

# **PERFORMANCE AND EMISSION CHARACTERISTICS OF DIESEL BLENDED WITH NEAT LEMONGRASS OIL, N-PENTANOL AND CeO<sub>2</sub> IN A DIESEL ENGINE**

Submitted in partial fulfilment of the requirements for the award of

Bachelor of Engineering degree in

Mechanical Engineering

By

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**SCHOOL OF MECHANICAL ENGINEERING**

**SATHYABAMA**

**INSTITUTE OF SCIENCE AND TECHNOLOGY**

**(DEEMED TO BE UNIVERSITY)**

**Accredited with grade "A++" by NAAC**

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**APRIL 2024**



# **SATHYABAMA**

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## **DEPARTMENT OF MECHANICAL ENGINEERING**

### **BONAFIDE CERTIFICATE**

This is to certify that this Project Report is the bonafide work of MARADANA MOHIT KUMAR (Reg. No. 40150024) and who carried out the project entitled "PERFORMANCE AND EMISSION CHARACTERISTICS OF DIESEL BLENDED WITH NEAT LEMONGRASS OIL, N-PENTANOL AND  $\text{CeO}_2$  IN A DIESEL ENGINE" under our supervision from December 2023 to April 2024.

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## DECLARATION

I M.Mohit Kumar (Reg.No. 40150024) hereby declare that the Project Report entitled **PERFORMANCE AND EMISSION CHARACTERISTICS OF DIESEL BLENDED WITH NEAT LEMONGRASS OIL, N-PENTANOL AND CeO<sub>2</sub> IN A DIESEL ENGINE**” done by me under the guidance of **Dr. S. GANESAN., M.E., Ph.D.**, is submitted in partial fulfilment of the requirements for the award of Bachelor of Engineering degree in Mechanical Engineering.

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## **ABSTRACT**

Numerous alternative fuels, including alcohols and biodiesels, have been made available for purchase in the transportation and industrial sectors. The goal of the research is to maximize the potential sources of renewable energy that are available domestically. Pentanol and lemongrass oil have piqued our interest in this regard. Diesel is mixed with lemongrass oil, pentanol, and cerium oxide added on a volumetric basis. The various blends are B10, B20, B25, and B30. The single-cylinder, four-stroke, water-cooled diesel engine, with a 3.5 kW power supply, is used for the experiments. Investigations were conducted on the diesel fuel blend and the impact of pentanol concentration on engine performance, emissions, and combustion. The tests were conducted with varying loads at a constant 1500 rpm speed. The addition of lemongrass oil has been shown in the results to boost brake thermal efficiency while reducing SFC. These mixes' test results were compared to those of diesel fuel and lemongrass oil, which may lead to higher combustion, reduced emissions of NO<sub>x</sub>, CO<sub>2</sub>, HC, O<sub>2</sub>, CO. Cerium oxide is added, which speeds up combustion and lowers pollutants. In diesel engines, mixed fuel will be utilized in place of diesel, according to the study's findings.

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## LIST OF SYMBOLS AND ABBREVIATIONS

|                 |                           |
|-----------------|---------------------------|
| $\mu$           | Dynamic Viscosity         |
| $\rho$          | Density of fluid          |
| $\nu$           | Kinematic Viscosity       |
| BP              | Brake Power               |
| SFC             | Specific fuel consumption |
| BTHE            | Brake thermal efficiency  |
| CO              | Carbon Monoxide           |
| CO <sub>2</sub> | Carbon Dioxide            |
| HC              | Hydro Carbons             |
| NO <sub>x</sub> | Nitrogen Oxide            |
| O <sub>2</sub>  | Oxygen                    |



# CHAPTER 1

## INTRODUCTION

Energy is becoming more and more crucial in the rapidly developing world of technology for the advancement of any nation. It is also seen as a measure of national social and economic development. With respect to the Per Capita Energy A nation's consumption is largely used, along with its GDP and per capita income, to gauge its level of wealth. The majority of the issues around the careless use of energy resources have been raised internationally as a result of the industrial revolution in the last century. The majority of countries' technological advancement is linked to increased energy consumption, greater industrial advancement, and less attention to the economic use of energy sources.

The Gulf War and the US oil embargo made it imperative for both wealthy and developing nations to figure out how to use energy most effectively. Then, when the oil exporting countries negotiated higher prices, it was the first time that the countries that purchased crude experienced shock value. All of the countries were compelled by this dire energy situation to explore novel renewable energy sources and efficient energy use.

Then, increased productivity, reduced manufacturing costs, and increased efficiency were the country planners' main priorities. This led to a sudden, comprehensive, and multifaceted resolution of the issues arising from limited resources and heightened global energy requirements. Since energy is now seen as a significant component of production costs, effective energy conservation, and management have grown in importance in the industrial sector. The global pattern of energy use has shifted as a result of this constructive approach. As a result, industrialized nations have seen increases in productivity while keeping levels of energy use constant. The final point is that, given the world's rapid growth, renewable energy sources are equally significant and pertinent.

## 1.1 IMPORTANCE OF ENERGY

Energy has significantly changed from being a common area of study for technologies to becoming a crucial component of financial planning and international interfaces. Even though India has an abundance of renewable energy sources and is rich in coal,

Energy comes from wind, bioenergy, solar, and hydropower. Its hydrocarbon reserve is barely 0.7 billion tons, or 0.4 percent of the world's total reserve, which is quite modest. In 2007, India accounted for 3.6% of global primary consumption as well as 10.63% of the Asia-Pacific region's total primary energy consumption. India's economy, the fourth largest in the world, depends heavily on energy use to sustain growth.

Despite not possessing substantial petroleum product reserves, India is highly dependent on imports to meet its energy, transportation, and agricultural needs. rising costs, insufficient

Petroleum production and reserve constraints have placed a significant strain on the nation's foreign exchange reserves. 110.89 million tons of crude oil were imported in 2006–07, despite 33.99 million tons being produced domestically and 144.88 million tons being consumed. India is importing crude petroleum for the sum of Rs. 2199.91 billion, a waste of important foreign cash that could be used for other advancements that could benefit the Indian people more.

India should incorporate more renewable resource investment, more efficient fuel conversion, less environmental effects, and more information in future energy conversion to alleviate the current energy crisis. To meet the energy requirement, efforts must be made to develop and promote the use of renewable energy sources, while the usage of traditional fossil fuels must be gradually reduced.

## 1.2 NEED FOR ALTERNATIVE FUELS

The discussions make it abundantly evident that India is currently dealing with the twin issues of rapid fossil fuel depletion and environmental deterioration. Therefore, it is imperative to lessen reliance on petroleum-derived fuels to improve the environment and economy. Both problems can be resolved by adapting unconventional fuels with a bio-origin. These fuels, which are essentially non-petroleum, improve the environment and provide energy security. The primary form of transportation is diesel. The global economy benefits from its widespread use, which may be attributed to its great combustion efficiency, adaptability, dependability, and affordability. Pollutant emissions are a significant disadvantage, though. Diesel engine emissions are one of the main sources of pollution and pose a severe risk to the environment. It has been established that these pollutants have a major negative influence on ecological systems, generate environmental issues, and contain carcinogenic substances that pose a serious risk to human health.

Concern over combustion-related pollutants, including acid rain, particulate matter oxides of nitrogen ( $\text{NO}_x$ ), carbon monoxide (CO), hydrocarbons (HC), and photochemical haze and depletion, is growing on a global scale. The ozone layer has prompted a number of nations to control emissions and issue guidelines for their implementation. It is well acknowledged that the achievement of clean combustion in diesel engines is contingent upon the congruence of engine development with either additive introduction or reformulation of diesel fuel. Thus, high-pressure injection, turbocharging, exhaust after treatments, and the use of fuel additives—which is regarded as one of the most appealing solutions—are ways to lower PM and  $\text{NO}_x$  emissions.

For almost a century, they have been accessible in one form or another. Studies on the identification of substitute fuels for use in internal combustion engines have been conducted all around the world. Investigations into performance have revealed suitability of a wide range of alternative fuels, including producing gas, hydrogen, alcohols, biogas, and many kinds of edible and non-edible oils. But in the Indian context, bio-origin fuels like biogas, vegetable oils, and alcohols can be used widely and help with fuel crisis issues.

Since diesel engines are the most efficient prime movers, it is vital to find alternative fuels with qualities similar to those of diesel in order to save the environment and address long-term energy security issues. Fuels derived from petroleum. India has a need for diesel fuels that is almost six times greater than that of the rest of the world, therefore it makes sense to look for alternatives to mineral diesel.

Eco-friendly, readily available, and able to meet energy security requirements without compromising engine performance are the goals of alternative fuels. The current trend in the choice of alternative energy sources is waste to energy of fuels. Among the alternative fuels for internal combustion engines are alcohol, biodiesel, liquid fuel made from plastic, and so forth.

A non-renewable energy source, diesel runs out in a few years. It has to be saved for later use. It is important to regulate pollution, especially air pollution from diesel. Thus, we require another fuel for this.

All that constitutes an alternative fuel is fuel that is not conventional fuel. Since alternative fuels are known to be made from plant and animal fats, they will pollute the environment less than traditional fuels. Additionally, pollution is having an impact on the ozone layer. We can now lessen the ozone layer's loss and shield the planet from the sun's harmful rays by employing the alternative fuel.

Alternative fuels are a sustainable energy source that won't run out quickly. They are also readily and often producible. A biodegradable fuel that breaks down quickly qualifies as an alternative fuel. The emissions similar because the alternative fuel has a lower hydrocarbon content than conventional fuel, NO<sub>x</sub>, CO, and other particulate matter can be regulated.

The use of alternative fuels will totally cut down on the amount of fossil fuels used. It is possible to manage the toxins that conventional fuels emit into the atmosphere, thereby contributing to a decent sustainable future. Comparing this to conventional fuel, we can somewhat reach a green environment. Fuel demand is rising gradually as technology opens up new frontiers for research. However, the indiscriminate extraction of fossil fuels may also contribute to the depletion of petroleum reserves. Given that diesel is the primary fuel for transportation in India, it is imperative to discover a suitable substitute for diesel.

The research of alternative fuels for internal combustion engines has gained attention due to environmental concerns and the depletion of petroleum resources. An eco-friendly substitute for diesel fuel is biodiesel.

It is made from edible or inedible oils, it is biodegradable. In light of this, there is currently a resurgence of interest in lemongrass. Because lemongrass oil has the ability to create huge jobs and relatively low scale degradation, it is suitable for compression ignition engines and should receive greater attention in India.

### 1.3 INTRODUCTION TO BIOFUELS

A biofuel is a fuel that is created by modern biological processes like anaerobic digestion and agriculture as opposed to a fuel that is created by geological processes like those that create fossil fuels like coal and petroleum, derived from living things from prehistory. Plants can be the direct source of biofuels, or agricultural, commercial, household, and/or industrial waste might be the indirect source.

### 1.4 CLASSIFICATION OF BIOFUELS

#### **1.4.1 *First generation biofuels.***

First-Generation Biofuel: The sugars and vegetable oils included in arable crops—which are easily harvested with traditional technology—are the raw materials used to make first-generation biofuels.

##### ➤ Types of First-Generation Biofuels

#### **1.4.1.1 *Bioethanol***

Alcohol that is formed biologically is mostly produced by the fermentation of sugars, starches, or cellulose by microorganisms and enzymes. Less frequently, butanol and propanol are also produced.

The most widely used biofuel in the world is ethanol. Any sugar or starch obtained from wheat, corn, sugar beets, sugar cane, molasses, or any combination of these will ferment to produce alcohol. Molasses and any other sugar or starch that can be used to make alcoholic drinks. The procedures used to make ethanol include fermentation of the sugars, distillation, drying, and enzyme digestion, which releases sugars from starches that have been stored. While pellets, wood chips, and waste heat are more prevalent in Europe, the most common fuel used in Brazil during the distillation process is cellulosic biomass, such as bagasse, which is the waste left over after sugar cane is pressed to extract its juice. This process requires a significant amount of energy for heat and is occasionally unsustainable when using fossil fuels like natural gas.

#### *1.4.1.2 Biodiesel*

In Europe, biodiesel is the most widely used biofuel. It is made from oils or fats by a process called transesterification, and its makeup is identical to that of fossil. Mineral-based diesel Chemically speaking, it is primarily made up of methyl or ethyl esters of fatty acids. Animal fats, vegetable oils, soy, rapeseed, jatropha, mahua, mustard, flax, sunflower, palm oil, hemp, algae, etc. are feedstocks for biodiesel. As of right now, pure biodiesel (B100) can cut emissions by up to 60% when compared to second-generation B100.

When combined with mineral diesel, biodiesel can be utilized in any type of diesel engine. Some manufacturers provide B100 coverage for their diesel engines under warranty, however, Volkswagen of Germany, for instance, advises drivers to double-check before converting to B100, over the phone with the VW environmental services department. At lower temperatures, B100's viscosity may increase based on the feedstock utilized. Diesel engines manufactured after 1994 that employ "Viton" synthetic rubber in their mechanical fuel injection systems are generally compatible with biodiesel. It should be noted, however, that prior to 2014, no vehicle was certified to run on clean biodiesel because there was no biodiesel-specific emission control technique available.

#### *1.4.1.3 Bio Methanol*

Now, natural gas—a non-renewable fossil fuel—is used to make methanol. It is intended to be made from biomass as bio-methanol in the future. Although technically possible, the production has been put on hold due to concerns. The question of economic viability remains unanswered. In contrast to the current method of producing hydrogen from natural gas, the methanol economy offers an alternative to the hydrogen economy.

#### *1.4.1.4 Green Diesel*

Hydrocracking biological oil feedstocks, such as vegetable and animal fats, yields green diesel. A refinery process called hydro cracking breaks down materials by using high pressure and temperatures along with a catalyst. Breaking down bigger molecules—like those in vegetable oil—into shorter hydrocarbon chains that are utilized in diesel engines. It is also known as hydrogen-derived renewable diesel, hydro treated vegetable oil, or renewable diesel made from hydrogen. Diesel derived from petroleum and green diesel share the same chemical characteristics. It can be distributed and used without the need for new engines, pipelines, or infrastructure because it is not as expensive to generate as petroleum. Versions that run on gasoline are also in development.

#### *1.4.1.5 Vegetable oil*

Although lower-quality oil has been used, gasoline made from straight, unaltered edible vegetable oil is not often used for this purpose. Vegetable oil waste is increasingly being converted into biodiesel or, less frequently, being dried and refined to remove water and particles before being utilized as fuel.

Similar to 100% biodiesel, or B100, vegetable oil fuel needs to be heated using electric coils or heat exchangers to lower its viscosity to that of diesel in order for the fuel injectors to atomize it in the proper pattern for effective combustion. In warm or temperate climates, this is simpler.

Many older diesel engines that do not have electronic diesel injection systems such as common rail or unit injection can also run on vegetable oil. These are the greatest because of the way indirect injection engines' combustion chambers are designed. Engines designed to run on vegetable oil. This mechanism prolongs the burning period of the larger oil molecules.

It is possible to hydrogenate oils and lipids to create a diesel alternative. The end result is a straight-chain hydrocarbon devoid of oxygen, low in sulphur and aromatics, and with a high cetane number. Oils that are hydrogenated can be combined in exact amounts with diesel. Compared to biodiesel, they have several benefits, including as superior low- temperature performance, no issues with storage stability, and immunity to microbiological attack.

#### *1.4.1.6 Bio ethers*

Bio ethers, commonly known as oxygenated fuels or fuel ethers, are inexpensive substances that raise the octane rating of gasoline. Bioethanol reacts with iso-olefins, like isobutylene, to form bio ethers. Bioethics are produced by sugar beet and wheat. In addition, they improve engine performance while lowering harmful exhaust emissions and engine wear considerably.

Because of their low energy density, bio ethers are unlikely to become a fuel in and of themselves, even if they are expected to replace petroleum ethers. As a result of their significant reduction in ground-level ozone emissions, they improve air quality.

#### *1.4.1.7 Biogas*

Methane, or biogas, is created when anaerobes break down organic matter anaerobically. It can be made by feeding energy crops into anaerobic digesters or using biodegradable waste products. Gas yields from supplements. Digestate, a solid byproduct, has two uses: fertilizer and biofuel.

#### *1.4.1.8 Syngas*

Syngas, a combination of carbon monoxide, hydrogen, and other hydrocarbons, is produced when biomass is partially burned, or when there is not enough oxygen present to convert the biomass completely to carbon. Carbon dioxide with water. After being periodically pyrolyzed and dried, the biomass is partially burnt. When the fuel is burnt directly, less energy is recovered from the original biofuel than from the resulting gas mixture, syngas. Syngas can be burnt directly in turbines, high-temperature fuel cells, or internal combustion engines. The wood gas generator is a fuel-fueled gasification reactor that may be connected to an internal combustion engine.

#### *1.4.1.9 Solid biofuels*

Agricultural waste, dry manure, wood, sawdust, grass clippings, home garbage, charcoal, and non-food energy crops are a few examples. When biomass is already in a suitable form, such firewood, it can be burnt directly to create heat or steam in a stove or furnace. When the raw biomass is in an inconvenient form (such as sawdust, wood chips, grass, urban waste wood, or agricultural leftovers), densifying it is the standard technique.

### **1.4.2 Second Generation Biofuels**

Advanced biofuels, sometimes referred to as second generation biofuels, are fuels made from several kinds of biomass. Any source of organic carbon that is quickly replenished as a component of the carbon cycle is referred to as biomass, which is a broad phrase. Although it can sometimes contain animal elements, biomass is primarily sourced from plant materials.

#### ➤ Types of Second-Generation Biofuels

#### *1.4.2.1 Sustainable Biofuels*

Liquid biofuels made from plant resources are making their way onto the mark, primarily due to the belief that they lower greenhouse gas emissions, but also because of reasons like oil price hikes and the demand for greater energy security.

However, a lot of the biofuels that are now being supplied have come under fire because of their detrimental effects on land use, food security, and the environment.

#### *1.4.2.2 Ethanol biofuels*

Despite being generated all over the world, ethanol biofuel is a biologically produced biofuel. There are several steps involved in the creation of bioethanol. In order to allow the sugar or starch in the plant material to break down, the biomass is first fermented anaerobically for a while. But a growing number of businesses are already making bioethanol by turning plant cellulose into sugars, which opens up the possibility of using a larger variety of biomass. To enable the elimination of water, the fuel needs to be distilled after fermentation. Nevertheless, dehydration is gradually taking the place of this ten-stage process since it yields greater outcomes while consuming less energy, boosting the fuel's net energy gain.

#### *1.4.2.3 Algal biofuels*

Algal biofuel is a fuel substitute for liquid fossil fuels that obtains its energy-dense oils from algae. As an alternative to well-known biofuel sources like corn and sugarcane, algal fuels can be produced. In an effort to lower capital and operating costs and achieve commercial viability for algal fuel generation, a number of businesses and government organizations are providing support. Algae fuel and other biofuels release CO<sub>2</sub> when burned, much like fossil fuels do, but only after the algae or plant has grown and undergone photosynthesis, removing CO<sub>2</sub> from the environment.

### 1.5 REVOLUTION OF BIOFUELS

The diesel engine was invented in Germany by Rudolf Diesel. He created a diesel engine that ran on peanut oil, and Henry Ford subsequently created the Model T automobile, which was manufactured between 1903 and 1926. This vehicle was built exclusively to run on biofuel made from hemp. However, the discovery of enormous crude oil reserves made petroleum in some areas of Texas and Pennsylvania extremely inexpensive, which reduced the demand for biofuels. Due

to its higher efficiency and lower cost, this type of fuel was first used by the majority of cars and trucks.

Biofuels were in high demand during World War II because they were being used more frequently as an alternative to imported fuel. Germany was among the nations that experienced a severe fuel scarcity during this time. It was also around this time that other inventions such as the usage of gasoline and alcohol derived from potatoes were made. Grain alcohol combined with gasoline was an idea first introduced by Britain.

The numerous significant technological advancements occurred during the conflicts, but during the peacetime cheap oil from the Middle East and the Gulf countries again relieved strain. The geopolitical and commercial interest in biofuel diminished as supplies rose. Because of the geopolitical struggle, the different countries had a significant fuel crisis once more from 1973 and 1979.

As a result, the group of countries that export petroleum drastically reduced shipments, particularly to non-OPEC countries. The persistent scarcity of fuel drew the interest of scholars and policymakers to the problems surrounding the energy crisis and the utilization of biofuels.

People began to pay more attention to the usage of biofuels in the 20th century. Rising oil prices, greenhouse gas emissions, and interests in rural development were some of the primary factors that caused people to become more interested in biofuels. Lemongrass has a place in biodiesels because of the long-standing demand for biofuels. Because lemongrass has a larger calorific value than other biodiesels, we were able to use it to create a different biodiesel that performs better and emits less emissions.

## 1.6 INTRODUCTION OF LEMON GRASS OIL

Because of its adaptable qualities and invigorating scent, lemongrass oil which is derived from the tropical herb *Cymbopogon citratus* has become extremely popular across a wide range of businesses. The lemongrass leaves are steam-distilled to extract this essential oil, which results in a strong, zesty-scented liquid with a wealth of medicinal uses. Lemongrass oil, with its characteristic lemon scent, is used extensively in aromatherapy to improve mood, reduce tension, and encourage relaxation.

It is an important component of natural cleaning solutions and insect repellents due to its antibacterial and antifungal qualities. In addition, lemongrass oil is well-known for its possible health advantages. In conventional medicine, it is used to treat digestive problems, lower inflammation, and ease aches in the muscles.

Lemongrass oil is highly valued in the beauty and cosmetics sector for its astringent qualities, which make it a great cleanser and toner for skin that is greasy or prone to acne. Its inclusion in lotions, soaps, and perfumes gives them a rejuvenating and refreshing feel.

With its potential to provide both medicinal benefits and a pleasing aroma, lemongrass oil is still in high demand as an ingredient in many different products due to the growing popularity of natural medicines and aromatherapy. It is a mainstay in homes, spas, and wellness centres across the globe due to its energizing aroma and several health advantages.

## CHAPTER 2

### LITERATURE SURVEY

A lot of research has been done Lemongrass which proves that lemongrass oil can indeed be converted to useful biodiesel.

Naveen Kumar (2007) has conducted a study on using high FFA rice bran oil to produce biodiesel and using it in a tiny diesel engine. Viscosity and density of biodiesel produced from high FFA rice bran oil through a two-stage formulation procedure were comparable to those of diesel. Biodiesel had a calorific value that was around 7% less than diesel's. Because biodiesel has a higher flash point than diesel, it is safer to carry and store. Biodiesel has a higher cetane number than diesel. When compared to diesel, the engine produces less power. Compared to diesel, biodiesel had reduced smoke opacity, making it a more environmentally friendly fuel.

Sajith V et al (2009), has conducted experiments looking into how a fuel additive containing cerium oxide nanoparticles affects biodiesel. Adding additives can change a hydrocarbon fuel's physicochemical qualities and combustion characteristics. Additives work best when they are in the form of nanoparticles since they increase the surface area to volume ratio. This study reported on ASTM standard testing for engine performance tests and fuel property measurements for biodiesel that has been altered by the inclusion of cerium oxide nanoparticles. To find out how the nanoparticle additions affected the physicochemical characteristics, engine performance, and emissions, experiments were conducted at various dose levels.

Mohamed Hanaa A.R (2012), Three distinct drying techniques were used to dry the leaves of lemongrass (*Cymbopogon citratus*): 36 hours of sun drying, 48 hours of shade drying, and 7 hours of oven drying at 45 C. The leaves that had been dried after each treatment were hydro-distilled to extract the essential oil, which was then examined using GC/mass and capillary GC equipment. Significant 12 variations in

the essential oil concentration of leaves dried using various drying techniques were revealed by statistical analysis.

In comparison to methods of sun-drying (2.10%) and shade-drying (2.12%), oven-drying produced the highest percentage of essential oils (2.45%). The essential oil of fresh and dried *C. citratus* leaves, obtained by various drying techniques, contained eighteen components, with the primary ones being myrcene, neral (citral-b), and geranial (citral-a). The drying techniques had a noticeable impact.

Abbas Alli Taghipoor Bafghi et al (2015), has conducted an experimental study to determine the compression ignition engine's performance characteristics while adding cerium oxide nanoparticles to straight diesel and diesel-biodiesel mixes. The stability of pure diesel and diesel-biodiesel fuel mixes with cerium oxide nanoparticle addition is examined in the first phase of the research. Following a series of tests, it was discovered that the mixes that were exposed to high-speed mixing and then ultrasonic bath stabilization had better stability. The stable fuel blends in a single cylinder, four stroke engine paired with an electrical dynamometer and a data gathering device are used to study performance parameters in the second phase. Cerium oxide supplies oxygen for burning by functioning as a catalyst that donates oxygen. Reduced HC emissions are the result of  $\text{CeO}_2$  activation energy, which acts to burn off carbon deposits inside the engine cylinder at wall temperature and stop non-polar molecules from depositing on the cylinder wall. The research showed that cerium oxide nanoparticles can be added to diesel and diesel-biodiesel blends to greatly increase the fuel's ability to burn completely.

Sathyamoorthi R (2015), The performance, combustion, and emission characteristic of a direct-injection diesel engine were investigated in this study using four different fuel blends, which included diesel, LGO25, LGO50, and neat lemongrass oil. The injection timings of the blends were varied, with the positions of  $21^\circ$  (retarded),  $23^\circ$  (normal), and  $27^\circ$  (advanced) bTDC. The experimental findings demonstrate that for all test fuels, enhanced fuel injection time led to an increase in maximum cylinder pressure and heat release rate. With enhanced injection timing, there was a decrease in BSFC and a notable increase in brake thermal efficiency 13 (BTE). In comparison to alternative injection timings, the advanced injection timing resulted in

significantly higher NO<sub>x</sub> emissions from the diesel engine, but emissions such as smoke and hydrocarbon (HC) were reduced. Advancement of the injection timing causes an increase in ignition delay, which makes the premixed region's initial phase of combustion more noticeable. The ideal injection time for LGO-diesel mixes was discovered to be 27° bTDC based on the trial findings.

Swarup Kumar Nayak et al (2015), A test utilizing mixtures of diesel and Calophyllum inophyllum biodiesel was examined to determine the impact of compression ratio on the combustion parameters of a VCR engine. Variable compression ratio (VCR) engines' conventional design parameters fail to provide targeted performance when using biodiesel with different sources. In addition to extensive research on the performance and emission analysis of various types of biodiesel, very limited work has been done on combustion analysis using VCR. The purpose of this study was to determine how the compression ratio affected the combustion parameters of a diesel engine running on blends of diesel and Calophyllum inophyllum oil methyl ester. Experiments were run with varying compression ratios, full load, and a constant speed of 1500 RPM.

Koushik Guha Biswas et al (2016), has investigated biodiesel's function in India's renewable energy sector. According to him, India is currently not at a very high position on the global biodiesel map. Nonetheless, the nation intends to grow the biodiesel industry. Since crude oil imports supply the majority of our nation's energy needs, energy security has emerged as the key factor influencing economic growth. Because it is made from renewable resources and offers advantages for the environment, biodiesel is currently gaining popularity as a diesel engine alternative fuel. Transesterification is the most widely used of the various production techniques for natural oils and fats. Lowering the oil's or fat's viscosity is the process' goal. Due to their accessibility and familiarity, edible oils are the subject of more research and development in the biodiesel industry. There are two further factors that affect production costs: the transesterification process and the recovery of glycerol from byproducts. One of options to reduce manufacturing costs is to use a continuous transesterification process. Shorter reaction times and higher manufacturing capacities are the cornerstones of this method. Recovering high-grade glycerol is a further method to reduce production costs. Land is becoming more and more scarce

due to population increase. To combat this, high-yielding biodiesel plants (those that don't produce food) can be planted in waste and marginal land regions.

Avinash Alagumalai (2017), The process of producing biodiesel by transesterifying Jatropha oil was examined. This study examines the effects of reaction temperature, time, molar ratio of methanol to oil, and KOH (catalyst) quantity on the yield of Jatropha biodiesel. Using Taguchi's techniques, the best possible combination of process parameters for maximum yield was determined. Performance and emission tests were conducted using a single-cylinder, four-stroke diesel engine. Tests were conducted on various mixtures of Jatropha biodiesel and regular diesel. The findings showed that jatropha oil does not require engine changes to be used as an alternative fuel in current diesel engines.

Ganapathy Subramanian L.R (2017), Numerous alternative fuels, including biodiesel and alcohols, have been made available for purchase in both the industrial and transportation sectors. Cottonseed oil and isobutanol piqued our curiosity in this situation. The single cylinder, four-stroke diesel engine used in the experiments has a power output of 5.2 kW. The engine is tested at 1500 rpm and under various load conditions for blends of cottonseed oil and isobutanol with diesel that are prepared according to volume, such as B10, B10 + 5%, B10 + 10%, B20, B20 + 5%, and B20 + 10%. The outcome demonstrates that adding cottonseed oil lowers exhaust gas temperature and specific fuel consumption while increasing brake thermal efficiency. Along with a rise in HC emissions, adding more cottonseed oil to the blend also lowers other emission parameters like CO, CO<sub>2</sub>, NO<sub>x</sub>, and O<sub>2</sub>. The addition of isobutanol to a blend of diesel fuel including cottonseed oil has a comparable impact to the addition of pure cottonseed oil in different proportions, which lowers exhaust gas temperature and specific fuel consumption while increasing brake thermal efficiency.

Pinkesh R. Shah (2017), Therefore, the goal of this study is to use soy lecithin, which is naturally occurring, as a bioadditive with SVO to address engine performance issues. It is commonly known that soy lecithin has emulsifying and surfactant qualities. This study's primary goal is to determine how soy lecithin combined with non-edible karanj oil (*Pongamia pinnata*) affects a CI engine's short-term test

performance, combustion, and emission characteristics. This study also clarified how soybean lecithin affects the Sauter mean diameter (SMD) and physical characteristics of Karanj oil. This investigation also looks at how soy-lecithin affects injector deposits. A Cummins DXP 15-5, two-cylinder, DI diesel engine that had not been modified was put through its paces with a variable braking load. The test findings showed that, when compared to karanj oil without additive and without affecting brake-specific fuel consumption, the inclusion of soy-lecithin significantly decreased NO<sub>x</sub> and CO emissions. When compared to karanj oil without additive, the addition of soy-lecithin significantly decreased cylinder pressure, HRR, ignition delay, and mean gas temperature while increasing mechanical efficiency over the whole load range. It was discovered that soy lecithin significantly reduced injector deposits.

Purnachandran Ramakrishnan (2017), Petroleum-based fuels have long been used with alcohol as an additive. In this investigation, blends of Calophyllum inophyllum (CI) biodiesel and diesel were treated with the higher alcohol, n-pentanol, at volumes of 10,15, and 20%. The proportion of CI was kept constant at 20% by volume in all mixes. The diesel and CI20 (Calophyllum inophyllum 20% and diesel 80%) biodiesel blends were compared with the engine characteristics of the pentanol fuel blends. Compared to CI20 and pure diesel fuel, the pentanol fuel mixes' nitrogen oxide (NO) emissions were higher. When pentanol addition to fuel mixes increased relative to CI20 fuel blend and diesel, so did the carbon dioxide (CO<sub>2</sub>). Compared to CI20 fuel and diesel, the blend's emissions of carbon monoxide (CO) and hydrocarbons (HC) reduced as the fraction of pentanol increased. Using mixed fuels with pentanol decreased the amount of smoke released into the air and also enhanced the engine's combustion characteristics. Based on the findings of this study, a 20% pentanol addition to biodiesel or diesel fuel is recommended for better engine performance and combustion characteristics without requiring any engine modifications. Pentanol also increased CO<sub>2</sub> and NO emissions because of efficient combustion.

Sathyamoorthi R (2017), In this experiment, ethanol was combined with a neat lemongrass oil (LGO) diesel fuel blend, and the impact of the ethanol concentration on the engine's performance, emissions, and combustion was examined. The

effects of small ethanol concentrations (2.5 and 5%) in the plain lemongrass oil-diesel blend were investigated. The test outcomes obtained with diesel fuel and various mixtures were contrasted. When compared to diesel fuel, the studied blends produced varied performance, emission, and combustion characteristics. In comparison to diesel and LGO25 (75% neat diesel + 25% neat lemongrass oil), the ethanol blends produced higher combustion pressure and heat release rate, brake specific fuel consumption, and brake thermal efficiency. However, they also produced lower smoke and HC emissions and higher NO<sub>x</sub> and CO<sub>2</sub> emissions.

M. Sunil Kumar, In this investigation, different fuel types, including diesel and lemongrass biodiesel, were tested on diesel engines in an effort to improve performance and combustion with lower exhaust emissions. In addition, three different types of nano- additives—zinc oxide, titanium dioxide, and aluminum dioxide—were added to lemongrass oil to improve its performance and combustion characteristics as well as reduce exhaust emissions from diesel engines. The remaining 70% of the oil is blended at a ratio of 30% over 100% and used as diesel, or 30% LOBD. It was determined that FT-IR characterization of lemongrass oil and XRD, SEM, and FT-IR characterisation of ZnO, TiO<sub>2</sub>, and Al<sub>2</sub>O<sub>3</sub> nanoparticles conformed their behavior in the anatase phase. The brake specific fuel consumption of B3050TiO<sub>2</sub>, B3050ZnO, and B3050Al<sub>2</sub>O<sub>3</sub> increased by 1.3% compared to diesel fuel, but the brake thermal efficiency of B3050ZnO increased by 4.9%. Analysis was done on emissions including CO, NO<sub>x</sub>, and HC. For B3050TiO<sub>2</sub>, B3050ZnO 17, and B3050Al<sub>2</sub>O<sub>3</sub>, the reduction in carbon monoxide emissions was 17%, 39%, and 5%, respectively. The emission of nitrogen oxide rose by 73PPM for B3050Al<sub>2</sub>O<sub>3</sub>, 290PPM for B3050TiO<sub>2</sub>, and 310PPM for B3050ZnO. For B3050TiO<sub>2</sub>, B3050ZnO, and B3050Al<sub>2</sub>O<sub>3</sub>, the hydrocarbon emissions were reduced by 3.3%, 32.5%, and 1%, in that order. B3050ZnO has a substantial and significant dependence on brake thermal efficiency beyond 3%, according to the ANOVA table. Following four fuel types' validation, B3050ZnO significantly affects performance, combustion parameters, and exhaust emissions.

## CHAPTER 3

### AIM AND SCOPE

#### 3.1 AIM OF THE PROJECT

The main aim of this project is to reduce the emissions of the CI diesel engine by blending neat lemongrass oil with diesel along with oxygen buffering agents. The biodiesel also increases the power and efficiency of the engine when compared to that of diesel engines. It also aims to increase the usage of biodiesels than the crude oil and petroleum product fuels.

By using the steam distillation method, lemongrass can be converted into biodiesel, which might be used as a fuel for diesel engines. The process of turning lemongrass oil into lemongrass biodiesel involves extracting the free fatty acids that cause the biodiesel and glycerol to separate. The biodiesel that has been separated is thoroughly cleaned to remove any traces of glycerol. as well as learning about lemon grass oil's qualities. Next, the biodiesel is mixed with regular diesel in the necessary ratios, denoted as B10, B20, B25, and B30, where B stands for biodiesel. The performance, combustion, and emission properties of lemongrass oil biodiesel is determined through an experimental examination, and blends of the biodiesel doped with cerium oxide ( $\text{CeO}_2$ ) nanoparticles are provided. Cerium oxide 25 ppm functions as a catalyst that donates oxygen, allowing carbon monoxide to be oxidized and nitrogen oxides to be reduced. The addition of  $\text{CeO}_2$  nanoparticles to blends has a considerable negative impact on hazardous exhaust gas emissions and promotes green combustion. Pentanol is also blended with the biofuel which has oxygenated fuel properties which reduces particulate emission in diesel engines. Based on the study, modified fuel performs well closer to conventional diesel on the source of experimental work.

Our aim is to study the performance characteristics of lemongrass biodiesel and diesel blended with cerium oxide nano additive and pentanol on single cylinder VCR diesel engine, study various emissions characteristics of lemongrass biodiesel and

to find an alternative by comparing the results of lemongrass biodiesel blends with base fuel performance and emissions characteristics

### 3.2 SCOPE OF THE PROJECT

The need for biodiesel production is extremely strong due to the daily decline in the supply of petroleum goods. Since petroleum products aren't available everywhere in the world, home oils can be converted into biodiesels. Additionally, biodiesel emits fewer emissions than diesel, which mitigates the greenhouse effect, which is currently the world's biggest issue. The renewable and eco-friendly substitute for traditional diesel fuel, biodiesel, has garnered a lot of interest and awareness lately. Because of its broad application across multiple industries, it's a great subject for a project report. In the allotted 300 words, this paragraph seeks to give a broad overview of the applications of biodiesel.

The natural biodiesel sources—vegetable oils, animal fats, and algae—offer several advantages in terms of economic growth, environmental sustainability, and energy security. The reduction of reliance on fossil fuels, which are limited resources and a primary cause of climate change, is one of the primary benefits of biodiesel. Due to its practicality in reducing greenhouse gas emissions and battling global warming, biodiesel is viewed favorably by businesses, governments, and individuals alike as an alternative fuel. In the transportation industry, biodiesel can be used either pure or combined with regular diesel fuel to directly replace petroleum-based diesel fuel. This adaptability makes it possible for current diesel engines to function properly without the need for major modifications, which makes the switch to renewable energy sources easier. Biodiesel also has excellent lubricating qualities, which prolongs engine life and performance. Because of this, the transportation industry—which includes both public and private fleets—can greatly lower its carbon footprint and improve the quality of the air.

The manufacturing of biodiesel can promote rural development and economic progress. The production of feedstocks for biodiesel, such as palm oil, rapeseed, and soybeans, generates jobs in agricultural and associated sectors. Furthermore, localized biodiesel manufacturing plants can lessen reliance on imported fossil fuels, enhancing energy independence and fostering economic stability.

## CHAPTER 4

### MATERIALS AND EXPERIMENTAL METHOD

#### 4.1 MATERIALS USED

##### **4.1.1. *Lemon grass oil***

In the grass family, the genus *Cymbopogon*, commonly referred to as lemongrass, includes plants from Asia, Africa, Australia, and tropical islands. Due to their lemon-like scent, some species are frequently grown for their culinary and medicinal uses. Common names for these plants include lemon grass, barbed wire grass, silky heads, citronella grass, cha de Dartigalongue, fever grass, tanglad, hierba Luisa, or gavaticahapati, among many others.



**Fig:4.1: *Lemon grass***

The base stems of citronella grass have a magenta tint and can grow up to 2 meters (6.6 feet). These species are used to make citronella oil, which is used in soaps, candles, insect sprays, and aromatherapy. Citronella oil is very effective against mosquitoes. Since geraniol, citronella, and citronellol are the main chemical ingredients of these substances, they are used in household disinfectants. And cleaning products. In addition to being used to produce oil, citronella grass is flavourful in food. Both lemongrass and attractant pheromones, which are produced by the honeybee's Nasonov gland, function quite well. For this reason, lemongrass oil can be used as a bait when trying to attract hive bees or trapping swarms.



**Fig:4.2: Lemon grass oil**

#### **4.1.2 N-PENTANOL**

When compared to butanol, N-Pentanol, a straight chain alcohol with a 5-carbon structure, has an even higher energy density and cetane number. The mass and concentration of black particulate matter may be decreased by n-pentanol. N-Pentanol is utilized in this procedure as an O<sub>2</sub> buffer to speed up fuel combustion.

**Table 4.1: Properties of N-Pentanol**

| <b>Properties</b>                                    | <b>N-Pentanol</b> |
|------------------------------------------------------|-------------------|
| Cetane number                                        | 20                |
| Lower heating value [MJ kg <sup>-1</sup> ]           | 34.65             |
| Density at 20 C [kg m <sup>-3</sup> ]                | 814               |
| Viscosity at 40 C [mm <sup>2</sup> s <sup>-1</sup> ] | 2.88              |
| Vaporization latent heat [kJ kg <sup>-1</sup> ]      | 308               |
| Flashpoint [C]                                       | 49                |
| Boiling point [C]                                    | 138               |

#### **4.1.3 Cerium oxide (CeO<sub>2</sub>)**

When cerium oxide was added to diesel, the oxidation rate increased greatly and the number weighted size distributions and light-off temperature were significantly reduced. Because it can buffer oxygen, cerium oxide, a rare earth metal with two

valence states, exhibits remarkable catalytic activity, particularly when it is in the nanoscale form. Therefore, when added to diesel fuel, it causes the emissions of hydrocarbons and nitrogen dioxide from diesel engines to be reduced and oxidized simultaneously.



**Fig:4.3: Cerium oxide (CeO<sub>2</sub>)**

**Table 4.2: Properties of Cerium  
Oxide Nonadditive**

|                     |                                                  |
|---------------------|--------------------------------------------------|
| Molecular formula   | CeO <sub>2</sub>                                 |
| Molar mass          | 172.115 g/mol                                    |
| Appearance          | White or pale yellow solid, Slightly Hygroscopic |
| Density             | 7.215 g/cm <sup>3</sup>                          |
| Melting point       | 2,400 °C (4,350 °F; 2,670 K)                     |
| Boiling point       | 3,500 °C (6,330 °F; 3,770 K)                     |
| Solubility in water | Insoluble                                        |
| Crystal structure   | Cubic (fluorite)                                 |

## 4.2 EXPERIMENTAL METHOD

### 4.2.1 *Transesterification setup*

The transesterification set up contains separation flask, heater, round bottom 3 neck flask etc. The round bottom 3 neck flask is used to heat the Lemon Grass oil to 60°C and to add methanol and sodium hydroxide to the lemongrass oil. The separation flask is used for separation of glycerol from the lemongrass oil after adding methanol and sodium hydroxide. The separation flask is also used for washing the Lemon Grass oil which is free from glycerol until it reached neutral pH. The heater is used for drying the Lemon Grass oil to eliminate water content.



**Fig:4.4: Round bottom 3 neck flask**

### 4.2.2 *Bomb calorimeter*

An experimental tool for calculating a substance's or fuel's calorific value is a bomb calorimeter. It is a closed system where the amount of heat released is measured after a sample of the material is fully burned in a regulated setting. The calorimeter is made of metal and has wires for ignition, a thermometer, and a pressure gauge. The calorimeter vessel is filled with the sample that will be analysed and oxygen. After that, the vessel is sealed and immersed in water. By passing an electric current via the ignition wires, the sample is ignited. The water bath absorbs the heat

produced during combustion, raising the water's temperature. The amount of heat released is calculated

by measuring the temperature change of the water and the heat capacity of the calorimeter vessel. This method of measuring heat release is called direct calorimetry. Bomb calorimeter is used to determine the calorific value of the Lemongrass oil.

Bomb calorimeters are incredibly accurate, dependable, and exact. They can be used to ascertain a substance's calorific value to within 0.1%. However, they require a lot of money and effort to operate. Furthermore, they don't reveal anything about a substance's chemical makeup or other characteristics—they only measure the amount of heat it releases.



**Fig:4.5 Bomb Calorimeter**

#### **4.2.3 Kinematic viscometer bath**

A laboratory tool for determining a liquid's viscosity is a kinematic viscometer bath. The characteristic of a fluid that controls its resistance to flow is called viscosity. Under circumstances, the kinematic viscometer bath calculates the amount of time it takes a liquid to pass through a capillary tube.

A glass capillary tube with a specified diameter that is suspended vertically in a bath with regulated temperature makes up the device. The liquid to be tested is put into the bath, and the temperature is adjusted to a predefined level. After that, a syringe is used to fill the capillary tube with the liquid, and a timer is used to time how long it takes for the liquid to flow through the tube.

Stokes' Law, which states that a particle's rate of sedimentation in a fluid is proportional to its size, density, and fluid viscosity, provides the basis for the operation of the kinematic viscometer bath. A Stokes' Law-based formula can be used to determine the viscosity of a liquid by timing how long it takes for it to pass through a capillary tube. Kinematic viscometer bath is used to determine the kinematic viscosity of the Lemongrass oil.



***Fig:4.6: Kinematic viscometer bath***

#### ***4.2.4 Pensky martens flash point apparatus***

A laboratory tool called the Pensky-Martens flash point apparatus is used to find the flash point of liquids, including petroleum products. The temperature at which a liquid releases enough vapor in the presence of a flame or spark to cause it to ignite is known as its flash point. The device is made out of a metal cup with a lid that has a gas burner and a thermometer attached to it. The sample to be examined is placed into the cup, and the lid is shut. Next, a controlled rate of heating is applied to the cup using the gas burner, and regular intervals are used to record the temperature.

When a test flame is run over a sample, the flash point is attained when a little flame is briefly visible at the sample's surface. The flash point is the temperature at which this happens. Pensky martens flash point apparatus is used to determine flash point and fire point of lemongrass oil.

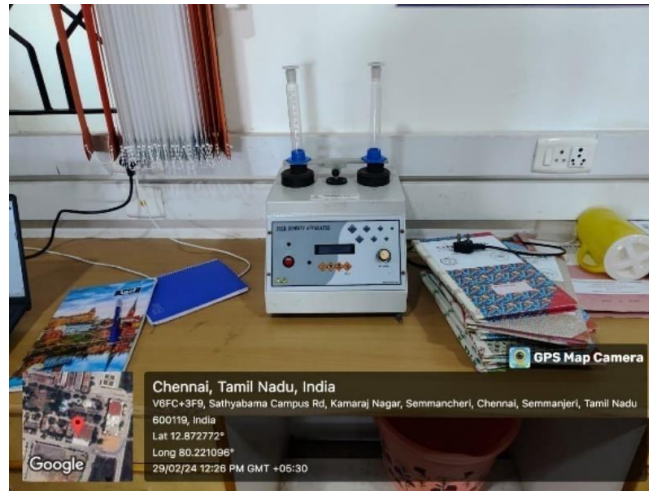


***Fig:4.7: Pensky martens flash point apparatus***

#### ***4.2.5 Bulk density test apparatus***

A laboratory tool used to ascertain the bulk density of powders and other dry materials is the bulk density test device. The weight of a substance in its natural or uncompacted state per unit volume is known as its bulk density. It has a significant impact on how powders and other materials behave during processing, storage, and transportation, making it a crucial parameter in their characterization.

The device is made up of a funnel fastened to the top of a cylindrical container with a known volume. Using the funnel, the container is filled with the substance to be examined, and any surplus material is scraped out with a straight edge. A balance is then used to determine the weight of the material and the container. Bulk density test apparatus is used to determine the density of the Lemongrass oil.



**Fig:4.8: Bulk density test apparatus**

#### **4.2.6 VCR diesel engine**

The engine performance and emission properties of lemongrass biodiesel were assessed using a single-cylinder, constant speed Direct Injection engine. With varying blend proportions, the diesel operates at a steady 1500 rpm and 3.5 kW of power under various load scenarios. An eddy current dynamometer was directly linked to the diesel engine to allow for load variations from zero percent (0%) to 100%. Depending on the engine's power, There are different engine load conditions: 0%, 25%, 50%, 75%, and 100% at full load. With the use of an eddy current dynamometer, the engine loads are manually adjusted.

Fuel flow was measured using the volumetric calibrated burette method, and air flow rate was determined using an air drum with a calibrated aperture. Two fuel tanks were utilized to test fuel flow; one was filled with pure diesel and the other with transesterified lemongrass biodiesel. Temperatures of the exhaust gases and smoke opacity were recorded using an AVL smoke meter that was mounted. AVL Indi mini software was placed on the test rig in order to collect a variety of readings and findings while it was in use.

A five-gas analyzer was used to test the emission parameters of the exhaust gas, such as the amounts of HC, CO, CO<sub>2</sub>, O<sub>2</sub>, and NO<sub>x</sub>. A 17.5% compression ratio and rated power were used for the performance and emissions testing. Brake thermal

efficiency (BTE), specific fuel consumption (SFC), and different mix ratios of lemongrass biofuel mixed with pure diesel fuel were tested.

The engine's rated power fluctuated depending on emissions parameters (HC, CO, CO<sub>2</sub>, O<sub>2</sub>, and NO<sub>x</sub>), according to the engine performance analysis.



**Fig:4.9: VCR diesel engine**



**Fig:4.10: VCR diesel engine testing**

**Table 4.3: Specifications of the Test Engine**

|                     |                                                                                       |
|---------------------|---------------------------------------------------------------------------------------|
| Engine Type         | Single Cylinder, 4 Stroke, Water Cooled<br>Engine Stoke 110mm, bore 87.5mm,<br>661 cc |
| Power               | 3.5 KW @ 1500 rpm                                                                     |
| Compression ratio   | 17.5                                                                                  |
| Injection variation | 0-25 deg BTDC                                                                         |
| Dynamometer         | Eddy current, Water cooled with<br>Loading unit                                       |
| Fuel tank           | 15 lit, Dual compartments with fuel<br>metering                                       |

#### **4.2.7 Engine testing software**

EngineSoft is a suite of LabVIEW-based software for engine performance monitoring systems, produced by Apex Innovations Pvt. Ltd. EngineSoft may be able to meet the majority of engine testing application requirements, such as monitoring, reporting, data entry, and data recording. The software evaluates power, efficiency, fuel consumption, and heat release. It is programmable based on engine configuration. At various working conditions, different graphs are produced. Signals that are required for online engine testing in RUN mode are scanned, saved, and shown on a graph. The data is seen in tabular and graphical formats by accessing the stored data file. It is possible to print the graphs and findings. Additional analysis can be performed using the excel formatted data.

#### **4.2.8 Smoke meter**

An instrument called a smoke meter is used to evaluate the density or opacity of smoke released by combustion engines, especially diesel engines. By directing a light beam into the exhaust gas plume, it operates on the basis of light absorption. The opacity of the gas is derived from the amount of light absorbed by the smoke particles and is expressed as a percentage or a numerical value. Smoke meters are essential instruments for evaluating how car emissions affect the environment and making sure that laws governing pollution and air quality are followed. These instruments assist authorities in enforcing emission rules and keeping an eye on vehicle performance by precisely measuring the opacity of smoke. Smoke meters are also used in auto repair to identify issues with engines and maximize combustion, which eventually results in healthier air and better public health.



**Fig:4.11: Smoke meter**

#### **4.2.9 Gas Analyzer**

A tool called a gas analyser is used to determine how much of a certain gas is present in a sample. These devices are widely used in many different industries, such as industrial operations, medical diagnostics, vehicle emissions testing, and environmental monitoring. To precisely measure the presence of gases, gas analysers employ a variety of detection mechanisms, including thermal conductivity, electrochemical sensing, and spectroscopy.

Gas analysers are essential for tracking air quality, identifying contaminants, and determining if regulations are being followed in environmental applications. By monitoring gas composition and guaranteeing safety, they aid in process

optimization in industrial settings. Measurement of exhaust emissions by automotive gas analysers contributes to the creation of cleaner and more fuel-efficient automobiles. Gas analysers are used in medical applications to track patient health and diagnose respiratory conditions.

Gas analyser data facilitates well-informed decision-making, regulatory compliance, and the execution of strategies aimed at reducing environmental pollution and guaranteeing worker safety.



***Fig:4.12 :Gas analyser***

## CHAPTER 5

### RESULTS AND DISCUSSIONS

#### 5.1 RESULTS

The lemongrass oil was used for the preparation of biodiesel. For the transesterification of lemongrass oil, methanol and sodium hydroxide were used. The oil to methanol ratio is 1:6 and 5 grams of sodium hydroxide is used as catalyst per liter. The reaction time was 90 minutes at the temperature of 60°C. The yield was 96.8%.

**Table 5.1: Transesterification of lemon grass oil**

| S.No | Parameters                  | Results    |
|------|-----------------------------|------------|
| 1    | Free fatty acid             | 0.31 %     |
| 2    | Catalyst (NaOH) quantity    | 5 grams    |
| 3    | Oil to Methanol molar ratio | 1:6        |
| 4    | Temperature                 | 60 °C      |
| 5    | Reaction time               | 90 minutes |
| 6    | Yield                       | 96.8 %     |

#### 5.2 PROPERTIES OF LEMONGRASS OIL

##### **5.2.1 Kinematic Viscosity**

A fluid's resistance to progressive deformation caused by tensile or shear stress is measured by its viscosity. It is equivalent to the loose definition of thickness for liquids.

The ratio of the dynamic viscosity ( $\mu$ ) to the fluid density ( $\rho$ ) is known as the kinematic viscosity, commonly referred to as "momentum diffusivity". The Greek letter nu is typically used to represent it ( $\nu$ ).

### **5.2.2 Flash Point**

The lowest temperature at which volatile material vapors will ignite in the presence of an ignition source is known as the flash point. The temperature at which vapor spontaneously ignites without the need for an ignition source is known as the auto ignition temperature, and it can occasionally be confused with the flash point. The lowest temperature at which vapor will continue to burn after being lit and the ignition source removed is known as the fire point. Because the vapor may be counted on to dependably stop burning when the ignition source is withdrawn, the fire point is greater than the flash point. The temperature of the ignition source will obviously be much higher than the flash point or fire point, even if they are not directly correlated.

### **5.2.3 Fire Point**

A fuel's fire point is the lowest temperature at which, when ignited by an open flame, the fuel's vapour will burn for at least five seconds. Substances will ignite momentarily at the flash point, which is a lower temperature, but they may not release enough vapour to keep the fire going. The majority of material property tables simply include the material flash points. Though it's generally safe to presume that the fire points are around 10°C higher than the flash points. Testing to see if the fire site is safety essential is still necessary. The fire point is tested using an open cup apparatus.

### **5.2.4 Calorific Value**

When a material completely burns with oxygen under conventional conditions, the total energy produced as heat is known as the calorific value. Usually, when oxygen and a hydrocarbon or other organic molecule combine, carbon dioxide, water, and heat are released. It may be expressed with the quantities:

- energy/mole of fuel (kJ/mol)
- energy/mass of fuel
- energy/volume of the fuel

**Table 5.2: Properties of lemon grass oil**

| <b>S.No</b> | <b>Properties</b>             | <b>Results</b> |
|-------------|-------------------------------|----------------|
| 1           | Density(g/cc)                 | 0.908 V        |
| 2           | Kinematic Viscosity @40 (cSt) | 1.23           |
| 3           | Flashpoint by PMCC method(°C) | 110            |
| 4           | Fire point by PMCC method(°C) | 119            |
| 5           | Calorific value (Cal/g)       | 7278.73        |

### 5.3 BLEND PROPORTION OF BIODIESEL

Diesel and lemongrass oil biodiesel with additives in various mixes were evaluated under various load conditions for engine performance and emissions.

**Table 5.3: Blend proportion of biodiesel**

| <b>S.No</b> | <b>Blends</b> | <b>Diesel (Wt %)</b> | <b>Biodiesel (Wt %)</b> | <b>Cerium oxide (ppm)</b> | <b>N-pentanol (Wt %)</b> |
|-------------|---------------|----------------------|-------------------------|---------------------------|--------------------------|
| 1           | B10           | 85                   | 10                      | 25                        | 5                        |
| 2           | B20           | 75                   | 20                      | 25                        | 5                        |
| 3           | B25           | 70                   | 25                      | 25                        | 5                        |
| 4           | B30           | 65                   | 30                      | 25                        | 5                        |



***Fig 5.1: B<sub>10</sub> Sample***



***Fig 5.2: B<sub>20</sub> Sample***



***Fig 5.3: B<sub>25</sub> Sample***



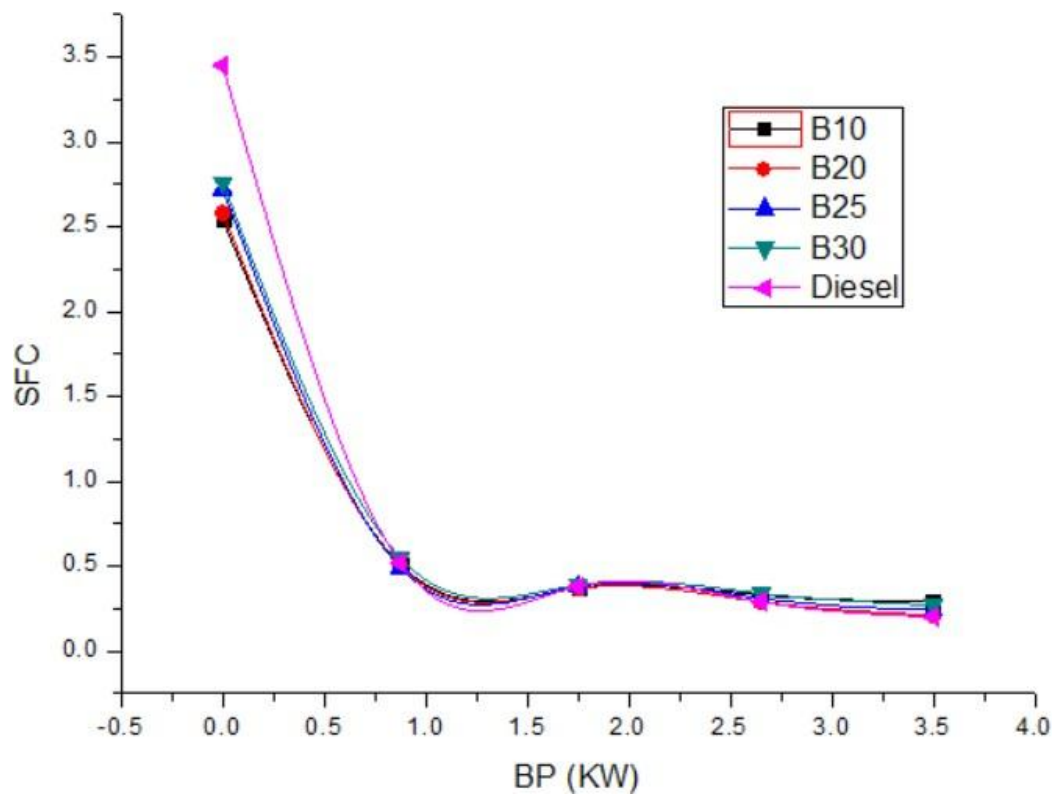
***Fig 5.4: B<sub>30</sub> Sample***

#### 5.4 VARIATION OF SFC VS BP

The difference in SFC for various BP (KW) applied to the engine for various ratios of blends of lemongrass biodiesel with an addition of cerium oxide and n-pentanol are shown below in the figure.

**Table:5.4: Variation of SFC vs BP**

| BP    | B10  | B20  | B25  | B30  | Diesel |
|-------|------|------|------|------|--------|
| 0     | 2.54 | 2.58 | 2.72 | 2.76 | 3.45   |
| 0.875 | 0.51 | 0.5  | 0.49 | 0.55 | 0.52   |
| 1.75  | 0.37 | 0.37 | 0.38 | 0.39 | 0.38   |
| 2.65  | 0.33 | 0.29 | 0.31 | 0.34 | 0.29   |
| 3.5   | 0.29 | 0.21 | 0.24 | 0.27 | 0.2    |



**Fig:5.5: SFC vs BP Graph**

At 0% BP, B30 exhibits the highest SFC among the biodiesel blends, with a value of 2.76, which is lower than that of pure diesel (3.45). At 25% BP, B30 also has the

highest SFC among the biodiesel blends, with a value of 0.55, which is higher than that of pure diesel (0.52). At 50% BP, B30 maintains the highest SFC among the biodiesel blends, with a value of 0.39, exceeding that of pure diesel (0.38). At 75% BP, B30 continues to have the highest SFC among the biodiesel blends, with a value of 0.34, which is higher than that of pure diesel (0.29). At 100% BP, B30 again exhibits the highest SFC among the biodiesel blends, with a value of 0.27, surpassing that of pure diesel (0.2).

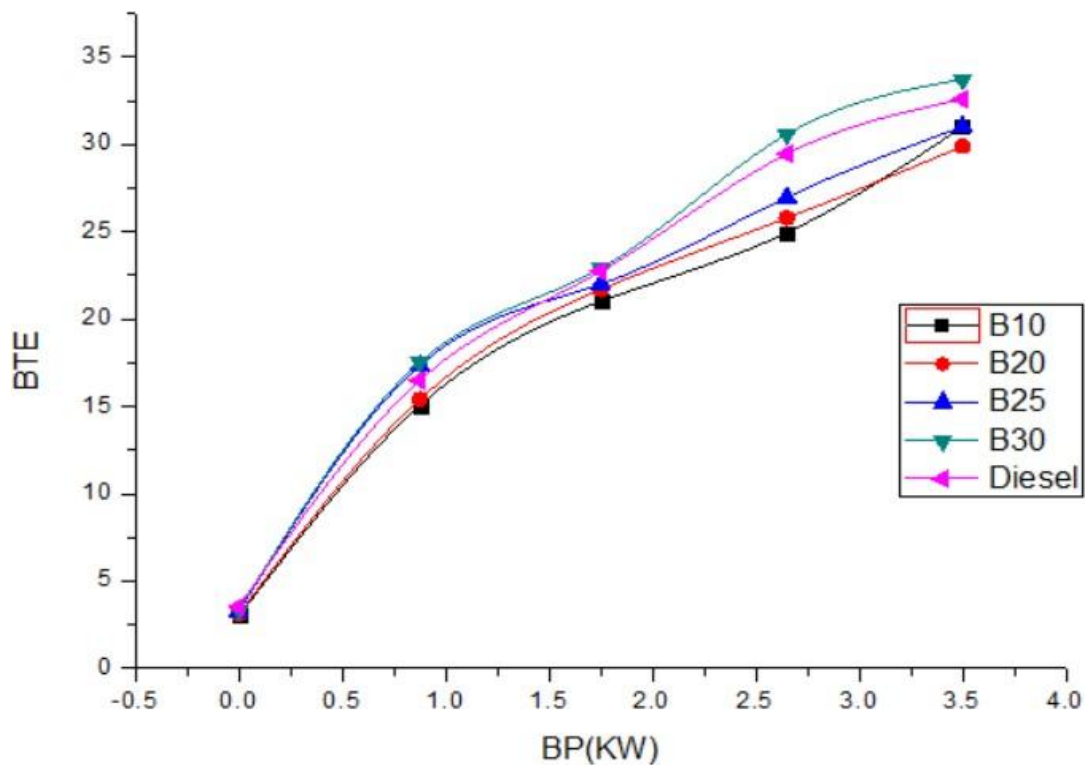
B30 values are close to diesel values. This is because B30 has higher viscosity like diesel which reduces the combustion efficiency. Higher engine speeds lead to better fuel and air mixing, which improves fuel combustion. While the engine continues to run at a high load, the cylinder temperature rises, which improves combustion and partially enhances the fuel atomization and evaporation processes as well as the fuel air mixing process.

## 5.5 VARIATION OF BTE VS BP

The difference in BTE for various BP (KW) applied to the engine for various ratios of blends of lemongrass biodiesel with an addition of cerium oxide and N-pentanol are shown below in the figure.

**Table:5.5: Variation of BTE vs BP**

| <b>BP</b> | <b>B10</b> | <b>B20</b> | <b>B25</b> | <b>B30</b> | <b>Diesel</b> |
|-----------|------------|------------|------------|------------|---------------|
| 0         | 3.01       | 3.13       | 3.26       | 3.34       | 3.52          |
| 0.875     | 15.05      | 15.41      | 17.35      | 17.53      | 16.49         |
| 1.75      | 21.02      | 21.7       | 22.01      | 22.91      | 22.75         |
| 2.65      | 24.96      | 25.8       | 26.98      | 30.59      | 29.47         |
| 3.5       | 31.01      | 29.9       | 31.02      | 33.72      | 32.59         |



**Fig:5.6: Brake thermal efficiency vs BP Graph**

At 0% BP, B30 exhibits the highest BTHE among the biodiesel blends, with a value of 3.34, which is lower than that of pure diesel (3.52). At 25% BP, B30 also has the highest BTHE among the biodiesel blends, with a value of 17.53, which is higher than that of pure diesel (16.49). At 50% BP, B30 maintains the highest BTHE among the biodiesel blends, with a value of 22.91, exceeding that of pure diesel (22.75). At 75% BP, B30 continues to have the highest BTHE among the biodiesel blends, with a value of 30.59, which is higher than that of pure diesel (29.47). At 100% BP, B30 again exhibits the highest BTHE among the biodiesel blends, with a value of 33.72, surpassing that of pure diesel (32.59).

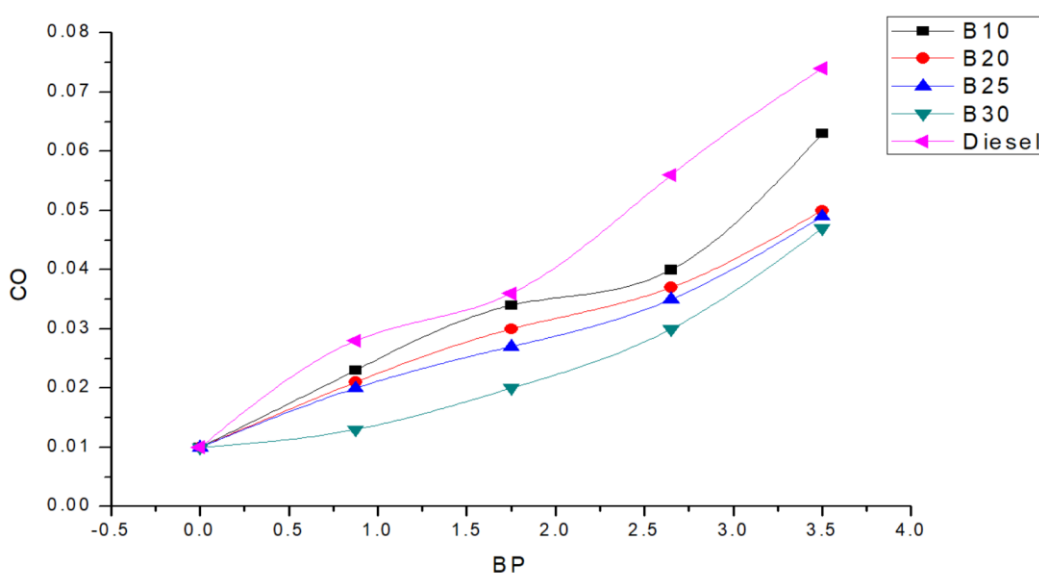
At a high load, the cylinder temperature rises, which improves combustion and partially enhances the fuel atomization and evaporation processes as well as the fuel air mixing process. Moreover, incorporating pentanol and cerium oxide into the mixtures assisted in raising the oxygen content. Oxygen acts as a combustion promoter by speeding up the combustion process and increasing the combustion chamber's temperature. The combustion is now finished.

## 5.6 VARIATION OF CO VS BP

The difference in CO for various BP (KW) applied to the engine for various ratios of blends of lemongrass biodiesel with an addition of cerium oxide and N-pentanol are shown below in the figure.

**Table 5.6: CO vs BP**

| BP    | B10   | B20   | B25   | B30   | Diesel |
|-------|-------|-------|-------|-------|--------|
| 0     | 0.01  | 0.01  | 0.01  | 0.01  | 0.01   |
| 0.875 | 0.03  | 0.03  | 0.02  | 0.01  | 0.021  |
| 1.75  | 0.034 | 0.03  | 0.027 | 0.02  | 0.036  |
| 2.65  | 0.04  | 0.037 | 0.035 | 0.03  | 0.056  |
| 3.5   | 0.06  | 0.05  | 0.049 | 0.047 | 0.08   |



**Fig:5.7: CO vs BP Graph**

At 0% BP, B30 exhibits the same CO among the biodiesel blends, with a value of 0.01, which is same as that of pure diesel (0.01). At 25% BP, B30 also has the lowest CO among the biodiesel blends, with a value of 0.01, which is lower than that of pure diesel (0.021). At 50% BP, B30 maintains the lowest CO among the biodiesel blends, with a value of 0.02, lower that of pure diesel (0.036). At 75% BP, B30

continues to have the lowest CO among the biodiesel blends, with a value of 0.03, which is lower than that of pure diesel (0.056). At 100% BP, B30 again exhibits the lowest CO among the biodiesel blends, with a value of 0.47, surpassing lower that of pure diesel (0.08).

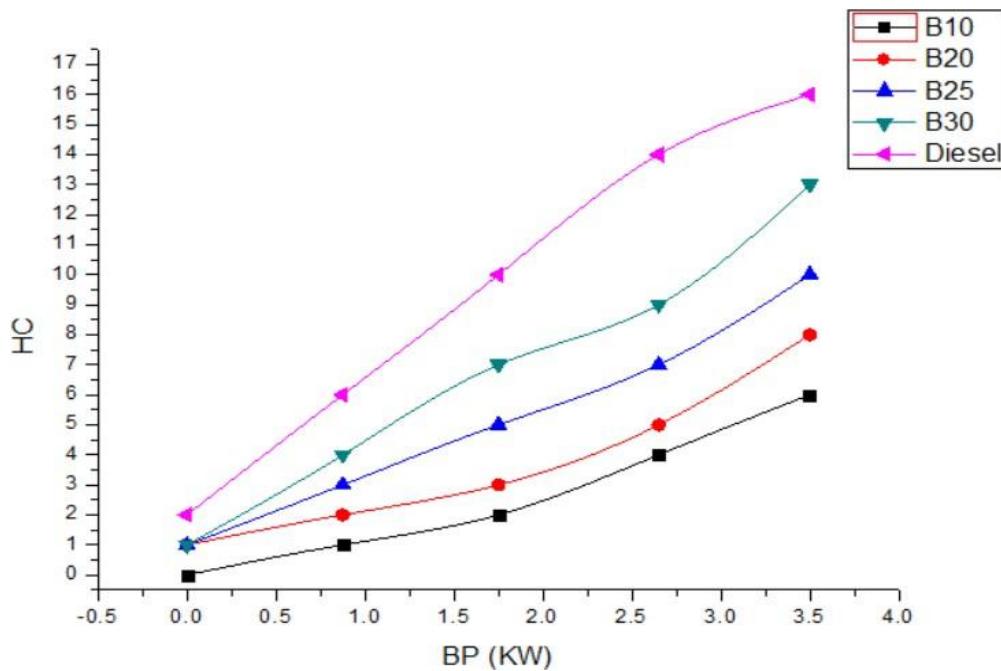
Biodiesel contains oxygen, which facilitates more complete combustion in the engine. This enhanced combustion process leads to a reduction in the formation of carbon monoxide during the combustion of biodiesel blends. Secondly, biodiesel often has a higher cetane number compared to conventional diesel, which promotes more efficient combustion and reduces the likelihood of incomplete combustion, a common cause of elevated CO emissions. Additionally, biodiesel generally has lower levels of impurities such as sulfur and aromatics compared to traditional diesel, which can contribute to lower CO emissions. The absence of sulfur in biodiesel reduces the formation of sulfur oxides (SO<sub>x</sub>), which can act as catalysts in the formation of CO.

## 5.7 VARIATION OF HC VS BP

The difference in unburnt HC for various BP (KW) applied to the engine for various ratios of blends of lemongrass biodiesel with an addition of cerium oxide and N-pentanol are shown below in the figure.

**Table 5.7: Variation of HC vs BP**

| <b>BP</b> | <b>B10</b> | <b>B20</b> | <b>B25</b> | <b>B30</b> | <b>Diesel</b> |
|-----------|------------|------------|------------|------------|---------------|
| 0         | 0          | 1          | 1          | 1          | 2             |
| 0.875     | 1          | 2          | 3          | 4          | 6             |
| 1.75      | 2          | 3          | 5          | 7          | 10            |
| 2.65      | 4          | 5          | 7          | 9          | 14            |
| 3.5       | 6          | 8          | 10         | 13         | 16            |



**Fig:5.8: HC vs BP Graph**

At 0% BP, B30 exhibits the higher HC among the biodiesel blends, with a value of 1, which is lower than that of pure diesel (2). At 25% BP, B30 also has the higher HC among the biodiesel blends, with a value of 4, which is lower than that of pure diesel (6). At 50% BP, B30 maintains the higher HC among the biodiesel blends, with a value of 7, lower that of pure diesel (10). At 75% BP, B30 continues to have the higher HC among the biodiesel blends, with a value of 9, which is lower than that of pure diesel (14). At 100% BP, B30 again exhibits the lowest HC among the biodiesel blends, with a value of 13, surpassing lower that of pure diesel (16).

Biodiesel typically contains oxygen, which promotes more complete combustion in the engine. This enhanced combustion process reduces the presence of unburned hydrocarbons in the exhaust gases, resulting in lower HC emissions. Additionally, biodiesel generally has a higher cetane number compared to conventional diesel, which leads to more efficient combustion. Improved combustion efficiency means that there are fewer unburned fuel molecules in the exhaust, consequently reducing HC emissions. Furthermore, biodiesel typically has lower levels of aromatic hydrocarbons and sulphur compared to traditional diesel. Aromatics and sulphur

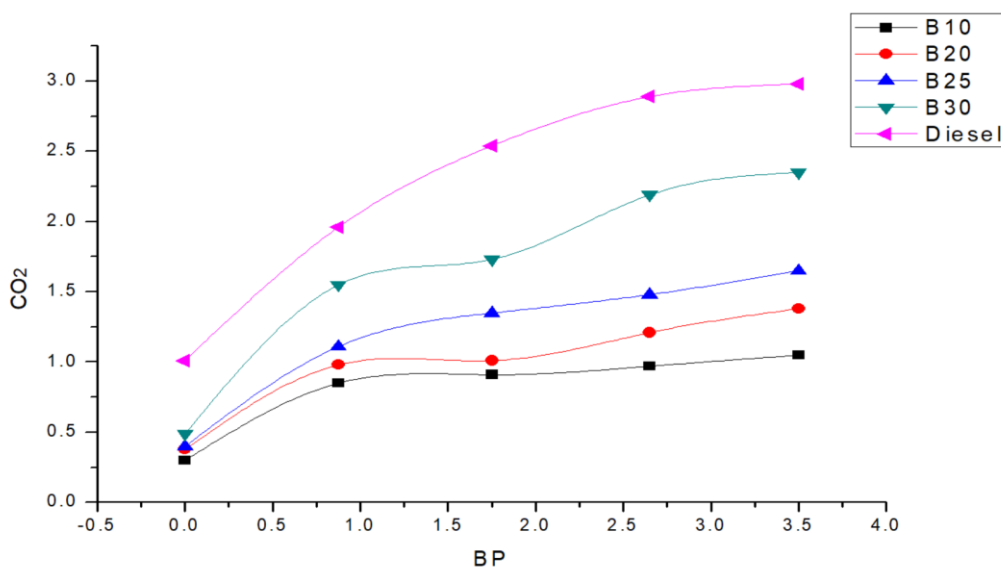
compounds present in diesel fuel can contribute to increased HC emissions. By using biodiesel, which contains fewer of these compounds, the overall HC emissions are reduced.

## 5.8 VARIATION OF CO<sub>2</sub> VS BP

The difference in CO<sub>2</sub> for various BP (KW) applied to the engine for various ratios of blends of lemongrass biodiesel with an addition of cerium oxide and N-pentanol are shown below in the figure.

**Table 5.8: Variation of CO<sub>2</sub> vs BP**

| BP    | B10  | B20  | B25  | B30  | Diesel |
|-------|------|------|------|------|--------|
| 0     | 0.20 | 0.27 | 0.36 | 0.40 | 1.6    |
| 0.875 | 0.58 | 1.30 | 1.43 | 1.55 | 1.96   |
| 1.75  | 0.60 | 0.69 | 1.11 | 1.73 | 2.54   |
| 2.65  | 0.70 | 0.78 | 1.48 | 2.19 | 2.89   |
| 3.5   | 0.85 | 0.95 | 1.65 | 2.35 | 2.98   |



**Fig:5.9: CO<sub>2</sub> vs BP Graph**

At 0% BP, B30 exhibits the higher CO<sub>2</sub> among the biodiesel blends, with a value of 0.40, which is lower than that of pure diesel (1.6). At 25% BP, B30 also has the

higher CO<sub>2</sub> among the biodiesel blends, with a value of 1.55, which is lower than that of pure diesel (1.96). At 50% BP, B30 maintains the higher CO<sub>2</sub> among the biodiesel blends, with a value of 1.73, lower than that of pure diesel (2.54). At 75% BP, B30 continues to have the higher CO<sub>2</sub> among the biodiesel blends, with a value of 2.19, which is lower than that of pure diesel (2.89). At 100% BP, B30 again exhibits the lowest CO<sub>2</sub> among the biodiesel blends, with a value of 2.35, surpassing lower than that of pure diesel (2.98).

Biodiesel is produced from renewable resources such as vegetable oils, animal fats, or recycled cooking oil. These feedstocks absorb carbon dioxide from the atmosphere during their growth or production process, effectively offsetting the CO<sub>2</sub> emissions generated when biodiesel is burned in an engine. This process is known as carbon sequestration, where the carbon absorbed during feedstock growth is retained within the biodiesel and does not contribute to net CO<sub>2</sub> emissions when the fuel is used.

Additionally, biodiesel combustion tends to be more complete compared to traditional diesel due to its oxygen content and higher cetane number. Complete combustion results in more efficient utilization of the fuel's energy content, producing fewer CO<sub>2</sub> emissions per unit of energy output.

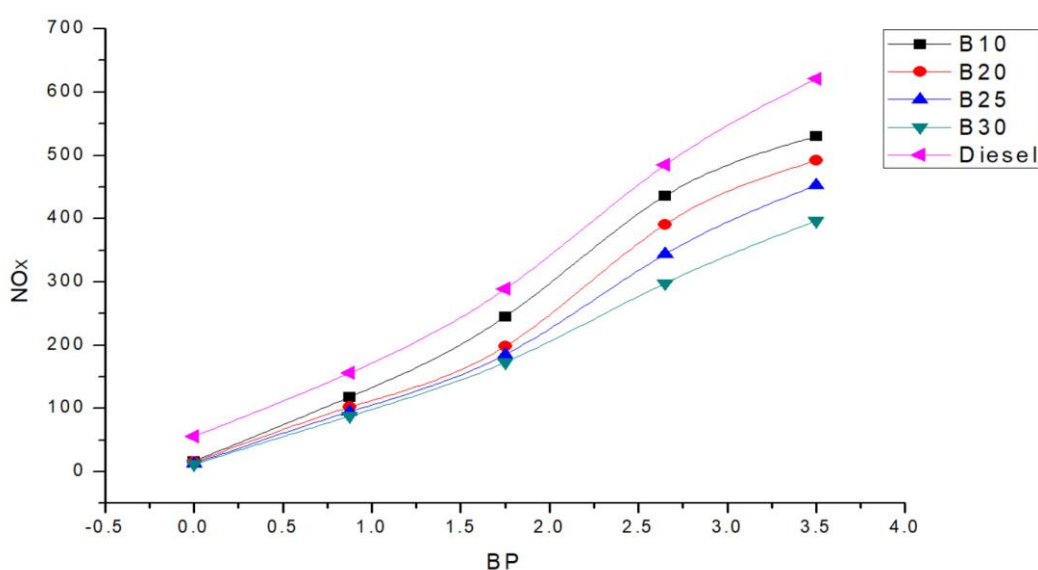
Furthermore, biodiesel typically contains lower levels of sulphur and aromatics compared to traditional diesel. When burned, sulphur and aromatic compounds in diesel fuel can contribute to the formation of particulate matter and other pollutants, which may indirectly influence CO<sub>2</sub> emissions. By using biodiesel with lower sulphur and aromatic content, the combustion process becomes cleaner, resulting in reduced emissions overall, including CO<sub>2</sub>.

## 5.9 VARIATION OF NO<sub>x</sub> VS BP

The difference in NO<sub>x</sub> for various BP (KW) applied to the engine for various ratios of blends of lemongrass biodiesel with an addition of cerium oxide and N-pentanol are shown below in the figure.

**Table 5.9: Variation of NO<sub>x</sub> vs BP**

| BP    | B10 | B20 | B25 | B30 | Diesel |
|-------|-----|-----|-----|-----|--------|
| 0     | 17  | 15  | 13  | 12  | 56     |
| 0.875 | 118 | 102 | 95  | 88  | 156    |
| 1.75  | 245 | 198 | 185 | 173 | 289    |
| 2.65  | 436 | 391 | 344 | 298 | 485    |
| 3.5   | 530 | 524 | 513 | 492 | 750    |



**Fig:5.10 NO<sub>x</sub> vs BP Graph**

At 0% BP, B30 exhibits the lower NO<sub>x</sub> among the biodiesel blends, with a value of 12, which is lower than that of pure diesel (56). At 25% BP, B30 also has the lower NO<sub>x</sub> among the biodiesel blends, with a value of 88, which is lower than that of pure diesel (156). At 50% BP, B30 maintains the lower NO<sub>x</sub> among the biodiesel blends,

with a value of 173, lower than that of pure diesel (289). At 75% BP, B30 continues to have the lower NO<sub>x</sub> among the biodiesel blends, with a value of 298, which is lower than that of pure diesel (485). At 100% BP, B30 again exhibits the lower NO<sub>x</sub> among the biodiesel blends, with a value of 492, surpassing lower than that of pure diesel (750).

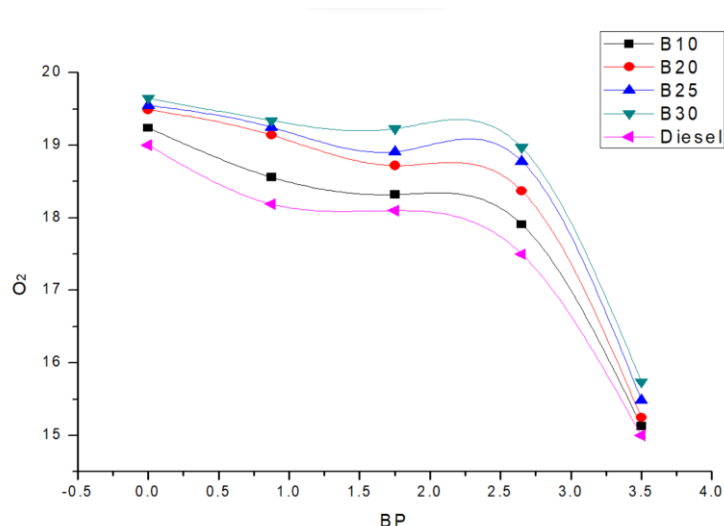
Biodiesel combustion tends to occur at lower peak temperatures compared to conventional diesel, primarily due to its higher cetane number and oxygen content. Lower combustion temperatures inhibit the formation of nitrogen oxides, as NO<sub>x</sub> formation is favoured at higher temperatures where nitrogen and oxygen molecules react within the combustion chamber. By reducing the peak combustion temperatures, biodiesel inherently lowers the potential for NO<sub>x</sub> formation during the combustion process. Additionally, biodiesel contains lower levels of sulphur compared to traditional diesel. Sulphur in diesel fuel can act as a catalyst in the formation of nitrogen oxides by promoting the oxidation of nitrogen during combustion. By using biodiesel with reduced sulphur content, the likelihood of NO<sub>x</sub> formation is further diminished.

#### 5.10 VARIATION OF O<sub>2</sub> VS BP

The difference in O<sub>2</sub> for various BP (KW) applied to the engine for various ratios of blends of lemongrass biodiesel with an addition of cerium oxide and N-pentanol are shown below in the figure.

**Table 5.10 Variation of O<sub>2</sub> vs BP**

| <b>BP</b> | <b>B10</b> | <b>B20</b> | <b>B25</b> | <b>B30</b> | <b>Diesel</b> |
|-----------|------------|------------|------------|------------|---------------|
| 0         | 20.24      | 20.49      | 20.55      | 20.65      | 19            |
| 0.875     | 19.56      | 20.14      | 20.18      | 20.34      | 18.6          |
| 1.75      | 19.32      | 19.72      | 19.91      | 20.23      | 17.8          |
| 2.65      | 18.91      | 19.37      | 19.78      | 19.97      | 16.5          |
| 3.5       | 15.13      | 15.25      | 15.49      | 15.74      | 15            |



**Fig:5.11 O<sub>2</sub> vs BP Graph**

At 0% BP, B30 exhibits the higher O<sub>2</sub> among the biodiesel blends, with a value of 20.65, which is higher than that of pure diesel (19). At 25% BP, B30 also has the higher O<sub>2</sub> among the biodiesel blends, with a value of 20.34, which is higher than that of pure diesel (18.6). At 50% BP, B30 maintains the higher O<sub>2</sub> among the biodiesel blends, with a value of 20.23, higher than that of pure diesel (17.8). At 75% BP, B30 continues to have the higher O<sub>2</sub> among the biodiesel blends, with a value of 19.97, which is higher than that of pure diesel (16.5). At 100% BP, B30 again exhibits the higher O<sub>2</sub> among the biodiesel blends, with a value of 15.74, surpassing higher than that of pure diesel (15).

Biodiesel typically results in higher oxygen (O<sub>2</sub>) emissions compared to traditional diesel fuel due to its chemical composition and combustion characteristics. Biodiesel contains oxygen atoms within its molecular structure, which are incorporated during the transesterification process used to produce biodiesel from vegetable oils, animal fats, or recycled cooking oil. This inherent oxygen content in biodiesel contributes to higher levels of oxygen emissions when the fuel is combusted in an engine.

During the combustion process, oxygen in biodiesel molecules reacts with carbon and hydrogen atoms in the presence of air to form carbon dioxide (CO<sub>2</sub>) and water (H<sub>2</sub>O). Unlike conventional diesel, which lacks oxygen atoms in its molecular structure, biodiesel does not require additional oxygen from the air for combustion. Therefore, the oxygen content in biodiesel directly contributes to the oxygen content of the exhaust emissions.

## CHAPTER 6

### SUMMARY AND CONCLUSION

#### 6.1 SUMMARY

The combination of lemongrass oil, N-pentanol, and  $\text{CeO}_2$  in a diesel engine represents an innovative approach to address both environmental and performance challenges associated with diesel engines. By reducing emissions and improving combustion efficiency, this combination has the potential to make diesel engines more environmentally friendly and energy-efficient. However, it's important to note that further research and testing are needed to fully understand the practical implications and benefits of this approach.

#### 6.2 CONCLUSION

Pentanol and  $\text{CeO}_2$  can be utilized to oxygenate diesel-lemongrass biodiesel blends and raise the cetane number value for improved combustion, according to studies on the fuel and additives conducted collectively. These blends can be used to improve performance and emission characteristics. Additives can increase viscosity to guarantee that the injection pump is adequately lubricated. They can also stabilize the mixture when there is a high-water content, ensuring fuel homogeneity in all circumstances. Because of its strong detergent qualities, fuel injection equipment stays clean and atomizes well.

To ensure homogeneity and avoid phase separation, 25 ppm of additive was given to each blend during the experiments, which were conducted without altering the engine. The engine is put through several performance tests using different blend ratios, and the optimal mix of additives and blends was researched.

The Lemongrass biodiesel mix is a good alternative fuel that offers good performance and superior emission characteristics, according to the Engine Performance and Emission test results. When compared to diesel in this investigation, biodiesel blends have good performance and emission characteristics. When compared to diesel, the emissions are drastically decreased. In comparison to diesel, biodiesel emits more oxygen into the atmosphere.

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