

EXPERIMENTAL ANALYSIS OF ADDITIVES IN BIODIESEL USING HYDROGEN AS FUEL

Submitted in partial fulfilment of the requirements for the award of

Bachelor of Engineering degree in

Mechanical Engineering

By

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INSTITUTE OF SCIENCE AND TECHNOLOGY

(DEEMED TO BE UNIVERSITY)

Accredited with grade "A++" by NAAC

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BONAFIDE CERTIFICATE

This is to certify that this Project Report is the Bonafide work of ARON JEFFERYLAL A (Reg. No. 40150002) and MARIA DICKSON J (Reg. No. 40150025) who carried out the project entitled "**EXPERIMENTAL ANALYSIS OF ADDITIVES IN BIODIESEL USING HYDROGEN AS FUEL**" under our supervision from December 2023 to April 2024.

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We, ARON JEFFERYLAL A (Reg. No. 40150002) and MARIA DICKSON J (Reg. No. 40150025) hereby declare that the Project Report entitled "EXPERIMENTAL ANALYSIS OF ADDITIVES IN BIODIESEL USING HYDROGEN AS FUEL" done by us under the guidance of Dr. HEMANANDH J., M.E., Ph.D., is submitted in partial fulfilment of the requirements for the award of Bachelor of Engineering degree in Mechanical Engineering.

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ABSTRACT

Non-renewable fossil fuels are depleting at a faster rate and causing energy crises. Alternative fuel sources must be discovered to replace fossil fuels to meet energy demands. However, it has to be noted that it is the primary cause for numerous environmental pollutants, such as CO, HC, and NO_x. The goal of this study is to examine how the addition of zinc oxide nanoparticles to hydrogen-lavender blended biodiesel impacts its combustion and exhaust emission. A four-stroke single-cylinder vertical water-cooled engine has been employed for the evaluation. Lavender Biodiesel and zinc oxide were combined using the ultrasonication process. According to the research findings, the addition of nanoparticles increased the brake thermal efficiency by 9.6%. Compared to pure diesel, there is a 13.7% reduction in brake-specific fuel consumption as the load increases. Furthermore, the addition of nanoparticles resulted in a reduction of 13.64% in hydrocarbon emissions, 9.16% in carbon dioxide emissions, 12.5% in carbon monoxide emissions, 9.63% in nitrogen oxide emissions, and finally, 29.6% in smoke opacity emissions. Therefore, the findings demonstrate that adding nanoparticles to hydrogen-Lavender biodiesel produces good results for diesel engines without requiring major engine modifications. The fuel mixtures are evaluated in a diesel engine using hydrogen injection, and the results are then compared with regular diesel fuel.

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LIST OF ABBREVIATIONS

ZnO ₂	Zinc oxide
CI	Compression ignition
BTE	Brake thermal efficiency
BSFC	Brake specific fuel consumption
HC	Hydrocarbons
CO ₂	Carbon dioxide
CO	Carbon monoxide
NO _x	Nitrogen oxide
H ₂	Hydrogen
ASTM	American Society for Testing and Materials
LPM	Liters Per Minute
kJ/kg	Kilo Joule per Kilogram
kg/m ³	Kilo gram per meter cube
ppm	parts per million
B20	80% diesel and 20% blends
B100	100% of Basil Biodiesel
DH	Diesel with Hydrogen
ZB20	Basil biodiesel with ZnO ₂ nanoparticle
ZHB20	Hydrogen Blended biodiesel with ZnO ₂ Nanoparticle

CHAPTER 1

INTRODUCTION

In a world increasingly aware of the environmental and sustainability challenges posed by traditional fossil fuels, the pursuit of alternative and cleaner energy sources has become a paramount focus of scientific research and innovation. Biodiesel, a renewable and more environmentally friendly substitute for conventional diesel fuel, has emerged as a promising solution to reduce carbon emissions and dependence on finite fossil fuel reserves. However, the ongoing quest for improved fuel performance and reduced environmental impact continues to drive innovation in the field. This study sets out to undertake a comprehensive experimental analysis of bio additives in biodiesel, in conjunction with hydrogen as an auxiliary fuel, with the aim of enhancing both fuel efficiency and environmental sustainability. Biodiesel, derived from renewable feedstocks like vegetable oils and animal fats, has gained prominence for its potential to reduce the carbon footprint associated with transportation and various industrial applications. Nevertheless, biodiesel faces inherent challenges pertaining to its combustion characteristics. These challenges encompass issues such as elevated nitrogen oxide (NO_x) emissions, incomplete combustion, and lower energy density in comparison to traditional diesel fuel. These limitations have spurred considerable interest in identifying innovative solutions to enhance the efficiency and environmental performance of biodiesel. Bio additives, a diverse category of organic compounds, have emerged as a promising avenue for optimizing biodiesel's combustion efficiency and emissions profile. When integrated into biodiesel formulations, these bio additives can influence vital parameters such as ignition delay, combustion stability, and emissions reduction. Additionally, the introduction of hydrogen as a supplementary fuel source presents a compelling opportunity, owing to its clean-burning properties and potential to address some of the inherent challenges in biodiesel combustion. The amalgamation of bio additives and hydrogen with biodiesel presents a multifaceted approach to address these challenges. By improving combustion characteristics and mitigating emissions, this approach holds the potential to foster the development of more sustainable and efficient biofuels.

The present study aims to conduct a thorough experimental analysis of these unique fuel combinations, examining their effects on combustion efficiency, engine performance, and emissions reduction. This research encompasses the production and meticulous characterization of biodiesel and a variety of bio additives. Subsequently, a series of systematic engine tests is conducted using a compression ignition engine, scrutinizing parameters such as brake-specific fuel consumption (BSFC), brake thermal efficiency (BTE), and exhaust emissions, including nitrogen oxides (NO_x), carbon monoxide (CO), carbon dioxide (CO₂), and particulate matter. The experiments span a range of operating conditions to comprehensively evaluate the performance of different fuel blends. Preliminary findings suggest that the inclusion of bio additives, in conjunction with hydrogen as a co-fuel, can lead to improved engine efficiency, reduced emissions, and enhanced combustion properties when compared to pure biodiesel. These findings not only hold promise for the development of more sustainable and efficient biofuel blends but also contribute significantly to the broader efforts to advance alternative fuels and mitigate the environmental impact of transportation. In summary, the experimental analysis of bio additives within biodiesel, coupled with hydrogen as a co-fuel, represents a pioneering step towards addressing the challenges associated with sustainable and eco-friendly transportation fuels. By enhancing combustion efficiency and curbing emissions, this research strives to catalyse the development of greener and more efficient alternative fuels, marking a significant stride towards a more sustainable and environmentally conscious future.

1.1 NEED OF ALTERNATIVE FUELS

The need for alternative fuels has become increasingly critical due to a variety of environmental, economic, and geopolitical reasons. Here are some of the key drivers behind the demand for alternative fuels:

Environmental Concerns: Perhaps the most compelling reason for alternative fuels is the urgent need to address environmental issues, particularly climate change.

Conventional fossil fuels, such as gasoline and diesel, release greenhouse gases (e.g., carbon dioxide) when burned, contributing to global warming and climate instability. Alternative fuels, such as biofuels, electricity, and hydrogen, offer cleaner and more sustainable options, reducing carbon emissions and air pollution.

Reducing Greenhouse Gas Emissions: Alternative fuels play a crucial role in efforts to reduce greenhouse gas emissions. Transitioning to low-carbon or carbon-neutral fuels is essential for meeting international climate goals, such as those outlined in the Paris Agreement, and for mitigating the impacts of climate change.

Energy Security: Many nations are dependent on imported fossil fuels, which can lead to energy security vulnerabilities. Alternative fuels, especially those produced domestically, reduce reliance on foreign oil and enhance energy security. For example, biofuels can be produced from locally grown crops.

Fossil fuels are finite resources, and their extraction can lead to environmental degradation, habitat destruction, and geopolitical conflicts. As reserves dwindle, the search for sustainable and renewable energy sources becomes increasingly critical.

Air Quality Improvement: The combustion of conventional fuels contributes to poor air quality, leading to health issues and smog formation. Alternative fuels, especially those with lower emissions, can help improve air quality and reduce respiratory diseases.

Innovation and Technological Advancements: The development and adoption of alternative fuels drive technological innovation. This innovation can lead to more efficient and cleaner energy production and transportation systems, fostering economic growth and job creation.

Diversification of Energy Sources: Relying solely on one energy source, such as oil, makes an economy vulnerable to price fluctuations and supply disruptions. The use of alternative fuels diversifies the energy mix, reducing economic risks associated with energy dependence.

Promotion of Sustainable Agriculture: Many alternative fuels, such as biofuels, are derived from renewable resources like crops and algae. This can promote sustainable agricultural practices, reduce deforestation, and enhance rural development.

Urban Planning and Liveability: Alternative fuels can play a crucial role in urban planning and improving the quality of life in cities. Electric vehicles, for instance, reduce noise and air pollution in urban environments.

Regulatory And Policy Initiatives: Governments around the world are implementing regulations and incentives to promote the use of alternative fuels. This includes tax incentives, emission reduction targets, and fuel economy standards, which encourage the adoption of cleaner energy sources.

1.2 ADVANTAGES OF THE USE OF BIODIESEL

- *Emissions Reduction:* It emits fewer greenhouse gases, mitigating climate change.
- *Biodegradable:* Biodiesel is biodegradable and less harmful to the environment in case of spills.
- *Improved Lubrication:* It enhances engine lubrication, reducing wear and tear.
- *Diverse Feedstocks:* Can be made from a variety of sources, including waste materials.
- *Domestic Production:* Supports local economies by using domestically sourced feedstocks.
- *Reduced Dependence on Petroleum:* Decreases reliance on imported petroleum-based diesel fuels.
- *Air Quality Improvement:* Lowers emissions, leading to better air quality.
- *Compatibility:* Can be used in existing diesel engines with minimal modifications

1.3 DISADVANTAGES OF THE USE OF BIODIESEL

Feedstock Competition: Biodiesel production can compete with food production, leading to concerns about potential food shortages and rising prices.

- *Land Use Change:* Expanding biodiesel crop cultivation may result in deforestation and habitat destruction, impacting biodiversity.
- *Resource Intensive:* Biodiesel production requires significant agricultural resources like water and land, potentially straining already stressed resources.
- *Land Use Conflicts:* Biodiesel feedstock production can displace food crops, leading to conflicts over land use.
- *Variable Feedstock Costs:* The cost of biodiesel feedstocks can fluctuate with market conditions, affecting fuel prices.
- *Reduced Fuel Economy:* Biodiesel may have slightly lower energy content compared to petroleum diesel, resulting in reduced fuel efficiency.
- *Colder Climate Challenges:* Biodiesel can gel in cold weather, necessitating the use of additives or cold-flow improvements.
- *Storage and Handling:* Biodiesel has different storage and handling requirements compared to petroleum diesel, which can pose challenges.
- *Emission Differences:* Biodiesel may produce higher levels of nitrogen oxides (NO_x), a precursor to smog formation, compared to petroleum diesel.
- *Fuel Quality Variability:* The quality of biodiesel can vary depending on feedstock sources and production processes, potentially affecting engine performance and emissions.

1.4 MATERIALS FOR BIODIESEL PREPARATION

Biodiesel is a renewable and environmentally friendly alternative to traditional diesel fuel, typically made from renewable resources. The primary raw materials used in the preparation of biodiesel are vegetable oils or animal fats, and a chemical catalyst. Here's a basic overview of the raw materials:

Feedstock (Vegetable Oils, waste cooking oil, leaves, flowers or Animal Fats):
Biodiesel can be produced from a variety of feedstocks, including:

- *Alcohol (Methanol or Ethanol):* Biodiesel production typically involves a transesterification reaction, where the feedstock (vegetable oil or animal fat) reacts with alcohol (usually methanol or ethanol) to produce biodiesel and glycerin. Methanol is the most commonly used alcohol in biodiesel production due to its efficiency, but ethanol can also be used.
- *Catalyst:* A catalyst, usually sodium or potassium hydroxide (NaOH or KOH), is needed to facilitate the transesterification reaction. The catalyst helps break down the feedstock into biodiesel and glycerin. It is important to handle these chemicals with care, as they can be corrosive.
- *Methanol Recovery System:* In some cases, a methanol recovery system is used to recover and recycle the alcohol, reducing costs and waste.
- *Water:* Small amounts of water are needed in the biodiesel production process, primarily to remove impurities and catalyst residues.
- *Equipment and Labor:* Biodiesel production also requires equipment such as reactors, mixers, and separation equipment. Additionally, labor is required to handle and monitor the production process.

It's important to note that the quality and characteristics of the raw materials used can impact the quality and properties of the biodiesel produced. Additionally, the specific process used for biodiesel production can vary, with some variations using different raw materials or additional additives to meet certain specifications and performance requirements.

Biodiesel production can be a complex process, and it is essential to follow safety protocols and regulations, especially when working with hazardous materials like methanol and catalysts. Additionally, the sustainability and ethical considerations related to feedstock selection are critical in biodiesel production.

1.5 VARIOUS RAW MATERIALS FOR OIL PREPARATION

1.5.1 Rapeseed

Rapeseed as shown in fig. 1.1 adapts well to low fertility soils, but with high Sulphur content. With a high oil painting yield (40 – 50), it may be grown as a downtime-cover crop, allows double civilization and crop gyration. It's the most important raw material for biodiesel product in the European Community. still, there were technological limitations for sowing and harvesting in some Central and South American countries, substantially due to the lack of acceptable information about fertilization, seed running, and storehouse (the seeds are veritably small and bear technical agrarian ministry). also, low prices in comparison to wheat (its main contender for crop gyration) and low product per unit area have limited its use. Rapeseed flour has high nutritive value, in comparison to soybean; it's used as a protein supplement in cattle sections. occasionally canola and rapeseed are synonymous; canola (Canadian oil painting low acid) is the result of the inheritable revision of rapeseed in the once 40 times, in Canada, to reduce the content of erucic acid and glycosylates in rapeseed oil painting, which causes vexation when used in beast and mortal consumption. Canola oil painting is largely appreciated due to its high quality, and with olive oil painting, it's considered as one of the stylish for cuisine as it helps to reduce blood cholesterol situations.



Fig. 1.1 Rapeseed plant with seeds

1.5.2 Soybean

It's a legume forming in East Asia. Depending on environmental conditions and inheritable kinds, the crops show wide variations in height. Leading soybean (as shown in fig. 1.2) producing countries are the United States, Brazil, Argentina, China, and India. Biodiesel product from soybean yields other precious subproducts in addition to glycerine soybean meal and hulls (used as food for beast) and flour (which have a high content of lecithin, a protein). Grain yield varies between 2,000 and 4,000 kg/ hectare. Since the seeds are veritably rich in protein, oil painting content is around 18.



Fig. 1.2 Soyabean with seeds

1.5.3 Sunflower

Sunflower seeds as shown in fig. 1.3 are really a fruit, the indigestible wall (cocoon) girding the seed that's in the kernel. The great significance of sunflower lies in the excellent quality of the comestible oil painting uprooted from its seeds. It's largely regarded from the point of view of nutritive quality, taste, and flavour. also, after oil painting birth, the remaining cutlet is used as a beast feed as shown in fig. 1.3. It must be noted that sunflower oil painting has a veritably low content of linoleic acid, and thus it may be stored for long ages. Sunflower adapts well to adverse environmental conditions and doesn't bear technical agrarian outfit and can be used for crop gyration with soybean and sludge. oil painting yield current mongrels is in the range 48 – 52.



Fig. 1.3 Sunflower with seeds

1.5.4 Castor Seed

The castor oil as shown in fig. 1.4 painting factory grows in tropical climates, with temperatures in the range 20 – 30C; it cannot endure frost. It's important to note that once the seeds start2.2 Raw Accoutrements for Biodiesel Production 11 germinating, the temperature mustn't fall below 12C. The factory needs a warm and sticky period in its vegetative phase and a dry season for growing and harvesting. It requires plenitude of sun and adapts well to several kinds of soils. The total downfall during the growth cycle must be in the range 700 – 1,400 mm; although it's resistant to failure, the castor oil painting factory needs at least 5 months of rain during the time. Castor oil painting is a triglyceride, ricinolein acid being the main element

(about 90). The oil painting is nonedible and poisonous owing to the presence of 1 – 5 of ricin, a poisonous protein that can be removed by cold pressing and filtering. The presence of hydroxyl groups in its moles makes it surprisingly polar as compared to other vegetable canvases.



Fig. 1.4 Castor seeds

1.5.5 Jatropha

Jatropha as shown in fig.1.5. is a shrub that adapts well to thirsty surroundings. Jatropha corpse is the most given variety; it requires little water or fresh care; thus, it's acceptable for warm regions with little fertility. Productivity may be reduced by irregular downfall or strong winds during the flowering season as shown in fig.1.5. Yield depends on climate, soil, downfall, and treatment during sowing and harvesting. Jatropha shops come productive after 3 or 4 times, and their lifetime is about 50 times. oil painting yield depends on the system of birth; it's 28 – 32 using presses and up to 52 by solvent birth. Since the seeds are poisonous, jatropha oil painting is eatable. The toxin is due to the presence of curcasin (a globulin) and jatrophaic acid (as poisonous as ricin).



Fig. 1. 5 Jatropha seeds

1.5.6 Lavender Flower

Lavender as shown in fig.1.6 biodiesel refers to a type of biodiesel energy produced from lavender oil painting. Biodiesel is a renewable energy deduced from organic sources similar as vegetable canvases or beast fats. Lavender oil painting, uprooted from lavender shops, can potentially be used as a feedstock for biodiesel product through a process called transesterification. Transesterification involves replying a triglyceride (similar as the oil painting from lavender) with an alcohol, generally methanol or ethanol, in the presence of a catalyst to produce biodiesel (adipose acid methyl or ethyl esters) and glycerin as a derivate. Lavender biodiesel has been explored as a implicit indispensable energy source due to its renewable nature and the possibility of reduced hothouse gas emigrations compared to conventional reactionary fuels. However, it's worth noting that the feasibility and scalability of lavender biodiesel product depend on colorful factors similar as the vacuity of lavender oil painting, the effectiveness of the conversion process, profitable considerations, and environmental impacts. While lavender biodiesel may offer some advantages, it's still fairly niche compared to other biodiesel feedstocks like soybean oil painting or recycled cuisine oil painting.



Fig. 1.6 Lavender Flower

1.6 NANOPARTICLES

A nano additive refers to a tiny, nanoscale-sized material that is added to enhance the properties of a substance or material. These additives are typically composed of nanoparticles, which are particles with dimensions on the nanometer scale (one billionth of a meter). Due to their incredibly small size, nano additives can exhibit unique and improved characteristics compared to their bulk counterparts.

Nano additives find applications across various industries, including manufacturing, electronics, medicine, and more. For instance, in manufacturing, they can be incorporated into materials like polymers or metals to enhance strength, conductivity, or other desirable properties. In medicine, nano additives are used in drug delivery systems to improve the efficiency and targeted delivery of medications. Because of their potential to revolutionize materials and processes, nano additives are an area of active research and development, with the aim of creating more advanced and functional materials for a wide range of applications. However, it's crucial to consider safety and potential environmental impacts when working with nano additives.

1.6.1 Types of Nanoparticles

Metal Nanoparticles: These are composed of metals like gold, silver, platinum, and copper. They exhibit unique electronic, optical, and catalytic properties, making them valuable in fields such as catalysis, electronics, and medicine.

Metal Oxide Nanoparticles: Examples include titanium dioxide (TiO₂), zinc oxide (ZnO₂), and iron oxide (Fe₃O₄). They find applications in sunscreens, sensors, drug delivery, and environmental remediation due to their semiconducting and catalytic properties.

Quantum Dots: These are semiconductor nanoparticles, often made of materials like cadmium selenide (CdSe) or indium phosphide (InP). They possess size-tunable optical properties, making them valuable in displays, imaging, and photovoltaics.

Carbon Nanotubes: Cylindrical carbon structures with extraordinary mechanical, electrical, and thermal properties. They're used in nanocomposites, sensors, drug delivery, and more.

1.6.2 Zinc Oxide (ZnO₂) Nanoparticles

Zinc oxide nanoparticles are nanoparticles of zinc oxide (ZnO₂) that have diameters lower than 100 nanometers. They have a large surface area relative to their size and high catalytic exertion. The specific physical and chemical characteristics of zinc oxide nanoparticles are contingent upon the numerous styles employed in their conflation. Some possible ways to produce ZnO₂ nano- patches are shaft ablation, hydrothermal styles, electrochemical grounds, sol – gel system, chemical vapor deposit, thermal corruption, combustion styles, ultrasound, microwave oven roaster- supported combustion system, two- step mechanochemical – thermal emulsion, rush, electrophoretic deposit, and rush processes using result attention, pH, and washing medium. ZnO₂ is a wide- bandgap semiconductor with an energy gap of 3.37 eV at room temperature.

CHAPTER 2

LITERATURE SURVEY

In recent years, data from the Energy Information Administration has revealed a projected surge of over 50% in energy consumption by 2040 compared to 2018 [1,2]. This projection is accompanied by an anticipated increase in fossil fuel emissions, raising significant environmental concerns. Consequently, extensive research efforts have been channeled towards mitigating the adverse impacts of fossil fuels on environmental pollution. Developing new technologies to reduce NO_x emissions has been a challenging endeavor in energy research, with two primary strategies proposed to address this issue: the adoption of alternative energy sources such as biodiesel and hydrogen, and the use of additives to enhance combustion efficiency and reduce emissions [3-5]. Diesel engines are favored over other engine types due to their superior thermal efficiency, lower fuel consumption, and reduced operating costs [6]. However, a major drawback is the emission of nitrogen oxides (NO_x) [7-10]. Fuel additives play a crucial role in altering fuel properties to improve combustion efficiency [11,12], with recent studies showing promising results with the addition of hydrogen alongside nanoparticles [13]. Achieving complete fuel combustion in the combustion chamber is essential for controlling harmful emissions [14]. Alcohol presence in biodiesel blends has shown potential in significantly reducing emissions. Methyl ester blends have been identified in numerous literature sources as the optimal diesel alternative without requiring extensive modifications to existing diesel engine designs [15-17]. The transportation sector's diesel consumption continues to rise annually, with global daily consumption reaching nearly 80 million barrels of petroleum products. Combustion of these products releases toxic gases such as hydrocarbons (HC), carbon monoxide (CO), carbon dioxide (CO₂), and NO, posing significant threats to the environment, including climate change and acid rain [18]. Reducing emissions is crucial, leading to extensive research into promising alternative fuels. These include non-edible oils, alcohol, biohydrogen, vegetable oil, non-feedstock, and animal fats, among others [19]. As industry demands expand, finding suitable alternatives to fossil fuels becomes increasingly important. Governments are actively promoting research on

alternative fuels with reduced emissions to replace petroleum products. While primary blends using corn have been extensively researched, the utilization of green fuel hydrogen as a secondary fuel with nanoparticles remains limited [20-23]. Many experts advocate for biodiesel and hydrogen as the best alternatives to traditional petroleum products, despite the rapid increase in fossil fuel prices [24]. Numerous academic studies have noted that the calorific values of biodiesels are typically lower than those of pure diesel. However, improvements can be made by incorporating additives or hydrogen into biodiesel [25,26]. The injection of hydrogen into the biodiesel leads to proportional increases in engine power and torque [27]. Hydrogen, being colorless and emitting no pollutants, is regarded as a green fuel with minimal environmental impact, producing only water and steam as byproducts. Various methods for hydrogen production exist, including electrolysis, photoelectrochemical methods, gasification, dark fermentation, thermolysis, plasma arc decomposition, thermochemical processes, anaerobic digestion, and photo fermentation [28]. Compared to diesel operation without hydrogen integration, adding hydrogen results in improved brake-specific fuel consumption and brake thermal efficiency, along with reduced levels of air pollutants such as CO, UHC, and soot. However, there is a simultaneous increase in NO_x emissions [29]. Hydrogen can be utilized as an alternative resource through two primary methods: fuel cells and internal combustion engines. Hydrogen fuel cells can achieve 60% efficiency while emitting zero pollutants. Hydrogen possesses rapid flame velocity, low ignition energy demand, minimal quenching thickness, and wide flammability limits, but it also presents inherent hazards. Therefore, a mixture of hydrogen and oxygen used in water electrolysis can serve as a safer alternative [30]. The cetane number serves as a measure of the fuel's ignition properties, with a higher value indicating a shorter ignition delay period and improved performance. Generally, biodiesel blended with hydrogen exhibits a higher cetane number than pure diesel due to the presence of long hydrocarbon (HC) chains. Concurrently, the engine's performance attributes are influenced by the calorific value of the fuel [31].

CHAPTER 3

AIM AND SCOPE

3.1 AIM

Investigating the revolutionary potential of nano additives to maximize a diesel engine's performance when hydrogen is used as the main fuel source is the main goal of this study. Our goal is to improve combustion properties in the fuel mixture by including nanoscale elements, which will result in higher engine efficiency and cleaner emissions. A thorough evaluation of combustion kinetics, ignition characteristics, and pollutant emissions are included in the specific objectives. Our objective is to examine the impact of nano additions on the rates of heat release, ignition delay, and combustion stability. We will also investigate the effect on emissions, concentrating on important pollutants like nitrogen oxides (NO_x). In addition, this research aims to clarify the mutually beneficial impacts of hydrogen and nano additions in order to determine the best formulas for maximizing performance benefits. It also seeks to identify the fundamental processes by which nano additives improve combustion efficiency, illuminating the nanoscale interactions that occur during combustion. The ultimate goal of this research is to advance environmentally friendly transportation solutions. The results could completely change how we think about diesel engines and how they work with other fuels like hydrogen. The consequences of the findings would be profound. Our goal is to help the automobile industry move towards a cleaner, more efficient, and ecologically conscious future by utilizing the potential of nano additives.

3.2 SCOPE

The project scope is listed in the following order.

Examine the practicality of generating biodiesel from a variety of feedstocks. This could entail analysing the subject matter's physical and chemical qualities in addition to looking at its accessibility and sustainability.

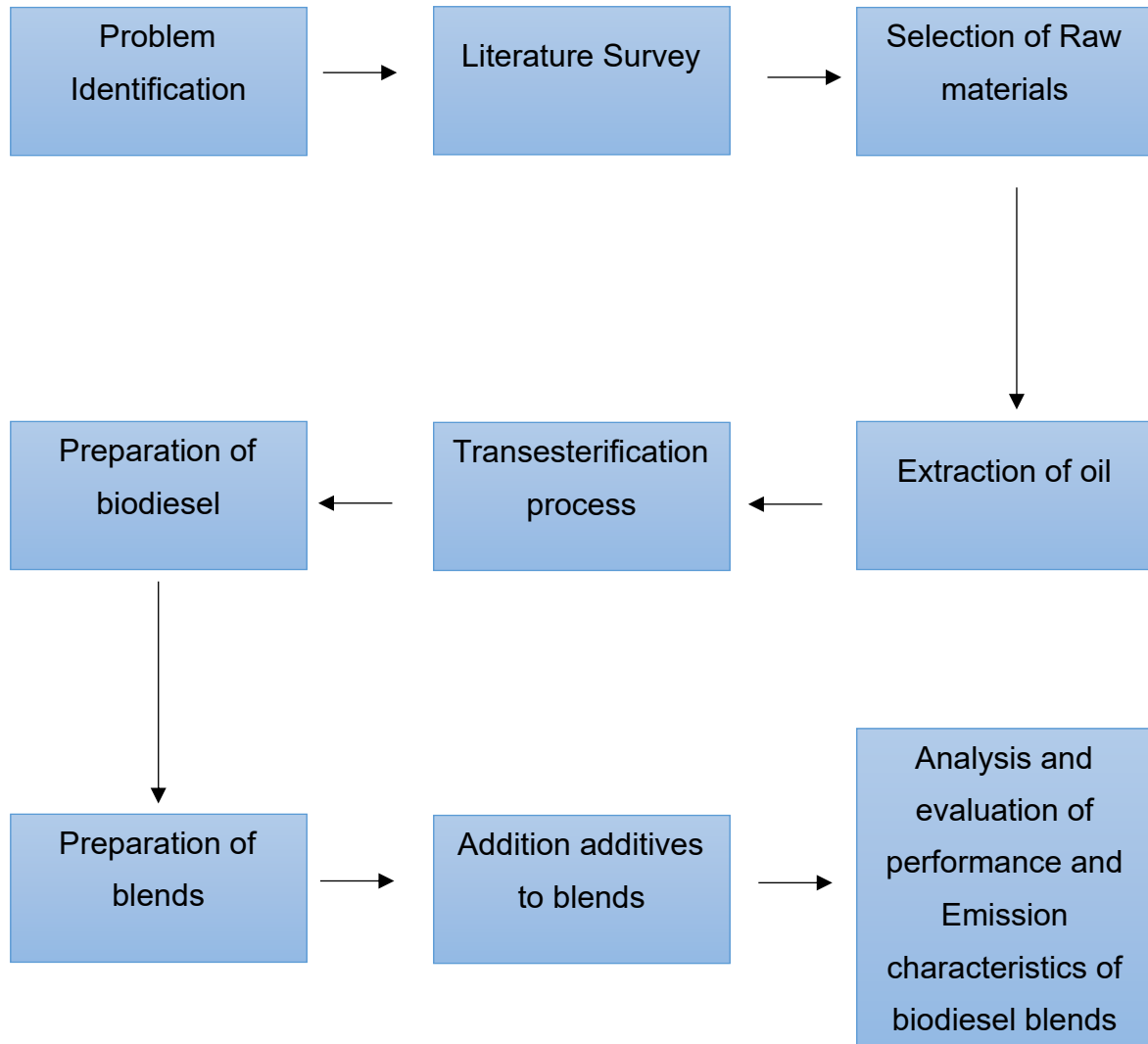
- *Biodiesel production:* Create and refine processes for turning a variety of basic materials into biodiesel. This can entail looking at various processing methods and assessing how effective they are as well as how they affect the environment.
- *Engine performance and emissions:* Examine how adding titanium dioxide nanoparticles to biodiesel affects emissions and engine performance. This could entail testing engines, examining how various biodiesel mixes burn, assessing the emissions of specific pollutants and greenhouse gases, and performing other relevant duties.

Promoting the production and use of biodiesel as a sustainable and renewable alternative to traditional fossil fuels is the overarching objective of biodiesel projects. These programmes could promote rural development, increase energy security, and reduce greenhouse gas emissions.

CHAPTER 4

MATERIALS AND EXPERIMENTAL METHODS

4.1 METHODOLOGY



4.2 PREPARATION OF BLENDS

"Blends" typically refers to mixtures or combinations of two or more substances. In the context of fuels like biodiesel, it often refers to the mixing of different fuel components or additives to create a new fuel with specific properties or characteristics. As an illustration, a biodiesel blend could comprise a combination of biodiesel and a petroleum-derived diesel fuel, commonly denoted as a proportion (e.g., B20, including 20% biodiesel and 80% petroleum diesel).

4.2.1 Types of Test Fuels

The conversion of vegetable oils, animal fats, or used cooking oils into biodiesel is referred to as transesterification. The procedure entails a chemical reaction between the oil or fat and an alcohol, commonly methanol or ethanol, in the presence of a catalyst, such as sodium hydroxide or potassium hydroxide.

B5 (5 Biodiesel): This mix contains 5 biodiesel and 95 conventional diesel. It's one of the most common biodiesel composites and is frequently used in diesel machines without any variations.

B10 (10% Biodiesel): B10 consists of 10% biodiesel and 90% conventional diesel. It's used as a slightly eco-friendlier option while remaining compatible with most diesel engines.

B20 (20% Biodiesel): With a higher biodiesel content of 20%, B20 is used to reduce emissions and dependence on fossil fuels. It may require some engine modifications or use in newer diesel engines.

B100 (100% Biodiesel): B100, also known as pure biodiesel, contains 100% biodiesel and no petroleum diesel. It's suitable for vehicles and equipment designed to run on biodiesel exclusively.

Biodiesel Blends for Cold Weather: In cold climates, lower-level biodiesel blends like B5 or B10 may be used to prevent gelling issues. Biodiesel has a higher cloud point and can gel in very cold temperatures, so adjustments are made to improve cold-weather performance.

Custom Blends: In some cases, custom biodiesel blends are created to meet specific performance or emissions requirements. These blends may have varying percentages of biodiesel to achieve the desired outcome. In this we have chosen B20 blend for the experiment

4.3 TRANSESTERIFICATION

The conversion of vegetable oils, animal fats, or used cooking oils into biodiesel is referred to as transesterification. The procedure entails a chemical reaction between the oil or fat and an alcohol, commonly methanol or ethanol, in the presence of a catalyst, such as sodium hydroxide or potassium hydroxide.

The transesterification reaction occurs in several stages:

- *Preparation of the oil or fat:* The oil or fat is heated to a certain temperature to remove any water that may be present. The oil is then filtered to remove any impurities or solid particles.
- The process of alcohol preparation involves subjecting the alcohol, commonly methanol or ethanol, to a specific temperature in order to eliminate any potential water content. Subsequently, the alcohol is combined with the catalyst, commonly sodium hydroxide or potassium hydroxide.
- The oil or fat is subsequently combined with the alcohol-catalyst combination in a reactor vessel after being heated. The mixture is subjected to stirring or agitation in order to achieve thorough mixing and facilitate the reaction.
- The process of biodiesel and glycerol generation involves the reaction between an oil or fat with an alcohol-catalyst mixture, leading to the production of two distinct products: biodiesel and glycerol. The lighter nature of biodiesel allows for its separation from the heavier glycerol, hence enabling its subsequent utilisation for alternative applications.
- The biodiesel undergoes a washing and drying process in order to eliminate any residual contaminants or catalyst residues. The biodiesel is commonly subjected to a washing process including water or a mixture of water and methanol.

- Quality control is an essential process that involves conducting tests on the final biodiesel product to verify its compliance with the required quality requirements, such as viscosity, density, and acid value.

The transesterification process plays a crucial role in the hydrolysis of vegetable oils, animal fats, or discarded cooking oils to produce biodiesel. The method is generally uncomplicated and direct, and can be implemented on either a small or large scale, depending on the producer's requirements.

4.4 BIODIESEL

Biodiesel is an environmentally friendly and abundant energy deduced from organic sources, including vegetable canvases, beast fats, and algae. Transesterification is a biofuel product system wherein canvases or fats suffer a chemical response with an alcohol, generally methanol, and a catalyst, generally sodium hydroxide or potassium hydroxide, performing in the conformation of adipose acid methyl esters (FAME).

Biodiesel can serve as a direct relief for traditional diesel energy in diesel machines, or it can be combined with diesel energy in different proportions. The energy in question is characterised by its cleanliness and low emigrations, flaunting reduced situations of hothouse gas emigrations and particulate matter in comparison to conventional diesel. also, it's both biodegradable and non-toxic, rendering it a more secure substitute. The utilisation of biodiesel holds the capacity to dwindle dependence on fossil energies and foster sustainable development. A different range of feedstocks, similar as waste and leftover cuisine canvases, can be utilised for its product, hence presenting profitable prospects in pastoral regions. nonetheless, the relinquishment and commercialization of this technology continue to encounter obstacles pertaining to the vacuity of feedstock, manufacturing charges, and legislative impulses. In general, biodiesel exhibits considerable eventuality as a feasible cover energy, playing a vital part in mollifying hothouse gas emigrations, promoting air quality, and bolstering energy security.

4.4.1 Biodiesel Characteristics

Biodiesel has several important characteristics that distinguish it from conventional diesel fuel. Some key characteristics of biodiesel include:

- **Renewable:** Biodiesel is made from renewable sources such as vegetable oils and animal fats, which can be sustainably produced and replenished.
- **Biodegradability:** Biodiesel exhibits biodegradability and non-toxicity, rendering it comparatively less environmentally detrimental in comparison to traditional diesel fuel.
- **Low emissions:** Biodiesel has lower greenhouse gas emissions and less particulate matter compared to diesel fuel. This makes it a cleaner-burning fuel and helps to improve air quality.

4.5 PROPERTIES OF BIODIESEL

Biodiesel is an environmentally friendly alternative fuel made from vegetable oils, animal fats, or recycled cooking oil. It has comparable qualities to petroleum-based diesel fuel, however there are notable distinctions due to its differing chemical makeup. Biodiesel has the following key properties:

- **Density:** Because biodiesel has a lower density than petroleum fuel, the energy content per unit volume might be affected.
- **Viscosity:** Because biodiesel has a higher viscosity than petroleum diesel, its flow via fuel injectors and pumps might be affected.
- **Flash point:** Because biodiesel has a greater flash point than petroleum diesel, it is safer to handle and store.
- **Cetane number:** Biodiesel has a higher cetane number than petroleum diesel, indicating that it has a better ignition and combustion quality.
- **Oxygen content:** Because biodiesel contains more oxygen than petroleum diesel, it can enhance combustion efficiency and minimize

carbon monoxide (CO) and unburned hydrocarbons (HC) emissions.

- *Sulphur content:* Biodiesel has almost little Sulphur, which minimizes Sulphur oxide(SOx) and particulate matter emissions.
- *Cold flow qualities:* Biodiesel has poor cold flow properties, which can cause it to thicken and form gels at low temperatures, resulting in fuel filter blockage and engine stalling.

Table 4.1: Properties of Diesel, ZB20, lavender Oil, Lavender Biodiesel

Test Properties	Test Method	Diesel	ZB20	LAVENDER OIL	LAVENDER BIODIESEL
Density Kg/m ³	ASTMD4052	830	841	829	810
Viscosity @ 40° in CST	ASTM D975	4.1	2.3	1.24	1.04
Flash Point °c	ASTMD93	52	115	141	134
Fire Point °c	ASTMD93	-	-	153	146
Calorific Value (KJ/Kg)	ASTMD240	42500	41502	40290	41896

4.6 METHODS AND METHODOLOGY

The local market in Chennai, India where the lavender biodiesel fuel was obtained. In the process of transesterification, the glycerin from the lavender flower separates, convert the flowers to the methyl ester of lavender oil. To break the molecules, catalyst will be added to the lavender oil. Following the normal test protocols (ASTM standard) and summarized in Table 4.1, the obtained lavender oil was filtered using an appropriate filter cloth to eliminate any undesirable residues. Lavender oil was first produced from lavender flowers after they were collected. Next, the number of fatty acids in the Lavender oil is quantified. Into the conical flask, add 25 milliliters of lavender essential oil. The temperature is set at 50 degrees Celsius. Methanol is purified by heating it in a flask with a circular bottom. After swirling and vigorously mixing the Lavender oil solutions (as shown in fig.4.1) for 50 minutes, the mixture is left to settle for 24 hours. The ultimate product is a blend of lavender biodiesel and glycerol. The purple biodiesel floats to the top while the glycerol sinks to the bottom because to its greater weight. The glycerol is collected in a different +The excess water is extracted from the lavender biodiesel by the evaporation process. It takes the above steps to make one liter of biodiesel (B100 as shown in fig. 4.2).



Fig. 4.1 Lavender oil & B100



Fig. 4.2 Blends of Lavender Biodiesel



Fig. 4.3 Flow Regulator of

4.7 EXPERIMENTAL PROCEDURE

As seen, the apparatus is confided for testing. After both diesel and hydrogen gas are taken out of the fuel tank and hydrogen cylinder, the hydrogen gas is allowed to pass through a flame or spark arrester. After that, a flow meter measures the flow rate and sets it to 6 LPM (Liters per minute). Subsequently, the hydrogen is mixed with fresh air and gasoline extracted from the fuel tank at the input air chamber before being pumped into the cylinder at a pressure of 200 bar. An eddy current dynamometer that is water-cooled is used to apply various engine loads. The engine's emissions are measured using the smoke and gas analyzer. To assess power, efficiency, and fuel consumption, use the Engine Soft Software. Similar to this, data is acquired using a variety of fuels, including diesel, B20 (lavender biodiesel with ZnO₂ nanoparticles), and diesel with hydrogen. Data is collected about smoke opacity, CO, HC, NO_x, and CO₂ emissions. Subsequently, an analysis is conducted to ascertain the ideal fuel blend that will minimize emissions while enhancing overall performance.

CHAPTER 5

EXPERIMENTAL SETUP

5.1 KIRLOSKAR TV1 ENGINE

The fig. 5.1 shows that setup consists of single cylinder, four stroke, Diesel machine connected to eddy current type dynamometer for loading. The set up has stage - alone panel box conforming of air box, energy tank, manometer, energy measuring unit, transmitters for air and energy flux measures, process indicator and machine indicator. Rotameters are handed for cooling water and calorimeter water flux dimension. The setup enables study of machine performance for corpse power, indicated power, frictional power, BMEP, IMEP, corpse thermal effectiveness, indicated thermal effectiveness, Mechanical effectiveness, volumetric effectiveness, specific energy consumption, A/ F rate and heat balance. LabVIEW predicated Engine Performance Analysis software package "Engine soft" is handed for on line performance evaluation.

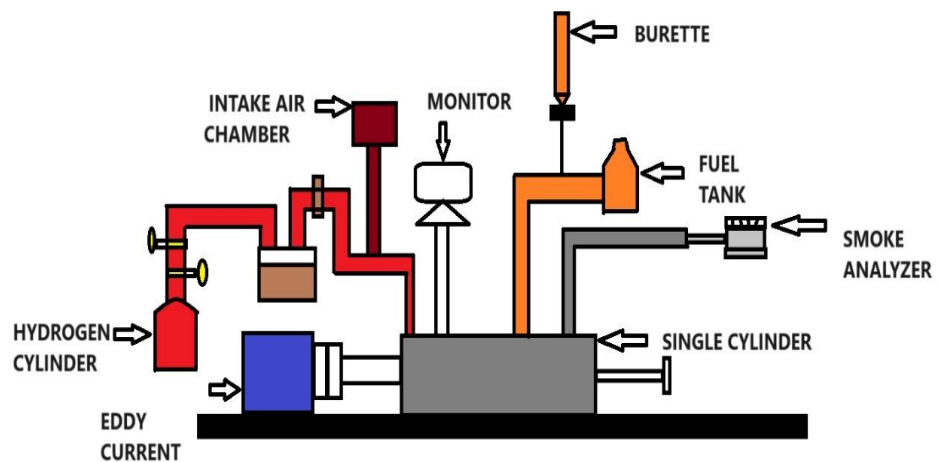


Fig. 5.1 Schematic Representation of the Diesel Engine.

1. The hydrogen cylinder is a container that holds pressurized hydrogen gas.
2. Intake Air Chamber: The chamber is filled with air to facilitate combustion.
3. The eddy current dynamometer is utilized to provide the engine with a load.

4. Individual Cylinder 4-Stroke The propulsion system of the vehicle is a single-cylinder, 4-stroke diesel engine. Fig. 5.3
5. The smoke analyzer is a gadget utilized for the examination of exhaust smoke generated by an engine subsequent to a fire incident.
6. The monitor is utilized for the purpose of monitoring the performance and combustion of the engine across various crankshaft angles.
7. The burette is a device utilized for the determination of brake-specific fuel combustion of the fuel.
8. The fuel tank serves the purpose of storing the fuel prior to its combustion.



Fig. 5.2 Hydrogen Cylinder

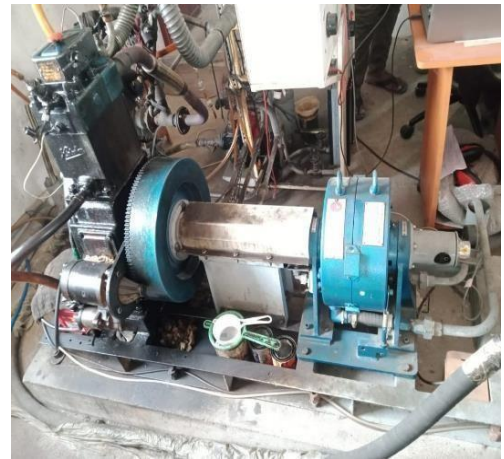


Fig. 5.3 Diesel Engine

5.2 KIRLOSKAR TV1 ENGINE SPECIFICATIONS

Table 5.1: ENGINE PARAMETERS

Parameter	Specification
Engine Model	Kirloskar Engine TV1
Type/Configuration	Vertical, four-stroke diesel engine
Cylinder	1
Cooling	Water-cooled
Ignition	Compression-Ignition
Compression Ratio	17:5:1
Displacement volume 661 cc	Displacement volume 661 cc
Rated Power 5.2 kW @1500 rpm	Rated Power 5.2 W @1500 rpm
Bore Diameter(D)	87.5 mm
Stroke Length (L)	110 mm
Eddy current dynamometer	Techno Mech
dynamometer Power	Maximum Power 7.5 kW @ 1500-6000 rpm
Test Conditions	Constant Speed @1500 rpm from 0% to 100% Percentage Load Conditions.

CHAPTER 6

RESULTS AND DISCUSSIONS

6.1 EMISSION ANALYSIS

6.1.1 Carbon monoxide Emissions (CO)

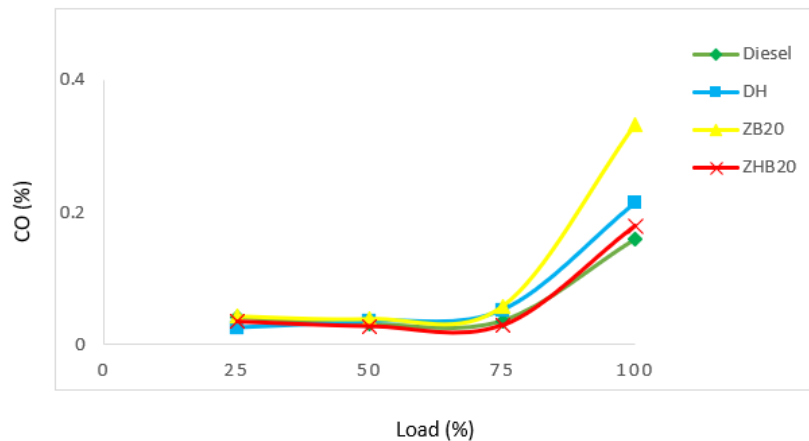


Fig. 6.1 Emission of Carbon monoxide

Fig. 6.1 makes it clear that carbon monoxide (CO) emissions follow a largely constant pattern, with very minor fluctuations seen until the CO exceeds 75% of the load. Still, when the load hits 100%, there's a noticeable spike in carbon monoxide (CO) gas emissions. Despite utilizing 6 LPM of hydrogen, the ZB20 fuel emits less carbon monoxide (CO) at maximum load as compared to alternative fuels. On the other hand, the ZB20 mixture releases more carbon monoxide. When carbon monoxide (CO) emissions from ZB20 and ZHB20 are compared, there has been a notable 22.97% decrease. Hydrogen added to the fuel combination resulted in a significant increase in the oxygen content of the biodiesel, which in turn led to a significant reduction in carbon monoxide (CO) emissions. It is possible to link the observed decline in CO emissions to the reduction in carbon emissions.

6.1.2 Carbon dioxide Emission (CO_2)

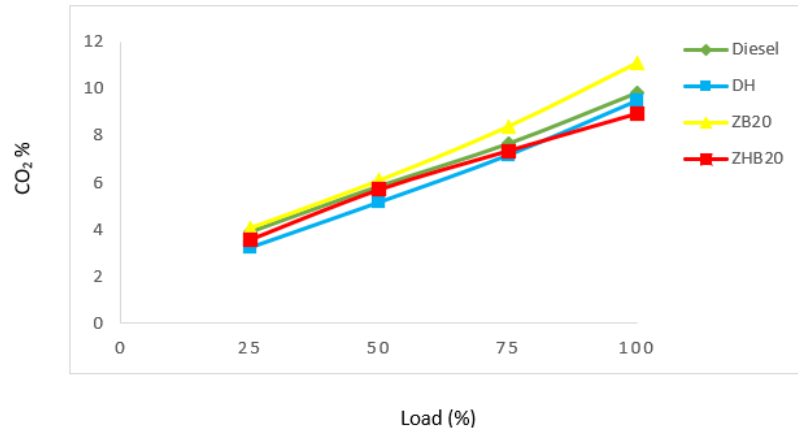


Fig. 6.2 Emission of Carbon dioxide

Fig. 6.2 shows that there is a positive relationship between the rise in CO₂ emissions and the load in the cylinder. When the engine is operating at maximum power, ZB20 gasoline produces more CO₂ whereas ZHB20 emits less. In comparison to ZHB20 and DH, the CO₂ emissions in ZB20 and Pure Diesel have increased by 19.55% and 3.45%, respectively. The addition of hydrogen to the combustion process lowers the release of carbon particles and improves the overall cleanliness of the combustion, which is responsible for the decrease in CO₂ emissions.

6.1.3 Hydrocarbons Emission (HC)

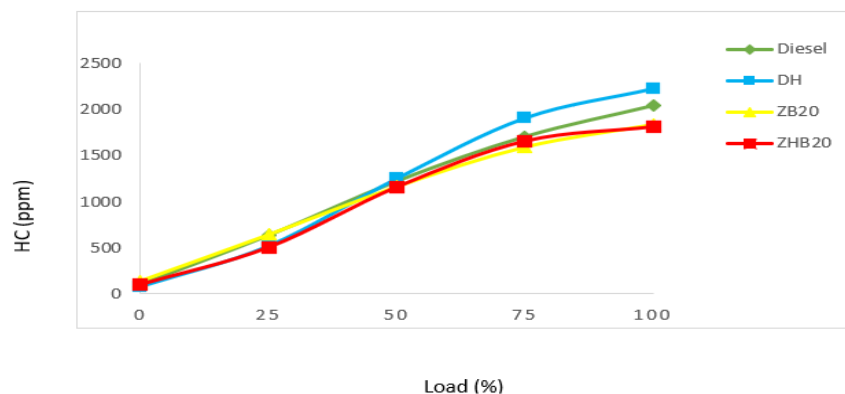


Fig. 6.3 Emission of Hydrocarbons

The hydrocarbon emission (HC) at different engine loads is shown in fig. 6.3. It is important to note that when engine load increases, hydrocarbon emissions also rise. This effect is mostly caused by reduced fuel droplet evaporation and the combination of many formulas. The addition of ZnO_2 to B20, on the other hand, results in less hydrogen than diesel. By adding a high concentration of oxygen and achieving complete combustion, hydrogen blends and nanoparticle additions can effectively improve combustion. Because the nanoparticles act as an oxygen buffer, their integration reduces the amount of hydrocarbons released when compared to diesel fuel. Diesel fuel releases more hydrocarbons into the atmosphere when it is used at 100% load, but ZB20 biodiesel with hydrogen releases comparatively less. ZHB20 has a 13.63% lower HC concentration than Diesel with Hydrogen.

6.1.4 Nitrogen oxide Emission (NO_x)

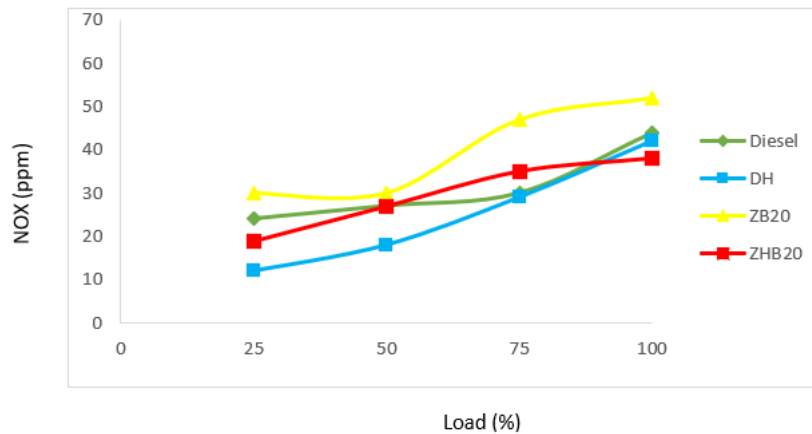


Fig. 6.4 Emission of Nitrogen Oxide

Data showing a direct correlation between load and NO_x emissions is shown in Fig. 6.4. When DH is used instead of just diesel, there is an increase in NO_x emissions. The amount of NO_x in DH has increased by 9.37% when compared to diesel fuel. The relationship between NO_x emission and fuel oxygen concentration as well as cylinder wall temperature can be used to explain the rise in NO_x levels during the emission process. The introduction of hydrogen during combustion raises the temperature of the cylinder wall, which increases the amount of NO_x released into the atmosphere. Comparing the ZHB20 fuel blend with H_2 to other gasoline blends,

the emissions are lower. When ZB20 is loaded to 100% with H₂, NO_x emissions are 7.53% lower than when ZB20 is used. The high combustion of nanoparticles in fuel is attributed to their intrinsic oxygen content.

6.1.5 Opacity Smoke Analysis

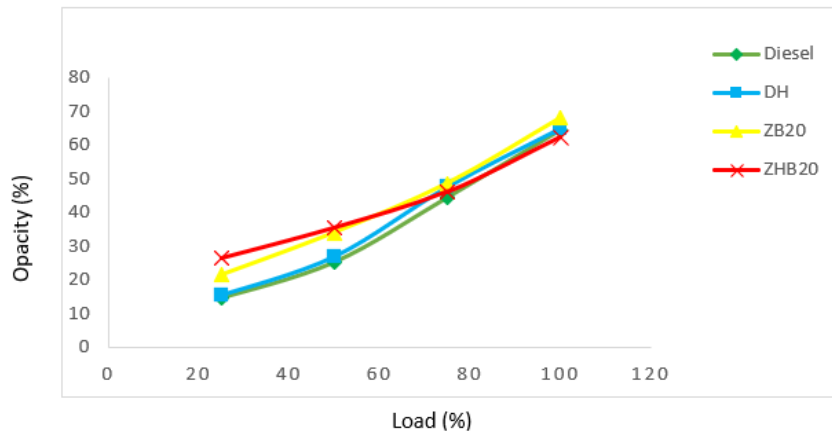


Fig. 6.5 Emission of Opacity Smoke

The positive correlation between the load and the fuel's opacity is seen in picture 6.5. Diesel usually burns incompletely, which contributes to its high opacity. The soot level of DH is 2.95% higher than that of diesel alone. Because hydrogen is used during the combustion process, ZB20 with hydrogen exhibits a fall in opacity. Due to hydrogen's pure fuel quality, less soot is released into the environment, which lowers the opacity of diesel fuel mixed with hydrogen.

6.2 PERFORMANCE ANALYSIS

6.2.1 Brake Thermal Efficiency (BTE)

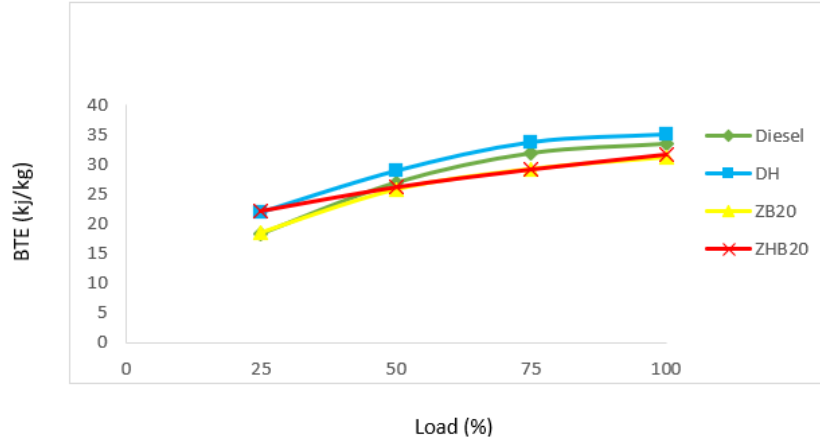


Fig. 6.6 Brake Thermal Efficiency (BTE)

The positive correlation between the load and the fuel's opacity is seen in fig. 6.6. Diesel usually burns incompletely, which contributes to its high opacity. ZHB20 has a soot percentage that is 2.95% higher than diesel. One can see that ZHB20 has less opacity because hydrogen is used in the combustion process. Because of its status as a clean fuel, hydrogen contributes to less soot being released into the atmosphere, which lowers DH's opacity.

6.2.2 Brake Specific Fuel Consumption (BSFC):

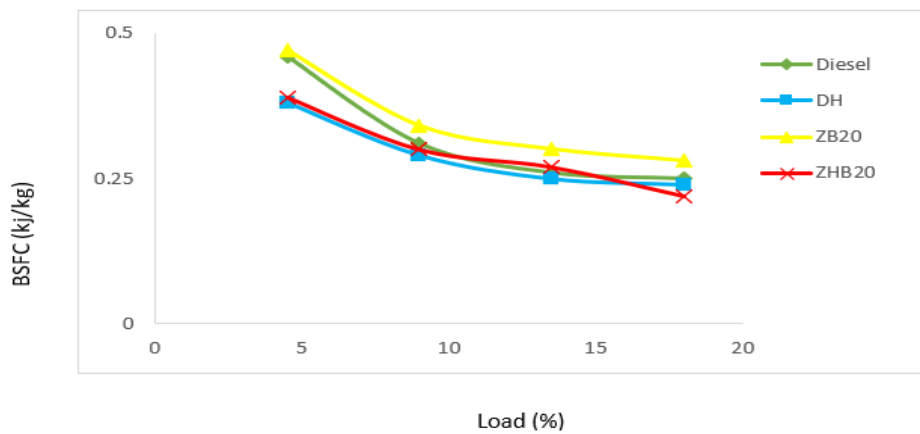


Fig. 6.7 Brake Specific Fuel Consumption (BSFC)

In a compression ignition (CI) engine, the ignition time plays a major role in improving the engine's performance characteristics by positively modifying its chemical and physical properties. More specifically, for every fuel that was assessed, determining the ideal ignition time lowers the Brake Specific Fuel Consumption (BSFC). Fig. 6.7 shows that the fuel combustion primarily associated with the brakes reduces as the load increases. The ZB20 with H₂ offers the lowest brake-specific fuel consumption when hydrogen is used at 100% load. As the load rises, the fuel's Brake Specific Fuel Consumption (BSFC) falls. Because the fuel burns more efficiently and completely when hydrogen is added to the combustion chamber, the rate of combustion increases. As a result, when the load grows, the (BSFC) drops. The (BSFC) of diesel, DH, ZB20, and ZB20 with H₂ are shown in Fig. 6.7. Because of its higher calorific value, the fuel combining hydrogen and nanoparticles performs better than diesel fuel. Of all the fuels that were tested, ZB20 and Diesel had the highest BSFC values. Because of their high calorific content, pure diesel and fuel without hydrogen hence have higher fuel consumption.

CHAPTER 7

CONCLUSION

The main objective of this work is to produce Lavender biodiesel from Lavender oil using transesterification, which uses NaOH as a catalyst. After then, it burns as the primary fuel while hydrogen is used as a backup fuel. Based on a single-cylinder diesel engine, the present study's findings show how ZnO₂ nanoparticles affect ZHB20. ZB20 provides better BTE and BSFC performance when it contains hydrogen and nanoparticles. ZnO₂ nanoparticles have a large surface area, which increases the rate at which they burn. Furthermore, by enriching the hydrogen in the air system, they improve the heat and pressure values in the cylinder. The impact of hydrogen in the atmosphere is the main reason for the reduction in emissions. An overview of the results is possible in this manner: According to the CO emission graph, ZB20 emits more CO than ZHB20, with the former emitting less. ZHB20 shows a reduced HC emission at 100% load, but both Diesel and DH show a marginal HC emission, according to the HC emission graph. The CO₂ emissions graph shows that ZHB20 emits less CO₂ than HB20, but HB20 emits more CO₂ than ZHB20. As can be seen from the NO_x emission graph, ZHB20 and ZB20 show a somewhat lower NO_x emission than does DH, which shows a considerable release of releases. Based on the opacity graph, ZHB20 has a lower level of opacity than DH, which has a higher level. The braking thermal efficiency of ZB20 is significantly lower than that of DH emissions, as can be seen from the graph that compares loading and BTE. Fuel combustion is shown to decrease with increasing load on the brake-specific fuel combustion diagram. Under 100% load, ZHB20 shows a lower brake-specific fuel consumption (BSFC).

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