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Research Article

Experimental Investigation on the Effect of Three Elemental Nanoparticles on the Performance Characteristics of Ethanol-Diesel Emulsion

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The utilization of nanoparticle in ethanol-diesel emulsions combustion catalyst is important. For this study, ethanol and diesel fuels are emulsified varying the ethanol amount as 5, 10, and 15% volume ratio designated as E5, E10, and E15, respectively, by using span 80 and tween 80 emulsifying agents. Nickel Zinc Iron Oxide ($NiZnFe_2O_4$) nanoparticle is used in each fuel sample with a dose rate of 25, 50, and 100 ppm. Cetyl Trimethyl Ammonium Bromide (CTAB) surfactant is used to keep the nanoparticle homogeneously suspended in the fuel. Mechanical steering and ultrasonic vibrator are used to prepare the sample fuel. A single-cylinder diesel engine testing rig is used to test the performance. For the ethanol-diesel emulsion, the power and torque output decreased as the ethanol percentage and the BSFC increased. The nanoparticle addition improved power and torque output and reduced BSFC. Ethanol-diesel emulsion fuel performance characteristics could be improved with the utilization of $NiZnFe_2O_4$.

1. Introduction

Diesel engines are durable and are the highest fuel competent equipment ever made in the history of engine development, so far implemented on the market. Because of their durability and high fuel efficiency, diesel engines are widely applied for heavy-duty vehicles, electric generators, and small and mid-level transport vehicles and trucks[1].

Due to the depletion of petroleum, the price fluctuation, and increment from time to time, it is not reliable to fully depend on petroleum fuel resource for running diesel engines. This indicates that depending on petroleum products to meet energy demands should be reduced. Thus, for energy security, it is preferable to focus on renewable energy sources such as ethanol that can be produced locally [2]. Blending ethanol with diesel fuel has several benefits. The first one is an economic benefit. It helps to reduce the amount of diesel fuel imported with a hard currency of up to 20%. It encourages local ethanol producers such as the sugar industry by establishing additional market opportunities in addition to blending with gasoline fuel and supplying to beverage industries. The second one is the environmental benefit. Ethanol is an oxygenated and sulfur-free fuel, so blending with diesel fuel reduces exhaust emissions by reducing the formation of CO and SO_2. The third benefit is energy security [3].

Researchers have concentrated on using bioethanol due to the growing demand for petroleum resources in the world and the diminishing supply of fossil fuels as a result of population growth and rising energy consumption. Furthermore, strict government emission regulations have forced researchers to find appropriate and renewable alternative fuels for diesel engines in order to improve performance and achieve effective emission control in the transportation sector [4]. As a result, the production of biofuels has been rising throughout the world over the most recent decade, but the growing biofuel industry has raised significant worries such as its contribution to the climatic change, environment, and dislocation of food crops. Biofuel technologies have to become more efficient to reduce greenhouse gas (GHG) emissions, environmentally friendly, and socially sustainable [5].

Biofuels could be gaseous or liquid fuels that are obtained from animals or vegetables. They include alternative fuels such as bioethanol, biomethanol, biogas, and biodiesel. Biogas is a gaseous fuel which mainly consists of methane and is widely used for home cooking in place of transport fuel because of large storage requirement. Biodiesel is liquid fuel produced from straight vegetable oil, animal fat, and waste cooking oil through transesterification reaction. However, the most commonly used biofuel is bioethanol [6, 7]. Alcohols are now being used as an alternative, cleaner fuel because of the dependence of the globe and its soaring energy needs, as well as the likely future degradation of international petroleum supplies [8, 9].

Bioethanol could be produced by fermentation of starch plants or from cellulosic sources in acidic hydrolysis. Vegetables, such as corn, sugar beet, potatoes, and wheat, and woody plants, such as sugarcane, agricultural waste, and molasses, are among the resources [10]. Ethanol has high oxygen content (34% by weight) among various alternative fuels. In addition, this makes it more preferred to be used as a fuel combined with petroleum-based fuels, which helps to enhance combustion [11].

Ethanol could run diesel engines without any technological modifications. However, it still has a lot of drawbacks, such as a lower heating value and cetane number when compared with diesel fuel, which limits the fuel's ability to ignite automatically resulting in a longer delay period [4]. Furthermore, ethanol has a higher latent heat of vaporization than diesel fuel, which causes charge cooling and combustion quenching. To overcome the drawbacks of ethanol utilization in diesel engines, the use of additives such as nanoparticles is believed to be greatly important [12].

Several research results have been reported on the effect of nanoparticles when applied to different fuel samples. For instance, cerium oxide nanoparticle (CeO_2) is used as a catalyst in biodiesel-diesel emulsification and fuelled into a marine diesel engine to test the characteristics of its performance. The result revealed that the fuel with air mixing in the cylinder is improved due to the microexplosion occurrences that happened as a result of the nanoparticle adding in the fuel. Microexplosion enhanced the combustion process and makes the performance of the engine to be improved [13]. In addition to that, the catalytic effect of nanoparticles improved the oxidation process; as a result, the engine power and the brake thermal efficiency have increased [14].

Prabakaran et al. studied the zinc oxide (ZnO) nanoparticle effect in ethanol, biodiesel, and diesel blend for its characteristics of performance and emission in a diesel engine. The result showed that the addition of the nanoparticle has considerably reduced the emission; however, the effect on the performance is noticed low [15]. Manjunath C. applied an aluminium oxide nanoparticle (Al_2O_3) of 75 ppm in a diesel biodiesel blend of B20 and investigated its effect on the engine performance and exhaust emission characteristics by using the fuel to run a diesel engine. The report indicated that the brake thermal efficiency (BTE) and heat release rate (HRR) were increased by 9.33% and 13.56%, respectively; moreover, 16.56% of BSFC reduction is testified [16].

Prabakaran and Vijayabalan conducted experiments to see the performance and emission properties of butanol–diesohol blends (45% diesel, 45% ethanol, and 10% butanol) adding 100 ppm ZnO nanoparticles. They reported the result as there is a significant increment in BTE, HRR, and combustion pressure (CP) [17]. Lapuerta et al. studied the effect of Fe_3O_4 nanoparticles by adding 0.4% and 0.8% amount on a volume basis in diesel fuel. The conclusion showed that the BSFC has significantly reduced due to the effect of the nanoparticle in reducing the ignition delay time and at the same time increasing the brake thermal efficiency of the engine [18]. Varatharajan et al. have tested diesel fuel with zinc oxide nanoparticles addition of 250 and 500 ppm amount concentration. The result is reported as the nanoparticle addition increased the rate of heat release and the brake thermal efficiency also increased when compared with pure diesel [19].

These days the nanotechnology dominated industrial development and was reflected on a lot of advanced research. New nanotechnology products are expected to lead the further development of new technologies. Nanoparticles are also used in different fuels to increase the engine operating performance and reduce exhaust gas pollutant emission [20]. Nanoparticle addition to different fuels increases fuel properties such as viscosity, density, and flash point temperature and improves cetane number and the heating value, which improves combustion efficiency [21]. In addition, nanomaterial added diesel fuel can have a low flash point temperature, which requires an obvious improvement in fuel handling safety [22]. Nanoparticle additives also reduce the cloud point temperature, improve engine cold starting in cold weather environment, and raise the surface area-to-volume ratio. This improves the rate of mass transfer due to microexplosion, resulting in better and faster combustion [23–25].

From the literature, survey tried to cover and indicated above, ethanol diesel and ethanol-diesel-biodiesel could be in use as diesel fuel. In addition, the effects of different single element nanoparticles added in various fuels are studied to identify their consequence on the performance of an engine and emission properties. However, the effect of three elemental nanoparticles, Nickel Zinc Iron Oxide ($NiZnFe_2O_4$) nanoparticles, in ethanol diesel emulsion is not so far reported. The purpose of this study is to examine the effect of ethanol and three elemental nanoparticles in ethanol diesel emulsion with the variation of ethanol amount 5, 10, and 15% volume ratio and 25, 50, and 100 ppm nanoparticle addition in each emulsion sample fuel on the performance characteristics of diesel engine. The compositions of bioethanol diesel emulsion are presented, and the fuel parameters of the optional blended fuel were obtained. The compositions and fuel parameters of the emulsified fuels are compared with standard diesel fuel properties to run the selected engine with the sample fuels.

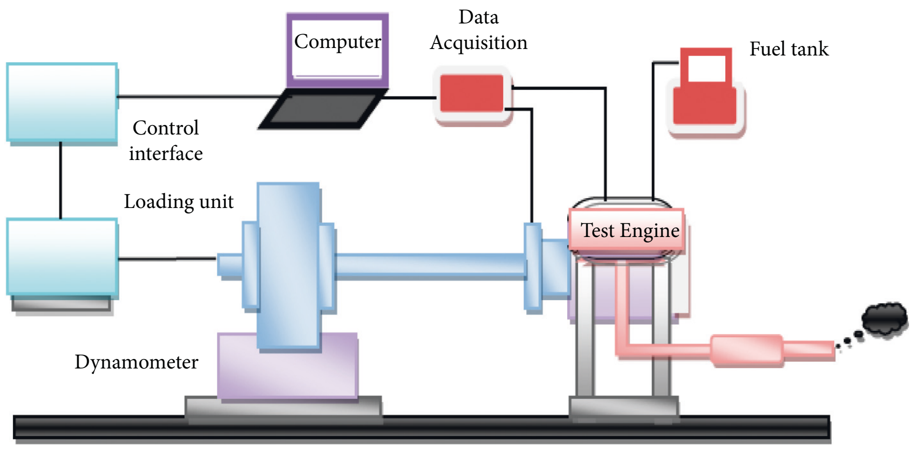

Figure 1: Performance test setup.

2. Materials and Methods

Emulsion of ethanol and diesel is prepared in different proportions as sample fuels. A mixture of tween 80 and span 80 is used as an emulsifying agent. Three elemental nanoparticles are applied in the emulsion, and Cetyl Trimethyl Ammonium Bromide (CTAB) is used as a surfactant to help the nanoparticle homogeneously mix and remain suspended in the fuel. A single-cylinder engine with an eddy current type dynamometer is used to test the performance characteristics of the fuels. The arrangement of the performance test setup is shown in Figure 1.

2.1. Materials. The materials used to prepare the sample fuels are diesel fuel, purchased from the locally available gas station; ethanol, produced in Methara sugar factory which is used as biofuel; emulsifier, span 80, and tween 80 used to emulsify the ethanol in diesel fuel; three elemental nanoparticles, having Nickel Zinc Iron Oxide with 10–30 nm size as indicated in Figure 2 as combustion enhancement additive; Cetyl Trimethyl Ammonium Bromide (CTAB), as a surfactant for homogenization of the nanoparticle. Laboratory equipment such as a magnetic stirrer for mechanical agitation and an ultrasonicator for microemulsion mixing is used. The specifications of the materials used are indicated in Tables 1–4.

To see the performance and the emission characteristics of the various test fuel samples prepared, the engine performance test rig with single-cylinder engine, eddy current type dynamometer, loading unit, control interface, and data management computer are used as shown in Figure 3. The engine used for the test is a single-cylinder four-stroke diesel engine. The specification of the test engine is given in Table 5.

2.1.1. Dynamometer. Computer Controlled Test Bench for Single Cylinder to test internal combustion engines of up to 7.5 kW is used for this research work. The dynamometer used is an eddy current electromagnetic brake type that offers loading torque with a variator that allows control of the supply voltage and to vary its torque characteristics. The unit also includes a number of sensors which provide the measured values of the variables to be studied. The test bench is used to measure the torque, power, and fuel flow rate by varying the loading condition from 0 to 100% and temperature values at different measuring points. Thus, the power or torque versus load percentage curves are obtained. This computer-controlled unit includes an eddy current type dynamometer, control interface box data acquisition board, and computer control, and for controlling parameters, data management software packages and data acquisition are incorporated.

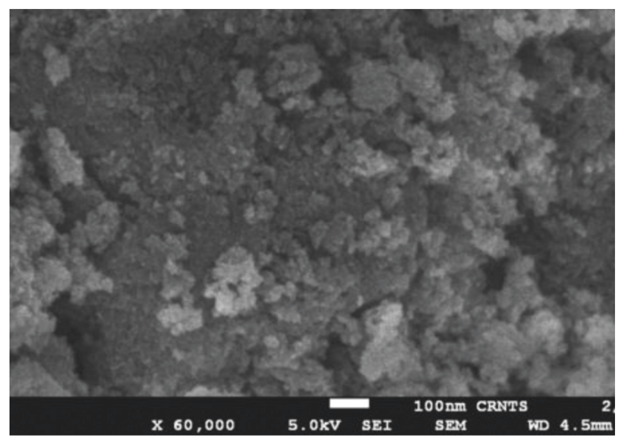

Figure 2: Scan electronic microscope image of Nickel Zinc Iron Oxide nanoparticle.

2.2. Method

2.2.1. Fuel Sample Preparation. The ethanol used to make the sample test fuel is obtained from Metehara Sugar Factory, Ethiopia, which is produced from molasses, the byproduct of sugar production. The diesel fuel is purchased from locally available gas station in Adama town, Ethiopia. Span 80, tween 80 chemicals, and different glassware are purchased from Addis Ababa city. Nickel Zinc Iron Oxide ($NiZnFe_2O_4$) nanoparticles and Cetyl Trimethyl Ammonium Bromide (CTAB) are purchased from India.

Table 1: Properties of diesel and ethanol [23].

Fuel	Formula	Mole weight (g.mol^{-1})	Heat content (MJ/kg)	Viscosity (mPa s)	Density at 20°C (10^3 kg/m^3)	Flashpoint (°C)	Boiling point (°C)	Pour point (°C)	CN
Diesel	C_xH_y	190–220	42.5	3.35	0.829	65–82	180–360	−1 to 3	45–50
Ethanol	C_2H_5OH	46.07	26.8	1.20	0.789	13–14	78.4	−117.3	5–8

Table 2: Physical and chemical properties of span 80 and tween 80.

	Appearance	Molecular weight (g.mol^{-1})	HLB (unitless)
Tween 80	Amber sticky liquid	1309.63	15
Span 80	Brown liquid	428.59	4.3

Table 3: Physical properties of Cetyl Trimethyl Ammonium Bromide (CTAB).

Item	Molecular formula	Molecular weight (g.mol^{-1})	Melting point	pH
Cetyl Trimethyl Ammonium Bromide (CTAB)	$C_{19}H_{42}BrN$	364.45	249–253°C	6.0–7.5

Table 4: Nickel Zinc Iron Oxide ($NiZnFe_2O_4$) nanoparticles physical properties.

S. no.	Parameters	Nickel Zinc Iron nanoparticles
1	Manufacturer	Nano Research Lab (India)
2	Chemical name	$NiZnFe_2O_4$
3	Atomic weight	411.46 g/mol
4	Average particle size (APS)	10–30 nm
5	Morphology	Nearly spherical
6	Appearance	Dark brown
7	Density	2.81 g/cm3
8	Bulk density g/cm^3	0.87–0.90 g/cm^3
9	Purity	%

The blending ratios are prepared by measuring and pouring it in the prearranged mixing beaker. The mixing ratio of diesel, ethanol, emulsifier nanoparticles, and surfactant is shown in Table6. The sample fuels are prepared in Materials Science and Materials Engineering Laboratory, Adama Science And Technology University. The stage-by-stage (standard) emulsion preparation procedures to get ready emulsified fuels are shown in Figure 4; the stage-by-stage procedures are obtained after many trials, through varying the time of mechanical agitation and rpm and the time of ultrasonication and sonication time. The working condition and procedure details of each step are shown in Table 7. The first step is the same for all the fuels.

Ethanol-diesel emulsions are observed to be stable, when used with a surfactant, having hydrophilic–lipophilic balance (HLB) value of 8–10. Thus, HLB of 9 was used. The mixture of high and low HLB surfactants (tween 80 + span 80) forms the most stable emulsion, and the properties of tween 80 and span 80 are shown in Table 8. To obtain an HLB of 9 for the new emulsifier, the proportional amount of tween 80 and span 80 is determined by the following formula:

$$\text{HLB of emulsifier mixture} = \text{mass of span80} \times \text{HLB of span80} + \text{mass of tween80} \times \text{HLB},$$

$$(\text{tween80})/(\text{mass tween80} + \text{mass span80}),$$

$$\%\text{tween80} = \frac{\text{HLB of emulsifier mixture} - \text{HLB of span80}}{\text{HLB of tween80} - \text{HLB of span80}}, \tag{1}$$

$$\%\text{tween80} = \frac{9 - 4.3}{15.0 - 4.3} = 0.44 = 44\%,$$

$$\%\text{span80} = 100\% - 44\% = 66\%.$$

Figure 3: Materials used in the laboratory include (1) engine with eddy current type dynamometer, (2) control interface, (3) loading unit, and (4) data acquisition and management computer.

Table 5: Specification of the test engine.

Make/model	Kubota corporation, E300-ES01
Engine type	Single-cylinder, water-cooled, 4-stroke diesel engine
Bore stroke	77.0 mm × 70.0 mm
Compression ratio	24 : 1
Displacement	309 cc
Rated power	5.2 kW @ 3000 r/min (rpm)
Bare idle speed	900–1000 rpm
Injecting timing	27° BTDC
Injection pump	Bosch K type mini pump
Injection pressure	140 kgf/cm^2

The emulsion preparation setup in Figures 3 and 4 comprises a stirrer with a speed controller and an ultrasonicator. The speed controller can go up to a maximum of 1500 RPM.

Test fuels are prepared by varying the amount of ethanol as 5%, 10%, and 15% to pure diesel fuel, and 2% volume ratio of emulsifier is used. In each emulsion ratio, a nanoparticle additive is used with amount of 25, 50, and 100 ppm, and the same amount of Cetyl Trimethyl Ammonium Bromide (CTAB) surfactant is used. The test fuel preparation constituents are shown in Table 6.

2.2.2. Engine Performance Test. Engine performance test is performed in Addis Ababa Science and Technology University, Mechanical Engineering Department. The methodology applied for the engine testing is to measure the engine brake torque, brake power, and brake specific fuel consumption by varying the load at a fixed 50% throttle position. When the load is increased, the engine speed decreases due to the resistance because of the counter electromotive force by the eddy current on the dynamometer. At low load conditions, the engine runs at its maximum speed and the lowest speed is recorded at the maximum load conditions. At more than 80% load, the engine starts to hesitate running so the maximum testing load condition is restricted to 80%. Engine is allowed to run for thirty minutes to reach its operating temperature, until instrumentation setup is completed and the remaining fuel is fully drained from the fuel system. Load condition is varied using the computer software to load and unload on the eddy current type dynamometer brake. Power and torque measurements are recorded by a click with the aid of the data acquirement system. The test data is collected by varying the load condition from 0% to 80% with 10% variation. For each fuel sample, the test is done three times and average value is used. To see the effect of the ethanol and nanoparticles variation, the average value of the performance parameters: power, torque, and specific fuel consumption of all the nine load conditions are used to compare.

3. Results and Discussion

3.1. Torque. In this test, four fuel samples, E0, E5, E10, and E15, are used. For the entire test fuels, the engine torque decreases as the load increases from no load to 60% load and showed a slight increment with further increment of up to 80% load. When we compare the torque output of each sample at low load condition, the torque output of E10 fuel sample is higher than all the other fuel samples. This is due to the additional oxygen atoms available in the ethanol fuel, and the sufficient time available for combustion enhances the combustion efficiency resulting in the increase of cylinder pressure so that the torque recorded is higher. The addition of ethanol content lowers the cetane number of the sample fuel requiring elongated time for combustion; this makes the torque output of E0 to be the highest of all the other fuels at higher engine speed as shown on the graph in Figure 5. The overall result showed that the sample fuels with ethanol emulsion reduced the torque value by 15.52%, 5.38%, and 15.78% for E5, E10, and E15 fuels, respectively.

The torque produced by E5 fuel sample is less than 15.52% compared to E0. Three elemental nanoparticle

Table 6: Test fuel preparation.

Fuel sample	Fuel mixture in percent	Surfactant	Emulsifier
E0	Pure diesel		
E5D	95 diesel + 5 ethanol		
E10D	90 diesel + 10 ethanol		
E15D	85 diesel + 15 ethanol		
E5D3N25	95 diesel + 5 ethanol+25 ppm		
E10D3N25	90 diesel + 10 ethanol+25 ppm		
E15D3N25	85 diesel + 15 ethanol+25 ppm	Cetyl trimethyl ammonium bromide (CTAB)	Tween 80, HLB = 15, and span 80, HLB = 4.3 Emulsifier (44% tween 80 + 56% span 80) About 2%
E5D3N50	95 diesel + 5 ethanol+50 ppm		
E10D3N50	90 diesel + 10 ethanol+50 ppm		
E15D3N50	85 diesel + 15 ethanol+50 ppm		
E5D3N100	95 diesel + 5 ethanol+100 ppm		
E10D3N100	90 diesel + 10 ethanol+100 ppm		
E15D3N100	85 diesel + 15 ethanol+100 ppm		

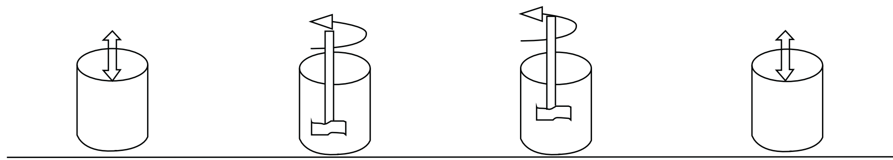

Figure 4: Stage-by-stage emulsion preparation process.

Table 7: Operating conditions for emulsified fuels preparation.

Stapes	Process	Factors	Composition
1	Sonication	25°C, 40 kHz, 30 min	Tween 80 + span 80
2	Magnetic steering	25°C, 1,500 rpm, 20 min	Diesel + ethanol + emulsifier
3	Magnetic steering	25°C, 1,500 rpm, 10 min	Emulsion + nanoparticle + surfactant
4	Sonication	25°C, 40 kHz, 30 min	Emulsion + nanoparticle + surfactant

Table 8: Properties of tween 80 and span 80.

Emulsifier	Appearance	Molecular weight ($g.mol^{-1}$)	HLB (unitless)
Tween 80	Amber sticky liquid	1309.63	15
Span 80	Brown liquid	428.59	4.3

additions improved the torque output due to the improvement of the combustion characteristics. The torque improvement for fuel with 25 ppm nanoparticle added sample (E53N25) is not significant; however, for 50 ppm (E53N50) and 100 ppm (E53N100) nanoparticle added fuel samples, increment of 11.3% and 9.1% is recorded, respectively, and the characteristics pattern is illustrated on Figure 6.

The torque characteristics of the fuel sample with 10% ethanol and with the addition of three elemental nanoparticles in 25 ppm, 50 ppm, and 100 ppm are illustrated in Figure 7. Compared to E10 fuel sample, the nanoparticle added fuel samples resulted in a better torque output with increment of 3.5%, 3.03%, and 3.53% for E103N25, E103N50, and E103N100, respectively.

The last fuel sample used in this investigation is a fuel sample with 15% ethanol and with 25 ppm, 50 ppm, and 100 ppm nanoparticle doping. As shown in Figure 8, the graph indicates that the lowest torque output is recorded by E15 fuel sample. This is due to the low calorific value of the fuel and poor combustion as a result of low cetane number. When compared with the E15 fuel sample, E153N25, E153N50, and E153N100 have shown torque improvement of 10%, 13%, and 16%, respectively.

Power is a function of torque and engine speed, and the speed of the engine decreases when load is increased. Therefore, as shown in Figure 9, the trend of power for all fuel samples is decreasing as the load on the engine increases. When we see the influence of ethanol concentration, due to the lowering effect of the emulsion calorific value, the power output is reduced for all ethanol added fuels. Then, the amount of power reduction for E5, E10, and E15 fuel samples recorded on the test is 19.41%, 7.53%, and 12.74%, respectively. Due to the high oxygen content of ethanol and

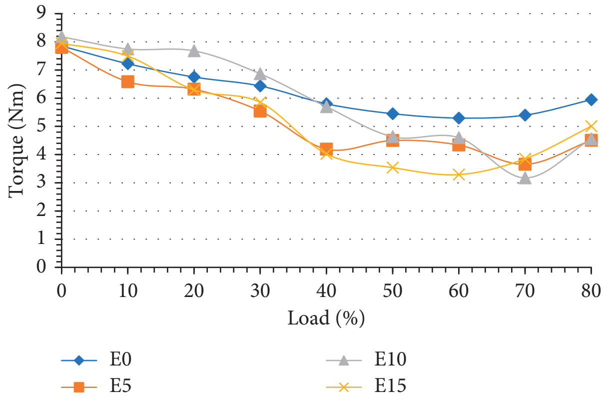

Figure 5: The effect of ethanol amount on engine torque.

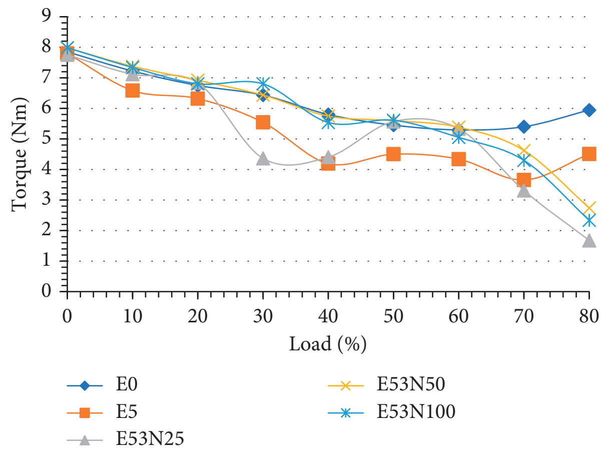

Figure 6: The effect of three elemental nanoparticles amounts on engine torque.

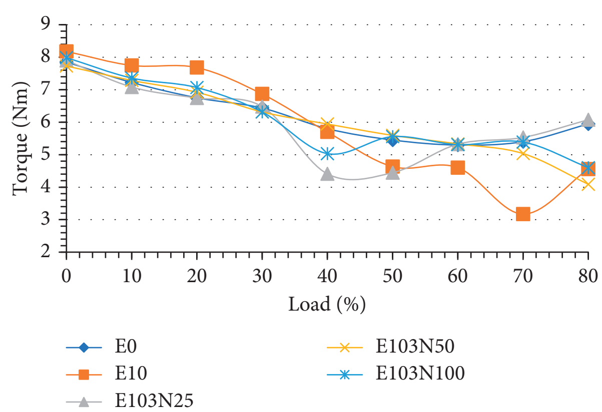

Figure 7: The effect of 3 elemental nanoparticles addition on the engine torque output of E10 fuel sample.

microexplosion effect, combustion improvement is expected though the calorific value of the fuel is lowered. From the abovementioned characteristics, the trade of result indicates that the lowest reduction of power is noted by E10 fuel sample.

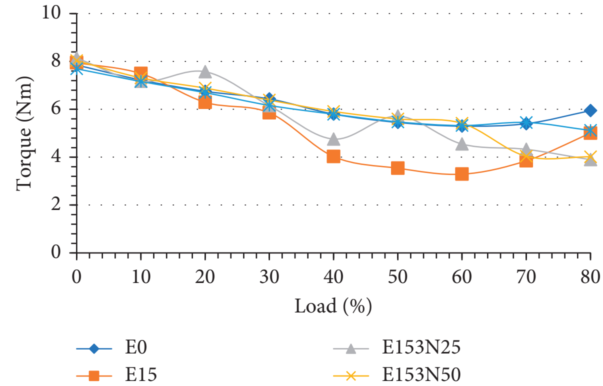

Figure 8: The effect of three elemental nanoparticles in E15 on engine torque output.

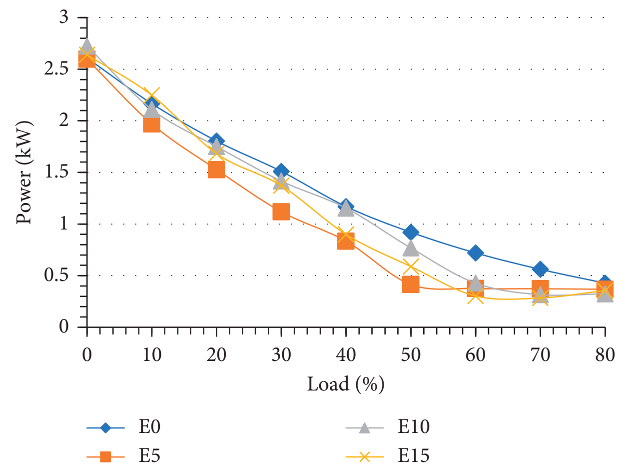

Figure 9: The effect of ethanol on engine power.

The use of 3 elemental nanoparticles in E5 improved the power output. The catalytic behaviour and high surface area to volume ratio of the nanoparticle property enhance the combustion resulting in improvement in the engine power output. Figure 10 presents the engine power change as the nanoparticle amount is changing at varying load condition. Compared to E5, the nanoparticle added fuels E53N25, E53N50, and E53N100 improved the engine power output by 12.64%, 22.84%, and 22.47%, respectively.

Figure 11 shows the effect of 3 elemental nanoparticles on the power output of E10 fuel emulsion. From the graph, it is seen that there is improvement of power due to the use of nanoparticle. In comparison to E10, the fuel samples E103N25, E103N50, and E103N100 have shown improvement of 5.43%, 7.74%, and 6.97% engine power output, respectively.

The influence of three elemental nanoparticles in E15 on the power output of the engine is shown in Figure 12. The overall effect of the nanoparticle on the engine power output is improvement. The specific increase for 25 ppm nanoparticle doping is 6.65%, and for 50 and 100 ppm nanoparticle doping, the power improvement is recorded to be the same 12.31%. The same power improvement results on E153N50 and E153N100 show that the 50 ppm nanoparticle

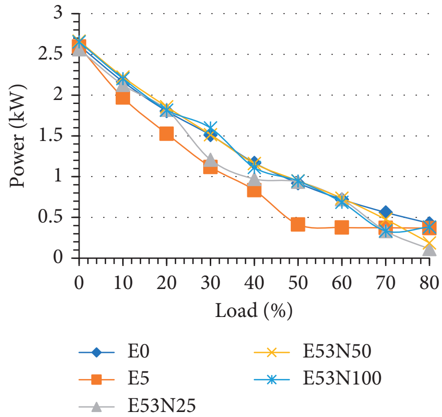

Figure 10: The effect of 3 elemental nanoparticles in E5 on engine power.

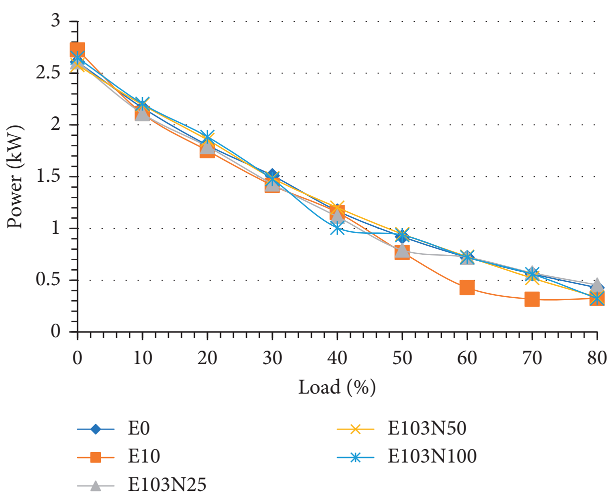

Figure 11: The effect of 3 elemental nanoparticles in E10 on engine power.

amount saturated the fuel sample, so the additional 50 ppm is used in excess.

3.2. Brake Specific Fuel Consumption. The brake specific fuel consumption of the test result showed the same pattern from no load to 80% load with a variation of 10% for all the fuel samples. At low load condition, the BSFC is low because at this load condition even though the engine runs at high speed the control rack at the fuel pump is set to the minimum fuel delivery position. As the load increases, the fuel consumption also increases up to 50% load. The BSFC starts to decrease as we increase the engine load further from 50% to 80% as indicated in Figures 13–16. The further load increment makes the engine to vibrate harshly and leads to shut down. The BSFC at high engine load is low because the engine speed becomes low, and the fuel could takesufficient time to complete its combustion process, and the engine compression pressure and temperature also increase as the engine load increases resulting in improved combustion. As shown in Figure 13, the amount of ethanol in diesel ethanol

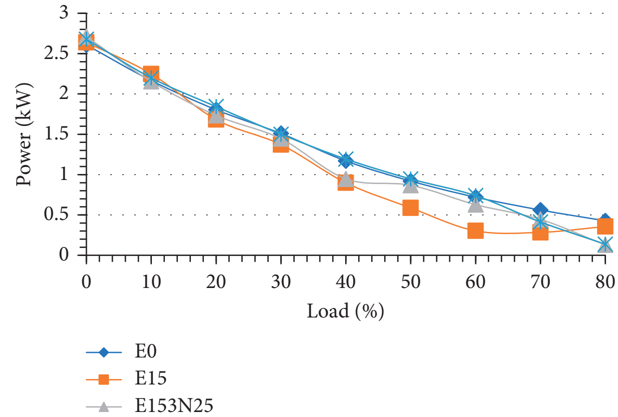

Figure 12: The effect of three elemental nanoparticles in E15 on engine power.

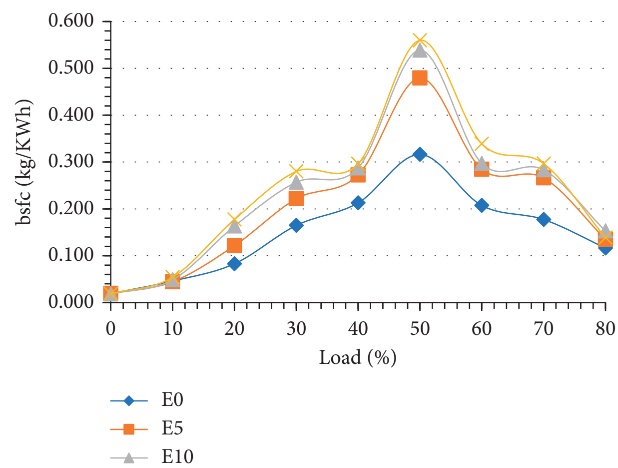

Figure 13: The effect of ethanol on engine fuel consumption.

emulsion greatly affected the BSFC. As ethanol amount increases, mainly the calorific value and the cetane number, which highly influence the combustion efficiency, decrease. The collected data showed 27.17%, 34.39%, and 37.87% BSFC increment for E5, E10, and E15 fuel samples, respectively.

The nanoparticle effect in E5 on BSFC is plotted on the graph in Figure 14. As it shows, the nanoparticle use reduced the BSFC for the fuel samples E53N25, E53N50, and E53N100 compared to E5 by 13.06%, 18.8%, and 17.79%, respectively. In the same way, the nanoparticle also reduced the fuel consumption of E10 emulsion prepared as E103N25, E103N50, and E103N100 by 16.79%, 27.86%, and 27.48%, as shown in Figure 15.

The effect of the nanoparticles also reduced BSFC when applied on E15. The amount of BSFC reduction for E153N25, E153N50, and E153N100 is 24.22%, 25.67%, and 26.6%, respectively. The overall result obtained by using three elemental nanoparticles reduced the BSFC for all the fuels used in this specific research work. From the chemical property of ethanol, it is known that the heating value and the combustibility in diesel engine are low, so these properties also affect the emulsion. Nanoparticles improve

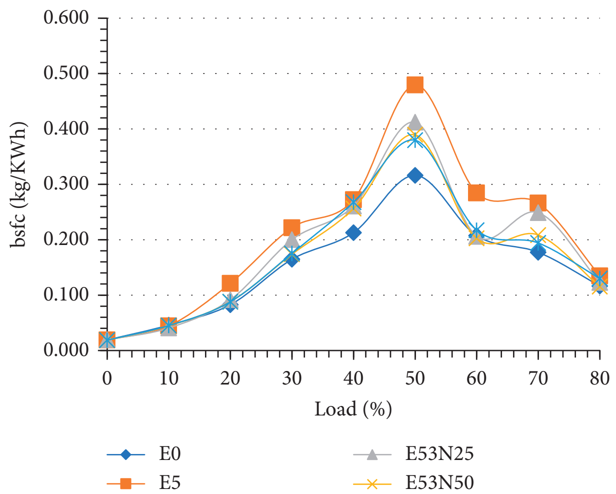

FIGURE 14: The effect of 3 elemental nanoparticles addition in E5 on engine fuel consumption.

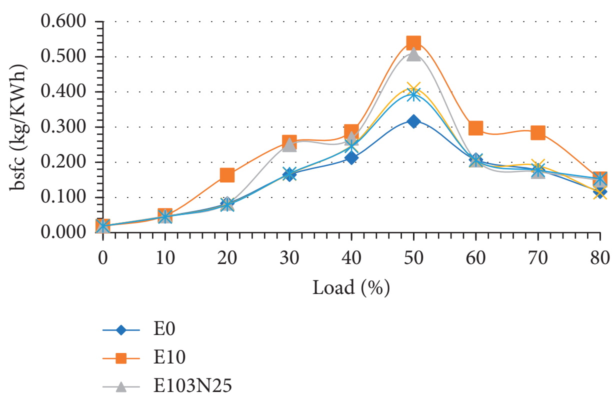

FIGURE 15: The effect of 3 elemental nanoparticles addition in E10 on engine fuel consumption.

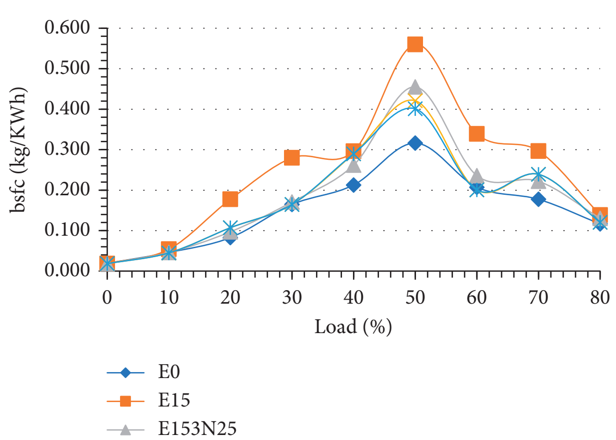

FIGURE 16: The effect of 3 elemental nanoparticles addition in E15 on engine fuel consumption.

combustion efficiency by acting as a chemical reaction catalyst and creating microexplosion in the combustion chamber.

4. Conclusions

In this research, the effect of ethanol diesel emulsion fuel is prepared varying the ethanol amount as 5, 10, and 15 percentages, which are studied by applying different amounts of three elemental nanoparticles specifically Nickel Zinc Iron Oxide ($NiZnFe_2O_4$) nanoparticles in the ratio of 25, 50, and 100 ppm. From the performance, test results tried to see the effect of ethanol and the addition of the nanoparticle on the emulsified fuel, and the following conclusions are drawn.

All the ethanol diesel emulsion fuel runs the engine smoothly; however, the torque, the specific fuel consumption, and the power output are reduced as the amount of ethanol content increases. The reason for this is the lower calorific value of the ethanol and the poor combustion characteristics due to extended ignition delay period.

Nickel Zinc Iron Oxide ($NiZnFe_2O_4$) nanoparticles improved both the engine torque and power output. The addition of 25 ppm nanoparticle on E5 does not bring much significance on the torque; however, there is improvement in the power output, and the fuel consumption is also reduced. E10 is the fuel sample with the best results in improving the torque and the power output as well as in reducing BSFC compared to the other emulsions studied in this research. On top of that, the addition of the Nickel Zinc Iron Oxide ($NiZnFe_2O_4$) nanoparticles further improved the performance characteristics of the torque and power output. The E15 fuel sample result shows closer output with the E10 fuel sample in all performance aspects.

Bioethanol could be used as a substitute for petrodiesel up to a portion of 10% as long as performance is concerned. However, due to the reduction of torque and power and the increment of BSFC, the utilization of combustion enhancer additives like nanoparticles is important. Due to the chemical catalyst, improvement in thermal conductivity, high surface area to volume ratio, and microexplosion effects, nanoparticle additives improve the performance output of a diesel engine.

Data Availability

The data used to support the findings of this study are available from the corresponding author upon request.

Conflicts of Interest

The authors declare that they have no conflicts of interest.

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