Experimental investigation on diesel Engine Performance with Diesel-alcohol Emulsion: Effect of Ethanol content, Injection Timing and $NiZnFe_2O_4$ Nanoparticle Addition

Deresse Firew

A Dissertation Submitted to

The Department of **Mechanical engineering**

School of **Mechanical Chemical and Materials Engineering**

Presented in Partial Fulfillment of the Requirement for the Degree of Doctor of Philosophy in Automotive Engineering

Office of Graduate Studies

Adama Science and Technology University

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Declaration

I hereby declare that this Dissertation entitled "**Experimental investigation on diesel Engine Performance with Diesel-alcohol Emulsion: Effect of Ethanol content, Injection Timing and $NiZnFe_2O_4$ Nanoparticle Addition**" is my original work. That is, it has not been submitted for the award of any academic degree, diploma or certificate in any other university. All sources of materials used for this thesis have been duly acknowledged through appropriate citations.

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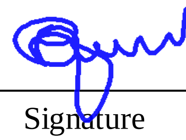
We, the supervisors of this dissertation, hereby certify that we have read and revised the dissertation entitled "**Experimental investigation on diesel Engine Performance with Diesel-alcohol Emulsion: Effect of Ethanol content, Injection Timing and NiZnFe$_2$O$_4$ Nanoparticle Addition**" prepared under our guidance by Deresse Firew submitted in partial fulfillment of the requirements for the degree of Doctor of Philosophy in Automotive Engineering, Therefore, we recommend the submission of the dissertation to the department for further review and defense.

Dr. Rajendiran Gopal		31-07-2024
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Approval of Board of Examiners

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We, the undersigned, members of the Board of Examiners of the final open defense by Deresse Firew have read and evaluated his/her thesis entitled "**Experimental investigation on diesel Engine Performance with Diesel-alcohol Emulsion: Effect of Ethanol content, Injection Timing and $NiZnFe_2O_4$ Nanoparticle Addition**" and examined the candidate. This is, therefore, to certify that the dissertation is accepted in partial fulfillment of the requirement of the Degree of Doctor of Philosophy in Automotive Engineering.

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NOMENCLATURE

Al_2O_3	Aluminum oxide nanoparticle
B10	10% biodiesel
BDE	Biodiesel diesel ethanol blend
BP	Brake power
bsfc	Brake specific fuel consumption
BT	Brake torque
BTE	Brake thermal efficiency
CAbTDC	Crank angle before top dead center
CeO_2	Cerium oxide nanoparticle
CI	Compression ignition
CIME	Calophyllum inophyllum biodiesel
CNT	Carbon nanotube
CO	Carbon Monoxide
CP	Cylinder pressure
CTAB	Cetyl Trimethyl Ammonium Bromide
DI	Direct injection
DNA	Deoxyribonucleic Acid
EGR	Exhaust gas recirculation
Fe_3O_4	Iron oxide
GHG	Greenhouse gas
GHG	Greenhouse gas
GQD	Graphene quantum dot
HC	Hydro carbon
HLB	Hydrophilic-lipophilic balance
HRR	Heat release rate
IC	Internal combustion engine
IT	Injection timing
LHR	Low heat release
MoO_3	Molybdenum trioxide

NiO	Nickel oxide
NOx,	Oxide of Nitrogen
PAHs	Polycyclic aromatic hydrocarbons
SI	Spark ignition engine
TDC	Top dead center
TiO_2	Titanium oxide
UHC	Unburned hydrocarbons
w/o	water in oil
ZnO	Zinc oxide
ZnO	Zink oxide

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ABSTRACT

The depletion of petroleum resources and hazardous emissions from conventional fuels are pushing researchers to work on biofuels. Many alternative solutions with the use of alcohols, vegetable oils, blends of diesel and alcohols, and biodiesel have been studied. Out of the numerous works carried out so far, this research aims to investigate the performance and emission characteristics of ethanol-diesel emulsions by adding $NiZnFe_2O_4$ *three-element nanoparticles and the influence of varying the fuel injection timing on selected fuel samples. Emulsifying ethanol in diesel has many advantages, such as reducing the amount of diesel fuel imported, protecting the environment by controlling harmful exhaust emissions, and encouraging local ethanol producers. The methodology followed includes the preparation of ethanol-diesel emulsion by using stirrer and ultrasonicator with different proportions, studying the stability of the fuel, and then conducting performance and emission experiments on a CI engine with the prepared emulsions as fuel. The performance test is conducted on a single cylinder engine with eddy current type dynamometer. Exhaust gas analyzer and smoke opacity meter are used to measure the exhaust emission. The test results are compared with the baseline data obtained with diesel fuel. The Stability test showed ethanol amount increment in the emulsion shortened the stability of the sample fuel. To obtain the performance and emission data Single cylinder air cooled engine with eddy current type dynamometer, exhaust gas analyzer and smoke opacity meter are used. The torque and power output of the engine when rune with the sample fuels indicated reduction with the amount of ethanol increase. The torque reduction for the fuel samplesE5, E10 and E15 are 15.5, 5 and 15.7% respectively. To improve the power output of the ethanol diesel emulsion the three elemental nanoparticle adding improved by 2.8% for the fuel sample E10with 100ppm nanoparticle addition. More over the advancing of the injection timing also improved the torque output by about 2.6%. In the same way the power reduction for the same fuel samples are recorded in the same manner. Specific fuel consumption is also increased with the amount of ethanol increase. The use of nanoparticle as additive reduced the fuel consumption* by *27.86 % for E10-3N-50 fuel sample compared with E10. To obtain the performance and emission data Single cylinder air cooled engine with eddy current type dynamometer, exhaust gas analyzer and smoke opacity meter are used. The torque and power output of the engine when rune with the sample fuels indicated reduction with the amount of ethanol increase. The torque reduction for the fuel samplesE5, E10 and E15 are 15.5 5 and 15.7% respectively. To improve the power output of the ethanol diesel emulsion the three elemental nanoparticle adding improved by 2.8% for the fuel sample E10with 100ppm nanoparticle addition. More over the advancing of the injection timing also improved the torque output by about 2.6%. In the same way the power reduction for the same fuel samples are recorded in the same manner. Specific fuel consumption is also increased with the amount of ethanol increase. The use of nanoparticle as additive reduced the fuel consumption* by *27.86 % for E10-3N-50 fuel sample compared with E10. The emission test results indicated the use of ethanol increased the* CO_2 *and reduced HC, CO, NOx and smoke emission. The use of nanoparticle and advancing the injection timing also further reduced HC, CO and smoke emission. However NOx emission is noticed to be increased as the nanoparticle amount is increased and injection timing is advanced.*

KEYWORDS: Ethanol-diesel emulsion, Atmospheric pollution, Global warming, CI engine, Three elemental metallic oxide nanoparticle, Emission.

CHAPTER ONE

INTRODUCTION

1.1.Background

In the past decades, the rapid industrial development, the growth of population, and the simultaneous improvement in living standards were significantly supported by the use of fossil fuels. Burning fossil fuels produces large amounts of carbon dioxide, which worsens global warming, environmental pollution, and climatic changes Naik, Goud et al. (2010). Moreover, as fossil fuels are limited resources, reducing fuel consumption and developing green energy sources are important development goals for sustainability Aydogan, Hirz, et al. (2014). The production of fossil fuels is limited, though the demand for their use is increasing, resulting in cost increases. The global oil storage market was valued 12.6 billion USD in 2021 and is expected to worth 25.7 billion USD by the end of 2030, growing at an 8.24% compound annual growth rate from the year 2022 to 2030 as per Precedence Research report (2022).

Due to their better power conversion efficiency and fuel economy, the compression ignition (CI) engines dominate in mass transportation, industrial, and agricultural sectors Lin, C. Y., & Wang, K. H. (2003). However, they are also main sources of pollution, emitting particulate matter (PM), black smoke, nitrogen oxides (NOx), sulfur oxides (SOx), unburned hydrocarbons (HC), carbon monoxide (CO), and carbon dioxide (CO_2).

Fuels from fossil sources are widely used in automobiles and transportation vehicles because of its drivability and thermal efficiency. The strict regulation on exhaust emissions and the fast depletion of worldwide petroleum reserves provide strong encouragement to research for alternative fuels. So fuels from renewable sources such as biodiesel or bio-alcohols are getting more attention because of their less environmental impact. Mixtures of fossil fuel and bio-fuels are also promising. The high oxygen content of the alcohols can improve the burning efficiency of the fuel blend and also can reduce emissions of the particulate matter (PM), carbon monoxide (CO) and hydrocarbon (HC) Hajba, Eller et al. (2011).

Ethanol can be produced from simple agricultural products such as sugarcane, cassava, molasses, waste biomass materials, sorghum, corn, barley, and sugar beets. It can also be manufactured from agricultural crops, food, and wood wastes. It is also a renewable energy source which can be derived chemically from ethane or ethylene and it has a simple molecular structure with carbon, hydrogen and oxygen atoms by Shi J., Balamurugan et al. (2014). It is a volatile and colorless liquid with a slight odor.

As a fact, biofuels can be derived from agricultural products; they can mitigate the problem of dependence on oil imports and contribute to energy security and economic welfare, especially in those countries that have inadequate or no fossil fuel sources. From an economic point of view, it is also interesting that they are more uniformly distributed (produced) than fossil fuel resources.

Many researchers have been reported, diesel fuel combustion is the major contributor to atmospheric levels particulate matter and nitric oxides emissions, being hazardous to both environment and human. In addition, as it is stated by the Paris agreement about climate change, reducing the use of non-renewable fuels is urgent to keep the world temperature rise below 2 °C above pre-industrial levels. Therefore, a solution to energy, mobility and transport needs could be provided by fossil-fuel replacement with renewable and advanced fuels. It has been reported that optimized use of advanced biofuel in combination with other engine technologies, could produce favorable particle-NOx trade-off mainly when to oxygenate fuels are applied. Aguirre, Quizhpe et al. (2018).

One of the fuel mixtures in which complete combustion occurs is emulsified diesel-ethanol. The advantages of an emulsified solution are that it can meet the application needs without modifying the diesel engine setup. Hansdah, Murugan et al. (2013). For Diesel-Ethanol blend fuel the performance and emission characteristics were found and it resulted in the reduction of NOx and smoke emissions. Ethanol was a potential alternative fuels that can be produced from molasses, the byproduct of sugar production. The ignition delay of the diesel-ethanol emulsions was larger due to inadequate cetane number of the ethanol fuel. Chen, Yan et al, (2011). The difficulty of dissolving ethanol in diesel and the stability of the blends is influenced by the temperature and water content. The use of additives that is surfactant improves the solubility of ethanol in diesel and finally it was found that solubility of ethanol in diesel was affected by aromatic hydrocarbons, the temperature of middle distillates. Torres, Jerman et al. (2011). Physical and chemical properties of diesel-ethanol fuel indicate closely identical behavior with neat diesel fuel. Research result have been proven that additives can improve not only the stability of ethanol-diesel blends, but their blends can reduce the NOx emission by 10% and smoke emission by 15%. Lubricity of the emulsified solution increases with addition of Ethanol fuel. Lin, C. Y. and Wang, K. H. (2003).

1.2. Ethanol diesel emulsion

Ethanol is an alcohol considered as one of the broad based alternative fuel which could be used to operate diesel engine in different methods such as ethanol fumigation, dual injection, alcohol-diesel fuel blends and alcohol-diesel fuel emulsions. Ethanol diesel emulsion is the best method of using ethanol without any engine modification. Stability of the mixture is one of the problems faced on the implementation of the fuel. Ethanol could be considered as fuel extender by substituting the portion of the diesel fuel required to power the engine thus reducing the diesel fuel use. Ethanol has extremely low cetane number so the amount of the diesel fuel replaced is limited due to this property, which is restricted by the engine knock Labeckas, Slavinskaset al. (2017).

Since emulsions are difficult to achieve and tend to be unstable, mixing either as micro-emulsions or using co-solvents is the most common approach to have a stable emulsion and which can be used in engines without modifications. Emulsion of ethanol in diesel fuel are often referred to as “oxygenated diesel” a term that is not particularly precise, as diesel blends containing methyl ester or any other oxygen containing additive that can be also described as oxygenated diesel. In ethanol diesel blends, standard diesel fuel is usually blended with up to 15% (by volume) of ethanol using an additive that helps maintain blend stability and other properties most importantly cetane number and lubricity. The additive package may comprise from 0.2% to 5.0% of the blend by Fayyazbakhsh, A., and Pirouzfar, V. (2017).

The difficulty of dissolving ethanol in diesel and the stability of the blends is influenced by the temperature and water content. The use of additives that is surfactant improves the solubility of ethanol in diesel and finally it was found that solubility of ethanol in diesel was affected by aromatic hydrocarbons, the temperature of middle distillates according to Chen, Yan et al, (2011). Physical and chemical properties of diesel-ethanol fuel indicate the behavior as compared to neat diesel fuel. Some research result have been proven that the additives can improve not only the stability of ethanol-diesel blends, but their blends can reduce the NOx emission and smoke by upto10% and 15% respectively. Lubricity of the emulsified solution increases with addition of Ethanol fuel. Furthermore, the stability of the blends was more sensitive to water content and additives than the temperature Torres-Jimenez, Jerman et al. (2011). Due to lack of miscibility between ethanol and diesel fuels, only a small amount of ethanol was allowed in blends for good results. The surfactant or an emulsifier solution should be used to prevent the separation of ethanol from diesel fuel in that case homogenizer is used as an additive to stabilize the blend solution. The cetane value of the surfactant solution could compensate the decrease of cetane number of the blends caused by the presence of ethanol. The main advantages of ethanol blends were to generate low smoke due to the presence of oxygen. The research has been done on the optimum HLB value scale for the emulsification of diesel-ethanol blends by Fang Q., Fang, J. et al. (2013). To solve the phase separation in the Diesel-Ethanol emulsions, addition of tween 80 and span 80 was selected as additive for the mixing of the solution Huang, Wang, et al. (2009).

Additionally, compared to emulsification, micro emulsification can provide a fuel that is more spontaneous and stable. A typical surfactant used in the creation of emulsions or micro-emulsions, hydrophobic Span 80, showed promising results in the upgrading of foam properties. Given the limitations of a single surfactant, several studies combined hydrophobic and hydrophilic surfactants as an emulsifier to achieve a narrower range of HLB values, which had superior results. These investigations showed that blended surfactant emulsions produced a more stable emulsion, increased combustion efficiency, and shortened the ignition delay time and NOx emission reduction. Researchers are driven by the lack of comprehensive research on the effects of mixed surfactants on the development of bio-fuel microemulsions, which motivates them to carry out this technology. Liang, Qian et al. (2018).

On the experiment conducted to examine the stability of ethanol and diesel blends with various surfactant concentrations (biodiesel and span 80), it was found that as surfactant content increased, the destabilization of the blends and the amount of backscattering decreased. The blends were found to be most stable when 25% biodiesel and 1.5% span 80 were added. The second phase consisted of determining the fuel characteristics and engine performance of the most stable mixtures. Both of the chosen stable blends exhibited good similarity to diesel in terms of characteristics like density, kinematic viscosity, and copper strip corrosion; however, due to the inclusion of ethanol, which has a lower heating value, flash point, and net calorific value, these properties showed a slight drop. Mehta, Barad et al. (2012).

Storage stability of water-diesel (15%-83%) and water- diesel-alumina nanoparticle (25, 50 and 100 ppm) emulsified fuel using 2% emulsifier prepared from the mixture of Span 80 and Tween 80. The report indicated the emulsion stayed for five days maintaining its stability by Basha, J. S. and Anand, R. B. (2011). The higher content of water, mixing with diesel emulsified fuel, may reduce the storage stability period because surfactant molecules may not be sufficient to combine with all water molecules. The metal oxide nanoparticles tend to settle down very soon in the absence of emulsifier. Patil et al. used Span 80 and Tween 80 emulsifier mixture to create the most stable water-in-diesel emulsified fuel. Patil, Gadhave et al. (2015).

The combination of two or more emulsifier was found to be more effective than an individual emulsifier. The combined effect of a mixed surfactant system could possibly reduce surface and interfacial tension between different compounds of an emulsion, which could result in an improvement in the stability of the emulsion. The combined effect represents an attractive interaction between hydrophobic and hydrophilic groups of different compounds of an emulsion. El-Din, El-Hamouly et al. (2013).

According to Sajeevan and Sajith (2013), to achieve a stable cerium oxide nanoparticle added diesel fuel 2% dodecenyl succinic anhydride surfactant is used by Ghannam and Selim (2009). On the other hand a 2% Triton X-100 is applied to get the most stable water-in-diesel emulsion. In common, 2% surfactant was optimized to achieve the highest emulsion stability for water in oil (w/o) emulsions. Based on the emulsion categories the required surfactant and emulsifier may vary in quantity. Lower quantity of emulsifier than 2% may not be sufficient to become stable for an emulsion or to achieve the best possible stability of an emulsion. The higher quantity of surfactant greater than 2% would not improve the stability further because optimum stability was achieved using 2% surfactant the emulsifier may also increase the viscosity and the cost of the emulsion.

The increased viscosity may create an improper fuel injection into the combustion chamber, which may result in engine performance reduction. Furthermore the increased cost may put an obstacle for the fuel to be commercialized. The emulsion stability is affected by various factors such as stirrer speed and time, surfactant concentration, and temperature. The emulsion stability may get affected at lower temperatures, especially in winter season, so some kind of remedy has to be made for maintaining an optimum temperature of the emulsion to avoid the undesirable thermal effect on its stability. The temperature range greater than optimum temperature can cause wastage of energy. The mixing speed, time and hydrophilic-lipophilic balance (HLB) value were optimized as 1500 rpm, 90 minutes and 9 respectively as stated by Patil, Gadhave et al. (2015). All the emulsion categories have been assigned a particular HLB value range to achieve the optimum stability and its 8-12 for ethanol in diesel emulsion category. In the present study, the emulsion is treated as ethanol diesel emulsion.

The nanoparticle dispersion and stability could be maintained by the implementation of Cetyl Trimethyl Ammonium Bromide (CTAB) surfactant by adding the same amount as the nanoparticle by El-Din, El-Hamouly et al. (2013). The stability of ethanol diesel emulsion was changed with respect to the temperature and ethanol content by Taib, Mansor et al. (2017). The ethanol concentration may suppose to affect the hydrogen bonding between ethanol and other compounds of blend. Thus, it can be predicted that the stability of the emulsified fuel may change with ethanol concentration. The emulsion stability improvement was reported with an increased stirring time, ultra sonication duration and surfactant concentration according to Abdalla, Al-Wafi et al. (2017). But at the same time, it consumed a lot of input energy. This energy could be calculated to decide the commercial cost of the emulsion.

The variation in temperature and the percentage of blend constituent's had a significant effect on the alcohol diesel emulsion stability. Lapuerta, García et al. (2010). and Lapuerta, Armas et al. (2009). It was observed that an increase in stirrer speed, diesel to water concentration and emulsification time improved the ethanol in diesel emulsion stability Vellaiyan, and Amirthagadeswaran (2016). The increased amount of water in ethanol and low temperature accelerated a phase separation in the ethanol diesel fuel emulsion Lapuerta, Armas et al. (2007). The high ethanol content in the emulsified fuel reduced its storage stability.

The effect of metal nanoparticles was studied on the stability of emulsified fuels. Abdalla, Al-Wafi et al. (2017). The dynamic light scattering results reported the cerium oxide nanoparticles blended diesel fuel with 35 ppm cerium oxide nanoparticles as the most stable fuel. Sajeevan and Sajith (2013). The metal nanoparticles have a great impact on the stability of emulsified fuel because of their small size and high surface area characteristic but their optimum concentration to be mixed with the fuel has to be determined. A very low or high quantity could have an adverse effect on the stability of the fuel. A higher concentration of metal nanoparticles will certainly increase the cost of emulsified fuel. Abdalla, Al-Wafi et al. (2017) studied the stability aspect of different nanoparticles metals with diesel-ethanol emulsion and diesel-biodiesel blends. The blends were stable only for two weeks. The short-chain alcohol-diesel emulsion showed poor stability. Mehta, Chakraborty et al. (2012) and (2014). The hydrous/anhydrous ethanol-ethyl acetate-diesel micro-emulsions have been stabilized for the temperature range of 5 - 45°C using ethyl acetate as a surfactant by Chandra and Kumar (2007).

For this specific research work, ethanol is considered as the driving range extender by substituting up to 15% volume percentage of the diesel fuel so that the amount of petro-diesel consumption necessary to power the engine could be reduced accordingly. One of the main problems with the utilization of ethanol diesel emulsion is its stability. The stability of ethanol diesel emulsion depends on the amount of water content in the base ethanol and ambient temperature. As the amount of water in the fuel is higher the tendency of separation also increases according to Liu, Haifeng et al. (2016). The ethanol used for this specific research is produced from molasses which is the byproduct of sugar production. The process of removing water from ethanol incurs an additional cost on the ethanol so the bioethanol obtained for the test is the one having a purity of 97%. The solution to maintaining its stability is to use an emulsifying agent. The emulsifier used to stabilize the solution is the mixture of Tween 80 and span 80 to obtain the proper hydrophilic-lipophilic balance (HLB) Vasistha, Vishal et al. (2019).

1.3.Nanoparticle effect

Recently, many researchers focused their attention on fuel formulation technique in order to achieve better performance and emission characteristics. Among the recent fuel additives, the nanoparticle additives emerged as a new promising fuel additive for achieving utmost improvement in the performance and highest reduction of exhaust emission by Prabu and Anand (2015).

Advances in nanotechnology, nano-science, and materials technology have resulted in the expansion of nano-scale particulate matters with physicochemical properties that are relatively diverse when compared to micron-scale elements of the same source material, such as greater contact surface area, better stability, fast oxidation, a lower melting point, enormous heat of combustion, a reduced heat of fusion rate, and large heat and mass transfer rates as per Demirbas, A. (2009) and Saxena, Kumar et al. (2017). Many researchers are familiar in fuel modification and revision techniques for producing specific fuel properties. Many studies have been conducted to investigate the effect of adding nanoparticles to fluids. The high thermal conductivity fluid in engine cooling systems and the higher density fuel in propulsion systems have favorable heat release rates, so they are used as additives for improving fuel combustion rates. Adding nanoparticles to a fluid can improve its physical properties, such as thermal conductivity, evaporation rate, shortened ignition delay period, and stimulation of secondary atomization Keskin, Gürü et al. (2007). Because of the large surface area (high surface area to volume ratio) and high energy level, catalytic performance is improved by Khond and Kriplani, (2016). Nano-Al particles are more conducive to the creation of micro-explosions during combustion, leading to the air-fuel mixing and resulting in a complete combustion. Cobalt nano-additives reduces NOx production, magnalium particles act as a heat sink inside the combustion chamber by decreasing the overall temperature, and it avoids hotspots and reducing NOx production by Mahalingam and Ganesan(2020). Mn based nanoparticle additives reduces emissions such as polycyclic aromatic hydrocarbons (PAHs) Fazliakmetov and Shpiro (1997). The hydrogen from water could be generated by using TiO_2 nano-additive due to its photoelectric catalytic effect and its capability to activate the molecular bond in the water-diesel emulsion by Ichikawa S. (1997).

To improve the performance and exhaust emission characteristics of the emulsified fuel, Nickel Zinc Iron Oxide Nanoparticles ($NiZnFe_2O_4$) are doped in different ppm amount. To mix the nanoparticle with the prepared sample fuels homogeneously and maintain the nanoparticle to remain suspended in the fuel, a surfactant called, Cetyl Trimethyl Ammonium Bromide (CTAB) is used. Cetyl trimethyl ammonium bromide is an organic bromide salt of cetyl trimethyl ammonium, which functions as a detergent and a surfactant. It is an organic bromide salt of quaternary ammonium by Syed Aalam (2020).

The addition of surfactant improves the stability of the nanoparticles added in to the fuel by converting the surfaces of nanoparticle, from hydrophobic to hydrophilic and vice versa. It also reduces the surface tension, coagulation and agglomeration by breaking the asymmetric bonds. The surfactant particle positions them and creates a point of continuity between the nanoparticle and the base fuel at the interface by Yakasai and Jaafar (2021).

1.4. Injection timing

Injection timing is one of the most determinant factors that could affect the combustion process in a diesel engine. The physical characteristics of the air into which the fuel is injected change with the position of the piston at top dead center (TDC). To obtain the maximum performance and the minimum amount of pollutant gasses, pointing out the optimum point of fuel injection is mandatory. If the fuel is injected far before the TDC, a drop in air temperature and pressure before the mixing process, the ignition delay period in the cylinder increases and results in excessively high pressure and temperature resulting poor performance high NOx emission and engine fatigue. The temperature and pressure will be higher before the fuel and air combine if the fuel is injected into the cylinder near TDC (retarded). This makes the ignition delay period short, but the intended maximum pressure happens far after TDC, which reduces the engine torque. As a result, the ignitions delay changes as the injection timing changes, which have a significant impact on engine performance by Venu and Madhavan (2016).

For the current research case, injection timing was changed by varying the number of shims under the fuel injection pump. To adjust the fuel injection timing, the shims under the injection pump were removed and inserted under. At standard injection timing (27^0 CAbTDC), the number of shims placed under the pump were two. The thickness of each shim is 0.15 mm. By adding and removing a shim, about 1.5 CA injection timing was changed, and the intended injection timing was adjudicated. The injection timing is advanced to 28.5^0 by removing one adjusting shim and to 25.5^0 by adding one adjusting shim by Krishnamoorthi, Malayalamurthi et al. (2018).

However, Krishnamoorthi and Malayalamurthi (2017). Experimented using a diesel-ethanol fuel mixture in a diesel engine necessitates some adjustments, such as an improved injection time. Improved premixed combustion time and reduced fuel usage are also benefits of advanced injection timing. A single-cylinder, naturally aspirated, air-cooled, direct injection diesel engine's operating parameters have been examined in this study, along with the impacts of diesel-ethanol emulsion and injection timing. The test is conducted at 27^0 BTDC with the engine's standard injection timing and two additional injection timings in both the advance and retard directions with an injection timing change of 1.5^0.

1.5. Statement of the problem

Developing a stable and efficient diesel-ethanol emulsion as an alternative fuel causes technical challenges related to emulsion stability, engine performance, and emissions control. Addressing these challenges it is crucial to connect the performance, environmental and economic benefits of using diesel-ethanol emulsion as a sustainable transportation fuel.

The current reliance on fossil fuels for energy production is leading to environmental degradation and climate change. Developing sustainable and cost-effective biofuels as an alternative energy source is essential to reduce greenhouse gas emissions and mitigate the negative impacts of fossil fuel consumption.

Diesel fuel is becoming increasingly necessary to meet transportation and other energy demands. Every year, countries pay a large amount of hard currency to purchase diesel fuel. This is one of the key causes of today's financial shortages. On the other hand, exhaust gas emissions from diesel engines account for the majority of atmospheric pollution. They are also strongly claimed to produce black smoke (soot) and NOx emissions. Continuous exposure to soot may harm human health by blocking the respiratory system. NOx, a toxic gas, causes respiratory system cancer and contributes to acid rain.

Ethanol, being hygroscopic, is difficult to mix uniformly with diesel fuel. Pure ethanol, because of its low cetane number, is not suitable for running diesel engines. To increase the performance of diesel engines powered by ethanol diesel emulsion, changes to fuel injection time are required.

1.6. Objectives

1.6.1. General objective

The general objective of this research is to experimentally investigate the performance and emission characteristics of CI engine fuelled with ethanol-diesel emulsion by varying injection timing and with the addition of $NiZnFe_2O_4$ nanoparticle.

1.6.2. Specific objectives

The specific objectives of this work are to:-

- To determine and prepare test fuel samples
- Study the stability characteristics of ethanol in diesel fuel emulsion

- Study the performance of the fuel on CI engine experimentally
- Study the emission and performance variation with the addition of three elemental nanoparticle
- Study the influence of injection timing on the engine performance and emission characteristics of the fuel

1.7.Research questions

This research project answers questions:

1. How does the ratio of Ethanol in fuel blend affect the life of homogeneous emulsion?

2. How does the blend ratio affect the physio-chemical property?

3. How does the blend ratio affect the emission and other performance parameters of the engine?

4. How the injection timing of the fuel does affects the performance of the engine?

5. How does the addition of three elemental nanoparticles affect the performance and emission of the engine?

1.8. Hypotheses

The difficulty of emulsifying ethanol in diesel fuel and maintaining the stability of the emulsion is influenced by the water content of the ethanol and temperature. The use of emulsifying agent improves the solubility of ethanol in diesel fuel. It is possible to keep ethanol diesel emulsion without separation for prolonged time by using Tween 80 and Span 80 emulsifiers. The emulsifying of ethanol in diesel fuel changes the physical and chemical properties of the diesel fuel. Some properties, such as density, flash point temperature, viscosity, heating value, and cetane number, of the emulsified fuel decrease. The performance and emission characteristics of the emulsion are expected to change with the change in ethanol amount and the amount of nanoparticle is also changes the performance and emission characteristics of the CI engine. As the amount of ethanol increases the bsfc should increase and the BT and BP should reduce. The effect of nanoparticle also has influence on ethanol diesel emulsion fuel. As we use more amounts of nanoparticle the bsfc shall reduce and the BT and BP shall increase compared with the emulsion without nanoparticle additive.

To ensure the happening of the maximum pressure at the right crank angle position the fuel injection timing shall be advanced some degrees from the standard injection timing with the use of ethanol diesel emulsion.

1.9. Significance of the study

The significance of this research is to develop awareness about the utilization of emulsified fuels among concerned parties including researchers, business society, ethanol producers and policy makers. It also contributes additional potential information on the performance and emission characteristics of ethanol-diesel emulsion. Researchers could use it as a platform to proceed with further research on the utilization of Ethanol-diesel emulsion as fuel in CI engines. It also motivates researchers to turn their face to this area.

The business community also gets information on the ethanol-diesel emulsion and is encouraged to participate by supporting research activities and investments in the various supply chains processes of the product. This research work also gives background information for an open discussion between the business community and government regarding the development of potential fuel samples to be used in CI engines and import substitution. Knowing the significance of fuel ethanol producers is also an incentive to devote more attention to production.

The investigation also gives a series of available information that could be considered for adoption in countries with no or scarce petroleum resources to maintain bioethanol development. The socio-economic and environmental benefits, difficulties, and risks highlighted in the research, along with the means to conquer them, could also play an important role for policymakers supporting for sustainable domestic bio-ethanol programs.

1.10. Scope and limitations of the study

1.10.1. Scope of the study

The scope of this study include the test sample fuel preparation of ethanol-diesel emulsion, applying different amounts of nanoparticles to the ethanol-diesel emulsion, Studying the stability of prepared emulsions, and testing the performance and emission characteristics of a CI engine with the sample fuel. Testing the performance conditions of the engine by varying the injection timing is done.

1.10.2.Limitations of the study

The limitations include that, due to a lack of laboratory facilities, combustion-related data such as cylinder pressure, cylinder temperature, and heat release rate are not included. Due to the factory setup of the test rig, the performance and emission data are taken within a limited range of power output. Due to the design of the test engine injection timing, minor adjustment of injection timing is not possible.

1.11. Organization of the dissertation

Chapter One: Introduction, the first chapter of the dissertation covers the background of bio-fuels particularly the comparative advantages of emulsified fuels over petroleum-based diesel fuel and the effect of nanoparticle adding in Ethanol diesel emulsion on the performance and emission characteristics. The statement of the problem; the objective of the research; research questions; hypotheses, significance, delimitations and limitations of the study are also included.

Chapter Two: Literature Review, this chapter contains the findings, considerations, study gaps and discussions of previous researches regarding Ethanol-Diesel emulsion and the research gap observed by the researcher is incorporated. Ethanol production, ethanol diesel emulsion physiochemical properties, the effect of nanoparticle adding in different bio-fuels on the performance and emission characteristics is reviewed. The influence of injection timing on the performance and emission results is also covered.

Chapter three: Materials and Methods, the materials required and the methodology followed to accomplish the research successfully are covered in this chapter.

Chapter four: Result and Discussion, this chapter consisted of the results obtained from the experimental data and the scientific analysis of the results obtained.

Chapter Five: Conclusions and Recommendations, this chapter included the conclusions drawn from the results obtained and recommendation which suggests possible extensions of ideas from the current work and indicating the future direction in the area.

CHAPTER TWO
REVIEW OF LITERATURE

2.1. Introduction

Diesel engines are the most fuel-efficient equipment ever created in the history of engine development and have been widely implemented on the market. Because of their durability and higher fuel efficiency, diesel engines are widely applied for heavy-duty vehicles, electric generators, small and mid-level transport vehicles, and tracks by Chen, Su et al. (2019). Despite their high efficiency and performance, diesel engines are still a threat to a clean environment. Researchers have to keep working on further increases in thermal efficiency and reducing harmful pollutants to reduce environmental pollution attributable to internal combustion engines by Zhang, Wang et al. (2020) In China, WEICHAI Power Co., Ltd. has announced that it has developed the first commercial diesel engine that has greater than 50% brake thermal efficacy. On the other hand, exhaust emissions from diesel engines have an increasing tendency to cause environmental pollution by Chen, Su et al. (2019) One of the challenges in diesel engine emissions is reducing both NOx and PM emissions at the same time. So there is always a trade-off connection among NOx and PM emissions by Duan, Jansons et al. (2021)

With the growing requirement to reduce the hazardous emissions of the transportation division, researchers have focused on the utilization of biofuel. The production of biofuels has been rising worldwide over the most recent decade, but the growing biofuel industry has important and significant worries, such as its contribution to climate change, the environment, and the dislocation of food crops. Biofuels technologies have to become more efficient to reduce greenhouse gas (GHG) emissions and be environmentally friendly and socially sustainable by Eisentraut, A. (2010).

Biofuels are gaseous or liquid fuels that are obtained from animals or vegetables. It includes alternative fuels such as bio-ethanol, bio-methanol, biogas, and biodiesel. However, the most commonly used biofuel is bioethanol by Aydın, F. and Öğüt, H. (2017). Bioethanol is created through acidic hydrolysis of starch plants or cellulosic sources. Vegetables such as corn, sugar beet, potatoes, wheat, and woody plants such as sugarcane, agricultural waste, and molasses are among the resources from which bioethanol could be produced as per Balat M., Balat, H. et al. (2008). Ethanol has high oxygen content (34% by weight) among various alternative fuels. As a result, it is more preferable to use as a fuel with combined petroleum fuel, which aids in combustion by Sakthivel, Subramanian et al. (2018).

Several research results have been reported on the effect of nanoparticles when applied to different fuel samples. For example, a cerium oxide nanoparticle (CeO_2) is used as a catalyst in biodiesel-diesel emulsification and then fuelled into a marine diesel engine to test its performance characteristics. The results revealed that the micro-explosion caused by the nanoparticle addition improved the fuel and air mixing. The micro-explosion improved the combustion process and engine performance Jiaqiang, Zhang et al. (2018). The catalytic effect of the nanoparticle improved the oxidation process, so the engine power and the brake thermal efficiency have increased by Saxena, Kumar et al. (2017).

Prabakaran B. and Udhoji A. (2016). studied zinc oxide (ZnO) nanoparticle effect in ethanol, biodiesel, and diesel blends 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 not noticeable . Manjunath applied an aluminum 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 while utilized to run a diesel engine. The report indicated that the BTE and HRR were increased, and emissions of HC and CO were decreased by Channappagoudra, M. (2021). Prabakaran and Vijayabalan (2018) conducted experiments to see the performance and emission properties of butanol–diesohol blends with 100 ppm ZnO nanoparticles. They reported the result as a significant increment in BTE, HRR, and CP and a reduction in NOx, HC, and CO emissions. Srinidhi et al. studied the emission characteristics of a diesel engine fueled with a diesel biodiesel blend of B25 and nickel oxide (NiO) nanoparticles doped at different concentration ratios of 25, 50, 75, and 100 ppm. The result showed a significant reduction in HC and CO emissions for the nickel oxide mixed biodiesel compared with a biodiesel blend Srinidhi, Madhusudhan et al. (2019).

Shafil, Herreros et al. (2008). studied the effect of Fe_3O_4 nanofluid by adding 0.4% and 0.8% on a volume basis to diesel fuel. The conclusion showed the BSFC has been significantly reduced due to the effect of the nanoparticles on reducing the ignition delay time and, at the same time, increasing the brake thermal efficiency of the engine. Selvaganapthy Cheralathan, et al. (2011). have tested diesel fuel with zinc oxide nanoparticles with the addition of a 250–500 ppm dosing concentration. The result is reported as the nanoparticle addition increasing the rate of heat release rate and the brake thermal efficiency when compared with pure diesel.

Karthikeyan, Elango et al. (2014). mentioned that zinc oxide nanoparticles have an antioxidant behavior, non-corrosive properties, wear-resistant properties, and the lowest cost. They used the ZnO nanoparticle in biodiesel diesel and water emulsion in two different concentrations of 50 and 100 ppm to reduce the exhaust emission. The test result is reported as due to the micro-explosion effect, which shortens the ignition delay time and helps the smaller amount of fuel be collected through the premixed combustion phase. Shortening of the delay period reduced the pick temperature, as a result, reducing the NOx emission by about 13 %. In the case of 100 ppm nanoparticle addition, the HC, CO, and smoke emissions are also reduced by 40, 33, and 17%, respectively.

Nanotechnology dominated industrial development and many types of research. New nanotechnology products have to lead to the further development of new technology. Nanoparticles are also used in different fuels to increase engine operating performance and reduce exhaust gas pollutant emissions by Venkatesan, Sivamani et al. (2017). Nanoparticle addition to different fuels increased fuel properties such as viscosity, density, flash point temperature, cetane number, and heating value, which improved combustion efficiency as per Dhahad, H. and Ali, S. (2019). In addition, nanomaterial added diesel can have a low flash temperature, which leads to an obvious enhancement in fuel handling safety by Sezer, I. (2019). Nanoparticle additives also reduce the cloud point temperature, improve engine cold starting in cold weather environments, and raise the surface area-to-volume ratio. This improves the rate of mass transfer due to micro explosions, resulting in better and faster combustion by Ranjan, Dawn et al. (2018).

From the literature survey tried to cover and indicated above, ethanol-diesel and ethanol-diesel-biodiesel could be used as diesel fuel. And the effects of different single-element nanoparticles added to various fuels are studied to identify their consequences on the performance of an engine and emission properties. However, the effect of three elemental nanoparticles, Nickel Zinc Iron Oxide Nanoparticles ($NiZnFe_2O_4$), in an ethanol-diesel emulsion has not yet been reported. The purpose of this study is to examine the effect of ethanol and three elemental nanoparticles in ethanol-diesel emulsions with variations in ethanol amounts (5, 10, and 15% by volume) and nanoparticle additions of 25, 50, and 100 ppm in each emulsion sample fuel on the performance and emission characteristics of a diesel engine. The compositions of bio-ethanol diesel emulsion and gasoline 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.

2.2. Alcohol based fuels

It's important to note that numerous investigations on alcohol-based fuels began more than two decades ago and are obtaining huge attention by Baranescu, R. A. (1986). Furthermore, in the current environment, the depletion of non - renewable and crude oil supplies, combined with rising petroleum fuel prices, has emphasized the need for alcohols to be used as an alternative fuel for IC engines. After revealing alcohol as a viable fuel for IC engines, previous research has revealed that ethanol and methanol are the most generally recognized alcohol fuels, with SI engines benefiting more than CI engines by Karabektas, Ergen et al. (2013). The usage of alcohol as a replacement for petroleum fuels in internal combustion engines originates from the belief that the raw ingredients used to make it are both inexpensive and renewable. While sugarcane, sugar beet root, and sugar sorghum are ideal feedstock for bioethanol production, barley, corn, and wheat containing starch could also be used as stated by Sarkar, Ghosh et al. (2012). Previous research have extensively reviewed and documented on the production and evaluation of ethanol as a vehicle fuel by Luo, Van et al. (2019).

2.3. Blend mode operation of alcohol based fuels

One of the organic compounds that contain oxygen is ethanol, or CH_3CH_2OH. It is a chemical compound that is volatile, flammable, and colorless. It boils at 78.5 °C and is a monohydric primary alcohol. In all ratios, it can mix with water. Absolute ethanol is ethanol that contains no water at all by Ayanie, A. K. (2011).

Commercial and industrial uses for alcohol are significant. Commercial alcohols, including methanol, ethanol, isopropanol, and ethylene glycol, are among the most crucial ones. Ethyl alcohol, often known as ethanol, is a gasoline additive, solvent, and ingredient in lotions, tinctures, perfumes, and medications. According to Teffera B. (2007), ethanol is a flexible product that may be used for a variety of tasks, primarily as a solvent in drinks and as a raw material to create hundreds of chemicals, including aldehydes, ethyl acetate, acetic acid, glycols, ethyl chloride, and many other organic compounds. Alcohol has a number of physiological and behavioral effects and has been called a psychoactive substance.

When the world saw how well alcohols can be used in gasoline engines, research and development into combining alcohols in diesel engines has been moving forward. Because alcohol is an oxygenated fuel with a lower viscosity, it should emit less HC and CO than diesel due to its superior burning. In general, smokeless combustion can be achieved when the oxygen concentration in the fuel would be around 30% by mass moreover, alcohols can be burned by Yilmaz, N. and Donaldson, A. B. (2007). Despite this benefit, using 100% alcohol in a diesel engine would be ineffective due to the greater self-ignition temperature and lower calorific value. Preheating the intake air, on the other hand, could solve the problem of lower ignition quality of alcohols, allowing combustion to take place by Lawrence, Mathewsz et al. (2012). Additionally, alcohols can be used in diesel engines by altering the engine design, notably the fuel injection systems by Shadidi, Yusaf et al. (20174). Both of these ways of making alcohols appropriate for diesel engines would be costly and time-consuming, considering that diesel engines are standardized for the use of only diesel fuel, and any use of a different fuel necessitates extensive engine changes. In a recent study, researchers have proposed adding ethanol in diesel mixtures, referred to as diesohol, to overcome the aforementioned restrictions by Rakopoulos, Rakopoulos et al. (2008). With the goal of making the fuel-air mixture leaner and to have more efficient combustion ethanol is added to diesel fuel. Because of its lower viscosity and boiling point, it allows for better atomization and subsequent mixing with air, resulting in better fuel evaporation and full combustion by Can, Celikten et al. (2004). The majority of the experiments with ethanol–diesel mixes show lower HC, CO, and smoke emissions by Sayin, C. (2010). However, because of the extended ignition delay, combustible air/fuel mixture accumulates throughout the delay period, creating a higher peak heat release rate to boost the in-cylinder temperature, resulting in increased NO_X emission according to Zhang, Zhai et al. (2014).

Despite the numerous experimental studies on the use of alcohol–diesel blend the reduced viscosity and solubility in diesel likely to cause future issues. Because ethanol's reduced viscosity causes injector leaks and pump damage, researchers proposed adding lubricants to the mix, such as 2% castor oil by Yilmaz, Donaldson et al. (2005). Moreover, the solubility of ethanol in diesel is complicated as it may be prone to separation at cold condition. The encountered separation problem could be overcome by adding emulsifier or additives such as do-deconal and surfactant span 80 that help enhance splash blending of ethanol and diesel by Ashok, M. P., & Saravanan, C. G. (2007). Furthermore, because ethanol's lower cetane number influences auto ignition temperature, researchers devised techniques to adjust the blend features in order to optimize the ignition characteristics of ethanol–diesel blends. Researchers considered adding cetane improvers to the ideal blend, such as ethyl hexyl nitrate, peroxides, and diethyl ether, and studied combustion parameters such as ignition delay, peak heat release rate, combustion duration, and pressure increase rate by Liu, Zhu, et al. (2010). According to the findings of this report, adding a cetane number improver improves the ignition characteristics of the mix significantly. Remarkably, the additives' influence prevented the increased NOx emission, which is generally linked with lower cetane fuels. Though the separation problem and lower cetane number of blend fuels can be fixed, ethanol has a reduced calorific value, which has an impact on engine performance. Because of the lower calorific value, a substantial amount of fuel is required to create the requisite power output; hence ethanol to diesel blending has been limited to 25% by Abu-Qudais, Haddad et al. (2000).

According to Lapuerta, García-Contreras et al. (2010). Despite the numerous advantages of alcohols as an alternative fuel for diesel engines, there is a limit to the amount of alcohol that can be blended with diesel.When compared to straight diesel; the physical and chemical properties of diesel-ethanol fuel reveal the behavior. According to certain research findings, additives can increase not only the stability of ethanol-diesel blends, but they can also reduce NOx emissions by 10% and smoke emissions by 15%. With the addition of Ethanol fuel, the lubricity of the emulsified solution increases. Furthermore, water quantity and additives had a greater impact on blend stability than temperature.

ASTM standards are used to test fuel qualities such as fuel stability, density, viscosity, cloud point, pour point, flash point, fire point, turbidity, and water content.

2.3.1. Fuel Stability

The stability of an emulsion depends on various factors, such as the type and concentration of the emulsifying agent, the size and distribution of the droplets, and the environmental conditions. In the case of diesel ethanol emulsion, the stability may depend on the type and concentration of the emulsifying agent used to mix the two liquids. The emulsion may also be affected by temperature changes, shear forces, and other external factors that can cause the droplets to coalesce or break apart. Therefore, it is important to conduct stability testing to determine the shelf life of the fuel. The fuel stability of the solution, which is diesel-ethanol, can be improved by adding a surfactant solution to the mixture. It was examined by placing each sample in a beaker and storing it for a longer period of time. Finally, the fuel stability of the samples was discovered at 25^0C ambient temperature.

2.3.2. Density

When compared to Diesel, the combustion parameters of Ethanol solution were considerably poor, such as flash point, fire point, and calorific value. The blended fuel will be impacted by this low density. When ethanol is added to a propulsion system, the fuel's specific energy content decreases significantly. The density of the fuel blends falls when the temperature and ethanol content increase simultaneously, as seen in Figure 1. The injection timing and exhaust pollutants are affected by the decrease in the density of blended fuel. Density varies between the ASTM standard values for all of the samples by Mažeika, Labeckas et al. (2014).

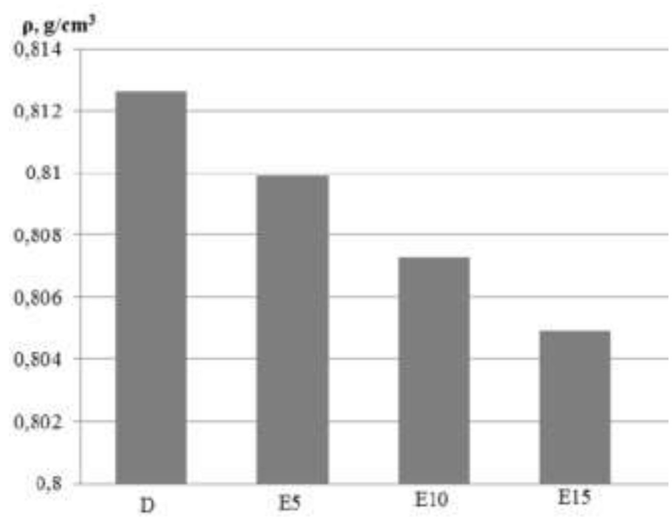

Figure 1. The density of diesel fuel (D) and its blends with ethanol (E5, E10, E15) at the temperature of 40^oC (Mažeika, Labeckas et al. 2014).

2.3.3. Lubricity

Lubricity is a feature of lubricant behavior that lowers scar wear in the diesel fuel system and engine's combustion chamber. The lubricating property was lowered when Ethanol was added to Diesel in quantities. Lapuerta, García-Contreras et al. (2010). Reported When Ethanol was added to diesel fuel in various quantities in volume basis, there ia an improvement in lubricity for high temperatures. This lubricity was evaluated in accordance with ASTM criteria for neat diesel fuels.

2.3.4. Viscosity

A saybolt viscometer is used to measure the viscosity of the combined diesel-ethanol fuels. The average kinematic viscosity of ethanol fuel is 1.121 mm^2 / s. The viscosities of diesel and ethanol fuels are shown in Figure 2, and it has been proven that the addition of ethanol to diesel fuels reduces viscosity. Because the viscosity of the blend has decreased due to the addition of ethanol, the rate of atomization of fuel in the diesel engine injection has degraded. Although, in comparison to the ASTM requirements, the blended solutions have lower viscosity values than diesel fuel,

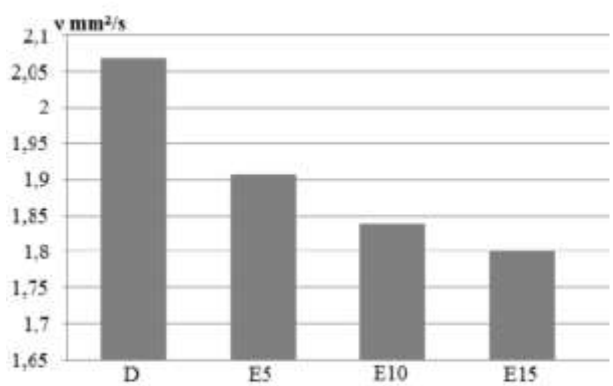

Figure 2. Kinematic viscosity of diesel fuel (D) and its emulsion with ethanol (E5, E10, E15) at the temp erature of 40 oC (Mažeika, Labeckas et al. 2014).

2.3.5. Flash Point

With the Pensky-Martin closed cup apparatus, the flash point of several types of blended fuels was investigated. When comparing different mix ratios, ASTM standards were followed. When compared to diesel fuels, the tested result demonstrate that ethanol blended fuels have a lower flash point. The diesel engine's performance will be affected as a result of this.

2.3.6. Calorific Value

The calorific value of the blended diesel ethanol solution could be calculated using Bomb Calorimeter for various proportions. The various samples of testing solution were prepared in separate beakers, and a small amount was used to heat the fuel to determine the calorific value. In addition, greater and lower heating values were established. The calorific value of the emulsifying solution was found to be reduced when ethanol fuel was added to plain diesel.

Heat generated = mass of liquid X Heat capacity of liquid X temperature difference

Calorific value = Heat generated / mass of fuel used

2.3.7. Water Content

Due to the hygroscopic property of ethanol fuel, the water content of the mix will grow as the amount of ethanol fuel added to diesel increases. When the amount of ethanol added to the diesel fuel in proportions increases, the water content of the diesel ethanol emulsion also increases. This increase in water content in the emulsion has an impact on the stability and quality of combustion, which reduces the diesel engine's efficiency.

2.3.8. Volatility

The tendency of a material to evaporate the combined diesel-ethanol fuel in combustion zones is measured by volatility. The addition of ethanol to diesel fuel reduces the tendency of vaporization, of the diesel-ethanol emulsion. The use of nanoparticle improves the volatility of the fuel resulting in improved combustion properties.

2.3.9. Turbidity

The turbidity value for combustion was relatively low for the various diesel-ethanol blends. Turbidity plays an important role in the complete combustion of blended fuels. This allows for fluid cloudiness or haziness induced by a larger number of individual particles in the blended solution. The addition of surfactant to diesel-ethanol emulsions promotes turbidity, which induces turbulence in fuel combustion for complete combustion. The surfactant cetyl trimethyl ammonium bromide gives the diesel-ethanol blends a closure value of turbidity to diesel fuel.

2.3.10. CHO content

The carbon (C) and hydrogen (H) percentage in diesel fuel was quite high for burning, whereas both elements are low in ethanol. Ethanol is an oxygenated fuel that contains a significant amount of oxygen. Carbon and hydrogen content in blend solutions are reduced when ethanol is added to diesel fuel. This has the advantage of lowering the emission rate of diesel-ethanol fuels. Some important properties associated with this research work are listed in table 1 below.

Table 1 properties of diesel Ethanol emulsion fuel Kuszewski, H., Jaworski, A., & Mądziel, M. (2021).

Property	Test Method	E0D	E5D	E10D	E15D
Density at 60^{o}C (g/cm^{3})	PNE NISO 12185	0.803	0.799	0.796	0.793
Flash Point (^{o}C)	EN ISO 2719 A	65.5	19.1	18.3	17.8
Higher heating value (MJ/kg)	PN-C04375-3	45.97	44.8	43.98	43.25
Kinematic viscosity60^{o}C (mm^{2}/s)	PNE NISO 3104	2.04	1.80	1.67	1.60
Dynamic viscosity 60^{o}C (mPa.s)	PNE NISO 3104	1.64	1.45	1.33	1.27
Cetane Number	ASTM D7668	55.2	48	45.4	40
Lubricity WSD (µm)	PN-EN ISO 12156 (1)	189.5	188	180.5	-

2.4. Ethanol production trend

The development of alternative sources of energy and its efficient utilization is increasing with the rising scarcity of petroleum fuels. Long dependence on fossil fuels particularly for the transport sector has made life vulnerable to unpredictable prices and supply changes of those fuels. As a result, interest in producing and using biofuels as an alternative source of energy increased worldwide.

The production and use of bio-ethanol are rising as a result of various driving factors. Licht, (2013) report indicated, as shown in Figure 3 below, that the world's production in 1990 was only 4 billion gallons (15.14 billion liters), and it took 15 years for the quantity to double to around 8 billion gallons (30.28 billion liters) in 2005. But in recent years, it only took three years to double again to around 17 billion gallons (64.35 billion liters) in 2008, and today around 23 billion gallons (87 billion liters) of ethanol are produced annually worldwide. Moreover, with Dufey A. (2007) included, predictions indicate that the production would reach 34 and 48 billion gallons (128.7 and 181.7 billion liters) by the years 2020 and 2030, respectively. With this, the global future demand of bio-ethanol is expected to exceed the supply which signifies that there will be market opportunities for low-cost producer developing countries, especially for tropical countries with low labor and land costs.

2.5. Ethanol production

Janssen, R., and Rutz, D. D. (2011) indicated ethanol can be produced from various resources available domestically. Those include agriculture and forestry residues, the organic portion of municipal solid waste, woody and herbaceous crops, and dedicated starchy crops. Rutz, D., and Janssen, R. (2007) discussed that ethanol is commercially produced using either a wet mill or dry mill process. Wet milling involves separating the grain kernel into its component parts (germ, fiber, protein, and starch) prior to fermentation. The dry mill process, where the entire grain kernel is ground into flour and the starch in the flour is converted to ethanol during the fermentation process, creates carbon dioxide and distiller's grain. In both processes the phisiochenical property ot the product is the same.Table 2 indicates the physiochemical properties of ethanol.

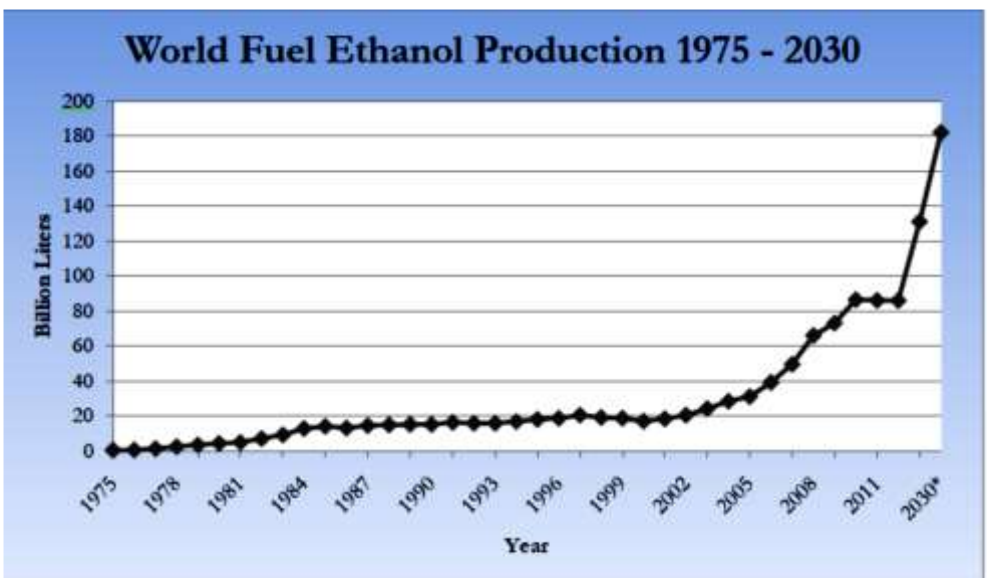

Figure 3. Current Status and future trend of bio-ethanol production

Source: Adapted from World watch Institute, 2006 and Bio-fuel market, 2007

Table 2. Physico-chemical characteristic of ethanol as a liquid fuel

Parameter	Characteristic properties
Molecular formula	C_2H5OH
Molecular mass	46.07 g/mol
Appearance	Colorless liquid
Water solubility	(Between –117°C and 78°C)
Density	0.789 kg/l
Boiling temperature	78.5°C (173°F)
Freezing point	–117°C
Flashpoint	12.8°C(Lowest temperature of ignition)
Ignition temperature	425°C
Explosion limits	The lowest 3.5% (v/v) Upper 19% (v/v)
Vapor pressure at 38°C	50 mm Hg
Higher heating value (at 20°C)	29,800 kJ/kg
Lower heating value (at 20°C)	21,090 kJ/kg
Specific heat	0.665 kcal/kg 60°C
Acidity (pKa)	15.9
Viscosity	1.200 maps. s (20°C)
Cetane number	5-8

Ethanol production in Ethiopia is a growing industry. The country has abundant resources for producing ethanol, including agricultural crops such as sugarcane, maize, and sorghum. The government of Ethiopia has been promoting the use of biofuels as a way to reduce the country's dependence on imported fossil fuels and to promote rural development.

One of the major players in ethanol production in Ethiopia is the Ethiopian Sugar Corporation. The corporation operates several sugar factories across the country, which produces both sugar and ethanol. In addition, there are several private companies that produce ethanol from sugarcane and other crops. The Ethiopian government has set a target of producing 450 million liters of ethanol per year by 2025. To achieve this target, the government has been providing incentives to investors in the ethanol industry, including tax breaks and access to financing Lambe, F., and Jürisoo, M. (2015).
Overall, ethanol production in Ethiopia has the potential to contribute to the country's economic development and energy security. However, there are also concerns about the environmental impact of large-scale ethanol production, particularly in terms of land use and water resources.

Ethanol production in Ethiopia is mainly associated with sugar industries. Methara and Fincha sugar factories are producing more than 25 million liters of fuel ethanol per year. The two factories use molasses, which is the byproduct of sugar production, to produce ethanol. Fuel ethanol is denatured, by adding 2 to 5 volume percent additive. The term "denatured alcohol" refers to alcohol products adulterated with toxic and/or bad-tasting additives (e.g., methanol, benzene, pyridine, castor oil, gasoline, isopropyl alcohol, and acetone), making them unsuitable for human consumption by Lambe, F. and Jürisoo, M. (2015).

2.6. Ethanol diesel emulsion

Griffin, W. C. (1949) explained that emulsions are kinetically stable mixtures of two immiscible liquids in which one phase is dispersed into another. They are stabilized with the help of emulsifiers, which have polar and non-polar groups. Emulsions of ethanol with diesel fuel are often referred to as "E-Diesel" or "eDiesel." Sometimes, ethanol-diesel emulsions are also called "oxygenated diesel," a term that is not particularly for emulsions, as diesel blends containing methyl ester biodiesel or any other additive that includes oxygen can also be described as "oxygenated diesel." In ethanol-diesel emulsions, standard diesel fuel (such as US No. 2) is typically blended with up to 15% (by volume) of ethanol using an additive package that helps maintain blend stability and other properties, most importantly cetane number and lubricity. The additive package may comprise 0.2 to 5.0% of the blend.

The use of biofuels in diesel engines has been tried without mixing it with diesel fuel and with diesel fuel adding-on it in different forms, such as emulsions, blends, dual injection, and fumigation by Mahmudul, Hagos et al. (2017). Ethanol has a high volatility property, and its emulsion with diesel fuel was introduced because of its high volatility, which contributes to secondary atomization that is known as the microexplosion phenomenon by Boggavarapu P., and Ravikrishna R. V. (2019). Meanwhile, ethanol belongs to the alcohol family and has a polarity like that of water. Because ethanol and diesel are identified as being immiscible, an emulsifying agent has to be used to find a properly emulsified solution by Hulwan, D. B and Joshi, S. V. (2011). The other issue is how to resolve the immiscibility of alcohol with diesel fuel. By definition, an emulsion is a mixture of two or more liquids with the aid of an emulsifying agent, which is naturally immiscible Seifi, Hassan-Beygi et al. (2016).

Emulsion formation by using ordinary shaking and steering agitation is nearly impossible. Even with emulsification agent being there in it, the mixture separates within second’s right after the machine is switched off. However, an ultrasonic emulsifier has been identified as one of the most efficient mixing instruments developed by Guo, Wang et al. (2013). with the capability of producing a stable emulsion with a lower amount of surfactant required in comparison to conventional methods of blending or mixing. Nevertheless, information regarding the formulation ratio combined with the emulsifying setting, such as amplitude, cycle, and period, is determined based on the type of emulsified fuel by Bahrudin, Hagos et al. (2019).

Waterland Venkatesh et al. (2003). stated that the use of ethanol-diesel emulsions can result in some reductions of diesel PM emissions, while contradictory reports exist on its effect on NOx, CO, and HC emissions. Perhaps the biggest advantage of ethanol-diesel emulsions is its partially renewable character if renewable ethanol is used as the blending stock. Considering its potentially significant operational and safety issues, the latter, including very low flash points, will likely remain a designated market fuel with limited applicability.

Mussatto, Dragone et al. (2010) discussed that there are a number of fuel properties that are essential to the proper operation of a diesel engine. The addition of ethanol to diesel fuel affects certain key properties, with particular reference to blend stability, viscosity and lubricity, energy content, and cetane number. Material compatibility and corrosiveness are also important factors that need to be considered. Properties that affect safety should be primary in any fuel evaluation. These include flashpoint and flammability. Finally, fuel biodegradability has become a significant factor with respect to groundwater contamination.

2.7. Emulsion stability

Boruff Schwabet al. (1982) discussed that ethanol solubility in diesel is affected mainly by two factors: temperature and the water content of the blend. At warm ambient temperatures, dry ethanol blends readily with diesel fuel. However, below about 10 °C, the two fuels separate, a temperature limit that is easily exceeded in many parts of the world for a large portion of the year. Prevention of this separation can be accomplished in two ways: by adding an emulsifier, which acts to suspend small droplets of ethanol within the diesel fuel, or by adding a co-solvent that acts as a bridging agent through molecular compatibility and bonding to produce a homogeneous blend. Emulsification usually requires heating and blending steps to generate the final blend, whereas co-solvents allow fuels to be "splash-blended," thus simplifying the blending process.

Moses, Dragone et al. (2010) experimented with both emulsifiers and co-solvents. They have been evaluated with ethanol-diesel fuel and investigated micro-emulsions of aqueous ethanol (5% water) and diesel fuel using a commercial surfactant. They reported that the blends formed spontaneously and required only minor stirring. They also appeared transparent, indicating that the dispersion sizes were less than a quarter of a wavelength of light and were regarded as "infinitely" stable, i.e., thermodynamically stable with no separation even after several months. Approximately 2% surfactant was required for each 5% aqueous ethanol added to diesel fuel. They developed formulations for two micro-emulsion surfactants, one ionic and the other detergentless. Blends of these surfactants with aqueous ethanol and diesel were transparent and stable at temperatures as low as 15.5 °C. Researchers in Sweden tested a blend of 15% aqueous ethanol (5% water) with diesel containing, an emulsifying agent developed in Australia. Early studies identified tetrahydrofuran as an effective co-solvent, obtained at low cost from agricultural waste materials, and ethyl acetate, which could be made inexpensively from ethanol. Ternary liquid-liquid phase diagrams illustrating the relative effects of moisture content and temperature on blend stability and also the increasing amounts of co-solvent required with increasing moisture and temperature to maintain a single-phase.

2.8. Ethanol-diesel Emulsion investigations

There are many research articles published such as by Johnston, Mayo et al (2005) and Ampah, Yusuf et al. (2021). focusing on the search for an appropriate alternative fuel for the existing diesel engines. The rapid price rise and depletion of petroleum products are the major driving factors for focusing on looking for alternative fuel. The exhaust emissions produced by the combustion of fossil fuels have a harsh effect on the ecosystem and human health. To overcome this problem, it has become an international agenda to develop clean alternate fuels that are easily available, internationally acceptable, and technically practicable. Due to the realization of energy concerns and environmental problems related to the burning of petroleum-based fuels, numerous researchers have studied the opportunity of utilizing non-conventional energy sources as an alternative fuel source to fossil fuels and their derivatives.

Availability and efficient utilization of energy determine the socio-economic status of any country by Bauer, Calvin et al. (2017). Diesel engines have outstanding characteristics out of the various energy conversion devices, such as higher thermal efficiency, utilization of leaner air-fuel mixtures, high compression ratios, low specific fuel consumption, reliability, and low maintenance and operating costs. Regardless of their incredible superiorities, diesel engines emit a large quantity of pollutants such as carbon monoxide (CO), NOx, soot, and unburned hydrocarbons, which cause environmental degradation and serious health hazards by Agwu, O. (2020). Moreover, petroleum-derived fuels are depleting due to additional demand as a result of population growth and vast energy utilization by Energy outlook (2016).

Engine manufacturers are continuously improving their designs to increase fuel economy and reduce pollutants in exhaust emissions to meet emission standards by Kumar, Varun et al. (2016). This condition has motivated many researchers to focus on alternative fuels to alleviate the problem in addition to engine design improvements. Fuel modification strategies consist of mainly improving the fuel characteristics to improve combustion, which is responsible for better engine performance, low exhaust emissions, and high fuel economy by Saxena, Tiwari et al. (2013) .

The above-mentioned challenges can be overcome by developing more environmentally friendly oxygenated fuels, such as ethanol as indicated by Cahyono B. and Bakar RA (2011). Ethanol can be manufactured from agricultural supplies such as sugarcane, cassava, molasses, waste biomass materials, corn, sorghum, barley, and sugar beets. Ethanol can be derived from ethane or ethylene through a chemical process. It is a renewable fuel with a simple molecular structure having hydrogen, carbon, and oxygen atoms by Lincy R, and Wang KH (2003). Because of the water content, wide range of temperatures of the diesel fuel, hydrocarbon composition, and prevailing wax content, it is difficult to easily mix ethanol with diesel fuel. Water content in ethanol greater than 1% v/v ratio causes phase separation in the fuel blend by Mccormick R.L. and Parish R. (2001). Emulsifiers and co-solvents can be used as solutions for this problem. Important physicochemical properties, such as heating value and cetane number, are reduced in the diesel-alcohol blends. These properties can be improved through the use of additives. Gerdes K.R. and Suppes G.J. (2001).

The addition of ethanol in diesel fuel causes physicochemical change. It can reduce the heat content, cetane number, flashpoint and viscosity. For example the blended fuel heat content is reducing by 2% for 5v/v% addition of ethanol to diesel fuel. Table 3 shows the decrease in the heat content with the increase in ethanol content by Chao, Lin et al. (2000).

Table 3. Heat content of Diesel ethanol mixtures (Chao, Lin et al. 2000).

Mixtures Gross heat content	**(MJ/kg)**
Diesel	42.35
Diesel + 10% ethanol	40.98
Diesel + 15% ethanol	40.75
Diesel + 20% ethanol	39.59

Because ethanol has a very low cetane number, the cetane number of diesel ethanol blend fuel is significantly reduces by Shaafi T. and Velraj R. (2015). The cetane number reduces by four units in the diesel ethanol blend for each 5% v/v ethanol increase in the diesel fuel by Hunt E.M. and Pantoya M.L. (2005). Figure 4 shows the effect of ethanol content on cetane number.

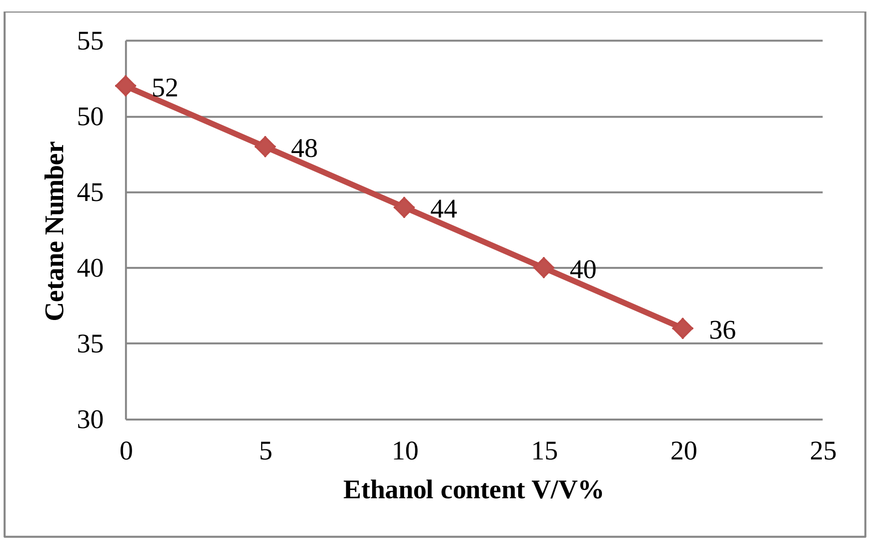

Figure 4. The effect of ethanol content on cetane number of diesel fuel (Hunt E.M. and Pantoya M.L. 2005)..

Ethanol-diesel blends usually need additives to improve stability, miscibility, lubricity, and cetane number to improve combustion efficiency, thereby decreasing knock and confirming the smooth operation of the engine by Dreizin E.L. and Schoentitz M. (2015). Based on their functions, fuel additives are categorized into a variety of groups by Wong K.V. and de Leon O. (2010). The additives category includes ignition promoters, combustion modifiers, antiknock compounds, antioxidant additives, anti-wear additives, stabilizers, etc., and based on their chemistry, they are classified as oxygenized, metal-based, non-metal-based additives, etc. Nanoparticles have amazing properties due to their size, they can considerably change the combustion properties of the fuel to which they are added. Moreover, in order to reduce exhaust emissions and improve engine performance, nanoparticles are used as fuel additives by Ribeiro NM (2007).

The combustion quality of conventional fuel is improved by adding a few micrometer-sized metallic particles. But the problem with micro-sized metallic particles is the increase in ignition delay, which results in engine knock by Tutak, Lukács et al. (2015). The reason for ignition delay is reported as being due to a smaller surface area to volume ratio compared to metallic nanoparticle fuel additives by Khan, Dewang et al. (2022). Fuels with nanoparticle additives called nanofluids are considered a new class of fuel that attracts the attention of many researchers because of their high heat transfer rate for heat exchangers and other strong thermophysical properties by Soudagara, Nik-Ghazalia et al. (2018).

Many researchers have accepted that the addition of nanoparticles improves the fuel's properties. The goal of nanoparticles is to improve fuel properties, reducing pollutant exhaust emissions, increasing engine performance, and allowing the use of biofuel without engine modification. Nanoparticles are added to commercially available fuel to achieve specific properties such as reduced exhaust pollution, increased oxygen content in the engine, fluid stability, reduced ignition delay, enhanced lubricity index, and reduced flash point. Under high-load conditions, the chemical-to-chemical contact must be enhanced rather than the metal-to-metal contact to reduce metal plane wear Chen, Akmal Adzmia et al. (2018).

Blending alcohol with diesel fuel results in a lower cetane number for the blended fuel. The lower cetane number of alcohol–diesel fuel blends could increase noise and vibration Qi D, Chen et al. (2010). In research done on a butanol–diesel fuel blend, the addition of a TiO_2-based additive significantly reduced vibrations and noise. The additional oxygen content and catalytic effect of the TiO_2 nanoadditive lead to a reduced ignition delay, thus lowering the knocking tendency. It is also mentioned that at lower percentages of alcohol, the nanoadditive was more effective, but at higher percentages of ethanol, the observed difference is not significant by Venu, Dhana et al. (2019).

The depletion of petroleum-based fuel and the hazardous emissions from engines are motivational factors for research in the area of unconventional fuel, specifically for diesel engines. In order to improve the performance properties such as power output (BP), brake specific fuel consumption (BSFC), brake thermal efficiency (BTE), and reduce the exhaust emission of diesel engines, the use of nanoparticle additives is promising. One of the objectives of this research is to see the effect of nanoparticle addition in diesel-ethanol emulsion fuels on the performance and emission characteristics of diesel engines. The information is extracted from research journals published through the year 2020, which gives an idea about the recent trends in nanoadditive research.

2.9. Performance characteristics

Bio-fuels having comparable properties to diesel are the most promising alternative fuels and are expected to replace diesel fuel in the near future. On the other hand, due to drawbacks like lower power and engine speed, higher specific fuel consumption, and lower mixture stability, bio-fuel is not fully utilized in diesel engines. Numerous researchers are trying to develop new methods and technologies to overcome the problems. One promising method of improving the properties of biofuel is the utilization of nanoadditives. In this section, the performance parameters of a CI engine, such as brake specific fuel consumption (BSFC), power output (BP), and brake thermal efficiency (BTE), of different bio-fuels with the addition of different nanoparticles have been reviewed. In many research papers, it is investigated that the addition of nanoparticles to diesel-biofuel (biodiesel and alcohol) emulsions advances a fast and comprehensive combustion process because of improved radiative and heat-mass transport properties, which improve combustion efficiency by Heidari-Maleni, Gundoshmian et al. (2020).

Compared to neat diesel, fuels with metallic-based additives showed a decreasing trend in BSFC by D'Silva, Binu et al. (2015). Studies have examined the effects of aluminum oxide (Al_2O_3) nanoparticles on the emission characteristics and performance enhancement of single-cylinder, four-stroke diesel engines. Two different amounts, 0.01% and 0.05% by weight of Al_2O_3 nanoparticles, were utilized as fuel additives. The performance test result is compared with neat diesel fuel. The results showed that fuel containing 0.05 % nanoparticles performed better than the fuel containing 0.01% nanoparticles, and the addition of Al_2O_3 resulted in a 31% reduction in BSFC at maximum load when compared to diesel by Mei, Zuo et al. (2019). Nanoparticle addition increases the calorific value of fuels slightly, causing a decrease in BSFC. The main reason for the decrease in BSFC is due to the high surface area of metallic additives, which results in improved combustion quality by Venu, Dhana et al. (2019).

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The characteristics of a diesel engine by adding 60 ppm graphene quantum dot (GQD) nanoparticles to bioethanol with 10% biodiesel (B10) and 2, 4, and 6% vol of ethanol at different engine speeds of 1800, 2100, and 2400 rpm is investigated. The research conclusion indicated that, addition of graphene quantum dots (GQD) improves engine performance while lowering exhaust emissions. The specific fuel selected as B10 + E4 + GQD60 is the most favorable fuel at all speeds. In comparison with the pure diesel fuel, the optimal fuel (B10 + E4 + GQD60) improved the engine power and torque by 24.59% and 20.02%, respectively by Mei, Zuo et al. (2019).

The research, which focuses on the effect of an alumina (Al_2O_3) nanoparticle on a diesel-biodiesel-ethanol blend (abbreviated "BDE") by varying injection timing, The effects of 25 ppm Al_2O_3 in the BDE blend at 19 deg bTDC in a single-cylinder diesel engine show that Al_2O_3 addition causes lower heat release and cylinder pressure away from TDC, resulting in lesser brake-specific fuel consumption (BSFC) and better engine performance and combustion by Chena, Akmal et al. (2018).

On the study conducted to see the combined effect of combustion chamber shape, direct injection, and nanoparticle additives on single-cylinder diesel engines with diesel, biodiesel, and ethanol mixture. Different combustion chamber geometries and injection timings, including 21^o, 22^o, 23^o, and 24^o bTDC, are used to test the fuel. The outcome showed that BTE was at its highest point, around 33.8%. The lowest BSFC profile, with an 11.51% BTE increase over neat diesel, was attained at 22 o bTDC by Nanthagopal, Ashok et al. (2017).

Performance and emission characteristics study on the use of TiO_2 nanoparticles addition in neat diesel fuel. On the study it is showed that properties of conventional diesel such as viscosity, density, calorific value and fire point improve with the addition of the nanoparticles. Engine performance test result showed improvement in brake thermal efficiency and Reduction in brake specific fuel consumption by 22% with the addition of the nanoparticles at highest load by Manigandan, Sarweswaran et al. (2020).
Investigation on the result of carbon nanotube (CNT) and molybdenum trioxide (MoO_3) nanoparticles on fuel consumption, performance and emissions characteristics of diesel in a common rail diesel engine is studied. The experiments are conducted in Single-cylinder common rail diesel engine for investigating and comparing the engine performance and emissions characteristics of the nano-fuels with pure diesel. The test fuels include 100CNT (Diesel+100 mg/L CTAB (cetyl trimethyl ammonium bromide) +100 mg/L CNT) and 100MoO_3 (Diesel+100 mg/L CTAB+100 mg/L MoO_3). The BTE of the 100CNTis and increased by 5.2% and 100MoO_3 by 2.3%, and BSFCs were decreased by 5.1% for100CNT and 2.3% for 100MoO_3, respectively compared to pure diesel by Prabu, Anand RB (2016).

Engine performance and emission characteristics of two fuel blends, B20 (80% diesel and 20% soybean biodiesel), and D80SBD15E4S1 alumina (80% diesel, 15% soybean biodiesel, 4% ethanol, and 1% surfactant, and alumina nanoparticles, 100 mg/L), are compared with neat diesel. Brake thermal efficiency is higher for B20 and D80SBD15E4S1 alumina fuel mixes than for neat diesel at maximum load. An increase in brake thermal efficiency of 15.8% and 17.9% was observed in the cases of B20 and D80SBD15E4S1 alumina fuel blends, respectively, compared with pure diesel at full load. It is due to the presence of more oxygen in the fuel that complete combustion occurred in the case of B20, and in the case of the D80SBD15E4S1 alumina fuel blend due to the presence of the alumina nanoparticle, the further increase in efficiency is due to the higher evaporation rate and micro explosion of the primary droplets. The brake-specific fuel consumption is minimal compared to the neat diesel at higher loads of 75%

and 100%. The existence of the alumina nanoparticle improves the atomization rate that enhances complete combustion and increases the heat transfer from the combustion, thus lowering the sink temperature and increasing engine performance. The brake-specific fuel consumption is 3.53 kg/kWh for D80SBD15E4S1 alumina, 3.7 kg/kWh for B20, and 4.33 kg/kWh for neat diesel. This shows the high viscosity within the cases of B20 and D80SBD15E4S1. In the case of full stack conditions, the alumina fuel mix is overcome by a decrease in viscosity at higher temperatures Nallamothu RB, Nallamothu et al. 2018.

The effects of three different nanoparticles, aluminum oxide, carbon nanotubes, and silicon oxide, as diesel fuel additives on the performance and exhaust emissions of a four-stroke single-cylinder diesel engine are investigated and compared. The nanoparticles were dispersed at doses of 25 ppm, 50 ppm, and 100 ppm with pure diesel. The blended fuels were experimentally tested at engine loads of 0, 25, 50, 75, and 100% at a constant engine speed of 1800 rpm. The test results revealed that the brake-specific fuel consumption of the CNT blend was reduced by up to 19.8% and brake thermal efficiency improved by 18.8%. Silicon oxide blends show better results than aluminum oxide blends in lowering brake-specific fuel consumption by Nallamothu RB, Niranjan (2018).

An investigation by Nallamothu RB, Birbirsa et al. (2018). which is made on the performance and emission characteristics of Calophyllum inophyllum biodiesel (CIME) nanoemulsions in a two-cylinder CI engine. The test is conducted with diesel, pure biodiesel, and biodiesel nanoemulsions dispersed with TiO_2 and ZnO nanoparticles. Calophyllum inophyllum biodiesel nanoemulsions at 50 ppm and 100 ppm concentrations have been studied, and the results were compared with pure biodiesel and neat diesel fuels. The engine performance result indicated that the highest brake thermal efficiency is 33% for diesel fuel, 31% for biodiesel T100, 30% for biodiesel T50, 27% for biodiesel Z100, 28% for biodiesel Z50, and 26% for pure biodiesel at full engine load. The BSFC of pure Calophyllum inophyllum biodiesel and CIME nanoemulsions is higher compared to diesel fuel at all loadings. At full engine load, the CIME-T100 has a BSFC of 0.24 kg/kWh, whereas the CIME-Z100 has a BSFC of 0.258 kg/kWh. The researchers concluded that the lower calorific value of the biodiesel increased fuel consumption to achieve the same power output. It is evident that all nanoemulsions of CIME (CIME-Z50, CIME-Z100, CIME-T50, and CIME-T100) resulted in lower BSFC compared to CIME without nanoparticle addition.

The effect of different nanoparticles and hydrogen mixes on engine performance and emissions in a dual fuel system is investigated by Nallamothu RB, Nallamothu SK et al. (2018). The nanoparticles used for the study are CuO, CNT, CeO_2, TiO_2, and Al_2O_3. The nanoparticles are added at a dosage level of 100 ppm with 20% hydrogen fuel. The test is conducted at a speed of 1800 rpm with different engine loads of 0%, 25%, 50%, 75%, and 100%. The brake thermal efficiency increases by 4.3% for CeO_2 and 2.5% for Al2O3. In the meantime, for CeO_2, brake-specific fuel consumption is observed to be insignificant. CNT and TiO_2 nanoparticles indicate a 23% and 22% decrease in BSFC, respectively, compared to other blends.

The addition of nanoparticles improves fuel properties such as heating value, fuel viscosity, and cetane number due to the nanoparticles' increased surface area/volume ratio, which results in an increase in engine performance. Nanoparticles have a catalytic property that promotes combustion by generating micro-explosions of primary droplets that could vaporize the fuel and enhance mixing with air to reduce ignition delay. The other significant effect of nanoparticle additives is the increment in heat transfer, so that it can facilitate combustion and increase the heat release rate. Therefore, adding nanoparticles to fuel increases the performance of engines by increasing the probability of complete combustion.

2.10. Emission characteristics

Research has shown that in densely populated municipal areas, the usual exposure of diesel exhaust could cause health harm. Despite their benefits, diesel engines are a major source of air pollution due to dangerous gas emissions such as carbon dioxide, carbon monoxide, nitrogen oxide, and sulfur oxide by Nallamothu RB, Nallamothu AK et al. (2018). The environmental and human well-being communities have been blaming the topic of diesel engine exhaust emissions for influencing human health. It is worrying to realize that engine pollution affects human health on a huge scale. Moreover, diesel engine emissions contain many toxic substances, such as NOx, SOx, CO, CO_2, carcinogens (a substance capable of causing cancer in living tissue), and mutagens (a change in the DNA of a cell). Furthermore, they have become a major source of lung cancer in both animal and human beings, which has been linked to health risks in studies. Research on truck drivers and railroad workers exposed to diesel engine exhaust due to their occupations shows that they tend to have an increased risk of getting lung cancer with escalating years of work in the exposed job, and the workers have been found to be at risk by Nallamothu RB, Anantha et al (2020).

D'Silva, Binu et al. (2015). Reported that, In order to improve the emission characteristics of diesel engines, many researchers have been working on fuel additives. The effect of metallic nanoparticles studied in various researches is reviewed. When compared to petroleum diesel fuel, the use of Aluminum Oxide (Al_2O_3) Nanoparticles as fuel additives reduces the emission of noxious waste such as CO_2 and HC.

On the research work done by Chena AF, Akmal et al. (2018) to evaluate the performance parameters and emissions characteristics of a diesel engine by adding 60 ppm graphene quantum dot (GQD) nanoparticle to bio-ethanol fuel, a considerable emission reduction is achieved with 10% biodiesel (B10) and 2, 4, and 6% volume of ethanol at different engine speeds of 1800, 2100, and 2400 rpm, respectively. The specific fuel selected as B10 + E4 + GQD60 reduced UHC and CO emissions by 42.05% and 35.60%, respectively, compared to the pure diesel fuel . An experimental study that focuses on the effect of alumina (Al_2O_3) nanoparticles on a mix of 20% biodiesel, 70% diesel, and 10% ethanol (called BDE) by varying injection timing is carried out. The effect of 25 ppm Al_2O_3 in BDE blend at 19^o bTDC IT in a single-cylinder diesel engine resulted in reductions of NOx, HC, CO, and smoke opacity.

Venu, Raju et al. (2019) experimented on the joint effect of nanoparticle additive, combustion chamber design, and injection timing in a diesel single-cylinder engine. Diesel, biodiesel, and ethanol blends, which they called Ternary fuel, have been added. After alumina nanoparticles have been added to the fuel, they have termed the resulting fuel "high performance fuel." The high-performance fuel is tested with different combustion chamber shapes and injection timings, namely 21^o, 22^o, 23^o, and 24^o BTDC. The test results showed lower HC and CO emissions of 9.18% and 16.83% at the injection timing of 22^o bTDC, respectively, and lower NOx emissions of 22.53% compared to neat diesel.

Graphene quantum dot nanoparticles are studied for performance and emissions on a diesel engine with an ethanol-biodiesel mix. The concentration of GQD nanoparticles used is 30 ppm. The experiment is conducted at various engine speeds of 800, 2100, and 2400 rpm. Emission parameters such as carbon monoxide (CO), carbon dioxide (CO_2), unburned hydrocarbons (UHC), and nitrogen oxides (NOx) were investigated. The results showed that CO and UHC emissions decreased by 29.54% and 31.12%, respectively, and nitrogen oxide (NOx) emissions resulted in a 1.29% increment compared to neat diesel fuel by Manigandan, Sarweswaran et al. (2020). The effect of TiO2 nanoparticle additive in neat diesel fuel on the emission characteristics of CI engines with and without TiO_2 nanoparticle additive is investigated. It is observed that with the addition of nanoparticles, there's a decrease in the emission of unburned hydrocarbons by 18% and carbon monoxide by 25%.

Mei, Zuo et al. (2019). have investigated the effects of carbon nanotubes (CNT) and nanomolybdenum trioxide (MoO_3) on the emissions characteristics of diesel in a common rail diesel engine. A single-cylinder common-rail diesel engine is used to conduct the experiments for investigating and comparing the engine emissions characteristics of nano-fuels with those of neat diesel. The test fuels include 100CNT (Diesel+100 mg/L CTAB+100 mg/L CNT) and 100MoO_3 (Diesel+100 mg/L CTAB+100 mg/L MoO_3). The test results showed that adding CNT and MoO_3 to pure diesel reduced emissions of HC, CO, NOx, and soot to various levels. CNT showed better capability in lowering all the emissions (HC 11.4%, CO 9.6%, NOx 8.9%, and smoke 15.2%) than neat diesel, and MoO_3 resulted in an emission reduction of HC 7.5%, CO 6.8%, NOx 5.2%, and smoke 8.3% than neat diesel.

Shaafi T. and Velraj R. (2015) have investigated the emission characteristics and engine performance of two modified fuel blends, B20 (80% diesel and 20% soybean biodiesel) and D80SBD15E4S1 alumina (80% diesel, 15% soybean biodiesel, 4% ethanol, and 1% isopropanol as an emulsifier, and alumina nanoparticles of 100 mg/L) in comparison to pure diesel. They also reported very encouraging results on the emission characteristics. They concluded that there is a reduction in major pollutants such as CO by up to 66% and CO_2 by 3.3% in the case of the D80SBD15E4S1 alumina fuel blend compared to pure diesel at full load. The reduction in emissions is due to the presence of oxygen in soybean biodiesel and its improved utilization due to the presence of alumina nanoparticles. However, when compared to pure diesel, alumina nanoparticles increased NOx emissions by 9.9% at full load in the case of the D80SBD15E4S1 alumina fuel blend .

Manigandan, Sarweswaran et al. (2020). investigated the exhaust emission characteristics of carbon nanotubes, aluminum oxide, and silicon oxide nanoparticles in a four-stroke single-cylinder engine. From the experiment, it is revealed that CNT nanoparticles produce elevated CO, CO_2, HC, and lower NOx emissions of 4.48%. Carbon nanotube blends with diesel perform better in terms of improving emission characteristics. Carbon nanotubes have the potential to be thoroughly researched as a diesel fuel additive due to their significant reduction in NOx emissions during combustion.

On the research done by Nanthagopal K, Ashok et al. (2017) to investigate the emission characteristics and performance of Calophyllum inophyllum biodiesel (CIME) nano emulsions on a two-cylinder CI engine, Unburned hydrocarbon and CO emissions are found to be lower for all CIME nano emulsions as compared to pure CIME and conventional diesel fuel because of the oxidation effect of TiO_2 and ZnO nano particles. The fuel CIME-T100 provided the maximum decrease in HC emission measurements compared to all other fuels. For the same concentration in the nano emulsion fuel, titanium oxide is found to be the best oxidizing agent when compared to zinc oxide. At full load, CO emissions from the CIME fuel process are 24.5% lower than those from pure diesel. CIME-T100 nanoemulsion fuel emits significantly less CO than neat Calophyllum inophyllum biodiesel fuel. A NOx emission reduction of 7–29% is observed for all CIME nanoemulsion fuels compared to neat Calophyllum inophyllum biodiesel at full engine load. This is because of the catalytic effect of the nanoparticles.

On the study conducted by Manigandan, Sarweswaran et al. (2020), Al_2O_3, CNT, TiO_2, CeO_2 and CuO nanoparticles and hydrogen mix emission characteristics, the test is done at different engine load conditions. The exhaust emission results showed that adding hydrogen and nanoparticles decreased carbon monoxide and hydrocarbon emissions considerably. However, for NOx emissions, CNT is the only blend that showed a decrease in NOx compared to other blends. From the results, they concluded that the addition of nanoparticles and hydrogen to pure diesel reduced exhaust gas emissions.

The expansion of nanoparticles in fuel advances total combustion due to their catalytic property and increase in cetane number. Complete combustion is characterized by the diminishment of CO and the concentration of HC emanation by Nallamothu, Lemma (2019). In diesel motors, NOx is formed due to the oxidation of the air nitrogen (N_2), at the peak combustion temperature. The blending of nanoparticles with diesel raises the top combustion temperature, causing more N_2 within the combustion chamber to be oxidized to NOx within combustion by Abu-Qudais, Haddad et al. (2000). Be that as it may, with diesel blended with nanoparticle-emulsified biodiesel, it has been found that NOx outflow levels were diminished in comparison with diesel fuel. This was recognized to the heat sink impact of the emulsified fuel, which restricts the in-cylinder gas temperatures within combustion. The summary of nanoparticle effect on the performance and emission characteristics is shown in table 4.

Table 4. Summary of nanoparticles influence on neat diesel and different biofuels

Reference	Fuel	Nanoparticle	BTE	BSFC	BP	Tb	CO_2	CO	UHC	NOx
33	Neat diesel	Al_2O_3	_	31%↓	_	_	↓	_	↓	_
34	bio-ethanol with10% (B10)	GQD	–	↓	24.59 %↑	20.02% ↑	–	35.60% ↓	42.05% ↓	–
35	Diesel, biodiesel and Ethanol emulsion	Al_2O_3	_	↓	_	_	_	↓	↓	↓
36	bio- diesel and ethanol blend	alumina nanoparticles	11.51% ↑	_	_	_	_	16.83% ↓	9.18% ↓	22.53% ↓
37	ethanol-biodiesel blends	GQD	_	12.42% ↓	28.18 %↑	14.35% ↑	–	29.54% ↓	31.12% ↓	1.29% ↑
38	Neat diesel	TiO_2	↑	22%↓	_	_	_	25%↓	18%↓	_
39	Neat diesel	CNT and MoO_3	5.2% and 2.3%, ↑	5.1% and 2.3%↓	_	_	_	9.6% And 6.8%↓	11.4%, and 7.5%↓	8.9% And 5.2%↓
40	Diesel, biodiesel and Ethanol emulsion	Al_2O_3	17.9%↑	18.5 %↓	_	_	3.3 % ↓	66% ↓	_	9.9%↑
41	Neat diesel	CNT	18.8%↑.	19.8% ↓	_	_	↑	↑	↑	4.48% ↑

42	Calophyllum inophyllum biodiesel	TiO_2 and ZnO	4% and 2%, ↑	0.24 and 0.258 kg/kWh↓	–	–	–	↓	↓	7–29%↓
43	Diesel+20% hydrogen	CeO_2 and Al_2O_3	4.3% and 2.5%↑	23% and 22%↓	–	–	↓	↓	↓	↓

Key: ↑- Increase ↓-decrease

2.11. The influence of ignition timing on performance and emission

In the last years, many studies on the IC engines aiming to improve performance and reduce exhaust emissions have been carried out by changing operating parameters such as valve timing, injection timing, and atomization rate. At the same time, depletion of fossil fuels and environmental considerations has led to investigations on the renewable fuels such as ethanol, hydrogen, and biodiesel.

While many studies related to the performance and exhaust emissions of diesel–ethanol emulsified fuels have been achieved, different conclusions regarding the engine operating conditions such as the injection timing and engine load have been reached. Therefore, in this work, experiments related to the performance and exhaust emission characteristics were conducted using ethanol diesel emulsion fuels. The purpose of this study is to investigate the effect of the amount of ethanol ratio on the Performance and exhaust emissions at various engine loads and the injection timings.

Fuel injection timing is a major parameter that affects the performance and exhaust emissions of a diesel engine. The state of air into which the fuel injected changes as the injection timing is varied, and thus ignition delay will vary. If injection starts earlier, the initial air temperature and pressure are lower so the ignition delay will increase. If injection starts later when piston is closer to TDC the temperature and pressure are initially slightly higher, a decrease in the ignition delay proceeds. Hence, injection timing variation has a strong effect on the engine performance and exhaust emissions, especially on the BSFC, BT, BP and NOx emissions, because of changing maximum pressure and temperature in the engine cylinder by Canakci, Sayin et al (2028)

On the other hand, it is reported by Murcak, Haşimoğlu et al. (2013), use of diesel ethanol fuel mixture in diesel engine needs some modifications like optimization of injection timing. Advanced injection timing enhance premixed combustion period and decreases the fuel consumption. In this study, the effects of diesel–ethanol mixtures and injection timing to engine operating parameters of a single cylinder, naturally aspirated, air cooled, direct injection diesel engine have been investigated. The test fuels were injected into the cylinder of test engine before the standard injection timing (27.5^0 BTDC) of the test engine with advance increment of 1.5^0 BTDC.

Payri, Benajes et al. (2006) conducted a study on a diesel engine operating at light load with standard injection and combustion systems. They retarded the start of injection timing for the aim of promoting the first phase of combustion in premixed condition. They reported that retarded fuel injection produces very low levels in smoke opacity and NOx emissions, but it causes to higher CO and THC emissions and a significant penalty in BSFC. At the light engine load, the combination of retarded fuel injection and introduction of exhaust gas recirculation (EGR) were proved to be very efficient in achieving smoke opacity and NOx levels .

Aktaş A. & Sekmen Y. (2008), investigated the effects of fuel injection advance on the performance and exhaust emissions of a four stroke, single cylinder DI diesel engine fueled with biodiesel. Engine torque, brake power, BSFC, exhaust gas temperature, CO, THC, and NOx emissions were measured for injection timings of 24.9^0, 26.6^0 and 28.5^0 crank angle at full load. When injection timing was increased to 26.6^0, the engine torque and BSFC increased by 6% and 8% respectively. In addition, it was also determined that CO and THC emissions decreased, while NOx emissions increased between 4% and 11% .

Sayin, C., & Canakci, M. (2009), studied the effect of injection timing on the exhaust emissions and engine performance of a DI diesel engine using ethanol-blended-diesel fuel. The original start of injection timing of the engine was 27^0 CA BTDC in the study. The tests were conducted at five different injection timings; 21^0, 24^0, 27^0, 30^0 and 33^0 BTDC. The results showed that BSFC, emissions of NOx and CO_2 increased however BTE, emissions of CO and THC decreased with increasing amount of ethanol in the fuel mixture. When compared to the results of original injection timing (27^0 BTDC), NOx and CO_2 emissions decreased, but THC and CO emissions increased at the retarded injection timings (21^0 and 24^0 BTDC) in all the test conditions. On the other hand, with the advanced injection timings (30^0 and 33^0 CA BTDC), THC and CO emissions decreased, and NOx and CO_2 emissions increased. In terms of BSFC and BTE, retarded and advanced injection timings gave negative results for all engine speeds and loads when compared to the results of original injection timing. Based on the above considerations, the objective of this study is to clarify the effects of injection timing on the performance and exhaust emissions of a diesel engine using ethanol- blended-diesel fuel.

Several studies have showed that the injection timing affects the level of exhaust emissions of CI engines. Parlak, Yaşar et al. (2005), studied the influence of injection timing on the NOx emissions and BSFC of a low heat release (LHR) indirect injection diesel engine using diesel fuel. The tests were conducted with variable loads at engine speeds of 1000, 1400, 1800 and 2000 rpm and the static injection timing of 38^0, 36^0, 34^0 and 32^0 crank angles BTDC. After the load tests were conducted for original diesel engine injection timing, same tests order was adopted for LHR engine. When the LHR engine was operated with the injection timing of 38^0 before top dead center (BTDC), which is the optimum value of the original engine, it showed that NOx emission increased about 15%. However, when the injection timing was retarded to 34^0 CA in the LHR case, it was observed some decreases on the exhaust emissions and BSFC about 40% and 6%, respectively, compared to that of the original injection timing.

Nwafor, O. M. I. (2000) examined the effect of advanced injection timing on the engine performance and exhaust emissions of natural gas used as a primary fuel in a dual-fuel CI engine. The test engine has original injection timing of 30^0 BTDC. The injection was advanced by 3.5^0 (i.e. 33.5^0 BTDC). The results indicated that dual fuel combustion produces larger percentage of HC emissions than those of pure diesel fuel. When running the engine at the advanced injection timing, significant reductions in CO and CO_2 emissions were obtained. On the other hand, advanced injection timing caused a slight increase in BSFC and decrease in BTE.

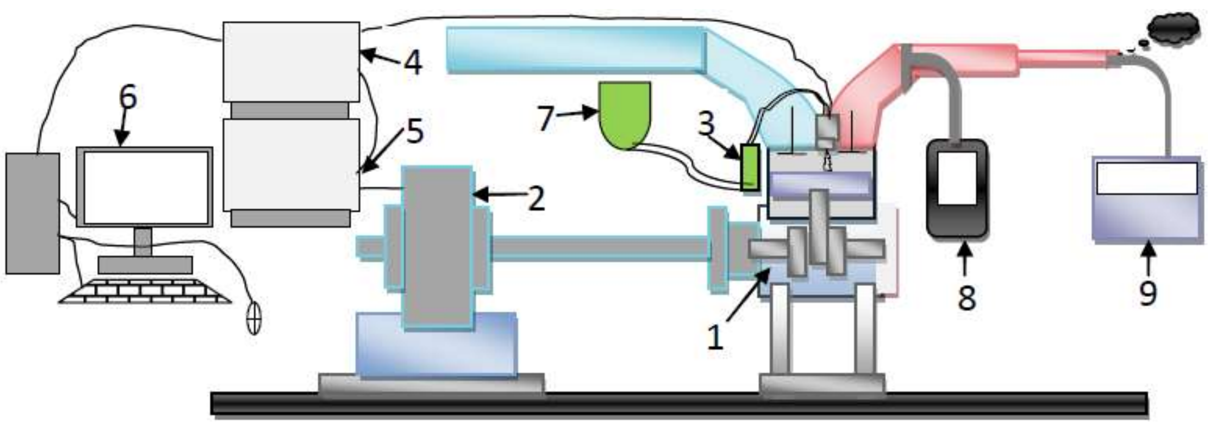
As shown above, the studies have not investigated the effects of advanced and retarded injection timings on the performance and emissions of a diesel engine using ethanol emulsified diesel fuel.

Metallic nanoparticles have different properties that come from the bulk metal, and the influence of the fuel properties is also affected accordingly. Iron oxide, nickel oxide, and zinc oxide nanoparticles are affordable due to the abundant availability of the sources. Nickel has a corrosion-resistant property that makes it preferable to reduce probable engine wear because of the presence of ethanol in the emulsified fuel, which reduces lubricity. It is also known for its corrosion resistance, making it suitable for use in ethanol-added fuel. Zinc oxide nanoparticles are a naturally occurring element with low toxicity and are widely used in industries such as cosmetics, electronics, and healthcare. Its low toxicity makes it an additive with no negative effect on human health. To get the combined advantage, the three elemental nanoparticles NiZn Fe2O4 with a proportion of O2 29.4, Fe 40.8, Ni14.6 and Zn 15.2 by weight percentage are selected as an additive to catalyze the combustion reaction.

From the literature review, it was concluded that exhaust emissions such as unburned HC, CO, CO_2 and NOx and performance parameters such as Torque, power and BSFC of a diesel engine have not been investigated when using ethanol emulsified diesel fuel. At the same time, the influences of injection timing on the engine performance and exhaust emissions have not been clearly studied when using ethanol emulsified diesel fuels in a CI engine. Therefore, these study investigated difficulties which are not well addressed in literature. For this reason, in the present study, the effects of ethanol content in ethanol emulsified diesel fuel, addition of $NiZnFe_2O_4$ nanoparticle and injection timing on the engine performance and exhaust emission are investigated.

CHAPTER THREE
MATERIALS AND METHODS

Various materials and laboratory equipment are utilized to achieve reliable result from this research. Emulsions of ethanol and diesel are prepared in different proportions as sample fuels by using a mixture of tween 80 and span 80 as an emulsifying agent. Three elemental Nickel Zinc Iron Oxide ($NiZnFe_2O_4$) nanoparticles are applied to the emulsion, and cetyl trimethyl ammonium bromide (CTAB) is used as a surfactant to help the nanoparticles remain homogeneously mixed in the fuel. To test the performance characteristics of the fuels, a single-cylinder engine with an eddy current type dynamometer is used. The arrangement of the performance and emission test is shown in figure 5.



1 Test engine, 2 Electromagnetic brake, 3 Fuel flow meter, 4 control Interface, 5 Loading unit, 6 Data acquisition computer, 7 Fuel tank, 8 Exhaust gas analyzer, 9 smoke opacity meter

Figure 5. Engine performance and emission test setup

3.1. Materials

The materials used to prepare the sample fuels are diesel fuel, purchased from the locally available gas station in Adama city; ethanol, produced in Methara sugar factory, which is used as biofuel; Emulsifiers, Span 80 and Tween 80, are used to emulsify the ethanol in diesel fuel; three elemental nanoparticles, Nickel Zink Iron Oxide, which are 10–30 nm in size as indicated in Figure 6, are used as combustion enhancement additives; and Cetyl Trimethyl Ammonium Bromide (CTAB) is used as a surfactant for homogeneous dispersion and stability of the nanoparticle. Laboratory equipment such as a magnetic stirrer for mechanical agitation and an ultrasonicator for ultrasonic vibration mixing are used. The specifications of the materials used are indicated in tables 5–8.

Table 5. property of diesel and ethanol (Sajeevan, A. C., and Sajith, V. 2013).

Fuel	Formula	Mole weight(g .mol^{-1}	Heat content (MJ/kg)	Viscosity (mPa s)	Density at 20 ^{o}C (10^3 kg/m^3)	Flashpoint (^{o}C)	Boiling point(^{o}C)	Pour point (^{o}C)	CN
Diesel	$C_{12}H_{23}$	190–220	42.5	3.35	0.829	65–82	180–360	-1 to 3	45–50
Ethanol	$C_2 H_5OH$	46.07	26.8	1.20	0.789	13–14	78.4	-117.3	5–8

Table 6. 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 7. Physical properties of Cetyl Trimethyl Ammonium Bromide (CTAB)

	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 8. Nickel Zinc Iron Oxide Nanoparticles ($NiZnFe_2O_4$) physical properties

S.N	Parameters	Nickel Zinc Iron Oxide 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)	10-30nm
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/cm3
9	Purity	99.5%

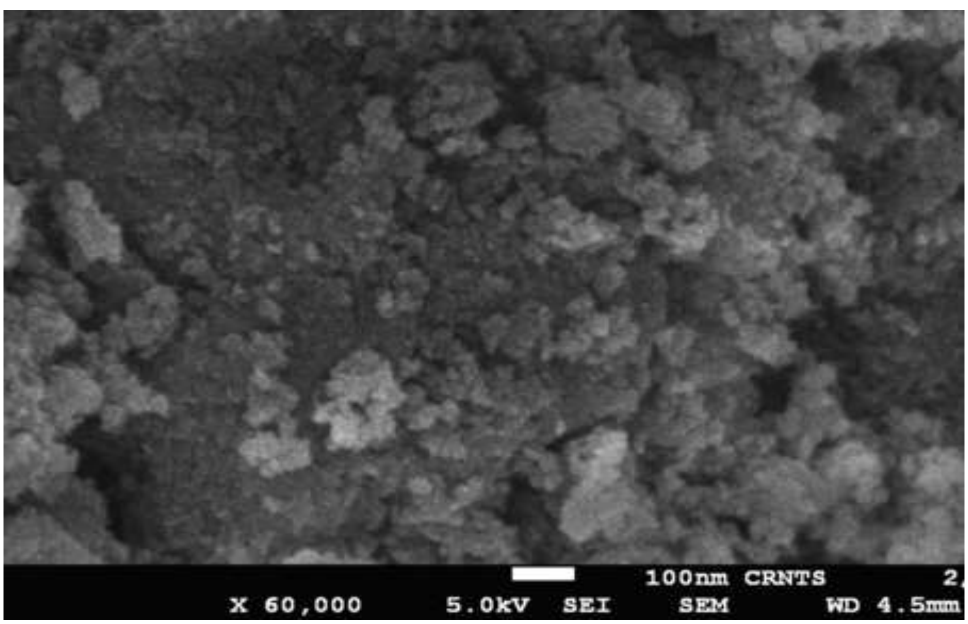


Figure 6. Scanelectronic microscop image

Sample fuel preparation is done with the use of a magnetic stirrer, an ultrasonicator, and a digital balance, which are available in the materials engineering department laboratory of the Adama Science and Technology University. The materials used are shown in figure 7.

A **B** **C**

Figure 7. The laboratory equipment used to prepare emulsion fuel samples (A) Digital balance (B) Magnetic stirrer and (C) Ultrasonicator

To measure the performance and the emission characteristics of the various test fuel samples prepared, different laboratory equipment such as an engine dynamometer, an exhaust gas analyzer and a smoke meter are used, as shown in figure 8. The engine used for the test is a single-cylinder, four-stroke diesel engine. The specification of the test engine is given in Table 9.

Table 9. 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	27^0 BTDC
Injection pump	Bosch K type mini pump
Injection pressure	140 Kgf/cm^2

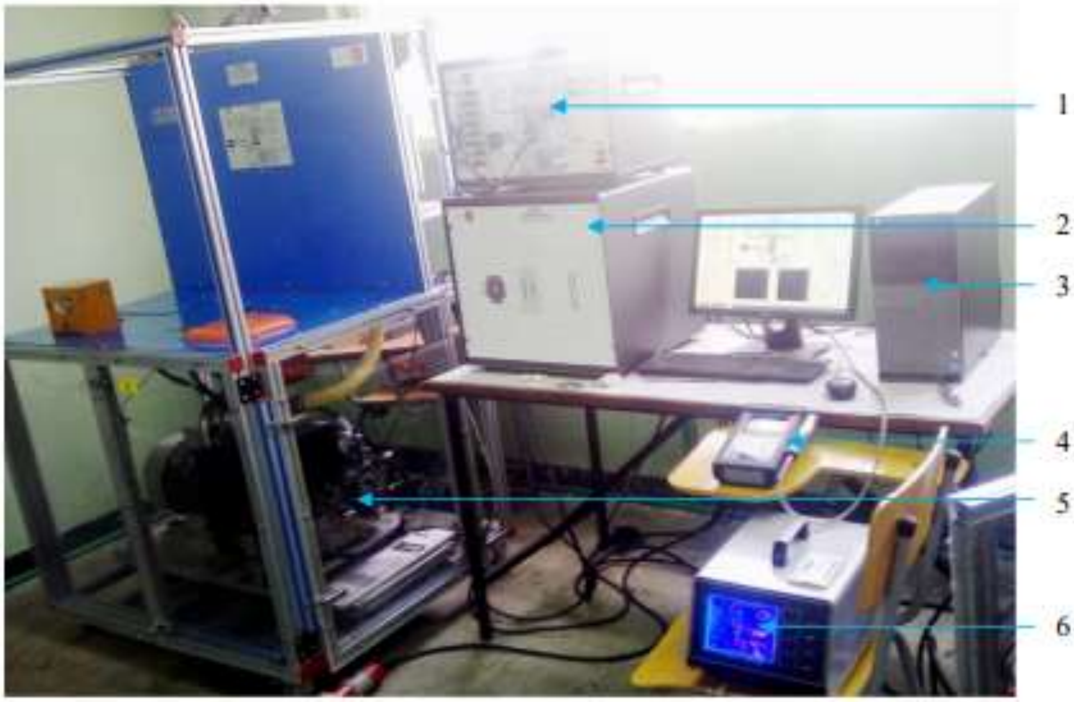


Figure 8. Experimental test setup, 1 – Control interface, 2 – Loading unit, 3 – Data acquisition and management computer, 4 – Exhaust gas analyzer, 5 – Engine with dynamometer, 6 – Smoke meter

3.1.1. Dynamometer

Engine data including torque, power, fuel consumption and pollutant emissions can be measured while the engine is being tested on the dynamometer. Various dynamometer tests come in a variety of forms. The most widely used techniques are:

(i) load-controlled Regardless of engine speed, a predetermined load is maintained by the dynamometer. These tests are also known as transient tests (with reference to speed).

(ii) speed controlled tests maintain a set speed independent of engine torque. According to the desired strategy, this operation mode is frequently employed for calibration of the engine control unit (ECU), which affects engine speed and other factors like fuel efficiency, power output, etc.

Eddy current dynamometers (ECDs) are the specific kind of dynamometers employed in this test. ECDs are made up of two parts: (i) a stator coil energised by DC current, and (ii) a rotor designed as a notched disc that, as it rotates, creates a difference in magnetic flux density and eddy currents. These eddy currents form an induced magnetic field that opposes the direction of rotation of the rotor, producing a brake torque. The transient speed variation with torque change due to the variation of load on the dynamometer is given in figure 10.

The main advantages of the ECD over the other categories of dynamometers are: (i) high brake torque at high speeds, (ii) simplicity and roughness, (iii) low cost of installation and maintenance, (iv) it does not uses friction to apply load, (v) It is not necessary for the operator to exert all of the brake force; additional brake torque is produced by the eddy currents in the rotor. Some ECD drawbacks should also be cited: (i) it cannot provide accelerating torque (only works as a brake), (ii) the energy from the braking process cannot be regenerated back to the power source, (iii) low brake torque at very low speeds. The schematic diagram showing the principle of operation of an eddy current dynamometer is shown in figure 9.

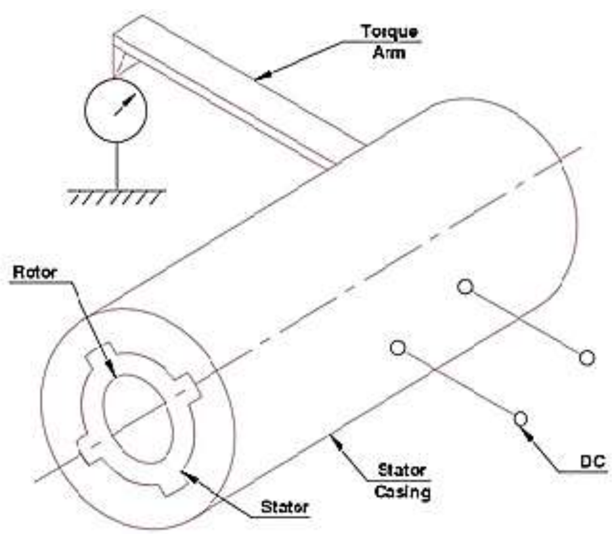


Figure 9. Eddy current dynamometer working diagram

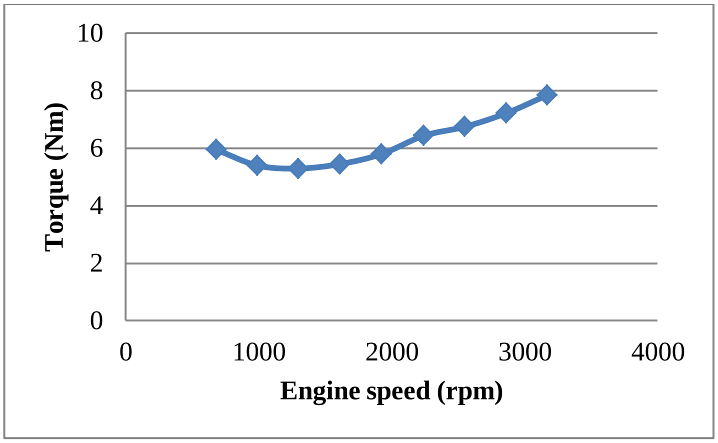


Figure 10. Engine speed vs torque

A computer-controlled test bench for single-cylinder internal combustion engines of up to 7.5 kW is used for this research. 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 varies its torque characteristics. The unit also includes a number of sensors that provide the measured values of the variables to be studied. The test bench is used to measure the torque, power, and pressure 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 is obtained. The computer-controlled unit includes an eddy current type dynamometer, a control interface box, a data acquisition board, and a controlling computer. For controlling parameters, data management software packages and data acquisition are incorporated.

3.1.2. Exhaust gas analyzer

In order to diagnose engine emission problems An exhaust gas analyzer is used to measure the amount of carbon monoxide (CO), carbon dioxide (CO_2), hydrocarbon (HC), oxygen (O_2), nitrogen oxide (NOx), and oxygen balance (Lambda) in the exhaust gas. The specification of the exhaust gas analyzer is given in Table 10.

Table 10. Technical Data of the Exhaust Gas Analyzer

ITEM	Measurement Range	Resolution
CO	(0-10%),	0.01
CO_2	(0-16%),	0.1
HC	(0-5000ppm),	1
O_2	(0-21%),	0.01
NOx	(0-5000ppm)	1
Lambda	(0.8-1.2)	

3.1.3. Smoke meter /Opacimeter

Diesel particle emissions can be indirectly measured using smoke opacity sensors, which detect the optical characteristics of diesel smoke. There are two types of instruments: smoke number meters, which optically assess soot gathered on paper filters, and opacity meters, which assess smoke in exhaust gas. Based on opacity measurement, correlations have been built to estimate PM mass emissions. The use of second-generation opacity meters based on laser light scattering with more recent engines with significantly lower particulate emissions appears to be promising because they are much more sensitive.

Intensity of smoke emitted from the exhaust is measured by smoke meter /opacimeter. It measures the smoke density within the range of 0-99.90% opacity with a resolution of 0.01% as indicated in the specification of the meter indicated in Table 11.

Table 11. Technical Data of the smoke meter /opacimeter

ITEM	Resolution	Measurement Range	Absolute Accuracy	Relative Accuracy
Opacity(N)	0.01%	0-99.90%	±2%	
Optical Absorption Coefficient(K)	$0.01m^{-1}$	$0\text{-}16.08m^{-1}$		$0.05m^{-1}$
Oil Temperature	1°C	0-200 °C	±5 °C	
Gas Temperature	1 °C	0-150 °C	±5 °C	

3.2. Method

3.2.1. Fuel sample preparation

The ethanol used to make the sample test fuel is obtained from the Metehara sugar factory in Ethiopia. It is produced from molasses, a byproduct of sugar production. The diesel fuel is purchased from a locally available gas station in Adama, Ethiopia. Span 80 and Tween 80 chemicals and different glassware are purchased from Addis Ababa city. Nickel Zinc Iron Oxide Nanoparticles ($NiZnFe_2O_4$) and Cetyl Trimethyl Ammonium Bromide (CTAB) are purchased from India.

The blending ratios are prepared by measuring and pouring them into the prearranged mixing beaker. The mixing ratio of diesel, ethanol, emulsifier nanoparticles, and surfactant is shown in Table 13. The sample fuels are prepared in the materials science and engineering department laboratory at Adama Science and Technology University. Figure 11 depicts the standard (stage-by-stage) emulsion preparation procedures for ready emulsified fuels. 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. The working condition and procedure details of each step are shown in Table 13. The first step is the same for all the fuels.

Ethanol-diesel emulsions are observed to be stable when used with a surfactant, having an HLB value of 8–10. Thus, an HLB of 9 was used. The mixture of high and low HLB surfactants (Tween 80 and Span 80) forms the most stable emulsion; the properties of tween 80 and Span 80 are shown in Table 12. To obtain an HLB of 9, the proportional amount of tween 80 and span 80 is determined by the formula:

$$HLB\ of\ Emulsifier\ Mixture = Mass\ of\ Span80 \times HLB\ of\ Span80 + Mass\ of\ tween80 \times HLB$$

$$\left(Tween80\right) / (MassTween\ 80 + MassSpan80)$$

$$\%Tween80 = \frac{HLB\ of\ Emulsifier\ Mixture - HLB\ of\ Span80}{HLB\ of\ Tween80 - HLB\ of\ Span80} \text{ x100}$$

$$\%Tween80 = \frac{9 - 4.3}{15.0 - 4.3} = 0.44 = 44\%$$

$$\%Span80 = 100\% - 44\% = 66\%$$

The emulsion preparation setup, as indicated in Figure 11, consists of a stirrer with a speed controller and an ultrasonicator. The speed controller can go up to a maximum of 1500 RPM.

Table 12. 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

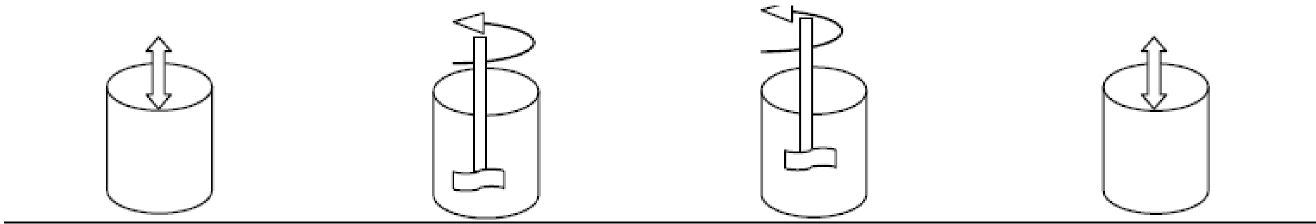


Figure 11. Stage by stage emulsion preparation process

Table 13. Operating conditions for emulsified fuel preparation.

Stapes	Process	Factors	Composition
1	Sonication	25°C, 40 kHz, 30 min	Tween 80+Span 80
2	Magnatic Steering	25°C, 1,500 rpm, 20 min	Diesel+ Ethanol+ emulsifier
3	Magnatic Steering	25°C, 1,500 rpm, 10 min	Emulsion+ nanoparticle+ surfactant
4	Sonication	25°C, 40 kHz, 30 min	Emulsion+ nanoparticle+ surfactant

Test fuels are prepared by varying the amount of ethanol (5%, 10%, and 15%) added to pure diesel fuel, and a 2% volume ratio of an emulsifier is used. In each emulsion ratio, a nanoparticle additive is used in amounts of 25, 50, and 100 ppm, and the same amount of cetyltrimethyl ammonium bromide (CTAB) as the nanoparticle surfactant is used. The test fuel preparation constituents are shown in Table 3.10.

Table 14. Test fuel preparation

Fuel sample	Fuel mixture in percent	Surfactant	Emulsifier
E0	Pure diesel		
E5	95Diesel +5Ethanol		Tween

E10	90Diesel +10Ethanol		80,HLB=15 and span 80, HLB=4.3
E15	85Diesel +15Ethanol		
E5-3N-25	95Diesel +5Ethanol+25ppm	Cetyl Trimethyl Ammonium Bromide (CTAB)	emulsifier (44%tween 80+ 56%span80) About 2%
E10-3N-25	90Diesel +10Ethanol+25ppm		
E15-3N-25	85Diesel +15Ethanol+25ppm		
E5-3N-50	95Diesel +5Ethanol+50ppm		
E10-3N-50	90Diesel +10Ethanol+50ppm		
E15D 3N50	85Diesel +15Ethanol+50ppm		
E5- 3N-100	95Diesel +5Ethanol+100ppm		
E10-3N-100	90Diesel +10Ethanol+100ppm		
E15-3N-100	85Diesel +15Ethanol+100ppm		

3.2.2. Fuel Stability

Five samples are chosen from the list of fuels produced to analyze performance and emission characteristics to determine the emulsion stability of the test fuels. The stability of emulsified fuels in various proportions is tested at room temperature, which varies from 20 to 30°C depending on the ambient weather conditions. As illustrated in figure 12(A) which is taken right after the emulsion is made as the sample fuels in table 14 are kept in a closed cup transparent glass container to visually evaluate the ethanol condition and nanoparticle stability. The inspection takes place every thirty minutes for the first four hours, then every hour for the next four hours, then every 12 hours for the next nineteen days. Figure 12(B) shows the status of separation of the sample fuel after it has been followed for nineteen days.

Table 15. List of fuel samples for stability test

Fuel sample	Fuel mixture	Surfactant	Emulsifier
D95E5	95%Diedel +5%Ethanol		Tween 80,HLB=15 and Span 80, HLB=4.3 44% Tween 56% Span About 2%
D90E10	90%Diedel +10%Ethanol		
D85E15	85%Diedel +15%Ethanol		
D90E10-3N-50	90%Diedel +10%Ethanol+50ppm	Cetyl Trimethyl Ammonium Bromide (CTAB)	
D90E10 3N100	90%Diedel +10%Ethanol+100ppm		

(A) (B)

Figure 12. Sample fuels prepared for stability inspection, (A) before separation; (B) after separation

3.2.3. Engine performance test

Engine performance testing is conducted in the Addis Ababa Science and Technology University Mechanical Engineering department. The engine is run for thirty minutes to reach operating temperature, and the remaining fuel from the fuel system is completely drained. To load and unload the eddy current type dynamometer brake, the load condition is varied using computer software with operator control. The data acquisition system records power and torque measurements with operator control. The test data is collected by varying the load condition from 0% to 80% with a 10% variation. For each fuel sample, the test is done three times, and the average value is used.

3.2.4. Engine exhaust gas emission test

A kane auto plus automotive five gas exhaust gas analyzer is used to measure the amount of CO, CO_2, HC, O_2, NOx, and oxygen balance (Lambda) in the exhaust gas. The measurement of exhaust gas emissions begins with calibrating the analyzer to automatic zero. During this sequence, the analyzer pumps fresh air into the sensors to allow the analyzer to be calibrated to zero for the CO, HC, CO_2, and NO sensors and the oxygen sensor to be set to 20.9 percent. Once the initialization is complete, the analyzer sets the CO, HC, CO_2, and NO to read zero and the oxygen to 20.9% when the exhaust sampling probe of the analyzer is kept open to pump in fresh air. Then the sample gas collector probe is properly connected to the end of the exhaust pipe. And each load variation is measured, with one minute of measurement settling time allowed. CO_2, CO, O_2, HC, NO, and measurements are recorded three times, and the average value is taken for each gas value.

3.2.5. Smoke opacity test

The variation in smoke density is measured using an opacity meter. According to the opacimeter manual, the sample collection probe is attached to the end of the exhaust pipe. The opacimeter is left running for approximately 30 minutes to warm up and calibrated to zero. After the instrument is calibrated, the level of opacity is measured according to the measuring scale.

3.2.6. Timing

At the point where the pump and engine are connected, the timing was adjusted by changing the thickness of the shim. The injection timing is advanced by 1.5° of crank angle when the shim thickness is decreased by 0.15 mm. Diesel fuel without any additives was used, and the engine's operating parameters, including injection pressure and timing, were 140 Kgf/cm^2 and 27° bTDC, respectively. The outcomes with the chosen fuel samples, E5-3N-100, E10-3N-100, and E15-3N-100, were compared to those with diesel under various injection timing conditions and diesel under regular operating conditions (140 Kgf/cm^2 and 27° bTDC). In order to attain the steady state condition by maintaining its temperature level, the engine was initially made to run in an idle state for 30 minutes. After the engine is reached to its steady state condition the measurement for torque and power are taken from the dynamometer with the help of the data acquisition system interfaced to it. Additionally the exhaust emission is also evaluated for the constituents of CO, CO_2, HC, NOx and Smoke opacity with exhaust gas analyzer and smoke meter. The ratios of the experimental values of the engine performance parameters and exhaust emissions obtained with the fuel blends to those with diesel fuel were determined and compared in graph.

3.3. Error and uncertainty

Errors are significant during experimental measurements and the calculation of performance measures. The occurrence of errors and uncertainties is influenced by a number of factors, including instrument selection, calibration, relative condition, environment, reading, observation, and test design. Uncertainty analysis is required in order to demonstrate the reliability of the results produced. Table 16 lists the range and resolution of the uncertainty of the instruments used on the experiment. The current experiment's total level of uncertainty is calculated as follows.

Table 16. List of devices and its range, accuracy and percentage uncertainties

S/No	Device specification	Measuring range	accuracy	Uncertainty
1	Engine speed	0-6000rpm	0.001rpm	1.66667E-05
2	load	0-100%	1%	1
3	power	0-7.5 kW	0.001kW	0.01
4	Fuel consumption	2 – 40 ml/min.	2 ml/min.	5
5	CO	0-10%	0.01%	0.1
6	CO_2	0-16%	0.1%	0.625
7	HC	0-5000ppm	1ppm	0.02
8	O_2	0-21%	0.01%	0.05
9	NOx	0-5000ppm	1ppm	0.02
10	smoke meter	0-99.90%	±2%	2

Overall uncertainty of the experiment = ±Square root of (uncertainty of engine speed)^2 + (uncertainty of load)^2 + (uncertainty of power)^2 +(uncertainty of fuel consumption)^2 + bnbn(uncertainty of CO)^2 + (uncertainty of CO_2)^2 + (uncertainty of unburned HC)^2 + (uncertainty of NOx)^2 + (uncertainty of smoke number)^2

$= \pm\sqrt{}(1.66667E\text{-}05)^2 + (1)^2 + (0.01)^2 +(5)^2 + (0.1)^2 + (0.625)^2 + (0.02)^2 + (0.02)^2 + (2)^2$

= ± 5.15%

CHAPTER FOUR

RESULT AND DISCUSSION

4.1. Stability of test fuel

The observing value of the emulsion stability showed that the nanoparticle added in to the emulsion remained suspended for four days. After the fourth day, the entire nanoparticle added into the fuel sediment at the bottom of the inspection glass, in line with Sajeevan, A. C., and Sajith, V. (2013). When the condition of the ethanol separation from the diesel fuel is seen, the D95E5 fuel sample took about 19 days to separate. The next fuel sample, D90E10, D90E10-3N50 and D90E10-3N100 stayed only for 144 hours without separating. The sample fuel D85E15 stayed the shortest time, 108 hours without separating. The evaluated result indicated the amount of ethanol in the emulsified fuel highly affects the stability of the emulsion. As the amount of ethanol increases the tendency of separation also increase due to the physical property such as density difference of ethanol and diesel fuel and the water contained in the ethanol in line with Ghannam, M. T., and Selim, M. Y. (2009). Figure 13 shows the time the emulsified fuels took to separate.

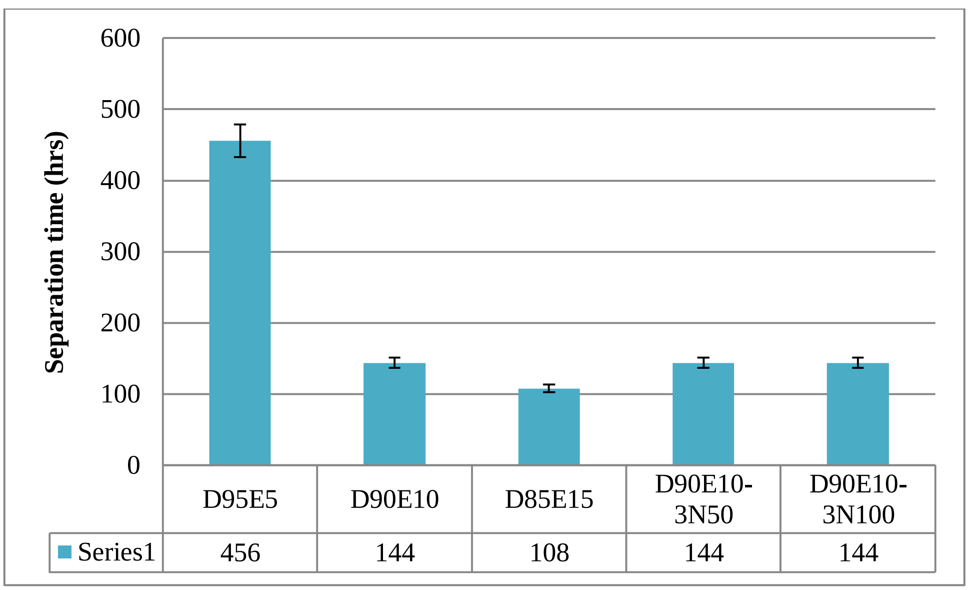


Figure 13. The influence of ethanol content on the stability of the emulsion

4.2. Measured Performance result

4.2.1. Torque

In this test, four fuel samples E0, E5, E10, and E15 are used. The engine torque decreased throughout the test as the load increased from no load to 60% load, with a slight increase with succeeding load increments up to 80% load. When we compare the torque output of each sample at low engine speed, the torque output of the 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, which enhances the combustion efficiency and results 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 an elongated time for combustion. This makes the torque output of E0 the highest of all the other fuels at higher engine speeds, as shown on the graph in Figure 14 below. The overall result showed 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 compared to E0. The decreased energy content of ethanol, which causes the calorific value of the sample fuel to decrease as per the proportion added compared to pure diesel fuel, is the cause of the reduced torque and power. Moreover, the burning quality of the fuel also changes with the ethanol addition; the increased amount of ethanol results in a lower sample fuel cetane number, which could potentially reduce engine performance. On the contrary, the oxygen content in the ethanol tends to facilitate combustion once the fuel starts to burn, and the best performance is recorded for the fuel sample with 10% ethanol out of the other emulsion fuels.

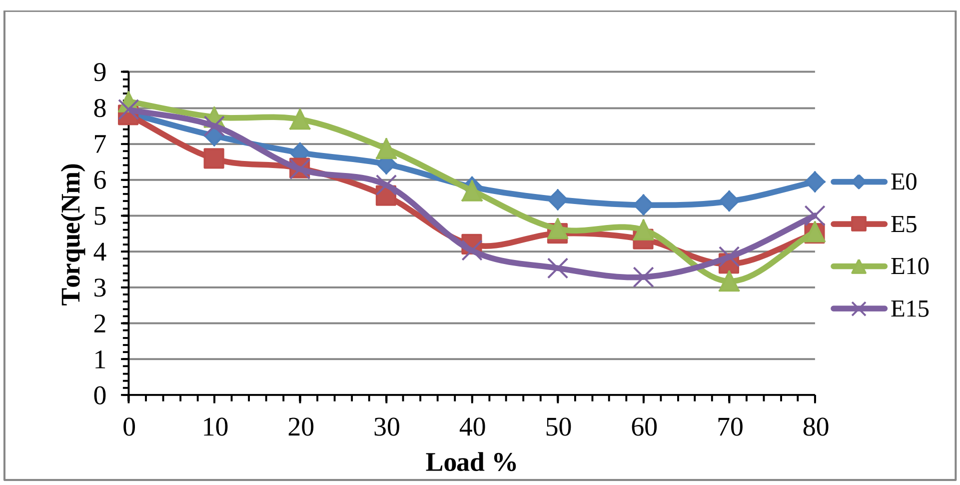


Figure 14. The effect of ethanol amount on engine Torque

When compared to the E0, the torque produced by the E5 fuel sample is 15.52 percent lower. Three elemental nanoparticle additions improved the torque output due to the improvement of the combustion characteristics. The torque improvement for fuel with a 25 ppm nanoparticle added sample (E5-3N25) is not significant; however, for 50 ppm (E5-3N50) and 100 ppm (E5-3N100) nanoparticle added fuel samples, increments of 11.3 and 9.1 % are recorded, respectively. The characteristic pattern is illustrated on figure 15.

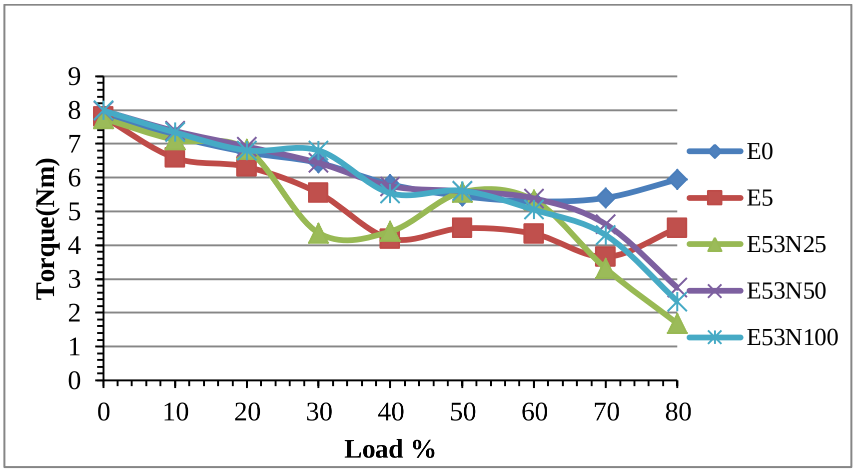


Figure 15. The effect of three elemental nanoparticle amounts on engine Torque

The torque characteristics of the fuel sample with 10 percent ethanol and with the addition of three elemental nanoparticles with 25, 50, and 100 ppm are as illustrated in figure 16. Compared to the E10 fuel sample, the nanoparticle-added fuel samples resulted in better torque output with increments of 3.5, 3.03 and 3.53% for E10-3N-25, E10-3N-50, and E10-3N-100, respectively.

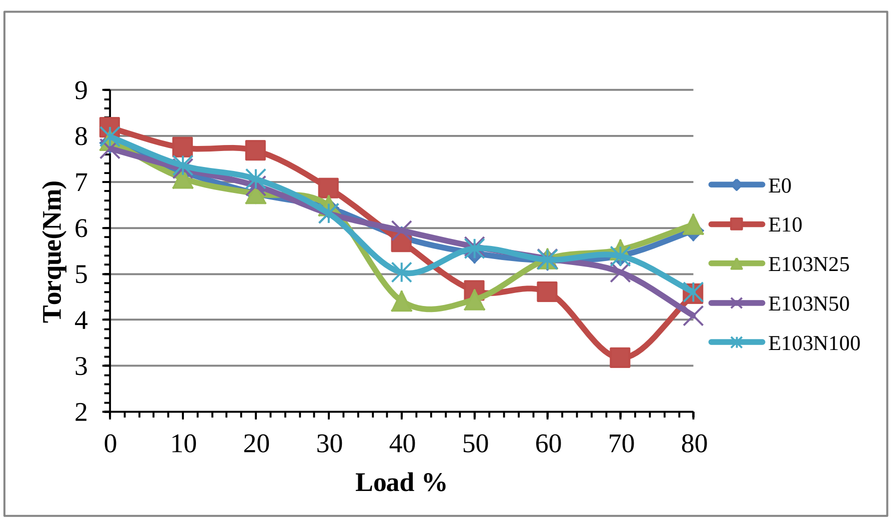


Figure 16. The effect of 3 elemental nanoparticle addition on the engine torque output of E10 fuel sample.

The last fuel sample used in this investigation is a fuel sample with 15 percent ethanol and with 25, 50, and 100 ppm of nanoparticle doping. The graph indicates the lowest torque output is recorded by an E15 fuel sample, as shown in Figure 17. This is due to the low calorific value of the fuel and poor combustion as a result of its low cetane number. Compared to the E15 fuel sample, E15-3N-25, E15-3N-50, and E15-3N-100 have shown torque improvements of 10, 13, and 16 percent, respectively.

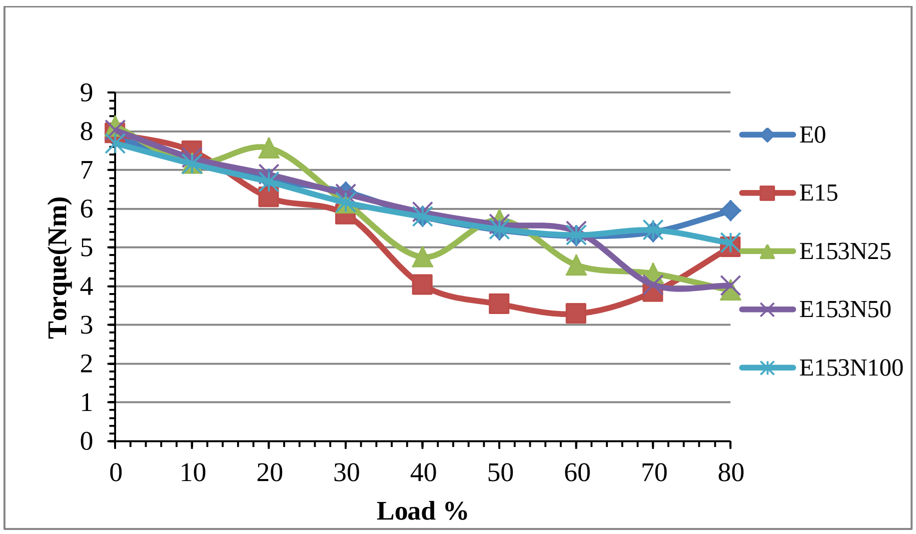


Figure 17. The effect of three elemental nanoparticles in E15 on engine torque output

4.2.2. Power

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 18, 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, the power output is reduced for all ethanol-added fuels because of the lowering effect of the emulsion calorific value. 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 the micro-explosion effect, a combustion improvement is expected even though the calorific value of the fuel is lowered. From the above-mentioned characteristics, the test result indicates the lowest reduction in power is noted in the E10 fuel sample.

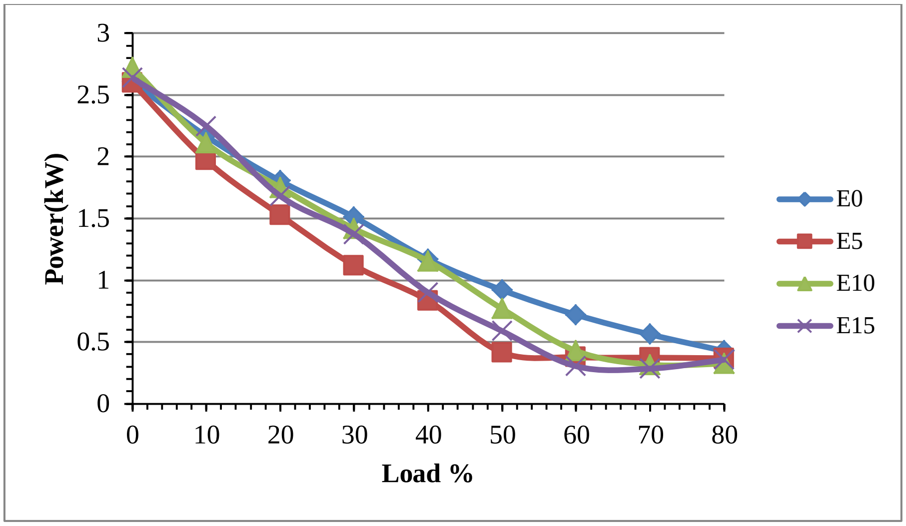


Figure 18. The effect of ethanol on engine power

The use of three elemental nanoparticles in E5 improved the power output. The catalytic behavior and high surface area to volume ratio of the nanoparticle property enhance the combustion, resulting in an improvement in the engine's power output. Figure 19 presents the engine power change as the nanoparticle amount varies at varying load conditions. Compared to E5, the nanoparticle-added fuels E5-3N-25, E5-3N-50, and E5-3N-100 improved the engine power output by 12.64, 22.84, and 22.47, respectively.

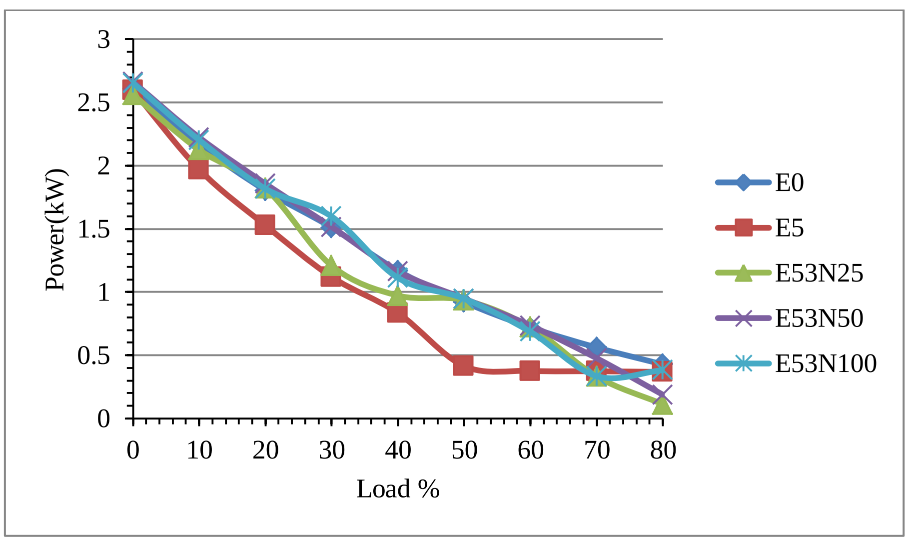


Figure 19. The effect of 3 elemental nanoparticle in E5 on engine power

Figure 20 shows the effect of three elemental nanoparticles on the power output of E10 fuel emulsion. From the result, it is seen that there is an improvement in power due to the use of nanoparticles. In comparison to E10, the fuel samples E10-3N-25, E10-3N-50, and E10-3N-100 have shown improvements of 5.43, 7.74, and 6.97% in engine power output, respectively.

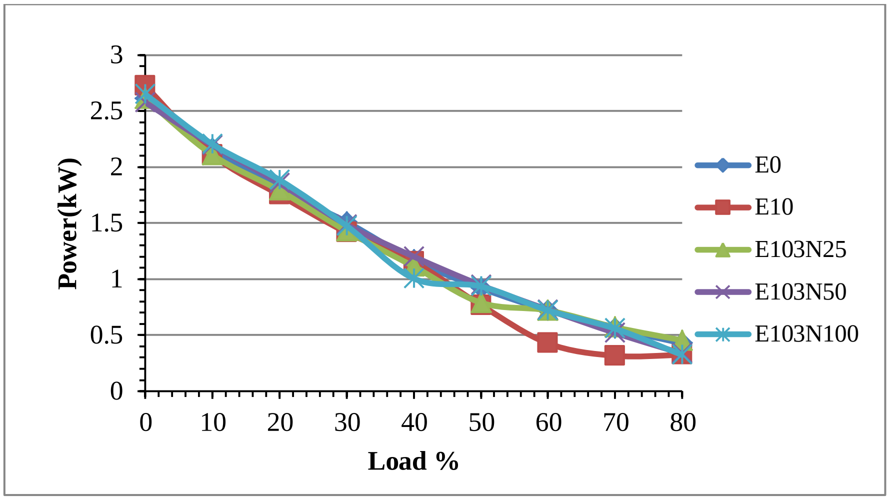


Figure 20. The effect of 3 elemental nanoparticle in E10 on engine power

The influence of three elemental nanoparticles in E15 on the power output of the engine is shown in figure 21. The overall effect of the nanoparticle on the engine's power output is an 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 E15-3N-50 and E15-3N-100 show that the 50 ppm nanoparticle amount saturated the fuel sample, so the additional 50 ppm was used in excess.

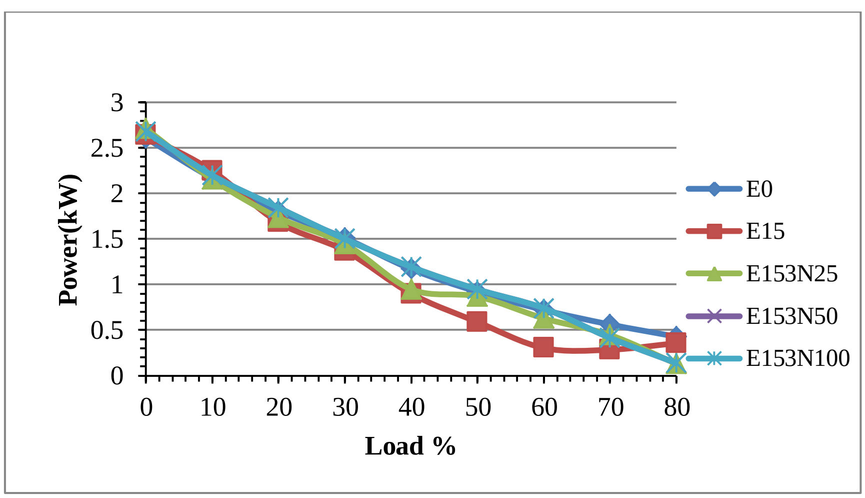


Figure 21. The effect of three elemental nanoparticle in E15 on engine power

4.2.3. 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 conditions, 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 22–25. The further load increment makes the engine vibrate harshly and leads to shut down. The low BSFC at high engine load is because the engine speed becomes low and the fuel has insufficient time to complete its combustion process. The engine compression pressure and temperature also increase as the engine load increases, resulting in improved combustion. As shown in Figure 22, the amount of ethanol in the diesel ethanol emulsion greatly affected the BSFC. As the ethanol amount increases, mainly the calorific value and the cetane number, which highly influence combustion efficiency, decrease. The collected data showed 27.17, 34.39, and 37.87% BSFC increments for E5, E10, and E15 fuel samples, respectively.

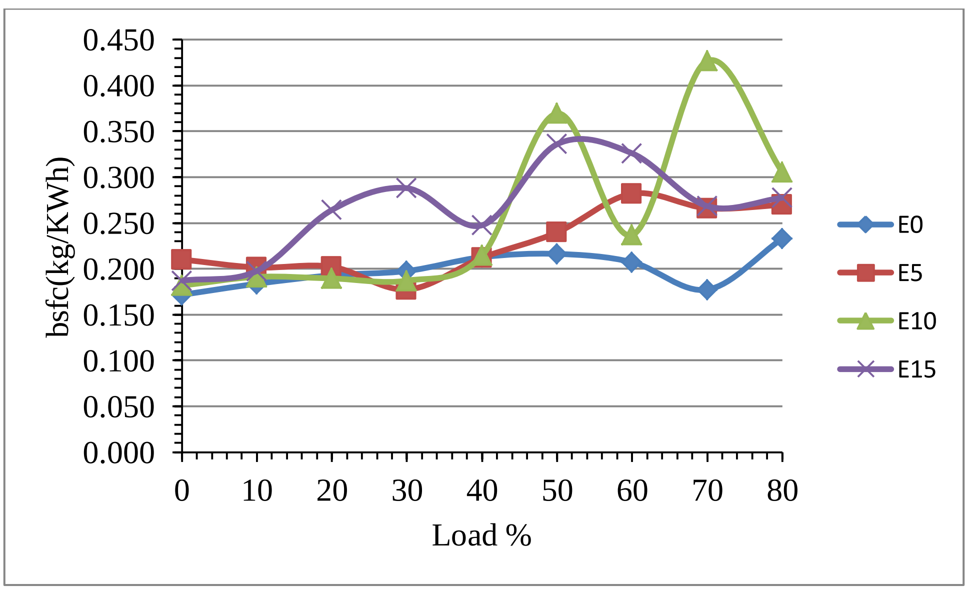


Figure 22. The effect of ethanol on engine fuel consumption

The nanoparticle effect in E5 on BSFC is plotted on the graph in Figure 23. As it shows, the nanoparticle use reduced the BSFC for the fuel samples E5-3N-25, E5-3N-50, and E5-3N-100 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 E10-3N-25, E10-3N-50, and E10-3N-100 by 16.79%, 27.86%, and 27.48%, respectively, as shown in figure 24.

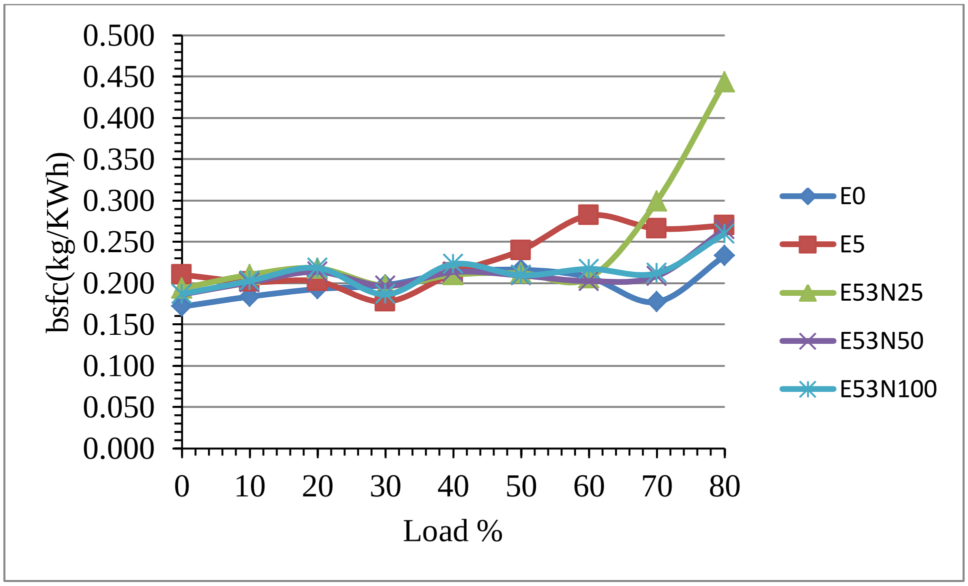


Figure 23. The effect of 3 elemental nanoparticle adding in E5 on engine fuel consumption

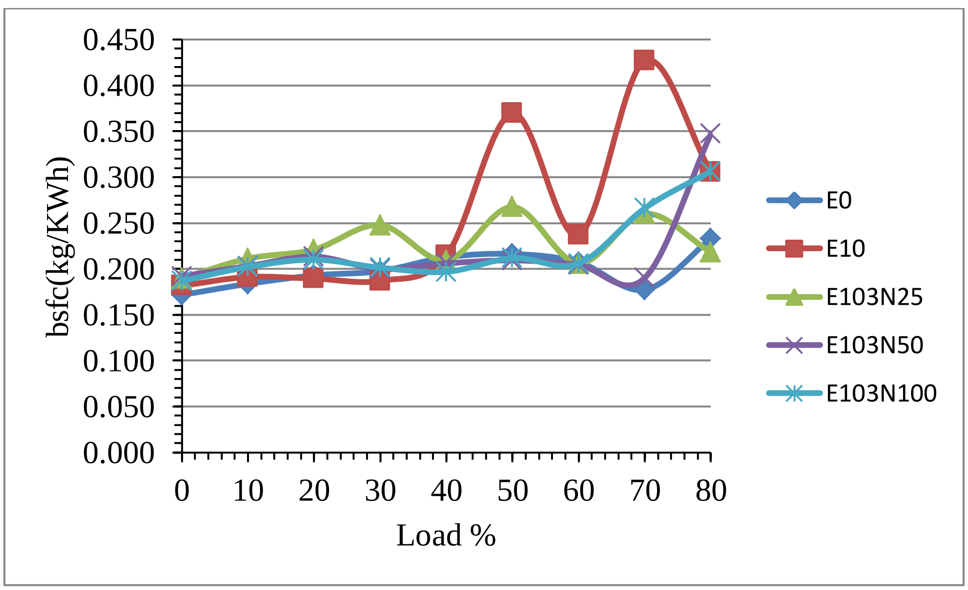


Figure 24. The effect of 3 elemental nanoparticle adding in E10 on engine fuel consumption

When applied to E15, the nanoparticle's influence is assessed as well, and the outcome is a lower BSFC as indicated in figure 25. Compared to E15, the amount of BSFC reduction for E15-3N-25, E15-3N-50, and E15-3N-100 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 known chemical properties of ethanol, it is known that the heating value and the combustibility in diesel engines are low, so these properties also affect the emulsion. Nanoparticles improve combustion efficiency by acting as a chemical reaction catalyst and creating a micro-explosion in the combustion chamber.

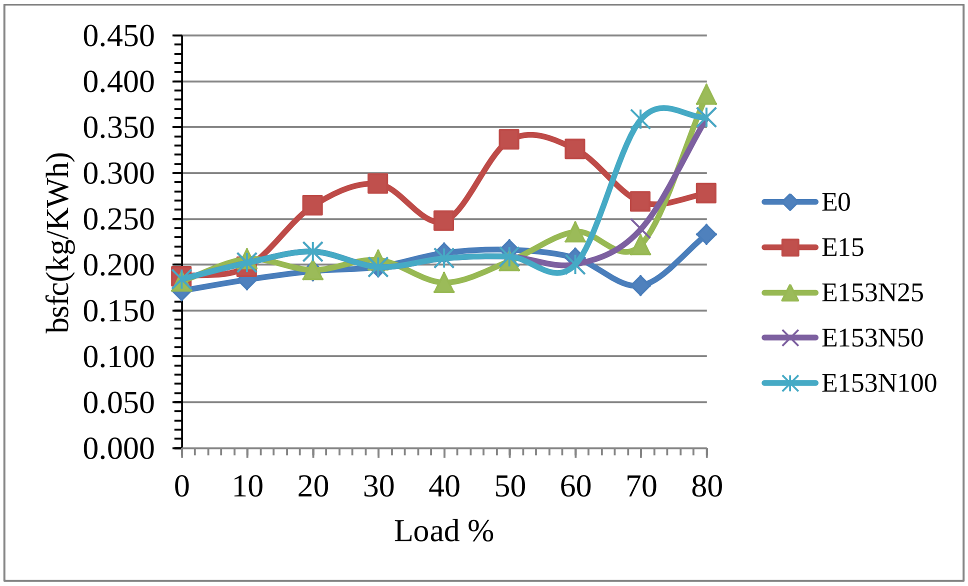


Figure 25. The effect of 3 elemental nanoparticle adding in E15 on engine fuel consumption

4.3. Emission results and discussion

4.3.1. Hydrocarbon Emission

Hydrocarbon (HC) emissions are hydrogen-carbon compounds that are produced due to incomplete combustion. Hydrocarbon (HC) emissions are influenced by fuel properties, combustion chamber design, crevice volume, deposits on walls, and engine operating parameters. Figure 26 shows the HC emissions trend with different engine loads varied by a 10% interval. The test result showed the emission increased with the increase in load for all the samples. At low engine load conditions, the amount of fuel delivered to the combustion chamber is low. Therefore, the HC emission also reduces accordingly. As the engine load increases, the HC emission increases with the amount of fuel injected into the combustion chamber. When the ethanol emulsified fuels are compared with neat diesel fuel, the HC emission is reduced for the 5% ethanol emulsified fuel sample, but for the ethanol amounts of 10 and 15 % the result shows an increment in the emission amount. The average HC reduction for an E5 fuel sample is 46%

compared to neat diesel. In the E10 and E15 fuel samples, the percentage increase of HC is 78 and 118%, respectively. The presence of ethanol in diesel fuel makes the fuel vigorously mix with air and enhance the combustion process at 5% ethanol. As the ethanol amount is increased to 10 and 15%, the cetane number of the emulsified fuel reduces, creating more ignition delay. The long ignition delay makes the complete combustion of the fuel difficult. More over, the additional ethanol caused the fuel's latent heat of vaporization to increase, leading to the accumulation of ethanol vapour in the cylinder and poor combustion quality. As a result, there was a considerable amount of unburned fuel in the engine cylinder, which comes from various sources. These are the reasons that led to the increase in HC emissions.

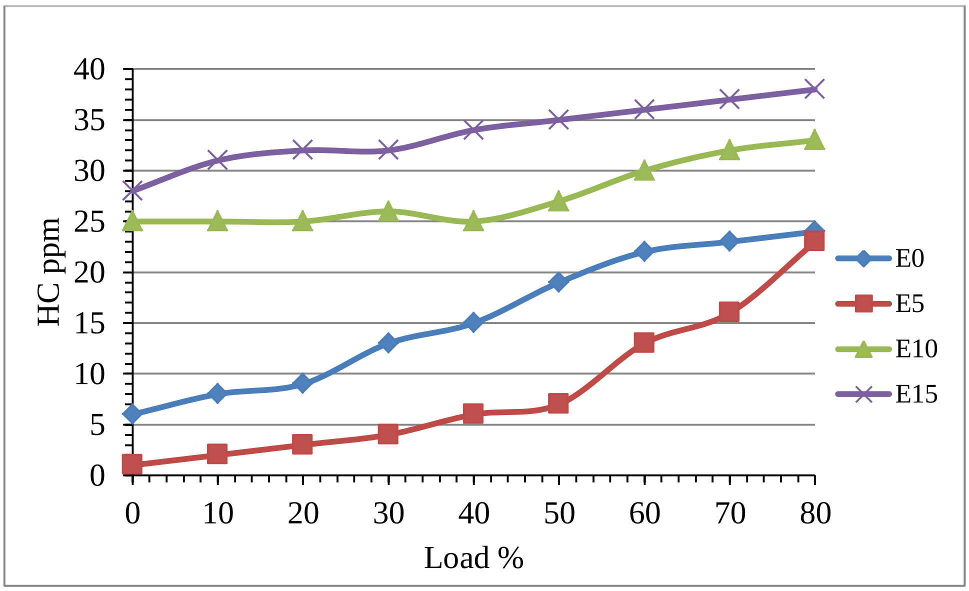


Figure 26. The effect of ethanol on HC emission

Figure 27 shows the influence of $NiZnFe_2O_4$ nanoparticle addition in 5% ethanol emulsion fuel. At low engine speeds, the HC emissions are low. This is because a smaller amount of fuel is injected into the cylinder, and the emission level gradually increases with the load increment. Only for the 5% ethanol emulsified fuel, the HC emissions are reduced by an average of 46% and the addition of the nanoparticle further reduces the HC emissions. As the amount of the nanoparticle added to the fuel is increased, the HC emission keeps on decreasing. When compared with neat diesel, the amount of reduction for the fuel samples E5-3N-25, E5-3N-50, and E5-3N-100 is 65, 76, and 86%, respectively. The further reduction with the addition of the nanoparticle increase is due to the increase in the surface area-to-volume ratio and improves the mass transfer properties due to micro explosion, causing better and faster combustion, which makes the hydrocarbon, react with oxygen. This phenomenon in the combustion chamber reduces the HC emissions further. The rate of HC emission when E5 is compared with E5-3N-25 is very high. However, the additional amount of the nanoparticle doping effect is smaller.

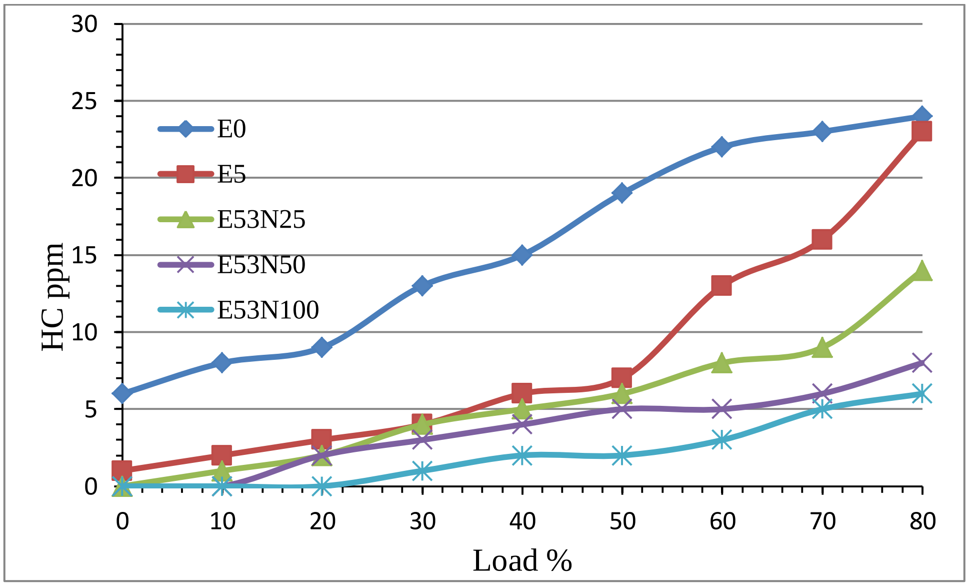


Figure 27. The effect of 3 elemental nanoparticle adding in E5 on HC emission

The HC emissions of E10 were very high compared with neat diesel. After the $NiZnFe_2O_4$ nanoparticle is added, the emission is reduced, and the value indicates that it is less than the one emitted by neat diesel. The nanoparticle improved the combustion efficiency and increased the tendency of complete combustion as a result, reducing unburned hydrocarbon. The emission test result showed the fuel samples prepared by adding different amounts of the nanoparticle in the 10% ethanol diesel emulsion are indicated in figure 28. Compared with diesel fuel, E10-3N-25, E10-3N-50, and E10-3N-100 have resulted in HC emissions of 50, 58, and 72%, respectively.

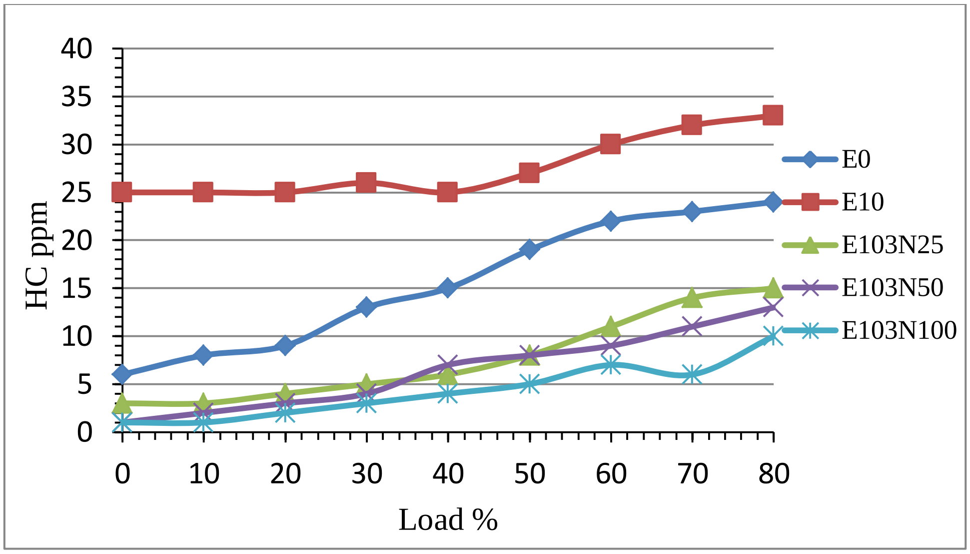


Figure 28. The effect of 3 elemental nanoparticle adding in E10 on HC emission

For the 15% ethanol amount in the emulsified fuel, the hydrocarbon emissions increased from the baseline for pure diesel. The reason for this increment is because of the poor combustibility of the fuel and some of its properties, such as the calorific value and cetane number reduction. The addition of $NiZnFe_2O_4$ nanoparticles to the E15 emulsion changed the HC emission characteristics of the engine. The catalytic effect of the nanoparticle facilitated the combustion reaction and caused most of the hydrocarbons to react with oxygen, resulting in reduced HC emissions. As shown on the graph in Figure 29, the nanoparticle amount caused the emission value to reduce. The reduction of the HC amount for the fuel samples E15-3N-25, E15-3N-50, and E15-3N-100 is 64% for the E15-3N-25 fuel sample and 58% for both the E15-3N-50 and E15-3N-100 fuel samples. From the HC emission test result, it is seen that for the E15 emulsion fuel, 25 ppm of the nanoparticle is sufficient to reduce the HC emission.

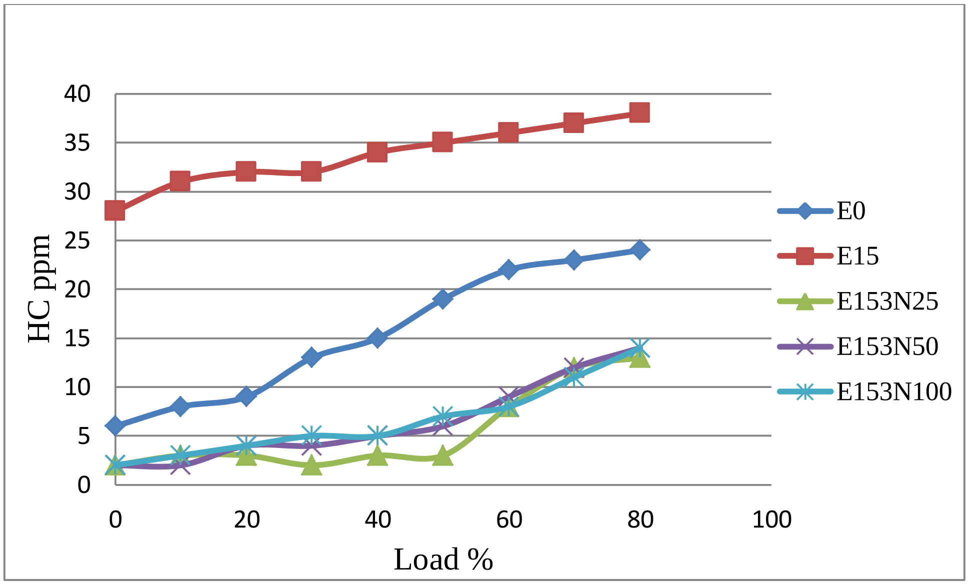


Figure 29.The effect of 3 elemental nanoparticle adding in E15 on HC emission

4.3.2. Carbon Monoxide emission

Carbon monoxide (CO) is colorless and odorless and is considered a product of incomplete combustion of hydrocarbons. When combustion reaction happens in a condition where there is insufficient amount of oxygen, the hydrocarbon with oxygen reaction results in CO instead of CO_2. The partially burned fuel is the cause of the production of carbon monoxide. Figure 30 shows the CO emissions for pure diesel and ethanol diesel emulsion with different ethanol percentages (5%, 10%, and 15%) at various engine loads with an interval of 10%. At low engine load, the amount of fuel injected into the cylinder is smaller, but the air amount is relatively high. This makes more oxygen available to react with the fuel, resulting in lower CO emission. At higher engine loads, the fuel system injects more fuel to overcome the load on the engine. Therefore, the air-fuel mixture at higher load conditions is relatively richer than at lower load conditions. This makes the combustion phenomenon face a shortage of oxygen, resulting in increased CO emissions.

The effect of ethanol in diesel emulsion was evaluated when compared to neat diesel fuel, and the result showed that there was a considerable reduction in CO emissions. The average percentage reduction for the fuel samples E5, E10, and E15 are 15, 21, and 32%, respectively, compared with pure diesel. Ethanol (C_2H_5OH) is used as an oxygenated additive, and the more ethanol is emulsified in diesel fuel, the more oxygen it has to oxidize the hydrocarbon during combustion. Because of the high oxygen concentration in ethanol, more complete combustion is likely, resulting in the conversion of CO to CO2. This result is in agreement with the previous study by Nabi Nabi, Rasul et al. (2021), which found that the higher the engine speed, the lower the production of CO emissions due to the increase in excess air as CO is formed by insufficient air supply. Other studies have also reported that a higher percentage of biofuel in the emulsion decreases CO emissions. This is because oxygen is inherently present in biofuels, making them easier to burn at higher temperatures in the chambers. Thus, the results prove that the higher percentage of ethanol in the emulsified fuel provides lower emissions of carbon monoxide.

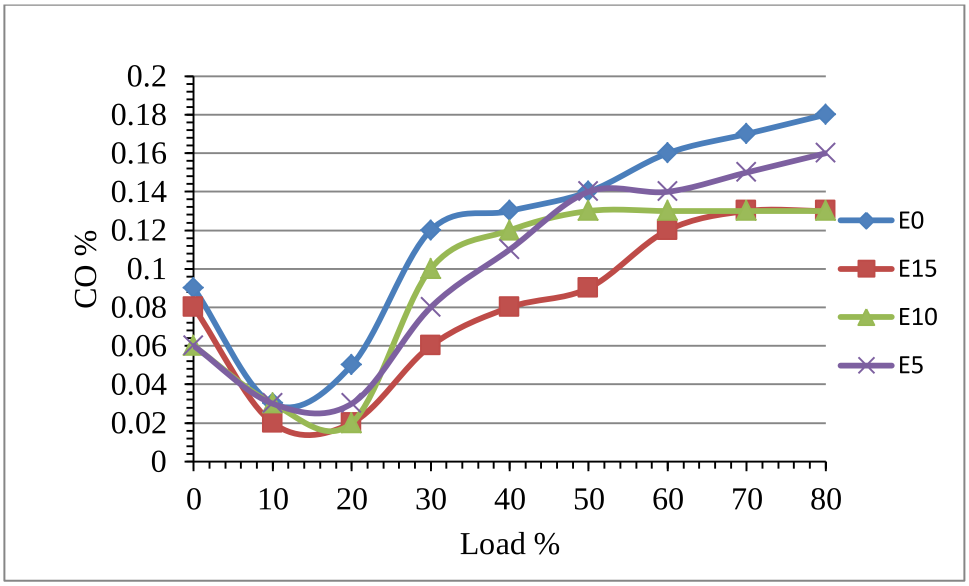


Figure 30. The effect of Ethanol on CO emission

$NiZnFe_2O_4$ nanoparticles have significantly reduced the CO emission of ethanol diesel emulsion with a 5% ethanol concentration. For the sample fuel to completely burn and the carbon atoms to be gate converted into CO_2, a sufficient amount of oxidant and reaction time must be available. The nanoparticle in the fuel makes the oxidation reaction happen more quickly due to its catalytic nature. Therefore, the addition of the nanoparticle reduced the emission of CO from the vehicle exhaust. As shown in Figure 31, compared with pure diesel fuel, the amount of CO reduction for the sample fuels prepared by varying the amount of the nanoparticle, which is designated as E5-3N-25, is 46%, and for E5-3N-50 and E5-3N-100, it is 57% and 56%, respectively. The 50 and 100 ppm of added nanoparticle fuel resulted in a very close CO emission value.

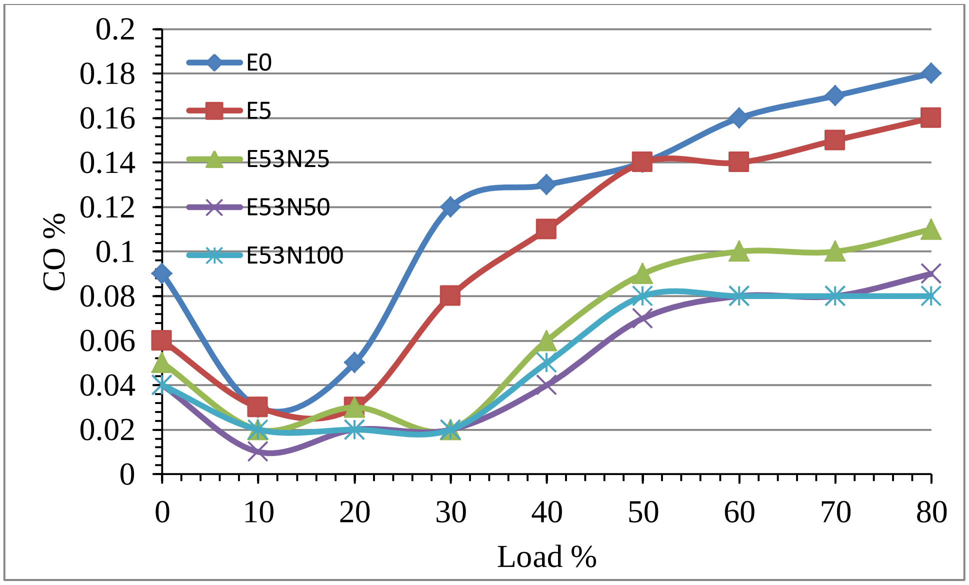


Figure 31. The effect of 3 elemental nanoparticle adding in E5 on CO emission

Figure 32 shows the graphical representation of the $NiZnFe_2O_4$ nanoparticle effect on 10% ethanol-content diesel emulsion fuel designated as E10. The average CO emission reduction for the fuel samples E10-3N-25, E10-3N-50, and E10-3N-100 is 67, 80, and 81%, respectively. The further reduction of CO emissions is due to the catalytic effect of the nanoparticle. As the amount of nanoparticles doped into the fuel samples increased, the CO emission decreased significantly. At low and medium load conditions, the effects of 50 ppm and 100 ppm are similar. However, the emission from the fuel sample with 25 ppm of nanoparticle additive is higher. At high engine load, there is a slight variation between the E10-3N-50 and E10-3N-100.

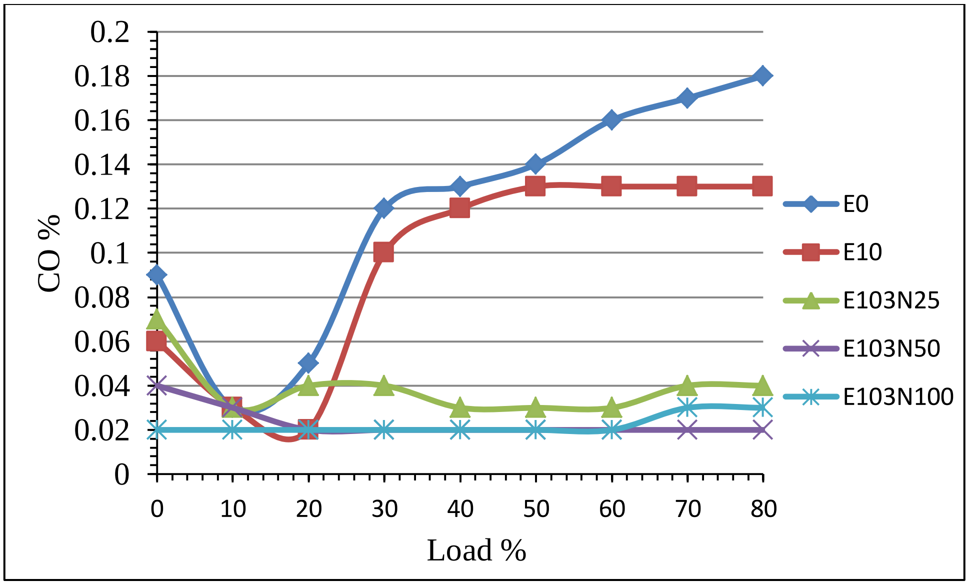


Figure 32. The effect of 3 elemental nanoparticle adding in E10 on CO emission

The CO emission test results obtained on the fuel samples of E15 having different amounts of nanoparticles (25, 50, and 100 ppm) in comparison with pure diesel (E0) are illustrated on Figure 33**.** From the collected data, it is clear that the fuel sample E15-3N-25 has a slight decrease in CO emissions. When compared with neat diesel fuel, the emission reduction is 34%, which is better than the E15 fuel sample's 30% reduction. The CO emission reduction for 50 ppm and 100 ppm nanoparticle-doped fuels is very high. CO emission results for E15-3N-50 and E15-3N-100 fuel samples are reduced by 64% and 72%, respectively, compared to neat diesel.

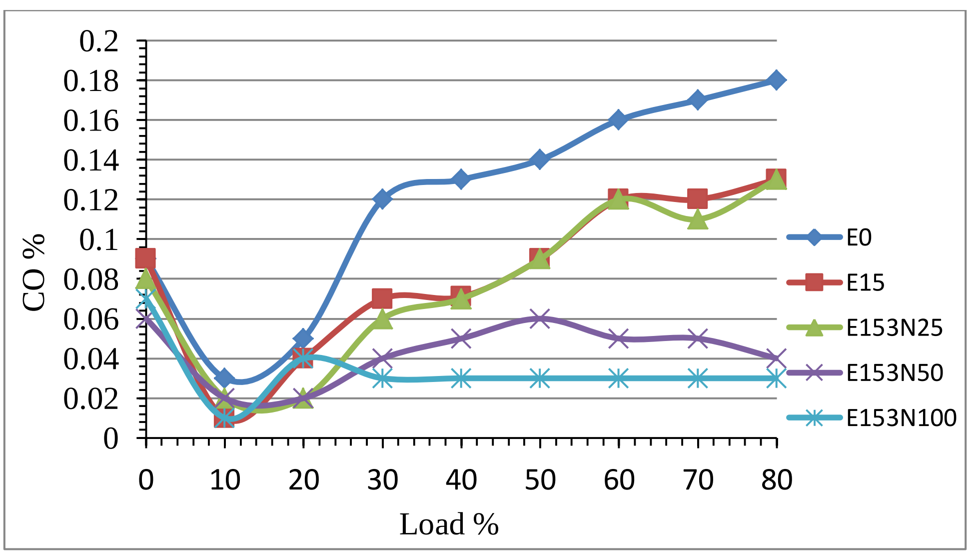


Figure 33. The effect of 3 elemental nanoparticle adding in E15 on CO emission

4.3.3. Carbon Dioxide emission

The products of any hydrocarbon combustion should be water (H_2O) and carbon dioxide (CO_2). CO_2 emissions are a concern for global warming, which cannot be avoided as long as hydrocarbon-fueled combustion engines are in use. In that sense, of all the other emissions, CO_2 emissions should be the least concerning, as they are an unavoidable source of emissions with a lesser amount of harm and can be reduced with the increase of biofuel or other vegetation. Figure 34 shows the variations of CO_2 emissions for neat diesel and ethanol diesel emulsions of 5%, 10%, and 15% at various engine loads. The results show that higher ethanol contents produce higher CO_2 emissions compared to neat diesel at all engine loads. The comparative result of E5, E10, and E15 compared with neat diesel is an increment of 0.15, 9, and 17%, respectively. The same trend of increasing CO_2 emissions is seen at every load for all the emulsion fuel samples. This is mainly due to the presence of oxygen in the emulsion fuels, which interact with unburned carbon atoms during combustion and produce higher amounts of CO_2. This result is in agreement with previous studies, which show that increasing the oxygen content of a fuel gradually increases the percentage of CO_2 emissions. CO_2 emissions increase due to improved combustion, a high post-combustion process, and a high oxygen content in the fuel.

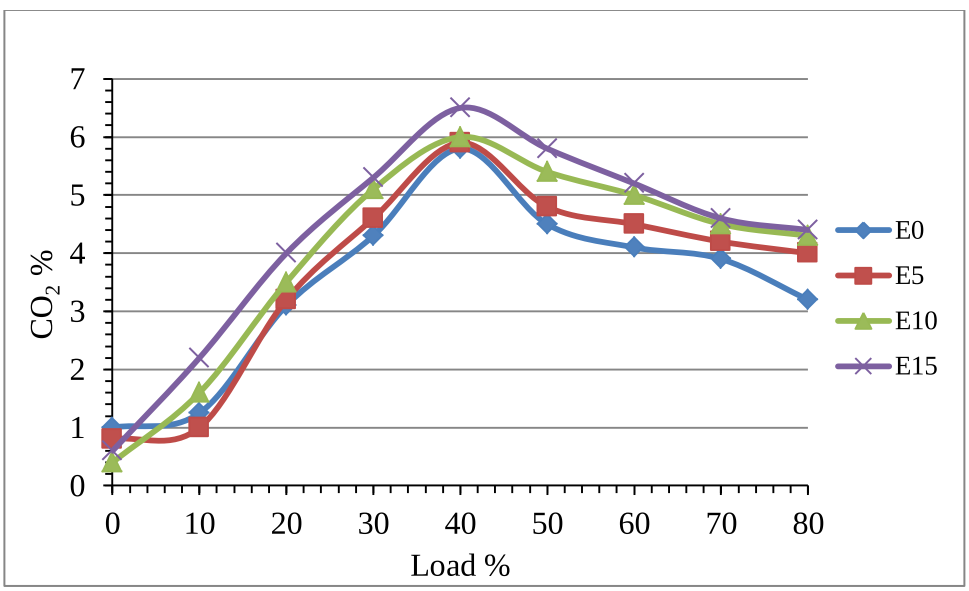


Figure 34. The effect of Ethanol on CO_2 emission

CO_2 emissions indicate complete combustion of the test fuel. Figure 35 shows CO_2 emissions with the engine load for 5% ethanol emulsified test fuel with 25, 50, and 100 ppm nanoparticle doping. The carbon dioxide emission was found to be higher with E5 fuel due to the oxygen content. The application of $NiZnFe_2O_4$ nanoparticles in E5 provides a higher surface area to volume ratio and therefore a higher oxygen value, enhancing the oxidation of CO and HC and resulting in a higher combustion chamber temperature and improved combustion efficiency. The addition of $NiZnFe_2O_4$ nanoparticle additive resulted in increased CO_2 emissions as compared to E5 fuel. It occurs due to the enhanced combustion process caused by the nanoparticle additives. This process maintains the balance between CO and CO_2 emissions; emission of CO reduces with the increase in the formation of CO_2. The average comparative emission test result at various engine loads for CO_2 emission is recorded at 10% and 13% higher for E5-3N-50 and E5-3N-100 fuel samples, respectively. The increment for E5-3N-25 fuel is 5%.

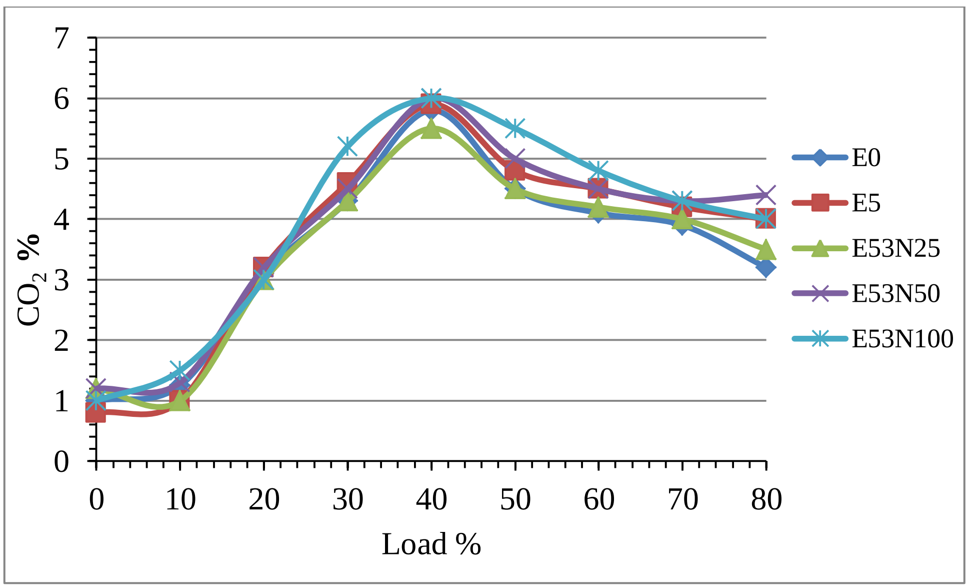


Figure 35. The effect of 3 elemental nanoparticle adding in E5 on CO_2 emission

The effect of $NiZnFe_2O_4$ added to an E10 emulsion is shown in figure 36. The percentage increase in CO_2 emissions for the ethanol addition was only 9%, but ever since the nanoparticle has been added to the fuel sample, the emission of CO_2 has increased to 14, 17 and 20% compared to neat diesel. The increment is due to the catalytic effect of the nanoparticle, which enhances the combustion reaction to approach a more complete state by oxidizing and reducing CO emission.

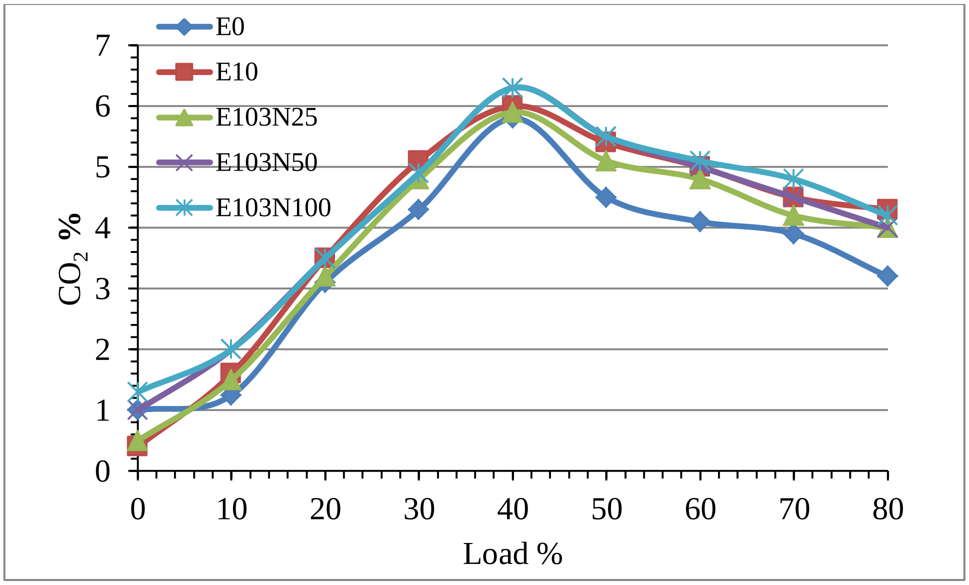


Figure 36. The effect of 3 elemental nanoparticle adding in E10 on CO_2emission

One of the major products the combustion process produces is CO_2, even though it is not considered a hazardous emission. The increment in CO_2 product has consequences for the reduction of CO, which is among the hazardous pollutants in engine exhaust. The higher oxygen content in ethanol's chemical composition compared to pure diesel accounts for the high concentration of CO_2 emissions in the ethanol diesel emulsified fuel combustion product. The graph in Figure 37 shows a representation of the $NiZnFi_2O_4$ nanoparticle additive effect in 15% ethanol with diesel emulsion (E15). $NiZiFe_2O_4$ nanoparticle addition makes for more complete fuel combustion because of its catalytic effect. Therefore, the CO_2 emission is increased by reducing the amount of CO emission with the nanoparticle addition. The percentage increase in CO_2 emissions due to the addition of the nanoparticle for the fuels E15-3N-25, E15-3N-50, and E15-3N-100 is 21, 23 and 34%, respectively, compared to neat diesel fuel, while the increase for the E15 fuel was only 17%.

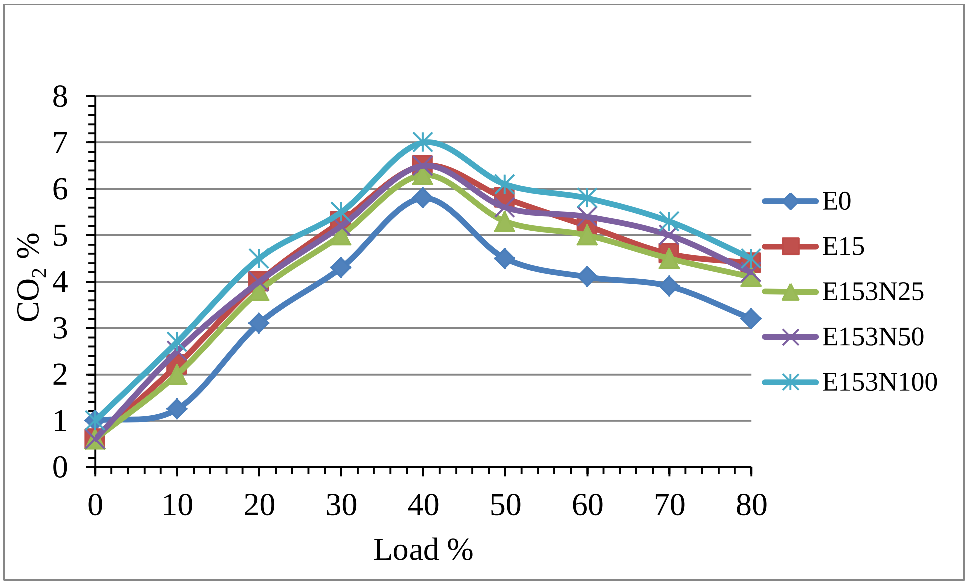


Figure 37. The effect of 3 elemental nanoparticle adding in E15 on CO_2 emission

4.3.4. Nitrogen Oxide Emission

Nitrogen oxide emissions (NO_X) are highly dependent on the temperature of the combustion chamber, the oxygen content, and the enthalpy of vaporization of the fuel. Figure 38 shows the comparative results of NO_X emissions between neat diesel (E0) and 5% ethanol diesel emulsion (E5), 10% ethanol diesel emulsion (E10), and 15% ethanol diesel emulsion. At lower load conditions, the level of NO_X emission is low because of the lower cylinder pressure and temperature. At higher load conditions, the amount of fuel consumed increases, which results in an increase in cylinder pressure and temperature, which facilitate favorable conditions for nitrogen (N_2) to react with oxygen (O_2), so as engine load is increased, the NO_X emissions are also increased. The effect of the ethanol content in the emulsified fuel is also clearly seen. The NO_X emissions decreased with the increase in the amount of ethanol in the emulsion. The results obtained from the test show that, compared to neat diesel fuel E5, E10, and E15, they reduce NO_X emissions by 8, 26, and 29%, respectively. The reduction with the increase in ethanol amount is because of the low cylinder temperature resulting from the low calorific value and poor combustibility of ethanol.

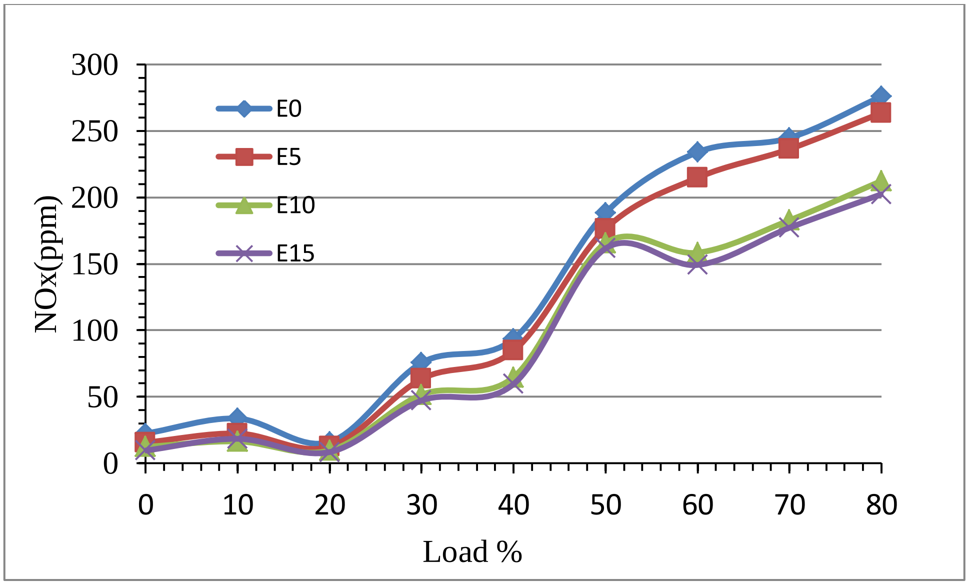


Figure 38. The effect of Ethanol on NOX emission

Figure 39 shows the graphical representation of $NiZnFe_2O_4$ nanoparticles having an added effect on NO_X emissions when comparing neat diesel with 5% ethanol diesel emulsion fuel. E5-3N-25, E5-3N-50, and E5-3N-100 fuel samples were tested, which resulted in 5%, 6%, and 7.7% reductions in NO_X emissions in comparison with neat diesel, respectively. When the nanoparticle-added fuel samples are compared with ethanol-diesel emulsions without nanoparticles added, which have a NO_X reduction of 8% from neat diesel, there is an increase in NO_X emissions. Nanoparticles added to the fuel enhance the combustion process by increasing the pressure and temperature of the combustion chamber, which leads to the formation of more NO_X emissions. The net result of the nanoparticles added to the E5 fuel sample is a reduction in NO_X emissions from the neat diesel fuel.

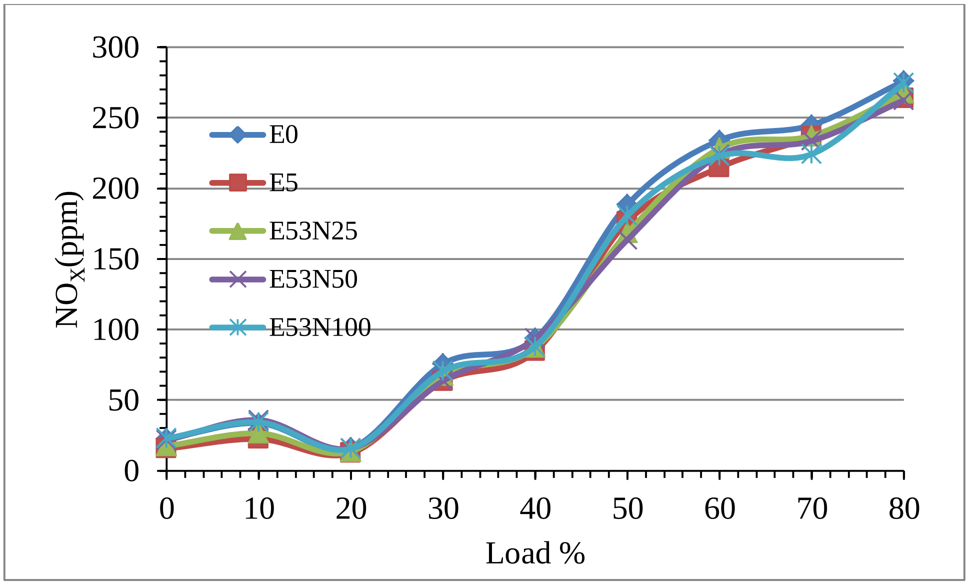


Figure 39. The effect of 3 elemental nanoparticle adding in E5 on NOX emission

The nanoparticle effect on the NO_X emission of 10% ethanol with diesel emulsion is indicated on figure 40. As the nanoparticle amount added to E10 increases, the NO_X emission also increases. Compared with neat diesel, the E10-3N-25 fuel sample showed a reduction of 3.8%; however, the fuel samples E10-3N-50 and E10-3N-100 have a comparative increment of 1.4% and 10.6% NO_X emissions, respectively, over the neat diesel fuel. As the amount of ethanol increases, the oxygen content of the fuel increases, and the increment in the nanoparticle amount causes the engine cylinder temperature to increase. The tradeoff incident between the ethanol and nanoparticle additive amount determines the level of the NO_X emission.

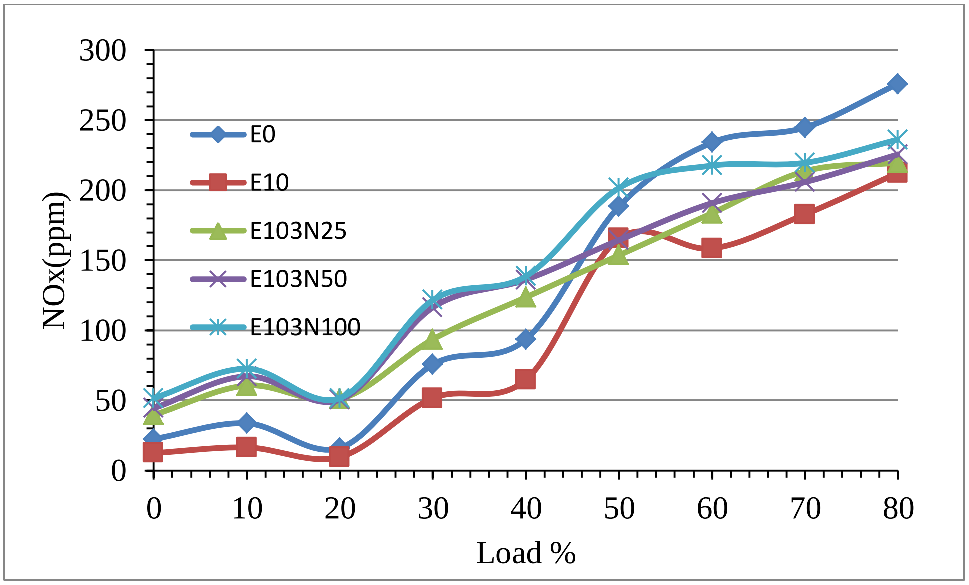


Figure 40. The effect of 3 elemental nanoparticle adding in E10 on NOx emission

The E15 fuel sample has the lowest NO_X emission value of all the other fuel samples studied in this research work. The nanoparticle addition increased the NO_X emission from the E15 emulsion fuel. However, the highest emission value for the fuel sample, E15-3N-100, is still less than the neat diesel emission value. Figure 41 shows the NO_X emission characteristics of an E15 emulsion with various nanoparticle amounts of doping. The comparative percentage difference from diesel fuel is 27, 21, and 4% for the fuel samples E15-3N-25, E15-3N-50, and E15-3N-100, respectively.

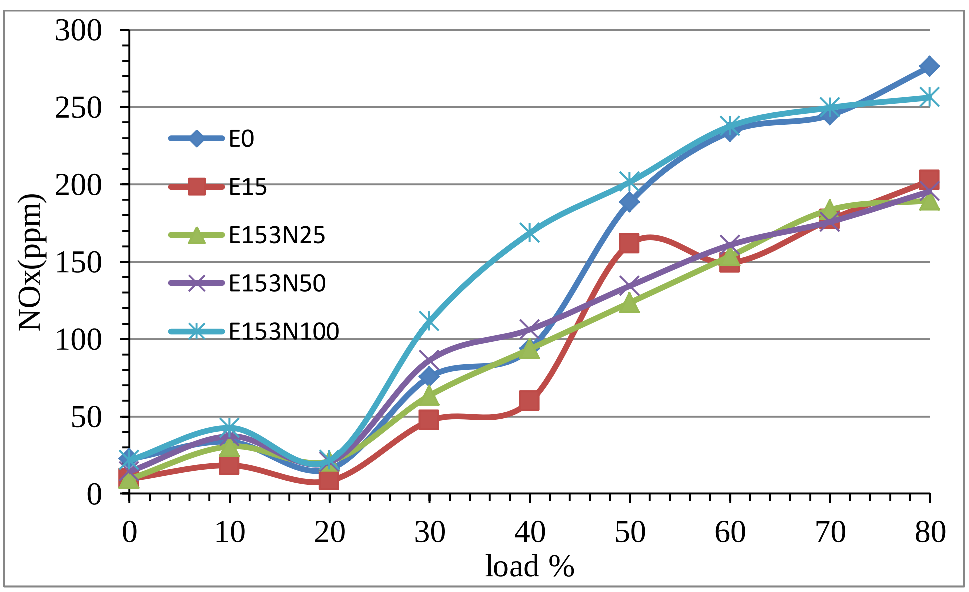


Figure 41. The effect of 3 elemental nanoparticle adding in E15 on NOx emission

4.3.5. Smoke opacity

At lower and medium load conditions, the smoke opacity level for all the fuel samples tested in this research is very low. At a higher load of more than 60%, the emission level starts to increase. At higher loads, a greater amount of fuel is injected into the combustion chamber, so the smoke opacity is increased at a faster rate with an increase in load for all the tested fuels, as shown in Figures 42. It is observed that the smoke opacity for ethanol emulsified fuels (E5, E10, and E15) is comparatively lower than that of conventional diesel fuel. The oxygen content of the emulsified fuels enhanced the combustion process, which resulted in lower smoke emissions. The smoke opacity reduces significantly as the amount of ethanol in the emulsion is increased; the percentage reduction is 20, 28, and 48% for E5, E10, and E15 fuel samples, respectively. According to research previously done, the catalytic activity of nanoparticles in different fuel samples enhances the chemical reaction during the combustion process and thereby lowers smoke emissions in the diesel engine exhaust.

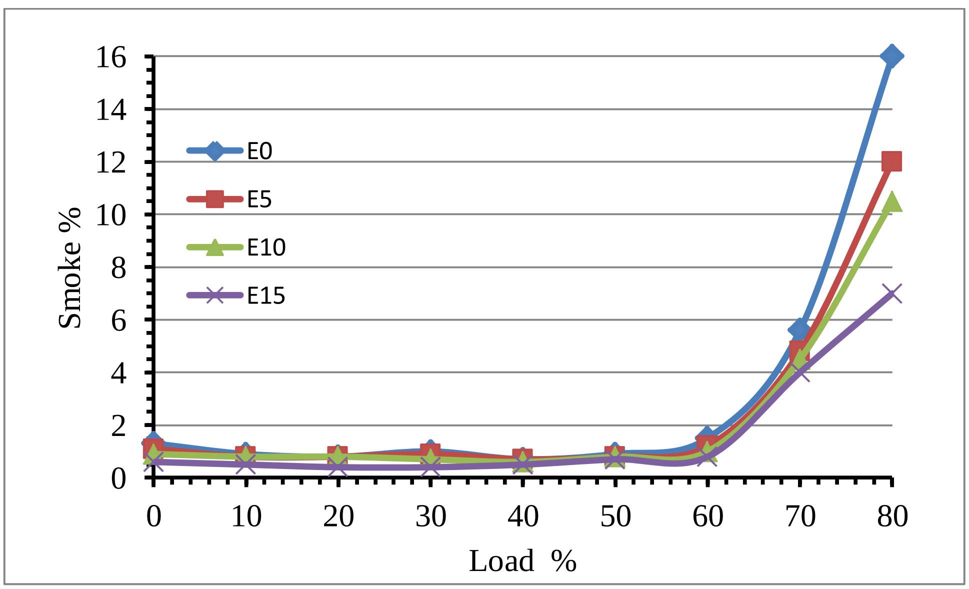


Figure 42. The effect of Ethanol on Smoke Emission

On the smoke emission test conducted on 5% ethanol diesel emulsion, promising results have been noticed towards reducing particulate matter emission from the exhaust gas. The smoke emission increased with the load for all the sample fuel emulsions, but with the addition of $NiZnFe_2O_4$, exhibited a reduction in emission compared to the neat diesel fuel. The reduction in smoke emission is due to the oxygen content in the emulsified fuel and nanoparticle additive. As shown in Figure 43, the addition of 25 ppm of nanoparticles to E5 exhibited a reduction of 44%; 50 ppm showed a 58% reduction, and 100 ppm of additive showed a 41% decrease in smoke emission in comparison with neat diesel fuel at average load conditions. These values are a great improvement when compared with E5 without nanoparticle smoke emission reduction values of only 19% from neat diesel fuel.

Smoke opacity is strongly dependent on the amount of air in the cylinder and oxygen in the fuel. The addition of ethanol to the fuel resulted in a shortened ignition delay, better evaporation, and improved ignition characteristics.

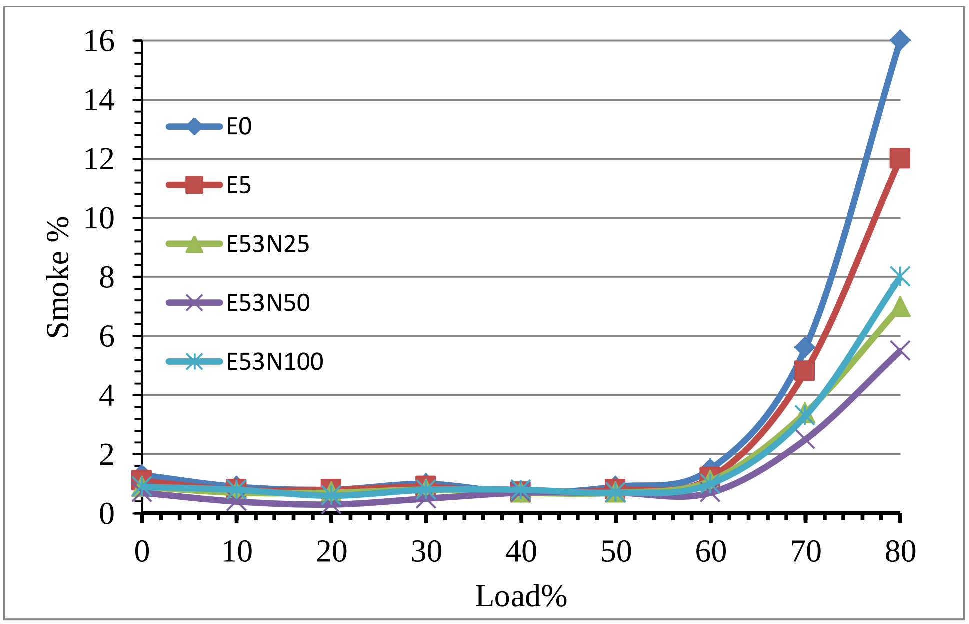


Figure 43. The effect of 3 elemental nanoparticl in E5 on Smoke emission

The nanoparticle effect on the fuel samples prepared with 10% ethanol in diesel emulsion is evaluated in the same manner as the other fuels as far as the load variation is concerned. As engine load increases, smoke emissions also increase. Figure 44 shows the smoke emission trend of E10 with the addition of different amounts of nanoparticle doping. The smoke emission reduction for the ethanol emulsifying was 28% from neat diesel. However, after the nanoparticle has been added, the emission reduction is tremendously increased. Compared to diesel fuel, the fuel samples E10-3N-25, E10-3N-50, and E10-3N-100 exhibited smoke emission reductions of 60, 69, and 61%, respectively.

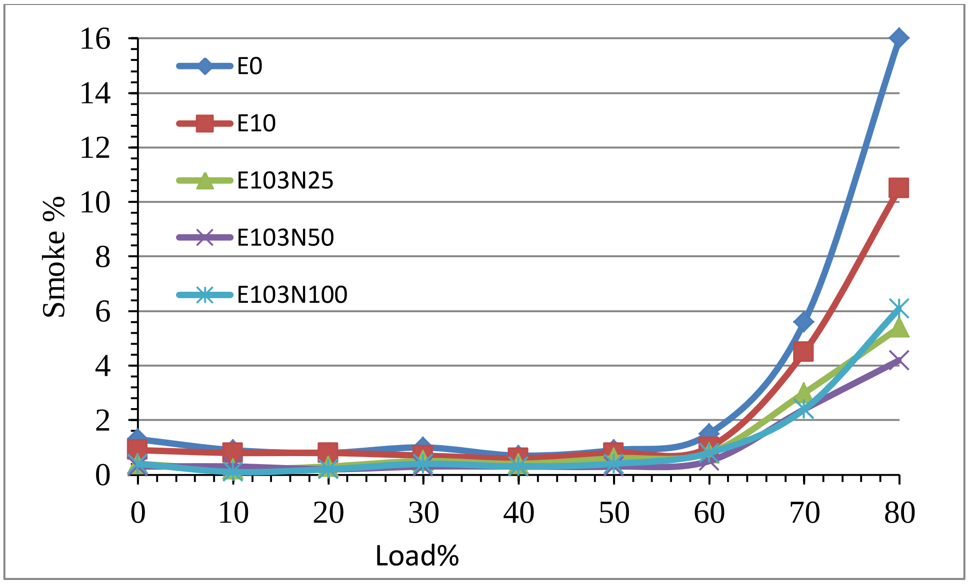


Figure 44. The effect of 3 elemental nanoparticle in E10 on Smoke emission

The E15 fuel sample is the highest ethanol-containing fuel sample prepared for the experiment. The smoke emissions decreased and reached the maximum reduction level due to the addition of ethanol, which is 48% lower than diesel fuel as shown in Figure 45. The smoke percentage reduction due to the addition of $NiZnFe_2O_4$ for the fuel samples E15-3N-25, E15-3N-50, and E15-3N-100 is 67, 74, and 65%, respectively.

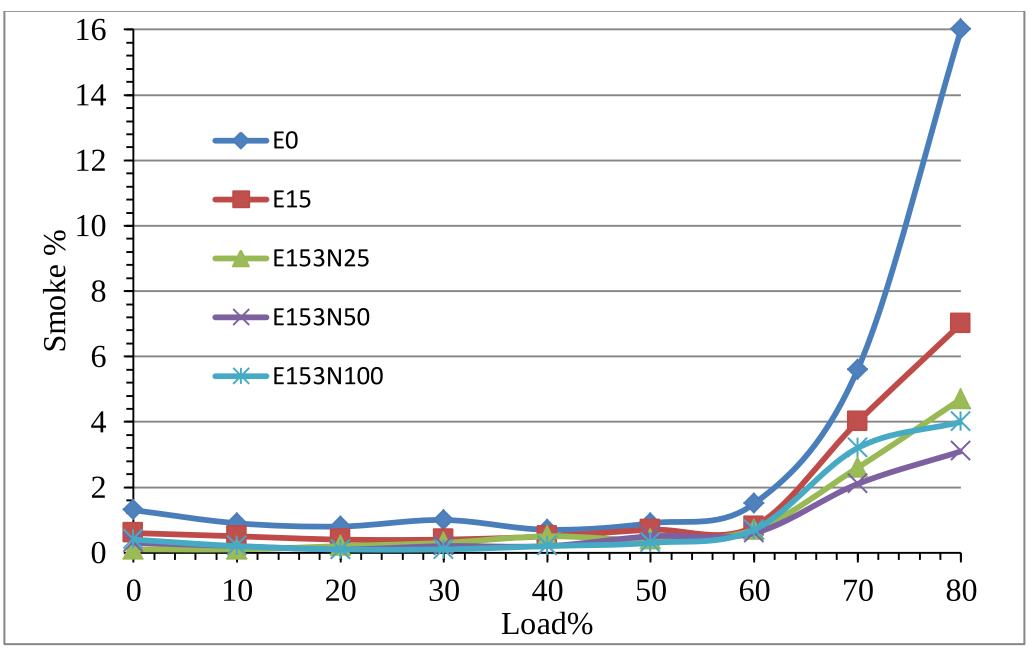


Figure 45. The effect of 3 elemental nanoparticl in E15 on Smoke emission

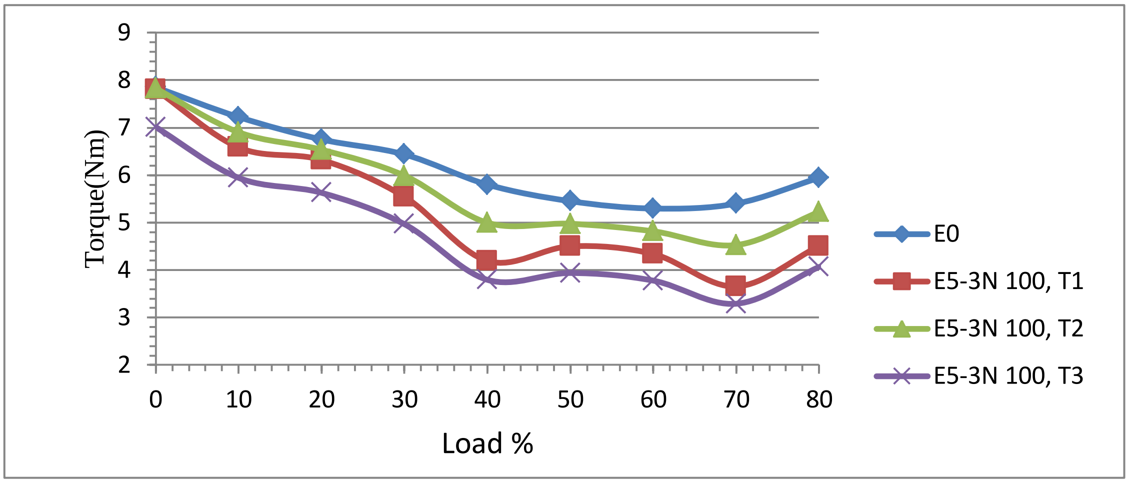
4.4. Influence of injection timing on engine performance and emission characteristics

4.4.1. Influence of injection timing on Brake torque by E5-3N-100, E10-3N-100, and E15-3N-100 fuel Samples

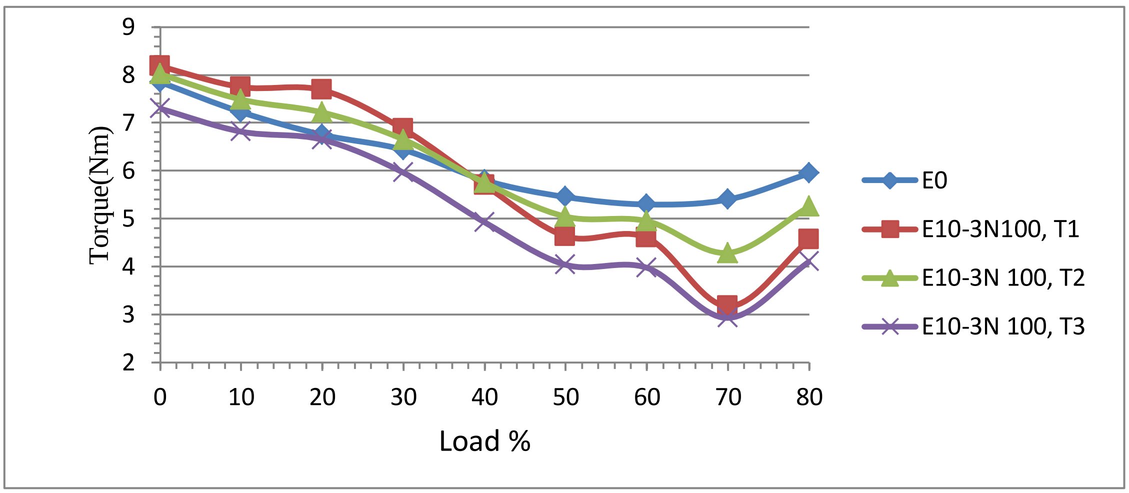
The comparison of brake Torque of the fuel samples for different injection timings is shown in Figure 46. For all the injection timings, the brake torque for diesel, E5-3N-100, E10-3N-100, and E15-3N-100 fuels are tested with increasing load variation. The figure 46 a, shows the influence of the ignition timing on the torque output of E5-3N-100 fuel sample. The result indicates that the injection timing slightly influenced the torque output compared to neat diesel. The slight difference is due to the smaller amount of ethanol content in the emulsified fuel sample. Advancing the injection timing by 1.5 degrees from the original ignition timing improved the torque output by 8%, and retarding the injection timing by the same degree reduced the torque by 9% compared to the average torque output at the original injection timing.

For the fuel sample E10-3N100, the variation in torque output, as shown in figure 46 b, follows the same pattern as that of the E5-3N100. Because of the increment in ethanol content, the intensity of the torque variation is also different when compared with neat diesel. When the timing effect is evaluated, advancing the injection timing by 1.5 degrees and retarding with the same amount of crank angle resulted in a 2.6% increment and an 11.5 percent reduction in torque output compared to the original injection timing. Figure 46 c represents the torque output by the E15-3N100 fuel sample. Compared to the former fuel samples, the torque output compared to diesel fuel is the smallest. On this fuel sample, the impact of injection timing is more significant than on the other fuel samples. The 1.5-degree injection timing advance improved the torque output by 8%, and the retarding reduced the torque by 9%.

(a)



(b)



(c)

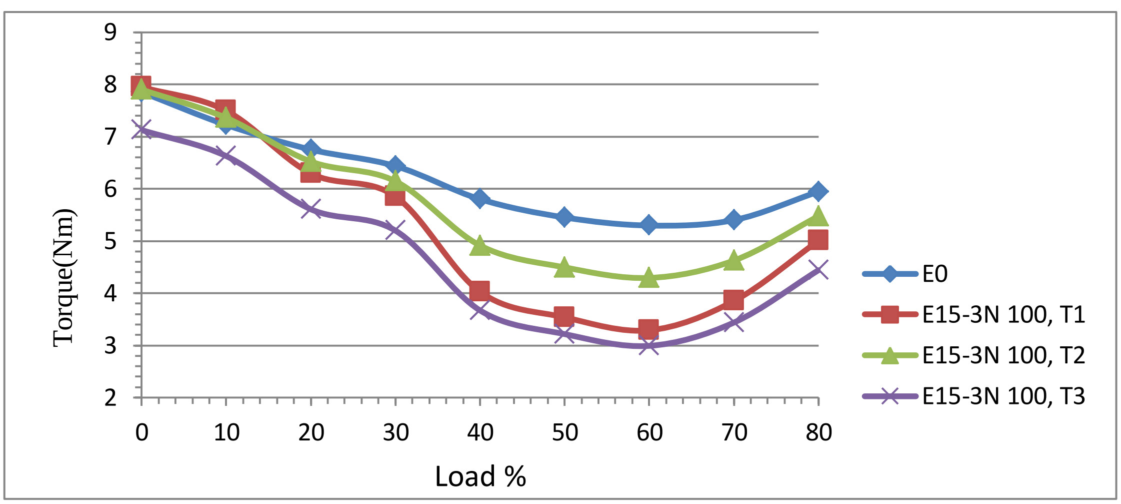


Figure 46. The effect of injection timing by the different fuel samples on engine torque. (a) E5-3N100, (b) E10-3N100 and (c) E15-3N100

4.4.2. Influence of injection timing on Brake power by E5-3N-100, E10-3N-100, and E15-3N-100 fuel Samples

The power output of the engine measured using diesel fuel samples E5-3N-100, E10-3N-100, and E15-3N-100 revealed that the injection time could significantly influence the power output. At the initial injection timing, the power output of all the fuel samples with ethanol content is low due to their poor combustibility and lower energy content compared to pure diesel fuel, as shown in figures 47 a–c. For the fuel E5-3N-100, the advancing of the injection timing improved the power output by 9%, and the retarding injection timing reduced it by 8% compared to the initial injection timing.

The E10-3N-100 fuel sample is the one that performed best next to pure diesel, and the power reduction from the pure diesel is measured at 7.5% less. With the injection timing adjustment made, the power output when advancing and retarding the timing is a 5% increment and a 10% reduction, respectively.

The use of the E10-3N-100 fuel sample reduced the power output by about 13% compared to using neat diesel fuel at the original injection timing. After the injection timing has been adjusted in the advance direction, the power output is improved by 7%, whereas the retard direction adjustment reduces the power output by 12%. The ethanol content affects the delay period of the fuel, which influences the maximum combustion pressure's occurrence at the position of the crank angle. For the maximum pressure to occur at the right point of the crank angle, the injection time shall be advanced for ethanol-added diesel emulsion fuel samples. This is the reason why the power output is improved due to the advanced injection timing position of the injection pump. While retarding the injection timing, there is less time for combustion, and the fuel cannot completely burn and provide the intended pick pressure at the intended crank shaft position, so this results in a reduction of the power output.

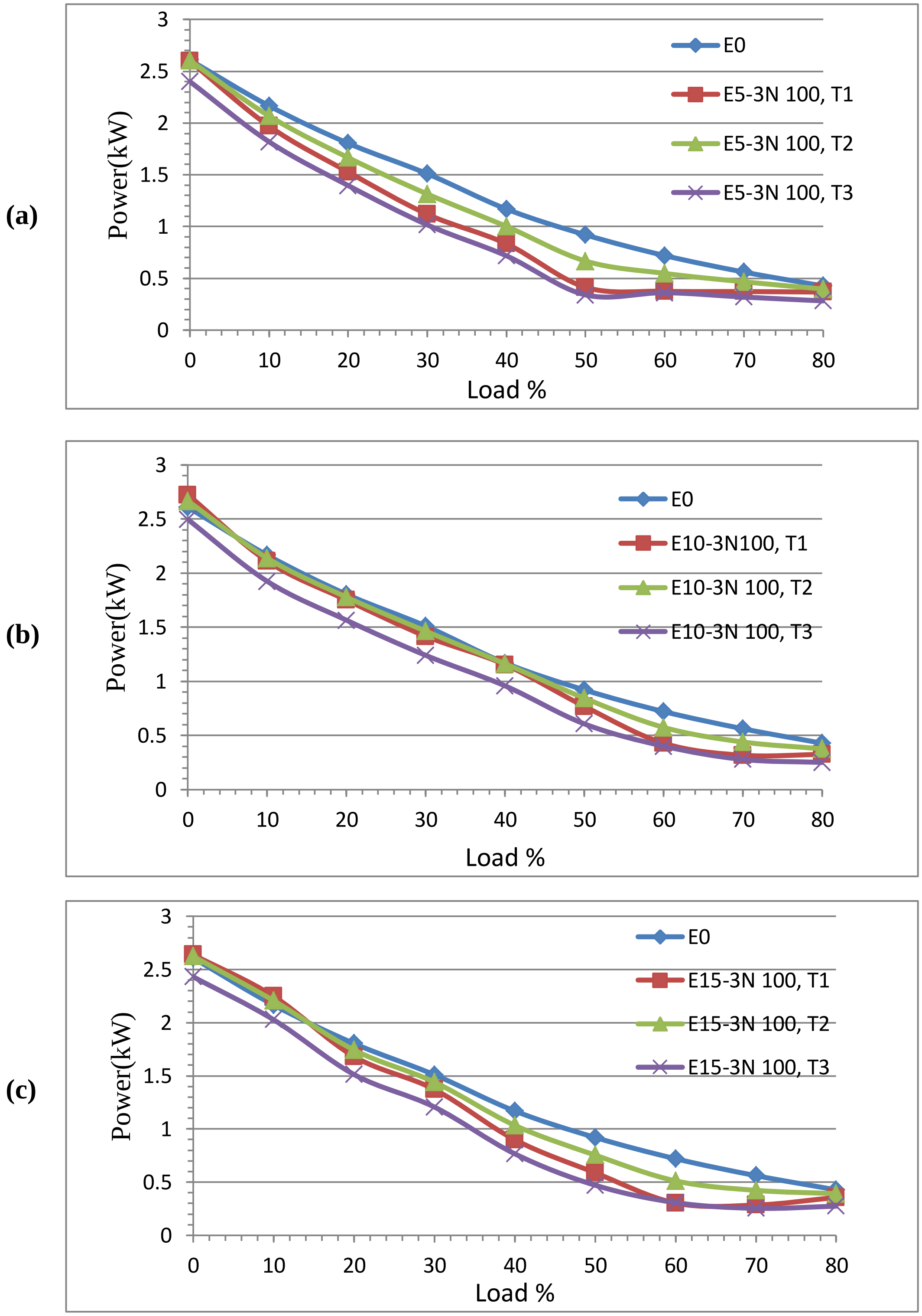


Figure 47. The effect of injection timing by the different fuel samples on engine power E5-3N100, (b) E10-3N100 and (c) E15-3N100

4.4.3. Influence of injection timing on Brake specific fuel consumption by E5-3N-100, E10-3N-100, and E15-3N-100 fuel Samples

The impact of injection timing on BSFC for various load circumstances for engines running on diesel and diesel ethanol emulsion is shown in Figure 48. For all injection timings, an increase in engine load up to 50% results in an increase in the brake-specific fuel consumption of neat diesel and the other fuel samples. However, BSFC starts to decrease when the load is increased beyond 50%. Figure 48 a shows that, for any given load, when the engine is run on E5-3N100 emulsion fuels, the BSFC decreases as the injection timing is advanced from the original ignition timing (27^{o} BTDC). As the injection timing is delayed at any given load while using E5-3N100 fuel, the BSFC increases. With full load and the same injection time of 27° BTDC, it can be seen in Figure 48 that the brake-specific fuel consumption of E5-3N100 is 37% greater than that of neat diesel. When the injection timing is delayed to 25.5° BTDC, the BSFC increases by 9.5%, and when it is advanced to 28.5° BTDC, it reduces by 18.6%. In the same trained, the retarding of the injection timing for the fuel samples E10-3N100 and E15-3N100 the increment of BSFC is 30.5 and 2%, respectively. For the advanced injection timing case, the BSFC was reduced by 26 and 30.5%, respectively. A longer, more stable combustion process as a result of improved injection timing leads to a higher peak pressure soon after TDC, which favors lessening compression work and lowering BSFC. The injection time is delayed, which causes a shorter ignition delay and unstable combustion with a lower peak in-cylinder pressure value. Hence, advancing the injection time results in reduced BSFC consumption than retarding the injection timings for all the load conditions.

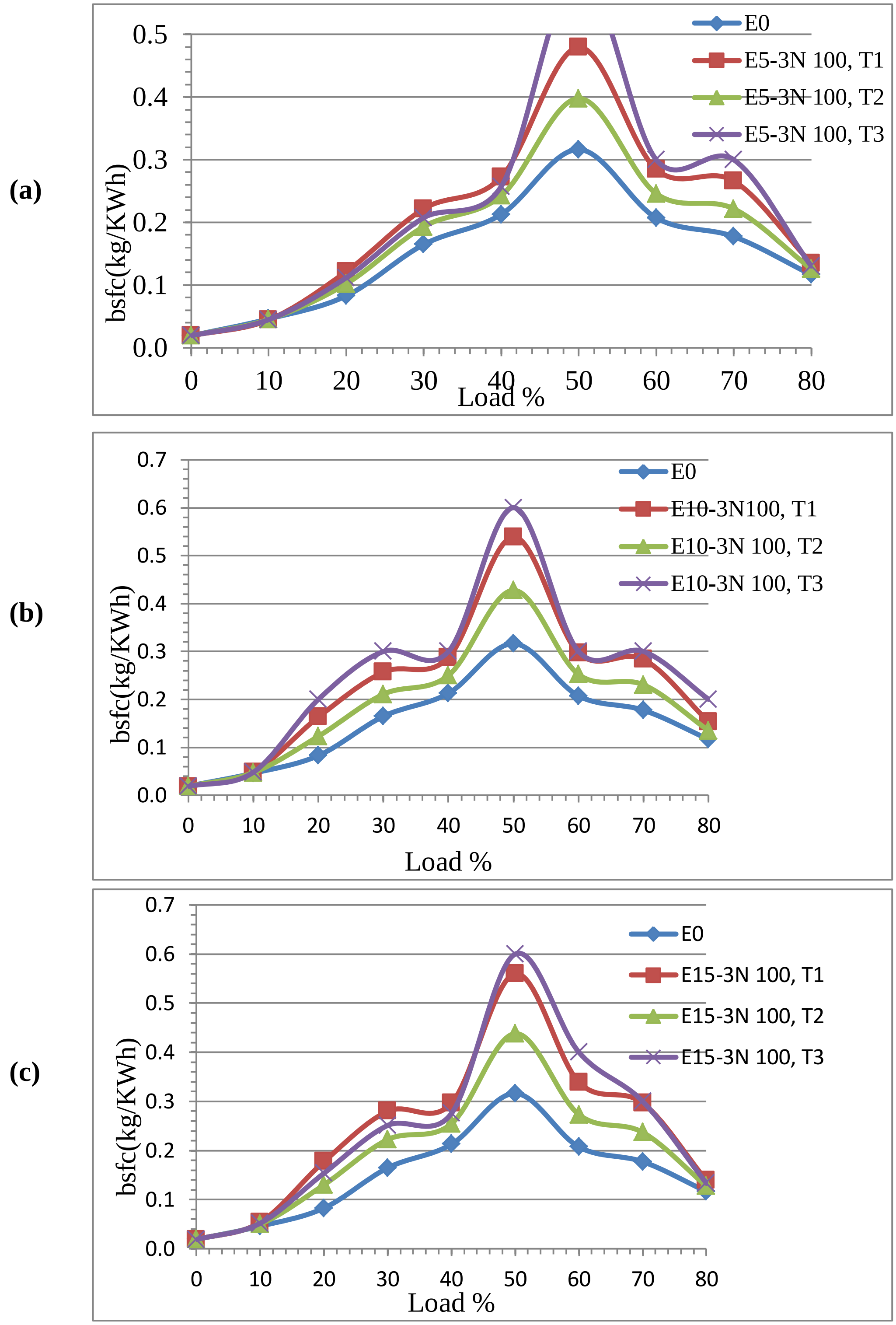
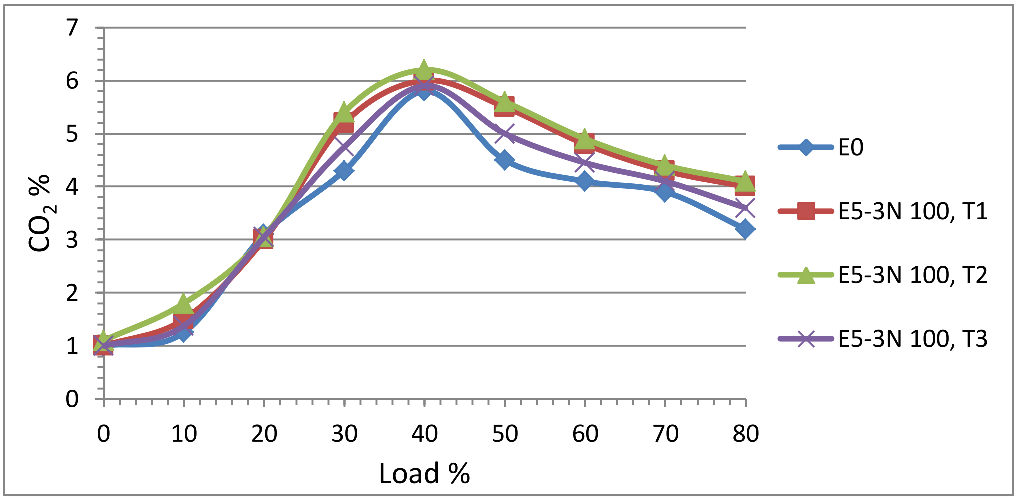


Figure 48. The effect of injection timing by the different fuel samples on brake specific fuel consumption (a) E5-3N100, (b) E10-3N100 and (c) E15-3N100

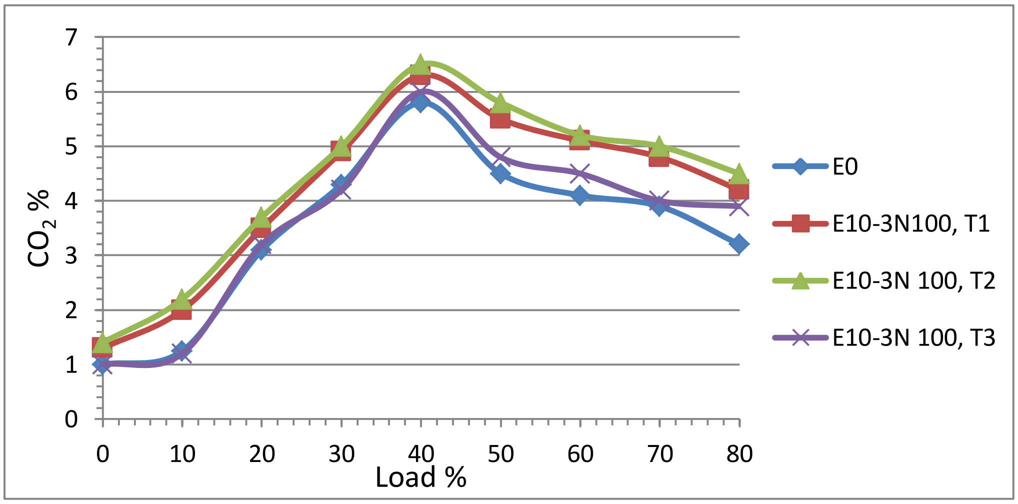
4.4.4. Influence of injection timing on CO_2 emission by E5-3N-100, E10-3N-100, and E15-3N-100 fuel Samples

Emission of carbon dioxide (CO_2) is usually expected from a complete combustion of fuel and unfortunately it is one of the major factors contributing to global warming. The CO_2 emission findings for diesel, E5-3N-100, E10-3N-100, and E15-3N-100 fuel samples at various injection timings are shown in Figure 49. The figure clearly shows that CO_2 emissions rose with increasing loads due to increased fuel injection. In this study, CO_2 emissions increased by about 4,5 and 7.5% for the E5-3N-100, E10-3N-100, and E15-3N-100 fuels, respectively, at the advanced injection timing of 28.5^o CA bTDC compared to the original injection timing because at the advanced injection timing more time is available for the oxidization process, resulting in a better air-fuel mixture and improved combustion. About 7, 15, and 30% reduced CO_2 emissions are seen with delayed injection timings of 25.5^o CA bTDC for the E5-3N-100, E10-3N-100, and E15-3N-100 fuels, respectively, due to partial combustion of the fuel as a result of insufficient time for combustion.

(a)



(b)



(c)

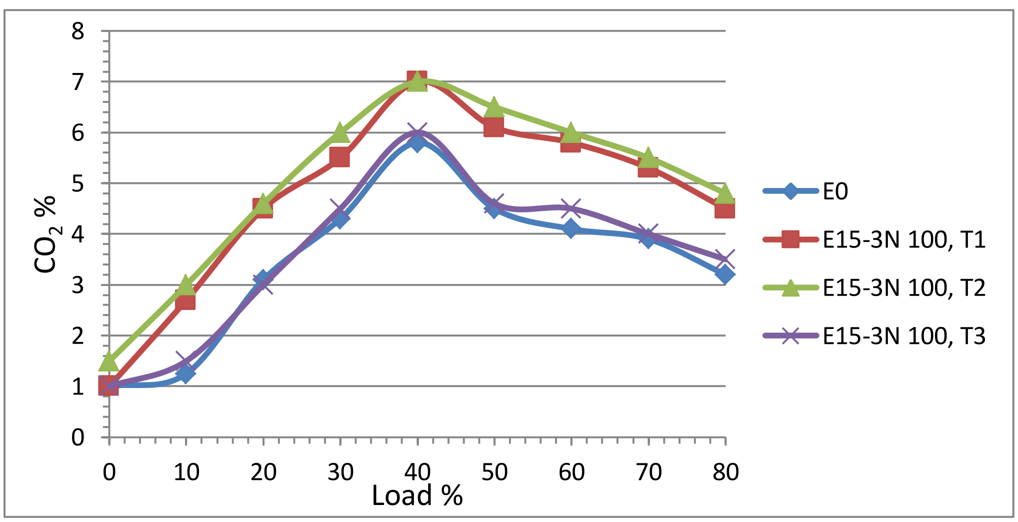


Figure 49. The effect of injection timing by the different fuel samples on CO_2 Emission E5-3N100, (b) E10-3N100 and (c) E15-3N100

4.4.5. Influence of injection timing on CO emission by E5-3N-100, E10-3N-100, and E15-3N-100 fuel Samples

Figure 50 indicates that as the injection timing is advanced, the CO emission decreases. Conditions for CO_2 oxidation include the presence of oxygen, a sufficient temperature, and a longer period of time. Under the same operating conditions, the CO emissions increase as the fuel injection timing is delayed. This is due to the fact that combustion occurs after TDC. The cylinder temperature is currently lower. With delayed injection time, the ignition delay is reduced, the fraction of premixed combustion is lowered, and CO from combustible mixture combustion is not oxidized and frozen. Under the same fuel injection timing as pure diesel fuel, the CO emissions of ethanol-emulsified fuel are minimized. Ethanol's oxygen content raises the oxygen concentration in the combustion process, resulting in more thorough burning of combustible mixtures.

The CO emission reduction ratio falls as the ethanol mixing ratio increases. This could be related to the synergistic effects of ethanol's latent heat of vaporization and its oxygen concentration. The percentage decrement due to the advancement of injection timing for the fuel samples E5-3N-100, E10-3N-100, and E15-3N-100 is 5, 2, and 28%, respectively. When the injection timing is retarded from the original injection timing the CO emissions increase by 18,40,42% for the mentioned fuel samples compared to the original injection timing.

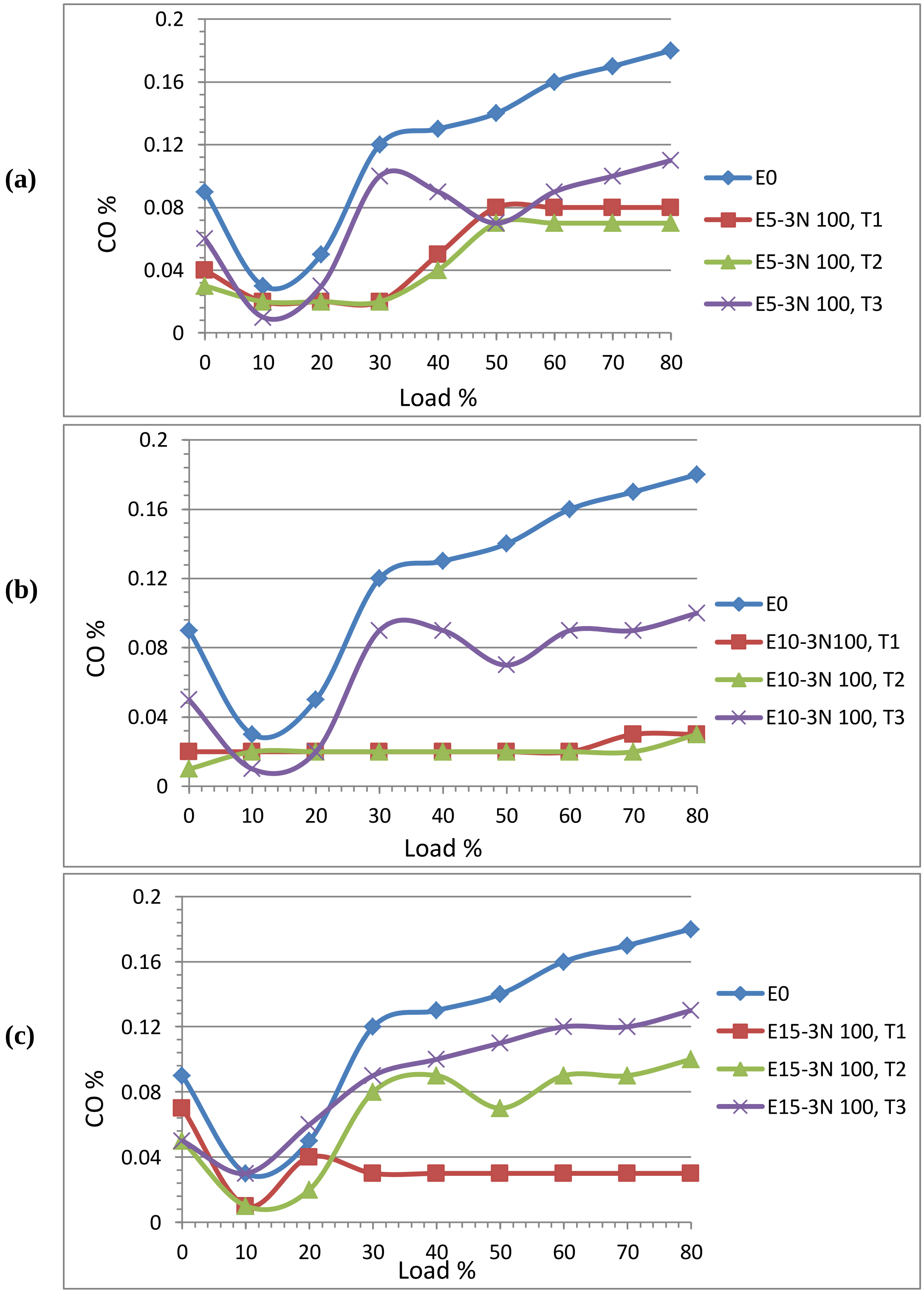


Figure 50. The effect of injection timing by the different fuel samples on CO Emission.

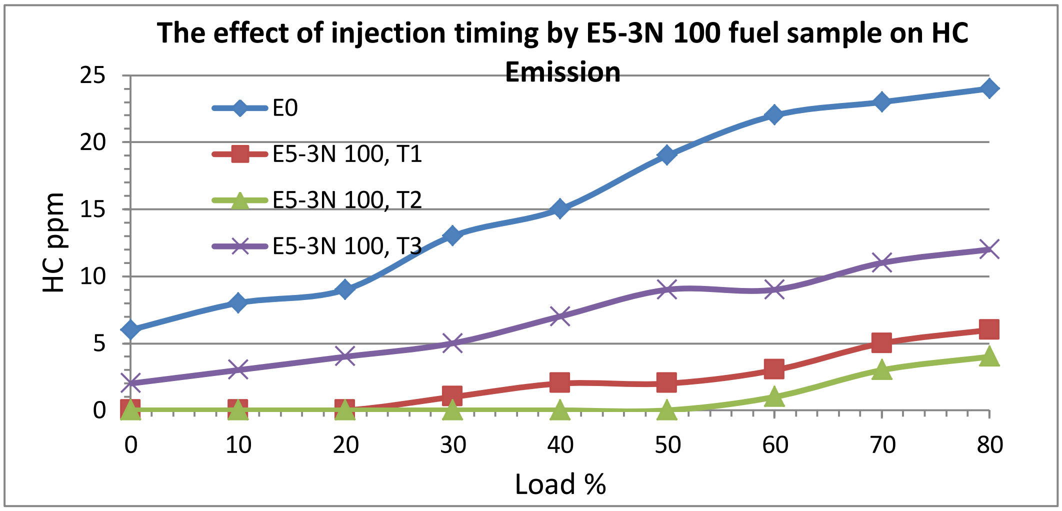
(a) E5-3N100, (b) E10-3N100 and (c) E15-3N100

4.4.6. Influence of injection timing on HC emission by E5-3N-100, E10-3N-100, and E15-3N-100 fuel Samples

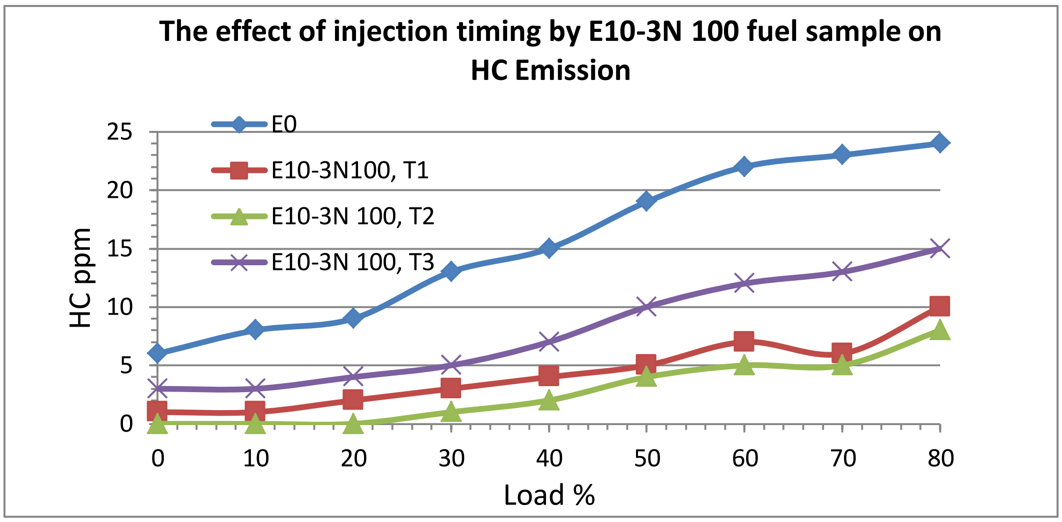
As can be seen from Figure 51, the HC emission decreases with the advancement of injection timing. HC emissions are mainly caused by unburned fuel and incomplete combustion. Under the same operating conditions, the amount of air entering the cylinder is equal. With the fuel injection timing advanced, the ignition delay period is prolonged; the proportion of premixed combustion increases, the pressure and temperature in the cylinder increase, and the oxidation process of hydrocarbon fuels is accelerated. Thus, the production of THC decreases as the injection timing advances. As the amount of ethanol in the mixing ratio increases, HC emissions decrease. Generally speaking, the shorter the ignitions delay period, the lower the HC emission. The cetane number of ethanol is low; the ignition delay period is long; and the more hydrocarbon wall quenching. At the same time, ethanol containing oxygen reduces the area of the over concentrated mixture in the cylinder, improves combustion efficiency. And the HC emission caused by the lack of oxygen in the combustion process of diesel engines is also decreased.

The HC emission reduction for the fuel samples E5-3N-100, E10-3N-100, and E15-3N-100 due to the injection timing advance angle of 1.5^{o} CA bTDC is 8, 10, and 5% more compared to the original injection timing. However, as the injection timing is retarded by the same CA bTDC, the HC emission is increased by 31, 23, and 38% more than at the original injection timing.

(a)



(b)



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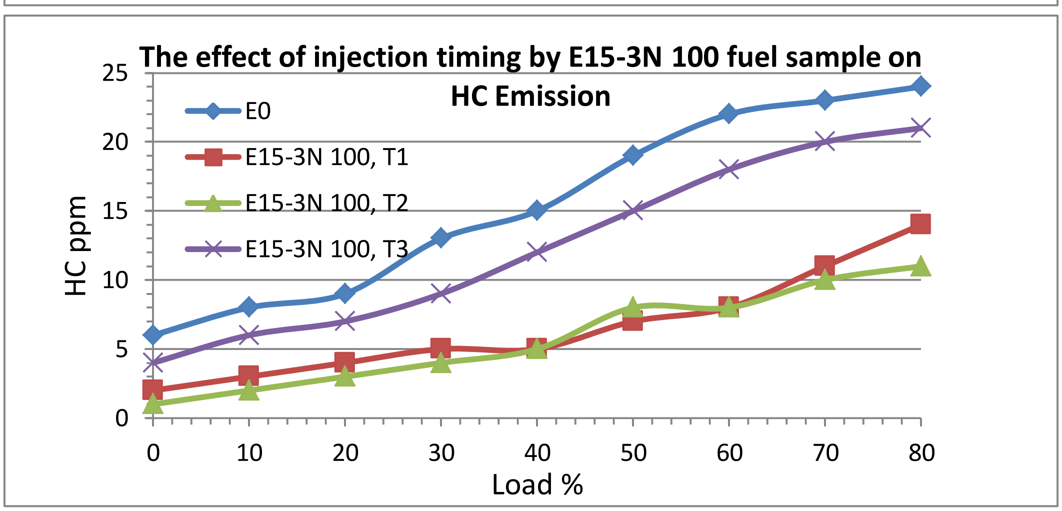


Figure 51. The effect of injection timing by the different fuel samples on HC Emission.
(a) E5-3N100, (b) E10-3N100 and (c) E15-3N100

4.4.7. Influence of injection timing on NOx emission by E5-3N-100, E10-3N-100, and E15-3N-100 fuel Samples

Exhaust gas contains nitrogen oxides (nitric oxide, NO, and some nitrogen dioxide, NO_2, generally known as NOx). The production of NOx is highly dependent on combustion chamber temperature, oxygen buildup, and reaction time. The ignition delay and injection timing are the most important engine factors that determine NOx generation.

The consequences of injection timing on NOx emissions with load for emulsion fuels E5-3N-100, E10-3N-100, and E15-3N-100 are demonstrated in figure 52. With increasing load, the combustion chamber's temperature rises, this leads to increased NOx emissions. With advanced injection timing, the amount of NOX emissions increases owing to the consequence of the premixed process of combustion time, which results at high pressure and cylinder temperature. From the test results, the average emissions of NOx for diesel at the original injection timing and the fuel samples E5-3N-100, E10-3N-100, and E15-3N-100 is demonstrated on the graph in figure---- ---. At the original injection timing, the influence of ethanol on NOx emissions is a slight difference. However the injection timing variation affected the NOx emission significantly. As the injection time is advanced from 27^o to 28.5^o the NOx emission is increased by 2, 5 % for the fuel samples E5-3N-100 and E10-3N-100, respectively, and for E15-3N-100 fuel, the NOx emission is about twice as much as at the original injection timing. When the injection timing is retarded by 1.5^o the NOx emissions for the fuels E5-3N-100, E10-3N-100, and E15-3N-100 decrease by 5.5, 12 and 18.5% respectively.

(a)

(b)

(c)

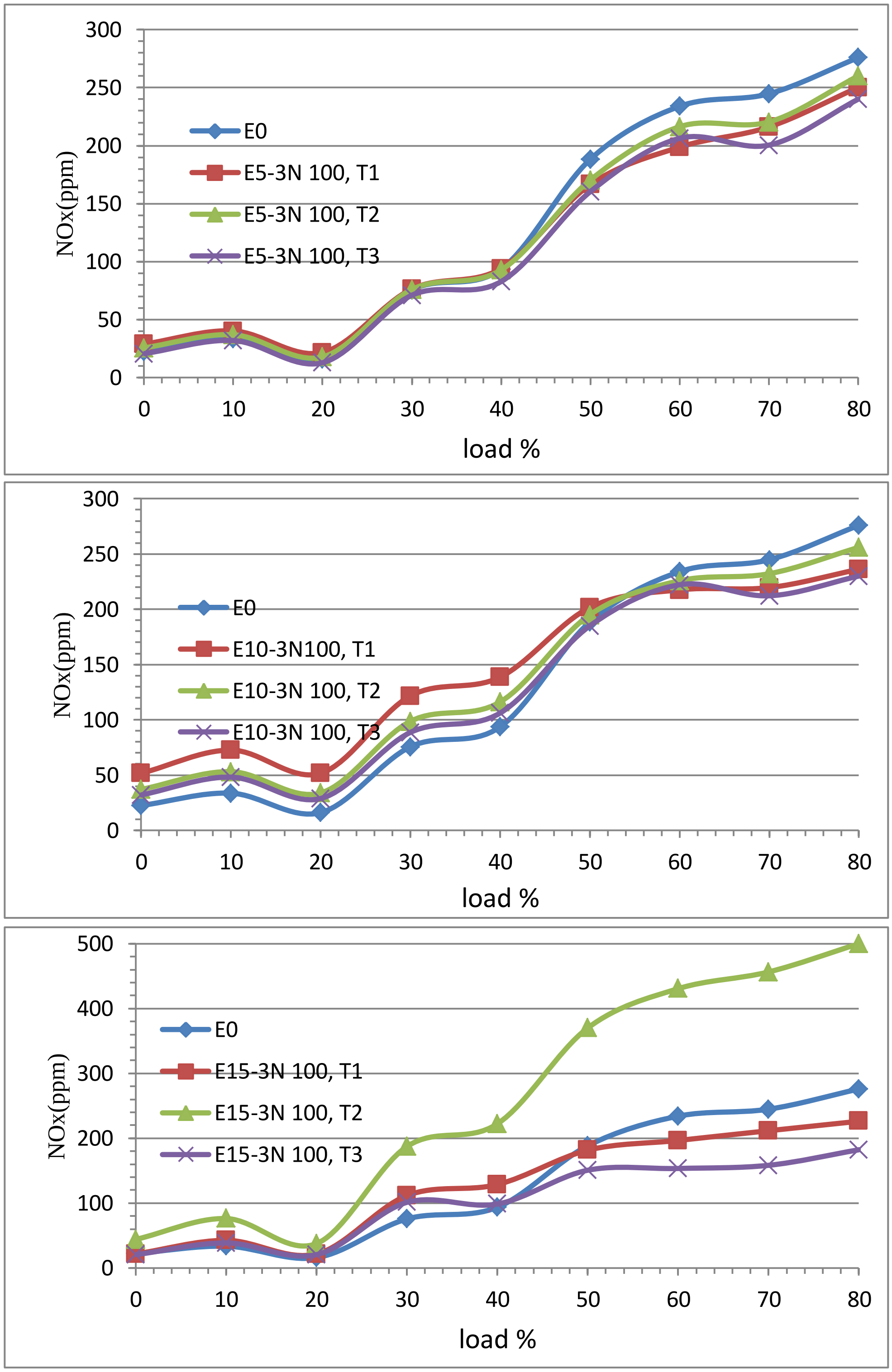


Figure 52.The effect of injection timing by the different fuel samples on NOx Emission E5-3N100, (b) E10-3N100 and (c) E15-3N100

4.4.8. Influence of injection timing on Smoke opacity by E5-3N-100, E10-3N-100, and E15-3N-100 fuel Samples

As shown in figure 53, the smoke opacity of a diesel engine can be reduced when ethanol is emulsified with diesel due to its oxygen content. This means that as the ethanol content increases in a diesel ethanol emulsion, the smoke opacity may decrease. However, the exact effect on smoke opacity may depend on various factors such as the injection timing and engine operating conditions. Therefore, finding the optimal ethanol blend ratio and injection timing is important to achieve low smoke emissions.

The injection timing of fuel in a diesel engine affects the combustion process and subsequently the smoke opacity. As mentioned before when the amount of ethanol is increased in ethanol-diesel emulsion, it can reduce the smoke opacity due to its oxygen content. However, the optimal injection timing for ethanol diesel blend may differ from that of pure diesel. Studies have shown that advancing the injection timing can reduce smoke opacity for ethanol diesel blends. This is because early injection leads to better fuel-air mixing and faster combustion, which reduces the formation of soot particles. However, advancing the injection timing too much can also increase NOx emissions.

On the other hand, retarding the injection timing can increase smoke opacity as it leads to incomplete combustion and higher soot formation. Therefore, finding the optimal injection timing for ethanol diesel blends is crucial to achieve low smoke emissions without compromising engine performance and emissions.

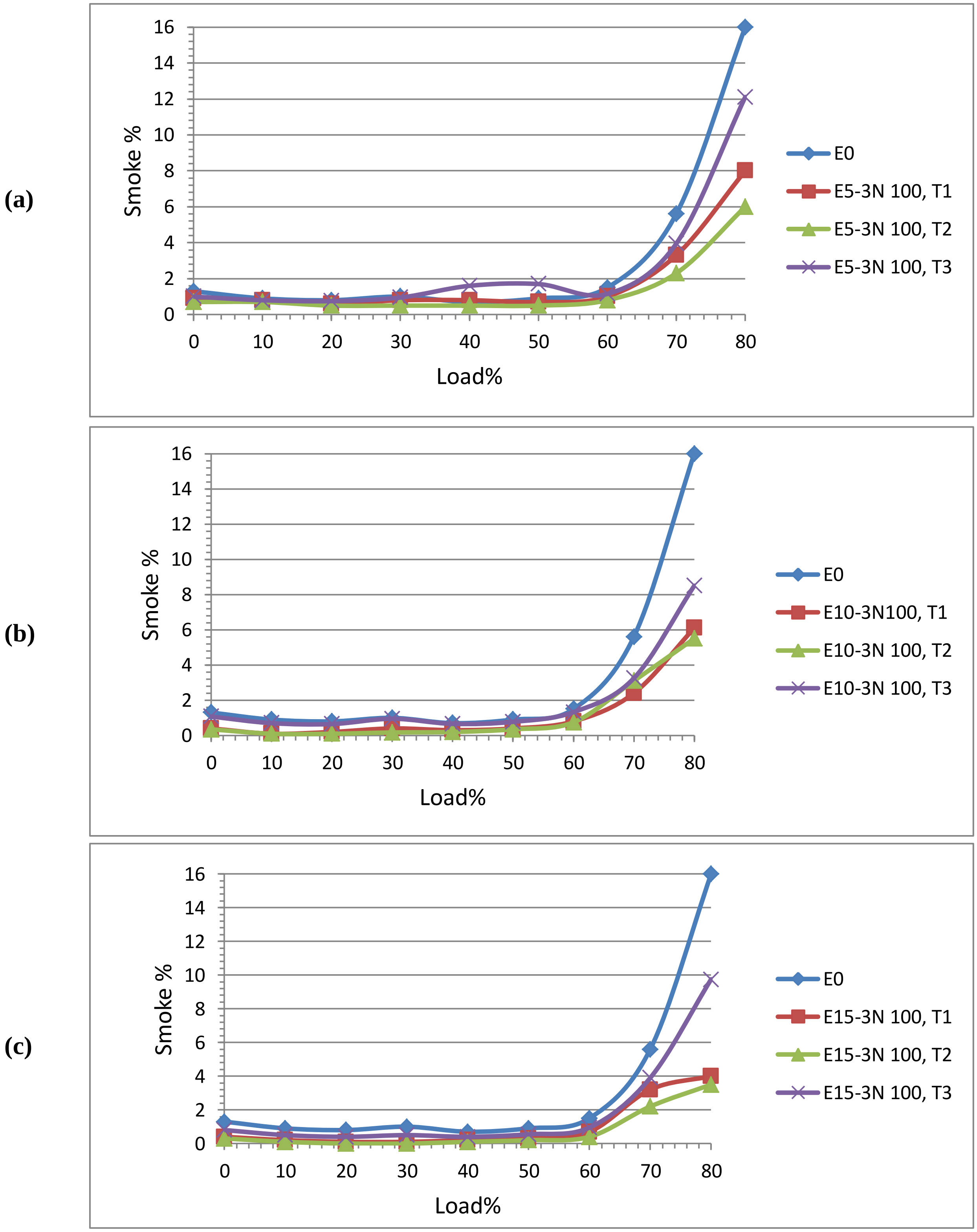


Figure 53. The effect of injection timing by the different fuel samples on Smoke Emission. E5-3N100, (b) E10-3N100 and (c) E15-3N100

4.5. Price comparison

The price comparison of ethanol-diesel emulsion with regular diesel fuel can vary depending on various factors, such as the current market prices of ethanol and diesel, production costs, taxes, and subsidies. Based on the local fuel suppliers and international current market prices, the accurate comparison for this specific case is that ethanol-diesel emulsion E10 with 50 ppm $NiZnFe_2O_4$ nanoparticles is about 0.243 USD more expensive than regular diesel fuel. The detail cost analysis is indicated on table 17.

In general, ethanol-diesel emulsion is slightly more expensive than regular diesel fuel due to the additional processing and blending required to create the emulsion. However, the exact price difference can fluctuate and may also be influenced by government policies promoting the use of alternative fuels.

Table 17. The price required to produce a litter of ethanol-diesel emulsion of E10 with 50 ppm $NiZnFe_2O_4$ nanoparticle

Item	*Unit Price in USD*	Amount require for a litter	Price USD/litter	remark
Diesel	*1.41/litter*	0.9 litter	1.269	
Ethanol	1/litter	0.1 litter	0.1	
Nanoparticle	947.62/kg	$2*10^{-8}$ kg	19*10-6	
CTMAB	5.41/kg	$2*10^{-8}$ kg	$1*10^{-7}$	
Tween 80	1.74/litter	0.0088 litter	0.015	
Span 80	20.44/litter	0.0132 litter	0.269	
Total			**1.653019**	

4.6. Summary

The solubility of the ethanol-diesel emulsions and the impact of using these fuel samples on engine performance and emissions characteristics were investigated experimentally. The ethanol content of the investigated emulsions ranged from 5% to 15% by volume, and they also contained additives of 25, 50, and 100 ppm $NiZnFe_2O_4$ nanoparticles. The engine was run with each blend under various load conditions ranging from zero to eighty percent load, with the engine speed changing as the load changed. The following conclusions can be derived from the test results:

The stability of ethanol diesel emulsion is highly influenced by the amount of ethanol content which increases with the increase in the amount of ethanol. The performance and emission characteristics of ethanol diesel emulsion fuel with adding Nickel Zinc Iron Oxide ($NiZnFe_2O_4$) nanoparticle is tested on attest rig of single cylinder four stroke diesel engines. From the test result, the following results are drawn. The amounts of ethanol in ethanol diesel emulsion fuel greatly in fluencies the fuel consumption of an engine. The test result showed 27.17, 34.39 and 37.87 % bsfc increment for E5, E10 and E15 fuel samples respectively. The presence of the nanoparticle in the fuel reduced the fuel consumption by 16.79, 27.86 and 27.48% for E10-3N-25, E10-3N-50 and E10-3N-100 respectively compared with E10 without nanoparticle addition. Brake torque increment of 3.5%, 3.03% and 3.53% for the fuel samples E10-3N-25, E10-3N-50 and E10-3N-100 respectively due to the nanoparticle addition compared to E10. The power output is also increased by 5.43, 7.74 and 6.97 % for the same fuel samples respectively. The addition of the nanoparticle gave tremendous reduction improvement in HC and CO emission. From the emission test result The HC emission reduction is recorded 50, 58 and 71% for E10-3N-25, E10-3N-50 and E10-3N-100 fuel samples. CO emission is also reduced by 20% due to the addition of ethanol for E10 fuel and 67, 80 and 81% for E10-3N-25, E10-3N-50 and E10-3N-100 fuel samples respectively. Ethanol diesel emulsion NO_X emission result gave a reduction of 26 % but after the nanoparticle have been added the NO_X emission started to increase with the ppm increment of the nanopaticle. The highest increment is recorded by the fuel sample E10-3N-100 which is 33% more compared to pure diesel fuel. Smoke opacity percentage is reduced with the use of ethanol emulsified fuel compared to pure diesel. More over the addition of the nanoparticle further reduced the smoke emission level. Due to the use of ethanol emulsion the reduction percentage is 28%, and a reduction of 59, 69 and 61% is recorded for the fuel samples E10-3N-25, E10-3N-50 and E10-3N-100 respectively. The test result showed the adding of nanoparticle reduces smoke emission upto a certain amount and further increment of the additive increases the smoke level and the optimum result is seen to be 69 % for the fuel sample E10-3N-50. Considering the performance and emission characteristics of the prepared sample fuels E10-3N-50, the one with 10% ethanol and 50ppm Nickel Zinc Iron Oxide ($NiZnFe_2O_4$) nano particle additive is more suitable than the other samples.

The impact of injection timing on the performance and exhaust emission of the engine using diesel fuel and ethanol-diesel blends with three elemental nanoparticle additives is investigated. The specific fuels selected based on their better performance are E5-3N100, E10-3N100 and

E15-3N100. The following are our conclusions: It was observed that advanced injection timing slightly improved the brake torque and power for all engine loads. The brake torque was increased by 8, 3, and 8% for the mentioned fuels, respectively, compared to the original injection timing. The brake power is also increased by 10, 4 and 6% for the fuels E5-3N100, E10-3N100 and E15-3N100 respectively. The BSFC decreased slightly with increasing ethanol content in emulsion fuel and the advance of the injection timing decreased by 19, 26 and 30% with respect to the fuels mentioned before. Advancing injection timing increased CO_2 and NOx emissions, but the results showed reductions in CO, HC and smoke emissions. Retarded injection timing of 25.5^o CA bTDC decreased NOx by an average of more than 8, 12, and 19% for all the respective fuels at all load conditions. The results demonstrated that ethanol addition significantly reduced CO emissions. Increasing the ethanol content in the emulsion reduced CO emissions due to the higher oxygen/carbon ratio of ethanol. At 28.5^o CA bTDC, the CO emissions were reduced by 2, 2 and 28% for the fuel samples E5-3N100, E10-3N100 and E15-3N100 respectively. Advancing the injection timing also reduced the HC emission by 8, 11 and 5% compared to the original injection timing. In the same way, smoke emissions have been reduced by 15, 2 and 8% with advanced injection timing for the same fuel samples tested.

CHAPTER FIVE
CONCLUSIONS AND RECOMMENDATIONS

5.1. Conclusion

The stability of an ethanol-diesel emulsion with a combined surfactant of span80 and tween80 is maintained by keeping the emulsion in a transparent, closed cup container. The stability results observed are included in this report. A four-stroke single-cylinder naturally aspirated direct injection diesel engine was used to study the performance and emission characteristics of ethanol-diesel emulsion with and without the addition of $NiZnFe_2O_4$ nanoparticles and compare them with those of diesel fuel. The influence of ethanol content on the performance and emission properties is evaluated, and selecting the optimum nanoparticle result of 100 ppm in the E5, E10 and E15 fuels, which are prepared as E5-3N-100, E10-3N-100 and E15-3N-100 fuels, is tested for their performance and emission characteristics when the fuel injection timing is varied. The following conclusions can be drawn from the collected data:

- The stability of an ethanol-diesel emulsion is influenced by the amount of ethanol content. As the amount of ethanol increases, the stability time becomes shorter. The shortest stability time is observed on the fuel sample having 15% ethanol content without nanoparticle additive and the stability duration is 144 hours. The fuel sample with 5% ethanol content maintained its stability for about 456 hours which is the longest stability time observed of all the fuel samples.
- At the engine's standard fuel injection timing, the maximum torque output is recorded by the fuel sample E10-3N-100. Even though the amount of ethanol emulsified in the fuel reduced the torque, the addition of 3N100 ppm nanoparticles significantly improved the torque output.
- The power output of all the sample fuels with ethanol resulted in a lower power output compared to neat diesel. However, comparing them to each other, the fuel sample E10-3N-100 produced the best power output compared to the other samples.
- As the amount of ethanol in the emulsified fuel is lower, the specific fuel consumption is reduced. The fuel sample with 5% ethanol content is observed to be the one with the smallest fuel consumption. After the nanoparticle has been added to the fuel samples, a

slight reduction in fuel consumption is seen and the fuel sample with the smallest specific fuel consumption is the E10-3N-50 fuel sample.

- The CO_2 emission is increased with the increase in the amount of ethanol and the maximum emission is recorded in a 15% ethanol-added fuel sample. The use of nanoparticles also further increased the CO_2 emission, so the maximum value is recorded by the E15-3N-100 fuel sample. The minimum CO_2 Emissions are recorded by the fuel sample E5 without any nanoparticle additive.
- The percentage increase in the ethanol content reduced CO emissions as a consequence of CO2 The lowest CO emission is recorded by the fuel sample E10-3N-100 and the highest is recorded by the fuel sample E5 for the ethanol-added fuel samples.
- The HC emission of ethanol-added fuel samples showed lower emission for E5 fuel sample but for E10 and E15 fuel samples, the HC emission was noticed to be increased as compared to diesel. The average HC emission of E5-3N-100 fuel is the smallest, but for E15, it is the largest of all the other fuel samples.
- When the ethanol content of diesel ethanol emulsion increases, the NOx emission decreases due to the higher concentration of ethanol in the emulsion. The highest emission of NOx is registered by the fuel sample E10-3N-100. The lowest NOx emission is registered by the fuel sample E15. This happened due to the lower heating value of the ethanol fuel, resulting in a lower combustion temperature, which hinders the reaction of N2with O_2.
- The effect of ethanol content on smoke emission in the ethanol-diesel emulsion is noticed to be that the emission reduces as the amount of ethanol is increased, and the addition of nanoparticles also reduced the emission further. This is due to the improved combustion effect as a result of oxygenation by the ethanol and the catalytic effect of the nanoparticle. The smallest smoke emission is recorded when the engine is run with an E15-3N-100 fuel sample. Out of the emulsified fuel samples, the highest emission of smoke was recorded by E5 fuel.
- Advancing injection timing improved the engine performance and reduced the specific fuel consumption in all the fuel samples. Retarding the injection timing resulted in reduced performance and increased specific fuel consumption.

- The influence of injection timing on exhaust emissions is seen as a reduction in CO, HC and smoke when the injection timing is advanced; however, the NOx and CO_2 emissions are increased. The retarded injection timing resulted in the reverse.

5.2. Recommendations

The authors recommend researchers to focus and conduct additional research as an extension of the currently produced research results. It is believed that the below list of areas are recommended to work in the area to promote ethanol diesel emulsion fuel and nanoparticle additives to its implementation stage in CI engine.

1 The effect of ethanol diesel emulsion fuel on the moving engine parts wear such as engine cylinder, piston, piston ring bearings valve and valve guide shall be seen in the future.

2 The influence of ethanol diesel emulsion fuel on the characteristics of engine lubricating oil shall be studied how it affects its physiochemical properties and determine the period of oil change interval.

3 The cost analysis of $NiZnFe_2O_4$ nanoparticle added fuels and its economic feasibility shall be studied.

4 The impact of $NiZnFe_2O_4$ nanoparticle on human health and environment shall be seen before marketing the fuel.

5 The design of mixing mechanism to maintain the stability of the emulsion during fuel storage and longtime vehicle parking shall be studied in the future.

6 The fuel thank of the machine operated with ethanol diesel emulsion should be tight seal to protect the escaping of the ethanol by evaporation.

REFERENCE

Abdalla, S., Al-Wafi, R., & Pizzi, A. (2017). Stability and combustion of metal nano-particles and their additive impact with diesel and biodiesel on engine efficiency: A comprehensive study. Journal of Renewable and Sustainable Energy, 9(2), 022701.

Abu-Qudais, M., Haddad, O., & Qudaisat, M. (2000). The effect of alcohol fumigation on diesel engine performance and emissions. Energy conversion and management, 41(4), 389-399.

Aguirre Mendoza, Z., Quizhpe C, W., & Pinza, D. (2018).Estimation of accumulated carbon in a permanent plot of Andean forest in the Francisco Vivar Castro university ark, Loja, Ecuador. Arnaldoa, 25(3), 939-952.

Agwu, O. (2020). Multiphase fuel combustion in a swirl diffusion burner: an operational and performance study (Doctoral dissertation, Cardiff University).

Aktaş, A., & Sekmen, Y. (2008). The effects of advance fuel injection on engine performance and exhaust emissions of a diesel engine fuelled with biodiesel. J. Fac. Eng. Arch. Gazi Univ, 23(1), 199-206.

Ampah, J. D., Yusuf, A. A., Afrane, S., Jin, C., & Liu, H. (2021). Reviewing two decades of cleaner alternative marine fuels: Towards IMO's decarbonization of the maritime transport sector. Journal of Cleaner Production, 320, 128871.

Ashok, M. P., & Saravanan, C. G. (2007). Performance and emission of the emulsified fuel in a DI diesel engine using oxygenated additive diethyl ether with surfactant of Span−80. energy & fuels, 21(4), 1878-1882.

Ayanie, A. K. (2011). Bioethanol Production And Optimization Test From Agricultural Waste: The Case Of Wet Coffee Processing Waste (Pulp)," A Thesis Submitted To The School Of Graduate Studies, Addis Ababa University In The Partial Fulfillment Of The Requirement For The Award Degree of Masters Of Science In Environmental Science,.

Aydın, F., & Öğüt, H. (2017). Effects of using ethanol-biodiesel-diesel fuel in single cylinder diesel engine to engine performance and emissions. Renewable energy, 103, 688-694.

Aydogan, H., Hirz, M., & Brunner, H. (2014). The use and future of biofuels. International Journal of Social Sciences, 3(4).

Bahrudin, M. N. H., Hagos, F. Y., Mamat, R., Abdullah, A. A., & Karim, Z. A. A. (2019, January). Comparison between tri-fuel (diesel-ethanol-biodiesel) emulsion with and without surfactant. In AIP Conference Proceedings (Vol. 2059, No. 1, p. 020056). AIP Publishing LLC.

Balat, M. (2007). Global bio-fuel processing and production trends. Energy Exploration & Exploitation, 25(3), 195-218.

Balat, M., & Balat, H. (2009). Recent trends in global production and utilization of bio-ethanol fuel. Applied energy, 86(11), 2273-2282.

Balat, M., Balat, H., & Öz, C. (2008). Progress in bioethanol processing. Progress in energy and combustion science, 34(5), 551-573.

Banapurmath NR, Budzianowski WM, Basavarajappa YH, Hosmath RS, Yaliwal VS, Tewari PG (2014) Effects of compression ratio, swirl augmentation techniques and ethanol addition on the combustion of CNG-biodiesel in a dual-fuel engine. Int J Sustain Eng 7:55–70

Baranescu, R. A. (1986). Fumigation of alcohols in a multicylinder diesel engine-Evaluation of potential (No. 860308). SAE Technical Paper.

Basha, J. S., & Anand, R. B. (2011). An experimental study in a CI engine using nanoadditive blended water–diesel emulsion fuel. International journal of green energy, 8(3), 332-348.

Bauer, N., Calvin, K., Emmerling, J., Fricko, O., Fujimori, S., Hilaire, J., ... & van Vuuren, D. P. (2017). Shared socio-economic pathways of the energy sector–quantifying the narratives. Global Environmental Change, 42, 316-330.

Boggavarapu, P., & Ravikrishna, R. V. (2019). Evaporating spray characteristics of a diesel-ethanol micro-emulsion. Fuel, 246, 104-107.

Boruff, P. A., Schwab, A. W., Goering, C. E., & Pryde, E. H. (1982). Evaluation of diesel fuel—ethanol microemulsions. Transactions of the ASAE, 25(1), 47-0053.

BroukhiyanE, LestzS(1981).Ethanol fumigation of a light duty automotive diesel engine SAE paper 811209.

Cahyono B, Bakar RA (2011) Effect of ethanol addition in the combustion process during warm-ups and half-open throttle on port injection gasoline engine. Am J Eng Appl Sci 4:66–69

Can, Ö., Celikten, I., & Usta, N. (2004). Effects of ethanol addition on performance and emissions of a turbocharged indirect injection diesel engine running at different injection pressures. Energy conversion and Management, 45(15-16), 2429-2440.

Canakci, M., Sayin, C., & Gumus, M. (2008). Exhaust emissions and combustion characteristics of a direct injection (DI) diesel engine fueled with methanol– diesel fuel blends at different injection timings. Energy & Fuels, 22(6), 3709-3723.

Chandra, R., & Kumar, R. (2007). Fuel properties of some stable alcohol–diesel microemulsions for their use in compression ignition engines. Energy & Fuels, 21(6), 3410-3414.

Channappagoudra, M. (2021). Influence of the aluminium oxide (Al2O3) nanoparticle additive with biodiesel on the modified diesel engine performance. International Journal of Ambient Energy, 42(15), 1776-1784.

Chao, H. R., Lin, T. C., Chao, M. R., Chang, F. H., Huang, C. I., & Chen, C. B. (2000). Effect of methanol-containing additive on the emission of carbonyl compounds from a heavy-duty diesel engine. Journal of Hazardous Materials, 73(1), 39-54.

Chen, H., Su, X., He, J., & Xie, B. (2019). Investigation on combustion and emission characteristics of a common rail diesel engine fueled with diesel/n-pentanol/methanol blends. Energy, 167, 297-311.

Chen, H., Su, X., Li, J., & Zhong, X. (2019). Effects of gasoline and polyoxymethylene dimethyl ethers blending in diesel on the combustion and emission of a common rail diesel engine. Energy, 171, 981-999.

Chen, H., Yan, W. S., Shen, L. Z., & Lei, J. L. (2011, April). Study on emulsification technology of diesel-ethanol based on functional group and emulsifying process. In 2011 International Conference on Electric Information and Control Engineering (pp. 6157-6160). IEEE.

Chena AF, Akmal Adzmia M, Adamb A, Fahmi Othmana M, Kamal Kamaruzzamana M, Mrwana AG (2018) Combustion characteristics, engine performances and emissions of a diesel engine using nanoparticle-diesel fuel blends with aluminium oxide, carbon nanotubes and silicon oxide. Energy Convers Manag 171:461–477

Chena AF, Akmal Adzmia M, Adamb A, Fahmi Othmana M, Kamal Kamaruzzamana M, Mrwana AG (2018) Combustion characteristics, engine performances and emissions of a diesel engine using nanoparticle-diesel fuel blends with aluminium oxide, carbon nanotubes and silicon oxide. Energy Convers Manag 171:461–477

Chockalingam SR, Sambandam A, Subramanian S, Ganapathy S (2010) Performance analysis of 1,4 dioxane-ethanol-diesel blends on diesel engines with and without thermal barrier coating. Thermal Sci 14:979–988

D'Silva R, Binu KG, Bhat T (2015) Performance and Emission Characteristics of a C.I. Engine fuelled with diesel and TiO2 nanoparticles as fuel additive. Mater Today: Proc 2:3728–3735.

Debbarma, S., & Misra, R. D. (2018). Effects of iron nanoparticle fuel additive on the performance and exhaust emissions of a compression ignition engine fueled with diesel and biodiesel. Journal of Thermal Science and Engineering Applications, 10(4).

DEMİRBAŞ A. (2005). Bioethanol from cellulosic materials: a renewable motor fuel from biomass. EnergySources; 27:327–37.

Demirbas, A. (2009). Progress and recent trends in biodiesel fuels. Energy conversion and management, 50(1), 14-34.

Dhahad, H. A., & Ali, S. A. G. (2019). Experimental study on the effect of nanoparticle addition on the pressure at the start of ignition, maximum pressure and timing of maximum pressure. ARPN J Eng Appl Sci, 14(8), 1478-1489.

Dreizin EL, Schoentitz M (2015) Correlating ignition mechanisms of aluminum-based reactive materials with thermoanalytical measurements. Prog Energy Combust Sci 50:81–105

Duan, X., Lai, M. C., Jansons, M., Guo, G., & Liu, J. (2021). A review of controlling strategies of the ignition timing and combustion phase in homogeneous charge compression ignition (HCCI) engine. Fuel, 285, 119142.

Dufey, A. (2007). International trade in biofuels: Good for development? And good for environment?.

Eisentraut, A. (2010). Sustainable production of second-generation biofuels: potential and perspectives in major economies and developing countries.

El-Din, M. N., El-Hamouly, S. H., Mohamed, H. M., Mishrif, M. R., & Ragab, A. M. (2013). Water-in-diesel fuel nanoemulsions: Preparation, stability and physical properties. Egyptian Journal of Petroleum, 22(4), 517-530.

El-Seesy, A. I., Hassan, H., & Ookawara, S. (2018). Effects of graphene nanoplatelet addition to jatropha Biodiesel–Diesel mixture on the performance and emission characteristics of a diesel engine. Energy, 147, 1129-1152.

Energy outlook (2016). “A Report of International Energy Agency”. www.eia.gov.cfm for executive summary: short-term energy outlook, analysis and projections. Report Number DOE/EIA-0484(2016), OECD/IEA (2016).

Fang, Q., Fang, J., Zhuang, J., & Huang, Z. (2013). Effects of ethanol–diesel–biodiesel blends on combustion and emissions in premixed low temperature combustion. Applied Thermal Engineering, 54(2), 541-548.

Fayyazbakhsh, A., & Pirouzfar, V. (2017). Comprehensive overview on diesel additives to reduce emissions, enhance fuel properties and improve engine performance. Renewable and Sustainable Energy Reviews, 74, 891-901.]

Fazliakmetov, R., & Shpiro, G. S. (1997). Selection and manufacture technology of antismoke additives for diesel fuel and boiler fuels oils. Izdetal Stvo Neft I Gaz, 4, 43-55.

Fernando, S., & Hanna, M. (2004). Development of a novel biofuel blend using ethanol‒biodiesel‒ diesel microemulsions: EB-diesel. Energy & Fuels, 18(6), 1695-1703.

Geng, L., Xiao, Y., Li, S., Chen, H., & Chen, X. (2021). Effects of injection timing and rail pressure on particulate size-number distribution of a common rail DI engine fueled with fischer-tropsch diesel synthesized from coal. Journal of the energy institute, 95, 219-230.

Gerdes KR, Suppes GJ (2001) Miscibility of ethanol in diesel fuels. Ind Eng Chem Res 40:949–956

Ghannam, M. T., & Selim, M. Y. (2009). Stability behavior of water-in-diesel fuel emulsion. Petroleum Science and Technology, 27(4), 396-411.

Griffin, W. C. (1949). Classification of surface-active agents by" HLB". J. Soc. Cosmet. Chem., 1, 311-325.

Guo, Z. G., Wang, S. R., & Wang, X. Y. (2013). Emulsification of bio-oil heavy fraction with diesel by mechanical and ultrasonic technologies. In Applied Mechanics and Materials (Vol. 316, pp. 1133-1137). Trans Tech Publications Ltd.

Guo, Z. G., Yin, Q. Q., & Wang, S. R. (2012). Bio-oil emulsion fuels production using power ultrasound. In Advanced Materials Research (Vol. 347, pp. 2709-2712). Trans Tech Publications Ltd.

Hajba, L., Eller, Z., Nagy, E., & Hancsók, J. (2011). Properties of diesel-alcohol blends. Hungarian journal of industrial chemistry, 39(3), 349-352.

Hamelinck, C. N., Van Hooijdonk, G., & Faaij, A. P. (2005). Ethanol from lignocellulosic biomass: techno-economic performance in short-, middle-and long-term. Biomass and bioenergy, 28(4), 384-410.

Hansdah, D., Murugan, S., & Das, L. M. (2013). Experimental studies on a DI diesel engine fueled with bioethanol-diesel emulsions. Alexandria Engineering Journal, 52(3), 267-276.

Hansen, A. C., Zhang, Q., & Lyne, P. W. (2005). Ethanol–diesel fuel blends—a review. Bioresource technology, 96(3), 277-285.

Heidari-Maleni A, Gundoshmian TM, Jahanbakhshi A, Ghobadian B (2020) Performance improvement and exhaust emissions reduction in diesel engine through the use of graphene quantum dot (GQD) nanoparticles and ethanol biodiesel blends. Fuel 267:117116

Hielscher, T. (2007). Ultrasonic production of nano-size dispersions and emulsions. arXiv preprint arXiv:0708.1831.

Huang, J., Wang, Y., Li, S., Roskilly, A. P., Yu, H., & Li, H. (2009). Experimental investigation on the performance and emissions of a diesel engine fuelled with ethanol–diesel blends. Applied Thermal Engineering, 29(11-12), 2484-2490.

Hulwan, D. B., & Joshi, S. V. (2011). Performance, emission and combustion characteristic of a multicylinder DI diesel engine running on diesel–ethanol–biodiesel blends of high ethanol content. Applied Energy, 88(12), 5042-5055.

Hunt EM, Pantoya ML (2005) Ignition dynamics and activation energies of metallic thermites: from nano- to micron-scale particulate composities. J Appl Phys 98:034909, 8

Ichikawa, S. (1997). Photoelectrocatalytic production of hydrogen from natural seawater under sunlight. International journal of hydrogen energy, 22(7), 675-678.

İçıngür, Y., & Altiparmak, D. (2003). Effect of fuel cetane number and injection pressure on a DI Diesel engine performance and emissions. Energy conversion and management, 44(3), 389-397.

Ileri, E., & Koçar, G. (2013). Effects of antioxidant additives on engine performance and exhaust emissions of a diesel engine fueled with canola oil methyl ester–diesel blend. Energy Conversion and Management, 76, 145-154.

Janssen, R., & Rutz, D. D. (2011). Sustainability of biofuels in Latin America: Risks and opportunities. Energy Policy, 39(10), 5717-5725.

Jiaqiang, E., Zhang, Z., Chen, J., Pham, M., Zhao, X., Peng, Q., & Yin, Z. (2018). Performance and emission evaluation of a marine diesel engine fueled by water biodiesel-diesel emulsion blends with a fuel additive of a cerium oxide nanoparticle. Energy Conversion and Management, 169, 194-205.

Johnston, B., Mayo, M. C., & Khare, A. (2005). Hydrogen: the energy source for the 21st century. Technovation, 25(6), 569-585.

Karabektas, M., Ergen, G., & Hosoz, M. (2013). Effects of the blends containing low ratios of alternative fuels on the performance and emission characteristics of a diesel engine. Fuel, 112, 537-541.

Karthikeyan, S., Elango, A., & Prathima, A. (2014). Performance and emission study on zinc oxide nano particles addition with pomolion stearin wax biodiesel of CI engine.

Keskin, A., Gürü, M., & Altıparmak, D. (2007). Biodiesel production from tall oil with synthesized Mn and Ni based additives: effects of the additives on fuel consumption and emissions. Fuel, 86(7-8), 1139-1143.

Keskin, A., Yaşar, A., Yıldızhan, Ş., Uludamar, E., Emen, F. M., & Külcü, N. (2018). Evaluation of diesel fuel-biodiesel blends with palladium and acetylferrocene based additives in a diesel engine. Fuel, 216, 349-355.

Khan, S., Dewang, Y., Raghuwanshi, J., Shrivastava, A., & Sharma, V. (2022). Nanoparticles as fuel additive for improving performance and reducing exhaust emissions of internal combustion engines. International journal of Environmental analytical chemistry, 102(2), 319-341.

Khond, V. W., & Kriplani, V. M. (2016). Effect of nanofluid additives on performances and emissions of emulsified diesel and biodiesel fueled stationary CI engine: A comprehensive review. Renewable and Sustainable Energy Reviews, 59, 1338-1348.

Khoobbakht, G., Najafi, G., Karimi, M., & Akram, A. (2016). Optimization of operating factors and blended levels of diesel, biodiesel and ethanol fuels to minimize exhaust emissions of diesel engine using response surface methodology. Applied Thermal Engineering, 99, 1006-1017.

Kim, H., & Choi, B. (2008). Effect of ethanol–diesel blend fuels on emission and particle size distribution in a common-rail direct injection diesel engine with warm-up catalytic converter. Renewable Energy, 33(10), 2222-2228.

Krishnamoorthi, M., & Malayalamurthi, R. (2017). Combined Effect of Compression Ratio, Injection Pressure, and Injection Timing on Performance and Emission of a DI Compression Ignition Engine Fueled with Diesel–Aegle Marmelos Oil–Diethyl Ether Blends Using Response Surface Methodology. Energy & Fuels, 31(10), 11362-11376.

Krishnamoorthi, M., Malayalamurthi, R., & Shameer, P. M. (2018). RSM based optimization of performance and emission characteristics of DI compression ignition engine fuelled with diesel/aegle marmelos oil/diethyl ether blends at varying compression ratio, injection pressure and injection timing. Fuel, 221, 283-297.

Kumar N, Varun, Chauhan SR (2016) Evaluation of the effects of engine parameters on performance and emissions of diesel engine operating with biodiesel blend. Int J Ambient Energy 37:121–135.

Kuszewski, H., Jaworski, A., & Mądziel, M. (2021). Lubricity of Ethanol–Diesel Fuel Blends—Study with the Four-Ball Machine Method. Materials, 14(10), 2492.

Labeckas, G., Slavinskas, S., & Kanapkienė, I. (2017). The individual effects of cetane number, oxygen content or fuel properties on the ignition delay, combustion characteristics, and cyclic variation of a turbocharged CRDI diesel engine–Part 1. Energy Conversion and Management, 148, 1003-1027.]

Ladommatos, N., Parsi, M., & Knowles, A. (1996). The effect of fuel cetane improver on diesel pollutant emissions. Fuel, 75(1), 8-14.

Lambe, F., & Jürisoo, M. (2015). Ethanol: towards a viable alternative for domestic cooking in Ethiopia.

Lapuerta, M., Armas, O., & Garcia-Contreras, R. (2007). Stability of diesel–bioethanol blends for use in diesel engines. Fuel, 86(10-11), 1351-1357.

Lapuerta, M., Armas, O., & Garcia-Contreras, R. (2009). Effect of ethanol on blending stability and diesel engine emissions. Energy & Fuels, 23(9), 4343-4354.

Lapuerta, M., Armas, O., & Garcia-Contreras, R. (2009). Effect of ethanol on blending stability and diesel engine emissions. Energy & Fuels, 23(9), 4343-4354.

Lapuerta, M., García-Contreras, R., Campos-Fernández, J., & Dorado, M. P. (2010). Stability, lubricity, viscosity, and cold-flow properties of alcohol− diesel blends. Energy & fuels, 24(8), 4497-4502.

Lapuerta, M., García-Contreras, R., Campos-Fernández, J., & Dorado, M. P. (2010). Stability, lubricity, viscosity, and cold-flow properties of alcohol− diesel blends. Energy & fuels, 24(8), 4497-4502.

Lapuerta, M., Herreros, J. M., Lyons, L. L., García-Contreras, R., & Briceño, Y. (2008). Effect of the alcohol type used in the production of waste cooking oil biodiesel on diesel performance and emissions. Fuel, 87(15-16), 3161-3169.

Lawrence, P., Mathewsz, P. K., & Deepanraj, B. (2012). Experimental investigation 0n performance and emission characteristics of low heat rejection diesel engine with ethanol as fuel.

Liang, J., Qian, Y., Yuan, X., Leng, L., Zeng, G., Jiang, L., & Li, X. (2018). Span80/Tween80 stabilized bio-oil-in-diesel microemulsion: Formation and combustion. Renewable Energy, 126, 774-782.

Licht, P. B., Jørgensen, O. D., Ladegaard, L., & Jakobsen, E. (2013). A national study of nodal upstaging after thoracoscopic versus open lobectomy for clinical stage I lung cancer. The Annals of thoracic surgery, 96(3), 943-950.

Lin, C. Y., & Chen, L. W. (2006). Emulsification characteristics of three-and two-phase emulsions prepared by the ultrasonic emulsification method. Fuel Processing Technology, 87(4), 309-317.

Lin, C. Y., & Wang, K. H. (2003). The fuel properties of three-phase emulsions as an alternative fuel for diesel engines. Fuel, 82(11), 1367-1375.

Lin, C. Y., & Wang, K. H. (2003). The fuel properties of three-phase emulsions as an alternative fuel for diesel engines☆. Fuel, 82(11), 1367-1375.

Lincy R, Wang KH (2003) The fuel properties of three phases emulsion as an alternative fuel for diesel engine. Fuel 82:1367–1375

Liu, Haifeng; Hu, Bin; Jin, Chao (2016). Effects of different alcohols additives on solubility of hydrous ethanol/diesel fuel blends. Fuel, 184(), 440–448.

Liu, S., Zhu, Z., Zhang, Z., Gao, G., & Wei, Y. (2010). Effect of a cetane number (CN) improver on combustion and emission characteristics of a compression-ignition (CI) engine fueled with an ethanol– diesel blend. Energy & Fuels, 24(4), 2449-2454.

Low, M. H., Mukhtar, N. A. M., Hagos, F. Y., & Noor, M. M. (2017, October). Tri-fuel (diesel-biodiesel-ethanol) emulsion characterization, stability and the corrosion effect. In IOP Conference Series: Materials Science and Engineering (Vol. 257, No. 1, p. 012082). IOP Publishing.

Luo, L., Van Der VOET, E., & Huppes, G. (2009). Life cycle assessment and life cycle costing of bioethanol from sugarcane in Brazil. Renewable and sustainable energy reviews, 13(6-7), 1613-1619.

Mahalingam, S., & Ganesan, S. (2020). Effect of nano-fuel additive on performance and emission characteristics of the diesel engine using biodiesel blends with diesel fuel. International Journal of Ambient Energy, 41(3), 316-321.

Mahmudul, H. M., Hagos, F. Y., Mamat, R., & Abdullah, A. A. (2018, March). Effect of alcohol on diesel engine combustion operating with biodiesel-diesel blend at idling conditions. In IOP Conference Series: Materials Science and Engineering (Vol. 318, No. 1, p. 012071). IOP Publishing.

Mahmudul, H. M., Hagos, F. Y., Mamat, R., Adam, A. A., Ishak, W. F. W., & Alenezi, R. (2017). Production, characterization and performance of biodiesel as an alternative fuel in diesel engines–A review. Renewable and Sustainable Energy Reviews, 72, 497-509.

Manigandan S, Sarweswaran R, Booma Devi P, Sohret Y, Kondratiev A, Venkatesh S, Rakesh Vimal M, Jensin Joshua J, (2020) Comparative study of nanoadditives TiO2, CNT, Al2O3, CuO and CeO2 on reduction of diesel engine emission operating on hydrogen fuel blends. Fuel

Mažeika, M., Labeckas, G., Klyus, O., & Kanapkienė, I. (2014). THE EFFECT OF THE BIOFUEL PROPERTIES ON THE AUTOIGNITION DELAY IN A DIESE ENGINE. Agricultural Engineering, 46, 51-65.

Mccormick RL, Parish R (2001) Advanced petroleum based fuels program and renewable diesel program, milestone report: technical barriers to the use of ethanol in diesel fuel. National Renewable Energy Laboratory

Mehta, R. N., Chakraborty, M., & Parikh, P. A. (2012). Comparative study of stability and properties of alcohol-diesel blends.
Mehta, R. N., Chakraborty, M., & Parikh, P. A. (2012). Comparative study of stability and properties of alcohol-diesel blends.
Mehta, R. N., Chakraborty, M., & Parikh, P. A. (2014). Study of stability, physical properties and engine performance of alcohol blended fuels.

Mehta, R. N.; Barad, J. M.; Chakraborty, M.; Parikh, P. A. (2012). A Stability and Performance Study of Ethanol-Diesel Microemulsion Fuel. Petroleum Science and Technology, 30(2), 159–169. doi:10.1080/10916461003773070

Mei D, Zuo L, Adu-Mensah D, Li X, Yuan Y (2019) Combustion characteristics and emissions of a common rail diesel engine using nanoparticle-diesel blends with carbon nanotube and molybdenum trioxide. Appl Therm Eng 162:114238

Mielenz, J. R. (2001). Ethanol production from biomass: technology and commercialization status. Current opinion in microbiology, 4(3), 324-329.

Mofijur, M. G. R. M., Rasul, A. M., Hyde, J., Azad, A. K., Mamat, R., & Bhuiya, M. M. K. (2016). Role of biofuel and their binary (diesel–biodiesel) and ternary (ethanol–biodiesel–diesel) blends on internal combustion engines emission reduction. Renewable and Sustainable Energy Reviews, 53, 265-278.

Murcak, A., Haşimoğlu, C., Çevik, İ., Karabektaş, M., & Ergen, G. (2013). Effects of ethanol–diesel blends to performance of a DI diesel engine for different injection timings. Fuel, 109, 582-587.

Mussatto, S. I., Dragone, G., Guimarães, P. M., Silva, J. P. A., Carneiro, L. M., Roberto, I. C., ... & Teixeira, J. A. (2010). Technological trends, global market, and challenges of bio-ethanol production. Biotechnology advances, 28(6), 817-830.

Nabi, M. N., Rasul, M. G., Arefin, M. A., Akram, M. W., Islam, M. T., & Chowdhury, M. W. (2021). Investigation of major factors that cause diesel NOx formation and assessment of energy and exergy parameters using e-diesel blends. Fuel, 292, 120298.

Naik, S. N., Goud, V. V., Rout, P. K., & Dalai, A. K. (2010). Production of first and second generation biofuels: a comprehensive review. *Renewable and sustainable energy reviews*, *14*(2), 578-597.

Nallamothu RB, Anantha Kamal N, Seshu Kishan N, Niranjan Kumar IN, Appa Rao BV (2020) Effect of multiple injection strategy on combustion of cotton seed oil biodiesel in CRDI diesel engine. In: Narasimham G, Babu A, Reddy S, Dhanasekaran R (eds) Recent trends in mechanical engineering. Lecture Notes in Mechanical Engineering. Springer, Singapore. https://doi.org/10.1007/978-981-15-1124-0_9

Nallamothu RB, Birbirsa G, Niranjan Kumar IN, Appa Rao BV, Seshu Kishan N (2019) A review on performance of biodiesel in engines with and without addition of nanoparticles. Int J Manag Technol Eng IJMTE/1592, IX(II)

Nallamothu RB, Lemma M, Niranjan Kumar IN, Appa Rao BV, Anantha Kamal N, Seshu Kishan N (2019) Performance of cotton seed biodiesel with nano additives in diesel engines: a review. J Appl Sci Comput VI(II):142–147. ISSN: 1076-5131

Nallamothu RB, Nallamothu AK, Nallamothu SK Emission characteristics of CSOME in CRDI diesel engine with multiple injection strategy. In: Narasimham GSVL, Babu AV, Reddy SS, Dhanasekaran R (eds) Recent trends in mechanical engineering. Lecture Notes in Mechanical Engineering. Springer, Singapore. https://doi.org/10.1007/978-981-15-7557-0_9. (2021).

Nallamothu RB, Nallamothu AK, Nallamothu SK, Niranjan Kumar IN, Appa Rao BV (2018) Experimental investigation on effect of injection timing in multiple injection on NOx and smoke from CRDI diesel engine fueled with biodiesel blend. The Ethiop J Sci Sustain Dev (EJSSD) 5(2)

Nallamothu RB, Niranjan Kumar IN, Appa Rao BV, Anantha Kamal N, Seshu Kishan N (2018) Emission analysis of CRDI diesel engine fueled with cotton seed oil biodiesel with multiple injection strategy. Int J Emer Technol Innov Res 5(9):707–712

Nallamothu RB, Niranjan Kumar IN, Appa Rao BV, Anantha Kamal N, Seshu Kishan N (2018) Emission analysis of CRDI diesel engine fueled with cotton seed oil biodiesel with multiple injection strategy. Int J Emer Technol Innov Res 5(9):707–712

Nanthagopal K, Ashok B, Tamilarasu A, Johny A, Mohan A (2017) Influence on the effect of zinc oxide and titanium dioxide nanoparticles as an additive with Calophyllum inophyllum methyl ester in a CI engine. Energy Convers Manag 146:8–19

Nwafor, O. M. I. (2000). Effect of advanced injection timing on the performance of natural gas in diesel engines. Sadhana, 25, 11-20.

Parlak, A., Yaşar, H., Haşimogˇlu, C., & Kolip, A. (2005). The effects of injection timing on NOx emissions of a low heat rejection indirect diesel injection engine. Applied Thermal Engineering, 25(17-18), 3042-3052.

Patil, H., Gadhave, A., Mane, S., & Waghmare, J. (2015). Analyzing the stability of the water-in-diesel fuel emulsion. Journal of Dispersion Science and Technology, 36(9), 1221-1227.

Payri, F., Benajes, J., Arregle, J., & Riesco, J. M. (2006). Combustion and exhaust emissions in a heavy-duty diesel engine with increased premixed combustion phase by means of injection retarding. Oil & gas science and technology, 61(2), 247-258.

Prabakaran, B., & Udhoji, A. (2016). Experimental investigation into effects of addition of zinc oxide on performance, combustion and emission characteristics of diesel-biodiesel-ethanol blends in CI engine. Alexandria Engineering Journal, 55(4), 3355-3362.

Prabakaran, B., & Vijayabalan, P. (2018, June). Influence of zinc oxide nano particles on performance, combustion and emission characteristics of butanol-diesel-ethanol blends in DI CI engine. In IOP conference series: materials science and engineering (Vol. 377, No. 1, p. 012069). IOP Publishing.

Prabu A, Anand RB (2015). Performance combustion and emission characteristics of a D.I. diesel engine fuelled with nanoparticle blended. Period PolytechMechEng 2015;59:88–93.

Prabu, Anand RB (2016) Emission control strategy by adding alumina and cerium oxide nano particle in biodiesel. J Energy Inst 89:366e372.

Precedence Research, Oil Storage Market Size, Trends, Growth, Report 2022 to 2030, (October 2022). Apt 1408 1785 Riverside Drive Ottawa, ON, K1G 3T7, Canada

Qi D, Chen H, Geng L, Bian YZ (2010) Experimental studies on the combustion characteristics and performance of a direct injection engine fueled with biodiesel/ diesel blends. Energy Convers Manag 51(12)2985–2992

Rahman, M. M., Rasul, M., Hassan, N. M. S., & Hyde, J. (2016). Prospects of biodiesel production from macadamia oil as an alternative fuel for diesel engines. Energies, 9(6), 403.

Rakopoulos, D. C., Rakopoulos, C. D., Giakoumis, E. G., Papagiannakis, R. G., & Kyritsis, D. C. (2008). Experimental-stochastic investigation of the combustion cyclic variability in HSDI diesel engine using ethanol–diesel fuel blends. Fuel, 87(8-9), 1478-1491.

Ranjan, A., Dawn, S. S., Jayaprabakar, J., Nirmala, N., Saikiran, K., & Sriram, S. S. (2018). Experimental investigation on effect of MgO nanoparticles on cold flow properties, performance, emission and combustion characteristics of waste cooking oil biodiesel. Fuel, 220, 780-791.

Rashed, M. M., Kalam, M. A., Masjuki, H. H., Habibullah, M., Imdadul, H. K., Shahin, M. M., & Rahman, M. M. (2016). Improving oxidation stability and NOx reduction of biodiesel blends using aromatic and synthetic antioxidant in a light duty diesel engine. Industrial Crops and Products, 89, 273-284.

Ribeiro NM (2007) The role of additives for diesel and diesel blended (ethanol or biodiesel) fuels: a review. Energy Fuels 21(4):2433–2445

Rutz, D., & Janssen, R. (2007). Biofuel technology handbook. WIP Renewable energies, 95.

Sajeevan, A. C., & Sajith, V. (2013). Diesel engine emission reduction using catalytic nanoparticles: an experimental investigation. Journal of Engineering, 2013.

Sakthivel, P., Subramanian, K. A., & Mathai, R. (2018). Indian scenario of ethanol fuel and its utilization in automotive transportation sector. Resources, Conservation and Recycling, 132, 102-120.

Sarkar, N., Ghosh, S. K., Bannerjee, S., & Aikat, K. (2012). Bioethanol production from agricultural wastes: an overview. Renewable energy, 37(1), 19-27.

Satgé De Caro P, Mouloungui Z, Vaitilingomb G Berge JCh (2001) Interest of combining an additive with diesel–ethanol blends for use in diesel engines. Fuel 80:565–574

Saxena VK, Tiwari HP, Banerjee PK (2013) A noble technique for accessing the cooking potential of coals/coal beds for non-recovery coke making process. Fuel 107:615622

Saxena, V., Kumar, N., & Saxena, V. K. (2017). A comprehensive review on combustion and stability aspects of metal nanoparticles and its additive effect on diesel and biodiesel fuelled CI engine. Renewable and Sustainable Energy Reviews, 70, 563-588.

Saxena, V., Kumar, N., & Saxena, V. K. (2017). A comprehensive review on combustion and stability aspects of metal nanoparticles and its additive effect on diesel and biodiesel fuelled CI engine. Renewable and Sustainable Energy Reviews, 70, 563-588.

Sayin, C. (2010). Engine performance and exhaust gas emissions of methanol and ethanol–diesel blends. Fuel, 89(11), 3410-3415.

Sayin, C., & Canakci, M. (2009). Effects of injection timing on the engine performance and exhaust emissions of a dual-fuel diesel engine. Energy conversion and management, 50(1), 203-213.

Seifi, M. R., Hassan-Beygi, S. R., Ghobadian, B., Desideri, U., & Antonelli, M. (2016). Experimental investigation of a diesel engine power, torque and noise emission using water–diesel emulsions. Fuel, 166, 392-399.

Sezer, I. (2019). Effect of nano materials additives on fuel properties and combustion characteristics. J. Fac. Eng. Archit. Gazi Univ, 34, 115-135.

Shaafi T, Sairam K, Gopinath A, Kumaresan G, Velraj R (2015) Effect of dispersion of various nano additives on the performance and emission characteristics of a CI engine fuelled with diesel, biodiesel and blends a review. Renew Sust Energ Rev 49:563

Shaafi T, Velraj R (2015) Influence of alumina nanoparticles, ethanol and isopropanol blend as additive with diesel soybean biodiesel blend fuel: Combustion, engine performance and emissions. Renew Energy 80:655

Shadidi, B., Yusaf, T., Alizadeh, H. H. A., & Ghobadian, B. (2014). Experimental investigation of the tractor engine performance using diesohol fuel. Applied energy, 114, 874-879. Huang, Z., Lu, H., Jiang, D., Zeng, K., Liu, B., Zhang, J., & Wang, X. (2004). Combustion behaviors of a compression-ignition engine fuelled with diesel/methanol blends under various fuel delivery advance angles. Bioresource technology, 95(3), 331-341.

Shi, J., Balamurugan, K., Parthasarathi, R., Sathitsuksanoh, N., Zhang, S., Stavila, V., ... & Singh, S. (2014). Understanding the role of water during ionic liquid pretreatment of lignocellulose: co-solvent or anti-solvent?. Green Chemistry, 16(8), 3830-3840.

Soudagara MEM, Nik-Ghazalia N-N, Abul Kalam M, Badruddin IA, Banapurmath NR, Akrama N (2018) The effect of nano-additives in diesel-biodiesel fuel blends: a comprehensive review on stability, engine performance and emission characteristics. Energy Convers Manag 178:146–177

Srinidhi, C., Madhusudhan, A., & Channapattana, S. V. (2019). Effect of NiO nanoparticles on performance and emission characteristics at various injection timings using biodiesel-diesel blends. Fuel, 235, 185-193.

Starke, L. (Ed.). (2006). State of the world 2006: A Worldwatch Institute report on progress toward a sustainable society. Worldwatch Institute.

Syed Aalam, C. (2020). Investigation on the combustion and emission characteristics of CRDI diesel engine fuelled with nano Al2O3 and Fe3O4 particles blended biodiesel. Materials Today: Proceedings.

Taib, N. M., Mansor, M. R. A., Mahmood, W. M. F. W., Shah, F. A., & Abdullah, N. R. N. (2017). Investigation of diesel-ethanol blended fuel properties with palm methyl ester as co-solvent and blends enhancer. In MATEC Web of conferences (Vol. 90, p. 01080). EDP Sciences.

Teffera, B. (2007). Cleaner Production Assessment In The Ethiopian Alcohol Industries A Case Study In The Sebata Alcohol & Liquor Factory," A Thesis Submitted To The School Of Graduate Studies Of Addis Ababa University In Partial Fulfillment Of The Requirement For The Degree Of Master Of Environmental Engineering.

Torres-Jimenez, E., Jerman, M. S., Gregorc, A., Lisec, I., Dorado, M. P., & Kegl, B. (2011). Physical and chemical properties of ethanol–diesel fuel blends. Fuel, 90(2), 795-802.

Torres-Jimenez, E., Jerman, M. S., Gregorc, A., Lisec, I., Dorado, M. P., & Kegl, B. (2011). Physical and chemical properties of ethanol–diesel fuel blends. Fuel, 90(2), 795-802.

Tutak, W., Lukács, K., Szwaja, S., & Bereczky, Á. (2015). Alcohol–diesel fuel combustion in the compression ignition engine. Fuel, 154, 196-206.

Varatharajan, K., Cheralathan, M., & Velraj, R. (2011). Mitigation of NOx emissions from a jatropha biodiesel fuelled DI diesel engine using antioxidant additives. Fuel, 90(8), 2721-2725.

Vasistha, Vishal; Bharj, Rabinder Singh (2019). Hydrous Ethanol–Diesel–Al2O3 Nanoemulsified Fuel Characterization, Stability, and Corrosion Effect Energy & Fuels, acs.energyfuels.9b00049.

Vellaiyan, S., & Amirthagadeswaran, K. S. (2016). The role of water-in-diesel emulsion and its additives on diesel engine performance and emission levels: A retrospective review. Alexandria Engineering Journal, 55(3), 2463-2472.

Venkatesan, H., Sivamani, S., Sampath, S., Gopi, V., & Kumar, D. (2017). A comprehensive review on the effect of nano metallic additives on fuel properties, engine performance and emission characteristics. International Journal of Renewable Energy Research (IJRER), 7(2), 825-843.

Venu H, Dhana Raju V, Subramani L (2019) Combined effect of influence of nano additives, combustion chamber geometry and injection timing in a DI diesel engine fuelled with ternary (diesel-biodiesel-ethanol) blends. Energy 174:386e406.

Venu, H., & Madhavan, V. (2016). Effect of Al2O3 nanoparticles in biodiesel-diesel-ethanol blends at various injection strategies: Performance, combustion and emission characteristics. Fuel, 186, 176-189.

Venu, H., & Madhavan, V. (2017). Influence of diethyl ether (DEE) addition in ethanol-biodiesel-diesel (EBD) and methanol-biodiesel-diesel (MBD) blends in a diesel engine. Fuel, 189, 377-390.

Venu, H., Raju, V. D., & Subramani, L. (2019). Combined effect of influence of nano additives, combustion chamber geometry and injection timing in a DI diesel engine fuelled with ternary (diesel-biodiesel-ethanol) blends. Energy, 174, 386-406.

Veza, I., Roslan, M. F., Said, M. F. M., Latiff, Z. A., & Abas, M. A. (2021). Physico-chemical properties of Acetone-Butanol-Ethanol (ABE)-diesel blends: Blending strategies and mathematical correlations. Fuel, 286, 119467.

Waterland, L. R., Venkatesh, S., & Unnasch, S. (2003). Safety and performance assessment of ethanol/diesel blends (E-diesel) (No. NREL/SR-540-34817). National Renewable Energy Lab., Golden, CO.(US).

Wong KV, de Leon O (2010) Applications of nanofluids: current and future. Adv Mech Eng. Article ID 519659

Xing-Cai, L., Jian-Guang, Y., Wu-Gao, Z., & Zhen, H. (2004). Effect of cetane number improver on heat release rate and emissions of high speed diesel engine fueled with ethanol–diesel blend fuel. Fuel, 83(14-15), 2013-2020.

Yakasai, F., Jaafar, M. Z., Bandyopadhyay, S., Agi, A., & Sidek, M. A. (2021). Application of iron oxide nanoparticles in oil recovery – A critical review of the properties, formulation, recent advances and prospects. Journal of Petroleum Science and Engineering, 109438.

Yilmaz, N., & Donaldson, A. B. (2007). Modeling of chemical processes in a diesel engine with alcohol fuels.

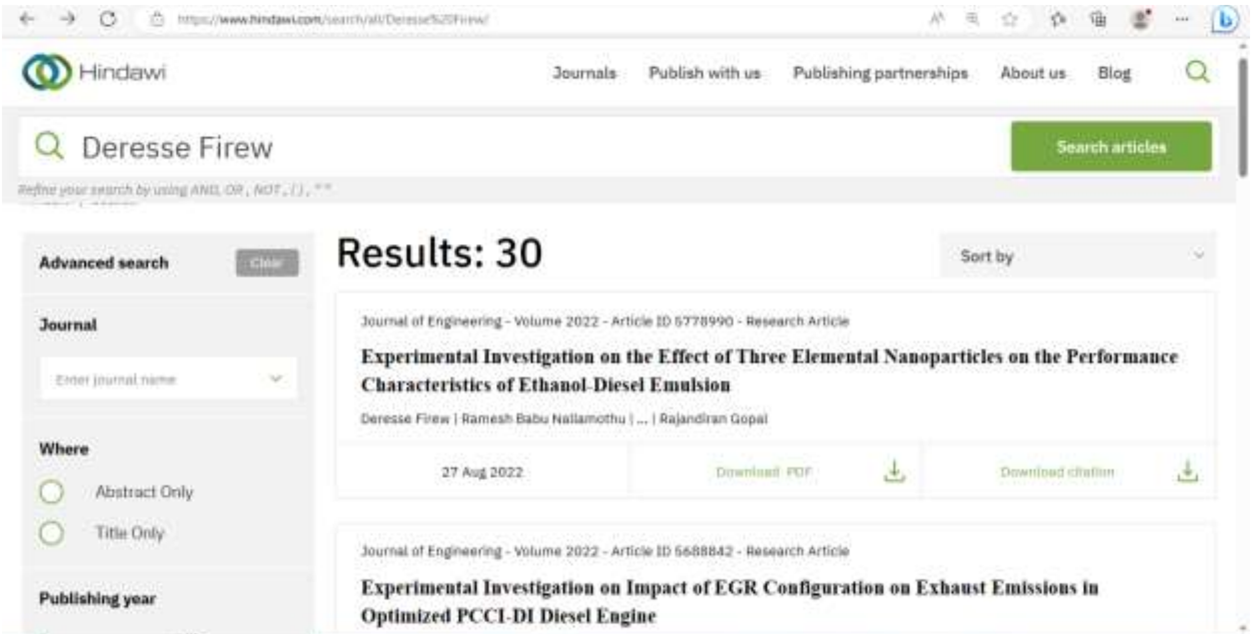
Yilmaz, N., Donaldson, A. B., & Johns, A. (2005). Some perspectives on alcohol utilization in a compression ignition engine. SAE transactions, 1198-1203.

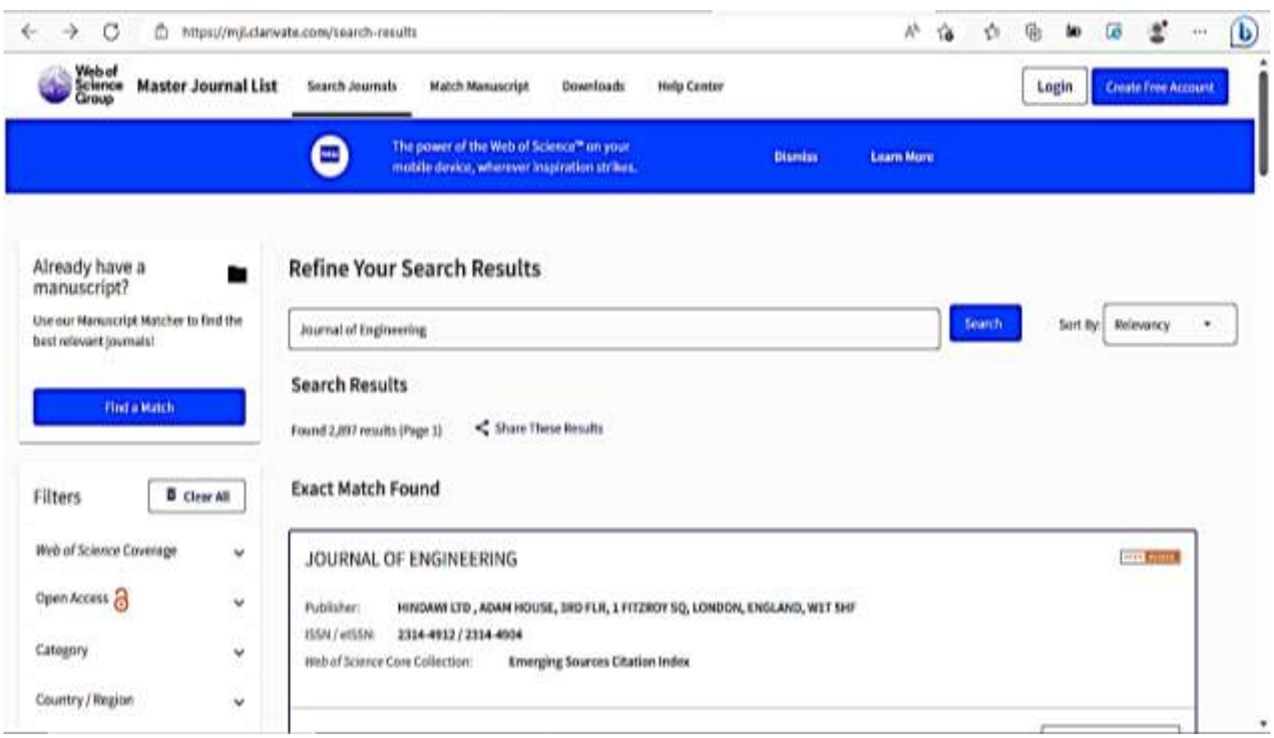
Zhang, C. P., Zhai, X. M., Li, Y. J., & Sun, Z. G. (2012). Research on combustion characteristics and emissions of methanol-diesel fuel with different additives. In Advanced Materials Research (Vol. 354, pp. 462-467). Trans Tech Publications Ltd.

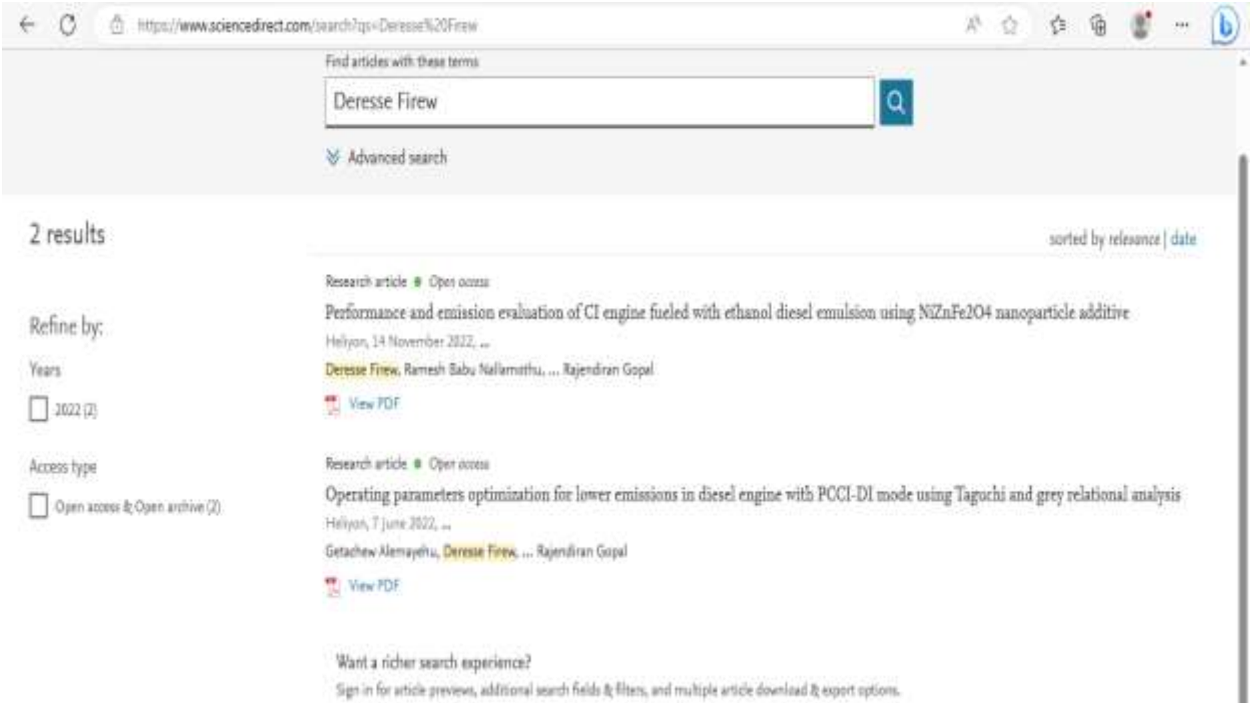
Zhang, S., Li, Y., Wang, S., Zeng, H., Liu, J., Duan, X., & Dong, H. (2020). Experimental and numerical study the effect of EGR strategies on in-cylinder flow, combustion and emissions characteristics in a heavy-duty higher CR lean-burn NGSI engine coupled with detail combustion mechanism. Fuel, 276, 118082.

Appendix

Appendix 1: Publication made from the results obtained during the study



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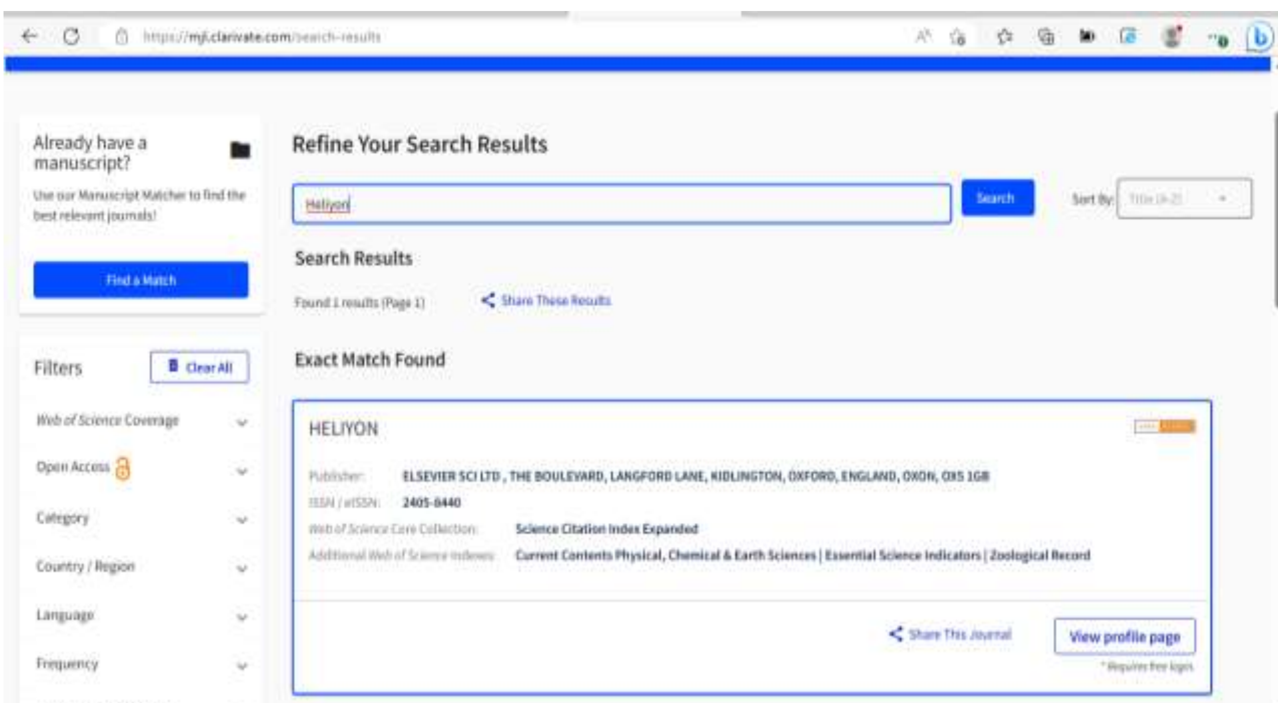
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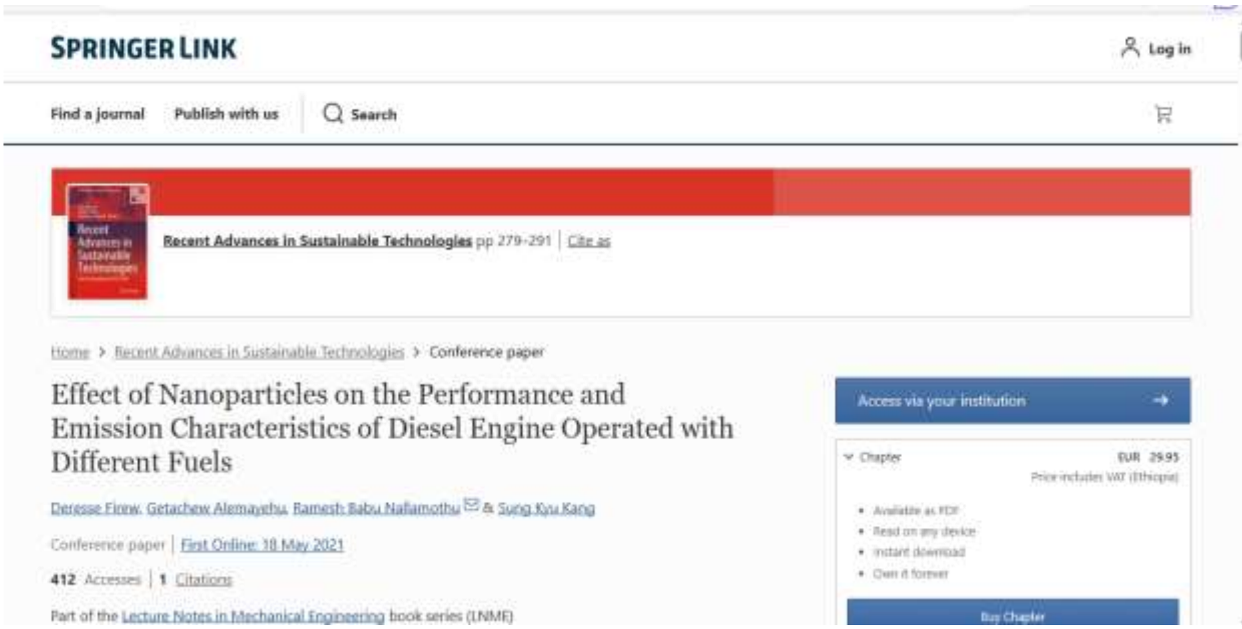
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Appendix 2: Torque performance data

The effect of Ethanol on engine torque

load %	E0	E5	E10	E15
0	7.851	7.8	8.178	7.949
10	7.223	6.583	7.746	7.494
20	6.751	6.319	7.68	6.293
30	6.435	5.543	6.867	5.853
40	5.8	4.192	5.698	4.026
50	5.451	4.501	4.632	3.538
60	5.296	4.338	4.601	3.29
70	5.4	3.654	3.173	3.849
80	5.945	4.506	4.558	5.005

The effect of 3 elemental nanoparticle adding in E5 on engine torque

load %	E0	E5	E5-3N-25	E5-3N-50	E5-3N-100
0	7.851	7.8	7.752	7.981	7.985
10	7.223	6.583	7.117	7.379	7.34
20	6.751	6.319	6.839	6.921	6.806
30	6.435	5.543	4.363	6.435	6.804
40	5.8	4.192	4.405	5.748	5.538
50	5.451	4.501	5.571	5.598	5.612
60	5.296	4.338	5.332	5.385	5.049
70	5.4	3.654	3.31	4.621	4.298
80	5.945	4.506	1.678	2.739	2.335

The effect of 3 elemental nanoparticle adding in E10 on engine torque

load %	E0	E10	E10-3N-25	E10-3N-50	E10-3N-100
0	7.851	8.178	7.9	7.729	7.987
10	7.223	7.746	7.082	7.286	7.358
20	6.751	7.68	6.745	6.92	7.065
30	6.435	6.867	6.481	6.315	6.314
40	5.8	5.698	4.41	5.944	5.032
50	5.451	4.632	4.445	5.594	5.556
60	5.296	4.601	5.324	5.332	5.309
70	5.4	3.173	5.53	5.035	5.388
80	5.945	4.558	6.076	4.09	4.601

The effect of 3 elemental nanoparticle adding in E15 on engine torque

load %	E0	E15	E15-3N-25	E15-3N-50	E15-3N-100
0	7.851	7.949	8.138	8.032	7.693
10	7.223	7.494	7.171	7.314	7.163
20	6.751	6.293	7.571	6.885	6.697
30	6.435	5.853	6.152	6.385	6.163
40	5.8	4.026	4.757	5.911	5.795
50	5.451	3.538	5.716	5.595	5.474
60	5.296	3.29	4.549	5.416	5.322
70	5.4	3.849	4.328	4.038	5.45
80	5.945	5.005	3.895	4.017	5.118

The effect of injection timing by E5-3N 100 fuel sample on engine torque

load %	E0	E5-3N 100, T1	E5-3N 100, T2	E5-3N 100, T3
0	7.851	7.8	7.8255	7.01275
10	7.223	6.583	6.903	5.943
20	6.751	6.319	6.535	5.627
30	6.435	5.543	5.989	4.966
40	5.8	4.192	4.996	3.794
50	5.451	4.501	4.976	3.9385
60	5.296	4.338	4.817	3.7775
70	5.4	3.654	4.527	3.2905
80	5.945	4.506	5.2255	4.06575

The effect of injection timing by E10-3N 100 fuel sample on engine torque

load %	E0	E10-3N100, T1	E10-3N 100, T2	E10-3N 100, T3
0	7.851	8.178	8.0145	7.29625
10	7.223	7.746	7.4845	6.81525
20	6.751	7.68	7.2155	6.64775
30	6.435	6.867	6.651	5.959

40	5.8	5.698	5.749	4.9235
50	5.451	4.632	5.0415	4.03675
60	5.296	4.601	4.9485	3.97475
70	5.4	3.173	4.2865	2.92975
80	5.945	4.558	5.2515	4.10475

The effect of injection timing by E15-3N 100 fuel sample on engine torque

load %	E0	E15-3N 100, T1	E15-3N 100, T2	E15-3N 100, T3
0	7.851	7.949	7.9	7.1245
10	7.223	7.494	7.3585	6.62625
20	6.751	6.293	6.522	5.6075
30	6.435	5.853	6.144	5.1985
40	5.8	4.026	4.913	3.6695
50	5.451	3.538	4.4945	3.21625
60	5.296	3.29	4.293	2.9915
70	5.4	3.849	4.6245	3.43675
80	5.945	5.005	5.475	4.44

Appendix 3: Power performance data

The effect of Ethanol on engine Power

load %	E0	E5	E10	E15
0	2.608	2.597	2.724	2.639
10	2.166	1.97	2.11	2.248
20	1.804	1.527	1.751	1.682
30	1.51	1.119	1.416	1.372
40	1.169	0.834	1.154	0.899
50	0.92	0.414	0.768	0.588
60	0.72	0.376	0.427	0.303
70	0.561	0.373	0.316	0.284
80	0.427	0.368	0.324	0.356

The effect of 3 elemental nanoparticle adding in E5 on engine Power

load %	E0	E5	E5-3N-25	E5-3N-50	E5-3N-100
0	2.608	2.597	2.562	2.663	2.654
10	2.166	1.97	2.125	2.223	2.203
20	1.804	1.527	1.82	1.857	1.817
30	1.51	1.119	1.208	1.515	1.597
40	1.169	0.834	0.972	1.162	1.112
50	0.92	0.414	0.936	0.948	0.947
60	0.72	0.376	0.722	0.735	0.685
70	0.561	0.373	0.332	0.476	0.334
80	0.427	0.368	0.112	0.187	0.382

The effect of 3 elemental nanoparticle adding in E10 on engine Power

load %	E0	E10	E10-3N-25	E10-3N-50	E10-3N-100
0	2.608	2.724	2.609	2.577	2.649
10	2.166	2.11	2.109	2.194	2.204
20	1.804	1.751	1.791	1.856	1.885
30	1.51	1.416	1.429	1.485	1.475
40	1.169	1.154	1.113	1.201	1.006
50	0.92	0.768	0.79	0.946	0.935
60	0.72	0.427	0.721	0.727	0.721
70	0.561	0.316	0.571	0.52	0.558
80	0.427	0.324	0.454	0.335	0.323

The effect of 3 elemental nanoparticle adding in E15 on engine Power

load %	E0	E15	E15-3N-25	E15-3N-50	E15-3N-100
0	2.608	2.639	2.711	2.678	2.678
10	2.166	2.248	2.155	2.199	2.199
20	1.804	1.682	1.734	1.843	1.843
30	1.51	1.372	1.445	1.5	1.5
40	1.169	0.899	0.947	1.193	1.193
50	0.92	0.588	0.868	0.946	0.946
60	0.72	0.303	0.628	0.739	0.739
70	0.561	0.284	0.445	0.413	0.413
80	0.427	0.356	0.128	0.137	0.137

The effect of injection timing by E5-3N 100 fuel sample on engine Power

load %	E0	E5-3N 100, T1	E5-3N 100, T2	E5-3N 100, T3
0	2.608	2.597	2.6025	2.39975
10	2.166	1.97	2.068	1.819
20	1.804	1.527	1.6655	1.39625
30	1.51	1.119	1.3145	1.01675
40	1.169	0.834	1.0015	0.71775
50	0.92	0.414	0.667	0.3405
60	0.72	0.376	0.548	0.362
70	0.561	0.373	0.467	0.32
80	0.427	0.368	0.3975	0.28275

The effect of injection timing by E10-3N 100 fuel sample on engine Power

load %	E0	E10-3N100, T1	E10-3N 100, T2	E10-3N 100, T3
0	2.608	2.724	2.666	2.495
10	2.166	2.11	2.138	1.924
20	1.804	1.751	1.7775	1.56425

30	1.51	1.416	1.463	1.2395
40	1.169	1.154	1.1615	0.95775
50	0.92	0.768	0.844	0.606
60	0.72	0.427	0.5735	0.40025
70	0.561	0.316	0.4385	0.27725
80	0.427	0.324	0.3755	0.24975

The effect of injection timing by E15-3N 100 fuel sample on engine Power

load %	E0	E15-3N 100, T1	E15-3N 100, T2	E15-3N 100, T3
0	2.608	2.639	2.6235	2.43125
10	2.166	2.248	2.207	2.0275
20	1.804	1.682	1.743	1.5125
30	1.51	1.372	1.441	1.2065
40	1.169	0.899	1.034	0.7665
50	0.92	0.588	0.754	0.471
60	0.72	0.303	0.5115	0.30725
70	0.561	0.284	0.4225	0.25325
80	0.427	0.356	0.3915	0.27375

Appendix 4: Fuel consumption performance data

The effect of 3 elemental nanoparticle adding in E5 on engine fuel consumption

load %	E0	E5	E5-3N-25	E5-3N-50	E5-3N-100
0	0.019	0.019	0.019	0.019	0.019
10	0.046	0.044	0.041	0.045	0.045
20	0.083	0.121	0.092	0.088	0.088
30	0.165	0.222	0.200	0.174	0.175
40	0.213	0.272	0.261	0.256	0.268
50	0.316	0.479	0.412	0.389	0.380
60	0.207	0.285	0.206	0.203	0.217
70	0.177	0.266	0.249	0.208	0.194
80	0.116	0.135	0.123	0.115	0.130

The effect of 3 elemental nanoparticle adding in E10 on engine fuel consumption

load %	E0	E10	E10-3N-25	E10-3N-50	E10-3N-100
0	0.019	0.018	0.019	0.019	0.019
10	0.046	0.048	0.047	0.045	0.045
20	0.083	0.163	0.083	0.080	0.079
30	0.165	0.257	0.250	0.167	0.168
40	0.213	0.287	0.268	0.247	0.245
50	0.316	0.539	0.508	0.409	0.392
60	0.207	0.297	0.206	0.204	0.206

70	0.177	0.283	0.173	0.190	0.177
80	0.116	0.153	0.149	0.114	0.153

The effect of 3 elemental nanoparticle adding in E15 on engine fuel consumption

load %	E0	E15	E15-3N-25	E15-3N-50	E15-3N-100
0	0.019	0.019	0.018	0.018	0.018
10	0.046	0.054	0.046	0.045	0.045
20	0.083	0.177	0.097	0.107	0.107
30	0.165	0.280	0.171	0.165	0.165
40	0.213	0.296	0.262	0.290	0.290
50	0.316	0.560	0.455	0.421	0.401
60	0.207	0.339	0.236	0.200	0.200
70	0.177	0.297	0.222	0.239	0.239
80	0.116	0.139	0.131	0.120	0.120

The effect of injection timing by E5-3N 100 fuel sample on engine fuel consumption

load %	E0	E5-3N 100, T1	E5-3N 100, T2	E5-3N 100, T3
0	0.0	0.0	0.0	0.0
10	0.0	0.0	0.0	0.0
20	0.1	0.1	0.1	0.1
30	0.2	0.2	0.2	0.2
40	0.2	0.3	0.2	0.3
50	0.3	0.5	0.4	0.6
60	0.2	0.3	0.2	0.3
70	0.2	0.3	0.2	0.3
80	0.1	0.1	0.1	0.1

The effect of injection timing by E10-3N 100 fuel sample on engine fuel consumption

load %	E0	E10-3N100, T1	E10-3N 100, T2	E10-3N 100, T3
0	0.0	0.0	0.0	0.0
10	0.0	0.0	0.0	0.0
20	0.1	0.2	0.1	0.2
30	0.2	0.3	0.2	0.3
40	0.2	0.3	0.3	0.3
50	0.3	0.5	0.4	0.6
60	0.2	0.3	0.3	0.3
70	0.2	0.3	0.2	0.3
80	0.1	0.2	0.1	0.2

The effect of injection timing by E15-3N 100 fuel sample on engine fuel consumption

load %	E0	E15-3N 100, T1	E15-3N 100, T2	E15-3N 100, T3

0	0.0	0.0	0.0	0.0
10	0.0	0.1	0.0	0.1
20	0.1	0.2	0.1	0.2
30	0.2	0.3	0.2	0.3
40	0.2	0.3	0.3	0.3
50	0.3	0.6	0.4	0.6
60	0.2	0.3	0.3	0.4
70	0.2	0.3	0.2	0.3
80	0.1	0.1	0.1	0.1

Appendix 5: CO_2 emission data

The effect of Ethanol on CO_2 emission

load %	E0	E5	E10	E15
0	1	1.2	0.5	0.6
10	1.25	1	1.5	2
20	3.1	3	3.2	3.8
30	4.3	4.3	4.8	5
40	5.8	5.5	5.9	6.3
50	4.5	4.5	5.1	5.3
60	4.1	4.2	4.8	5
70	3.9	4	4.2	4.5
80	3.2	3.5	4	4.1

The effect of 3 elemental nanoparticle adding in E5 on CO_2 emission

load %	E0	E5	E5-3N-25	E5-3N-50	E5-3N-100
0	1	1.2	0.8	1.2	1
10	1.25	1	1	1.3	1.5
20	3.1	3	3.2	3.2	3
30	4.3	4.3	4.6	4.5	5.2
40	5.8	5.5	5.9	6	6
50	4.5	4.5	4.8	5	5.5
60	4.1	4.2	4.5	4.5	4.8
70	3.9	4	4.2	4.3	4.3
80	3.2	3.5	4	4.4	4

The effect of 3 elemental nanoparticle adding in E10 on CO_2emission

load %	E0	E10	E10-3N-25	E10-3N-50	E10-3N-100
0	1	0.5	0.4	1	1.3
10	1.25	1.5	1.6	2	2
20	3.1	3.2	3.5	3.5	3.5
30	4.3	4.8	5.1	4.9	4.9

40	5.8	5.9	6	6.3	6.3
50	4.5	5.1	5.4	5.5	5.5
60	4.1	4.8	5	5	5.1
70	3.9	4.2	4.5	4.5	4.8
80	3.2	4	4.3	4	4.2

The effect of 3 elemental nanoparticle adding in E15 on CO_2 emission

load %	E0	E15	E15-3N-25	E15-3N-50	E15-3N-100
0	1	0.6	0.6	0.6	1
10	1.25	2	2.2	2.5	2.7
20	3.1	3.8	4	4	4.5
30	4.3	5	5.3	5.2	5.5
40	5.8	6.3	6.5	6.5	7
50	4.5	5.3	5.6	5.6	6.1
60	4.1	5	5.2	5.4	5.8
70	3.9	4.5	4.6	5	5.3
80	3.2	4.1	4.1	4.2	4.5

The effect of injection timing by E5-3N 100 fuel sample on CO_2 Emission

load %	E0	E5-3N 100, T1	E5-3N 100, T2	E5-3N 100, T3
0	1	1	1.1	1.0
10	1.25	1.5	1.8	1.4
20	3.1	3	3.1	3.1
30	4.3	5.2	5.4	4.8
40	5.8	6	6.2	5.9
50	4.5	5.5	5.6	5.0
60	4.1	4.8	4.9	4.5
70	3.9	4.3	4.4	4.1
80	3.2	4	4.1	3.6

The effect of injection timing by E10-3N 100 fuel sample on CO_2 Emission

load %	E0	E10-3N100, T1	E10-3N 100, T2	E10-3N 100, T3
0	1	1.3	1.4	1.0
10	1.25	2	2.2	1.2
20	3.1	3.5	3.7	3.2
30	4.3	4.9	5	4.2
40	5.8	6.3	6.5	6.0
50	4.5	5.5	5.8	4.8
60	4.1	5.1	5.2	4.5
70	3.9	4.8	5	4.0
80	3.2	4.2	4.5	3.9

The effect of injection timing by E15-3N 100 fuel sample on CO_2 Emission

load %	E0	E15-3N 100, T1	E15-3N 100, T2	E15-3N 100, T3
0	1	1	1.5	1.0
10	1.25	2.7	3.0	1.5
20	3.1	4.5	4.6	3.0
30	4.3	5.5	6.0	4.5
40	5.8	7	7.0	6.0
50	4.5	6.1	6.5	4.6
60	4.1	5.8	6.0	4.5
70	3.9	5.3	5.5	4.0
80	3.2	4.5	4.8	3.5

Appendix 6: CO emission data

The effect of Ethanol on CO emission

load %	E0	E5	E10	E15
0	0.09	0.06	0.06	0.08
10	0.03	0.03	0.03	0.02
20	0.05	0.03	0.02	0.02
30	0.12	0.08	0.1	0.06
40	0.13	0.11	0.12	0.08
50	0.14	0.14	0.13	0.09
60	0.16	0.14	0.13	0.12
70	0.17	0.15	0.13	0.13
80	0.18	0.16	0.13	0.13

The effect of 3 elemental nanoparticle adding in E5 on CO emission

load %	E0	E15	E15-3N-25	E15-3N-50	E15-3N-100
0	0.09	0.09	0.08	0.06	0.07
10	0.03	0.01	0.02	0.02	0.01
20	0.05	0.04	0.02	0.02	0.04
30	0.12	0.07	0.06	0.04	0.03
40	0.13	0.071	0.07	0.05	0.03
50	0.14	0.09	0.09	0.06	0.03
60	0.16	0.12	0.12	0.05	0.03
70	0.17	0.12	0.11	0.05	0.03
80	0.18	0.13	0.13	0.04	0.03

The effect of 3 elemental nanoparticle adding in E10 on CO emission

load %	E0	E10	E10-3N-25	E10-3N-50	E10-3N-100
0	0.09	0.06	0.07	0.04	0.02
10	0.03	0.03	0.03	0.03	0.02
20	0.05	0.02	0.04	0.02	0.02

30	0.12	0.1	0.04	0.02	0.02
40	0.13	0.12	0.03	0.02	0.02
50	0.14	0.13	0.03	0.02	0.02
60	0.16	0.13	0.03	0.02	0.02
70	0.17	0.13	0.04	0.02	0.03
80	0.18	0.13	0.04	0.02	0.03

The effect of 3 elemental nanoparticle adding in E15 on CO emission

load %	E0	E5	E5-3N-25	E5-3N-50	E5-3N-100
0	0.09	0.06	0.05	0.04	0.04
10	0.03	0.03	0.02	0.01	0.02
20	0.05	0.03	0.03	0.02	0.02
30	0.12	0.08	0.02	0.02	0.02
40	0.13	0.11	0.06	0.04	0.05
50	0.14	0.14	0.09	0.07	0.08
60	0.16	0.14	0.1	0.08	0.08
70	0.17	0.15	0.1	0.08	0.08
80	0.18	0.16	0.11	0.09	0.08

The effect of injection timing by E5-3N 100 fuel sample on CO Emission

load %	E0	E5-3N 100, T1	E5-3N 100, T2	E5-3N 100, T3
0	0.09	0.04	0.03	0.06
10	0.03	0.02	0.02	0.01
20	0.05	0.02	0.02	0.03
30	0.12	0.02	0.02	0.10
40	0.13	0.05	0.04	0.09
50	0.14	0.08	0.07	0.07
60	0.16	0.08	0.07	0.09
70	0.17	0.08	0.07	0.10
80	0.18	0.08	0.07	0.11

The effect of injection timing by E10-3N 100 fuel sample on CO Emission

load %	E0	E10-3N100, T1	E10-3N 100, T2	E10-3N 100, T3
0	0.09	0.02	0.01	0.05
10	0.03	0.02	0.02	0.01
20	0.05	0.02	0.02	0.02
30	0.12	0.02	0.02	0.09
40	0.13	0.02	0.02	0.09
50	0.14	0.02	0.02	0.07
60	0.16	0.02	0.02	0.09
70	0.17	0.03	0.02	0.09

80	0.18	0.03	0.03	0.10

The effect of injection timing by E15-3N 100 fuel sample on CO Emission

load %	E0	E15-3N 100, T1	E15-3N 100, T2	E15-3N 100, T3
0	0.09	0.07	0.05	0.05
10	0.03	0.01	0.01	0.03
20	0.05	0.04	0.02	0.06
30	0.12	0.03	0.08	0.09
40	0.13	0.03	0.09	0.1
50	0.14	0.03	0.07	0.11
60	0.16	0.03	0.09	0.12
70	0.17	0.03	0.09	0.12
80	0.18	0.03	0.10	0.13

Appendix 7: HC emission data

The effect of Ethanol on HC emission

load %	E0	E5	E10	E15
0	6	1	25	28
10	8	2	25	31
20	9	3	25	32
30	13	4	26	32
40	15	6	25	34
50	19	7	27	35
60	22	13	30	36
70	23	16	32	37
80	24	23	33	38

The effect of 3 elemental nanoparticle adding in E5 on HC emission

load %	E0	E5	E5-3N-25	E5-3N-50	E5-3N-100
0	6	1	0	0	0
10	8	2	1	0	0
20	9	3	2	2	0
30	13	4	4	3	1
40	15	6	5	4	2
50	19	7	6	5	2
60	22	13	8	5	3
70	23	16	9	6	5
80	24	23	14	8	6

The effect of 3 elemental **nanoparticle adding in E10 on HC emission**

load %	E0	E10	E10-3N-25	E10-3N-50	E10-3N-100
0	6	25	3	1	1
10	8	25	3	2	1

20	9	25	4	3	2
30	13	26	5	4	3
40	15	25	6	7	4
50	19	27	8	8	5
60	22	30	11	9	7
70	23	32	14	11	6
80	24	33	15	13	10

The effect of 3 elemental nanoparticle adding in E15 on HC emission

load %	E0	E15	E15-3N-25	E15-3N-50	E15-3N-100
0	6	28	2	2	2
10	8	31	3	2	3
20	9	32	3	4	4
30	13	32	2	4	5
40	15	34	3	5	5
50	19	35	3	6	7
60	22	36	8	9	8
70	23	37	12	12	11
80	24	38	13	14	14

The effect of injection timing with E5-3N 100 on HC emission

load %	E0	E5-3N 100, T1	E5-3N 100, T2	E5-3N 100, T3
0	6	0.0	0.00	2.00
10	8	0.0	0.00	3.00
20	9	0.0	0.00	4.00
30	13	1.0	0.00	5.00
40	15	2.0	0.00	7.00
50	19	2.0	0.00	9.00
60	22	3.0	1.00	9.00
70	23	5.0	3.00	11.00
80	24	6.0	4.00	12.00

The effect of injection timing with E10-3N 100 on HC emission

load %	E0	E10-3N100, T1	E10-3N 100, T2	E10-3N 100, T3
0	6	1.0	0	3.00
10	8	1.0	0	3.00
20	9	2.0	0	4.00
30	13	3.0	1	5.00
40	15	4.0	2	7.00
50	19	5.0	4	10.00

60	22	7.0	5	12.00
70	23	6.0	5	13.00
80	24	10.0	8	15.00

The effect of injection timing with E15-3N 100 on HC emission

load %	E0	E15-3N 100, T1	E15-3N 100, T2	E15-3N 100, T3
0	6	2.0	1.00	4
10	8	3.0	2.00	6
20	9	4.0	3.00	7
30	13	5.0	4.00	9
40	15	5.0	5.00	12
50	19	7.0	8.00	15
60	22	8.0	8.00	18
70	23	11.0	10.00	20
80	24	14.0	11.00	21

Appendix 8: NOx **emission data**

The effect of Ethanol on NOx emission

load %	E0	E5	E10	E15
0	22.4	15.6	12.4	9.6
10	33.6	22.4	16.4	18.4
20	16	12.4	9.6	8.4
30	75.6	63.4	51.6	47.2
40	93.6	84.6	64.8	59.6
50	188.4	176.4	165.6	161.6
60	234	214.8	158.4	149.2
70	244.8	236.4	182.8	177.2
80	276	263.6	212.4	202.4

The effect of 3 elemental nanoparticle adding in E5 on NOx emission

load %	E0	E5	E5-3N-25	E5-3N-50	E5-3N-100
0	22.4	15.6	23.4	27.6	28.8
10	33.6	22.4	32.4	41.8	40.2
20	16	12.4	19.6	21.8	21.6
30	75.6	63.4	73.2	74.6	76.4
40	93.6	84.6	93.2	89.6	94
50	188.4	176.4	174.4	169.6	166.6
60	234	214.8	206.4	201.6	198.8
70	244.8	236.4	236.2	229.6	216.2
80	276	263.6	266.2	258.4	250.4

The effect of 3 elemental nanoparticle adding in E10 on NOx emission

load %	E0	E10	E10-3N-25	E10-3N-50	E10-3N-100
0	22.4	12.4	39.6	44.4	51.6
10	33.6	16.4	60.6	67.2	72.6
20	16	9.6	51	50.4	51.6
30	75.6	51.6	93.6	116.4	121.6
40	93.6	64.8	123.6	136.2	138.6
50	188.4	165.6	153.6	164.4	201.6
60	234	158.4	183.6	190.8	217.6
70	244.8	182.8	213.6	205.8	219.6
80	276	212.4	219.6	225.6	236.2

The effect of 3 elemental nanoparticle adding in E15 on NOx emission

load %	E0	E15	E15-3N-25	E15-3N-50	E15-3N-100
0	22.4	9.6	9.6	14.4	21.6
10	33.6	18.4	30.6	37.2	42.6
20	16	8.4	21	20.4	21.6
30	75.6	47.2	63.6	86.4	111.6
40	93.6	59.6	93.6	106.2	128.6
50	188.4	161.6	123.6	134.4	181.6
60	234	149.2	153.6	160.8	196.6
70	244.8	177.2	183.6	175.8	211.6
80	276	202.4	189.6	195.6	226.2

The effect of injection timing by E5-3N 100 fuel sample on NOx Emission

load %	E0	E5-3N 100, T1	E5-3N 100, T2	E5-3N 100, T3
0	22.4	28.8	25.60	20.60
10	33.6	40.2	36.90	31.90
20	16	21.6	17.80	12.80
30	75.6	76.4	76.00	71.00
40	93.6	94	92.80	82.80
50	188.4	166.6	170.50	160.50
60	234	198.8	216.40	206.40
70	244.8	216.2	220.50	200.50
80	276	250.4	260.20	240.20

The effect of injection timing by E10-3N 100 fuel sample on NOx Emission

load %	E0	E10-3N100, T1	E10-3N 100, T2	E10-3N 100, T3
0	22.4	51.6	37	32.00
10	33.6	72.6	53.1	48.10
20	16	51.6	33.8	28.80

30	75.6	121.6	98.6	88.60
40	93.6	138.6	116.1	106.10
50	188.4	201.6	195	185.00
60	234	217.6	225.8	222.20
70	244.8	219.6	232.2	212.20
80	276	236.2	256.1	230.10

The effect of injection timing by E15-3N 100 fuel sample on NOx Emission

load %	E0	E15-3N 100, T1	E15-3N 100, T2	E15-3N 100, T3
0	22.4	21.6	44.00	20.5
10	33.6	42.6	76.20	38.6
20	16	21.6	37.60	20.5
30	75.6	111.6	187.20	101.2
40	93.6	128.6	222.20	98.6
50	188.4	181.6	370.00	150.7
60	234	196.6	430.60	153.4
70	244.8	211.6	456.40	158.3
80	276	226.2	500.00	182.3

Appendix 9: Smoke emission data

The effect of Ethanol on Smoke Emission

load %	E0	E5	E10	E15
0	1.3	1.1	0.9	0.6
10	0.9	0.8	0.8	0.5
20	0.8	0.8	0.8	0.4
30	1	0.9	0.7	0.4
40	0.7	0.7	0.6	0.5
50	0.9	0.8	0.8	0.7
60	1.5	1.2	1	0.8
70	5.6	4.8	4.5	4
80	16	12	10.5	7
	3.2	2.6	2.3	1.7

The effect of 3 elemental nanoparticle in E5 on Smoke emission

load %	E0	E5	E5-3N-25	E5-3N-50	E5-3N-100
0	1.3	1.1	0.9	0.7	0.9
10	0.9	0.8	0.7	0.4	0.8
20	0.8	0.8	0.7	0.3	0.6
30	1	0.9	0.8	0.5	0.8
40	0.7	0.7	0.7	0.7	0.8
50	0.9	0.8	0.7	0.7	0.7
60	1.5	1.2	1.1	0.7	1

70	5.6	4.8	3.4	2.5	3.3
80	16	12	7	5.5	8

The effect of 3 elemental nanoparticle in E10 on Smoke emission

load %	E0	E10	E10-3N-25	E10-3N-50	E10-3N-100
0	1.3	0.9	0.4	0.3	0.4
10	0.9	0.8	0.2	0.3	0.1
20	0.8	0.8	0.3	0.2	0.2
30	1	0.7	0.5	0.3	0.4
40	0.7	0.6	0.4	0.3	0.3
50	0.9	0.8	0.6	0.3	0.4
60	1.5	1	0.8	0.5	0.8
70	5.6	4.5	3	2.4	2.4
80	16	10.5	5.4	4.2	6.1

The effect of 3 elemental nanoparticle in E15 on Smoke emission

load %	E0	E15	E15-3N-25	E15-3N-50	E15-3N-100
0	1.3	0.6	0.1	0.3	0.4
10	0.9	0.5	0.1	0.2	0.2
20	0.8	0.4	0.2	0.1	0.1
30	1	0.4	0.3	0.2	0.1
40	0.7	0.5	0.5	0.2	0.2
50	0.9	0.7	0.4	0.5	0.3
60	1.5	0.8	0.7	0.6	0.7
70	5.6	4	2.6	2.1	3.2
80	16	7	4.7	3.1	4

The effect of injection timing by E5-3N 100 fuel sample on Smoke Emission

load %	E0	E5-3N 100, T1	E5-3N 100, T2	E5-3N 100, T3
0	1.3	0.9	0.70	1.00
10	0.9	0.8	0.70	0.80
20	0.8	0.6	0.50	0.75
30	1	0.8	0.50	0.95
40	0.7	0.8	0.50	1.60
50	0.9	0.7	0.50	1.70
60	1.5	1	0.80	1.15
70	5.6	3.3	2.30	3.95
80	16	8	6.00	12.11

The effect of injection timing by E10-3N 100 fuel sample on Smoke Emission

load %	E0	E10-3N100, T1	E10-3N 100, T2	E10-3N 100, T3
0	1.3	0.4	0.35	1.08

10	0.9	0.1	0.1	0.70
20	0.8	0.2	0.1	0.65
30	1	0.4	0.17	0.95
40	0.7	0.3	0.2	0.66
50	0.9	0.4	0.35	0.78
60	1.5	0.8	0.75	1.33
70	5.6	2.4	3.1	3.25
80	16	6.1	5.5	8.50

The effect of injection timing by E15-3N 100 fuel sample on Smoke Emission

load %	E0	E15-3N 100, T1	E15-3N 100, T2	E15-3N 100, T3
0	1.3	0.4	0.30	0.8
10	0.9	0.2	0.10	0.5
20	0.8	0.1	0.00	0.4
30	1	0.1	0.00	0.5
40	0.7	0.2	0.10	0.4
50	0.9	0.3	0.20	0.55
60	1.5	0.7	0.40	0.95
70	5.6	3.2	2.20	3.9
80	16	4	3.50	9.75