

SYNTHESIS AND DEVELOPMENT OF EFFECTIVE NANO COMPOSITE SUPPORTS FOR PRODUCTION OF BIO DIESEL

Submitted in partial fulfilment of the requirements for the award of

Bachelor of Engineering degree in
Mechanical Engineering

By

JOSEPH BRAITTON. S (Reg. No.40150018)



DEPARTMENT OF MECHANICAL ENGINEERING

SCHOOL OF MECHANICAL ENGINEERING

SATHYABAMA

INSTITUTE OF SCIENCE AND TECHNOLOGY

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JEPPIAAR NAGAR, RAJIV GANDHI SALAI, CHENNAI – 600119

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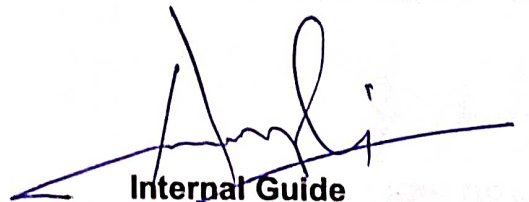
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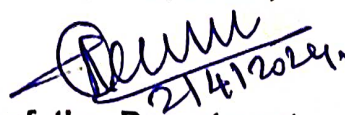
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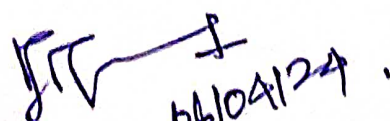
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This is to certify that this Project Report is the Bonafide work of JOSEPH BRAITTON. S (Reg No. 40150018) who carried out the project entitled "**SYNTHESIS AND DEVELOPMENT OF EFFECTIVE NANO COMPOSITE SUPPORTS FOR PRODUCTION OF BIO DIESEL**" under our supervision from December 2023 to April 2024.


Internal Guide
Dr. M. ANISH, M.E., Ph.D.,


Head of the Department
Dr. GANESAN S., M.E., Ph.D.,

**Submitted for Viva voce Examination held on
06-04 -2024**


Internal Examiner

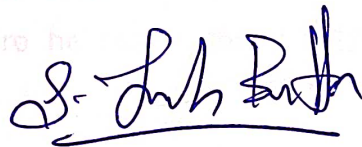

External Examiner

DECLARATION

I am JOSEPH BRAITTON. S (Reg No. 40150018) hereby declare that the Project Report entitled "SYNTHESIS AND DEVELOPMENT OF EFFECTIVE NANO COMPOSITE SUPPORTS FOR PRODUCTION OF BIO DIESEL" done by me under the guidance of Dr. M. ANISH, M.E., Ph. D., is submitted in partial fulfilment of the requirements for the award of Bachelor of Engineering degree in Mechanical Engineering.

DATE: 06.04.2024

SIGNATURE OF THE CANDIDATE



PLACE: CHENNAI

1. JOSEPH BRAITTON. S

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ABSTRACT

The present experimental work is carried out to analyse the performance, combustion, and exhaust emission characteristics of variable compression ratio (VCR) diesel engine using blended biofuel (B20) with Nano additives. Transesterified biodiesel was prepared from waste cooking oil (WCO). The Nano catalyst nanoparticles were produced and categorized by precipitation technique, SEM and XRD analysis. These Nano additives mixed with biofuel blend by magnetic stirrer and then by ultrasonication. The test procedure was carried out under the following fuel blends: 20% of biodiesel added to 80% diesel (B20), 15ppm, 30ppm, 45ppm, 60ppm and 75ppm cerium oxide nanoparticles added with B20 blend (diesel, B20, B20+Nanocatalyst15, B20+Nanocatalyst 30, B20+Nanocatalyst 45, B20+Nanocatalyst 60, B20+Nanocatalyst 75). The engine was operated at fixed compression ratio 20:1 and constant speed at various load conditions 0%, 25%, 50%, 75% and 100%, and results were compared to diesel at 100% load. The improvement in B20 fuel characteristics was observed by adding cerium oxide nanoparticles. The outcomes indicate better improvement in the blended sample of B20+Nanocatalyst 45 ppm with brake thermal efficiency increased by 3.62% and specific fuel consumption decreased by 3.3% than the neat diesel. Presence of added particles gives better atomization which prompts total burning in the combustion chamber and builds up the amplified pressure data. The emission of CO and HC outflow diminishes by the addition of Nano catalyst nanoparticles in blended biofuel. Additionally, there is a reduction in NO_x by expanding the Nano catalyst dosage in the fuel mixer. This occurs due to Nano catalyst particles presented in a fuel blend behaving as an oxygen buffer and engaging the O₂ for decreasing the NO_x formation.

Keywords: Biodiesel. VCR engine. WCO. Performance. Combustion. Emission.

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LIST OF ABBREVIATIONS

BTE	BRAKE THERMAL EFFICIENCY
SFC	SPECIFIC FUEL CONSUMPTION
RME	RAPESEED METHYL ESTER
SME	SOY METHYL ESTER
PME	PALM METHYL ESTER
WCOME	WASTE COOKING OIL METHYL ESTER
AFME	ANIMAL FAT METHYL ESTER
JME	JATROPHA METHYL ESTER
Nox	NITROGEN OXIDE
FAME	FATTY ACID METHYL ESTER
CO ₂	CARBON DIOXIDE
ATCC	AMERICAN TYPE CULTURE COLLECTION
PBR	PHOTOBIOREACTOR
VE	VOLUMETRIC EFFICIENCY
EGT	EXHAUST GAS TEMPERATURE
CO	CARBON MONOXIDE
HC	HYDROCARBON
SO	SMOKE OPACITY
CP	CYLINDER PRESSURE
CA	CRANK ANGLE
NHRR	NET HEAT LEASE RATE

CHAPTER 1

INTRODUCTION

1.1 HISTORY AND BACKGROUND

The broad application of the contemporary internal combustion engine may be traced back to the 18th and 19th centuries, specifically during the Industrial Revolution. Etienne Lenoir, a prominent French engineer, is widely acknowledged as the pioneer of the tiny gas-powered engine. This achievement took place during the early 1800s. However, Nikolaus Otto, a German engineer, was unable to successfully create the first operational internal combustion engine until a later period in the 19th century. This was because the early models lacked efficiency. The fundamental design of contemporary engines continues to be a manifestation of Otto's breakthrough. These engines employ a four-stroke cycle including of distinct phases for intake, compression, combustion, and exhaust. To efficiently convert fuel into mechanical energy, these engines utilise a piston housed within a cylinder. The Benz Patent-Motorwagen, invented by Karl Benz in 1885, is widely regarded as the inaugural automobile to utilise internal combustion engines and be employed in practical applications. Similarly, the Wright Brothers' groundbreaking flight in 1903 initiated the era of engine-powered aircraft, so establishing the foundation for the advancement of aviation. Jet engines, initially employed during the 1930s and 1940s, sparked a transformative revolution in the realm of air transportation by significantly enhancing both velocity and effectiveness. Later advancements, such as the introduction of diesel engines during the mid-20th century, significantly enhanced the efficiency of fuel use. As a result, these engines became widely utilised in several sectors, including power generation, maritime transportation, automobiles, and public transportation. In recent years, there has been a growing emphasis on the advancement of engines with enhanced efficiency and less environmental effect. As a result, hybrid and electric vehicles have been developed, including various technology to minimise fuel use and pollutant emissions.

1.2 INTRODUCTION OF BIODIESEL AND ITS GENERATIONS

Key and secondary biofuels are the two primary categories that differentiate biofuels from each other. Secondary biofuels encompass bioethanol, butanol, biodiesel, and hydrogen, whereas primary biofuels comprise landfill gas, firewood, wood chips, and pellets. The production of these biofuels entails the use of organic matter. Butanol, biodiesel, and bioethanol are among the initial products generated during the biofuel production process. Biodiesel can be chemically produced from several sources such as rapeseed, soybeans, sunflower, palm, coconut, and animal fats [1]. Additional sources encompass palm oil and coconut. Starch is obtained from several sources such as wheat, barley, corn, potatoes, sugarcane, and sugar beets. The process of fermentation is involved in the creation of starch [2].

Lignocellulosic materials such as grass, straw, and wood are utilised for the development of second-generation biofuels, which encompass the manufacturing of bioethanol, bio-butanol, and/or diesel. When producing bioethanol and biodiesel, common examples of crops used are jatropha, cassava, and miscanthus [3]. However, the early stage of biofuel production poses several economic and environmental challenges. These issues are exacerbated by the presence of a demand for agricultural land, which directly competes with the production of food to meet the needs of the growing global population. The presence of non-edible woody plant components poses challenges for the production of second-generation biofuels, including the need for large areas of cultivation [4]. Due to their ability to produce a significant quantity of biomass in a limited geographical area, microalgae provide a potentially valuable solution for resolving these challenges. Biodiesel is derived by the process of transesterification, which involves converting vegetable oils, animal fats, or recycled cooking oils into fuel. Biodiesel is an environmentally friendly and renewable fuel derived from biological sources. Methyl ester is a crucial element in biodiesel production. It is created through a chemical reaction that requires mixing the feedstock with an alcohol, typically methanol, and a catalyst like sodium hydroxide. The production of biodiesel can be categorised into various distinct groups, each of which has different options for generating sustainable energy [5].

First Generation of Biodiesel

- Rapeseed methyl ester (RME), sourced from rapeseed oil, stands as the primary biodiesel feedstock favored in Europe.
- Soy methyl ester (SME), extracted from soybean oil, holds the key position as the primary feedstock for biodiesel manufacturing in the United States.
- Palm methyl ester (PME), derived from palm oil, serves as the predominant biodiesel feedstock in the Asian region.

Second Generation of Biodiesel

- Waste cooking oil methyl ester (WCOME) is a produced biodiesel derived from recycled cooking oil, a residual by-product generated by various food enterprises, restaurants, and households, offering an alternative to traditional cooking oil.
- Animal fat methyl ester (AFME) is a residual substance derived from animal fats like tallow and lard, commonly produced as a by-product within the meat industry.
- Jatropha methyl ester (JME) is sourced from jatropha oil, an oilseed unfit for human consumption that can be cultivated on unproductive land

Third Generation of Biodiesel:

- Algal methyl ester (AME) comprises oil extracted from algae, which thrives in various water environments and yields a significant amount of oil.

Biodiesel, a sustainable energy source, plays a crucial role in reducing nitrogen oxides (NO_x) emissions and carbon content in the atmosphere. Its carbon content originates from plant feedstock, resulting in a diminished contribution to global warming [6]. Additionally, compared to fossil fuel-derived diesel, biodiesel reduces emissions of air pollutants like nitrogen oxides, carbon monoxide, and carbon dioxide. According to a 1998 study by the United States Department of Energy and the United States Department of Agriculture, the use of pure biodiesel in urban buses results in a substantial reduction in life cycle emissions of total particulate matter by approximately 32 percent, carbon monoxide by around 35 percent, and sulfur oxides by about 8 percent compared to petroleum diesel [7].

1.3 INTRODUCTION OF WASTE COOKING OIL

The process of extracting biodiesel from waste cooking oil involves transforming spent cooking oil, collected from various sources such as households and restaurants, into an environmentally friendly fuel. Transesterification is a commonly employed chemical reaction that converts the oil into biodiesel and glycerin. The oil, alcohol, and catalyst are combined in this reaction to produce the desired compounds. After the transesterification process, the biodiesel undergoes many phases, including separation, washing, and drying, to remove any potential impurities. By undertaking this comprehensive procedure, a fuel that meets the requirements for usage in diesel engines is ultimately generated. Reducing dependence on fossil fuels can be achieved by responsibly reusing waste cooking oil, which can be accomplished through the application of this technique.

1.4 CATALYST IN TRANSESTERIFICATION:

Biodiesel is synthesised by the transesterification process, where triglycerides combine with short-chain alcohols in the presence of a catalyst. To counteract the reversible nature of this reaction, an excess of alcohol is employed to shift the balance

towards the production of biodiesel [8]. Transesterification is a chemical reaction that utilises a catalyst to make biodiesel. This mechanism involves the interaction between triglycerides and short-chain alcohols. An excessive quantity of alcohol is utilised to tip the balance in favour of biodiesel synthesis. This technique is employed to recognise the reversible characteristic of this reaction [9]. The process comprises a sequence of three sequential reversible steps, which involve the conversion of triglycerides to diglycerides, followed by the transformation of diglycerides to monoglycerides, and finally, the conversion of monoglycerides to glycerol. Furthermore, once each glyceride is converted, the formation of ester molecules takes place [10]. Transesterification is affected by multiple factors. Hence, to attain biodiesel that fulfils the prescribed quality criteria, it is crucial to alter the manufacturing techniques to enhance the outcomes [11]. The quantities of released fatty acids, the proportion of moisture, and water content are vital attributes that significantly influence the quality and advancement of the process [11,12]. However, the presence of a catalyst might expedite the transesterification process, also known as esterification in the FFA, hence enhancing the product yield. Different catalysts are used in the transesterification process to produce biodiesel. The catalysts used in the transesterification process are essential to the group, as mentioned above. Based on recent review publications, catalysts can be categorised into four main groups: homogeneous catalysts, heterogeneous catalysts, biocatalysts, and nano catalysts [13].

1.5 TYPES OF CATALYSTS

1.5.1 Homogeneous Catalysts

The homogeneous base-catalyzed transesterification process has demonstrated remarkable catalytic efficacy by employing several catalysts, such as alkaline metal alkoxides [35,36], hydroxides [37,38,39], or sodium/potassium carbonates [14]. This technique produces biodiesel of superior quality and simplifies the retrieval of methanol, while the glycerol by-product obtained is appropriate for use in pharmaceuticals. Nevertheless, the process of burning biodiesel can generate formaldehyde or acetaldehyde, which requires the thorough elimination of glycerol.

Although homogeneous base-catalyzed transesterification is efficient, it faces difficulty in completely converting oil with high concentrations of free fatty acids into biodiesel. This results in the creation of a substantial amount of soap, which is a well-known issue [15]. Reference [16] states that the inclusion of a fundamental catalyst is essential in soap production to prevent the undesired separation of biodiesel, glycerin, and wash water. Transesterification of triglycerides necessitates an abundance of methanol and precise air pressure and temperature parameters (60-70 degrees Celsius) for its completion. Nevertheless, the alkali catalyst frequently necessitates prolonged reaction durations, lasting several hours, in order to guarantee the successful culmination of the transesterification process [17,18].

1.5.2 Bio Catalysts

Enzymes are widely acknowledged as essential catalysts in enabling a wide variety of chemical processes, as illustrated in Figure 4. Let's consider the widespread use of nitrile hydratases in many industrial settings. These enzymes have been instrumental in generating significant quantities of acrylamide, providing as a prominent example of a commendable use. An example scenario is the application of nitrile hydratases in industrial settings. In addition, enzymes have been a common ingredient in detergents for most of the thirty years from the beginning of the chemical industry [19]. Protein-based catalysts are being used more and more to create more complicated molecules, especially in modern times. The use of these catalysts has been given high priority in the pharmaceutical business. Enzymes provide consumers several benefits by combining the selectivity of a directed group with the efficiency of a single reagent in a single molecule [20]. Over the past twenty years, there has been a substantial rise in the utilisation of enzymes in conjunction with other enzymatic systems to facilitate simultaneous activities. The combination of synthetic and enzymatic approaches has been acknowledged for effectively accomplishing various extensive synthesis projects. Enzymes play a vital function in multiple chemical sectors within industrial operations [21]. Previously, the availability of enzymes for chemical synthesis was mostly restricted to lipases and ketoreductases (KREDs). Only a limited selection of enzymes within a specific range was accessible [22]. There has been a notable rise in the accessibility of enzymes that are acceptable for use in chemical

formulations in recent years. Due to this growth, researchers now have a wide array of enzymatic tools at their disposal. In 2014, the discovery that the nucleoside didanosine could only be synthesised by enzymatic means brought significant attention to the concept of "bio-retrosynthesis". The concept of "bio-retrosynthesis" [23] generated much interest following this discovery.

1.5.3 Heterogeneous Catalysts

The use of heterogeneous catalysts is a crucial element in many chemical processes. The catalysts function in a distinct phase that is separate from the gas or liquid products and reactants, typically in a solid state. Catalysts have a main purpose of increasing the speed of reactions, making them an essential component in various industrial processes such as chemical and fuel production, as well as environmental cleanup efforts [24]. Solid heterogeneous catalysts typically comprise metal oxides, metals, or metal-based compounds that are supported on porous substrates. It is crucial to recognise that this category encompasses more than just the sorts of catalysts discussed before. Heterogeneous catalysts can sometimes be present as liquids or gases that are fixed onto solid support structures. However, in these specific instances, they are not present in a solid form [25]. The effectiveness of a heterogeneous catalyst is determined by two crucial factors: its surface area and the concentration of active sites it possesses. The active sites are specific areas on the surface of the catalyst where reactant molecules can bind and participate in chemical reactions. These geographic regions are widely referred to as "hot spots" [26]. The surface of the catalyst acts as a substrate for the adsorption of the reactant molecules, so starting the start of the chemical reaction. Adsorption reduces the inherent binding strength of the reactants, hence promoting the subsequent reaction and the formation of products [27].

CHAPTER 2

LITERATURE SURVEY

Biodiesel is a sustainable fuel derived from renewable sources such as plant oils or animal fats. Compared to typical petroleum-based diesel fuel, it is seen as a more environmentally friendly choice because to its lower emissions when burned. Consequently, biodiesel has garnered growing interest as a viable remedy for several energy and environmental issues.

In recent years, there has been a substantial increase in research focused on the production, characterisation, and application of biodiesel. Numerous papers have been published on various parts of this topic. The objective of this literature review is to present a comprehensive analysis of the existing information on biodiesel, condensing the key discoveries from research articles in the topic.

Verma, M. L., Puri, and colleagues published a study in 2016. A study was done to assess the emissions and performance of diesel engines using various combinations. Energy is an essential factor for the development of every place in the world. The market has issued a cautionary notice to transition towards sustainable fuel in response to the rising prices of crude oil and the associated global emissions. The need for energy is increasing due to the expanding worldwide population, the imperative need for energy in industrial applications, the use of transportation, and power generating equipment [28].

In this study, Moreira, K. D. S., de Oliveira, A. L. et.al (2020) analysed the properties of tall oil methyl ester-diesel fuel blends as prospective substitutes for traditional fuels. The researchers investigated the potential of using blends of tall oil methyl ester and diesel fuel as a viable alternative for diesel engines. Tall oil methyl ester was synthesised by meticulously blending methyl alcohol with tall oil fatty acids. The addition of long oil methyl ester to the diesel fuel blends resulted in a significant enhancement in engine power and torque output, with gains of up to 6.1% and 5.9%

respectively. Nevertheless, the modified fuel mixtures led to a noteworthy increase in NO_x emissions, reaching a maximum of 30%, but CO emissions underwent a huge reduction of 38.9%. Curiously, the smoke's opacity remained constant during the research.[29].

In their 2022 study, Méndez, J. C., Arellano, U et.al examined the impact of engine speed and the concentration of alumina nanoparticles in diesel-biodiesel blended fuels on the performance and emission characteristics of a six-cylinder, four-stroke diesel engine. Alumina nanoparticles were produced and incorporated into the diesel-biodiesel mixture at concentrations of 40, 80, 120, and 160 parts per million. The diesel engine was operated at speeds ranging from 800 to 1000 rpm using these fuel mixtures.[30].

This illustrates the variability in emissions and the influence of nanoparticles. The use of nanoparticles had a positive effect on the variability of emission levels in all tested fuels, resulting in the most stable and consistent emission levels.[31].

In a study conducted by Liu, C. H., Huang, C. C., Wang et al. (2018), the researchers examined the properties of a microalgae oil biodiesel blend (B20) and its impact on combustion and emissions in a single-cylinder diesel engine. The findings indicated that B20 had comparable combustion properties to conventional diesel fuel, but with reduced emissions of particulate matter, carbon monoxide, and unburned hydrocarbons.[32].

The use of biodiesels, which are derived from vegetable oils or animal fats and consist of long-chain monoalkyl esters (such as methyl, ethyl, and propyl), can be minimised with negligible adverse effects on the environment.[33].

Subsequently, scientists have conducted trials using various biodiesel sources and compositions in order to enhance efficiency and minimise emissions. In recent years, researchers have been gradually substituting biodiesel for diesel, which is the most efficient method to comply with emission limits [34].

CHAPTER 3

AIM AND SCOPE

3.1 AIM

Utilising a nanocomposite of Magnesium Oxide and Titanium dioxide with ethanol is expected to improve the efficiency of biodiesel generation. Nanocomposites possess distinctive characteristics, including elevated surface area and catalytic efficacy, that have the potential to enhance the transesterification procedure in biodiesel manufacturing. Utilising ethanol as the alcohol in the process can enhance sustainability and reduce energy consumption when compared to conventional ethanol-based biodiesel manufacturing methods. Nevertheless, it is crucial to acknowledge that additional investigation and experimentation would be necessary to assess the efficacy and feasibility of this method.

3.2 SCOPE

Biodiesel is an alternative fuel that significantly contributes to the reduction of airborne pollution particles when emitted into the atmosphere. Additionally, it addresses the need for fossil fuels by offering a sustainable alternative. This research study offers a resolution for utilising highly viscous mixtures in unaltered diesel engines. In addition, to optimise the performance of the diesel engine, common rail direct injection is employed.

.

3.3 METHODOLOGY

- STEP 1; Take 1 liter of “Waste cooking oil” or any other oil in Glass Separatory Funnel.
- STEP 2; Preheat the oil at 60 degree and then add catalyst “Methanol + NaOH/KOH” in the ratio of 1:3. (naoh-5g and methanol-182ml)
- STEP 3: The reaction is allowed to conduct for 90 minutes.
- STEP 4; After 90 minutes, two layers are formed in glass funnel. Top layer is “Biodiesel” and the bottom layer is “Crude glycerin”. Separate the biodiesel from glycerin.
- STEP 5; Wash it by 1 liter of hot water until the PH is neutralized. After that heat the biodiesel for 110degree so that moisture is gone. Now we got our required product “BIO-OIL”.
- STEP 6; B20 blend formation (80% of diesel +20%bio-oil)
- STEP 7: In the addition of hydrogen with B20 blend formation for the testing of engine emission and performance characteristics
- Figure 3.1 shows Flow Chart of Biodiesel Preparation.

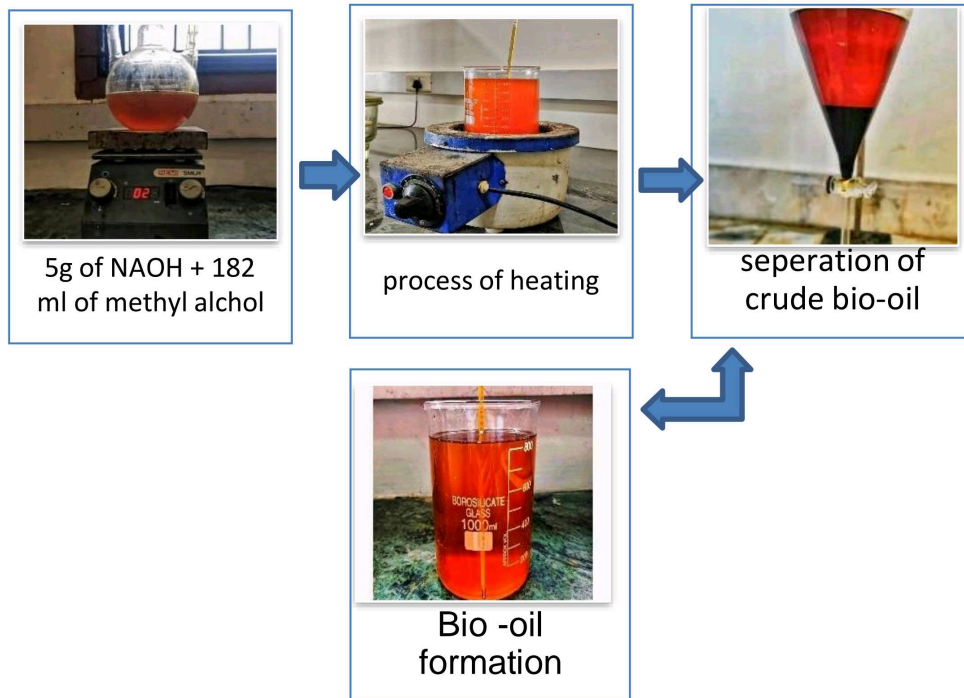


Fig:3.1: Flow Chart of Biodiesel Preparation

CHAPTER-4

EXPERIMENTAL OR MATERIALS AND METHODS; ALGORITHMS USED

4. MATERIALS AND METHODS

The manufacturing of biodiesel involves the utilization of a nano-composite consisting of magnesium oxide (MgO) and Titanium dioxide (TiO₂). These oxides possess exceptional quality, characterized by a purity level of 99% and an average particle size of 10 microns. The process involved five distinct mix weight ratios: 100:0, 75:25, 50:50, 25:75, and 0:100, denoted as NCPs1-5, respectively. After determining the accurate weights and ratios of the raw materials, they were mixed into an ethanol alcohol mixture and homogenized using a Hielscher ultrasonic device. The device operated at a power output of 2 watts, a frequency of 26 kilohertz, and a rotational speed of 1000 revolutions per minute to ensure uniform distribution across the materials. Following homogenization, the mixes underwent a four-hour processing period with a friction mill. Subsequently, the drying process was carried out using an IMS oven set at a temperature of 60 ± 5 °C for a duration of three hours. Finally, the combined powders were sintered in MTI Corporation's GSL1600X furnace at a temperature of 400 degrees Celsius for one hour.

4.1 MATERIALS USED

The materials used for this project are Magnesium oxide, Titanium dioxide and Ethanol. Figure 4.1 shows Materials used components.



Fig. 4.1 Materials used

4.2 INSTRUMENTS USED

Instruments used for this project are Ultrasonicator, Magnetic stirrer, Hot air oven.

4.2.1 Ultrasonicator

Ultrasound has been increasingly popular in the manufacturing of biodiesel over an extended period of time. The capacity of ultrasound to produce homogeneity among chemicals through sonic cavitation is the reason behind this occurrence. Acoustic cavitation refers to the creation of cavitation bubbles, which lead to an increase in temperature within the reaction medium. This method involves the rapid creation and subsequent disappearance of cavitation bubbles, leading to a decrease in reaction time from many hours to only a few minutes. As a result, the reaction rates increase while the amount of catalyst used decreases. Reactions are often carried out using basic ultrasonic baths or probes that operate within the frequency range of 20 to 50 kHz. These devices frequently possess an output power exceeding 200 W. Ultrasonography has become an essential component in the manufacturing of biodiesel. The attainment of this result has been made easier by the availability of

affordable equipment that has the capability to generate favourable conversion values, even when running at low power levels, such as 50 W or below. Figure 4.2 shows Current study is underway to investigate the capacity of ultrasonic to speed up the transesterification process and its usefulness in monitoring biodiesel reactions. Both of these opportunities are presently being examined in the realm of ultrasound. Integrating low-power ultrasonography into a method for evaluating reaction completion not only saves time and energy, but also helps reduce waste creation. Ultrasonography has been widely used in various fields for a long time, and has shown to be an essential technique for examining and understanding materials. The integration of ultrasonic analytical techniques in the biodiesel manufacturing process is a relatively recent development that deserves careful consideration. This chapter seeks to evaluate the progress made in utilising ultrasonic technology for the production and inspection of biodiesel. Moreover, this chapter will evaluate the current state of the technology and provide insights into the upcoming improvements in the field of engineering.



Fig: 4.2: Ultrasonicator

4.2.2 Magnetic Stirrer

The magnetic stirrer is a frequently used laboratory device. The system can comprise either a fixed electromagnet or a rotating magnet that generates a magnetic field. The described device has numerous functions, including the agitation and mixing of liquids, as well as the facilitation of rapid rotation. In addition, it is typical for magnetic stirring systems to include a built-in heating system to aid in the process of heating the liquid being stirred. Nevertheless, when it comes to the dispersion of minuscule particles, relying just on magnetic or mechanical agitation seems insufficient. In order to achieve the scattering of nanotubes, it is frequently necessary to combine this approach with supplementary dispersion techniques that demonstrate improved effectiveness, such as sonication. The polymerization procedure was carried out utilising a glass reactor with a capacity of 100 millilitres and a magnetic stirrer. The reactor utilised the semi-batch method. At first, the reactor was filled with MAO. Then, a certain quantity of 1-hexene was added once the reactor was completely loaded. Afterwards, the ethylene atmosphere system was implemented. Once the ethylene monomer had become fully saturated in the reaction medium, the polymerization process was started by adding a catalyst solution containing one millilitre (20 micromoles). Figure 4.3 shows Magnetic stirrer. The polymerization process for the borane and borate system was initiated by sequentially adding alkylaluminum, borane or borate, and the complex to the monomer solution. Afterwards, the polymerization reaction was allowed to continue for a predetermined period of time before it was stopped using acidic methanol. After the polymer was precipitated, it was filtered, washed with methanol, and then dried under vacuum at a temperature of sixty degrees Celsius for six hours. The polymer was evaluated by assessing its molecular weight through the use of Gel Permeation Chromatography (GPC) and evaluating its microstructure using ^{13}C Nuclear Magnetic Resonance (NMR).



Fig: 4.3: Magnetic stirrer

4.2.3 Hot Air Oven

The hot air oven is a flexible laboratory instrument that performs various activities, including drying, sterilising, and heating. The experimental procedure entails introducing hot air into the oven chamber, which is then circulated around the chamber to guarantee even dispersion of heat to the items being treated. Hot air ovens are commonly used in various settings, including research centres, industrial companies, and educational institutions. Usually, these devices have a temperature range that goes from the temperature of the surroundings to 250 degrees Celsius or higher. They also have a thermostat component that helps control the temperature. The improvement of air circulation within the chamber of specialised hot air ovens, especially those with a fan, allows for the achievement of uniform heating or drying of materials during the processing phase. Hot air ovens are frequently used for sterilisation since they can reach high temperatures. These baking machines provide the capacity to efficiently eliminate bacteria from a variety of goods and equipment. Moreover, these machines are used with the explicit purpose of

removing moisture from a wide range of things, such as glassware, biological specimens, and chemicals. In addition, hot air ovens are utilised to raise the temperature of substances for a variety of purposes, including sterilising chemicals and maintaining items at precise temperatures for quality control testing. Hot air ovens are renowned for their dependable functionality and versatility in many laboratory and industrial environments, including activities such as heating, drying, and sterilisation. Figure 4.4 shows Hot Air Oven.



Fig: 4.4: Hot Air Oven

4.3 PREPARATION OF BIODIESEL

Biodiesel is produced through the synthesis of various vegetable oils, encompassing both edible and non-edible varieties, along with animal fats. Although edible oils are frequently utilised in cooking, this practice leads to the production of substantial quantities of cooking oil. However, it is crucial to replace the oil used for cooking after only one or two uses due to its possible detrimental impact on the health of both humans and animals. The improper disposal of cooking oil presents a

substantial environmental hazard, particularly when it infiltrates streams and landfills. Given these considerations, it is possible to utilise waste cooking oil (WCO) as a fuel for engines. It is essential to convert this oil into biofuel because it is not suitable as an engine fuel in its original form. The biofuel production procedure utilised residual cooking sunflower oil acquired from our student accommodation, along with potential additional sources in Dindigul. This publication outlines the transesterification process employed to produce biofuel from Waste Cooking Oil (WCO). The first process entails combining diesel fuel with WCO biofuel, and then adding a 20:80 (B20) ratio of this combination. The energy is extracted from the resulting mixture, which is a crucial phase in the process. Table 4.1 displays Characteristics of the altered fuels and diesel.

Table 4.1 Displays Characteristics of the altered fuels and diesel

Properties	Diesel	B20	B20+Nano catalyst15	B20+Nano catalyst30	B20+Nano catalyst45	B20+Nano catalyst60	B20+Nano catalyst75	AST M Standard	Test methods
Gross calorific value (kJ/kg)	43,388	40,689	41,086	41,120	41,157	41,215	41,315	----	AST M D240
Density (kg/m ³)	835	845	850	852	858	862	863	860-900	AST M D4052
Kinematic viscosity at 40°C (mm ² /s)	2.6	3.2	3.25	3.3	3.33	3.4	3.49	1.9-6	AST M D445
Flash point in°C	48	52	55	57	58	64	70	>130	AST M D93
Fire point in°C	68	66	72	78	80	85	88	----	AST M D93
Cetane number	52	51.7	51.7	52.4	53.8	53.3	53.2	>47	AST M D613
Boiling point°C	255	325	NM	NM	NM	NM	NM	----	AST M D1120
Surface tension (mN/m) 80°C	22.05	24.16	NM	NM	NM	NM	NM	----	----
Latent heat of vaporization (kJ/kg)	260	340	NM	NM	NM	NM	NM	----	AST M D93

4.3.1 Diesel extraction from waste cooking oil

Extracting biodiesel from waste cooking oil offers a sustainable alternative for managing trash and producing renewable energy. Waste cooking oil, which is usually thrown away, contains significant amounts of triglycerides that can be transformed into biodiesel via a method known as transesterification. During this procedure, triglycerides undergo a reaction with an alcohol, typically methanol or ethanol, in the presence of a catalyst. This reaction yields biodiesel as the main result, along with glycerol as a secondary product. Waste cooking oil can be converted into biodiesel, which can be used instead of regular diesel fuel. This substitution helps to decrease greenhouse gas emissions and reduces reliance on fossil fuels. Furthermore, the use of waste cooking oil for biodiesel generation helps to mitigate environmental degradation by redirecting the oil away from landfills or inappropriate disposal practices. This strategy not only provides an ecologically sustainable substitute for conventional diesel, but also supports a circular economy by converting trash into a valuable asset. Fig 4.5 shows Extraction of bio-diesel from waste cooking oil



Fig: 4.5: Extraction of bio-diesel from waste cooking oil

4.3.2 Bio-diesel Properties and its Testing

The bio-diesel derived from this technique possesses several distinctive characteristics that render it an appealing fuel option. For example, it possesses a significant energy density, resulting in a greater energy output per unit of volume compared to numerous other fuel sources. Moreover, bio-diesel generated through the transesterification process exhibits a reduced sulphur content, rendering it a more environmentally friendly substitute for conventional fossil fuels [35]. Several important parameters that can be examined are viscosity, calorific value, moisture content, and elemental composition. Viscosity plays a vital role in determining the rate at which bio-oil moves. Contaminants in bio-diesel can be identified using elemental composition analysis, which can also provide insights into the potential applications of the bio-compatible oil [36]. The fuel blend that has been prepared is subjected to testing for its physical and chemical qualities using a range of scientific instruments, and the outcomes are acquired.

4.3.3 Blending of Nano catalyst Nanoparticles with Biofuel:

Nano catalyst, a scarce metallic oxide found in the Earth's crust, possesses distinctive qualities that make it an efficient oxidising agent in catalytic converters, while also having a modest affinity for absorbing moisture. The current study involved adding varying amounts of cerium oxide nanoparticles to a biodiesel mixture containing 20% biodiesel (B20) via ultrasonication. The nanoparticles were extensively mixed with the fuel mixture for a duration of thirty minutes. The doses ranged from 15 parts per million (ppm) to 75 ppm in magnitude. A mechanical agitator was used to achieve complete homogenization between the fuel samples and nanoparticles. Ongoing study is currently investigating the use of this fuel blend in variable compression ratio engines. The research is being undertaken under various load circumstances as an experimental fuel [37].

4.3.4 Properties of biodiesel

Biodiesel is a sustainable and ecologically conscious substitute fuel derived from vegetable oils, animal fats, or recycled cooking oil. It possesses similar characteristics to diesel fuel derived from petroleum, but there are significant differences because of its unique chemical composition. Biodiesel has the following key properties:

Density: Because biodiesel has a lower density than petroleum fuel, the energy content per unit volume might be affected.

Viscosity: Because biodiesel has a higher viscosity than petroleum diesel, its flow via fuel injectors and pumps might be affected.

Flash point: Because biodiesel has a greater flash point than petroleum diesel, it is safer to handle and store.

Cetane number: Biodiesel has a higher cetane number than petroleum diesel, indicating that it has a better ignition and combustion quality.

Sulphur content: Biodiesel has almost little sulphur, which minimises sulphur oxide (SO_x) and particulate matter emissions.

Lubricity: Because biodiesel is more lubricious than petroleum diesel, it helps minimize engine wear and lengthen engine life.

Oxygen content: Because biodiesel contains more oxygen than petroleum diesel, it can enhance combustion efficiency and minimize carbon monoxide (CO) and unburned hydrocarbons (HC) emissions.

Cold flow qualities: Biodiesel has poor cold flow properties, which can cause it to thicken and form gels at low temperatures, resulting in fuel filter blockage and engine stalling.

4.4 EXPERIMENTAL SETUP

The study employed biodiesel extracted from waste cooking oil. A single-cylinder, four-stroke diesel engine was utilized for the investigation. At the commencement of the engine, conventional diesel fuel was employed, considering all pertinent parameters as outlined in Table 4.2. The dynamometer employed eddy current for engine loading. Essential instrumentation for measuring crank angle and combustion pressure was included in the equipment to facilitate prompt utilization. The engine was equipped with a piezoelectric pressure sensor and a crank angle indicator device to monitor the combustion process. In order to ensure precise measurements of cylinder pressure, heat release rate, and ignition delay, it is imperative to calculate the average output signal from a pressure transducer across a span of fifty cycles. This procedure is essential for maintaining adherence to system standards and ensuring the accuracy of measurements. Figure 8 depicts the experimental configuration, encompassing a schematic portrayal of the system. It is imperative to initiate the engine without any external load and increase its rotational speed to 1,500 revolutions per minute (rpm) using a warm-up operation prior to conducting steady-state measurements. Steady-state measurements can only be carried out after this step. The study aims to monitor and analyze brake thermal efficiency and emission parameters during steady conditions, particularly focusing on engine performance and emission levels when the engine reaches 1500 RPM. These parameters include nitrogen oxides, ethane gas temperature and composition, carbon monoxide concentration and composition, smoke opacity, and smoke vapor pressure. The coordinated operation of a smoke meter and a particle size analyzer is depicted in Diesel exhaust smoke meters are utilized to gauge the extent of light obstruction resulting from smoke emissions from diesel engines.

The smoke meter serves a dual purpose: evaluating combustion efficiency and quantifying smoke density. Electrical components facilitate control over multiple measuring heads within smoke meters. These measuring heads feature an optical unit among their inventory of capabilities. Gas analyzers rely on the assumption that the gas being analyzed can absorb light to ensure precise measurements. In the experimental procedure, a laser beam is transmitted through a non-heated container while the analyzer measures the wavelength of the selected sample. The analyzer is

equipped with an optical filter that selectively removes any light that surpasses the detection wavelength of the gas molecule being studied, so guaranteeing the accuracy of the obtained results. The measurements generated by the detector remain unaffected by the presence of gas molecules other than the specific one under examination due to their inherent inability to absorb light at the particular wavelength. Four distinct load circumstances and three engine speeds (500, 800, and 1100 revolutions per minute) were employed during the course of the investigation. Nevertheless, as a result of limitations in engine power, only two loads were conveyed at a speed of 1100 revolutions per minute. A magnetic dynamometer was employed to apply the load, and data was collected under steady-state conditions at a consistent velocity. The dataset encompasses the emissions of five separate gaseous constituents, namely carbon monoxide (CO), hydrocarbons (HC), carbon dioxide (CO₂), oxygen (O₂), and nitrogen oxides (NO_x). Furthermore, the collected data includes assessments of fuel efficiency and optimization of engine combustion. The Opacity test device, calibrated by an Indian company, was utilized to assess emissions during production. Table 4.2 shows Specification of the variable compression ratio engine.

Upon activation, the machine requires approximately five minutes to attain its optimal operating temperature. Once all necessary preparations are completed and the system reaches full functionality, the display will show "PASS" to indicate the status. The second step entails applying pressure to the designated PURGE button to initiate the cleaning cycle of the internal components of the machine. Therefore, it is recommended to place the primary non-dispersive infrared (NDIR) sensor in the conditions of the surrounding environment. Activating the ZERO buttons is crucial for establishing the zero validation point. Once the primary sensor completes its auto-calibration process, typically lasting around twenty seconds, a "READY" notification will appear on the screen. This observation suggests that the sensor is prepared for insertion into the intake tube of the engine without encountering any further complexities. Subsequently, the gadget undergoes calibration in order to collect data pertaining to the exhaust emissions generated by the engine. Based on the instrument technical specifications, the indicated levels of uncertainty for carbon monoxide (CO), chloride of hydrogen (HCl), nitrogen oxides (NO_x), atmospheric carbon dioxide (CO₂), and oxygen (O₂) are 0.01%, 1 ppm, 0.1%, and 0.01% correspondingly. A slanted glass

container was utilized to measure the intake of the engine. Simultaneously, the time required for the container to reach its maximum capacity with gasoline was documented. To reduce the risk of observational errors, each experiment's duration was evaluated at least twice. The engine's output power can be calculated by multiplying the generator's output current with its output voltage, enabling an evaluation of the energy conversion process's effectiveness. With the generator operating at a speed 2.4% higher than the engine's rotational velocity, precise assessment of the load exerted on the engine required the use of multiple masses combined with a lever linked to the generator. Employing this method successfully facilitated achieving a well-balanced load and enabled accurate estimation of its magnitude.

Table 4.2: Specification of the variable compression ratio engine

General details	4 stroke, water cooled, variable, compression ratio engine, compression ignition
Compression ratio	5:1 to 22:1 (variable)
Number of cylinder	Single cylinder
Rated power	3 .7 kW at 1500 rpm
Ignition	Compression ignition
Bore	80mm
Loading	Eddy current dynamometer
Speed	1500 rpm (constant)
Stroke	110mm
Starting	Manual crank start
Air flow transmitter	Pressure transmitter
Load sensor	Strain gauge load cell

Rotometer	Pressure transmitter
Cooling	Water
Temperature sensor	TypeK—Chromel (nickel- chromium alloy)/ alumel (nickel- aluminium alloy) thermocouples

4.5 ENGINE SETUP

The current study offers a thorough examination of the performance, combustion, and emission characteristics of the VCR engine. The experiment involved systematically adjusting the load from 0 to 25 percent while keeping the compression ratio fixed at 20:1 and maintaining a constant speed of 1500 revolutions per minute. Furthermore, the engine was operated in a stable condition without any alterations. Each experiment was repeated five times, and the average result was utilized to determine the necessary parameters. To gather fundamental engine data, initial tests were conducted using standard diesel fuel across various operating conditions. Fig 4.6 is Experimental setup of engine. Schematic diagram of engine is shown in Fig 4.7.

After reaching sufficient temperature by the engine, the following nanoparticle blended biofuel samples such as B20, B20+Nano Catalyst15, B20+Nano Catalyst30, B20+Nano Catalyst45, B20+Nano Catalyst60 and B20+Nano Catalyst75 were utilized to operate the engine at different load conditions (0%, 25%, 50%, 75% and 100%) with fixed injection pressure at 160 bar, and this avoided the issues of cold start. Engine performances, combustion and emissions have been attained experimentally, and the results were compared with that of standard diesel at full load condition. The composition of fatty acids in waste cooking oil methyl ester is shown in Table 4.3. The emission characteristics of the engine for the biodiesel were measured by online MN-05 model MARS portable flue gas analyser. In this analyser, the zero setting function sets the sensor to zero using fresh air. The experimental data are stored and analysed with the help of sensors in the computerized data acquisition system. The different Indian standards used for emission analysis are specified in Table 4.4. Accuracy

measurements of engine is shows in Table 4.5.



Fig: 4.6: Experimental setup

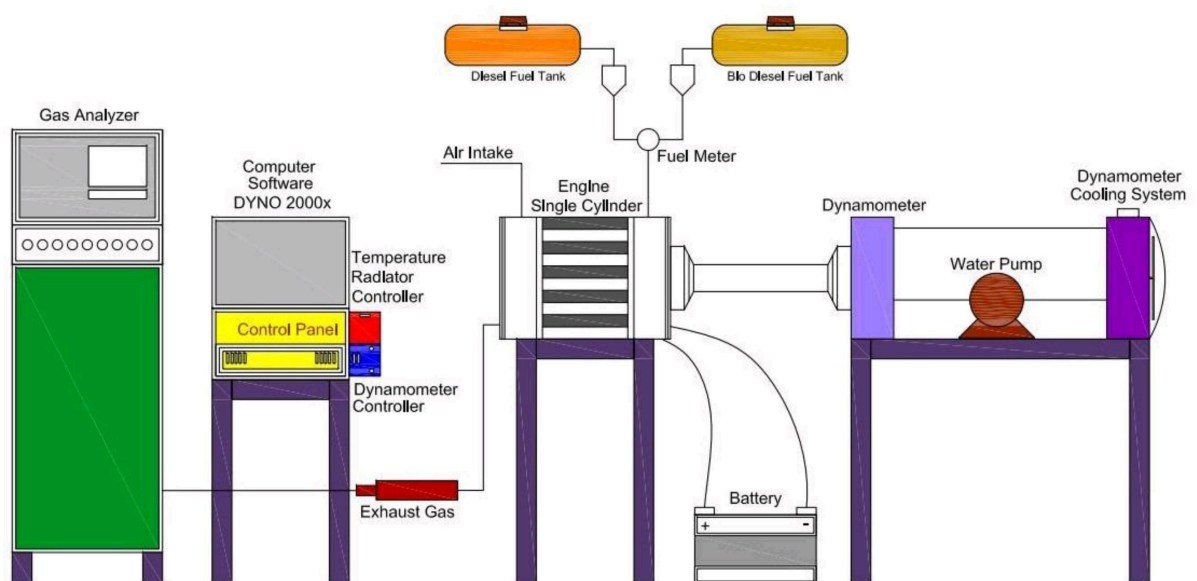


Fig: 4.7: Schematic diagram of the experimental setup

Table 4.3: Fatty acid composition of waste cooking oil

Fatty acid	Structure(xx:y)	Formula	Composition (wt %)
Palmitic acid	C16:0	C16H32O2	8.31
Stearic acid	C18:0	C18H36O2	6.46
Oleic acid	C18:1	C18H34O2	14.3
Linoleic acid	C18:2	C18H32O2	64.9
Linolenic	C18:3	C18H30O2	1.33
Arachidic acid	C20:0	C20H40O2	1.89
Lignoceric acid	C24:0	C24H48O2	1.51

xx indicates the number of carbons and y the number of double bonds in the fatty acid chain

Table 4.4: Indian standards used for emission analysis

Elements	Standard
Carbon dioxide	IS 13270: (reaffirmed 1999)
Carbon monoxide	IS 11293:1992
Nitrogen oxides	IS 11255 (Part 7)—2005
Hydrocarbon	--

Table 4.5: Accuracies of the measurements

Measurements	Accuracy
Engine speed	±4 rpm
Time	±0.20%
Specific fuel consumption	±1%
Temperature	±2 °C
Crank angle encoder	±0.5°CA
Piezoelectric sensor	±0.50%

Power	±3%
Calculated Results	Uncertainty
Power	± 1 %
Specific fuel consumption	± 2 %
Crank angle encoder	± 0.5° CA

4.6 ERROR ANALYSIS

Potential sources of inaccuracy in experiments include the choice of instrument, calibration, observation techniques, environmental factors, working conditions, human error, and methodology. Prior to utilising the instruments and sensors to obtain measurements for different parameters, it is important to do calibration. Typically, experimental data might be subject to two types of errors: instrumental errors and random errors. Equation 4.1 is used to measure Uncertainty measurements in engine testing.

$$U_{\text{total}} = \sqrt{\left\{ (U_{\text{bte}})^2 + (U_{\text{sfc}})^2 + (U_{\text{Egt}})^2 + (U_{\text{CA}})^2 + (U_{\text{PR}})^2 + (U_{\text{NOx}})^2 + (U_{\text{HC}})^2 + (U_{\text{CO}})^2 \right\}}$$

$$U_{\text{total}} = \sqrt{\left\{ (1.4)^2 + (1.3)^2 + (1.4)^2 + (1.6)^2 + (1.5)^2 + (2)^2 + (1)^2 + (1)^2 \right\}}$$

$$= \pm 4.05$$

(4.1)

4.7 RESULT

4.7.1 Fourier-transform infrared spectroscopy (FTIR)

FTIR stands for Fourier Transform Infrared Spectroscopy. It's a technique used to obtain an infrared spectrum of absorption or emission of a solid, liquid, or gas. It works by measuring the absorption of infrared radiation by the sample material versus wavelength. Fig 4.8 shows the result of FTIR. This absorption is indicative of the functional groups present in the material, which allows for the identification and characterization of chemical compounds. FTIR spectroscopy is widely used in various fields such as chemistry, biochemistry, pharmaceuticals, materials science, and forensic science, among others, for qualitative and quantitative analysis of samples.

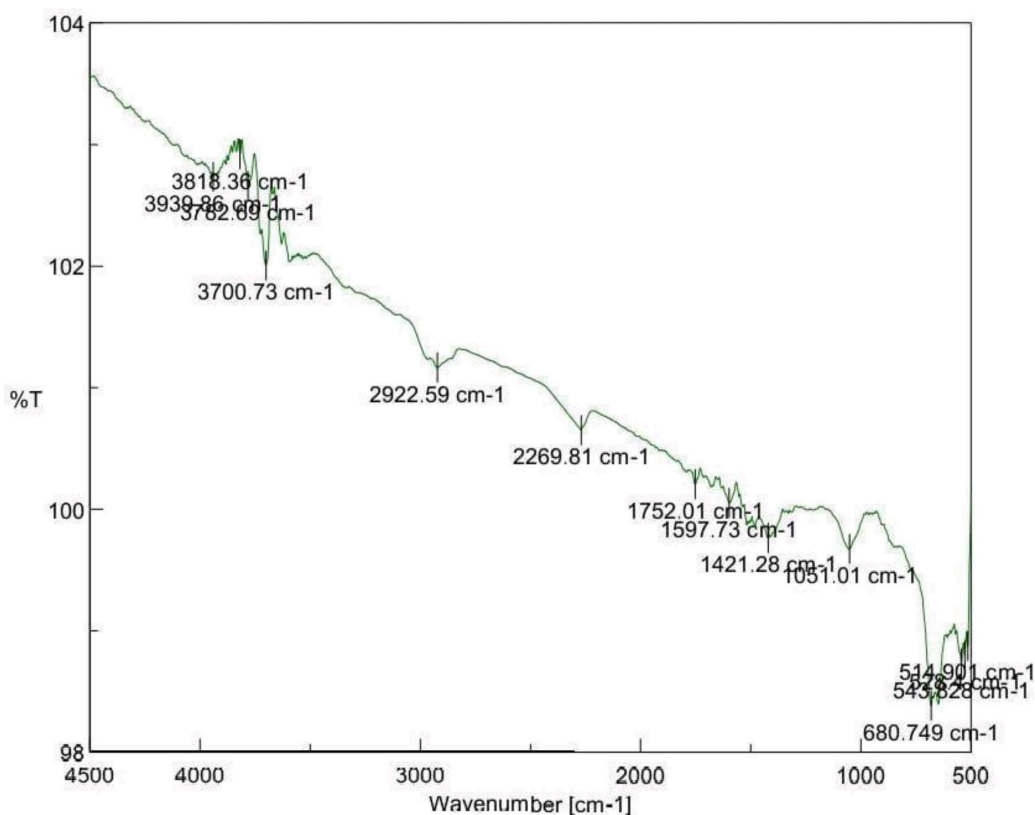
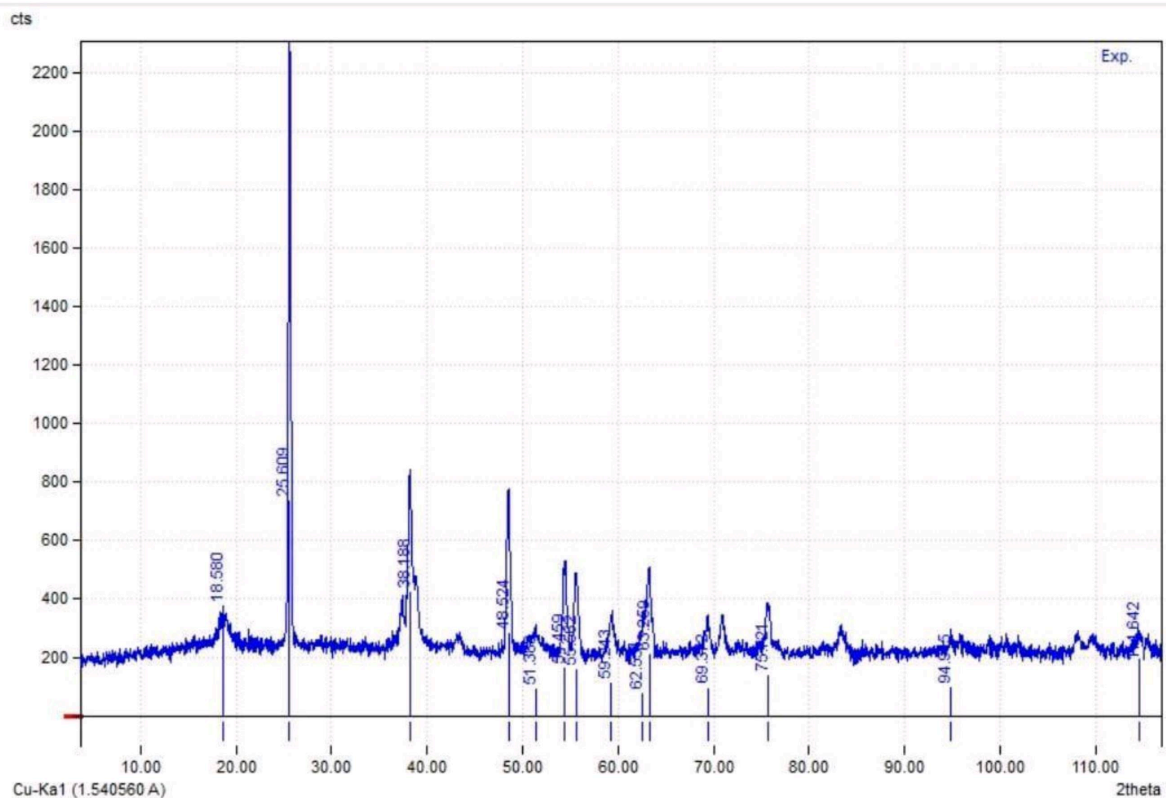


Fig: 4.8: FTIR Results of Nano catalyst 45

4.7.2 X-ray Diffraction (XRD):

X-ray diffraction (XRD) is a technique used to analyze the crystal structure of materials by measuring the scattering of X-rays. When it comes to nano composites, XRD can be particularly useful in determining the crystal structure, phase composition, crystallite size, and preferred orientation of the constituent phases within the composite material. Figure 4.9 shows the result of XRD. Nano composites are materials composed of two or more phases with at least one phase having nanoscale dimensions. These materials often exhibit unique properties due to their nanostructure, and understanding their crystallographic properties is crucial for optimizing their performance in various applications.



X-ray diffraction (XRD)

Fig :4.9: XRD Results of Nano catalyst 45

4.7.3 SEM Analysis:

SEM stands for Scanning Electron Microscopy, a powerful imaging technique used to examine the surface morphology and composition of materials at high magnification. SEM analysis involves bombarding a sample with a focused beam of electrons and collecting the signals generated from interactions between the electrons and the sample's surface. SEM analysis is widely used across numerous fields including materials science, geology, biology, nanotechnology, and forensic science, among others, due to its versatility in providing detailed surface information and elemental analysis at micro- to nanometer scales. Figure 4.10 shows the result of SEM image.

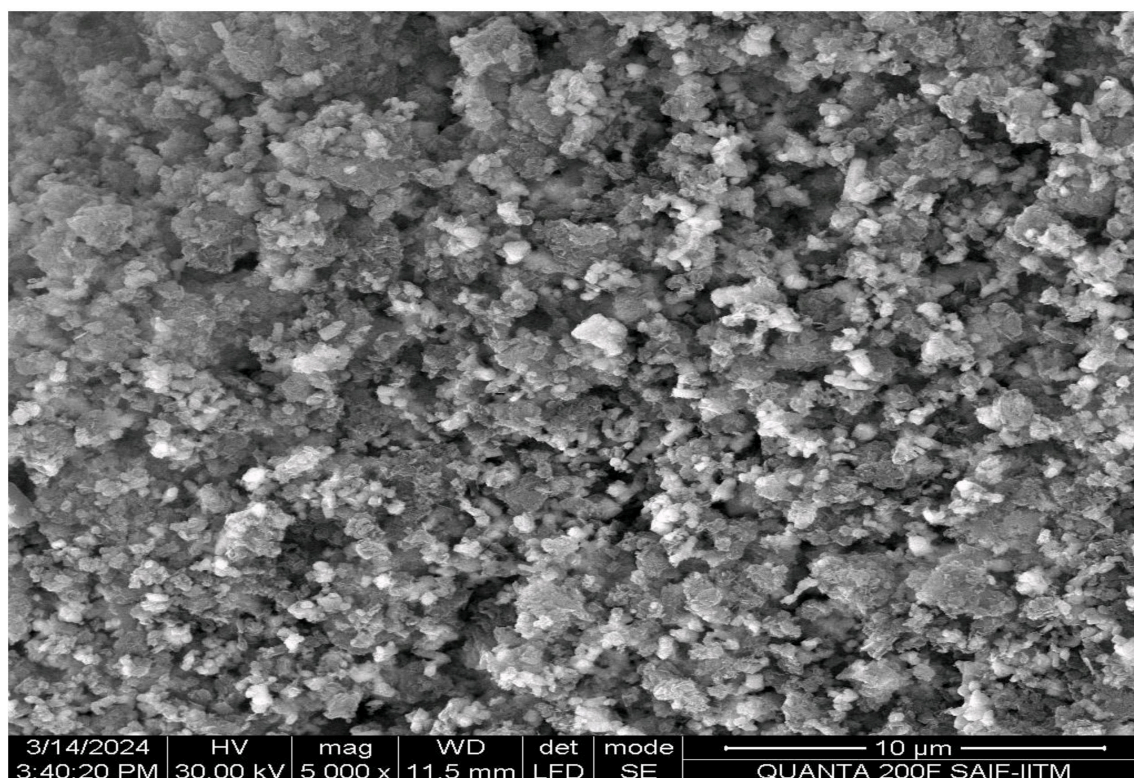


Fig: 4.10: SEM Result Nano catalyst 45

CHAPTER 5

RESULTS AND DISCUSSIONS

After completing the preparation of four test batches using different combinations. While the engine is running, the sample is consistently supplied to the fuel tank. Modifying the loads enables the assessment of efficiency as well as various measures of emission efficacy.

5.1 PERFORMANCE ANALYSIS

5.1.1 Brake Thermal Efficiency

Brake thermal efficiency will be one of the important parameters to measure the energy consumption by an engine related to heat delivered by the fuels. The variations of BTE for different blends at various load conditions are represented in Fig 5.1. It is noticed that the thermal efficiency continues to increase while load increases. BTE increases due to effective air-fuel ratio and is possibly obtained by means of better combustion. Owing to the O₂ present in biofuel, the B20 fuel mixture also gives improvement in efficiency. In addition, the BTE is improved by dispersed additives of B20 nanoparticle. This may be attributed to the presence of B20 nanoparticles, which increased the homogenization of air-fuel mixing inside the cylinder, improved the delay period and enriched the ignition [38,39]. Higher surface area-to-volume ratio of B20 particles helps to complete combustion and release high heat energy, which improves the efficiency of an engine [40,41]. The blend B20+Nano Catalyst⁴⁵ shows 10.5% higher BTE than neat diesel.

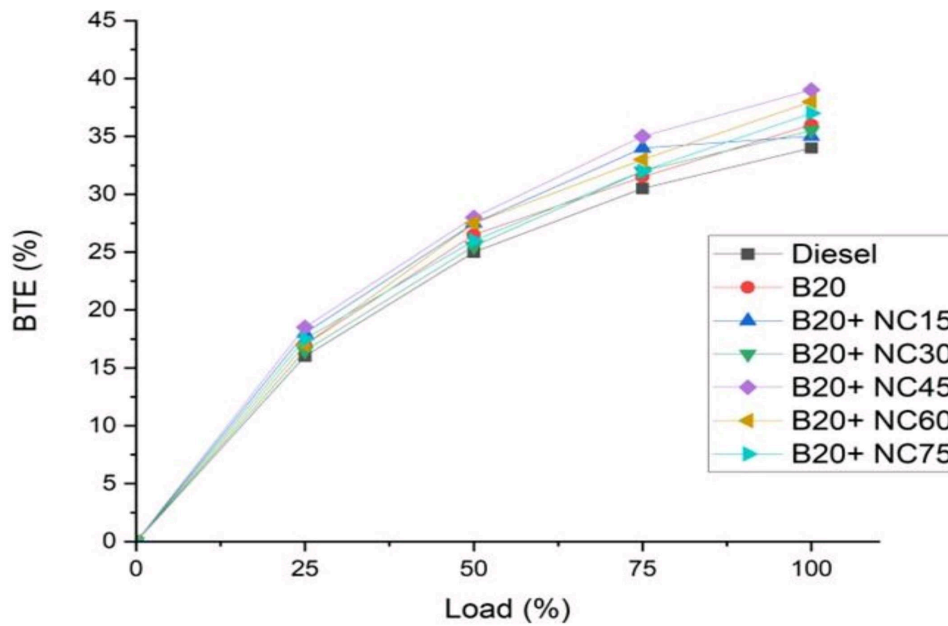


Fig: 5.1: BTE vs Load

5.1.2 Specific Fuel Consumption

The variations in the SFC for diesel, B20, B20+Nano Catalyst15, B20+Nano Catalyst 30, B20+Nano Catalyst 45, B20+Nano Catalyst60 and B20+ Nano Catalyst75 at various load conditions are indicated in Fig.5.2. It is utilized to calculate the fuel ingesting for unit power output [42]. SFC decreases while increasing engine loads from 0 to 100% with falling slope. The nanoparticle has higher surface-volume fraction, and it will act as an oxygen cushion which leads to improve the combustion process. This is the significant factor to show the reduction in SFC by added nanoparticles with B20 blend [43,44]. SFC at peak load conditions for all blends is 0.23, 0.22, 0.223, 0.213, 0.204, 0.23 and 0.235 kg/kW-hr, respectively. The blend B20+Nano Catalyst45 has decreased by 14.03% than the neat diesel at 100% load. However, the added nanoparticles to B20 biofuel have given reasonable reduction in fuel consumption

because the added nanoparticles avoid the deposit of carbon in cylinder wall which enhance the combustion process. MgO-TiO₂ nanoparticle improved thermal conductivity and thus gives better air-fuel mixing and better combustion and reduces the SFC [45,46]. The above quoted factors may reduce the friction in engine parts and thus provide higher output with less fuel consumption.

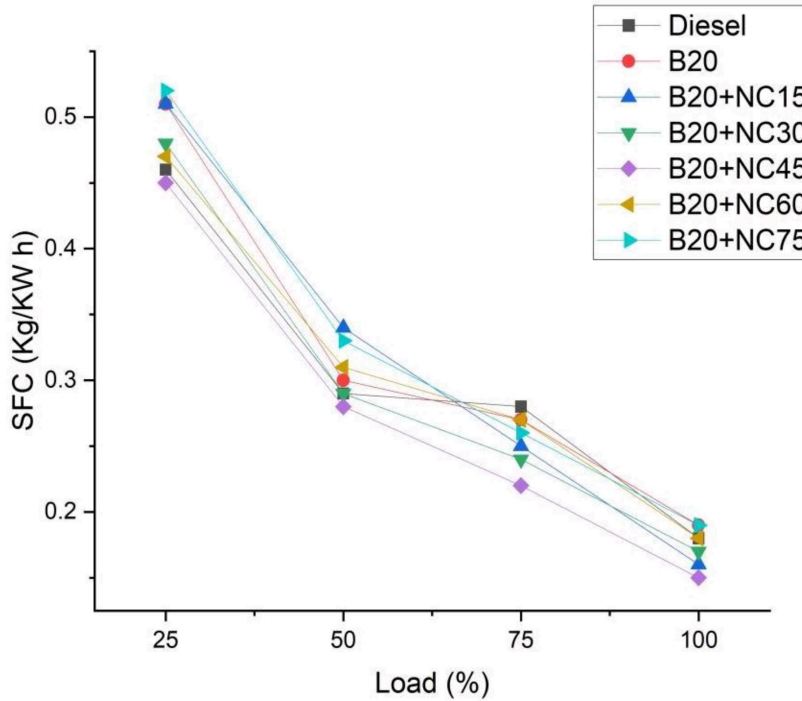


Fig:5.2: SFC vs load

5.1.3 Exhaust Gas Temperature

In view of EGT, it is not directly related to the quantity of the fuel supplied to the engine. It can be influenced by various factors like ignition delay time and complete combustion of the fuel [47]. Figure 5.3 illustrates the differences in exhaust gas temp for the various tested fuels. The outcomes show that the temperature of the exhaust gas decreases for the blended fuel than that of pure diesel. When MgO-TiO₂ nanoparticles are added to a biodiesel blend, they increase the evaporation rate of fuel droplets and the mixing of air and fuel. It is due to higher thermal conductivity and surface-to-volume ratio of MgO [48]. There is reduction in delay period when biofuel is mixed with additives, which improves the cetane number and rate of heat transfer. This could be the reason for reduction in exhaust gas temperature of particles mixed with fuel than the diesel

[49,50].

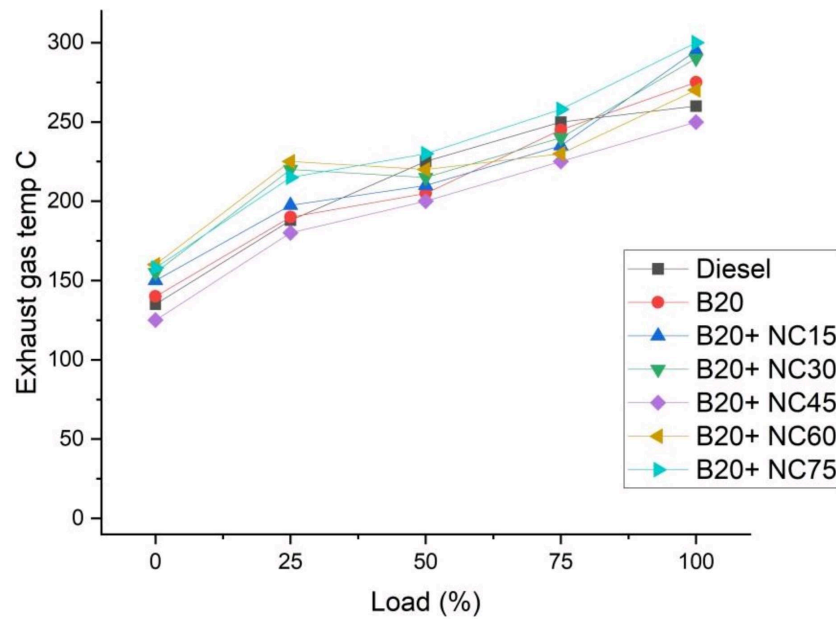


Fig:5.3: EGT vs load

5.2 EXHAUST EMISSION CHARACTERISTICS

5.2.1 Carbon monoxide (CO) emission

The primary variables that contribute to carbon monoxide emissions from a crankshaft ignition engine are the incomplete combustion of the fuel-air mixture and the insufficient amount of oxygen within the ignition chamber [51]. Insufficient conversion of carbon monoxide into carbon dioxide leads to higher amounts of carbon monoxide emissions in the exhaust [55]. Figure 5.4 graphically illustrates the levels of carbon monoxide emissions produced by several test fuels, namely B20, B20+Nano Catalyst15, B20+Nano Catalyst30, B20+Nano Catalyst45, B20+Nano Catalyst60, and B20+Nano Catalyst75. The emission levels for these fuel samples were measured to be 19.9%, 10.4%, 17.19%, 26.24%, 5.42%, and 15.38% greater than the emission levels of the basic fuel. Under different load settings, it is clear that carbon monoxide

(CO) emissions from all fuel blends are lower in comparison to diesel. Under maximum operating conditions, the combination of blend B20 with Nano Catalyst45 exhibits a notable reduction in carbon monoxide (CO) emissions compared to the original fuel. The recorded value for carbon monoxide levels is 26.24. The effect occurs because the addition of nanoparticles to the combustion chamber increases the amount of oxygen available, hence enhancing the chemical reaction with the surrounding air. Enhanced ignition and the conversion of carbon monoxide to carbon dioxide will be achieved as a result [52-55].

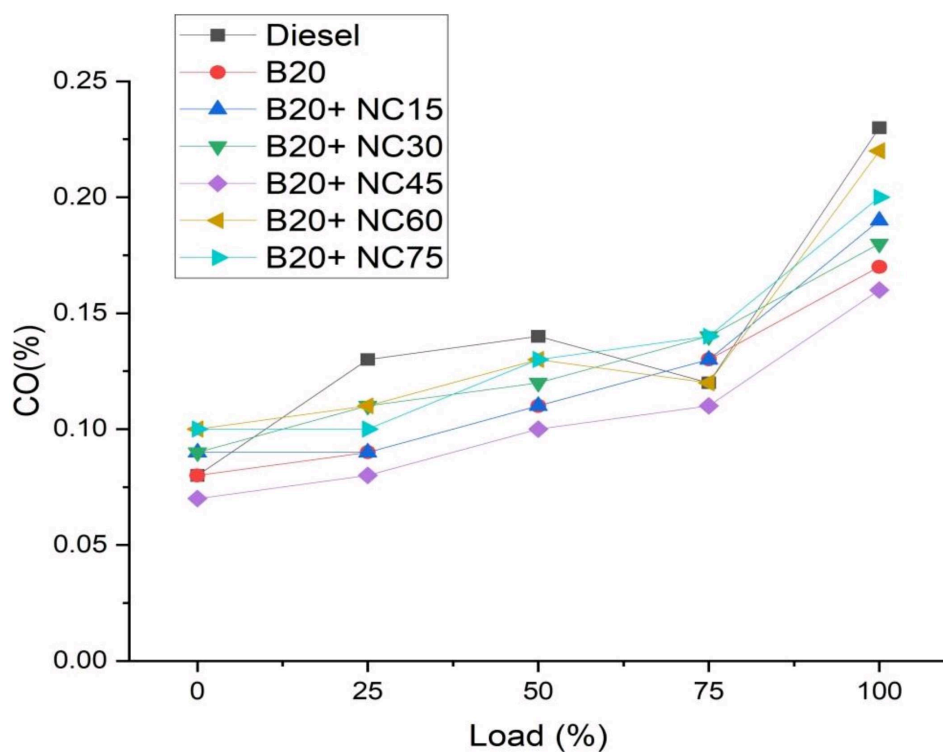


Fig: 5.4: CO vs load

5.2.2 Hydrocarbon emission

The generation of hydrocarbon (HC) emissions in the engine can be attributed to the presence of unburned fuel particles within the combustion chamber [56]. Figure 5.5 illustrates the disparity in hydrocarbon emissions among various fuel types, including diesel and biodiesel blended with nanoparticles, across different loads. At a load

condition of 100%, the hydrocarbon emissions of the tested fuels were measured to be 21, 24, 22, 20, 23, and 25 g/kWhr, with diesel exhibiting a value of 26 g/kWhr. Combining Nano Catalyst nanoparticles with B20 blend results in a slight decrease in hydrocarbon emissions across all loads compared to the base fuel. The inclusion of supplementary nanoparticles significantly contributes to mitigating hydrocarbon emissions. These nanoparticles possess the ability to increase surface area and act as an energy stimulant for the combustion of carbon particles within the cylinder walls. It is the presence of additional nanoparticles that is the most essential factor in reducing hydrocarbon emissions. These nanoparticles are able to tolerate a higher surface area and work as an energy stimulator to burn the carbon particles that are available in the cylinder walls, which ultimately results in improved combustion [60,61]. The incorporation of nanoparticles into the fuel samples results in a reduction in hydrocarbon (HC) emissions into the atmosphere. The presence of padding particles in the molecular structure enhances oxygen content, leading to the oxidation of unburnt particles and subsequent generation of carbon dioxide and water [57].

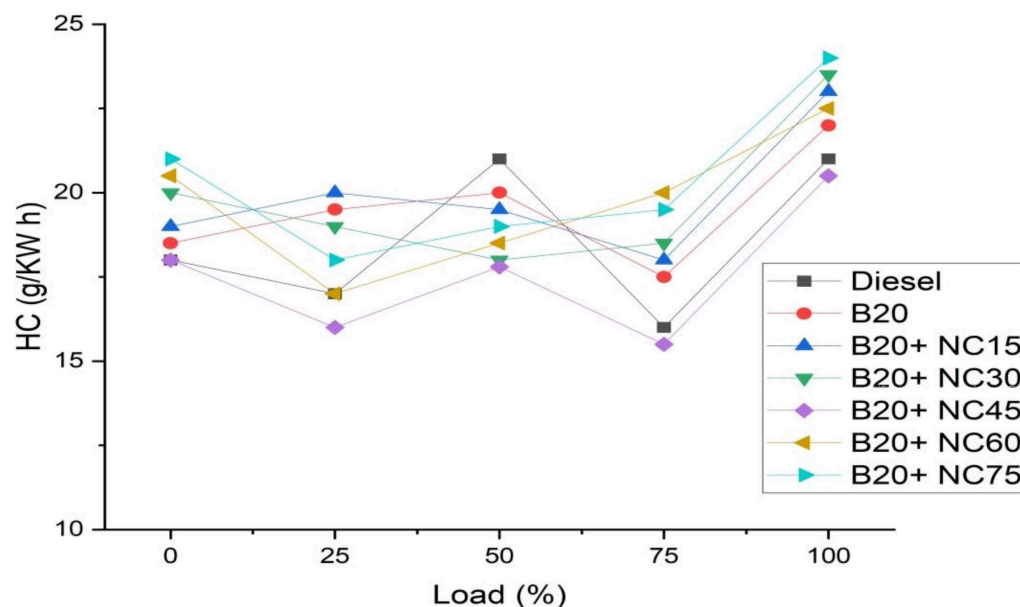


Fig: 5.5: HC vs load

5.2.3 Nitrogen oxides (NO_x)

Nitrogen oxides (NO_x) are potentially hazardous pollutants that increase with higher engine loads due to the elevated temperatures within the combustion chamber. Typically, vegetable-derived biofuels have higher oxygen content and lower nitrogen content. Additionally, the presence of particulate matter with a high oxygen concentration enhances combustion. As load increases, the engine experiences higher pressure and temperature within the cylinder, leading to increased NO_x emissions [58]. Existing literature confirms that biodiesel-powered engines emit higher levels of NO_x compared to diesel-powered engines, which is a significant drawback. However, incorporating a significant amount of nanoparticles into biofuel has the potential to reduce NO_x emissions. The enhancement of heat transfer qualities facilitates a higher quantity of heat transfer to the cylinder wall, hence resulting in a reduction in the charge temperature [59]. Analysis reveals that NO_x emissions increase across all samples at lower load conditions but decrease as the dose of cerium oxide nanoparticles increases. Figure 5.6 illustrates the fluctuation in hydrocarbon (HC) emissions of biofuel under different loads. The use of the B20+Nano Catalyst45 blend led to a 4.46% decrease in NO_x emissions compared to diesel fuel at full load. Cerium oxide acts as a catalyst, donating oxygen for the oxidation of carbon monoxide (CO) or absorbing oxygen, which is crucial in reducing nitrogen oxides (NO_x) [60-63].

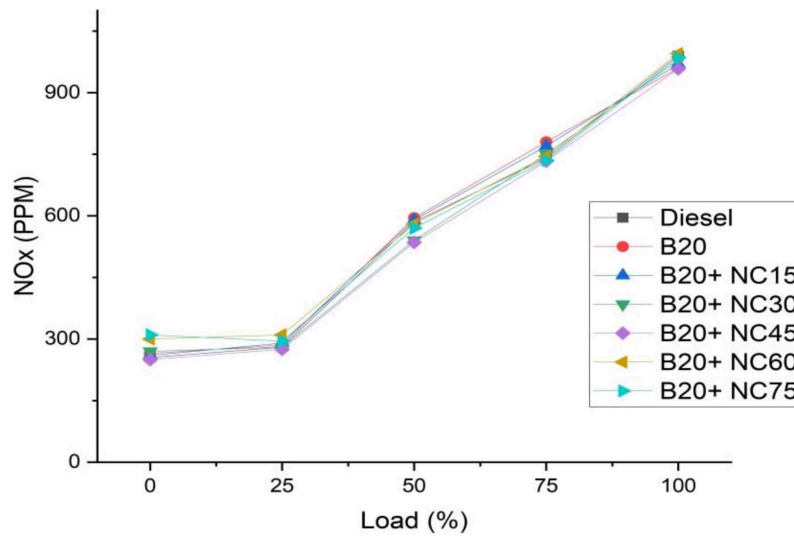


Fig: 5.6: NO_x vs load

5.4.3 Combustion duration

The combustion period is the time it takes for all the fuel to be fully burned by burning. An approach to determine this is to examine the quantity of fuel that is introduced into the cylinder during each cycle. Typically, there exists a positive correlation between the duration of fuel combustion by the engine and the magnitude of the applied load. The fuel supply is augmented to ensure the engine's consistent running irrespective of the load. The period of combustion exhibits variability among different blends, as depicted in Figure 5.7, which illustrates this volatility. The data shown in the image illustrates that the fuel blend B20+nano Catalyst45, which incorporates nanoparticles, exhibits a reduced combustion duration compared to conventional diesel when operating at maximum load [64,66]. The inclusion of particles leads to increased atomization, enhanced heat transfer, and an improved surface area-to-volume ratio. These factors collectively contribute to the enhancement of the combustion process, ultimately resulting in the complete combustion of fuel within the chamber, thereby reducing the duration.

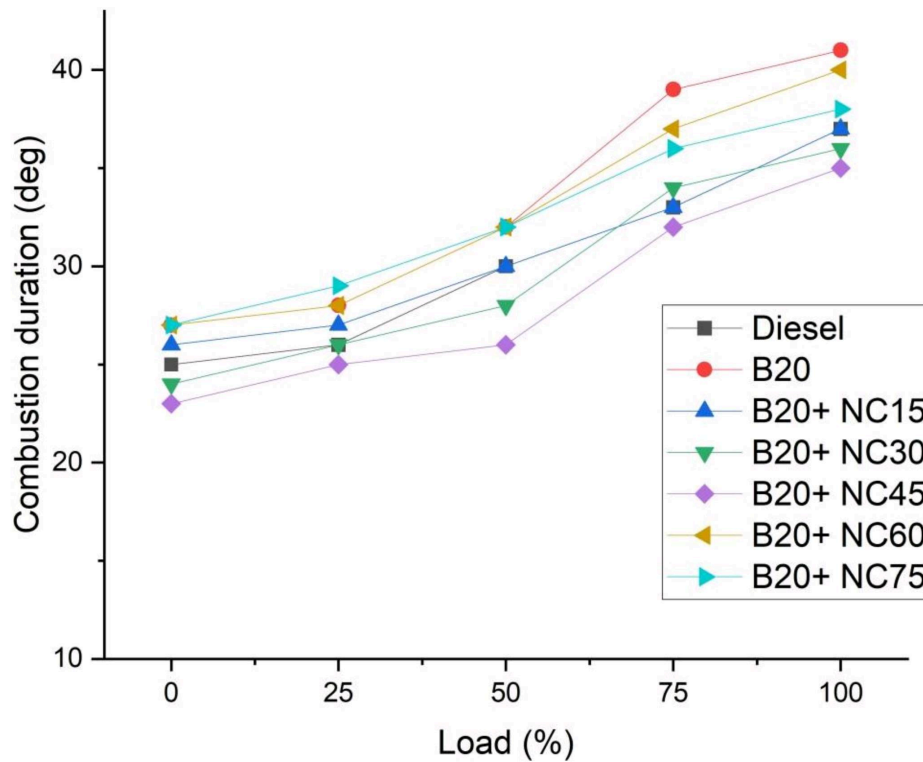


Fig:5.7: CD Vs Load

Equivalence ratio

Moreover, the equivalence ratio has a significant impact on both the cylinder pressure and the performance of the engine, making it an essential issue that must be considered. The graphic in Figure 5.8 illustrates the changes in the equivalency ratio between diesel and nanoparticles when added to waste cooking oil biofuel blends, under different load situations. The airflow to the engine is typically consistent, while the introduction of fuel into the engine is modified in response to changes in load to ensure engine stability. This results in variations in the equivalency ratio. To summarise, when there is an increase in demand from a low level to a high level, there is a commensurate augmentation in the supply of fuel. In addition, the equivalence ratio undergoes a change from 0.3 to 0.9 at zero load and peak load, respectively [67,68]. This behaviour continues regardless of the size of the load. As the equivalence ratio grows, the temperature in the combustion chamber also increases, leading to a decrease in the duration of the delay. Integrating nanoparticles into mixes improves

heat transport and increases the surface-to-volume ratio, which helps accomplish complete combustion.

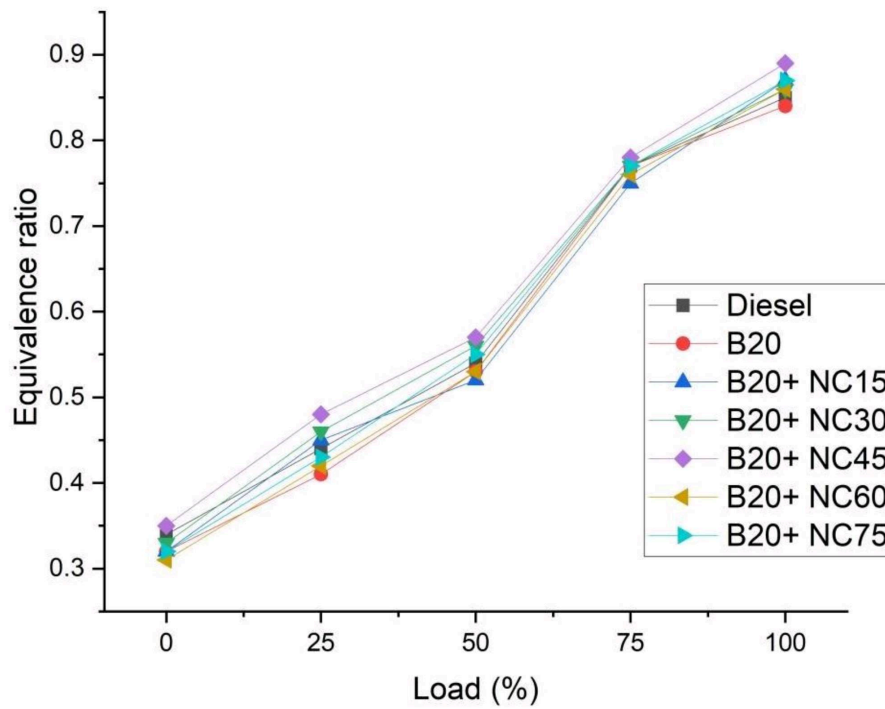


Fig: 5.8: ER Vs Load

CHAPTER 6

SUMMARY CONCLUSION

Methyl ester is produced through the effective completion of the transesterification processes of frying oil. Four samples of biodiesel were made according to the specified proportions. The four biodiesel samples are extensively tested in a diesel engine, exposed to different levels of stress. The use of the B05 blend leads to a cylinder pressure that drops below 100 bar, resulting in irregular combustion. The B10 blend produces a pressure of 100 bars with a relatively small tolerance. The B05 blend has a lower net heat rate when compared to the B10 mixture. The use of the B10 blend results in a substantial alteration in pressure. The emissions graph indicates that the B05 blend demonstrates the least amount of carbon monoxide (CO) emissions, with the B10 blend coming in a close second. The B05 blend demonstrates the lowest level of CO₂ emissions, while the B20 mixture ranks in second place. While the B15 blend has the lowest levels of NO_x emissions, it still produces the highest levels of NO_x emissions compared to the other mixes. When the load is increased, the B10 blend demonstrates the lowest levels of hydrocarbon emissions, with the B05 mix closely trailing behind. The smoke in the B10 combination displays diminished opacity. The B05 mix demonstrates the highest brake thermal efficiency, whereas the B10 blend ranks second in terms of efficiency. The B10 blend exhibits great volumetric efficiency when used with smaller loads, however this efficiency decreases when used with larger loads. The B05 blend has the lowest specific fuel consumption, while the B20 mix has the highest specific fuel usage. The exhaust gas of the B05 mix has the lowest temperature, with the B15 blend of the same type having a similar temperature. After conducting a comprehensive analysis, it has been determined that the B10 blend has greater effectiveness when compared to other biodiesel blends. Usually, this results in improved emission characteristics, increased fuel economy, and enhanced efficiency.

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