

PERFORMANCE ANALYSIS ON VCR DIESEL ENGINE USING GREEN SYNTHESIS TiO_2 WITH DUAL FUEL

Submitted in partial fulfillment of the requirements for the award of
Bachelor of Engineering degree in Mechanical Engineering

By

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(DEEMED TO BE UNIVERSITY)

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BONAFIDE CERTIFICATE

This is to certify that this Project Report is the bonafide work of **R.RAJKUMAR (39150105)** and **G.SANTHOSH (39150701)** who carried out the project entitled "**PERFORMANCE ANALYSIS ON VCR DIESEL ENGINE USING GREEN SYNTHESIS TiO_2 WITH DUAL FUEL**" under my supervision from December 2022 to April 2023.

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DECLARATION

We, **R.RAJKUMAR**, and **G.SANTHOSH** hereby declare that the Project Report entitled “**PERFORMANCE ANALYSIS ON VCR DIESEL ENGINE USING GREEN SYNTHESIS TIO₂ WITH DUAL**” done by us under the guidance of **Mr. S. LAKSHMI SANKAR M.E., (Ph.D.)**, at Sathyabama Institute of Science and Technology is submitted in partial fulfillment of the requirements for the award of Bachelor of Engineering Degree in Mechanical Engineering.

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ABSTRACT

Researchers are looking at alternative fuels and catalysts for diesel engines as a result of the desire for sustainable and clean energy. In this experiment, utilizing green synthetic TiO_2 as a catalyst, we examine the performance of a VCR diesel engine running on a mixture of diesel and biofuel blend made from aloe vera and avocado oil. Our environmentally friendly way of creating TiO_2 catalyst can lessen the negative effects of industrial operations on the environment. Several testing methods, including brake thermal efficiency, exhaust emissions, and combustion parameters, are used to evaluate the engine's performance. Our findings demonstrate that using a TiO_2 catalyst considerably enhances engine performance. TiO_2 is used as a catalyst, reducing the emissions of dangerous gases like NO_x and CO_2 , while also improving the engine's braking thermal efficiency. The addition of TiO_2 improves the combustion process, resulting in more efficient energy transfer from fuel to mechanical work, according to further investigation of the combustion process using the cylinder pressure diagram. Overall, the use of environmentally friendly synthetic TiO_2 as a catalyst in a VCR diesel engine running on dual fuel (diesel and biodiesel) can improve engine performance and lessen the engine's environmental effect. These results highlight TiO_2 's potential as an efficient and environmentally friendly diesel engine catalyst replacement and highlight the potential of our biodiesel blend as a sustainable and powerful fuel subs

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LIST OF SYMBOLS AND ABBREVIATIONS

HC	Hydro Carbon
CO	Carbon Monoxide
CO ₂	Carbon Dioxide
NO _x	Nitrous Oxides
BTE	Brake Thermal Efficiency
SFC	Specific Fuel Consumption
VCR	Variable Compression Ratio
D	Diesel
BD	Biodiesel
TiO ₂	Titanium Oxide
Ppm	Parts per million
kJ	Kilo Joule
kg	Kilogram
FAME	Fatty Acid Methyl Esters

CHAPTER 1

INTRODUCTION

1.1 BIODIESEL

Biodiesel is a sort of renewable and sustainable fuel made from used cooking oil, animal fats, and vegetable oils. Due to its many benefits over conventional diesel fuel, biodiesel has attracted a lot of interest recently. Biodiesel is less polluting, emits less greenhouse gases, and is ecologically benign when it is produced and used. Transesterification, a chemical process that transforms triglycerides from various sources into fuel-useable esters, is how biodiesel is created. With a lot of potential to replace conventional diesel fuel, biodiesel is a viable alternative fuel. In addition to being ecological and renewable, biodiesel may also be produced locally, which promotes energy independence and lessens reliance on imported oil. Due to its lower emissions of greenhouse gases and particulate matter into the environment than traditional diesel fuels, the use of biodiesel also presents a chance to lessen an organization's or person's carbon footprint. There are still obstacles in the way of biodiesel being a commonly used fuel source despite all of its advantages. These difficulties include a high cost of manufacturing, a constrained supply, and uncertainty about its long-term viability. These obstacles could soon be overcome, though, thanks to continued research, the creation of cutting-edge technology, and a rise in the demand for clean and renewable energy sources.

1.2 HISTORICAL BACKGROUND

The idea of utilising vegetable oils as fuel was initially proposed in the late 1800s, when Rudolf Diesel, the creator of the diesel engine, performed the initial tests using peanut oil. Diesel anticipated that fuels based from vegetable oils would be a less expensive and more environmentally friendly option. It wasn't until the oil crisis of the 1970s, though, that interest in utilising biodiesel as an alternative fuel source started to re-emerge. A business by the name of Vereinigte Bioölwerke established the first

biodiesel factory in the world in Germany in 1973. The possibility of utilising

transesterified vegetable oils as a diesel fuel alternative was first investigated by researchers in the 1980s and 1990s. The National Renewable Energy Laboratory (NREL) in the US created a procedure that is still commonly used today for manufacturing biodiesel from methanol and sodium hydroxide. Particularly in Europe, biodiesel started to gain favour in the early 2000s as a renewable and sustainable substitute for petroleum fuel. Numerous European nations, like as Germany, France, and the UK, started enacting requirements and incentives to encourage the use of biodiesel. The Renewable Fuel Standard, which mandated a specific percentage of renewable fuel, including biodiesel, be mixed into transportation fuel, was adopted by the US in 2004. The domestic biodiesel sector in the US was established in part because to this strategy. With its use increasing internationally, biodiesel is still a viable substitute for petroleum-based diesel fuel today. For instance, the European Union has established goals for the use of renewable energy in transportation, including a 14% objective for these fuels by 2030. Overall, since Rudolf Diesel's early trials with peanut oil, biodiesel has advanced significantly, with continued research, development, and innovation enhancing its promise as a renewable and sustainable fuel.

1.3 ENVIRONMENTAL BENEFITS

- *Lessening of greenhouse gas emissions:* Because biodiesel burns cleaner than conventional diesel, it emits less hazardous pollutants and less carbon dioxide when used in engines. By doing so, greenhouse gas emissions are decreased, and the negative effects of climate change are lessened.
- *Renewable and sustainable:* Vegetable oils and animal fats, which can be cultivated, collected, and produced responsibly without depleting the planet's resources, are used to make biodiesel. This makes it a sustainable way to lessen reliance on fossil fuels.
- *Greater energy security:* The ability to make biodiesel locally lowers reliance on imported oil and raises energy security. Additionally, it produces jobs in the area and offers farmers and rural areas an alternative source of income.

- *Better air quality:* Emissions from biodiesel generate less particulate matter and other air pollutants, which can lead to respiratory and other health issues. Air quality in inhabited regions, especially in metropolitan areas, can be improved by using biodiesel in automobiles and other equipment.
- *Less negative environmental effects:* The manufacturing of biodiesel has a smaller negative environmental impact than the production of conventional diesel fuel. Biodiesel lessens the effects of water pollution, changes in land use, and the bioaccumulation of dangerous substances in the environment.
- *Promotes agriculture:* The manufacture of biodiesel uses resources from both land and animals as feedstock, promoting both agriculture and animal husbandry. It aids in raising agricultural output, which improves soil fertility and increases vegetative cover, both of which benefit the environment.

1.4 OBJECTIVES

- *Reducing dependence on fossil fuels:* The primary objective of biodiesel is to reduce our dependence on fossil fuels and create a more sustainable energy source.
- *Reducing greenhouse gas emissions:* Biodiesel emits significantly less greenhouse gas emissions compared to traditional fossil fuels, thus helping to reduce the negative impact of climate change.
- *Renewable energy source:* Biodiesel is derived from renewable raw materials such as vegetable oils and animal fats, making it a sustainable source of energy.
- *Supporting farmers and rural economies:* The production of biodiesel can create new jobs and support farmers and rural economies by providing a market for renewable raw materials.
- *Improving air quality:* Biodiesel has lower emissions of pollutants that contribute to poor air quality, such as particulate matter and sulfur dioxide.
- *Increasing energy security:* By creating a domestic market for biodiesel, countries can reduce their reliance on imported oil and improve their energy security.

CHAPTER 2

LITERATURE SURVEY

2.1 LITERATURE SURVEY

Biodiesel is an alternative fuel made from renewable sources such as plant oils or animal fats. It is considered a more environmentally friendly option compared to traditional petroleum-based diesel fuel, in part because it produces fewer harmful emissions when burned. As a result, biodiesel has received increasing attention as a potential solution to several energy and environmental challenges.

In recent years, there has been a significant growth in research on the production, characterization, and application of biodiesel, with numerous studies published on various aspects of the topic. This literature review aims to provide an overview of the current state of knowledge on biodiesel, summarizing the major findings from research publications in the field.

The majority of the energy used to power the modern industrial world (about 80%) comes from fossil fuels[1] . For the growth of any region of the world, energy is a crucial issue. The market issues a warning to shift toward sustainable fuel for the coming generation as a result of the increase in crude oil prices and the accompanying global emissions. The need for energy is growing because of the expanding global population, the necessity for energy in industrial applications, the use of vehicles, and power generating equipment. In the current situation, it won't be long before we run out of fuel and experience a global fuel crisis. In addition, the environmental impact was created by exhaust emissions leads to global warming , the second most serious issue that world facing, is an important worry to looking for alternative fuels for engines [2],[3]. Important characteristics of an alternative fuel source include being non-toxic and reducing greenhouse gas emissions. (GHG) emissions, as well as their accessibility and affordability [4]. Numerous researches have shown that using eco-friendly, nontoxic, Moreover, substituting fresh vegetables for diesel could lower pollutants.

However, several characteristics of vegetable oils, such as high poor volatility, viscosity, and polyunsaturated nature led to unrated engine performance. other techniques, like Vegetable oils have been used to make biodiesel by the processes of transesterification, pyrolysis, micro-emulsion, and blending [5], [6]. The use of biodiesels, which are long-chain monoalkyl (methyl, ethyl, and propyl) esters extracted from vegetable oils or animal fats, can be reduced with minimal negative environmental impact [7]. Since then, researchers have experimented with different biodiesel sources and compositions to improve efficiency and reduce emissions [8]. Researchers have been switching increasingly to biodiesel in place of diesel in recent years, and this is the most effective way to meet emission standards [9], [10]. The usage of biodiesel made from a variety of renewable oils, including cottonseed oil, Karanja oil, and rice bran oil, has been supported by numerous assessments.[11]. It was found that using biodiesel in diesel engines (DE) had thermal performance that was equivalent to that of diesel and also had low energy content, but reduced BFSC, carbon dioxide (CO), hydrocarbon (HC), and particulate matter (PM) emissions gasoline[12]. However, there were some disadvantages, including inadequate atomization, poor flow characteristics, excessive viscosity, and poor fuel stability, and higher NO_x emissions have been realised[11].

TiO₂ reduces emissions like CO and HC and increases smoke opacity and NO_x, but brake thermal efficiency increased by 3.1%[13]. TiO₂ lowered the ignition delay period, which decreased the amount of fuel used specifically for the brakes[14]. TiO₂ additive improves combustion and engine performance by raising the maximum cylinder pressure and heat release rate[15].

The review will cover key aspects of the production and properties of biodiesel, including feedstock selection, transesterification process, product quality, and environmental impact. It will also examine the use of biodiesel as an alternative fuel in various applications, including transportation, power generation, and heating.

Overall, this review will highlight the major trends and advancements in biodiesel research, as well as the challenges and potential opportunities associated with its use. It will provide a comprehensive understanding of the current state of research on biodiesel, and identify areas where further investigation is required.

Here is list of information that we gathered via literature survey about the biodiesel, properties of biodiesel and effect of nanoparticles in biodiesel and more

TiO₂ reduces emissions like CO and HC and increases smoke opacity and NO_x, although brake thermal efficacy increased by 3.1%. TiO₂ lowered the ignition delay period, which decreased the amount of fuel used specifically for the brakes[13].

Nevertheless, despite the fact that biodiesel offers many benefits, it also has certain drawbacks, including a high viscosity, poor cold flow characteristics, and a low heating value. The addition of gasoline additives is a recently developed method to enhance fuel qualities and combustion characteristics[16].

Although biodiesel has an advantage over diesel fuel in terms of having a higher oxygen, the main drawback of biodiesel is that it has a higher density and viscosity, which ultimately affects the vaporization, atomization, and mixing of fuel-air rate[17].

When using a mixed TiO₂-ZnO nanocatalyst, the yield of biodiesel gradually rises with temperature up to 60 C before beginning to significantly decline after that. The high yield of 92.2% was achieved at 60 C, whereas only 83.2 was produced by the nanosized ZnO catalyst[18].

For maximal product yield, the ideal TiO₂ and Cu concentrations were 3% and 2%, respectively. The total reaction time was discovered to be 45 minutes. With a methanol to oil ratio of 20:1, the highest yield was obtained at a temperature of 45°C. Overall findings show that the Cu-impregnated TiO₂ can be used as a heterogeneous nano catalyst to produce biodiesel from less expensive feedstocks, such as palm oil[19].

According to reports, a blend of diesel, biodiesel, and butanol with TiO₂ NPs added is more successful at raising the BTE of DICl diesel engines by 25, 20, 12, and

9.74%, respectively. With both concentrations, an improvement in the brake-specific fuel consumption and BTE is noted[20].

When TiO_2 nanoparticles are added to diesel fuel, BSFC is reduced at various speeds and under partial loads in comparison to diesel fuel. Including TiO_2 nanoparticles in diesel fuel improves engine performance power, reduces HC and CO emission due to an improvement in the combustion process that may be produced by prolonged oxygen consumption due to higher combustion temperature[21].

Carrier materials promote porosity and offer a high surface area, which enhances catalytic activity. TiO_2 anatase form is one of these carrier materials that is frequently utilized because of its excellent SO_2 resistance and high SCR activity at low temperatures[22].

In comparison to blends without the TiO_2 additive, the addition boosted the brake engine torque and power by 10.20 and 9.74 percent, respectively, and decreased the brake-specific fuel consumption by 27.73 and 28.3 percent. TiO_2 additive improves combustion and engine performance by raising the maximum cylinder pressure and heat release rate[15].

It demonstrates the fluctuation in emission and the impact of nanoparticles. The inclusion of nanoparticles had a favorable impact on the variance of emission across all test fuels, being the best for maintaining stable and constant emission levels[23].

When TiO_2 nano additions are added to the biodiesel blend, CO and smoke emissions are seen to decrease. This is because the TiO_2 nano particles added to 12the biodiesel blends had a shorter ignition delay and better ignition properties[14].

TiO_2 nanoparticles added to the jamun oil biofuel blend improve engine performance. The improvement in cylinder pressure characteristics in the presence of the TiO_2 nanoparticles. When TiO_2 nanoparticles are added to J50D10Bu, the engine's carbon oxidation rate is increased, resulting in an efficient combustion process and a decrease in fuel consumption[24].

Harish Venu tested the engine with and without EGR after observing that 30% palm oil, 70% diesel, and 25 ppm TiO_2 was utilized as the fuel. EGR results in lower specific fuel consumption and emissions at lower loads[25].

The metal sol approach was used to successfully create the titania-supported nano-sized gold catalysts. The anatase type outperformed the rutile type in terms of NO_x reduction to N_2 and C_3H_6 oxidation, according to research on the catalytic activity of gold on various TiO_2 crystalline kinds. The NO_x concentration and C_3H_6 to NO_x ratio had an impact on the Au/TiO_2 catalyst's catalytic activity[26].

The goal of the current study is to examine recent developments of Pt/TiO_2 systems in various catalytic processes (such as thermocatalysts, photocatalysts, and photothermal catalysts) for managing air quality. Additionally, some catalysts can provide a beneficial resolution to achieve both energy generation and pollution reduction at the same time. Therefore, it is important to look into and evaluate the varied ways in which this special catalyst is used to reduce air pollution[27].

CHAPTER 3

AIM AND SCOPE

3.1 AIM OF THIS PROJECT

The aim of the project "Performance analysis on VCR diesel engine using green synthesis TiO_2 with dual fuel" is to investigate the effects of using green synthesis TiO_2 nanoparticles as an additive in a variable compression ratio (VCR) diesel engine running on dual fuel (diesel-biogas). The project aims to perform experimental studies to evaluate various performance characteristics of the engine, including engine efficiency, combustion characteristics, and exhaust emissions under different operating conditions.

The use of green synthesis TiO_2 nanoparticles as an additive in the VCR diesel engine is expected to improve the engine's combustion efficiency, reduce exhaust emissions, and lower fuel consumption. The project will investigate the effects of various nanoparticle concentrations on engine performance and emissions. In addition, the use of dual fuel (diesel-biogas) in the VCR diesel engine is aimed at reducing the dependency on fossil fuels and contributing to a more sustainable energy future. The project will explore the impact of biogas-diesel blends on engine performance, emissions, and combustion characteristics, including ignition delay, combustion duration, and rate of heat release.

Overall, the project seeks to evaluate the feasibility and potential benefits of using green synthesis TiO_2 nanoparticles and dual fuel in VCR diesel engines, providing insights into its application for a cleaner and more sustainable energy future.

3.2 SCOPE OF THIS PROJECT

The scope of this project is listed below:

- ✦ *Feedstock evaluation:* Evaluate the viability of various feedstocks as sources for producing biodiesel. This may involve analyzing the chemical and physical properties of and assessing their sustainability and availability.

- † *Biodiesel production*: Develop and optimize methods for producing biodiesel from various feedstocks. This may involve investigating different processing techniques, and evaluating their efficiency, and environmental impacts.
- † *Engine performance and emissions*: Assess the impact of using biodiesel on engine performance and emissions. This may involve conducting engine tests and analyzing the combustion characteristics of different biodiesel blends, as well as evaluating the emissions of criteria pollutants and greenhouse gases.
- † *Biorefinery integration*: Explore strategies for integrating biodiesel production into biorefineries that produce other high-value products, like biofuels, biochemicals, and bioplastics.
- † *Life cycle assessment*: Conduct life cycle assessments (LCAs) of biodiesel production and use to evaluate its environmental impacts, including carbon and water footprints, land use changes, and other environmental and social considerations.
- † *Policy and market analysis*: Analyze the policy and market environment for biodiesel, including policy incentives, regulations, and market trends, to identify opportunities and challenges for its adoption and commercialization.

Overall, biodiesel projects aim to promote the development and adoption of biodiesel as a renewable and sustainable alternative to traditional fossil fuels. These projects can contribute to reducing greenhouse gas emissions, promoting rural development, and enhancing energy security.

CHAPTER 4

METHODOLOGY

4.1 ALOE VERA OIL

Aloe vera oil is a type of carrier oil that is derived from the aloe vera plant. Unlike aloe vera gel, which is commonly used topically for its soothing and healing properties, aloe vera oil is used primarily in skincare and cosmetic products.

To produce aloe vera oil, the leaves of the aloe vera plant are first harvested and then washed to remove any dirt or debris. The leaves are then cut into small pieces and dried, either in the sun or in a dehydrator. Once the leaves are fully dried, they are soaked in a carrier oil, such as coconut or jojoba oil, for several weeks. During this time, the active compounds in the aloe vera plant are infused into the carrier oil.

Aloe vera oil is rich in vitamins, minerals, and antioxidants, which make it a popular ingredient in skincare products. It is known for its moisturizing and antiinflammatory properties, and it can help soothe and heal dry or irritated skin. Aloe vera oil is also believed to have anti-aging benefits, as it can help improve skin elasticity and reduce the appearance of fine lines and wrinkles.

In addition to its skincare benefits, aloe vera oil can also be used in hair care products to help moisturize and strengthen hair. It is typically used in small amounts as a blend with other carrier oils or as an ingredient in lotions, creams, serums, and other cosmetic formulations. Overall, aloe vera oil is a versatile and beneficial ingredient for both skincare and hair care products.

4.2 AVOCADO OIL

Avocado oil is a type of edible oil that is extracted from the flesh of avocados. It is known for its high smoke point, mild flavor, and numerous health benefits.

The oil is extracted by pressing the flesh of the avocado and then separating the oil from the pulp. Avocado oil is rich in monounsaturated fatty acids, which are

considered healthy fats that can lower cholesterol levels and reduce the risk of heart

disease. It also contains vitamin E, which is an antioxidant that can help protect cells from damage and improve skin health.

Avocado oil is commonly used in cooking, as it has a high smoke point of around 520°F (271°C), which makes it suitable for frying, roasting, and baking. It can also be used as a dressing for salads, as a substitute for mayonnaise in sandwiches, or as a dipping oil for bread.

Avocado oil is a renewable source of energy, as it is derived from the avocado fruit, which can be grown and harvested on a regular basis. It has been shown to have similar energy properties to other vegetable oils, making it a potential alternative fuel source.

4.3 BIODIESEL

4.3.1 Definition

Biodiesel is a renewable and sustainable fuel that is made from natural sources such as vegetable oils, animal fats, or algae. It is a type of biofuel that is produced through a process called transesterification, where the oils or fats are chemically reacted with an alcohol (usually methanol) and a catalyst (usually sodium hydroxide or potassium hydroxide) to produce fatty acid methyl esters (FAME).

Biodiesel can be used in diesel engines as a direct substitute for conventional diesel fuel, or blended with diesel fuel in various ratios. It is a clean and low-emission fuel, with lower greenhouse gas emissions and less particulate matter compared to traditional diesel. It is also biodegradable and non-toxic, making it a safer alternative.

Biodiesel has the potential to reduce reliance on fossil fuels and promote sustainable development. It can be produced from a variety of feedstocks, including waste and used cooking oils, and can provide economic opportunities in rural areas. However, its adoption and commercialization still face challenges related to feedstock availability, production costs, and policy incentives. Overall, biodiesel is a promising

alternative fuel that can contribute to reducing greenhouse gas emissions, improving air quality, and enhancing energy security.

4.3.2 Characteristics

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

1. *Renewable*: Biodiesel is made from renewable sources such as vegetable oils and animal fats, which can be sustainably produced and replenished.
2. *Biodegradable*: Biodiesel is biodegradable and non-toxic, which makes it less harmful to the environment than conventional diesel fuel.
3. *Low emissions*: Biodiesel has lower greenhouse gas emissions and less particulate matter compared to diesel fuel. This makes it a cleaner-burning fuel and helps to improve air quality.
4. *Safe*: Biodiesel has a higher flash point than conventional diesel fuel, which makes it less flammable and safer to handle and transport.
5. *Suitable for use in existing diesel engines*: Biodiesel can be used in diesel engines without the need for any modifications, and can be blended with conventional diesel fuel in various ratios.
6. *Lubrication*: Biodiesel has more lubricity than diesel fuel, which can help to reduce engine wear and prolong engine life.
7. *Energy security*: Biodiesel can be produced locally, which can help to increase energy security and reduce dependence on imported oil.
8. *Versatility*: Biodiesel can be produced from a variety of feedstocks, including waste oils and fats, which makes it a versatile fuel source. Overall, biodiesel has several important characteristics that make it a promising alternative fuel for the future. Its lower

emissions, biodegradability, and renewability make it an attractive option for reducing greenhouse gas emissions and promoting sustainable development.

4.3.3 Transesterification

Transesterification is the process by which vegetable oils, animal fats, or used cooking oils are converted into biodiesel. The process involves a chemical reaction between the oil or fat and an alcohol, typically methanol or ethanol, in the presence of a catalyst, such as sodium hydroxide or potassium hydroxide.

The transesterification reaction occurs in several stages:

- *Preparation of the oil or fat:* The oil or fat is heated to a certain temperature to remove any water that may be present. The oil is then filtered to remove any impurities or solid particles.
- *Preparation of the alcohol:* The alcohol, typically methanol or ethanol, is also heated to a certain temperature to remove any water that may be present. The alcohol is then mixed with the catalyst, typically sodium hydroxide or potassium hydroxide.
- *Mixing the oil or fat with the alcohol-catalyst mixture:* The heated oil or fat is then mixed with the alcohol-catalyst mixture in a reactor vessel. The mixture is stirred or agitated to ensure complete mixing and to promote the reaction.
- *Formation of biodiesel and glycerol:* The reaction between the oil or fat and the alcohol-catalyst mixture results in the formation of two products: biodiesel and glycerol. The biodiesel is lighter and separates from the heavier glycerol, which can be removed and used for other purposes.
- *Washing and drying:* The biodiesel is then washed to remove any remaining impurities or catalyst residues. The biodiesel is typically washed with water or a

water-methanol mixture. The biodiesel is then dried to remove any water that may be present.

- *Quality control:* The final biodiesel product is tested to ensure it meets the necessary quality specifications, including viscosity, density, and acid value.

The transesterification process is a key step in the production of biodiesel from vegetable oils, animal fats, or used cooking oils. It is a relatively simple and straightforward process that can be carried out on a small or large scale, depending on the needs of the producer.

4.3.4 Properties

Table 4.1: Properties of transesterified aloe vera oil and avocado oil blend

S NO	PROPERTIES	RESULT
1	Density in (kg/m ³)	882.5
2	Viscosity (in mm ² /s)	23.2
3	Calorific Value (in kJ/kg)	39,368
4	Flash point (in °C)	164
5	Fire point (in °C)	175

CHAPTER 5

EXPERIMENTAL SETUP

5.1 VCR DIESEL ENGINE

The VCR diesel engine (Variable Compression Ratio) is a type of internal combustion engine with an adjustable compression ratio. The compression ratio is the ratio of the volume of the combustion chamber at the bottom of the stroke (known as the "bottom dead centre" or BDC) to the volume of the combustion chamber at the top of the stroke

(known as the "top dead centre" or TDC). The compression ratio of a diesel engine is an important aspect in influencing its efficiency and power output.

The VCR diesel engine employs a technology that allows it to alter the compression ratio while the engine is operating, allowing it to optimise its performance for various driving circumstances. By adjusting the distance between the piston and the cylinder head, the compression ratio may be altered. This is done by the use of a moveable piston pin that may alter the length of the connecting rod that joins the piston to the crankshaft.

The engine is more efficient when the compression ratio is high, creating greater power from the same quantity of gasoline. High compression ratios, on the other hand, can induce banging or detonation, which occurs when the air-fuel combination ignites prematurely and damages the engine. Lower compression ratios can lessen the likelihood of knocking, but they also diminish the engine's efficiency and power production.

The VCR diesel engine enables for continuous and automated compression ratio adjustment based on operating variables such as speed and load. This permits the engine to run at its most efficient and powerful compression ratio while preventing knocking or explosion.

In summary, the VCR diesel engine is a novel type of internal combustion engine that allows for continuous and automated compression ratio change, resulting in increased economy and performance.



Figure 5.1: VCR Engine.

5.1.1 VCR Engine Specification:

Table 5.1: Engine Specification

Product	VCR Engine test setup 1 cylinder, 4 stroke, Diesel with EGR (Comp.)
Product code	234
Engine	Make Kirloskar, Type 1 cyl., 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	M S 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	“EngineSoft” 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

5.1.2 VCR Engine Setup

The VCR diesel engine (Variable Compression Ratio) is a type of internal combustion engine with an adjustable compression ratio. While the engine is operating, the compression ratio may be altered to optimise performance for varied driving circumstances. The VCR diesel engine arrangement is explained in full below:

1. *Engine Block*: The VCR diesel engine is centred around an engine block that houses the cylinders, pistons, and crankshaft. The engine block is constructed from high-strength materials like aluminium or cast iron.
2. *Piston*: The piston is a cylindrical component inside the cylinder that travels up and down. The piston is joined to the crankshaft by a connecting rod, which translates the piston's linear motion into the crankshaft's rotating motion.
3. *Cylinder head*: The combustion chamber, intake and exhaust valves, fuel injectors, and spark plugs (in gasoline engines) are all housed in the cylinder head, which is placed at the top of the engine block. Typically, the cylinder head is constructed of aluminium alloy.
4. *Connecting Rod*: The connecting rod is the link between the piston and the crankshaft. The connecting rod has two ends: one that connects to the piston and one that links to the crankshaft.
5. *Crank Shaft*: The crankshaft is the engine's primary spinning component. The crankshaft turns the pistons' reciprocating action into rotating motion, which powers the vehicle.
6. *Piston Pin*: The piston pin is the link that links the piston to the connecting rod. The piston pin of the VCR diesel engine is moveable and may modify the length of the connecting rod, allowing the compression ratio to be adjusted.

7. *Cylinder Liner:* A cylinder liner is a cylindrical sleeve that fits within the cylinder bore. The cylinder liner creates a smooth surface for the piston to travel up and down on while also sealing the combustion chamber.
8. *Fuel Injection System:* The fuel injection system is in charge of providing gasoline to the combustion chamber at the appropriate timing and amount. The fuel injection system of the VCR diesel engine is electronically controlled and can alter the timing and quantity of fuel injection dependent on driving circumstances.
9. *Variable Compression Ratio System:* The variable compression ratio system is a technology that allows the compression ratio to be automatically and continually altered. The compression ratio of the VCR diesel engine may be modified by adjusting the distance between the piston and the cylinder head. The moveable piston pin, which may adjust the length of the connecting rod, is used to do this.

Overall, the VCR diesel engine is a complex and sophisticated system that employs cutting-edge technology to optimise its performance and economy for a variety of driving scenarios.

5.1.3 WORKING OF VCR ENGINE:

The VCR diesel engine (Variable Compression Ratio) is a type of internal combustion engine with an adjustable compression ratio. While the engine is operating, the compression ratio may be altered to optimise performance for varied driving circumstances.

Here is a detailed explanation of the working of the VCR diesel engine:

- ✦ *Compression Stroke:* The piston rises up towards the cylinder head during the compression stroke, compressing the air in the combustion chamber. The

compression ratio of a normal diesel engine remains constant, and the air-fuel combination is compressed to a set volume. The compression ratio of the VCR diesel engine, on the other hand, is variable and may be altered depending on the driving circumstances.

- ✦ *Adjustment of Compression Ratio:* The VCR diesel engine's compression ratio may be modified by adjusting the distance between the piston and the cylinder head. This is accomplished by adjusting the length of the connecting rod using the moveable piston pin. When the piston pin is shifted, the length of the connecting rod changes, causing the piston's position and the volume of the combustion chamber to alter. The engine's performance may be optimised for varied driving circumstances by altering the compression ratio.
- ✦ *Fuel Injection System:* After the air in the combustion chamber has been compressed, fuel is fed into the chamber at the proper timing and quantity. The fuel injection system is electronically controlled, and the timing and quantity of fuel injection may be adjusted dependent on the driving circumstances. The heat created during compression ignites the fuel, and the ensuing expansion of gases pushes the piston down, providing power.
- ✦ *Power Stroke:* The expanding gases drive the piston down during the power stroke, creating rotational force on the crankshaft. The transmission and differential deliver this rotating force to the wheels, propelling the car forward.
- ✦ *Exhaust Stroke:* The exhaust valves open after the power stroke, and the combustion gases are discharged from the combustion chamber into the exhaust system. The piston then rises up towards the cylinder head, pushing the remaining exhaust gases out.

- ✦ *Advantages of VCR Engine:* The VCR diesel engine provides a number of benefits over standard diesel engines. Improved fuel economy is one of the primary benefits. By optimising the compression ratio, the engine can run at peak efficiency and power production while avoiding problems like banging or explosion. Reduced emissions are another advantage. The VCR diesel engine may be engineered to fulfil stringent pollution regulations while yet delivering high levels of performance and power.

5.2 EXHAUST GAS ANALYSER

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). The Schematic diagram of Exhaust gas analyser is figured in fig 5.2. Here's a more in-depth explanation of the exhaust gas analyzer:

- ✦ *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.
- ✦ *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 stream.
- ✦ *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

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.

- ✦ **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. Typically, the calibration system consists of a calibration gas cylinder with a known concentration of the gas being measured. The analyzer is calibrated with this gas before and after each usage to ensure accurate readings.



Figure 5.2 Exhaust Gas Analyser

- ✦ **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 analysed and utilised to discover patterns in the exhaust gas composition.

- ✦ *Benefits of Exhaust Gas Analyser:* Exhaust gas analyzers are used for a variety of purposes, such as car emission testing, engine tuning, and environmental monitoring. An analyzer can assist discover engine problems such as fuel system difficulties, combustion inefficiencies, and emissions concerns by measuring the concentration of different gases in the exhaust stream. This data may be utilised to improve engine performance, reduce emissions, and increase fuel efficiency.

Overall, an exhaust gas analyzer is a must-have instrument for any organisation or individual interested in monitoring and optimising the performance of combustion engines. These devices give precise and dependable measurements of exhaust gas composition, which may be utilised to optimise engine efficiency, minimise emissions, and maintain environmental compliance.

5.2.1 Gas Analyser Specification:

Table 5.2: Exhaust gas analyzer specification

Manufacturer	SMS Autoline Equipments private limited
Type	Crypton290 five gas analyser
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 Nitrous oxides -Electrochemical

5.2.2 Exhaust Gas Analyser Setup:

The setup of an exhaust gas analyzer can vary depending on the specific analyzer and application. However, here is a general overview of the components that make up an exhaust gas analyzer setup:

- ✦ *Sampling Probe:* The sampling probe is the part of the analyzer that extracts a sample of the exhaust gases from the tailpipe of the engine. The probe typically has a long, thin tube that is inserted into the exhaust pipe to collect the sample.
- ✦ *Sampling Line:* The sampling line is the tubing that connects the sampling probe to the analyzer. The tubing is usually made of a heat-resistant material such as stainless steel to prevent the sample from being contaminated or altered by the tubing material.

- † *Filter*: The filter is an optional component that can be added to the sampling line to remove any particulate matter or other contaminants from the exhaust gas sample.
- † *Pump*: The pump is responsible for drawing the exhaust gas sample through the sampling line and into the analyzer. The pump can be either electric or pneumatic and is typically powered by the analyzer itself.
- † *Analyzer Unit*: The analyzer unit is the core component of the setup. It measures the concentration of different gases in the exhaust stream and provides a detailed report of the exhaust gas composition. The analyzer unit typically consists of various sensors, detectors, and electronic circuits that work together to measure the concentration of different gases in the exhaust stream.
- † *Calibration Gas*: The calibration gas is used to calibrate the analyzer and ensure that it is providing accurate and reliable results. The calibration gas typically contains a known concentration of the gas being measured, and the analyzer is calibrated using this gas before and after each use.
- † *Display Unit*: The display unit is where the real-time readings of the exhaust gas composition are displayed. The display typically shows the concentration of different gases in parts per million (ppm) or percent (%) and can be either a digital or analog display.
- † *Data Logging System*: The data logging system is an optional component that can be added to the analyzer setup. It records the exhaust gas composition over a period of time, and this data can be used for analysis and to identify trends in the exhaust gas composition.

Overall, the setup of an exhaust gas analyzer is relatively simple, and the components can be easily assembled and disassembled. It is important to follow the manufacturer's instructions when setting up and using the analyzer to ensure that it is functioning correctly and providing accurate readings.

5.3.3 Working of Exhaust Gas Analyser:

The working of an exhaust gas analyzer involves several steps, including the sampling of the exhaust gases, the analysis of the gas composition, and the reporting of the results. Here is a detailed explanation of how an exhaust gas analyzer works:

- ✦ *Sampling of Exhaust Gases:* The first step in the process is to sample the exhaust gases. This is done using a sampling probe that is inserted into the tailpipe of the engine. The probe collects a small sample of the exhaust gas, which is then drawn through a sampling line by a pump and directed to the analyzer unit.

- ✦ *Analysis of Gas Composition:* Once the exhaust gas sample reaches the analyzer unit, it is analyzed to determine the concentration of different gases in the sample. The analyzer unit typically consists of various sensors and detectors that are designed to detect specific gases, such as carbon monoxide (CO), carbon dioxide (CO₂), oxygen (O₂), nitrogen oxides (NO_x), and hydrocarbons (HC). Each sensor measures the concentration of a specific gas in the exhaust stream and provides a signal to the electronic circuits in the analyzer unit.

- ✦ *Calculation of Gas Concentrations:* The electronic circuits in the analyzer unit process the signals from the gas sensors to calculate the concentration of each gas in the exhaust stream. The concentration of each gas is typically displayed in parts per million (ppm) or percent (%).

- ✦ *Calibration of Analyzer:* To ensure accurate results, the analyzer must be calibrated before each use. This is done using a calibration gas that contains a known concentration of the gas being measured. The analyzer is calibrated using this gas before and after each use to ensure that it is providing accurate readings.

- ✦ *Display and Reporting of Results:* The final step in the process is to display and report the results of the exhaust gas analysis. The analyzer typically has a display unit that shows the concentration of each gas in the exhaust stream. The display can be either digital or analog and can show the results in real-time or as an average over a period of time. The analyzer may also have a data logging system that records the exhaust gas composition over a period of time. This data can be used for analysis and to identify trends in the exhaust gas composition.

Overall, an exhaust gas analyzer is an essential tool for monitoring and optimizing the performance of combustion engines. These devices provide accurate and reliable measurements of the exhaust gas composition, which can be used to improve engine performance, reduce emissions, and ensure compliance with environmental regulations.

5.3 SMOKE OPACITY METER

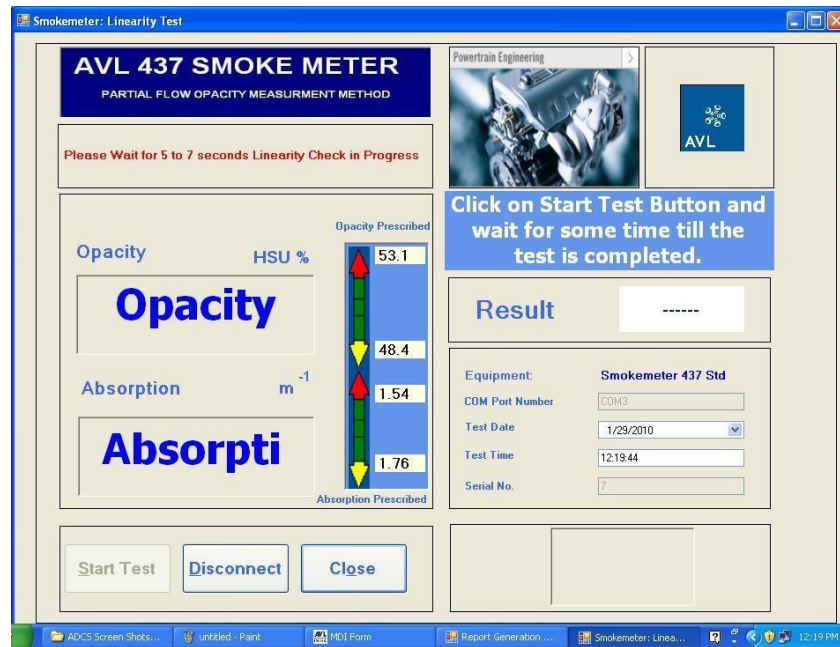


Figure 5.3: Smoke Opacity meter

A smoke meter is a device that is used to measure the amount of smoke emitted by diesel engines. It is an essential tool for monitoring and controlling the emissions of diesel engines to comply with environmental regulations. The smoke meter works by measuring the opacity of the exhaust gas, which is an indicator of the amount of particulate matter in the exhaust stream. The fig 5.3 shows schematic diagram of smoke opacity meter. Here is a detailed explanation of how a smoke meter works:

- ✦ **Sampling of Exhaust Gases:** The first step in the process is to sample the exhaust gases. This is done using a sampling probe that is inserted into the tailpipe of the engine. The probe collects a small sample of the exhaust gas, which is then drawn through a sampling line by a pump and directed to the smoke meter.
- ✦ **Analysis of Gas Opacity:** Once the exhaust gas sample reaches the smoke meter, it is analyzed to determine the opacity of the exhaust stream. The opacity of the exhaust gas is measured using a light source that is directed through the exhaust gas stream. The amount of light that is blocked by the exhaust gas is measured by a detector on the other side of the exhaust gas stream. The more

light that is blocked by the exhaust gas, the higher the opacity of the exhaust stream.

✦ *Calculation of Smoke Density:* The opacity of the exhaust gas is converted into a smoke density measurement using a calibration curve. The calibration curve is determined by measuring the opacity of a known concentration of smoke in the exhaust stream. The smoke density is typically reported in units of K (m⁻¹).

✦ *Display and Reporting of Results:* The final step in the process is to display and report the results of the smoke density measurement. The smoke meter typically has a display unit that shows the smoke density measurement. The display can be either digital or analog and can show the results in real-time or as an average over a period of time. The smoke density measurement can be used to determine if the diesel engine is emitting too much smoke and may need to be adjusted or repaired to reduce emissions.

Overall, a smoke meter is an essential tool for monitoring and controlling the emissions of diesel engines. These devices provide accurate and reliable measurements of the amount of smoke emitted by diesel engines, which can be used to improve engine performance, reduce emissions, and ensure compliance with environmental regulations.

Table 5.3: Smoke meter specification

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)

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