EFFECT OF BLENDING CUO NANOPARTICLES AND BIOFUEL (SUNFLOWER) WITH NEAT FUEL ON DIESEL ENGINE PERFORMANCE

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MASTER THESIS
MECHANICAL ENGINEERING

Sinan Mohsin Kareem KAREEM

Thesis Advisors
Assist. Prof. Dr. Abdulrazzak Ahmed Saleh AKROOT
Assist. Prof. Dr. Ibrahim Thamer NAZZAL

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Assist. Prof.Dr. Ibrahim Thamer NAZZAL

T.C.
Karabük University
Institute of Graduate Programs
Department of Mechanical Engineering
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I certify that in my opinion the thesis submitted by Sınan Mohsın Kareem KAREEM titled “EFFECT OF BLENDING CUO NANOPARTİCLES AND BİOFUEL (SUNFLOWER) WITH NEAT FUEL ON DİESEL ENGİNE PERFORMANCE” is fully adequate in scope and in quality as a thesis for the degree of Master of Science.

Assist. Prof. Dr. Abdurazzak Ahmed Saleh AKROOT ....
Thesis Advisor, Department of Mechanical Engineering
Assist. Prof. Dr. Ibrahim Thamer NAZZAL ....
Co-Advisor, Department of Mechanical Engineering of Iraq University of Tikrit

This thesis is accepted by the examining committee with a unanimous vote in the Department of Department of Mechanical Engineering as a Master of Science Master of Science thesis. 24/01/2024

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ABSTRACT

M. Sc. Thesis

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Sinan Mohsin Kareem KAREEM

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Thesis Advisors:
Assist. Prof. Dr. Abdurazzak Ahmed Saleh AKROOT
Assist. Prof. Dr. Ibrahim Thamer NAZZAL
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In this research, a diesel engine's performance characteristics were examined using a fuel additive in the biodiesel mixture. The biodiesel used in the current study was obtained from sunflower oil, and copper oxide (CuO) nanoparticle additive was added to the resulting biodiesel. Concentration of CuO nanoparticles used (50 ppm,75 ppm,100 ppm). This research used a Korean-origin KiaBongo2701 Model 12 type four-cylinder, 2.7-liter volume, four-stroke water-cooled direct injection diesel engine. The engine is equipped with seven types of fuel: pure diesel as the base fuel, type II (D95B5) is a mixture of pure diesel fuel and biofuels respectively (95-5%), type III (D92B10) is a mixture of pure diesel fuel and biofuels respectively (90-10%)), type IV (D85B15) is a mixture of pure diesel fuel and biofuels (85-15%), respectively, and three samples are mixed with three different proportions (50, 75 and 100 ppm) of nanoparticles into a mixture of pure diesel fuel and biofuels (85-15%), respectively.

The fuel mixtures obtained by the addition of fuel and coded as (D85B15PPM50), (D85B15PPM75), and (D85B15PPM100), respectively, were compared with biodiesel in terms of their effects on engine performance and they were mixed using both a mechanical mixer and an ultrasonic device. By operating the engine at three different speeds (1200, 1400, and 1600 rpm) and three other loads, Its effects on performance indicators, thermal efficiency (BTE), and specific fuel consumption (BSFC) were examined.

Copper oxide nanoparticles were added to the mixture (D85B15) because it showed less performance and brought it closer to the performance of pure diesel. It is observed that performance properties increase by increasing the concentration of CuO nanoparticles in a mixture (D85B15). Thermal efficiency (BTE) increased by 4.63% for the mixture (D85B15PPM50) compared to the nanoparticle-free mixture (D85B15) at the speed of 1600 rpm, and the thermal efficiency increased by 5.13% and 5.13%, respectively, for the mixture (D85B15PPM75) and mixture (D85B15PPM100) at the same speed. It increased by 5.56%.

A power close to diesel fuel was achieved with (D85B15PPM100) fuel. There was a noticeable increase in BTE with increasing speed and loads.

The results noted that D85B15 increases fuel consumption for sunflower oil due to the lower calorific value of biodiesel compared to diesel; it is clear that there is a significant difference in energy content. The incorporation of nanoparticles resulted in a substantial improvement in BSFC along with an increase in the concentration of nanoparticles in the mixtures. The best results were recorded at full load, as the 100 ppm scale addition of copper oxide resulted in a modest increase in fuel consumption.

Keywords **:** Nanoparticle; biodiesel; diesel engine; sunflower oil; fuel.
Science Code : 91413

ÖZET

Yüksek Lisans Tezi

CUO NANOPARTİKÜLLERİ VE BİYOYAKITIN (AYÇİÇEĞİ) SAF YAKITLA HARMANLANMASININ DİZEL MOTOR PERFORMANSINA ETKİSİ

Sınan Mohsin KAREEM

Karabük Üniversitesi
Lisansüstü Eğitim Enstitüsü
Makine Mühendisliği Anabilim Dalı

Tez Danışmanları:
Dr. Öğr. Üyesi Abdurazzak Ahmed Saleh AKROOT
Dr. Öğr. Üyesi Ibrahim Thamer NAZZAL
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Bu araştırmada, biyodizel karışımında bir yakıt katkı maddesi kullanılarak dizel motorunun performans özellikleri incelenmiştir. Mevcut çalışmada kullanılan biyodizel ayçiçek yağından elde edilmiştir ve elde edilen biyodizel içerisine bakır oksit (CuO) nanopartikül katkı maddesi ilave edilmiştir. Kullanılan CuO nanopartiküllerinin konsantrasyonu (50 ppm,75 ppm,100 ppm). Bu araştırma, Kore menşeili KiaBongo2701 Model 12 tipi dört silindirli, 2.7 litre hacimli, dört zamanlı su soğutmalı direkt enjeksiyonlu dizel motor kullanılarak yapılmıştır. Motor yedi tip yakıtla donatılmıştır: temel yakıt olarak saf dizel, tip II (D95B5) sırasıyla saf dizel yakıt ve biyoyakıtların bir karışımıdır (% 95-5), tip III (D92B10) sırasıyla saf dizel yakıt ve biyoyakıtların bir karışımıdır (% 90-10), tip IV (D85B15) sırasıyla saf dizel yakıt ve biyoyakıtların bir karışımıdır (% 85-15), ve üç numune sırasıyla saf dizel yakıt ve biyoyakıt karışımına (%85-15) üç farklı oranda (50, 75 ve 100 ppm) nanopartikül ilavesi ile elde edilen ve sırasıyla (D85B15PPM50), (D85B15PPM75),(D85B15PPM100) olarak kodlanan yakıt karışımlarının motor performansı üzerindeki etkileri açısından biyodizel ile karşılaştırılmış, bunlar hem mekanik karıştırıcı hem de ultrasonik bir alet kullanılarak karıştırılmıştır. Motor üç farklı hızda (1200, 1400 ve 1600 rpm) ve üç farklı yükte çalıştırılarak; performans göstergeleri, termik verim (BTE) ve özgül yakıt tüketimine (BSFC) etkileri incelenmiştir.

Karışıma (D85B15) daha az performans gösterdiği ve saf dizelin performansına yaklaştırdığı için bakır oksit nanopartikülleri eklenmiştir. Bir karışımdaki CuO nanopartiküllerinin konsantrasyonunun arttırılmasıyla performans özelliklerinin artığı görülmektedir (D85B15). Termik verim (BTE), 1600 dev/dak hızında nanopartikül içermeyen karışıma (D85B15) kıyasla karışım (D85B15PPM50) için %4,63 arttı ve termik verim aynı hızda karışım (D85B15PPM75) ve karışım (D85B15PPM100) için sırasıyla yüzde %5,13 ve %5,56 artmıştır.

(D85B15PPM100) yakıtıyla dizel yakıtına yakın bir güç elde edilmiştir Artan hız ve yüklerle BTE'de gözle görülür bir artış oldu.

D85B15'in yakıt tüketimini artırdığını unutmayın ayçiçek yağı için biyodizelin dizele kıyasla daha düşük kalori değeri nedeniyle, enerji içeriğinde önemli bir fark olduğu açıktır. Nanopartiküllerin dahil edilmesi, karışımlardaki nanopartiküllerin konsantrasyonunda bir artışla birlikte BSFC'de kayda değer bir gelişme ile sonuçlandı. 100 ppm ölçekli bakır oksit ilavesi yakıt tüketiminde makul bir artışla sonuçlandığından, en iyi sonuçlar tam yükte kaydedilmiştir.

Anahtar Kelimeler : Nanoparçacık, biyodizel, dizel motor, ayçiçeği, yakıt.
Bilim Kodu **:** 91413

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SYMBOLS AND ABBREVIATIONS INDEX

SYMBOLS

BP : Brake Power
BTE : Brake Thermal Efficiency
CI : Compression Ignition
CN : Cetane Number
CV : Calorific Value
I : Current
$\dot{m}$: Mass of fuel consumed per second
PF : Power Factor
rpm : Revolution per minute
t : Time
TP : Total Electric Power
V : Voltage
ρ : Density
μ : Viscosity

ABBREVIATIONS

ASTM : American Society for Testing and Materials
B.D.C. : Bottom dead center
BSFC : Brake specific fuel consumption (kg/kw.s)
CI : Cetane Index
CuO : Oxides of copper
D : diesel pure 100%
D85-B15 : Blend of 85% pure diesel and 15% biodiesel volume
D90-B10 : Blend of 90% pure diesel and 10% biodiesel volume
D95-B5 : Blend of 95% pure diesel and 5% biodiesel volume

KOH : Potassium hydroxide
N : Nanoparticles
ppm : Parts per million
T.D.C. : Upper dead center

PART 1

INTRODUCTION

1.1.INTRODUCTION

The Rudolph Diesel engine was invented and first introduced in August 1893. It is an internal combustion engine in which fuel ignition occurs as a result of the high temperature of the air in the cylinder due to mechanical stresses, so this engine is called a compression ignition engine (CI engine). Diesel engines are durable and efficient. Most diesel engines in commercial vehicles are direct injection engines, where fuel is injected directly into the cylinder and burned in the combustion chamber above the piston. The thermal efficiency of gasoline engines is 24%, while the thermal efficiency of diesel engines is 43%. Excluding calorific value or energy content, these engines differ from engines that use air and fuel with spark plugs, such as gasoline engines or gas engines (which use gaseous fuels such as natural gas or liquefied petroleum gas). The required properties of hydrocarbon fuel used in diesel engines differ significantly from those used in gasoline engines. The cetane number, density, viscosity, low-temperature characteristics, sulfur content, aromatic content, volatilization, and boiling range all form the basic properties of diesel fuel required for satisfactory diesel performance. The range of the boiling point is determined by the initial and final boiling points on the distillation curve [1].

Diesel engines work only by compressing air, which is introduced into the chamber during the drag stroke and compressed during the compression stroke. This increases the air temperature inside the cylinder, causing the dispersed diesel fuel to ignite and be injected into the combustion chamber. When fuel is injected into the air just before combustion, the fuel diffusion is uneven, which is known as a heterogeneous mixture. The torque produced by the diesel engine is controlled by changing the air-to-fuel ratio instead of throttling the air inside. Diesel engines rely on varying amounts of injected fuel, and the ratio of air to fuel is usually large. A diesel engine has the highest thermal efficiency (engine efficiency) of any practical internal or external combustion engine due to its high expansion ratio [2].

Diesel engines can be designed with two- or four-stroke combustion cycles and were originally used as a more efficient alternative to stationary steam engines. Diesel engines have been used in submarines and ships since 1910, in addition to being used in locomotives, buses, trucks, heavy machinery, agricultural equipment, and later, in power plants. In the 1930s, diesel engines gradually began to be used in some cars. After the energy crisis of the seventies, the need to increase fuel efficiency led most major automakers at one point to offer diesel-powered models, even for very small cars [3,4].

1.1.1. Two-Stroke Engine

This is a type of internal combustion engine that takes two piston movements (up and down) during one power cycle to complete the power cycle, which is also completed in one crankshaft cycle. A four-stroke engine, on the other hand, requires four piston strokes to complete a power cycle during two crankshaft cycles. In a two-stroke engine, the end of the combustion stroke and the beginning of the compression stroke occur at the same time, resulting in simultaneous intake and exhaust or scavenging operations.

Two-stroke engines often have a high power-to-weight ratio, making power available over a narrow rotational speed range called the power range. Two-stroke engines have fewer moving parts than four-stroke engines, so they are cheaper to manufacture. Countries and regions with strict emissions regulations are phasing out two-stroke engines in automotive and motorcycle applications. Two-stroke engines with small displacements remain common in scooters and motorcycles in areas with weak or non-existent regulations [5].

1.1.2. Four-Stroke Engine

A four-stroke internal combustion engine (IC) is a motor whose pistons perform four separate strokes during the rotation of the crankshaft. A stroke refers to the complete movement of the piston in any direction along the drum. The four separate strokes are described below:

1.1.2.1. Pull

This is also called induction or suction. The piston stroke begins at the upper dead center (T.D.C.) and ends at the lower dead center (B.D.C.). During this stroke, the intake valve must be in the open position while the piston pulls the mixture into the cylinder by creating a partial vacuum (negative pressure) in the cylinder by moving it downwards.

1.1.2.2. Pressure

This stroke starts at B.D.C., or the end of the suction stroke. and ends at T.D.C. During this stroke, the piston compresses the mixture to prepare it for ignition during the power stroke. At this stage, both the intake and exhaust valves are closed.

1.1.2.3. Combustion

Also known as energy or ignition, this is the beginning of the second cycle in the quadruple cycle. At this point, the crankshaft rotates a full 360 degrees. While the piston is at the top of the dead center. (at the end of the compression stroke), the compressed air-fuel mixture is ignited by a spark plug (in gasoline engines) or by heat from high pressure (in diesel engines), pushing the piston down the lower dead center. This movement creates mechanical action in the engine which in turn rotates the crankshaft.

1.1.2.4. Exhaust

Also called outlet, during the exhaust stroke, the piston returns to the lower dead center again to T.D.C., while the exhaust valve is open. This action forces the spent air-fuel mixture out of the exhaust port [6].

1.2.FOSSIL FUELS

These are substances containing hydrocarbons, examples of which include crude oil, natural gas and coal, found naturally within the Earth’s crust from the remains of long-extinct animals and plants[7]. These fossil fuels are extracted and can be burned to provide heat for direct use (such as heating or cooking), to power engines (such as internal combustion engines in cars), or to generate electricity. Some fossil fuels are filtered into derivatives such as kerosene, gasoline, and propane before being burned. The basis of fossil fuels is the anaerobic decomposition of dead buried organisms, which contain organic molecules resulting from photosynthetic action. Switching from these materials to high-carbon fossil fuels usually requires a geological process lasting for millions of years [8,9].

1.3. DIESEL FUEL

Diesel fuel is produced from a number of different sources, the most common of which is oil extracted from the ground (and which incidentally will be depleted in the near future) and is a mixture of several hydrocarbons. Diesel fuel has a higher calorific value than other fossil fuels, so it simultaneously provides both strong and economical torque. The cetane number can also be considered an identification mark indicating the performance of diesel fuel. Diesel fuel differs from other fuels in the way it ignites in the engine. The pressure inside the combustion chamber increases and the temperature rises, causing ignition. It is used in conventional diesel engines for trucks and public transport, as well as in generators. There are also types used to power ship engines [10,11].

1.4. BIODIESEL

Biodiesel is a form of diesel fuel derived from plants or animals and consists of esters of long-chain fatty acids. It is typically synthesized by chemically reacting fats, such as animal fats (talid), or other vegetable oils with alcohol, resulting in methylation, ethyl, or propyl ester through the process of cross-esterification [12].

Figure 1 shows the numerous sources of biodiesel production. For our ongoing study, we will be utilizing biodiesel derived from sunflower oil.

The process of converting sunflower oil to obtain biodiesel by replacing glycerol from triglycerides with short-chain alcohols is performed in the presence of a catalyst. The process is carried out in an alkaline medium, dissolving the catalyst in methanol, under conditions of low temperature and atmospheric pressure. Therefore, the established process was based on previous work and preliminary experiments in the laboratory. In this process, glycerol and methyl esters (biodiesel) are obtained and separated in two different immiscible phases, distributing an excess of added methanol and catalyst [13–16].

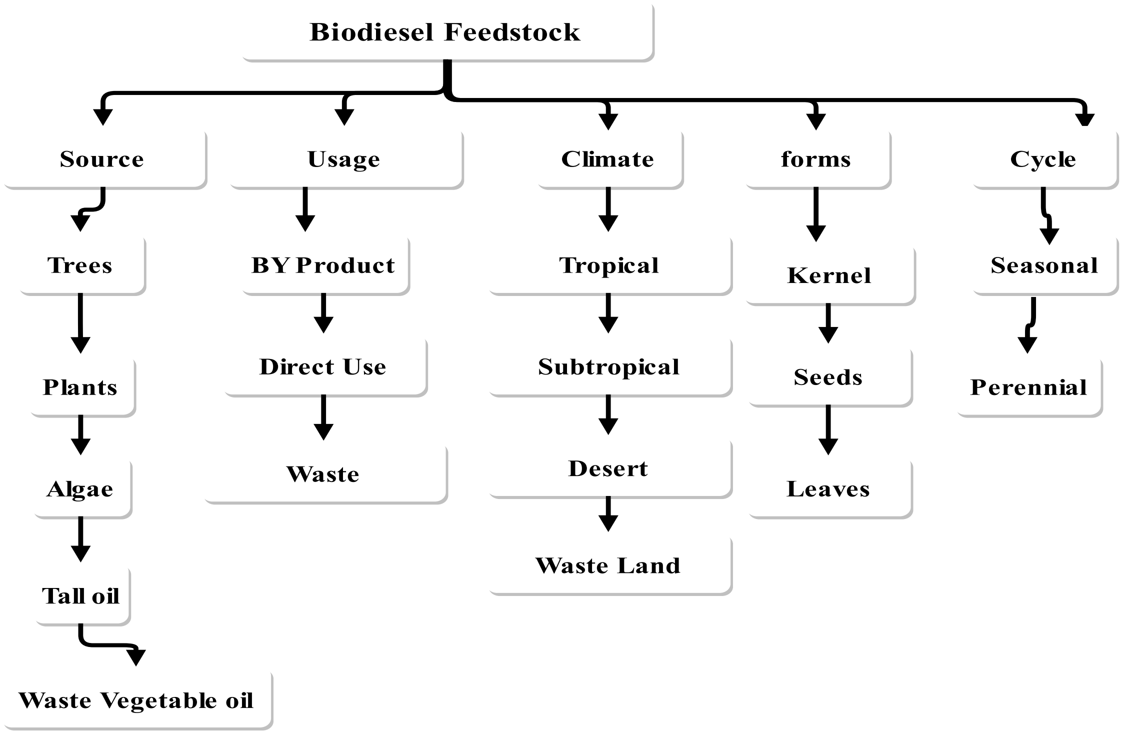


Figure 1.1. Classification of biodiesel feedstock sources.

1.4.1. Advantages of Biodiesel

- Biodiesel is non-toxic and decomposes four times faster than diesel fuel.
- The combination of biodiesel and diesel fuel increases engine efficiency.
- Oxygen content improves the biodegradation process.

- Biodiesel has a lower vapor pressure and a higher flash point than oil, making it safer to handle and store.
- It provides an inexhaustible renewable domestic energy source with an energy content similar to diesel fuel.
- Pure biodiesel decomposes 85-88% in water.
- The oxygen content of biodiesel improves the combustion process and reduces the likelihood of oxidation.
- The use of biodiesel can extend the life of diesel engines due to its lubricating properties being superior to petroleum diesel.
- Biodiesel from crops has positive effects on the environment, including reductions in acid rain and global warming caused by pollution.
- Biodiesel is viewed as being “carbon neutral.” This is due to the fact that the plants that produce biodiesel have a higher capacity for absorbing carbon dioxide from the atmosphere through photosynthesis compared to other plants. Carbon dioxide is what is added to the atmosphere when biofuel is used as fuel in pressure ignition engines.
- Biofuel reduces a country’s dependence on imported oil, and it supports agriculture by creating jobs and a market for local products.
- Petroleum diesel and biodiesel can be combined in any ratio or used separately.
- Biodiesel surpasses diesel in terms of sulfur content, and largely meets future European regulations setting sulfur content at 0.2% and 0.05% by weight in 1994 and 1996, respectively.
- There are fewer risks when handling, transporting and storing biodiesel than working with diesel.
- Biodiesel does not contain aromatic hydrocarbons.
- The by-product of raw glycerin obtained from the cross-esterification process can be used in the production of pharmaceuticals and industrial chemicals.

1.4.2. Disadvantages of Biodiesel

- High viscosity.

- Its density is higher than diesel fuel, but freezing conditions may require the utilization of mixtures.
- Vegetable oil is produced in smaller quantities, which makes it more expensive.

1.5. NANOPARTICLES

These are a modern technology that has been used recently in many fields. This technology has the ability to control and restructure matter at the molecular and atomic levels in the range of approximately 1 to 100 nanometers, exploiting the distinctive properties on this scale compared to those associated with atoms, single molecules or mass behavior. Nanoparticles have many chemical and physical properties due to their relatively infinitesimal size and surface area, which has made them the subject of study and development to reach many diverse applications [17]. Nanoparticles can be manufactured in more than one way, including the biological method, which is easy, fast, inexpensive, and environmentally safe [18–20]. The use of nanoparticles as fuel additives is the most feasible strategy to significantly improve combustion [21]. Nanoparticles exhibit unusual physicochemical properties due to their small size. They have a defined surface area that is much higher than their loose or larger counterparts. The percentage of atoms on the surface of nanoparticles is far higher compared to the inside of the particle, as shown in Figure 1.2. These factors are attributable to the high surface interaction of the nanoparticles. Moreover, the properties of nanoparticles depend on their size and shape.

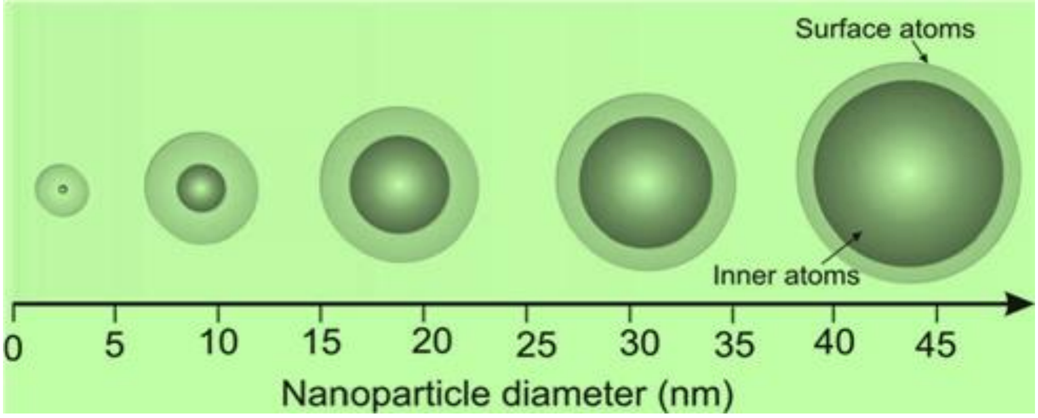


Figure 1.2. Increasing the ratio of surface atoms compared to internal atoms when the diameter of nanoparticles decreases [22].

1.6. METAL OXIDE ADDITIVES

Metal nanooxides such as CeO_2, Al_2O_3, MgO, TiO_2, CuO, ZrO_2, ZnO, etc. are used as fuel additives to promote complete combustion. Metal oxide nanoparticles loaded with fuel during the combustion process provide additional oxygen and greatly reduce harmful exhaust emissions. It has been reported that the high reactivity of nanoparticles leads to premature combustion and short ignition delays. Despite metal oxides or metals being more solid, at nanoscales, they can act as a lubricant [22].

1.7. THE CETANE NUMBER

The main measure of diesel fuel quality is the cetane number, which is a measure of the delay in the ignition of diesel fuel [23]. A higher cetane number indicates that fuel burns more easily when sprayed in hot compressed air The higher the number, the better the fuel burns inside the car engine. It is a classification applied to fuel to assess the quality of its combustion.

1.8. THE CETANE INDEX

The cetane index is a value derived and calculated from fuel density and temperature change as it is fairly close to the real cetane number and is widely used for regular monitoring of fuel ignition quality. A calculated cetane index mainly serves as an alternative method for determining the quality of diesel ignition in order to reduce the need for engine tests [24–26].

1.9. VISCOSITY (μ)

Viscosity refers to the amount of resistance of a liquid to flow and is expressed as the amount of internal friction in a liquid. Therefore, the viscosity of a fuel is an important point to consider when pumping fuel into the combustion chamber as it determines the ability of diesel fuel to flow within the injection system. The viscosity of fuel must not be too low because diesel fuel is also used to lubricate injection units and injectors. Viscosity is an important characteristic of fuel because it affects the form of fuel winnowing when injected into very small droplets in their diameters. This helps to mix the droplets with air easily and ignite the mixture. Therefore, fuel mixing, pressure, and conductivity rates are affected by viscosity [27].

1.10. DENSITY (ρ)

Density is the mass of a specific volume of fuel and is measured in kg/m^3 at a temperature of 15°C. Density is important in the performance of a diesel engine because the injection system in the engine depends on this characteristic and the cetane index can be estimated from fuel density. Fuel density increases with increasing carbon content. When fuel density decreases, it helps to reduce harmful emissions because it contributes to mixing fuel with air better and then completing the combustion of fuel [14,28].

1.11. FLASH POINT

The flash point is defined as the temperature at which the fuel must be heated to produce a mixture of steam and air (above the liquid) that burns and spreads over the surface of the liquid when using a small flame. It can be measured using an ASTM/D93 device Method and the Pensky Martens closed cup tester. The flash point is the lowest temperature that leads to a small flame of a certain size which then ignites steam over a sample and is self-sufficient as a flash point. The flash point is roughly proportional to the fuel boiling range and volatilization. Minimum values range from the flash point typical for diesel fuel from 38°C to 52°C in the United States and to 56°C in some European countries. In terms of engine performance, the flash point of diesel fuel is insignificant. The only factor to consider is the safety of fuel storage [29–32].

1.12. CALORIFIC VALUE

Calorific value is defined as the amount of energy or heat in a fuel or the heating value in a fuel, which is the heat emitted when burning a certain amount of fuel. It is expressed in kilojoules per kilogram (kJ/kg) and is very important. The calorific value of a fuel varies according to the type of fuel. For example, lighter fuels (less dense) have a higher calorific value based on weight, while heavy fuels (denser), such as diesel, have a calorific value based on volume. Determining calorific value depends on knowing the thermal efficiency of a fuel. Moreover, fuel consumption is related to the calorific value [33,34].

1.13. MOTIVATION

The motivation for the use of biofuels with nanoparticles stems from the possibility of improving the combustion properties of compression ignition engines. Despite ongoing studies on the use of nanoparticle additives with biodiesel in diesel engines, the effect of varying the amounts of sunflower oil and nanoparticles on the efficiency and exhaust emissions of a diesel engine has not been studied. Therefore, the effect of sunflower oil with nanoparticles in different proportions on the performance of diesel engines should be considered on a large scale. These ratios will be selected in different proportions of nanoparticles and sunflower oil to select the best ratio that gives the highest performance to diesel engines.

1.14. METHODOLOGY

The fuel mixture is first prepared with different amounts of nanoparticles and sunflower oil before being refueled in the test engine. Next, engine performance is evaluated based on these mixtures and pure diesel. Engine performance includes braking power, brake fuel consumption, and braking thermal efficiency. These parameters of the fuel mixture are evaluated based on experimental data that are collected and compared to pure diesel.

1.15. OBJECTIVE

The primary aims of this experimental study is to Investigate the impact of copper oxide (CuO) nanoparticles as a fuel additive in sunflower oil-based biodiesel blends and examine the impact of nanotechnology on brake-specific fuel consumption (BSFC) and overall engine performance.

PART 2

LITERATURE REVIEW

2.1. INTRODUCTION

The world is currently exploring alternative energy sources, prompting researchers to search for new types of energy sources and resources, also in addition to finding alternative energies to improve the performance of diesel engines and reduce emissions. Research is currently focused on engine fundamentals, fuel consumption and emissions.

This overview focuses on studies that have investigated the effects of nanoparticles on various types of fuel, including pure diesel and biodiesel, the impact of additives on fuel consumption and performance, as well as the emissions that arise from fuel usage. Using nanoparticles can enhance combustion and decrease emissions by improving fuel ignition delay and properties.

2.2. INVESTIGATION INTO THE IMPACT OF PURE DIESEL BLENDED WITH BIODIESEL ON THE PERFORMANCE OF A DIESEL ENGINE

Forson et al. [35], examined tests on a single-cylinder direct fuel injection engine to measure the potential impact of using jatropha oil as an additive to diesel fuel. A mixture of diesel fuel and jatropha oil was used in different proportions and the results were analyzed in terms of chemical and physical properties of the fuel, fuel consumption, power and thermal efficiency of the brakes, torque, and emissions of carbon monoxide, carbon dioxide and oxygen in exhaust gases. It was observed that the diesel fuel Jatropha oil blend at 97.4%/2.6% had a positive effect on brake power and brake thermal efficiency and achieved the lowest fuel consumption. Tests also showed that jatropha oil can be used as a diesel substitute in the engine. jatropha oil is recommended for use with diesel fuel in compression ignition engines, and jatropha oil is a good helper in the process of ignition of diesel fuel.

Azad et al. [36] presented comprehensive details about the use of biofuels as an alternative and sustainable source of energy. Biofuels were prepared from vegetable oil, such as mustard oil, and tested in a diesel engine in pure form and as a diesel blend. The blend percentages of mustard oil were 20%, 30%, 40% and 50% and were named as biofuel blends B20, B30, B40 and B50, respectively. The fuel testing laboratory determined the properties of pure mustard oil and its mixtures, such as density, viscosity, dynamic viscosity, carbon residues, ignition point and rate, and calorific value. Engine performance properties, such as brake power, specific fuel consumption and braking thermal energy efficiency, and active working pressure of pure diesel, were evaluated under conditions which comply with British standards. Finally, an analysis and comparison were made of the effect of different fuels on different engine characteristics.

Hafizil [37] studied the effect of pure PME on combustion performance and properties in a four-cylinder, four-stroke diesel engine using different fuel mixtures composed of conventional diesel fuel mixed with palm oil using methanol as a catalyst and compared with conventional diesel as the base fuel. The study showed the possibility of using biofuels in diesel engines without any modifications to the engine and the results showed a significant improvement in the fuel combustion process and a decrease in the percentage of pollutants released in the exhaust gases.

Mom et al. [31] researched the impact of a blend of different types of fuel, such as pure diesel, biodiesel-ethanol, and ethyl diesel-ethanol acetate, all of which were studied to analyze their impact on combustion and performance characteristics. Biofuels were derived from waste cooking oil. The inspection was conducted with a high level of expertise and attention to detail. The study covered the specifications of a four-stroke, single-cylinder engine with a power output of 4.8 kW and a compression ratio of 16.5:1:1, the cooling of water and a speed of 1500 rpm. The findings obtained were such that the thermal efficiency of the brakes (BTE) improved by 7.26%, the ratio of BSFC to B100 developed to 14.9 in comparison to pure diesel, and the BSEC showed a significant increase of approximately 10% when compared to pure diesel under full load conditions.

Bahar and Ali [38] conducted a power and energy analysis study for a four-cylinder, four-stroke diesel engine cooled with water. A mixture of 3% biodiesel, 92% diesel, and bioethanol were used in the experiments. The experiment was carried out at different engine speeds between 1000 and 3000 rpm. The fuel was mixed in different proportions, mixing biodiesel and diesel in varying proportions. The effect of these mixtures on the energy and electricity analysis of different engine speeds was studied and compared with the reference fuel D100. The maximum thermal efficiency obtained was 31.42% at 1500 rpm for D100 fuel, ranging from 27.18% to 31.42% for other mixtures at 1400 rpm. Small differences were also observed in energy efficiency between different mixtures. Based on the analyses, it was found that D100 fuel provided slightly higher thermal efficiency and energy than other mixtures, and mixture D92B3E5 was found to have given thermal efficiency and availability efficiency very close to the values given by D100. Therefore, the study recommended using this mixture as an alternative fuel to conventional diesel fuel because of the convergence of the results between them despite all the results being close to each other.

Bengi [39] conducted a study on the use of conventional diesel with biodiesel derived from microalgae (MB), which was carried out at different speeds ranging between 1500, 1800, and 2100 rpm on a four-cylinder four-stroke diesel engine. The study showed that increasing engine speed enhances the power volume and energy efficiency of a diesel and biodiesel engine. The study also showed that the results of the analyses of the diesel engine powered by the diesel fuel biometric (MB) are very close to the analytics of a conventional diesel engine only. Accordingly, this type of biofuel is recommended for use in internal compression ignition engines.

2.3. AN EXPERIMENTAL STUDY ON THE EFFECT OF NANOPARTICLES MIXED WITH BIODIESEL ON THE PERFORMANCE OF A DIESEL ENGINE

Santanamotho et al. [40] investigated the impact on IC diesel engine performance when incorporating iron oxide nanoparticles into pure diesel fuel with polanga oil. Nanoparticles of 50 nanometers were used at different concentrations (100 ppm, 200 ppm, and 300 ppm). The engine was designed with a single cylinder, operating on a four-stroke cycle, utilizing direct injection, and incorporating a variable compression ratio between 17.5:1 and 20:1. Engine power was 4.5 kW, had a consistent speed of 1,500 rpm, and was water-cooled. Results showed that the use of nanoparticles led to an improvement in fuel efficiency (BSEC) on par with pure diesel and an increase in BTE by 27%.

Appavu [41] found that the inclusion of nanoparticles, specifically zirconium oxide (ZrO_2), can significantly enhance the calorific value of the fuel. This, in turn, leads to an improvement in braking thermal efficiency. The addition of nanoparticles aids in better atomization of the fuel within the combustion chamber, resulting in a more efficient and complete combustion when mixed with air. Examining the composition of the fuel by combining it with various substances enhanced nanotechnology the fuel properties across the board, encompassing atomization, oxygen content, oxidation rate, and even the cylinder temperature.

Al-Kayiem et al. [42] studied the use of iron oxide nanoparticles in a diesel-biodiesel mixture to improve engine performance and reduce emissions. The study found that the addition of nanoparticles improved engine performance and reduced hydrocarbons, carbon dioxide, and nitrogen oxide emissions. The experiment was conducted in automotive laboratories. The main results of the study include the fact that the addition of 10 ppm of iron oxide (Fe_3O_4) nanoparticles to the diesel-biodiesel mixture led to an increase in fuel properties such as density, viscosity, and calorific value. It was found that the flash point and ignition point of the fuel mixture increased with the addition of iron oxide nanoparticles. Engine performance can be boosted with the addition of 10 ppm of Fe_3O_4 nanoparticles, thereby increasing the thermal efficiency and decreasing brake fuel consumption.The inclusion of Fe_3O_4 nanoparticles in the fuel mixture resulted in decreased emissions of hydrocarbons (HC), carbon monoxide (CO), and nitrogen oxides (NOx), indicating improved engine performance and reduced emissions. Further results include how fuel modification using iron oxide nanoparticles as additives, called nano fuels, showed improved thermal properties and improved engine performance due to the high energy density of the nanoparticles. These findings indicate that incorporating iron oxide nanoparticles into the blend of diesel-biodiesel and diesel yields a positive effect on fuel characteristics, engine performance, and emissions. This study recommends adding stabilizers to improve the stability of the nanofluids used in experiments. In addition, the study indicates that the use of nanoparticles in a diesel-biodiesel mixture shows promising results in improving engine characteristics and reducing environmental impact. The study also recommends the use of surfactants to improve the stability of nanoparticles.

Hafeez et al. [43] studied the impact of incorporating copper oxide nanoparticles into the biodiesel blend on the operational and emission characteristics of a compression ignition (CI) engine. The study found that the addition of copper oxide nanoparticles improved engine performance and emissions, with the highest concentration of nanoparticles leading to the best results. Fuel sample properties, such as viscosity, density and calorific value, were also measured. The study used a specific type of diesel engine for experiments and observed an increase in viscosity and calorific value with the addition of particulate matter. The study concluded that increasing the concentration of copper oxide nanoparticles (CuO) in the biodiesel mix positively affects engine performance and emissions. Specifically, it was found that the brake's thermal efficiency (BTE) increased since adding in copper nanoparticles to the biodiesel, with B20+50 mg/L of copper oxide, showed the highest BTE among the mixtures tested. In addition, brake fuel consumption (BSFC) decreased with the addition of copper nanoparticles, with B20+50 mg/L of copper showing the lowest fuel consumption compared to other mixtures. Furthermore, it was observed that the addition of nanoparticles to biodiesel reduces NOx emissions, as B20+50 mg/L of copper oxide emits less NOx than other mixtures. However, it was observed that hydrocarbon emissions increased slightly with the addition of nanoparticles, and carbon dioxide emissions decreased slightly at the same load. The study concluded that increasing the concentration of copper oxide nanoparticles in the biodiesel mix improved engine performance and reduced emissions.

Uday et al. [44] studied the effect of nano-additives and their performance characteristics on the combination of bio-sesame oil with titanium dioxide (TiO_2). The test fuels were diesel (D100) and biodiesel mixtures, such as B10, B20 and B30. The researchers found that maximum brake torque and power were measured at 1400 rpm and 2800 rpm, respectively, for all fuels tested compared to the B20 blend. By adding TiO_2 to the B20, there were increases in the torque and braking power of the engine by 10.22%, and fuel consumption for brakes decreased by 27.73%. It was concluded that the output of the engine was positively affected by the contribution of TiO_2 to the fuel mixture.

In a study conducted by Sajith [45], it was found that the presence of nanomaterials such as cerium oxide (CeO_2) and zirconium (Zr_2) in the fuel had a significant impact on thermal braking efficiency. Specifically, the efficiency of the fuel sample increased by 10%. The introduction of nanoparticles would enhance fuel stimulation and boost combustion by augmenting the oxygen levels in comparison to the fuel.

Shadidi et al. [46] conducted a study in which cerium nano oxide and molybdenum oxide were added as nano-additives in different concentrations to biodiesel B10 and B5. The results showed that the working rate of the engine’s net energy increased with the increase in the amounts of nano-additives. The highest engine operating rate was achieved at 7.71 kW (25.33% of the total fuel power rate) for the B10 blend with a concentration of 90 ppm of nano-additives, 6.63 kW (24.59% of total fuel power) of the B5 blend with a concentration of 90 ppm of nano-additives, at an engine speed of 2,500 rpm. As engine speed increases, fuel consumption decreases as does heat energy loss and heat transfer.

Zhang et al. [47] conducted a study on metal nanoparticles, metal oxide, carbon and organic to observe their impact on engine performance and exhaust emissions. While these additives enhance thermophysical properties and combustion properties, more research is needed to understand fully their potential environmental hazards and toxicity. The concentration and size of nanoparticle fuel additives also significantly affect engine performance and emissions. In general, while nanoparticle fuel additives have the potential to improve fuel efficiency, more comprehensive research is needed to fully understand their impact on the environment and human health.

John et al. [48] studied the conversion of waste cooking oil into biodiesel using iron oxide nanoparticles as a catalyst was studied. The study looked at the impact of biodiesel on engine performance and emission characteristics. The experimental setup involved testing with a single-cylinder diesel engine, with iron oxide nanoparticles of different sizes being blended from biodiesel samples at different concentrations (25 ppm, 50 ppm, 75 ppm, and 100 ppm) using ultrasound. The mixed samples were then analyzed for sedimentation at regular intervals (at 10, 15, 20, and 25 minutes) and at different speeds (1000, 2000, 3000, and 4000 rpm) using a centrifugal setting. An iron oxide sample containing 75 ppm was found to remain stable at up to 4000 rpm, suggesting its potential impact on biodiesel combustion efficiency. The results indicate that the inclusion of iron oxide nanoparticles improves the combustion efficiency of biodiesel fuels and that the addition of iron oxide nanoparticles slightly enhances the thermal efficiency of brakes and Don’t you mean increases fuel savings, The study also compared the biodiesel properties of waste cooking oil with and without iron oxide nanoparticles and recommends that biodiesel produced from waste cooking oil, especially with the addition of iron oxide nanoparticles, can enhance engine performance and contribute to fuel savings.

2.4. PART SUMMARY

Many studies have dealt with different types of biodiesels. Some studies have addressed the use of biodiesel produced from sunflower oil. These studies have shown that engine performance has increased. On the other hand, many researchers have studied the addition of nanoparticles to diesel and biodiesel. These studies have found that the addition of nano-additives led to an improvement and increase in performance. Furthermore, they concluded that aluminum oxide (Al_2O_3), graphene oxide (GO), copper oxide (CuO), carbon nanotubes (CNTs), cerium oxide, and titanium dioxide (TiO_2) are the most common nanoparticles used in diesel and biodiesel.

PART 3

METHODOLOGY

3.1. INTRODUCTION

This study focuses on biodiesel derived from sunflower oil using copper oxide nanoparticles. To evaluate the brake thermal efficiency and performance stages of the diesel engine were used in different doses (50 ppm, 75 ppm, and 100 ppm). Tests are conducted on an unmodified diesel engine that runs on a combination of biofuel and nanoparticles. Testing instruments provided by official sources are capable of effectively achieving the research goals and providing comprehensive variables to measure both outputs and inputs. Calibration of sensors and measuring devices involves adhering to standard values and ensuring accuracy by minimizing errors in readings.

3.2. DESCRIPTION OF EXPERIMENTAL MATERIALS AND EQUIPMENT

The experiment was conducted in the laboratory of the engineering workshop at the College of Agricultural Engineering Sciences, Department of Agricultural Machinery and Machinery, University of Baghdad, using a four-stroke, four-cylinder diesel engine with direct injection and water cooling. Seven types of fuel were prepared for testing: conventional diesel D (as the base fuel for comparison purposes), conventional diesel mixture, biodiesel, and three ratios of copper nano oxides with ratios of 75 ppm, 50 ppm, and 100 ppm (D85 B15 PPM 50, D85 B15 PPM 75, D85 B15 PPM 100), and a mixture of conventional diesel and biodiesel and three ratios (D85 B15, D90 B10, D95 B5). The engine started at three speeds: 1200 rpm, 1400 rpm and 1600 rpm, in three stages and three loads. Performance indicators were studied focusing on the specific consumption of braking fuel and thermal efficiency braking.

3.3. ENGINE

Tests for this research were conducted on a diesel engine of Korean origin, namely the KiaBongo2701 model 12 with a volume of 2.7 liters, four-stroke, water-cooled in the engineering workshop of the Department of Agricultural Machinery and Machinery, College of Agricultural Engineering Sciences, University of Baghdad. Several modifications were made for the purpose of conducting practical experiments. Table 3.1 shows the technical specifications of the engine and Figure 3.1 shows the engine.

Table 3.1. Technical specifications of the engine.

Engine Specification		
No.	Parameters	Engine
1	Type of engine	J2 2701
2	Engine cylinder number	4
3	Cooling system	Water type
4	Piston Displacement	2,694 cm^3
5	Stroke	95 mm
6	Bore	95 mm
7	Engine oil type	SAE 10W-30
8	Nominal Output	59.656 kW at 4,000 rev/min.
9	Maximum Torque	164.75 Nm at 2,400 rev/min.

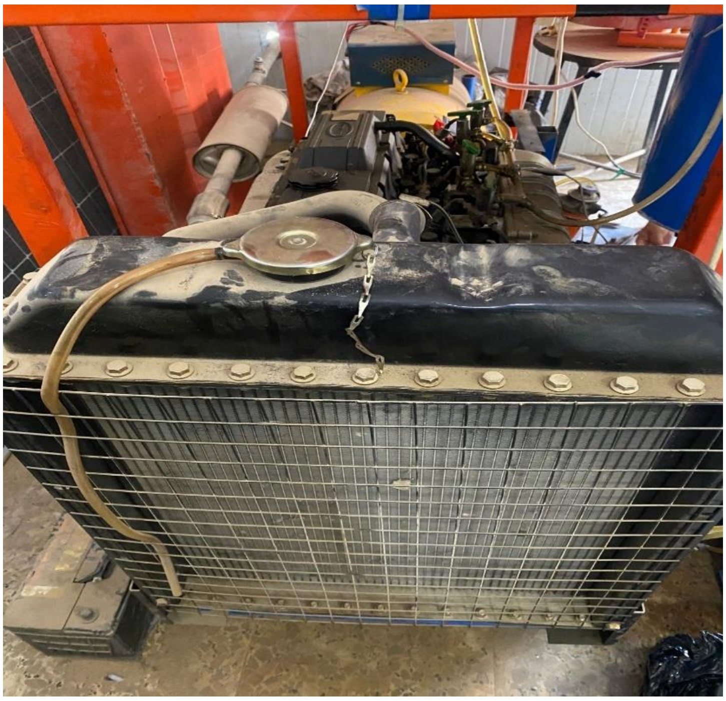


Figure 3.1. Engine.

3.4. ELECTRIC GENERATOR

We used an electric generator (Figure 3.2) of Chinese origin (STC-24) with three phases connected to the motor to obtain the required load. The generator produces an alternating current with a potential difference of 380 volts and a current of 45.6 amperes per line as detailed in Table 3.2 below.

Table 3.2. Technical specifications of the electric generator.

Specification Generation		
No.	Specifications	**Descriptions**
1	TYPE	**STC-24 kW**
2	ability	**30kva**
3	RPM	**1500 RPM**
4	phase	**3 phases**
5	reluctance	**50 Hz**
6	Class of stator	**E**
7	INSULATION ROTOR	**B**
8	COS	**0.8**

Figure 3.2. Electrode Dynamometer.

3.5. FUEL USED IN THE EXPERIMENT

Diesel fuel purchased from a local gas station in Salah al-Din was used, and the fuel used in the experiment was prepared in three stages. The first phase included the manufacture of biofuels, the second stage entailed mixing biofuel with diesel fuel, and the third stage was the addition of nanomaterial, as shown below.

3.5.1. First Stage (Biofuel Preparation)

A vegetable oil extracted from Altunsa brand sunflower oil, the type and components of which are shown in Figure 3.3.

Figure 3.3. Type of oil used in the experiment.

Table 3.3 shows the components of the vegetable oil used in the experiment.

Table 3.3. Components of Vegetable Oil.

No	Material	
1	Calories	900 cal
2	Total Fat	100 g
3	Vitamin A	35 mg
4	Protein	0 g
5	Carbohydrates	0 g
6	Fiber	0 g
7	Sodium	0 g

The biofuels were prepared by transesterification with the aforementioned catalytic activity according to the following method of action [49]:

- Put the vegetable oil in a large metal jar and heat it to a temperature of between 55℃ and 60℃.
- Add potassium hydroxide as a catalyst.
- A mixture of methyl alcohol (methanol) and a catalyst is added to the oil after ensuring the temperature of the oil is within the limits shown above to ensure

that the alcohol is not stirred. The container is closed tightly to ensure that the alcohol does not evaporate.

- Mixing occurs using an electric drill in which a fan is installed to mix the oils and dyes at a low speed for two hours, after which the mixture is left for 24 hours after sealing it to seal the glycerin precipitation followed by separating it.
- The glycerin material is separated following the traditional Tarifa as it is concentrated at the bottom of the pot by raising the product and leaving the glycerin in the pot.

Table 3.4. Materials for Transesterification.

Material / Compound	Quantity
Sunflower oil	500 ml
Methanol	100ml
Potassium Hydroxide (KOH)	3.5 gms

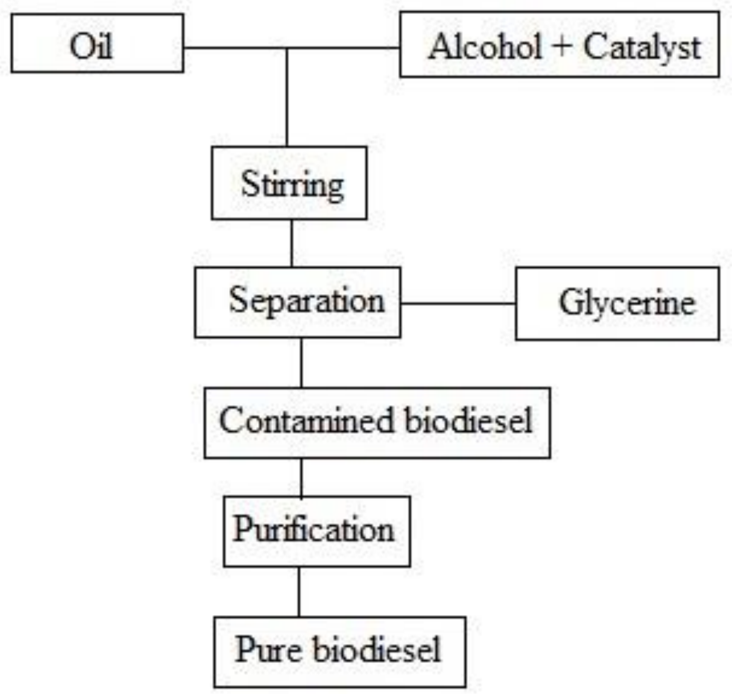


Figure 3.4. Diagram clarifying the stages of biodiesel production.

Figure 3.5. Potassium hydroxide flakes and methanol.

Detailed reviews about biodiesel production processes are available in the literature [50–53]. In this raw study Biodiesel resulting from the esterification process. Physical properties of crude sunflower oil (CSO)and biodiesel (B100), shown in Table 3.

Table 3.5. Physical properties of crude sunflower oil (CSO), biodiesel fuel (B100).

Properties	CSO	Biodiesel
Density @ 26oC (Kg/lt)	0918	**0.89**
Viscosity (mm2/s)@ 26 °C	34	**4.5**
Flash point (°C)	220	**85**
Calorific value (kJ/kg)	39342	**40565**
Setan number	36	**74**

3.5.2. Second Stage (Mixing Biofuels with Diesel Fuel)

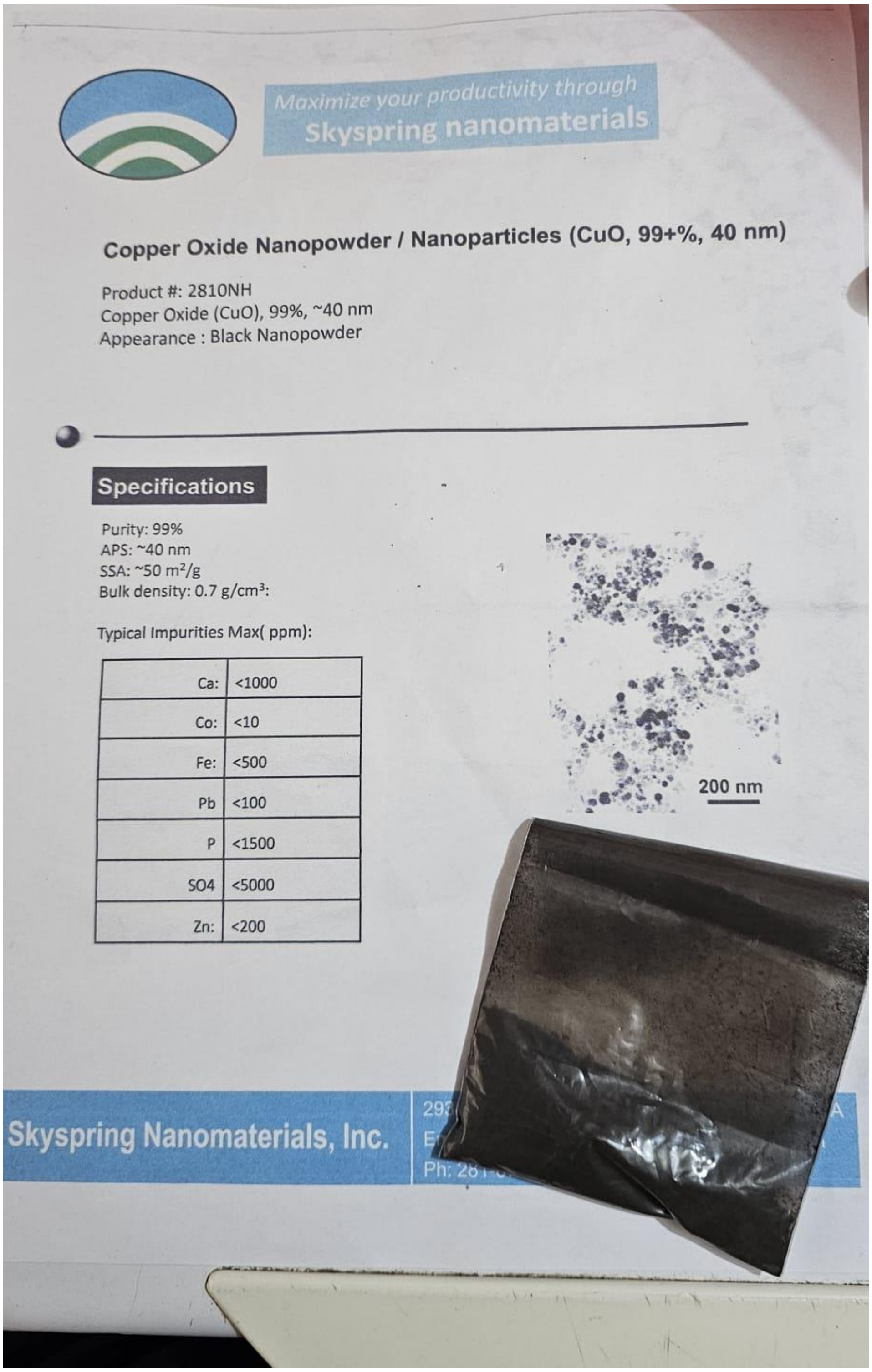
- Diesel fuel, which was produced at the Baiji refinery, was purchased from one of the gas stations in Salah al-Din province.
- Diesel fuel was mixed with biofuels in the following three mixing ratios [54]: 85%-15%, referred to as D85-B15, mixed at a ratio of 8 liters to 1.5 liters;

90%-10%, referred to as D90-B10, mixed at a ratio of 9 liters to 1 liter; and 95%-5%, referred to as D95-B5, mixed at a ratio of 9.5 liters to 0.5 liters.

- A graduated bowl was used to mix accuracy with three samples.
- The mixture was shaken for one minute for the purpose of homogenizing the mixture.

3.5.3. Third Stage (Nanomaterial Addition)

Determining three samples from each sample of diesel fuel mixed with biofuels and adding copper oxide is shown in Figure 3.6 at ratios 100 ppm, 75 ppm, and 50 ppm, which were weighed with the sensitive electronic balance shown in Figure 3.7.



Maximize your productivity through
Skyspring nanomaterials

Copper Oxide Nanopowder / Nanoparticles (CuO, 99+%, 40 nm)

Product #: 2810NH
Copper Oxide (CuO), 99%, ~40 nm
Appearance : Black Nanopowder

Specifications

Purity: 99%
APS: ~40 nm
SSA: ~50 m²/g
Bulk density: 0.7 g/cm³:

Typical Impurities Max(ppm):

Ca:	<1000
Co:	<10
Fe:	<500
Pb	<100
P	<1500
SO4	<5000
Zn:	<200

Skyspring Nanomaterials, Inc.

Figure 3.6. Nanomaterial (CuO).

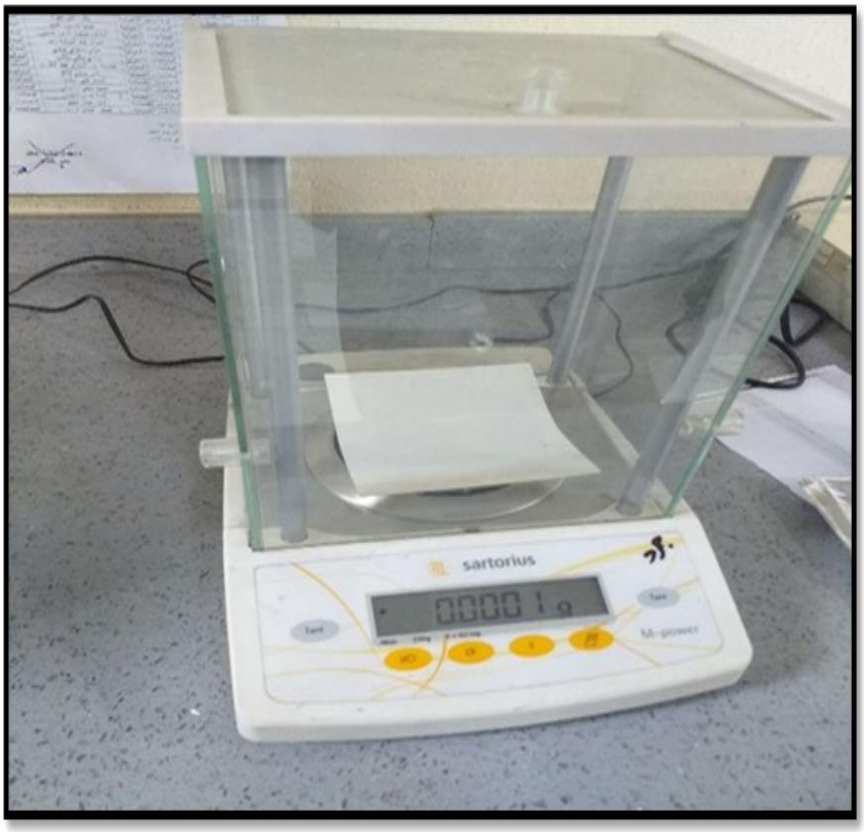


Figure 3.7 Sensitive electronic balance.

The nanomaterial was mixed with the fuel by ultrasound using the GT SONIC Figure 3.8with its specifications presented in Table 3.4 to disperse copper oxide particles in the fuel for two hours to ensure a good and homogeneous mixture and reducing their deposition in the vessel.

Figure 3.8. Ultrasound device.

Table 3.6. Specifications of the ultrasound device.

t	Details	Unit
1	Model	VGT-1620QTD
2	Voltage	AC220-240 V 50 Hz
3	Frequency	40 kHz
4	Ultrasonic Power	50 W
5	Heating Power	100 W
6	MADE IN CHINA	

The experiment was conducted using seven types of fuel shown below.

- Pure diesel (D100) produced by the North Refineries Company, Baiji Refinery.
- D85-B15 with 85% pure diesel and 15% biodiesel.
- D90-B10 with 90% pure diesel and 10% biodiesel.
- D95-B5 with 95% pure diesel and 5% biodiesel.
- D85-B15-50PPM consisting of 85% pure diesel and 15% biodiesel with 50 ppm nano.
- D85-B15-75PPM consisting of 85% pure diesel and 15% biodiesel with 75 ppm nano.

- D85-B15-100PPM consisting of 85% pure diesel and 15% biodiesel with 100 ppm nano.

All types of fuel used in the experiment were analyzed by the North Refineries Company, Laboratories and Quality Control Department, Division of Evaluation and Analysis of Products and Materials. Table 3.5 shows the results of the fuel test.

Table 3.7. Fuel Test Results.

Test	**D100**	**D95-B5**	**D90-B10**	**D85-B15**	**D85-B15-50PPM**	**D85-B15-75PPM**	**D85-B15-100PPM**
Density@ 15c kg/L	0.8451	0.8314	0.8331	0.8371	0.8324	0.8335	**0.8336**
API	41.6	38.7	38.3	37.5	38.2	37.9	**38.2**
Sulphur Content (wt%)	0.83	0.7137	0.6859	0.6173	0.6991	0.6952	**0.6991**
Cetane Index	53	54	54	52	54	53	**54**
Gross Calorific Value (kcal/kg)	10,950	10,879	10,861	10,855	10,862	10,867	**10,870**
Viscosity@40c	2.1	2.60	2.66	2.70	2.65	2.67	**2.69**

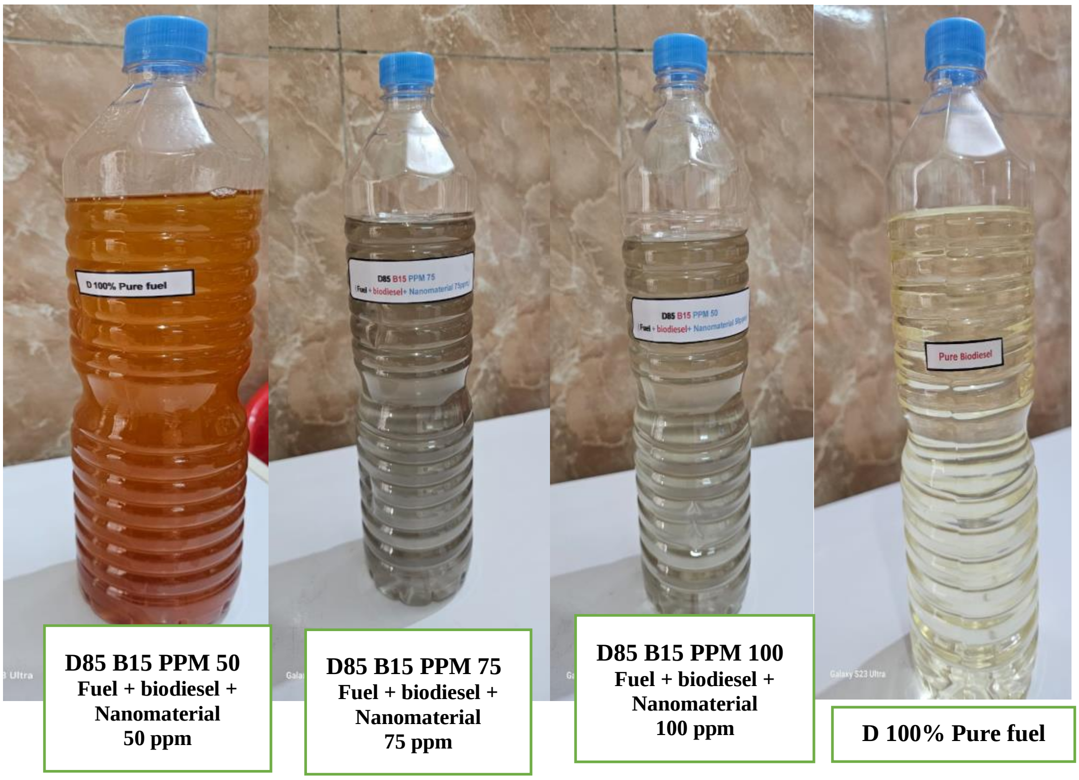


Figure 3.9. Samples of fuel used in the test.

3.6. MEASURING ENGINE SPEED

The speed of the engine was determined and measured electronically by a magnetic sensor linked to a speed-measuring device installed on the control panel and keys of the experimental engine. The measurement method was such that the sensor was placed perpendicular to the pilot wheel at a very short distance, where the pilot’s wheels are sensed, and the magnetic sensing is converted into electronic signals and displayed on the speed measuring device shown in Figure 3.10.

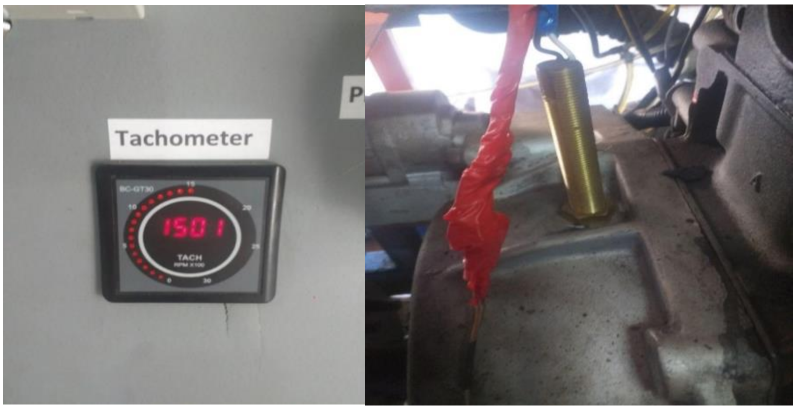


Figure 3.10. Motor speed measuring device and sensor.

3.7. ELECTRIC DYNAMOMETER

The electric dynamometer that was used in the experiment, and which is of Chinese origin, was the STC-24 kW type that works at a frequency of 50 Hz and generates a voltage of 220 volts and a current of 30 amperes for each line, which is three lines (phase 3) with technical specifications shown in Annex 4, as shown in Figure 3.11.

3.8. USED LOAD

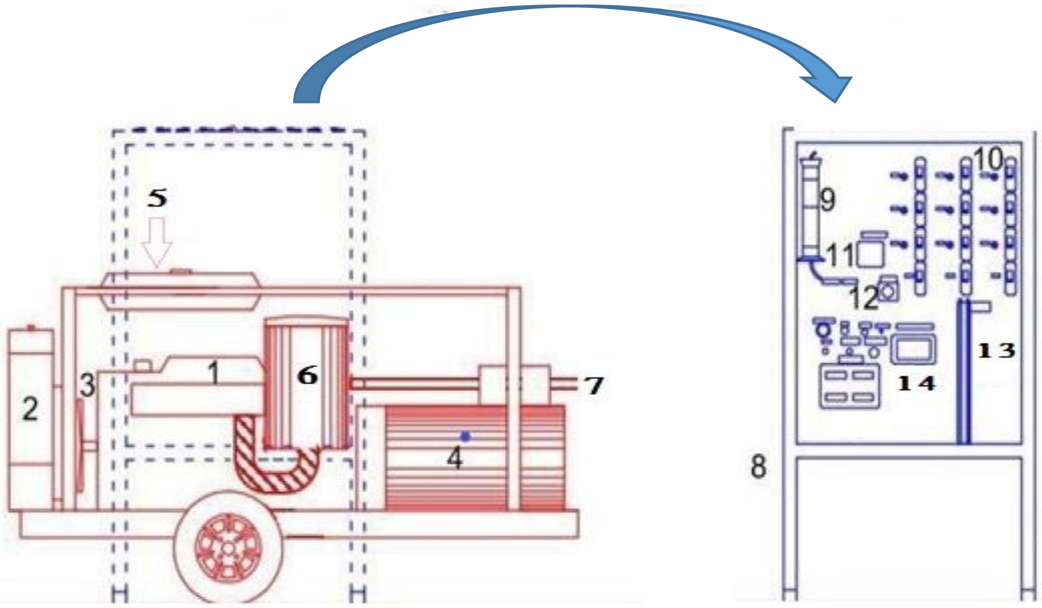
Electrical loads were used, consisting of a heating wire (heater) that converts electrical energy into thermal energy. The experimental engine is equipped with nine hydrates and every three hytriters are connected to an electrical line, a switch, and a voltage regulator, all of which are connected to control the amount of current passing through the heater, as each heater has a capacity of 1,500 watts, as shown in Figure 3.10.

Figure 3.11. Loads used.

3.9. MEASUREMENTS AND TESTING PANEL

Our testing panel is a board of wood on which is installed many scales that we need in the experiment to take readings. Electronic devices were installed to measure the speed of engine revolutions, to measure the electrical power of the dynamo generation head, in addition to an electronic screen to display readings from the sensors connected to the engine, and a manometer tube to measure the pressure difference. Also installed were nine loads (heater) and with each heater an electric switch for operation and extinguishing, a voltage regulator to control the amount of current that passes through it and install a fuel buret insertion, a key to start the engine with a switch to turn off the engine in case of emergency, engine lamps, and an oil sensor. The panel is shown in Figure 3.12 and the test system in Figure 3.13.

Figure 3.12. Keyboard and measuring devices.



1. Engine 2. Thermal radiator 3. Fan 4. Generating head (electric dynamometer) 5. Fuel tank 6. Air box 7. Exhaust 8. Scale panel 9. Buret 10. Switches and load regulators 11. Electronic electric power meter 12. Engine cycle measuring device 13. Water manometer 14. Atmospheric pressure measuring device

Figure 3.13. Test Platform.

3.10. ANALYTICAL ACCOUNTS

3.10.1. Calculation of the Brake Power

In this experiment, the braking power was measured by the generating head (electric dynamometer) through the electrical power measuring device installed in the control panel. This device measures the electrical power, voltages, and current for each line (PHASE) according to the following equation [55]:

$$\mathrm{BP} = \mathrm{P}_{Total}/\eta_{\mathrm{Gen}} \tag{3.1}$$

Where:

BP = Brake Power
P_{Total} = Total Electric Power (kW)
η_{Gen} = Electrode dynamometer efficiency (%)
The total electrical power output is calculated using the following equation [56–58]:

$$\mathrm{P}_{\mathrm{Total}} = \mathrm{P}_{\mathrm{L1}} + \mathrm{P}_{\mathrm{L2}} + \mathrm{P}_{\mathrm{L3}} \qquad ((3.2)$$

Where:

P_{L1} = First line capability (W)
P_{L2} = Second line wattage (W)
P_{L3} = Third Line wattage (W)
The electrical power of each line can also be calculated by the equation [59]:

$$P_{\mathrm{E}} = \mathrm{V} \times \mathrm{I} \times \mathrm{PF} \qquad ((3.3)$$

Where:

P_{E} = Electric Power (W)
V = voltage (potential difference) (V)

I = current (A)
PF = Power Factor (%)
*Power factor changes continuously depending on current and voltage

3.10.2. Measurement of Brake Thermal Efficiency

Brake Thermal Efficiency is how well the engine converts energy from the combustion of fuel into mechanical energy, and is calculated by dividing braking power by the calorific value of the fuel resulting from its combustion. Efficiency is calculated with the following equation [60–62]:

$$\eta_{bth} = \frac{\mathrm{BP}}{\dot{m}_f \times \mathrm{CV}} \qquad ((3.4)$$

Where:

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

3.10.3. Brake Specific Fuel Consumption

A graduated glass tube installed on the control panel is placed and filled by a small pump linked to the fuel tank and equipped with a valve to supply the engine with fuel during the measurement process. Consumption is calculated by taking a specific amount of fuel, which is 50 mL, with a specific period of time of seconds using a stopwatch. The following equation is used to calculate this property [63,64]:

$$\dot{m}_f = (\rho \times v/t) \qquad ((3.5)$$

Where:

ρ = specific weight of fuel (kg /L)
V = volume of fuel consumed (mL)
t = time taken to consume a certain amount of fuel

Brake Specific Fuel Consumption (BSFC), measured in kg/kW.sec, is the product of dividing the amount of fuel consumed by the braking power as in the following equation [65]:

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

Where:

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

3.11. PRACTICAL TESTS

In this experiment, the criteria below were followed:

- The use of conventional fuel, which is considered a base fuel with a fuel mixture, namely fuel + nanomaterial in three concentrations of 50 ppm, 75 ppm, and 100 ppm.
- Three loads of 4500 W, 9000 W, and 13500 W.
- Speed control for each experiment at 1200 rpm, 1400 rpm, 1600 rpm.

Initially, before operation, the oil and water levels in the radiator are checked, in addition to the fuel delivery pipes to ensure that no air gaps inside are present. Then the engine starts at a low speed which is gradually increased to 1200 rpm, after which we wait until the engine temperature stabilizes at 50°C. We start adding the first load of 4,500 W. Each load is fixed by running the engine for a full hour, and during this hour, the readings are taken and recorded. The electrical power, voltage and current for each electric line (phase) are recorded. The fuel consumption and these readings are completed by three repeaters for each load distributed at the 10-minute mark, at the 30-minute mark and finally at the end of a full hour.

The engine is then turned off for a full hour, and we restart it and wait until the engine temperature reaches 50℃. We add the second load of 9000 W and repeat the same previous steps with the three repeaters.

The engine is turned off again for a full hour and again restarted, after which we wait until the engine temperature reaches 50℃ yet again. We add the third load of 13500 W and again repeat the same previous steps and three repeaters.

Upon completion of the three loads, we turn off the engine and introduce the fuel mixed with nanomaterial after emptying the tank and all the pipes and connections. We fill them with nanofuel, and the same steps as presented above are performed, as was previously performed for each type of fuel.

After emptying the tank and all the pipes and connections, we introduce the fuel mixed with biofuels and fill them with fuel mixed with biofuels in different proportions and the same steps as expounded above are repeated for each type of fuel. Figure 13 shows the general plan of the study.

Table 3.8. Study Outline.

Fuel Type	**Speed (rpm)**	**LOAD**	**First repeater after 10 minutes**	**Second repeater after 30 minutes**	**Third repeater after 60 minutes**
D100	1,200	1			
		2			
		3			
D85B15PPM50		1			
		2			
		3			
D85B15PPM75		1			
		2			
		3			
D85B15PPM100		1			
		2			
		3			

3.12. UNCERTAINTY ANALYSIS

It is necessary to perform an uncertainty analysis [66].of the tests performed as it is important to provide the highest level of confidence in all results and can be obtained through the repetition of the results and accuracy in taking them where the variable values of the performance factors were used to calculate the uncertainty using the relative standard error percentage, Φ , as shown in equation [67].

$$\emptyset\% = \left(\frac{S}{Y}\right) \times 100 \qquad ((3.7)$$

where S is the standard error, and Y is the average of the data collected.
Standard error calculated according to equation [67].

$$s = \frac{\propto}{\sqrt{k}} \qquad ((3.8)$$

where α is the standard deviation, and k are the repeatable readings of the performance characteristics

The general empirical uncertainty, $\propto_n$, was calculated using equation [67]:

$$\propto_n = \sqrt{\propto_1{}^2 + \propto_1{}^2 + \cdots + \propto_i{}^2} \qquad ((3.9)$$

where αn is the total uncertainty, and $\propto_1$, $\propto_2$ and $\propto_i$ are the uncertainties of the individual parameters.

Uncertainties regarding the measured parameters are shown in Table 3.9.

Table 3.9. Uncertainties of the measured parameters.

Parameter	**Max.Value**	**Uncertainty**
Speed (rpm)	1600	± 0.09
BSFC (kg/kWh)	0.576	±1.50

BTE %	17.2	±1.42

PART 4

RESULTS AND DISCUSSION

4.1. INTRODUCTION

In this chapter, the presentation and discussion of the research are highlighted through the experimental results having been obtained after conducting calculations of the results of scientific tests on the engine. Seven mixtures consisting of conventional diesel fuel (D100) were used with three different mixtures of biodiesel in different proportions (D95-B15, D85-B15, D90-B10). Copper oxide particles were added to the mixture (D85-B15) being less performance and to bring it closer to the performance of the Pure diesel. The primary focus of all internal combustion research has been on thermal performance, which is considered to be the most crucial factor. Thermodynamic parameters such as brake efficiency and brake fuel consumption are important factors to consider. The data are presented and visualized through graphs. The performance charts were thoroughly examined to provide a comprehensive understanding of the performance characteristics exhibited by a diesel engine operating with different fuel mixtures, including diesel, biodiesel, traditional diesel, and biodiesel plus copper oxide nanoparticles mixed in at 50 ppm, 75 ppm, and 100 ppm, at three speeds (1200 rpm, 1400 rpm, and 1600 rpm), and with three loads of 25%, 50%, and 75%. The tests were conducted three times in order to ensure accuracy and minimize errors.

4.2. FUEL SAMPLE PREPARATION FOR PILOT TESTING

Biodiesel manufactured with diesel is mixed in the volume base with different blending ratios being supported regarding the tests. Pure diesel is denoted as D100. D95B5 denotes 5% biodiesel and 95% diesel, with B15, B10, and B5 indicating proportions of biofuel at 15%, 10%, and 5%, respectively. The baseline of engine performance is tested at different loads. This collection of baseline tests is utilized for the purpose of comparison to illustrate and understand the variations resulting from the addition of diesel fuel. Bio added to it are CuO nanoparticles.

4.3. SUNFLOWER OIL-FUELED DIESEL ENGINE PERFORMANCE

Our diesel engine operates using a blend of diesel and biodiesel fuel, namely D100, D95B5, D90B10, and D85B15. Performance parameters are examined in the context of academic research as follows:

4.3.1. Brake Thermal Efficiency

The correlations between BTE and load with various mixtures are plotted in Figures 4.1-4.3. In general, adding biodiesel to diesel reducess the thermal efficiency of the engine brake at 1600 rpm,1400 rpm, and 1200 rpm (engine rotational speeds). The low-calorie content of mixtures of 5%, 10% and 15% of the biodiesel of sunflower oil compared to the calorie content is the primary factor behind this Brake Thermal Efficiency, which is the net diesel (Figures 4.1- 4.3).

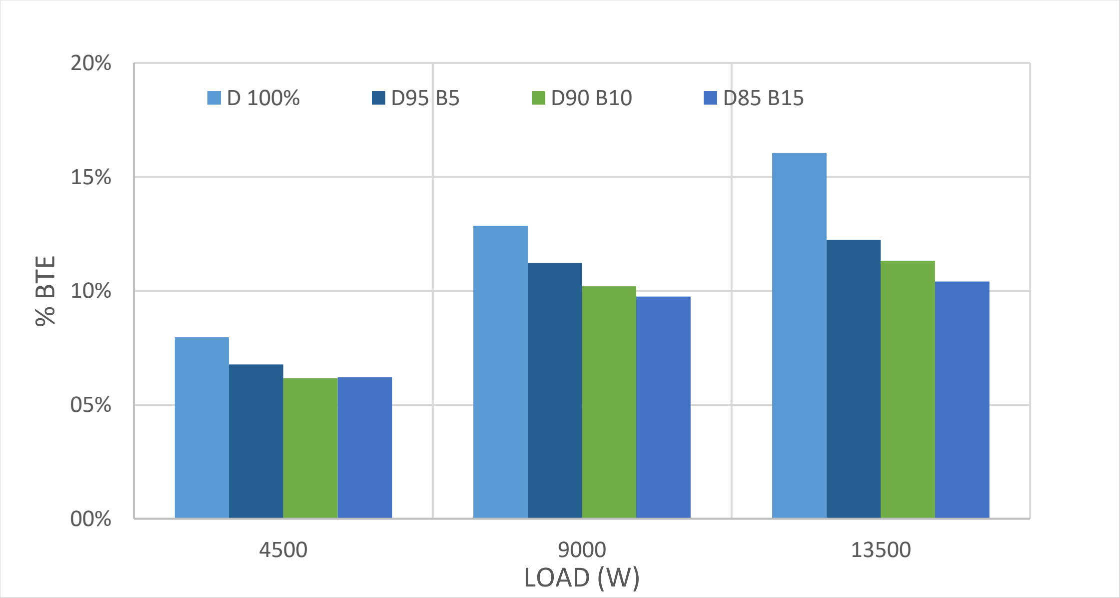


Figure 4.1. BTE vs. engine load with different mixtures at 1200 rpm.

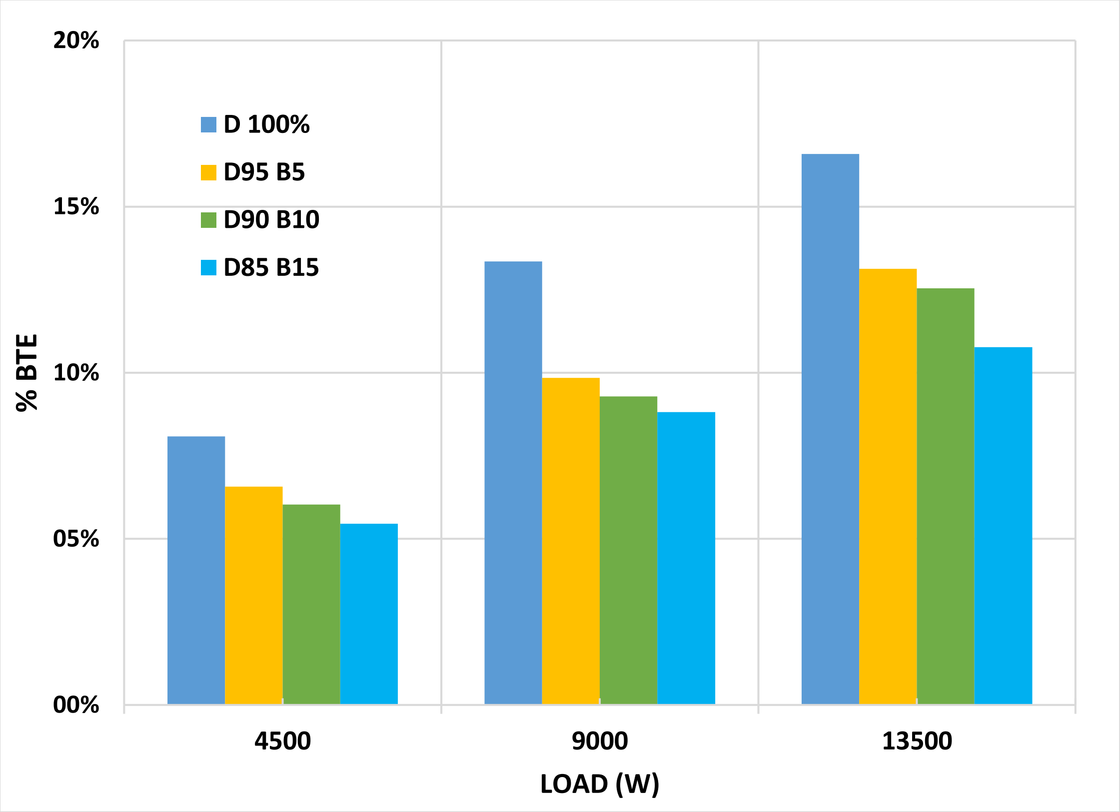


Figure 4.2. BTE vs. engine load with different mixtures at 1400 rpm.

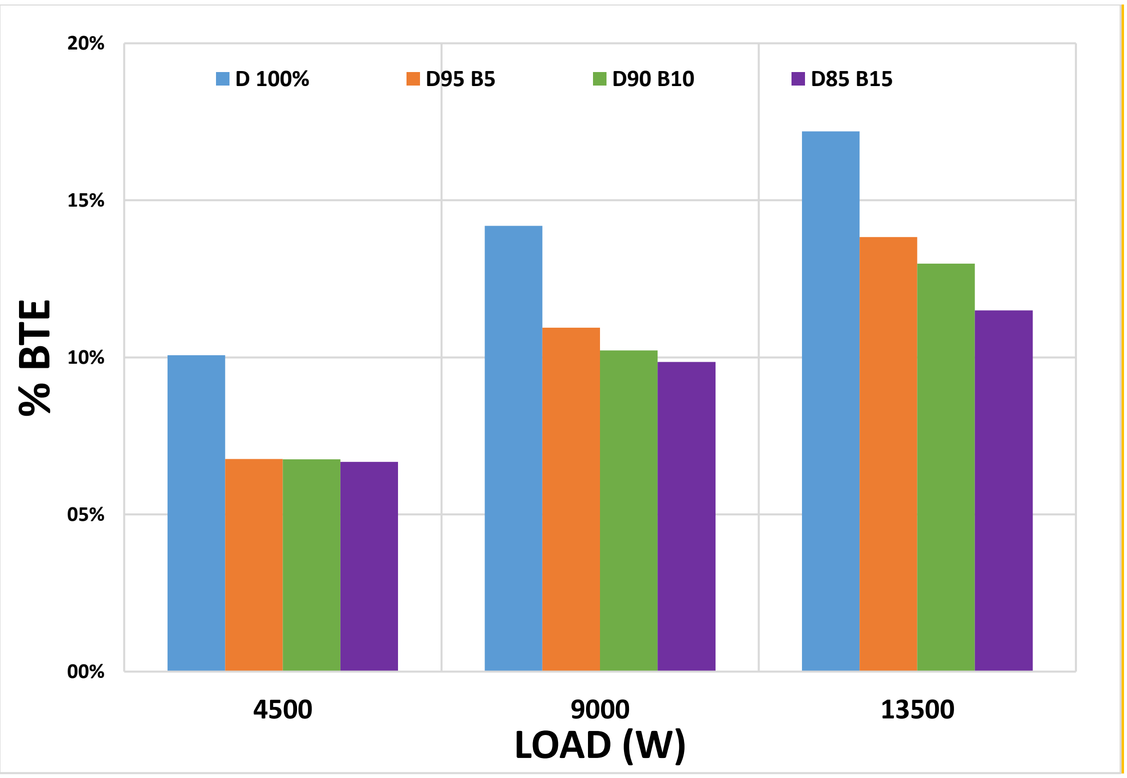


Figure 4.3. BTE vs. engine load with different mixtures at 1600 rpm.

4.3.2. Brake Thermal Efficiency with Speed Engin

We note that the BTE value in mixtures D85B15,D90B10,D95B15 at velocity 1200,1400,1600 rpm in Figure 4.4 is slightly lower than that of diesel fuel, and this reduction is due to a decrease in the calorific value and cetane number after adding vegetable oils compared to the calorific value of pure diesel fuel. Many researches The works reported that BTE is lower in the case of biodiesel These observations align with the findings reported in [68–71].

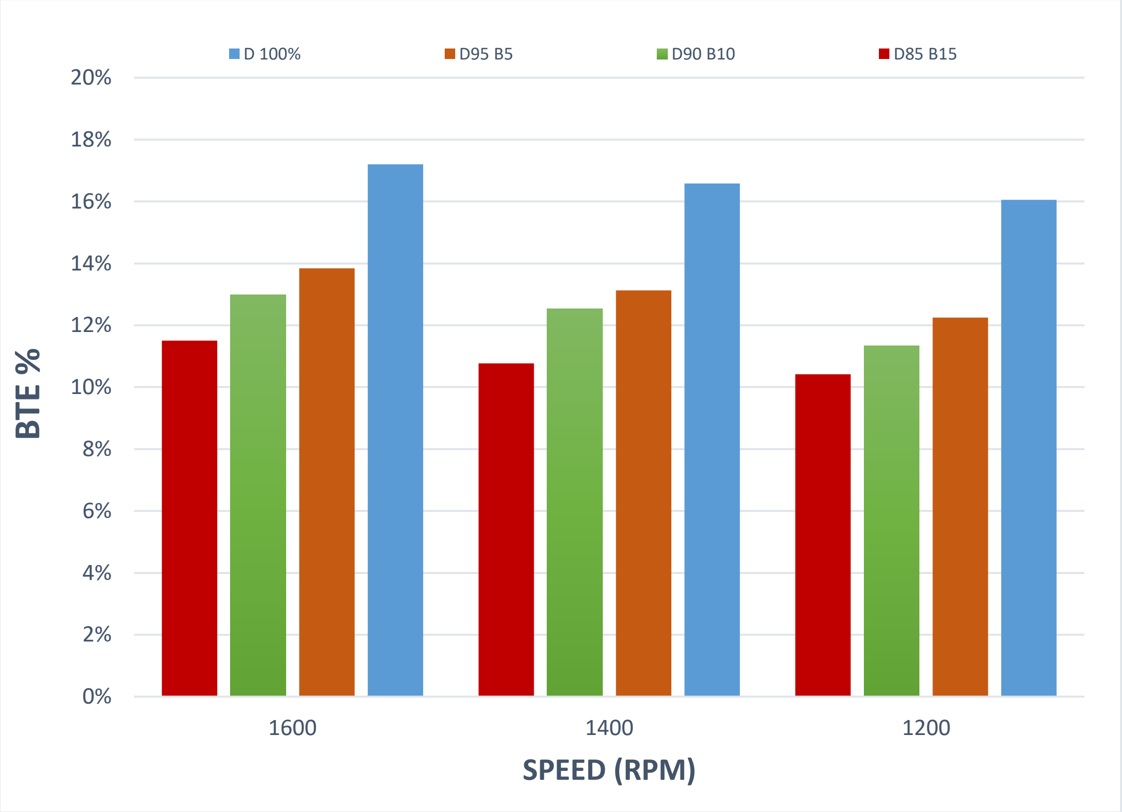


Figure 4.4. BTE rated for fuel mixture with engine speeds at load 13500W.

4.3.3. Brake Specific Fuel Consumption

Figures 4.5, 4.6 and 4.7 present the relationships between varying engine loads and the brakes’ particular fuel consumption at speeds of 1200 rpm 1400 rpm and 1600 rpm. The graphs display a clear trend. Load fuel consumption increases as the overload on the engine is overcome. It can be observed that the excess biodiesel of sunflower oil causes an increase in fuel consumption. The change in fuel consumption is determined by considering the caloric value of both biodiesel and diesel, as well as the caloric value of diesel alone when diesel is burned alone. Figures 4.5-4.7 show the variation in brake fuel consumption (BSFC) according to variable engine loads for each test fuel. BSFC processes the amount of fuel that must be burned to reach the engine load equivalent for different test fuels. Therefore, the BSFC values that are especially low for modified test fuels are reasonable These observations align with the findings reported in [72,73]. As can be seen from Figures 4.5-4.7, true diesel has the lowest BSFC value at all engine loads because it is directly dependent on fuel characteristics. A rise in BSFC is observed after the addition of biofuels to diesel fuel.

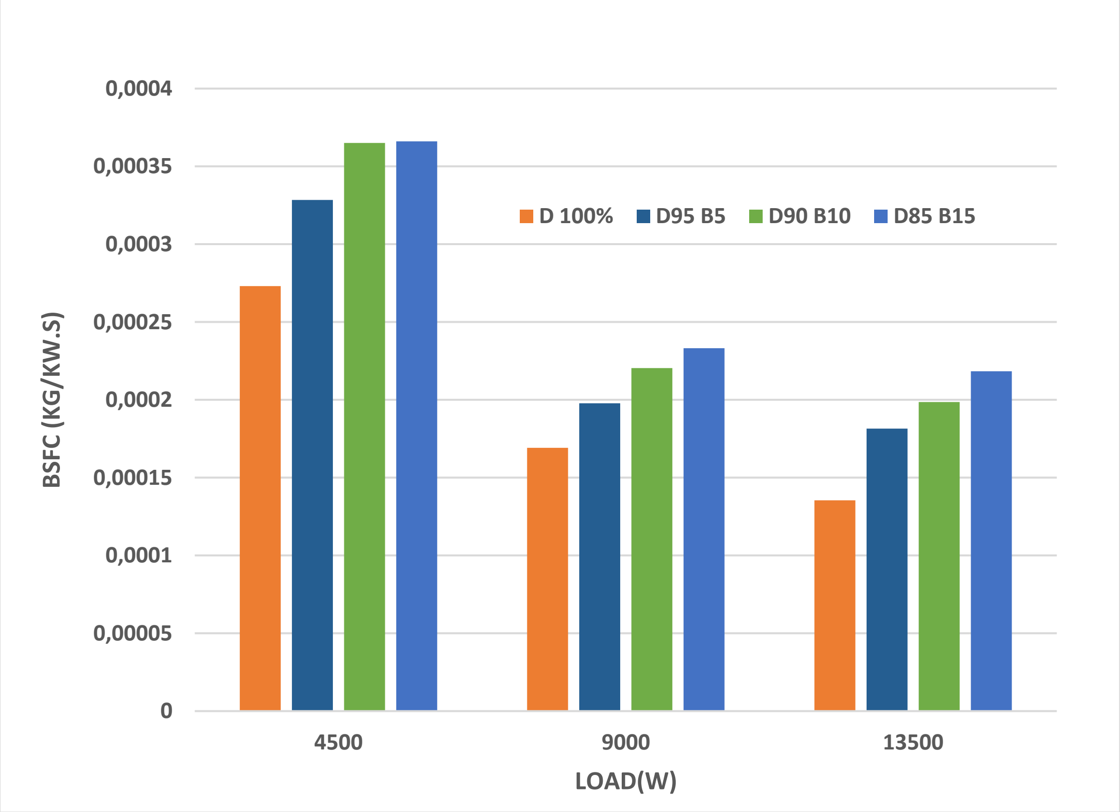


Figure 4.5. BSFC vs. engine load in different mixtures at 1200 rpm.

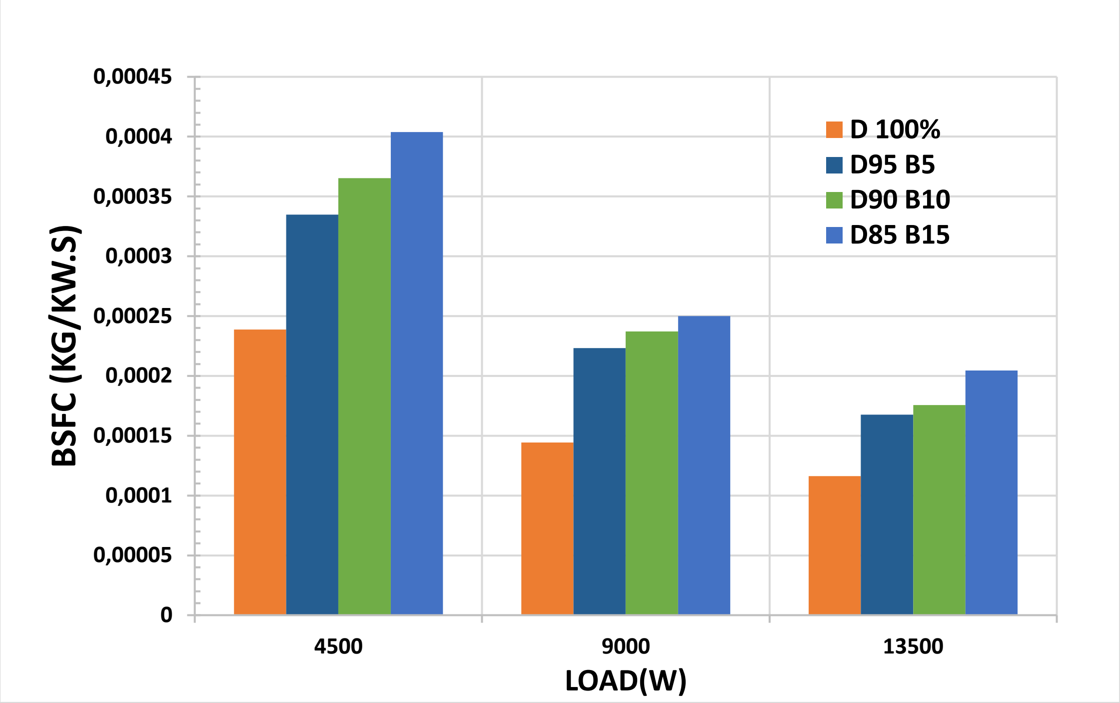


Figure 4.6. BSFC vs engine load in different mixtures at 1400 rpm.

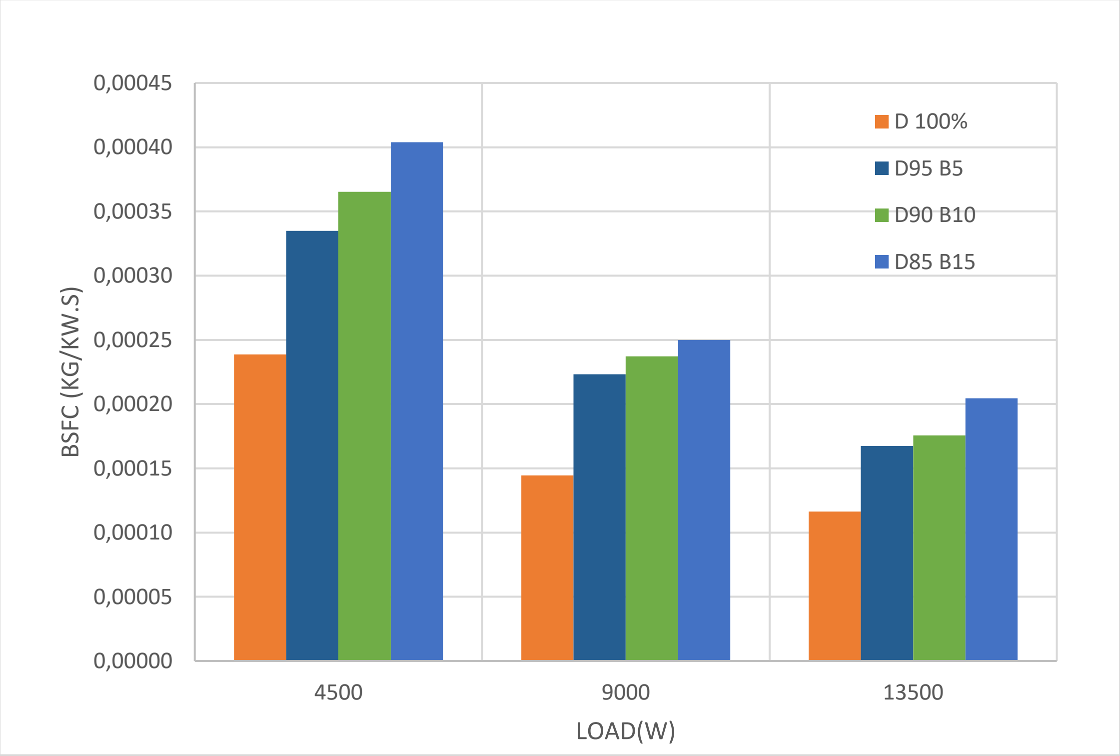


Figure 4.7. BSFC vs. engine load in different mixtures at 1600 rpm rotational speed.

(BSFC) It is an expression of the specific fuel consumption of the brakes defined as the ratio between the overall flow of fuel and the power of the engine. Figure 4.8

shows the variation of this parameter which operates in the engine at speeds of 1200, 1600, 1400, rpm, and a load of 13500W for three mixtures of different proportions. All types of mixtures followed the same trend, with the lowest values reaching 1600 rpm And the highest value is at 1200 rpm. The lowest BSFC level over the entire speed range corresponds to diesel. Moreno et al[74].The same deviation in BSFC for sunflower biodiesel was observed with respect to diesel in this work the authors attributed [75]the high BSFC of biodiesel to the lower level of the calorific value of this fuel. In order to produce the same energy output from the engine, it is necessary to inject a higher flow mass into the combustion chamber to compensate for the loss of energy due to the lower calorific value. As expected, the addition of biodiesel to diesel has expanded fuel consumption depending on load and operating conditions.

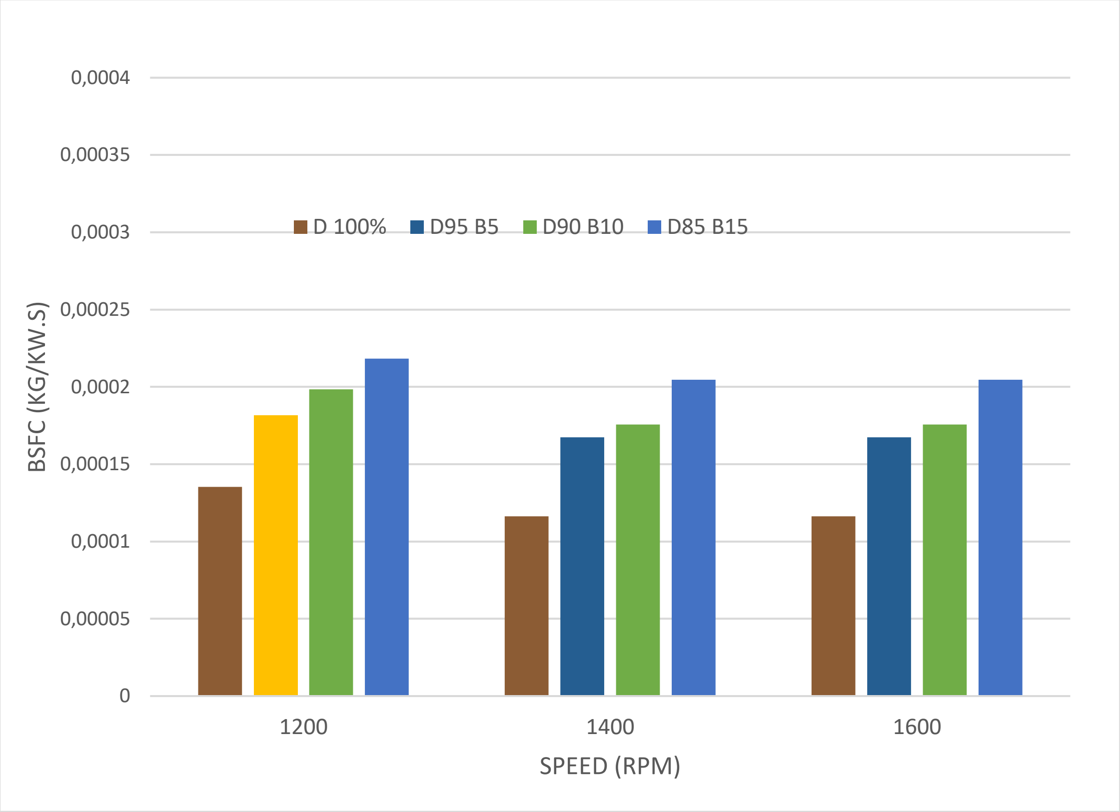


Figure 4.8. BSFC rated for fuel mixture with engine speeds at load 13500W.

4.4. ADDITION OF COPPER OXIDE NANOPARTICLES

Copper oxide particles were added to the following mixture, which showed a study of mixing 15% biodiesel with conventional diesel forming a toxicity mixture (D85B15) being the lowest performance among all three mixtures of diesel with biofuels in order to bring it closer to the performance of pure diesel, which was selected for experimental investigation. Based on this point, the addition of nanoparticles to the mixture was done in three amounts, namely 50 ppm, 75 ppm and 100 ppm. The findings are given below.

4.4.1. Brake Thermal Efficiency

When mixing biodiesel with CuO nanoparticles, BTE increased (15.05% D85B15PPM100, as shown in Figure 20, compared to diesel mixed with biofuels (D85B15) at 1200 rpm.

It can be seen that the addition of copper oxide nanoparticles led to a noticeable and reasonable enhancement in the thermal efficiency of the brakes as the addition of nanoparticles did not decrease fuel consumption, but increase the brake force and increased the thermal efficiency of the brakes. Due to the high surface size ratio of nanoparticles that gives high fuel oxidation, the high conductivity of copper oxide nanooxide caused a significant enhancement of Brake Thermal Efficiency by providing a heat transfer surface for combustion.

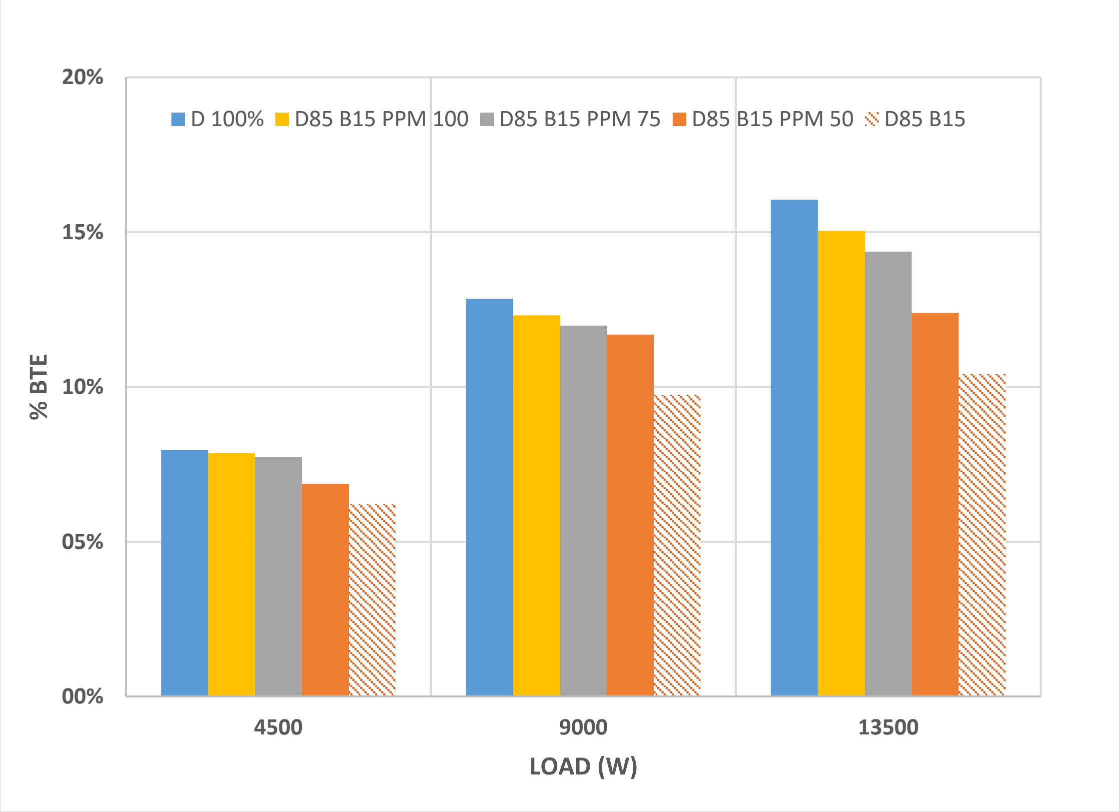


Figure 4.9. BTE offers different nano dosages compared to elegant diesel and a combination of 15% biodiesel at 1200 rpm.

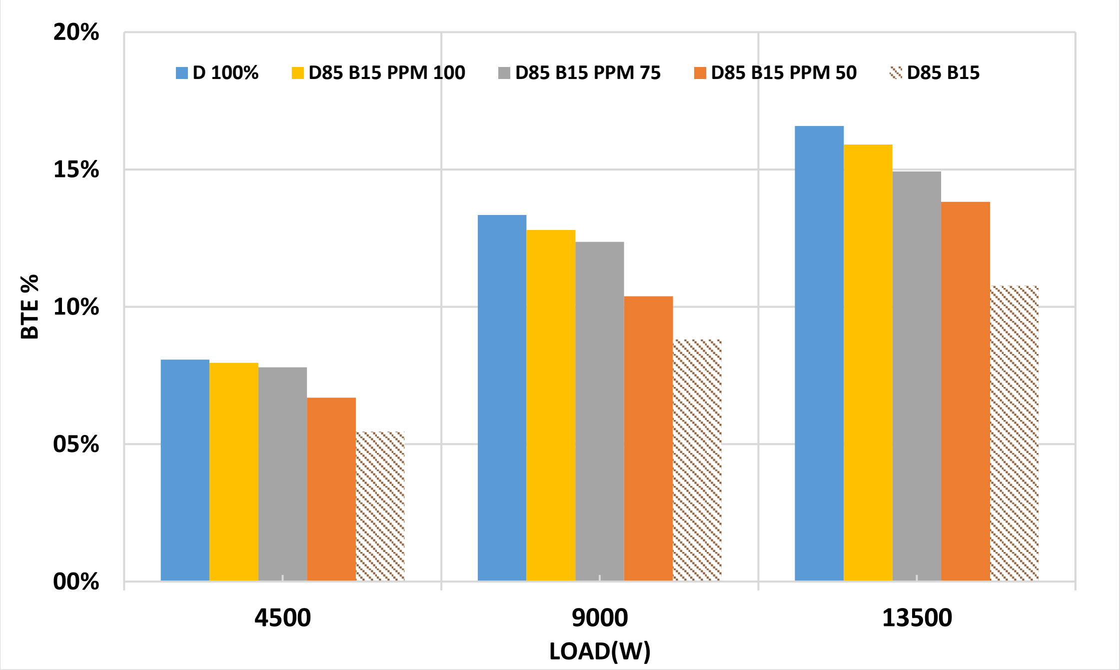


Figure 4.10. BTE variation with comparison of nanodoses to pure diesel and a mixture of 15% biodiesel at 1400 rpm.

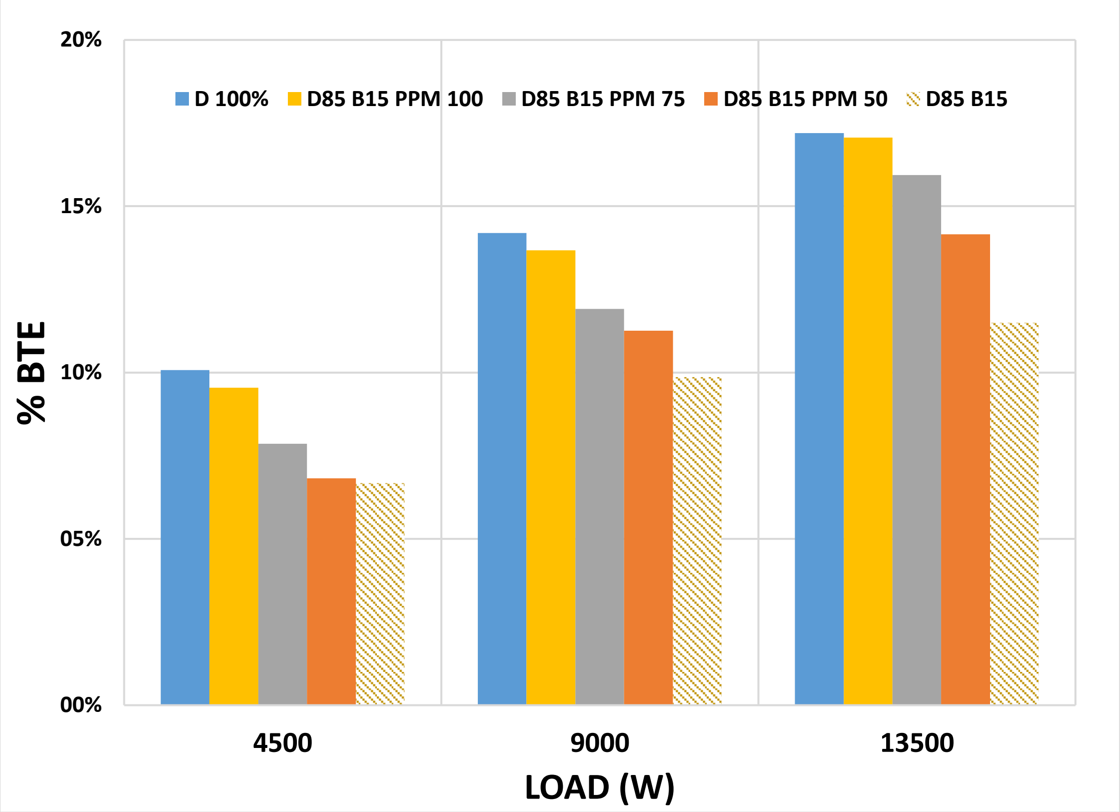


Figure 4.11. Variation in BTE appears at a different nano dose compared to the pure diesel and 15% biodiesel blend at 1600 rpm.

Figures 4.9-4.11 show the same direction of variation in BTE. There is a reasonable change and the same behavior of copper oxide nanoparticles by enhancing the efficiency of combustion force and brakes as well. Similar observations were made and observed regarding the results of [76,77].

BTE was calculated when the engine was running with a load capacity of 13500 watts and a variable motor speed of 1200, 1400 and 1600 rpm shown in Figure 4.12 BTE increases with increasing engine speed due to more work done with lower fuel consumption Similar observations were made and observed for the results of [76,78]. The maximum BTE value in percentage occurs at 1600 rpm when the engine was running in this speed range and values are 17.20 for pure diesel and 17.06, 15.93, 14.15 at mixtures to which CuO nanoparticles are added respectively. The fuel mix of the nanoparticles has shown an increase in overall engine efficiency. The nanoparticles act as an oxidizing agent that causes better thermal efficiency, thus increasing the efficiency of the engine.. We observe the obvious difference of an increase in the BTE value of the mixture D85B15 after adding nanoparticles to it 50PPM at all velocities in percentage and at a speed of 1600 rpm these values are 18.7%, 21.9% and 15.8% respectively.

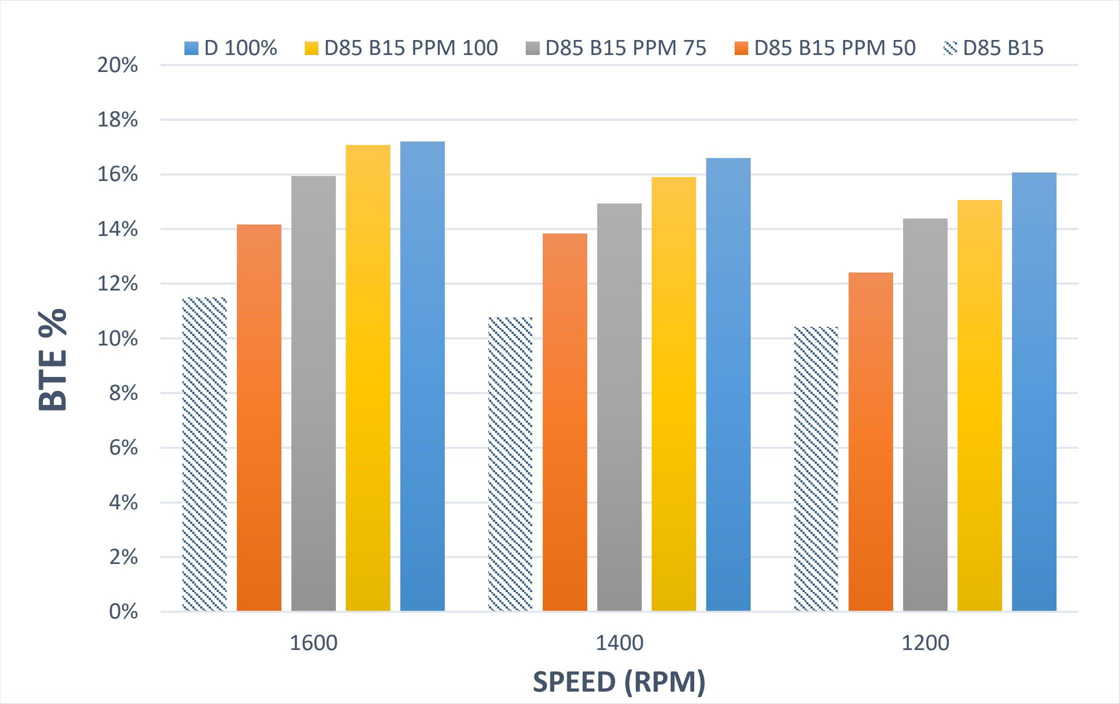


Figure 4.12. BTE rated for fuel mixture with engine speeds at load 13500W.

4.4.2. Brake Specific Fuel Consumption

Figures 4.13-4.15 show the variance of BSFC versus engine load. In the base fuel mixture with biodiesel (a combination of 15% biodiesel with 85% pure diesel), it is called D85B15 with nano copper oxide particles at 50, 75 and 100 ppm, respectively. Nano addition showed improvement in BSFC along with an increase in the concentration of nanoparticles in mixtures. Optimal results are achieved when the system operates at maximum capacity as the addition of 100 ppm of copper nanooxide resulted in a reasonable fuel consumption boost to produce engine brake force; i.e., more power with less fuel after the nano was added. In general, the addition of nanoparticles resulted in efficient combustion compared to the fuel combustion without. copper nanooxide.

Similar observations were made and observed for the results of [79].

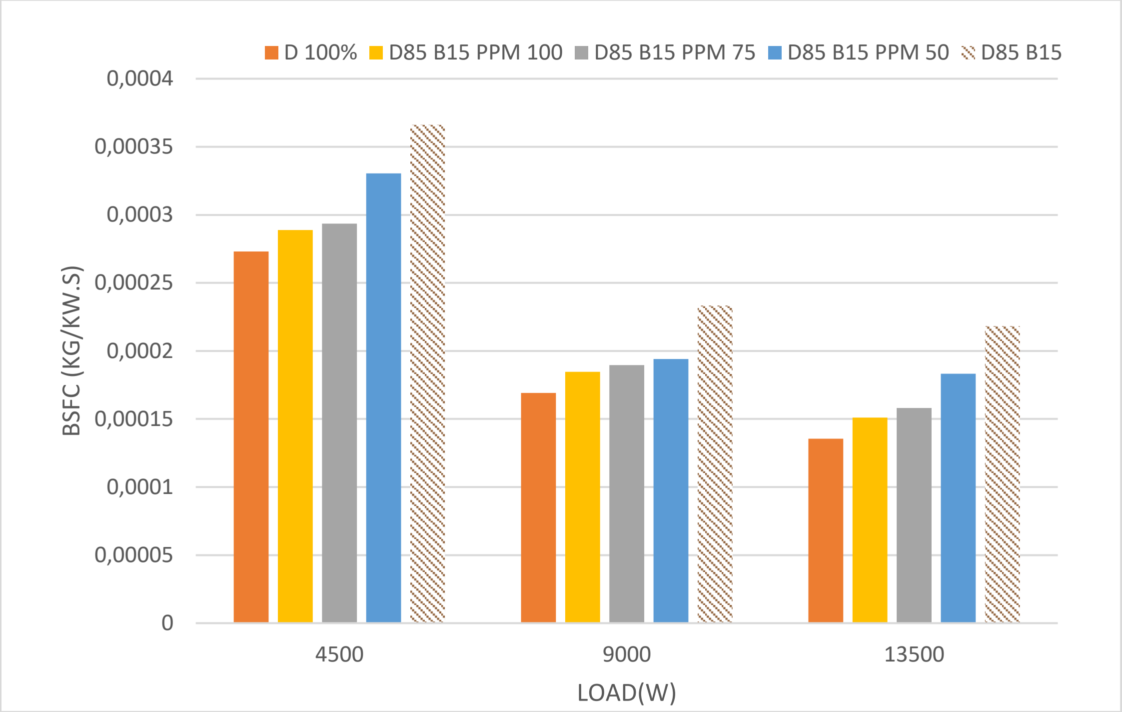


Figure 4.13. Change in BSFC appears using varying nano quantities of the diesel-biodiesel mixture at 1200 rpm.

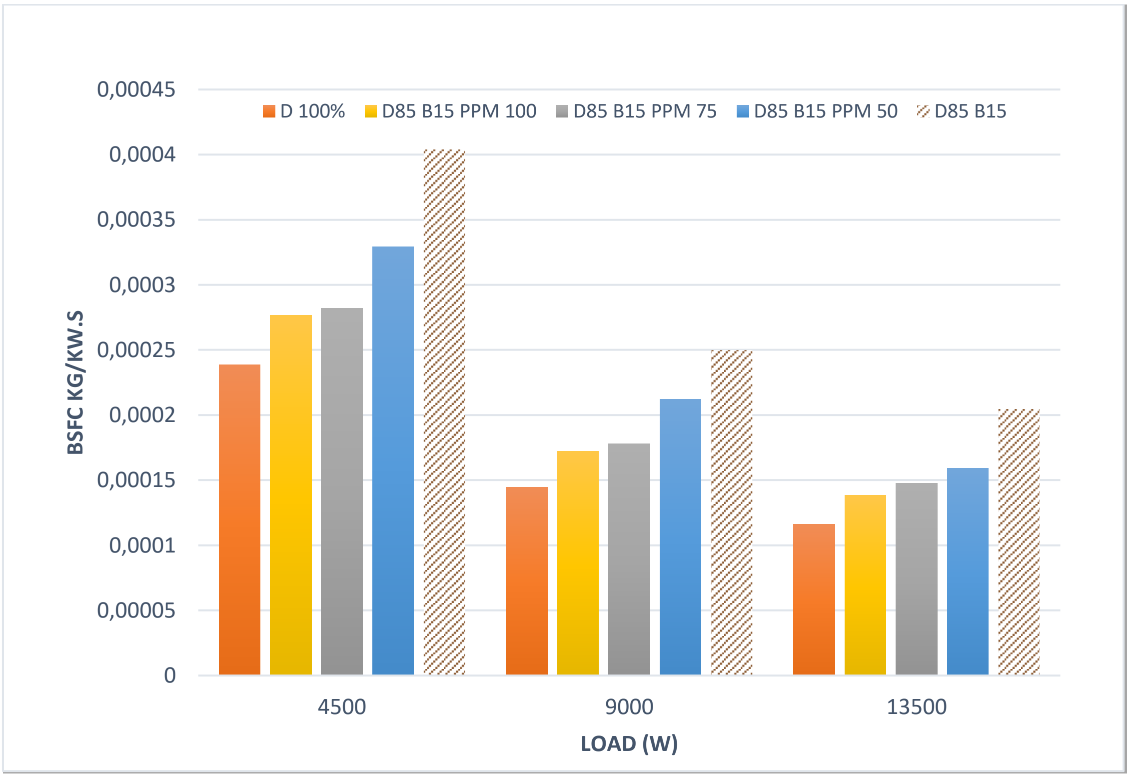


Figure 4.14. Change in BSFC appears using varying nano quantities of the biodiesel mixture at 1400 rpm.

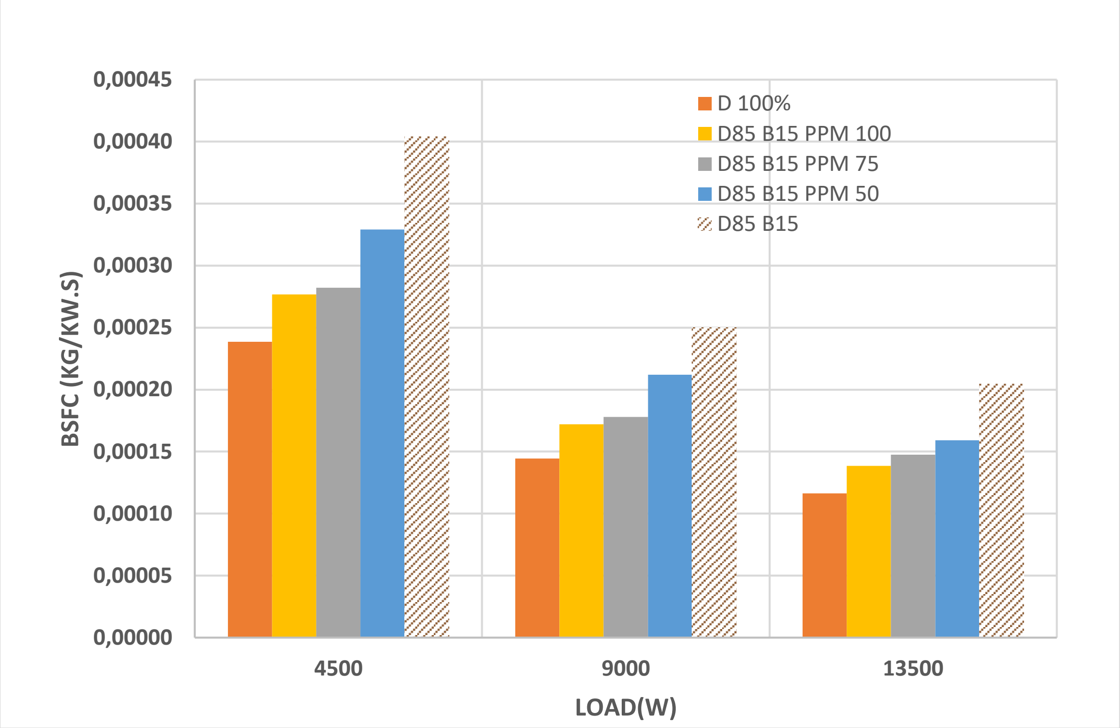


Figure 4.15. Variation in BSFC at different nano doses of diesel and biodiesel blend at 1,600 rpm.

The BSFC was calculated during engine operation at 13500 watts load with increasing speed from 1200 to 1600 rpm, as shown in Figure 4.16 In general, BSFC increases with increasing engine speed decreases with time. The BSFC value compared to pure diesel at 1200 rpm was 11.8%,17% ,34.6 respectively, for mixtures D85B15PPM100, D85B15PPM75 and D85B15PPM50.. The BSFC value compared to pure diesel at 1400 rpm was 18.9%, 26.7% and 37% respectively for mixtures D85B15PPM100, D85B15PPM75, D85B15PPM50 and The BSFC value compared to pure diesel at 1600 rpm was 16.6%, 25% and 33.3% respectively for mixtures D85B15PPM100, D85B15PPM75, D85B15PPM50 All fuel samples for nanoparticles showed lower fuel consumption as a value of BSFC Fewer. Compared to pure diesel fuel where we observe a clear decrease in BSFC after adding nanoparticles with the mixture (D85B15) Similar observations were made and observed for the results of [80,81]

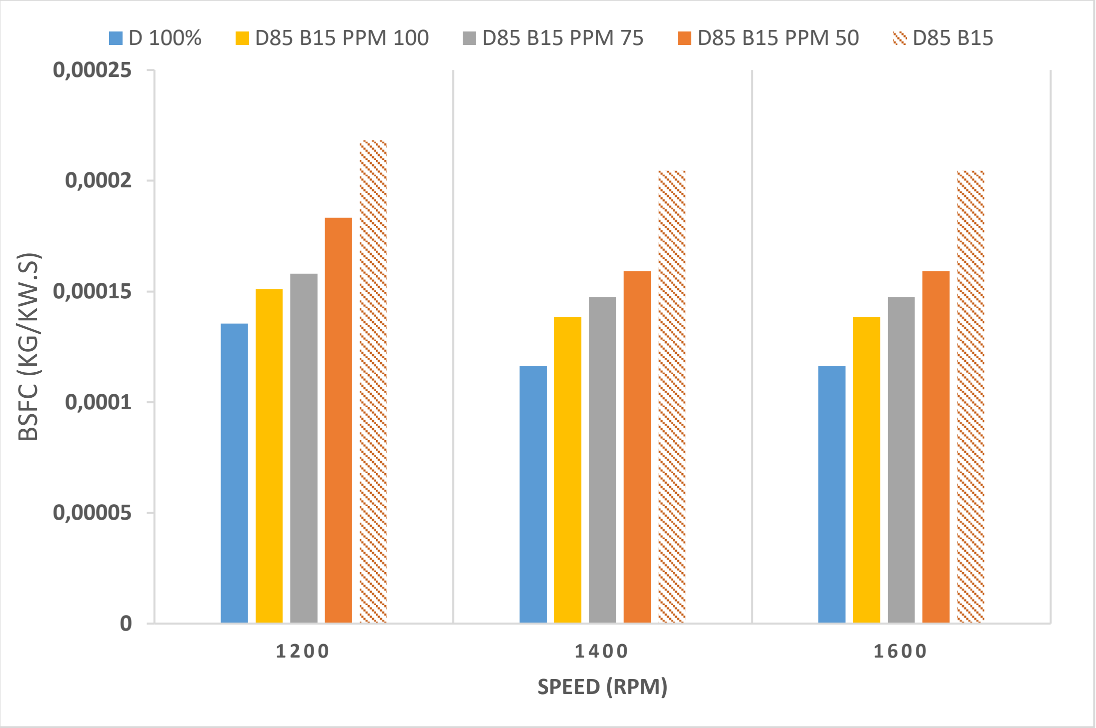


Figure 4.16. BSFC rated for fuel mixture with engine speeds at load 13500W.

PART 5

CONCLUSION AND RECOMMENDATIONS

5.1. CONCLUSIONS

In this research, the effects of adding copper oxide nanoparticles at different doses (such as at 100, 75, and 50 ppm) to biodiesel and pure diesel on engine performance were studied and the main conclusions of this study are presented below.

It was found that the viscosity and density of the fuel sample increases with the addition of nanoparticles. The thermal efficiency of the brakes (BTE) would increase with the addition of CuO nanoparticles to biodiesel.

Fuel Blend BTE for D85B15BPPM100 increased by 4.63% compared to D85B15 at 1200 rpm engine speed. BTE increased in fuel blend D85B15BPPM100 by 5.13% compared to D85B15 at 1400 rpm engine speed, and BTE increased for fuel mix D85B15BPPM100 by 5.56% compared to the D85B15 mix at 1600 rpm engine speed. However, the BSFC for the D85B15BPPM100 mix reduced compared to the D85B15 mix in full load conditions and at all speeds.

Of all the mixtures, it is noted that the D85B15BPPM100 mixture at a speed of 1600 rpm contains less BSFC compared to other blends.

It was noted that the calorific value improved with the addition of copper oxide nanoparticles to the D85B15mixture, and the utmost braking force and highest thermal efficiency of all engine speeds were obtained for pure diesel D100, and with the addition of biodiesel content, it tends to decrease. The closest thermal efficiency was obtained for a D85B15BPPM100 mixture of pure diesel.

The nanoparticles accelerated the chemical reactions in the combustion process as the ignition delay period was shortened and ensured more complete combustion.

It can be concluded that the performance characteristics can be increased with the increase of CuO nanoparticles to a D85B15 mixture.

5.2. RECOMMENDATIONS

- Using different nanoparticles with concentrations ranging from 150 to 300 ppm and mixing them with biodiesel for sunflower oil
- Adding nanoparticles such as iron oxide or aluminum oxide at different doses to biodiesel fuel with sunflower oil and testing their effect on engine performance
- Re-experiment with higher loads and high speeds
- Conducting an economic feasibility study for the experiment in terms of the costs per liter

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RESUME

Sinan Mohsin Kareem KAREEM he moved to the province of Salah al-Din and completed middle and preparatory studies at Tikrit High School with distinction and completed a Bachelor’s degree in Mechanical Engineering in 2001-2002. Sinan commenced work at the Ministry of Water Resources in the stations department as a maintenance engineer and then graduated and became the maintenance officer for the stations. Later he became the head of the stores department and then the head of the Department of Machinery and a Project Generator Maintenance Officer. In 2022, Sinan started studying Mechanical Engineering at Karabük University to complete his Master degree.