

SYNTHESIS AND CHARACTERIZATION OF MgO-MnO₂ NANOCOMPOSITE FOR THE PRODUCTION OF BIODIESEL FROM CATHARANTHUS ROSEUS SEED

Submitted in partial fulfilment of the requirements for the award of

Bachelor of Engineering degree in
Mechanical Engineering

By

RESHLIN RITHAN RAJ M (Reg. No. 40150037)

HARIHARAN V (Reg. No. 40150011)



DEPARTMENT OF MECHANICAL ENGINEERING

SCHOOL OF MECHANICAL ENGINEERING

SATHYABAMA

INSTITUTE OF SCIENCE AND TECHNOLOGY

(DEEMED TO BE UNIVERSITY)

Accredited with grade “A++” by NAAC

JEPPIAAR NAGAR, RAJIV GANDHI SALAI, CHENNAI – 600119

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BONAFIDE CERTIFICATE

This is to certify that this Project Report is the Bonafide work of RESHLIN RITHAN RAJ M (Reg. No. 40150037) and HARIHARAN V (Reg. No. 40150011) who carried out the project entitled "**SYNTHESIS AND CHARACTERIZATION OF MgO-MnO₂ NANOCOMPOSITE FOR THE PRODUCTION OF BIODIESEL FROM CATHARANTHUS ROSEUS SEED**" under our supervision from December 2023 to April 2024.


Internal Guide

Dr. NIVIN JOY, M.E., Ph.D.,


Head of the Department

Dr.S.GANESAN, M.E., Ph.D.,

Submitted for Viva voce Examination held on 06.04.2024


Internal Examiner


External Examiner

DECLARATION

We, RESHLIN RITHAN RAJ M (Reg. No. 40150037) and HARIHARAN V (Reg. No. 40150011) hereby declare that the Project Report entitled **"SYNTHESIS AND CHARACTERIZATION OF MgO-MnO₂ NANOCOMPOSITE FOR THE PRODUCTION OF BIODIESEL FROM CATHARANTHUS ROSEUS SEED"** done by us under the guidance of **Dr. NIVIN JOY., 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 CANDIDATES

PLACE: CHENNAI



1. RESHLIN RITHAN RAJ M



2. HARIHARAN V

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ABSTRACT

The present experimental work is carried out to analyze 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 catharanthus roseus seed oil (CRSO). The Nanocatalyst 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, CRSO, Performance, Combustion, Emission.

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LIST OF ABBREVIATIONS

BTE	BRAKE THERMAL EFFICIENCY
SFC	SPECIFIC FUEL CONSUMPTION
RME	RAPE SEED METHYL ESTER
SME	SOY METHYL ESTER
PME	PALM METHYL ESTER
CRSO	CATHARANTHUS ROSEUS SEED OIL
SEM	SCANNING ELECTRON MICROSCOPE
XRD	X-RAY DIFFRACTION
NO _x	NITROGEN OXIDE
FTIR	FOURIER-TRANSFORM INFRARED SPECTROSCOPY
CO ₂	CARBONDIOXIDE
EGT	EXHAUSTGASTEMPERATURE
CO	CARBONMONOXIDE
HC	HYDROCARBON
CD	COMBUSTION DURATION
EQ	EQUIVALENCE RATIO
MgO	MAGNESIUM OXIDE
MnO ₂	MANGANESE DI-OXIDE

CHAPTER 1

INTRODUCTION

1.1 HISTORY AND BACKGROUND

The present-day engine, which is utilized in contemporary times, emerged as a direct consequence of the Industrial Revolution, a transformative period spanning the 18th and 19th centuries. This revolution facilitated the advancement of the internal combustion engine. Etienne Lenoir, a French engineer, is attributed with the creation of the inaugural combustion engine, a compact vehicle fueled by petrol. The inception of this engine occurred around the early 19th century. The development of the first functioning internal combustion engine by Nikolaus Otto, a German engineer, did not occur until the late 1800s. This can be attributed to the engine's lack of sufficient power. The engine employed by Otto was a four-stroke cycle, which remains the prevailing design for the bulk of contemporary engines. A four-stroke cycle is comprised of four strokes. The four distinct strokes in question encompass consumption, compression, combustion, and exhaust. In order to transform fuel to mechanical energy, the engine employs a piston that undergoes oscillation within a cylinder throughout the operation. Karl Benz created the Benz Patent-Motorwagen in 1885, utilizing a combustion engine. This vehicle is often regarded as the inaugural practical automobile made by an individual. During the early 1900s, when motors were being introduced into aircraft, the Wright Brothers accomplished the inaugural triumphant powered flight in 1903. The advent of the jet engine throughout the 1930s and 1940s brought about a transformative era in the field of air transport, leading to substantial enhancements in both the velocity and effectiveness of air travel. Diesel engines were developed over the latter part of the 20th century, resulting in enhanced efficiency and reduced fuel usage. The utilization of diesel engines is prevalent in heavy-duty vehicles, including trucks, buses, and power generators. There is currently a strong emphasis on the advancement of environmentally-friendly and highly efficient engines, including hybrid and electric types. In order to reduce fuel consumption and minimize pollution, these engines employ a diverse range of technology.

1.2 Introduction of Biodiesel and Its Generations

Biofuels are typically categorized into two broad groups: (i) primary biofuels, encompassing petrol derived from wastes, firewood, wood chips and pellets; and (ii) secondary biofuels, comprising bioethanol, butanol, biodiesel and hydrogen. Biofuels are derived from sources of organic matter. In accordance with the findings of Amaro, Macedo, and Malcata, the initial iteration of biofuels encompasses biodiesel derived from organic sources such as rapeseed, soybeans, sunflowers, palm, coconut, and animal fats. Furthermore, bioethanol and butanol are generated via the process of fermenting starch obtained from various crops such as wheat, barley, potato, and maize, sugarcane, and sweet beets. Second-generation biofuels encompass the production of ethanol from biomass, bio-butanol, and diesel by the utilization of lignocellulosic resources, such as straw, wood, and grass. In addition, the utilization of *Jatropha* and cassava for the manufacture of bioethanol and biodiesel is seen as an illustration of the second-generation of biofuels [1]. In conjunction with the heightened demand on agricultural land for food production to sustain the continuously expanding global population, estimated to reach 7.2 billion individuals by 2050, the initial iteration of biofuel production systems presents significant economic and environmental challenges [2]. The main disadvantages of the second phase of biofuel production are the non-competing woody portions from plants. One drawback of the current generation is the requirement for a substantial cultivation area. The ability of microalgae to generate substantial amounts of biomass and subsequently produce biofuels on smaller land areas is a potential solution to overcome the constraints associated with the first and following generations of biofuels [3]. The production of biodiesel, a form of sustainable biofuel, involves the use of recycled cooking oils, animal fats, or vegetable oils. The synthesis of methyl ester, the principal constituent of biodiesel, is achieved by the chemical mechanism known as transesterification. The aforementioned procedure entails the amalgamation of the feedstock with an alcohol, commonly methanol, and a catalyst, typically sodium hydroxide. In this study, [4] provided a comprehensive overview of several biodiesel kinds and their respective production methodologies.

1.2.1. First Generation of Biodiesel

The biodiesel feedstock derived from rapeseed oil, which is the predominant feedstock in Europe, is commonly known as rapeseed methyl ester (RME). Sodium methyl ester (SME) is a methyl ester derivative derived from soybean oil, which serves as the predominant feedstock for biodiesel synthesis in the United States. The biodiesel feedstock palm methyl ester (PME), derived from palm oil, is extensively utilized in Asia.

1.2.2 Second Generation of Biodiesel

The production of waste cooking oil methyl ester (WCOME) involves the utilization of reclaimed cooking oil, a residual output derived from many sources such as eating establishments, households, and food companies. This product is alternatively referred to as WCOME. A by product derived from the meat industry, namely animal fat methyl ester (AFME), is generated by the utilization of animal fats such as tallow and lard. Jatropha methyl ester (JME) is derived from jatropha oil, an inedible oilseed that may be cultivated in difficult soil conditions.

1.2.3 Third Generation of Biodiesel

Algal methyl ester (AME) is a form of methyl ester created from oil obtained from algae, which may thrive in many water conditions and yield a substantial quantity of oil. The utilization of biodiesel as a sustainable energy resource has promise in mitigating the release of nitrogen dioxide (NO_x) and reducing the carbon footprint of the environment. Based on the findings [5] the utilization of plant feedstock leads to a decrease in the carbon content integrated into the fuel. The reason for this is that the carbon was derived from the Earth's atmosphere. In addition, biodiesel, in comparison to fossil fuel-derived diesel, decreases the emission of air pollutants such as carbon monoxide, nitrogen oxides, and carbon dioxide. In a 1998 study conducted by the United States Department of Energy and the United States the Department of Agriculture, it was found that using pure biodiesel in urban buses results in a significant decrease in the life cycle emissions of total particulate matter by around 32 percent, carbon monoxide by around 35

percent, and sulphur oxides by around 8 percent compared to the life cycle emissions of conventional diesel fuel

1.3 Introduction

At present, a significant proportion of countries worldwide are classified as energy importers. There is a substantial demand for commodities derived from petroleum resources in the global energy system [6]. Biodiesel is a suitable option in this situation because of its environmental benefits, renewable characteristics, non-toxic attributes, and capacity for natural decomposition. The main source of bio-oils is derived from plants and their by-products [7]. Furthermore, this substance is obtained from several origins, including vegetable oil, animal fats, algae, and non-edible oils. In addition, the substance comprises monoalkyl esters derived from long-chain fatty molecules. Vegetable oils from different sources, such as soy, palm, rapeseed, sunflower, and others, contain triglycerides, which are used in the manufacturing of biodiesel [8], [9]. Furthermore, this collective comprises a wide range of non-consumable resources, such as Pongamia oil, Castor oil, Mahua oil, Jatropha oil, Camelina oil, Neem oil, and Cottonseeds oil. The process of obtaining biodiesel, often referred to as methyl ester of fatty acids (FAME), is commonly denoted as "transesterification" [10-12]. Biodiesel demonstrates comparable properties to petrol, diesel and is utilized in the production of various automotive vehicles. After the process of combustion, biodiesel and its byproducts demonstrate a decreased environmental footprint [13-18]. This research aims to analyze the emissions and performance characteristics of biodiesel when used in an internal combustion engine. the primary objective of the circular economy is to address the impacts of modern and anthropogenic pollution through the production of environmentally sustainable goods derived from waste materials and by-products. There has been a significant increase in demand within the energy sector, namely for petrochemicals [19]. Biodiesel is a feasible alternative in this scenario because of its environmentally friendly characteristics, capacity to be replenished, lack of toxicity, and limited duration. The composition of this substance consists predominantly of bio-oils generated from plants and plant-derived materials [20]. The composition of this substance consists of monoalkyl esters that are obtained from long-chain fatty compounds. These compounds are acquired from many

sources such as oils, animal fats, plant debris, and undesirable oils [21]. The conversion of vegetable oils, including soybean oil, palm oil, canola oil, and sunflower seed oil, into vegetable oils has been facilitated by the production of biodiesel. Additional non-consumable sources that can be utilized include Pongamia, Castor oil, Jatropha oil, Camellia, Neem oil, and cottonseed oil [22]. A recent research study examining the expenses related to the manufacture of biodiesel using *Catharanthus roseus* as a raw material has revealed a significant potential decrease in the overall production cost of biodiesel when compared to biodiesel generated from non-consumable sources. It is expected that there will be a reduction in feedstock costs ranging from sixty to seventy percent [23]. Consequently, employing *Catharanthus roseus* for biodiesel production has the potential to decrease the expensive feedstock. The plant species *Catharanthus roseus* is currently performing a crucial function in promoting the economically viable implementation of biodiesel production [24]. The cost of the catalyst is another factor that affects the overall cost of the biodiesel production process. Numerous studies have been undertaken to enhance the advancement of economically viable catalysts for the successful production of biodiesel, employing waste materials [25]. The purification and separation operations encounter numerous obstacles as a result of the highly detrimental and non-compassable nature of homogeneous catalysts. Furthermore, the expenses related to their manufacturing and upkeep are significantly increased [26]. There are various challenges associated with homogeneous catalysts in the fields of decontamination and partitioning. Moreover, their extremely harmful characteristics and inability to be recycled contribute to the increased costs linked to their production and upkeep [27]. Previous studies have demonstrated that the incorporation of heterogeneous catalysts and photo catalysts can effectively decrease both the production cycle and production cost, while simultaneously obviating the necessity for saponification interaction [28], [29]. There exists a certain type of heterogeneous catalyst that demonstrates superior performance in relation to both reactant and phase when compared to catalysts that are homogenous. The utilization of heterogeneous catalysts comprising acid and basic groups holds significant value in the context of biodiesel generation [30]. Biodiesel, which shares comparable characteristics with diesel fuel, demonstrates considerable potential for utilization within the automotive sector [31]. The reduction

of the ecological footprint associated with biodiesel and its by-products is significant. Simultaneously, it is imperative to transform newly constructed petrol compression engines and guarantee compliance with the requisite criteria for biodiesel and petrodiesel blends [32]. The compatibility of biodiesel with diesel engines is evident, regardless of the particular fuel used, and it may be easily incorporated into various layouts of diesel engines. The biodiesel blends commonly classified as B5 to B20 consist of varying proportions of biodiesel, ranging from 5% to 20% [33]. Currently, automobile manufacturers are required to make determinations regarding the suitability of their vehicles for biodiesel. Blended biodiesel is favoured by the automotive industry at concentrations of up to twenty percent for its application in automobiles, particularly when combined with ultra-low sulphur diesel, owing to its favorable lubricating properties [34]. The main aim of this research is to examine the production of a calcium oxide nanocatalyst doped with barium, utilizing waste gypsum (PoP) obtained from *Catharanthus roseus*. The objective is to accomplish this synthesis in optimal microenvironments. The control of waste generated during the production stage is the primary aspect that contributes to the reduction of the overall cost of the biodiesel production process. The process parameters are modified by employing conducted experiments, which rely on data related to biodiesel emissions and performance evaluations in a closed combustion engine. The advent of biofuels is anticipated to exert a significant influence on the conservation of the forthcoming energy provision and the alleviation of ozone layer depletion by means of emission reduction. To fully use the potential of biofuels for transportation and commercialization in the sector, additional progress is required. Furthermore, it is crucial to exert deliberate endeavors to ensure that costs are adequate, particularly with regard to the expenditures linked to the essential elements. The current research endeavor encompassed the synthesis of a nanocatalyst comprising barium-doped calcium oxide by the utilization of waste resources. This action was undertaken with the objective of maximizing biodiesel production from *Catharanthus roseus*. In addition, a series of engine experiments were conducted in order to determine the possible effectiveness of biofuel.

CHAPTER 2

LITERATURE SURVEY

2.1 Biodiesel Blends

Mardhiah et al. (2017) a study says Biodiesel stable under storage and distribution process is the alternative biofuel that can either be blended with petroleum diesel fuel in proportion for a conventional engine without any additional changes. A common blend of 20:80 biodiesel with petroleum diesel (B20) is broadly executed around the world

Verma, M. L., Puri et al. (2016) An experimental study was conducted to evaluate diesel engine emissions and performance using combinations. For the growth of any region of the world, energy is a crucial issue. The market issues a warning to shift toward sustainable fuel for the coming generation as a result of the increase in crude oil prices and the accompanying global emissions. The need for energy is growing because of the expanding global population, the necessity for energy in industrial applications, the use of vehicles, and power generating equipment

Avinash Kumar and Rupesh Kumar Tripathi conducted research that led to the establishment of biodiesel blends with concentrations of 10% and 20%. Regarding oblique, the amount of fatty acids has a substantial influence. The B10, B20, B40, and B50 biodiesel blends had chemical and physical properties that were similar to those of diesel oil. In 2020, Kumar et al. did a study to examine the performance characteristics and exhaust emissions of a diesel engine that utilized a blend of diesel fuel and biodiesel.

Wang et al. (2018) conducted a study to investigate the combustion and emissions properties of a microalgae oil biodiesel mix (B20) in a single-cylinder diesel engine. The results indicated that B20 exhibited combustion characteristics similar to petroleum-derived diesel fuel, while generating reduced amounts of particulate matter, carbon monoxide, and unburned hydrocarbon emissions.

In a separate study, Silva et al. (2019) examined the performance and emissions attributes of a biodiesel blend (B30) derived from microalgae oil, specifically in the context of a diesel engine. Notwithstanding its reduced emissions of nitrogen oxides and particulate matter, the findings indicated that B30 diesel exhibited engine performance that was on par with petroleum-derived diesel.

Moreira, K. D. S., de Oliveira, A. L. et.al (2020) in this investigation, the characteristics of tall oil methyl ester-diesel fuel mixes were examined as potential alternative fuels. The researchers explored the use of blends consisting of tall oil methyl ester and diesel fuel as a promising option for diesel engines. To produce tall oil methyl ester, methyl alcohol and tall oil fatty acids were carefully combined. The inclusion of tall oil methyl ester in the diesel fuel blends led to a notable increase in engine power and torque output, with improvements of up to 6.1% and 5.9% respectively. However, the revised fuel combinations also resulted in a significant rise in NO_x emissions, reaching up to 30%, while CO emissions experienced a substantial decrease of 38.9%. Interestingly, the opacity of the smoke did not exhibit any noticeable changes throughout the study.

Méndez, J. C., Arellano, U et.al (2022) conducted a study to investigate the effects of engine speed and the concentration of a nanoparticles in diesel-biodiesel blended fuels on the performance and emission characteristics of a six-cylinder, four-stroke diesel engine. Nanoparticles were synthesized and added to the diesel-biodiesel blend at concentrations of 15, 30, 45, 60 and 75 parts per million. These fuel blends were used to operate the diesel engine at various speeds ranging.

Karthikeyan, P et al. (2019) looked at MgO and SiO₂, two distinct nanoparticle additions, were added to the biodiesel at dosages of 15 and 30 parts per millilitres. Examined were the changed fuels' fuel qualities, engine performance, and exhaust characteristics. The findings involve including nanoparticle additives reduced emissions while marginally increasing performance values.

Liu, C. H., Huang, C. C., Wang et al. (2018) investigated the combustion and emissions characteristics of a microalgae oil biodiesel blend (B20) in a single-cylinder diesel engine. The results showed that B20 had similar combustion characteristics to petroleum-based diesel, but with lower emissions of particulate matter, carbon monoxide, and unburned hydrocarbons.

Macario, Anastasia, Francesca Verri et al. (2015) studied the cerium oxide effect in emissions & performance added to clean blends of biodiesel & diesel. Following a series of tests, it was discovered that the mixes that were stabilized with an ultrasonic bath after high-speed blending had better stability. Cerium oxide supplies oxygen for burning by functioning as a catalyst that donates oxygen.

Sivakumar et al. (2013) Studies have identified that magnesium oxide (MgO) is one of the promising heterogeneous base catalysts as it does not get dissolved in the reaction medium and also gives high yield biodiesel during transesterification process.

Ranjan, Alok et al. (2018) the MgO nanoparticles at 30 ppm concentration can be used as additives for the biodiesel to improve cold flow properties, performance and combustion characteristics and to decrease exhaust emissions when used in diesel engines.

Keskin A, Guru M et al. (2011) reported that use of MnO₂ or MgO additive has enhanced the properties (viscosity, flash point) of diesel fuel. In general, there is less work given on the utilization of metal-based additive to enhance cold flow properties of waste cooking oil biodiesel.

Tamilvanan, A., K. Balamurugan et al. (2019) This study provides an overview of the numerous nanoparticles that have been utilized to enhance the production of biofuels. Several nanocatalysts have been studied for biodiesel production like ZnO, CaO, MgO, TiO₂, ZrO₂, carbon-based nanocatalysts, and other nanocatalysts. These nanocatalysts can be used as supported nanocatalysts, doped nanocatalysts, impregnated nanocatalysts, and mixed nanocatalysts. The nanocatalysts give better conversion and yield than heterogeneous catalysts with better optimum conditions.

Jaya Prabakar Jayaraman, M. Karthik et al. (2020): examined how well a CI engine runs on a B20 blend of Manilkara zapota seed oil biodiesel. Examined are the engine's emissions and performance when using this blend both with and without blended titanium oxide nano additions. The combined impact of additives and EGR on performance is assessed using 15% EGR. B20 + 50 + EGR and B20 + 100 + EGR blends yield higher brake thermal efficiency values, according to the test

results. The engine used fewer of the three blends that were evaluated, B20 + 50 + EGR. Blends of B20 + 50 + EGR and B20 + 75 + EGR claim lower NOX emissions. These combos have higher carbon emissions. To improve emissions & performance, blend B20 can first be used to run an IC engine with including of TiO₂ nanoelements and an EGR.

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

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

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

Sathyamoorthi R (2017) ,In this study, ethanol was mixed with a pure lemongrass oil (LGO) diesel fuel blend to analyze the effects of ethanol concentration on the engine's performance, emissions, and combustion. The impact of small ethanol concentrations (2.5 and 5%) in the regular lemongrass oil-diesel blend was examined. The results from tests conducted with diesel fuel and different blends

were compared. The blends studied showed varying performance, emission, and combustion characteristics when compared to diesel fuel. Compared to diesel and LGO25 (75% pure diesel ÷ 25% pure lemongrass oil), the ethanol blends exhibited higher combustion pressure and heat release rate, brake specific fuel consumption, and brake thermal efficiency. However, they also resulted in lower smoke and HC emissions, as well as higher NO_x and CO₂ emissions.

A.S. Husayyin Rady A. Dawood and A.H. Bawady, MA Title: An experimental study was conducted to evaluate diesel engine emissions and performance using combinations of jojoba oil and diesel fuel. Research has demonstrated that blending mahua oil with petrol can effectively reduce engine problems caused by thick oil. Substituting regular petrol with blends of jojoba oil and petrol in single-chamber, naturally aspirated, direct-injection engines has generally resulted in minimal loss of engine power, a slight increase in brake-specific fuel consumption, and a reduction in engine NO_x and particulate emissions. The accumulation of engine deposits has decreased gradually over time.

CHAPTER 3

AIM AND SCOPE

3.1 Aim

The efficiency of the biodiesel synthesis process is expected to be enhanced by employing a nanocomposite comprising magnesium oxide and manganese dioxide in combination with ethanol. The inquiry focuses on B20 biodiesel because to its favourable combination of cost-effectiveness, reduced emissions, cold-weather performance, and compatibility with various equipment. A transesterification technology will be employed to create a blend of diesel and nanocatalyst biodiesel, with 20% biodiesel and 80% diesel. To conduct engine testing on a VCR engine, the B20 mixture will be supplemented with nanoparticles of magnesium oxide and manganese dioxide. To track the advancements achieved in reducing NO_x emissions. Enhanced the efficacy of the test's outcomes and examination

3.2 Scope

Biodiesel, considered an alternative fuel, plays a crucial role in mitigating the release of harmful particles into the environment due to emissions. Furthermore, it offers a sustainable remedy that aids in mitigating the issue of fossil fuel demand. This series of studies presents a resolution to the issue of employing high viscosity mixes in diesel-powered vehicles that have not undergone any modifications. Furthermore, to facilitate simultaneous rail direct injection. By implementing this approach, the diesel engine can operate with optimal efficiency.

CHAPTER-4

EXPERIMENTAL OR MATERIALS AND METHODS

4.1. Methodology:

The inclusion of magnesium oxide and manganese dioxide is important for the formulation of the mixtures to be made. The approach described in this study employs *Catharanthus roseus* seeds as the oil, similar to the use of ethanol as the alcohol in the process. This chapter provides a comprehensive description of the specifically required supplies, techniques, instrument specifications, operational principles, and experimental procedures employed in the research. A comprehensive experimental strategy, as depicted in Figure 4.1, was recommended for the inquiry.

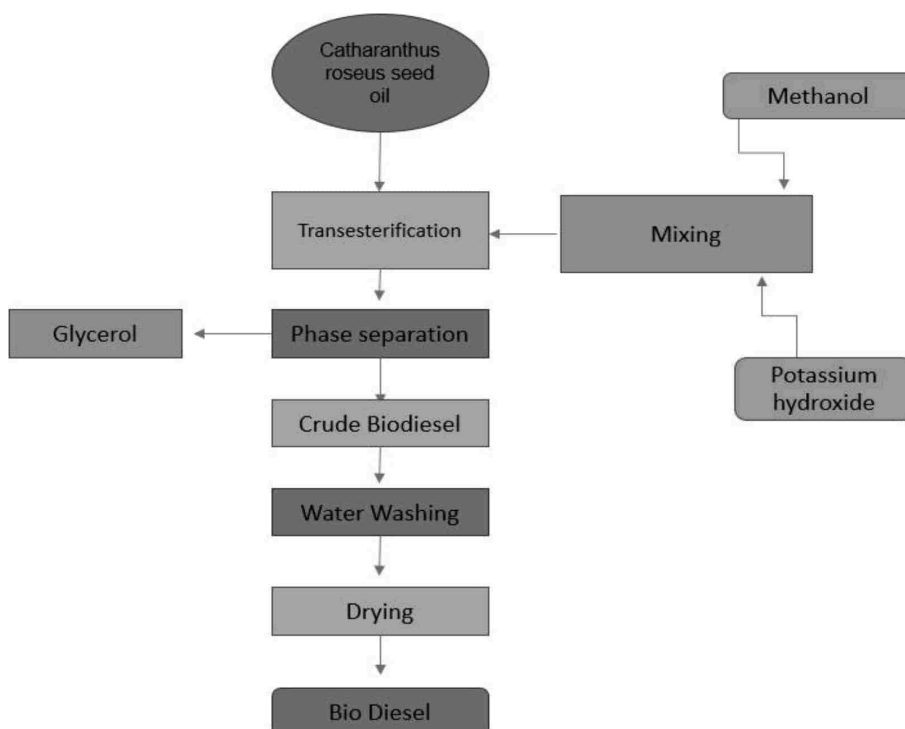


Fig. 4.1 Flow chart of biodiesel preparation

4.2 Materials and Processes

The nano-composite employed for biodiesel production consists of magnesium oxide (MgO) and manganese dioxide (MnO₂). The oxides of MgO and MnO₂ exhibit a high level of purity, with an average size of 10 microns, reaching a value of 99%. The composition of the mixture was found to have weight ratios of 100:0, 75:25, 50:50, 25:75, and 0:100, where each ratio corresponds to a distinct weight percentage denoted by NCPs1-5. Once the accurate weights and ratios of the raw materials were determined, they were introduced into the ethanol alcohol suspension and subjected to homogenization using a Hielscher ultrasonic device with a power output of 2 watts, a frequency of 26 kilohertz, and a rotational speed of 1000 revolutions per minute. This measure was implemented to ensure that the distribution was consistent and equitable. Subsequently, the combinations were ground using a friction mill for a duration of four hours. The drying process was conducted using an IMS oven, operating at a temperature of 60 ± 5 °C, for a period of three hours. The powders that were acquired were subjected to sintering in a GSL1600X furnaces manufactured by MTI Corporation, at an internal temperature of 400°C per hour.

4.2.1 Materials used

The materials used for this project are Magnesium oxide, Manganese di-oxide and Ethanol are shown as in figure 4.2



Fig. 4.2 Materials used

4.2.2. Instruments used

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

4.2.2.1 Sonicator

Sonication is the process of manipulating particles in solutions by using sound waves to agitate them. To expedite the dissolution of a solid into a liquid, these interruptions are employed to facilitate the mixing of solutions. The process of sonication involves the utilization of ultrasonic sound waves. Due to the application of pressure during the method, the solution exhibits the ability to generate numerous tiny vacuum bubbles. The cavitation mechanism causes the bubbles to dissipate into the solution. The phenomenon of bubble collapse in the cavitation field gives rise to the generation of waves, subsequently resulting in the accumulation of a substantial quantity of energy. This phenomenon leads to the disruption of chemical bonds between water molecules. The reduction in molecular interactions leads to the initiation of particle separation, facilitating the occurrence of the mixing process. The solution involves the generation of friction by the interaction of sound waves, resulting in the subsequent release of energy. Figure 4.3 shows Ultra Sonicator device. To prevent overheating of the sample, ice cubes are employed both during and following the sonication technique.



Fig 4.3 Sonicator

4.2.2.2 Magnetic Stirrer

A magnetic stirrer refers to a device that is specifically designed to agitate a liquid through the application of a magnetic field that rotates. This laboratory equipment is commonly utilized for the creation of solutions, specifically for the mixing of liquids with low viscosity. The mechanism responsible for generating agitation is a magnetic stirrer, consisting of a bar of magnets that is immersed in the liquid. The stirrer device, positioned below the liquid vessel, contains an additional rotating magnet or electromagnet assembly that propels the stir bar. Polytetrafluoroethylene (PTFE) is the predominant material employed for coating stir bars, with occasional utilization of glass. These coatings are specifically engineered to possess chemical inertness, ensuring that they remain uncontaminated and unreactive with the surrounding reaction mixture. In situations when PTFE is deemed unsuitable due to the presence of elevated temperatures or chemical exposure, glass may serve as a viable replacement. PTFE may experience a certain degree of degradation during the dissolution of metal reductions using an alkali metal dissolved in the primary amine. Given that Birch reductions, a common form of dissolving metal reduction, are commonly conducted in a glass container, it implies that a glass stir bar would also be suitable for the procedure. Figure 4.4 shows magnetic stirrer process. Glass is susceptible to damage caused by potent alkalis, such as lye, which is contingent upon factors such as temperature, duration of exposure, and concentration.



Fig 4.4 Magnetic stirrer

4.2.2.3 Hot Air Oven

A hot air oven is a scientific apparatus that can be employed for the objective of desiccating, sterilizing, or heating objects. Figure 4.5 shows hot air oven process. Typically, heat is evenly dispersed to the items undergoing processing via a mechanism that employs the circulation of hot air within the oven's chamber. Hot air ovens are commonly found and used in various locations, including research laboratories, industrial environments, and educational institutions. A thermostat is commonly employed in hot air ovens to maintain a consistent temperature and provide a temperature range that spans from the ambient temperature to 250 Celsius degrees or more. Furthermore, certain hot air ovens are fitted with a fan that facilitates the circulation of hot air within the temperature-controlled oven chamber. This fan has the capability to facilitate the uniform heating or drying of the materials during processing. Hot air ovens are commonly used to sterilize equipment and materials due to their ability to kill bacteria at high temperatures. These devices are capable of facilitating the drying process for many materials, including chemicals, biological specimens, and glassware. Furthermore, hot air ovens can be employed for the goal of heating materials for various applications, such as the combustion of chemical or the elevation of materials to specific temperatures for testing purposes.



Fig 4.5 Hot Air Oven

4.3 Extraction of Biodiesel from *Catharanthus roseus* seed

Catharanthus roseus seeds are found from the botanical garden and from the local areas of Thanjavur in Tamilnadu state, India. Solvents and chemicals of anhydrous grade (99.99%) such as Methanol, Barium Chloride, Titanium dioxide, Barium nitrate tetra hydrate, and molybdic acid collect from SRL Chemicals Pvt. Ltd., Mumbai in Maharashtra state, India. The extraction processes were carried out by [35]. Production of biodiesel from *Catharanthus roseus* bio-oil using $\text{BaMoO}_4/\text{TiO}_2$ nanocatalyst using a Soxhlet apparatus and with the help of a heating oil at 65°C for 3 h [36]. Figure 4.6 represents the *catharanthus roseus* seed oil biodiesel [36].



Fig 4.6 *catharanthus roseus* seed oil biodiesel

4.3.1. Soxhlet process:

The Soxhlet extraction technique is extensively employed in the extraction of lipids from various biological materials, such as the seeds of the *Catharanthus roseus* plant. The Soxhlet extractor is a specialist glassware including a round-bottom flask, a thimble, a reflux condenser, and a heating mantle. The utilization of this procedure is seen. The initial step in the lipid extraction from microalgae involves the placement of the moist algal biomass into a thimble, followed by its subsequent transfer to the Soxhlet extractor. A solvent, such as chloroform, methanol, or hexane, is introduced into the round-bottom flask, followed by the act of heating the flask until it reaches

it boiling point. The upward movement of the solvent vapour within the thimble facilitates the extraction of lipid from the algal biomass, subsequently leading to their condensation on the reflux condenser. Subsequently, the concentrated solvent is returned to the round-bottom flask, and the extraction process is reiterated by reheating the flask. The process of solvent extraction, condensate, and reboiling must be repeated for a significant duration, or until the ideal level of lipids extraction effectiveness is attained. Shortly after the completion of the extraction process, the solvent undergoes evaporation, leading to the generation of the crude lipids extract. Subsequently, this extract can undergo processing and growth to produce biodiesel. Nevertheless, despite its high cost and demand for a substantial quantity of solvent, the Soxhlet extraction approach is a dependable and efficient technique for extracting lipids from microalga biomass. Researchers are currently investigating lipid extraction techniques that exhibit enhanced efficacy and reduced environmental impact as a result of this phenomenon. The proximity of the specimen's matrix to the removal solvent is a crucial factor in the Soxhlet extraction method are shown in figure 4.7. This process can be employed to accommodate a diverse array of chromatographic techniques, enabling the separation and concentration of organic molecules that exhibit either water-insolubility or water-non-solubility.



Fig. 4.7 Soxhlet extraction process

4.4 Transesterification

Transesterification is a chemical method employed to produce biodiesel from diverse feed stocks, such as *Catharanthus roseus* seed oil. The conversion of triglycerides, the main component of fats and oils, into fatty acid methyl esters (FAMEs), which serve as the principal constituent of biodiesel, is now underway. The chemical reaction described is commonly known as transesterification, wherein triglycerides undergo a reaction with an alcohol, commonly methanol, in the presence of a catalyst such as potassium or sodium hydroxide. In conjunction with several more byproducts, the aforementioned procedure yields the generation of FAMEs and glycerol. In order to ensure thorough reaction of the reactants, it is common practice to conduct the reaction in either a single-step or continual reactor vessel, wherein simultaneous mixing occurs throughout the operation. Several factors can influence the transesterification process, such as temperature, pressure, catalyst concentration, and the molecular weight ratio of oil to alcohol. Various variables can influence the speed of the reaction, the yield, and the final product of the biodiesel produced. Post-reaction, it is common to allow the liquid to settle to aid in the separation of biodiesel from glycerol and other byproducts. After the elimination of contaminants and the improvement of the ultimate integrity of the product, the unrefined biodiesel undergoes further refinement by means of processes such as washing, drying, and distillation. The predominant technique for synthesizing methyl esters is the transesterification of fats and oils, as indicated by the reaction at hand. Triglycerides undergo transesterification in multistep reactors utilizing an excess of methanol and an alkaline catalyst, such as sodium methylate or potassium hydroxide, at a temperature range of roughly 60-70 degrees Celsius and under atmospheric pressure. This procedure can be executed either on a batch-by-batch basis or in a continuous manner. The response to figure 4.8 is presented. Prior to the occurrence of transesterification, it is imperative to remove free fatty acids from the oil under moderate reaction conditions. Refinement or pre-esterification can be employed to achieve this objective. In order to prevent the formation of soap, which is aided by the presence of the alkaline catalyst, this procedure is undertaken. After the conclusion of the reaction, the mixture is let to undergo a period of sedimentation. It is the methyl ester that plays a prominent role in the process. The removal of the lower layer of glycerin is necessary to eliminate

any residual glycerin that may have become entrapped subsequent to the clearance of the upper layer of glycerin. Subsequently, the processing was conducted. The excess methanol is gathered, subjected to filtration, and subsequently recycled through the utilization of a rectifying column. suggest that the identical distillation apparatus employed for the extraction of fatty acids might also be utilized for the purification or fractionation of methyl esters, resulting in the formation of smaller slices or even individual constituents.

4.4.1. *Transesterification for Biodiesel Conversion*

Transesterification is a chemical process employed for the production of biodiesel, wherein materials such as animal fats, vegetable oils, and other feed types are converted. When a catalyst such as potassium or sodium hydroxide is present, the triglycerides present in the feedstock undergo a chemical reaction with an alcohol, commonly methanol or ethanol. Fatty acid methyl ester (FAMES), being the fundamental constituents of biodiesel, are synthesized by the transesterification procedure. Furthermore, the treatment process yields glycerol, a valuable by product. In order to ensure thorough reaction of the reactants, the reaction is commonly conducted in either a batch or continual reactors vessel, with mixing occurring during the operation. The transesterification process can be influenced by several circumstances. Factors that influence the outcome of a reaction encompass the kind and concentration of the catalyst employed, the molar ratio of alcohol to oil, the temperature and length of the reaction, and the existence of impurities such as water or free fatty acids. Enhancing the transesterification stage, a crucial phase in the biodiesel production process utilizing diverse feedstock such as microalgae, has the potential to greatly influence the overall efficiency and cost of the procedure.

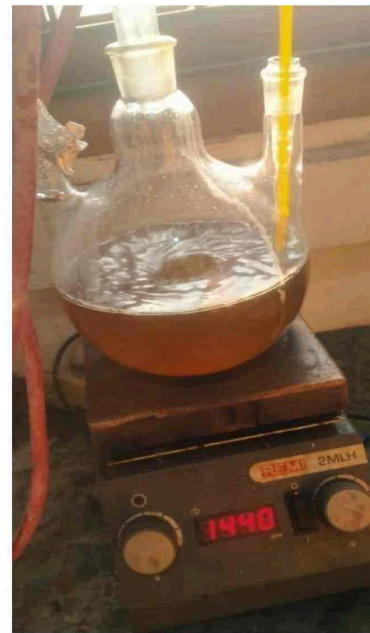


Fig. 4.8 Transesterification Process

4.5. Properties of biodiesel

Biodiesel, apart from its environmental benefits, can be derived from vegetable oils, animal fats, or recycled cooking oil. Petrol-derived diesel fuel exhibits comparable characteristics to its petroleum-derived counterpart; nevertheless, notable distinctions arise from variations in its chemical composition. In essence, biodiesel has the following fundamental attributes:

Density: Biodiesel's energy content per unit volume may be affected by its decreased density compared to petroleum fuel.

Viscosity: There is a potential for the obstruction of biodiesel flow through fuel injectors and pumps as a result of its increased viscosity compared to petroleum diesel.

Flash point: The greater flash point of biodiesel in comparison to petroleum-based diesel fuel renders it a safer option for handling and storage.

Cetane number: Biodiesel exhibits a higher cetane number than petroleum-based diesel fuel, indicating its superior ignition and combustion characteristics.

Sulphur content: Biodiesel significantly decreases both sulphur oxide (SO_x) and particulate matter emissions due to its minimal sulphur content.

Lubricity: Biodiesel, which is more lubricious than petroleum-based diesel, reduces engine wear and increases its lifespan.

Oxygen content: Due to its higher oxygen content than petroleum diesel, biodiesel can improve combustion efficiency and reduce CO and HC emissions.

Cold flow qualities: Biodiesel thickens and solidifies at low temperatures due to poor cold flow, clogging fuel filters and stopping engines.

4.6 Characterization of particle size and fuel test

The crystalline size, structure and phase formation of catalyst were categorized by XRD analysis with help of X-ray diffractometer, and the outcomes are presented in fig 4.9. Scherrer formula was used to determine the size of the crystallite (τ); $\tau = (0.94 \lambda) / (\beta \cos \theta)$, where τ = crystallite size, β = (FWHM) line broadening (radians), θ = Bragg angle in radians, and λ = wavelength. Utilizing the Scherrer formula and peaks model, the average size of the crystallite was obtained as 13.3 nm for a peak of 2θ . Scanning electron microscope (SEM) was used so as to get the morphological structure of cerium oxide nanoparticle, and it is appeared in Fig 4.9. The lab test has been directed to get the properties of this nanoparticle mixed with waste cooking oil biofuel and diesel mixes adhered to the ASTM standard. In this test, the following properties were observed: actual density, viscosity, point of fire, flash point and calorific value. Samples were named as B20, B20 + Nano catalyst 15, B20 + Nano catalyst 30, B20 + Nano catalyst45, B20 + Nano catalyst 60 and B20 +Nano catalyst 75 for this test, and it is indicated in Table 1. It is noticed from the test by adding Nano catalyst particle with biofuel blend, there is considerable increment in flash point, fire point and density. Calorific value is the important property of any fuel, and it is less for the particle blended sample than diesel, but it increased in the biodiesel (B20) sample. Figure 4.9 shows the result of XRD image. The nanoparticle blended biofuel increases the thermal efficiency with decrease in fuel consumption.

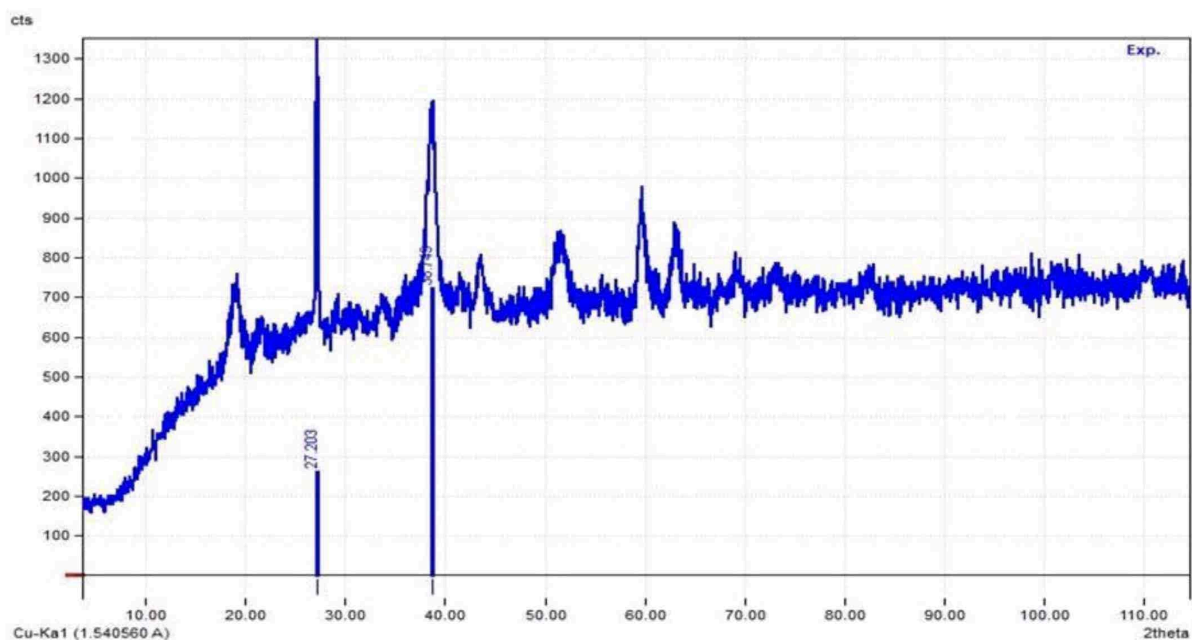


Fig 4.9 XRD image of catalyst 45

4.6.1 SCANNING ELECTRON MICROSCOPY (SEM)

Scanning electron microscopy (SEM) is a robust imaging technique employed to examine the surface morphology and composition of materials at high magnification levels. In the context of scanning electron microscopy (SEM) analysis, a specimen is exposed to a focused electron beam, and the resulting signals arising from the interactions between the electrons and the sample's surface are gathered. SEM examination is extensively utilized in various fields such as materials science, geology, biology, nanotechnology, and forensic science due to its ability to provide accurate surface information and elemental analysis at micro- to nanoscale scales. Figure 4.10 shows the result of SEM image.

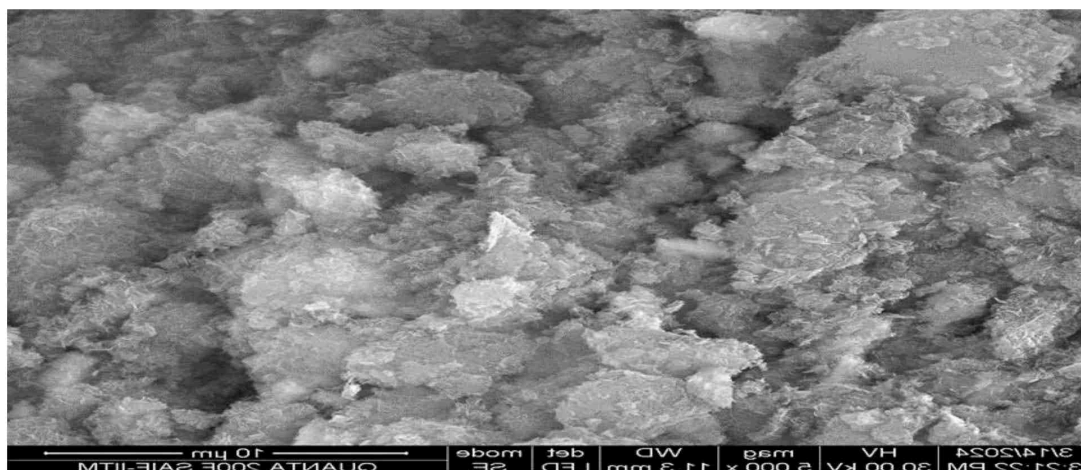


Fig 4.10 SEM image of catalyst 45

4.6.2 FOURIER-TRANSFORM INFRARED SPECTROSCOPY (FTIR)

FTIR is an acronym that stands for Fourier transform infrared spectroscopy. This instrumentation approach can be used to obtain an infrared spectrum of the absorption or emission of a solid, liquid, or gas. To operate, it quantifies the extent to which the sample material absorbs infrared light relative to its wavelength. The ability to identify and characterize chemical compounds is facilitated by the absorption of light, which serves as an indicator of the functional groups present in the substance. Fig 4.11 shows the result of FTIR. Fourier transform infrared (FTIR) spectroscopy is widely employed in various industries, such as chemistry, biochemistry, pharmaceuticals, materials science, and forensic science, among others, to perform qualitative and quantitative analysis of samples.

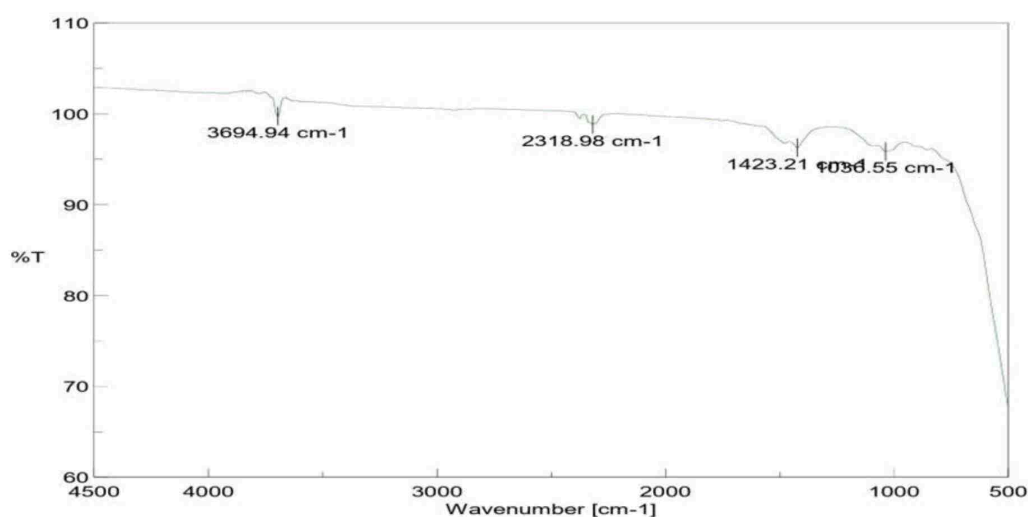


Fig 4.11 FTIR image of catalyst 45

4.7 Blending of Nano catalyst nanoparticles with biofuel

Nano catalyst is a rare metallic oxide in the earth. It has little bit moisture-absorbing tendency and can be utilized as oxidizing agent in the catalytic convertors. In present work, various dosage levels as 15ppm, 30ppm, 45ppm, 60ppm, and 75ppm of magnesium oxide and manganese di-oxide nanoparticles blended with the biodiesel 20%(B20) by Ultra Sonication process and fine mixing of particles with the fuel mixture was allowed for 30 min. Figure 4.12 to 4.16 shows the blending ratio of MgO& MnO₂. Mechanical agitator is utilized to get the great blending of the fuel samples with nanoparticle. This fuel

blend is used as the test fuel in variable compression ratio engine experiments under different load conditions.



Fig 4.12 Ratio of MgO& MnO₂ (100:0)



Fig 4.13 Ratio of MgO& MnO₂ (75:25)



Fig 4.14 Ratio of MgO & MnO₂ (50:50)



Fig 4.15 Ratio of MgO& MnO₂ (25:75)



Fig 4.16 Ratio of MgO& MnO₂ (0:100)

Table 4.1 Properties of the modified fuels and diesel

	Die sel	B2 0	B20+ Nano catal yst15	B20+Nanoc atalyst30	B20+Nanoc atalyst45	B20+Nanoc atalyst60	B20+Nanoc atalyst75	AST M Stan dard	Test met hod s
Gross calorifi c value (kJ/kg)	42, 348	40, 689	41,08 6	41,120	41,157	41,215	41,315	----	AST M D24 0
Densit y (kg/m3)	835	845	850	852	858	862	863	860- 900	AST M D40 52
Kinem atic viscosit y at 44°C(mm2/s)	2.6	2.3	2.25	2.3	2.33	2.4	2.49	1.9-6	AST M D44 5
Flash point in°C	49	51	54	56	57	63	71	>130	AST M D93
Fire point in°C	68	66	72	78	80	85	88	----	AST M D93
Cetane numbe r	52	51. 7	51.7	52.4	53.8	53.3	53.2	>47	AST M D61 3
Boiling point°C	255	325	NM	NM	NM	NM	NM	----	AST M D11 20
Surfac e tension (m N/m)80 °C	22. 05	24. 16	NM	NM	NM	NM	NM	----	----
Latent heat of vaporiz ation (kJ/kg)	260	340	NM	NM	NM	NM	NM	----	AST M D93

4.8 Experimental setup

The study employed biodiesel extracted from *Catharanthus roseus* seed 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 4.17 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 analyse 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. 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. 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's 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 cylinders	Single cylinder
Rated power	3 .8 kW at 1500 rpm
Ignition	Compression ignition
Bore	80mm
Loading	Eddy current dynamometer
Speed	1500 rpm
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

4.9 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. 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. Figure 4.18 shows the schematic diagram of Experimental setup. Engine performances, combustion and emissions have been attained experimentally, and the results were compared with that of standard diesel at full load condition. The emission characteristics of the engine for the biodiesel were measured by online MN-05 model MARS portable flue gas analyzer. In this analyzes, the zero Setting function sets the sensor to zero using fresh air. The experimental data are stored and analyses with the help of sensors in the computerized data acquisition system. The different Indian standards used for emission analysis are specified in Table 4.3.

Table 4.3 Indian standards used for emission analysis

Elements	Standard
CO ₂	IS 13270: (reaffirmed 1999)
CO	IS 11293:1992
NO _x	IS 11255 (Part 7)—2005
Hydrocarbon	--



Fig 4.17 Experimental setup

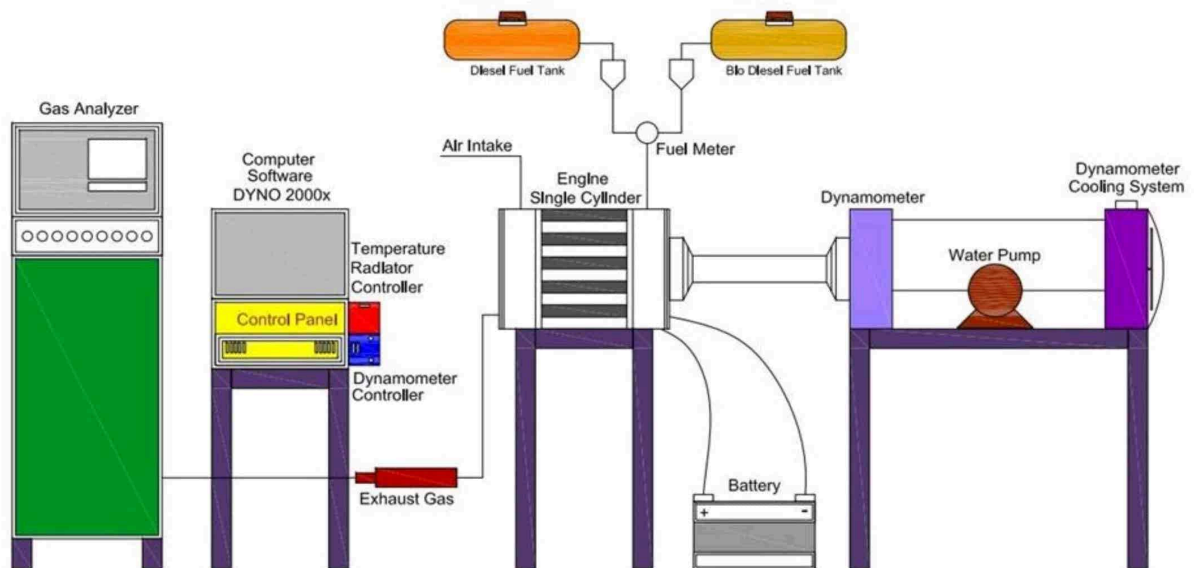


Fig 4.18 schematic diagram of Experimental setup

4.10 Error Analysis

The selection of the instrument, calibration, observation, environment, working condition, human error and methodology used for conducting the experiments may cause inaccuracies in the experimentations. The calibration must be done on the instruments and sensors before used to take measurements for various parameters. The calibrated measuring devices were Presented in Table 4.4. Usually, there are two kinds of errors in experimental data that may occur, such as instrumental error and random error. The random errors can be eliminated through the repeatability of the experiments, so that the errors of instrumental only were considered. Uncertainty analysis of various instruments was compulsory to show the accuracy of the experiments, and for the present experiments, the root sum-square method (equation given below) was utilized to calculate uncertainties for the instruments. Equation 4.1 is used to measure uncertainty measurements in engine testing.

Table 4.4 Accuracies of the measurements

Measurements	Accuracy
Speed of engine	± 4 rpm
Time	$\pm 0.20\%$
Specific fuel consumption	$\pm 1\%$
Temperature	± 2 °C
Crank angle encoder	$\pm 0.5^\circ\text{CA}$
Piezoelectric sensor	$\pm 0.50\%$
Power	$\pm 3\%$
Calculated Results	Uncertainty
Power	$\pm 1 \%$
Specific fuel consumption	$\pm 2 \%$
Crank angle encoder	$\pm 0.5^\circ \text{CA}$

$$U_{\text{total}} = \sqrt{\left\{ (U_{\text{bte}})^2 + (U_{\text{sfc}})^2 + (U_{\text{Egt}})^2 + (U_{\text{CA}})^2 + (U_{\text{PR}})^2 + (U_{\text{NOx}})^2 + (U_{\text{HC}})^2 + (U_{\text{CO}})^2 \right\}} \quad (4.1)$$

$$\begin{aligned} U_{\text{total}} &= \sqrt{\left\{ (1.4)^2 + (1.3)^2 + (1.4)^2 + (1.6)^2 + (1.5)^2 + (2)^2 + (1)^2 + (1)^2 \right\}} \\ &= \pm 4.05 \end{aligned}$$

CHAPTER 5

RESULTS AND DISCUSSIONS

An analysis was conducted on the performance, combustion, and exhaust gas emission of a VCR engine using blended fuels consisting of CRSO biodiesel (B20) and blends containing nanoparticles. The data was measured and compared to that of pure diesel fuel. The engine performance is influenced by two parameters: brake thermal efficiency (BTE) and specific fuel consumption (SFC). Additionally, emission characteristics such as CO, HC, NO_x, CD, and ER are influenced by the load. The cylinder pressure is determined by comparing it to the crank angle using combustion data.

5.1 PERFORMANCE ANALYSIS

5.1.1 Brake Thermal Efficiency

Brake thermal efficiency is a crucial aspect in quantifying the energy consumption of an engine relative to the heat generated by the fuels. The variations in BTE that arise for different blends under different load conditions are illustrated in Figure 5.1. The phenomenon of thermal efficiency exhibiting a consistent improvement with increasing load has been duly noted. The increase in BTE can be attributed to the presence of an efficient air-fuel ratio, which can be attained by enhancing the combustion process. The efficiency of the B20 fuel blend is enhanced due to the inclusion of oxygen in biofuel. The inclusion of B20 nanoparticles in various locations further enhances the BTE. The observed phenomena may be attributed to the presence of B20 particles, which resulted in enhanced air-fuel mixing within the cylinder, reduced delay period, and improved ignition. The increased surface area-to-volume ratio of B20 particles plays a significant role in facilitating combustion and generating substantial heat energy, hence enhancing the overall efficiency of an engine [35], [36]. The blend B20+Nano Catalyst₄₅ exhibits a 10.5% increase in BTE when compared to neat diesel.

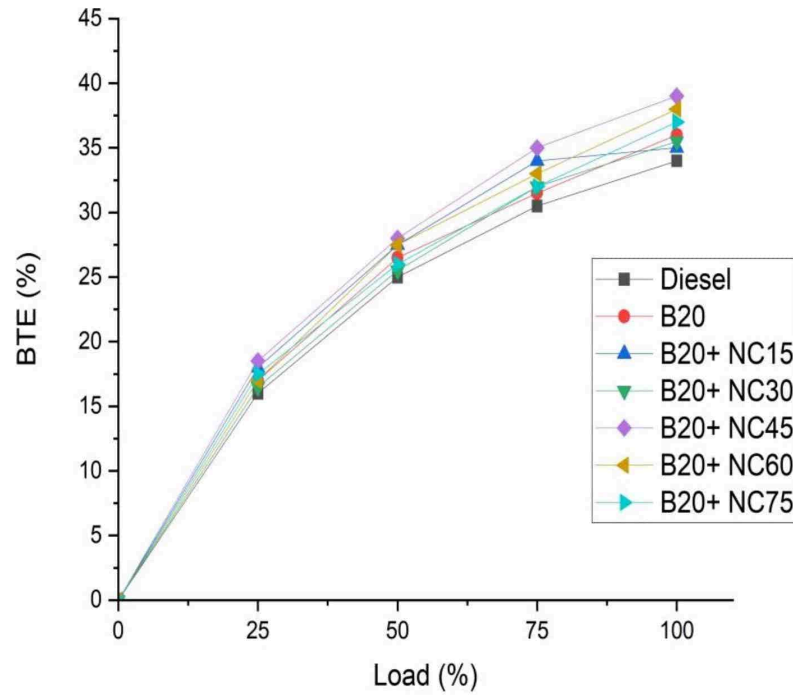


Fig. 5.1 BTE vs Load

5.1.2 Specific fuel consumption

In Figure 5.2, the fluctuations in specific fuel consumption (SFC) are illustrated for several fuel types, specifically diesel, B20, B20+Nano Catalyst15, B20+Nano Catalyst 30, B20+Nano Catalyst 45, B20+Nano Catalyst60, and B20+Nano Catalyst75, under different load circumstances. In the calculation of fuel consumption per unit of power generated, this method is utilised. As the engine loads increase from 0 to 100 percent, the SFC drops due to a decrease in the slope. Due to its higher surface-to-volume ratio, the nanoparticle exhibits the ability to function as an oxygen buffer, so augmenting the combustion process. The inclusion of nanoparticles in the B20 blend is essential for demonstrating the reduction in SFC [37], [38]. At peak load circumstances, the specific fuel consumption (SFC) for each blend is 0.23, 0.22, 0.223, 0.213, 0.204, 0.23, and 0.235 kg/kW-hr, respectively. When operating at maximum load, the blend B20+Nano Catalyst45 demonstrates a decrease of 14.03% compared to the plain diesel. On the other hand, the integration of nanoparticles into B20 biofuel has resulted in a significant reduction in fuel use. The presence of nanoparticles hinders the accumulation of carbon within the

cylinder wall, hence improving the combustion process. Cerium oxide nanoparticles have been found to improve thermal conductivity, resulting in better air-fuel mixing and combustion, as well as a reduction in specific fuel consumption (SFC) [39], [40]. The aforementioned factors have the potential to reduce friction between the components of the engine, resulting in increased power production and a simultaneous decrease in fuel consumption.

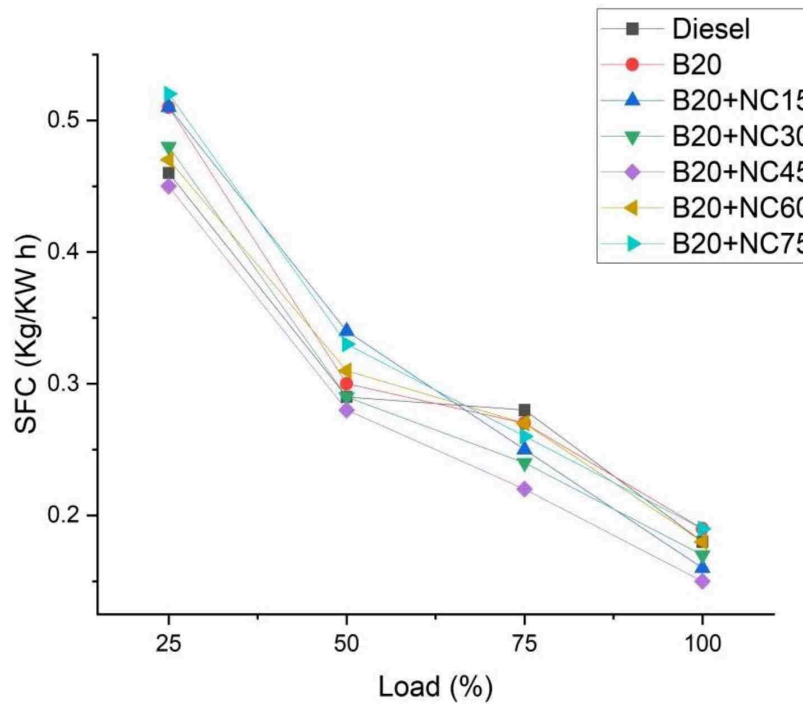


Fig.5.2 SFC vs load

5.1.3 Exhaust gas temperature

The quantity of gasoline supplied to the engine does not exert a direct influence on the exhaust gas temperature (EGT), a noteworthy observation. Several factors can influence it, such as the duration of ignition delay and the combustion efficiency of the fuel [41]. The observed differences in exhaust gas temperature among the several fuels that were assessed are illustrated in Figure 5.3. The results indicate that the exhaust gas temperature is lower while using blended fuel, as compared to pure diesel. The incorporation of MnO₂ nanoparticles into a biodiesel mixture leads to an augmentation in the rate of fuel droplet evaporation and the interaction between air and fuel. [42] This phenomenon can be attributed to the fact that MnO₂

exhibits a greater surface-to-volume ratio and a higher thermal conductivity (TC). The combination of additives with biofuel leads to a decrease in the delay duration when the cetane number and heat transfer rate are increased. There exists a potential explanation for the comparatively lower temperature of the exhaust gas emitted by particles mixed with fuel in comparison to diesel fuel.

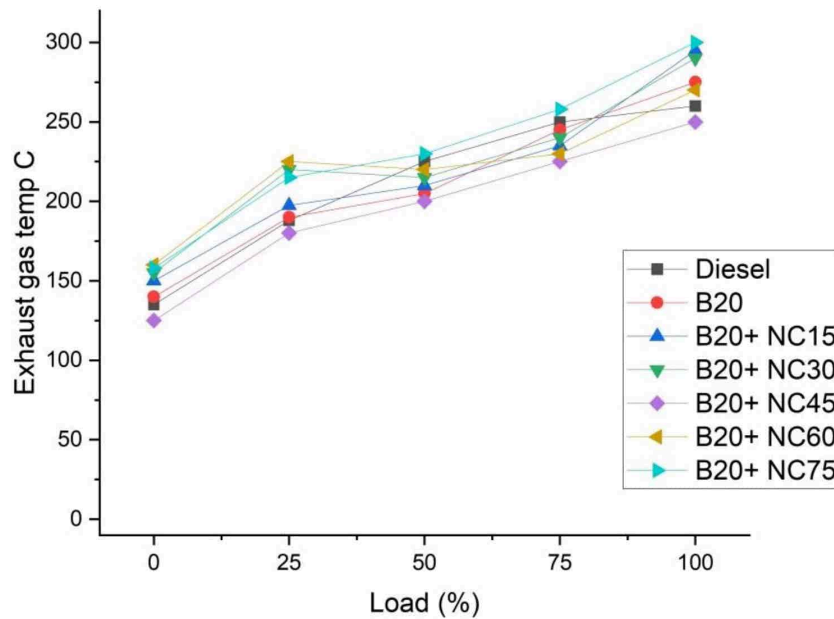


Fig.5.3 EGT vs load

5.2 EMISSION CHARACTERISTICS

5.2.1 Carbon monoxide

Carbon monoxide emissions from a crankshaft ignition engine are primarily caused by inadequate combustion of the rich air fuel ratio and suboptimal oxygen delivery within the ignition chamber [43]. High quantities of carbon monoxide emissions are present in the exhaust as a result of insufficient conversion of carbon monoxide into carbon dioxide [44]. Figure 5.4. depicts the carbon monoxide emissions produced by the test fuels B20, B20+Nano Catalyst15, B20+Nano Catalyst30, B20+Nano Catalyst45, B20+Nano Catalyst60, and B20+Nano Catalyst75. The analysed fuel samples exhibited emissions levels that were 19.9%, 10.4%, 17.19%, 26.24%, 5.42%, and 15.38% greater than the reference fuel. All fuel blends, unlike diesel,

demonstrate decreased levels of carbon monoxide (CO) emissions under various load circumstances. When exposed to maximum load, the blend B20+Nano Catalyst 45 exhibits a notable decrease in carbon monoxide (CO) emissions compared to the conventional fuel, as indicated by a measured value of 26.24. The observed effect can be ascribed to the advent of nanoparticles within the combustion chamber, resulting in an augmented availability of oxygen. As a result, the increased availability of oxygen enables a more severe chemical reaction with the surrounding air in the chamber. The final result will involve the improvement of ignition and the transformation of carbon monoxide into carbon dioxide [45].

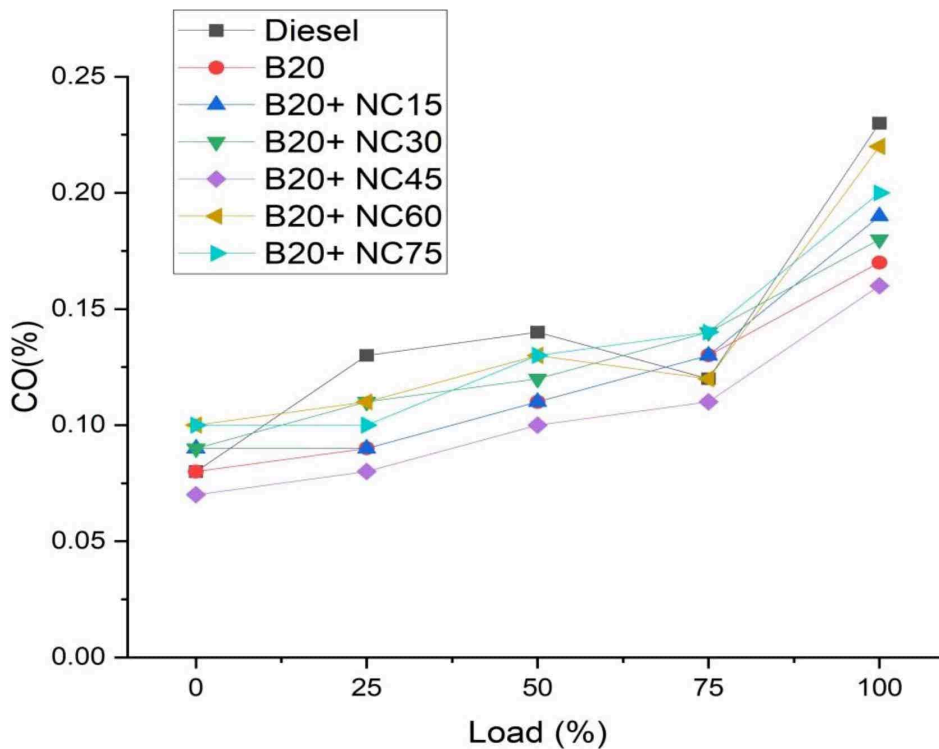


Fig 5.4 CO vs load

5.2.2 Hydrocarbon emission

The presence of unburned fuel particles within the combustion chamber may have been identified as a contributing factor to the creation of hydrocarbon (HC) emissions by the engine [46]. The internal combustion engine was responsible for the generation of the emissions. Comparative investigation of hydrocarbon emissions created by different fuel sources, such as diesel and biodiesel when combined with nanoparticles, is depicted in Figure 5.5. A comprehensive

comparison examination is performed on a diverse range of loads. Under a 100% load condition, the fuels under investigation demonstrated hydrocarbon emissions of 21, 24, 22, 20, 23, and 25 g/kWhr. Among the several fuels, diesel fuel demonstrated the greatest value, measuring 26 g/kWhr. Utilising Nano Catalyst nanoparticles in conjunction with B20 mix leads to a moderate reduction in hydrocarbon emissions across all loads. This decline stands in opposition to the primary source of energy. The incorporation of additional nanoparticles plays a substantial role in the reduction of hydrocarbon emissions. The utilization of nanoparticles has the potential to enhance the surface area and serve as an energy stimulant, so facilitating the combustion of carbon particles within the walls of the cylinder. The predominant determinant in mitigating hydrocarbon emissions is the substantial proliferation of nanoparticles. These nanoparticles can enhance the combustion of carbon particles within the cylinder walls by increasing their surface area tolerance and acting as an energy stimulator [47]. By integrating nanoparticles into petrol samples, the amount of hydrocarbon (HC) emissions released into the environment is decreased. The inclusion of padding particles inside the molecular framework results in an elevation of oxygen levels, hence facilitating the oxidation of unburned particles and the consequent generation of carbon dioxide and water [48].

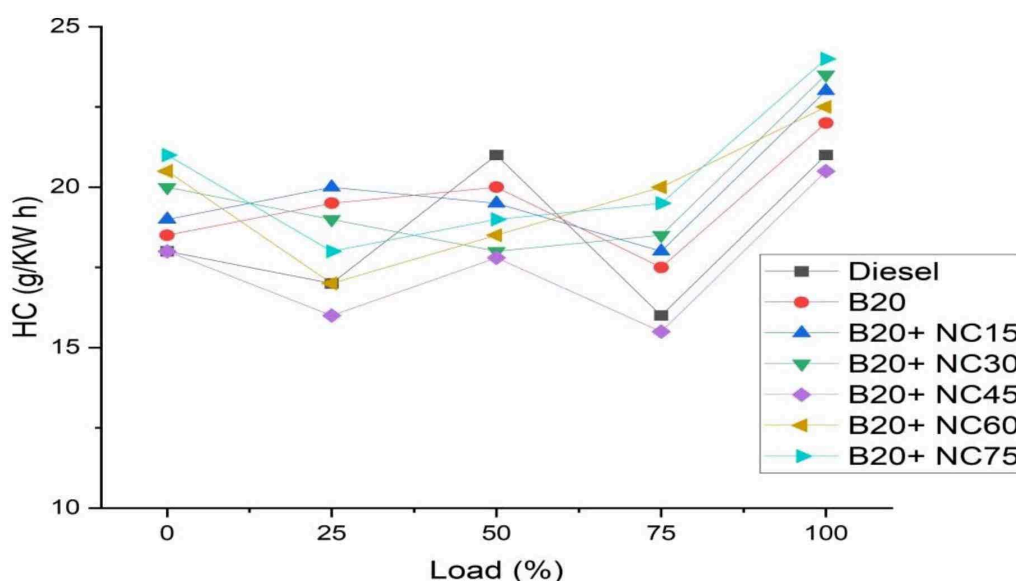


Fig 5.5 HC vs load

5.2.3 Nitrogen Oxide

The existence of nitrogen oxides (NO_x), which are harmful pollutants, is a result of the elevated temperatures that arise within the combustion chamber at higher engine loads. Biofuels derived from vegetables typically have a greater oxygen concentration and a comparatively lower nitrogen content in their overall composition. Furthermore, the existence of particulate matter that possesses a substantial concentration of oxygen results in an augmentation of the combustion rate. Raising the load induces elevated pressure and temperature within the cylinder of the engine, leading to a subsequent augmentation in the emission of nitrogen oxides [49]. One significant drawback is that the existing literature confirms that biodiesel-fueled engines emit greater quantities of nitrogen oxides (NO_x) compared to diesel-powered engines. Conversely, the integration of a substantial proportion of nanoparticles into biofuel has promise for reducing nitrogen oxides (NO_x) emissions. Enhanced heat transfer properties facilitate a higher volume of heat transfer to the cylinder wall, resulting in a subsequent reduction in the temperature of the charge. The investigation reveals that NO_x emissions consistently increase for all samples when the load conditions are decreased, but decrease when the dose of cerium oxide nanoparticles is raised. The depiction of the fluctuation in hydrocarbon (HC) emissions of biofuel under different loads is illustrated in Figure 5.6, accessible at this location. The B20+Nano Catalyst45 blend demonstrated a decrease in NO_x emissions by 4.46% when the vehicle was operating at maximum load, in comparison to diesel fuel. Cerium oxide serves as a catalyst in the reduction of nitrogen oxides (NO_x), either by providing oxygen for the oxidation of carbon monoxide (CO) or by absorbing oxygen, which is crucial for the reduction of NO_x [50].

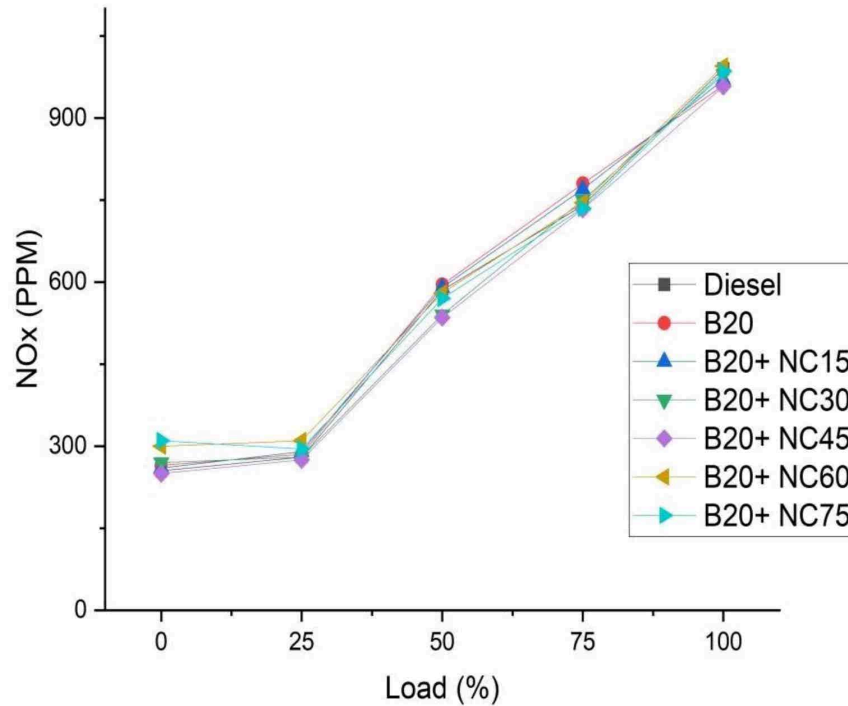


Fig 5.6 NO_x vs load

5.2.4 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+CERIA45, which incorporates nanoparticles, exhibits a reduced combustion duration compared to conventional diesel when operating at maximum load. The inclusion of particles leads to increased atomization, enhanced heat transfer, and an improved surface area-to-volume ratio [51]. 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.

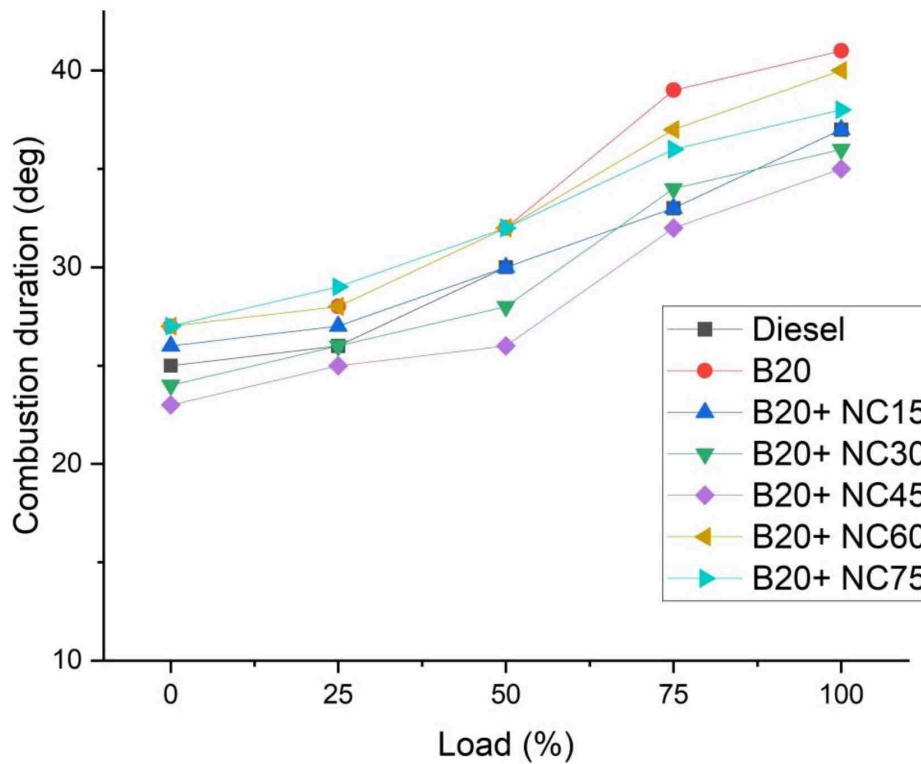


Fig 5.7 CD Vs Load

5.2.5 Equivalence ratio

Furthermore, the equivalency ratio plays a crucial role in influencing both the cylinder pressure and the engine's performance, making it a key factor to be taken into account. The diagram presented in Figure 5.8 depicts the variations in the equivalency ratio between diesel and nanoparticles when incorporated into catharanthus roseus seed oil biofuel blends, as influenced by varied load conditions. The supply of air to the engine remains generally constant, but the injection of fuel into the engine is adjusted in reaction to variations in load to maintain engine stability. The outcome of this leads to fluctuations in the equivalence ratio. In summary, when there is a movement in load from low to high, there is a corresponding increase in the supply of fuel. Additionally, the equivalency ratio observes a shift from 0.3 to 0.9 at zero load and peak load, respectively. This phenomenon persists irrespective of the magnitude of the load. As the equivalency ratio increases, there is a corresponding rise in temperature within the combustion chamber, resulting in a reduction in the duration of the delay [52]. The incorporation

of nanoparticles into mixtures leads to enhanced heat transfer and a high surface-to-volume ratio, both of which facilitate the achievement of full combustion.

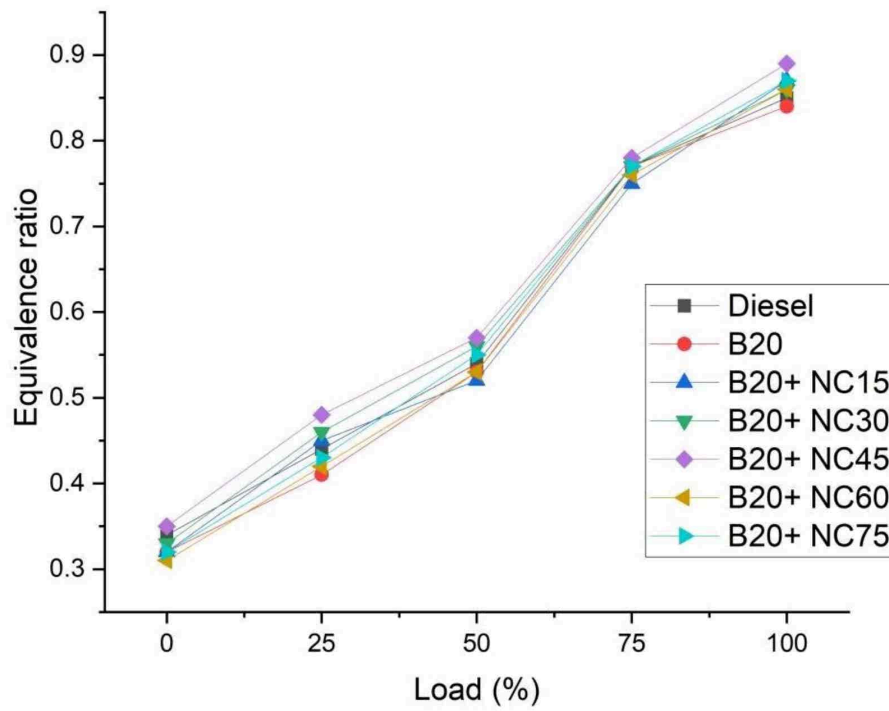


Fig 5.8 ER Vs Load

CHAPTER 6

SUMMARY AND CONCLUSIONS

The seeds of *Catharanthus roseus* exhibit a highly efficient transesterification mechanism, resulting in the formation of methyl ester as a secondary product. Four samples of biodiesel have been produced using the correct ratios. A series of tests are conducted on four types of biodiesel using a diesel engine, with different loads applied. Abnormal combustion arises when the cylinder pressure in the B05 mix falls below 100 bar. By employing the B10 mix, it is feasible to attain a pressure of 100 bar while maintaining a local tolerance. The blend B05 exhibits the lowest net heat rate, with the B10 mix ranking second in terms of heat rate. A significant degree of pressure variation is generated by the B10 mixture. The emissions graph illustrates that the B05 blend has the lowest carbon monoxide content, with the B10 mix following closely behind. The blend B05 exhibits the lowest carbon dioxide (CO₂) emissions, with the B20 blend ranking second in terms of emissions. The B15 blend has a comparatively reduced level of NO_x production, whilst the remaining blends demonstrate a commensurately elevated emission of NO_x. Under higher loads, the B10 blend exhibits the least amount of hydrocarbon emissions, with the B05 mix ranking second. The B10 blend exhibits a reduced smoke opacity compared to other blends. The B10 blend closely trails behind, exhibiting the maximum brake thermal efficiency. The volumetric efficiency of the B10 mix exhibits a high value at larger loads, while it diminishes under lower loads. The particular fuel consumption of the B05 blend is the lowest, with the B20 blend following closely behind by a substantial margin. The exhaust gas of the B05 blend exhibits the lowest temperature, while the B15 blend demonstrates the highest temperature. The outcomes of the comprehensive analysis indicate that the B10 blend exhibits superior efficiency compared to other biodiesel blends. The aforementioned outcomes encompass enhanced emission characteristics, heightened fuel economy, and augmented efficiency.

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REVIEW ARTICLE

Exploring the Potential of Nanoparticles in Biofuel Production: Challenges and Future Directions – A Comprehensive Review

Nivin Joy¹, Anish M^{2,*}, Hariharan V³, Reshlin Rithan Raj M³, Jayaprakash V² and Jayaprabakar J¹

¹School of Mechanical Engineering, Associate Professor, Sathyabama Institute of Science and Technology, Jeppiar Nagar, Chennai, India; ²School of Mechanical Engineering, Assistant Professor, Sathyabama Institute of Science and Technology, Jeppiar Nagar, Chennai, India; ³School of Mechanical Engineering, Student, Sathyabama Institute of Science and Technology, Jeppiar Nagar, Chennai, India

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Abstract: The utilization of nanotechnology and nanotechnology in contemporary society has garnered significant interest due to their captivating properties across various academic disciplines. The investigation and development of biodiesel production and fabrication using nanotechnology and nanomaterials have emerged as a central area of scholarly inquiry worldwide. Implementing strategies to accelerate biodiesel production is essential to its success; there is an increasing focus on utilizing state-of-the-art nanotechnology, which enables achieving maximum output while minimizing costs. Consequently, the investigation will center on using various nanomaterials and nanocatalysts to explore the manufacture of biodiesel from diverse materials. The examination of this research project will primarily focus on the culture of algae utilizing nanomaterials and the subsequent collection of lipids. Furthermore, the present investigation is intended to serve as a comprehensive examination of the foremost obstacles and prospective ahead-of-time enhancements regarding the utilization of biodiesel blended with nanoparticle additives in internal combustion engines. Furthermore, this essay will specifically address the problems related to the welfare of individuals and the environment in using nanomaterials in mass manufacturing biodiesel. Consequently, future producers, researchers, and academics stand to gain valuable insights from this study, as it offers a comprehensive understanding of the existing body of research on the application of nanoparticles and nanotechnology in making biodiesel, along with the advancements in enhancing its efficiency.

Keywords: Nanomaterials, efficiency, nano additives, utilization, biodiesel.

1. INTRODUCTION

One of the most notable characteristics of modern society is the presence of accessible and cost-effective energy sources that can be relied upon. Regrettably, many nations globally persist in being substantially dependent on fossil fuels, namely coal, biogas, and oil, to fulfill their energy requirements. The advancement of petroleum and coal has substantially impacted human society and the natural environment. The impact of this effect encompasses the techniques employed in producing these fuels and their subsequent applications. This phenomenon leads to modifications in global temperatures, affecting the earth, atmosphere, and water, hence contributing to changing the climate on a global level. Alternative energy sources, such as nuclear electricity and various forms of alternative energies (e.g., wind power, solar electricity, and biomass), exemplify potential energy sources that offer innovative and economically viable

options for energy generation [1]. These resources help lessen the negative environmental effects while increasing energy efficiency. Nanotechnology is commonly defined as advancing machines and gadgets at the molecular level, with dimensions typically measuring a few nanometers, making them considerably smaller than a typical cell. Currently, several types of nanotechnology, such as nanofibers, improved nanotubes, and nanometals, are being employed to investigate the impact of nanoparticles on the production and fabrication of biofuels and biodiesels [2].

The production of fossil fuels encompasses a series of processes, each with its own environmental ramifications that collectively contribute to climate change and environmental degradation. Exploration and drilling activities aimed at accessing fossil fuel reserves like oil and natural gas often result in habitat disruption, soil erosion, and habitat destruction. Additionally, drilling operations can lead to catastrophic oil spills, devastating marine ecosystems, and methane leaks, intensifying the greenhouse effect. Coal extraction through surface or underground mining exacerbates environmental harm, causing deforestation, soil erosion, and habitat loss. Methane, a potent greenhouse gas, is released

*Address correspondence to this author at the School of Mechanical Engineering, Assistant Professor, Sathyabama Institute of Science and Technology, Jeppiar Nagar, Chennai, India; E-mail: anish2010me@gmail.com

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