

**STUDY ON PERFORMANCE AND EMISSION
CHARACTERISTICS OF BIODIESEL FROM MAHUA OIL
ON VCR DIESEL ENGINE**

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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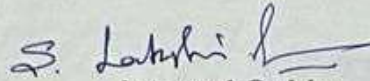
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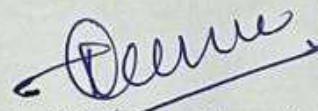
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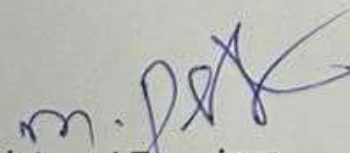
This is to certify that this Project Report is the bonafide work of B. KESHAVA KALYAN (Reg.no 40150713) and MUTHU KUMAR V (Reg.no 40150711) who carried out the project entitled "STUDY ON PERFORMANCE AND EMISSION CHARACTERISTICS OF BIODIESEL FROM MAHUA OIL ON VCR DIESEL ENGINE" under our supervision from December 2023 to April 2024.


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DECLARATION

We, B. KESHAHA KALYAN (Reg.No. 40150713) and MUTHU KUAMR (Reg.No 40150711) hereby declare that the Project Report entitled **STUDY ON PERFORMANCE AND EMISSION CHARACTERISTICS OF BIODIESEL FROM MAHUA OIL ON VCR DIESEL ENGINE.** done by us under the guidance of **Dr. S LAKSHMI SANKAR., 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

The main objective of this research is to analyze the performance and emission features of biodiesel derived from mahua oil. The study focuses on various important characteristics such as smoke opacity, braking specific fuel consumption, HC, CO, and NO_x. Three different blends (B10, B20, and B30) were examined in this investigation. The addition of mahua oil to diesel resulted in a reduction in brake specific fuel consumption in B10 blend, while the brake thermal efficiency of B10 blend showed an improvement compared to other blends and pure diesel. Moreover, B30 blend exhibited a decrease in CO, HC, and CO₂ emissions, but an increase in NO_x emissions.

This research offers a comparative evaluation of biodiesels concerning fuel characteristics, engine efficiency, and emission traits. Biofuels are eco-friendly alternatives to traditional fuels, playing a crucial role in mitigating global worries regarding fossil fuel emissions. Sourced from renewable biomass materials, biofuels possess a distinct advantage in supporting sustainable progress and complementing conventional energy supplies to cater to the escalating demand for transportation fuels linked to rapid economic expansion, while also fulfilling the energy requirements of India's extensive rural populace.

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CHAPTER 1

INTRODUCTION

1. 1 INTRODUCTION OF FOSSIL FUELS AND BIOFUELS

Fossil fuels have long been the backbone of global energy systems, providing the primary source of power for industries, transportation, and households worldwide. However, their widespread use has raised significant concerns about environmental degradation, climate change, and energy security. As a result, there is a growing imperative to transition towards more sustainable and renewable alternatives. Biofuels, originating from organic sources like plants, algae, and animal waste, are being recognized as a viable option to reduce the adverse effects of using fossil fuels.

This introduction explores the dynamic relationship between fossil fuels and biofuels, examining how the latter are increasingly utilized to replace or supplement traditional fossil fuel sources. We will delve into the various types of biofuels, their production processes, and their applications across different sectors. Additionally, we will assess the environmental benefits and challenges associated with the widespread adoption of biofuels, as well as the policy frameworks driving their development and deployment.

By understanding the interplay between fossil fuels and biofuels, we can chart a course towards a more sustainable energy future, one that prioritizes renewable resources, reduces greenhouse gas emissions, and enhances energy resilience. From bioethanol powering cars to biodiesel fueling trucks and planes, biofuels offer a promising pathway to transition away from fossil fuels and towards a cleaner, greener energy landscape.

1.2 Biodiesel:

Biodiesel has gained significant recognition as a sustainable energy solution globally, serving as a renewable and eco-friendly substitute for traditional diesel fuel. It is produced from organic sources like vegetable oils, animal fats, and recycled cooking grease. By providing a cleaner-burning option compared to petroleum-based diesel, biodiesel effectively reduces greenhouse gas emissions and helps alleviate the environmental consequences linked to fossil fuel usage.

This introduction delves into the multifaceted world of biodiesel, exploring its production processes, properties, applications, and potential impact on energy systems and the environment. From its origins in agricultural byproducts to its integration into transportation fleets, industrial machinery, and heating systems, biodiesel presents a compelling solution to the challenges posed by climate change, energy security, and air quality.

Through an analysis of the technical, economic, and policy factors related to biodiesel production and utilization, we can acquire a deeper understanding of its significance in the overall shift towards a more sustainable and robust energy landscape. From grassroots community projects to major industrial endeavors, biodiesel serves as a practical route to lessen our reliance on limited fossil fuels and pave the way for a cleaner, more environmentally friendly era of energy advancement and sustainability.

1.3 Need of alternative fuels:

The demand for substitute fuels has grown more urgent as communities confront the difficulties presented by climate change, air pollution, and energy security. Conventional fossil fuels, although they have supplied the majority of the world's energy requirements for many years, come with notable disadvantages. When burned, they emit greenhouse gases like carbon dioxide, which contribute to the escalation of global warming and climate disturbances. Additionally, depending on limited fossil fuel reserves exposes economies to price fluctuations and geopolitical conflicts.

Alternative fuels offer a pathway to address these challenges by providing cleaner, renewable, and more sustainable energy options. From biofuels derived from organic materials to hydrogen fuel cells and electric vehicles powered by renewable electricity, the range of alternatives continues to expand. This introduction explores the compelling reasons driving the shift towards alternative fuels, including environmental concerns, energy independence, technological innovation, and economic opportunities

Alternative fuels offer a pathway to address these challenges by providing cleaner, renewable, and more sustainable energy options. From biofuels derived from organic materials to hydrogen fuel cells and electric vehicles powered by renewable electricity, the range of alternatives continues to expand. This introduction explores the compelling reasons driving the shift towards alternative fuels, including environmental concerns, energy independence, technological innovation, and economic opportunities.

By embracing alternative fuels, societies can reduce their carbon footprint, improve air quality, diversify energy sources, and stimulate innovation and job creation in the burgeoning green economy. From local initiatives to international collaborations, the pursuit of alternative fuels represents a critical step towards building a more resilient, equitable, and sustainable energy future for generations to come.

1.4 Merits of using biodiesel:

- 1) **Environmental Benefits:** Biodiesel offers significant environmental advantages over conventional diesel fuel. It produces lower levels of harmful emissions such as sulfur oxides, particulate matter, and carbon monoxide, leading to improved air quality and reduced pollution. Additionally, biodiesel has a lower carbon footprint compared to fossil diesel, as it is derived from renewable organic sources, thereby helping to mitigate climate change by reducing greenhouse gas emissions.
- 2) **Renewable Resource:** Biodiesel is produced from renewable resources such as vegetable oils, animal fats, and recycled cooking grease. Unlike finite fossil

fuels, these feedstocks can be replenished through sustainable agricultural practices, providing a continuous and reliable source of fuel.

- 3) **Biodegradability:** Biodiesel possesses the qualities of being biodegradable and non-toxic, thereby reducing its detrimental effects on the environment in the event of accidents or leaks. Its swift decomposition guarantees minimal long-lasting consequences on the environment, particularly in delicate ecosystems like water bodies and soil.
- 4) **Compatibility and Performance:** Biodiesel has the advantage of being compatible with current diesel engines and infrastructure, requiring minimal adjustments. It can be mixed with regular diesel fuel in different proportions, providing a range of fueling choices. Biodiesel blends generally demonstrate comparable or enhanced performance attributes, such as engine efficiency, lubrication, and power output.
- 5) **Economic Opportunities:** The manufacturing and utilization of biodiesel present economic prospects across different stages of the supply chain, starting from farmers growing feedstocks to biodiesel manufacturers, suppliers, and sellers. Through backing local farming and biofuel sectors, biodiesel has the potential to enhance rural growth, generate employment, and bolster economic stability.
- 6) **Energy Security:** Biodiesel enhances energy security and reduces vulnerability to supply disruptions and price fluctuations in the global oil market, thereby reducing dependence on imported fossil fuels. By promoting domestic production and diversifying energy sources, biodiesel strengthens national energy independence and resilience.
- 7) **Regulatory Incentives:** Numerous governments across the globe provide regulatory incentives, tax credits, and subsidies to foster the manufacturing and utilization of biodiesel. Such policies serve as catalysts for investments in renewable energy technologies, spur market demand, and expedite the shift towards a more sustainable energy landscape.

In general, the advantages of utilizing biodiesel include environmental, economic, and societal perks, positioning it as a convincing option for decreasing dependence on fossil fuels and progressing towards a more sustainable energy future.

1.5 Demerits of using biodiesel:

- 1) **Land Use and Food Security Concerns:** Biodiesel production often competes with food production for land resources, leading to concerns about deforestation, habitat destruction, and food security. Cultivating feedstocks such as soybean, palm oil, and corn for biodiesel can result in land-use changes that may exacerbate environmental degradation and food scarcity, particularly in regions with vulnerable ecosystems and limited arable land.
- 2) **Impact on Agriculture and Water Resources:** Intensive monoculture farming practices associated with biodiesel feedstock production can lead to soil degradation, erosion, and water pollution from agrochemical runoff. Large-scale cultivation of biofuel crops may require significant amounts of water, exacerbating water scarcity issues and competing with other agricultural and ecological needs.
- 3) **Greenhouse Gas Emissions from Land Use Change:** The conversion of natural ecosystems, such as forests and grasslands, into biofuel crop cultivation areas can release significant amounts of stored carbon into the atmosphere, offsetting the carbon savings achieved by using biodiesel. This phenomenon, known as indirect land-use change (ILUC), can undermine the environmental benefits of biodiesel production and contribute to climate change.
- 4) **Energy Intensive Production Processes:** Biodiesel production involves various energy-intensive processes, including cultivation, harvesting, transportation, and conversion of feedstocks into fuel. Depending on the production methods and energy sources used, the overall energy balance and carbon footprint of biodiesel production can vary, potentially diminishing its environmental advantages compared to fossil diesel.

- 5) **Limited Feedstock Availability and Competition:** The availability of suitable feedstocks for biodiesel production is limited by factors such as climate, soil quality, and land availability. Competition for feedstocks between different sectors, such as food, feed, and fuel, can drive up prices and exacerbate socioeconomic inequalities, particularly in developing countries where food security is a concern.
- 6) **Fuel Compatibility and Infrastructure Challenges:** Biodiesel blends may have compatibility issues with certain engine types, fuel storage systems, and distribution infrastructure, requiring modifications or upgrades to ensure proper performance and durability. Additionally, cold weather operability and storage stability can be challenges for biodiesel blends in certain climates, impacting fuel availability and reliability.
- 7) **Subsidy Dependence and Market Volatility:** The biodiesel industry often relies on government subsidies, tax incentives, and regulatory mandates to remain economically viable and competitive with fossil fuels. Dependence on policy support exposes the industry to market volatility and regulatory uncertainty, potentially hindering long-term investment and growth.

While biodiesel offers several environmental and economic benefits as a renewable alternative to fossil diesel, addressing its demerits requires careful consideration of sustainability principles, land use practices, technological innovations, and policy frameworks to ensure a balanced and equitable transition towards cleaner energy solutions.

1.6 Various raw materials used for biodiesel preparation:

- 1) **Vegetable Oils:** Vegetable oils, including those derived from soybean, canola, palm, sunflower, and corn, are frequently used as feedstocks in the production of biodiesel. These oils contain high levels of triglycerides that can be transformed into biodiesel via the transesterification process.
- 2) **Animal Fats:** Animal fats, commonly referred to as tallow or grease, serve as an additional reservoir of triglycerides that are well-suited for the production of

biodiesel. The by-products obtained from meat processing facilities and rendering plants, including beef tallow and poultry fat, can be effectively utilized as raw materials for the manufacturing of biodiesel.

- 3) **Recycled Cooking Oil:** Recycled cooking oil, obtained from used vegetable oils used in food preparation, is an environmentally friendly feedstock for biodiesel production. Collecting and processing waste cooking oil into biodiesel not only diverts it from landfills but also reduces the environmental impact associated with disposal.
- 4) **Algae:** Algae show great potential as a feedstock for biodiesel production because of their high lipid content and fast growth rates. The oils from algae can be extracted and turned into biodiesel through processes similar to those used for vegetable oils. Cultivating algae for biodiesel production presents various benefits, including minimal land usage, wastewater treatment, and carbon dioxide capture.
- 5) **Waste Grease and Oils:** Various waste streams, including grease traps from restaurants, food processing residues, and sewage sludge, contain fats and oils suitable for biodiesel production. Recycling these waste materials into biodiesel not only reduces environmental pollution but also contributes to resource conservation and waste management.
- 6) **Jatropha:** *Jatropha* caracas is a drought-resistant shrub whose seeds contain oil suitable for biodiesel production. *Jatropha* cultivation on marginal lands has been explored as a sustainable biofuel feedstock, particularly in regions where arable land is limited or degraded.
- 7) **Waste Vegetable Oil (WVO):** Waste vegetable oil collected from commercial food service establishments, such as restaurants and cafeterias, can be processed into biodiesel after filtration and purification. WVO recycling offers an environmentally friendly solution for utilizing waste resources and reducing dependency on virgin feedstocks.
- 8) **Microbial Oils:** Certain microorganisms, such as yeast, fungi, and bacteria, can produce oils that can be converted into biodiesel. Microbial oils can be

synthesized from renewable feedstocks such as sugars, starches, and cellulosic biomass through fermentation processes.

- 9) **Used Cooking Grease:** Used cooking grease collected from households, catering facilities, and food processing industries can serve as a feedstock for biodiesel production. Recycling used cooking grease into biodiesel helps

reduce waste disposal costs and environmental pollution while promoting sustainable energy practices.

Overall, the diverse range of raw materials available for biodiesel production offers flexibility and opportunities for sustainable feedstock sourcing, contributing to the development of a more resilient and environmentally friendly biofuel industry.

1.7 Introduction to Mahua oil:

Mahua oil, derived from the seeds of the mahua tree (*Madhuca indica*), holds a significant place in traditional Indian culture and economy. Revered for its versatility and numerous beneficial properties, mahua oil has been utilized for centuries in various industries, including food, medicine, and cosmetics. This introduction explores the rich history, extraction process, composition, and diverse uses of mahua oil, shedding light on its importance in both traditional practices and modern applications.

The mahua tree, native to the Indian subcontinent, is a valuable resource in rural communities, providing not only edible fruits but also seeds rich in oil. The extraction of mahua oil involves a traditional cold-pressing method, which preserves the oil's natural integrity and nutritional qualities. The resulting oil boasts a rich golden color and a distinctive aroma, making it prized for culinary purposes in regional cuisines across India.

Beyond its culinary uses, mahua oil is esteemed for its medicinal properties in Ayurvedic and traditional folk medicine systems. It is believed to possess anti-inflammatory, antimicrobial, and antioxidant properties, making it a valuable ingredient

in herbal remedies for various ailments, including skin conditions, digestive disorders, and respiratory ailments.

Moreover, mahua oil finds applications in the cosmetic and personal care industry, where it is valued for its moisturizing, emollient, and conditioning properties. It is commonly used in skincare products such as soaps, creams, and lotions, as well as hair care formulations like shampoos and hair oils, to nourish and rejuvenate the skin and hair.

In addition to its culinary, medicinal, and cosmetic uses, mahua oil holds potential as a renewable and sustainable biofuel feedstock. Its high energy content and favorable fatty acid composition make it suitable for biodiesel production, offering an eco-friendly alternative to fossil fuels and contributing to efforts towards energy security and environmental sustainability.

In conclusion, mahua oil stands as a versatile and valuable natural resource with a rich cultural heritage and myriad practical applications. Its continued utilization in various industries underscores its significance in both traditional and modern contexts, while its potential as a sustainable biofuel feedstock highlights its role in shaping a more sustainable future.

CHAPTER – 2

LITERATURE SURVEY

Atila Koca, Duran Altıparmak, Ali Keskin, and Metin Gürü In the investigation, the characteristics of tall oil methyl ester-diesel fuel mixes were examined as potential alternative fuels. The researchers explored the use of blends consisting of tall oil methyl ester and diesel fuel as a promising option for diesel engines. To produce tall oil methyl ester, methyl alcohol and tall oil fatty acids were carefully combined. The inclusion of tall oil methyl ester in the diesel fuel blends led to a notable increase in engine power and torque output, with improvements of up to 6.1% and 5.9% respectively. However, the revised fuel combinations also resulted in a significant rise in NO_x emissions, reaching up to 30%, while CO emissions experienced a substantial decrease of 38.9%. Interestingly, the opacity of the smoke did not exhibit any noticeable changes throughout the study. [1].

It is feasible to differentiate between the elaborate and simplified (skeletal) kinetic mechanisms for a chemical kinetic model, which will be the primary emphasis of the fundamental combustion study in this section. Despite the absence of research on pentanol, Sarathy et al. (2014)[3]

A.S. Husayyin Rady A. Dawood and A.H. Bawady, MA Title: An experimental study was conducted to evaluate diesel engine emissions and performance using combinations of jojoba oil and diesel fuel. Research has demonstrated that blending mahua oil with petrol can effectively reduce engine problems caused by thick oil. Substituting regular petrol with blends of jojoba oil and petrol in single-chamber, naturally aspirated, direct-injection engines has generally resulted in minimal loss of engine power, a slight increase in brake-specific fuel consumption, and a reduction in engine NO_x and particulate emissions. The accumulation of engine deposits has decreased gradually over time.

An experimental study was conducted to evaluate diesel engine emissions and performance using combinations of jojoba oil and diesel fuel. Research has demonstrated that blending mahua oil with petrol can effectively reduce engine problems caused by thick oil. Substituting regular petrol with blends of jojoba oil and petrol in single-chamber, naturally aspirated, direct-injection engines has generally resulted in minimal loss of engine power, a slight increase in brake-specific fuel consumption, and a reduction in engine NO_x and particulate emissions. The accumulation of engine deposits has decreased gradually over time[5].

Lakshmi Sankar S, Ganesan S et al. (2021) they discovered through a study that melon seed oils could be extracted with an impressive yield of 82.2%. Once the oil was extracted and its consistency checked, the methyl esters underwent transesterification. Experimental research revealed that the extracted oil had similar specific gravity and viscosity to gasoline. To produce high-quality biodiesel that addresses various issues, enzymatic transesterification was employed using the lipase enzyme. Five different bio samples were created by blending the extracted oil with neat diesel in ratios of 10%, 20%, 30%, and 40%. An engine test was conducted to evaluate performance and emission parameters, including BTE and SFC, as well as CO₂, CO, NO_x, HC, O₂, and smoke emissions.

Jaya Prabakar Jayaraman, M. Karthik et al. (2020): The study focused on the performance of a CI engine running on a B20 blend of Manilkara zapota seed oil biodiesel. The engine's emissions and performance were analyzed with and without the inclusion of blended titanium oxide nano additives. The impact of additives and EGR on performance was evaluated with a 15% EGR. Test results showed that B20 + 50 + EGR and B20 + 100 + EGR blends exhibited higher brake thermal efficiency values. Among the three blends tested, the engine consumed less fuel when using the B20 + 50 + EGR blend. Both B20 + 50 + EGR and B20 + 75 + EGR blends reported lower NO_x emissions but higher carbon emissions. To enhance performance and reduce emissions, the B20 blend with TiO₂ nanoparticles and EGR can be utilized in the CI engine.

The paper authored by Obed M. Ali and Rizalman Mamat is titled "Enhancing Engine Performance and Cold Weather Properties of Blended Palm Biodiesel through Additives." The vast rural areas across the globe do not fully reap the benefits of this development. Hence, agricultural practices should encompass the production of non-food items that are suitable for the local climate. This approach aims to reduce dependence on petroleum-based fuels and promote the utilization of biodiesels as a sustainable energy source in the national market. Researchers have been closely monitoring the progress of biodiesel due to concerns regarding ozone-depleting substances and environmental limitations. Numerous experimental studies are currently underway to assess the impact of various additives[6].

Xichao Chen, Yan Yang, Fanghua Yin, Ran Xu, and Longyao Wang carried out experimental research on 2-ethylhexyl nitrate. During the experiment, nitric acid, 2-ethyl hexanol, and sulfuric acid were employed as catalysts in a micro-channel reactor to produce 2-ethylhexyl nitrate (2-EHN). Through experimentation, the optimal synthetic conditions were identified: The perfect liquid hourly space velocity when nitric acid and sulfuric acid are used in their respective mole ratios of 1:2 and 1:1 is determined to be 4000h⁻¹. EHN exhibits a significantly high yield and purity under these conditions. In theory, this technology lays the groundwork for industrialized production due to its user-friendly, environmentally friendly, safe, reliable, and energy-efficient nature.[7]

Purnachandran Ramakrishnan^{1,2}, Ramesh Kasimani³, Mohamed Shameer Peer⁴, and Sakthivel Rajamohan¹ conducted a study on the impact of n-pentanol/Calophyllum inophyllum/diesel blends on the performance, carbon dioxide emissions, and combustion properties of a direct injection diesel engine with a constant-speed parameter compression ratio. The researchers assessed the performance of biodiesel, pentanol, and diesel blends using a computerized single-cylinder variable compression DI diesel engine under heavy load conditions and various compression ratio settings. The findings were compared to those obtained from neat diesel fuel and CI20 fuel blends.[8]

Prabhu and M. Venkata Ramanan conducted a study titled "Emission and Performance Studies for Pentanol Diesel Blends for Unmodified Diesel Engines." Their research focused on comparing the impact of adding pentanol to diesel fuel on performance and emission characteristics. The empirical data collected during the

study revealed some interesting findings.

One of the key observations was that blends of pentanol and diesel fuel had a higher Brake Thermal Efficiency (BTE) compared to pure diesel fuel. However, when comparing gasoline-pentanol mixes, the BTE was only slightly lower than that of pure diesel at all loads.

It was also noted that adding pentanol to diesel fuel resulted in a decrease in both the energy content and the specific fuel utilization of the blend. This can be attributed to the higher oxidation impact of pentanol.

On the positive side, the enhanced calorific value of pentanol had a beneficial effect on oxidation, leading to lower emissions of NO_x, HC, and CO. This suggests that the fuel blend's oxidizing ability was improved due to the presence of pentanol. [9]

Sathyamoorthi R (2017) [3], In this study, ethanol was mixed with a pure lemongrass oil (LGO) diesel fuel blend to analyze the effects of ethanol concentration on the engine's performance, emissions, and combustion. The impact of small ethanol concentrations (2.5 and 5%) in the regular lemongrass oil-diesel blend was examined. The results from tests conducted with diesel fuel and different blends were compared. The blends studied showed varying performance, emission, and combustion characteristics when compared to diesel fuel. Compared to diesel and LGO25 (75% pure diesel ÷ 25% pure lemongrass oil), the ethanol blends exhibited higher combustion pressure and heat release rate, brake specific fuel consumption, and brake thermal efficiency. However, they also resulted in lower smoke and HC emissions, as well as higher NO_x and CO₂ emissions

M. Sunil Kumar, In this investigation, Various fuel types, such as diesel and lemongrass biodiesel, underwent testing on diesel engines in an attempt to enhance performance and combustion while reducing exhaust emissions. Additionally, three different nanoadditives, namely zinc oxide, titanium dioxide, and aluminum dioxide, were introduced to lemongrass oil to improve its performance, combustion characteristics, and decrease exhaust emissions from diesel engines. The remaining 70% of the oil was blended at a ratio of 30% over 100% and utilized as diesel, or 30%

LOBD. It was determined that the behavior of lemongrass oil and the nanoparticles ZnO, TiO₂, and Al₂O₃ in the anatase phase was confirmed through FT-IR characterization of lemongrass oil and XRD, SEM, and FT-IR characterization of the nanoparticles. The brake specific fuel consumption of B3050TiO₂, B3050ZnO, and B3050Al₂O₃ increased by 1.3% compared to diesel fuel, while the brake thermal efficiency of B3050ZnO increased by 4.9%. Analysis was conducted on emissions including CO, NO_x, and HC. For B3050TiO₂, B3050ZnO 17, and B3050Al₂O₃, the reduction in carbon monoxide emissions was 17%, 39%, and 5% respectively. The emission of nitrogen oxide increased by 73PPM for B3050Al₂O₃, 290PPM for B3050TiO₂, and 310PPM for B3050ZnO. The hydrocarbon emissions were reduced by 3.3%, 32.5%, and 1% respectively for B3050TiO₂, B3050ZnO, and B3050Al₂O₃. According to the ANOVA table, B3050ZnO exhibits a significant and substantial dependence on brake thermal efficiency beyond 3%. After validating the four fuel types, it was concluded that B3050ZnO has a significant impact on performance, combustion parameters, and exhaust emissions.

Mani Ghanbari, Lotfali Mozafari-Vanani et.al (2021) conducted a study to investigate the effects of engine speed and the concentration of alumina nanoparticles in diesel-biodiesel blended fuels on the performance and emission characteristics of a six-cylinder, four-stroke diesel engine. Alumina nanoparticles were synthesized and added to the diesel-biodiesel blend at concentrations of 40, 80, 120, and 160 parts per million. These fuel blends were used to operate the diesel engine at various speeds ranging from 800 to 1000 rpm. By employing response surface methodology (RSM), the researchers analyzed the interaction between these variables and the engine's performance and emissions. The highest recorded brake power and torque values were 42.82 kW and 402.8 Nm, respectively, at an engine speed of 1000 rpm and a nanoparticle concentration of 160 ppm. Additionally, the lowest values of BSFC, CO, and HC were 207.21 gr/kWh, 1.15%, and 9%, respectively. At a nanoparticle concentration of 160 ppm and an engine speed of 1000 rpm, the maximum levels of CO₂ and NO_x were measured at 11.76% and 1899 ppm, respectively. The experimental findings suggested that the inclusion of alumina nanoparticles in diesel-biodiesel blends can enhance engine performance and reduce emissions. It was also noted that the developed mathematical model can accurately predict engine emissions and performance.

CHAPTER – 3

AIM AND SCOPE

3.1 AIM

The objective of this experimental study is to evaluate Study of performance and emission characteristics of biodiesel from mahua oil on VCR diesel engine. The main aim of this project is to reduce the emissions of the CI diesel engine by blending mahua oil with diesel. by using the alternative fuels it decreases the impact on the environment and decreases the dependency on the crude oil imports. It is the aim of the project.

3.2 SCOPE OF THE WORK

The demand for biodiesel production is highly significant as the supply of petroleum products decreases on a daily basis. As petroleum goods are not accessible worldwide, household oils can be transformed into biodiesel. Moreover, biodiesel releases fewer emissions compared to diesel, thereby reducing the greenhouse effect, which is presently the most pressing global concern. Biodiesel, as a renewable and environmentally friendly alternative to conventional diesel fuel, has recently gained considerable attention and recognition. Due to its wide-ranging applications in various industries, it serves as an excellent topic for a project report.

Biofuel researchers are currently conducting experiments on various mixing ratios and the operation of single-chamber diesel engines. One of the tests involves the combination of diesel and mahua oil. The oil mixes being tested include B10, B20, and B30. To reduce the reliance on diesel, fillers are being used. Vegetable oils are widely used in automobiles and transportation systems worldwide. The need to consider biodiesel arises from the depletion of petroleum resources, increasing energy demands, and the growing concern over emissions harmful to the ozone layer. Conventional diesel fuel may not be easily accessible in all regions, hence countries are striving to find readily available oils for use as biofuel. Biodiesel is produced by combining spirits (usually methanol) with vegetable, animal, or used cooking oil.

Bioenergy is commonly used as a substitute for diesel fuel in engines or as an additive to reduce vehicle emissions by about 20%. As the world's energy demands evolve and grow, it is crucial to optimize every aspect of the bioenergy production process. This includes developing more efficient bio treatment facilities and researching bio hydrogen as an energy carrier. To meet the promises of biomass for power generation, existing energy infrastructure needs to be modified and upgraded. Bio Energies offers a platform for discussions and provides articles on audits, innovative research, analysis, and news related to the bioenergy sector.

Biodiesel is produced from domestically produced plant oils or waste fats, switching from Petroleum-based diesel to Biodiesel decreases dependence on foreign petroleum, reduces net greenhouse gas emissions, and provides tangible benefits for the domestic economy. The potential benefits associated with Biodiesel have driven national, state, and local governments to adopt policies that mandate or make it financially beneficial to produce and use Biodiesel. The limited supply of fossil fuels and the increasing level of global environmental consciousness suggest that additional incentives and mandates are likely in the future. Biodiesel incentive programs can be delineated into two main categories—production and consumption. Both types of incentives lower the cost of Biodiesel, eroding the price differential that currently prevents its widespread adoption. It appears that there may be significant public policy momentum for Biodiesel soon that combines local, state, and federal mandates and incentives into a sustainable business opportunity.

CHAPTER – 4

MATERIALS AND EXPERIMENTAL METHODS

4.1 METHODOLOGY

- ✓ Problem Identification
- ✓ Literature survey
- ✓ Selection of raw material for making biodiesel
- ✓ Collection of raw material(seed) from plant.
- ✓ Extraction of oil from seeds by various methods
- ✓ Extracted oil properties testing.
- ✓ Preparation of biodiesel from oil by transesterification process
- ✓ Preparation of biodiesel- diesel blends (with mahua oil)
- ✓ Analysis and evaluating the performance and emission characteristics of biodiesel blends.

FLOW CHART:

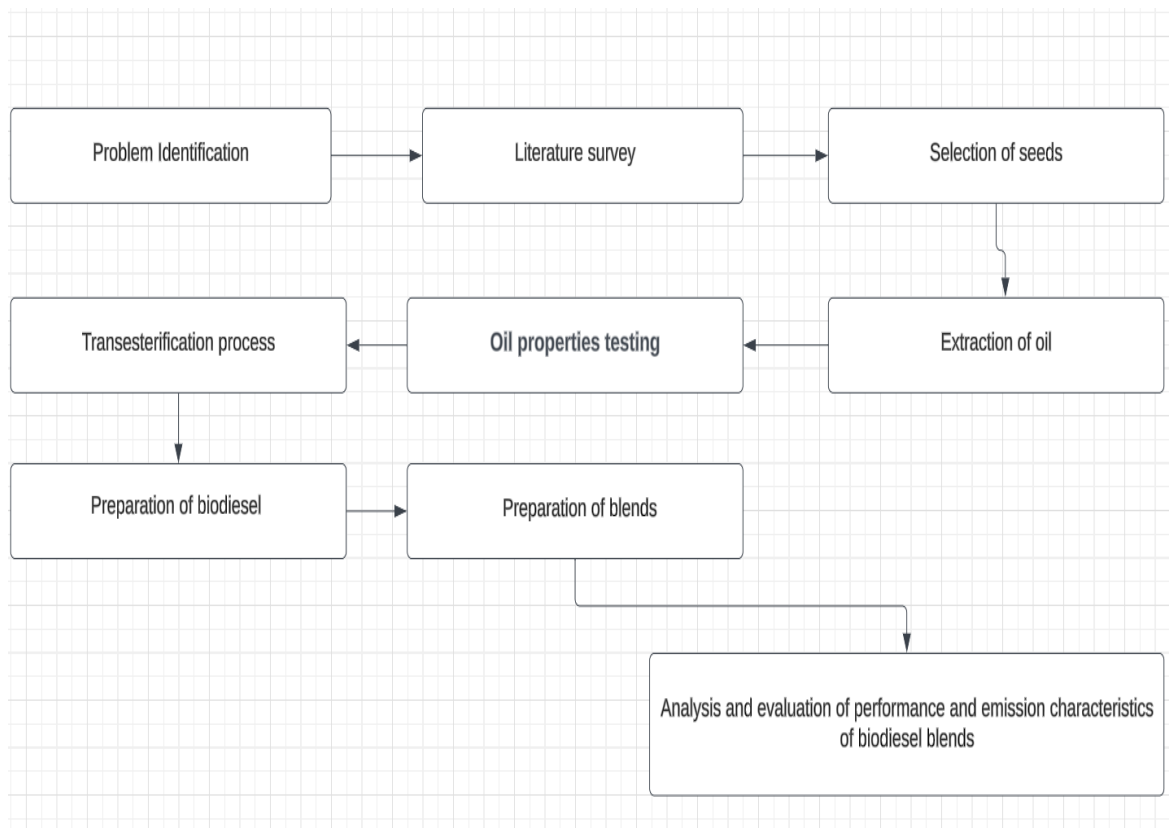


Fig.4.1 Flow chart

4.2 Materials and processes used:

4.2.1 Seed collection:

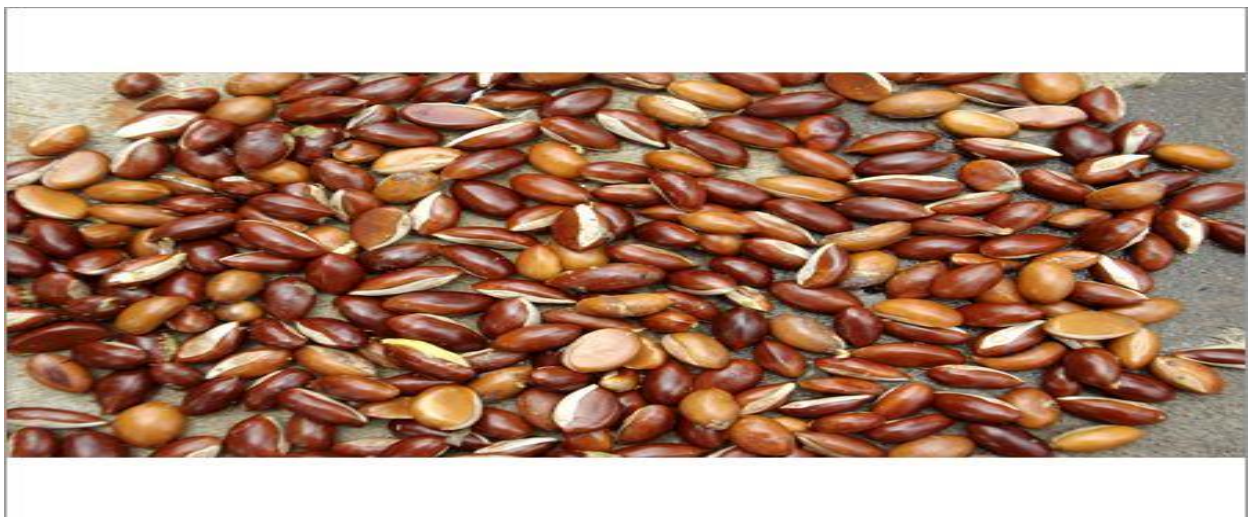


Fig:4.2 Mahua seeds

Mahua seed collection is a crucial aspect of harnessing the potential of the mahua tree (*Madhuca indica*) as a valuable natural resource. Here's an overview of the mahua seed collection process:

- 1) **Identification of Mature Seeds:** Mahua seeds ripen and mature on the trees typically during the spring or summer months, depending on the local climate. Mature seeds are characterized by a brownish-black color and a hard outer shell.
- 2) **Harvesting:** Mahua seeds are collected by handpicking them directly from the trees or gathering them from the ground after they naturally fall. Harvesting is typically done during the early morning or late afternoon when the temperatures are cooler to minimize seed damage and ensure optimal seed quality.
- 3) **Collection Techniques:** In traditional practices, collectors climb the mahua trees using ladders or improvised climbing tools to reach the seed-bearing branches. They carefully pluck the ripe seeds using their hands or small tools to avoid damaging the seeds or the tree.
- 4) **Storage:** After collection, mahua seeds are usually stored in well-ventilated containers or sacks to prevent moisture buildup and fungal growth. Proper storage conditions help maintain seed viability and quality until further processing or utilization.
- 5) **Transportation:** Depending on the scale of collection and distance to processing facilities or markets, mahua seeds may be transported in bulk sacks, baskets, or other suitable containers. Care is taken during transportation to prevent damage and ensure that the seeds arrive in optimal condition.
- 6) **Processing:** Once collected, mahua seeds can be processed to extract the valuable mahua oil. Traditional methods of oil extraction involve crushing or grinding the seeds to release the oil, followed by pressing or heating to separate the oil from the seed cake. Modern mechanical presses or solvent extraction techniques may also be employed for large-scale oil extraction.

- 7) **Utilization:** Mahua seeds and the extracted oil have various traditional and modern applications. In addition to culinary uses, mahua oil is utilized in traditional medicine, cosmetics, and as a potential feedstock for biodiesel production.

Overall, mahua seed collection plays a vital role in harnessing the economic and ecological potential of the mahua tree, while also contributing to rural livelihoods and sustainable development in regions where the tree is abundant. Proper collection practices, coupled with sustainable management of mahua resources, can ensure the long-term viability and resilience of this valuable natural asset.

4.2.2 Extraction of oil

After collecting the seeds, we clean the seeds from impurities such as dirt, debris and small twigs it is done by manually by hand picking separate the seeds from unwanted materials. After cleaning is done, we dried the seeds under the sunlight by spreading seeds in a thin layer on a clean surface to reduce the moisture content. After drying We extracted the oil from grinding and pressing the seeds by wooden press oil. After extracting the oil we filter it by using filter material to eliminate the suspended solids or impurities then we achieved high quality product for preparing biodiesel from it.

The extraction of oil from mahua seeds involves several steps, traditionally performed using manual or mechanical methods. Here's an overview of the extraction process:

- 1) **Cleaning:** The collected mahua seeds may contain impurities such as dirt, debris, and small twigs. To prepare the seeds for extraction, they are first cleaned to remove these impurities. This can be done manually by handpicking or using simple sieves and screens to separate the seeds from unwanted materials.
- 2) **Drying:** After cleaning, the mahua seeds are typically dried to reduce moisture content, which helps improve the efficiency of the oil extraction process. Drying

can be achieved by spreading the seeds in a thin layer on clean, dry surfaces under the sun or using mechanical dryers.

- 3) **Crushing or Grinding:** Once dried, the mahua seeds are crushed or ground to break open the hard outer shell and release the oil-containing kernel. Traditional methods involve crushing the seeds using a mortar and pestle, a wooden crusher, or grinding stones. Modern mechanical methods may include using crushers, hammer mills, or milling machines for more efficient processing.
- 4) **Pressing:** After crushing or grinding, the oil-bearing kernels are subjected to pressing to extract the oil. We utilize traditional method mechanical presses to squeeze the oil from the crushed seeds. The pressure applied ruptures the oil-containing cells, releasing the oil, which then flows out through small openings in the press.
- 5) **Filtering:** The extracted oil may contain suspended solids or impurities that need to be removed to obtain a clean, high-quality product. Filtering the oil helps remove these impurities and improve its clarity and shelf life. Filtration can be done using simple cloth or paper filters or more advanced filtration systems.
- 6) **Settling and Storage:** After filtration, the oil is allowed to settle to separate any remaining solids or water. The clarified oil is then transferred to clean, dry containers for storage. Proper storage conditions, such as cool, dark environments, help preserve the quality and freshness of the oil.

Overall, the extraction of oil from mahua seeds can be achieved using a combination of traditional and modern methods, with careful attention to quality, efficiency, and sustainability. Proper extraction techniques ensure the production of high-quality mahua oil for various culinary, medicinal, cosmetic, and industrial applications.



Fig- 4.3 Wood press oil machine

4.2.3 Properties testing of mahua oil:

Table 4.1: Properties of Mahua oil

S.No	Parameters	Results
1	Density (g/cc)	0.936
2	Kinematic Viscosity @ 40°C (cSt)	29.31
3	Flash point by PMCC method (°C)	Above 300
4	Fire point by PMCC method (°C)	Above 300
5	Calorific value (Cal/g)	7463.612

4.2.4 Esterification and Transesterification:

It involves two steps

- ❖ Calculating (or) Checking the “Free Fatty Acid (FFA)” value.
- ❖ Transesterification process which is used when FFA value is less than or equal to 4%. Otherwise, Esterification process.

Our mahua oil has more than 4% of free fatty acid

So, esterification process take place.

Step:1 Esterification process:

In the initial stage, the Mahua seed oil with a free fatty acid content exceeding 4% undergoes an Esterification process. This process involves placing the Mahua oil in a flask, adding 4ml of H₂SO₄ Sulfuric acid as a catalyst, maintaining a 1:3 oil to methanol molar ratio, and heating the mixture to 60°C. The reaction is then allowed to proceed for 120 minutes at 600 rpm, resulting in a reduction of the free fatty acid content to less than 4%, enabling the transition to the Transesterification process.

- 1) **Preparation of Feedstock:** The raw materials used for esterification usually include vegetable oils, animal fats, or recycled cooking oils. In our specific case, we utilize mahua oil as the feedstock. Prior to the esterification process, these feedstocks may undergo various pretreatment procedures, such as heating, filtration, and degumming. These processes aim to eliminate impurities and enhance the overall quality of the feedstocks.
- 2) **Acid Catalysis:** In the esterification reaction, a small amount of acid catalyst such as sulfuric acid(H₂SO₄) is added to the Mahua oil mixture. The acid catalyst helps facilitate the reaction by increasing the rate of ester formation and promoting the separation of water, a byproduct of the reaction.
- 3) **Addition of Alcohol:** A molar ratio of 1:3 of methanol to oil, in the presence of an acid catalyst, is combined with the mahua oil mixture. The alcohol interacts with the triglycerides found in the feedstock, resulting in the production of fatty

acid alkyl esters (biodiesel) and glycerol. It is important to note that this reaction is reversible and takes place in equilibrium.

4) **Esterification Reaction:** The acid catalyst promotes the reaction between the alcohol and the triglycerides, resulting in the formation of fatty acid esters and glycerol. This reaction proceeds through a series of intermediate steps, including the formation of fatty acid alkyl esters and glycerolysis. The esterification reaction taken 120minutes

5) **Separation of Products:** After the esterification reaction is complete, the mixture is allowed to settle, allowing the glycerol to separate from the oil. The glycerol, being denser than oil, sinks to the bottom of the reaction vessel and can be easily removed.

After completing the esterification process, we reduced the free fatty acid to below 4%

Step:2 Transesterification:

In the subsequent phase, the Transesterification mechanism directly utilizes the Mahua oil to produce biodiesel due to the FFA value being below 4%. A small-scale transesterification procedure was conducted by the Centre for Waste Management of the International Research Centre, Sathyabama University, Chennai, Tamil Nadu. For this reaction, a magnetic stirrer with a heater and speed controller was utilized. A one-liter flask with a three-way round bottom was filled with Mahua seed oil after precise measurement. A magnetic pellet was introduced into the reactor flask, which was then placed on a magnetic stirrer. A water pipeline was connected to the reflux condenser, securely attached to the middle neck of the three-way flask. After preheating the Mahua oil to 60°C, 5 grams of NaOH solution with a 1:3 oil-to-methanol ratio were added. The reaction was allowed to progress for 120 minutes at 600 rpm. Following this, the reaction mixture was transferred to a separating funnel and left to settle for two hours. Within the designated time frame, the reaction mixture separated into two layers, with glycerine at the bottom and biodiesel at the top. The cock of the separating funnel was opened to eliminate the glycerine. Subsequently, soap particles, entrained glycerine, excess methanol, and catalyst were removed from the biodiesel through a washing process with warm distilled water at 70°C. The moisture was eliminated from

the biodiesel by subjecting it to a temperature of approximately 100 °C in an oven. The resulting biodiesel displayed a golden yellow tint.

The International Research Centre's Centre for Waste Management at Sathyabama University in Chennai, Tamil Nadu, carried out a minor transesterification process the transesterification process, which is the key step in biodiesel production.

- 1) **Preparation of Feedstock:** The feedstock for transesterification mahua oil. These feedstocks may undergo pretreatment processes such as filtering to remove impurities and moisture.
- 2) **Addition of Alcohol:** In the transesterification reaction, a molar excess of alcohol, oil to of methanol ratio 1:3, is added to the feedstock. The alcohol serves as the reactant that will replace the glycerol backbone of the triglyceride molecules, forming fatty acid alkyl esters (biodiesel) and glycerol as byproducts.
- 3) **Catalyst Addition:** A catalyst is added to the reaction mixture to facilitate the transesterification process. Commonly used catalysts sodium hydroxide (NaOH) 5 grams which act as strong bases to accelerate the reaction rate.
- 4) **Mixing and Heating:** The reaction mixture is thoroughly mixed and heated to an optimal temperature, typically 60 degrees Celsius. Heating the mixture helps increase the rate of reaction and promote the conversion of triglycerides into biodiesel and glycerol.
- 5) **Transesterification Reaction:** During the transesterification reaction, the alcohol molecules react with the triglycerides present in the mahua oil, resulting in the formation of fatty acid alkyl esters (biodiesel) and glycerol. This reaction involves the displacement of the glycerol molecule by the alcohol, resulting in the formation of three molecules of biodiesel and one molecule of glycerol from each triglyceride molecule. The mahua oil reaction time is 120minutes with 600rpm.
- 6) **Phase Separation:** Once the transesterification reaction has finished, the mixture is left to settle, enabling the separation of the biodiesel and glycerol

phases. Due to its lower density, the biodiesel rises to the top and can be effortlessly removed from the glycerol layer.

- 7) **Washing and Purification:** The unrefined biodiesel undergoes a water washing step to eliminate lingering impurities, leftover catalyst, and contaminants that are soluble in water. This procedure plays a crucial role in enhancing the overall purity and quality of the biodiesel output.
- 8) **Drying and Filtration:** The biodiesel that has been washed undergoes a drying process to eliminate any surplus water, as it may lead to stability problems when stored or utilized. Subsequently, the biodiesel is subjected to filtration in order to eliminate any residual solid particles or traces of impurities.
- 9) **Quality Control:** The biodiesel is subjected to quality control testing in order to verify its compliance with the necessary standards for fuel usage. This testing encompasses various parameters, including viscosity, acidity, moisture content, and ester content, to ensure its quality.

Overall, Transesterification plays a vital role in the biodiesel manufacturing process by converting the triglycerides found in mahua oil into fatty acid alkyl esters (biodiesel) through a chemical reaction involving alcohol and catalysts. This essential step allows for the conversion of renewable resources into a sustainable substitute for fossil diesel fuel.

Table.4.2 Transesterification process parameters

S.No	Parameters	Results
1	Free fatty acid	1.69 %
2	Catalyst (NaOH) quantity	5 grams
3	Oil to methanol molar ratio	1:3
4	Temperature	60 °C
5	Reaction time	120 minutes
6	Yield	63.5 %

4.2.5 Preparation of Biodiesel diesel blends:

- B10: 450 ml of diesel and 50 ml of mahua oil
- B20: 400 ml of diesel and 100 ml of mahua oil.
- B30: 350 ml of diesel and 150 ml of mahua oil.



Fig.4.4 B10, B20 and B30 blends of biodiesel

CHAPTER-5

EXPERIMENTAL SETUP

5.1 VCR Diesel Engine:

A VCR (Variable Compression Ratio) diesel engine is an innovative type of internal combustion engine designed to vary its compression ratio dynamically during operation. Unlike traditional diesel engines with fixed compression ratios, VCR engines can adjust the compression ratio to optimize performance, fuel efficiency, and emissions across a wide range of operating conditions.

Here's how a VCR diesel engine typically works:

- 1) **Variable Compression Ratio Mechanism:** At the heart of a VCR diesel engine is a mechanism that allows the compression ratio to be adjusted. This mechanism may involve movable components such as pistons, connecting rods, or cylinder heads that can change the volume of the combustion chamber, thereby altering the compression ratio.
- 2) **Compression Ratio Adjustment:** The compression ratio of an engine is the ratio of the maximum to the minimum volume of the combustion chamber. By varying this ratio, a VCR diesel engine can optimize combustion conditions based on factors such as engine load, speed, and temperature.
- 3) **Benefits of Variable Compression Ratio:** The ability to adjust the compression ratio offers several advantages. At low loads and speeds, a lower compression ratio can improve fuel efficiency by reducing heat losses and pumping losses. At higher loads and speeds, a higher compression ratio can enhance power output and thermal efficiency by promoting more complete combustion.
- 4) **Optimized Performance and Emissions:** By dynamically adjusting the compression ratio, VCR diesel engines can deliver improved performance and lower emissions compared to conventional engines. This optimization allows

the engine to operate more efficiently across a wider range of operating conditions, resulting in reduced fuel consumption and exhaust emissions.

- 5) **Engine Management System:** VCR diesel engines typically incorporate sophisticated engine management systems that monitor operating parameters such as engine speed, load, temperature, and pressure. Based on real-time data, the engine management system adjusts the compression ratio to optimize performance, efficiency, and emissions.
- 6) **Application:** VCR diesel engines have potential applications in various sectors, including automotive, marine, and stationary power generation. They offer a promising solution for meeting increasingly stringent emissions regulations while improving fuel economy and overall engine performance.

Overall, VCR diesel engines signify a notable progression in engine technology, providing advantages in flexibility and efficiency that can support the development of more sustainable and eco-friendly transportation and power generation systems..



Fig .5.1 VCR diesel engine.

VCR Engine Specification:

Table5.1 VCR engine specification

Product	VCR Engine test setup 1 cylinder, 4 stroke, Diesel with EGR (Comp.)
Product code	234
Engine	Make Kirloskar, Type 1, 4 stroke Diesel, water cooled, power 3.5kW at 1500rpm, stroke 110mm, bore 87.5mm. 661cc, CR17.5, Modified to VCR engine CR 12 to 18. With electric start arrangement, battery, and charger
Dynamometer	Type eddy current, water cooled
Propeller shaft	With universal joints
Air box	Mild steel fabricated with orifice meter and manometer
Fuel tank	Capacity 15 lit with glass fuel metering column
Calorimeter	Type Pipe in pipe
EGR	Water cooled, SS, Range 0-15%
Piezo sensor	Range 5000 PSI, with low noise cable
Crank angle sensor	Resolution 1 Deg, Speed 5500 RPM with TDC pulse.
Data acquisition device	NI USB-6210, 16-bit, 250kS/s.
Piezo powering unit	Model AX-409.
Temperature sensor	Type RTD, PT100 and Thermocouple, Type K
Temperature transmitter	RTD PT100, Range 0–100°C, 3 Nos; Thermocouple, Range 0-1200 °C, 2 Nos
Load indicator	Digital, Range 0-50 Kg, Supply 230VAC
Load sensor	Load cell, type strain gauge, range 0-50 Kg

Fuel flow transmitter	DP transmitter, Range 0-500 mm WC
Air flow transmitter	Pressure transmitter, Range (-) 250 mm WC
Software	“Engine Soft” Engine performance analysis software
Rotameter	Engine cooling 40-400 LPH; Calorimeter 25-250 LPH
Pump	Type Monoblock
Overall dimensions	W 2000 x D 2500 x H 1500 mm
Optional	Computerized Diesel injection pressure measurement with injection variation 0-25 deg BTDC

5.2 Exhaust gas analyzer:

An exhaust gas analyzer is a device that measures the composition of exhaust gases produced by a combustion engine. These analyzers are often used to measure the concentration of various gases in the exhaust stream, such as carbon monoxide (CO), carbon dioxide (CO₂), oxygen (O₂), nitrogen oxides (NO_x), and hydrocarbons (HC).

Here's a more in-depth explanation of the exhaust gas analyzer:

- 1) **Sampling System:** The sampling system is in charge of obtaining an exhaust gas sample from the engine's tailpipe. The sampling system typically consists of a probe or hose put into the exhaust pipe to collect an exhaust gas sample. The sample is subsequently sent to the analyzer for examination.
- 2) **Measurement System:** The heart of an exhaust gas analyzer is its measuring system. It monitors the concentrations of various gases in the exhaust stream and generates a comprehensive report on the exhaust gas composition. The measuring system is made up of several sensors, detectors, and electronic circuits that work together to determine the concentration of various gases in the exhaust streams.

- 3) **Gas Sensors:** The gas sensors are in charge of detecting the presence of various gases in the exhaust stream. To detect gases, these sensors employ
- 4) various technologies such as electrochemical, infrared, and UV absorption. Each sensor type is intended to detect a specific gas, such as CO, CO₂, NO_x, O₂, or HC.
- 5) **Calibration System:** An exhaust gas analyzer's calibration system is a critical component. It is used to calibrate the gas sensors and guarantee that the analyzer produces accurate and consistent findings. The analyzer is calibrated with this gas before and after each usage to ensure accurate readings.
- 6) **Display and Data Logging:** The exhaust gas analyzer's display system provides the user with real-time readings of the exhaust gas composition. The concentration of various gases is shown in parts per million (ppm) or percent (%). The analyzer also has a data logging device for recording the exhaust gas composition over time. This information may be analyzed and utilized to discover patterns in the exhaust gas composition.



Fig.5.2 Shows AVL gas analyzer.

5.2.1 Working of Exhaust Gas Analyzer:

An exhaust gas analyzer is an instrument utilized for the measurement and analysis of the exhaust gas composition emitted by combustion engines, including those present in automobiles, power plants, and industrial machinery. The following outlines the typical functioning of an exhaust gas analyzer:

Sampling: The exhaust gas analyzer samples exhaust gases directly from the exhaust pipe or stack of the engine being tested. A probe or sampling tube is inserted into the exhaust stream to collect a representative sample of the gases.

Gas Analysis: The sampled exhaust gases are then analyzed to measure various components and pollutants present in the exhaust. Common parameters measured by an exhaust gas analyzer include:

Oxygen (O₂) concentration: Oxygen levels are measured to determine the air-to-fuel ratio of the combustion process. An ideal air-to-fuel ratio ensures efficient combustion and minimal emissions.

Carbon dioxide (CO₂) concentration: CO₂ levels are indicative of the completeness of combustion. Higher CO₂ levels generally indicate efficient combustion, while lower levels may suggest incomplete combustion or fuel-rich conditions.

(CO) Carbon monoxide concentration: Carbon monoxide is a hazardous gas that is generated when combustion is not fully completed. Increased levels of carbon monoxide in emissions suggest ineffective combustion or issues with the engine.

Hydrocarbons (HC): Hydrocarbons are unburned fuel molecules that can contribute to air pollution and smog formation. Measuring HC levels helps assess the effectiveness of fuel combustion.

Nitric oxide (NO) and nitrogen dioxide (NO₂) concentrations: NO_x emissions result from combustion at high temperatures and can contribute to air pollution and acid rain. Measuring NO_x levels helps evaluate the combustion efficiency and environmental impact of the engine.

Detection Methods: Exhaust gas analyzers utilize various detection methods to measure the concentrations of different gases. Common detection methods include infrared (IR) absorption, electrochemical sensors, and nondispersive infrared (NDIR) spectroscopy. Each method has its advantages and limitations in terms of accuracy,

sensitivity, and response time.

Data Display and Analysis: The measured gas concentrations are displayed on a digital screen or outputted to a computer for further analysis. Some exhaust gas analyzers may also provide real-time data logging capabilities, allowing users to track emissions over time and identify trends or abnormalities.

Calibration and Maintenance: To ensure accurate and reliable measurements, exhaust gas analyzers require periodic calibration and maintenance. Calibration involves adjusting the analyzer's settings to match known reference values, while maintenance may include sensor replacement, cleaning, and quality control checks.

Overall, exhaust gas analyzers play a crucial role in monitoring and controlling emissions from combustion engines, helping to ensure compliance with environmental regulations, optimize engine performance, and minimize air pollution.

5.2.2 Gas Analyzer Specification:

Table.5.2 Gas analyzer specifications.

Manufacturer	SMS Autoline Equipments private limited
Type	Crypton290 five gas analyzer
Range	Carbon monoxide -0 to 10 %, Carbon dioxide -0 to 20 %, Hydrocarbon -0 to 10000 PPM, Oxygen-0 to 25, Nitrousoxides- 0 to 5000 PPM
Resolution	Carbon monoxide -0.01 %, Carbon dioxide -0.10%, Hydrocarbon -1PPM, Oxygen -0.01 %, Nitrous oxides -1 PPM
principle	Carbon monoxide -NDIR, Carbon dioxide -NDIR, Hydrocarbon -NDIR,Oxygen-Electrochemical,Nitrousoxides-Electrochemical

5.3 Smoke opacity meter:

A smoke opacity meter, also known as a smoke meter or smoke opacity tester, is a device used to measure the opacity or darkness of smoke emitted from combustion sources, such as diesel engines, boilers, furnaces, and industrial processes. Here's how a smoke opacity meter typically works:

- 1) **Sampling:** The smoke opacity meter samples the exhaust gases directly from the stack or exhaust pipe of the combustion source being tested. A probe or sampling tube is inserted into the exhaust stream to collect a representative sample of the smoke.
- 2) **Light Transmission:** The collected smoke sample is then passed through a measurement chamber within the smoke opacity meter. Within this chamber, a light source, often an infrared (IR) or visible light source, is directed through the smoke sample.
- 3) **Detection of Light:** On the opposite side of the measurement chamber, a light detector or sensor measures the intensity of light that passes through the smoke sample. The amount of light that is transmitted through the smoke is inversely proportional to the opacity or darkness of the smoke.
- 4) **Opacity Measurement:** The smoke opacity meter converts the measured light intensity into a numerical value representing the opacity of the smoke. This value is typically expressed in units such as percent opacity or Smoke Density (SD). Lower values indicate cleaner, less opaque smoke, while higher values indicate dirtier, more opaque smoke.
- 5) **Display and Output:** The measured opacity value is displayed on a digital screen or outputted to a computer for further analysis and record-keeping. Some smoke opacity meters may also provide real-time data logging capabilities, allowing users to track smoke emissions over time and identify trends or fluctuations.
- 6) **Calibration and Maintenance:** To ensure accurate and reliable measurements, smoke opacity meters require periodic calibration and maintenance. Calibration involves adjusting the meter's settings to match known reference values, while maintenance may include sensor cleaning,

inspection, and quality control checks.

Smoke opacity meters are commonly used by regulatory agencies, environmental authorities, and industrial operators to monitor and control smoke emissions from combustion sources. By accurately measuring smoke opacity, these devices help ensure compliance with air quality regulations, minimize environmental impact, and optimize combustion efficiency

Table5.3 AVL smoke Opacity meter specifications.

Types	AVL437 Smoke meter
Make	Mars Technologies inc
Range	0-100 HSU
Temperature of smoke	2500 C(degrees)
Ambient Temperature	0-50°C
Humidity	90% during 50°C
Power	205 Ampers, 11.5-36Volts Direct current
Working Principle	LAP (Light absorption principle)



Fig.5.3 experimental setup.

CHAPTER - 6

RESULTS AND DISCUSSIONS

6.1 RESULTS:

The Mahua oil was used for the preparation of biodiesel. For the transesterification of mahua oil, methanol and sodium hydroxide were used. The oil to methanol ratio is 1:6 and 5 grams of sodium hydroxide is used as catalyst per liter. The reaction time was 120 minutes at the temperature of 60°C. The yield was 63.5%.

Table.6.1 Transesterification of Mahua oil

S. No	Parameters	Results
1	Free fatty acid	1.69 %
2	Catalyst (NaOH) quantity	5 grams
3	Oil to methanol molar ratio	1:3
4	Temperature	60 °C
5	Reaction time	120 minutes
6	Yield	63.5 %

6.2 Performance characteristics:

6.2.1 Brake Specific Fuel Consumption:

Brake Specific Fuel Consumption (BSFC) is a measure used to evaluate the efficiency of an engine. It represents the amount of fuel consumed per unit of power produced. BSFC is typically expressed in units of mass per unit of power per unit of time, such as grams per kilowatt-hour (g/kWh) or pounds per horsepower-hour (lb/hp·hr).

A lower BSFC value indicates better fuel efficiency because it means the engine consumes less fuel to produce a given amount of power. BSFC values can vary depending on factors such as engine design, operating conditions (e.g., speed, load), and fuel type.

Engine manufacturers and researchers utilize BSFC data to enhance engine performance, enhance fuel efficiency, and minimize emissions. Through the examination of BSFC curves, engineers can pinpoint the most effective operating points for an engine and implement adjustments to enhance its overall efficiency..

The BSFC of the biodiesel blend is measured with help of VCR diesel engine and the readings are tabulated in table 6.4

Table.6.2 BSFC values of biodiesel blends and diesel

BRAKE POWER(BP)	B10	B20	B30	DIESEL
0.2	0.84	1.11	1.12	0.85
1	0.47	0.51	0.52	0.52
1.8	0.34	0.39	0.41	0.37
2.6	0.32	0.34	0.34	0.32

By giving detailed information on the precise fuel usage over a range of loads for multiple samples, table 6.3 allows us to compare the results with diesel. When all the biodiesel blends B10 are compared, sample B10 has the lowest Brake Specific Fuel Consumption (BSFC) And sample B20, B30 both are similar having the highest brake specific fuel consumption. Compare with diesel and among the all blend B10 blend has lowest Brake Specific Fuel Consumption (BSFC)

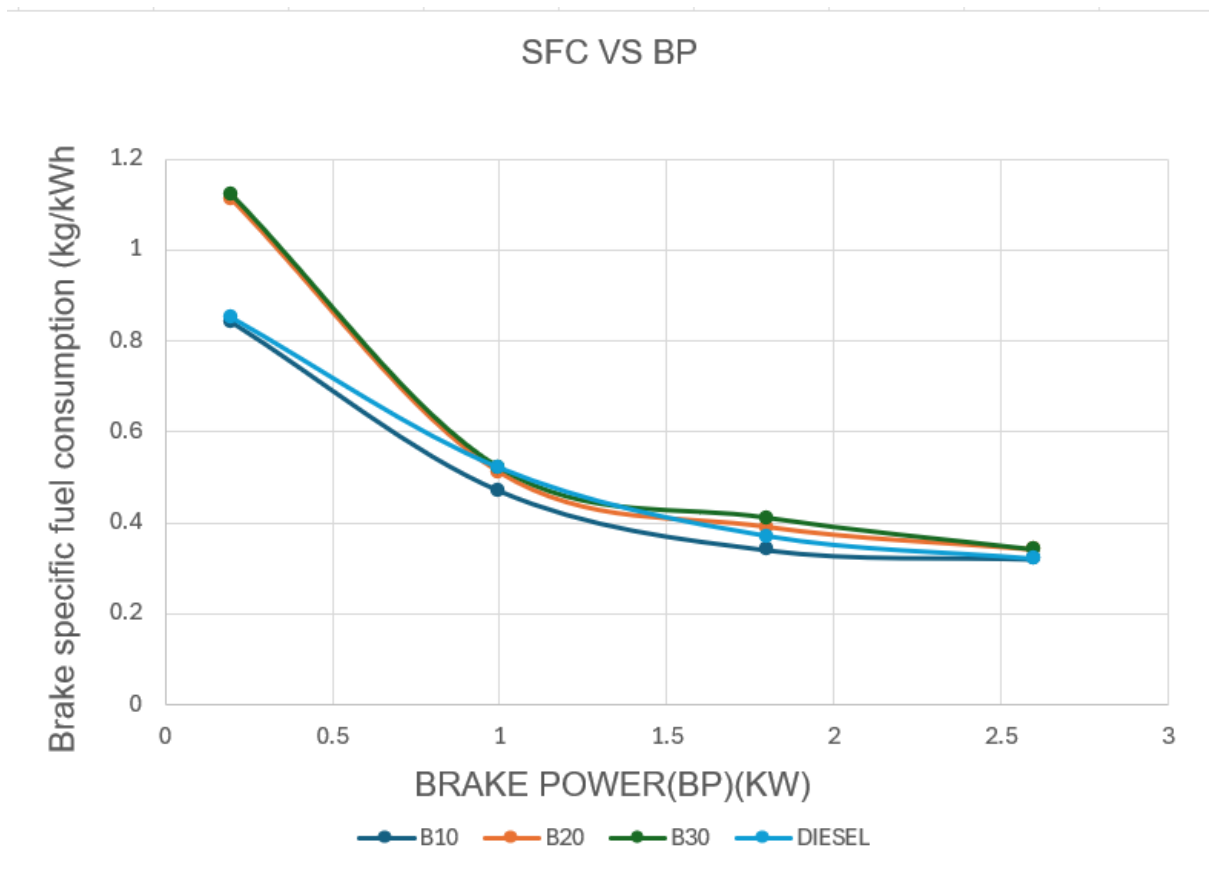


Fig.6.1 Brake specific fuel consumption of biodiesel blends and diesel

6.2.2 Brake thermal efficiency (BTE):

Brake thermal efficiency (BTE) is another important metric used to evaluate the efficiency of an engine. It measures the effectiveness of converting the energy contained in the fuel into useful mechanical work.

In other words, it represents the percentage of the total energy content of the fuel that is converted into useful work. A higher brake thermal efficiency indicates better efficiency, as more of the input energy from the fuel is being converted into useful work, while less is lost as waste heat.

Improving brake thermal efficiency is a key goal in engine design and development, as it leads to better fuel economy and reduced emissions. Engineers achieve this through various means such as optimizing combustion processes, reducing frictional losses, and improving thermal management systems.

Table.6.3 Brake thermal efficiency (BTE) of biodiesel blends and diesel

BRAKE POWER(BP)	B10	B20	B30	DIESEL
0.2	10.2	7.7	7.6	10
1	18.4	16.6	16.6	16.6
1.8	23	21.8	22	23.4
2.6	26.3	26	27	26.5

By giving detailed information on the precise brake thermal efficiency over a range of loads for multiple samples, table 6.4 allows us to compare the results with diesel.

Sample B10 has the highest break thermal efficiency and the sample B20 has the lowest break thermal efficiency. The B20 and B30 they are slightly similar together but B20 sample has lowest break thermal efficiency compare to the B30 sample. And B20 and B30 has break thermal efficiency lower than diesel

When compare to all and diesel B10 has the highest break thermal efficiency.

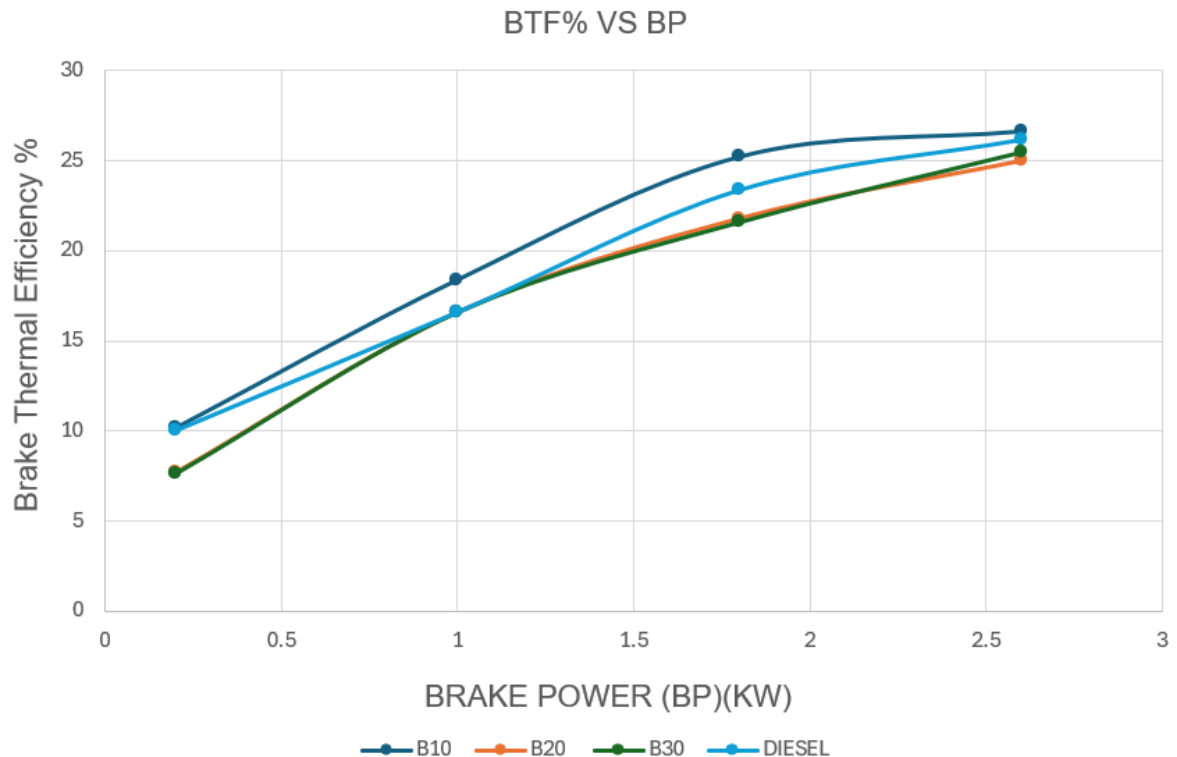


Fig.6.2 Brake thermal efficiency (BTE) of biodiesel blends and diesel

6.3 Emission characteristics:

6.3.1 Hydrocarbons:

Hydrocarbons (HC) are organic compounds consisting entirely of hydrogen and carbon atoms. They are fundamental constituents of fossil fuels such as petroleum, natural gas, and coal, as well as being produced during incomplete combustion processes.

Hydrocarbons play a significant role in various industrial processes, including fuel production, petrochemical manufacturing, and energy generation. They serve as the primary source of energy for transportation, heating, and electricity generation in many parts of the world.

Depending on their molecular structure, hydrocarbons can exist in different forms, including alkanes, alkenes, alkynes, and aromatic compounds. These different classes of hydrocarbons have distinct chemical properties and applications.

In environmental contexts, hydrocarbons are a concern due to their role as pollutants. Incomplete combustion of hydrocarbons, such as in vehicle engines or industrial processes, can lead to the emission of unburned hydrocarbons into the atmosphere, contributing to air pollution and the formation of smog. Additionally, hydrocarbons released into water bodies can have detrimental effects on aquatic ecosystems.

Overall, while hydrocarbons are essential for various aspects of modern life, managing their production and use responsibly is crucial to minimize environmental impacts and ensure sustainable development.

Table.6.4 HC emissions of biodiesel blends and diesel

BRAKE POWER (BP)	B10	B20	B30	DIESEL
0.2	2	2	1	2
1	3	3	2	4
1.8	5	4	3	5
2.6	5	4.3	3.3	6

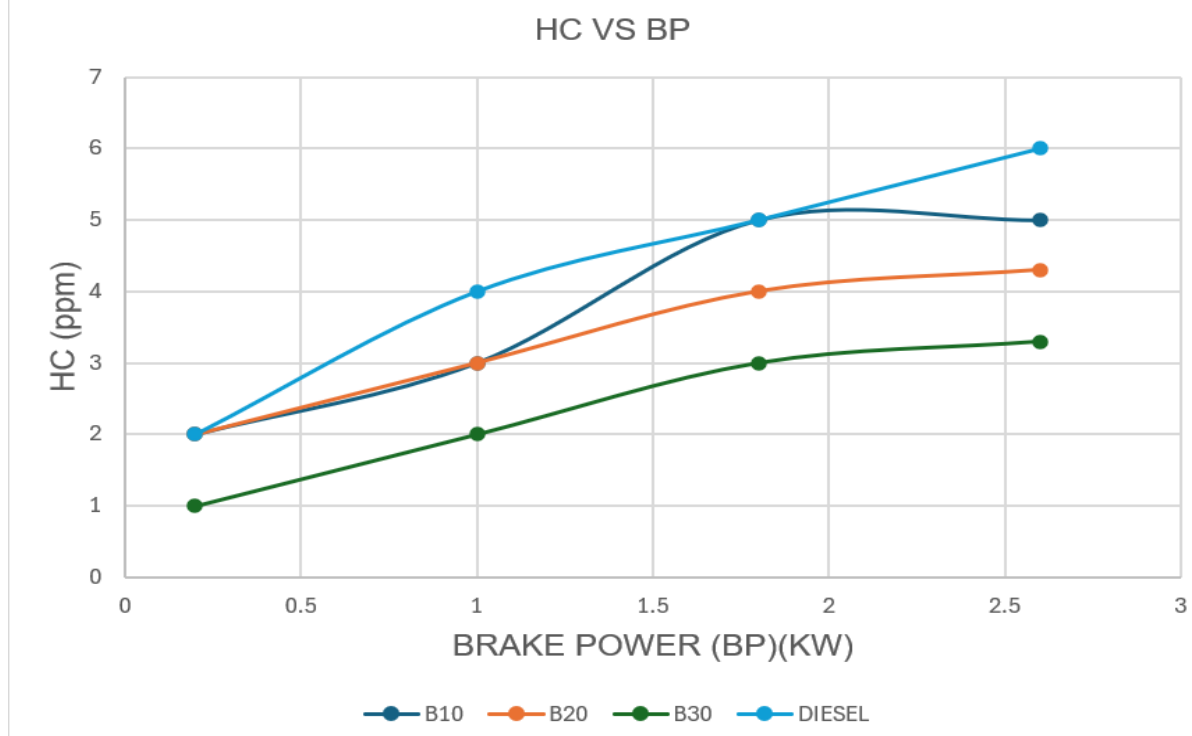


Fig.6.3 HC emissions of biodiesel blends and diesel

The table 6.5 and fig6.3 provides us compare the hydrocarbon emissions of diesel and biodiesel. In the comparison of all the biodiesel samples.

The B10 sample emits more hydrocarbon at maximum load than other blends, while sample B30 emits less hydrocarbons at maximin load because of blending of mahua oil in diesel it reduces emitting of hydrocarbons.

Comparing all blends with diesel the diesel emits more hydrocarbons and B30 sample emits less hydrocarbons.

6.3.2 Carbon monoxide (CO):

Carbon monoxide (CO) is a colorless, odorless, and tasteless gas composed of one carbon atom and one oxygen atom. It is a byproduct of incomplete combustion of carbon-containing fuels such as gasoline, natural gas, coal, and wood. CO is produced when there is insufficient oxygen available during combustion, leading to the partial oxidation of carbon.

Carbon monoxide is a notable air contaminant and presents grave health hazards to both humans and animals upon inhalation. It has the potential to disrupt the bloodstream's capacity to carry oxygen, resulting in a spectrum of symptoms ranging from slight headaches and dizziness to more severe consequences like impaired vision, cognitive decline, and even fatality in cases of elevated levels or prolonged contact.

Sources of carbon monoxide emissions include vehicle exhaust, industrial processes, residential heating systems, and wildfires. In urban areas, motor vehicles are often the primary source of CO emissions.

In order to reduce the dangers linked to carbon monoxide exposure, several steps are implemented. These include fitting catalytic converters in vehicles to decrease emissions, installing carbon monoxide detectors in residences and structures to warn individuals of elevated CO levels, and enforcing regulations to restrict emissions from industrial sources.

Monitoring and controlling carbon monoxide levels in indoor and outdoor environments are essential for protecting public health and reducing air pollution.

Table.6.5 CO emissions of biodiesel blends and diesel

BRAKE POWER (BP)	B10	B20	B30	DIESEL
0.2	0.01	0.01	0.001	0.02
1	0.02	0.01	0.01	0.03
1.8	0.03	0.02	0.01	0.04
2.6	0.05	0.04	0.035	0.06

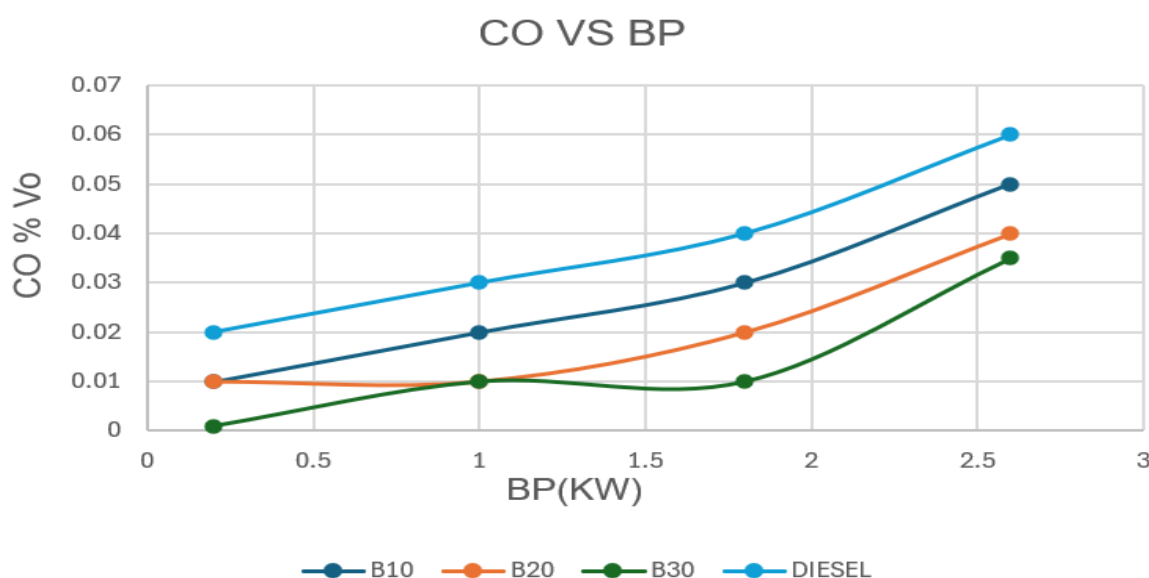


Fig.6.4 CO emissions of biodiesel blends and diesel

The table 6.6 and fig6.4 provides us compare the Carbon monoxide (CO) emissions of diesel and biodiesel. In the comparison of all the biodiesel samples.

From the all the samples and all blends of biodiesel sample B30 emits less carbon monoxide in high load. And B10 sample emits more carbon monoxide in high load compare with all blends.

The B30 sample blend has emitting less carbon monoxide because in the b30 blend less presences of diesel in it 30% of mahua oil is present in it.

Compare with all blends with diesel, diesel emit more carbon monoxide compare with

all blends

6.3.3: Oxides of Nitrogen (NO_x):

Oxides of nitrogen (NO_x) are a group of highly reactive gases composed of nitrogen and oxygen atoms. The two most common oxides of nitrogen are nitrogen monoxide (NO) and nitrogen dioxide (NO₂), although other compounds such as nitrous oxide (N₂O) also contribute to NO_x pollution.

NO_x is formed primarily during high-temperature combustion processes, such as those occurring in vehicles, power plants, industrial boilers, and aircraft engines. The primary sources of NO_x emissions include:

Transportation: Combustion engines in vehicles, including cars, trucks, ships, and aircraft, produce significant amounts of NO_x, especially diesel engines.

Industrial Processes: Combustion of fossil fuels in industrial boilers, power plants, and manufacturing processes generate NO_x emissions.

Agriculture: Nitrogen-based fertilizers used in agriculture can lead to the release of nitrous oxide, a potent greenhouse gas and contributor to NO_x pollution.

Residential Heating: Combustion of fossil fuels for heating in residential buildings can also contribute to NO_x emissions.

NO_x plays a significant role in air pollution and environmental degradation. It contributes to the formation of ground-level ozone and particulate matter, which can harm human health and the environment. Health effects associated with NO_x exposure include respiratory problems, cardiovascular diseases, and exacerbation of asthma and other respiratory conditions.

In addition to their impact on human health, NO_x emissions also contribute to environmental issues such as acid rain, eutrophication of water bodies, and the formation of smog. Efforts to control NO_x emissions include implementing regulations and emission standards for vehicles, industrial processes, and power plants, promoting the use of cleaner fuels and technologies, and adopting emission control technologies such as selective catalytic reduction (SCR) and exhaust gas recirculation (EGR) in vehicles and stationary sources.

Table.6.6 NOx emissions of biodiesel blends and diesel

BRAKE POWER (BP)	B10	B20	B30	DIESEL
0.2	25	28	40	13
1	35	38	45	39
1.8	38	42	52	60
2.6	57	57	65	80

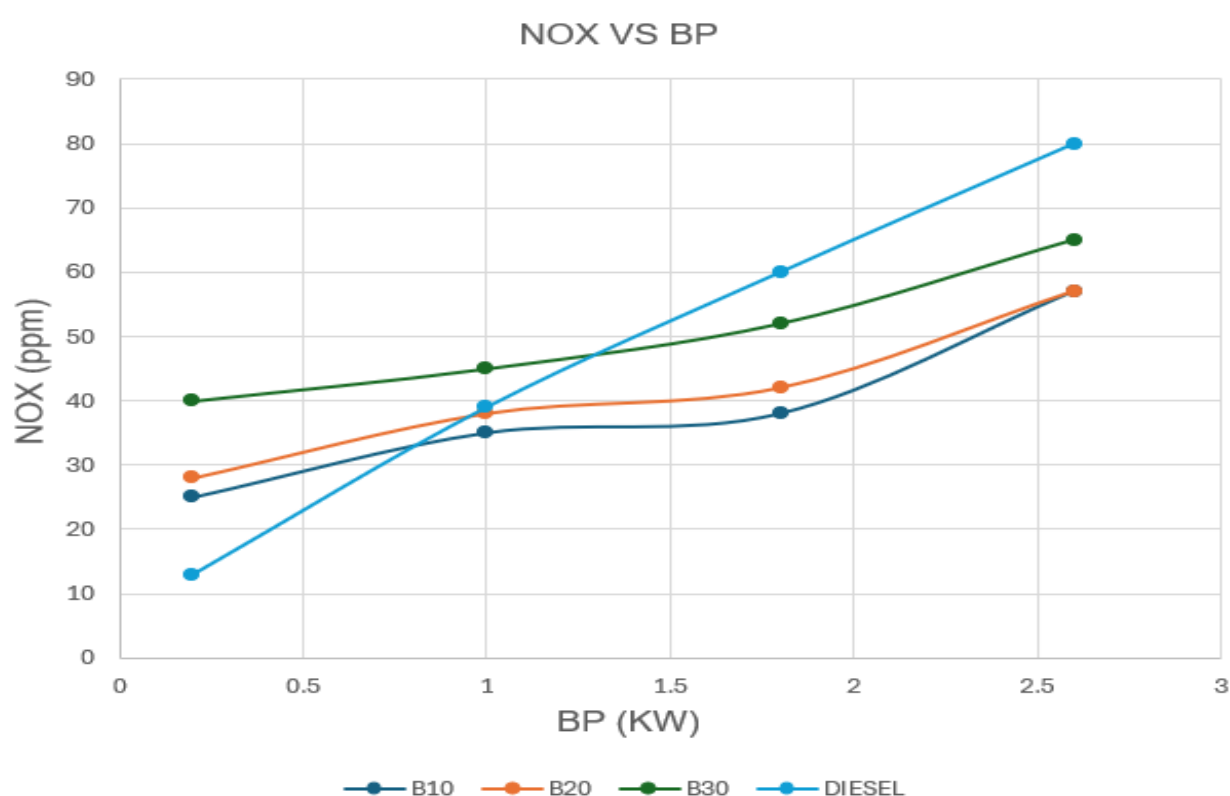


Fig:6.5 NOx emissions of biodiesel blends and diesel

From the above table and figure shows that how much NOx emission as be emitted into the environment by different blends and diesel.

The sample B30 emits the more NOx emission when compare to all blends. the sample B10and B20Emits less NOx emission compares with B30 blend sample.

When comparing with all blends and diesel, diesel emits more NO_x than all the blends

6.3.4 Carbon dioxide:

Carbon dioxide (CO₂) is a colorless, odorless, and non-flammable gas composed of one carbon atom and two oxygen atoms. It is a naturally occurring component of Earth's atmosphere and is produced through various natural processes, such as respiration of living organisms, volcanic eruptions, and decomposition of organic matter.

However, human activities, particularly the combustion of fossil fuels (such as coal, oil, and natural gas) for energy production, transportation, industry, and deforestation, have significantly increased the concentration of CO₂ in the atmosphere. This increase in atmospheric CO₂ levels is a major contributor to global warming and climate change, primarily due to its role as a greenhouse gas.

Carbon dioxide absorbs and re-emits infrared radiation, leading to the greenhouse effect, which traps heat in the Earth's atmosphere and warms the planet. Excessive levels of CO₂ emissions have resulted in rising global temperatures, melting ice caps and glaciers, sea level rise, altered weather patterns, and other environmental impacts.

Efforts to mitigate CO₂ emissions and address climate change include transitioning to renewable energy sources, improving energy efficiency, adopting carbon capture and storage (CCS) technologies, reforestation and afforestation projects, and international agreements such as the Paris Agreement aimed at reducing greenhouse gas emissions.

Monitoring and reducing CO₂ emissions are crucial steps in combating climate change and promoting a sustainable future for the planet and its inhabitants.

Table.6.7 variation of CO2 Emissions with respect to BP

BRAKE POWER (BP)	B10	B20	B30	DIESEL
0.2	0.6	0.5	0.5	0.7
1	0.7	0.6	0.7	0.8
1.8	0.8	0.7	0.7	0.9
2.6	0.9	0.8	0.7	1.1

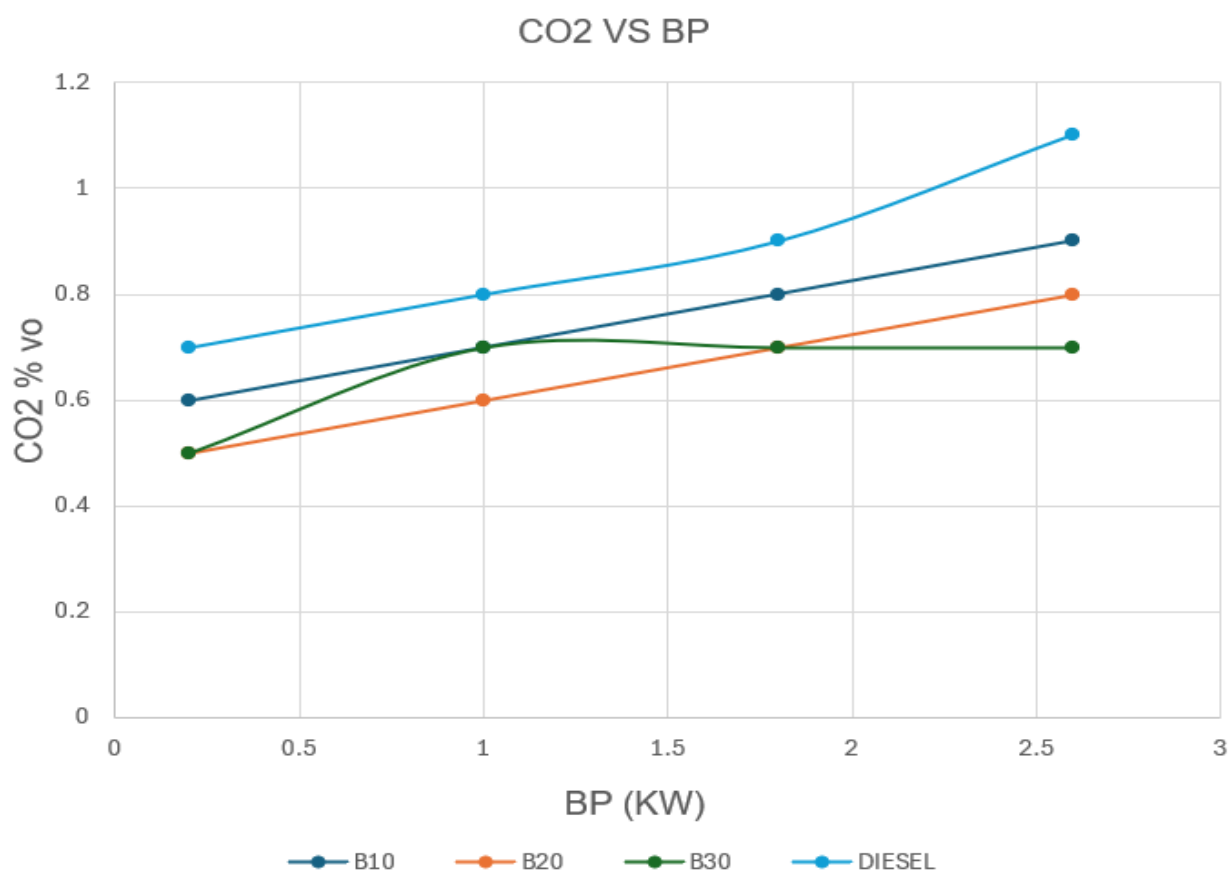


Fig.6.6 CO2 emissions of biodiesel blends and diesel

The blends B10, B20 and B30 lower CO2 emissions are primarily due to its production from renewable resources like plant oils or animal fats (mahua oil), which absorb

carbon dioxide during growth. Consequently, the carbon dioxide absorbed during the feedstock's growth cycle balances the CO₂ emissions linked to the synthesis of biodiesel.

By the above table:6.8 and fig:6.6 the sample of B10 emits more CO₂ emission more than B20 and B30 samples. The both B20 and B30 samples produce less CO₂ emission compared to the B10 sample.

When we compare all blends and diesel the diesel emits more CO₂ emission.

6.3.5 Variation of O₂ vs BP:

Oxygen (O₂) in fuels refers to the amount of oxygen present in a fuel compound. In the context of hydrocarbon fuels, such as gasoline, diesel, natural gas, and coal, oxygen is typically very limited or absent in their chemical composition.

Traditional hydrocarbon fuels are composed primarily of carbon (C) and hydrogen (H) atoms, with smaller amounts of other elements such as sulfur, nitrogen, and oxygen. However, the oxygen content in these fuels is usually very low, often less than 1% by weight.

The presence of oxygen in fuel molecules can affect their combustion characteristics. For example:

Complete Combustion: In ideal conditions, hydrocarbon fuels burn in the presence of oxygen to produce carbon dioxide (CO₂) and water (H₂O) as the main combustion products. Complete combustion occurs when there is sufficient oxygen available to react with all the fuel molecules.

Incomplete Combustion: In cases where there is insufficient oxygen for complete combustion, incomplete combustion occurs, leading to the formation of carbon monoxide (CO), unburned hydrocarbons (HC), and other harmful pollutants.

BRAKE POWER (BP)	B10	B20	B30	DIESEL
0.2	20.45	20.34	20.62	18.33
1	20.15	20.1	19.63	17.88
1.8	20.03	20.03	19.63	17.67
2.6	19.03	19.75	19.9	15.52

Table.6.8 Variation of O2 vs BP values

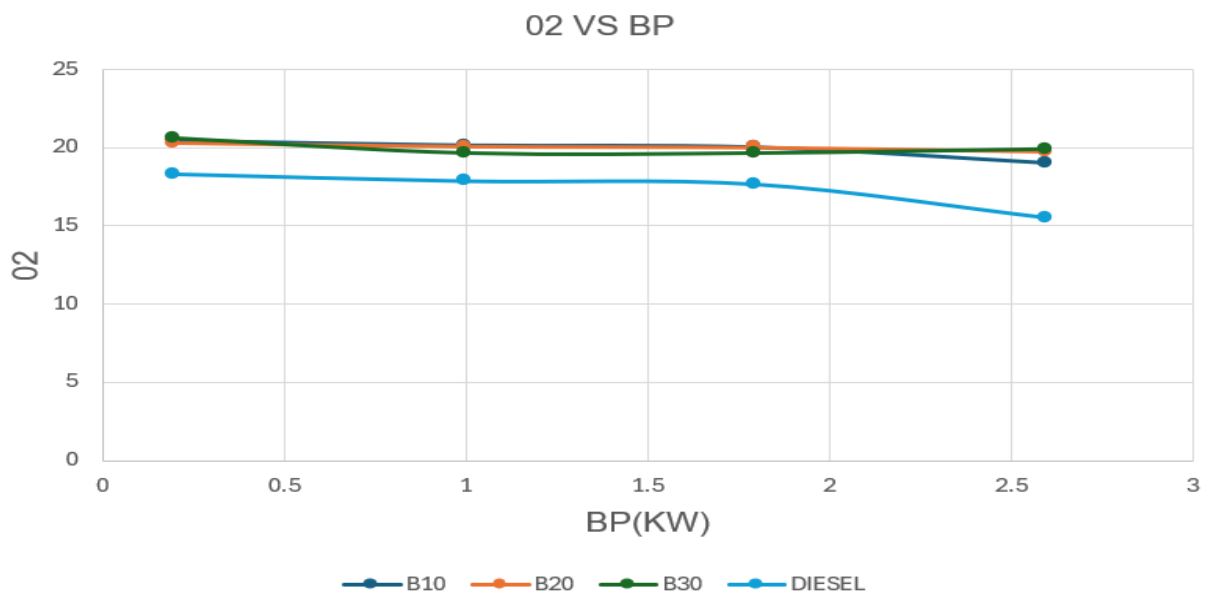


Fig:6.7 O2 vs BP Graph.

If O2 levels are low in the fuel means it creates incomplete combustion due to incomplete combustion fuel it emits high level of emission, particle hydrocarbons are produced due to incomplete combustion of fuel.

From the above table:6.9 and fig:6.7 graph shows the variation of O2 in different blends and diesel. From that B20 and B30 has high level of O2 compare with B30. but sample B10, B20 and B30 are slightly similar.

But when we compare all blends with diesel, diesel has very low O2 content.

CHAPTER –7

SUMMARY AND CONCLUSION

SUMMARY:

The integration of Mahua oil into a diesel engine offers a novel solution to tackle the environmental and performance issues linked with diesel engines. Through emission reduction and enhanced combustion efficiency, this integration could enhance the eco-friendliness and energy efficiency of diesel engines. Nevertheless, it is crucial to emphasize that additional research and experimentation are required to comprehensively grasp the practical implications and advantages of this integration.

CONCLUSION:

The research on biodiesel made from Mahua oil has yielded the following conclusions.

- Sample B10 has the lowest Brake Specific Fuel Consumption (BSFC) and sample B20, B30 both are similar having the highest brake specific fuel consumption. Compare with diesel and among the whole blend B10 blend has lowest Brake Specific Fuel Consumption (BSFC)
- Sample B10 has the highest break thermal efficiency and the sample B20 has the lowest break thermal efficiency. The B20 and B30 they are slightly similar together but B20 sample has lowest break thermal efficiency compare to the B30 sample. And B20 and B30 has break thermal efficiency lower than diesel. When compare to all and diesel B10 has the highest break thermal efficiency.
- The B10 sample emits more hydrocarbon at maximum load than other blends, while sample B30 emits less hydrocarbons at maximum load because of blending of mahua oil in diesel it reduces emitting of hydrocarbons. Comparing all blends with diesel the diesel emits more hydrocarbons and B30 sample emits less hydrocarbons

- Sample B30 emits less carbon monoxide in high load. And B10 sample emits more carbon monoxide in high load compare with all blends. The B30 sample blend has emitting less carbon monoxide because in the b30 blend less presences of diesel in it 30% of mahua oil is present in it. Compare with all blends with diesel, diesel emit more carbon monoxide compare with all blends
- The sample B30 emits the more NOx emission when compare to all blends. the sample B10and B20Emits less NOx emission compares with B30 blend sample. When comparing with all blends and diesel, diesel emits more NOx than all the blends
- The sample of B10 emits more CO2 emission more then B20and B30 samples. The both B20 and B30 samples are produce less CO2 emission compare to the B10 sample. When we compare all blends and diesel the diesel emits more CO2 emission.
- From that B20 and B30 has high level of O2 compare with B30.but sample B10, B20 and B30 are slightly similar. But when we compare all blends with diesel, diesel has very low O2 content.

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