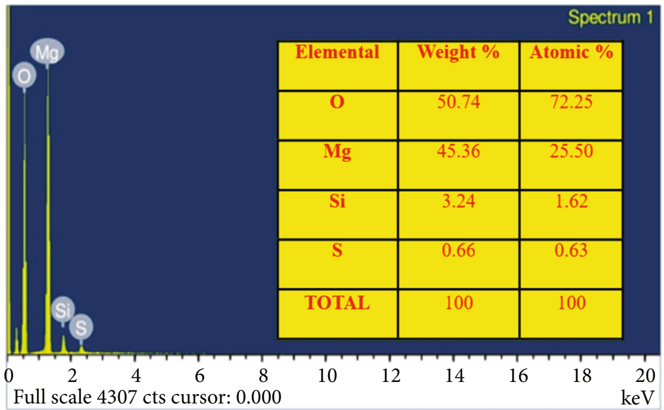

FIGURE 6: Energy dispersive X-ray spectroscopy image of MgO.

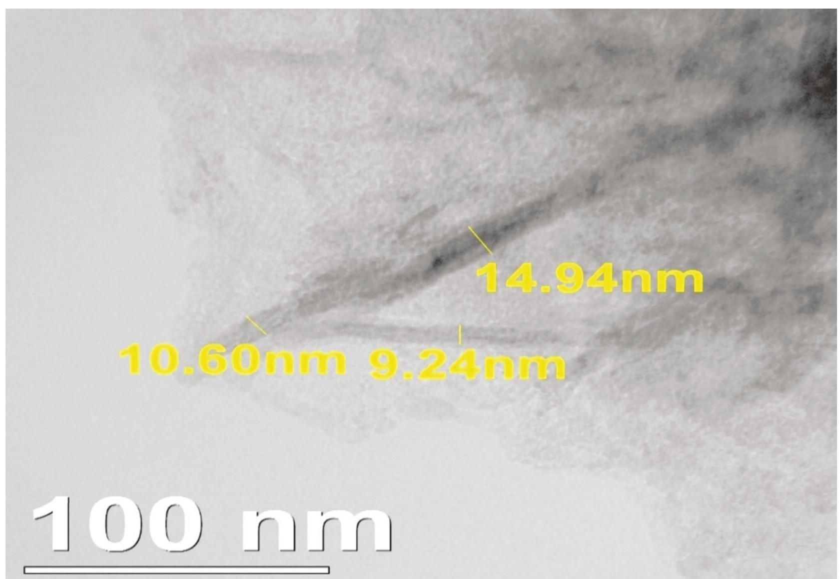

FIGURE 7: TEM image of MgO.

3.4. Brake-Specific Fuel Consumption. Using kg/kWh, the BSFC is a measure of how much fuel the engine uses for each unit of power generated over time. Figure 8 shows the trend in the specific fuel consumption with increase of load. As load in the engine rises, so do the BSFC values. It was found that the specific fuel consumption values of the B20, B20+50 ppm MgO, and B20+100 ppm MgO fuel blends ranged from 0.54 to 0.38 kg/kWh, respectively. The incorporation of MgO nanoparticles results in a constant-speed drop in BSFC as a consequence of additional oxidation and combustion. Because magnesium oxide nanoadditives have a higher oxygen concentration, they promote more complete burning and lower the combustion chamber's fuel-rich zone. Earlier research on biodiesel and nanoadditives supports these conclusions [10, 11].

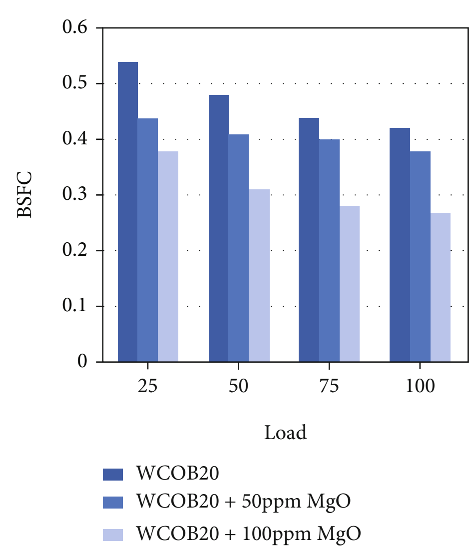

FIGURE 8: Load vs. brake-specific fuel consumption.

3.5. Brake Thermal Efficiency. By definition, BTE is the ratio of fuel energy to mechanical energy in an internal combustion engine. A variety of elements, including fuel mix type, carbon and hydrogen content, cetane number, specific

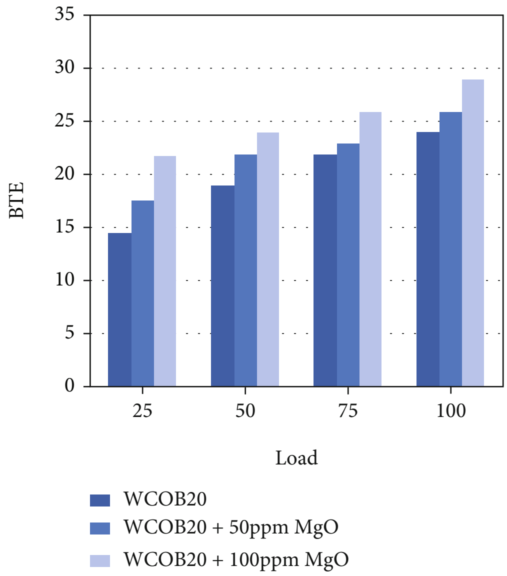

FIGURE 9: Load vs. brake thermal efficiency.

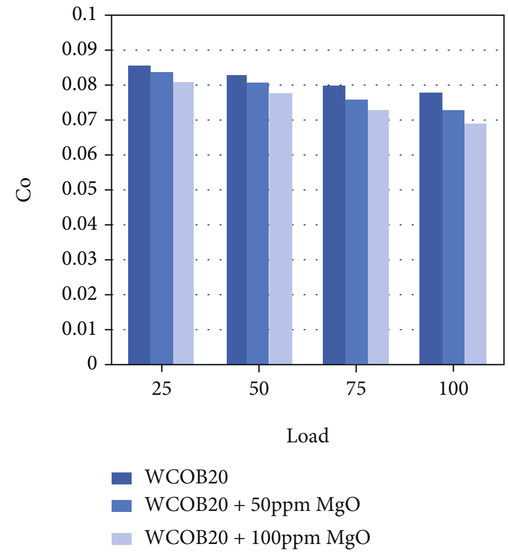

FIGURE 10: Load vs. carbon monoxide.

gracity, and heating value, have an impact on fuel energy. Figure 9 shows that the BTE of various fuel blends at increasing loads may vary significantly. The brake thermal efficiency is 14.4 percent for B20, 17.6 percent for B20+50 ppm MgO, and 21.7 percent for B20+100 ppm MgO. B20+100 ppm MgO improved brake thermal efficiency by 2.1 percent as compared to B20. Because of the lower ignition delay of biodiesel, it can be burned for extended periods of time. As a result, the biodiesel BTE is lowered since the claimed power, peak in-cylinder pressurization, and the rise in pressure all drop with increased pressure. The insertion of magnesium oxide nanoparticles into the braking system has resulted in an improvement in the thermal efficiency of the system. When compared to B20, nanoparticle-containing biodiesel blends have a larger surface area-to-volume ratio, allowing them to be burnt at higher temperatures than the latter. When nanoparticles were present, comparable results were attained [12, 13].

3.6. Emission of Carbon Monoxide. The incomplete combustion of the carbon with in fuel resulted in the release of CO into the atmosphere. Due to the lack of an oxygen-carrying fuel with in chemical structure of diesel, it is possible that CO will be formed. Because of the absence of oxygen, fuel burning at low flame temperatures leads in a rise in CO. Changes in CO emissions for all the fuel samples with is shown in Figure 10. The amount of CO emitted by an engine decreases as the load on the engine rises. When the engine is running gently, carbon monoxide emissions are at their lowest, and when it is functioning aggressively, they are at their highest. At maximum load, CO emissions from B20, B20+50 ppm MgO, and B20+100 ppm MgO were 0.078, 0.073, and 0.069 percent, respectively. CO emissions reduce by 11.5 percent by adding 100 ppm of MgO nanoparticles to B20 at the full load. Fuels containing MgO nanoadditives have a greater oxygen content which thereby allows complete combustion. A more complete combustion process may be responsible for lower CO emissions [14, 15].

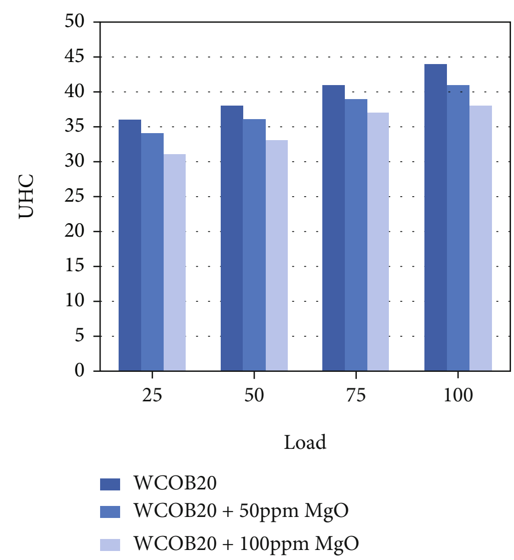

FIGURE 11: Hydrocarbon emission vs. load.

3.7. Hydrocarbon Emission. Hydrocarbon emissions are measured in parts per million (ppm) and are mostly generated by incomplete combustion of fossil fuels in the engines. Figure 11 shows variation in HC emissions for each of the samples. Fuels with a high HC emission were shown to have a higher burden. Compared to B20, B20+100 ppm MgO decreases HC emissions 13.63 percent. By lengthening the time it takes for the fuel to erupt, enhancing the explosion cycle, and boosting the pace at which heat escapes, this nanoparticle increases the combustion process. Hydrocarbon emissions are decreasing when magnesium oxide nanoparticles were added to the biodiesel mix [16, 17].

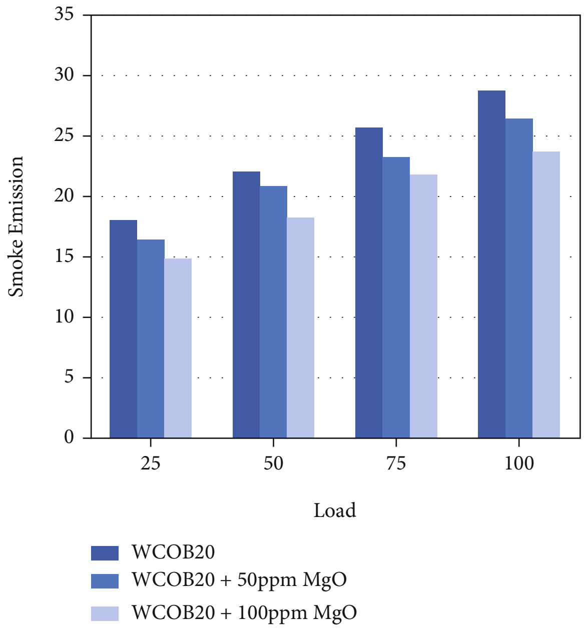

Figure 12: Smoke emission vs. load.

3.8. Smoke Emission. Rich mixture development and incomplete combustion were caused by an increase in fuel consumption as the load increased. Smoke emission is caused by a large amount of unburned hydrocarbons. Figure 12 shows the HC emission data for all test fuels while the engine is running at full capacity. B20, B20+50 ppm of MgO, and B20+100 ppm of MgO test fuels had a smoke opacity percentage of 28%, 25.42%, and 23.67%, respectively; This combination of B20 and MgO provides the greatest decrease in opacity. In full load, the smoke emission of B20 +100 ppm MgO was 17.55 percent lower than that of B20 alone. To guarantee full combustion, magnesium oxide nanoparticles speed up the evaporation process. With nanoparticles in the biodiesel mix, oxidation of soot particles was accelerated even further, leading to a significant decrease in smoke emissions [18, 19].

4. Conclusion

(1) Waste cooking oil biodiesel was utilized to evaluate the performance and emission properties of MgO nanoparticles using waste cooking oil. The properties were established using ASTM D6751 standards

(2) Since the biodiesel included MgO nanoparticles, it had superior combustion characteristics, which improved engine performance

(3) MgO mixed fuel also reduced emissions of HC, CO, and smoke. In light of the evidence, these conclusions were drawn

(4) B20 test fuel had a 29.6% higher BSFC than the B20 +100 ppm MgO fuel because of its higher density, viscosity, and calorific value. According to this research, MgO improves the thermal efficiency of B20 by 1.7 percent and 2.1 percent, respectively, when compared to B20 alone

(5) B20+50 ppm MgO reduces CO emissions by 6.41 percent, whereas B20+100 ppm MgO reduces emissions by 11.5%. CO emissions fell as the concentration of nanoparticles was increased. In comparison to B20, carbon emissions are reduced by 6.8% and 13.6% when MgO is added to B20

(6) The incorporation of MgO nanoadditives into biodiesel/diesel mixes resulted in improved combustion. Lower HC emission levels may be achieved using MgO nanoparticle-based blended gasoline. There was a 79% decrease in smoke emissions when compared to B20 with 50 ppm MgO and 100 ppm MgO. The nanoparticle concentration was raised to lower the emissions of smoke by 17.55 percent

Data Availability

The data used to support the findings of this study are included in the article.

Conflicts of Interest

The authors declare that they do not have any conflicts of interest regarding the publication of this paper.

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