

TRANSESTERIFICATION OF MAFURA OIL TO BIODIESEL USING 10NI-10W/AL-MCM-41 BIMETALLIC CATALYST AND ANALYSIS OF ENGINE CHARACTERISTICS ON VCR ENGINE

Submitted in partial fulfillment 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)**

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BONAFIDE CERTIFICATE

This is to certify that this Project Report is the bonafide work of **J.M. NIJOHN (38150903)** who carried out the project entitled "**TRANSESTERIFICATION OF MAFURA OIL TO BIODIESEL USING 10NI-10W/AL-MCM-41 BIMETALLIC CATALYST AND ANALYSIS OF ENGINE CHARACTERISTICS ON VCR ENGINE**" under my supervision from December 2021 to March 2022.

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I **J.M.NIJOHN** hereby declare that the project report entitled **“TRANSESTERIFICATION OF MAFURA OIL TO BIODIESEL USING 10NI-10W/AL-MCM-41 BIMETALLIC CATALYST AND ANALYSIS OF ENGINE CHARACTERISTICS ON VCR ENGINE”**, done by me under the guidance of **Prof. Dr.S. GANESAN, M.E., Ph.D.** at **SATHYABAMA INSTITUTE OF SCIENCE AND TECHNOLOGY, CHENNAI** is submitted in partial fulfilment of the requirements for the award of Bachelor of Engineering degree in Mechanical Engineering.

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ABSTRACT

Environmental problems caused by the use of fossil fuels can be solved by the use of biofuels. Alternative fuels such as vegetable oils, biodiesels, biogas, LPG, and CNG have been gaining popularity as a suitable diesel oil substitute for internal combustion engines in order to fulfil rising energy demands. Because of their agricultural origins, vegetable oils may have a lower carbon content than mineral diesels, resulting in fewer CO₂ emissions into the atmosphere. It also reduces import of petroleum products. This work shows the application of the oil of Mafura seeds originating from Mozambique as a feedstock for biodiesel production by Transesterification process with 10Ni–10W/Al-MCM-41 bimetallic catalyst. In this, experimental study is carried out on a four-stroke variable compression ratio (VCR), direct injection diesel engine to analyze the performance and emission characteristics of pure diesel and Mafura oil – diesel blended fuels with various blended rate. Experiments have been carried out to estimate the performance, emission and combustion characteristics of a single cylinder, four-stroke VCR engine fueled with biodiesel and its blends with standard diesel.

Keywords: Mafura oil, Transesterification, 10Ni–10W/Al-MCM-41 bimetallic catalyst, variable compression ratio (VCR Engine).

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LIST OF ABBREVIATIONS

CO	- Carbon Monoxide
CO ₂	- Carbon Dioxide
HC	- Hydro Carbons
MCM	- Mobil Composition of Matter
NO _x	- Nitric Oxide
O ₂	- Oxygen
SFC	- Specific Fuel Consumption
TEM	- Transmission Electron Microscopy
XPS	- X-ray Photoelectron Spectroscopy
XRD	- X-ray diffraction

CHAPTER 1

INTRODUCTION

To meet the growing energy needs resulting from spiraling demand and diminishing supply, alternative energy sources like biofuels are receiving more attention. Furthermore, due of the pollution created by internal combustion engines, a growing global concern has prompted a focus on oxygenated diesel fuels. As a result of these concerns, several research efforts have been conducted to substitute petroleum-based diesel fuel with biofuel. Crude oil is plainly a limited resource, and while predicting when unrefined petroleum will no longer be a monetarily sensible item is difficult, various authors have attested to this fact. Continuous price increases, combined with unpredictability in the global crude oil market and supply disruptions owing to conflict in major oil-producing countries, have sparked interest in finding an alternate fuel. Increased public awareness of the dangers of diesel emissions on the environment, as well as the need for any country to become self-sufficient, has sparked interest in biodiesel fuels.

1.1 BIO-DIESEL

Biodiesel, a biofuel made primarily from oily plants and algae and to a lesser extent from other oily sources (such as waste cooking fat from restaurant). Biodiesel, is used in diesel engines and is usually blended with petroleum diesel fuel in various percentages. Soybean and oil palm are common plants used in biodiesel production. The use of algae and cyanobacteria as sources for biodiesel holds promise but has been difficult to develop economically. Some algal species contain up to 40 percent lipids by weight, which can be converted into biodiesel or synthetic petroleum. Some estimates state that algae and cyanobacteria could yield between 10 and 100 times more fuel per unit area than plant-based biofuels. The conversion of oil and fats to biodiesel occurs in three steps. Base-catalyzed transesterification of the oil, followed by direct acid-catalyzed transesterification, and lastly conversion

of the oil to lipids and biodiesel generation. Biofuel refers to any fuel made from biomass, such as plant or algal materials, or animal waste. Because the feedstock material is readily available, biofuel is considered a renewable energy source, as opposed to fossil fuels such as petroleum, coal, and natural gas. Biofuel is frequently promoted as a cost-effective and environmentally friendly alternative to petroleum and other fossil fuels, especially in light of rising petroleum prices and growing concern about fossil fuels contribution to global warming. Because of the economic and environmental expenses connected with the refining process, as well as the possible displacement of enormous swaths of fertile land from food production, many critics are concerned about the extent of the spread of certain biofuels. Bio-fuels have environmental benefits, but they can also have major environmental problems, depending on how they are created. Plant-based biofuels have little net contribution to global warming and climate change as a renewable energy source because the carbon dioxide (a key greenhouse gas) that enters the air during combustion is withdrawn from the air earlier as growing plants engage in photosynthesis. This is referred to as "carbon neutral." However, in fact, the industrial production of agricultural biofuels might result in additional greenhouse gas emissions, which may outweigh the advantages of using a renewable fuel.

1.1.1 Advantages of Bio-Diesel

1.1.1.1 Sustainability

One of the most major advantages of using biogas or biofuel is that it is more environmentally friendly than fossil fuels. Fossil fuels are a finite resource that will run out one day. Biofuels, on the other hand, are plant-based renewable energy sources. We can train plants to grow indefinitely, allowing us to continue producing biofuel. Biofuels derived from several sorts of plants are also available in a variety of forms. Biofuels appear to have infinite possibilities when compared to standard fossil fuels.

1.1.1.2 Health benefits

Every year in the India, it is estimated that 1.7 million people die as a result of pollution caused by gasoline engines. Because gasoline emits nitrogen

oxide and acetaldehyde into the atmosphere, this is the case. Smog is formed when these molecules combine with sunlight, resulting in air pollution. Lung illness, cancer, and other diseases are caused by air pollution. The use of biodiesel or biomethane reduces the amount of particulates emitted into the air, resulting in better air quality and reduced pollution.

1.1.1.3 Reducing greenhouse gases

Global warming is a result of human activity, most people recognize that it is a major problem that must be addressed. By now, almost every scientist thinks that fossil fuels have played a significant role in global warming. However, using renewable energy sources such as biofuels can dramatically reduce greenhouse gas emissions that contribute to global warming. In fact, according to one Australian study, using biodiesel derived from cooking oil can cut greenhouse gas emissions by up to 87 percent.

1.1.1.4 Energy efficiency

One of the most significant advantages of using biodiesel is its energy efficiency. While petroleum diesel is currently efficient for usage in a car or truck, biodiesel production is more energy efficient. According to studies, four and a half units of energy are generated for every unit of fossil fuel energy used to grow and refine soybeans for biodiesel. In the case of petroleum diesel, less than one unit of energy is produced.

1.1.1.5 Improved performance

Another advantage of employing biofuels is that they provide excellent performance. Biofuels can be used in current diesel engines with few or no system adjustments required. The performance of most of these vehicles is comparable, if not superior. Biofuels also help engines run longer, according to studies, because they do not have a high viscosity rate.

1.1.1.6 Reduce reliance on foreign oil

In tandem with other sustainable initiatives, choosing renewable energy such like biofuel can help lessen India's reliance on foreign oil. Experts suggest that using biogas, in this increasing fuel economy, will help India wean itself off foreign oil.

1.1.1.7 Can be used in existing diesel engines

One of the most significant advantages of using biodiesel is that it can be used in current diesel engines with minimal or no changes, allowing it to replace fossil fuels as the preferred primary transport energy source. Biodiesel can be used alone or in mixtures with petroleum diesel.

1.1.2 Disadvantages of Bio-Diesel

1.1.2.1 Gelling

When the temperature drops below a certain point, the paraffin component of diesel begins to solidify and become gel-like substance. At 32 degrees, diesel fuel begins to cloud as the liquid wax crystallizes, and at roughly 10 degrees, it becomes a gel, which can block the tank, narrow fuel lines, and gasoline filters. Biodiesel has also been known to gel when it becomes cold. This technique limits the usage of biodiesel because it is not practical to utilize in cold locations. One alternative could be to install the tank underground or indoors if it is required to be utilized in cold climates. This would allow the biodiesel to remain in its ideal state.

1.1.2.2 Damage filters and pipes in vehicles

Vehicles that ran on biodiesel experienced their seals and gaskets erode over time, according to research. Furthermore, it clogs the filters, causing damage to the pipes. This is due to the fact that when biodiesel cleans dirt from engines and narrow pipes, the dirt can block fuel filters and gaskets, causing damage. This issue is caused by the bio-fuel blending.

1.1.2.3 More expensive than petroleum

Biodiesel has become significantly more expensive than other conventional fuels in recent years. It is currently over 1.5 times the cost of petroleum. Using biodiesel could so become too expensive for many.

1.1.2.4 Regional suitability

Oil-producing crops are not suited in all areas. The most productive crops cannot be grown anywhere and must be carried to the plants, increasing the cost and amount of pollution involved with production and transportation.

1.1.2.5 Use of petroleum diesel to produce biodiesel

Producing biodiesel fuel from soy crops necessitates a significant amount of energy, as does sowing, fertilizing, and harvesting crops. Aside from that, raw materials must be carried via trucks, which may need the use of additional gasoline. According to some scientists, creating one liter of biofuel requires the same amount of energy as manufacturing many liters of petroleum fuel.

1.2 MAFURA OIL

The mafura tree, also known as *Trichilia Emetica* and cape mahogany, produces mafura oil, sometimes known as natal mahogany oil. It can be found in Mozambique and other Southern African countries. This miracle is abundant in important fatty acids including palmitic, stearic, and linoleic, and may be used as a butter at room temperature or as an oil at 65 degrees or higher. The oil is derived from the bright red fleshy seeds and is extremely hydrating. Because to the presence of limonoids like trichilin, one single tree provides roughly 20 liters of oil, which has antibacterial and anti-inflammatory qualities. It's also used to heal wounds and treat rheumatism.

1.2.1 Origin and its Nature

Trichilia emetica Vahl is a mahogany tree that is generally referred to as the Mafura tree an evergreen tree that reaches typical heights of 25-35 meters. Its

commercial name is Cape Mahogany or Natal Mahogany. *Mafura* is a native plant of Sub-Saharan Africa, with populations concentrated in Ethiopia, Mozambique, South Africa, and Zimbabwe. One single tree yields around 20 liters of oil. *Mafura* has been studied for a wide range of biological activities, including antibacterial, anti-inflammatory, antischistosome, antiplasmodial, antioxidant, and anticancer properties because of the presence of limonoids. *Trichilia emetica* may be grown in a variety of soil types, including sandy, loamy and clay. It favors well-drained soil and can withstand drought. Because the seeds of this plant contain 23-65% wt. of oil and a high grade of fatty acids equivalent to palm oil, they are regarded promising as a biodiesel raw material. The properties of vegetable oils used in biodiesel synthesis, according to the literature, may vary greatly depending on location and climate. As a result, the beneficial properties of the oil make this species intriguing for commercial development, both for food and non-food reasons.

CHAPTER 2

LITERATURE SURVEY

Syed Aalam evidently exhibited the enhancement in ZJME25 fuel properties with the addition of alumina nanoparticles. AONP50 gave better results with ZJME25 than AONP25 blend with increased flash point.

Shaafi and Velraj used alumina, ethanol and isopropanol as fuel additive for B20-Soybean biodiesel. They mixed 100 mg/l of AONP in D80SBD15E4S1 blend, and noticed a drastic decrease in viscosity and calorific value along with an increase in efficiency.

Anbarasu and Bharathi raja studied the effect of blending AONP with Canola methyl ester emulsion and straight diesel, and noticed a significant increase in flash point, density along with a significant decrease in viscosity.

Grey Relational Analysis for Multi-Objective Optimization of VCR Diesel Engine Performance and Emissions Using Diesel-Lime Steam Oil Blends by Karthikeyan, YananGan, NagarajBanapurmath

The goal of grey relational analysis is to "optimize a response that is influenced by numerous independent variables. "Homogeneous combustion catalysts are additives that are homogeneously dissolved in diesel fuels in order to play a catalytic role during the engine's combustion process. In the future, lemon distilled oil could be a safe alternative fuel. The parameter of Nano catalyst CeO₂ composition is 62 percent, followed by Biodiesel blend 16 percent, BP 11 percent, and Injection Pressure 9 percent, according to the ANOVA results. The CeO₂ composition has the greatest impact on engine performance, while the Lemongrass oil blend has the second greatest impact.

SadhikBasha and Anand compared the characteristics of JME fuels with and without AONP and CNT. The results showed that combining CNT and JBD produced better outcomes with improved fuel characteristics.

When compared to neat JBD and AONP blended JBD, the flash point of CNT blended Jatropha biodiesel was the lowest.

The addition of CNT to biodiesel increased flash point, viscosity, calorific value, and Cetane number, according to Balaji and Cheralathan, and Narinder Singh and Bhar. The values were observed to grow as the amount of CNT concentration increased. The addition of CNT to HOME changed the features of HOME, according to Prajwal Tewari and group. According to the author, HOME+50 ppm CNT produced better results than HOME+25 ppm CNT.

Sadhik Basha and Anand studied the CNT blended JME water emulsion and found that flash point for 100 CNT blend was 1220C, which was lowest among all the blends. With the increase in CNT concentration, viscosity, density, calorific value and Cetane number also showed an increased trend.

Using the Taguchi approach, investigation the effect of nano catalysts on the performance of DI diesel engines using Citronella oil mixes done by S. Ganesan, K. S. Sridhar raja, N. Beem Kumar, J. Hemanandh, G. Senthilkumar, K. S. Sreenivasan, R. Rajasekar.

The emissions characteristics of diesel engines were evaluated using a variety of engine process parameters, including Citronella oil, injection pressure, braking power, and ZnO. For various engine performance and emissions, the best combination is found using the major impacts plot for both mean of signal to noise ratio. The experimental data shows that the engine performance is comparable to that of a diesel at this combination. When compared to diesel, the emissions are lower.

The addition of ZnO to B20-Grape seed oil methyl ester raised the flash point, fire point, density, and viscosity, according to Karthikeyan, Jebarajan and Rajkumar.R. The addition of ZnO and CeO₂ nanoparticles to straight diesel and

B20-Pomoline stearin wax biodiesel resulted in an increase in calorific value and a drop in flash/fire point, according to Rao and Srinivas Rao and Karthikeyan.

YananGan et al. looked into the burning properties of several nanoparticles at dilute and dense concentrations. The researchers looked examined spherical iron nanoparticles with sizes ranging from 15 to 80 nm (covered with a thin layer of carbon between 2 and 6 nm) and non-spherical boron nanoparticles with sizes ranging from 80 nm.

Kannan et al. reported that adding FBC (FeCl_3) to waste cooking palm oil biodiesel decreased the flash point, fire point, and density values while increasing the kinematic viscosity, calorific value, and Cetane number.

Nagaraj Banapurmath discovered that combining AgNP with HOME reduced the flash point while increasing the viscosity, density, and calorific value. When compared to the qualities of HOME, HOME+50 ppm of Ag produced good results.

Bhagwat et al. discovered that adding graphene NP to HOME increased its characteristics. HOME+50 ppm graphene had the best performance of all the combinations.

Recent trends in nano fluids, their preparation, and uses were discussed by Mohammed Suhail Ansari and others. One-step nano fluid synthesis and two-step nano fluid synthesis are the two types of nano fluid synthesis.

The performance and emission characteristics of a single cylinder four stroke air cooled diesel engine fueled with nano ceria enhanced diesel-biodiesel produced from waste fried oil were researched by Abbas Alli Taghipoor Bafghi and others. CeO_2 particles ranging in size from 10 to 30 nm were blended with diesel-biodiesel mixtures ranging from 5 to 25 ppm.

Sunil Kumar Sharma et al. studied the effects of adding CeO_2 and CNT to a JME+TPO blend and found that CeO_2 reduced viscosity and density while CNT increased it.

The addition of Mn (12mol/L) to B25 of pomace oil lowered viscosity by up to 20.37 percent and flash point by up to 7%, according to Sinem Kaynak and colleagues. The pour point was lowered from 00 to -150 degrees Celsius.

Demibra and others, as well as Jayde, have shown the importance of nano metal additives in biodiesel, as well as their effect on increasing the physio-chemical properties of nano metal blended biodiesel. The physiochemical parameters of diesel, bio-diesel, and fuel combined with nano metallic additions are compared.

Experimental and synthesis of chicken slaughter waste biodiesel in DI diesel engine. Hema Janarthanam, Ganesan Subbiah, Sridhar Raja, Senthilkumar Gnanamani, Amarjit Roy, Vineet Chougale. The produced biofuel has a low emission rate and lowers the cost of fuel. In comparison to pure diesel, the blend produces less HC emission than with a yield of 9.68 percent at 100 percent load condition. Biochar is formed as a by-product throughout the experiment that might be employed as a bio-fertilizer due to the rich nitrogen content to improve soil quality.

CHAPTER 3

MATERIALS AND METHORDS

3.1 AIM

The main target of this study is producing bio-diesel with Mafura oil as feed-stock with added catalyst to blend it with different portion of pure diesel to analyze the engine characteristics which is, study of emission and performance in a VCR engine

3.1.1 *Scope of Present Investigation*

The purpose of this study is to examine the engine's performance at various rated powers in the aspects of Specific Fuel Consumption, Brake Thermal Efficiency, and emissions characteristics like HC, CO, CO₂, O₂, and NO_x. The transesterification method turns Mafura oil into biodiesel. The biofuel is put through its paces in the VCR engine. The engine was initially driven at no load before the test blends were introduced and the sample's emission and performance characteristics were recorded.

3.2 GENERAL SAMPLE PREPARATION

The method of manufacturing the biofuel or biodiesel with chemical reactions such as transesterification and esterification is known as biodiesel production. Short-chain alcohols are used to react with vegetable or animal fats and oils (typically methanol or ethanol). Alcohols with a low molecular weight should be used. Because of its low cost, ethanol is the most commonly used; nevertheless, methanol can achieve higher conversions into biodiesel. Although either acids or bases can catalyze the transesterification reaction, the reaction catalyzed by bases is more prevalent. Compared to acid catalysis, this approach has shorter reaction

durations and cheaper catalyst costs. Alkaline catalysis, on the other hand, has the disadvantage of being extremely sensitive to water and fatty acids in the oils. Biodiesel and its impure coproduct, glycerol, are produced via base-catalyzed transesterification, which combines lipids (fats and oils) with alcohol (usually methanol or ethanol). Acid-catalyzed esterification can be utilized to react fatty acids with alcohol to make biodiesel if the feedstock oil is used or has a high acid content. Other methods, such as fixed-bed reactors, supercritical reactors, and ultrasonic reactors, avoid or limit the usage of chemical reactions, which lower the quality of the material.

3.3 MATERIALS USED

3.3.1 *Mafura Oil*

The mafura tree, also known as *Trichilia Emetica* and cape mahogany, produces mafura oil, sometimes known as natal mahogany oil. It can be found in Mozambique and other Southern African countries. The oil is derived from the bright red fleshy seeds. This is high in important fatty acids such palmitic, stearic, and linoleic acid, and is a butter at room temperature and an oil at 65 degrees or above. Mafura Oil is made from the *Trichilia emetica* tree's bright red seeds, which are expeller pressed. An expeller press, sometimes known as a "screw press," is a machine that extracts oil by pressing seeds and nuts through a chamber with high friction and pressure. There is no additional heat applied during this procedure, yet heat is generated (about 140-210 F) because the seeds are squeezed utilizing friction. The oil is extracted after the seeds have been crushed. The seeds are usually left in the press to create a hard "brick" that may be utilized as animal feed later.

3.3.2 *Catalyst (10Ni–10W/Al-MCM-41)*

MCM-41 (Mobil Composition of Matter No. 41) is a mesoporous material with a hierarchical structure that is derived from a family of silicate and aluminosilicate solids produced by Mobil Oil Corporation researchers and were utilized as catalysts or catalyst supports. The M41S family of nanostructured mesoporous materials was discovered by a team of Mobil researchers. Al-MCM-41 is a member of the M41S

family of mesoporous molecular sieves. The hexagonal phase, Mobil Composition of Matter (MCM) 41, is a well-known and researched component of this family. AL MCM 41 and other mesoporous silicates have a significant surface area and pore size inside an organized array of cylindrical mesopores. This shape improves the chances of a reactant molecule in solution making contact with a catalyst's surface and reacting. It also makes sure the reactant molecules are tiny enough to pass through the big pores. As a result, Al-MCM-41 is an effective catalyst or catalytic support, as well as an adsorbent.

Catalytic deoxygenation is a biofuel upgrading technique that removes excess oxygen, which causes corrosion, instability, and decreased heating value. Biofuels have a high oxygen concentration, which degrades the quality of the fuel. To catalytically convert vegetable oils into hydrocarbons, primarily two types of catalysts have been studied: noble-metal catalysts and transition-metal sulphides catalysts. Noble metals (mainly Pd and Pt) were beneficial to DO reactions, but their availability was restricted due to their rarity and expensive prices. Zhang and colleagues looked into using sulfided CoMo catalysts to improve waste cooking oil and discovered that hydrodecarbonylation/decarboxylation processes were the main routes for oxygen removal. Toba and coworkers investigated the performance of sulfided catalysts in hydrodeoxygenation. They discovered that sulfided Ni–Mo and Ni–W catalysts had stronger hydrodeoxygenation activity than sulfided Co–Mo catalysts, and that at 350 °C, low-grade waste oils could be entirely transformed into hydrocarbons. Sulfur leaching, however, resulted in catalyst deactivation and contamination of alkane products in these systems. Peng and colleagues investigated the catalytic DO of microalgae oil and discovered that the function of Ni nanoparticles caused triglycerides to be hydrogenated and the C–O of fatty acid esters to be preferentially cleaved. As a result, low-cost Ni-based catalysts could be a viable alternative to noble-metal catalysts. Furthermore, Ni–W bimetallic catalysts have recently been suggested as potential DO catalyst materials.

With bimetallic catalyst Ni-W, the results of X-ray diffraction (XRD), X-ray photoelectron spectroscopy (XPS), transmission electron microscopy (TEM), and high-resolution TEM suggested that the right amount of Ni and W would form a Ni₁₇W₃ active phase, with particle sizes varying depending on Ni and W content and

preparation methods. When both Ni and W concentrations reached 10%, the solid Ni_{17}W_3 phase developed. The crystal size of Ni_{17}W_3 rose from 7 to 14 nm or 20 nm when the concentration of W or Ni was increased to 15%, however the biofuel yield fell as the crystal size of Ni_{17}W_3 grew from 7 to 14 nm or 20 nm. For the conversion of mafura oil into high-grade biofuel, the 10Ni–10W/Al-MCM-41 catalyst with a Ni_{17}W_3 crystal size of 7 nm performed well when compared to other catalysts. Ni–W catalysts also has a better hydrodeoxygenation activity. Catalytic deoxygenation is a biofuel upgrading technique that removes excess oxygen, which causes corrosion, instability, and decreased heating value. Biofuels have a high oxygen concentration, which degrades the quality of the fuel.

3.4 SAMPLE PREPARATION

3.4.1 *Transesterification*

Transesterification is a chemical procedure that transforms triglycerides (fats) in oils into useable biodiesel. Biodiesel generated by the transesterification process has a substantially lower viscosity than petroleum diesel, making it suitable for use in diesel engines. The alkalosis (transesterification) of triglycerides, which are the major component of vegetable oils and animal fats, is the industrial biodiesel manufacturing process. Methyl esters are the most prevalent sort of esters, owing to the fact that methanol is generally the cheapest alcohol. Bases, acids, and enzymes catalyze the reaction, which can occur at low or high temperatures. Biodiesel is made from the methyl esters of fatty acids generated, whereas glycerol is obtained as a reaction byproduct.

The additional alcohol (usually methanol or ethanol) is deprotonated with a base to make it a stronger nucleophile during the transesterification process. The reaction has no additional inputs than the triglyceride and the alcohol, as can be observed. This reaction would normally occur very slowly or not at all under normal conditions, thus heat and catalysts (acid and/or base) are needed to speed it up. It is crucial to note that the acid or base is not used during the transesterification process, hence they are catalysts rather than reactants. Sodium hydroxide, potassium hydroxide, and sodium methoxide are common transesterification catalysts. The base-catalyzed procedure is used to make almost all biodiesel from

virgin vegetable oils because it is the most cost-effective method for processing virgin vegetable oils, requiring just modest temperatures and pressures and yielding over 98 percent conversion yield. Biodiesel made from other sources or using other processes, on the other hand, may need acid catalysis, which is significantly slower.

3.4.1.1 Procedure

- One liter of Mafura oil is to be taken.
- 300-330 ml of CH_3OH and 10 ml of concentrated Sulfuric acid is to be added to mineral oil.
- Mixture is kept at 60-70°C temperature for 6 hours with regular stirring.
- In the next step, the hot mixture is left alone for eight hours to settle down.
- The oil obtained from the acid esterification process is preheated to the temperature of 50-60°C in the flask.
- .5 gram of 10Ni-10W/Al-MCM-41 is dissolved in the pre heated oil.
- Heating and stirring of mixture are continued for about 30 min then the mixture the left alone to form two separate layers.
- Lower layer contains the impure glycerol is separated and upper layer is taken into another funnel for the further process.
- It is rinsed with 2.5% (w/w) sulfuric acid and distilled water. To avoid emulsion during washing process NaCl solution was used. Then the washed methyl ester was treated with anhydrous sodium sulphate to remove excess water. It was then filtered and dried by heating at low temperature of 60°C for 30 minutes.

CHAPTER 4

EXPERIMENTAL SETUP

The engine performance and emission properties of Mafura oil biodiesel were evaluated using a single cylinder, constant speed Direct Injection engine. The engine runs at a constant speed of 1500 rpm with various blend amounts under various load circumstances. An eddy current dynamometer was directly connected to the diesel engine to alter the loads from zero percent to full load (100 percent). The engine load is varied based on the engine power, with no load conditions of 0%, 25%, 50%, 75 percent, and full load conditions of 100%. An eddy current dynamometer is used to manually vary the engine loads. The fuel flow was measured using a volumetric calibrated burette method and the air flow rate was measured with an air drum fitted with a calibrated aperture. Two fuel tanks were utilized to test fuel flow: one was filled with pure diesel and the other with trans esterified Mafura blend biodiesel. The emission properties of the exhaust gas, such as HC, CO, CO₂, O₂, and NO_x, were measured using a five-gas analyzer. At a compression ratio of 17.5 and rated power, the performance and emission tests were carried out.



Fig. 4.1: Experimental Setup

4.1 ENGINE SPECIFICATIONS

Engine	Make Kirloskar, Type 1 cylinder, 4 stroke Diesel, water cooled, power 3.5 kW at 1500 rpm, stroke 110 mm, bore 87.5 mm. 661 cc, CR 17.5, Modified to VCR engine CR range 12 to 18
Dynamometer	Type eddy current, water cooled, with loading unit
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
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	Make-Cuadra, Model AX-409.
Digital milivoltmeter	Range 0-200mV, panel mounted
Temperature sensor	Type RTD, PT100 and Thermocouple, Type K
Temperature transmitter	Type two wire, Input RTD PT100, Range 0-100 Deg C, Output 4-20 mA and Type two wire, Input Thermocouple, Range 0-1200 Deg C, Output 4-20 mA
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	"EnginesoftLV" 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

Fig. 4.2: Engine Specifications

4.2 SOFTWARE USED

Apex Innovations Pvt. Ltd. created EngineSoft, a LabVIEW-based software suite for engine performance monitoring. Most engine testing application demands, such as monitoring, reporting, data entering, and data recording, may be met by EngineSoft. Power, efficiency, fuel usage, and heat emission are all evaluated by the program. It may be customized according to the engine configuration. At various working conditions, various graphs are obtained. The

relevant signals are read, saved, and shown in a graph during on-line testing of the engine in RUN mode. The data is accessible from a stored data file in graphical and tabular representations. The graphs and findings can be printed. Further analysis may be done with the data in excel format.

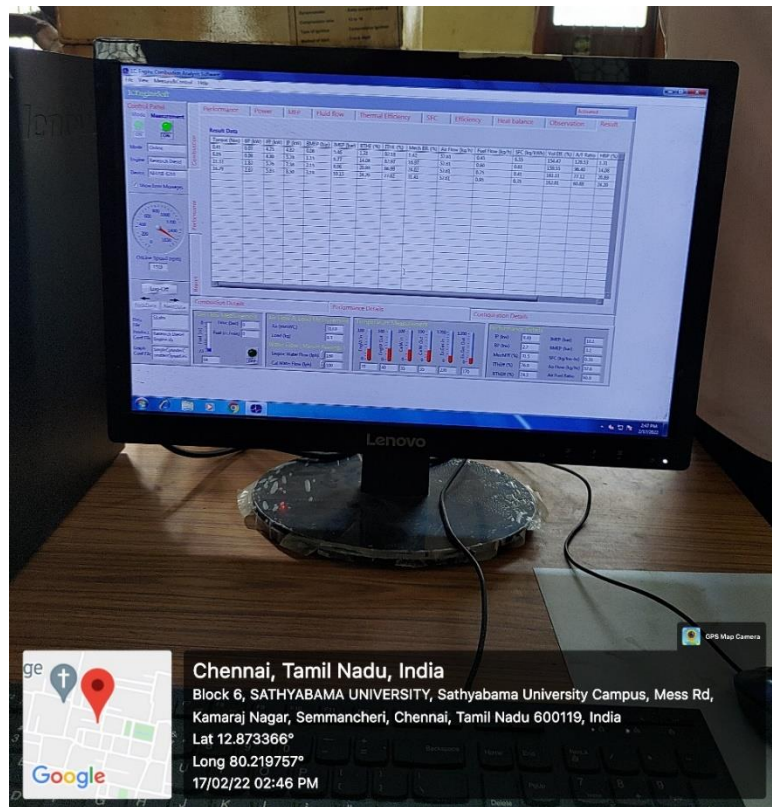


Fig. 4.3: EngineSoft Software

4.3 GAS ANALYZER

The five-gas analyzer detects the concentration of exhaust byproducts such as Carbon Monoxide (CO), Carbon Dioxide (CO₂), Hydro Carbons (HC), Oxygen (O₂), and Nitric Oxide (NO_x). This is accomplished by inserting a probe, also known as a detector, into the tailpipe. Connect the 5-gas analyzer to the computer, turn on the gas analyzer, push the zero button after connecting the hose and probe. The analyzer is ready to sample exhaust emissions gas after the zero is complete. The emission readings are displayed in the analyzer and are noted.



Fig. 4.4: 5-Gas Analyzer

CHAPTER 5

RESULTS

The trans-esterified biodiesel is made in to three samples S1, S2, S3 of petroleum diesel blends off 10%, 20%, 30% of volume respectively. Each sample is a total of 300ml blend. The engine's performance and emission analysis were carried out when fueled with Mafura oil biodiesel for three different volumetric fuel blends with petroleum diesel at different loads and compared with diesel fuel operation.

Table 5.1: Emission values from experiment

BLEND	HC	CO	CO ₂	O ₂	NO _x
S1	1	0.012	0.8	19.56	78
	3	0.027	1.01	19.37	137
	7	0.031	1.32	19.17	207
	9	0.042	1.6	18.79	257
	11	0.049	1.8	18.52	305
S2	3	0.019	0.8	19.79	75
	5	0.021	1.0	19.97	132
	7	0.030	1.2	19.10	214
	8	0.039	1.4	18.67	293
	10	0.042	1.8	17.12	352
S3	2	0.012	0.7	19.93	105
	4	0.024	0.9	19.45	178
	7	0.034	1.1	18.14	229
	9	0.043	1.4	17.93	317
	11	0.051	1.9	17.58	412

5.1 EMISSION ANALYSIS

5.1.1 *O₂ Emission*

This graph represents the emission of oxygen gas during the combustion of sample fuel and neat diesel. Sample 1 emits more oxygen for the first three power inputs. The sample 2 also emits a similar level of oxygen content. The oxygen emission from the diesel decreases as the power increases. The reason that the oxygen content should be is, if the engine does not receive enough oxygen during the combustion process, complete conversion of carbon and hydrogen is impossible, resulting in particulates and carbon monoxide, which leads to increased exhaust emissions. The highest oxygen emission is noted as 19.93% (sample 3) at no load condition and the least as 17.12% (sample 2) at load condition 3.5KW.

Table 5.2: O₂ vs BP

BP(KW)	0	0.875	1.75	2.62	3.5
S1	19.56	19.37	19.17	18.79	18.52
S2	19.79	19.97	19.1	18.67	17.12
S3	19.93	19.45	18.14	17.93	17.58
Diesel	18	19	15	12	11

Graph representing O₂ Emission

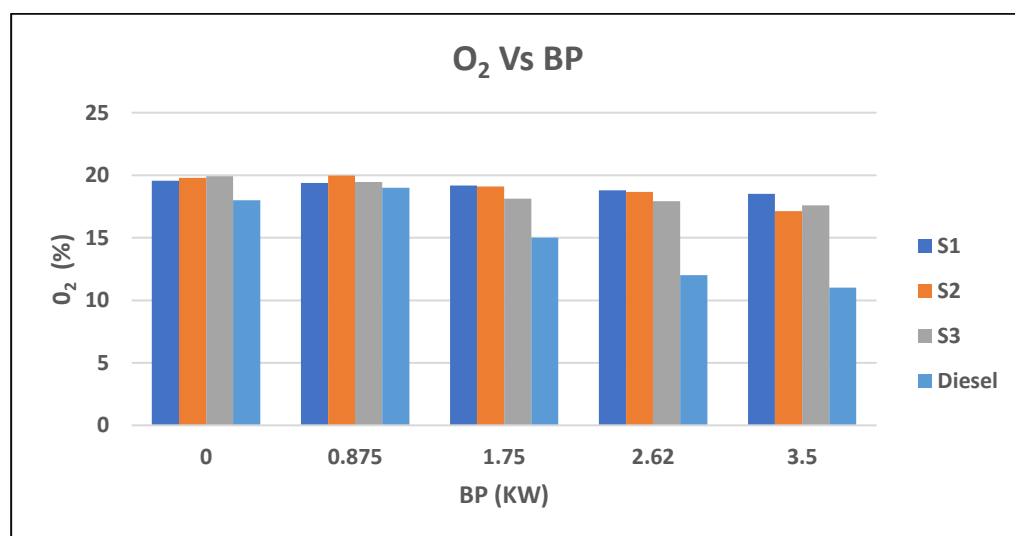


Fig. 5.1: O₂ vs BP

5.1.2 CO_2 Emission

This indicates the emission of carbon di oxide gas during the combustion of samples and neat diesel. Reducing the carbon emissions is one of the main goals to achieve on a global level to reduce the impact of greenhouse effect and problems arising from it. The carbon emissions cannot be reduced all of a sudden but steps taken towards its reduction may help future breakthroughs. The high CO_2 emission from neat diesel is obviously clear, whereas its biodiesel mixed counterparts are emitting less CO_2 . Sample 2 has the least CO_2 emission of 0.7% at no load condition. Sample 3 has the highest emission of 1.9% at the load condition of 3.5KW.

Table 5.3: CO_2 vs BP

BP(KW)	0	0.875	1.75	2.62	3.5
S1	0.8	1.01	1.32	1.6	1.8
S2	0.7	1	1.2	1.4	1.8
S3	0.8	0.9	1.1	1.4	1.9
Diesel	1.6	1.96	2.54	2.89	2.98

Graph representing CO_2 Emission

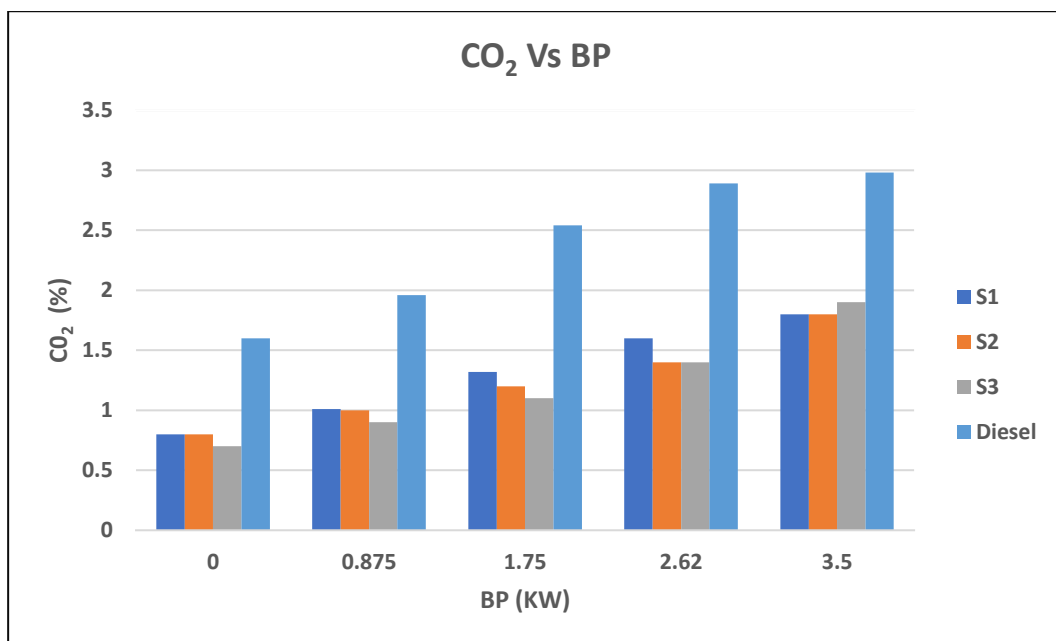


Fig. 5.2: CO_2 vs BP

5.1.3 CO Emission

Carbon monoxide (CO) is emitted as a waste product from the exhaust system of vehicles due to the incomplete combustion process that occurs in an engine. When combustion processes are not fully completed, either owing to a shortage of oxygen or poor mixing, carbon monoxide (CO) is created. Carbon monoxide is a gas that is both colorless and odorless. Carbon monoxide is not harmful, although it does have a short-term effect on the respiratory system. Carbon monoxide binds to red blood cells and prevents oxygen absorption. The Neat diesel emits less CO than the other samples.

Table 5.4: CO vs BP

BP(KW)	0	0.88	1.75	2.62	3.5
S1	0.01	0.03	0.03	0.04	0.05
S2	0.02	0.02	0.03	0.04	0.04
S3	0.01	0.02	0.03	0.04	0.05
Diesel	0.01	0.01	0.02	0.02	0.03

Graph representing CO Emission

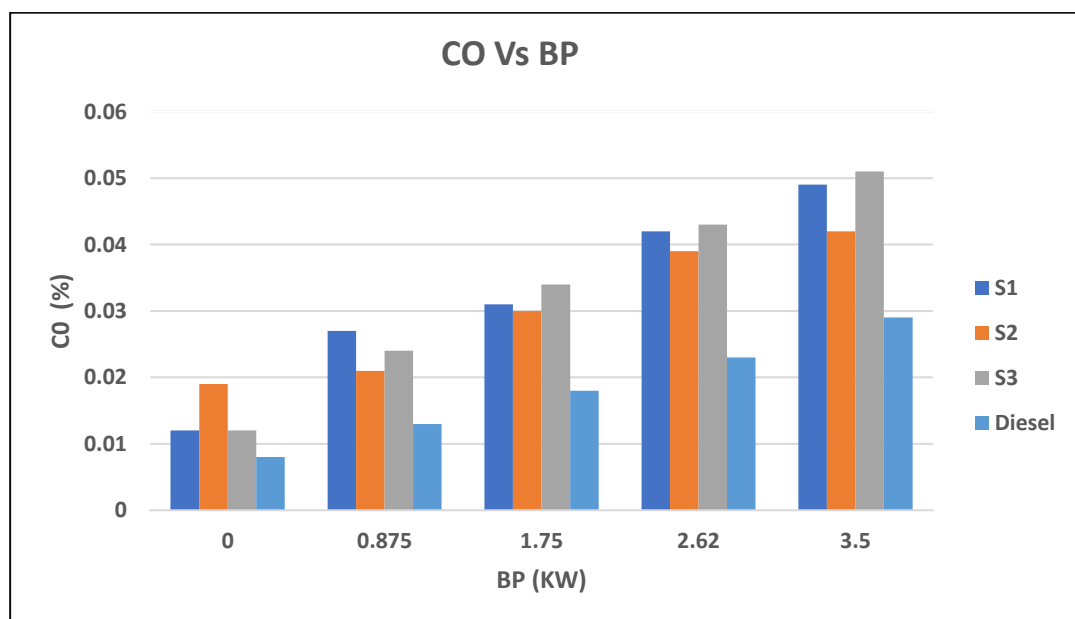


Fig. 5.3: CO vs BP

5.1.4 HC Emission

A lack of spark energy can be caused by a variety of ignition defects, such as dirty spark plugs, leaking or open-circuited spark plugs or wires, or defective ignition coils. High HC emissions can result from a lack of spark energy. Incomplete combustion and high hydrocarbons may result if the spark occurs at the wrong time. The sample 1 emits less HC among all. HC emission from every bio-diesel blend were less compared to plain diesel. Sample 1 emitted the less HC (1%) in relative to the other samples.

Table 5.5: HC vs BP

BP(KW)	0	0.875	1.75	2.62	3.5
S1	1	3	7	8	10
S2	3	5	7	9	11
S3	2	4	7	9	11
Diesel	2	6	10	15	19

Graph representing HC Emission

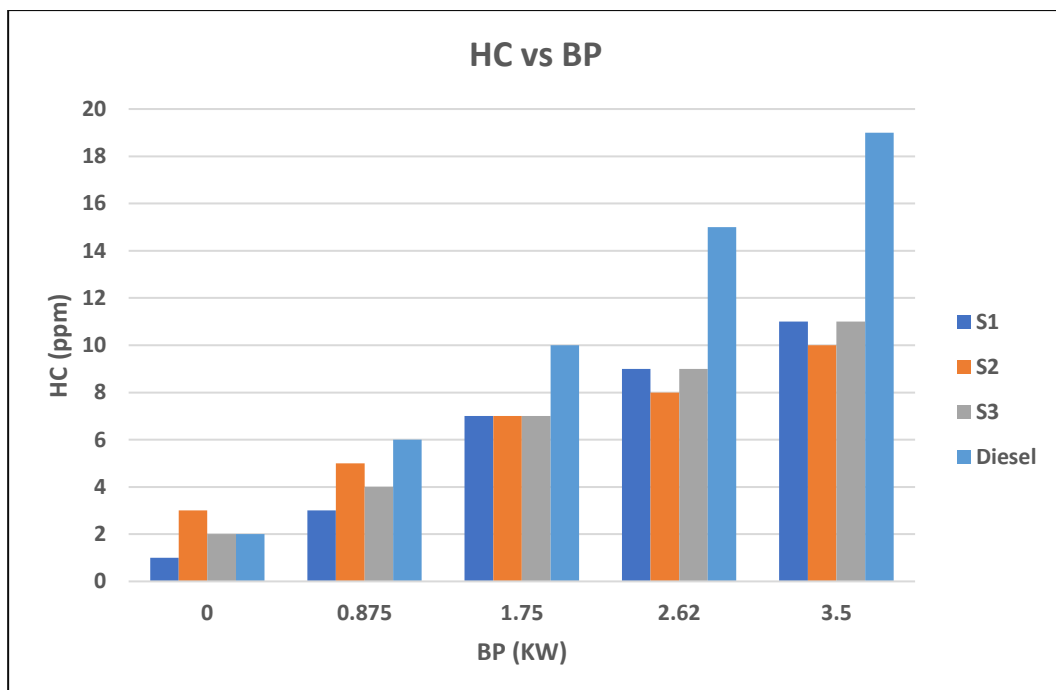


Fig. 5.4: HC vs BP

5.1.5 *NOx Emission*

NOx is formed during combustion when nitrogen and oxygen gases react in the air, particularly at high temperatures. The amount of nitrogen oxides discharged into the atmosphere as air pollution may be significant in regions with substantial vehicle traffic, such as big cities. The graph represents the emission of NOx gas produced during emission. The reason why NOx emission is bad for environment is that, Humans can suffer serious health consequences from NOx, including respiratory diseases. Acid rain and ground-level ozone generation are caused by NOx emissions, which can impact ecosystems, animals, and plants. When NOx combines with ammonium (NH_4^+), water vapor, and other substances, it produces nitric acid (HNO_3) and tiny particles. The Sample 1 by a big difference reduces the emission of NOx and is least among other samples. Sample 2 has similar has similar emission results with slight increment of NOx level.

Table 5.6: NOx vs BP

BP(KW)	0	0.875	1.75	2.62	3.5
S1	78	137	207	257	305
S2	75	132	214	293	352
S3	105	178	229	317	412
Diesel	56	156	289	485	750

Graph representing NOx Emission

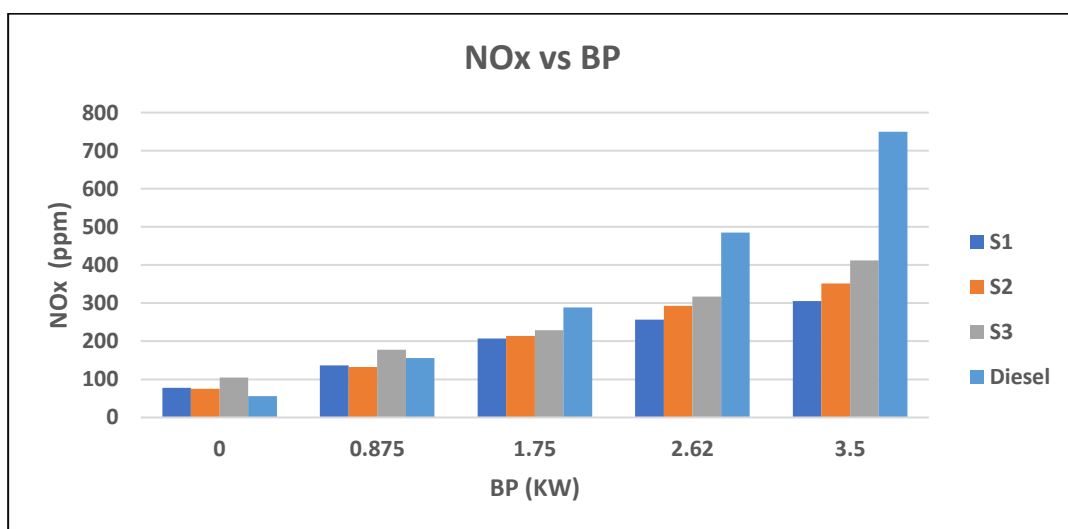


Fig. 5.5: NOx vs BP

5.2 PERFORMANCE ANALYSIS

5.2.1 Brake Thermal Efficiency

The brake thermal efficiency is a type of engine thermal efficiency that is defined as the ratio of braking power at the engine crankshaft to power generated by fuel combustion. The power absorbed by the engine crankshaft out of the total power created by the burning of the fuel is shown by the brake thermal efficiency. Using sample bio-diesel and neat diesel, the graph depicts the break thermal efficiency of a diesel engine. The performance of each sample is comparable to that of plain diesel. Overheating, brake fade, and brake pad deterioration are few issues that might occur. Significant braking inefficiency is caused by vapor lock and a mushy pedal sensation. The maximum Brake Thermal Efficiency obtained is about 31.7 for Sample 2 which is quite lesser than that of baseline diesel 32.59 percent at full load.

Table 5.7: BTHE vs BP

BP(KW)	0	0.875	1.75	2.62	3.5
S1	0	13.3	19.79	24.26	29.77
S2	0	13.6	21.07	25.49	31.7
S3	0	13.77	21.28	23.86	28
Diesel	0	16.49	22.75	29.47	32.59

Graph Representing Brake Thermal Efficiency Analysis

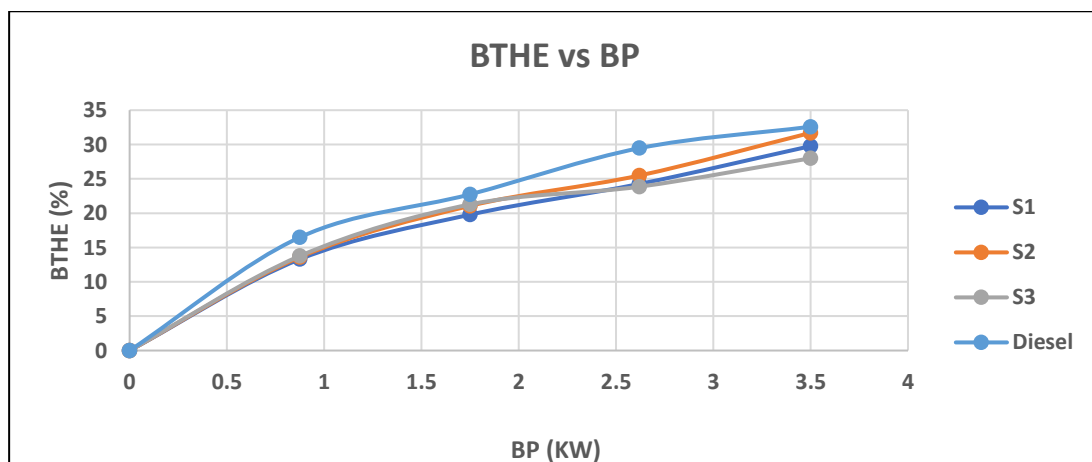


Fig. 5.6: BTHE vs BP

5.2.2 Specific Fuel Efficiency

The amount of fuel burnt in unit time to achieve a certain engine output is known as specific fuel consumption (SFC). The SFC is a mathematical measurement that shows how well an engine turns fuel into power. The fuel efficiency of any prime mover that consumes fuel and provides rotational, or shaft power is measured by brake-specific fuel consumption. It's most commonly used to compare the efficiency of the IC engines with shaft output. It is calculated by dividing the rate of fuel consumption by the amount of energy generated. The SFC of sample 2 was the least (0.20%) compared to other samples and plain diesel which shows sample 2 consumed the less fuel compared to the rest.

Table 5.8: SFC vs BP

BP(KW)	0	0.875	1.75	2.62	3.5
S1	4.97	0.64	0.43	0.35	0.23
S2	4.94	0.63	0.41	0.36	0.20
S3	5.05	0.62	0.40	0.33	0.24
Diesel	2.45	16.49	22.75	29.47	32.59

Graph representing Specific Fuel Efficiency

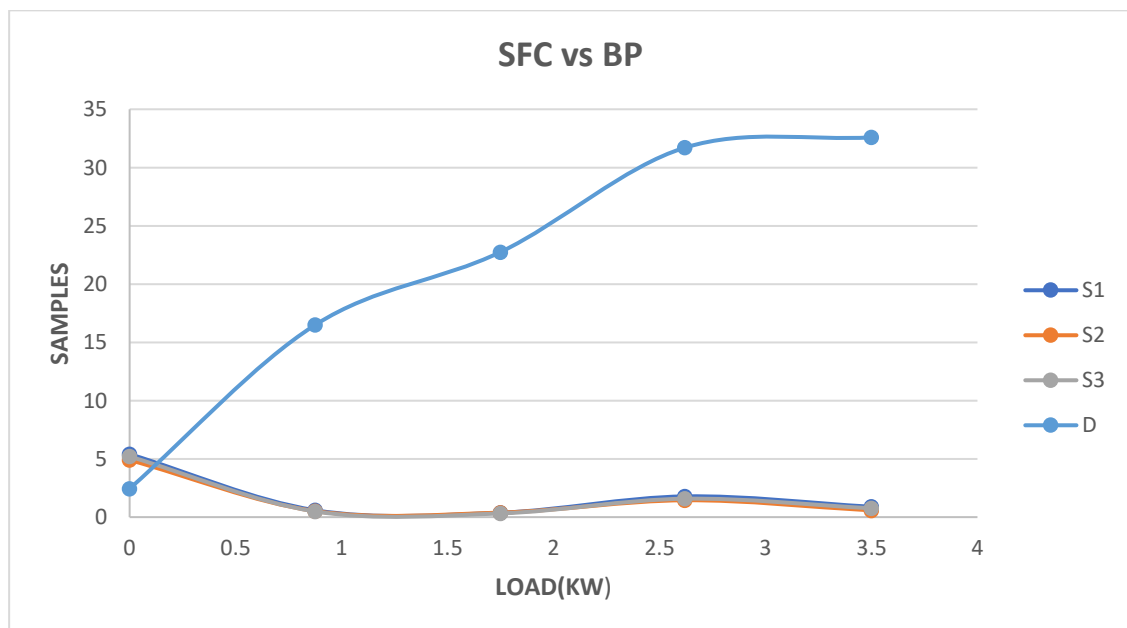


Fig. 5.7: SFC vs BP

CHAPTER 6

SUMMARY AND CONCLUSUION

6.1 SUMMARY

An experiment has been carried out to find the performance and emission of bio-diesel (from Mafura oil) in the VCR engine. The results obtained from the experimental analysis of the bio-diesel blend was compared with the plain diesel which showed varying difference which shows that bio-diesel blended from Mafura oil is a good alternative for diesel as it proved lesser emissions and better efficiency.

6.2 CONCLUSION

- O₂ emissions of all samples were higher than diesel in all load conditions. Sample 3 emits more oxygen for the first three power inputs that is 19.93ppm, 19.45ppm, 19.1ppm at load no condition and 0.875KW, 1.75KW respectively whereas diesel has the values of 18ppm, 19ppm, 15ppm for the same loads. The highest oxygen emission is noted as 19.93ppm (sample 3) at no load condition and the least as 17.12ppm (sample 2) at load condition 3.5KW.
- The high CO₂ emission from neat diesel is obviously clear, whereas its biodiesel mixed counterparts emitted way less CO₂. Sample 2 has the least CO₂ emission. Sample 2 has the least CO₂ emission of 0.7ppm at no load condition. Sample 3 has the highest emission of 1.9ppm at the load condition of 3.5KW. Sample 2 is the best performing sample under all load conditions with values 0.7ppm, 1ppm, 1.2ppm, 1.4ppm and 1.8ppm with no load condition followed by 0.875KW, 1.75KW, 2.82KW and 3.5KW respectively.
- CO emission of every sample had slight increment than that of plain diesel at all load conditions. The least emission is noted in sample 1 (0.01ppm) at no load condition which is same as diesel and the highest is observed as

0.05ppm at full load condition. Furthermore, least values are obtained from sample 2 at no load condition 0.2ppm also same with load 0.875KW. Sample 2 and sample 3 have same values of 0.3ppm at 1.75KW which is the highest emission in plain diesel at load 3.5kw.

- HC emission from every bio-diesel blend were less compared to plain diesel. Sample 1 emitted the less HC (1ppm) at no load condition in relative to the other samples. Sample 1 is the best amongst all with emission values of 1ppm, 3ppm, 7ppm, 9ppm and 11ppm with load conditions (0, 0.875, 1.75, 2.62 and 3.5) KW respectively. At load condition of 3.5KW sample 2 and sample 3 shows the highest value of 11ppm whereas diesel has the highest value of 19ppm at full load condition.
- NOx emission of all samples were relatives less compared to plain diesel except no-load condition. Sample 2 had the least emission of 74 ppm at no load condition and Sample 3 had the highest emission of 412 ppm in full load condition where as diesel have the highest value of 750ppm at load condition of 3.5KW. Sample one was noted with the values 78ppm, 132ppm, 207ppm, 293ppm, 352ppm whereas diesel tends to have 58ppm, 156ppm, 289ppm, 485ppm, 750ppm at load conditions 0 KW, 0.875KW, 1.75KW, 2.62KW AND 3.5KW respectively
- It was found that Sample 2 had a maximum Brake Thermal Efficiency of 31.7 percent, which is significantly lower than the 32.59 percent of baseline diesel at full load.
- The SFC of sample 2 was the least (0.20%) compared to other samples and plain diesel which shows sample 2 consumed the less fuel compared to the rest.

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