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Original Article

Experimental Investigation and Modeling of C.I Engine with Graphite Oxide Dose as Nano Particle with Ethanol Diesel Blends

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Abstract *- The present study conducts an empirical examination and modeling of the performance of a C.I engine when powered by ethanol-diesel mixes containing graphite oxide nanoparticles. The use of graphite oxide as a nanomaterial in fuel mixes is intended to augment the combustion properties, promote engine efficiency, and mitigate detrimental emissions. Ethanol is a potentially viable alternative fuel for diesel engines. Thus far, many strategies have been attempted, including ethanol fumigation, dual injection, and mixing. The previous methods need various engine modifications to allow the integration of extra systems into the current engines. Blending is the optimal method for replacing the present diesel fuel, provided that we prepare it according to the minimal requirements of the current diesel fuel. The blends were tested at full load, comparing key performance indicators against conventional diesel. It was observed that the BTE decreased by 21% and 9% for C6 and nano C6 blends, respectively, while BSFC increased by 39% and 14%, indicating a trade-off between fuel economy and blend characteristics. Additionally, the introduction of graphite oxide nanoparticles led to an increase in maximum pressure by 8% and 13% and a significant rise in the HRR by 118% and 129%, signifying more efficient combustion with nano C6. Emission levels also saw significant improvement, with CO emissions dropping by 62% and 92%. These results confirm that incorporating graphite oxide nanoparticles into ethanol-diesel blends offers potential advantages in terms of improved combustion efficiency and reduced harmful emissions, making it a promising approach for sustainable engine technology.*

Keywords *- Compression ignition engine, Graphite Oxide Dose, Fuel consumption, Nanoparticles, BSFC.*

1. Introduction

Compression Ignition (C.I.) engines remain the mainstay of global transportation and industrial operations. However, their use is now hampered by the desire for sustainable and efficient energy solutions, making serious research into alternative fuels for these engines a top priority. While conventional diesel fuel used in these engines is responsible for significant greenhouse gas and air pollution emissions, this means further development of cleaner, more efficient fuel options is needed. One set of these blends, ethanol-diesel blends, have been studied for their ability to decrease harmful emissions (CO, unburned HC, as well as particulate matter) while promoting the use of renewable energy sources. These advantages, however, are beleaguered by fuel properties like decreased calorific value and increased SFC and BTE that impede their use in practical application. Recent achievements in nanoparticle technology have led to nanoparticles as potential additives to enhance fuel properties and engine performance [1]. It has been shown that nanoparticles such as alumina (Al_2O_3), ceria (CeO_2), and titanium dioxide (TiO_2) are able to improve combustion efficiency due to providing atomization improvements and proportionately greater atomization surface area to volume ratios and catalytic combustion during combustion. Despite this, studies of GO nanoparticles in ethanol/diesel blends are uncharacterized. Graphite oxide's exceptional catalytic activity, high thermal conductivity, and large surface area suggest that it may be able to get around the restrictions placed on ethanol-diesel blends.

Intensified C.I. engines using ethanol diesel blends with graphite oxide nanoparticles were investigated in the study for performance, combustion and emission properties [2]. The research seeks to mitigate the tradeoffs normally seen in ethanol diesel blends, that is, reduced BTE and increased SFC, as well as reduced emissions and increased CE through the use of the catalytic properties of GO. Unlike previous studies, which are focused on steady-state conditions, this work investigates the performance of nanoparticle-enhanced blends under various engine load conditions to understand their practical usage better.

This research is novel in that it is the synergistic junction of ethanol, diesel and graphite oxide nanoparticles, which have not been fully examined previously. Ethanol offers environmental benefits as a renewable fuel, but performance and emission modifiers are overcome through improvements in combustion dynamics and catalytic effects by adding graphite oxide nanoparticles. This study also bridges a number of the gaps existing in the literature through the detailed analysis of each of the aforementioned key engine performance indicators, including BTE, BSFC, and emissions across multiple engine load conditions under the influence of nanoparticles.

The objectives of this study are threefold:

- Engine Performance Analysis: This work evaluates the effect of GO NPs on engine performance metrics, including BTE, maximum pressure, and HRR.
- Emission Parameter Investigation: To study the impact of the catalytic action of GO nanoparticles on lowering the dangerous CO, HC, and smoke emissions from ethanol-diesel blends.
- Specific Fuel Consumption (SFC) Evaluation: However, the assessment of GO nanoparticle's effects on fuel economy and specific fuel consumption is needed to determine the trade-offs generally observed in ethanol diesel blends.

This research addresses these objectives as a means to provide a complete understanding of the impact of GO NPs on improving the performance and sustainability of ethanol diesel blends and eventually helping to develop further fuels for CI engines that are cleaner and more effective.

1.1. Research Gap and Problem Statement

The effectiveness as well as emission properties of a C.I. engine running on ethanol and diesel blends doped with Graphite Oxide nanoparticles (GO) are investigated in the researched presented. The use of ethanol as a different fuel for diesel engines is no stranger to being an alternative to decrease undesirable emissions, whereas using nanomaterials such as graphite oxide is still not exploited for ethanol-diesel fuel blends.

Other studies showed promising results, yet significant knowledge gaps persist in how the addition of graphite oxide nanoparticles affects key engine performance indicators, emission characteristics and fuel consumption.

1.1.1. Research Gap

Limited Exploration of Engine Performance with Nanoparticle-Enhanced Blends

Other studies exist on ethanol diesel blends, but they are limited to the synergistic effects of the nanoparticles, like graphite oxide. Nanoparticles have been shown to improve CE, but the complete understanding of their impact on critical performance parameters like BTE, combustion pressure, and HRR at realistic conditions is not known.

Trade-offs Between Efficiency and Emission Reduction

The use of ethanol diesel blends is able to reduce emissions but at the cost of tradeoffs in engine performance in terms of BTE and SFC. One has not seen in the existing literature any analysis of how engineering's incorporation of graphite oxide nanoparticles can simultaneously improve engine performance (BTE, maximum pressure) and reduce these tradeoffs, especially when considering different load conditions.

Emission Parameters in Nanoparticle-Enhanced Fuels

Graphite oxide nanoparticles have been shown to reduce CO and smoke emissions but do not reduce HC or particulate matter emissions as well. Additionally, nanoparticles may decrease emissions through improved combustion or catalytic action; however, the mechanisms by which nanoparticles reduce emissions, that is, improvements in combustion, must be further investigated.

SFC and Fuel Economy Concerns

SFC is one of the major concerns of ethanol–diesel blends, as ethanol possesses a lower CV than diesel. It remains unclear the effect of nanoparticle addition, in particular of graphite oxide, on mitigating or exacerbating this issue. Understanding how nanoparticles affect fuel efficiency and overall SFC at different engine loads is crucial to enabling the adoption of ethanol–diesel blends as a substitute for pure diesel.

Load-Dependent Performance and Emissions

Previous studies on ethanol diesel blends with nanoparticles have been limited to steady-state engine conditions, and little work has been carried out on load conditions across a range of operating conditions. To assess the practicability of nanoparticle-enhanced blends fully, a complete investigation is required into how nanoparticle-enhanced blends perform under a range of engine loads.

1.1.2. Introducing the Problem

Compression Ignition (C.I.) engines, although extensive in use, are a major contributor to harmful emissions, particularly CO, HC, and particulate matter. To mitigate these emissions, alternative fuels such as ethanol, which have significant environmental advantages over diesel, have been used. However, the use of ethanol frequently reduces engine efficiency and raises fuel usage since ethanol has a lower energy density. The inclusion of ethanol with diesel provides a potential solution; however, the industry still needs to deal with the tradeoffs between BTE and SFC.

To enhance the combustion properties of fuels, nanomaterials like graphite oxide nanoparticles have been reported to improve fuel atomization, increase surface area, and increase combustion efficiency. The effect of these nanoparticles was, however, not yet studied in ethanol/diesel blends. In addition, the characterization of the impact of NPs on emissions, including CO, HC, and smoke, is still incomplete, particularly in terms of engine load variation.

2. Biodiesel and the Importance of Additives

As biodiesel is renewable, it offers environmental benefits, and it can be used compatibly with existing diesel engines, biodiesel has become a new alternative to conventional fossil fuels [3][4]. Transesterification processes are used to produce it from varied Feedstocks, varying from edible oils, non edible oils to Waste materials. Biodiesel use in diesel engines produces less harmful emissions of PM, HC, and CO than conventional diesel fuel oils and produces a sustainable energy source [5-8]. Despite having a lower CV, higher viscosity, and cold flow properties, biodiesel may not perform well under C.I. engine conditions. The limitations in fuel properties and engine operation have been addressed with fuel additives, particularly metal-based additives, to improve fuel properties and reduce engine emissions [9].

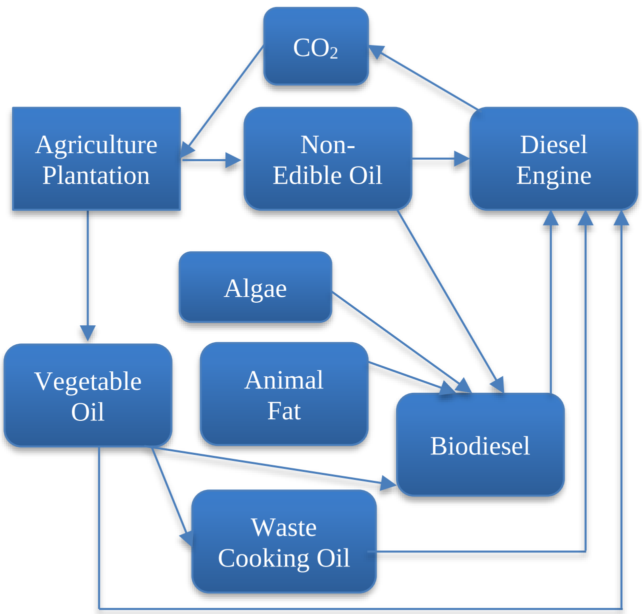

Fig. 1 The biofuel run in diesel engines is used to create the cycle of biofuel [18]

2.1. Edible Feedstocks

Numerous edible feedstocks, such as rapeseed oil, palm oil, sunflower oil, and soybean oil, are used as biodiesel feedstocks because of their higher oil content and ease of processing [10]. However, using edible oil for biodiesel is a matter of food security and has a high adverse impact on the economy through the diversion of foods to energy production [11]. Researchers have been forced to explore alternative feedstocks, namely non-edible oils or waste materials, as better biodiesel production feedstocks than edible oils.

2.2. Non-Edible Feedstocks

Attention has turned to non-edible feedstocks for use as sources of biodiesel from edible oils such as castor oil, karanja oil, jatropha oil, and algae oil [12]. Typically, these feedstocks are from plants grown on marginal lands or waste sources, which gives them a better environmental and sustainable source. Since non-edible oils can typically have higher levels of Free Fatty Acids (FFA), which necessitates additional processing during biodiesel production, using non-edible oils minimizes the competition with food crops [13]. Non-edible oils such as POME in ethanol–diesel blends are utilized in this research because of their renewable nature and their ability to increase the sustainability of biodiesel [14-15].

2.3. Fuel Additives and Their Importance

Biodiesel and biodiesel blends have shown improved performance and emission characteristics due to the use of fuel additives [16]. Biodiesel, while environmentally beneficial, suffers from certain limitations, such as:

- Lower CV compared to diesel, resulting in reduced engine efficiency.
- High viscosity affects fuel atomization and combustion quality.
- Poor cold flow properties lead to operational challenges in colder climates.

To address these issues, fuel additives are introduced to enhance the fuel's physical as well as chemical properties. Additives can improve:

- CE by promoting better atomization and mixing of air and fuel.
- Emission characteristics by reducing harmful pollutants such as CO, HC, and smoke.
- Fuel stability under varying temperature conditions, improving the practicality of biodiesel blends.

The coming into being of graphite oxide nanoparticles in ethanol−diesel−biodiesel blends is introduced as a novel additive in this research. Compared to graphite oxide, the vehicle's combustion is characterized by the enhancement in catalytic activity, the improvement in TE, and the reduction in emissions.

Fig. 2 Various edible and non-edible biodiesel feedstock

2.4. Metal-Based Additives

Additives based on metal compounds have been previously studied for their capability of improving combustion characteristics along with emission profiles in diesel and biodiesel fuels [17]. The additives, much of which exists in nanoparticle form, imbue catalytic combustion by speeding oxidation rates and improving combustion chamber reaction kinetics [19]. Commonly used metal-based additives include:

- Alumina (Al_2O_3): Improves atomization and thermal efficiency.
- Ceria (CeO_2): It acts as an oxygen storage material promoting full combustion and the release of CO and particulates.
- Titanium dioxide (TiO_2): Improves heat transfer and reduces emissions enhancing combustion.

Fig. 3 Metal and metal-oxide nano additives as a performance enhancer

In this study, we introduce graphite oxide nanoparticles as a novel metal based additive with its own unique properties. Unlike conventional metal-based additives, graphite oxide offers:

- High surface area-to-volume ratio: Better atomization along with mixing.
- Thermal conductivity: Improving heat transfer in combustion.
- Catalytic activity: Reductions in negative emissions and promotion of oxidation reactions.

The incorporation of graphite oxide nanoparticles into ethanol-diesel blends offers a dual advantage:

- Performance Enhancement: In order to increase the BTE and increase the HRR.
- Emission Reduction: It catalyzes combustion, leading to a drastic reduction in CO, HC and smoke emissions.

This work shows that graphite oxide nanoparticles have the potential to overcome the limitations of biodiesel blends and thus have the potential to be a more viable and sustainable alternative for use in C.I. engines. This work provides insights into the development of cleaner, more efficient engine technologies by interfacing renewable feedstocks and advanced additives.

3. Review of Literature

The use of nanotechnology to enhance diesel engine performance and emission characteristics has attracted a lot of attention in recent years. It is well known that the incorporation of NPs into fuel blends can bring in multiple potential benefits, including catalytic properties, thermal efficiency improvements, and an ability to reduce harmful emissions. Key findings from recent literature are reviewed, and gaps that correspond to the objectives of this research are identified.

3.1. Fuels with Graphene and Graphite Based Nanoparticles

In the laboratory study, Bayindirli et al. (2023) [20] investigated the use of GO nanoparticles in fuel due to their high conductivity and reactivity along surface area. Results showed significant improvements in BTE, with a strong correlation between heat release rate and nanoparticle concentrations. Boosts in the thermophysical properties of the fuels were accompanied by reductions in HC emissions by up to 15.73%. These results suggest that graphene oxide nanoparticles can improve both the combustion and emissions, yet leave open questions regarding the emissions behavior of GO NPs in ethanol diesel blends under diverse engine loads.

Pullagura et al. (2024) [21] have also explored using graphene nanoplatelets and hydrogen as additives in biodiesel-diesel blends. The study demonstrates that reductions of 19.75 per cent in carbon monoxide (CO) and 24.86 per cent in hydrocarbon (HC) emissions can be achieved under high load conditions when just 50 mg/L of graphene nanoplatelets are added, along with hydrogen; this replaces the current baseline in which only EGR is used and also increases fuel economy by reducing CO emissions. In particular, this work outlines the benefits of using graphene-based additives, but it focuses principally on stationary engines. This is then extended in the present study by integrating graphite oxide nanoparticles into ethanol-diesel blends and evaluating their performance and emissions over a more diverse field of applications.

3.2. Hybrid Additives and Nanoparticle Blends

Sule et al. (2024) [22] investigation into hybrid additives like ethanol, butanol, and magnetite nanoparticles within palm oil biodiesel blends revealed improvements to combustion and emissions, most significantly a reduction in BSFC. Their research centered on B100 biodiesel exclusively, whereas this study explores ethanol-diesel mixtures. Introducing graphite oxide nanoparticles to such combinations could further enhance their combustion properties, filling an essential void in the existing literature.

In Siddiqui et al. (2023) [23] analysis of the effects of graphite and iron oxide (Fe2O3) nanoparticles within gasoline blends, they uncovered notable decreases in brake-specific fuel consumption alongside increases in brake power and torque. While their work inspected gasoline mainly, the catalytic characteristics of graphite-based additives exhibited huge potential. Applying similar principles to ethanol-diesel mixtures can likely improve performance and emissions in compression ignition engines, addressing issues left unresolved.

3.3. Metal Oxide Nanoparticles in Diesel Engines

Rajak et al. 2023 [24] study investigated the impacts of zinc oxide nanoparticles in diesel engines at concentrations from 0.025% to 0.1%. Strikingly, they observed an 11.7% increase in BTE alongside a 1.67% reduction in SFC, markedly lower exhaust gas temperatures, and NOx emissions. This highlights the role metal additives can play in improving CE. However, research on graphite oxide nanoparticles—which possess distinct catalytic and thermal properties compared to other nanoparticles—remains sparse, particularly regarding their effects in ethanol-diesel blends.

Gad et al. 2021[26] experiments with alumina nanoparticles in diesel fuel are also illuminating. They documented improvements in TE and reductions in SFC of up to 5.5%, while alumina nanoparticles enhanced fuel stability and decreased injector fouling issues. These outcomes demonstrate nanoparticles' potential for enhancing fuel performance, but more studies of alternative nanoparticles like graphite oxide are still needed to uncover their specific advantages in ethanol-diesel blends.

3.4. Biodiesel and Graphite Oxide Nanoparticles

Billa et al. 2022 [25] work applying graphite oxide nanoparticles in biodiesel/diesel/alcohol mixtures is relevant. Optimizing engine parameters using response surface methodology showed reductions of 15.6% in carbon monoxide emissions and 21.78% in unburned hydrocarbons. Likewise, Agbulut et al.'s 2022 investigation of graphite oxide nanoparticles' impacts on waste cooking oil methyl ester blends revealed improvements in combustion and emissions. While illuminating graphite oxide nanoparticles' benefits, these studies center on biodiesel, not ethanol-diesel blends, leaving a gap that the present research aims to address.

Jayaraman et al. 2021[27] examination of graphite oxide nanoparticles' effects on sapota seed biodiesel blends under varying injection pressures demonstrated lowered carbon monoxide and hydrocarbon emissions alongside better thermal efficiency with the addition of 50 ppm graphite oxide NPs. However, graphite oxide's role in ethanol-diesel blends, especially regarding the tradeoff between TE and SFC, remains underexplored.

3.5. Graphene Oxide in Biodiesel Blends

Hoseini et al. 2020 [28] evaluation of an engine made from diesel running on Oenothera lamarckiana biodiesel supplemented with graphene oxide nanoparticles is also relevant. The nanoparticles led to significant improvements in power and exhaust gas temperatures. While these findings show graphene oxide's effectiveness in biodiesel, more work is still needed to explore such additives' potential and impacts—such as on NOx and particulate matter emissions—in ethanol-diesel blends.

3.6. Addressing the Research Gap

While the existing literature underscores the benefits of nanoparticle additives in enhancing fuel performance and emissions, key gaps remain in the study of ethanol-diesel blends with graphite oxide nanoparticles:

1. Limited research focuses on the impact of GO nanoparticles in ethanol-diesel blends, which could

address the trade-offs between reduced thermal efficiency and higher specific fuel consumption.
2. Most studies have examined steady-state engine conditions, with limited exploration of how nanoparticle-enhanced blends perform under varying engine loads.

This research addresses these gaps by investigating the impacts of GO NPs on engine performance, emission parameters, and SFC in ethanol-diesel blends. The findings will provide a deeper understanding of how these blends can be optimized for practical applications in C.I. engines.

4. Novelty of the Work

This study presents a novel approach to improving the performance and emission characteristics of C.I. engines using GO NPs incorporated into ethanol-diesel blends.

While previous research has explored the use of ethanol-diesel blends as an alternative to diesel and investigated the role of various nanoparticles in enhancing fuel properties, this work stands out for several key reasons:

- Use of Graphite Oxide Nanoparticles: Although nanoparticles such as alumina, ceria, and titanium dioxide have been widely studied for enhancing combustion as well as lowering emissions in diesel engines, Graphite Oxide nanoparticles (GO) have received limited attention in the context of ethanol-diesel blends. Graphite oxide nanoparticles are known for their high surface area, catalytic properties, and potential for enhancing fuel combustion through improved atomization and heat transfer. The novel application of graphite oxide in ethanol-diesel blends for CI Engines represents a significant innovation, as it explores a material with unique properties that may offer new advantages in performance and emission reduction.
- Ethanol-Diesel-Nanoparticle Blends: While ethanol-diesel blends themselves have been studied extensively, this research adds a new dimension by integrating nanoparticles specifically aimed at improving the combustion properties of these blends. Most research on ethanol-diesel blends either focuses on ethanol fumigation, dual injection, or simple fuel blending, often without incorporating nanomaterials. The novelty here lies in the synergistic combination of ethanol, diesel, and graphite oxide nanoparticles to optimize the blend's performance without requiring extensive engine modifications.
- Comprehensive Assessment Under Variable Load Conditions: Many studies on alternative fuel blends are conducted under steady-state conditions. However, few provide a detailed analysis of how these blends perform under varying engine loads. This study evaluates the effect of GO NPs on engine performance (BTE, maximum pressure, heat release rate), emissions (CO, HC, smoke), and specific fuel consumption (SFC) under different load conditions. By examining the full range of operational loads, this work offers insights into the practical applicability and performance consistency of ethanol-diesel-nanoparticle blends in real-world engine operations.
- Emissions Reduction and Catalytic Mechanisms: While previous research has demonstrated the emissions-reducing properties of ethanol and various nanoparticles, this study uniquely investigates the catalytic role of GO nanoparticles in promoting cleaner combustion. In particular, the reduction in CO and smoke emissions across different load conditions, as well as the impact on hydrocarbon emissions, is significant. In the context of ethanol-diesel blends, the catalytic effect of nanoparticles—particularly graphite oxide—in encouraging more thorough combustion and lowering hazardous emissions has not been thoroughly investigated.

5. Research Methodology

The current investigation focuses on the solubility of ethanol-Palm oil methyl ester (POME)-diesel blends with between 20 and 30 percent ethanol, between 5 and 30 percent POME, and the remaining diesel at three distinct temperatures: 5, 15, and above 25 ℃. Following the solubility research, one blend is chosen from among the eighteen blends.

This blend is then used to investigate the performance, combustion, along emission properties of diesel engines with as well as without GO microparticles. A comparison is made between diesel and the findings that are stated.

5.1. Solubility Test

There were a variety of various proportions of the fuels that were combined. At three different temperatures—five, fifteen, and twenty-five degrees Celsius—the mixes were examined to determine their stability. Table 1 represents the current state of the mixture overview.

5.2. NP Blending

The characteristics of GO nanoparticles are detailed in the table, which can be found here. Through the use of an ultrasonicator, the graphite oxide microparticles were continually mixed into the fuel until a clear mixture was produced. A device known as an ultrasonicator uses ultrasonic radiation to treat particles in order to improve their dispersion.

5.3. Properties of Fuels

The ASTM blend standards are used to conduct tests on stable mixes to determine their varied qualities. The attributes are organized in tabular form in Table 3.

Table 1. Phase stability of fuel mixtures at various temperatures

Parameter	**A1**	**A2**	**A3**	**A4**	**A5**	**A6**
Diesel (%)	75	70	65	60	55	50
Ethanol (%)	20	20	20	20	20	20
POME (%)	5	10	15	20	25	30
Stability > 25°C	0	0	1	1	1	1
Stability at 15°C	0	0	0	0	1	1
Stability at 5°C	0	0	0	0	1	1
Parameter	**B1**	**B2**	**B3**	**B4**	**B5**	**B6**
Diesel (%)	70	65	60	55	50	45
Ethanol (%)	25	25	25	25	25	25
POME (%)	5	10	15	20	25	30
Stability > 25°C	0	0	0	1	1	1
Stability at 15°C	0	0	0	1	1	1
Stability at 5°C	0	0	0	0	1	1
Parameter	**C1**	**C2**	**C3**	**C4**	**C5**	**C6**
Diesel (%)	65	60	55	50	45	40
Ethanol (%)	30	30	30	30	30	30
POME (%)	5	10	15	20	25	30
Stability > 25°C	0	0	0	1	0	1
Stability at 15°C	0	0	0	0	0	1
Stability at 5°C	0	0	0	0	1	1

In Table 1, 1 represents Stable and 0 represents Unstable.

Table 2. NPs specifications

Chemical formula	**GO**
Purity	>99%
Average particle size	20-50mm
Density	2.2 gm
Color	Brownish-yellow
Crystal phase	Amorphous layered structure

Table 3. Properties of fuel

Property	**Diesel**	**Ethanol**	**Palm oil biodiesel**	**D40 B30 E20**	**D40 B30 E30+ GO**
Density at 30℃	855	820.4	866	830.5	837.6
Kinematic viscosity (at 40℃)	2.95	1.2	4.85	2.5	2.4
Flashpoint (℃)	60-80	13	174	10	16
Calorific value	43000	27000	36764	34907	36896
Oxygen number	_	35	11.4	0.84	0.81
Cetane number	52	8	63	57	55

5.4. Engine setup

Figure 4 depicts the experimental setup, and Table 4 contains a tabular representation of the specifications for the experiment.

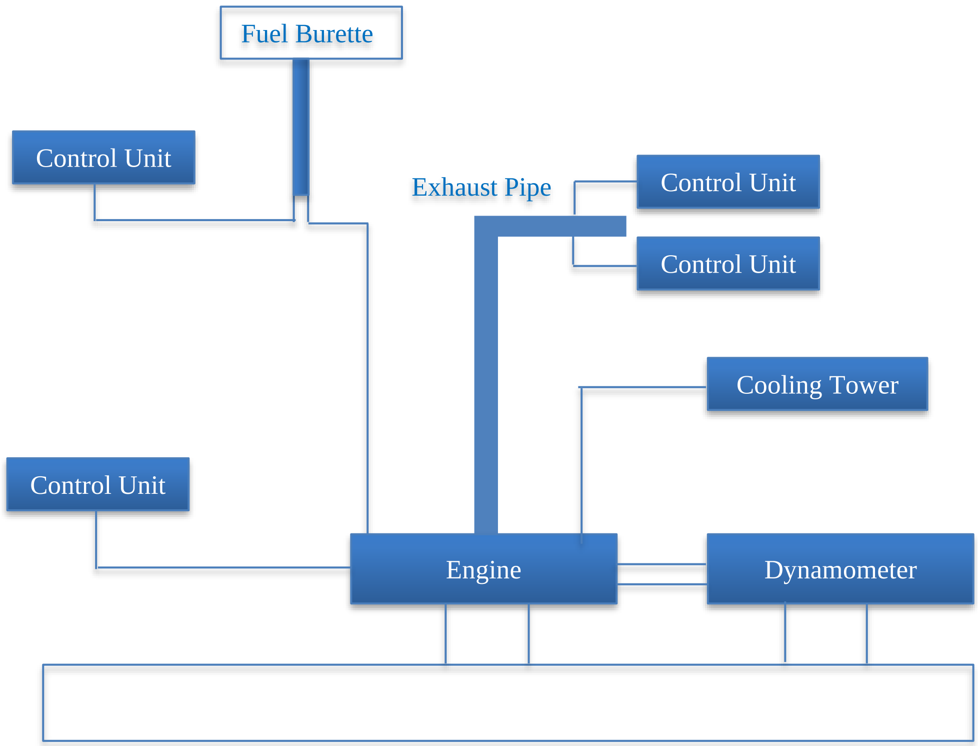

Fig. 4 Layout of test engine

Table 4. Engine specification

Name	**Kirloskar**
No of cylinders	1
Displacement volume	662cc
Bore x stroke	87.5mm x 110mm
CR	17.5:1
Operating speed	1500 rpm
Injection timing	23 deg BTDC
Power	4.41kw

All elements of combustion, performance, and pollution were studied in a Kirloskar diesel engine that was a single-cylinder, four-stroke, direct injection engine that operated at a constant speed. A thorough evaluation of the performance of the test fuel was given. It was discovered that the piston had a displacement of 662 cubic centimeters, and the CR was 17.5:1. The angle 23 degrees before the top dead center of the crankshaft was the angle at which the gasoline was pumped into the engine. The maximum amount of power that the engine was able to generate was 4.4 kilowatts, and the top speed at which it could operate was 1500 revolutions per minute. The kind of dynamometer that was used was one that utilized eddy current. A piezoelectric pressure transducer manufactured by Kistler was used to measure the pressure within the cylinder. For the purpose of conducting further combustion analysis, the pressure that is collected from the combustion chamber is then sent into the data-gathering system. The time it took to consume 10 cc of gasoline was used as a measurement for the amount of fuel that was used. Voltage and current were used in the computing process to ascertain the performance characteristics.

6. Result and Discussion

In the framework of an experimental investigation into the usage of renewable fuels, three stages are carried out: testing the solubility of the fuel at three different temperatures, evaluating its properties, and incorporating GP nanoparticles.

In this study, the performance, combustion, as well as emission features of the fuel mix in a diesel engine are investigated, and the results are given in the following manner.

6.1. Solubility Test

Of the 18 blends assessed for solubility, five exhibited stabilities over all three temperatures (5℃, 15℃, and >25℃).

It has been determined that blend C6 will be the subject of further inquiry since it contains the lowest percentage of diesel and has shown stability throughout all three temperatures.

In comparison to other combinations, the quantities of ethanol and POME, which are both sustainable fuels, are much higher. Because of this, the use of renewable fuels as a replacement for fossil fuels (diesel) is made easier.

Table 5. Phase stability of fuel mixtures at various temperatures

Parameter	A5	A6	B5	B6	C6
Diesel (%)	55	50	50	45	40
Ethanol (%)	20	20	25	25	30
POME (%)	25	30	25	30	30
Stability > 25°C	1	1	1	1	1
Stability at 15°C	1	1	1	1	1
Stability at 5°C	1	1	1	1	1

In Table 5, 1 represents Stable and 0 represents Unstable.

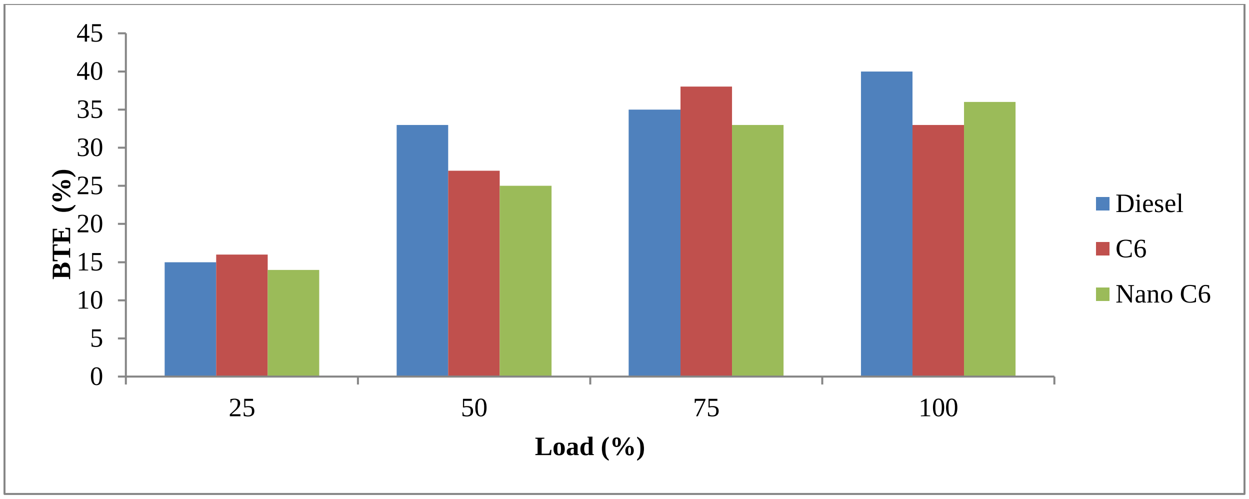

Fig. 5 BTE

6.2. Performance Characteristics

6.2.1. Brake Thermal Efficiency

Figure 5, which shows the load-related fluctuation, illustrates the variance in braking thermal efficiency of the blends in comparison to the performance of diesel engines. Blends have a lower calorific value in contrast to diesel, which is the reason why blends have a poorer thermal efficiency when it comes to braking than diesel does. The BTE of nano C6 is better than that of C6 while the vehicle is operating under full load. This is because nanoparticles were incorporated into the mixture, which led to an increase in the ratio of surface area to volume as well as an increase in the average temperature of the combustion process. The fact that the rise in EGT correlates with the expansion in load is another piece of evidence that lends more credibility to these decisions.

6.2.2. BSFC

Figure 6 demonstrates the relationship between load and blends while also depicting the variability of brake-specific fuel consumption of blends relative to diesel cars. Blends have a BSFC that surpasses that of diesel, irrespective of the applied load. Ethanol reduces the calorific value of the blends, hence diminishing the energy content of the mixes. This is the reason why this is the case. Furthermore, there is an increase in the latent heat of vaporization of mixes after the reaction has taken place. As a consequence of this, the length of time necessary for it to evaporate is increased, which in turn causes the temperature of the CC to decrease as the load is being reduced. The BSFC, on the other hand, tends to drop as the load rises. This is because the load is increasing. This is seen in conjunction with the rising temperatures that occur at higher loads. Through the use of catalytic action, Graphite Oxide (GO) nanoparticles in the mixture promote combustion activity, which in turn makes it easier to achieve better combustion at higher temperatures. At higher temperatures, the ratio of nanoparticles' surface area to their volume is increased, which leads to an improvement in the atomization of the fuel mixture.

6.2.3. Exhaust Gas Temperature (EGT)

Figure 7 depicts the fluctuation in EGT generated by nano C6 relative to diesel under varying load conditions. The exhaust gas temperature generated by the mixes is somewhat lower than that of diesel. This effect is caused by the elevated latent heat of evaporation associated with the ethanol-containing fuel mix. Furthermore, the heightened average temperature inside the CC results in an increase in the EGT of the mixes as the load intensifies. The hob functions at an increased temperature. The incorporation of ethanol leads to a lower EGT owing to ethanol's elevated heat of vaporization. The catalytic efficacy of GO nanoparticles enhances the combustion process, leading to a rise in the average temperature of the combustion chamber. Furthermore, the data reveals that the EGT of the nanoparticle-infused blend surpasses that of the ethanol-biodiesel combination when the load reaches fifty percent.

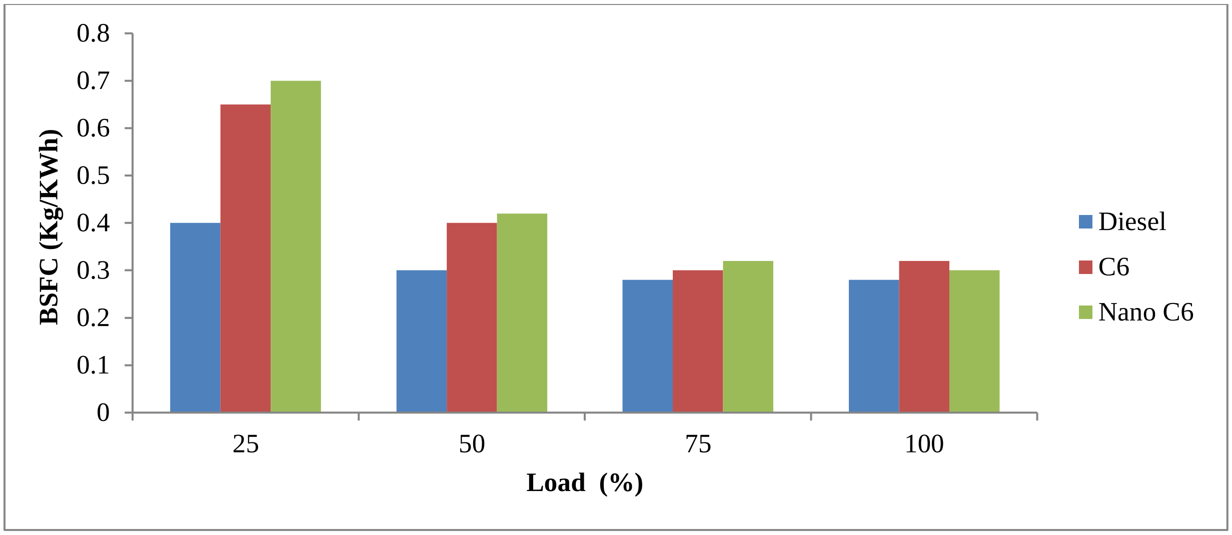

Fig. 6 BSFC

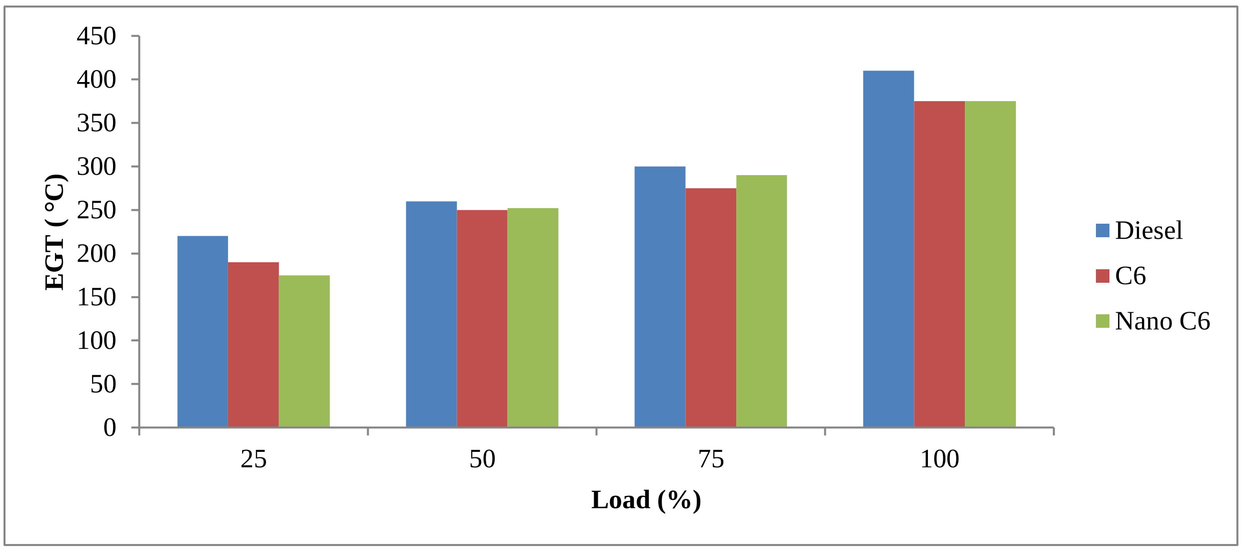

Fig. 7 EGT

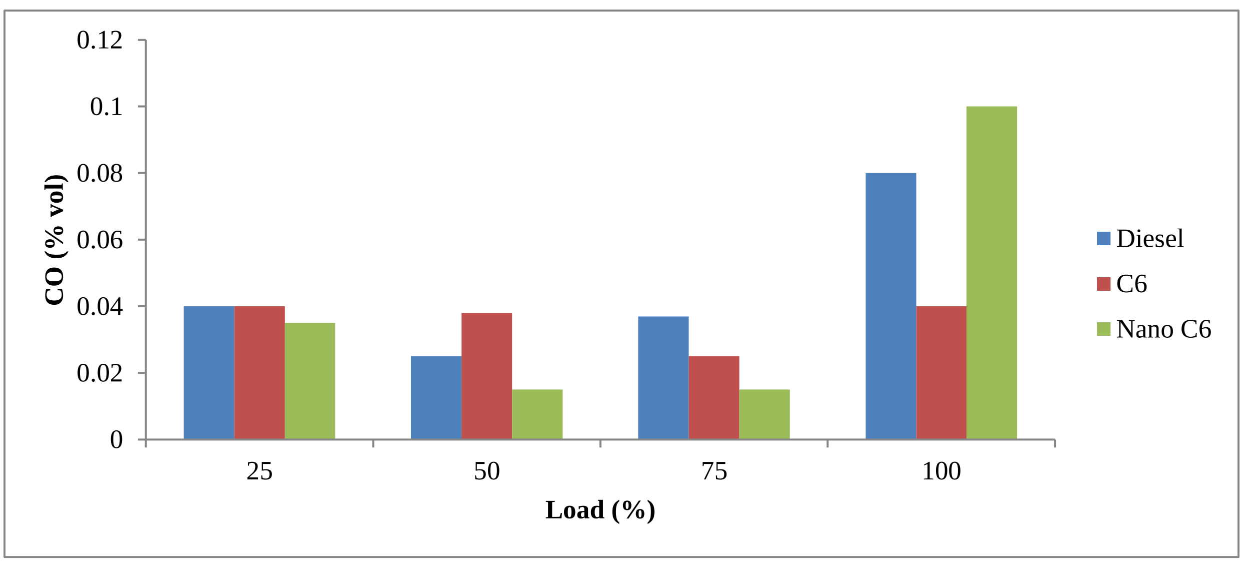

Fig. 8 Carbon monoxide emissions

6.3. Emission Characteristics

6.3.1. Carbon Monoxide

Figure 8 illustrates the fluctuation of carbon monoxide levels in blends relative to diesel concerning load. The carbon monoxide emissions of mix C6 exceed those of diesel prior to part load conditions. The ethanol in the combination results in a greater heat of vaporization compared to diesel, leading to worse atomization and cooling effects. The Exhaust Gas Temperature (EGT) under partial loads indicates a reduction in the average temperature of the CC. When the load is increased, the relevance of the heat of vaporization decreases, which leads to a more thorough combustion and a reduction in the amount of carbon monoxide emissions. CO emissions from mix nano C6 are lower than those of diesel across the board for all loads. This results from the incorporation of nanoparticles, which facilitate combustion through catalytic action, thereby diminishing CO emissions.

6.3.2. Hydrocarbon

Figure 9 depicts the variation in unburned HC concentrations of blends compared to diesel as a function of load. The hydrocarbon emissions of C6 are lower than those of diesel at loading of 75%. It exceeds diesel alone in full-load conditions. This results from the reduced duration permitted for the mixture to combust at maximum efficiency. Nano C6 exhibits increased hydrocarbon emissions at lower loads, namely up to 25% load, but underperforms compared to diesel beyond this threshold. This results from the presence of nanoparticles that enhance burning via chemical mechanisms. Furthermore, the elevated temperature of the cylinder at full load facilitates more thorough combustion, resulting in reduced hydrocarbon emissions.

6.3.3. Smoke

Figure 10 illustrates the fluctuation of smoke levels of nano C6 in comparison to diesel concerning load. When compared to diesel, the smoke emissions produced by mix C6 are much lower. There is a possibility that this is the consequence of increased fuel combustion inside the CC. The use of ethanol in the mixture markedly reduces smoke emissions. The fuel's decreased viscosity facilitates improved atomization. Improved atomization of blend nano C6 resulted in reduced smoke emissions. This is also demonstrated by an increase in EGT.

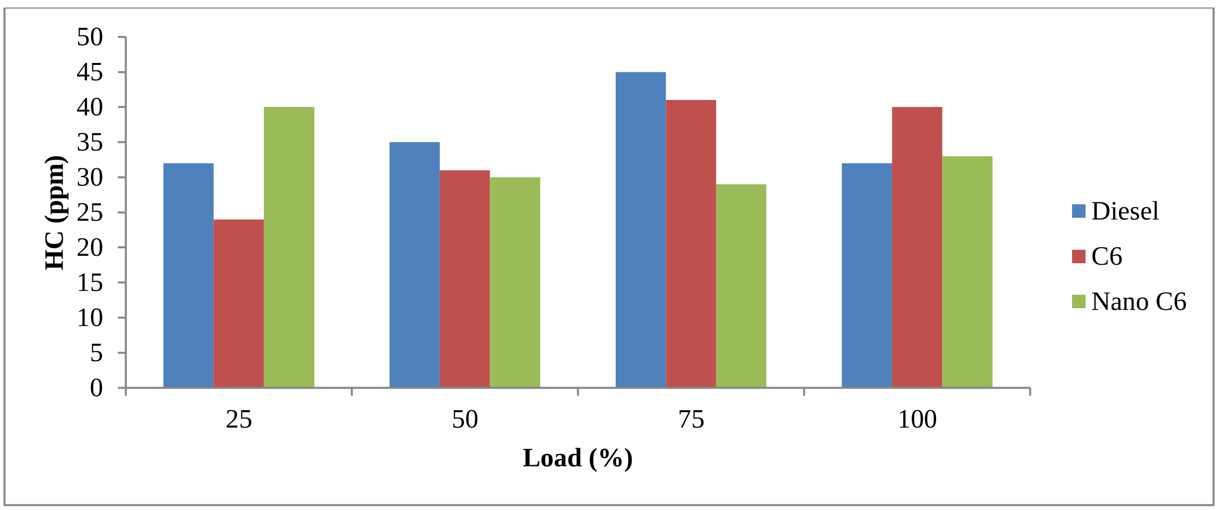

Fig. 9 Hydrocarbon emissions

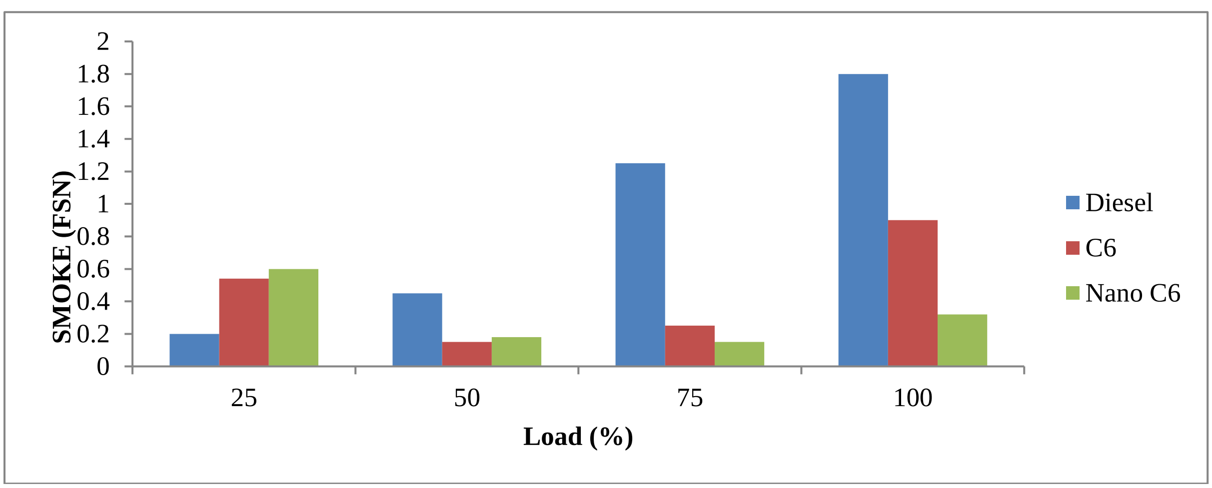

Fig. 10 Emissions of smoke

7. Conclusion

The study involves conducting experiments and creating a model of a Compression Ignition (C.I) engine that utilizes graphite oxide nanoparticles in ethanol-diesel mixtures. The conclusions derived from the outcomes of an experimental research aimed at using renewable fuels were executed in three phases. The stages included testing the solubility of the mixture at three different temperatures, evaluating its properties, integrating GO NPs, and examining the performance, combustion, and emission properties of the blend in a diesel engine. The research and modelling of a C.I engine using ethanol-diesel mixed with graphite oxide nanoparticles (nano C6) has shown substantial improvements in engine performance and emission attributes. In full load operation, the BTE of C6 along with nano C6 decreased by 21% and 9%, respectively, when compared to standard diesel. This indicates a little reduction in efficiency. Nonetheless, the BSFC increased by 39% and 14%, perhaps due to the reduced energy density of the ethanol-diesel blends. Notably, the maximum pressure increased by 8% and 13%, while the HRR surged by 118% and 129%, suggesting enhanced combustion characteristics with the nanoparticle addition. Emission reductions were also observed, with CO levels decreasing by 62% and 92% and smoke emissions dropping by 54% and 82%, indicating cleaner combustion. Additionally, HC emissions showed a mixed result, increasing by 21% with C6 but decreasing by 9% with nano C6. These findings demonstrate that the use of graphite oxide nanoparticles in ethanol-diesel blends can improve CE and reduce harmful emissions, making it a promising approach for improving engine performance and lessening the effects of C.I. engines on the environment.

Abbreviation

CI	Compression Ignition
BSFC	Brake Specific Fuel Consumption
CE	Combustion Efficiency
CC	Combustion Chamber
HRR	Heat Release Rate
SFC	Specific Fuel Consumption
EGR	Exhaust Gas Recirculation
GO	Graphite Oxide
NPs	Nanoparticles
EGT	Exhaust Gas Temperature
PM	Particulate Matter
CV	Calorific Value
TE	Thermal Efficiency
CR	Compression Ration
BTE	Brake Thermal Efficiency
POME	Palm Oil Methyl Ester

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