INFLUENCE OF NANO-MATERIALS ADDITIVES AND BIOFUEL (EUCALYPTUS) ON DIESEL ENGINE PERFORMANCE

2024
MASTER THESIS
MECHANICAL ENGINEERING

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Prepared as
Master Thesis

KARABÜK
January 2024

I certify that in my opinion the thesis submitted by Hasan Ali Hasan HASAN titled“INFLUENCE OF NANO-MATERIALS ADDITIVES AND BIOFUEL (EUCALYPTUS) ON DIESEL ENGINE PERFORMANCE” is fully adequate in scope and in quality as a thesis for the degree of Master of Science.

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This thesis contains information that I have gathered and presented in a manner that is consistent with academic regulations and ethical principles, and I affirm that I have appropriately cited any and all sources that are not my own work.

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ABSTRACT

M. Sc. Thesis

INFLUENCE OF NANO-MATERIALS ADDITIVES AND BIOFUEL (EUCALYPTUS) ON DIESEL ENGINE PERFORMANCE

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January 2024, 70 pages

The purpose of the current study is to investigate the use of eucalyptus biodiesel on diesel engine performance parameters, such as brake thermal efficiency and specific brake fuel consumption. Biodiesel has been identified as a potentially viable alternative fuel in the coming years. To increase their quality, biodiesel and diesel are blended and mixed with eucalyptus biodiesel produced with oxide particles and nano aluminum. The biodiesel was prepared from eucalyptus oil using the transesterification process, where the proportions of reaction components, reaction temperature, methanol-to-oil ratio, and catalyst concentration were known. Nanoparticles were dispersed in biodiesel by an ultrasonic device. These mixtures were tested on a water-cooled, four-stroke, four-cylinder diesel engine at speeds of 1200 rpm, 1400 rpm, and 1600 rpm with different loads (25%, 50% and 75%). Biofuel was mixed with diesel fuel in different proportions (D95-B5, D90-B10, D85-B15). The results for these mixtures showed a drop in brake thermal efficiency and a rise in brake specific fuel consumption, as increasing the percentage of biodiesel from eucalyptus increased the BSFC. Nanoparticles were also added to a D85-B15 mixture in different proportions (50 ppm, 75 ppm and 100 ppm). The results showed a clear refinement in brake thermal efficiency and a decrease in brake specific fuel consumption. The results also improved as the percentage of nanoparticles increased and speeds and loads increased.

Keywords **:** Nanoparticles, Eucalyptus, Diesel Engine.
Science Code : 91413

ÖZET

Yüksek Lisans Tezi

NANO MALZEME KATKILARIN VE BİYOYAKITIN (OKALIPTUS) DİZEL MOTOR PERFORMANSINA ETKİSİ

Hasan Ali Hasan HASAN

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Ocak 2024, 70 sayfa

Bu çalışma, nanopartiküllerin ve okaliptüsün, fren termal verimliliği ve özgül yakıt tüketimi gibi dizel motor performansı üzerindeki etkisini incelemeyi amaçlamaktadır. Biyodizel önümüzdeki yıllarda potansiyel bir alternatif yakıt olarak kabul edilmektedir. Biyodizel ve dizel, özelliklerini geliştirmek için karıştırılır, ayrıca nano alüminyum oksit parçacıkları ile üretilen okaliptüs biyodizelinin karıştırılmasıyla biyodizel, reaksiyon bileşenlerinin oranlarının, reaksiyon sıcaklığının, metanol/yağ oranının ve Katalizör konsantrasyonu biliniyordu. Nanopartiküller ultrasonik bir cihazla biyodizel içerisinde dağıtıldı. Bu karışımlar su soğutmalı, dört zamanlı, dört silindirli dizel motorda hızlarda (1200, 1400, 1600 rpm) ve farklı yüklerde (%25, %50, %75) test edilmiştir. Biyoyakıt dizel yakıtla farklı oranlarda karıştırılmıştır (D95-B5, D90-B10, D85-B15). Bu karışımlara ilişkin sonuçlar, okaliptüsten elde edilen biyodizel yüzdesi arttıkça (BSFC) frenleme termal verimliliğinde bir azalma ve spesifik frenleme yakıt tüketiminde bir artış olduğunu gösterdi. Karışıma (D85-B15) farklı oranlarda (50,75,100 ppm) nanopartiküller de eklendi. Sonuçlar, Termik verim belirgin bir iyileşme ve Özgül yakıt tüketimi bir azalma gösterdi. Nanopartiküllerin yüzdesi arttıkça ve hız ve yük arttıkça sonuçlar iyileşti.

Anahtar Kelimeler **:** Nano parçacık, Okaliptüs, dizel Motor.
Bilim Kodu **:** 91413

ACKNOWLEDGEMENT

In the beginning, Alhamdulillah. Allah is the First and Last Helper, and if it were not for His Mercy, I would not have reached where I am now. Many thanks to my supervisor, Assist. Prof. Dr. Abdurazzak AKROOT for all the information and recognition I received from him and for his endless support, understanding, and kindness. I am extremely happy and grateful to have had the opportunity to be his student. Moreover, I do not forget my teacher, Dr. Ibrahim THAMER, who has done much for me in my BA and MA. Finally, acknowledge those to whom I dedicate the fruits of my efforts and who have support me: my beautiful family. Words of gratitude are not enough for you.

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SYMBOLS AND ABBREVITIONS INDEX

SYMBOL

BP	:	Brake power (kW).
P_{ELECT}	:	Total Electrical Power (kW)
η_{Gen}	:	Efficiency of electric generator (%)
P_{L1}	:	Electrical power the first line (W)
P_{L2}	:	Electrical power the second line (W)
P_{L3}	:	Electrical power the third line (W)
P_{ELECT}	:	Electrical power (W)
V	:	Voltage (potential difference) (V)
I	:	Current (A)
PF	:	Power factor (%)
η_{bth}	:	Brake thermal efficiency (%)
BP	:	Brake power (kW)
CV	:	Calorific value (kJ/kg)
$\dot{m}_f$	:	Fuel consumption (kg/s).
sg_f	:	Specific weight of fuel (kg/cm^3).
V	:	Volume of spent fuel (cm^3)
t	:	Time spent
BP	:	Braking power (kW)

ABBREVIATIONS

BTE	:	Brake Thermal Efficiency
BSFC	:	Brake Specific Fuel Consumption (kg/kW.s)

PART 1

INTRODUCTION

1.1. INTRODUCTION

The world has experienced tremendous scientific and industrial advancement in recent decades, along with a steady rise in population, and the need for transportation that has also increased dramatically. As a result, scientists and engineers have been considering ways to consolidate the performance and efficiency of internal combustion engines, which are a defining feature of our modern industrial and technological age as these engines directly impact modern human existence and its many needs [1,2]. The first internal combustion engine using combustion compression was created in 1892 by Rudolf Christian Karl Diesel. Since then, internal combustion engines have advanced significantly in the twentieth century. Engines use compressed ignition, which involves injecting fuel after air is compressed in the combustion chamber, resulting in the fuel suddenly igniting. Humans utilize fossil fuels excessively as a non-renewable resource. As a result of this, there is an urgent need for fuels that can be used to replace fossil fuels, as well as a search for newer sources of renewable fuels, especially green alternative fuels with comparable performance, which are currently in high demand. In the future, internal combustion engines (ICEs) will continue to be the principal source of transportation power. In light of this, the diesel engine needs to increase high combustion efficiency while lowering pollutants. Furthermore, conventional fuels should be phased out while increasing the use of renewable energy. Researchers have now investigated a number of diesel fuel alternatives for engines and have discovered that biodiesel is a highly preferred alternative [3,4]. Biodiesel is a renewable resource that is produced in vast amounts using a variety of processes and is mostly created in the presence of a catalyst by the esterification of animal fats, vegetable oils, and waste oils. When used as engine fuel, biodiesel's principal benefit is that it necessitates almost no engine modifications. It has almost the same engine performance in terms of brake thermal efficiency (BTE), brake specific fuel consumption (BSFC), and braking power. Nevertheless, researchers have discovered various negative consequences in trials of diesel-biodiesel fuel mixtures [5,6], such as low cloud and pour points, poor fuel injection atomization, low calorific value, and overall high NOx emissions [7]. As a result, researchers have been experimenting with fresh techniques to boost engine performance, with the addition of nanomaterials to fuel mixes. Therefore, it is critical to look for alternate fuel and improved diesel fuel. The current study is focused on the use of biodiesel fuel in diesel engines and the enhancement of diesel fuel and engine performance by adding nanoparticles.

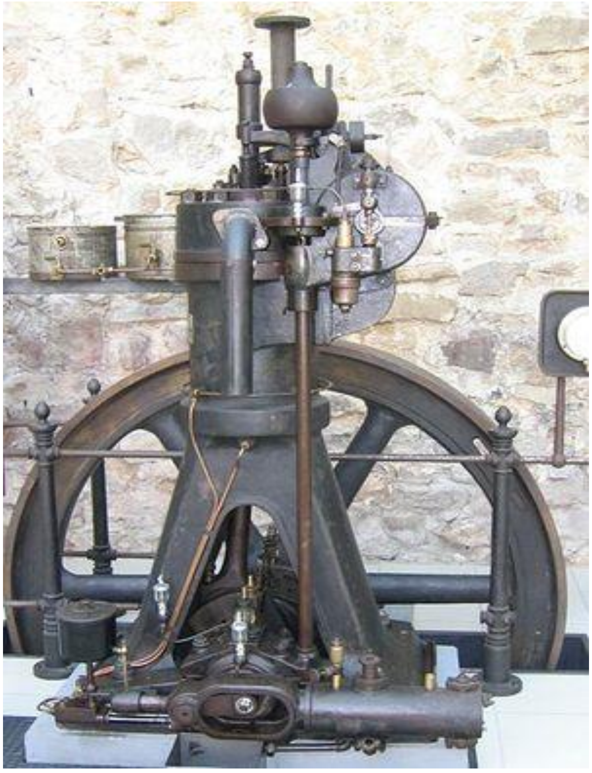

Figure 1.1. Diesel engine [8].

1.2. THE INTERNAL COMBUSTION ENGINE

The internal combustion engine is an engine in which fuel is burned with air in an enclosed space called a combustion chamber, in which the chemical energy contained in the fuel is transformed into thermal energy and then into mechanical energy. This exothermic reaction releases gases high temperatures and pressures and allows the gases to expand. The main differentiating feature of the internal combustion engine is that the initial work is done by the hot, expanding gases that are compressed directly to cause the movement of the solid engine parts, thereby pressing on the piston or rotating portion, or even moving the entire engine [9,10]

Internal combustion engines are among the most important and widespread sources of air pollution at present. This has been confirmed by United Nations statistics, which state that 40% of air pollution is caused by internal combustion engines [11].

Many elements, such as techniques of ignition, positioning of valves, the cooling system, or the design of the engine, and other factors, determine how internal combustion engines are classed [5].

We can classify internal combustion engines into two main types as expounded below:

1.3. SPARK-IGNITION ENGINE

Any of a group of internal combustion engines known as gasoline engines generate energy by using an electric spark to ignite a volatile liquid fuel (such as petrol or a petrol mixture such as one containing ethanol). A petrol engine may be constructed to meet almost any potential power plant application. Passenger automobiles, small trucks and buses, general aviation aircraft, outboard and small inboard marine units, medium-sized stationary pumps, lighting plants, and machine tools are among the most important applications. The majority of cars, light trucks, medium-to-large motorbikes, and lawnmowers are powered by four-stroke gasoline engines. Less often used two-stroke gasoline engines can be found in use in various portable landscape tools, including chainsaws, hedge trimmers, and leaf blowers, as well as small outboard marine engines [12].

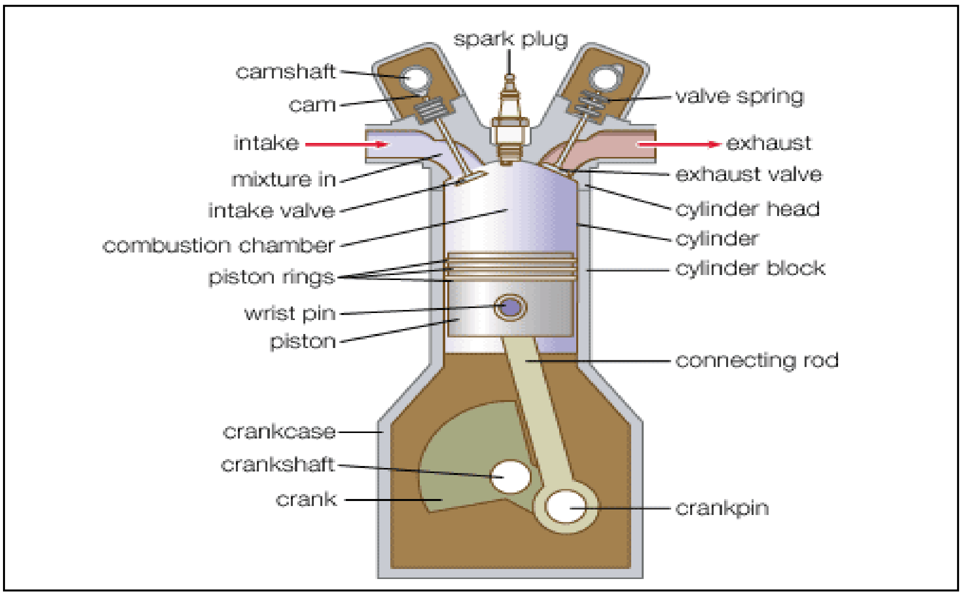

Figure 1.2. Spark ignition engine [12].

1.4. THE DIESEL ENGINE

The Rudolf Diesel-inspired diesel engine is a kind of internal combustion engine known as a compression-ignition engine because it ignites the fuel by heating the air in the cylinder as a result of mechanical compression (CI engine). This contrasts with engines that ignite the air-fuel combination using spark plugs, such as gasoline or gas engines (when using a gaseous fuel such as natural gas or liquefied petroleum gas) due to their extremely high expansion ratio and innate lean burn, which facilitates heat dissipation via any surplus air[13]. The thermal efficiency (engine efficiency) of a diesel engine is the highest of any conceivable internal or external combustion engine. As there is no unburned fuel during valve overlap and no fuel travels immediately from the absorption/injection to the exhaust, a slight efficiency loss is also avoided in comparison to gasoline engines without direct injection. Low-speed diesel engines can achieve effective efficiency of up to 55% (as used in ships and other applications where total engine weight is mostly immaterial) [14].

1.5. DIESEL ENGINE OPERATION

The diesel engine operates using the principle of internal combustion.

- Intake: The engine takes in air through the intake valve while compressing it at the same time.
- Compression: The air is compressed to a high temperature and pressure by a piston that moves upwards inside the cylinder.
- Fuel injection: Once the air is compressed, diesel fuel is injected into the combustion chamber. The high temperature of the compressed air causes the fuel to ignite spontaneously without the need for a spark plug.
- Power stroke: When the fuel is ignited, it burns and expands rapidly, forcing the piston down with great force. This downward motion is converted into rotational motion, which is used to operate a vehicle or machinery.
- Exhaust: Exhaust gases from the combustion process are ejected through the exhaust valve as the piston moves up, in preparation for the next cycle.

This process is repeated in a continuous cycle, with each piston in the engine passing through the same steps at different intervals [15].

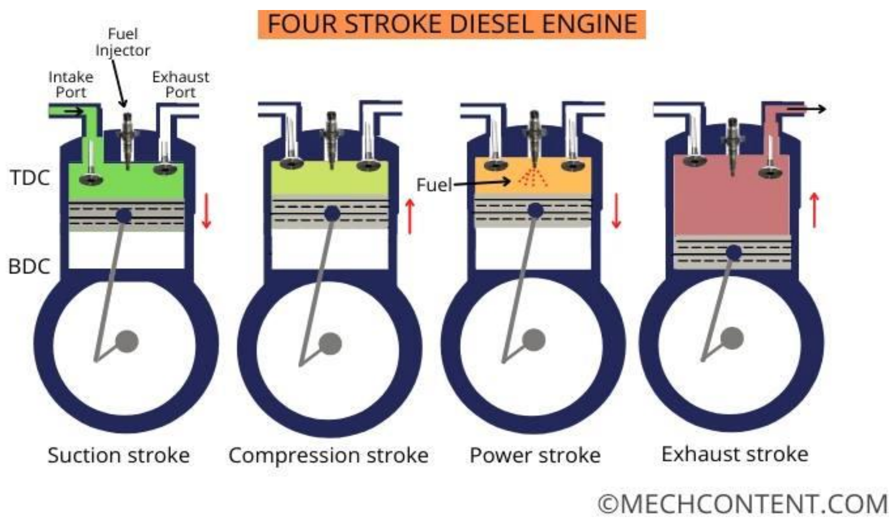

Figure 1.3. The four strokes of a diesel engine [16].

1.6. ADVANTAGES AND DISADVANTAGES OF DIESEL ENGINES

Diesel engines have several advantages over gasoline engines. A number of key advantages of diesel engines are listed below:

- Fuel efficiency: Diesel engines are known for their eminent fuel efficiency compared to gasoline engines. The former extract more energy from each unit of fuel, making them more economical for long-distance driving or heavy-duty applications.
- Torque and towing capability: Diesel engines generate higher levels of torque, which provides better towing power and acceleration. This makes them suitable for hauling heavy loads or towing trailers.
- Durability and longevity: Diesel engines are generally built to withstand higher compression ratios and heavier workloads, making them more durable and longer-lasting than gasoline engines. They often have longer service intervals and require less frequent maintenance.
- Better mileage and range: Due to their higher fuel efficiency, diesel engines offer better mileage and extended range per tank of fuel. This makes them popular for long-haul transportation and commercial applications.
- Resale value: Diesel vehicles often have higher resale values compared to their gasoline counterparts. Their reputation for durability and fuel efficiency contributes to their value retention over time.

It is worth noting that diesel engines also have a number of disadvantages, such as higher initial costs, higher emissions of certain pollutants, and a tendency to produce more noise and vibration. However, advancements in technology and emissions control systems have helped to mitigate these drawbacks in modern diesel engines [17].

1.7. FUEL AND TYPES OF FUEL

One of the elements that are paramount to influencing the thermal efficiency of internal combustion engines, and which have led to the development and spread of internal combustion engines, is fuel type selection. Internal combustion engines were originally powered by petrol/gasoline, but due to concerns about global fossil oil depletion, they evolved into diesel and petrol fuels. Additionally, to reduce harmful emissions from exhaust gases, alternatives to fossil fuels such as biodiesel and some types of alcohol have been used to power diesel engines [18].

1.7.1. Fossil Fuels

The remains of living organisms, including plants and animals, were subjected to pressure and very high temperatures after burial under the ground, which resulted in the concentration of carbon in the ground and sequentially converted into fossil fuels that are utilized to generate fossil energy.

This fuel also depends on the carbon cycle and is extracted from coal, black oil, gas, petroleum, and all other fossil materials. Fossil fuels were used in conjunction with the Industrial Revolution during the 18th and 19th centuries until they played a prominent role in meeting human energy needs [19].

1.7.2. Biofuel

Biofuel is a type of fuel obtained from renewable biological sources, most notably plants, algae, or organic animal waste. It may be used to replace traditional fossil fuels such as petrol and diesel. Notable biofuels include ethanol, which is mostly derived from crops such as maize or sugarcane, and biodiesel, which is frequently generated from vegetable oils or animal fats. Biofuels have gained attention for their environmental benefits, particularly their ability to reduce greenhouse gas emissions and reduce dependency on finite fossil fuel sources [20].

1.8. ADVANTAGES OF BIODIESEL

As an alternative to typical fossil diesel fuel, biodiesel has a variety of utility, as expounded below:

- Lower Greenhouse Gas Emissions: Biodiesel is produced using renewable resources such as vegetable oils or animal fats. When compared to fossil fuels, it usually produces lower greenhouse gas emissions, particularly carbon dioxide (CO_2). This makes it a more ecologically friendly alternative, aiding in the mitigation of climate change.
- Renewable Resource: Biodiesel feedstocks including soybeans, canola, and algae are renewable and can be cultivated and harvested in a sustainable manner, minimizing dependency on finite fossil fuel resources.
- Biodegradability: Because biodiesel is biodegradable and less harmful than regular diesel fuel, spills or leaks can cause less environmental damage.
- Energy Security: Because biodiesel production can be localized, it reduces reliance on foreign oil imports and improves energy security.
- Compatibility: Biodiesel is compatible with existing diesel engines and requires minimal to no modification. It may be mixed in various amounts with conventional diesel fuel, such as B5 (5% biodiesel) or B20 (20% biodiesel), making it simple to incorporate into current infrastructure.
- Lubricity: Because biodiesel has better lubricating characteristics than fossil fuels, it may help diesel engines last longer and save money on maintenance.
- Lower Particulate Matter Emissions: Biodiesel combustion produces lower particulate matter emissions, which can help health by reducing air pollution and related respiratory ailments.
- Diverse Feedstock Options: Biodiesel may be made from a range of feedstocks, giving greater flexibility in raw material resources [21].

1.9. DISADVANTAGES OF BIODIESEL

The following are the disadvantages of biodiesel:

- It is more viscous.
- The corrosion of copper strips is more severe.
- Fuel efficiency on energy basics has somewhat dropped (approximately 10% to pure biodiesel).

- Because it tends to gel at low temperatures, biodiesel has poor cold flow characteristics, which might clog filters or produce it too thick to be transferred from the fuel tank to the engine.
- Its density is greater than diesel fuel; however, sub-frozen circumstances might necessitate the use of mixtures.
- It oxidizes faster than pure diesel, resulting in fuel acidity and the production of insoluble gums and sediments that, in advanced stages, may block filters.
- Because of its lower output, vegetable oil is more costly [21].

1.10. NANO FUEL AND NANOPARTICLES

Nanofuel and nanoparticles are topics connected to nanotechnology and energy.

- Nano Fuel: A form of fuel that combines nanotechnology to improve its qualities is referred to as a “nano fuel.” Nanotechnology is the manipulation of materials at the nanoscale, i.e., at the molecular or atomic level. Nanotechnology, when used in fuels, has the potential to increase combustion efficiency, energy density, and certain environmental effects. Nanoparticles, for example, can be added to standard fuels such as petrol or diesel to enhance combustion efficiency and minimize emissions.
- Nanoparticles: Nanoparticles are incredibly small particles that extend in size from 1 nanometer to 100 nanometers[22]. Because of their extremely small size and increase in the surface area-to-volume ratio, they have unique features. Nanoparticles can be employed in a variety of ways in the context of fuels, such as catalysts to improve combustion, carriers for targeted drug delivery in medicinal applications, or additives to improve the efficiency of solar cells and batteries.

Overall, the use of nanoparticles in fuels and energy-related applications is a research and development topic that has the potential to profoundly affect energy generation, storage, and utilization [23].

1.11. PROBLEM OF THE STUDY

Because many internal combustion engines rely on traditional fuel, which is derived from crude oil, and to reduce the reliance on a single source of energy due to fears of future depletion of oil fields, there is a need to find alternatives that meet economic, commercial, and environmental requirements, as well as to benefit from any waste, such as from cooking oils and vegetable oils that are used in the manufacturing of fuel.

1.12. OBJECTIVE OF THE CURRENT WORK

The present project aims to investigate the performance of a four-cylinder, four-stroke, variable engine that runs on various fuel mixtures, namely diesel fuel with eucalyptus fuel in various proportions, and diesel fuel with eucalyptus fuel with the addition of nano aluminum hydroxide. Some engines presently employ nanoparticles and biodiesel fuel which will be used with diesel to enhance fuel characteristics.

The key objective of this research is as follows:

- Investigate the impact of eucalyptus, nanoparticles on diesel engine performance parameters.

1.13. THESIS LAYOUT

This research is divided into five chapters. The first chapter presents an introduction to and aims of the research. The second chapter covers recent practical and theoretical research and studies on the use of various types of alternative fuel mixes and how to select optimum mixing ratios that achieve favorable performance coefficients. The third chapter addresses the practical component, the calculations, and devices utilized, as well as how to record the practical readings and laboratory tests, the materials used in the study, and the mathematical equations employed in the study. The fourth chapter discusses the practical outcomes generated from this data and compares them to earlier research results. The results of the study and suggestions are detailed in the fifth chapter.

PART 2

LITERATURE REVIEW

2.1. INTRODUCTION

In the past decade, the improvement of diesel fuel has become an urgent challenge in today's world due to its increased use in various applications. Therefore, the researchers' interest has increased in how to improve diesel fuel or replace it with other materials to increase engine efficiency, reduce emissions of harmful gases to the environment, and reduce costs by replacing diesel fuel with less expensive materials.

2.2. EXPERIMENTAL STUDIES ON THE EFFECTS OF BIODIESEL AND NANOPARTICLES ON DIESEL ENGINES

Khond et al. [24] provided knowledge and information on nanofuel additives for CI engines powered by diesel, biodiesel, and water-emulsified fuels. The also reported on the influence of prospective nano fuel additions on fuel characteristics, engine execution, exhaust emissions, combustion, and evaporation characteristics under various operating. It was found that adding nanoparticles to diesel and biodiesel fuel would increase their calorific value and cetane index and marginally increase fuel density, flash point, and viscosity. The dosage of nanoparticle additives reduces brake-specific consumption due to increased calorific value, catalytic oxidation, and full fuel combustion. Most of the additives demonstrated reductions in HC and NOx because of the greater evaporation rates and catalytic oxidation.

Venkatesan et al. [25] developed a unique fuel mix that blends aqueous zinc oxide nanofluid with diesel to increase diesel engine performance and combustion. Blends that are denser have a greater kinematic viscosity, and have a higher flash point than diesel, although their total calorific values are much higher. Due to the extremely energetic involvement in the combustion process of nanofluid, which in turn aids in improved combustion of blends within the cylinder, all blends have cylinder combustion pressures that are higher and occur more in advance about the crank angle than does diesel when operating at full loads, while the diesel operation's peak pressure reaches 64.201 bar at 9°aTDC. D + 50ZN mix provides the greatest combustion pressure among the ZN blends, at 69.129 bar in 2° advances. The highest rate of maximum heat liberation from 81.145 J/°CA is obtained for D + 50ZN, whereas diesel at 4.3 kW of BP only achieves 60.984 J/°CA. A mix with 50 CC of ZN compared to clean diesel operation at 100% of load shows the greatest improvement in BTE and BSFC across the board, with a maximum improvement of roughly 5.38% in BTE, and a maximum decrease of around 5.79% in BSFC. The engine run on ZN mixes considerably reduces NOx, smoke, HC, and CO. At maximum rated power output, the D + 50ZN mix records the highest decrease of 24.54% in HC, 12.97% in NOx, 22.08% in smoke, and 10.34% in CO emissions in the termination. It was determined that D + 50ZN may replace diesel since it exhibits superior performance and a greater decrease in emissions than other aqueous zinc oxide blends.

Radhakrishnan et al. [26] examined how alumina nanoparticles affect biodiesel made from cashew nut shells in addition to their emissions and performance properties. Alumina nanoparticles do not require surfactants to gel with gasoline compared to BD100. Moreover, BD100A exhibits fewer HC and CO emissions. When BD100A was compared to BD100, a clear decrease of 8.8% and 10.1% in HC and CO emissions were recorded, respectively. Smoke and NOx emissions were observed to be reduced for BD100A because the transformation of alumina nanoparticles in the fuel enhances the tendency for evaporation, which in turn leads to full combustion and the lowering of HC and CO emissions. When BD100A was compared to BD100, the highest reduction in smoke and NOx emission was observed to be 18.4% and 12.4%, respectively. The gas temperature was reduced because of the alumina nanoparticles. For B100A and B100, the BTE reduced by 1.1% and 2.3%, respectively, while the BSFC increased by 3.8% and 5.1%, respectively.

Rangabashiam et al. [27] presented an experimental analysis to examine the combustion, execution, and emission characteristics of Pongamia biodiesel fuel in a four-stroke, one-cylinder, water-cooled, compression-ignition (CI) engine. At varying mixes of 50 ppm and 100 ppm, TiO_2 nanoparticles were added to Pongamia biodiesel (PBD100) fuel. It was found that TiO_2 nanoparticle-infused biodiesel had better combustion than regular biodiesel fuel. At maximum loads, HC and smoke emissions from biodiesel with 100 ppm. TiO_2 nanoparticles were observed to be 2.1% and 2.7% lower, respectively, than those from standard biodiesel. When compared to biodiesel, NOx and CO emissions were reduced by 3.8% and 1.9%, respectively. In this study, PBD100 was added with TiO_2 nano additives at a rate of 50 ppm and 100 ppm to enhance the fuel and burning characteristics of biodiesel and reduce its tailpipe emissions.

Shekofteh et al. [28] compared the execution and emission characteristics of a eucalyptus oil-diesel blend in direct injection diesel engines at the advanced injection time. Eucalyptus oil boosts brake thermal efficiency when added to diesel. Eucalyptus oil concentrations in diesel fuel increase as the percentage increases, and it was discovered that this had a greater influence on NOx concentration at increasing engine loads than at low engine loads. HC reduced somewhat at the typical injection timing, but it fell dramatically when the injection timing advanced. Under full loads, this is occurred more frequently than under part loads.

Tarabet et al. [29] made an exploration of utilizing eucalyptus biodiesel as fuel in diesel engines as the main emphasis of their work. Biodiesel is produced by trans-esterifying eucalyptus oil. The second step involved testing neat eucalyptus biodiesel and blends of it with diesel fuel at various ratios (75, 50, and 25 by v%) at various engine loads utilizing a single-cylinder air-cooled, DI diesel engine. Engine combustion characteristics were calculated, including the maximum pressure, pace of increasing pressure and rate of heat release. In all operating circumstances, performances and exhaust emissions were likewise assessed. The findings reveal that eucalyptus biodiesel in its pure form and in blends significantly reduces carbon monoxide, unburned hydrocarbons, and other pollutants and particle emissions, particularly at high loads, with performance levels comparable to those of diesel fuel. However, when the blend's biodiesel proportion increased, NOx emissions would rise significantly.

Anandavelu et al. [30] used a combination of eucalyptus oil and diesel fuel to provide minimal heat rejection, and was used in an engine to increase engine performance. Their experiment consisted of two phases. In the initial stage, a direct injection, four-stroke TV1 Kirloskar-made diesel engine was used to inject mixtures of eucalyptus oil and diesel fuel at varying weights. To provide the heat barrier for the piston crown in the second step, rather than using a single-property yttria-stabilized zirconia covering, a functionally graded material with a range of qualities was employed for the valves, cylinder head, and head, together with an aluminum oxide coating. As a consequence, a thermal barrier for the combustion chamber's components was produced, particular fuel consumption was significantly reduced, and brake thermal efficiency would rise. In addition, all test fuels employed in the coated engine had much lower levels of carbon monoxide, nitrogen oxides. and smoke density when compared to the uncoated engine. Only unburned hydrocarbon emissions remained unchanged.

Verma et al. [31] aimed to examine how eucalyptus biodiesel would affect engine qualification and emission characteristics. The findings of this investigation indicate that the BSFC for two distinct samples of the B10 mix of eucalyptus biodiesel is lower than that for diesel by 2.34% and 2.93%, respectively. It was discovered that the BTE for the B10 blends was 0.52% and 0.94% less than that for diesel. Emissions parameters demonstrated an improvement in smoke opacity for both patterns, with smoke being 64.5% and 62.5% cleaner than diesel. Out of all the blends, B10 was found to be an excellent substitute for traditional diesel fuel to reduce air pollution without having a substantial impact on engine performance. When the two samples were compared, biodiesel made from eucalyptus oil Sample A was shown to be better in all aspects of performance and emissions.

Ellappan et al. [32] aimed to increase BTE equivalents and decrease emissions from biodiesel, additives, and eucalyptus oil in LHR engines as compared to diesel. With the exception of NOx emissions, 30% of secondary biodiesel would deliver the greatest BTE and pollution reductions, Also with the exception of NOx, eucalyptus oil biodiesel offers better BTE and pollution reductions among the other biodiesels. Moreover, a blend of 30% biodiesel and 70% eucalyptus oil reduced exhaust emissions by 3% to 4% while increasing NOx emissions relative to diesel. It was found that LHR

engines have better performance metrics and much lower HC, CO, and smoke emissions than diesel engines. The best combination of eucalyptus-infused biodiesels demonstrated improved BTE and a decrease in pollutants other than NOx emission. Moreover, a combination of 30% biodiesel and 70% eucalyptus oil performed better than other blends while increasing BTE by 3%. Pollutants were significantly decreased, although increased NOx emission was implied for the blend of 30% biodiesel and eucalyptus oil. The execution parameters of the LHR engine were greatly enhanced with the addition of 10% DEE, the optimum ratio of biodiesel, and eucalyptus oil with the addition of DEE. The LHR engine's HC, CO, and smoke emissions were significantly reduced, and the NOx emission were significantly cut.
Azad et al. [33] investigated empirically the utilized biofuel made from mustard oil blended with regular diesel fuel. The trials were conducted in a diesel engine with B5, B40, B30, and B20 mixtures. The mixing ratios used were 20%, 30%, 40%, and 50%. According to the study, as the amount of mustard oil in the combination increased, the fuel's calorific value decreased. Moreover, it was found that two of the blends (B30 and B20) had higher brake thermal efficiency than the other mixtures. Regarding the engine's lubricating oil temperature, the study demonstrated a drop in lubricating oil temperature with the addition of biodiesel fuel, with the B40 combination performing better than other blends. Additionally, with an increase in the biofuel mixture ratio, exhaust gas temperatures would rise.

Bahar et al. [34] performed an experimental investigation on a single-cylinder, four-stroke diesel engine that used a D92B3E5 fuel combination, containing 92% conventional diesel fuel, 3% biofuel, and 5% bioethanol. Other combinations used included D80B15E5 (80% conventional diesel, 15% biofuel, and 5% bioethanol), and D75B10E5 (75% conventional diesel, 10% biofuel, and 5% bioethanol), all of which are examples of conventional diesel mixtures. Moreover, 5% bioethanol and 20% biofuel are indicated by the code D75B20E5, while 100% conventional diesel fuel is indicated by the code D100. At various speeds, energy and availability were examined which varied from 1,500 to 3,000 rpm. The maximum thermal efficiency, the best availability efficiency, and the best braking capacity were all found to be at the mixture (D100), and all of them dropped as the amount of biofuel added to the mixture increased. The research suggested using this blend as a substitute for conventional diesel fuel.

Hoseinpour et al. [35] investigated the impact of gasoline vaporization on energy availability and balance by Hastinapur et al. The investigation was conducted on a four-stroke, diesel engine that ran on a mixture of used cooking oil and regular diesel. The engine was run on four different kinds of fuel, including regular diesel fuel in its purest form and regular diesel fuel mixed with gasoline vapor (D + FG). Moreover, a biodiesel fuel known as B20, containing 80% conventional diesel fuel and 20% used cooking oil, was utilized. The diesel fuel utilized in the engine was a blend of conventional diesel and biofuel (B20), together with vaporized gasoline. The study also found that the combination of gasoline vapor with conventional diesel and biofuel results in a decrease in waste heat in exhaust gases by 2.6% and 6.4%, respectively. t was found that gasoline boosts energy efficiency and availability efficiency at medium loads by 5%. When operating diesel engines under heavy loads with high availability efficiency and a reduction in the quantity of accessible energy contained in the exhaust gases, biofuel (B20) with gasoline vapor can be a stand by for conventional diesel fuel. Calam et al. [36] used a homogeneous charge compression ignition engine and investigated the impact of various fuel mixtures on engine performance and gas emissions that result from combustion. The fuels used in the experiments were E25 containing 75% conventional diesel fuel and 25% ethanol alcohol, M25 containing 75% conventional diesel fuel and 25% methanol alcohol, and F25 containing 75% conventional diesel fuel and 25% ethanol alcohol. Other fuels that were utilized included B25 and IP25, comprising 75% ordinary diesel fuel and 25% isopropanol alcohol. The IP25 also contained 75% conventional diesel fuel and 25% butyl alcohol. Lastly, gasoline (25) was utilized, wherein 75% conventional diesel fuel was used and 25% naphtha was mixed with 25% heptane since the findings revealed that using naphtha (N25) led to a broader working range and a lower rate of HC and CO gas emissions than the other combinations.

Qi D, Geng et al. [37] aimed to describe how biodiesel made from soybean crude oil affected a diesel engine's performance, exhaust emissions, and combustion characteristics. Diesel and biodiesel engine features, execution, emissions, and combustion characteristics were compared. Biodiesel has a higher viscosity than diesel, particularly at low temperatures. Biodiesel has a specific gravity that is approximately 6.1% higher than that of diesel. Compared to diesel, the LHV of biodiesel is around 10.2% lower. In comparison to diesel, the flash point is greater. Biodiesel has an acid value of 1.8 mg KOH/g. Moreover, biodiesel has a limited boiling range, and between 310°C and 360°C, 95% of it is cooked out. The maximum cylinder pressure as well as the peak rate of pressure increases, and the peak rate of heat release for biodiesel is somewhat greater at lower engine loads. Peak cylinder pressures are nearly comparable for both fuels at higher engine loads; however, biodiesel has a lower peak rate of pressure rise and heat release. The crank angles at which the greatest values emerge in biodiesel are known in advance. Because of a reduced ignition delay and enhanced injection timing at every engine load, biodiesel combustion would begin earlier. Under speed characteristics and at full load, the power output of biodiesel is approximately identical to that of diesel. Compared to diesel, biodiesel has a greater BSFC. Its lower heating value is reflected in the increased fuel usage. Both fuels produce BSEC, which is quite similar. At speed characteristics at full load, the emissions of carbon monoxide, hydrocarbons, nitrogen oxides and smoke are typically reduced by 27%, 27%, 5% and 52%, respectively.

Buyukkaya et al. [38] explored how plain rapeseed oil and its mixes of 5%, 20%, and 70% would compare to normal diesel fuel in terms of combustion, execution, and emissions. As compared to diesel fuel, the utilization of biodiesel results in reduced smoke opacity (by up to 60%) and greater BSFC (by up to 11%). B5 and B100 fuels were found to have CO emissions that measured, respectively, 9% and 32% less than those of diesel fuel. The BSFC of biodiesel was discovered to be 8% and 8.5% greater than that of diesel fuel, respectively, for the highest torque and rated power settings. According to the combustion investigation, plain rapeseed oil and its tested mixes had a shorter ignition delay than conventional diesel. The combined properties of rapeseed oil and its diesel mixes closely matched these of regular diesel.

Devan et al. [39] in their study showed how biofuels can completely replace diesel fuel. To achieve this, mixes of the methyl ester of paradise oil and eucalyptus oil were utilized. To evaluate the performance and emission characteristics of these fuels, different volume ratios of eucalyptus oil and paradise oil were produced and used as fuels in a four-stroke, DI single-cylinder diesel engine. In the study, a methyl ester derived from paradise oil was employed as an ignition booster. The Me50-Eu50 mix had a 2.7% increase in NOx emissions at full loads, a 49% decrease in smoke, a 34.5% reduction in HC emissions, and a 37% reduction in CO emissions, according to the data. Under full loads, the brake thermal efficiency of the Me50-Eu50 blend increased by 2.4%. The study showed that the combustion properties of the Me50-Eu50 blend were close to those of diesel.

Senthil et al. [40] observed how antioxidant compounds affect NOx emissions in a robust diesel engine by Annona biodiesel. Antioxidant additions used included p-phenylenediamine (PPDA), A-tocopheryl acetate, and L-ascorbic acid. The results of the experimental inquiry clearly show that using an antioxidant addition to decrease NOx emissions in diesel engines works. Compared to diesel without any significant alterations, a 250 mg dosage of a PPDA additive with A20 is ideal for NOx reductions by up to 25.7%.

Balaji et al. [41]presented an experimental evaluation of the impact of an antioxidant additive (A-tocopherol acetate) on the stability of oxidation and NOx emissions in a direct-injection diesel engine running on a methyl ester of neem oil. The methyl ester of neem oil and the antioxidant ingredient were combined in varied concentrations (100-400 ppm). The execution and emissions of a computerized 4-stroke water-cooled, single-cylinder diesel engine with a rated power of 3.5 kW were examined, as well as the oxidation stability, in the Rancimat apparatus. The antioxidant addition was found to be beneficial in boosting the oxidation stability and reducing the NOx emissions of the methyl ester produced by diesel engines that burn neem oil. However, it was shown that the addition of antioxidants caused HC, CO, smoke emissions, and brake-particular energy consumption to rise.

Yilmaz et al. [42] conducted an experimental investigation into an internal combustion engine with compression ignition operating on a number of fuel mixes, including one made up of 45 distinct fuels and symbolized by (BMD), which contains 45% biofuel, 10% methanol, and 45% conventional diesel, as well as a blend of 45% conventional diesel, 10% ethanol, and biodiesel (BED). Additionally, an increase in the particular consumption of brake fuel was known with an increase in the percentage of alcohol in the mixture when comparing the performance and emissions coefficients of the diesel engine when it operating on these mixtures with the engine operating on conventional diesel fuel. This was symbolized by D100, and under the same operating conditions. Regarding emissions, the ratio of CO to HC grew as the alcohol concentration rose. For nitrogen oxides, however, the proportions reduced.

Oner et al. [43] examined alternative fuel for diesel engines made from unsound animal tallow and its suitability for use in nano diesel engines as pure biodiesel as well as a biodiesel mix with petroleum diesel fuel. Through base-catalyzed transesterification of the fat with methanol in the presence of NaOH as the catalyst, a tallow methyl ester was created for use as a biodiesel fuel. Fatty acid methyl ester has been determined to fulfill the requirements of ASTM D6751 and EN 14214 for density and viscosity. The density and viscosity of tallow methyl esters were discovered to be quite similar to those of diesel. It was also discovered that biodiesel has a marginally lower calorific value than diesel. An experimental investigation was conducted to see whether tallow methyl ester might be used in direct-injection diesel engines as a substitute fuel. It was found that adding biodiesel to diesel fuel causes the engine's effective efficiency to drop and the engine's specific fuel consumption to rise, due to biodiesel having a lower heating value than diesel fuel.

Jeryajkumar et al. [44] conducted a study in which they dosed Calophyllurn iodophilic biodiesel containing nanoparticles such as titanium oxide (TiO2) at a rate of 50 mg/L and observed the performance of a water-cooled single-cylinder engine. Biodiesel was used to minimize carbon monoxide (CO) emissions in combination with nanoparticles. A CO reduction was achieved by adding cobalt oxide (Co_3O_4). 30% was attained when biodiesel was combined with TiO_2, indicating a 25% decrease in CO. Unburned hydrocarbons were reduced by 80% and 70%, respectively, using TiO2 and Co_3O4.

Örs et al. [45] conducted an exploratory investigation to assess the influence of blending biodiesel fuel generated from spent titanium dioxide and n-butanol cooking oil (C_4H_9OH) on the execution and combustion parameters of a diesel engine. The power source of the test combination consisted of fuel, TiO_2 nanoparticles, biodiesel, and n-butanol. The fuel doses tested were D100, B100, B20, B30, B20 + TiO_2, B20But10, and B20But10 + TiO_2, in that order. The engine for testing was a 9 kW, water-cooled, four-stroke, one-cylinder unit operating at 1,500 rpm. The testing results showed a reduction in the torque of the brakes by approximately 21%, 6.60%, 10.96%, and 2.30% For B100, B20, B20BUT10, and B20But10 + TiO_2, respectively. while rising compared to euro diesel, B20 + TiO_2 saves about 2.89%. HC, CO, and smoke-darkening emissions are reduced; however, nitrogen oxide and carbon dioxide emissions are higher when compared to diesel fuel. Adding n butanol reduced CO, HC, and NO smoke emission opacity, while CO_2 levels increased compared to diesel. Yuvarajan et al. [46] investigate how the addition of titanium dioxide to biodiesel fuel (oil methyl ester) impacts the operation and combustion and emission parameters of a diesel engine. An investigation was made on an engine that was single-cylinder, four-stroke, air-cooled, 4.2 kW, with a 17.5:1 compression ratio, and a 1500 rpm speed. The dimensions TiO2 nanoparticles were 50 nm at dosages of 100 ppm and 200 ppm. The outcomes achieved may be summarized as MOME and MOMET100 minimize HC, CO, and smoke emissions and MOMET200 vs diesel. Nitrogen oxides are higher in MOMET100, MOME, and MOMET200 when compared to MOMET100, MOME, and MOMET200 in diesel fuel. Adding TiO_2 to methyl mustard oil results in lower HC, CO levels, and emissions. OMET100 and MOMET200 NOx emissions are significantly reduced when TiO_2 nanofluid is added to them; as a result, they become more stable.

Jo Han et al. [47] investigated the performance of a four-stroke diesel engine powered by biodiesel (PME) and conventional diesel fuel. According to their findings, the greatest thermal efficiency recorded for conventional diesel fuel was 22.1% at a speed of 2750 rpm, and 24.3% at a speed of 3000 rpm for biodiesel (PME). Furthermore, the researchers discovered that the usage of PME fuel is advantageous owing to the high proportion of oxygen in its composition, which will assist in enhancing combustion inside the chamber and the efficiency of the fuel combustion process.

Ibrahim and Raaid [48] investigated the energy and availability of a single-cylinder, four-stroke diesel engine that operates on two forms of biodiesel. The first is represented by CB8, which includes 92% traditional diesel fuel and 8% maize oil, while the second is represented by CB15, which contains 85% conventional diesel fuel and 15% corn oil. The researchers took all of the tests at various rates ranging from 1500 rpm to 3000 rpm. They found that increasing the engine speed increases the destructive availability for all blends, and increasing the biofuel percentage increases the destructive energy. The research also demonstrated the viability of utilizing diesel fuel mixed with maize oil in diesel engines instead of regular diesel fuel.

Solero [49] investigated how the addition of aluminum oxide affected the fuel combustion process and emission properties. The size of nanoparticles used in the investigation was 10 nm. This enhancement improved combustion properties, decrease carbon monoxide generation, and developed combustion stability and efficiency.

Madhavan[50] confirmed that after adding a nanomaterial to the fuel, it led to a significant decrease in the specific consumption of the fuel brake, as it appeared by 0.2858 kg / kW, and the reason for this is that the nanoparticles work as a good active amount of combustion (due to the abundance of oxygen) inside the engine, while the rest of the mixtures showed a slight increase in consumption.

He Yaşara [51] that the addition of nanomaterials to fuel showed good results for the decrease in specific consumption, and this is a very important performance for the engine due to giving data on the efficiency of converting a quantity of fuel into energy that can be used from it, and it was found that there is a variation in the specific consumption of fuel according to the concentration of the additive and the load, as it showed a noticeable decrease in the fuel mixture (nan _fuel) by 12.12%, and the reason for this is because the addition of nanoparticles led to a slight increase in the calorific value and thus a decrease in consumption. Specific fuel because nanomaterials give more space to the surface of the materials added to them, which leads to the best ignition inside the piston.

Appavu [52]confirmed that the use of nanoparticles such as zirconium oxide Zro2 leads to an increase in the thermal value of the fuel and thus increases the thermal efficiency of the brake because the addition of nanoparticles improves the atomization of fuel inside the combustion chamber and burns well when mixed with air, that mixing fuel with improved nanomaterials changes the properties of the fuel in general from atomization, oxygen content, oxidation rate and even at cylinder temperature.

PART 3

METHODOLOGY

3.1. INTRODUCTION

Practical studies are very important to verify the performance of the various types of internal combustion engines produced by manufacturers, who depend on conducting all necessary laboratory tests before marketing them to consumers. To evaluate internal combustion engines, a number of operational performance parameters of the engine have relied upon brake capacity, specific brake fuel consumption rate, and thermal efficiency. In addition to the laboratory work, different devices and accurate machines were used to measure fuel properties, such as calorific value, density, and the cetane number of the fuel used. Other devices were also used to measure the engine rotation speed and the amount of fuel consumed. In this chapter, the test engine is described in addition to a comprehensive description of the laboratory test devices, in addition to the computational aspect, where mathematical equations were used for the purpose of finding the value of braking power, brake thermal efficiency, specific fuel consumption, and other factors affecting the performance of the internal combustion engine.

3.2. LABORATORY WORK STEPS

Figure 3.1 shows the practical steps for the testing process for the current study. The basic part of laboratory work, which includes the creation and operation of the engine also appears to select the appropriate fuel mixtures that ensure the correct operation of the testing device. This includes the necessary readings such as the current, voltage and power factor, all of which, according to this scheme, have been compiled in a convenient and correct way.

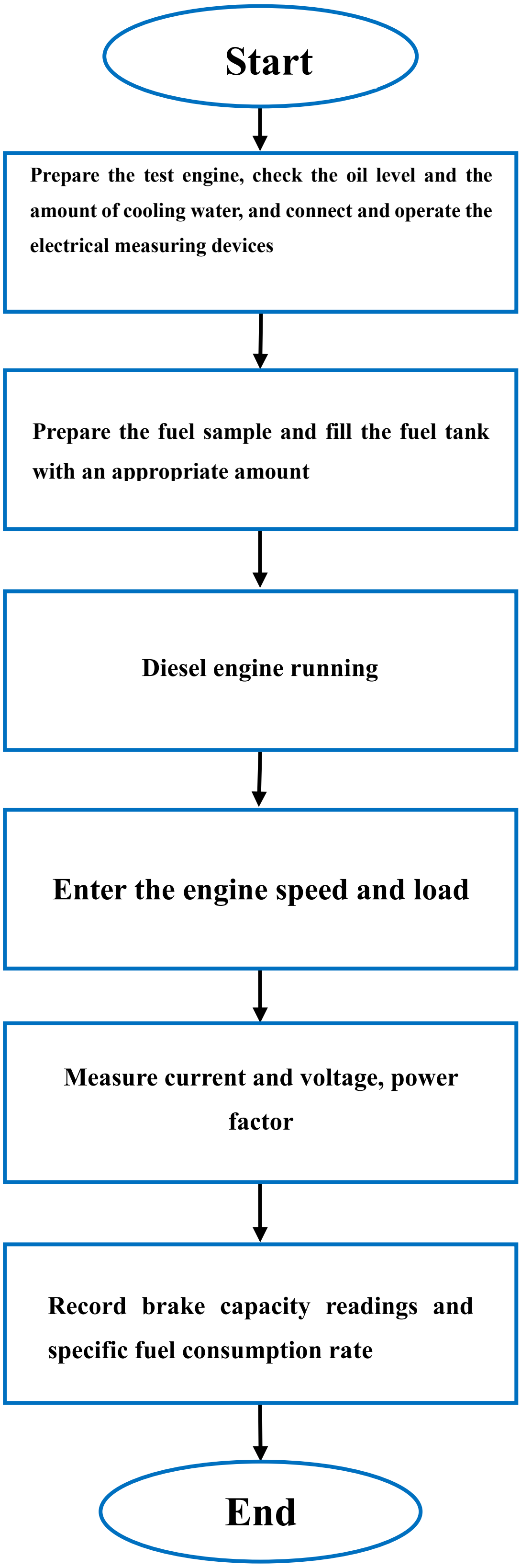

Figure 3.1. Laboratory work steps.

3.3. DIESEL ENGINE

In this experiment, we used, a four-cylinder, four-stroke, water-cooled diesel engine of Korean origin with specifications as presented in Table 3.1. and depicted in Figure 3.2.

Figure 3.1. Engine used in the study.

Table 3.1. Engine specifications.

Engine Manufacturer	Kia Bongo (Korea)
Type of Engine	J2 2701
Piston Displacement	2694 cm^3
Stroke	95 mm
Bore	95 mm
Nominal Output	80 HP at 4000 rpm
Maximum Torque	16.8 N.m at 2400 rpm

3.4. GENERATOR

The electric generator used in the experiment was of Chinese origin, type STC-24 kW, operating at a frequency of 50 Hz and generating a voltage difference of 220 volts and a current of 30 amperes for each line. It has three lines (phase 3) with technical specifications shown in Table 3.2. (See also Figure 3.3)

Table 3.2. Specifications of the electric generator.

A.C. SYNCHRONOUS GENERATOR				
TYPE	STC-24 kW	No.	070606256	
30	**KVA**	3 PHASE	COSØ	0.8
50	**Hz**	1,500		rpm
380	**V**	MADE IN CHINA		
45.6	**A**			

Figure 3.3. Generator.

3.5. FUSED LOAD

Electric loads were used, which are thermal heating wires (heaters) that convert electrical energy into thermal energy. The experimental engine was equipped with nine heaters, and every group of three heaters was connected to an electric line. An operating switch and a voltage regulator were connected to control the amount of current passing through the heaters. Each heater had a capacity of 4,000 watts (Figure 3.5)

Figure 3.2. Electric load.

3.6. ENGINE SPEED MEASUREMENT

The engine speed was determined and measured electronically by means of a magnetic sensor connected to a speed-measuring device nominated on the control panel and the keys of the experimental engine. The method of measurement is that the sensor was placed vertically on the pilot wheel at a very small distance, where it senses the teeth of the pilot wheel, and the magnetic sensitivity is converted into electronic signals and displayed on a speed measuring device with specifications shown in Appendix (1) and shown in Figure 3.5.

Figure 3.3. Engine speed measuring device.

3.7. CONTROL PANEL AND MEASUREMENT

A plank of wood with some measurements that we need in the experiment is required to take the readings. An electronic device was installed to measure the speed of the engine's rotations, as well as a device to measure the electrical potential of the dynamic generating head, an electronic screen to display the readings from the sensors connected to the engine, and an installation of nine loads (heater). With each heater, there is an electric switch to turn on and off, as well as a voltage regulator to control the amount of current that passes through it, to install a graduated fuel burr, to operate as a key to start the engine as well as a key to turn off the engine in an emergency, engine lamps, an oil sensor, and the plate shown in Figure 3.6 and the test system Figure 3.7.

Figure 3.4. Control panel and measurement.

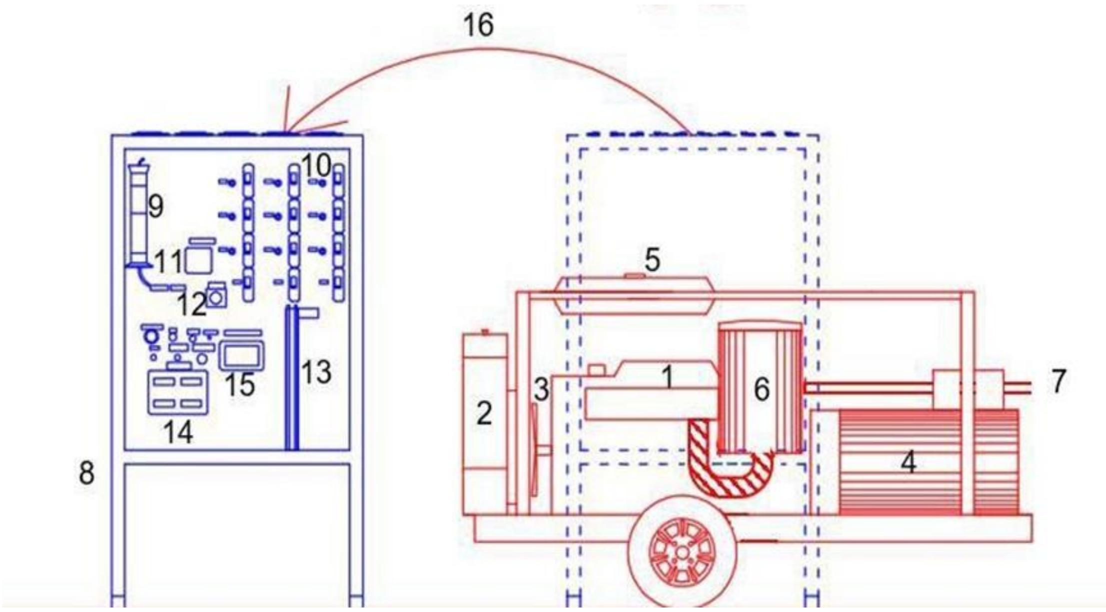

Figure 3.7. Test platform.

1. Engine 2. Radiator 3. Fan 4. Generating head (electric dynamometer) 5. Fuel tank 6. Air box 7. Exhaust 8. Gauges panel 9. Burette 10. Switches and load regulators 11. Electronic power meter 12. Engine revving device 13. Water manometer 14. Sensors electronic display 15. Barometric pressure gauge.

3.8. CALORIFIC VALUE MEASUREMENT

Calorific value is defined as a measure of the calorific energy contained in a fuel. The calorific value of the mixtures was measured using a type of device (CAL 3K), as shown in Figure 3.8, based on the ASTM D240 standard. Through the calorific value of the fuel, we can calculate the calorific energy entering the diesel engine and measure its efficiency. The way the device works is by using 1 g of the fuel sample. It is placed inside the container of the explosive bomb, made of high-resistance stainless steel and tightly closed. This container is placed in a bucket containing water with a temperature ranging between 20°C and 35°C. The pressure inside the bomb is increased and oxygen is pumped into it through pressure control valves. An explosion occurs for the components of the sample, so that the heat is transmitted to the bucket and then to the temperature sensors, after which the computer connected to the device calculates the calorific value of this sample.

Figure 3.5. Heat Capacity Measuring Device.

3.9. DENSITY MEASURING DEVICE

The density of the diesel fuel and other mixtures was measured using a digital device and according to Standard Specification No. ASTM D4052 (as shown in Figure 3.9). The fuel injector is filled with 3 ml of the fuel sample to be tested, which is injected into the hole at the top of the device, after which it is confirmed that there are no bubbles in the measurement cell after filling it with the form while leaving the syringe in the cell hole. After waiting for several minutes for the device to sense by integrating the required reading requirements, a signal is given to the digital device to read the sample density and record its value digitally on the device screen.

Figure 3.6. Density measuring device.

3.10. VISCOMETER

The viscosities of the samples of the diesel fuel and other mixtures intended for laboratory examination were measured using the digital device as shown in Figure 3.10 using the standard specification (ASTM 445 D). The device is set at a certain temperature, after which the viscometer and calibration thermometer are selected depending on the mentioned standard above. The device is filled with the form to be examined to the indicated limit in the device, after which it is immersed in the water bath, followed by waiting time until the viscometer absorbs the temperature of the bath. Then we withdraw the form with a rubber pipette and calculate the time for the form to descend from the upper line to the lower line of the device. The viscosity reading of the required sample is then recorded.

Figure 3.7. Viscometer.

3.11. STANDARD DISTILLATION APPARATUS

Because the fuel sample is composed of different hydrocarbon compounds, determining the boiling point of the mixture requires examining it with a standard distillation apparatus. The K45290 type device Figure 3.11 is used to measure the oil sections of which the mixture is composed. According to ASTM D (86), 100 is taken. Mills of the sample are examined and transferred to the distillation flask by means of the inserted cylinder. The thermometer is installed tightly so that the bulb of the thermometer is opposite the steam opening. The initial boiling point (I.B.P.) is recorded from the first drop that descends into the recipient, after which the temperatures corresponding to the volumes of 5 ml are recorded up to 100 ml, with an increment of 5 ml for each step. After that, the final boiling point at which the thermometer is fixed after the end of distillation is recorded, followed by the extent of the total distillate collected in the inserted cylinder being measured. The remaining volume is measured in the distillation flask, after which the lost volume is calculated. The purpose of the distillation process is to determine the boiling points of the mixture to be used. Later, the cetane number of the fuel sample used.

Figure 3.8. Standard distillation apparatus.

3.12. CETANE INDEX

The cetane index is one of the most important distinguishing features of diesel fuel. Through this number, we can know the quality and combustion efficiency of diesel fuel. It corresponds to the octane number in gasoline fuel. The cetane number is also an indicator of the speed at which diesel fuel burns. The higher the cetane number, the better the quality of the fuel. After finding the values of density, viscosity, and temperatures for the standard distillation process, we can find the cetane number from the chart shown in Figure 3.12, where the column on the left of the figure mentioned above represents the gravity value, while the column on the right of the figure represents the percentage temperatures of the distillation process. The standard column of the fuel sample and the column in the middle show the values of the cetane number.

A straight line is connected between the value of the standard distillation temperature and the value of the API Gravity, where the intersection point in the middle column is the value of the cetane number.

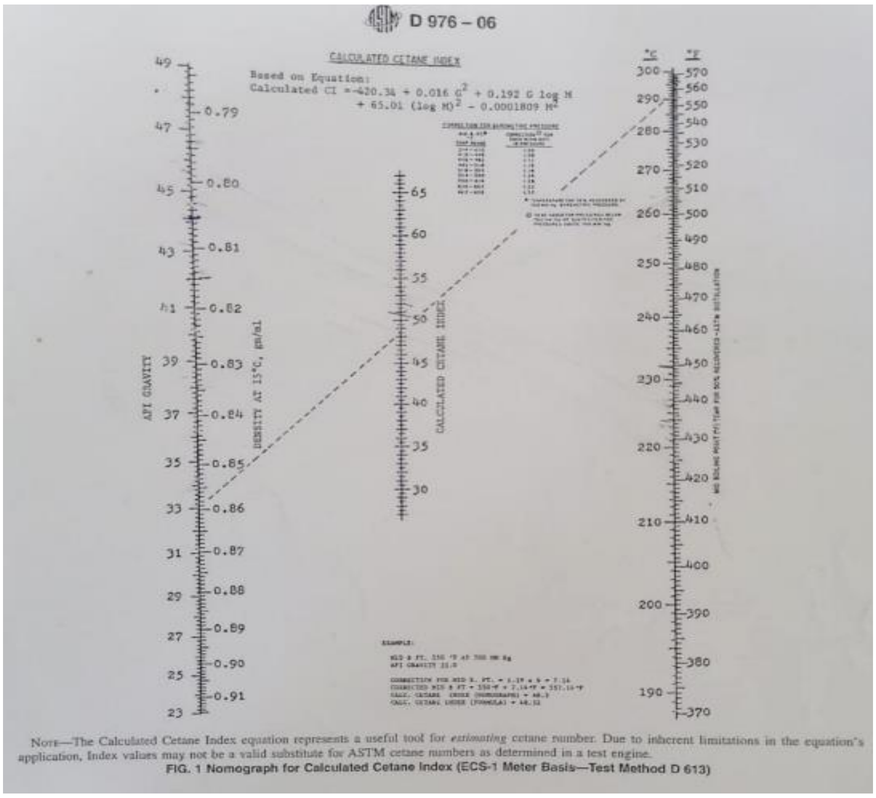

Figure 3.9. Cetane number diagram.

Table 3.3. Fuel properties.

TEST	D100	B100	D95-B5	D90-B10	D85-B15	D85-B1550 ppm	D85-B1575 ppm	D85-B15100 ppm
DENSITY@15°C	0.8173	0.8955	0.8262	0.8300	0.8345	0.8318	0.8311	0.8309
API	41.6	-	40	39.7	39	39.6	39.7	39.9
SULFUR CONTENT WT%	0.83	0.0	0.6563	0.6324	0.6102	0.6856	0.6901	0.7031
CETANE INDEX	53	52	55	54.1	54.3	53	54	55
GROSS CALORIC VALUE Kcal/Kg	10950	10351	10906	10895	10891	10901	10910	10918
VISCOSITY@40 °C CST	2.1	3.2	2.60	2.65	2.66	2.69	2.68	2.66

3.13. PREPARING THE FUEL SAMPLE

Diesel fuel purchased from a local gas station in Iraq was used. There are seven types of fuel that were used in the experiment Figure 3.14, three of which were mixed with nanomaterials and biofuel, three of which were mixed with biofuel, and the last of which was pure fuel, as the work basis for comparison. The nanomaterials used were aluminum oxide purchased from the market. The local solution shown in Figure 3.13 and the nanomaterials were mixed with the fuel by a device (Ultrasonic) made in China Figure 3.15. The nanomaterial was weighed by an electronic scale Figure 3.16.

Figure 3.13. Nano aluminum oxide.

Figure 3.14. Fuel mixtures.

Figure 3.15. Ultrasonic cleaner.

Figure 3.16. Balance weight.

Table 3.4. Fuel mixtures and their volumetric ratios.

No.	Mixture	Mixture Symbol	Volumetric proportions of components of mixture
1	Diesel	D100%	Diesel 100%
2	Diesel + biodiesel	D95% + B5%	95% Diesel 5% biodiesel(v/v)
3	Diesel + biodiesel	D90% + B10%	90% Diesel 10% biodiesel(v/v)
4	Diesel + biodiesel	D85% + B15%	85% Diesel 15% biodiesel(v/v)
5	Diesel + biodiesel + nanoparticles	D85% + B15% + 50 ppm	85% Diesel 15% biodiesel(v/v) + 50 ppm nanoparticles(w/w)
6	Diesel + biodiesel + nanoparticles	D85% + B15% + 75 ppm	85% Diesel 15% biodiesel(v/v) + 75 ppm nanoparticles(w/w)
7	Diesel + biodiesel + nanoparticles	D85% + B15% + 100 ppm	85% Diesel 15% biodiesel(v/v) + 100 ppm nanoparticles(w/w)

3.14. BIOFUEL PRODUCTION

Biodiesel was produced from eucalyptus oil obtained from the local market, using methanol alcohol as a solvent and potassium hydroxide as a catalyst.

3.14.1. Materials

Eucalyptus oil obtained from the local markets was used, as it is available in containers of different capacities with an equal density of 913 kg/m^3. Laboratory methanol alcohol, which is available in the markets, has a purity of up to 99.9% and a density of 972 kg/m^3 in addition to potassium hydroxide as a basic catalyst for the reaction. Figure 3.17 shows the materials used in the production.

Figure 3.17. Materials used in production.

3.14.2. Method Of Production of Biodiesel by Esterification

Eucalyptus oil is initially heated to a temperature of 80°C to remove any excess water that may be present in the oil, after which the oil is taken and placed in a beaker until the temperature of the oil reaches the reaction point, which is between 60°C and 70°C. In the meantime, we dissolve a certain percentage of potassium hydroxide in another percentage of methyl alcohol to become methoxide, and this percentage is known; i.e., for each 200 ml of the oil, we add 50 ml of methyl alcohol and 4 g of potassium hydroxide as a catalyst for the reaction[53]. Then we add the methoxide to the oil and mix these materials well; the reaction time is more than two hours. The reaction product consists of biofuel reaching the top of the beaker and glycerin at the bottom, as shown in Figure 3.18.

Figure 3.18. The product of a chemical reaction.

3.15. BRAKE POWER

In this experiment, the braking power was measured by means of the generating head (the electric generator) by means of the electric power measuring device installed in the control panel. This device measures the electric power, voltage, and current for each line (PHASE) and according to the following equation [54]:

$$BP = P_{ELECT}/\eta_{Gen} \tag{3.1}$$

Where

BP = brake power (kW)
P_{ELECT} = Total Electrical Power (kW)
η_{Gen} = efficiency of electric generator (%)

For the resulting total electrical power, it can be calculated from the following equation [55].

$$P_{ELECT} = P_{L1} + P_{L2} + P_{L3} \tag{3.2}$$

Where

P_{L1} = electrical power the first line (W)
P_{L2} = electrical power the second line (W)
P_{L3} = electrical power the third line (W)

Moreover, the electrical power of each line can be calculated using the following equation [56–58]:

$$P_{ELECT} = V * I * PF \tag{3.3}$$

Where

V = voltage (potential difference) (V)
I = current (A)
PF = power factor (%)

The power factor changes continuously depending on the amount of current and the amount of voltage.

3.16. MEASUREMENT OF BRAKING THERMAL EFFICIENCY (BTE)

BTE is the extent of the engine's efficiency in converting the energy resulting from fuel combustion into mechanical energy, and it is the result of dividing each of the braking power values by the calorific value of the fuel resulting from its combustion. The efficiency is calculated from the following equation [59–61]:

$$\eta_{bth} = \frac{\mathrm{BP}}{\dot{\mathrm{m}}_f * \mathrm{LCV}} \tag{3.4}$$

Where

η_{bth} = braking thermal efficiency (%)
BP = brake power (kW)
$\dot{m}_f$= average fuel consumption (kg/s)
CV = calorific value (kJ/kg)

3.17. BRAKE-SPECIFIC FUEL CONSUMPTION

A graduated glass tube was placed on the control panel and it was filled with a small pump connected to the fuel tank and equipped with a valve to supply the engine with fuel during the measurement process, as the consumption is calculated by calculating a specific amount of fuel, which is 50 ml for a specific time period of seconds by means of a stopwatch Figure 3.19) shows the consumption measurement plan, and it is done according to the equation [62–64]

$$\dot{m}_f = (sg_f \times v \times 0.001 / t) \quad (3.5)$$

where

$\dot{m}_f$ = fuel consumption (kg/s)
sg_f = specific weight of fuel (kg/cm^3)
V = volume of spent fuel in cm^3
t = time spent

The brake-specific fuel consumption is the result of dividing the amount of fuel consumption by the braking power through the following equation [65]:

$$BSFC = \dot{m}_f/BP \quad (3.6)$$

Where

BSFC = Brake Specific Fuel Consumption (kg/kW.s)

$\dot{m}_f$= fuel consumption (kg/s)

BP = Braking power (kW).

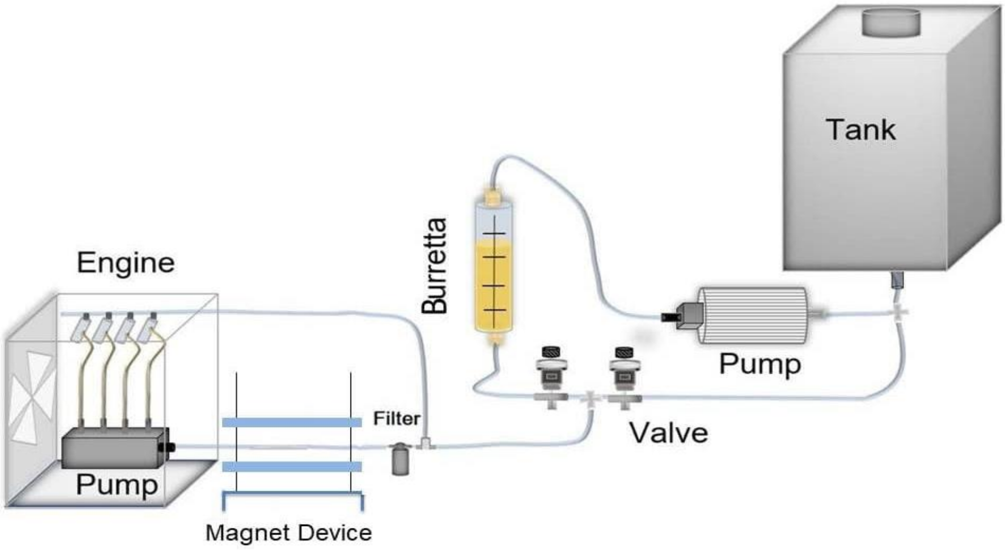

Figure 3.19. Fuel consumption measurement.

3.18. UNCERTAINTY ANALYSIS

Conducting uncertainty analysis in the tests is crucial to provide a high degree of trust in the accuracy of the outcomes. The findings are obtained by assessing the repeatability and increment of interest. The tests were repeated three times. The uncertainty was calculated by using the percent relative standard error, $\emptyset$, which was derived from the variations of the anticipated values of performance factors, as shown in Eq.7 [66]

$$\emptyset\% = (S/Y) \times 100 \qquad (3.7)$$

where S is the standard error and Y is the mean of the collected data. The standard error is calculated using Eq.8 [66]

$$S = \frac{\alpha}{\sqrt{K}} \tag{3.8}$$

Table 3.5. Uncertainties of the measured parameters.

Parameter	Max. value	Uncertainty
Speed (rpm)	1600	±0.09
BSFC (kg/kw.hr)	0.324	±1.3
BTE (%)	19.7	±0.88

PART 4

RESULTS AND DISCUSSION

4.1. INTRODUCTION

The results of the practical engine testing are presented and discussed in this chapter utilizing seven varieties of mixes consisting of standard diesel fuel with six types of other mixtures in varied volumetric proportions, as indicated in Table 3.2, which was used to operate a four-stroke, four-cylinder diesel engine at various speeds and loads. The emphasis on thermal performance is the most significant component in all internal combustion studies. The parameters of performance such as braking efficiency, brake-specific fuel usage, and so on are shown and graphed. The performance data are reviewed in order to clarify the performance conduct of a diesel engine when partially fueled with diesel fuel, biofuel (eucalyptus), diesel fuel, and biofuel with diesel fuel containing nano aluminum oxide.

4.2. DIESEL ENGINE PERFORMANCE FUELLED BY EUCALYPTUS BIODIESEL

Biodiesel-diesel mixtures D100, D95-B5, D90-B10, and D85-B15 power the diesel engine, and their performance parameters are examined below.

4.2.1. Brake Thermal Efficiency

Figures 4.1-4.3 show the correlation between BTE and load at varying speeds and mixing ratios. The spin speeds available are 1200, 1400, and 1600 rpm. The blends consist of varying proportions of eucalyptus biodiesel, namely 5%, 10%, and 15%, respectively. The findings indicated that including biodiesel in regular diesel significantly reduced the brake thermal efficiency value. This may be attributed to the disparity in thermal properties between diesel and biodiesel. The BTE is directly correlated with the rise in load and speed. The findings also indicated that the blend with 5% biodiesel had the most similarity to pure diesel, followed by the blends with 10% and 15% biodiesel, respectively. The same observations were made in the results [67].

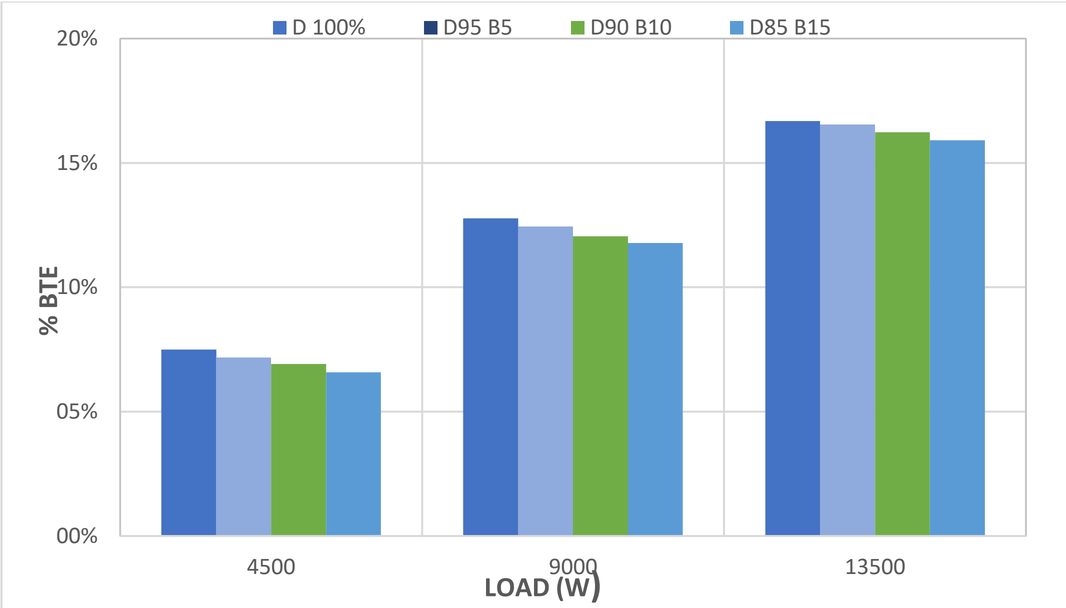

Figure 4.1. BTE vs. engine load at 1200 rpm.

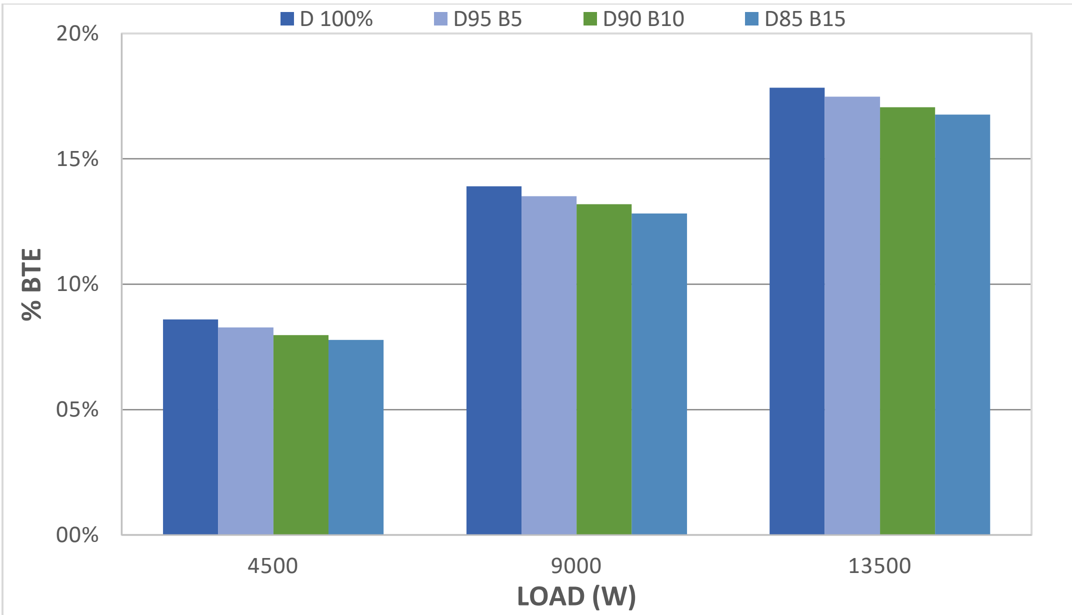

Figure 4.2. BTE vs. engine load at 1400 rpm.

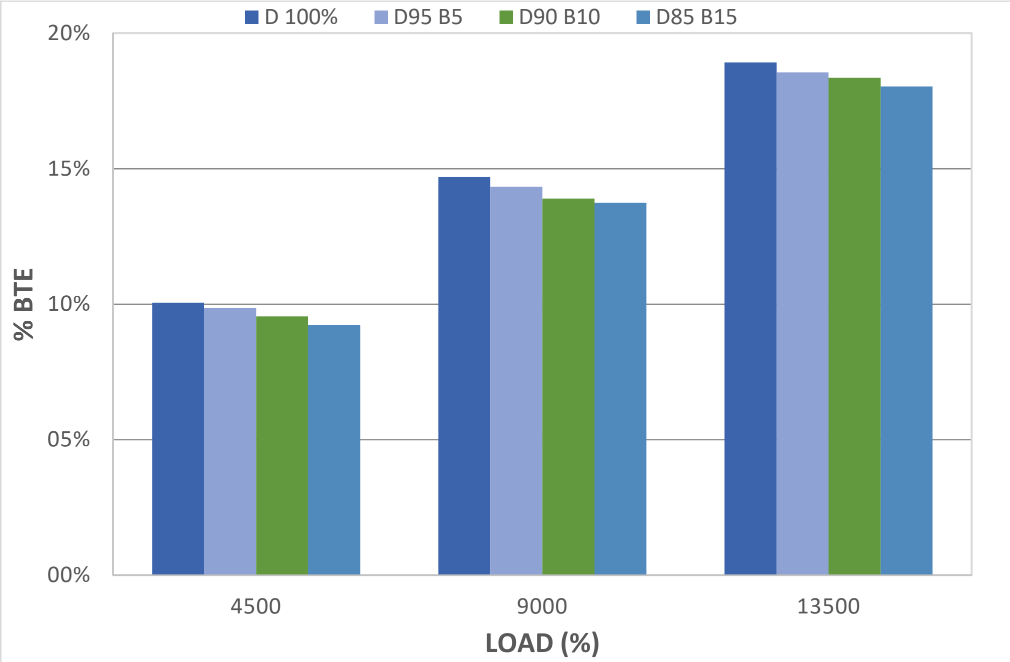

Figure 4.3. BTE vs. engine load at 1600 rpm.

4.2.2. Brake Thermal Efficiency with Speed

BTE was calculated during engine operation at load 13500 w with speed increased from 1200 to 1600 rpm, as shown in Figure 4.4 generally, BTE increases with engine speed and decreases with increasing biofuel ratio at the same speed. The difference value for BTE from pure diesel recorded at 1200 rpm was 1%, 3%, and 4% respectively for D95-B5, D90-B10, and D85-B15. The difference values for BTE recorded at 1400 rpm were 1.7%, 4%, and 5% respectively for mixtures D95-B5, D90-B10, and D85-B15, and the difference values for BTE recorded at 1600 rpm were 1.58%, 3.7%, 4.8%respectively for mixtures D95-B5, D90-B10, and D85-B15. All fuel samples showed a decreased BTE value compared to diesel fuel. For you because the calorific value is lower than the net value of the diesel.[68,69]

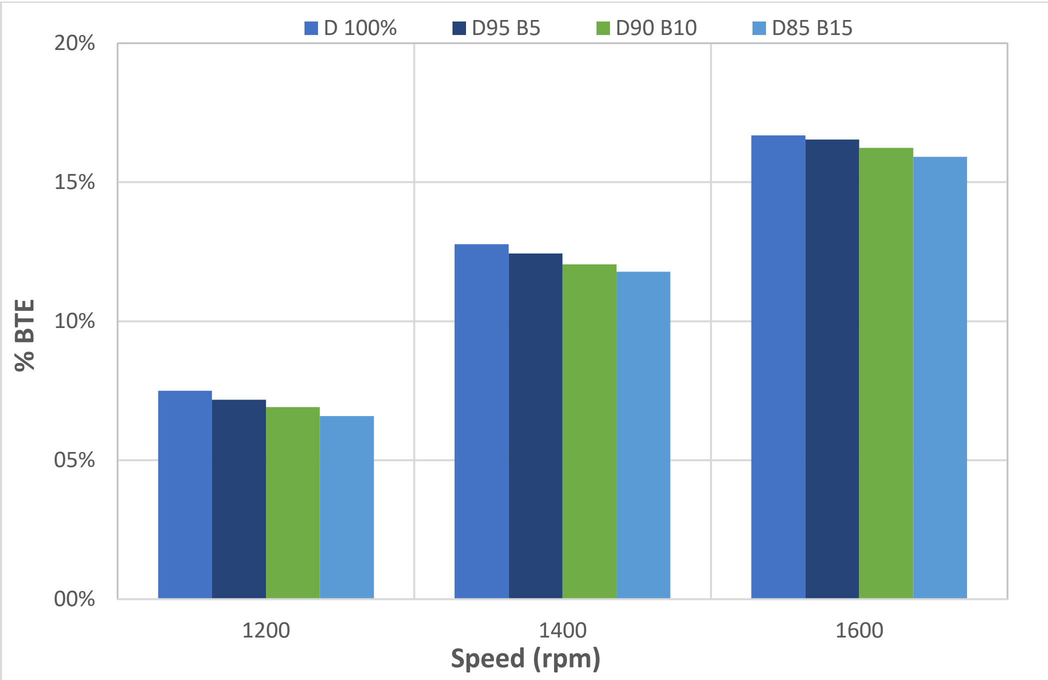

Figure 4.4. BTE vs. speed at 13500 w load.

4.2.3. Brake-Specific Fuel Consumption

Figures 4.5, 4.6, and 4.7 show the correlation between different brake-specific fuel consumption (BSFC) motor loads at 1200, 1400, and 1600 rpm speeds. The graph illustrates that when the load is augmented, there is a corresponding rise in fuel consumption until the engine's overload is surpassed. The rise in fuel usage may be attributed to the surge in the use of eucalyptus biodiesel. The caloric value of biodiesel diminishes as the speed ratio rises, owing to the growing need for energy. As speed rises, the percentage of brake fuel consumption also increases dramatically. Additionally, a more significant proportion of brake fuel leads to improved overall fuel consumption. The findings for (D95-B5, D90-B10, and D85-B15) exceeded the net diesel consumption in that order. The change in fuel consumption is calculated by comparing the total calorific value of biodiesel and diesel with the calorific value of diesel when combusted alone. The same observations were observed in the reference [67].

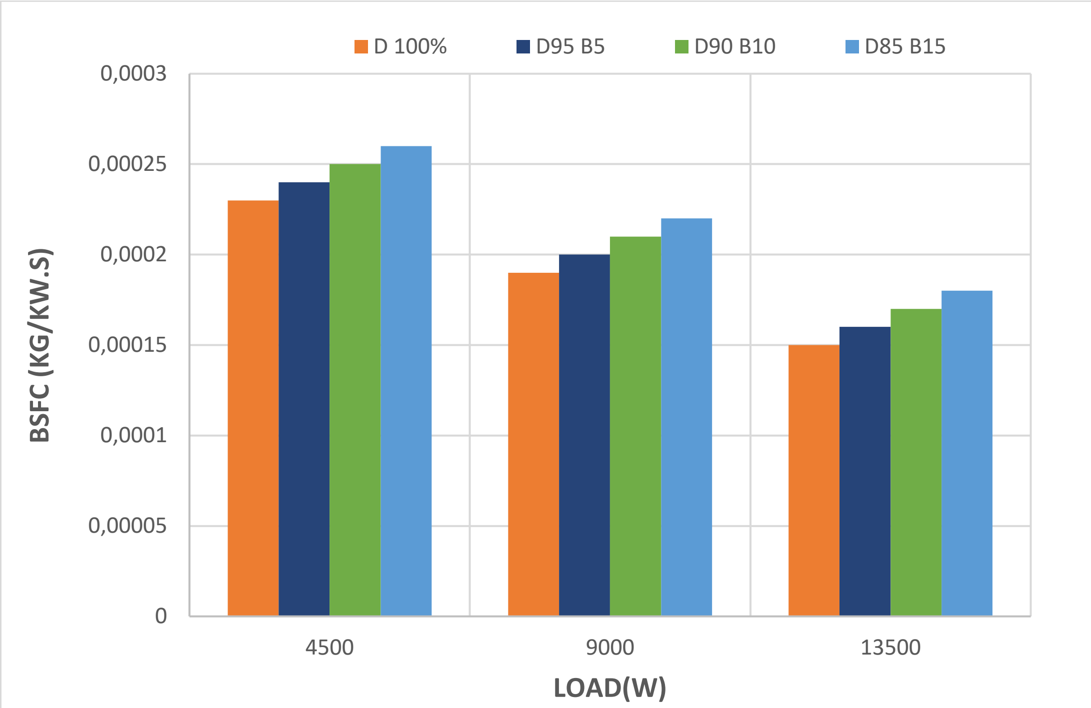

Figure 4.5. BSFC vs. engine load at 1200 rpm.

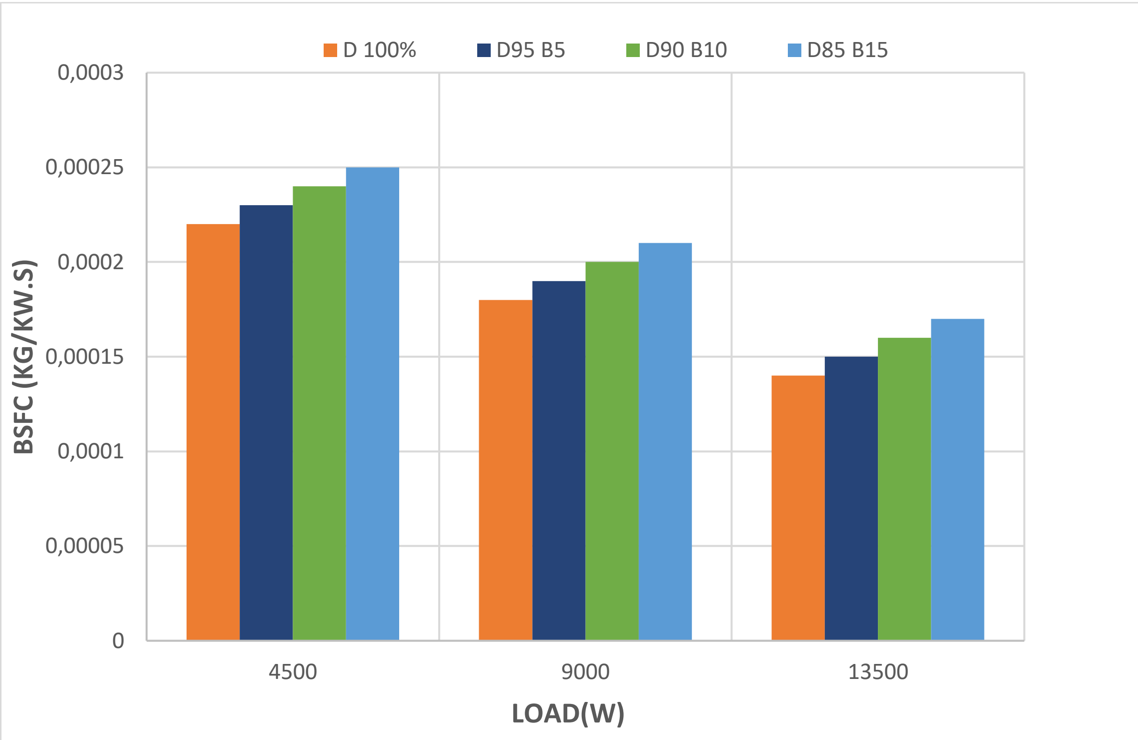

Figure 4.6. BSFC vs. engine load at 1400 rpm.

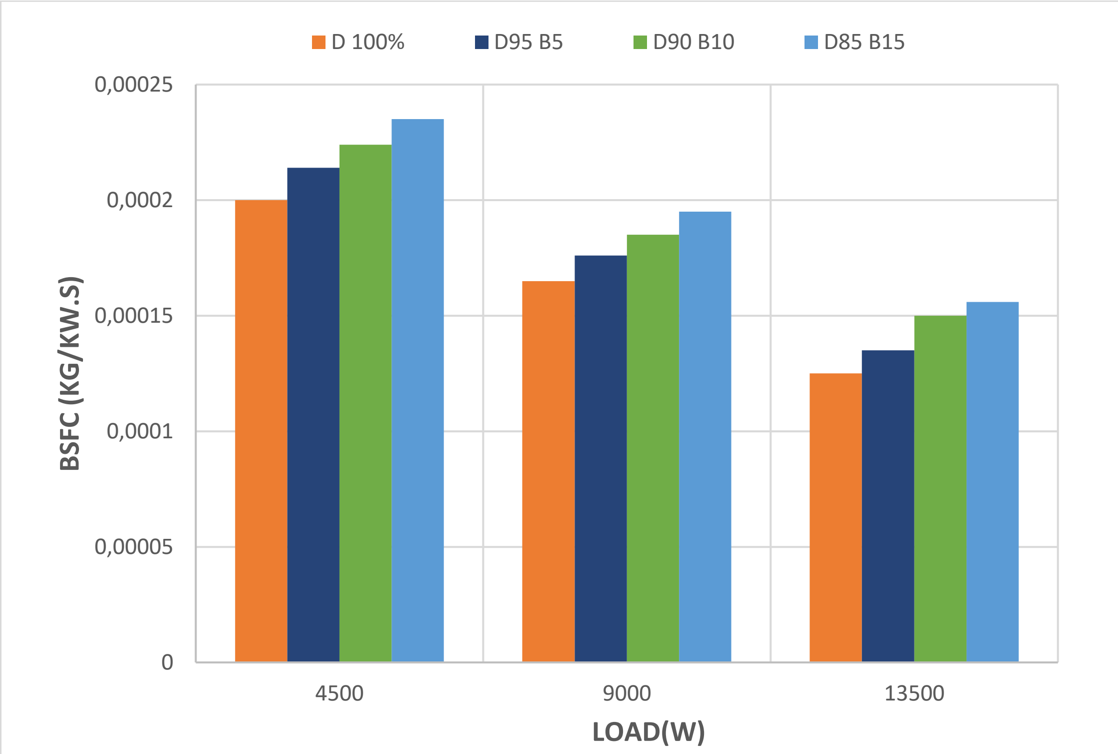

Figure 4.7. BSFC vs. engine load at 1600 rpm.

4.2.4. Brake-Specific Fuel Consumption with Speed

Figure 4.8 shows the relationship between brake specific fuel consumption and speed at a load of 13500 w. In general, BSFC increases with increasing engine speed and the percentage of biofuel in the mixture. The recorded difference BSFC from pure diesel value was at 1200 rpm with values of 6%, 13.3%, and 20% respectively for mixtures D95-B5, D90-B10, and D85-B15. The difference BSFC values recorded at 1400 rpm were 7%,14.3%, and 25% respectively for mixtures D95-B5, D90-B10, and D85-B15, and the difference BSFC values recorded at 1600 rpm were 8%,20%, and 25% respectively for mixtures D95-B5, D90-B10, and D85-B15 All mixtures showed an increase in fuel consumption to compensate for the energy shortfall, To get the same energy output from the engine, it is essential to inject a greater mass flow into the combustion chamber to offset the energy loss caused by the lower calorific value. As anticipated, the use of biodiesel in diesel fuel has increased fuel consumption in accordance with the load and operating circumstances. The same observations were observed in the reference [68,69].

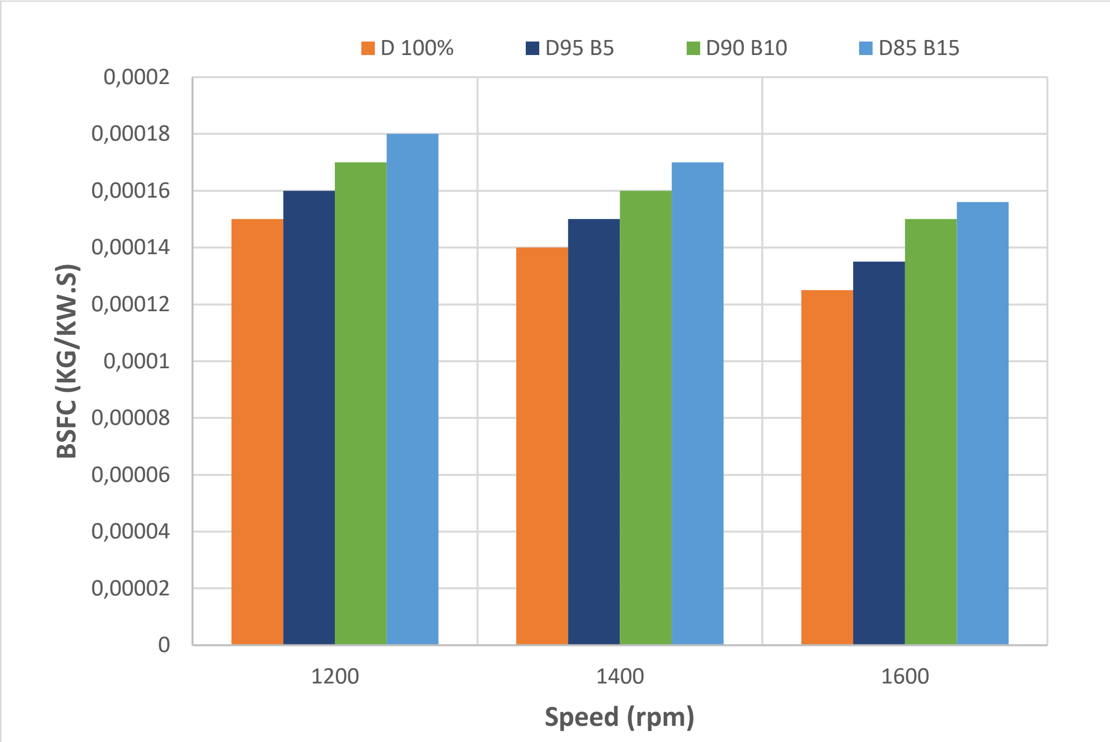

Figure 4.8. BSFC vs. speed at 13500 w load.

4.3. ADDING OF NANO ALUMINUM OXIDE PARTICLE

The research on blending biodiesel with diesel revealed that D85-B15 is the best combination of all mixes used in the trial. Accordingly, the addition of nanoparticles to this mix has occurred only at three levels of 50 ppm, 75 ppm and 100 ppm.

The following is a discussion of the results.

4.3.1. Brake Thermal Efficiency

Figures 4.9, 4.10, and 4.11 illustrate the impact of introducing aluminum oxide particles into a blend of diesel and biofuel at various loads and varied speeds (1200, 1400, and 1600 rpm) on Brake Thermal Efficiency (BTE). An increased engine speed increased brake thermal efficiency (BTE) for all mixes. The engine operates within a speed range of 1200 to 1600 revolutions per minute (rpm). Including nano aluminum oxide resulted in a significant improvement in the thermal efficiency of the brakes. Effective dispersion of nanoparticles in biodiesel blends may address issues related to blockage and fuel atomization. Nanoparticles possess a highly responsive surface that facilitates their role as a possible catalyst in chemical reactions. These nanoparticles increase the surface area to volume ratio, improving combustion and reducing fuel consumption. The findings indicated a positive correlation between the mixture's proportion of aluminum oxide particles and the speed and BTE. Specifically, the thermal braking efficiency also increased when the percentage of aluminum oxide particles and the speed increased. The blends, namely D85-B15-50ppm, D85-B15-75ppm, and D85-B15-100ppm, exhibited superior performance to pure diesel. The same observations were observed in the results [70,71]

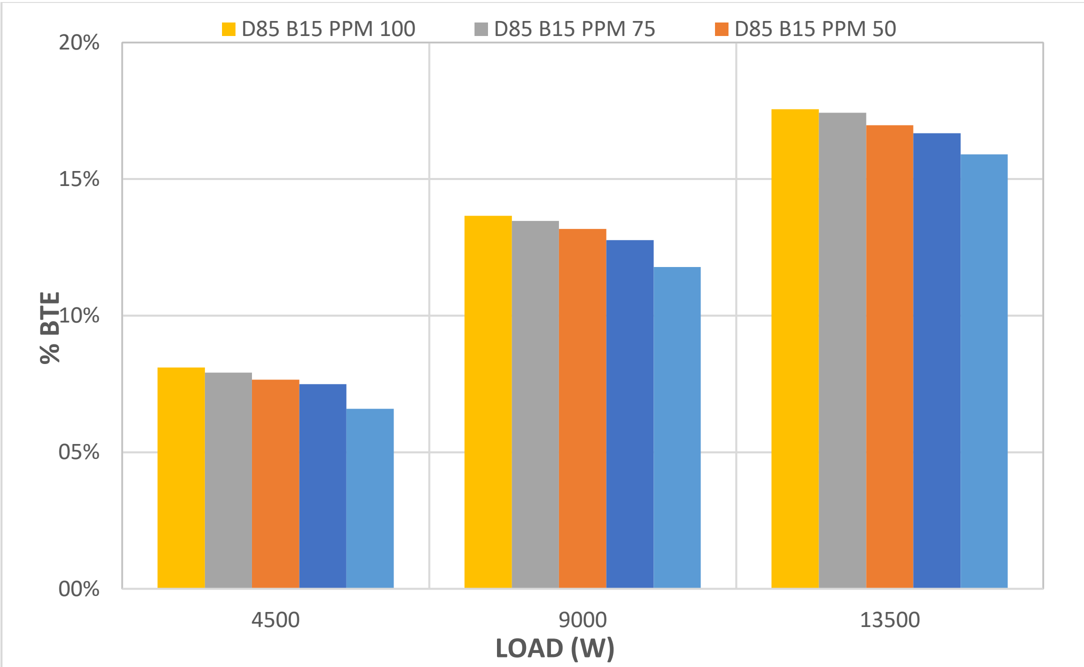

Figure 4.9. Effect of adding aluminum oxide particles to a mixture of diesel and biofuel at different loads at a speed of 1200 rpm.

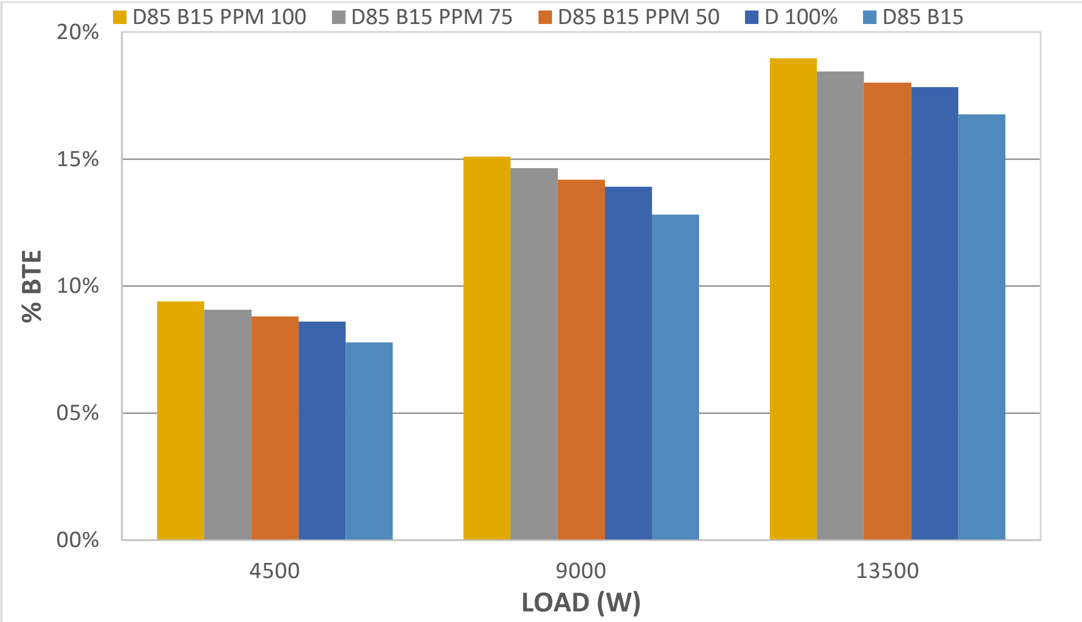

Figure 4.10. Effect of adding aluminum oxide particles to a mixture of diesel and biofuel at different loads at a speed of 1400 rpm.

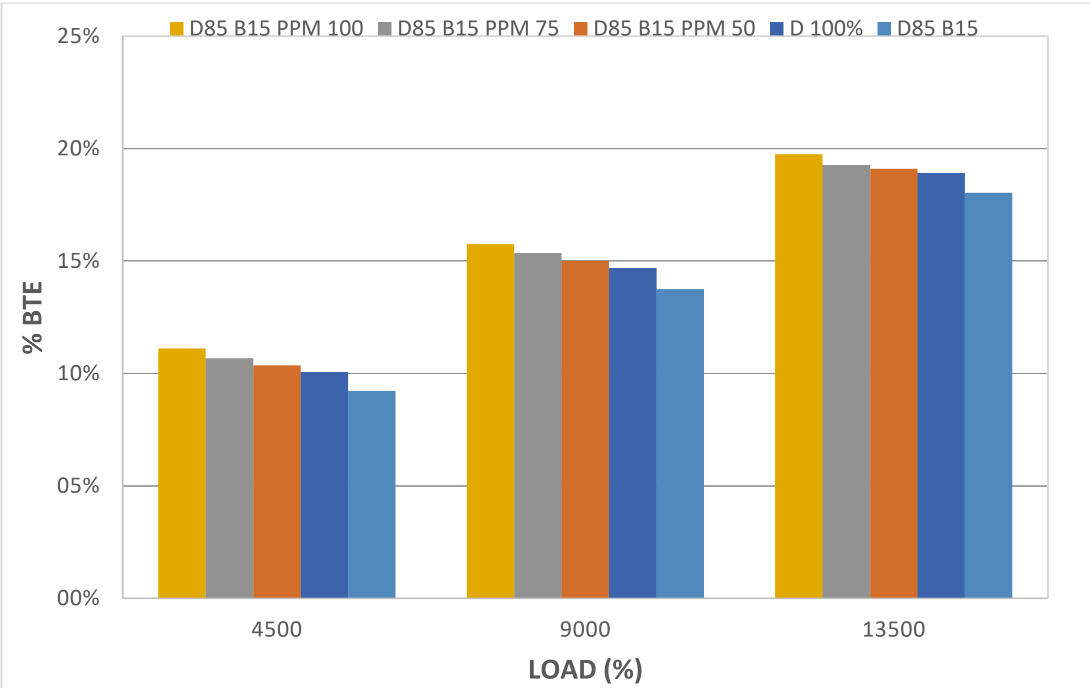

Figure 4.11. Effect of adding aluminum oxide particles to a mixture of diesel and biofuel at different loads at a speed of 1600 rpm.

4.3.2. Brake Thermal Efficiency with Speed

Figure 4.12 shows the relationship between braking thermal efficiency and speed at load 13500 W. Generally, BTE increases with engine speed. The difference value for BTE from pure diesel recorded at 1200 rpm was 1.7%, 4%, and 5%, respectively, for D85B15PPM50, D85B15PPM75, and D85B15PPM100. The difference values for BTE recorded at 1400 rpm were 1.1%, 4.93%, and 6% respectively for mixtures D85B15PPM50, D85B15PPM75, D85B15PPM100, and the difference values for BTE recorded at 1600 rpm were 0.9%, 2.1%, 4.2%, respectively, for mixtures D85B15PPM50, D85B15PPM75, D85B15PPM100. All fuel samples showed an increased BTE value compared to diesel fuel. effective dispersion of nanoparticles in biodiesel blends may address issues related to blockage and fuel atomization. nanoparticles possess a highly responsive surface that facilitates their role as a possible catalyst in chemical reactions, improving combustion and reducing fuel consumption. The same observations were observed in the reference [72,73]

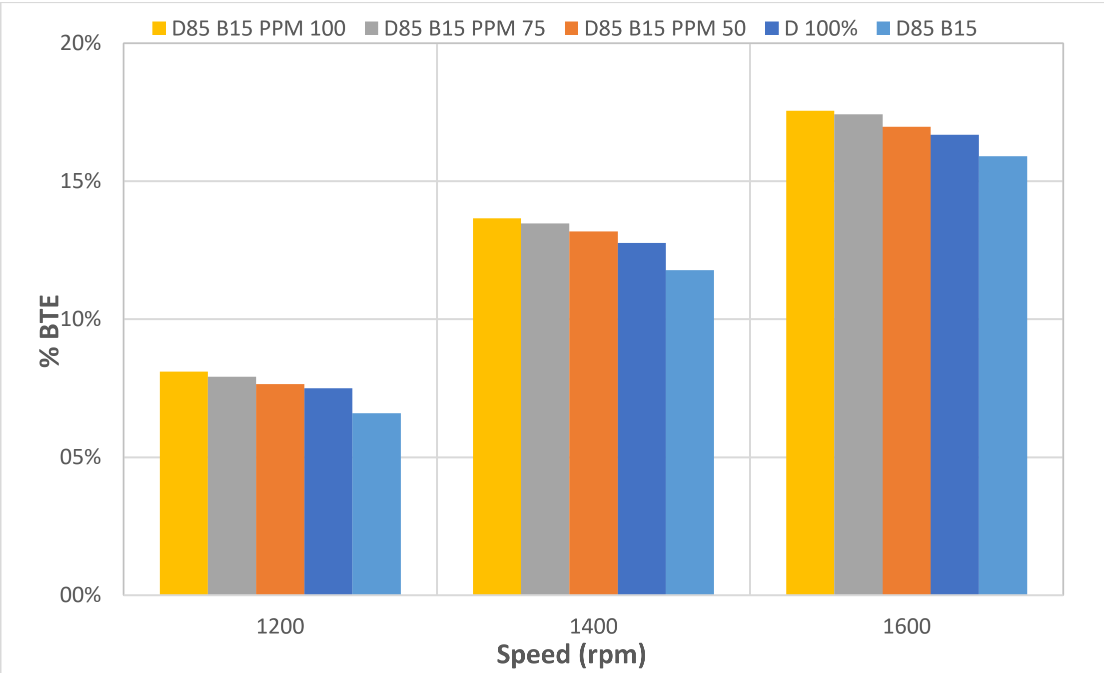

Figure 4.12. BTE vs. speed at 13500 w load.

4.4. INFLUENCE OF NANO-ADDITIVES ON BRAKE-SPECIFIC FUEL CONSUMPTION

Figures 4.13, 4.14, and 4.15 illustrate the variation in brake-specific fuel consumption (BSFC) at various nano doses compared to pure diesel and a 15% biodiesel blend at an engine speed of 1200 rpm. BSFC, or Brake Specific Fuel Consumption, measures the fuel used per unit of power and time. Typically, biodiesel has a higher BSFC compared to diesel. This is because biodiesel has a lower calorific value than diesel, which means more fuel is needed to maintain the same power output in an engine. The researchers found that adding nanoparticles to diesel fuel effectively improved the engine's BSFC. This section investigates the impact of incorporating nano-aluminum oxides into biodiesel and diesel fuels on BSFC. Three nanoparticles (Al_2O_3, CNT, and TiO_2) were dispersed into a biodiesel mixture to form a nanofuel combination. The obtained findings closely aligned with those reported in the literature by Fayez et al.[74]. The findings indicate that when the speed increases, the BSFC decreases. Moreover, fuels with nano additives exhibit significantly reduced BSFC compared to diesel, particularly those with Al2O3 additives. The dispersion of nanoparticles in biodiesel enhanced the fuel mixture by addressing issues related to clogging and atomization. Furthermore, these nanoparticles enhance the surface area to volume ratio, enhancing combustion and reducing fuel consumption. The consumption of the blends (D85-B15-50PPM, D85-B15-75PPM, D85-B15-100PPM) was lower than that of pure diesel fuel. The same observations were observed in the reference [70,71].

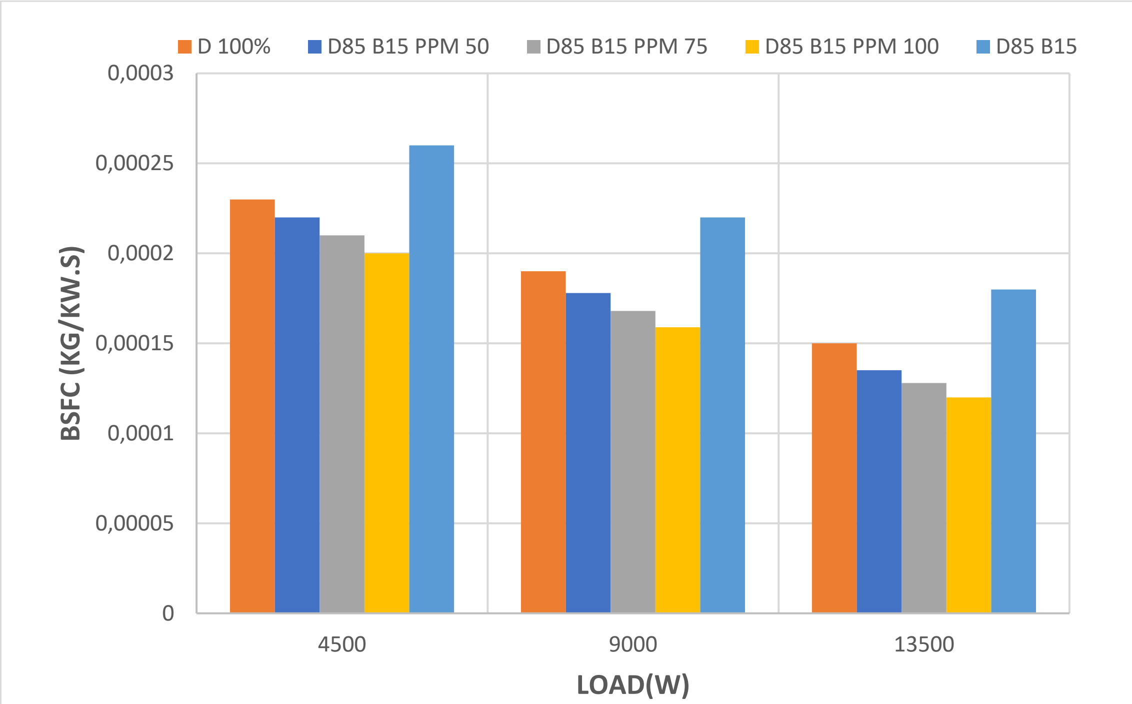

Figure 4.13. Difference in BSFC at different nano dosages when compared to plain diesel and a 15% biodiesel mix at 1200 rpm.

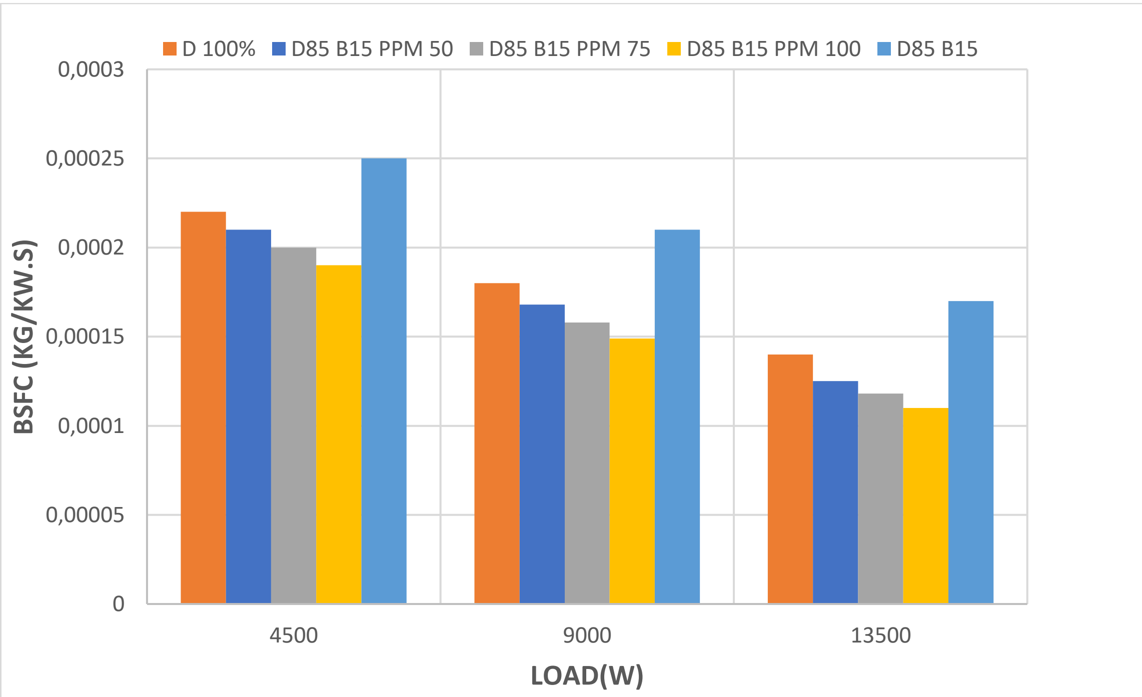

Figure 4.14. Difference in BSFC at different nano dosages when compared to plain diesel and a 15% biodiesel mix at 1400 rpm.

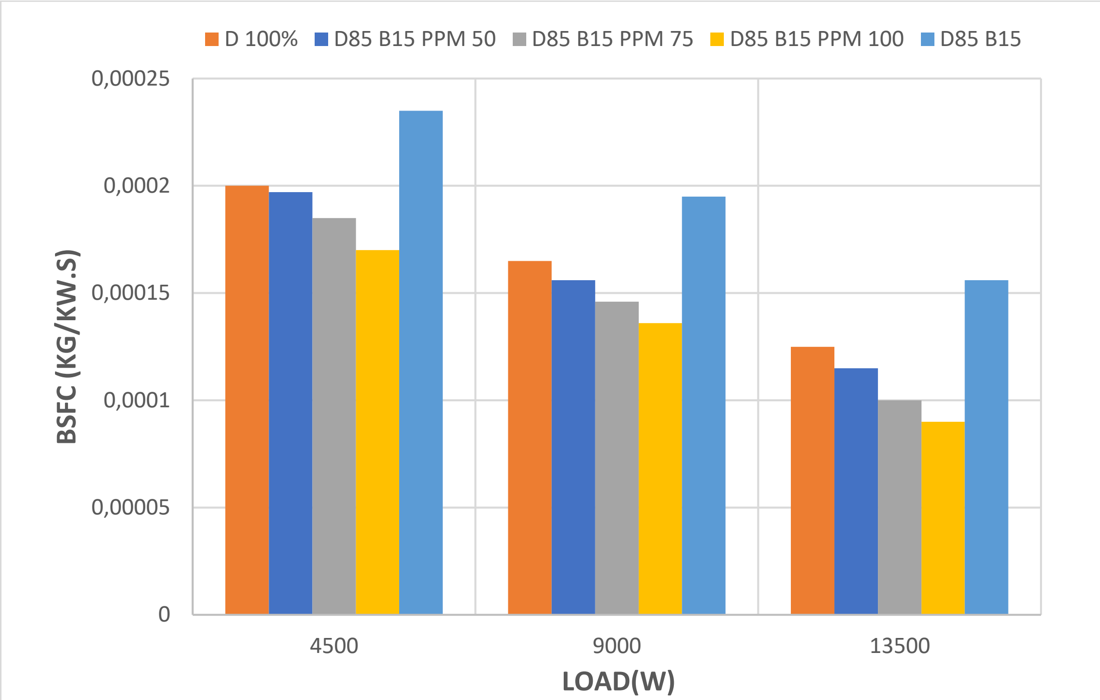

Figure 4.15. Difference in BSFC at different nano dosages when compared to plain diesel and a 15% biodiesel mix at 1600 rpm.

4.4.1. Brake-Specific Fuel Consumption with Speed

The BSFC was calculated during engine operation at 13500 W loads with increasing speed from 1200 to 1600 rpm, as shown in Figure 4.16. In general, the value of BSFC decreases as the engine speed increases. The recorded difference BSFC value was at 1200 rpm with values of 10%, 15%, and 20%, respectively, for mixtures D85B15PPM50, D85B15PPM75, and D85B15PPM100. The difference BSFC values recorded at 1400 rpm were 10.7%,16%, and 22%, respectively, for mixtures D85B15PPM50, D85B15PPM75, and D85B15PPM100, and the difference BSFC values recorded at 1600 rpm were 8%,20%, and 28%, respectively, for mixtures D85B15PPM50, D85B15PPM75, and D85B15PPM100 all fuels with nano additives exhibit significantly reduced BSFC compared to diesel, The dispersion of nanoparticles in biodiesel enhanced the fuel mixture by addressing issues related to clogging and atomization. Furthermore, these nanoparticles enhance the surface area-to-volume ratio, enhancing combustion and reducing fuel consumption. The same observations were observed in the reference [72,73].

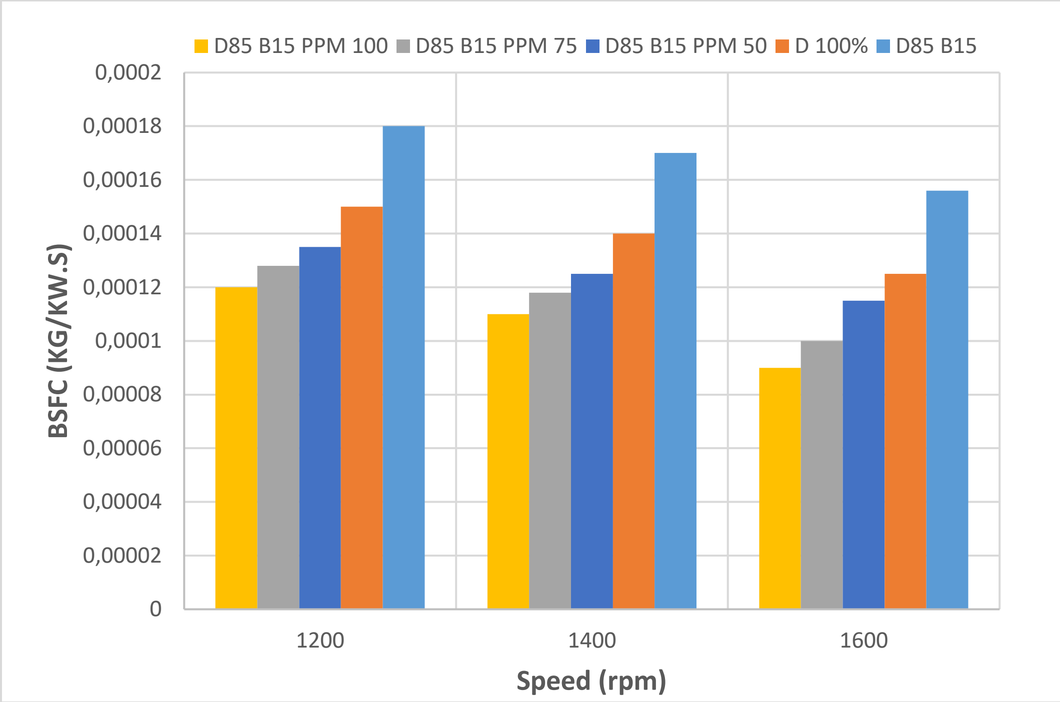

Figure 4.16. BSFC vs. speed at 13500 w load.

PART 5

CONCLUSIONS AND RECOMMENDATIONS

5.1. INTRODUCTION

This chapter summarizes the findings of experimental studies conducted on compression ignition engines when fed with various supplemental fuels. As a result, the stages of the study yielded the following results and recommendations for further work.

5.2. CONCLUSIONS

- Eucalyptus biodiesel may be used in compression ignition engines that do not require instrument modifications. When compared to other types of biodiesel, eucalyptus biofuel is less expensive.
- Eucalyptus trees are considered non-edible sources and, therefore, suitable for biodiesel production. As a green energy fuel, eucalyptus biodiesel has performed admirably.
- Many great qualities of nano-additives include a wide contact surface area, great stability, excellent catalytic performance, high combustion heat, and so on. These benefits may be used in fuel to promote internal combustion engine burning.
- Researchers have generally explored nano-additives such as CuO, Al_2O_3, MWCNT, CeO_2, GO, CNT, and TiO_2, all of which are included in biodiesel and diesel fuel mixes. These modifications also yielded impressive outcomes.
- Adding nano-aluminum oxide is important to improve performance. Adding 50 ppm, 75 ppm, and 100 ppm of nano-aluminum oxide had indeed led to improved engine performance.

- When nano-additives accomplish substantial success in the field of internal combustion engines, concern should be given regarding their adverse consequences. This is because nanoparticles not engaged in the combustion process are expelled into the atmosphere following the engine combustion process.

5.3. RECOMMENDATIONS FOR FURTHER STUDIES

- Testing of different mixing ratios (such as between B30 and B100) to obtain the full amount of eucalyptus biodiesel for use in compression ignition engines.
- Using several nanoparticle types in concentrations ranging from 100 ppm to 200 ppm and adding eucalyptus biodiesel to the mix.
- Testing the influence of several Fe_3O_4-Al_2O_3 hybrid nanoparticles on combustion and performance in eucalyptus biodiesel.
- Studying the impact of eucalyptus biodiesel and nanomaterials on exhaust gas emissions.
- Calculating the economic feasibility of any of the potential endeavors suggested above.

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APPENDIX A.

SPECİFİCATİONS OF THE SPEED MEASURİNG DEVİCE

BOCE
发电机组控制器专业制造商

重庆博策科技有限公司
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BC−GT30 RPM Meter

◆ **Brief Introduction**

BC-GT30 is one small and light module with low price used for checking and demonstrating RPM of the engine. The switch on its back can adjust and set parameters in order to meet different requests from users. Besides, it uses the European-style terminals for connection which is more convenient for installation and detachment.

◆ **Features**

- LED circuit can demonstrate rough RPM
- 4-digital tube can demonstrate accurate RPM
- The option of over-speed alarm and its demonstration function is available.
- The switch on the back can set and adjust the parameters.

◆ **Specifications and setting**

Note:

The meter shall be available after re-supplying power once the parameters is changed.

The power shall be cut off once the over-speed alarms.

➢ SW1：Rated Engine Speed

No	SW1	Rated speed
1	OFF	1500 RPM
2	ON	1800 RPM

➢ SW2、SW3：Output of Over-speed

No	SW2	SW3	output
1	OFF	OFF	Not available
2	OFF	ON	Interval 6sec
3	ON	OFF	Output 10sec
4	ON	ON	Output sustainable

➢ SW4、SW5、SW6：Alarm of Over-speed

No	SW4	SW5	SW6	Alarm
1	OFF	OFF	OFF	Not available
2	OFF	OFF	ON	105%
3	OFF	ON	OFF	110%
4	OFF	ON	ON	115%
5	ON	OFF	OFF	120%
6	ON	OFF	ON	125%
7	ON	ON	OFF	130%
8	ON	ON	ON	135%

➢ SW7、SW8、SW9、SW10：Flywheel teeth

No	SW7	SW8	SW9	SW10	teeth
1	OFF	OFF	OFF	OFF	60
2	OFF	OFF	OFF	ON	96
3	OFF	OFF	ON	OFF	108
4	OFF	OFF	ON	ON	110
5	OFF	ON	OFF	OFF	118
6	OFF	ON	OFF	ON	125
7	OFF	ON	ON	OFF	129
8	OFF	ON	ON	ON	136
9	ON	OFF	OFF	OFF	138
10	ON	OFF	OFF	ON	141
11	ON	OFF	ON	OFF	142
12	ON	OFF	ON	ON	143
13	ON	ON	OFF	OFF	145
14	ON	ON	OFF	ON	159
15	ON	ON	ON	OFF	173
16	ON	ON	ON	ON	195

◆ **Secification**

Power：*DC 8～36 V*
Consuming power：*MAX 1 W*
Weight：*100 G*
Negative output maximum：*DC1A*
Frequency range of input signals：*0～10kHz，AC 5～100 V*
Size(W * H * D)：*72mm * 72mm * 58mm*
Installation hole(W * H)：*67mm * 67mm*
Operation temperature：*-10℃ ～ 85℃*

专业技术 专心服务
Professional Technology Honest Service

RESUME

Hasan Ali Hasan HASAN, a mechanical engineer, graduated from the College of Engineering, Tikrit University, and obtained a Bachelor degree in 2021. He is currently studying for a Master degree at Karabük University in Mechanical Engineering.