

PERFORMANCE AND EMISSION CHARACTERISTICS OF WASTE COOKING OIL BIODIESEL BLENDED WITH NANO ADDITIVES ON SINGLE CYLINDER DIESEL ENGINE

Submitted in partial fulfilment of the requirements for the award of
Bachelor of Engineering degree in Mechanical Engineering

by

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**INSTITUTE OF SCIENCE AND TECHNOLOGY
(DEEMED TO BE UNIVERSITY)**

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BONAFIDE CERTIFICATE

This is to certify that this Project Report is the bonafide work of George. A (Register Number: 39150043) and Kaushik Subbiah Ganesan (Register Number: 39150065) who carried out the project entitled "**PERFORMANCE AND EMISSION CHARACTERISTICS OF WASTE COOKING OIL BIODIESEL BLENDED WITH NANO ADDITIVES ON SINGLE CYLINDER DIESEL ENGINE**" under our supervision.

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We George. A (Register Number: 39150043) and Kaushik Subbiah Ganesan (Register Number: 39150065) declare that the project report entitled “**PERFORMANCE AND EMISSION CHARACTERISTICS OF WASTE COOKING OIL BIODIESEL BLENDED WITH NANO ADDITIVES ON SINGLE CYLINDER DIESEL ENGINE**” done by us under the guidance of Dr. R.B. Durairaj M.Tech. Ph.D., at Sathyabama institute of Science and Technology, Chennai-600119 is submitted in partial fulfilment of the requirements for the award of Bachelor of Engineering degree in Mechanical engineering.

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ABSTRACT

Because of the usage of fossil fuels, the world is currently undergoing serious environmental pollution. However, those fuels are finite and diminishing on an everyday basis as use rises dramatically. As a result, developing a clean substitute gasoline generated from renewable sources is important, because of depleting petroleum substances and poor environmental results, biodiesel manufacturing and packages have grown in recognition in latest years. Trans-esterification of suitable for edible and non-edible oils inside the presence of ethanol and a sufficient catalyst creates the esters of the corresponding alcohol, which is commonly known as biofuels. Biofuel is a sustainable energy source that may both be used straight or combined with diesel gas in diesel engines, it's far created the use of a technique referred to as transesterification, in which a monohydric alcohol and an oil or fats are blended in the catalyst to create the matching mono alkyl ester. Mixing with diesel fuel is labelled as "Bx" in which "x" means the amount of biodiesel in the combination. The blending of nano components are chemical substances brought in biodiesel to enhance the perfect chemical residences for better overall performance of the engine and moreover, it will increase biodiesel's performance, lowers its emissions, and reasons biofuel to burn completely.

In this paper, used edible oil was investigated as a possible source of biodiesel and blending with (CeO₂) cerium oxide and (MgO) magnesium oxide nano particles and testing its properties which include density, Kinematic Viscosity, Flash and fire point, Calorific value. The test being conducted using the sequence of fuel blends: 80% of diesel and 20% of WCO biofuel and 30ppm Cerium oxide, 90% of diesel and 10% of WCO biofuel and 45 ppm of Cerium oxide, 80% diesel and 20% of WCO biofuel and 30 ppm of magnesium oxide, 90% of Diesel and 10% of WCO biofuel and 45ppm of magnesium oxide and using a variable compression ratio (VCR) engine, we test its BP, BTHE, SFC, and emissions characteristics such as NO_x, CO, HC, CO₂, and O₂. Evaluating different blends and determining which one is a renewable alternative fuel by comparing their characteristics.

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LIST OF ABBREVIATIONS

FFA	- free fatty acid
B100	- 100% Biofuel
B20	- Mixture of 20% biofuel and 80% diesel)
DC30/ D30	- Diesel + CeO30 (Cerium Oxide nanoparticles at 30ppm)
BDC45	- Biofuel + CeO45 (Cerium Oxide nanoparticles at 45ppm)
PPM	- Parts per million
CeO2	- cerium oxide
MgO	- magnesium oxide
CeO30	- Cerium Oxide nano-particles at 30ppm
CeO45	- Cerium Oxide nano-particles at 45ppm
EGR	- Exhaust gas recirculation
BP	- Brake Power
BTE	- Brake Thermal Efficiency
BSFC	- Brake specific fuel consumption

CHAPTER – 1

INTRODUCTION

The ever-growing population of the world has caused the rise in consumption of finite fossil resources. The diesel engine was created by Rudolf Diesel, who also included vegetable oils in the list of fuels that it could run on. However, the engine was eventually switched to petroleum-based diesel fuel due to its higher thermal effectiveness and wide availability. Conventional fuels are notorious for releasing gases like SO₂, CO₂, particulate matter, and other pollutants into the air. As a result, research into alternative fuels and renewable energy sources has intensified. Biodiesel has better lubricity than petroleum diesel, so the lifespan of diesel engines can be extended. Moreover, the world's energy consumption is on the rise, leading to a decrease in fuel resources. The transportation sector alone accounts for 61.5% of global fuel consumption, particularly in the last decade. As a result, there is an increasing focus on research for an effective replacement for diesel. India makes only 30% of the petroleum fuel it needed, with the other 70% imported. Mixing 5% biodiesel fuel with the current diesel fuel could save million rupees annually. Biofuel is made by trans-esterification of edible oils and other lipids. Animal fats from food manufacturing industries and used edible oil from restaurants are examples of biofuel fuel sources.[6] Conventional oils are key for biofuel renewable sources. Algae really does have the potential to be used as a source of biofuel. Localized fat in algae helps them stay alive, and all these fats are collected and turned into biofuels.

Biofuels made from cooking oil provide an additional fuel source for IC engines. On the contrary, biofuel has a higher oxygen concentration, which causes NO_x emissions when burned in a high temperature environment. Fuel reformulation procedures have been used to smooth fuel purity by making various fuel particles to achieve the values which has lower hazardous emissions, higher efficiency, flash point, etc., As a way to reduce the price of biofuel feed and provide a remedy to the food-fuel issue, researchers have concentrated on the use of used edible oil, that is created at a rate of roughly fifteen million tonnes annually worldwide, resulting in a significant environ-

mental effect. As per the WHO's analysis, just one liter of WCO affects a thousand liters of water. Furthermore, there is a reduction in drainage efficiency and a rise in energy usage in wastewater treatment facilities. Despite the positive aspects of utilizing WCO, prior exposure to excessive temperatures and food contact enhances the amount of moisture, the quantity of lipids, and particle substance concentrations. The fundamental disadvantage of having an excessive FFA concentration, as shown by the acidity value, is that it reduces conversion because those react with a catalyst in the transesterification phase and create surfactants. Consistent with the biomasses, biofuels are divided into 4 stages. The biofuel boom timeline starts with the extraction of food oils and finishes with the genetic alteration of algae. meals elements are vital feed for first degree biofuels, but they also can contribute to food competition, even some of the lands are used to supply natural sources inside the shape of first-technology biofuels, the effect on increasing meals and feed expenses has been substantial but, the contemporary results of biofuels on food rate increases are unknown. Biofuels derived from agricultural waste, as well as non-food plants, have the potential to remedy the situation. 2nd generation biofuels contain grass, woody biomass, and areas containing food processing compounds and fiber are present. These crops, however, have higher energy outputs than 1st generation biofuels or their derivatives. The pursuit of alternative sources has reduced rivalry in agricultural crops to the point where algal cells are being exploited as a natural and abundant source of biofuel known as the third-generation biofuels. between two thousand and two thousand twenty, study involved 4th-generation biofuels.

In the previous three years, this is evident because stated research articles on 3rd generation biofuels have garnered the most value. In general, plants can be categorized as edible oil or non-edible oil, algae oil, as the raw materials in biofuel manufacturing. Even so, their utilization confronts several challenges, including a food compared to fuel problems, an along with significant ecological issues like as significant soil depletion, destruction of forests and the use of the majority of accessible land for farming. Many might not be capable of fulfilling the global energy requirements properly, and they perform badly in cold weather. Tallow, yellow grease, chicken fat,

and byproducts of oil from fish are the most frequently found sources of dietary fats, however several kinds of animal-based fats are difficult to get since they contain substantial amounts of saturated fats. Biodiesel is a good option, according to the study, for a wide range of causes, like its extensive biodegradability and low toxicity. In addition, it is superior to gasoline-based diesel for the purpose of reducing ignition pollutants, along with its closed carbon loop implies it doesn't add to climate change. A more intriguing aspect lies in the fact that biofuel may be utilized by current IC engines with little change or just a minor performance reduction. Several studies have indicated that the availability of adequate oxygen in biofuel results in considerable decreases in engine exhaust emissions in terms of CO, CO₂, O₂, hydrocarbons, particulate matter etc., especially compared to diesel fuel. This is because of the existence of adequate O₂ in biofuel, that allows for full combustion and minimal emissions.

1.1 WASTE COOKING OIL

Used edible oil is a big issue in many regions. It uses oil that has been thrown from cafes, apartments, and other food-preparation facilities. If not properly disposed of, this oil might have a negative influence on the environment. It may clog sewer systems, taint drinking water, and pollute the air when it reaches the atmosphere. It may also be hazardous to animals and aquatic life, causing illness and even death. Because waste cooking oil is very flammable, it can potentially be a fire threat. Waste cooking oil should be recycled and repurposed to limit its environmental effect. Reusing it as fuel is an excellent solution to decrease emission of greenhouse gases. A higher saturated fatty acid concentration in the oil suggests a worse oil quality and vegetable oil having less than 2% organic fatty acids, and cross-esterification can be conducted. WCO which is leftovers of frying or cooking food made of vegetable or tallow with used oil. Food oil is an ester gum that contains a variety of important lipids that can only be dissolved by organic solvents. Cooking oil waste is detrimental to the ecosystem and people's lives. It is thought that eating deep-fried things can trigger disease due to the toxic substances released when the oil oxidizes.

1.2 TRANSESTERIFICATION

There are Several techniques, including pyrolysis, micro emulsification, and transesterification, can be employed to make biofuel from refined oil or used cooking oil. Transesterification is a popular and widely utilized technology in biodiesel manufacturing. Esters and glycerol are formed when triglycerides interact with alcoholic. The type of fatty acid associated with glycerol determines the properties of lipids. In turn, the type of fatty acids can affect the properties of biodiesel. The alcohol and fatty acids react to generate mono alkyl ether, which is also known as biodiesel and crude glycerin. Methanol or ethanol, which is mostly catalyzed by potassium or sodium hydroxide, is the most often used alcohol in manufacture. However, both compounds may be used to make methyl ester, KOH has been discovered to be better choice for the creation of biofuel ethyl ester.

There are basically 2 forms of trans-esterification's, one with a catalyst made from alkali and another with a catalyst made of acid. Acids & alkali-based trans-esterification techniques have been shown to be faster and less costly. Catalysts boost the rise and outcome of the reaction. Furthermore, it divides molecules of oil plus alcohol, which combine with split ester to form an alkyl ester. Although, using alkali catalysts is difficult if the fatty acid amount is large, despite producing an increased yield of biofuel and good quality of the products. To deal with elevated FFA levels, a 2-step method of transesterification is performed. An acid-catalyzed reaction is employed in the 1-stage of this technique to esterify the lipids into fatty acids methyl esters (FAME), this is followed by an alkali-catalyzed transesterification reaction.

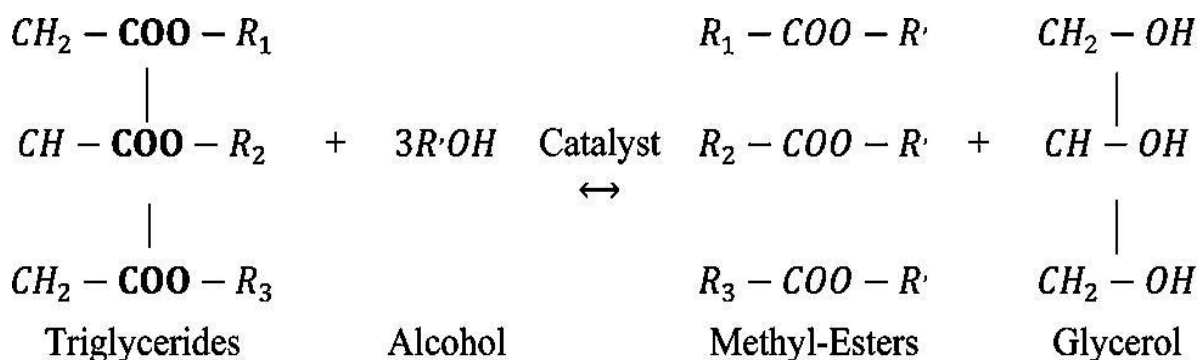


Fig: 1.1 Transesterification process

1.3 NANO ADDITIVES

Small particles known as nano-additives can give biodiesel competitive advantages over diesel. The surface is where the heterogeneous reaction takes place, the entire region of the nanoparticles is more than that of the majority particles, permitting the reaction to arise. The atoms at the surface are bumpier and extra touchy. Their lattice position is associated with an instability that forces them to separate neighboring atoms or molecules. Among the techniques created for proteins immobilization. NPs can be used to improve compounds that are bioactive, protein chains, and surface assimilation, potentially lowering biofuel prices. The usage of nano techniques compromises an effective and compassionate enzymatic machinery capable of withstanding the adverse outcomes of numerous diluents used to create biofuels. Because of the complicated nature of its carbs and glycol-proteins which resist chemicals, the lipid extraction techniques consume most of the expense of algae biofuel extraction.

However, with the addition of NPs, a more dependable, secure, and simple method of extracting lipids with better oil purity and reduced production costs is achievable. Metals (Fe, Al, Mg, Mn, Ag, etc.), metallic oxides (Al_2O_3 , Co_3O_4 , CeO_2 , etc.), and metallic mixtures (Mg-Al, CNT) are used as chemicals in the manufacture of biofuel, and it is used to improve the physiological features and efficiency of the energy. When comparing with a free biocatalyst, it has some positive effects, like improved catalyst filling and operation, enhanced temperature as well as pH stability, recovery, and biocatalyst reuse ability. Concerning nanoparticles, as the ratio between surface area and mass of atoms increases, the instability and reactivity also increase. As an outcome, nanoparticles have a have an enormous surface area to their volume. The main advantage of nanoparticles is their small size, which facilitates their binding to biodiesel. It increases the efficiency of biodiesel, reduces its emissions, and ensures that the fuel burns completely.

CHAPTER – 2

LITERTATURE SURVEY

Junshuai Lv¹, Su Wang¹, Beibei Meng¹, “The Effects of Nano-Additives Added to Diesel-Biodiesel Fuel Blends on Combustion and Emission Characteristics of Diesel Engine: A Review”. *Energies* 2022, 15(3), 1032; <https://doi.org/10.3390/en15031032>

A major research topic within the vehicle engine area and related domains has been how to improve combustion efficiency and decrease harmful pollution. This analysis highlights the latest advances in nano-particle research as substances for biofuel mixture. Nanoparticles to diesel-biofuel mixtures have produced significant results, according to research. The findings of this study and other recent and earlier studies on particles, have revealed the vital function that nano-additives perform in improving the fuel economy of combustion engines and decreasing potentially dangerous pollutants. In general, studies using nano-particles added to biofuel combinations such as CuO, Al₂O₃, MWCNT, CeO₂, GO, CNT and TiO₂ have produced impressive outcomes. When it comes to increasing engine efficiency, CeO₂ was the best at reducing SFC by up to 30% and MWCNT was the most effective at raising BTE by up to 36.81%. TiO₂ has the best effect influence on emission reduction for NO_x, with an average loss of 22.57%, and the GNPs had the greatest impact in categories of emission reduction for CO, with the lowest fall of 70%. Therefore nano-additives have a promising future in biofuel engines. It must be noted clearly that adding nano-particle to biofuel mixtures has considered to be a crucial method for preserving human health and enhancing the ecosystem.

Mohammad Ibrahim AlMishlah Alghamdi¹, Ilhami Colak², Musaddak Maher Abdul Zahra^{3,4} and T. Bothichandar⁵, “Environmental Emission Analysis of Biodiesel with Al₂O₃ Nanometal Additives as Fuel in a Diesel Engine”. 2021, Article ID 2544098, <https://doi.org/10.1155/2021/2544098>

Similar to those described in the books, In the trials CI engine using biofuel produced from algal based oil and as raw particle. Even though it was still greater than what was required by the ASTM standard, the viscosity of the biofuel used was suitable for the engine. When biofuel is used, nitrogen oxide emissions are cut in half and sulphur dioxide emissions are completely eliminated. Emissions of carbon monoxide have also decreased. As engine revolutions rise, the variations in engine characteristics when using diesel and biofuels grow. The behavior of engine characteristics when using biodiesel as well as diesel is at 1450 rpm, which is why the variations are most noticeable. The torque is indicated by the 1st set of bars from one side to another, which follows indicating the actual power, which is 9.45% lower when using biofuel. This is reduced by 9.76% when biofuel is used. The last set of bars depicts the usage schedule, which demonstrates that biofuel generation is 11.95% more than diesel usage. The 4th set of bars reveals that biofuel usage is 24.25% greater than diesel utilization. Finally, the last bars represent engine efficiency when running on biofuel, which is 18.99% less than diesel.

In comparison, the highest limit for biofuel is 115 ppm, displaying an almost two-fold drop in these pollutants. the actions of extra air and the residual free O₂ within the exhaust gases. The O₂ found in biofuel exhaust emissions is greater compared to that produced fuel exhaust gases. A certain quantity of oxygen is contained in biofuel, which is more than in diesel, and helps in the process of combustion reaction. A portion of the O₂ comes by the inflow of air and exits unreacted to the exhaust gases. When operating at low rotation rates, these discrepancies become considerably more pronounced, reaching a variance of 65%. As a result, the extra air for biofuel is more than that for diesel, and the lowest rate is roughly 1250rpm. The engine's torque, output, hourly consumption, and particular usage variations are all easily measurable.

R. S. Gavhane¹, A. M. Kate², Manzoore Elahi M.Soudagar³, V. D. Wakchaure¹, Sagar Balgude⁴, I. M. Rizwanul Fattah⁵, Nik-Nazri Nik-Ghazali³, H. Fayaz⁶, T. M. Yunus Khan⁷, M. A. Mujtaba³, Ravinder Kumar⁸ and M. Shahabuddin⁹, “Influence of silica nano-additives on performance and emission characteristics of Soybean

biodiesel fueled diesel engine". *Energies* 2021, 14(5), 1489; <https://doi.org/10.3390/en14051489>.

The current study looks at how SiO₂ nano-additives affect a IC engine running on soybean biofuel in terms of performance and exhaust emissions. To explore the morphology of nanoparticles, several tests including FESEM, XRD, EDS, etc. were used to characterize nano-additives. The ultrasonication procedure was utilized to properly combine nano-additives with biodiesel. The improvement of performance measures such as BTE and BSFC was enhanced by 3.48-6.39% and 5.81-9.88%, correspondingly, with the adding of SiO₂ nano particles to soy biofuel combination. The application of nano particles reduced all emissions except NO_x. Depending on the physical parameters of fuel mixtures, the inclusion of biofuel results in higher density & lowered value for heating. Due to the enormous surface size of nanoparticles, the addition of SiO₂ nano-particle shows decrease in density and a minor rise in temperature because of SiO₂'s heating property. The inclusion of nano-additives resulted in a increase in NO_x emissions for all fuel mixes, but CO, HC, and smoke exhaust fell by 6.36%, 18%, and 23.54%, respectively. But NO_x levels increased somewhat for all nano fuel mixtures due to an increase in-cylinder temp plus the presence of a significant number of oxygen molecules due to the use of silicon oxides and the presence of air in biofuel. As a suggestion, recirculation of exhaust gases can be utilised for managing NO_x generation.

G. Ninawe¹ & M. Tariq², "Influence of carbon nanotubes as additive in diesel-biodiesel blends in CI engine - an experimental investigation". (2021) 14:5, 1110 1121, <https://doi.org/10.1080/19397038.2020.1790059>

This article details the experimental research done to determine the ideal carbon nanotube dosage for the diesel-biodiesel fuel combination. With various loads, four-stroke single-cylinder internal combustion engines underwent performance and efficiency testing. Lower emissions of HC, CO, and smoke are the result of oxygen being present in the biodiesel mixture's molecular structure. In comparison to B0 fuel, BTE dropped as the blend ratio increased. For all of the loads, the B15 blend had the lowest BSFC. As an outcome of the CNTs' good impacts on viscosity, density, and

heating value, the vaporization of fuel drops when combustion takes place was improved. Ignition lag was drops in biofuel with CNT blend-fuel when Comparing biofuel with CNT mixed fuel to D100, the ignition timing was reduced because of the greater cetane digit. The adding of nanoparticles to the fuel mixes was shown to decrease the amount of CO, HC, and smoke. When the ratio of nano materials in D100 biofuel blends grew because of rise in oxygen content, heat transfer and efficiency improved. Compared to blends with CNTs for greater loads, B10 and B15 blends have demonstrated superior BTE. The findings demonstrated that, when compared to other fuel mixes and D100, the performance characteristics of the B15C100 fuel blend such as torque, SFC, and BTE are at their peak. Comparing B15C100's exhaust pollutants to those of pure diesel and other gasoline mixes, it was discovered that they were less opaque smoke, HC, and CO. Larger area and volume ratio of nanoparticles improve engine efficiency.

¹S. Kaviyarasu, ²J. Ubaidullah, ³K. Yuvaraj, ⁴P. Shanmugasundaram, ⁵T. Tamilarasu, ¹Assistant Professor, “Production and performance analysis of biodiesel from used cooking oil with nanofluid alumina (Al₂O₃)”. Volume 6, Issue 1 March 2018, ISSN: 2320-2882 <https://www.researchgate.net/publication/324200782>

This study examines the efficiency, emission features, and output of biofuel from recycled oil using biofuels mixed with alumina nanoparticles. Using an ultrasonicator, the alum Nps were blended into the biofuel in mass components of 30ppm and 50ppm. A single-cylinder, four-stroke diesel motor and a vortex dynamometer were used for the test. Let's draw the conclusion from the research that the inclusion of Al₂O₃ blends raises the flash point while lowering the calorific value.

Better thermal efficiency and reduced fuel usage are produced by a decline in calorific value, and secure fuel handling is produced by a rise in flashpoint. The particular consumption of fuel of UCOB20ALUMINA50 (200ml UCO+50ppm+800ml Petro diesel) is lesser compared to that of D100 and UCOB20 (800ml Petro diesel + 200ml UCO). The particulate density is lower for UCOB20ALUMINA50 (200ml Used Cooking Oil +

50ppm Alumina + 800 ml Petro Diesel) compared to D100 (1000ml Petro Diesel) and UCOB20 (800ml Petro Diesel + 200 ml UCO).

Tadesse Anbessie Degfe^{1,2}, Tadios Tesfaye Mamo^{1,3} and Yedilfana Setarge Mekonen¹, “Optimized Biodiesel Production from Waste Cooking Oil (WCO) using Calcium Oxide (CaO) Nano catalyst”. (2019) 9:18982, <https://doi.org/10.1038/s41598-019-55403-4>

Manufacturing biofuel from reusable edible oil (WCO) provides an innovative form of energy for producing liquid fuels from biomass for a range of uses. The manufacturing of biofuel from recovered WCO and ethanol in with the inclusion of a calcium oxide (CaO) nano-catalyst provides a number of benefits include financial, ecological, and waste disposal benefits. A Calcium oxide nano-catalyst was generated using a thermal-decomposition process and heated at 500 °C before being analysed using a combination of x-ray diffraction (XRD) and scanning electron microscopy (SEM). The XRD tests revealed nano-scale crystalline structures having an average particle dimension of 28 nm. The SEM pictures revealed the morphology of the synthesized nano catalysts' uneven forms and pore-like structure. At optimised testing circumstances of 50 °C, 1:8 WCO oil to alcohol ratio, 1% by weight of catalyst loading rate, and 90 minutes react duration, the maximum transformation of WCO to biodiesel was calculated to be 96%, one of the few highest conversions reported so far. The characteristics of biofuel were evaluated using (ASTM D6571). Each of the test were carried out at atmospheric pressure with agitation at 1500 rpm.

The results of the study demonstrated a highest yield of 95.0%, implying that the greatest quantity of biofuel production was achieved at 2% loading catalyst, a 1:8 oil to methanol molar ratio at fifty degrees Celsius temperature, and a reaction period of ninety minutes. The viscosity, low fuel gravity, water and total acidity, ash and SiO₂ content of the generated biofuel and tested in according to ASTM D6571 and determined to be in excellent agreement. Biofuel made from leftover oil from stoves might be utilised as a D100 as well as a cleaner culinary energy source in the home and was considered as regenerative energy.

CHAPTER – 3

AIM AND SCOPE OF THE PRESENT INVESTIGATION

3.1 AIM

The goal of this investigation is to compare the properties of different fuel blends, like density, kinematic viscosity, flash, and fire point by PMCC method, calorific value, and identify which blends give better performance and testing its BP, BTHE, SFC, and emissions characteristics like NO_x, CO, HC, CO₂, and O₂, on the Kirloskar TV1 1 - cylinder, 4 - stroke, Constant Speed, Water Cooled, Diesel Engine, Evaluating the different blends and determine which one is a renewable alternative fuel by comparing their characteristics.

3.2 SCOPE

Short- and long-term environmental benefits will be worthwhile. Biodiesel has the possibility of decreasing incomplete combustion of particulate emissions from diesel engines, while requiring minimal or no modifications to the engine. This means that biofuels could be easily utilized in any diesel engine. Biofuels assist to lower the carbon footprint of transportation and other sectors by improving the carbon cycle on our entire globe. Each gallon of biofuel that substitutes for a gallon of fossil energy helps to lower global emissions. Biodiesel usage is expected to rise substantially in the future years as countries seek methods to decrease their reliance on fossil fuels. Biofuel is a sustainable, cleaner-burning biofuel which can be employed in every diesel motor. Because it is manufactured from renewable energies such as edible oils and fats, it helps to reduce the production of greenhouse gases and our reliance on fossil fuels. The blending of nano components are chemical substances brought in biodiesel to enhance the perfect chemical residences for better overall performance of the engine and moreover, it will increase biodiesel's performance, lowers its emissions, and reasons biofuel to burn completely.

CHAPTER – 4

MATERIALS AND METHODOLOGY

4.1 PREPARATION OF WASTE COOKING OIL BIODIESEL

Waste sunflower oil (WCO) is collected from home and used to make biodiesel, first we find the free fatty acid contained within cooking oil to test the oil sample and the value less than four is considered as an edible oil the FFA examine is carried out the oil pattern is titrated towards a base with a normality of 0.01N as burette solution and the darkish crimson color is obtained as the result of indication consequently, the FFA content material is determined to be 0.11% consequently the FFA is much less than 4 we undergo a unmarried step method to received biodiesel The transesterification system was completed the use of methanol (6:1 molar ratio to WCO) and base catalyst NaOH pellets (0.5 wt. Percent WCO). To create biodiesel from WCO, a batch reactor along with a three-necked round backside glass flask with an ability of 5 liters become set up. The response took 90 mins to finish. A condenser, a magnetic stirrer with a mounted tachometer, a thermometer pocket with a thermocouple, and a stopper to remove samples have been all blanketed in this reactor. To keep the response temperature within zero.1°, a constant temperature heating mantle changed into used.

The batch reactor was warmed with the advocated amount of WCO. In a conical flask, the catalyst and methanol were blended. After accomplishing the desired reaction temperature, the solution in the conical flask transferred to the batch reactor. The solution was put into a separate funnel after the response to cast off the bottom glycerol layer. A rotating concentrator is used to remove any remaining methanol. To get the ph. value back to regular, the ensuing biodiesel crude was washed several instances with heat deionized water. The biofuel is then heated to 100degree Celsius in order that there are not any water molecules present inside the biofuel. All the water molecules get evaporated when heated on the temperature of boiling factor of water and edible oil is trans-esterified.

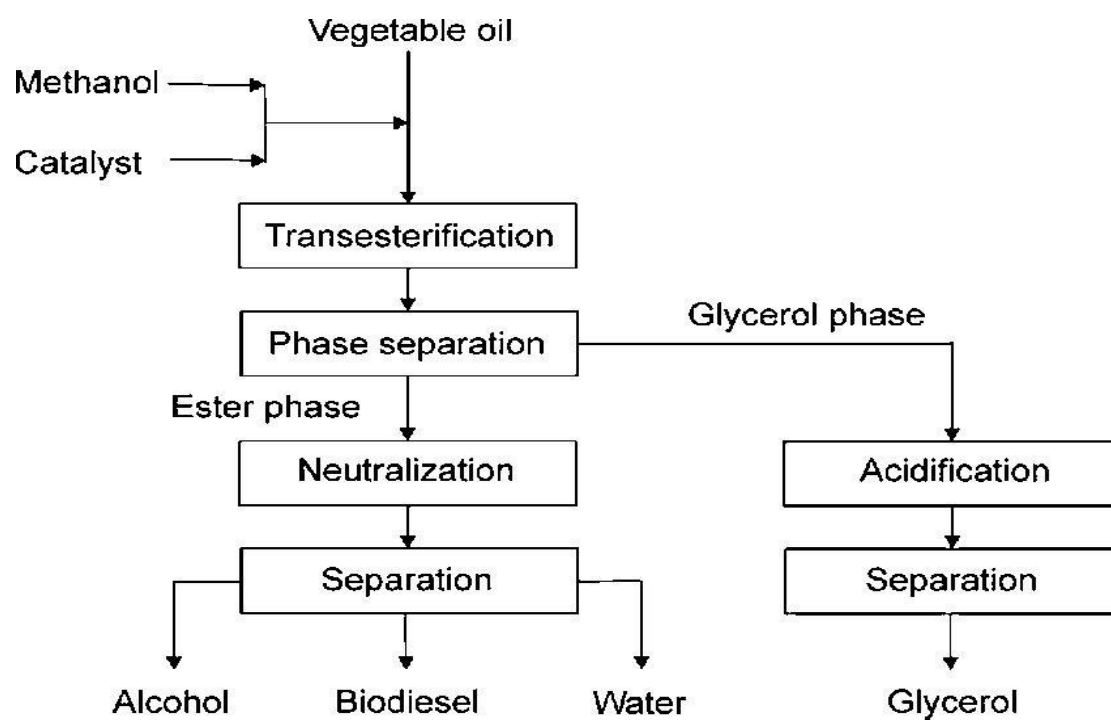


Fig 4.1 Biodiesel production path



Fig 4.2 (a) Batch reactor



Fig (b) WCOB formed with glycerol



Fig (c) Washing of WCO biodiesel



Fig (d) Waste cooking oil biodiesel

4.2 PREPARATION OF NANOPARTICLE ADDED FUEL

Cerium oxide and magnesium oxide nanoparticles have been suggested for dosing levels of Cerium oxide 30 ppm (part per million) and 45 ppm and Magnesium oxide 30 ppm and 45 ppm (by weight) into the diesel fuel and biodiesel fuel as part of the experimental process. To obtain a uniform suspension, fuel mixing has been done using standard ultrasonic suspension. To create a stable nano fuel, the desired dosage was added and stored for 30-45 minutes. The given fuel was ordered in the form of Diesel (80%) + B20(Waste cooking oil biodiesel) + CeO30 (cerium oxide nanoparticles at 30ppm), Diesel (90%) + B10(Waste cooking oil biodiesel) + CeO45 (cerium oxide nanoparticles at 45ppm) and Diesel (80%) + B20(Waste cooking oil biodiesel) + MgO30 (Magnesium oxide nanoparticles at 30ppm), Diesel (90%) + B10(Waste cooking oil biodiesel) + MgO45 (Magnesium oxide nano particles at 45ppm). Following that, the CeO₂ and MgO nano particles were added to the biofuel blend and thoroughly stirred with a magnetic stirrer at 60 °C for 30 minutes to eliminate residues of water molecules. The same ultrasonication procedures were then used to achieve a consistent dispersion of the CeO₂ and MgO nano-additives combination.



Fig 4.3 (a) Ultrasonic bath sonicator



Fig (b) Blending of WCO with nano particle

4.3 PROPERTY TESTING

Identify the physio-chemical characteristics of the fuels that leading for further study into these fuel blends and the major purpose is to compare the values of created fuel blends and discover which is better fuel blends.

4.3.1 Density measurement

The density of high-performance fuel and its blends were measured using a device called hydro-meter. The hydrometer is a device that is used to find out the specific gravity with an accuracy of 0.01, Initially 250ml of biodiesel was poured into a beaker and a hydrometer with a suitable specific gravity range was selected. After selection, the hydro-meter was immersed into the beaker and stabilization process took place. On by immersion, the specific gravity value was displayed on the graduated scale of the hydrometer device.



Fig 4.4 Hydrometer

4.3.2 Viscometer measurement

The kinematics viscosity was measured by using a device called Canon-Fenske viscometer. The viscosity tube was first cleaned and rinsed using acetone solution and dried up. 50 ml of high-performance fuel blend was poured into the viscosity tube. This is accomplished by immersing the tube's shorter end in a beaker filled with high performance. Suction force was used after placement to bring the diesel up to the upper mark of the viscometer. The viscometer was put within a constant temperature bath using a holder and adjusted to a target temperature of 40°C for 30 min to allow the high-performance samples to attain heating rate. By applying a suction force to the thinner arm, the high-performance sample was dragged slightly over the top mark. The sample travelled freely from the up to down in order to capture the passing of time.



Fig 4.5 Canon-fenske viscometer

4.3.3 Flash and fire point measurement

The test the ignition temperature and heat of vaporization of fuels within the temperature variety of 40°C to 360°C. In this test, about 200 ml of high-performance is poured into a brass cup which is then fit with a cover. The sample is heated and stirred steadily. An ignition source (fire) is introduced into the cup at regular intervals while simultaneously stirring until it reaches a temperature at which the volatile material ignites, and a flash is produced that spreads evenly throughout the inside of the cup. This temperature was recorded as flash point. On further heating and stirring, an ignition source was introduced at regular intervals until it reaches a temperature where vapors are created at a pace sufficient to keep the flame running for least 5 seconds. This temperature was noted down as the fire point.

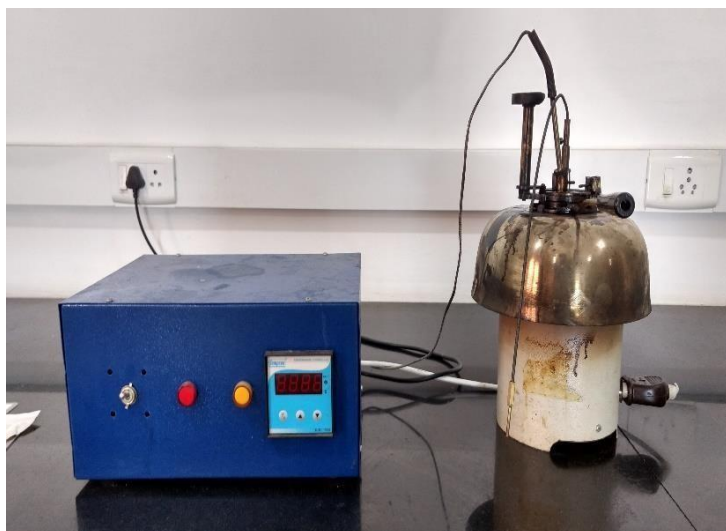


Fig 4.6 Pensky-martens closed-cup apparatus

4.3.4 Calorific value measurement

A bomb calorimeter was used to evaluate the calorific value, this was achieved by measuring the amount of heat generated when high-performance of 10ml was burnt in a closed chamber. This apparatus comprises of bomb, bomb firing unit, illuminator with magnifier, offset stirrer, calorimeter vessel, gas release valve, water jacket, pellet press vibrator, timer, pressure gauge, crucible, and ignition wire.



Fig 4.7 Bomb calorimeter

4.4. EXPERIMENTAL SET-UP

The testing setup includes an electric start diesel engine with a 1-cylinder and four-stroke design, featuring a variable compression ratio connected to a loading dynamometer using eddy currents. The unique tilting cylinder block structure gives compression ratio adjustment while the engine is operating, without changing the dimensions of the combustion area or turning down the engine. The testing equipment includes crank angle and combustion pressure monitoring sensors that are linked to a computer for PPV diagrams. Load monitoring, temperature, fuel flow, and airflow measures are also possible with this arrangement. An airflow unit, multiple fuel containers for blend testing, a mano-meter, a fuel measurement tool, transmitters enabling both fuel and air flow estimation, an operation indication, and an engine indication. are all housed in a separate panel box. Rotameters can be used to monitor the flow of water used for cooling and calorie gauge water. Engine-soft tool was used to analyze the data. The test rig is made up of various gasoline tanks and a three-way stop cock assisted for the various fuel mixtures. The configuration allows for the investigation of the BP, IP, FP, BMEP, IMEP, mechanical efficiency, volumetric efficiency, specific fuel consumption, A/F ratio, and heat balance for VCR engines as shown in Fig. 4.8 with EGR. For online performance assessment, the Lab view-based Engine Performance Analysis software package "Engine-soft" is offered.



Fig 4.8 VCR Engine setup

Table 4.1 Engine specification

Enginetype	Direct injection Kirloskar TV1 diesel engine
Rated Power	5.20 kW@ 1500 rpm
Number of Cylinders	1
Stroke & bore	4 & 87.50 mm
Cooling System	Water cooled
Type of fuel	Diesel
Stroke Length	110.00mm
Connecting Rod Length	234.00mm
Compression Ratio	17.50
Swept Volume	661.45 cc

CHAPTER – 5

RESULTS AND DISCUSSION

Table 5.1 Property testing results.

Blend	Additive	Density (g/cc)	Kinematic Viscosity (cst)	Flash Point (°C)	Fire Point (°C)	Calorific Value (cal/g)
WCO 20% + Diesel 80%	Cerium oxide 30 ppm	0.837	2.50	69	78	9324.45
WCO 10% + Diesel 90%	Cerium oxide 45 ppm	0.828	2.13	56	67	9812.33
WCO 20% + Diesel 80%	Magnesium oxide 30 ppm	0.845	2.80	71	80	6974.13
WCO 10% + Diesel 90%	Magnesium oxide 45 ppm	0.846	3.08	60	69	7463.61

5.1 FUEL BLENDS PROPERTIES

5.1.1 Density

The density of the fuel affects the fuel injection and combustion processes. Lower density fuels result in better atomization and combustion. Among the given blends, the combination of 10% WCO biodiesel and 90% diesel with cerium oxide 45 ppm has the lowest density of 0.828 g/cc, making it the optimal choice for engine testing.

5.1.2 Kinematic viscosity

Kinematic viscosity is a gauge of the fuel's resistance to flow. Lower viscosity fuels result in lower pumping losses and better fuel economy. Among the given blends, the

combination of 10% edible oil biofuel and 90% diesel with cerium oxide 45 ppm has the lowest kinematic viscosity of 2.13 cst, making it the optimal choice for engine testing.

5.1.3 Flash point and fire point

Flash & fire point are indicators of the fuel's safety during handling and storage. Higher values indicate better safety characteristics. Among the given blends, the combination of 20% edible oil biofuel and 80% diesel with magnesium oxide 30 ppm and 20% edible oil biofuel and 80% diesel with cerium oxide 30 ppm has the highest flash point of 71°C, 69°C and fire point of 80°C, 78°C, making it the optimal choice for engine testing.

5.1.4 Calorific value

Calorific value is a measure of the fuel's energy content per unit volume. Higher calorific value fuels result in higher engine power output. Among the given blends, the combination of 10% edible oil biofuel and 90% diesel with cerium oxide 45 ppm has the highest calorific value of 9812.33 cal/g, making it the optimal choice for engine testing.

5.2 ENGINE TESTING RESULTS

Four different fuel samples were prepared for testing, and the engine was started to evaluate their performance. Each fuel sample was added to the fuel tank, and the engine was operated at varying loads to measure its efficiency and emissions and results were compared.

5.2.2 Brake Power vs Brake Thermal Efficiency

Fig 5.1 presents the comparison between BP and BTHE at various loads for various blends. BTHE varies by the engine's temperature and the applied pressure. The higher the BP and BTE, the better the engine performance. Based on the given data B20MgO blend and B20CeO₂ blend produces higher BTHE, indicating that the engine is less efficient in converting the fuel energy into usable work. B20CeO₂ blend and B10MgO

blend have higher brake power than B10CeO₂ blend, but lesser brake thermal efficiency than B20MgO blend, indicating that they are less efficient in utilizing fuel energy. B20MgO blend gives more BTHE than Diesel. At a higher load of 3.5kW, D100, B20MgO blend are 32.59%, 32.83% respectively.

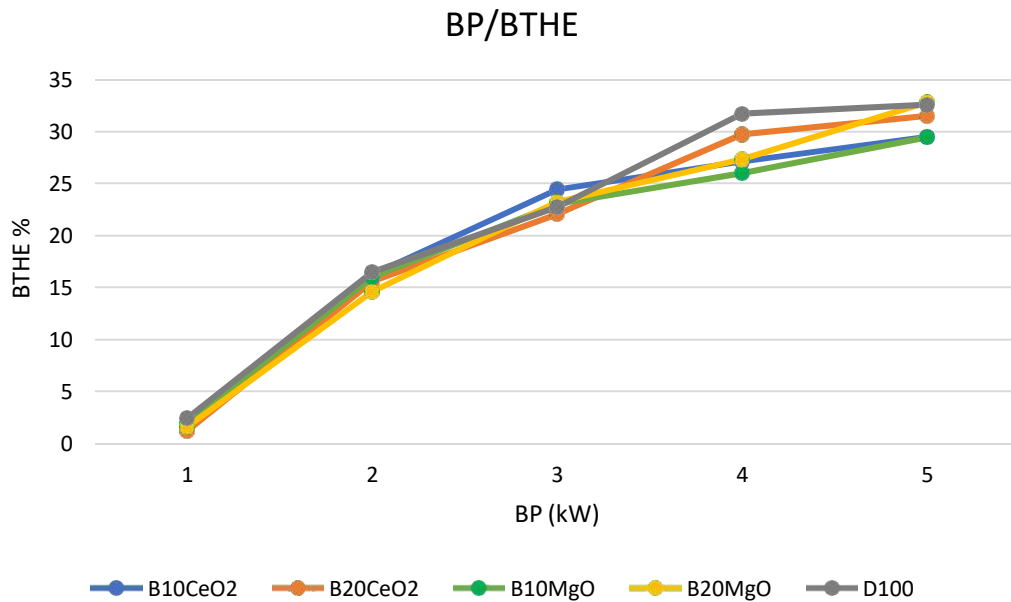


Fig 5.1 BP VS BTHE

5.2.3 Brake Power vs Specific Fuel Consumption

Fig 5.2 presents the comparison between BP and SFC at various loads for various blends and D100. SFC drops with a rise in load given to the VCR engine. Based on the given data, the addition of 30 and 45 ppm of CeO₂ and MgO nano-particles results in B20CeO₂ followed by B10MgO blend gives low fuel consumption, the load rises, the cylinder temperature rises, causing the duration of the ignition delay to shorten, resulting in a decrease in SFC. Because of their larger reactive surface area at combustion, nano-particles function as a catalyst. This improves combustion once a droplet is fed into the combustion chamber. When compared with diesel, all four samples consumed more. This is maybe because of the low calorific value. At a higher load of 3.5 kW, the D100, B20CeO₂ and B20MgO blend has less SFC of 0.2 kg/kWh, 0.27 kg/kWh and 0.27 kg/kWh respectively.

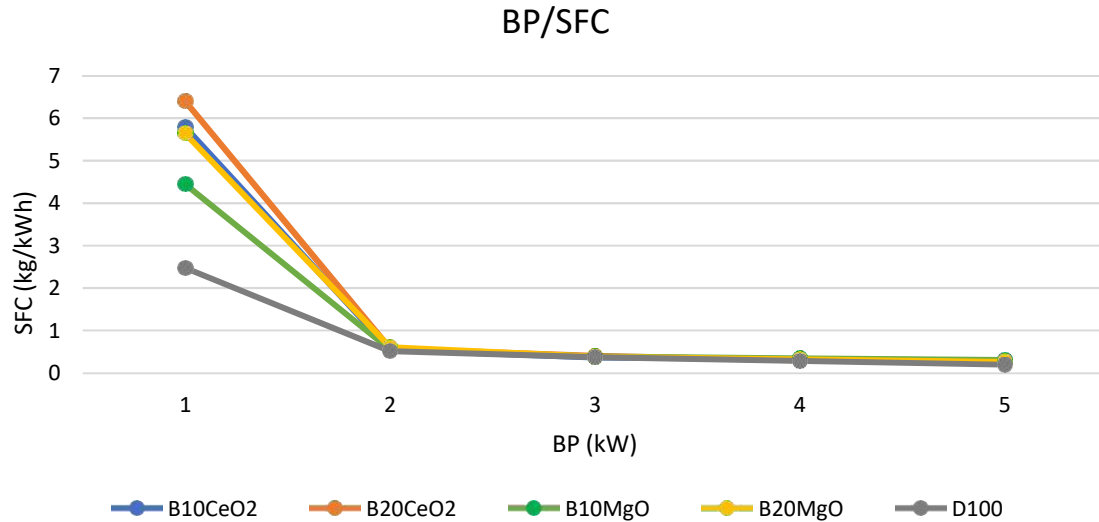


Fig 5.2 BP VS SFC

5.2.4 Brake Power vs Hydrocarbon

Fig 5.3 presents the comparison between Brake Power and Hydrocarbon at various loads for various blends. According to the fuel incomplete burning, hydrocarbons are created. When the load rises, the amount of HC also rises. Less HC emissions are produced in diesel engines. Based on the given data, B10CeO2 blend has the less HC emission at all brake power levels followed by B20CeO2 blend. B10CeO2 blend and B20CeO2 blend gives less HC emission when compared with the Diesel. At a higher load of 3.5 kW, the D100, B10CeO2 and B20CeO2 blend produces less HC emission of 12 PPM, 9 PPM and 10 PPM respectively.

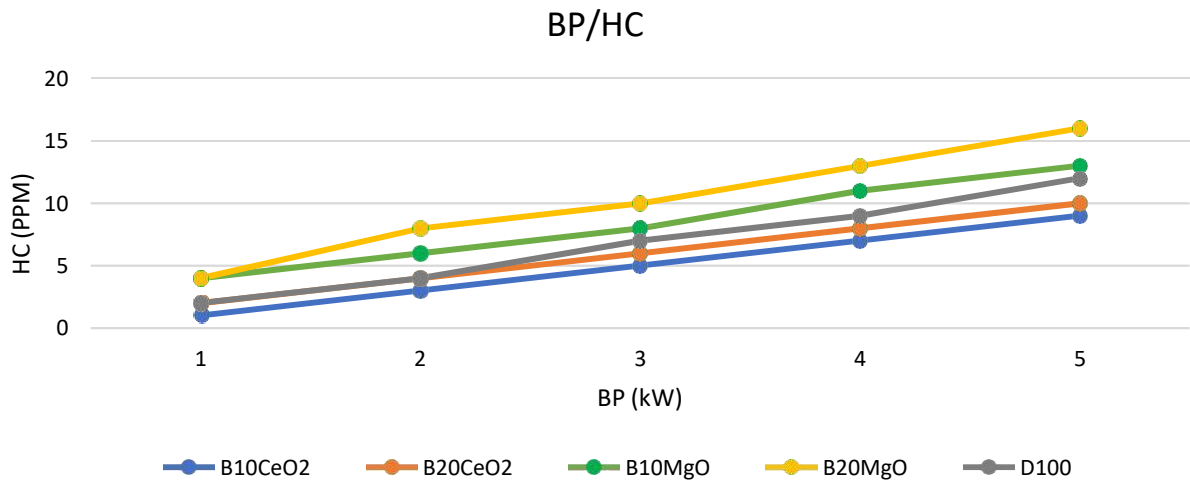


Fig 5.3 BP VS HC

5.2.5 Brake power vs Carbon dioxide

CO₂ emissions are not as harmful as NO_x, CO, and HC emissions. However, needs to be managed to decrease Climate change. When compared to petrol, biofuel emits more CO₂. Fig 5.4 presents the comparison between Brake Power and carbon dioxide at various loads for various blends. Based on the results the CO₂ emitted less in the B20CeO₂ blend has less CO₂ emission followed by the B10CeO₂ blend. At a higher load of 3.5 kW, D100, B20CeO₂ blend produces less CO₂ emission of 1.42%, 0.52% respectively.

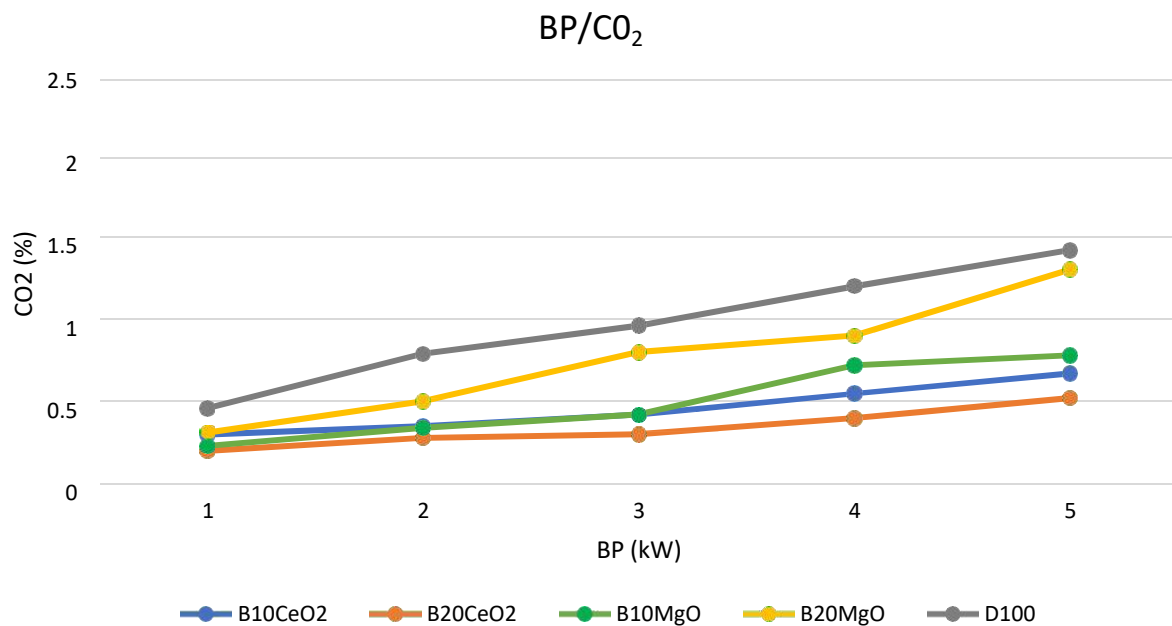


Fig 5.4 BP VS CO₂

5.2.6 Brake power vs Nitrogen oxide

Fig 5.5 presents the comparison between Brake Power and Nitrogen Oxides at various loads for various blends. NO_x is one of the components of exhaust gases. Nitrogen Oxides react with oxygen in the air which gives nitric oxide. The usage of oxidised fuel, such as biofuel, improves combustion thus raises NO_x emissions. Adding of nano particles causes a quicker pre-prepared combustion, resulting in improved combustion

degree within the chamber and, as a result, greater NO_x emissions than baseline fuel. Based on the results the B10CeO₂ blend has less NO_x value followed by B20CeO₂. B10CeO₂ blend produces less NO_x emission 163 PPM at higher load of 3.5 kW. The value of B20MgO is very high at a higher load of 3.5 kW is 342 PPM. It is because of its high viscosity.

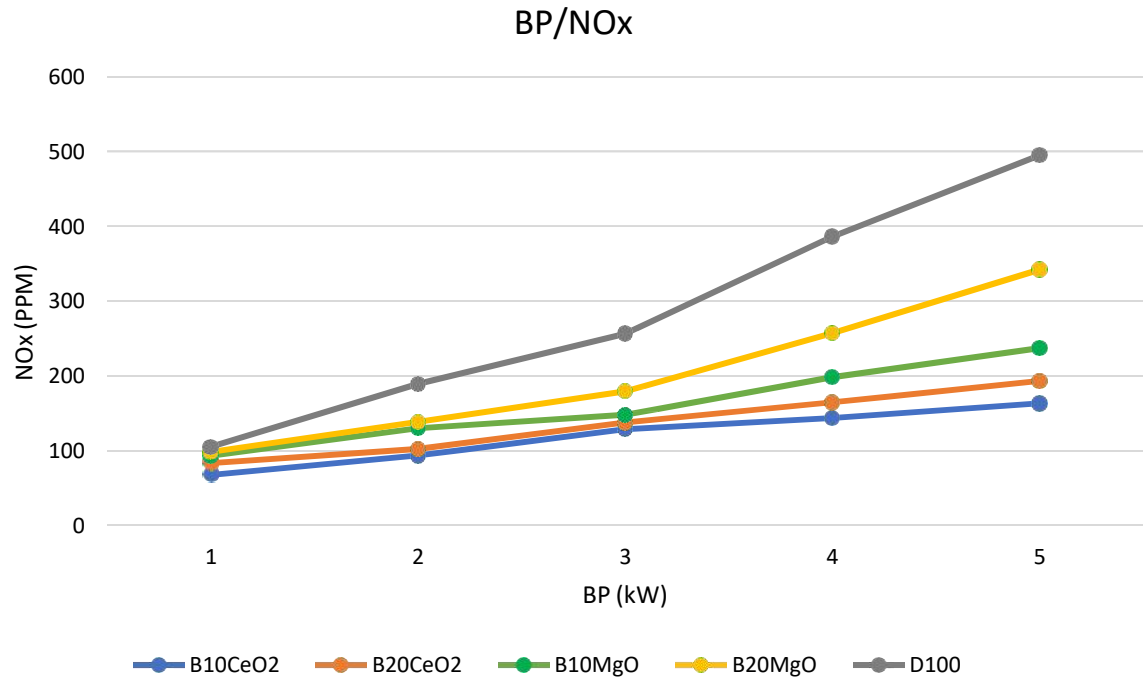


Fig 5.5 BP VS NO_x

5.2.7 Brake power vs Carbon monoxide

Fig 5.6 presents the comparison between BP and CO at various loads for various blends. Carbon monoxide is created when the carbon is burnt without the presence of oxygen. CO emission is toxic and hazardous for the atmosphere. CO is produced during burning when an inadequate air supply is combined with a low flame temperature. The rise in BP resulted in an increase in CO emission, as seen in Fig 5.6. The volumetric efficiency rises steadily as the load increases. However, due to a lack of combustion time, partial combustion occurs, which leads to creation of CO. Based on the results the CO is emitted less in the B20CeO₂ blend and B10CeO₂ blend both

have less CO emission. At a higher load of 3.5 kW, the B20CeO2 and B10CeO2 blend produced less CO emission of 0.047% and 0.043% respectively.

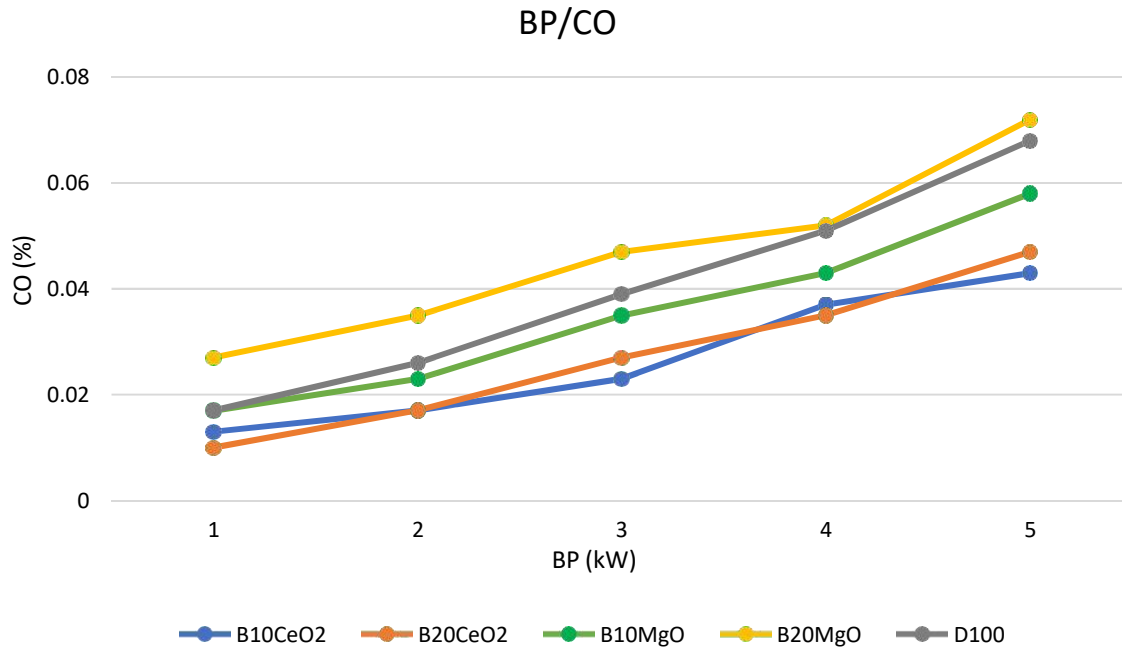


Fig 5.6 BP VS CO

5.2.8 Brake power vs Oxygen

Fig 5.7 presents the comparison between BP and O2 at various loads for various blends. Oxygen emission refers to the measurement of the quantity of oxygen present in the exhaust gas; the oxygen emission level can affect the efficiency and emission of an engine where less oxygen in the exhaust gas can indicate incomplete combustion and poor engine performance, while too much oxygen can indicate excessive air in the engine which can lead to reduced power output and increased emissions of unburned hydrocarbons and carbon monoxide. Based on the results O2 is produced high in the B20CeO2 blend followed by the B20MgO blend. The B20CeO2 and B20MgO blends give more O2 than D100. At a greater load of 3.5 kW, D100 and B20CeO2 blend produces O2 emission of 18.52%, 18.7% respectively.

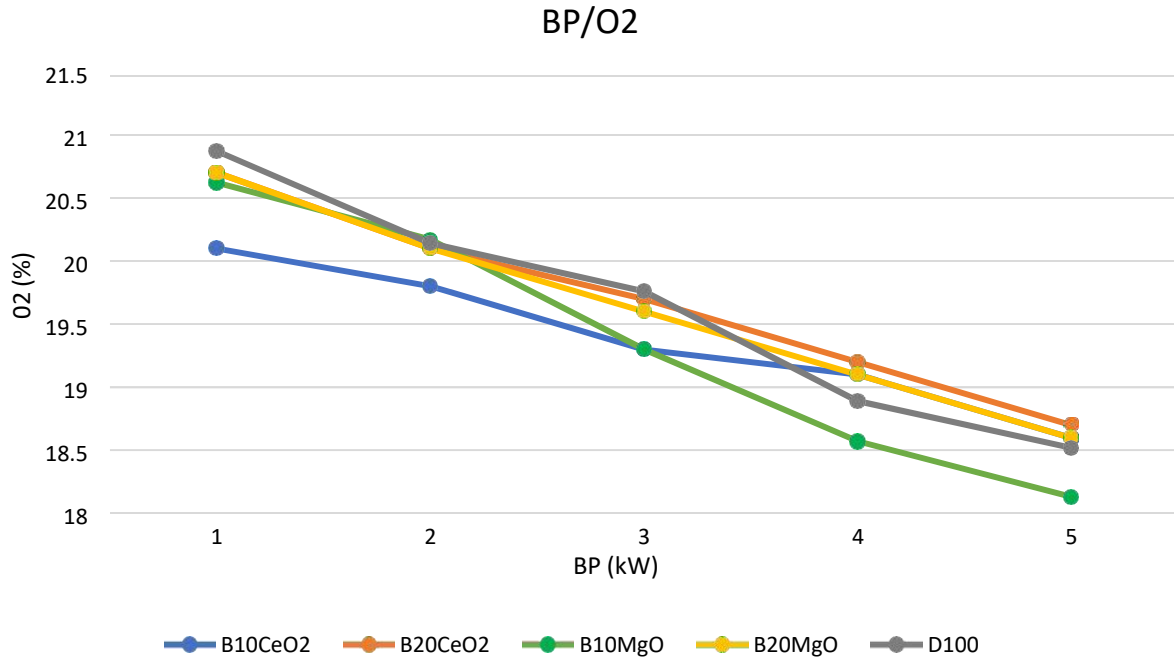


Fig 5.7 BP VS O₂

5.3 EFFICIENCY AND EMISSIONS PARAMETERS

Overall results show that in BTHE the B20MgO blend gives a higher BTHE and followed by B20CeO2 blend. At higher load of D100, B20MgO and B20CeO2 blend has 32.59% ,32.83%, 31.52%, the B20MgO produces higher BTE than diesel. The B20CeO2 blend gives low fuel consumption followed by B20MgO. At high brake power 3.5 kW, D100, B20CeO2 and B20MgO blend has 0.20 kg/kWh, 0.27 kg/kWh and 0.27 kg/kWh. B10CeO2 blend has the less HC emission at all brake power levels followed by B20CeO2 blend. The B10CeO2 blend has less NO_x value followed by B20CeO2. B10CeO2 blend produces less NO_x emission 163 PPM at higher load of 3.5 kW. B20CeO2 blend produces less CO₂ emission of 0.52% followed by the B10CeO2 blend. The CO is emitted less in the B20CeO2 blend and B10CeO2 blend both have less CO emission. At a higher load of 3.5 kW, the B20CeO2 and B10CeO2 blend produced less CO emission of 0.047% and 0.043%. O₂ is produced high in the B20CeO2 blend of 18.7% followed by the B20MgO blend of 18.6%.

CHAPTER – 6

CONCLUSION

The trans-esterification process of used edible oil is done successfully and converted into Waste cooking oil biofuel (WCOB) and the subsequent blending of WCOB with (CeO₂) cerium oxide and (MgO) magnesium oxide nano-particles have shown promising results in enhancing the properties of the biofuel. The preparation of four biofuel samples with appropriate ratios and testing them in a Variable Compression Ratio (VCR) engine at various loads revealed that the use of the blended CeO₂WCOB and MgOWCOB samples resulted in increased engine efficiency compared to conventional diesel fuel. Additionally, the emission standards of the blended WCOB samples were evaluated and found to be lower than those of conventional diesel fuel, indicating that the use of blended WCOB has the potential to be a more environmentally friendly alternative.

- B10 edible oil biofuel and 90% diesel with cerium oxide 45 ppm has the lowest density of 0.828 g/cc and followed by B20 WCO and 80% diesel and cerium oxide 30 ppm produce 0.837 g/cc. Lower density fuels result in better atomization and combustion. B10 edible oil biofuel and 90% diesel with cerium oxide 45 ppm has the lowest kinematic viscosity of 2.13 cst, followed by B20 WCO and 80% diesel and cerium oxide 30 ppm produce 2.50 cst. Oils that have less viscosity enhance fuel efficiency and hence lower emissions of greenhouse gases.
- B20 edible oil biofuel and 80% diesel with magnesium oxide 30 ppm and 20% edible oil biofuel and 80% diesel with cerium oxide 30 ppm has the highest flash point of 71°C, 69°C and fire point of 80°C, 78°C. Flash & fire point are indicators of the fuel's safety during handling and storage. Higher values indicate better safety characteristics. B10 edible oil biofuel and 90% diesel with cerium oxide 45 ppm has the highest calorific value of 9812.33 cal/g. and followed by B10

WCO biofuel and 90% diesel with cerium oxide 45 ppm produce 9324.45 cal/g. Higher calorific value fuels result in higher engine power output.

- B20MgO30ppm blend gives a higher BTHE of 32.83% and its higher than 32.59% diesel and followed by B20CeO2 45ppm biofuel blends with magnesium and cerium oxide nano-particles are better in terms of BTE compared to diesel. The higher the BP and BTE, the better the engine performance. The B20CeO45ppm blend gives low fuel consumption 0.27 kg/kWh at high brake power 3.5 kW and followed by B20MgO30ppm blend. A lesser SFC value indicates greater effectiveness.
- B10CeO2 and B20CeO2 blend has the less HC emission at all brake power compared to D100. At a higher load of 3.5 kW, the D100, B10CeO2 and B20CeO2 blend produces less HC emission of 12 PPM, 9 PPM and 10 PPM. At all BP, the level of NOx is lower for all biofuel mixtures than for D100. Overall, the B10CeO2 and B20CeO2 blend has less NOx values.
- B20CeO2, B10CeO2, B10MgO blends have less CO emission than D100. At a higher load of 3.5 kW, D100, B20CeO2 and B10CeO2 blend has less CO emission of 0.068%, 0.047% and 0.043%. B20CeO, B10CeO, B20MgO blends have less O2 than D100. At higher BP, D100, B20CeO2 blend produce 18.52%, 18.7%.

SUMMARY

Overall analysis shows that the B10CeO2 blend and B20CeO2 blend produces lower density, lowest kinematic viscosity, the highest flash and fire point and highest calorific value and B20CeO2 45 PPM blend is more efficient than other biofuel blends. It gives higher BTHE and lower SFC. It also produces less HC, NOx, CO2 emission and high O2. That concludes B20CeO2 45 PPM blend indicating that the use of blended WCOB has the potential to be a more environmentally friendly alternative fuel.

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