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PERFORMANCE CHARACTERISTICS OF VCR SINGLE CYLINDER DIESEL ENGINE FUELLED WITH BIO DIESEL & CeO_2 NANOPARTICLES

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ABSTRACT

The emissions originating from Diesel engines pose a significant hazard to the environment and are widely recognized as a prominent contributor to air pollution. It has been demonstrated that these pollutants have adverse effects on ecological systems, give rise to environmental issues, and include carcinogenic constituents that pose a major threat to human health.In response to the challenges posed by fossil fuels, alternative fuels, such as Biodiesels, are being utilized and garnering growing interest. This is primarily driven by the escalating costs of fossil oil and the adverse environmental consequences associated with its utilization in diesel engines. Biodiesel is an alternative fuel to diesel that is renewable, biodegradable, and oxygenated. It is produced using the transesterification process of different vegetable oils, waste cooking oils, or animal fats.Prior research on biodiesel has shown that diesel engines powered by biodiesel can decrease levels of CO, CO2, and hydrocarbon (HC) emissions. However, it does slightly increase brake specific fuel consumption (BSFC) due to its lower heating value. Additionally, the torque and power output of biodiesel are comparable to those of diesel fuel.This study offers a comprehensive examination of the predominant method for biodiesel production, which involves the transesterification of sunflower oils with an alcohol (Methanol) in the presence of an alkaline catalyst (KOH). The reaction occurs under conditions of low temperature and low pressure. The process produces a high conversion rate of 96% to 98%, with minimal occurrence of side reactions and a rapid reaction time. It is a straightforward transformation into biodiesel without the presence of any intermediary chemicals.The utilization of CeO2 - NanoParticle as an additive in combination with Bio-Diesel has demonstrated potential in mitigating emissions and enhancing fuel characteristics. The properties of Bio-Diesel blends, such as density, specific gravity, viscosity, calorific values, carbon residue, flash point, and fire point, are measured. A comparison is made between the performance parameters and emissions of all the blends, both with and without nano particles, and the results are then analyzed.

CHAPTER 1

INTRODUCTION

The demand for energy continues to rise due to increased industrialization and population growth. Primary energy sources plays a crucial role globally in power generation, transportation, and industry. Diesel engines offer advantages such as durability, lower fuel consumption, and reduced emissions compared to gasoline engines, making them appealing for light-duty vehicles. However, reliance on petroleum fuels poses challenges like dwindling reserves and environmental pollution, notably greenhouse gas emissions.

India ranks sixth globally in oil consumption, facing longstanding pollution issues. The transportation sector, responsible for over 50% of oil use, significantly contributes to environmental degradation, primarily through CO emissions. While alternative fuels are being explored, their use often requires engine modifications and may not optimize fuel efficiency. Biodiesel presents lower sulfur content, and biodegradability.

Furthermore, incorporating metal and metal oxide nanoparticles into fuel can enhance its properties, leveraging the unique characteristics of nanoparticles like increased surface area and catalytic activity. Research indicates that fuel-borne catalysts can improve fuel efficiency and mitigate harmful emissions, presenting opportunities for cleaner and more efficient energy solutions.

1.1 COMPRESSION IGNITION ENGINES

The diesel engine, alternatively referred to as a Compression-Ignition (CI) engine, functions based on the principle of compression ignition. In this system, fuel is introduced into the combustion chamber and undergoes ignition as a result of the elevated temperature produced by the compression of air within the cylinder. Diesel engines, in contrast to spark-ignition engines like gasoline engines, utilize a hot compressed air to ignite atomized diesel fuel instead of relying on a spark plug. In cold temperatures or when the engine has a reduced compression ratio, the utilization of glow plugs can potentially facilitate the starting process. Diesel engines commonly function within a "constant pressure" cycle characterized by slow combustion, hence reducing the occurrence of audible knock.

The diesel engine is renowned for its remarkable thermal efficiency, which is attributed to its high expansion ratio and lean burn, which facilitates the dissipation of excess heat through the use of excess air. Diesel engines circumvent the problem of efficiency loss caused by unburned fuel, unlike two-stroke gasoline engines. Low-speed diesel engines, which are frequently utilized in marine applications, have the capability to exceed a thermal efficiency of 50%.

The diesel engine operates as an internal combustion engine, adhering to the Diesel cycle, which is distinguished by compression ignition rather than spark ignition. At the outset, solely air is introduced into the combustion chamber, undergoing compression to a significant degree, so elevating its temperature. Subsequently, the fuel is introduced into the compressed air, undergoing vaporization and ignition as a result of the thermal energy. During the initial phase of the power stroke, combustion takes place under a consistent pressure, resulting in the distinctive diesel knocking sound. The process of complete combustion leads to the expansion of combustion gasses, which in turn propels the piston and provides power to the crankshaft.

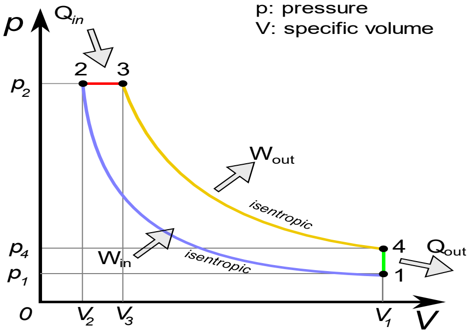


Figure 1.1 Diesel Cycle

The above figure presents a P-V diagram that provides a comprehensive representation of the ideal Diesel cycle. In this diagram, the symbol 'P' represents pressure, while 'V' represents volume or specific volume on a unit mass basis. The optimal Diesel cycle encompasses four separate cycles:

Processes 1 to 2 entail the application of isentropic compression to the fluid, as seen in the blue diagram.

Processes 2 to 3 include the application of reversible constant pressure heating, as indicated by the color red.

Processes 3 to 4 exhibit isentropic expansion, as indicated by the yellow coloration.

Process 4 to 1 involves the implementation of reversible constant volume cooling, as indicated by the color green.

The key parameters encompass:

The work performed by the piston in compressing the air within the system.

Heat in (Qin): The thermal energy generated by the process of fuel combustion.

The work out (Wout) refers to the amount of work performed by the working fluid when it expands and pushes a piston, resulting in the production of useable work.

The heat dissipated by the process of air venting.

The network formed is equal to the difference between Qin and Qout.

The network that is generated, as indicated by the region encompassed by the cycle on the photovoltaic diagram, is commonly referred to as useful work. This task has the potential to be transformed into alternative energy types, such as kinetic energy for the purpose of propelling a vehicle or generating electrical energy. The aggregate of these cycles within a given time interval is commonly denoted as developed power. Wout, often referred to as gross work, is utilized in the subsequent cycle to compress the subsequent air charge in the engine.

1.1.1 Essential Characteristics

Fuels utilized in Compression-Ignition (CI) engines must exhibit specific essential qualities to ensure smooth engine operation. The following are some crucial fuel properties:

a) Knock Characteristics:

Knocking in CI engines arises from an ignition delay in fuel combustion between injection and actual burning. A shorter ignition delay is desirable to prevent excessive fuel accumulation in the combustion chamber, which leads to sudden energy release and audible knocking. A favorable CI engine fuel should ignite readily, aiding starting, warm-up, and reducing exhaust smoke. The Cetane rating serves as a modern measure, with higher ratings indicating fuels less prone to objectionable knocking.

b) Volatility:

Fuel volatility within the engine's temperature range is vital for effective mixing and combustion.

c) Starting Characteristics:

Ideal fuel facilitates easy engine starting, necessitating high volatility for swift combustible mixture formation and a low self-ignition temperature indicated by a high Cetane rating.

d) Smoking and Odor:

Fuels should not contribute to exhaust smoke or unpleasant odors, with optimal volatility ensuring complete combustion through improved mixing.

e) Viscosity:

CI engine fuels must flow smoothly through fuel systems and filters, even at low operating temperatures.

f) Corrosion and Wear:

Fuel should not induce corrosion or wear on engine components, a concern typically linked to sulfur, ash, and residue content.

g) Handling Ease:

The fuel should remain a liquid under various conditions encountered during use, assessed through pour point and viscosity, while also possessing high flash and fire points for safety.

h) Sulphur Content:

Presence of sulfur compounds in fuels can lead to corrosion and damage to engine parts, along with forming harmful substances like sulfur dioxide.

i) Flash and Fire Points:

These points indicate the potential fire hazards during storage, with fuels ideally possessing optimized levels to mitigate risks.

Table 1.1 Variable Compression Ratios

Scale, 'mm'	CR
0.0	23.12
0.5	21.10
1.0	19.43
1.5	18.00
2.0	16.77
2.5	15.72
3.0	14.80
3.5	14.00
4.0	13.25
4.5	12.61
5.0	12.02

Biodiesel functions as a viable substitute fuel for diesel engines, obtained from many sources such as plant oils (e.g., soybean, cottonseed, canola), recycled cooking greases or oils (e.g., yellow grease), or animal fats (e.g., beef tallow, swine lard), occasionally in hybrid forms. Recycled cooking oils, which are primarily derived from plants but may occasionally include animal fats, possess the dual qualities of being both recycled and renewable. With the increasing production of biodiesel, there is a growing development of novel feedstocks such as pennycress, camelina, cuphea, brown grease, and other algae strains. This has the potential to increase the supply of biodiesel.

Esterification is the process by which oils and fats are converted into long-chain mono alkyl esters, sometimes referred to as fatty acid methyl esters (FAME), during the manufacturing of biodiesel. In general, the reaction between 100 pounds of oil or fat and 10 pounds of a short-chain alcohol, commonly methanol, occurs in the presence of a catalyst, typically sodium hydroxide or potassium hydroxide. This reaction results in the production of 100 pounds of biodiesel and an additional 10 pounds of glycerin, which is a byproduct.

It is advisable to refrain from using straight vegetable oil (SVO) and comparable products, which refer to unprocessed or refined plant oils, fats, or greases that have not undergone biodiesel processing. According to existing research, the utilization of these compounds in diesel engines, even when present in low quantities, has been found to result in enduring engine complications, including the formation of deposits, ring sticking, lubricating oil gelling, and a diminished lifespan of the engine. The issues largely arise due to the notably greater viscosity (about 40 square millimeters per second [mm2/s]) and boiling point of unprocessed fats and oils in comparison to ordinary diesel fuel (ranging from 1.3 to 4.1 mm2/s). When plant oils or greases are transformed into biodiesel, their viscosity and boiling point are decreased to values that are more similar to those of conventional diesel fuel, often ranging from 4 to 5 mm2/s.

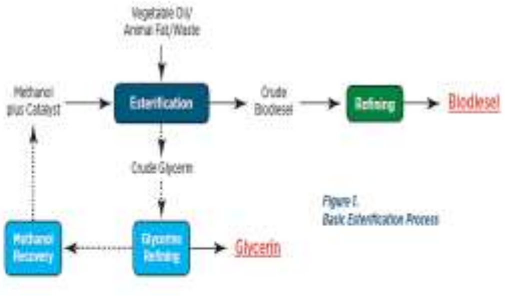


Figure 1.2 Esterification Process

1.1.2 Variation in Biodiesel Properties

The ASTM specification for biodiesel permits the utilization of several feedstocks and manufacturing methods, akin to petroleum-based fuels. Biodiesel in the current market often comprises a mixture of B100 obtained from two or more feedstocks. Numerous manufacturers amalgamate feedstocks derived from diverse sources in order to get B100 with specific characteristics and enhance the economic viability of production.

Commercial production of biodiesel involves the utilization of various oils and fats, encompassing animal fats like tallows, lard, choice white grease, yellow grease, poultry fats, and fish oils, alongside plant oils such as soy, corn, canola, sunflower, rapeseed, cottonseed, and corn. Utilized are recycled oils such as discarded cooking oil and restaurant frying oil.

In addition, biodiesel can be obtained from other sources such as mustard, palm, coconut, peanut, olive, sesame, and safflower oils, as well as recycled oils, trap greases, and oils generated from algae, fungi, bacteria, molds, and yeast. The feedstock has an impact on specific characteristics of the final biodiesel, such as its Cetane number, cloud point, and stability.

The chemical composition of many fats and oils utilized in the creation of biodiesel bears resemblance to that of diesel fuel. These fats and oils have comparable glycerine backbones and long-chain fatty acids, which undergo a reaction with methanol to yield methyl esters, commonly referred to as biodiesel. The resulting glycerine is subsequently extracted and marketed. Commercial biodiesel commonly consists of ten prevalent fatty acids, each possessing carbon chains that span from 12 to 22. Notably, more than 90% of these fatty acids are situated within the 16 to 18 carbon range. The saturation of these chains can change, which can affect various fuel qualities within specified limitations.

As previously mentioned, the performance characteristics of B100 might vary considerably from those of traditional diesel. Combining biodiesel with petroleum fuel can reduce these disparities while preserving certain advantages of B100. The labeling of biodiesel blends is based on their percentage composition, with B100 indicating 100% biodiesel, B5 indicating 5% biodiesel and 95% diesel, B10 indicating 10% biodiesel and 90% diesel, and B15 indicating 15% biodiesel and 85% diesel.

1.1.3 Sunflower Oil

The non-volatile oil known as sunflower oil, derived from the seeds of the sunflower plant (Helianthus annuus), is extensively employed in culinary applications as a frying oil and in the cosmetics industry as an emollient. The global output in 2014 amounted to approximately 16 million tons, with Ukraine and Russia emerging as the main producers. Sunflower oil is composed of a combination of monounsaturated (MUFA) and polyunsaturated (PUFA) fats, predominantly comprising oleic acid (referred to as omega-9) and linoleic acid (referred to as omega-6). The seeds have an oil content ranging from 22% to 36%, with an average of 28%. On the other hand, the kernel contains oil ranging from 45% to 55%. In its raw form, sunflower oil has a light amber hue and possesses a mild, agreeable taste, but refined oil manifests as a pale yellow hue. The product demonstrates negligible refining losses and displays favorable shelf stability, resulting in minimal variation in flavor over an extended period.

The product in question exhibits a high concentration of vitamin E, sterols, squalene, and other aliphatic hydrocarbons. Consisting mainly of triglycerides, it commonly comprises a diverse range of components, including those illustrated in a typical profile.

1.1.4 Sunflower Oil as Bio Diesel

Sunflower oil possesses significant potential to reduce reliance on petroleum diesel, particularly on a farm scale. It is already utilized as a premium high-grade food oil, and the byproduct, sunflower meal, can be easily incorporated into livestock feed. The composition of sunflower oil closely resembles that of other vegetable oils like soy and safflower, making biodiesel derived from sunflower expected to exhibit properties akin to soy-based biodiesel.

While a substantial portion of sunflower oil is manufactured for human consumption, fetching premium prices for producers, its economic viability for biodiesel use may not be as lucrative in certain oil-producing regions.

1.2 NANO TECHNOLOGY

Nanotechnology, often abbreviated as "nanotech," involves the manipulation of matter at the atomic, molecular, and supramolecular levels. Initially, nanotechnology focused on the precise manipulation of atoms and molecules to create larger-scale products, a concept now termed molecular nanotechnology.

Nano particles are particles ranging in size from 1 to 100 nanometers (nm), encompassing a surrounding interfacial layer that significantly influences their properties. This layer typically comprises ions, inorganic and organic molecules. Organic molecules that coat inorganic nano particles serve various functions, such as stabilization, capping, surface ligands, or passivating agents. In nanotechnology, a particle is defined as a small object exhibiting unit-like behavior concerning its transport and properties.

Nanotechnology primarily employs two approaches:

1. Top-down approach: Involves the synthesis of nanostructures from bulk materials.
2. Bottom-up approach: Involves the formation of nano particles from constituent atoms.

Nano fluids, a type of heat transfer fluid, are created by integrating very small particles (with an average size of less than 100 nm), such as metallic, non-metallic, and polymeric particles, into conventional fluids. According to Yu and Choi, the modified Maxwell model posits that molecules of the base fluid near the solid surface of nano particles form solid-like layered structures. Consequently, the nano layer acts as a thermal bridge between the liquid base fluid and the solid nano particles, enhancing effective thermal conductivity. As illustrated in Figure 1, a nano fluid comprises the liquid base fluid, solid nano particles, and nano layers.

1.2.1 Base Fluids

Base fluids are also called host fluids. They are single-phase conventional fluids having poor heat transfer properties.

Table 1.5 Lists of Base Fluids

S. No	Description	Examples
1	Metallic liquids	Sodium
2	Non-metallic liquids	Water, Ethylene glycol (EG) Engine oil (EO)

Table 1.6 Types of Nano Materials

S. No	Description	Example
1	Non-metals	Si, Al2O3, Graphite, Carbon nanotubes
2	Metals	Cu, Al, Ag, Au
3	Nitride ceramics	AlN, SiN
4	Semiconductors	TiO2, SiC
5	Carbide ceramics	SiC, TiC
6	Composite materials	Alloyed nano particles, Al70Cu30
7	Oxide ceramics	Al_2O_3, CuO
8	Layered	Cu + C, Al + Al2O3
9	Earth oxide	CeO_2

1.2.2 CeO_2 Nano Particles

Cerium oxide possesses the capability to catalyze combustion reactions by providing oxygen atoms from its lattice structure. This catalytic function relies on factors such as surface area, making the utilization of nano particles advantageous compared to bulk materials or larger particles.

Incorporating cerium oxide nano particles into fuel facilitates the decomposition of unburnt hydrocarbons and soot, thereby decreasing the emission of these pollutants in the exhaust and enhancing fuel efficiency. Additionally, studies have demonstrated that cerium oxide reduces pressure in the combustion chamber, resulting in decreased production of nitrogen oxides (NOx) and enhanced efficiency of combustion reactions.

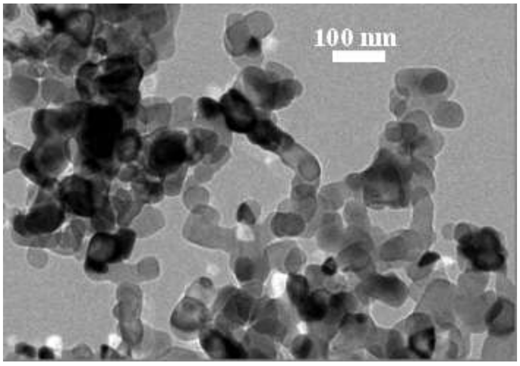


Figure 1.3 Nano Structure of Cerium Oxide

1.3 Emission Analyzer

An exhaust gas analyzer, also known as an exhaust CO analyzer, is a device designed to measure carbon monoxide levels, along with other gases present in exhaust emissions resulting from incorrect combustion. The most commonly employed measurement method is the Lambda coefficient. Carbon monoxide sensors, including other gas sensors, utilize principles such as infrared gas sensors (NDIR) and chemical gas sensors to assess CO levels during testing.

1.3.1 Types of Sensors Used:

a) Chemical CO sensors:

Chemical CO gas sensors utilize sensitive layers composed of polymers or heteropolysiloxanes, offering the advantage of very low energy consumption and potential miniaturization to integrate into microelectronic systems. However, drawbacks include short- and long-term drift effects, as well as relatively limited lifetimes compared to the NDIR measurement principle. An alternative method, Henry's Law, can be utilized to measure dissolved CO levels in a liquid, provided foreign gas levels are negligible.

b) Non dispersive Infrared (NDIR) CO Sensors:

NDIR sensors are spectroscopic devices crafted for the identification of carbon monoxide (CO) in a gaseous setting through its distinctive absorption features. Vital elements of these sensors encompass an infrared source, a light tube, an interference filter that controls the wavelength, and an infrared detector. The gas is introduced into the light tube, where the electronic system gauges the absorption of the characteristic light wavelength. NDIR sensors find widespread application in the measurement of carbon monoxide, with sensitivities typically falling within the range of 20 to 50 parts per million (PPM).

Most CO sensors undergo full calibration prior to shipment from the factory. However, periodic calibration of the zero point is necessary over time to maintain long-term stability. Ongoing developments aim to utilize micro electro mechanical systems to reduce sensor costs and create more compact devices.

Figure1.4 Emission Analyser

1.3.2 Gases Measured

- CO (Carbon Monoxide)
- HC (Hydro Carbon)
- CO_2 (Carbon Dioxide)
- O_2 (Oxygen)
- NOx (Nitric Oxide)

1.3.4Principle of Operation

The Multi Gas Analyzer (5 gas version) utilizes a combination of infrared spectrometry technology and signal inputs from an electrochemical cell. It employs a non-dispersive infrared measurement technique for gases like carbon monoxide (CO), carbon dioxide (CO_2), and hydrocarbons (HC). This technique relies on the specific absorption rates of each gas for infrared radiation, and the absorbed radiation's quantity facilitates the calculation of the sample gas concentration.

For measuring oxygen concentration, the analyzer utilizes an electrochemical cell with two electrodes separated by an electrically conductive liquid. Behind a poly tetra fluoro ethylene membrane allowing oxygen diffusion, the cell gauges oxygen partial pressure. The application of a polarizing voltage between the electrodes induces a current proportional to the oxygen partial pressure.

To measure RPM (Revolutions per Minute), the RPM Inductive Pickup transforms the magnetic field produced by the current in the spark plug wire into a pulse, initiating an RPM measurement. Connecting the probe to any accessible spark plug wire enables the measurement of RPM using the pickup.

1.4 ULTRA SONICATION:

The process of sonication entails the utilization of sound energy to induce agitation in particles inside a given sample, hence fulfilling diverse objectives such as the extraction of different chemicals from plants, microalgae, and seaweeds. The procedure, commonly known as ultrasonication, typically utilizes ultrasonic frequencies exceeding 20 kHz.

Sonication is a frequently employed technique in laboratory environments, wherein an ultrasonic bath or probe, generally referred to as a sonicator, is utilized. Ultrasonic foil is utilized in paper manufacture to uniformly disperse cellulose fibers and augment the strength of the paper.

The utilization of sonication encompasses a wide range of applications, including the synthesis of nano particles (such as nano-emulsions, nano crystals, liposomes, and wax emulsions), the purification of wastewater, the removal of gas, the extraction of seaweed polysaccharides and plant oils, the extraction of anthocyanins and antioxidants, the production of biofuels, the desulfurization of crude oil, the disruption of cells, the processing of polymers and epoxys, and the thinning of adhesives, among numerous other applications. The utilization of this technology is observed in various sectors such as pharmaceutical, cosmetic, water treatment, food processing, ink, paint, coating, wood treatment, metalworking, nano composite, pesticide, fuel, and wood product industries, among others.

Figure1.5 Ultra Sonicator

CHAPTER 2

LITERATURE REVIEW

In 1895, Dr. Rudolf Diesel, the inventor of the initial Diesel Engine, utilized biofuel as the only fuel source in his engine. He anticipated a future in which vegetable oils would hold comparable significance to petroleum and coal tar products. The aforementioned forecast is currently being realized as biodiesel has a growing global adoption. Vegetable oils have been the subject of investigation by engineers and scientists as a potential fuel for diesel engines since 1900. However, it is only in recent times that the crucial fuel qualities and engine parameters necessary for reliable operation have become apparent.

The initial operating difficulties were due to the elevated viscosity of vegetable oils in comparison to petroleum diesel fuel, leading to inadequate fuel atomization and the formation of deposits in the injector and valve. In order to tackle this issue, several approaches were employed, such as elevating the temperature of the oil, combining it with diesel obtained from petroleum, ethanol, pyrolysis, cracking, micro-emulsification, and transesterification. The process of transesterification, which involves the reaction between vegetable oil triglycerides and a lower alcohol to generate fatty acid alkyl esters similar to mineral diesel, may be traced back to the year 1853, predating the development of the initial diesel engine. The transformation technique for vegetable oils was patented by G. Chavanne in 1937. However, the recognition and technological significance of biodiesel experienced a significant increase during the energy crisis of 1973.

Recent research has advanced the comprehension and enhancement of biodiesel manufacturing. In their study, Hossain and Boyce (2009) examined the most favorable parameters for alkaline-catalyzed transesterification using both pure and waste sunflower frying oil. The researchers successfully obtained biodiesel yields that met the established standards. In their study, Khine and Tun (2013) investigated the viability of utilizing alkali-catalyzed transesterification to produce biodiesel from sunflower oil. They successfully achieved conversions that met the parameters set by the ASTM biodiesel standards.

The study conducted by Nadir Yilmaz et al.

(2016) aimed to assess the impact of hazelnut oil methyl ester on engine performance and emissions, revealing positive results. In a study conducted by Prabu (2017), nanoparticle-dispersed biodiesel blends were examined, resulting in notable enhancements in both performance and emission characteristics. In their study, Jayanthi and Srinivasa Rao (2016) investigated the use of copper oxide additives in linseed oil-based biodiesel. They found that these additives improved engine performance and helped manage emissions. The study conducted by Arul Mozhi Selvan et al. (2015) demonstrated the efficacy of cerium oxide nanoparticles in enhancing combustion efficiency and mitigating exhaust pollutants. In their study, Sajith, Sobhan, and Peterson examined the impact of cerium oxide nanoparticles on the characteristics, performance, and emissions of biodiesel. They observed a decrease in emissions when nanoparticles were incorporated into the biodiesel mixture.

CHAPTER 3

EXPERIMENTAL WORK

3.1 PERFORMANCE CHARACTERISTICS OF ENGINE FUELLED WITH DIESEL

a) The performance of a Direct Injection Single cylinder 4-Stroke Diesel engine was evaluated by a series of tests done under various situations, including Natural aspirated settings, Pure Diesel, Bio-Diesel blends, and Bio-Diesel with Nano Particle mixes. In order to evaluate the performance of the engine under different loads and compression ratios, a load test was conducted on the engine while it was operating at its set speed. In addition, the exhaust emissions of the engine were examined under various load circumstances using the AVL Multi exhaust gas analyzer.

b) **Indicated Horse Power (IP)**

$$\mathrm{IP} = \frac{\mathrm{pLAN}}{60}$$

Where, p = Pressure on the piston, N/m^2
L = Length of stroke, m
A = Area of the piston, m^2
N = Speed in RPM

c) **Brake Power (BP)**

$$\mathrm{BP} = \frac{2\pi N\tau}{60000} \quad \text{in KW}$$

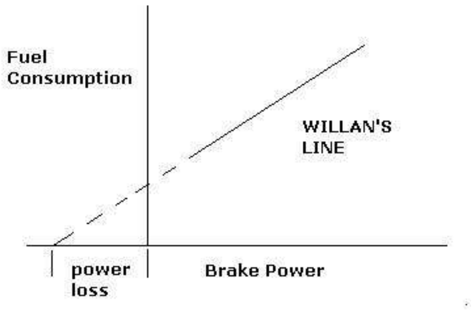
Where, N = Speed in RPM
τ = Torque = F x r x 9.81 (N-m)
r = Torque arm radius = 0.15m

d) **Mechanical Efficiency(η_{mech})**

$$\eta_{\mathrm{mech}} = \frac{\mathrm{BP}}{\mathrm{IP}} X100$$

The determination of Friction Power (FP) is conducted within the framework of Willian's Line approach. To accomplish this, create a graph illustrating the relationship between Fuel Consumption (mf) and Brake Power (BP).
Continue extending the resultant line until it intersects the axis representing Brake Power.

The point at which the junction of the axis intersects with zero represents the occurrence of power losses, specifically in the form of friction power loss.
The supplied relationship can be utilized to compute the Indicated Power (IP).
$\mathrm{IP} = \mathrm{BP} + \mathrm{FP}$



e) Heat Input (HI)

HI = m_f x Calorific Value of Fuel in KW

f) Mass of Fuel Consumed (m_f)

$$m_f = \frac{X_{cc} * S}{1000 * t} \quad \text{in KJ/Sec}$$

Where, X_{cc} = Volume of Fuel consumed (10ml)
t = Time taken in seconds

g) Specific Fuel Consumption (SFC)

$$\mathrm{SFC} = \frac{m_f * 3600}{\mathrm{BP}} \quad \text{in } \frac{\mathrm{Kg}}{\mathrm{KW-hr}}$$

h) Brake Thermal Efficiency (η_{Bth})

$$\eta_{Bth} = \frac{3600}{\mathrm{SFC} * \mathrm{CV}} X 100$$

i) Calculation of head of air (H_a)

$$H_a = H_w * \frac{\rho_{water}}{\rho_{air}}$$

Where,

The density of water, denoted as ρwater, is 1000 kilograms per cubic meter (Kg/m^3). The density of air, represented as ρair, is 1.2 kilograms per cubic meter (Kg/m^3) at standard room temperature and pressure (R.T.P). Hw stands for the head in the water column, measured in meters of water.

j) Volumetric Efficiency (η_{vol})

$$\eta_{vol} = \frac{Q_a}{Q_{th}} \text{ X } 100$$

Here,
Q_a = Actual volume of air taken = $C_d * a * \sqrt{2gH_a}$

Q_{th} = Theoretical volume of air taken $= \frac{\left(\frac{\pi}{4}\right) * D^2 * L * N}{60 * 2}$

Where,

Cd, representing the coefficient of discharge of the orifice, is set at 0.62. The variable 'a' denotes the area at the orifice, with a value of

3.14 x 10-4. Ha represents the head in the air column, measured in meters of air. Other parameters include 'D,' the bore diameter of the engine, set at 0.08 meters, and 'L,' indicating the length of the stroke, equal to 0.110 meters. 'N' stands for the speed of the engine, measured in revolutions per minute (rpm).

3.1.1 Description of Equipment/Test Rig

The equipment comprises a KIRLOSKAR AV1 type Diesel Engine, which is started by cranking and has a power output of 5 horsepower (3.7 kilowatts). The water-cooled engine is connected to an Eddy Current Dynamometer in order to apply loads. This connection is formed through an extension shaft located in a dedicated bearing house. A Load Cell, equipped with digital load indicator, is connected to the dynamometer.

Thermocouples that are strategically placed are linked to a digital temperature meter, which has a channel selector that allows for the selection of certain positions. Rota meters are employed for the direct measurement of water flow rates to the engine and calorimeter, with flow rate ranges of 15LPM and 10LPM, respectively.

The use of the Digital RPM Indicator and spring balance readings is employed for the purpose of ascertaining engine speed and applied load across diverse circumstances. The system incorporates a self-contained air box equipped with an orifice assembly to control and quantify the rate of air flow. The pressure differential at the orifice is assessed by use of an ACRYLIC Manometer.

The engine configuration consists of a dual fuel tank system, with one tank dedicated to diesel fuel and the other for biodiesel. The measurement and directed supply of fuel to the engine are facilitated by a volumetric flask, in conjunction with a fuel distributor.

The experimental setup is affixed on a robust, self-sustaining structure composed of MS channels and incorporates anti-vibration mounts. The test rig comprises a distinct control panel, which is fabricated using NOVAPAN board. This panel serves as a housing for all indications, accessories, and essential instrumentation, ensuring their proper placement.

3.1.2 Procedure for Performance Tests

It is imperative to conduct regular inspections and uphold the recommended amounts of fuel and lubricating oil in the engine.

To enable the passage of the designated fuel (either diesel or mixed oil) to the engine, employ the three-way cock.

It is recommended to facilitate the flow of cooling water within the engine jacket, calorimeter, and brake drum of the rope dynamometer.

The engine can be supplied with air through an air box under naturally aspirated conditions. Alternatively, the compressor (also known as a supercharger) can be used to feed air to the engine at the required supercharging pressure.

Commence the commencement of the engine's operation, making any required adjustments to the speed by moving the governor nut.

The engine can be loaded by affixing the necessary dead weights onto the hanger.

•Modify the cooling water within the brake drum in order to mitigate the risk of spillage.

The flow rates of engine cooling water and calorimeter cooling water should be coordinated in accordance with the cooling demands.

• The following measurements should be recorded for each engine load:

a) The revolutions per minute (RPM) of the engine is equal to N. b) The tension readings obtained from the Rope Dynamometer are expressed as the load (F) in Newtons.

c) Readings from the air box water manometer: The left column represents the value of h1 in millimeters. The value in the right column is h2 in millimeters. Determine the quantity of water, denoted as Hw, by subtracting h2 from h1.

d) The time it takes to consume 10cc of fuel is equal to t seconds.

To record emissions measurements (CO, CO2, unburnt HC, unused O2, NOx), employ the exhaust gas analyzer and smoke meter.

Following this, proceed to compute and organize all performance parameters.

Figure 3.1 Diesel Engine setup

Figure 3.2 Instrumentation Panel

3.2TRANSESTERIFICATION FOR BIO DIESEL

The Transesterification process is widely recognized as the most appropriate method for turning oils and fats into biodiesel fuels. The reaction in question, which has gained significant acceptance, has demonstrated notable efficacy in reducing the viscosity of vegetable oils. The process entails the amalgamation of an alcohol, commonly methanol, with the triglycerides found in oils, fats, or recycled grease. This process results in the production of biodiesel, specifically fatty acid alkyl esters, as well as glycerol. In order to carry out this chemical reaction, it is necessary to apply heat and utilize a potent base catalyst, such as sodium hydroxide or potassium hydroxide. The transesterification process involves the reaction between vegetable oils and alcohols such as methanol or ethanol. This reaction is promoted by a catalyst, often sodium hydroxide or potassium hydroxide, and occurs at a temperature of around 70⁰ C. As a result, esters are produced along with the waste glycerin. Previous studies have provided evidence suggesting that the methyl and ethyl esters obtained from vegetable oil exhibit enhanced efficacy in comparison to the unmodified vegetable oils.

Table 3.4 Compounds for Transesterification

Material / Compound	Quantity
Sunflower oil	500 ml
Methanol	100ml
Potassium Hydroxide (KOH)	3.5 gms

3.2.1 Procedure for Bio Diesel

- Obtain a volume of 500ml of sunflower oil from a nearby grocery store and transfer it into a beaker, then subjecting it to a temperature within the range of 60-65°C.

During the heating process, it is recommended to prepare a catalyst solution comprising 100 mL of methanol and 3.5 grams of potassium hydroxide flakes.

The catalyst solution should be well mixed using a magnetic stirrer.

- Extract the hot oil from the designated source and allow it to undergo a period of rest lasting roughly 10-15 seconds. Following that, proceed to bring the catalyst solution into the heated oil.

The oil and catalyst solution should be placed on a magnetic stirrer for a duration of approximately 10-15 minutes.

The solution should be extracted from the stirrer and left undisturbed for a duration of 24 hours.

Following a 24-hour duration, the production of biodiesel occurs, followed by the presence of residual glycerine. The glycerine will undergo sedimentation behind the layer of biodiesel that is generated.

- The biodiesel and glycerine should be separated.

Figure 3.3 Heating the Sunflower Oil

Figure 3.4 Catalyst Solution

Figure 3.5 Mixing warm Sunflower Oil and Catalyst Solution

3.2.2 Blending The biodiesel obtained through the transesterification process is combined with pure diesel to operate the engine. The specified blending ratios are outlined below.

Table 3.5 Proportions for Blends

Blends	**Bio - Diesel**	**Diesel**
B5	5%	95%
B10	10%	90%
B15	15%	85%
B100	100%	0%

Figure 3.6 Blends

3.3 DETERMINING THE PROPERTIES OF BLENDS

3.3.1 Flash & Fire Point

Apparatus: Pensky Marten’s

The Pensky Martens apparatus comprises a small container, commonly including a hermetically sealed lid, housing a fluid fuel. The cup and lid are designed in a manner that enables them to endure the aforementioned excessive pressure without experiencing rupture. The fuel temperature experiences a slow rise, and periodically, a small pilot flame is introduced into the airspace above the liquid for a short period of time. The momentary ignition of the fuel-air mixture by the pilot flame is commonly known as the "flash-point," but the sustained ignition of the flame in the fuel-air mixture for a minimum duration of five seconds is referred to as the "fire-point."

Figure 3.7 Pensky Marten's Apparatus

Table 3.6 Flash & Fire points

Blends	Flash Point	Fire Point
B5	68	82
B10	72	86
B15	76	89.5
B100	170	180

3.3.2 Viscosities Measurement

Apparatus: Redwood Viscometer

The equipment consists of a silver-plated brass oil cup featuring an open upper end and a bottom agate jet. The opening and shutting of the cup are controlled by a valve rod, which is a silver-plated brass ball attached to a robust wire. The oil or fuel under examination is introduced into the cup until it reaches a predetermined level, after which the jet is sealed by means of the valve rod. A measuring flask is located just beneath the jet. The cup undergoes thermal treatment by means of its neighboring water bath, which is electrically heated. Upon reaching the desired temperature, the heating process is terminated, and subsequently, the ball valve is elevated and suspended from a thermometer bracket. The duration necessary for the accumulation of 50cc of oil in the flask is documented, and expeditiously, the valve is shut to avert any potential overflow of oil. The result is shown as "Redwood No.1 seconds" at the designated temperature, where a greater duration of flow signifies a reduced viscosity of the oil. Following this, the kinematic and dynamic viscosities of the oil at the specified temperature are calculated utilizing the given models.

a) Viscosity in Redwood Number, n

$$n = \frac{K * t * S_{oil}}{t_s * S_s}$$

Where,

K represents the constant (set at 100 for standard oil),

t denotes the time required for 50cc of oil in seconds,

ts signifies the time taken for the flow of 50cc of standard oil (535 seconds),

and Ss stands for the standard oil's specific gravity, set at 0.915.

b) Kinematic Viscosity, η

$\eta = \left(0.260t - \frac{179}{t}\right)$ in CSt for (34<t<100) ------- (1)

(or)

$\eta = \left(0.260t - \frac{179}{t}\right) X\ 10^{-6}$ in $\frac{m^2}{Sec}$ for (34<t<100) -------- (1)

$\eta = \left(0.247t - \frac{50}{t}\right)$ in CSt for $(100 < t < 2000)$ --------- (2)

(or)

$$\eta = \left(0.260t - \frac{179}{t}\right) X\, 10^{-6} \text{ in } \frac{m^2}{Sec} \text{ for}$$

(100<t<2000) ------- (2)

c) Dynamic Viscosity, μ

$$\mu = \eta * \rho$$

Where, ρ = density of the fluid under test in Kg/m^3-Sec

Figure 3.8 Redwood Viscometer

3.3.3 Density & Specific Gravity

These properties can be calculated from viscosity apparatus.

$$\rho = \frac{\text{mass of oil}}{\text{volume of flask used}} \text{ in } \frac{Kg}{m^3}$$

$$\text{Specific Gravity} = \frac{\rho}{1000}$$

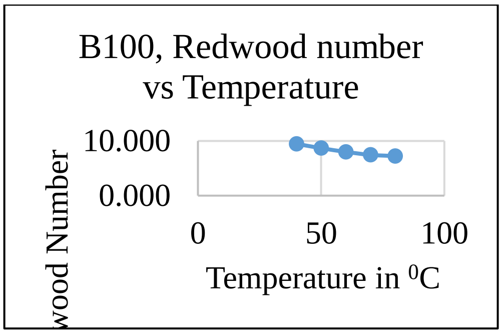


Figure 3.9 Viscosity in Redwood Number vs Temperature, B100

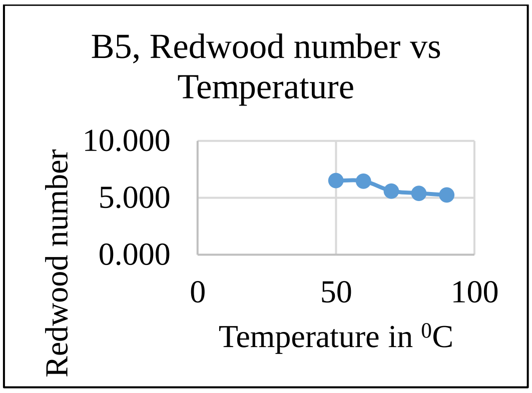


Figure 3.10 Viscosity in Redwood Number vs Temperature, B5

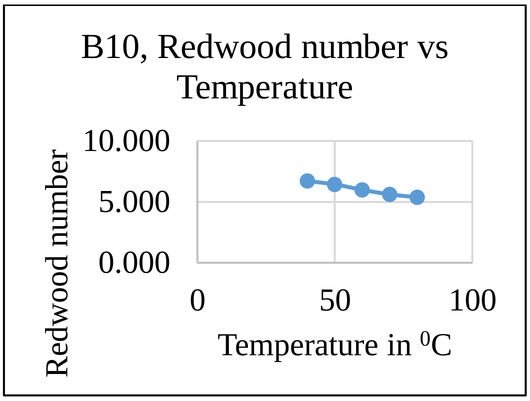


Figure 3.11 Viscosity in Redwood Number vs Temperature, B10

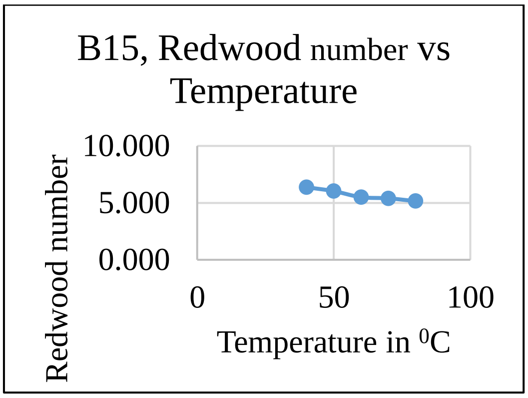


Figure 3.12 Viscosity in Redwood Number vs Temperature, B15

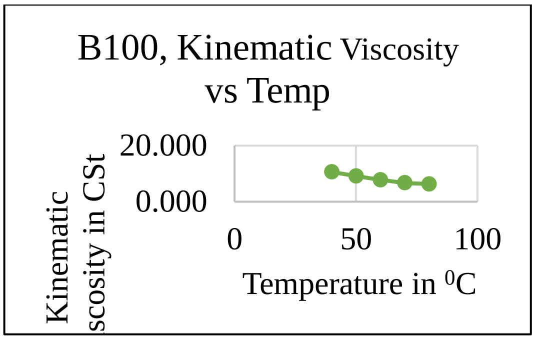


Figure 3.13 Kinematic Viscosity vs Temperature, B100

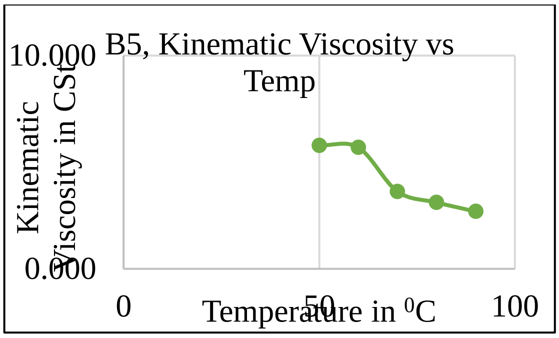


Figure 3.14 Kinematic Viscosity vs Temperature, B5

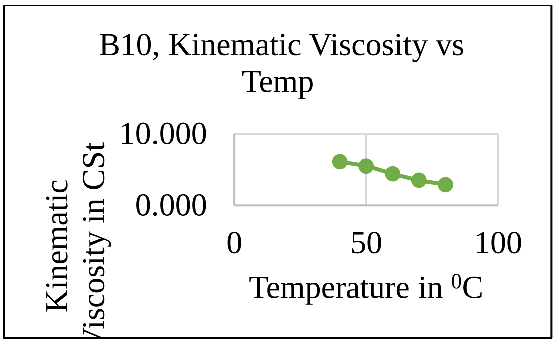


Figure 3.15 Kinematic Viscosity vs Temperature, B10

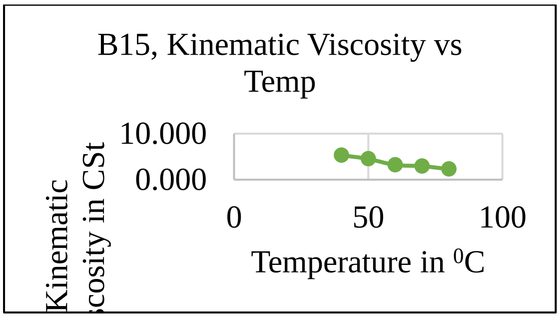


Figure 3.16 Kinematic Viscosity vs Temperature, B15

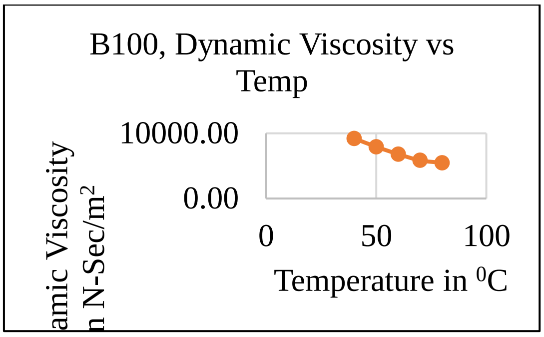


Figure 3.17 Dynamic Viscosity vs Temperature, B100

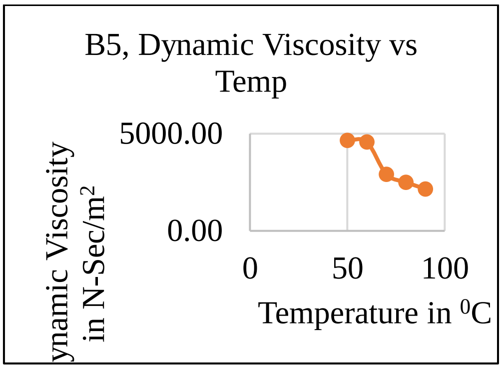


Figure 3.18 Dynamic Viscosity vs Temperature, B5

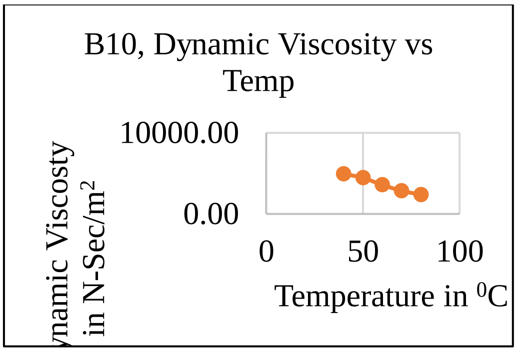


Figure 3.19 Dynamic Viscosity vs Temperature, B10

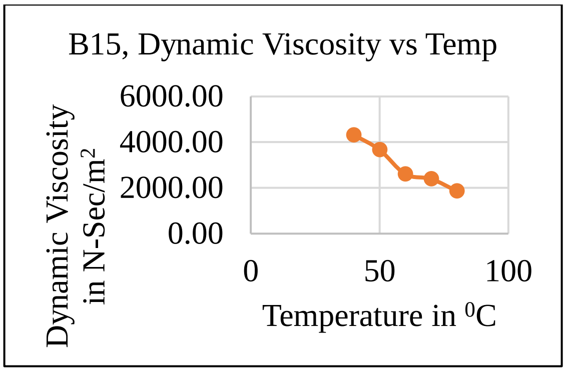


Figure 3.20 Dynamic Viscosity vs Temperature, B15

3.3.4 Calorific Value

Apparatus: Bomb Calorimeter

In order to do the experiment, a predetermined mass (ranging from roughly 0.5 to 1.0g) of the given fuel is introduced into a sterile crucible that is supported by a ring. The fuel sample is in touch with a fine fuse wire, which is elongated between the electrodes. The lid of the bomb is firmly fastened, and the bomb is filled with oxygen at a pressure of 25 atmospheres. Following this, the explosive device is dropped into the copper calorimeter, which houses a certain quantity of water. The stirring mechanism is initiated, and the initial temperature of the water is documented. The completion of the circuit occurs when the electrodes are connected to a 6-volt battery, resulting in the combustion of the sample and the subsequent release of heat. Continuous agitation guarantees homogeneity, and the highest attained temperature is recorded.

3.3.5 Carbon Residue

Apparatus: Conradson Carbon Residue

Conradson carbon residue, colloquially known as "Concarbon" or "CCR," serves as a laboratory assessment indicating the propensity of an oil to form coke. In a quantitative manner, this test gauges the quantity of carbonaceous residue that persists after the evaporation and pyrolysis of the oil. Typically, the test is relevant for petroleum products characterized by low volatility, which decompose during distillation under atmospheric pressure. The term "Conradson carbon residue" and its common aliases can denote either the test procedure or the numerical result derived from it.

$$\text{Carbon Residue} = \frac{(W_3 - W_1)}{(W_2 - W_1)}$$

Where, W1 represents the Crucible weight,

W2 signifies the weight of the Crucible with oil,

W3 denotes the weight of the Crucible with residual carbon after the combustion of oil.

Figure 3.22 Conradson Carbon Residue Apparatus

3.5 MIXING NANO PARTICLES WITH BLENDS (B5 & B10)

The Digital Ultra Sonicator is used to introduce Cerium oxide (CeO2) Nano Particles into Bio-Diesel blends via an Ultra-sonication technique.

A precision weight equipment is utilized to measure accurate quantities of 400mg and 600mg of Nano Particles for every 800ml of Bio-Diesel blend (B5 & B15).

The resulting mixture is placed in a water bath within the Digital ultrasonic machine, and the timer is set for a total duration of 480 seconds, repeated four times (adjusting according to the specific type of Nano Particles) to achieve complete blending of the Bio-Diesel. The aforementioned procedural sequence is subsequently replicated for each additional mix.

Parts Per Million (PPM)

PPM stands for "parts per million" and is alternatively represented as milligrams per liter (mg/L). It quantifies the mass of a chemical or contaminant in relation to the volume of water. When indicated as ppm or mg/L in a laboratory report, they convey the same information. Specifically, one ppm equals the absolute fractional quantity multiplied by one million

Figure 3.23 Sensitive Weighing Machine

Figure 3.24 Mixture of CeO_2 & Bio Diesel Blends in Water Bath of Ultra Sonicator

3.6 DETERMINING THE PROPERTIES OF NANO PARTICLE BLENDS

In the college laboratories, the experimental determination of the properties of blends comprising Bio-Diesel and Nano Particles (CeO_2) is conducted using a procedure akin to that of conventional Bio-Diesel. Specifically, the blends examined are denoted as follows:

- B5C500: Blend consisting of 5% biodiesel and 500ppm CeO_2
- B15C750: Blend consisting of 15% biodiesel and 750ppm CeO_2

PERFORMANCE CHARACTERISTICS OF ENGINE FUELLED WITH NANO PARTICLE BLENDS

The methodology for evaluating performance parameters closely resembles that of engine; with the distinction employed in context are blends of Bio-Diesel and Nano Particles, such as B5C500 and B15C750.

CHAPTER 4

RESULTS & DISCUSSION

•Various performance parameters are assessed during the operation of the engine under natural aspiration, using pure diesel, biodiesel, and biodiesel-nano particle blends.

•Exhaust gas analysis is conducted at different engine loads, utilizing pure diesel, biodiesel, and biodiesel-nano particle blends

The obtained results are as follows:

4.1PERFORMANCE PARAMETERS

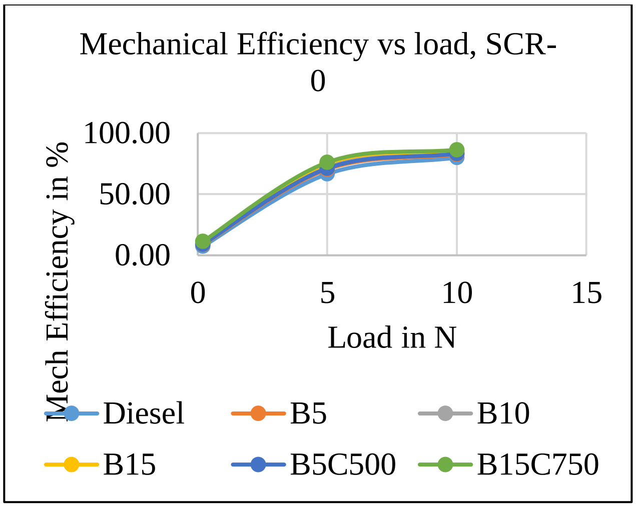


Figure 4.1 Mechanical Efficiency vs Load for scale, 0mm

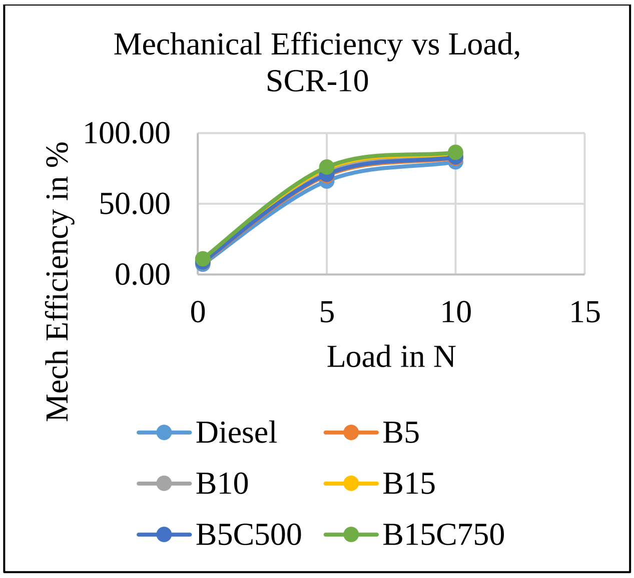


Figure 4.2 Mechanical Efficiency vs Load for scale, 10mm

- Mechanical efficiency of the engine is increased slightly (about 7-10%) with

B15C750 blend when used instead of pure diesel.

4.1.2 Volumetric Efficiency

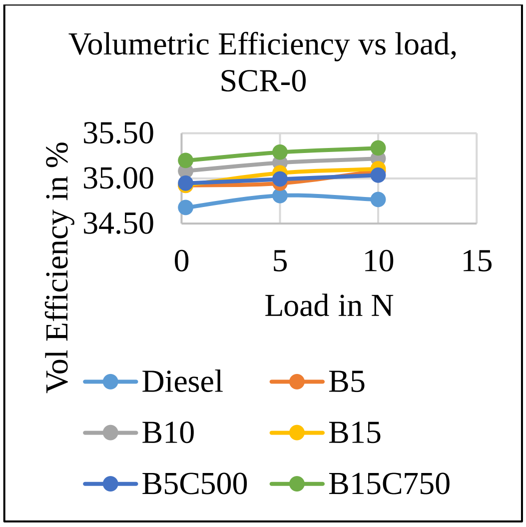


Figure 4.3 Volumetric Efficiency vs Load for scale, 0mm

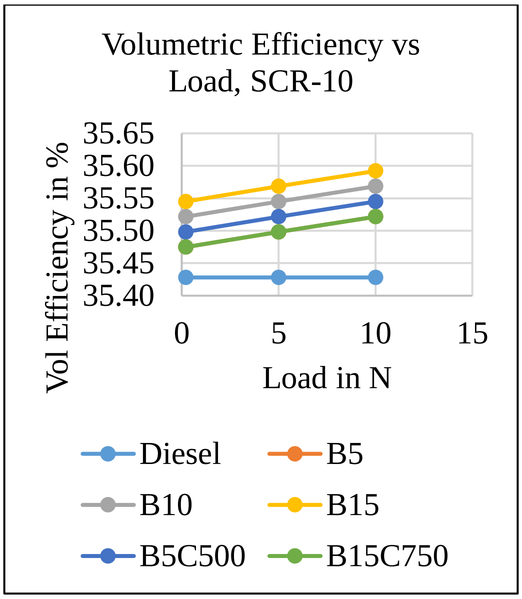


Figure 4.4 Volumetric Efficiency vs Load for scale, 10mm

Based on the aforementioned outcomes, it is noted that the B15C750 blend exhibits superior volumetric efficiency at SCR-0, while the B15 blend demonstrates higher volumetric efficiency at SCR-10.

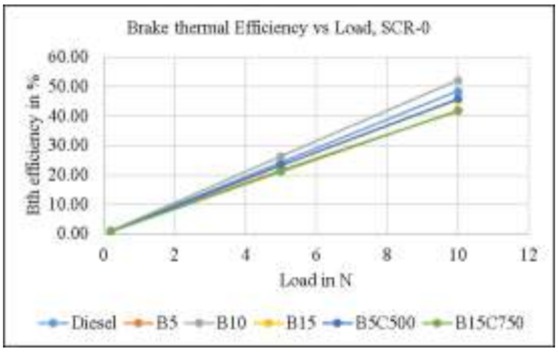


Figure 4.5 Brake Thermal Efficiency vs Load for scale, 0mm

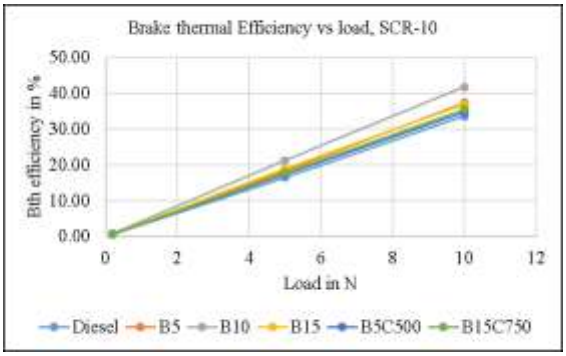


Figure 4.6 Brake Thermal Efficiency vs Load for scale, 10mm

The examination reveals that at SCR-0 and 10, the brake thermal efficiency for the B10 blend surpasses that of other fuels and blends. Furthermore, B15C750 and B15 exhibit comparable efficiencies at SCR-0, while B15C750, B5C500, and diesel share similar brake thermal efficiencies at SCR-10.

4.1.4 Heat Input

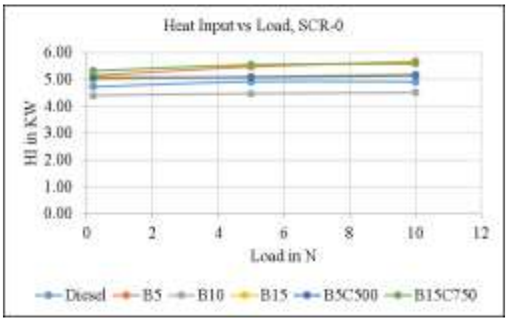


Figure 4.7 Heat Input vs Load for scale, 0mm

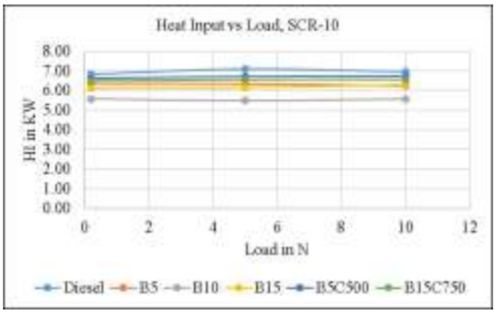


Figure 4.8 Heat Input vs Load for scale, 10mm

The heat input for B15C750 and B5 is marginally higher at SCR-0 when contrasted with others. However, at SCR-10, the heat input is higher for diesel, followed by B15C750.

4.1.5 Brake Power

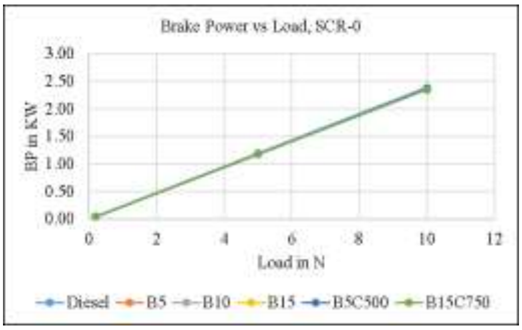


Figure 4.9 Brake Power vs Load for scale, 0mm

Figure 4.10 Brake Power vs Load for scale, 10mm

4.1.6 Mass of Fuel

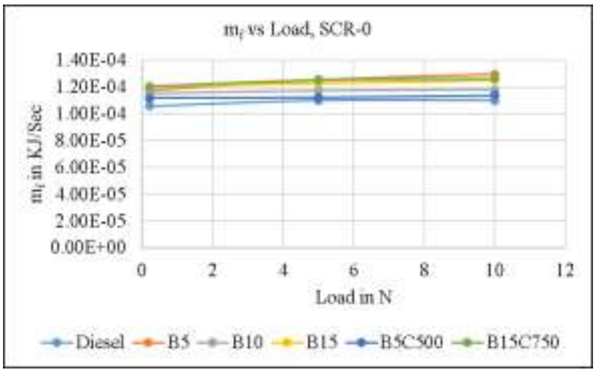


Figure 4.11 Mass of Fuel Consumed vs Load for scale, 0mm

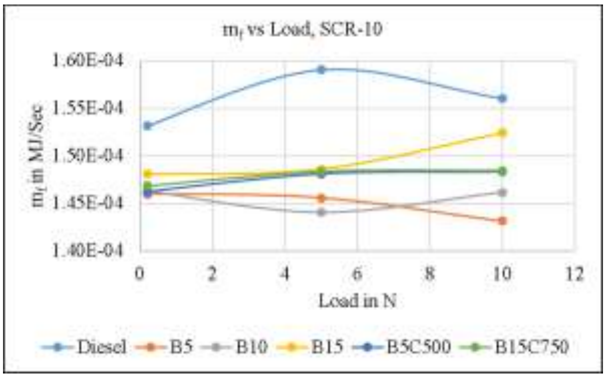


Figure 4.12 Mass of Fuel Consumed vs Load for scale, 10mm

In the provided tables and figures, the fuel consumption rate for B15 and B15C750 is elevated compared to other fuel blends at SCR-0. However, the fuel consumption rate of diesel surpasses others significantly at SCR-10.

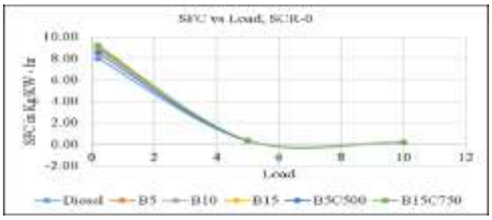


Figure 4.13 Specific Fuel Consumption vs Load for scale, 0mm

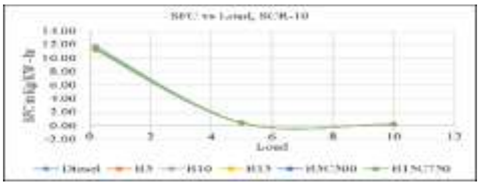


Figure 4.14 Specific Fuel Consumption vs Load for scale, 10mm

- SFC for all the blends is similar at SCR-10. But B15C750 is slightly higher at SCR-0 & Load-0 when compared to others.

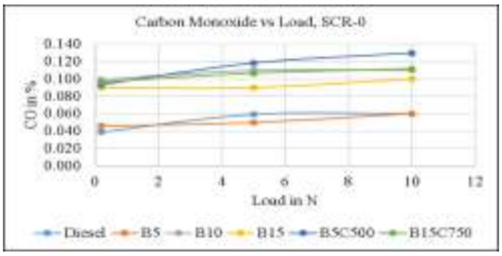


Figure 4.15 Carbon Monoxide vs Load for scale, 0mm

CHAPTER 5
CONCLUSIONS

5.1 CONCLUSINS

It investigates the performance and emission properties of several fuel blends, such as pure Diesel, Bio-Diesel, and blends containing cerium oxide nanoparticles. The objective of this study is to evaluate the feasibility of emission reduction in a single-cylinder compression ignition (CI) engine. The primary outcomes are outlined as follows:

Bio-Diesel and Bio-Diesel-nano particle blends have similar characteristics to commercial Diesel, rendering them appropriate for use in vehicles and railways, as well as for heating oil when combined with other fuel oils. These blends demonstrate economic viability and exhibit reduced emissions of pollutants, characterized by notably lower flash and fire points in comparison to diesel fuel.

Both Bio-Diesel and Nano Particle mixes have lower densities compared to Diesel (850.768 kg/m3), however their calorific values are similar to that of Diesel. It is worth noting that B5C500 exhibits a greater calorific value in comparison to Diesel, hence suggesting its potential suitability as a Bio-Diesel.

The mechanical efficiency of B15C750, particularly, surpasses that of Pure Diesel, indicating its potential as a viable biofuel option.

Bio-Diesel with Nano Particles reduces emissions, such as Carbon Residue and particulate matter, leading to decreased levels of Hydrocarbons in comparison to Diesel. The assessment of various blend compositions has the potential to yield a Bio-Diesel mix that exhibits reduced emissions and enhanced performance.

5.2 FUTURE SCOPE

The experimental investigations undertaken in this study demonstrate the feasibility of small-scale production of bio-diesel with satisfactory quality, utilizing a range of cost-effective raw materials. Nevertheless, it is imperative to continue the investigation into alternate feedstocks. Further investigation is required to ascertain the process prerequisites for attaining optimal output and quality in the esterification of used vegetable oil. Furthermore, it is imperative to focus on improving the low-temperature characteristics of the substance, hence facilitating its integration into bio-diesel blends to a larger extent.

The performance and durability of the engine were assessed within a limited timeframe, indicating the necessity for additional assessment throughout extended periods of operation using these specific blends. The investigation on the compatibility of nano materials can provide valuable insights into the potential of these fuel blends in reducing emissions. Moreover, it is necessary to conduct a comprehensive examination of several factors, including water content, surfactant concentration, agitation speed, and nano particle recovery, in order to gain a comprehensive understanding of their influence on fuel qualities.

The field of environmental studies offers a complete perspective on the overall ramifications associated with the utilization of nano particle-blended fuels.

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