

INFLUENCE OF ALUMINA NANOPARTICLES ON PERFORMANCE AND EMISSION CHARACTERISTICS OF BIODIESEL FROM PITHECELLOBIUM DULCE SEED OIL

Submitted in partial fulfilment of the requirements for the award of

Bachelor of Engineering degree in
Mechanical Engineering

By

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DEPARTMENT OF MECHANICAL ENGINEERING

SCHOOL OF MECHANICAL ENGINEERING

SATHYABAMA

INSTITUTE OF SCIENCE AND TECHNOLOGY

(DEEMED TO BE UNIVERSITY)

Accredited with grade “A++” by NAAC

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BONAFIDE CERTIFICATE

This is to certify that this Project Report is the Bonafide work of HARIPRAKASH T (Reg.No.40150012) and MOHAN N (Reg.No.40150026) who carried out the project entitled **"INFLUENCE OF ALUMINA NANOPARTICLES ON PERFORMANCE AND EMISSION CHARACTERISTICS OF BIODIESEL FROM PITHECELLOBIUM DULCE SEED OIL"** under our supervision from December 2023 to April 2024.

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DECLARATION

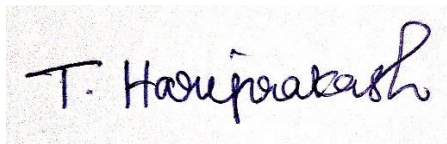
We, HARIPRAKASH T (Reg.No.40150012) and MOHAN N (Reg. No. 40150026) hereby declare that the Project Report entitled **“INFLUENCE OF ALUMINA NANOPARTICLES ON PERFORMANCE AND EMISSION CHARACTERISTICS OF BIODIESEL FROM PITHECELLOBIUM DULCE SEED OIL”** done by us under the guidance of **Dr. S LAKSHMI SANKAR., M.E., Ph.D.**, is submitted in partial fulfilment of the requirements for the award of Bachelor of Engineering degree in Mechanical Engineering.

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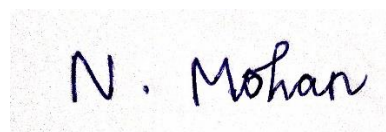
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ABSTRACT

The experimental examination of the "Influence of Alumina Nanoparticles on performance and emission characteristics of biodiesel from "Pithecellobium Dulce Seed Oil" is the primary focus of this work. The use of alumina nanoparticles as a catalyst in biodiesel is investigated, with focus on key emission and performance characteristics such smoke opacity, braking specific fuel consumption, HC, CO, and NOx. In this study, three blends (B10 + Al₂O₃ 50ppm, B20 + Al₂O₃ 50ppm, and B30 + Al₂O₃ 50ppm) are made, and an ultrasonication procedure is used to add alumina nanoparticles to them. When alumina nanoparticles are added to biodiesel-diesel blends, the brake specific fuel consumption is decreased and the brake thermal efficiency of B30 + Al₂O₃ 50ppm is increased in comparison to other blends and diesel. It is found that EGT of B30 + Al₂O₃ 50ppm has higher than other blends as well as diesel. Furthermore, in B30 + Al₂O₃ 50ppm, there is a decrease in CO, HC, and CO₂ emissions, but an increase in NOx emissions.

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CHAPTER-1

INTRODUCTION

The world's energy needs are growing daily due to population growth and technological advancements. Right now, coal and petroleum-based fossil fuels meet this enormous demand. [1]. CI engines are popular because of their excellent characteristics. However, they also contribute significantly to pollution, which has an adverse effect on soil, water, air, and other priceless resources. Fossil fuels demand is predicted roughly 180MMT by upcoming 10 years and then twice the following ten years [2]. This introduces the possibility of their replacement shortly by alternative fuels, namely biodiesel and different additives with qualities close to those of diesel [3]. A sustainable and biodegradable energy source, biodiesel is made from edible and inedible oils, leftover cooking oil, microalgae, animal fats, etc. An alternative to lower environmental pollution is biodiesel[4]. Biodiesel can be made from vegetable oil and animal fat in various ways, such as through the transesterification, microemulsion, and pyrolysis processes. To make biodiesel, transesterification is a popular process [5]. Most researchers have made three contributions to the attempt to lower emissions from compression ignition engines. 1) Making changes to the engine's design 2) gasoline alteration 3: the exhaust gas is treated. Various pollutants are produced by CI engines. Finding renewable fuels for diesel engines is therefore crucial due to the negative effects of using fossil fuels[6]. It is thought that biodiesel is a benign, and cheap that may be recycled and utilized straight into diesel engines without needing modification [7]. Numerous studies have demonstrated that supplementing biodiesel with metal powder supplement can boost and improve engine output and lower NO_x emissions[8]. It has been discovered via numerous studies that viscosity, fire point, and other characteristics of the fuels are increased by adding nanoparticles [9]. Materials such as ceramic, metallic, and polymeric materials make up many nanoparticles. Metal oxides are the most prevalent types of nanoparticles[10]. It is observed that When Al₂O₃ and CeO₂ nanoelements are added to physic nut biofuel, Diesel engine's exhausts are reduced, performance is raised[11]. The emissions and performance of an IC engine powered by biodiesel from waste cooking oil were studied by with the inclusion of

nanoparticles of alumina [12]. When nanoparticles are incorporated to blends, they saw a raise in emissions of NO_x by 44%, but a decrease in Carbon monoxide and hydrocarbon emissions of 3 & 21%. BTE & EGT raised by 11% & 6%. It is observed that effects of adding CeO₂ nanoelements to rice bran biodiesel blends on emission parameters of an IC engine. The CeO₂ nanoparticle, they saw, decreased emissions & simultaneously improving engine performance [13]. Magnesium oxide can be utilized to raise cetane number for better burning and oxygenate mixes of diesel and water melon seed oil biodiesel.[14]. Transesterification process was used to esterify camelina and lemongrass oil. The findings demonstrated that the combination of BHT and camelina and lemongrass oils increased BTHE and SFC[15]. The primary goals of the current study. **i)** Investigating the viability of producing and characterizing Pithecellobium Dulce seed biodiesel. **ii)** Identifying essential characteristics **iii)** Analyzing emissions and performance of an IC engine with different biodiesel blends with addition of alumina nanoparticles.

1.1 Need of alternative fuels

The following are the list of need for alternative fuels.

- Declining conventional fuel reserves
- To lesser pollutants in the environment
- The cost of fossil fuels increases daily
- Fulfilling the world's present energy needs

1.2 Merits of Biodiesel

The following are the merits of biodiesel

- Renewable fuel made from animal or vegetable fats.
- Less harmful than diesel fuel, in terms of comparison.
- Reducing the amount of spilled biofuel.
- Decreased aldehyde, particulate matter, and carbon monoxide emissions.
- A lower risk to health as a result of less carcinogenic chemical emissions.
- No emissions of Sulphur dioxide (SO₂).
- Greater flash point (minimum 100°C).

1.3 Disadvantages of the use of biodiesel

It is important to keep in mind the following drawbacks while substituting diesel fuel with biodiesel. Because of low calorific value, the fuel consumption is high in biodiesel.

- Higher freezing point than diesel fuel; slightly higher emissions of nitrous oxide (NO_x).
- When utilized in their pure form, plastic and natural rubber gaskets may deteriorate; in this instance, Teflon components should be used instead.
- It dissolves silt and other pollutant deposits from diesel in reservoir & fuel passages. These deposits subsequently entered into the engine by the biodiesel, which causes issues in injection systems & valves. Therefore, it is advised to clean tanks before adding biodiesel to them. It should be mentioned that when biodiesel is blended with diesel fuel, these drawbacks are much diminished.
- Biodiesel production may not always be economically viable, especially when crude oil prices are low. Subsidies or incentives may be required to make biodiesel competitive with conventional diesel fuel.

1.4 Raw materials for biodiesel preparation

Vegetable oils, animal fats, and short-chain alcohols are the raw materials used to make biodiesel. The most common oils used in the production of biodiesel worldwide are rapeseed (primarily in the countries of the European Union), soybean (Argentina and the United States of America), palm (Asian and Central American countries), and sunflower (although other oils, such as peanut, linseed, safflower, used vegetable oils, and animal fats, are also used). While ethanol can also be used, methanol is the most commonly utilized alcohol. The use of non-edible vegetable oils has been researched for a number of years with positive outcomes, since cost is the primary problem in the manufacturing and selling of biodiesel (mostly because of oil prices).

1.5 Various Materials used for preparation of biodiesel:

The materials used for preparation of biodiesel as given below,

1.5.1 Rapeseed:

Rapeseed can thrive on soils with high sulphur content but low fertility. Due to its high oil output (40–50%), double cultivation and crop rotation are possible when growing it as a winter cover crop. But in several Central and South American nations, there were technological barriers to seeding and harvesting. This was mostly because there was insufficient knowledge about fertilizing, processing, and storing seeds (which are tiny and call for specialized farming equipment). Its use has also been restricted by low prices relative to wheat, which is its primary crop rotation rival, and low yield per unit area. When compared to soybean flour, rapeseed flour has a higher nutritional value and is utilized as an additional source of protein in cattle feed.



Fig: 1.1 Rapeseed plant with seeds.

1.5.2 Soybean:

This legume has its origins in East Asia. The plants vary greatly in height according to genetic variants and environmental factors. China, India, Brazil, Argentina, and the United States are the top producers of soybeans. In addition to glycerine, soybeans used in the manufacturing of biodiesel also provide important byproducts such as soybean meal, pellets, and flour (which contain a high amount of the protein lecithin). The production of grains varies from 2,000 to 4,000 kg/hectare. The seeds have about 18% oil content since they are high in protein.



Fig: 1.2 Soyabean with seeds

1.5.3 Sunflower:

The "seeds" of sunflowers are actually the husk which is inedible of the sunflower seed. In terms of flavor, taste, and nutritional value, it is well appreciated. Moreover, the leftover cake is fed to animals after the oil is extracted. Sunflowers are a crop that may be rotated with soybeans and maize because they are hardy and don't require specialist equipment for farming. The present hybrids have an oil production between 48 and 52%.



Fig: 1.3 Sunflower with seeds

1.5.4 Castor Seed:

The castor oil plant cannot withstand frost; it thrives best in tropical settings with temperatures between 20 and 30 degrees Celsius. It is crucial to remember that the temperature cannot drop below 12°C once the seeds begin to germinate. This grows well in variety soil types but needs lots of sunlight. This requires rainy weather annually, even though it is drought-tolerant. 90% of castor oil is made up mostly of ricinolein acid, which is a triglyceride. Compared to other vegetable oils, it is remarkably polar due to the hydroxyl groups that are present in its molecules.



Fig: 1.4 Castor seeds

1.55 Jatropha:

The shrub jatropha is well-suited to dry climates. The most popular type, jatropha caracas, needs little water or extra attention and is well for warm climates with low fertility. Strong winds or erratic rains during the flowering season can also diminish productivity. Climate, soil, rainfall, and practices used while planting and harvesting all affect yield. Jatropha plants have a four- to five-year reproductive cycle and a 50-year lifetime. The extraction process determines the oil yield, which ranges from 26-32% when employing presses to up to 52% when using solvent extraction. Jatropha oil is inedible due to the toxicity of its seeds. The presence of jatrohic acid, which is just as deadly as ricin, and curcasin, a globulin, is what causes the toxicity.



Fig: 1.5 Jatropha seeds

1.56 Pithecellobium dulce:

It is also known by the popular names "Manila tamarind, Madras thorn, monkeypod tree, or camachile." Monkeypod is another name for it that is occasionally used, while Samanea saman is also referred to by that name. Due to the Manila galleons, this invasive species has become widely naturalized in the Philippines & Guam. Pithecellobium dulce was first discovered in Mexico and subsequently spread to America, Central Asia, and India. Despite knowing that these trees are common along Indian highways, no one was aware of their culinary application. It's commonly referred to as Manila Tamarind and looks like tamarind. It is an organic, caustic fruit that is generally used for cooking and other experimental applications.



Fig: 1.6 Pithecellobium dulce

CHAPTER-2

LITERATURE SURVEY

Jaya Prabakar Jayaraman, M. Karthik et al. (2020): examined how well a CI engine runs on a B20 blend of Manilkara zapota seed oil biodiesel. Examined are the engine's emissions and performance when using this blend both with and without blended titanium oxide nano additions. The combined impact of additives and EGR on performance is assessed using 15% EGR. B20 + 50 + EGR and B20 + 100 + EGR blends yield higher brake thermal efficiency values, according to the test results. The engine used fewer of the three blends that were evaluated, B20 + 50 + EGR. Blends of B20 + 50 + EGR and B20 + 75 + EGR claim lower NOX emissions. These combos have higher carbon emissions. To improve emissions & performance, blend B20 can first be used to run an IC engine with including of TiO₂ nanoelements and an EGR.

Imtiyaz ul Islam Laskar, Kaushik Dey et al. (2020) studied by utilizing Pig fat oil in this work as a biodiesel production substrate. The generated biodiesel's B20 blend was tested. As fuel additives, TiO₂ particles were included in the mixture. Up to ppm of 150 of blend, the engine's efficiency was improved by using TiO₂ nanoelements. 200-ppm blend exhibits lower NOx emissions and lower BSFC values than the other blends. Increasing additives has also resulted in somewhat lower numbers for carbon emissions. Good characteristics obtained by using biodiesel blends that have been developed.

Tayfun Ozgura, Mustafa Ozcanli et al. (2019) looked at MgO and SiO₂, two distinct nanoparticle additions, were added to the biodiesel at dosages of 25 and 50 parts per millilitres. Examined were the changed fuels' fuel qualities, engine performance, and exhaust characteristics. The findings involve including nanoparticle additives reduced emissions while marginally increasing performance Values.

Lakshmi Sankar S, Ganesan S et al. (2021) studied that, melon seed oils were extracted with a high output of 82.2%. After extracting oil and checking its consistency, the methyl esters were trans esterified. Transesterification process with enzymes was utilized in create biodiesel which helps with a number of problems by using the lipase enzyme. Five bio samples were generated using varying blend ratios. Test was conducted & several emissions and performance was discovered.

Syed Javed, V. Satyanarayana Murthy et al. (2016) studied that Metal-borne fuel additives can be used to lower emissions. Thus, research was done to find out how fuel additives made of nano-metallic oxides affected the main physicochemical characteristics and output jatropa biodiesel blends diesel engine. After decreasing FFA to 2% & completing transesterification jatropa methyl ester (JME) is formed. In main fuel of JME biodiesel, ZnO nanoparticles were suspended at a concentration of 100 ppm. Nitrogen oxide emissions were decreased in gasoline mixes with nanoparticles. Rising H₂ flowrate, the effects of size and concentration were, however, negligible. Hydrocarbon (HC) emissions rose for 40 nm nanoparticles but fell for 20 nm nanoparticles with an increase in H₂ flow rate. The surfactant Triton-X100 was present, which caused the smoke opacity to rise as compared to pure biodiesel.

Abbas Alli Taghi poor Bafghi, Hosein Bakhoda et al. (2015) studied the cerium oxide effect in emissions & performance added to clean blends of biodiesel & diesel. Following a series of tests, it was discovered that the mixes that were stabilized with an ultrasonic bath after high-speed blending had better stability. Cerium oxide supplies oxygen for burning by functioning as a catalyst that donates oxygen. Reduced HC emissions are the result of energy of activation of cerium oxide particles, which acts to eliminate carbon. According to the research, cerium oxide nanoparticles can be added to blends of biodiesel & diesel blends to greatly increase fuel's ability to burn completely.

CHAPTER-3

AIM AND SCOPE

3.1 AIM:

The "Influence of alumina nanoparticles on performance and emission characteristics of biodiesel from *Pithecellobium dulce* seed oil" project aims to conduct experimental studies to assess different traits in various scenario as well as to investigate impact of alumina nanoelements as a supplement in biofuel from *Pithecellobium dulce* seed oil. The supplement of Al_2O_3 nanoelements in blends in VCR diesel engine will increase fuel efficiency, decrease exhaust emissions, and enhance engine performance. Furthermore, the VCR diesel engine's dual fuel (diesel-biodiesel) technology aims to lessen dependence on underground fuels promote a good energy life. The study will investigate how engine performance characteristics such as BTE, BSFC, EGT and emissions such as HC, Carbon monoxide, NO_x , CO_2 & smoke opacity affected by diesel& biofuel blends. Main project primary objective is to assess the viability and possible advantages of utilizing dual fuel and Al_2O_3 nanoparticles in VCR diesel engines, offering insights into their potential use for a cleaner and more sustainable energy future.

3.2 SCOPE:

The following are the list of the project scope.

- Examine the feasibility of using different feedstocks as a source for biodiesel production. This could encompass examining their availability and sustainability as well as analyzing their physical and chemical characteristics.
- Production of biodiesel: Create and enhance processes for turning a variety of feedstocks into biodiesel. This could involve looking at various processing methods and assessing the effectiveness and behaviour in environment.
- Emissions and Performance: Examine how utilizing biodiesel affects emissions and performance of engine by adding alumina nanoelements as additive. This might involve testing engines, examining the properties of various biodiesel blends' combustion, assessing the emissions of certain pollutants and greenhouse gasses, and more.

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

CHAPTER-4

MATERIALS AND EXPERIMENTAL METHODS

4.1 Methodology

The following methodology is used in this project

Step-01: Problem Identification

Step-02: Literature survey

Step-03: Selection of plant for making biodiesel

Step-04: Collection of seeds from plant.

Step-05: Extraction of oil from seeds by various methods.

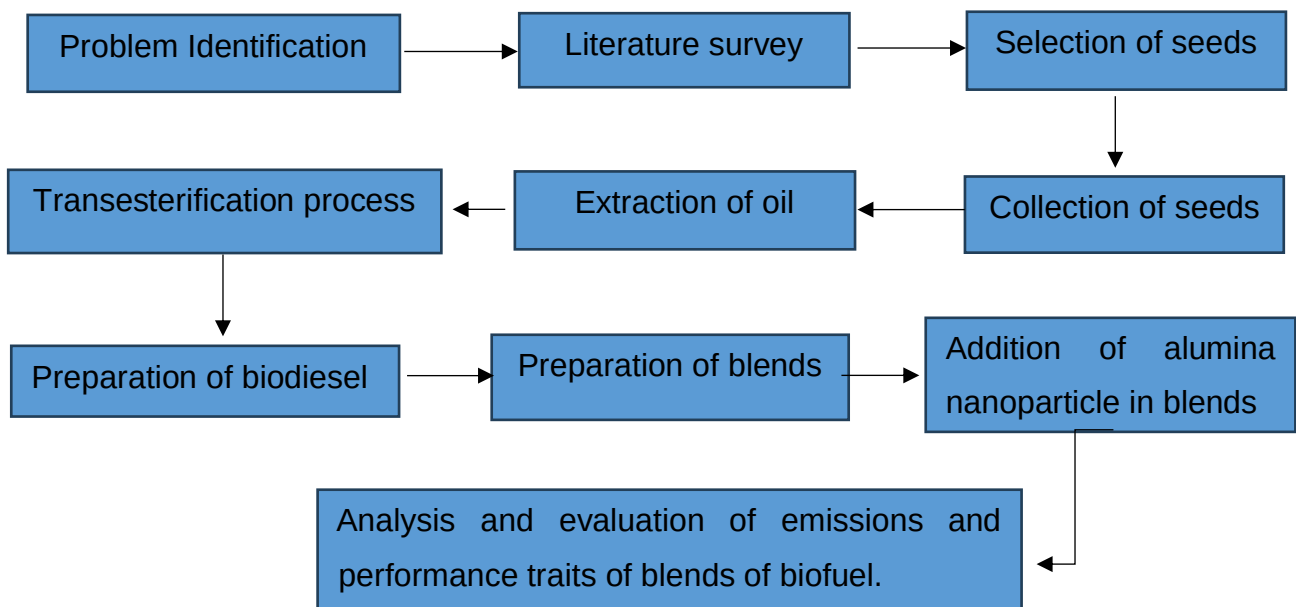
Step-06: Preparation of biodiesel from oil by transesterification process.

Step-07: Preparation of biodiesel- diesel blends

Step-09: Addition of nanoparticle on biodiesel- diesel blends

Step-10: Analysis and asses the emissions and performance traits of blends of biofuel.

Flowchart



4.2 Materials and processes used

Here *Pithecellobium dulce* seed is used as substrate to making inoculum.

- The first step is to collection of seeds from various resources such as markets, villages, trees etc.
- The second step involves extraction of oil by various methods such as saponification methods etc.
- The third step involves making biodiesel by transesterification or esterification process

4.2.1 Seed collection

P. Dulce was first discovered in Mexico and subsequently spread to America, Central Asia, and India. Despite knowing that these trees are common along Indian highways, no one was aware of their culinary application. It's commonly referred to as Manila Tamarind and looks like tamarind. It is an organic, caustic fruit that is generally used for cooking and other experimental applications[16].



Fig: 4.1 Pithecellobium dulce seeds

4.2.2 Extraction of oil

Methanol and NaOH were used in this process which is obtained from the International Research Centre, Sathyabama University. First, distilled water was used to wash the P. Dulce seeds after the bad ones were screened out. For a week, the cleaned seeds were left to dry in the sun. After that, Crushing and dehulling of seeds takes place. Lastly, before oil extracted, the powdered seeds were kept dry in plastic bags[17]. The technique of hexane-aided immersion is utilized to extract oil. Procedure for extraction of oil from seeds is shown. i) A round-bottom flask containing 300 g of seed powder was filled with hexane in a 1:2 ratio and put at room temperature for eight hours and mix at speed of 700 revolutions per minute. ii) Following filtrate extraction, hexane is recovered using distillation at 343K. The filtrate is then collected.iii) Lastly, oil extracted with a yield of 27% [18].



Fig: 4.2 Pithecellobium dulce seed oil

4.2.3 Transesterification

It involves the following two steps,

- Calculating (or) Checking the “Free Fatty Acid (FFA)” value.
- If FFA value is less than or equal to 4%, transesterification. Otherwise, Esterification process.

Step 1: Calculation of Free Fatty Acid Content (FFA)

- Take 5 grams of Pithecellobium dulce seed oil.
- Add 25ml of “Isopropyl alcohol”.
- Add 4 drops of “0.1 Normality of Sodium Hydroxide (NaOH)”.
- Now heat the entire mixture at 60°C and quench it.
- Give drop of 2 “Phenolphthalein Indicator” and adjust against 10%N of NaOH
- Titrate it until the “Pink colour” appearance come. Take this as end point.

Formula

Free Fatty Acid % = $\frac{\text{Oleic acid molecular weight} \times \text{Normality of NaOH} \times \text{Burette reading}}{\text{Weight of sample}} \times 100$

Oleic acid Molecular weight= 28.2gm

Normality of NaOH= 0.1N

Burette reading (From Experiment) = 1.2ml, Weight of sample= 5.03gms.

% of FFA= $\frac{28.2 \times 0.1 \times 1.2}{5.03} \times 100 = 1.5 < 4$.

So, transesterification process takes place.

Step 2: Transesterification

The substrate oil has a FFA content 1.4%. Oil must be pretreated to reduce the amount of FFA if the FFA value is more than 4%. However, in the current investigation, the transesterification mechanism directly uses the P. Dulce seed oil to create biodiesel because the FFA value is less than 4%[19]. The Centre for Waste Management of the International Research Centre, Sathyabama University, Chennai, Tamil Nadu, conducted a small-scale transesterification procedure. A beaker filled by 0.5L P. Dulce seed inoculum after it was measured [20]. After preheating the P. Dulce seed oil to 60°C, 0.15L CH₃OH and 0.005g of sodium hydroxide solution containing a ratio of 1:4 was added. Wait for 1.5 hrs at 600 rpm. The reacted substance after 90 minutes, was left 2 hours to settle. The substance was separated into layer of two within allotted time, glycerine was formed in down and biofuel in upper side[21]. The separating funnel's cock is released to remove the glycerine. Following the glycerine separation process, soap particles, entrained glycerine, excess methanol, and catalyst eliminated from biodiesel by using demineralized water at (70 °C). It is warmed to roughly 373K in an oven. The resultant biodiesel was obtained with a golden yellow colour.



Fig: 4.3 Biodiesel from Pithecellobium dulce seed oil

4.2.4 Purification of biodiesel

The separated biodiesel is further purified to remove any remaining impurities, such as soap and catalyst residues. This is typically done through a series of filtration steps.

- Washing: Separated biodiesel is cleanse with water.
- Drying: Cleansed biodiesel dried to eliminate any residual water that may be present in the biofuel.



Fig: 4.4 Washing and drying of biodiesel

Table 4.1 Transesterification process parameters

S. No	Factors	Values
1	FFA	1.4 %
2	Sodium Hydroxide	0.005kg
3	Ratio of methanol and oil	4:1
4	Working Temperature	333K
5	Period	1.5Hrs
6	Output	89.23 %

Table 4.2 Biodiesel properties

S.no	Properties	Unit	Value	Standards in ASTM
1.	Relative Density at 288K	-	.870	ASTM-D1298
2.	viscosity at 313K	sqmm/s	2.14	ASTM-D445
3.	Flash point	°C	142	ASTM-D93
4.	Density	g/cc	0.861	ASTM-D4052
5.	Fire-point	K	424	ASTM-D93
6.	Calorific value	Cal/g	7881.23	ASTM-D240
7.	Cloud-point	K	279	ASTM-D2500
8.	Pour-point	K	265	ASTM-D97
9.	Content of Ash	Mass %	.015	ASTM-D129
10.	Cetane index	-	68	ASTM-D976

4.2.5 Preparation of Biodiesel diesel blends

The following is a detailed method for preparing 500ml of biodiesel into blends of B10, B20 and B30.

Materials& Equipment

- 500 ml of biodiesel
- commercial diesel
- Gradient cylinder or measuring cup
- Container for mixing
- Stirring stick or blending implement
- Funnel

Procedure

➤ Measure Biodiesel:

To measure 500ml of biodiesel precisely, use a graduated cylinder or measuring container.

➤ Find the Blend Ratios:

B10: 0.45L of diesel and 0.05L of biodiesel.

B20: 0.5L of diesel and 0.1L of biodiesel

B30: 0.35L of diesel and 0.15L of biodiesel

➤ Measurement of Traditional Diesel:

Based on the blend ratio, calculate how much conventional diesel is needed.

Adjust based on the selected blend:

0.45L of diesel for B10.

0.4L of diesel for B20.

0.35L of diesel for B30.



Fig: 4.5 B10, B20 and B30 blends of biodiesel

4.2.6 Alumina Nanoparticles

Alumina nanoparticles were purchased from "Sigma Alrich Private Limited." Heat exchangers often use nanoparticles of Al_2O_3 to improve heat transfer. In order to enhance combustion, it is also added to fuel. Heat transmission between fuel droplets is accelerated by it because of its increased thermal conductivity. Al_2O_3 nanoparticles utilized as supplement in biofuel engines, as demonstrated by number of published studies[22]. Alumina nanoparticles of quantity 50ppm are measured and added to biodiesel blends with the help of ultra sonication process by sonicator.

Table 4.3 Alumina Nanoparticles properties

Characteristics	Details
Name	Alumina
Molar weight	0.102kg/mol
Mean size (diameter)	$50 \times 10^{-9}\text{m}$
Appearance	White
Area of Surface	$31500\text{m}^2/\text{kg}$
Pureness	98.9%



Fig: 4.6 Sonicator for mixing alumina nanoparticles with biodiesel blends

CHAPTER-5

EXPERIMENTAL SETUP

5.1 VCR Diesel Engine

Internal combustion engines having a variable compression ratio are known as VCR (variable compression ratio) diesel engines. CR is defined as the ratio of the addition of swept and clearance volume to clearance volume. Diesel engine efficiency and power production are significantly influenced by CR of the engine.

The compression ratio can be changed by changing the distance between the piston and the cylinder head. This is accomplished by using a movable piston pin, which has the ability to change the connecting rod's length from the piston to the crankshaft. A high compression ratio makes the engine more efficient and produces more power from the same amount of fuel. However, when the air-fuel mixture ignites too soon and destroys the engine, high compression ratios can cause pounding or detonation. Although they can reduce the chance of knocking, lower compression ratios can reduce the engine's output and efficiency.

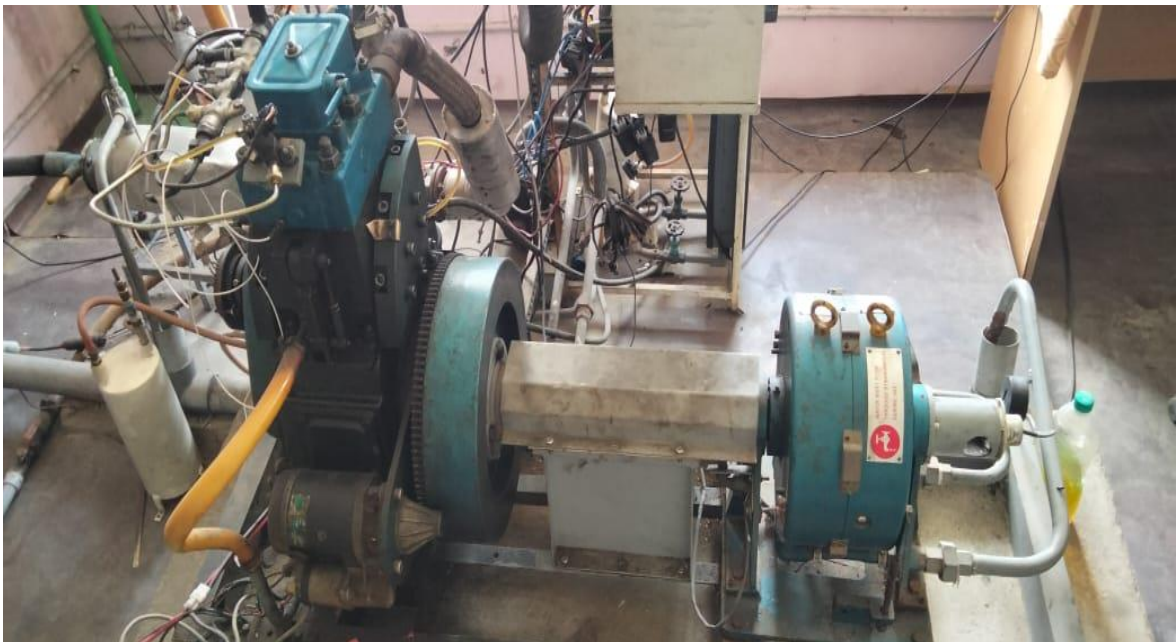


Fig: 5.1 VCR engine for testing

5.1.1 VCR Engine Specification

Table 5.1 VCR engine specifications

Product	VCR Engine test setup 1 cylinder, 4 stroke, Diesel with EGR (Comp.)
Product code	234
Engine	Make Kirloskar, Type 1, 4 stroke Diesel, water cooled, power 3.5kW at 1500rpm, stroke 110mm, bore 87.5mm. 661cc, CR17.5, Modified to VCR engine CR 12 to 18. With electric start arrangement, battery, and charger
Dynamometer	Type eddy current, water cooled,
Air box	Mild steel fabricated with orifice meter and manometer
Fuel tank	Capacity 15 lit with glass fuel metering column
Calorimeter	Type Pipe in pipe
EGR	Water cooled, SS, Range 0-15%
Piezo sensor	Range 5000 PSI, with low noise cable
Crank angle sensor	Resolution 1 Deg, Speed 5500 RPM with TDC pulse.
Data acquisition device	NI USB-6210, 16-bit, 250kS/s.
Piezo powering unit	Model AX-409.
Temperature sensor	Type RTD, PT100 and Thermocouple, Type K
Temperature transmitter	RTD PT100, Range 0–100°C, 3 Nos; Thermocouple, Range 0-1200 °C, 2 Nos
Load indicator	Digital, Range 0-50 Kg, Supply 230VAC
Load sensor	Load cell, type strain gauge, range 0-50 Kg
Fuel flow transmitter	DP transmitter, Range 0-500 mm WC
Air flow transmitter	Pressure transmitter, Range (-) 250 mm WC
Rotameter	Engine cooling 40-400 LPH; Calorimeter 25-250 LPH
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

One kind of internal combustion engine that has a variable CR is the engine Variable ratio of compression. This ratio will be changed while the IC engine running maximize performance under different driving conditions. Below is a detailed explanation of the VCR diesel engine arrangement:

- **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.
- **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 straight motion into the crankshaft's circular motion.
- **Cylinder head:** The combustion chamber, intake and exhaust valves, fuel injectors, and spark plugs (in gasoline engines) are all housed in the cylinder head. Typically, the cylinder head is constructed of aluminium alloy
- **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.
- **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.
- **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.
- **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.
- **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.

5.2 Gas Analyzer

A Gas analyzer is device that measures the composition of exhaust gases produced by a combustion engine. These analyzers are used to evaluate the gases in the discharge. Here's a more in-depth explanation of the Gas analyzer:

- **Sampling System:** 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 gases concentration in the discharge & generates a comprehensive report on the exhaust gas composition. The measuring system is made up of several sensors, detectors, and electronic circuits.
- **Sensors:** Sensors are in charge of detecting the gases in the discharge. 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. The analyzer is calibrated with this gas before and after each usage to ensure accurate readings.
- **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.



Fig: 5.2 AVL gas analyser

5.2.1 Gas Analyzer Specification

Table 5.2 Specifications of Gas analyser

Supplier	SMS Autoline Equipment 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 Analyzer Working Principle

The gas analyser working 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, evaluate different gases concentration. The analyzer unit typically consists of various sensors and detectors that are designed to detect specific gases.
- **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. 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 composition of discharge gas.

Overall, gas analyser 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 is utilized to lower emissions, and increase performance of IC engine ensures compliance with environmental regulations.

5.3 Smoke opacity meter



Fig: 5.3 AVL smoke opacity meter

A smoke opacity meter helps to evaluate the amount of smoke emissions 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 discharge gas, which is nothing but particulate matter in 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 discharge gas, which is drawn and sent to smoke meter.
- **Analysis of Gas Opacity:** Once the exhaust gas sample reaches the smoke meter, it is analysed 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.
- **Calculation of Smoke Density:** The smoke opacity of gas is converted into smoke density measurand using calibration curve. The calibration curve is calculated based on opacity of standard concentration of smoke in the exhaust stream.

- **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. 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.

Table 5.3 AVL smoke Opacity meter specifications

Types	AVL437 Smoke meter
Make	Mars Technologies inc
Range	0-100 HSU
Temperature of smoke	2500 C(degrees)
Temperature	0-60°C
Moisture	95% during 60°C
Power in kW	205 Ampers, 11.5-36Volts, 4.8kW Direct current

5.4 Schematic diagram of Project Setup:

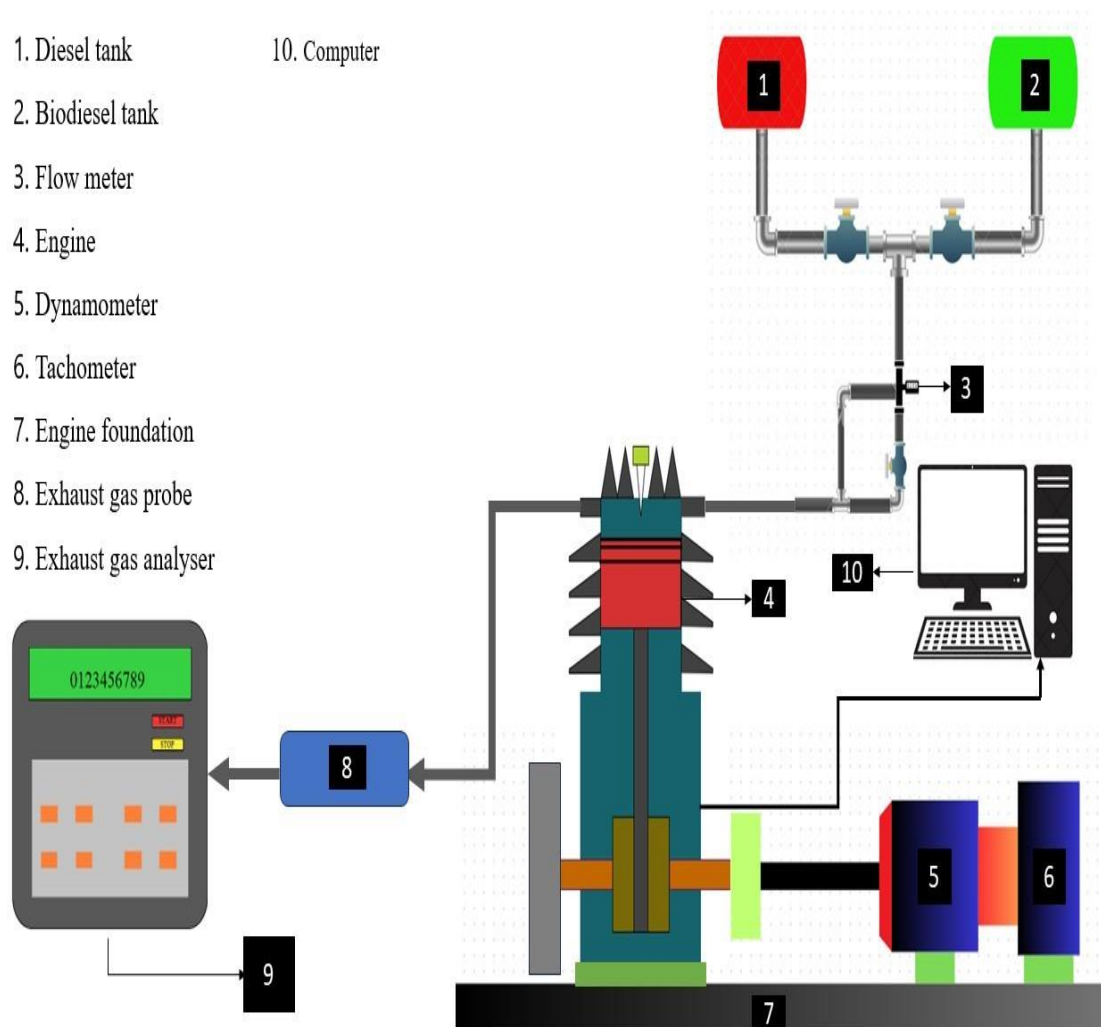


Fig: 5.4 Schematic diagram of Project Setup

CHAPTER 6

RESULTS AND DISCUSSIONS

6.1 Performance characteristics

Performance characteristics are the characteristics that characterized the engine behavior in speed-load conditions. The various performance characteristics are BSFC, BTE & EGT against BP.

6.1.1 Brake Specific Fuel Consumption

The brake specific fuel consumption (BSFC) is the total fuel amount burn by an IC engine. BSFC is calculated by dividing the mass flow rate of fuel into the engine over a defined time by the engine's power output over the same period[23]. The unit of BSFC is g/kWh. Comparison between load and BSFC is a crucial criterion for evaluating engine performance. When the load increases, BSFC often drops. The primary variables controlling the BSFC need of diesel engines are calorific value, density and viscosity [24]. In any type of engine the BSFC value is always low. The BSFC of diesel & biodiesel blends are in table 6.1.

Table 6.1 BSFC values of diesel & biodiesel blends

BP (kW)	B10+Al ₂ O ₃ 50ppm	B20+Al ₂ O ₃ 50ppm	B30+Al ₂ O ₃ 50ppm	DIESEL
0.18	1.12	1.13	0.85	2.48
0.99	0.45	0.55	0.52	0.52
1.78	0.36	0.37	0.37	0.38
2.51	0.28	0.32	0.32	0.2

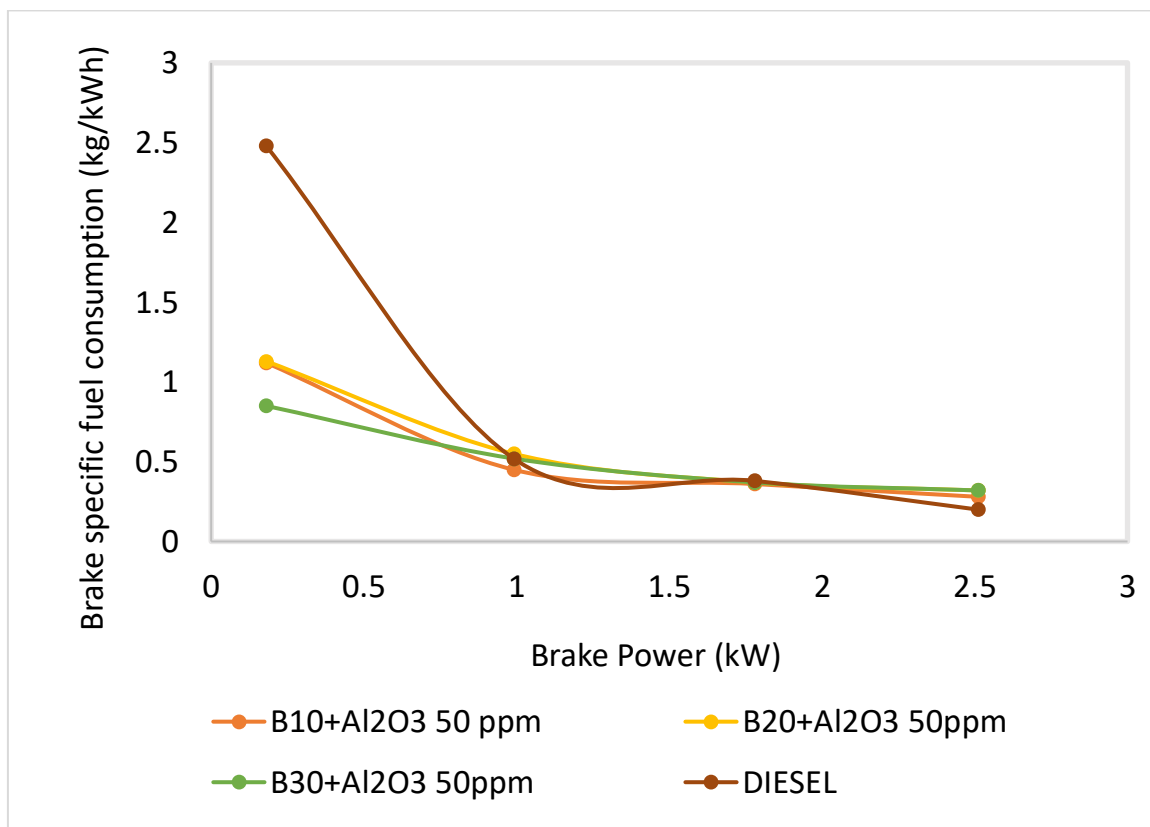


Fig 6.1 BSFC of diesel & biodiesel blends against BP

In fig 6.1 it is found that when all biodiesel blends are compared, sample B10 + Al₂O₃ 50 ppm has less BSFC at high brake power, while sample B30 + Al₂O₃ 50ppm has the highest specific fuel consumption. The value of B20 + Al₂O₃ 50ppm and B30 + Al₂O₃ 50ppm are nearly identical. When all factors considered, diesel has the lowest BSFC value of any biodiesel mixture. This could be because of the biodiesel samples' potentially lower energy content than diesel. Sample B10 + Al₂O₃ 50 ppm has the best BSFC value among the samples we prepared, and several of the BSFC values are really similar to the diesel BSFC values.

6.1.2 Brake thermal efficiency (BTE)

BTE stands for Brake Thermal Efficiency is nothing but measurement used to measure conversion of thermal energy of fuel into useful mechanical effort by an engine. BTE is used for evaluation of the behaviour of IC engines, including gasoline and diesel engines[25]. The useful work is divided by energy from fuel to get BTE. Reducing greenhouse gas emissions and improving the fuel efficiency of internal combustion engines both depend on improving BTE[26].

Table 6.2 BTE of diesel & Biodiesel blends

BP (KW)	B10+ Al ₂ O ₃ 50ppm	B20+ Al ₂ O ₃ 50ppm	B30+ Al ₂ O ₃ 50ppm	DIESEL
0.18	7.2	7.62	10.04	2.45
0.99	10.1	13.5	16.57	16.49
1.78	20.3	21.8	22.5	23.42
2.51	25	27.01	30.88	32.59

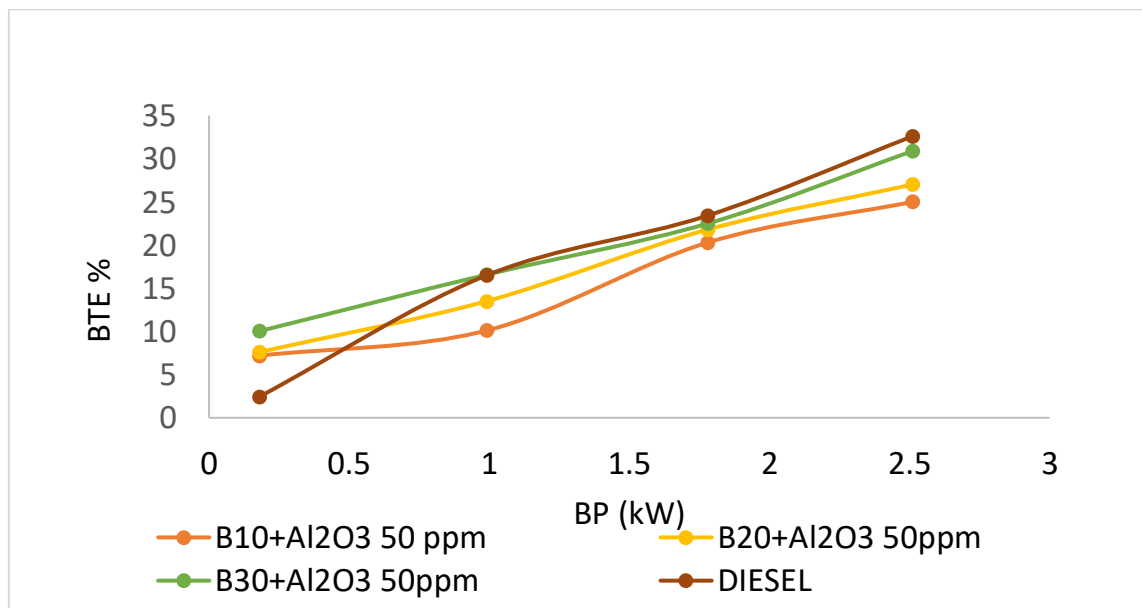


Fig: 6.2 BTE of diesel & Biodiesel blends against BP

In fig 6.2 out of all other biodiesel blends, sample B30 + Al₂O₃ 50ppm has the highest BTE in a maximum brake power, But the sample B10 + Al₂O₃ 50 ppm has the lowest BTE. The findings demonstrate that adding Al₂O₃ to the biodiesel increases the diesel engine's braking thermal efficiency. In comparison to the basic fuel, the fuel's Al₂O₃ nanoparticle encourages a longer and more efficient combustion since it functions as an oxygen buffer, increasing efficiency[27]. Nevertheless, of all the biodiesel mixes, diesel has the highest BTE value. This is due to the possibility that the biodiesel samples have a larger density than the diesel samples. This reduces biodiesel's BTE. Sample B30 + Al₂O₃ 50ppm has the best BTE value out of all the samples we developed, and some of the BTE values are more identical to diesel.

6.1.3 Exhaust Gas Temperature

The utilization of thermal energy efficiently in engine is represented by the exhaust gas temperature (EGT). The amount of thermal energy converted to good work is diminished by loss of heat in the discharge pipe or raising of temperature in discharge. Elevated EGT readings explained that the machine is not using as much thermal energy, which translates to decreased thermal efficiency[28]. The EGT values make it clear that the amount of EGT at a given load is simply the reverse value of BTE[29]. Table 6.3 shows EGT against brake power.

Table 6.3 EGT variation against BP

BP (kW)	B10 + Al ₂ O ₃ 50ppm	B20 + Al ₂ O ₃ 50ppm	B30 + Al ₂ O ₃ 50ppm	DIESEL
0.18	89.18	136.35	136.72	86
0.99	161.38	189.82	185.4	157
1.78	225.93	250.15	249.56	222
2.51	276.6	293.85	297.51	273

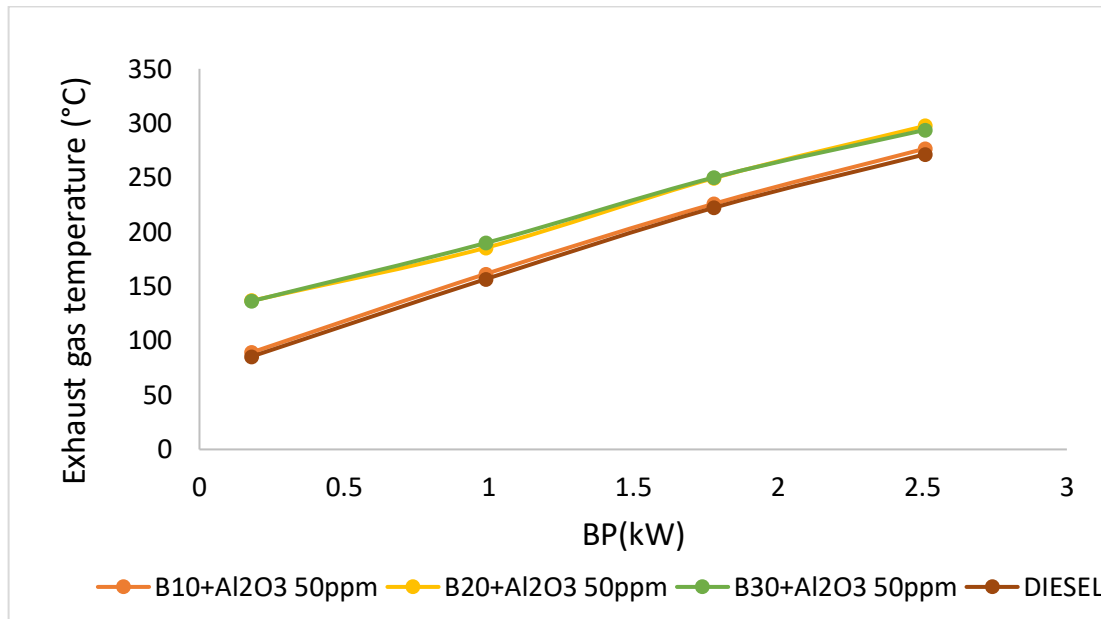


Fig 6.3 EGT variation against BP

In fig 6.3, it is found that EGT of B30 + Al₂O₃ 50ppm has higher than other blends as well as diesel. The reason is reduced volatile nature and increased viscous force resulting in inadequate mixture development. As a result, diffusion combustion is more controlling, extending the heat release process and raising exhaust gas temperature, NO_x emissions, and particulate smoke opacity.

6.2 Emission characteristics

The emissions are the substances that comes from engine exhaust and consists of various gases that are harmful to environment. The major emissions are hydrocarbons, oxides of Nitrogen and smoke opacity, Carbon dioxide, carbon monoxide.

6.2.1 Hydrocarbons

Emissions of hydrocarbons result from incomplete or unburned fuel combustion. Engine hydrocarbon (HC) emissions contribute significantly to air pollution, especially in urban areas. Hydrocarbons, a class of volatile organic compounds (VOCs), are released into the environment after fuel combustion[30]. The three primary sources of hydrocarbon emissions from engines are incomplete fuel combustion, engine exhaust leaks, and fuel evaporation losses. The primary cause of hydrocarbon emissions is incomplete fuel combustion.

Table 6.4 HC emissions of biodiesel blends and diesel

BP (kW)	B10 + Al ₂ O ₃ 50ppm	B20 + Al ₂ O ₃ 50ppm	B30 + Al ₂ O ₃ 50ppm	DIESEL
0.18	1.87	0.93	0.8	2.8
0.99	2.32	1.98	1.74	3.5
1.78	3.1	2.77	2.02	4.2
2.51	4.6	3.84	2.91	5.7

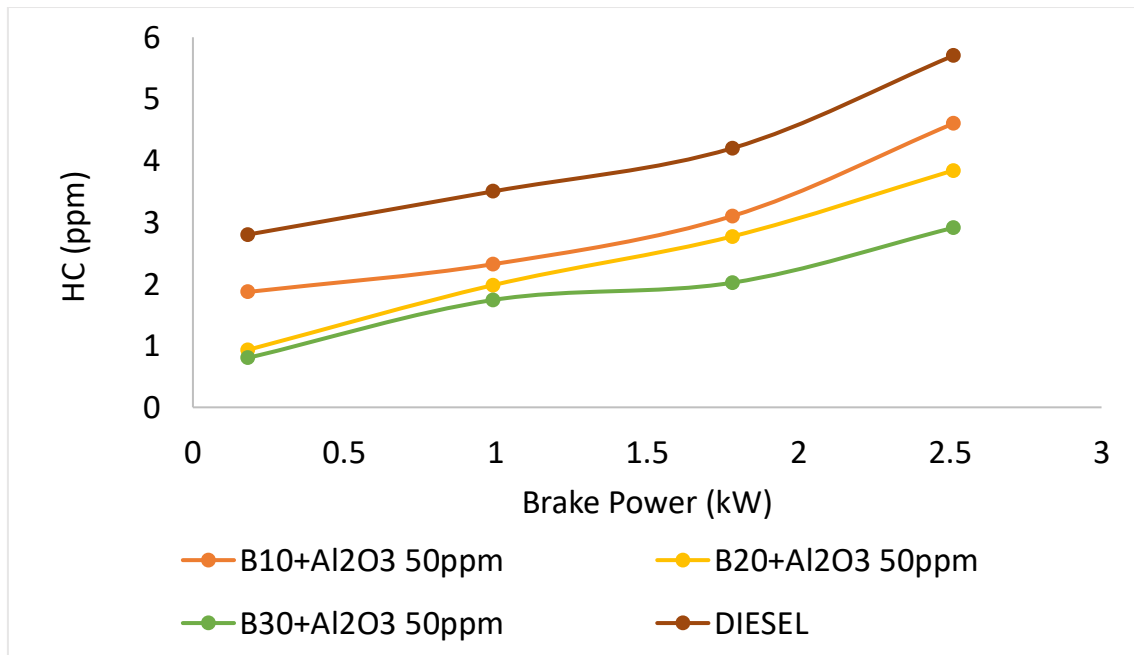


Fig 6.4 HC emissions of diesel & biodiesel blends against BP

In fig 6.4 In the comparison of all the biodiesel samples, sample B10 + Al₂O₃ 50ppm emits more hydrocarbon at maximum load than the other blends, while sample B30 + Al₂O₃ 50ppm emits less hydrocarbon at maximum load. This is because more oxygen in fuel is the reason for reducing process of hydrocarbon emission and complete burning[31]. In B30 + Al₂O₃ 50ppm both biodiesel as well as alumina produce more oxygen which leads to reduction of HC emissions.

6.2.2 Carbon monoxide:

In IC engines, improper fuel burning results in the release of carbon monoxide (CO) emissions. When there is not enough oxygen available for carbon-based fuels to completely oxidize during combustion, carbon monoxide (CO) is created[32]. CO is a dangerous gas that significantly contaminates the air. In addition to contributing to the creation of ground-level ozone, a component of smog, high ambient CO levels can also accelerate climate change by trapping heat in the atmosphere. Table 6.5 shows CO against BP.

Table 6.5 CO emissions of biodiesel blends and diesel

BP (kW)	B10+Al ₂ O ₃ 50ppm	B20+Al ₂ O ₃ 50ppm	B30+Al ₂ O ₃ 50ppm	DIESEL
0.18	0.01	0.031	0.01	0.01
0.99	0.03	0.03	0.02	0.025
1.78	0.03	0.03	0.02	0.04
2.51	0.05	0.04	0.03	0.06

In the table 6.5, It is clear that mixtures of biodiesel and diesel emit less carbon monoxide (CO). Diesel has lower oxygen concentration than biofuel, which is one of the main causes of this. The extra oxygen in biofuel causes to burn completely during burning, which reduces CO emissions[33].

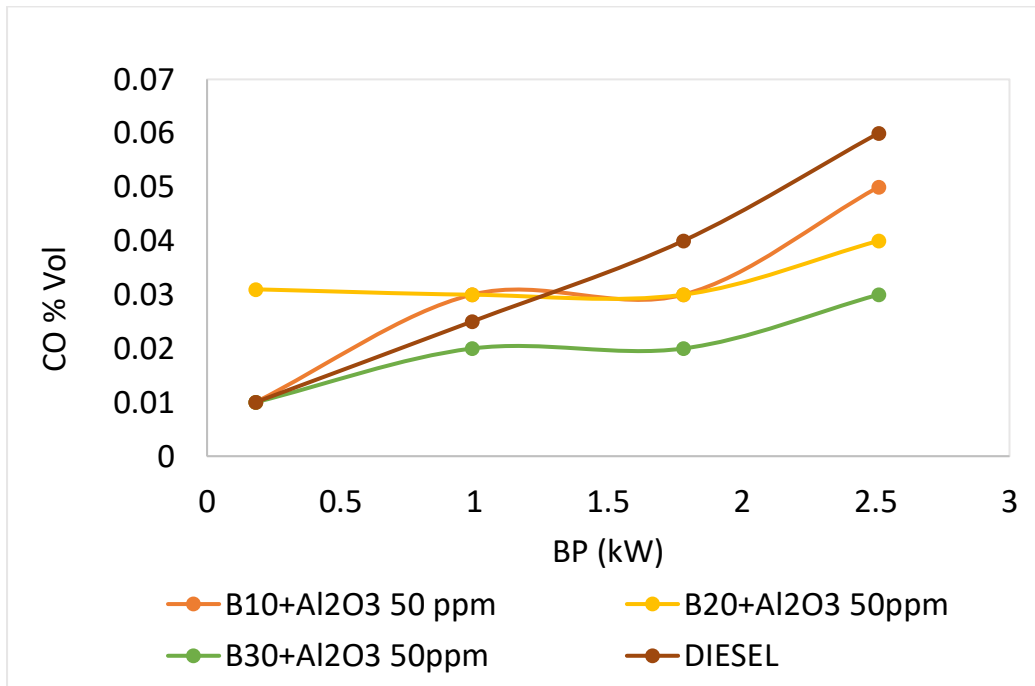


Fig 6.5 CO emissions of diesel& Biodiesel blends against BP

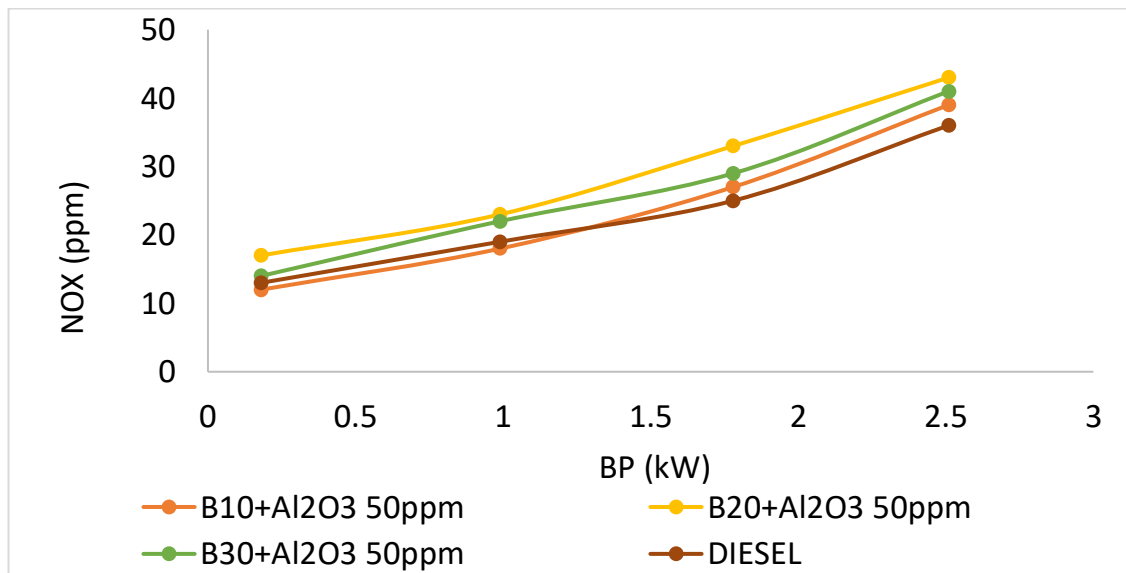
In fig 6.5 Sample B10 + Al₂O₃ 50ppm is by far the best of all the samples we produced; it emits almost half as much CO as diesel, although sample B30 + Al₂O₃ 50ppm produces less CO than the other samples as load increases. This is due to more O₂ in biofuel which supports complete burning and reduce the formation of CO.

6.2.3 Oxides of Nitrogen

Among the main pollutants of air created by combustion processes, such as internal combustion engines, is nitrogen oxide (NO_x) emissions. When fuel is burned at high temperatures, oxygen & Nitrogen in air combine and generate NO and nitrogen dioxide (NO₂) molecules, which make up NO_x. Since NO_x generation is a highly temperature-dependent phenomena, it occurs when the load increases and the combustion chamber's temperature rises[34]. Table 6.6 shows NO_x emissions with respect to brake power.

Table 6.6 NO_x emissions of biodiesel blends & diesel

BP (kW)	B10 + Al ₂ O ₃ 50ppm	B20 + Al ₂ O ₃ 50ppm	B30 + Al ₂ O ₃ 50ppm	DIESEL
0.18	12	14	17	12
0.99	18	22	23	19
1.78	29	29	30	25
2.51	39	41	39	36



. Fig 6.6 NO_x emissions of biodiesel blends and diesel against BP

In fig 6.6 it has been found that NO_x emission from B30 + Al₂O₃ 50ppm is more than that of other blends & diesel as BP increases. The ultimate reason is the more amount of oxygen in biofuel combines with nitrogen produced when engine temperature rises because of an increase in load[35].

6.2.4 Carbon dioxide

One of the main causes of global warming and environmental change is carbon dioxide (CO₂) from engines. Burning fuel in an engine produces CO₂ [36]. Table 6.7 shows CO₂ emissions vs brake power.

Table 1 CO₂ Emissions with BP

BP (kW)	B10+Al ₂ O ₃ 50ppm	B20+Al ₂ O ₃ 50ppm	B30+Al ₂ O ₃ 50ppm	DIESEL
0.18	0.2	0.36	0.2	0.1
0.99	0.5	0.5	0.7	0.8
1.78	0.7	0.7	0.7	0.8
2.51	1	0.9	0.9	1.1

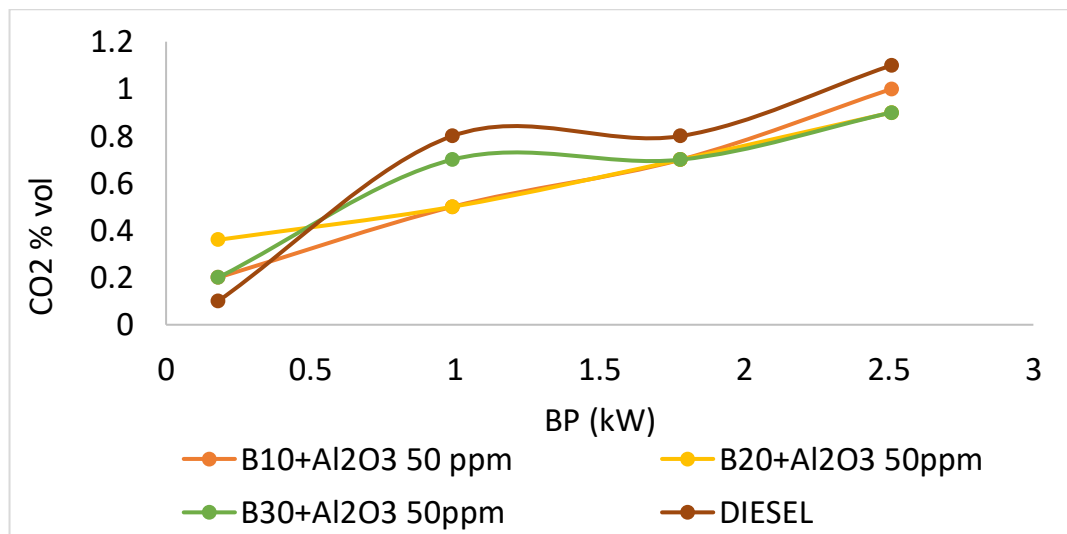


Fig 6.7 CO₂ emissions of diesel & biodiesel blends against BP

From fig 6.7 Sample B30 + Al₂O₃ 50ppm has the lowest CO₂ emission value, which is still less than the emission value of diesel, but Sample B10 + Al₂O₃ 50ppm has more CO₂ emissions than other biodiesel blends as brake power increases. This is because due to oxygen in alumina nanoparticles as well as biodiesel leads to complete combustion which produces more CO₂ emissions.

6.2.5 Smoke Opacity

The amount of smoke that obstructs light is known as smoke opacity, and it is frequently utilized for determining the amount of visible particulate matter in engine exhaust. Because it shows the presence of particulate matter emissions, smoke opacity is an essential parameter when discussing biodiesel and diesel engines[37]. The incomplete combustion of biodiesel or diesel in IC engine can result in the generation of particulate matter, which comprises minute soot and other material particles. It is represented in measures like percentages or parts per million (ppm). Since excessive amounts of particulate matter in exhaust emissions can worsen respiratory health and contribute to air pollution, controlling smoke opacity is crucial for both environmental and health reasons[38]. Table 6.8 shows Smoke opacity to brake power.

Table 6.8 smoke opacity of biodiesel blends and diesel

BP (kW)	B10+Al ₂ O ₃ 50ppm	B20 + Al ₂ O ₃ 50ppm	B30 + Al ₂ O ₃ 50ppm	DIESEL
0.18	15	4.2	3.2	8
0.99	61.3	40.3	41.9	46
1.78	64.3	56.13	46.8	64
2.51	71.03	63.9	56.8	69

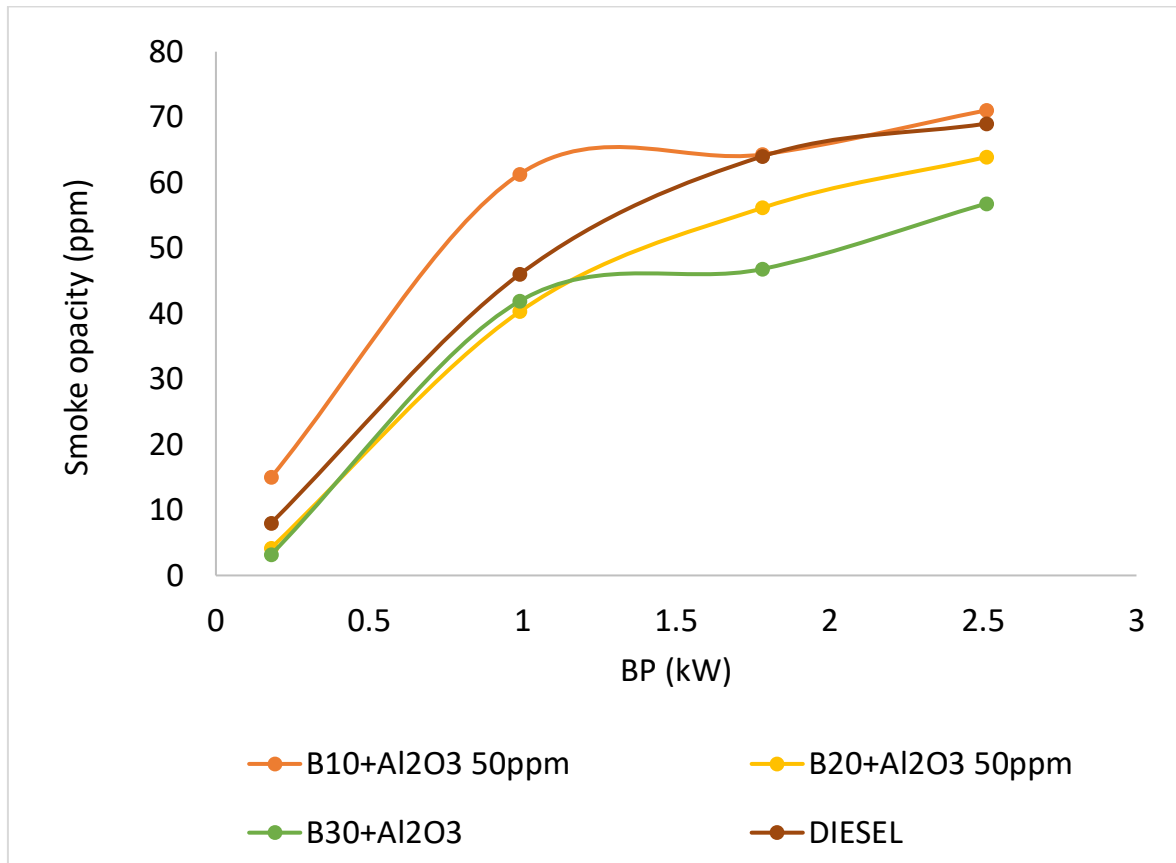


Fig 6.8 smoke opacity of biodiesel blends and diesel against BP

From fig 6.8 Blend B30 + Al₂O₃ 50ppm has a lower smoke than commercial diesel, while blend B10 + Al₂O₃ 50ppm has more smoke than commercial diesel, as can be seen in the Fig 6.8. This is because B30 + Al₂O₃ 50ppm has more oxygen than other blends plus, the more oxygen from alumina which enhancing burning & lowers smoke emissions.

CHAPTER-07

CONCLUSION

We can draw the following findings from the research that was done utilizing alumina nanoparticles combined with biodiesel made from *Pithecellobium dulce* seed oil.

- Sample B10+Al₂O₃50 ppm has less (BSFC) at the high BP when all the biodiesel blends are compared, while sample B30+Al₂O₃50ppm has the highest specific fuel consumption. The BSFC's tendency to decrease and then increase with engine speed is shown to be caused by inadequate fuel atomization and fuel-air mixing. As a result, the BSFC rises at lower engine speeds. Speeding up the engine can improve fuel atomization, speed up fuel mixing, and reduce the BSFC value. However, when the engine speed increased, more fresh air entered the cylinder more frequently, which decreased the cylinder temperature, prevented combustion, and raises BSFC.
- From samples we created, sample B30+Al₂O₃50ppm has the best BTE value. This shows that the diesel engine's braking thermal efficiency is increased when Al₂O₃ is added to the biodiesel. The fuel's Al₂O₃ nanoparticle promotes a longer and more effective burning than the basic fuel because it acts as an oxygen buffer, which boosts efficiency.
- It is discovered that the Exhaust gas temperature of B30+Al₂O₃50ppm is more than that of diesel & other blends. This is because there was insufficient mixture development as a result of more viscosity and decreased volatile nature. Diffusion combustion is therefore more controlled, prolonging the heating and increasing exhaust gas temperature.
- Sample B10+Al₂O₃50 ppm emits more hydrocarbon at maximum load than the other blends in the comparison of all the biodiesel samples, but sample B30+Al₂O₃50ppm emits less hydrocarbon at maximum load. This is because oxygen content of fuel as well as from alumina nanoparticles.
- Out of all the samples produced, sample B10+Al₂O₃50 ppm is clearly the best; it emits almost half as much CO as diesel, although sample B30+Al₂O₃50ppm produces less CO than the other samples. The reason is because of oxygen

increases which causes the biodiesel to burn more completely during combustion, which reduces CO emissions.

- Sample B10+Al₂O₃50 ppm has more CO₂ emissions than other biodiesel blends, however Sample B30+Al₂O₃50ppm has the lowest CO₂ emission value, which is still less than the emission value of diesel. This is because as B30+Al₂O₃50ppm has a larger percentage of biodiesel than B10, CO₂ emissions per unit of fuel burned should be lower with it.
- It has been observed that B30+Al₂O₃50ppm emits more NO_x than diesel and other blends combined. This is because as the engine temperature rises due to an increase in load, the reaction rate of nitrogen and oxygen rises leads to more NO_x emissions.
- In comparison to diesel, blend B30+Al₂O₃50ppm has a lower smoke opacity, but blend B10+Al₂O₃50 ppm has a higher smoke opacity. This is since B30+Al₂O₃50ppm has more oxygen than other blends and that alumina's high oxygen concentration promotes better burning, which reduces smoke emissions.

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