

IMPACT OF NANO ADDITIVES IN DIESEL ENGINE USING HYDROGEN AS FUEL

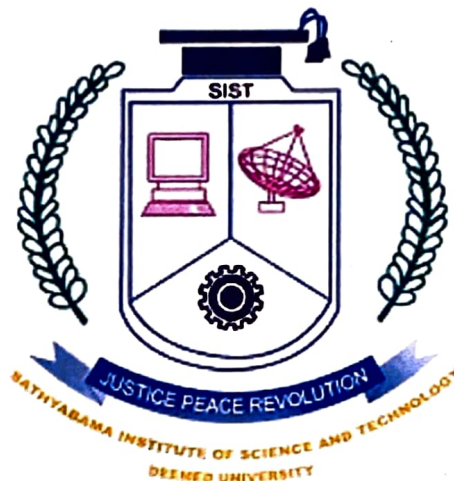
Submitted in partial fulfilment of the requirements for the award of

Bachelor of Engineering degree in
Mechanical Engineering

By

SUDHARSHAN SARAVANAN (Reg. No. 40150708)

NITISH L V (Reg. No. 40150032)



DEPARTMENT OF MECHANICAL ENGINEERING

SCHOOL OF MECHANICAL ENGINEERING

SATHYABAMA

INSTITUTE OF SCIENCE AND TECHNOLOGY

(DEEMED TO BE UNIVERSITY)

Accredited with grade "A++" by NAAC

JEPPIAAR NAGAR, RAJIV GANDHI SALAI, CHENNAI – 600119.

APRIL 2024



SATHYABAMA

INSTITUTE OF SCIENCE AND TECHNOLOGY

(DEEMED TO BE UNIVERSITY)

Accredited "A++" Grade by NAAC | 12B Status by UGC | Approved by AICTE

www.sathyabama.ac.in

DEPARTMENT OF MECHANICAL ENGINEERING

BONAFIDE CERTIFICATE

This is to certify that this Project Report is the Bonafide work of SUDHARSHAN SARAVANAN (Reg. No. 40150708) and NITISH L V (Reg. No. 40150032) who carried out the project entitled **"IMPACT OF NANO ADDITIVES IN DIESEL ENGINE USING HYDROGEN AS FUEL"** under our supervision from December 2023 to April 2024.

Internal Guide

Dr. HEMANANDH J., M.E., Ph.D.,

Head of the Department

Dr. GANESAN S., M.E., Ph.D.,

Submitted for Viva voce Examination held on 06.04.2024

Internal Examiner
External Examiner

DECLARATION

We, SUDHARSHAN SARAVANAN (Reg. No. 40150032) and NITISH L V (Reg. No. 40150032) and hereby declare that the Project Report entitled **“IMPACT OF NANO ADDITIVES IN DIESEL ENGINE 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.

DATE: 06.04.2024

PLACE: CHENNAI

SIGNATURE OF THE CANDIDATES



1. SUDHARSHAN SARAVANAN



2. NITISH L V

ACKNOWLEDGEMENTS

We are pleased to acknowledge our sincere thanks to Board of Management of **SATHYABAMA INSTITUTE OF SCIENCE AND TECHNOLOGY** for their kind encouragement in doing this project and for completing it successfully. We are grateful to them.

We convey our sincere thanks to **Dr. GANESAN S., M.E., Ph.D.**, Head of the Department, Department of Mechanical Engineering for providing us necessary support and details at the right time during the progressive reviews.

I would like to express my sincere and deep sense of gratitude to my Project Guide **Dr. HEMANANDH J., M.E., Ph.D.**, Associate Professor, Department of Mechanical Engineering for his valuable guidance, suggestions, and constant encouragement paved way for the successful completion of my project work.

We also express our thanks to all Teaching and Non-teaching staff members of the Department of Mechanical Engineering who were helpful in many ways for the completion of the project.

ABSTRACT

The depletion of fossil fuel resources necessitates a search for alternative fuel sources. Biodiesel holds the potential to serve as a substitute for fossil fuels. Biodiesel is a type of fuel that is obtained from plant and zoological sources, primarily consisting of esters, which are long chain fatty acids. Nevertheless, it is imperative to acknowledge that it is responsible for the majority of environmental pollutants such as CO, HC, and NO_x. This study aims to assess the impact of incorporating Titanium dioxide nanoparticles on the combustion performance and exhaust emission of hydrogen basil blended biodiesel. The evaluation was conducted utilizing a Four Stroke Single Cylinder vertical water-cooled engine. The findings of the study indicated that the incorporation of nanoparticles with Hydrogen resulted in a 12.6% enhancement in brake thermal efficiency. As the load increases, there is a 14.3% decrease in brake-specific fuel consumption compared to using pure diesel. In addition, the incorporation of nanoparticles and Hydrogen led to a decrease in emission levels by 11.36% for hydrocarbons, 7.9% for carbon dioxide, 18.75% for carbon monoxide, 15% for nitrogen oxide, and subsequently, 26% for smoke opacity. Hence, the findings demonstrate that the use of nanoparticles as an additive in hydrogen-basil biodiesel yields favourable outcomes for diesel engines, without necessitating significant engine modifications. The fuel mixtures are assessed within a diesel engine through the use of hydrogen injection, and subsequently, the outcomes are juxtaposed with conventional diesel fuel.

TABLE OF CONTENTS

CHAPTER No.	TITLE	PAGE No.
	ABSTRACT	v
	LIST OF FIGURES	viii
	LIST OF TABLES	x
	LIST OF SYMBOLS AND ABBREVIATIONS	xi
1	INTRODUCTION	1
	1.1 NEED OF ALTERNATIVE FUELS	2
	1.2 ADVANTAGES OF THE USE OF BIODIESEL	2
	1.3 DISADVANTAGES OF THE USE OF BIODIESEL	2
	1.4 RAW MATERIALS FOR BIODIESEL PREPARATION	3
	1.5 VARIOUS RAW MATERIALS FOR BIODIESEL PREPARATION	4
	1.5.1 Cottonseed	4
	1.5.2 Rapeseed	5
	1.5.3 Corn seed	6
	1.5.4 Jatropha	6
	1.5.5 Sunflower	7
	1.5.6 Basil Leaves	8
	1.6 NANOPARTICLES	9
	1.6.1 Types of Nanoparticles	9
	1.6.2 Titanium Dioxide (TiO ₂)	10
2	LITERATURE SURVEY	11
3	AIM AND SCOPE	14
	3.1 AIM	14
	3.2 SCOPE	15
4	MATERIALS AND EXPERIMENTAL METHOD	16
	4.1 METHODOLOGY	16
	4.2 TRANSESTERIFICATION	17

CHAPTER No.	TITLE	PAGE No.
4.3	PREPARATION OF BLENDS	18
	4.3.1 Types of Test Fuels	18
4.4	BIODIESEL	18
	4.4.1 Biodiesel Characteristics	19
4.5	PROPERTIES OF BIODIESEL	20
4.6	MATERIALS AND PROCESSES USED	21
4.7	EXPERIMENTAL PROCEDURE	23
5	EXPERIMENTAL SETUP	24
5.1	KILOSKAR TV1 ENGINE	24
5.2	KILOSKAR TV1 ENGINE SPECIFICATIONS	26
6	RESULTS AND DISCUSSION	27
6.1	PERFORMANCE ANALYSIS	27
	6.1.1 Brake Specific Fuel Consumption (BSFC)	27
	6.1.2 Brake Thermal Efficiency (BTE)	28
6.2	EMISSION ANALYSIS	29
	6.2.1 Carbon Monoxide (CO) Emission	29
	6.2.2 Carbon Dioxide (CO ₂) Emission	30
	6.2.3 Hydrocarbons (HC) Emission	30
	6.2.4 Nitrogen Oxide (NO _x) Emission	31
	6.2.5 Opacity Smoke Analysis	32
7	CONCLUSION	33
	REFERENCES	35

LIST OF FIGURES

FIG No.	TITLE	PAGE No.
1.1	Cottonseed	5
1.2	Rapeseed plant with seeds	6
1.3	Corn Seed	6
1.4	Jatropha seeds	7
1.5	Sunflower with seeds	8
1.6	Basil Leaves	9
4.1	Basil Oil	22
4.2	Blends of Basil Biodiesel	22
4.3	Flow Regulator of Hydrogen gas	23
5.1	Schematic Representation of the Diesel Engine	24
5.2	Hydrogen Cylinder	25
5.3	Diesel Engine	25
6.1	Brake Specific Fuel Consumption (BSFC)	27
6.2	Brake Thermal Efficiency (BTE)	28
6.3	Emission of Carbon monoxide	29
6.4	Emission of Carbon dioxide	30
6.5	Emission of Hydrocarbons	30

6.6	Emission of Nitrogen Oxide	31
6.7	Emission of Opacity Smoke	32

LIST OF TABLES

TABLE No.	TITLE	PAGE No.
4.1	PROPERTIES OF DIESEL, TB20, BASIL OIL, BASIL BIODIESEL	21
5.1	ENGINE PARAMETERS	26

LIST OF ABBREVIATIONS

TiO ₂	Titanium dioxide
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
TB20	Basil biodiesel with TiO ₂ nanoparticle
HTB20	Hydrogen Blended biodiesel with TiO ₂ Nanoparticle

CHAPTER 1

INTRODUCTION

The automotive industry is witnessing a transformative shift towards further sustainable and eco-friendly modes of transportation. One of the crucial areas of interest in this metamorphosis is the development of indispensable energies to reduce greenhouse gas emissions and combat the adverse effects of conventional internal combustion machines. Hydrogen, with its clean-burning properties and potential to significantly lower emissions, has emerged as a promising alternative fuel. However, using hydrogen in diesel engines poses certain technical challenges, which this study aims to address through the investigation of nano additives. In recent years, the imperative to decarbonize the transportation sector has driven extensive research into alternative fuels and advanced engine technologies. Among these, the integration of hydrogen as a primary fuel source in internal combustion engines holds significant promise. This paradigm shift towards hydrogen-powered propulsion systems necessitates a reevaluation of conventional combustion dynamics and the potential for enhancement through innovative approaches. One such avenue of exploration is the incorporation of nano additives into the fuel mixture of diesel engines using hydrogen. Nano additives, composed of particles at the nanoscale, have demonstrated remarkable properties that can potentially revolutionize combustion processes. Their minuscule size allows for unprecedented surface area interactions, influencing ignition kinetics, heat release rates, and emissions profiles. This research endeavors to probe the transformative impact of nano additives on the performance of diesel engines in a hydrogen-fueled environment. By systematically evaluating combustion characteristics and emissions outcomes, this study aims to elucidate the mechanisms through which nano additives augment combustion efficiency. Additionally, it seeks to uncover potential synergies between hydrogen and nano additives, ultimately striving to unlock the full potential of this innovative approach. The findings of this investigation hold the promise of not only advancing our understanding of combustion at the nanoscale but also providing critical insights for the development of cleaner and more efficient transportation solutions in the pursuit of a sustainable energy future.

1.1 NEED OF ALTERNATIVE FUELS

- Reducing Greenhouse Gas Emissions
- To reduce environmental pollutions.
- Technological Innovation and Economic Opportunities
- Meeting the current global energy demand
- Improving Air Quality

1.2 ADVANTAGES OF THE USE OF BIODIESEL

- Renewable fuel, obtained from vegetable oils or animal fats.
- Biodiesel can be made from waste oils and fats, including recycled cooking oil, reducing waste and offering an environmentally responsible way to dispose of these materials.
- Biodiesel reduces dependence on fossil fuels, contributing to energy security and reducing reliance on unstable or foreign oil sources.
- Biodiesel's lower Sulphur content can help mitigate acid rain, as it produces fewer Sulphur oxides (Sox) emissions that contribute to acid rain formation.
- Biodiesel production can create opportunities for farmers by providing a new market for oilseed crops and other feedstocks used in biodiesel production.

1.3 DISADVANTAGES OF THE USE OF BIODIESEL

There exist specific drawbacks associated with the utilization of biodiesel as a substitute for conventional diesel fuel that necessitate careful consideration:

- Biodiesel has a lower energy content per unit volume compared to conventional diesel, which can result in reduced fuel economy in vehicles using biodiesel.
- Slightly higher nitrous oxide (NOx) emissions than diesel fuel.

- Biodiesel has an affinity for water, which can lead to fuel-water separation issues and potential microbial growth in fuel tanks and systems.
- Higher freezing point than diesel fuel; slightly higher emissions of nitrous oxide (NO_x). In colder climates, this could be inconvenient.
- Biodiesel is more susceptible to oxidation and microbial contamination, which can lead to fuel degradation during storage. This makes proper storage and handling essential.
- Biodiesel can lead to engine compatibility issues in vehicles not designed for its use, which may necessitate modifications or upgrades to engines and fuel systems.
- While biodiesel is often seen as a fuel with fewer emissions, its environmental advantages can be undermined by various variables like alterations in land use, the transportation of feedstocks, and energy-intensive production methods.
- The proliferation of biodiesel feedstock cultivation can result in alterations to land use, such as deforestation and the transformation of natural habitats into agricultural land, leading to the loss of habitats and a fall in biodiversity.

Therefore, it is advisable to clean tanks before filling them with biodiesel. It is important to acknowledge that the drawbacks are considerably mitigated when biodiesel is used into diesel fuel blends.

1.4 RAW MATERIALS FOR BIODIESEL PREPARATION

The basic components employed in the production of biodiesel include vegetable oils, animal fats, and short-chain alcohols. Rapeseed oil is widely employed in the global production of biodiesel, particularly in European Union member states. Soybean oil is prevalent in Argentina and the United States of America, while palm oil is utilized in Asian and Central American countries. Sunflower oil is the most utilized oil, although peanut, linseed, safflower, used vegetable oils, and animal fats are also utilized. While methanol can also be utilized, it is the alcohol that is more commonly applied. The examination of non-edible vegetable oils has been in progress for several years, producing positive outcomes, since the primary

challenge in the manufacturing and dissemination of biodiesel is cost, mostly attributed to fluctuations in oil prices. Numerous countries are currently engaged in extensive and moderate-scale investigations on the manufacture of biodiesel, employing non-edible oils such as castor oil, tung, cotton, jojoba, and jatropha. These endeavors are being driven by various considerations, among others. Animal lipids offer a promising opportunity, particularly in nations with substantial animal resources. However, they require previous treatment to be processed effectively due to their solid consistency. In addition, it is possible to utilize oil obtained from sources with high acidity levels, such as fish, poultry, pigs, and cattle. Microalgae show great potential as a feasible choice for future biodiesel production, because to their remarkably high oil yield. However, it is important to note that only certain species are suitable for biofuel production. Biodiesel must exhibit consistent qualities that align with the standards established by international organizations, notwithstanding potential variations in the properties of the fats and oils utilized as source materials.

1.5 VARIOUS RAW MATERIALS FOR BIODIESEL PREPARATION

The various raw materials used for production of biodiesel as given below,

1.5.1 Cottonseed

Cottonseed Fig. 1.1 has been identified as a feasible feedstock for the generation of biodiesel. The procedure involves the combination of cottonseed oil with an alcohol, commonly methanol or ethanol, along with a catalyst that aids in the facilitation of the reaction. The process involves the decomposition of triglycerides into biodiesel, specifically methyl or ethyl esters, as well as glycerin. Cottonseed methyl ester (CME), derived from cottonseed oil, has the potential to serve as a sustainable and ecologically sound alternative to traditional diesel fuel. Nevertheless, it is imperative to guarantee the implementation of sustainable and responsible sourcing and production methodologies, alongside the appropriate purification of biodiesel to adhere to established quality benchmarks.



Fig. 1.1 Cottonseed

1.5.2 Rapeseed

Rapeseed Fig. 1.2 can thrive on soils with high sulphur content but low fertility. Due to its high oil output (40–50%), double cultivation and crop rotation are possible when growing it as a winter cover crop. It is the most significant raw material used in the European Community to produce biodiesel. But in several Central and South American nations, there were technological barriers to seeding and harvesting. This was mostly because there was insufficient knowledge about fertilizing, processing, and storing seeds (which are tiny and call for specialized farming equipment).



Fig. 1.2 Rapeseed plant with seeds

1.5.3 Corn seed

Corn seed Fig. 1.3 which is obtained from corn kernels, has the potential to serve as a viable feedstock for the production of biodiesel. Triglycerides present in it can undergo transesterification, a process that converts them into biodiesel. The procedure involves the combination of corn oil with an alcohol, typically methanol or ethanol, along with a catalyst that aids in the facilitation of the chemical reaction. The process involves the hydrolysis of triglycerides into biodiesel and glycerin. Corn oil-derived biodiesel, specifically referred to as corn oil methyl ester (CME), is widely regarded as a feasible substitute for traditional diesel fuel. The substance exhibits characteristics such as a high cetane number, which signifies favourable ignition characteristics, and demonstrates a comparatively low concentration of Sulphur. Nevertheless, it is crucial to maintain a harmonious equilibrium between the utilisation of maize oil in biodiesel manufacturing and its diverse applications, including but not limited to food processing and industrial sectors.



Fig. 1.3 Corn Seed

1.5.4 Jatropha

Jatropha, a shrub species, exhibits remarkable adaptability to arid settings. The Jatropha carcass is widely recognized as the most prominent form, characterized by its low water requirements and minimal care needs. Consequently, it is well-suited for warm climates with limited fertility. Fig. 1.4 Irregular rainfall or strong winds during the blossoming season might diminish productivity. The yield is

contingent upon factors including as climate, soil composition, precipitation, and pre-sowing and harvesting practices. *Jatropha* plants exhibit productivity during a range of approximately 3 to 4 years, with an average lifespan of approximately 50 years. The oil yield varies depending on the extraction method, with presses yielding 28-32% and solvent extraction yielding up to 52%. Due to the toxicity of the seeds, *jatropha* oil is considered non-consumable.



Fig. 1.4 Jatropha seeds

1.5.5 Sunflower

The edible husk of the sunflower seed, which is a fruit, is commonly referred to as the "seeds" of sunflowers as shown in Fig. 1.5. The immense relevance of sunflower seeds might be attributed to the high quality of the edible oil they yield. It is highly valued for its flavour, taste, and nutritional content. Additionally, the residual cake is provided as sustenance for animals subsequent to the extraction of oil. Sunflowers may be cultivated alongside soybeans and maize because to their resilience and lack of need for specialised agricultural equipment. The current hybrid plant varieties exhibit an oil production range of 48 to 52%.



Fig. 1.5 Sunflower with seeds

1.5.6 Basil leaves

Basil leaves, also known as *Ocimum basilicum*, are popular herbs widely used in various cuisines around the world, particularly in Mediterranean, Thai, and Italian dishes as shown in Fig. 1.6. Here are some details about basil leaves. Basil leaves are typically bright green in colour, oval-shaped, with a smooth texture. They grow in pairs opposite each other on the stem, with the leaves arranged in a symmetrical pattern. Basil leaves are typically bright green in colour, oval-shaped, with a smooth texture. They grow in pairs opposite each other on the stem, with the leaves arranged in a symmetrical pattern. There are many different varieties of basil, each with its own unique flavor and aroma. It's best to harvest basil leaves in the morning when their flavor is most intense. Overall, basil leaves are not only prized for their culinary versatility but also for their potential health benefits and cultural significance.



Fig. 1.6 Basil Leaves

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 research and development, with the aim of creating more advanced and functional materials for a wide range of applications. However, it is crucial to consider safety and potential environmental impacts when working with nano additives.

1.6.1 *Types of Nanoparticles*

- Metal nanoparticles consist of metallic elements such as gold, silver, platinum and copper. Due to their distinctive electrical, optical and catalytic characteristics, these materials provide significant value in various domains including catalysis, electronics, and medicine.
- Metal oxide nanoparticles encompass Titanium dioxide (TiO_2), zinc oxide (ZnO) and iron oxide (Fe_3O_4) as illustrative examples. Due to their semiconducting and catalytic capabilities, they are utilized in sunscreens, sensors, medicine delivery, and environmental cleanup.
- Quantum dots, commonly composed of cadmium selenide or indium phosphide, are semiconductor nanoparticles. They exhibit adjustable optical characteristics, rendering them highly beneficial in applications such as displays, imaging, and photovoltaics.
- The carbon nanotubes are cylindrical structures composed of carbon that exhibit exceptional mechanical, and thermal characteristics.

1.6.2 Titanium dioxide (TiO₂)

Titanium dioxide nanoparticles (TiO₂) have attracted significant attention in recent years due to their unique properties and potential application in various fields, including biodiesel production. The following is a comprehensive examination of TiO₂ nanoparticles and their utilization in the context of biodiesel. The praiseworthy attributes of TiO₂ nanoparticles include their photocatalytic activity, surface area, and stability. When subjected to ultraviolet (UV) light, these materials exhibit a wide energy bandgap, which enhances their efficiency as photocatalysts. TiO₂ nanoparticles possess chemical inertness, non-toxicity, and biocompatibility, making them highly suitable for various applications in the biological and environmental fields. The utilization of titanium dioxide (TiO₂) nanoparticles as catalysts in transesterification processes, which are essential for the production of biodiesel, holds significant promise. TiO₂ nanoparticles have significant promise as catalysts in the field of biodiesel production, offering chances for improved efficiency, environmental sustainability, and economic viability. However, further research and progress are necessary to address challenges and improve the effectiveness of commercial biodiesel production processes.

CHAPTER 2

LITERATURE SURVEY

The latest data from the Energy Information Administration indicates a projected surge of over 50% in energy demand by the year 2040 relative to the baseline established in 2018, showcasing a significant escalation in energy consumption trends [1,2]. The heightened utilization of extensive quantities of fossil fuels raises concerns regarding their potential depletion for subsequent generations. Scientists are exploring alternative fuel sources possessing analogous properties to conventional fuels yet exhibiting reduced environmental emissions. Biodiesel stands out as a viable option worthy of consideration in this pursuit [3]. Biodiesel synthesis entails the esterification or transesterification of fatty acids derived from plant or animal oils with methanol or ethanol as catalysts. Biodiesel exhibits potential benefits encompassing energy resilience, economic viability, agricultural diversification, and environmental mitigation [4]. In recent times, the pursuit of novel technologies aimed at reducing NO_x emissions has presented a significant challenge within the realm of energy research. Two principal strategies have been identified to tackle this issue: the substitution of conventional fossil fuels with alternative energy sources such as biodiesel and the integration of hydrogen as an energy carrier [5]. Moreover, the incorporation of additives is aimed at reducing emissions by enhancing the rate of combustion [6,7]. Fuel additives are chemical compounds capable of modifying fuel characteristics favourably to enhance combustion efficiency [8,9]. In recent studies, the introduction of hydrogen combined with nanoparticles has shown enhanced characteristics [10]. Diesel consumption within transportation sectors exhibits an annual increase, with global consumption reaching approximately 80 million barrels of petroleum products daily. Combustion of petroleum products releases hazardous gases, including hydrocarbons (HC), carbon monoxide (CO), carbon dioxide (CO₂), and nitrogen oxides (NO), posing significant atmospheric concerns. These emissions contribute to climate change and the formation of acid rain, underscoring the critical need for emission reduction measures [11]. However, the phasing out of fossil fuels by identifying appropriate substitutes is crucial as industry requirements grow. Moreover, governments are eager to expand research into alternative fuels emitting lower emissions to replace

petroleum-based products. Nonetheless, despite the utilization of green fuel hydrogen as a secondary option alongside nanoparticles, there is limited literature available to the author's awareness [12-15]. In contrast to diesel, biodiesel exhibits reduced emissions of pollutants such as carbon monoxide (CO), hydrocarbons (HC), and carbon dioxide (CO₂). Nevertheless, in comparison with diesel, biodiesel exhibits heightened levels of NO_x emissions [16]. Numerous innovators have determined that biodiesel and hydrogen represent the most advantageous alternatives to conventional petroleum products. Despite the rapid escalation in fossil fuel prices, their continued utilization persists due to their notable thermal efficiency and superior fuel economy [17]. Hence, it is imperative to conduct experiments involving blends of fossil fuel and biodiesel. Typically, these blends are within the B20 range (20% biodiesel and 80% neat diesel). However, in recent times, the biodiesel content has been raised beyond 20%, following approval from the American Society for Testing and Materials (ASTM) for various content levels to ensure safe operation in compression ignition (CI) engines. [10]. The inclusion of alcohol within biodiesel blends has demonstrated the ability to substantially decrease emissions to significant extents. A wealth of literature substantiates that the methyl ester blend stands out as the optimal substitute for diesel, requiring no major adjustments to diesel engine configurations [18-20]. Hydrogen, being colourless and emitting zero pollutants, is considered a green fuel. Its environmental impact is minimal as its only byproducts are water and steam. Various methodologies exist for hydrogen production, including electrolysis, photoelectrochemical methods, gasification, dark fermentation, thermolysis, plasma arc decomposition, thermochemical processes, anaerobic digestion, and photo fermentation, among others [21]. Hydrogen can be utilized as an alternative resource through two primary methods: fuel cells and internal combustion engines. Hydrogen fuel cells demonstrate the capability to achieve 60% efficiency while emitting zero pollutants. Hydrogen possesses a rapid flame velocity, low ignition energy demand, minimal quenching thickness, and wide flammability limits, presenting inherent hazards. Consequently, a mixture of hydrogen and oxygen utilized in water electrolysis can serve as a safer alternative [22]. The engine's power and torque increase proportionally with the quantity of hydrogen injected [23]. The utilization of hydrogen within the combustion chamber results in a reduction in diesel consumption [24]. Compared to diesel operation without hydrogen integration, the

addition of hydrogen results in enhanced brake-specific fuel consumption and brake thermal efficiency, along with decreased levels of air pollutants such as CO, UHC, and soot. However, there is a concurrent increase in NO_x emissions [25]. The engine's performance is also contingent upon the fuel properties, which encompass characteristics such as viscosity, flash point, cloud point, heating value, and calorific value [10]. Elevated fuel viscosity results in an increased mass flow rate, typically leading to a reduction in Brake Specific Fuel Consumption (BSFC). Conversely, burning high-viscosity fuel necessitates higher fuel pressure and atomization degree. However, a higher density value is associated with inefficient combustion [26]. 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 [27]. Numerous scholarly works have documented that the calorific values of biodiesels are lower than those of pure diesel. Still, enhancements can be achieved by incorporating additives or hydrogen into the biodiesel [28,29]. Thus, exceptional caution and significant diligence are requisite for the storage and transportation of hydrogen due to its remarkable diffusivity and flammability. Hence, it is imperative to develop a more potent alternative fuel to neat diesel while ensuring minimal environmental impact. This study aims to identify a sustainable alternative fuel with superior performance and reduced emissions compared to neat diesel and Diesel with Hydrogen. Introducing H₂ as a fuel source for biodiesel enhances the thermal efficiency of the engine and decreases the duration of combustion. This study focuses on the impact of hydrogen basil blends and nanoparticles on diesel engines, presenting new and innovative discoveries. The primary aim of the study is to create a sustainable fuel by utilising Basil hydrogen blends and nanoparticles to reduce emissions and ensure its long-term viability.

CHAPTER 3

AIM AND SCOPE

3.1 AIM

The main objective of this study is to examine the capacity of nano additives to enhance the efficiency of a diesel engine when using hydrogen as the main fuel. Our objective is to increase combustion characteristics and improve engine efficiency and emissions profiles by including nanoscale elements into the fuel mixture. The specific goals of this study involve doing a thorough evaluation of combustion kinetics, ignition characteristics, and the release of pollutants. Our objective is to examine the impact of nano additions on the stability of combustion, the delay in ignition, and the rates of heat release. In addition, we will examine the influence on emissions, with a specific emphasis on significant pollutants like nitrogen oxides (NO_x). Furthermore, this study seeks to elucidate the synergistic effects between hydrogen and nano additives, aiming to identify optimal formulations that maximize performance gains. It also aims to discern the underlying mechanisms through which nano additives enhance combustion efficiency, shedding light on the nanoscale interactions within the combustion process. Ultimately, this research aspires to propel advancements in sustainable transportation technologies. The findings will have far-reaching implications, potentially revolutionizing the way we approach diesel engines and their integration with alternative fuels like hydrogen. By leveraging the potential of nano additives, we aim to contribute to a cleaner, more efficient, and environmentally responsible future for the automotive industry.

3.2 SCOPE

The following are the list of the project scope.

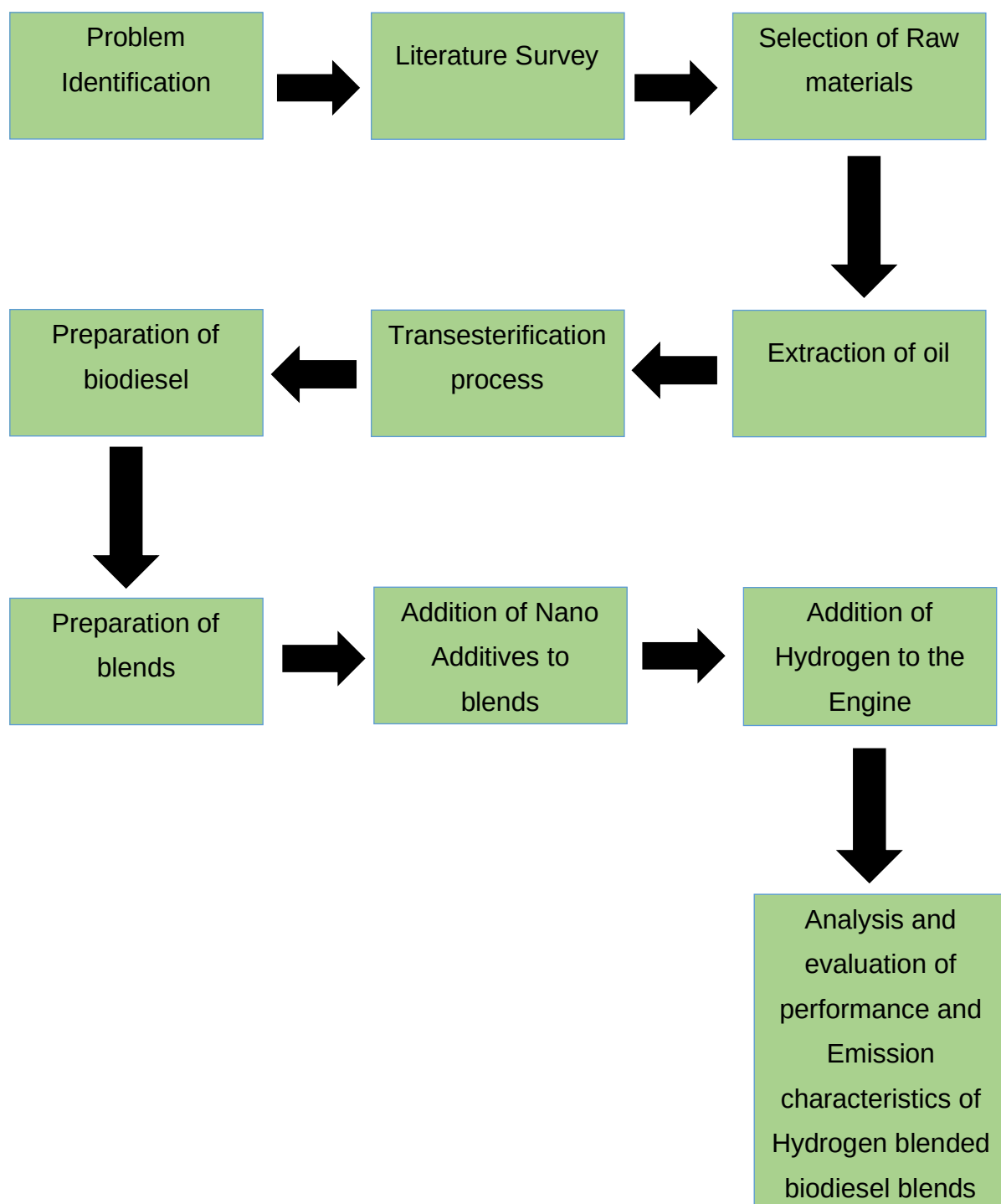
- Analyze the viability of utilizing various feedstocks as a means of producing biodiesel. This may involve an examination of the availability and sustainability of the subject matter, as well as an analysis of its physical and chemical properties.
- *Production of biodiesel:* Develop and optimize methodologies for converting diverse raw materials into biodiesel. This could include examining diverse processing techniques and evaluating their effectiveness and environmental impacts.
- *Performance of engines and emissions:* The present research aims to examine the effects of using Titanium dioxide nanoparticles as an additive on emissions and engine performance characteristics in the context of biodiesel utilization. The scope of this study encompasses several activities such as performing engine testing, examining the combustion properties of diverse biodiesel blends, assessing the emissions of certain pollutants and greenhouse gas emissions, and undertaking other associated duties.

The overall goal of biodiesel initiatives is to advance the production and use of biodiesel as a sustainable and renewable substitute for conventional fossil fuels. These initiatives have the potential to improve energy security, encourage rural development, and lower greenhouse gas emissions.

CHAPTER 4

MATERIALS AND EXPERIMENTAL METHODS

4.1 METHODOLOGY



4.2 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 subjected to a specific temperature to eliminate any potential water content. Subsequently, the oil undergoes filtration to eliminate any impurities or solid particles.
- *Preparation of the alcohol:* The alcohol, commonly methanol or ethanol, is subjected to a specific temperature to eliminate any potential water. In the subsequent step, the alcohol is combined with the catalyst, commonly sodium hydroxide or potassium hydroxide.
- *Mixing the oil or fat with the alcohol-catalyst mixture:* The oil or fat that has been heated is subsequently combined with the mixture of alcohol and catalyst within a reactor vessel. The mixture is subjected to stirring or agitation to achieve thorough mixing and facilitate the reaction.
- *Formation of biodiesel and glycerol:* When the oil or fat reacts with the alcohol-catalyst mixture, two products are formed biodiesel and glycerol.
- *Washing and drying:* Biodiesel undergoes a washing 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:* The ultimate biodiesel product undergoes rigorous testing to verify its compliance with essential quality criteria, 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.

4.3 PREPARATION OF BLENDS

The term "blends" commonly denotes amalgamations or fusions of two or more components. In the realm of fuels such as biodiesel, the term frequently pertains to the amalgamation of diverse fuel constituents or additives in order to generate a novel fuel possessing distinct features or attributes. 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). The process of blending can be employed to attain certain objectives related to fuel performance, emissions, and cost.

4.3.1 Types of Test Fuels

The designation of biodiesel blends is commonly indicated by the letter "B" followed by a numerical value, which signifies the proportion of biodiesel present in the blend. The prevailing categories of biodiesel mixes encompass:

- *B5 (5% Biodiesel)*: The composition of this mix consists of 5% biodiesel and 95% conventional diesel. This biodiesel mix is widely prevalent and frequently employed in diesel engines without undergoing any alterations.
- *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.

4.4 BIODIESEL

- Biodiesel is an abundant and environmentally friendly 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 replacement for traditional diesel fuel in diesel engines, or it can be combined with diesel fuel in different proportions. The fuel in question is characterised by its cleanliness and low emissions, exhibiting reduced levels of greenhouse gas emissions and particulate matter in comparison to conventional diesel.
- The utilisation of biodiesel has promise in diminishing dependence on fossil fuels and fostering sustainable development. A diverse range of feedstocks, such as waste and leftover cooking oils, can be utilised for its production, hence presenting economic prospects in rural regions. In general, biodiesel exhibits considerable potential as a viable substitute fuel, playing a pivotal role in mitigating greenhouse gas emissions, 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*: Renewable sources, such as vegetable oils and animal fats, are utilised in the production and replenishment of biodiesel, thereby ensuring its sustainability.
- *Biodegradable*: Biodiesel exhibits biodegradability and non-toxicity, rendering it comparatively less environmentally detrimental in comparison to regular diesel fuel.
- *Low emissions*: In comparison to diesel fuel, biodiesel exhibits reduced greenhouse gas emissions and lower levels of particulate matter.

4.5 PROPERTIES OF BIODIESEL

Eco-friendly biodiesel is a sustainable substitute for conventional fuel, derived from vegetable oils, animal fats, or repurposed cooking oil. It possesses similar characteristics to diesel fuel derived from petroleum, yet it exhibits significant differences because of its unusual chemical composition. Biodiesel possesses several fundamental characteristics:

- *Density*: Because biodiesel has a lower density than petroleum fuel, the energy content per unit volume might be affected.
- *Viscosity*: The flow of biodiesel through fuel injectors and pumps may be influenced due to its increased viscosity compared to petroleum diesel.
- *Flash point*: Due to its higher flash point compared to petroleum diesel, biodiesel has enhanced safety characteristics in terms of handling and storage.
- *Cetane number*: Biodiesel has a higher cetane number than petroleum diesel, indicating that it has a better ignition and combustion quality.
- *Oxygen content*: Due to its higher oxygen content compared to petroleum diesel, biodiesel has the potential to improve combustion efficiency and reduce emissions of carbon monoxide (CO) and unburned hydrocarbons (HC).
- *Sulphur content*: Biodiesel has almost little Sulphur, which minimizes Sulphur oxide(Sox) and particulate matter emissions.
- *Cold flow qualities*: Biodiesel exhibits inadequate cold flow characteristics, leading to its tendency to thicken and solidify at low temperatures, hence causing fuel filter obstruction and engine halting.

Table 4.1: PROPERTIES OF DIESEL, TB20, BASIL OIL, BASIL BIODIESEL

Test Properties	Test Method	Diesel	TB20	BASIL OIL	BASIL BIODIESEL
Density Kg/m ³	ASTMD4052	830	840	870	820
Viscosity @ 40° in CST	ASTM D975	4.1	2.6	1.42	1.2
Flash Point °c	ASTMD93	52	110	133	126
Fire Point °c	ASTMD93	-	-	146	135
Calorific Value (KJ/Kg)	ASTMD240	42500	41563	40532	41393

4.6 MATERIALS AND PROCESSES USED

The Basil leaves were collected from a local market in Chennai, India. Basil oil was then extracted from them. The quantity of fatty acids in the basil oil is then measured. Pour 20 millilitres of basil oil into the conical flask. It is heated to fifty degrees Celsius. Heat is applied to methanol in a flask with a circular bottom to purify it. After 50 minutes of vigorous mixing and agitation of the basil oil solutions, the mixture is permitted to settle for a duration of 24 hours as shown in Fig. 4.1. The mixture of glycerol and Basil Biodiesel is the result. The glycerol exhibits a lower buoyancy because to its higher mass, whereas the basil biodiesel demonstrates a higher buoyancy. The basil biodiesel is separated from the glycerol using warm water, and the glycerol is subsequently collected in a separate beaker. The evaporation procedure separates the extra water in the Basil Biodiesel. Using the following procedure, one litre of Biodiesel (B100) is made as shown in Fig. 4.2.



Fig. 4.1 Basil Oil



***Fig. 4.2 Blends of Basil
Biodiesel***

4.7 EXPERIMENTAL PROCEDURE

The apparatus is set up in the testing configuration as shown in the figure above. The hydrogen gas is let to pass via a flame or spark arrester after the fuel and hydrogen gas are removed from the fuel tank and hydrogen cylinder. It then passes through a flow meter and has its flow rate adjusted to 3 LPM (litres per minute) as shown in Fig. 4.3. Next, at the inlet air chamber, the hydrogen is combined with the fresh air and fuel that is drawn from the fuel tank and injected into the cylinder. Different engine loads are applied via a water-cooled eddy current dynamometer. The smoke and gas analyzer is used to measure the emissions from the engine. Use the Engine Soft Software to evaluate fuel consumption, power, and efficiency. Similarly, data is obtained using multiple fuels: TB20 (Basil biodiesel with TiO_2 nanoparticle), diesel, DH, and HTB20. Information is gathered about emissions of NO_x , CO, HC, CO_2 , and opacity smoke. A study is then carried out to determine the optimal fuel mix that will reduce emissions and improve overall performance.



***Fig. 4.3 Flow Regulator
of Hydrogen gas***

CHAPTER 5

EXPERIMENTAL SETUP

5.1 KIRLOSKAR TV1 ENGINE

The experimental configuration comprises a single-cylinder, four-stroke Diesel engine that is physically linked to an eddy current type dynamometer for the purpose of loading Fig. 5.1. The configuration comprises a self-contained panel enclosure that includes an air box, fuel tank, manometer, fuel measuring unit, transmitters for measuring air and fuel flow, a process indication, and an engine indicator. Rotameters are utilized for the purpose of measuring the flow of cooling water and calorimeter water. The experimental configuration facilitates the examination of many engine performance parameters, including brake power, indicated power, frictional power, brake mean effective power (BMEP), indicated mean effective power (IMEP), brake thermal efficiency, indicated thermal efficiency, mechanical efficiency, volumetric efficiency, specific fuel consumption, air-to-fuel ratio.

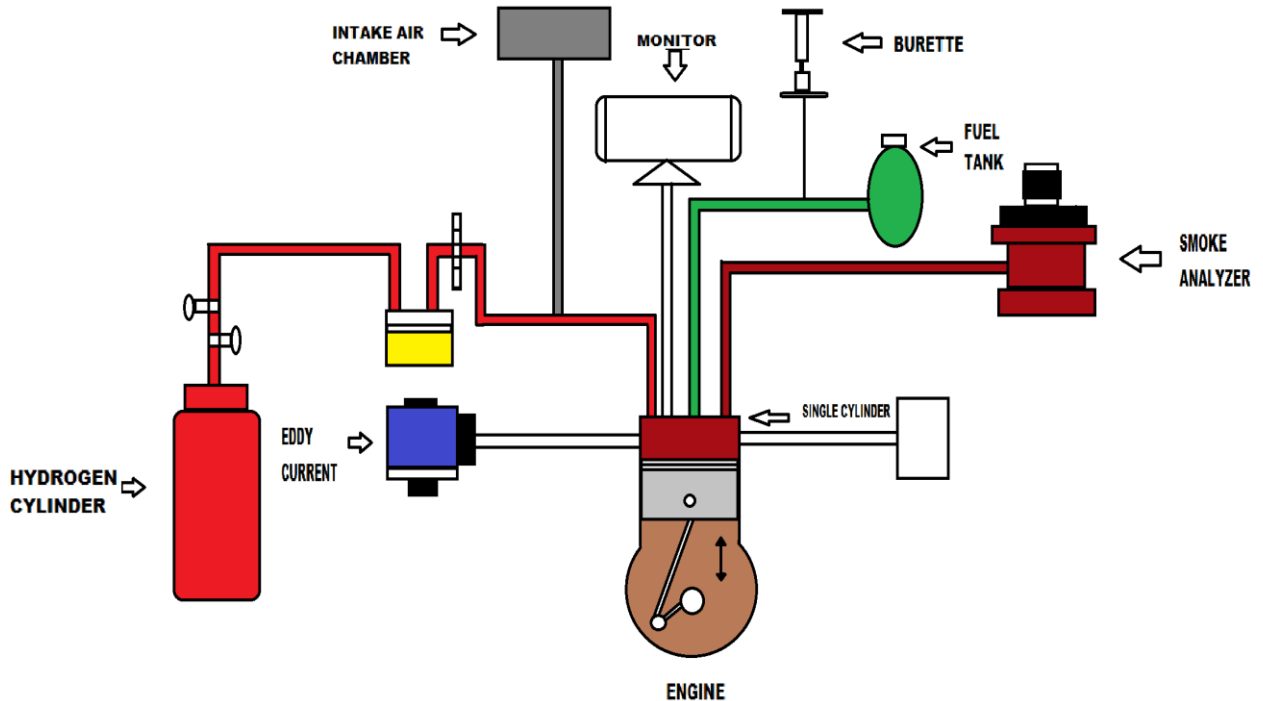


Fig. 5.1 Schematic Representation of the Diesel Engine

1. The hydrogen cylinder is a container that holds pressurized hydrogen gas. Fig. 5.2
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 after a fire incident.
6. The monitor is employed to observe and assess the engine's performance and combustion characteristics at different 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

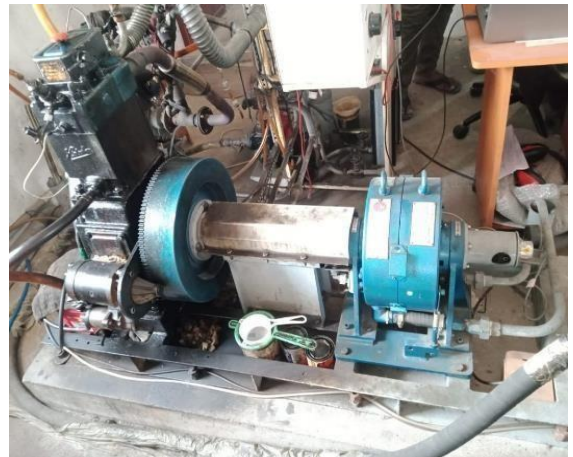


Fig. 5.3 Diesel Engine

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 PERFORMANCE ANALYSIS

6.1.1 Brake Specific Fuel Consumption (BSFC)

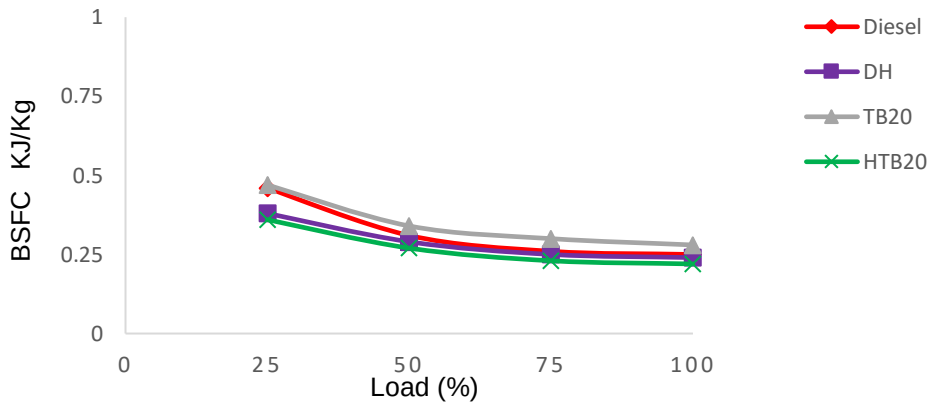


Fig. 6.1 Brake Specific Fuel Consumption (BSFC)

The duration of ignition in a compression ignition (CI) engine plays a crucial role in improving the engine's performance characteristics by positively influencing both its physical and chemical properties. The selection of an optimal ignition time has been found to have a significant impact on reducing the Brake Specific Fuel Consumption (BSFC) across all tested fuels. Figure 6.1 demonstrates a negative correlation between load and fuel combustion, notably in relation to the brakes, as the load increases. The BT20 with H₂ exhibits the lowest brake-specific fuel consumption when hydrogen is utilized at 100% load. The Brake Specific Fuel Consumption (BSFC) of the fuel has a negative correlation with the load. The introduction of hydrogen into the combustion chamber results in an augmentation of the combustion rate as a consequence of the intensified combustion of the fuel to its maximum potential. Therefore, the Battery State Failure Capability (BSFC) diminishes with an increase in load. The BSFC of diesel, DH, TB20, and HTB20 is illustrated in Figure 6.1. Diesel fuel exhibits inferior performance in comparison to fuel containing hydrogen and nanoparticles, mostly due to its higher calorific value [30]. Among all evaluated fuels, BT20 and Diesel have the highest BSFC value. Therefore, it can be observed that both pure diesel and fuel without hydrogen demonstrate increased fuel consumption due to their calorific value.

6.1.2 Brake Thermal Efficiency (BTE)

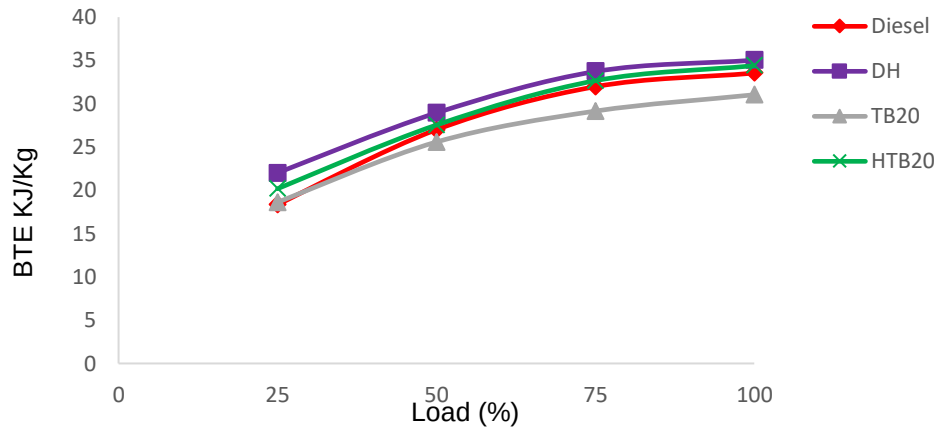


Fig. 6.2 Brake Thermal Efficiency (BTE)

Brake thermal efficiency (BTE) is the quantitative measure of the power produced by the brake system in relation to the heat provided by the fuel. The aforementioned measure is utilized to determine the engine's ability to transform chemical energy into productivity. The reduced BTE can be attributed mostly to the insufficient atomization and spray qualities. The data shown in Figure 6.2 demonstrates a positive correlation between load and brake thermal efficiency. The DH exhibits the highest brake thermal efficiency, whereas the TB20 showcases the lowest. The primary reason for this occurrence can be ascribed to the increased density and viscosity of biodiesel, which causes a prolonged delay in ignition and ultimately leads to incomplete combustion. Our analysis revealed a higher BTE (Burden of Total Emission) in pure diesel as compared to biodiesel mixes. The test findings obtained with and without the utilization of hydrogen appear to be similar. The integration of hydrogen into the petrol and TB20 blends has led to an enhancement in the thermal efficiency of brake systems.

6.2 EMISSION ANALYSIS

6.2.1 Carbon monoxide (CO) Emission

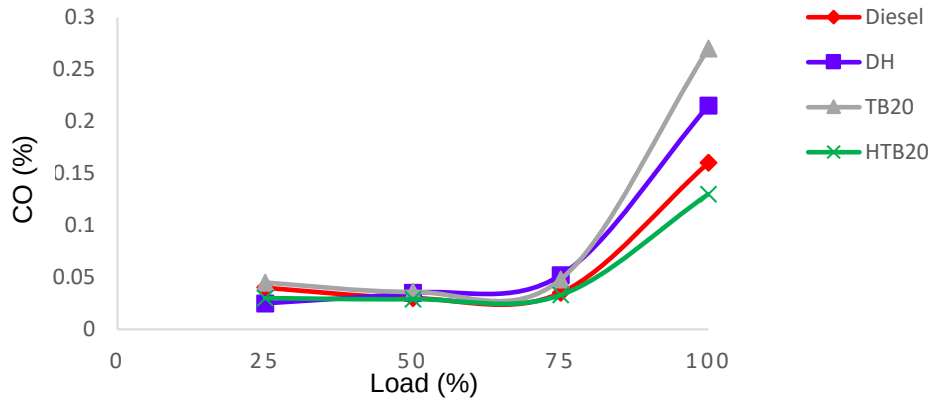


Fig. 6.3 Emission of Carbon monoxide

Based on the figure 6.3, it is evident that the emission of carbon monoxide (CO) has a relatively consistent pattern, with slight variations observed until it reaches 75% of the load. Nevertheless, a significant increase in carbon monoxide (CO) emissions occurs when the load reaches 100%. At its highest load, the TB20 fuel has a lower carbon monoxide (CO) emission rate when compared to alternative fuels, despite using 3 LPM of Hydrogen. In contrast, the TB20 mixture emits a greater amount of carbon monoxide. A comparative analysis of TB20 and HTB20 in terms of carbon monoxide (CO) emissions demonstrates a significant reduction of 14%. The inclusion of hydrogen in the fuel mixture yielded a notable augmentation in the oxygen concentration of biodiesel, hence resulting in a considerable decrease in carbon monoxide (CO) emissions. The observed dip in CO emissions can be attributed to the decrease in carbon emissions.

6.2.2 Carbon dioxide (CO₂) Emission

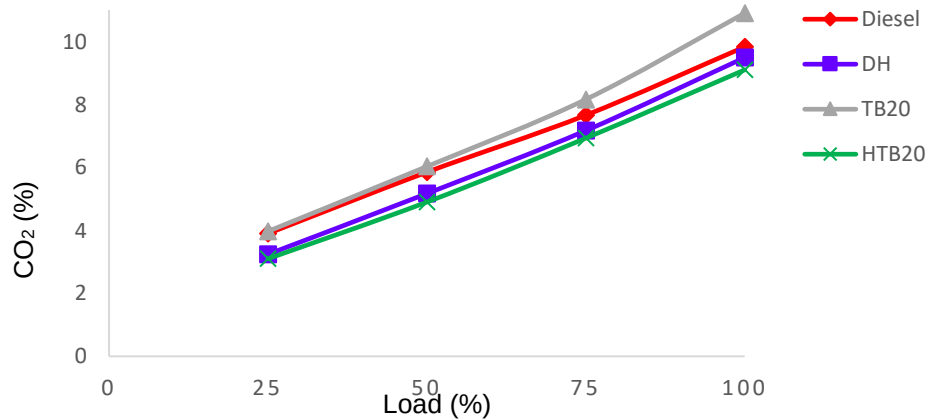


Fig. 6.4. Emission of Carbon dioxide

The figure 6.4 illustrates a positive correlation between the load in the cylinder and the increase in CO₂ emissions. At full engine load, TB20 fuel releases a higher quantity of CO₂, while HTB20 emits a lower quantity of CO₂. The CO₂ emissions in BT20 and Pure Diesel have increased by 16.5% and 3.6% respectively, compared to HTB20 and pure Diesel with H₂. The decrease in CO₂ emissions can be attributed to the incorporation of hydrogen into the combustion process, resulting in a reduced emission of carbon particles and so enhancing the overall cleanliness of the combustion.

6.2.3 Hydrocarbons (HC) Emission

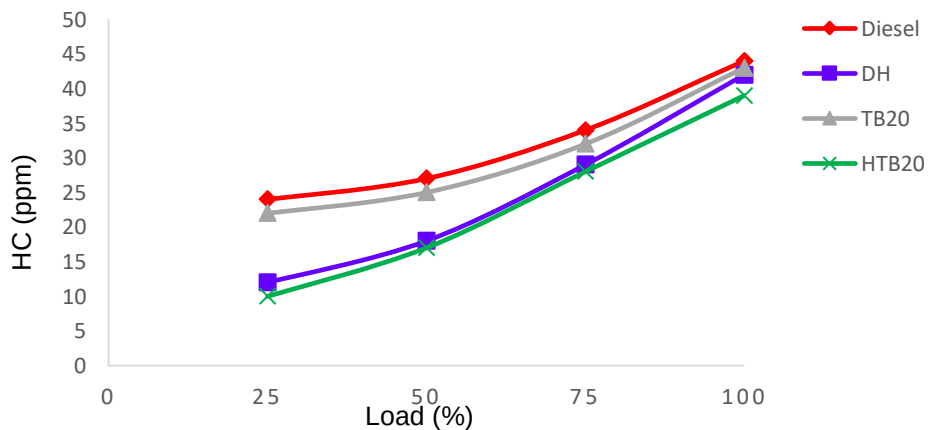


Fig. 6.5 Emission of Hydrocarbons

The figure 6.5 illustrates the hydrocarbon emission (HC) at various engine loads. It is worth noting that there is an increase in hydrocarbon emissions due to an increase in engine load. This phenomenon mostly arises due to the diminished evaporation of fuel droplets, as well as the amalgamation of several formulations. Conversely, the inclusion of TiO_2 on B20 results in a lower hydrogen content in comparison to diesel. Nanoparticle additions and hydrogen blends can efficiently enhance combustion by introducing a high concentration of oxygen, resulting in complete combustion. The incorporation of nanoparticles results in a reduced emission of hydrocarbons compared to diesel fuel due to the nanoparticles' function as an oxygen buffer. Diesel fuel emits a greater quantity of hydrocarbons into the environment at 100% load, while TB20 bio-diesel with hydrogen emits a less amount of hydrocarbons. The HC content of HTB20 decreases by 7.1% compared to Diesel with Hydrogen.

6.2.4 Nitrogen oxide (NOX) Emission

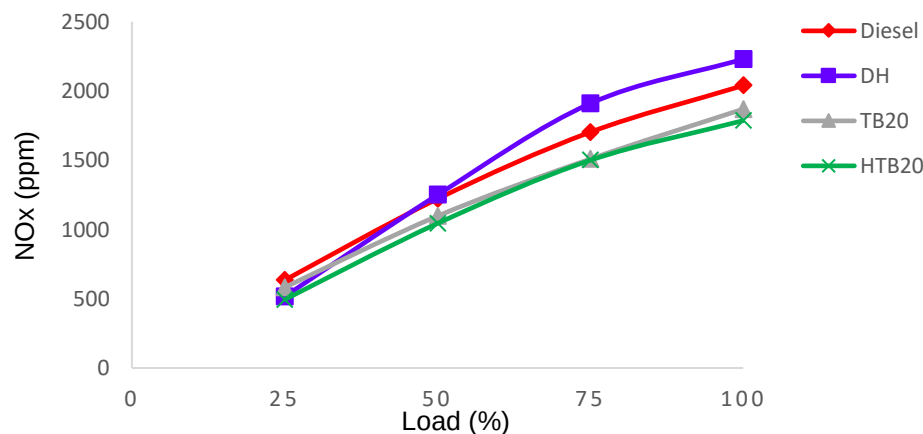


Fig. 6.6 Emission of Nitrogen Oxide

The Figure 6.6 displays data that demonstrates a direct relationship between load and NOx emissions. The emission of NOx is higher in DH as compared to diesel alone. The NOx concentration in DH has exhibited a 9.8% rise in comparison to diesel fuel. The increase in nitrogen oxide (NOx) levels during the emission process can be ascribed to the correlation between NOx emission and both the oxygen content of the fuel and the temperature of the cylinder wall. Hydrogen introduction during combustion causes the cylinder wall temperature to increase, leading to a higher emission of NOx into the atmosphere. The HTB20 fuel blend including H_2 demonstrates reduced emissions compared to other fuel blends. When BT20 with

H₂ at 100% load, it demonstrates a 4.5% decrease in NO_x emissions in comparison to BT20. The intrinsic oxygen concentration of nanoparticles is responsible for their high combustion in fuel.

6.2.5 Opacity Smoke Analysis

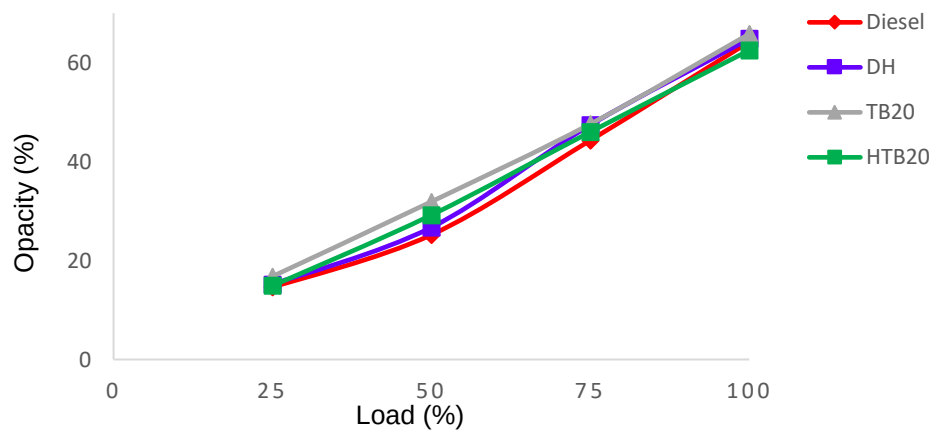


Fig. 6.7 Emission of Opacity Smoke

The figure 6.7 illustrates the positive relationship between the load and the opacity of the fuel. Typically, diesel undergoes incomplete combustion, leading to its high opacity. HTB20 exhibits a 3% rise in soot content compared to diesel. A decrease in opacity is observed in HTB20 due to the utilization of hydrogen during the combustion process. This characteristic of hydrogen as a clean fuel result in a reduced emission of soot into the atmosphere, consequently leading to a decrease in opacity in DH.

CHAPTER 7

CONCLUSION

The research conducted using TiO₂ nanoparticles and Hydrogen in combination with biodiesel derived from Basil Leaves yielded the following data.

The primary objective of this research is to investigate the synthesis of Basil biodiesel by a transesterification technique, employing NaOH as a catalyst for the conversion of Basil oil. Following this, the primary fuel is combusted, while hydrogen is employed as an additional fuel source. The present study's findings elucidate the influence of TiO₂ nanoparticles on HTB20 in a single-cylinder diesel engine. The performance of BTE and BSFC is improved by integrating nanoparticles and hydrogen into TB20. The addition of TiO₂ nanoparticles leads to an increase in the combustion rate as a result of their significant surface areas. Furthermore, the enrichment of hydrogen in the air system serves to boost both the cylinder pressure and heat values. The diminution in emissions can be mostly attributed to the influence of hydrogen within the atmospheric system. To summarize the findings, the following can be stated that the CO emission graph shows that HTB20 emits a lower quantity of CO, while BT20 emits a higher quantity of CO.

- In the HC emission graph, it can be observed that at a 100% load, HTB20 exhibits a lower emission of HC, whereas both Diesel and DH have a marginal emission of HC.
- In the graph depicting CO₂ emissions, it can be observed that HTB20 exhibits a lower quantity of CO₂ emissions, whereas HB20 demonstrates a higher quantity of CO₂ emissions.
- In the NO_x emission graph, it can be observed that DH exhibits a significant release of NO_x emissions, whereas HTB20 and TB20 demonstrate a somewhat lower emission of NO_x.
- The opacity graph illustrates that DH exhibits a higher level of opacity, while HTB20 demonstrates a lower level of opacity.

- The graph comparing Load and BTE reveals that DH emissions exhibits superior brake thermal efficiency, while TB20 has comparatively poorer brake thermal efficiency.
- The brake-specific fuel combustion diagram demonstrates a reduction in fuel combustion as the load increases. At 100% load, HTB20 indicates a decreased brake-specific fuel consumption (BSFC).

REFERENCES

1. Brown SPA. New estimates of the security costs of U.S. oil consumption. *Energy Policy* 2018; 113:1 71-92. [https://doi.org/ 10.1016/j.enpol.2017.11.003](https://doi.org/10.1016/j.enpol.2017.11.003).
2. Nepal P, Ince PJ, Skog KE, Chang SJ. Projection of U.S. Forest sector carbon sequestration under U.S. and global timber market and wood energy consumption scenarios. *2010e2060 Biomass Bioenergy* 2012; 45:25 1-64.
3. Daming Huang, Haining Zhou Lin Lin, Biodiesel: An Alternative to Conventional Fuel, *SciVerse Science Direct*, 1874-1885, 2012.
4. Karthik, Amrish, Dharmaraj, Dhivesh, Krishna Kumar P R, Extraction of Biodiesel from Jatropha Oil by Transesterification Process, *International Journal of Engineering Research & Technology (IJERT)*, 1-4, 2017.
5. Ashok B, Nanthagopal K, Vignesh DS. Calophyllum inophyllum methyl ester biodiesel blends as an alternate fuel for diesel engine applications. *Alexandria Eng J* 2018;57(3):12 39-47. <https://doi.org/10.1016/j.aej.2017.03.042>.
6. Dinesha P, Kumar S, Rosen MA. Combined effects of water emulsion and diethyl ether additive on combustion performance and emissions of a compression ignition engine using biodiesel blends. *Energy* 2019; 179:92 8-37. <https://doi.org/10.1016/j.energy.2019.05.071>.
7. Senthil R, Pranesh G, Silambarasan R. Leaf extract additives: a solution for the reduction of NO_x emission in a biodiesel operated compression ignition engine. *Energy* 2019; 175:8 62-78. <https://doi.org/10.1016/j.energy.2019.03.039>.
8. Atmanli A. Comparative analyses of diesel waste oil biodiesel and propanol, n-butanol or 1-pentanol blends in a diesel engine. *Fuel* 2016; 176:20 9-15. <https://doi.org/10.1016/j.fuel.2016.02.076>.
9. Baltacioglu MK, Arat HT, Ozcanli M, Aydin K. Experimental € comparison of pure hydrogen and HHO (hydroxy) enriched biodiesel (B10) fuel in a commercial diesel engine. *Int J Hydrogen Energy* 2016;41(19):83 47-53. [https://doi.org/ 10.1016/j.ijhydene.2015.11.185](https://doi.org/10.1016/j.ijhydene.2015.11.185).

10. Manigandan S, Gunasekar P, Poorchilamban S, Nithya S, Devipriya J, Vasanthkumar G. Effect of addition of hydrogen and TiO₂ in gasoline engine in various exhaust gas recirculation ratio. *Int J Hydrogen Energy* 2019; 44(21):112 05-18. <https://doi.org/10.1016/j.ijhydene.2019.02.179>.
11. Tan YH, Abdullah MO, Nolasco-Hipolito C, Zauzi NS, Abdullah GW. Engine performance and emissions characteristics of a diesel engine fueled with diesel biodiesel-bioethanol emulsions. *Energy Convers Manag* 2017; 132:54-64. <https://doi.org/10.1016/j.enconman.2016.11.01>.
12. Balamurugan T, Arun A, Sathishkumar GB. Biodiesel derived from corn oil is a fuel substitute for diesel. *Renew Sustain Energy Rev* 2018; 94:77 2-8. <https://doi.org/10.1016/j.rser.2018.06.048>.
13. Gu' lu'm M, Bilgin A. Density, flash point and heating value variations of corn oil biodiesel diesel fuel blends. *Fuel Process Technol* 2015; 134:4 56-64. <https://doi.org/10.1016/j.fuproc.2015.02.026>.
14. Nouredдини H, Bandlamudi SRP, Guthrie EA. A novel method for the production of biodiesel from the whole stillage extracted corn oil. *J Am Oil Chem Soc* 2009; 86:83-91.
15. Taheripour F, Tyner WE. Corn oil biofuel land use change emission impacts: sharing emission savings between ethanol and biodiesel. *Biofuels* 2014; 5:3 53-64. <https://doi.org/10.1080/17597269.2014.977582>.
16. Rachan D Shekar, H R Purushothama, Hydrogen Induction to Diesel Engine Working on Bio Diesel: A review, 11, 385 - 392, 2015.
17. Mahmudul HM, Hagos FY, Mamat R, Adam AA, Ishak WF, Alenezi R. Production, characterization, and performance of biodiesel as an alternative fuel in diesel engines review. *Renew Sustain Energy Rev* 2017; 72, 497-509. <https://doi.org/10.1016/j.rser.2017.01.001>.
18. Thangaraj S, Govindan N. Evaluating combustion, performance and emission characteristics of diesel engine using Karanja oil methyl ester biodiesel blends enriched with HHO gas. *Int J Hydrogen Energy* 2018;43(12):64 43-55.

19. Gonca G, Dobrucali E. The effects of engine design and operating parameters on the performance of a diesel engine fueled with diesel-biodiesel blends. *J Renew Sustain Energy* 2016;8(2):025702.
20. Li L, Wang J, Wang Z, Xiao J. Combustion and emission characteristics of diesel engine fueled with diesel/biodiesel/ pentanol fuel blends. *Fuel* 2015; 156:211e8. [https://doi.org/ 10.1016/j.fuel.2015.04.048](https://doi.org/10.1016/j.fuel.2015.04.048).
21. Yusri IM, Mamat R, Akasyah MK, Jamlos MF, Yusop AF. Evaluation of engine combustion and exhaust emissions characteristics using diesel/butanol blended fuel. *Applied Thermal Engineering* 2019; 156:20 9-19. <https://doi.org/10.1016/j.applthermaleng.2019.02.028>.
22. Dincer Akal, Semiha Oztuna, Mustafa Kemalettin Bu yukakin, A review of hydrogen usage in internal combustion engines (gasoline-Lpg-diesel) from a combustion performance aspect, *ScienceDirect*, 1-12, 2020.
23. Santoso. W. B, Nur. A, Ariyono .M, Combustion characteristics of Diesel Hydrogen Dual Fuel Engine, *National Conferencing in Mechanical Engineering and Postgraduate studies*, 23-32, 2010.
24. Koten. H, Hydrogen effects on diesel engine performance and emissions, *International Journal on Hydrogen Energy*, 43, 2018, 5-9.
25. Sompop Jarunghammachote, Sathaporn Chuepeng and Prateep Chaisermtawan, Effect of Hydrogen Addition on Diesel Engine Operation and NO_x Emission: A Thermodynamic Study, *American Journal for Applied Sciences*, 9, 1472-1478, 2012.
26. Mohod A, Jain S, Powar A, Rathore N, Kurchania A. Elucidation of unit operations and energy consumption pattern in small scale cashew nut processing mills. *J Food Eng* 2010;99(2):18 4-9.
27. Harrington KJ. Chemical and physical properties of vegetable oil esters and their effect on diesel fuel performance. *Biomass* 1986; 9(1):1-7. [https://doi.org/10.1016/0144-4565\(86\)90008-9](https://doi.org/10.1016/0144-4565(86)90008-9).
28. Nithya S, Manigandan S, Gunasekar P, Devipriya J, Saravanan WS. The effect of engine emission on canola biodiesel blends with TiO₂. *Int J Ambient Energy* 2018; 10:1-4. <https://doi.org/10.1080/01430750.2017.1421583>.

29. Gunasekar P, Manigandan S, Ilangovan N, Nithya S, Devipriya J, Saravanan WS. Effect of TiO_2 and nozzle geometry on diesel emissions fuelled with biodiesel blends. *International Journal Ambient Energy* 2017; 14:1-5. <https://doi.org/10.1080/01430750.2017.1410229>.
30. Tu ccar G, Uludamar E. Emission and engine performance analysis of a diesel engine using hydrogen enriched pomegranate seed oil biodiesel. *International Journal Hydrogen Energy* 2018;43(38):18 14-19.

ORIGINALITY REPORT

19%

SIMILARITY INDEX

12%

INTERNET SOURCES

15%

PUBLICATIONS

4%

STUDENT PAPERS

PRIMARY SOURCES

1	S. Manigandan, Vinoth Kumar Ponnusamy, P.Booma Devi, Sunday Ayoola Oke et al. "Effect of nanoparticles and hydrogen on combustion performance and exhaust emission of corn blended biodiesel in compression ignition engine with advanced timing", International Journal of Hydrogen Energy, 2020 Publication	2%
2	fastercapital.com Internet Source	2%
3	link.springer.com Internet Source	1%
4	www.tandfonline.com Internet Source	1%
5	www.researchgate.net Internet Source	1%
6	www.mdpi.com Internet Source	1%
