# Influence of Nanoparticles on Biodiesel Engine- A Review

**Ramozon Khujamberdiev**

Master Student, Dept. of Mechanical Engineering, Kongju National University, Republic of Korea,

**Haeng Muk Cho[2]***

Professor, Dept. of Mechanical Engineering, Kongju National University, Republic of Korea,

## ABSTRACT

Biodiesel is an unrivaled alternative fuel that aims to increase the value of fossil fuels while also extending the life and cleanliness of diesel engines. Because of its closed carbon cycle, it decreases reliance on foreign fuels while also lowering greenhouse gas emissions. The numerous benefits of biodiesel are outweighed by a few disadvantages, such as increased nitrogen oxide emissions, incompatibility with cold weather conditions, and the need to repair engine equipment such as fuel filters, fuel tanks, and fuel lines on a frequent basis owing to clogging. By using nanoparticles as fuel additives, there is even more potential for improving fuel qualities and overcoming limitations.The thermophysical characteristics of the fuel mixes were improved, the heat transfer rate was increased, and the fuel mixtures were stabilized. In addition, depending on the dose of nanofluid additives, there was an improvement in engine performance metrics and a reduction in exhaust emissions.The current study highlights the most recent research on nanoparticles as a liquid fuel additive. The impact of dispersion of various nanoparticles on improving performance parameters and lowering emissions in a CI engine running on diesel-biodiesel blends is examined. The creation of an economically viable and practicable nanoparticle addition for diesel and biodiesel fuel is suggested as a future goal. However, a few of the constraints and problems identified in this analysis must be overcome before they can be completely implemented in commercial applications.

**KEYWORDS:** Nanoparticles, biodiesel blends, nano-additives, Graphene Quantum Dots (GQD)

## 1. Introduction

Countries all across the world are becoming more industrialized and mechanized, increasing their demand for fossil fuels. However, the usage of fossil fuels produces a large amount of greenhouse gases, which has a negative impact on the environment. The introduction of renewable, sustainable, efficient, and cost-effective resources with reduced pollutant emissions has resulted from a decrease in fossil fuel sources as well as an increase in energy consumption and greenhouse gas emissions. Biodiesel fuel is one of the most important alternative energy sources that can replace fossil fuels.It has a number of advantages, including being environmentally friendly, non-toxic, and renewable, as well as having a high flash point and outstanding performance. On the other hand biodiesel fuel has its own drawbacks, including increased $NO_X$, poor atomization, and incomplete combustion. The use of additives and catalysts in biodiesel fuel can help to lessen the negative consequences of this fuel [1].

Diesel engines are a type of internal combustion engine that can be found in a variety of vehicles, both heavy and light. The biggest disadvantage of diesel engines is the production of polluting gases during the combustion of the fuel. Diesel engines emit nitrogen oxides (NOx), unburned hydrocarbons (UHC), carbon oxides (COx), sulfur oxides (SOx), and smoke, among other pollutants. Many researchers have attempted to develop a suitable combustion system for entirely burning hydrocarbons up to this point. The problem, however, continues to be difficult [2-4]. One option being studied for overcoming this problem is to improve fuel quality and provide better combustion of gasoline in engines. There is no need to change the engine structure with these procedures. Biofuels, water, nanoparticles, and other additives are some of the solutions that have been studied to improve combustion and fuel quality [5, 6].Bidita et al. investigated the effect of adding water to diesel fuel on engine performance. To stabilize the water inside the diesel fuel, they used the Triton X-100 surfactant. Water was added to diesel fuel at various volume concentrations of 0.5-0.9 in their study, and the resulting emulsions were stable for two weeks. According to their findings, the sample containing 0.9 vol. percent water resulted in the greatest reduction in pollutant emissions as well as the greatest brake power and thermal efficiency [7]. Annamalai et al. used biodiesel containing cerium oxide (CeO2) nanoparticles to study pollutant emissions and diesel engine performance. The primary purpose of their research was to reduce harmful emissions from vehicle exhaust. Their fuel had 5% water, 93% biofuel, 2% Span80, and 30 parts per million CeO2 nanoparticles. Their findings revealed that adding water to fuel reduces NOx and smoke emissions while also improving brake thermal efficiency. They also discovered that adding CeO2 to fuel reduces CO, HC, NOx, and smoke emissions[8]. Mirzajanzadeh et al. also developed a CeO2 nanoparticles/CNT hybrid catalyst to improve the performance of diesel engines and minimize CO, HC, NOx, and smoke emissions. They applied the synthesized catalyst in varying concentrations of 30, 60, and 90 ppm to a diesel-biodiesel (B20 and B5) mixture [9].E. Ettefaghi, A. Rashidi, B. Ghobadian et al conducted an experiment to tackle problems such as toxicity, low stability, erosion, and uneconomical usage of metallic and metal oxide nanoparticles in prior studies; for the first time, the diesel-biodiesel-water-bionanoparticles compound was utilized. It was sought to mitigate the additions' drawbacks while maximizing their benefits. As a result, bio-derived graphene quantum dots and water were employed as additives to improve fuel efficiency, minimize pollutant emissions, and improve the performance of diesel engines. For this objective, graphene quantum dot nanoparticles were initially produced using a straightforward method. To improve the performance of the B15 fuel, the prepared nanoparticles were mixed with water and added to it. A single-cylinder engine was used to carry out the engine trials in order to examine the fuel performance [10].

According to researchers, the oxygen in the additives can deliver enough oxygen to the fuel, resulting in more complete combustion of the engine and hence fewer polluting emissions from the engine. Adding nanoparticles to biodiesel fuel has recently been found to reduce greenhouse gas emissions and increase combustion efficiency. Many studies have been conducted on the use of metallic nanoparticles as fuel additives, such as manganese and copper, sodium, iron, and zinc.Despite substantial study into fuel additives, this field still has a lot of issues. Furthermore, the use of metal oxide and metal nanoparticles is associated with a number of environmental risks. The usage of biodegradable nanoparticles is one method for reducing the detrimental impacts of nanoparticles. Quantum dots are a type of nanostructure that has a wide range of uses. They are a collection of nanoparticles with sizes ranging from 1 to 10 nm. These materials' distinctive optical and electrical capabilities provide a solid foundation for their use in a variety of disciplines. Solar cells, quantum lasers, super-capacitors, fuel cells, sensors, quantum computers, and other products are currently made with these materials. In comparison to other nanoparticles, quantum dots have a very high stability and low toxicity [1, 11].

Graphene Quantum Dots (GQD) are one of the newer varieties of quantum dots, and their special attributes have made them increasingly popular in recent years. GQD stands for graphene sheets with zero-dimensional lighting, which is a new generation of carbon nanotubes. Graphene is a one-of-a-kind semiconductor with a band gap of zero. As a result, in comparison to other quantum dots and any other semiconductor, we expect to find a lot of fascinating events in GQD [12]. GQD has exceptional properties such as biocompatibility, high thermal conductivity, great solubility, low production cost, non-toxicity, ease of operation, and chemical inactivity due to its capacity to generate inexpensive and ecologically benign materials [13,14]. Graphene quantum dots GQDs have gained a quick growth as breakthrough instruments for use in numerous domains of science, including photonics, composites, energy, and electronics, due to their outstanding mechanical characteristics, biocompatibility, transparency, and electrical conductivity [15]. Given the toxicity of metallic nanoparticles on live creatures, using biological nanoparticles like GQD can alleviate this problem greatly [16]. Many research investigations have indicated that adding carbon-based nanoparticles to diesel-biodiesel fuel improves performance characteristics and reduces exhaust gas emissions. The effect of adding biocompatible GQD nanoparticles to diesel-bioethanol fuel, as well as the performance and emissions of a diesel engine, was explored in the current study.

## 2. Production Process of Various Graphene Quantum Dots

Amphiphilic GQDs are made using bottom-up molecular fusion in a one-pot hydrothermal reaction, as shown in Fig. 1. Amphiphilic GQDs can act as a 0D inorganic surfactant to stabilize reverse-phase (water-in-oil) Pickering emulsions, self-assemble into a self-supporting monolith, promote water spreading on super-hydrophobic surfaces, disperse insoluble carbon nanotubes to form ultra-light aerogels, and enable interfacial polymerization to synthesize hollow polystyrene microspheres due to their Furthermore, amphiphilic GQDs with a sulfonate group (SGQDs) have a high catalytic efficiency in Pickering interfacial catalysis of soybean oil transesterification with methanol to make biodiesel.

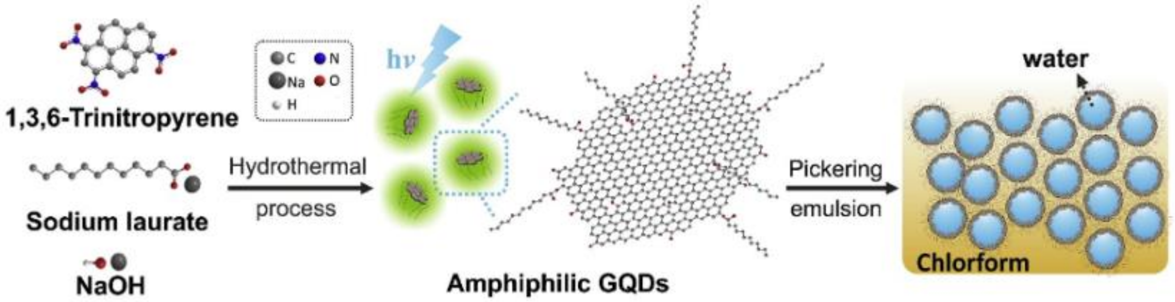
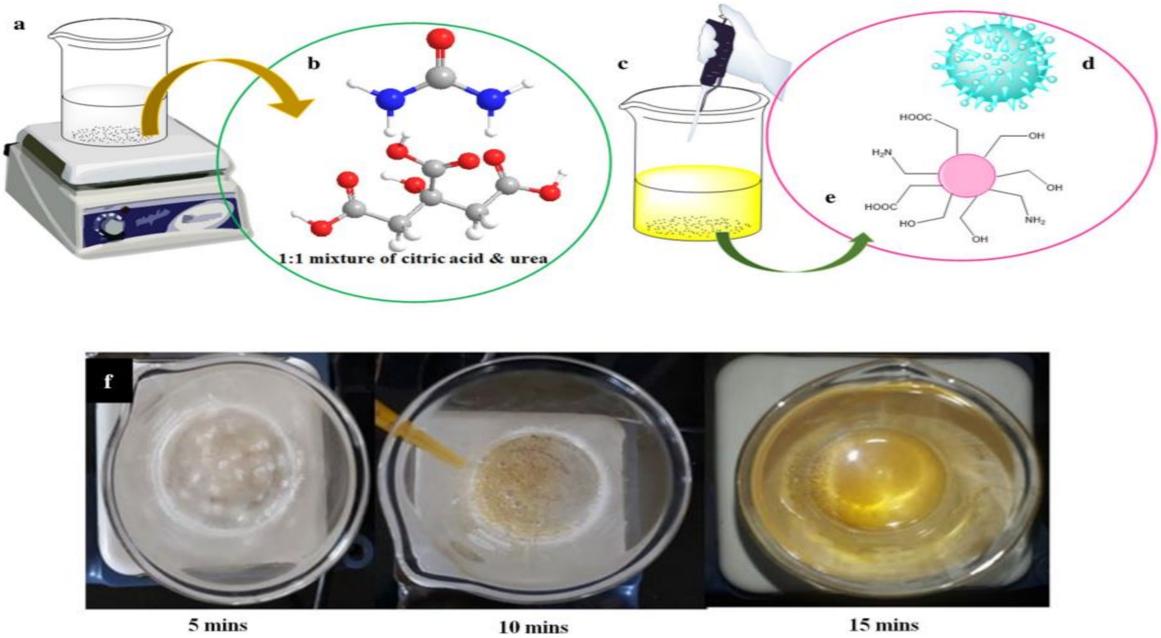


Fig. 1:The production of Pickering emuls and the one-step synthesis of amphiphilic GQDs [17].

In a compression ignition engine, V. K. Kolli et colleagues investigated the effects of mixing the synthetic additive nitrogen-doped graphene quantum dot (N-GQD) with biodiesel as an alternative fuel to fossil diesel.The N-GQDs were made in accordance with green chemistry principles, using little energy in an environmentally responsible procedure. In keeping with previous techniques that included the creation of graphene nanosheets, graphene oxide, and GQDs, the authors have modified the fabrication process to produce N-GQDs in a short period of time (15 minutes). In a typical technique, citric acid was mixed with urea (1:1 weight ratio) and heated to 150 to 155 °C, which was above the melting point of both precursors.The creation of N-GQD was quick and relied on low-cost reagents, making the entire experimental approach environmentally friendly and cost-effective. After about 5 minutes of heating, the precursors transformed into a colorless liquid, and after 15 minutes, the entire mixture turned into a chrome yellow syrupy liquid, as seen in the images in Fig. 2.



5 mins 10 mins 15 mins

Fig. 2: A digitalized representation of the heating process of citric acid and urea at 150 to 150 °C, which results in the creation of N-GQDs. b Citric acid and urea molecules are highlighted in a 3D ball and stick model, with methyl acetate added after 15 minutes in the chrome yellow syrupy molten fluid. N-GQD model with accents in d 3D and e 2D. f Pictographs depicting the creation of N-GQDs throughout time [18].

Hurmathulla Khan et al adopted a two-step procedure to make nanofluids. A probe sonicator, also known as the indirect technique of sonication, is used to evenly scatter the graphene oxide nanoparticles in the SDBS surfactant and distilled water.During the ultrasonication of NPs and fuel, the oxygenated additive n-butanol is combined with biodiesel at a constant proportion of 10%. The fuel mixes are dosed with graphene oxide nanoparticles at dosage levels of 30, 60, 90, and 120 mg/L using a magnetic stirrer for 25 minutes, an ultrasonicator bath for 1 hour, and a probe sonicator for 20 minutes at a frequency of 15–20 Hz per three seconds.By combining NSME25(Nigella sativabiodiesel) with 30 ppm graphene oxide NPs and 15 ppm SDBS surfactant, the fuel blend fuel (properties with nanofuel and n-butanol blends) NSME25B10GO30 is created. NSME25 is blended with 60 ppm graphene oxide NPs and 25 ppm SDBS surfactant for the NSME25B10GO60 blend. NSME25 biodiesel is blended with 90 ppm graphene oxide NPs and 35 ppm and 45 ppm (Sodium Dodecylbenzene Sulfonate Surfactant) SDBS surfactant, respectively, for NSME25B10GO90 and NSME25B10GO120 fuel. Ultrasonic waves are applied to a mixture of distilled water (5 mL), graphene nanoparticles, and SDBS surfactant using a probe sonicator at a frequency of 20 KHz for 20–30 minutes for each nanofluid blend for the creation of nanofluids. Sonication prevents agglomeration by breaking intermolecular and symmetric connections.After that, the NSME25 biodiesel is blended with the nanofluids, the mixture is stirred for 15 minutes at 60 degrees Celsius to remove the water and moisture content, a bath-type sonicator is used to blend the different sets of nanofuel blends for one hour each, and the nanoparticle stability is increased by sonicating in a probe sonicator. These methods ensure that stable nanofuel mixes are created. Fig 3 depicts the methods and approach used in the nanofuel blends investigation.

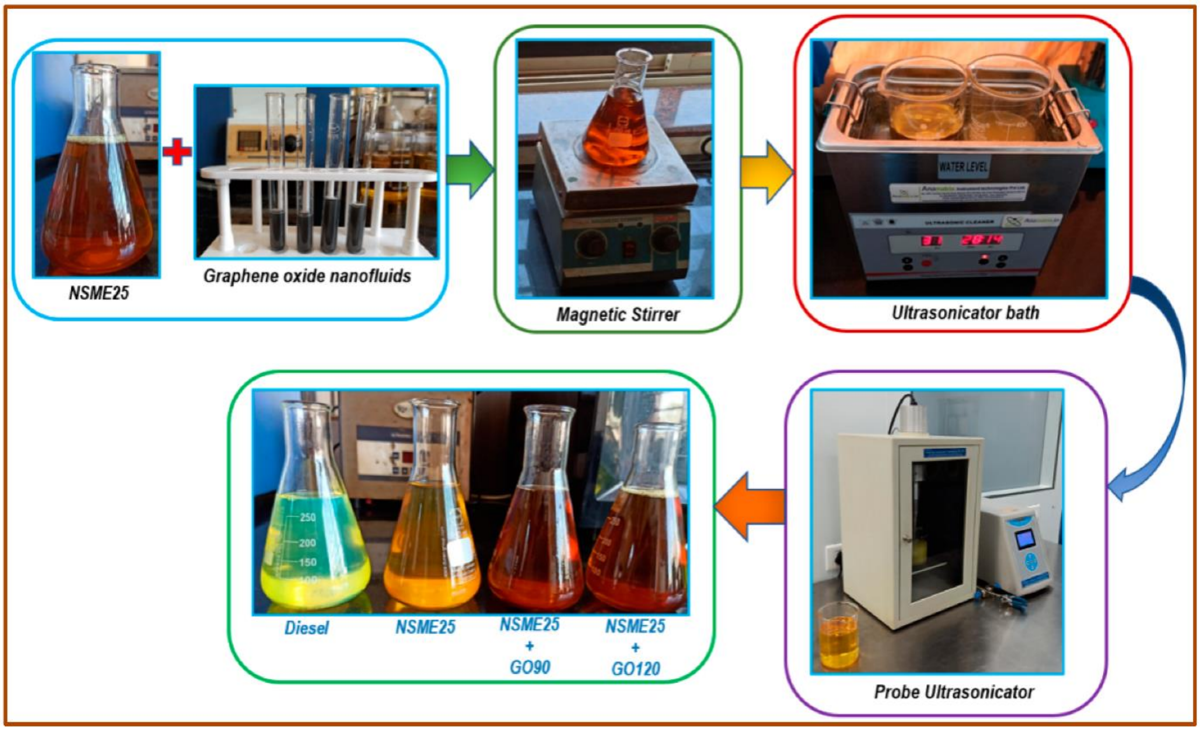


Fig. 3: The methodology used in the research on nanofuel mixtures [19].

## 3. Experiments with Nanoparticles

Sivakumar Muthusamy et. al. carried an experiment to test the performance, combustion, and emission characteristics of various blends on a four stroke single cylinder diesel engine, including B20 (80% diesel + 20% pongamia methyl ester (POME)), B20Fe3O450 (80% diesel + 20% POME + 50 ppm Fe3O4), and B20Fe3O4100 (80% diesel + 20% POME + 100 ppm Fe3O4). Transesterification of pongamia oil with methanol and potassium hydroxide (KOH) as a catalyst produces pongamia methyl ester (POME). Iron oxide nanoparticles with an average size of less than 100 nm were commercially accessible. An ultrasonicator was used to combine POME biodiesel with iron oxide nanoparticles in mass fractions of 50ppm and 100ppm. In an ultrasonicator set at a frequency of 40 kHz and 120w for 60 minutes, the biodiesel with iron oxide nanoparticles was blended with neat diesel. To conduct the test for varied loads at constant speed, a single cylinder four stroke naturally aspirated direct injection water cooled diesel engine equipped with data acquisition system was employed. The engine was immediately connected to an eddy current dynamometer, and the data gathering system was used to load it. An AVL five gas analyzer was used to measure exhaust emissions [20].

For the research, M.A. Mujtaba and colleagues utilized a diesel engine test rig (Model: Yanmar (TF 120 M)) to analyze the diesel engine characteristics of various fuel samples. The schematic perspective of the experimental diesel engine setup is shown in Fig. 4. Initially, B10 (commercial diesel) was used to examine the properties of CI engines. The fuel flow rate was measured using a graduated measuring cylinder fitted to the gasoline tank. Three readings were obtained and averaged for every 10 ml of fuel sample, and time was observed using a stopwatch for each test and engine speed. (DASTEP8) software was used to calculate brake torque (BT) and brake pressure (BP). The BOSCH gas analyzer was used to determine engine gas emissions (HC, CO, and NOx), and the results are listed in Table 1. After running B10 (commercial diesel) in a diesel engine to establish stable operating conditions, ternary fuel mixes were charged to the diesel engine to investigate engine characteristics. The engine was flushed with B10 (commercial diesel) after each ternary fuel blend to remove any traces of the tested ternary fuel blend. For each ternary fuel blend, this approach is used. B10, B30, B30 + CNT, B30 + TiO2, B30 + DMC, and B30 + DEE were the fuel samples that were analyzed. Under full load (100 percent), the experimental test rig diesel engine was ran at 6 different speeds (1050–2300 rpm) with a 250-rpm step [21].

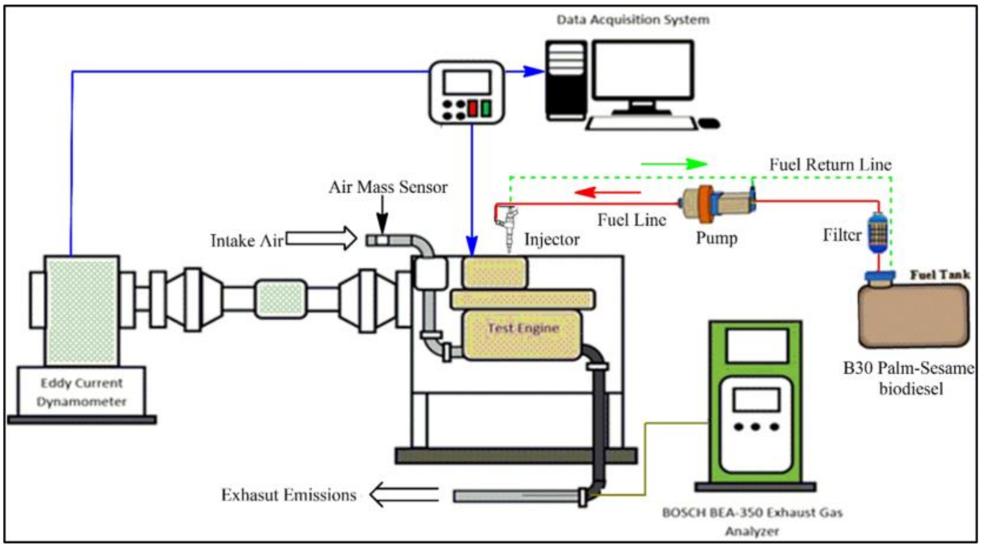


Fig. 4: Engine test set-up schematic diagram [21].

Table 1

| Equipment | Method | Measurement | Measurement range | Resolution |
|---|---|---|---|---|
| BOSCH BEA 350 | Flame ionization detector (FID) | HC | 0–9999 ppm | ± 1 ppm |
| | Heated vacuum type (CLD) | NOx | 0–5000 ppm | ± 1 ppm |
| | Non-dispersive infrared | CO | 0–10% vol. | ± 0.001% vol |

For testing NBE25 with Ni–O nanofuels, C. Srinidhi et al. chose a VCR DI-CI water-cooled diesel engine. The observations were made in a steady-state environment at a constant speed of 1500 rpm. The schematic representation of experimental setup is depicted in Fig.5.Each mixed NBE-Ni–O Nanofuel was tested in a CI engine, and the fuel's performance and emission characteristics were monitored while the fuel injection timing and braking torque were varied. At the fuel pump, calibrated shims were used to create the FIT variation. The error estimation was performed using uncertainty analysis, which depicts the value's fitness. The error analysis was validated using Taylor's theorem, and the overall uncertainty was calculated to be ±2.32 percent [22].

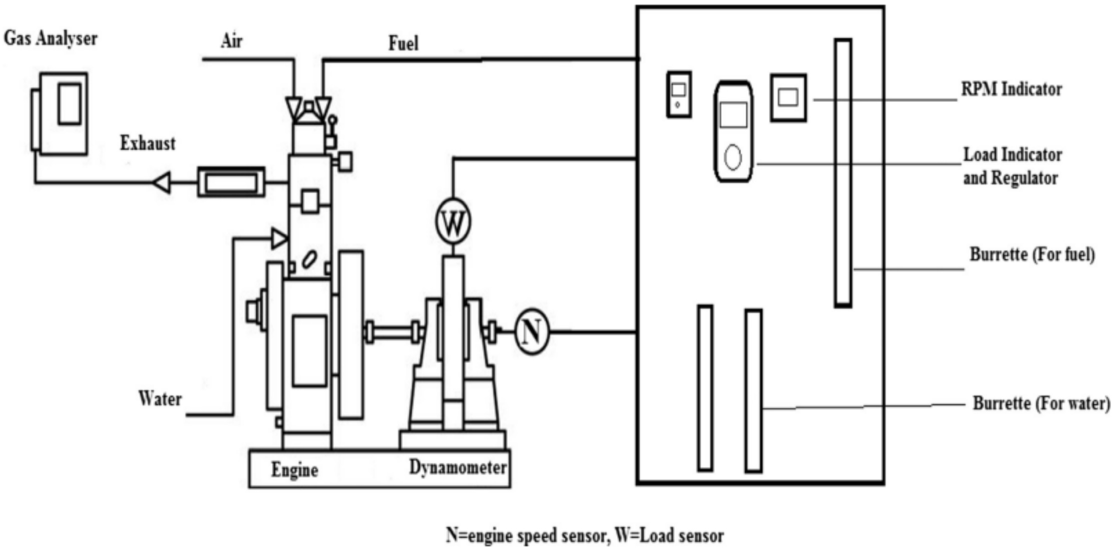


Fig. 5. Schematic diagram for experimental setup [22].

### 3.1 Brake thermal efficiency

This section reviews the literature on the effects of various biodiesel and diesel fuel blends containing nano-additives on engine performance and emissions (metal-based, organic, originated, antioxidizing, non-metallic, carbon nanotubes, water emulsion fuels).Brake thermal efficiency(BTE) is the relationship between the actual BP generated by the engine and the energy delivered to the engine. BTE can be used to explore the effects of various fuels and fuel blends on engine performance. Due to improved radiative and heat-mass transport capabilities, the inclusion of nanoparticles to diesel-biodiesel fuel emulsions supports a quick and extensive combustion process, resulting in a significant increase in combustion efficiency [23].According to the results of V. K. Kolli, the blend D50B50A100 had the highest braking thermal efficiency of all the fuel blends evaluated, at 33%. In comparison to neat diesel, the highest improvement in BTE is 2–3%, as illustrated in Fig. 6. The beneficial effect of additive N-GQD on biodiesel may be seen in the increase in BTE that occurs when it is added to biodiesel. The graphene quantum dot has a higher surface-to-volume ratio than any other nano-additive in that class, and the nitrogen doping makes it more functional. The greater surface to volume ratio, enhanced functionality with methyl ester, and associated oxygen content of the N-GQD boost the thermal input from the fuel, resulting in improved fuel combustion.This enhancement was further aided by factors such as increased calorific value and energy density due to the blend's higher oxygen content and cetane number. For the D50B50 combination, the best blending of N-GQD additive with the blend was 100 ppm, and it is obvious from this result that N-GQD mixing of 100 ppm may replace 50% of diesel with biodiesel without any performance degradation [18].

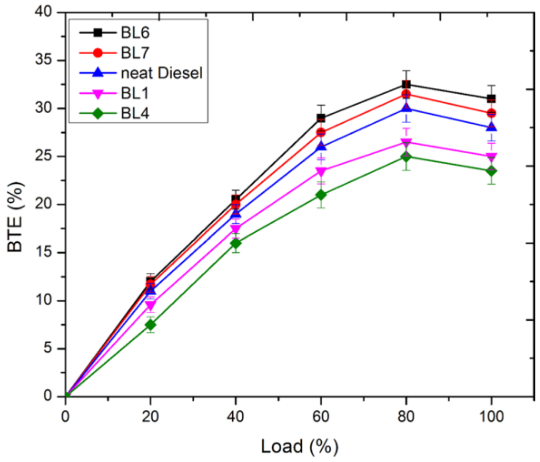


Fig 9: BTE of a blend-fuelled engine under various load situations [18].

The variance of BTE with BP at constant load is shown in Figure 10; the results demonstrate that the BTE of the CRDI diesel engine rose at all graphene oxide NP dosage levels. The oxides of carbon-based nanoparticles enhance complete combustion of the fuel charge when compared to neat diesel—biodiesel fuel mixtures. The BTE is increased by graphene oxide, which acts as an oxygen buffer. The BTE rises as the amount of graphene NPs in the fuel blends rises. As 90 ppm of GO NPs and 10% n-butanol additions were added to Nigella sativa biodiesel at maximum load, the BTE increased by 18.37 percent when compared to the plain NSME25. However, with greater concentrations of asymmetric GO NPs (120 ppm), the BTE reduces dramatically, resulting in a rise in the fuel blend's viscosity and density. The BTE values for the nanofuel blends NSME25B10GO90 were likewise equivalent to diesel. The improved symmetric micro-explosion phenomena and higher catalytic activity of NSME25 GO NPs are responsible for the rise in BTE for all nanofuel combinations at certain loading [19].

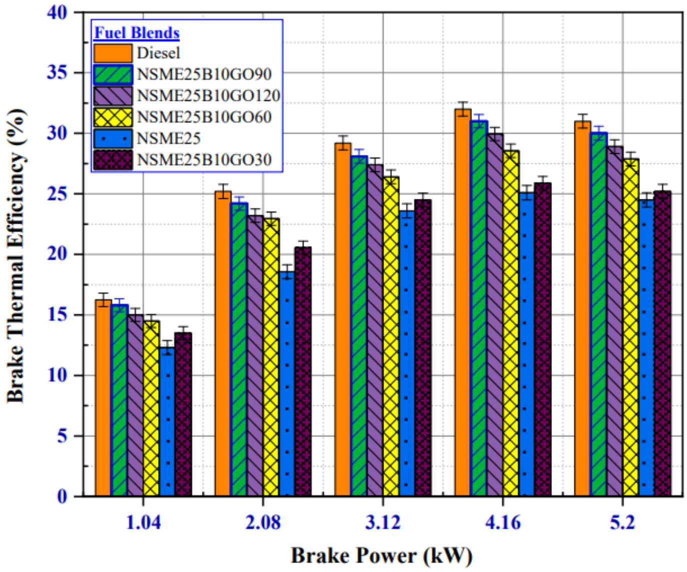


Fig 10. Variation in BTE and load for different fuel blends at various BPs [19].

The fluctuation of BTE with BMEP for clean CIME, CIME emulsions with ZnO and TiO2 at dose levels of 50 and 100 ppm, and diesel was examined by Nanthagopal et al. [24]. The BTE improved as the engine load increased, owing to higher BP and a higher fuel rate. At the highest BMEP, diesel had a maximum BTE of 3%, CIME-T100 had a maximum BTE of 31%, CIME-T50 had a maximum BTE of 30%, CIME-Z100 had a maximum BTE of 28%, CIME-Z50 had a maximum BTE of 26%, and CIME biodiesel had a maximum BTE of 26%. The scientists discovered that at greater loads, CIME nano-emulsion blends have a larger BTE than neat CIME, which they believe is due to the micro-explosion of water molecules in the fuel and the catalytic impact of metallic oxides.The water molecule aids in the better mixing of fuel atoms with air and the rapid evaporation of the fuel. Because the nanoparticles in the emulsion have a high surface-to-volume ratio, they evaporate quickly and atomize well [25]. Furthermore, the nanoparticle may aid in the separation of hydrogen atoms from water, which could lead to combustion. The author observed that the BTE of CIME–Z100 was lesser than the CIME-T100, consequently titanium dioxide was shown to have more oxidizing qualities as compared to zinc oxide.

According to Ranjan, Alok, et al. [26], the BTE of all test fuels improved as engine load increased.For an engine load of 18.11 kg, the maximum BTE was observed. Various emulsions were evaluated, and B100 had a BTE of 27.4 percent on average. For a weight of 13.41 kg, the maximum BTE for PBD fuel was 34.3 percent; PBD fuel has a lower density, viscosity, and calorific value. PBD fuel's reduced viscosity and density resulted in more combustion, fuel atomization, and evaporation, resulting in a higher BTE [27]. The BTE of fuels mixed with nanoparticles increased by 4.01 percent, 4.91 percent, and 4.8 percent, respectively, for B100W30A, B20W30A, and B10W30A, which were greater than B100, B20, and B10 fuel.Furthermore, nanoparticles in general have a larger surface area and more responsive surfaces, resulting in increased chemical reactivity and the ability to operate as a catalyst [28]. The addition of graphene nanoparticles GNPs to a diesel-biodiesel blend at a dose range of 25–50 mg/L boosts brake thermal efficiency by 25% [29]. GNPs improved brake thermal efficiency by 9.14 percent in Simarouba biodiesel and diesel blends [30]. Due to the capabilities of carbon nanotubes (CNT) to exhibit a high surface area/volume ratio and contribute more efficiently in the combustion, a maximum of 30.5 percent BTE was attained by adding 150 ppm CNT blended with water-diesel emulsion.Itis because of the reactive surfaces of CNT which acts as a potentialcatalyst in the combustion process [31].

The addition of 25 ppm silvernanoparticles to the biodiesel blend increases the BTE by 51.44%, theincrease is due to the action of Ag as an oxidative catalyst which resultsin increased combustion [32]. Some investigational studies were carried on diesel engine performance to investigate the BTE using ferro-fluid with diesel, biodiesel fuel mixtures. Ferrofluid emulsion fuelsdeliver fast flame propagation in the combustion chamber, which results in an improved heat release patterns and complete combustions.The thermal efficiencies of MOME and MOMEF were lower than diesel at all loads, according to Yuvarajan et al. [33]. This was owing to the presence of moisture in biofuels, which ranged from 0.09 to 0.12% in comparison to zero moisture in diesel. The combustion of biofuels resulted in an increased moisture content in the engine. As a result, the energy required to generate the same amount of power as diesel was higher, resulting in worse efficiencies and heat losses. Due to higher moisture in the engine, the BTE for MOMEF was increased by 2.27 percent.Furthermore, the inclusion of ferrofluid raises the temperature, resulting in a longer and more thorough combustion and hence improved efficiency [34]. The magnetic field converts hydrogen in the fuel to para-H, which combines with oxygen in the chamber during combustion, resulting in better combustion and a greater BTE [35]. MOMEF had a BTE of 28.54 percent at full load, whereas MOME and diesel had BTEs of 25.25 percent and 29.01 percent, respectively.As a result of the ferrofluid inclusion, the BTE increased. In a stationary diesel engine, the effect of Fe nanoparticles additions on BTE in relation to biodiesel blends and diesel fuels was explored experimentally. The ultrasonication procedure was used to combine palm biodiesel (PB20) and neat diesel (D) with fuel additive. In comparison to PB20 and D, the BTE of the modified fuels D + 50Fe and PB20 + 50Fe is improved by 2.06% for PB20 + 50Fe and 0.36 percent for D + 50Fe [36].

Only a few investigations on organic and non-organic additives in diesel and biodiesel blends have been undertaken. Yang et al. [37] investigated the impact of organic materials on engine performance, using glycerine as a nano-additive. The glycerine was mixed with diesel-water blended fuel and put through its paces on a CI engine. In comparison to clean diesel, the BTE for the diesel-glycerine blend increased dramatically with an increase in engine rpm.At steady speed and full load, the BTE rose by 7.8% and 14.2% for E10 (10 percent water conc.) and E15 (15 percent water conc.) respectively. The micro-explosion phenomena, in which small droplets break from bigger fuel droplets, was blamed for the improvement. This small droplet has a bigger active surface and contact area, and the particles speed up the vaporization process by increasing the A-F ratio, resulting in a total improvement in the combustion process and a rise in the engine's output.

### 3.2 Brake Specific Fuel Consumption

The BSFC is the ratio of the engine's fuel consumption to the engine's power output during a specified time period. Because the engine consumes more gasoline for the same performance, it is expected to obtain a lower BSFC number. Because BSFC decreases as the load increases, a comparison with engine load is a significant measure. The viscosity, density, volumetric fuel injection, and calorific value are the performance factors that control the BSFC [23]. The research on different nano-additives is examined in this section.

The impact of MgO NPs on WCO biodiesel was studied by Ranjan et al. [38]. In comparison to the other test fuels, the fuel sample B100W30A generated the most BSFC 0.49 kg/kW, while petroleum-based diesel (PBD) produced the least BSFC 0.35 kg/kW-h, both at a constant load of 4.73 kg. The BSFC is reduced when the engine load is increased from 4.73 kg to 18.11 kg for all test fuels. As a result, when the A-F mixture was improved and the loads were raised, the BSFC was reduced. Because of the less dense fuel blend, the average BSFC of PBD was 10.37 percent, 9.43 percent, 7.54 percent, 41.5 percent, 9.81 percent, and 10.18 percent lower than B100, B20, B10, B100W30A, B20W30A, and B10W30A, respectively.In compared to neat biodiesel, Kumar et al. [39] found that adding ferrofluid to pongamia biodiesel results in a decrease in specific fuel consumption.

The use of ferrofluid shortened the ignition delay and changed the fuel characteristics, resulting in a complete burning of the fuel. Furthermore, because of the enhanced combustion efficiency, water content, and higher viscosity of the fuel, the momentum of the fuel and its propagation is modified, which may boost the combustion effect and promote a cloud-like atomization of the emulsified moisture during injection. The inclusion of ferrofluid additive resulted in a maximum reduction of 11.1 percent in BSFC for B20-1F at full load when compared to the pure B20 fuel mix.In comparison to B20, B20-1.5F and B20-0.5F demonstrated a 6.7 percent and 4.8 percent drop in BSFC at maximum load. Furthermore, due to insufficient fuel mixing, BSFC increased as the dose of nanoparticles in biodiesel increased. Ganesh et al. [40] studied the impact of a combination of Magnalium and Cobalt oxide nanoparticles in Jatropha biodiesel. The nanoparticles were disseminated in the fuel using an ultrasonicator with an optimum surfactant to hold the nanoparticles in the fuel at a dose level of 100 mg/l. The researchers discovered that by adding cobalt oxide nanoparticles, the BSFC was lowered at all load settings, and that by adding Magnalium nanoparticles, the energy consumption was reduced and the thermal efficiency was increased.According to Khalife et al. [41], when the water content of biodiesel increases, the BSFC increases with the addition of nanoparticles to the biodiesel. As a result, adding water to B5 raises the bsfc, and adding cerium oxide to B5 that already contained water increased the BSFC values. The BSFC of B5W3m, for example, was 5% and 16 percent lower than that of neat B5 and neat B5W3, respectively. Before the vaporization of fuel and water, metal-based NPs decompose, releasing active metal atoms (cerium), which could reduce the formation of unburned carbon deposits on the cylinder interior surface, resulting in reduced friction in the engine, i.e., parts like the piston and cylinder, resulting in abridged BSFC [23].Water in diesel-biodiesel blends might lead to an increase in specific fuel consumption and CO emissions. However, because WDE fuels have a decent NOX reducing capability, some authors have proposed a novel method of combining metallic-based additive with WDE as an effective approach to simultaneously overcome the disadvantages of using water in CI engines while also taking advantage of its benefits [41].Due to a reduction in the ignition delay time, adding TiO2 nanoparticles to Calophyllum Inophyllum biodiesel blends and increasing the load results in lower BSFC values when compared to B20 fuel. Furthermore, the combined action of EGR and TiO2 nano-additives in biodiesel blends marginally raises the BSFC [42]. Because of the catalytic oxidation of the fuel, the cobalt oxide (Co3O4) NPs with biodiesel emulsion resulted in a 4% drop in BSFC. The incorporation of TiO2 in biodiesel blends resulted in a 2% reduction in BSFC. The nanoparticles act as an oxygen buffer, allowing for full burning. As a result, as compared to straight biodiesel, fuel usage is reduced [43].

## 4. CONCLUSION

The preceding sections provided a thorough overview of nanoparticle synthesis and application in diesel and biodiesel fuels. The use of nanoparticles in liquid fuel can provide a number of benefits, including improved performance and lower emissions. The findings of the extensive literature review are summarized in the next section.

- When compared to pure CIME, CIME nano emulsions incorporating nanoparticles have a higher brake thermal efficiency. Due to the catalytic impact of nano particles contained in the nano emulsions, all CIME nano emulsions have a higher braking thermal efficiency than all other CIME nano emulsions and plain CIME fuel [24].
- Due to its oxidation agent of cerium oxide nanoparticle, the LGO nano emulsion fuel reduced unburned HC and CO emissions by 35.5 percent, 16.03 percent, and 15.69 percent, 26 percent, respectively, as compared to LGO and pure diesel fuel. Because of the high latent heat of vaporization of water molecules contained in the fuel as well as the reduction agent of cerium oxide nanoparticle, NOX emissions for LGO nano emulsion fuel were reduced by 24.8 percent and 20.3 percent, respectively, when compared to neat LGO and neat diesel fuel.Due to its micro explosion and secondary atomization, the LGO

nano emulsion fuel reduced smoke by 6.4 percent and 19.8 percent when compared to neat LGO emulsion and neat diesel fuel, respectively. Ceria nanoparticles increased the combustion rate, resulting in faster evaporation of the air-fuel mixture and improved ignition characteristics [25].

- The engine's power and torque increased when GQD nanoparticles were added to the gasoline. Adding GQD nanoparticles to B10 gasoline boosted engine power and torque by 12.42 percent and 28.18 percent, respectively, when compared to diesel fuel (D100) [12].
- Iron oxide nanoparticles mixed biodiesel fuel qualities were tested and compared to mineral diesel. The calorific value of the nanoparticles mixed biodiesel has increased slightly. The drop in BSFC might be attributed to nanoparticles' positive impacts on fuel physical qualities as well as a shorter igniting delay period. With increased engine loads, the thermal efficiency of the brakes improves. Due to the superior combustion properties of nanoparicles, the brake thermal efficiency improves as the dosage amount of nanoparticles fuel increases in the fuel [20].
- All other harmful emissions were decreased when GO NPs were added to Nigella sativa (CO2, HC, smoke, and CO). When compared to NSME25 fuel blend, NSME25B10GO90 fuel mix smoke, HC, and CO emissions dropped by 31.68 percent, 48.571 percent, and 50.15 percent at maximum load [19].
- With the addition of additive N-GQD, the energy density and heating value of biodiesel were significantly improved. The addition N-GQD increased other physical–chemical characteristics of biodiesel, such as viscosity, cetane number, and oxygen weight percent, and its optimal mixing ratio was determined to be 100 ppm in the blend. With an increase in the proportion of biodiesel in a mix, engine efficiency degrades and NOx emissions rise. The limiting biodiesel ratio was discovered to be 50% by volume [18].

## ACKNOWLEDGEMENT

This work was supported by the National Research Foundation of Korea (NRF) grant funded by the Korea government (MSIT) (NRF-2019R1A2C1010557).

## Conflicts of interest

The authors have no conflicts of interest to declare.

## Authors Biography

Ramozon Khujamberdiev has completed his bachelors in English language and literature from Uzbekistan State World Languages University, Tashkent, Uzbekistan. After his graduation he has worked in the faculty of Automotive Engineering as an interpreter-teacher at Korea International University in Fergana for a year. In 2021, he has been selected as a GKS scholar and got accepted to pursue his master’s degree from Kongju National University, Cheonan, Korea in Mechanical Engineering. His area of interest is IC engines and renewable energy.

Professor HaengMuk Cho is a renowned professor in South Korea. He is working as professor at Kongju National University in South Korea. He did Post Doctorate Fellowship from Department of Automotive Engineering of Loughborough University in UK and North Texas University in USA. He earned his Ph.D. from Hanyang University, South Korea in 1997 and completed his M.D. in Environment Engineering from Yonsei University in S Korea. He is working on national and international projects in the field of Bio-fuels for IC engines and renewable energy. Professor HaengMuk Cho is working in the field of Renewable Energy and Biofuels. He is also a member of many societies, like Korea Society of Automotive Engineers, Korean Society of Energy (Korea), Korea Society of Marine Engineering (Korea) & Korea Society of Environment Engineer (Korea). He has published many national and internal research papers. Most of his papers are indexed in Scopus and SCI.

## REFERENCES:

[1] Aram H M, Tarahom M. G., Behzad K., Ahmad J., Barat G. A novel fuel based on biocompatible nanoparticles and ethanol-biodiesel blends to improve diesel engines performance and reduce exhaust emissions. Fuel 2020 276; 118079

[2] Seyyed H. H., Ahmad T. A., Barat G., Ahmad A. M. Performance and emission characteristics of a CI engine fuelled with carbon nanotubes and diesel-biodiesel blends, Renewable Energy, 2017 111: 201-213

[3] ShaafiT., VelrajR. Influence of alumina nanoparticles, ethanol and isopropanol blend as additive with diesel soybean biodiesel blend fuel: Combustion, engine performance and emissions. Renewable Energy 2015 80 655-663

[4] Khadijeh H. M., Ahmad T. A., Barat G, Ahmad A. M., Analyzing and evaluation of carbon nanotubes additives to diesohol-B2 fuels on performance and emission of diesel engines. Fuel 2017 196:110–123

[5] TesfaB., MishraR., GuF., BallA.D. Water injection effects on the performance and emission characteristics of a CI engine operating with biodiesel. Renewable Energy 2012 37:333-344

[6] Pranil J. S., Jagjit K., Anirudh S. Preparation, characterisation, engine performance and emission characteristics of coconut oil based hybrid fuels. Renewable Energy 2010 35: 2065-2077

[7] BiditaB.S., SurayaA.R., ShazedM.A., Mohd SallehM.A., IdrisA. Preparation, characterization and engine performance of water in diesel nanoemulsions. Journal of the Energy Institute 2016 89: 354-365

[8] AnnamalaiM., DhineshB., Nanthagopal K., SivaramaK.P., Isaac L.J., ParthasarathyM., et al. An assessment on performance, combustion and emission behavior of a diesel engine powered by ceria nanoparticle blended emulsified biofuel. Energy Conversion and Management 2016 123:372–380

[9] Mehrdad M., Meisam T., Mehdi A, Alimorad R., Barat G., Mohammad B., et al. A novel soluble nano-catalysts in diesel–biodiesel fuel blends to improve diesel engines performance and reduce exhaust emissions. Fuel 2015 139:374–382

[10] Ehsanollah E., Alimorad R., Barat G., NajafiG., Ebrahim G., Mohammad H. K.,et al. Bio-nano emulsion fuel based on graphene quantum dot nanoparticles for reducing energy consumption and pollutants emission. Energy 2021 218:119551

[11] Avanish Sh., Dhanasekaran P., Nagaraju, S.N., BhatD., Vijayamohanan,et al.. A facile synthesis of graphene nanoribbon-quantum dot hybrids and their application for composite electrolyte membrane in direct methanol fuel cells. Electrochimica Acta 2019 297: 267-280

[12] Aram H. M., Tarahom M. G., Ahmad J., Barat G. Performance improvement and exhaust emissions reduction in diesel engine through the use of graphene quantum dot (GQD) nanoparticles and ethanol-biodiesel blends. Fuel 2020 267: 117116

[13] Vivian S, Frederico D. M., Clenilton C. S., Luciana M. R., Edardo R. J., Cláudia R. E.,et al. Graphene quantum dots nanoparticles changed the rheological properties of hydrophilic gels (carbopol). Journal of Molecular Liquids 2019 287: 110949

[14] Fei Ch., Weiyin G., Xiaopei Q., Hong Z., Lianhua L., Pu L.,et al. Graphene quantum dots in biomedical applications: Recent advances and future challenges. Frontiers in Laboratory Medicine 2017 1: 192–199

[15] Paolo E., Elizabeth B., Angela V. Graphene quantum dots: effect of size, composition and curvature on their assembly. RSC Adv., 2017 7: 17704–17710

[16] Ehsanollah E., Barat G., Alimorad R., NajafiG., Mohammad H. K., et al. A novel bio-nano emulsion fuel based on biodegradable nanoparticles to improve diesel engines performance and reduce exhaust emissions. Renewable Energy 2018 125: 64-72

[17] Fengna X., Jingwen Z., Chao Sh., Jingbo H, Jie Ch., Yibo Y.,et al. Amphiphilic graphene quantum dots as a new class of surfactants. Carbon 2019 153:127-135

[18] KolliV. K., MandalP. Experimental exploration of additive NGQD as a performance and emissions improver of the C.I. engine with biodiesel–diesel blends. International Journal of Environmental Science and Technology https://doi.org/10.1007/s13762-021-03463-3

[19] Hurmathulla K, Manzoore E. M., Rajagopal H. K., Mohammad R. S., Muhammad F.,et al. Symmetry 2020, 12, 961; doi:10.3390/sym12060961

[20] Sivakumar M., Shanmuga S. N., Ramesh K. R., Syed T. M., Effects of Nanoparticles blended Biodiesel on Single Cylinder CI Engine. Materials Today: Proceedings 5 (2018) 6831–6838

[21] MujtabaaM.A., KalamaM.A., MasjukiaH.H., GulaM., Manzoore E., SoudagaraM.,et al. Comparative study of nanoparticles and alcoholic fuel additives-biodieseldiesel blend for performance and emission improvements. Fuel 2020 279: 118434

[22] SrinidhiaC., MadhusudhanbA., ChannapattanacS.V., Effect of NiO nanoparticles on performance and emission characteristics at various injection timings using biodiesel-diesel blends. Fuel 2019 235: 185–193

[23] Manzoore E. M., Nik-Nazri G., Abul K.,Badruddinb I.A., et al. The effect of nano-additives in diesel-biodiesel fuel blends: A comprehensive review on stability, engine performance and emission characteristics. Energy Conversion and Management 2018 178: 146–177

[24] Nanthagopal K, Ashok B, Tamilarasu A, Johny A, Mohan A. 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 Manage 2017 146:8–19.

[25] Annamalai M, DhineshB., NanthagopalK., Sivarama K.P., J. Isaac J. L.,et al. An assessment on performance, combustion and emission behavior of a diesel engine powered by ceria nanoparticle blended emulsified biofuel. Energy Convers Manage 2016 123:372–80.

[26] Ranjan A, Dawn S, Jayaprabakar J, Nirmala N, Saikiran K, Sriram SS. Experimental investigation on effect of MgO nanoparticles on cold flow properties, performance, emission and combustion characteristics of waste cooking oil biodiesel. Fuel 2018 220:780–91.

[27] Yadav A.K., Khan M.E., Dubey A.M., Pal A. Performance and emission characteristics of a transportation diesel engine operated with non-edible vegetable oils biodiesel. Case Stud Therm Eng 2016 8:236–44.

[28] Sadhik B. J., Anand R. Role of nanoadditive blended biodiesel emulsion fuel on the working characteristics of a diesel engine. J Renew Sustain Energy 2011 3(2):023106.

[29] El-Seesy A.I., Hassan H., Ookawara S. Effects of graphene nanoplatelet addition to jatropha biodiesel-diesel mixture on the performance and emission characteristics of a diesel engine. Energy 2018 147:1129–52.

[30] Paramashivaiah B., Banapurmath N., Rajashekhar C., Khandal S. Studies on effect of graphene nanoparticles addition in different levels with Simarouba biodiesel and diesel blends on performance, combustion and emission characteristics of CI engine. Arab J Sci Eng 2018:1–9

[31] Singh N., Bharj R. Effect of CNT-emulsified fuel on performance emission and combustion characteristics of four stroke diesel engine. Int J Curr Eng Technol 2015 5(1):477–85.

[32] Nireeksha K., Sanjana S., Jathhan S. S., Nayak S., Santhosh G., Rao C.V. Ecofriendly synthesis of silver nanoparticles using oil seed cake and its application in biodiesel for performance evaluation of 4 stroke diesel engine. Energy Power 2017 7(3):75–80.

[33] Yuvarajan D., Ramanan M.V. Effect of magnetite ferrofluid on the performance and emissions characteristics of diesel engine using methyl esters of mustard oil. Arabian J Sci Eng 2016 41(5):2023–30.

[34] Shafii M., Daneshvar F., Jahani N.A., Mobini K. Effect of ferrofluid on the performance and emission patterns of a four-stroke diesel engine. Adv Mech Eng 2011 3:529049.

[35] Faris A.S., et al. Effects of magnetic field on fuel consumption and exhaust emissions in two-stroke engine. Energy Procedia 2012 18:327–38.

[36] Debbarma S., Misra R.D. Effects of iron nanoparticle fuel additive on the performance and exhaust emissions of a compression ignition engine fueled with diesel and biodiesel. J Therm Sci Eng Appl 2018 10(4):041002.

[37] Yang W, et al. Emulsion fuel with novel nano-organic additives for diesel engine application. Fuel 2013 104:726–31.

[38] Ranjan A., Dawn S., Jayaprabakar J., Nirmala N., Saikiran K., Sriram S.S. Experimental investigation on effect of MgO nanoparticles on cold flow properties, performance, emission and combustion characteristics of waste cooking oil biodiesel. Fuel 2018 220:780–91.

[39] Kumar S., Dinesha P., Bran I. Influence of nanoparticles on the performance and emission characteristics of a biodiesel fuelled engine: an experimental analysis. Energy 2017 140:98–105.

[40] Ganesh D., Gowrishankar G. Effect of nano-fuel additive on emission reduction in a biodiesel fuelled CI engine. Electrical and Control Engineering. IEEE; 2011. p.3453–9.

[41] Khalife E.,Meisam T., Bahman N., Seyed M. M., Ayat G., Pouya M., Mortaza A. et al. A novel emulsion fuel containing aqueous nano cerium oxide additive in diesel–biodiesel blends to improve diesel engines performance and reduce exhaust emissions: Part I-Experimental analysis. Fuel 2017 207:741–50.

[42] Praveen A, Lakshmi R. G, Balakrishna B. Performance and emission characteristics of a diesel engine using Calophyllum inophyllum biodiesel blends with TiO2 nanoadditives and EGR. Egypt J Pet 2017/11/10/2017.

[43] Jeryrajkumar L., Anbarasu G., Elangovan T. Effects on nano additives on performance and emission characteristics of Calophyllim inophyllum biodiesel. Int J ChemTech Res 2016 9 (4):210–9.