

Effect of Alumina and Calcium Oxide Nano Additives on Reduction of NO_x emissions in a CRDI diesel engine fueled with B20 blend of Waste cooking oil Biodiesel

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

By

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SCHOOL OF MECHANICAL ENGINEERING

SATHYABAMA

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

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BONAFIDE CERTIFICATE

This is to certify that this Project Report is the bonafide work of EATHA SRI SAI PRASANNA KUMAR (38150027) CHILAKAMARTHI NAGA SESA PRASANNA KUMAR (38150021) who carried out the project entitled 'Effect of Alumina and Calcium Oxide Nano Additives on Reduction of NO_x emissions in a CRDI diesel engine fueled with B20 blend of Waste cooking oil Biodiesel' under our supervision from December 2021 to MARCH 2022

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DECLARATION

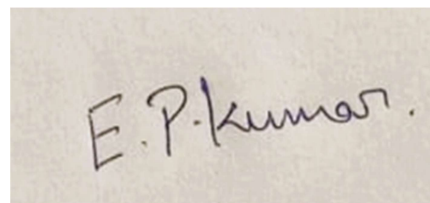
We, EATHA SRI SAI PRASANNA KUMAR (38150027) CHILAKAMARTHI NAGA SETHA PRASANNA KUMAR (38150021) hereby declare that the Project Report entitled “ Effect of Alumina and Calcium Oxide Nano Additives on Reduction of NOx emissions in a CRDI diesel engine fueled with B20 blend of Waste cooking oil Biodiesel” done by us under the guidance of **Dr. J. JAYAPRABAKAR, M.E. Ph.D.**, at Sathyabama Institute of Science and Technology, Chennai is submitted in partial fulfilment of the requirements for the award of Bachelor of Engineering degree in Mechanical Engineering.

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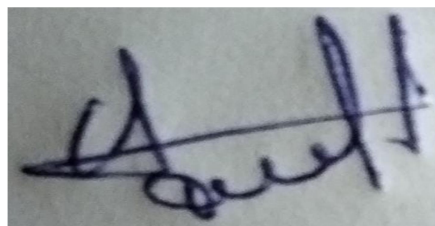
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ABSTRACT

The present study is to investigate the Effect of Alumina and Calcium Oxide Nano Additives on reduction of NO_x emissions in a CRDI diesel engine fueled with B20 blend of Waste cooking oil Biodiesel.

To prepare a blend of waste cooking oil and diesel by the process of transesterification with 20% biodiesel and 80% diesel. Now the mixture of Al₂O₃ and CaO Nano particles are added with the B20 blend of bio diesel in three different kinds of injection of 30PPM, 60PPM and 90PPM. As per the result NO_x emissions were reduced

Now we perform engine test on CRDI engine and analyze the outcome values.

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LIST OF SYMBOLS AND ABBREVIATIONS

ASTM	-	American Society for Testing and Materials
B20	-	20% biodiesel and 80% diesel
CRDI	-	Common rail Direct injection
BSFC	-	Brake Specific Fuel Consumption
SFC	-	Specific fuel consumption
BTE	-	Brake thermal efficiency
EGT	-	Exhaust gas temperature
CP	-	Cylindrical pressure
HR	-	Heat release
PM	-	Premixed
RB20	-	Rice bran biodiesel

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CHAPTER 1

INTRODUCTION

1.1 INTRODUCTION TO BIO-DIESEL

Biodiesel is an alternative fuel which can be used in the place of diesel. The preparation of biodiesel can be made using variety of oils, fats, and greases and it is very helpful to farmers and the reasons include: It increases the market for vegetable oils and animal fats, it can allow farmers to grow the fuel and use them for their farm machinery, and it can decrease the dependency of fuel on other countries was told by Zahira Yaakob, Masita Mohammad, Mohammad Alherbawi, Zahangir Alam, Kamaruzaman Sopian.

Biodiesel is a renewable source of energy that can help in reducing NO_x emissions and minimize the “carbon content” in the atmosphere. It contributes less to global warming because the carbon in the fuel was removed from the air by the plant feedstock.

Along with this biodiesel produces less air pollution like NO_x, Carbon mono oxide, carbon di oxide than diesel made from fossil fuels. A 1998 study by the USDA and US DOE found that using pure biodiesel in urban buses shows that there is a lot of decrease in the life cycle emissions of the total particulate matter around 32%, carbon monoxide around 35% and sulfur oxides around 8% relative to petroleum diesel's life cycle this was concluded by Amin Talebian-Kiakalaieh, Nor Aishah Saidina Amin, Hossein Mazaheri.

1.2 BACKGROUND ON BIODIESEL

Before proceeding to answer the research questions, it is important to establish some background about what biodiesel is, what it is made of, what its principal properties are, and the extent of its current usage in the state. This chapter will provide that foundation.

Definition

In 1895, Rudolf Diesel developed a new engine with the intention that it could use a variety of fuels, including vegetable oil. When he showcased it to the public at the 1900 Paris World's fair, he had the engine run on peanut oil. As the diesel engine became more widely adopted in subsequent years, however, petroleum-based diesel fuel proved to be less expensive and became the fuel of choice.

Biodiesel's definition has been a work in progress. Since the early 1900s, biodiesel has been defined as an alternative form of diesel fuel made from vegetable oils or animal fats and alcohol. The definition of biodiesel was neither legally definable nor defensible in the United States for about a century. This changed when biodiesel was registered with the U.S. Environmental Protection Agency (EPA) as a fuel and a fuel additive under section 211(b) of the Clean Air Act. With help from the American Society of Testing & Materials (ASTM), subsequent legislation such as the Energy Policy Act (EPA) helped further define biodiesel. In December 2001, the ASTM issued defined physical/chemical constraints for biodiesel and subsequently for mixtures of biodiesel with diesel fuel. An important distinction needs to be made between biodiesel and biodiesel blends. Biodiesel is commonly mixed with diesel No. 2 to form a biodiesel blend. As stated above, a mixture of biodiesel and diesel is not biodiesel, but is referred to as a biodiesel blend. Pure biodiesel, also known as neat biodiesel, is commonly noted as B100, indicating that the fuel has 100 percent biodiesel (noted by the 100) and 0 percent diesel. The most common biodiesel blend is B20, which contains 20 percent biodiesel and 80 percent diesel.

1.3 GENERATIONS OF BIODIESEL

Subhash Lahane, K.A. Subramanian survey stated that when this biodiesel came into light many started producing it from food crops. Due to which there was instability in food supply and sudden hike in cost of food crops. So with this the generations of biodiesel have started.

There are three generations of biodiesel. They are:

- i. The first generation

- ii. The second generation
- iii. The third generation

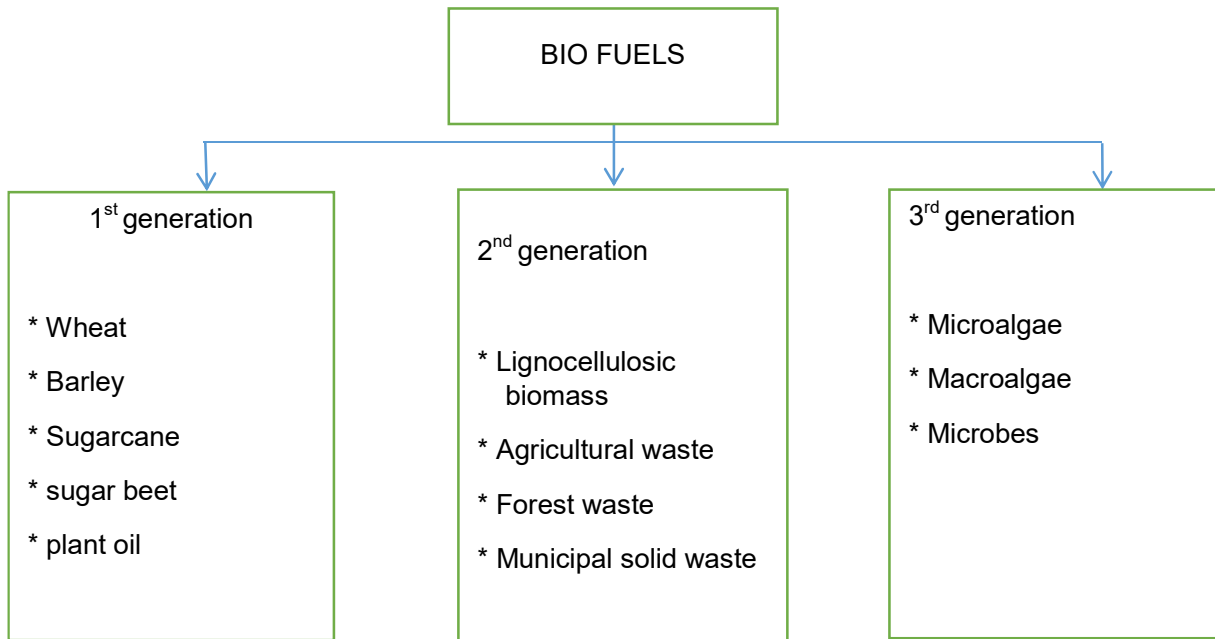


Table no.1.1 Generations of Biodiesel

1.3.1 THE FIRST GENERATION OF BIODUELS

Mohammad Rasul and Nur Md Sayeed Hassan stated that these first generation of biofuels are produced from agricultural crops, which are a vital food source for humans. In this generation the biodiesel is made from corn starch, sugar from potatoes and vegetable oil obtained from the crops which humans consume on a daily basis. Scientist feared that it may cause an instability in the environment because of the growing demand for the oils. This would also create competition within the farmers. Thus leading to usage of excess fertilizers and pesticides to increase the crop yield. This would change the chemical properties of the biodiesel to a certain extent. So this type of production of biodiesel was not entertained.

1.3.2 THE SECOND GENERATION OF BIOFUELS

Rahman, Md M., Mohammad Rasul, and Nur M.S. Hassan investigation showed that the second generation has come into existence because of the fear of the scientists that the first generation may cause imbalance and shortage of food supply. This led to change of feed stock to non-edible sources such as harvest wastes, municipal solid waste, foods that already fulfilled their purpose (Used cooking oil). These second generation biofuels are made from cellulosic biomass or waste plant materials. This helps to reduce the burden on the edible oil for preparation of biodiesel. So here no arable land is used solely for production of biodiesel, Biodiesel production from waste animal fat and improvement of its characteristics by synthesized nickel and magnesium additive. Energy Convers Management 2009; 50(3): 498-502.its waste product is used for production of biodiesel. Non-edible food second generation feedstock include used cooking oil, jatropha oil, grasses and other seed oils. To convert cellulose biomass to biodiesel a series of pre-treatment is required.

1.3.3 THE THIRD GENERATION OF BIOFUELS

M.Mofijur, M.G.Rasul, N.M.S.Hassan, M.N.Nabi studied and stated that Scientists found that algae is rich in oil content and it is unwanted plant. It grows in wastewater and absorbs oxygen from the water bodies. It also does not require any arable land for growing. So this feature has made algae very efficient to grow. These algae can be grown in pond and wastewater treatment plants. It is not used commercially because its extraction is costly and pretreatment is required. Eventually after extraction is made easier it will be commercially used on a large scale.

1.4 Common rail Direct injection (CRDI)

Pathikrit Bhowmick, A.K. Jeevanantham, B. Ashok stated that fuel is held at changeable pressure in an electronically controlled engine's cylinder or 'rail' which is connected to the engine's fuel injectors via individual pipes, making it a 'common

rail' to all injectors. The pressure is controlled by the fuel pump, while the timing and amount of fuel injected are controlled by the fuel injectors, which work in tandem with the fuel pump. Earlier mechanical systems, on the other hand, relied on the fuel pump for pressure, timing, and quantity. The CRDi system also has the advantage of injecting the gasoline directly into the combustion chamber. In older engines, the indirect injection (IDI) system pumped fuel into a pre-combustion chamber before feeding it to the main combustion chamber.

C. Syed Aalam, C.G. Saravanan, M. Kannan investigations proved that Meeting emission regulations requires improved combustion efficiency. Soot or particles in the exhaust and deposits in the engine waste less fuel. A cleaner-running engine is better for the environment — and less expensive to own. Cleaner operating increases your engine's long-term longevity and reliability.

The engines have been built to handle more demanding working conditions. Improved fuel filtration, for example, ensures that the fuel injected from the common rail is of greater purity. To keep your engine running effectively and within the limitations of the applicable emission requirements, clean servicing procedures are required.

CHAPTER 2

LITERATURE SURVEY

2.1 INTRODUCTION

The transportation industry is one of the fastest developing areas in the modern world and has a huge influence on globalization and the economy of any nation. As a result of the oil crisis and global warming, research has been focused on finding viable alternative fuels to petroleum oil. Now biodiesel is made from non-edible vegetable oils, Due to the high cost of edible vegetable oils, they were becoming an environmentally friendly alternative to diesel fuel the use of biodiesel and biodiesel blends with diesel fuel is being researched. tackle the problem of fossil fuel depletion and environmental pollution impact. Biodiesel is a methylated biodiesel that can be used as a substitute for diesel fuel or ethyl esters, which are derived from vegetable or animal fats process of transesterification. Now with this non -edible oils the biodiesel is prepared and will take the B20 blend from it. The motivation behind this study is to explore B20 blend of waste cooking oil biodiesel performance in the CRDI engine as the waste cooking oil is very low at cost and it is available at every houses commonly as per our work, we got to know that B20 blend is the best blend for diesel engine. At ORG IT, the effect of 25 ppm Al_2O_3 in a BDE blend the following results were obtained when ADV IT and RET IT were tested in a single cylinder diesel engine. The inclusion of Al_2O_3 at ADV IT resulted in a greater peak pressure and a faster heat release rate at to TDC, increased hydrocarbon (HC), carbon monoxide (CO), carbon dioxide (CO_2), nitrogen oxides (NO_x), exhaust gas oxygen (EGO), combustion duration (CD), and ignition postponement (ID). Al_2O_3 addition in RET IT, on the other hand, results in decreased cylinder pressure and heat dissipation away from the core TDC, followed by reductions in HC, CO, NO_x , and smoke opacity all at the same time. Furthermore, higher amounts of EGO and ID were found, as well as reduced brake specific fuel consumption (BSFC) and CD. Along with this the Cao is also mixed with the different types of blends for this the thermal decomposition

approach was used to make Cao nano-catalyst, which was described by Zhen-Xing Tang and David Claveau²⁴. A nitrate solution was made by dissolving 11.81 g of calcium nitrate tetrahydrate ($\text{Ca}(\text{NO}_3)_2 \cdot 4\text{H}_2\text{O}$) in 25 ml of ethylene glycol solution and vigorously swirling 2.10 g of sodium hydroxide into the aforesaid liquid. After being agitated for 10 minutes, the gel solution was held at a static condition for roughly 5 hours in order to obtain homogenous size nanoparticles. It was then vacuum dried after being rinsed with distilled water. After calcination at 500 °C, different sizes of Cao nanoparticles were formed and finally the both the nano particles (Al_2O_3 and Cao) are added to B20 blend and NO_x emissions emitted from the smoke is calculated comparing with NO_x emission emitted from Diesel smoke.

2.2 Common rail Direct injection.

In a CRDI engine Atul Dhar and Avinash Kumar Agarwal investigated the combustion properties of B40. The heat release rate (HRR) investigation revealed that delaying the SOI timing to the ATDC side improved premixed combustion at all load circumstances. Increased FIP resulted in higher HRR and a somewhat earlier start of combustion (SOC) at the same SOI, according to the authors.

Karthickeyan, K.C. Vora, Aatmesh investigations showed that Biodiesel fueling accelerated the SOC and reduced the pre-mixed heat emission at lower loads. Biodiesel fueling, on the other hand, had no effect on the HRR at moderate to high loads. Yamane et al. discovered that the bulk modulus difference between biodiesel and diesel is greater at lower temperatures and higher pressures.

Pathikrit Bhowmick, A.K. Jeevanantham, B. Ashok, K. Nanthagopal, D.Arumuga Perumal, V. Jain investigated on Calophyllum Inophyllum oil starting from various biodiesel production techniques to its application in modern day diesel engines.

Rahman et al have demonstrated a two-stage transesterification for biodiesel production from raw Calophyllum Inophyllum oil.

Nanthagopal et al. have examined the significance of fuel injection pressures on single cylinder DI-CI engine working with CIB100 fuel. As per the results, the BTE of CIB100 was found to be directly proportional to the increment in fuel injection pressure concurrently escalating the overall NO_x emissions.

C. Syed Aalam, C.G. Saravanan, M. Kannan investigations have shown that using of biodiesel in direct injection diesel engines can reduce carbon oxides, carbon monoxide, hydrocarbon, and particulate matter emissions, but nitrogen oxide emission may increase.

Kao et al. have studied the effects of aluminium nanofluid combustion in diesel fuel. Their experiments showed that the addition of aluminium nanoparticles to diesel provides a large contact surface area with water and high activity for the decomposition of hydrogen from water during the combustion process. During combustion, alumina serves as a catalyst and the aluminium nanoparticles are denuded and decomposed the water to yield the hydrogen.

2.3 Waste cooking oil blend

K.A. Abed, A.K. El Morsi, M.M. Sayed, A.A. El Shaib, M.S. Gad investigations showed that Increased waste cooking-oil biodiesel percentages in diesel biodiesel blends resulted in increased waste cooking-oil biodiesel mix exhaust gas temperatures in biodiesel-fueled engines.

Y. Zhang a, M.A. Dube a, D.D. McLean a, M. Kates Due to the lower heating value of biodiesel and its blends when compared to diesel fuel, an increase in specific consumption was seen while utilizing biodiesel blends. Also, as the percentage of biodiesel in a blend increase, the thermal efficiency of the blend decreases.

Ahmad Mohammad shirazi, Asadolah Akram, Shahin Rafiee, Elnaz Bagheri Kalhor investigated on a single cylinder diesel engine, waste cooking-oil biodiesel blends of B5 and B10 were compared to diesel fuel. Biodiesel mixes resulted in a 4% increase in specific fuel consumption and a 2.8 percent decrease in thermal efficiency.

Y. Zhang, M.A. Dube, D.D. McLean, M. Kates investigations showed that Transesterification is the most popular route to make biodiesel, which is a catalyzed chemical reaction that involves vegetable oil and an alcohol to form fatty acid alkyl esters (i.e., biodiesel) and glycerol. Triacylglycerols (triglycerides) are three long-chain fatty acids esterified to a glycerol backbone and are the major component of vegetable oil. The three fatty acid chains are liberated from the glycerol skeleton and join with the alcohol to form fatty acid alkyl esters when triacylglycerols react with an alcohol (e.g., methanol) (e.g., fatty acid methyl esters or FAME). As a by-product, glycerol is created. Because of its low cost, methanol is the most often used alcohol, and it is the alcohol of choice in the procedures studied in this study.

Zahira Yaakob, Masita Mohammad, Mohammad Alherbawi, Zahangir Alam, Kamaruzaman Sopian investigation on Biodiesel from renewable resources is one of the most attractive alternative fuels currently being developed because of its low emissions and desirable chemical features, such as non-toxicity, biodegradability, and carbon neutrality biodiesel from renewable resources is one of the most appealing alternative fuels currently being explored.

Mohammed Abdul Raqeeb and Bhargavi R. J. Chem. Pharm. R studies showed that furthermore, unlike non-renewable fuels, biodiesel can be utilized in any regular diesel engine (petroleum or diesel). Nonrenewable fuel has a finite lifespan and emits pollutants like nitrogen, Sulphur, and carbon dioxide, as well as lead and hydrocarbons. The sources of cooking oil vary from country to country. Plant-based lipids, such as corn oil, margarine, coconut oil, palm oil, olive oil, soybean oil, grape seed oil, and canola oil, or animal-based lipids, such as butter, ghee, Kermanshah oil, and fish oil, serve as the foundation for these products. Cooking oil derived from oil palm is the most common in Malaysia.

2.4 Aluminum Oxide Nanoparticles.

Nur Allif Fathurrahman, Cahyo Setyo Wibowob, Mohammad Nasikinc , Munawar Khalila worked on the size of the crystals is very important in nanocomposites to evaluate the mechanical, and chemical properties [26]. The SEM images showed that, most of the nanoparticles obtained from all the abated laser energies have spherical shape with a particle size of less than 100 nm [24]. The SEM of aluminium oxide nanoparticles is shown in Fig. 1. Surface and morphological characterization of aluminium oxide nanoparticles was carried out using scanning electron microscopy. Nanosized spherical shaped aluminium oxide particles obtained were confirmed. The mean size of the particles varies from 31.6 to 47.5 nm.

Venu H, Madhavan V. Effect of Al₂O₃ nanoparticles in biodiesel-diesel-ethanol 2016 investigations showed that Modification in the both base biofuel and engine design is highly distinctive to accomplish extent fuel conversion efficiency for the biodiesel-operated diesel engine. In the present study, the effect of aluminium oxide (Al₂O₃) (75 ppm) nanoparticles on the performance of baseline (unmodified) and modified diesel engine is studied. The experimental results are compared with those of the baseline engine run with sole 20% dairy scum biodiesel (B20) and petro–diesel. From the study, it is clear that the modified engine run with 75-ppm Al₂O₃ blended biodiesel has revealed the better performance than the baseline engine run with sole B20 fuel blend.

2.5 Calcium Oxide Nanoparticles.

Poves, M. D. Z., Martı, D. & Lo, M. Biodiesel from sunflower oil by using activated calcium oxide. 73, 317–326 (2007)work showed that Biodiesel is a clean, renewable, liquid fuel that can be used in existing diesel engines without modification as pure or blend. Transesterification (the primary process for biodiesel generation) via heterogeneous catalysis using low-cost waste feedstocks for catalyst synthesis improves the economics of biodiesel production. Heterogeneous catalysts are preferred for the industrial generation of biodiesel due to their robustness and low costs due to the easy separation and relatively higher reusability. Calcium oxides found in abundance in nature, e.g., in seashells and eggshells, are promising candidates for the synthesis of heterogeneous catalysts. However, process improvements are required to design productive

calcium oxide-based catalysts at an industrial scale. The current work presents an overview of the biodiesel production advancements using calcium oxide-based catalysts (e.g., pure, supported, and mixed with metal oxides). The review discusses different factors involved in the synthesis of calcium oxide-based catalysts, and the effect of reaction parameters on the biodiesel yield of calcium oxide-based catalysis are studied. Further, the common reactor designs used for the heterogeneous catalysis using calcium oxide-based catalysts are explained.

Wendi, Cuaca, V. & Taslim. Effect of Reaction Temperature and Catalyst Concentration for Producing Biodiesel from Waste Beef Tallow Using Heterogeneous Catalyst CaO from Waste Eggshell conducted detailed work on the catalytic activity mechanism, challenges and prospects of the application of calcium oxide-based catalysts in biodiesel generation are discussed. The study of calcium oxide-based catalyst should continue to be evaluated for the potential of their application in the commercial sector as they remain the pivotal goal of these studies.

2.6 SUMMARY OF LITERATURE REVIEW.

A set of literature reviews were referred, and a valid course of action was determined and used in the current research work. The arrived conclusions are:

- Bio- diesel from waste cooking oil efficient in medium loads compared to low or high loads, so it is a good alternative fuel for CRDI engines.
- As we know that non-edible oils are suitable for the performance.

CHAPTER 3

AIM AND SCOPE

3.1 AIM

- Investigation is led on B20 biodiesel because of its good balance of cost, less emissions, cold-weather performance and equipment compatibility.
- To prepare a blend of waste cooking oil and diesel by the process of transesterification with 20% biodiesel and 80% diesel.
- To perform engine test on common rail direct injection (CRDI) by adding Al_2O_3 and Cao nanoparticles to B20 blend.
- To check the reduction of NOx emissions.
- Optimizing the result and analysis of the test

3.2 SCOPE

Biodiesel is considered to be an alternate fuel, plays a major role in the reduction of pollutant particles suspended into atmosphere on emission. It also solves fossil fuels demand by providing a sustainable solution. This research work provides a solution for using high viscous blends in unmodified diesel engines. Also to provide common rail direct injection for the most efficient way of functioning of the diesel engine.

CHAPTER 4

MATERIALS AND METHODS

The process is classified into four phases:

- Preparation of biodiesel.
- A 5L B20 oil blend was prepared using 80% of diesel(1.6L) and 20% of biodiesel (0.4L of waste cooking oil) also known as high performance fuel blend.
- Al₂O₃ and CaO nanoparticles are added to the B20 blend.
- Engine testing and analysis.

4.1 MATERIALS

- Methanol.
- Diesel.
- Waste cooking Oil.
- NaOH (catalyst).
- Al₂O₃ nanoparticles.
- CaO nanoparticles.

4.2 PRODUCTION OF BIO-DIESEL FROM WASTE COOKING OIL

Initially for preparation of Bio Diesel, Waste cooking oil is purchased from outside. Before starting the preparation of bio diesel 5g of Waste cooking oil, 25ml of isopropal alcohol, 4drops of 0.1 n NAOH is taken in a beaker and stired it well. Now the mixture is heated up to 60 degrees and then cooled to the room

temperature. Now 2 drops of phenolphthalein is added to it then the mixture is turned in to pink colour this is a indication that the transesterification process should be started. To start the transesterification process we take 1 liter waste cooking oil and heat it to 60 degrees now 182ml of methanol and 4.5g of NaOH is added now react this mixture till 90 min maintaining up to 60 degree. After reaction is complete the sample solution is poured into a separating funnel, Here the glycerol is separated from the required Biodiesel. Residual Methanol is removed from the sample by a rotatory

TRANSESTERIFICATION PROCESS



Fig 4.1 transesterification of bio-diesel

S.No	Parameters	Results
1	Free fatty acid	0.50%
2	Catalyst (NaOH) quantity	5 grams
3	Oil to methanol molar ratio	1:6
4	Temperature	60 °C
5	Reaction time	90 minutes
6	Yield	93.4 %

Table no. 4.1 Transesterification properties

4.3 BLENDING

- Bio diesel used is B20 which is 20% bio diesel and 80% diesel.
- Quantity is 2L in which 1.6L is diesel and 0.4L is waste cooking oil
- The prepared blend is emulsified using power ultra sound machine which creates fine size emulsions with droplets in the micron and Nano ranges. This helps to mix the prepared blend very efficiently leading to constant viscosity throughout the fuel. This helps in better atomization and burning of fuel.



Fig: 4.2 ultrasonic mixing machine

4.4 PROPERTY TESTING

The main aim of property testing is to compare the physical and chemical properties of the fuel blend with the standard values. The prepared fuel blend is tested for their physical and chemical properties using various scientific instruments, and the results are obtained.

4.4.1 Density measurement

MJ Pratas, SVD Freitas, MB Oliveira, SC Monteiro worked on Density and told that Hydrometer, it is a device which is used to find the specific gravity. It has an accuracy of 0.01. The density of biodiesel blend is measured using hydrometer. Hydrometer with a suitable specific gravity is selected and 250ml of biodiesel blend is poured into the beaker. The hydrometer was immersed into the beaker and stabilization took place. After immersion the specific gravity value was displayed on the hydrometer



Fig 4.3. density measurement

4.4.2 Viscosity measurement

S Kerschbaum, G Rinke worked on viscosity and told that viscosity is measured using a Canon-Fenske Viscometer. The viscosity tube was cleaned with acetone solution and dried. 50ml of biodiesel was poured into the viscosity tube. Suction force was applied to pull the diesel to the upper mark of the viscometer. Viscometer was placed in constant temperature bath with the help of a holder and set the bath temperature at 40°C for a duration of Half hour in order to bring the biodiesel sample to the bath temperature. Once the biodiesel has reached the upper mark the suction force was removed and time was recorded for the biodiesel to reach lower mark from the upper mark.



Fig 4.4 viscosity measurement

4.4.3 Calorific value measurement

K Sivaramakrishnan, P Ravikumar worked on calorific value and told that the calorific value is determined using a Bomb calorimeter, The calorimeter consist of bomb, firing unit, offset stirrer, gas release valve, water jacket, timer, pressure gauge, crucible, ignition wire, thermometer and calorimeter vessel. Calorific value is determined by calculating the amount of heat generator when 10ml of biodiesel blend was burnt in a closed chamber.



Fig 4.5. calorific value measurement

4.5 ENGINE SPECIFICATIONS

The specifications of the engine are used to carry out the tests are as follows:

Rated power	5.2 kW
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Rated speed	1500rpm
Bore diameter (D)	87.5mm
Stroke (L)	110mm
Compression ratio	17:5:1
C.V of Fuel for diesel	42,000kJ/kg
Density of diesel	830 kg/m ³

CHAPTER 5

RESULTS AND DISCUSSION

5.1 FUEL PROPERTY ANALYSIS

The production of biodiesel is optimized and evaluated by performing transesterification process. The transesterification process took place at 60°C for about 90 minutes. Excess methanol at a ratio of 6:1 methanol to oil was used in order to achieve higher yields of biodiesel. NaOH was used as a catalyst with to achieve maximum yield of 96%. It is also observed that properties of high performance fuel sample given in table 5.1 were within the range of ASTM standards of biodiesel. If we consider different property tests of high performance fuel, Biodiesel and Diesel it is observed that copper corrosion test gave the same results for all types of fuels mentioned. In case of Cloud point it is at 9°C for conventional diesel, biodiesel and high-performance fuel blend. During combustion process the calorific value places a very vital role, higher calorific values are recommended. Referring to the figure 5.1 it is observed that there is very less variation in the calorific values (i.e., Diesel-9235.23 Cal/g, Biodiesel-7536.165 Cal/g and high-performance fuel blend-8818.116 Cal/g). Similarly, all the properties were in par with the Conventional diesel. High performance fuel and biodiesel are exhibiting very high pour point temperature, that means these fuels can be used in very low temperature up to -2°C. This is a very desirable quality of the fuel because in many countries like U.S.A, Russia, China, and Canada have temperature below 0 °C.

S.NO	PARAMETERS	RESULT
1.	Acid value	0.42 mg NaOH/g of oil
2.	Density	0.8524 g/cc
3.	Kinematic Viscosity @ 40° C	1.69 cSt
4.	Copper Strip Corrosion @ 60° C for 3hrs	1 a
5.	Flash point by PMCC method	153° C
6.	Fire point by PMCC method	161° C
7.	Cloud point	20° C
8.	Pour point	13° C
9.	Moisture content	0.06%
10.	Calorific value	9842.6 Cal/g

Table no. 5.1 RB20 Fuel properties

5.2. PERFORMANCE GRAPHS

5.2.1 Brake thermal efficiency

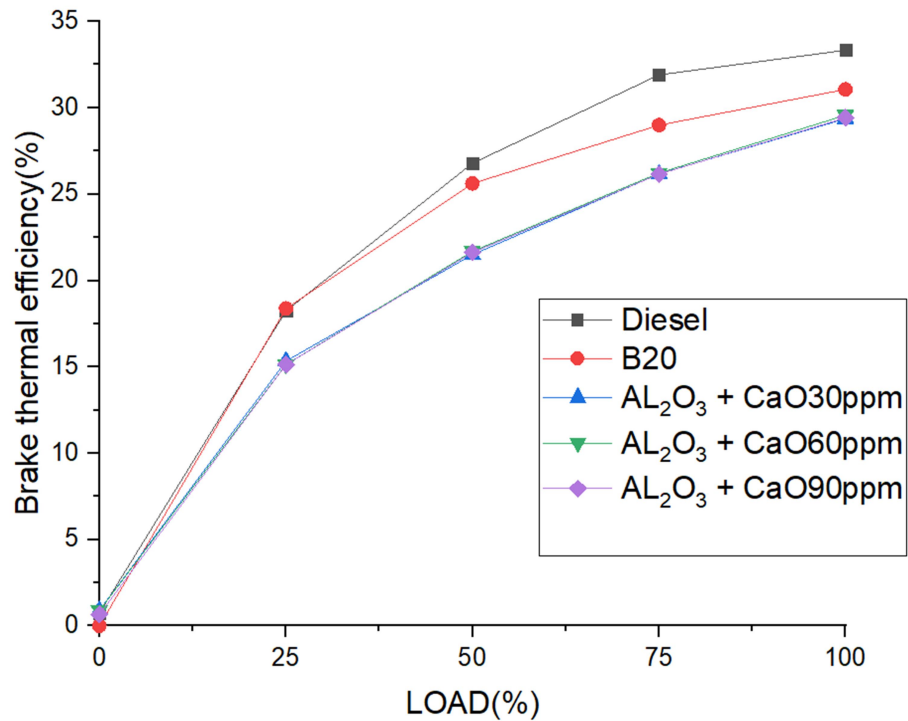


Fig 5.1 brake thermal efficiency

The ratio of the output power to the input power which is equivalent to the energy consumed to produce that power is known as Brake thermal efficiency. The fuel properties like heating value and density will largely affect the brake thermal efficiency. This gives the information of engine performance which converts the heat energy into the mechanical energy.

Brake thermal efficiency will decrease with an increase in the load in all cases of blended fuels. As the load increases there will be a reduction in the heat loss. This brake thermal efficiency of the engine will increase with increase in the ester content in preparing blend. It can be inferred from the graph that the Diesel has the highest BTE followed by B20 and $AL_2O_3 + CaO30ppm$ and $AL_2O_3 + CaO60ppm$ and $AL_2O_3 + CaO90ppm$. It clearly shows that the ($AL_2O_3 + CaO$) has lower BTE and S. Ganesan & S. Mahalingam (2018) investigations stated that among different biodiesels blends, S1 showed better BTE than conventional diesel fuel. This is due to mentha longifolia lower heating value, higher density and increased viscosity which leads to poor atomization and fuel vaporization.

5.2.2 Volumetric efficiency

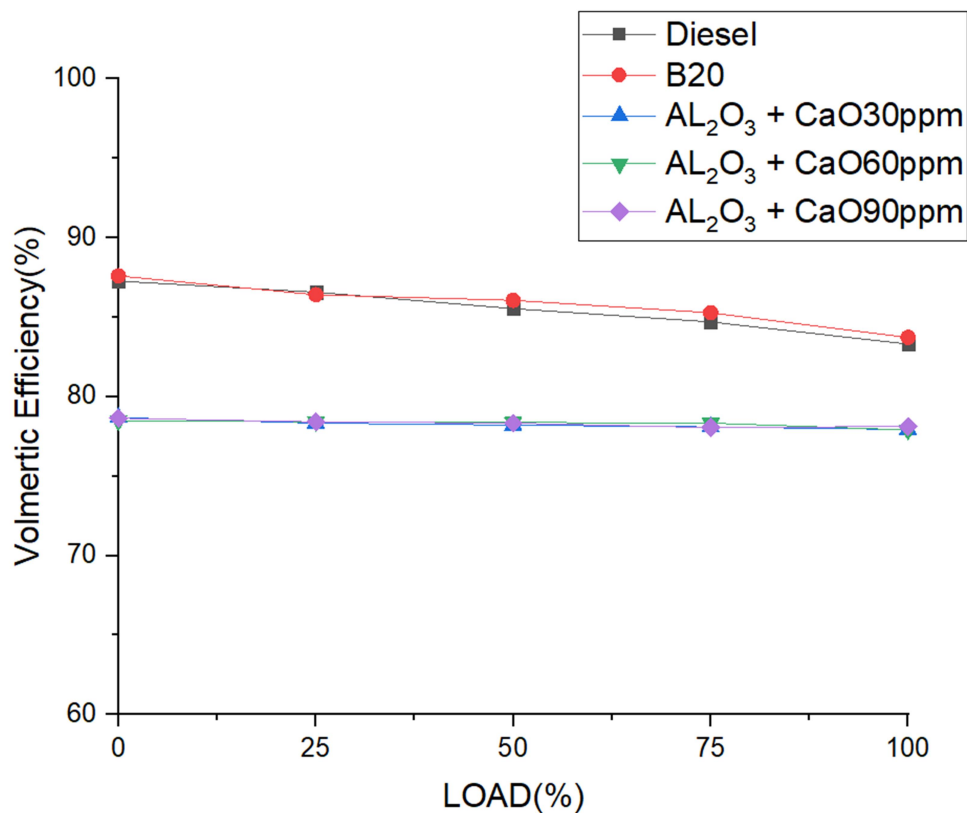


Fig 5.2 volumetric efficiency

Volumetric efficiency is the ratio of volume of air sucked by the engine to volume swept by the piston. Piston moves towards bottom dead center in expansion stroke but the volume it sucks from outside is not the same it has swept while expanding.

As shown in the graph Diesel and B20 has the highest volumetric efficiency but by increasing the load we can see that volumetric efficiency of diesel and B20 is decreased. Whereas $AL_2O_3 + CaO30ppm$, $AL_2O_3 + CaO60ppm$ and $AL_2O_3 + CaO90ppm$ has the lowest volumetric efficiency and equal volumetric efficiency at all load.

5.2.3 Exhaust gas temperature.

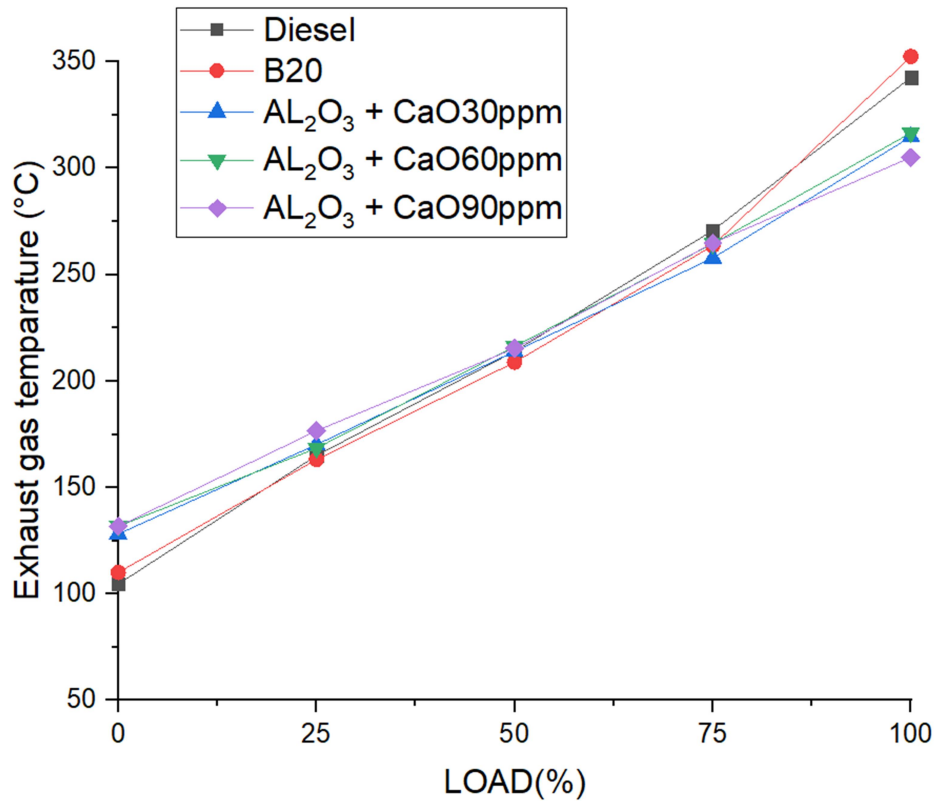


Fig 5.3 exhaust gas temperature.

Exhaust Gas Temperature is a measurement of exhaust gas temperature. It measures gas at the manifold of the engine. For proper functioning of catalytic converter in an internal combustion engine, exhaust gas temperature (EGT) is

needed. As shown in the graph exhaust gas temperature is getting increased by increase in loads, at the maximum load B20 has the highest exhaust gas temperature compared to other fuels. At maximum load $Al_2O_3 + CaO90ppm$ has the lowest exhaust temperature. Abed, K.A.; El Morsi, A.K.; Sayed, M.M.; Shaib, A.A. El; Gad, M.S. (2018) stated that among different biodiesels blends. Exhaust gas temperature increases with increase of engine load for all fuels.

5.2.4 Specific fuel consumption

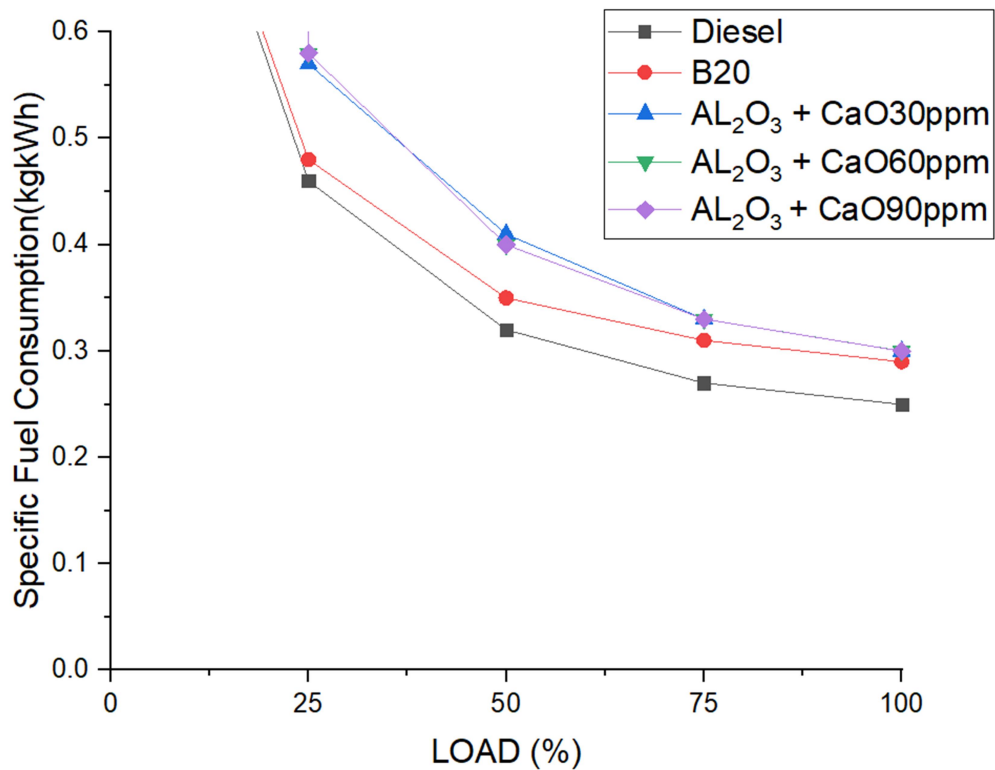


Fig 5.4 specific fuel consumption.

It is amount of fuel consumed by a vehicle for each unit of power output. specific fuel consumption of an engine is the rate of fuel burnt to produce a unit of thrust. It is used to compare the efficiency of IC engines with shaft output.

The graph shows the specific fuel consumption at different loads, As the load increases the specific fuel consumption decreases. In this Diesel has the lowest specific fuel consumption compared to diesel and B20 and others. Aalam, C. Syed; Saravanan, C.G.; Kannan, M. (2015) stated that among different biodiesels blends Aluminum oxide nanoparticles, oxidize the carbon deposits in the engine cylinder leading to decrease fuel consumption

5.3 EMISSION CHARACTERISTICS

5.3.1 Carbon monoxide

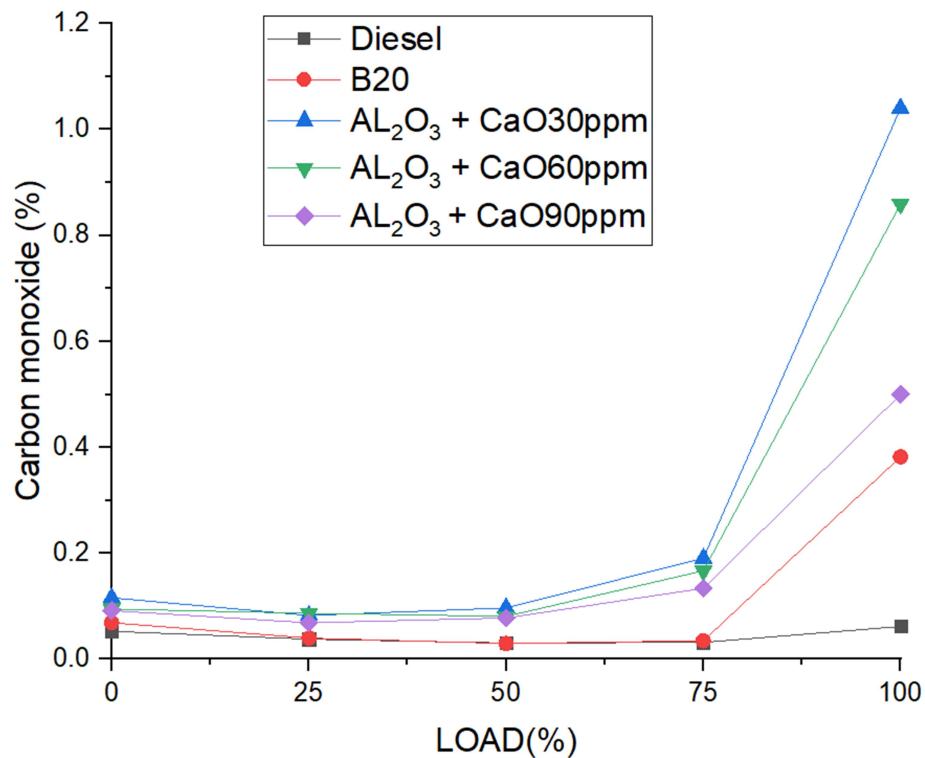


Fig 5.5 carbon monoxide

CO is transparent, tasteless gas. It is very harmful when it is inhaled in large amount. It is very harmful for every living being. Its is released when something is burned outside. It mainly caused due to vehicle emission, burning of fossil fuels.

In this graph the lowest CO emission is for diesel and B20 is approximately same for all loads except 100% load. The highest CO emission is $Al_2O_3 + CaO$ 30ppm at 100% load, but after the maximum load it is as low as diesel. Harish Venu, Venkataramanan Madhavan the nanoparticle blended fuels showed accelerated combustion due to the shortened ignition delay. Due to shortened of ignition delay, the degree of fuel–air mixing and uniform burning could have enhanced. Hence, there was an appreciable reduction in carbon monoxide emissions for aluminum oxide blended biodiesel.

5.3.2 Carbon dioxide

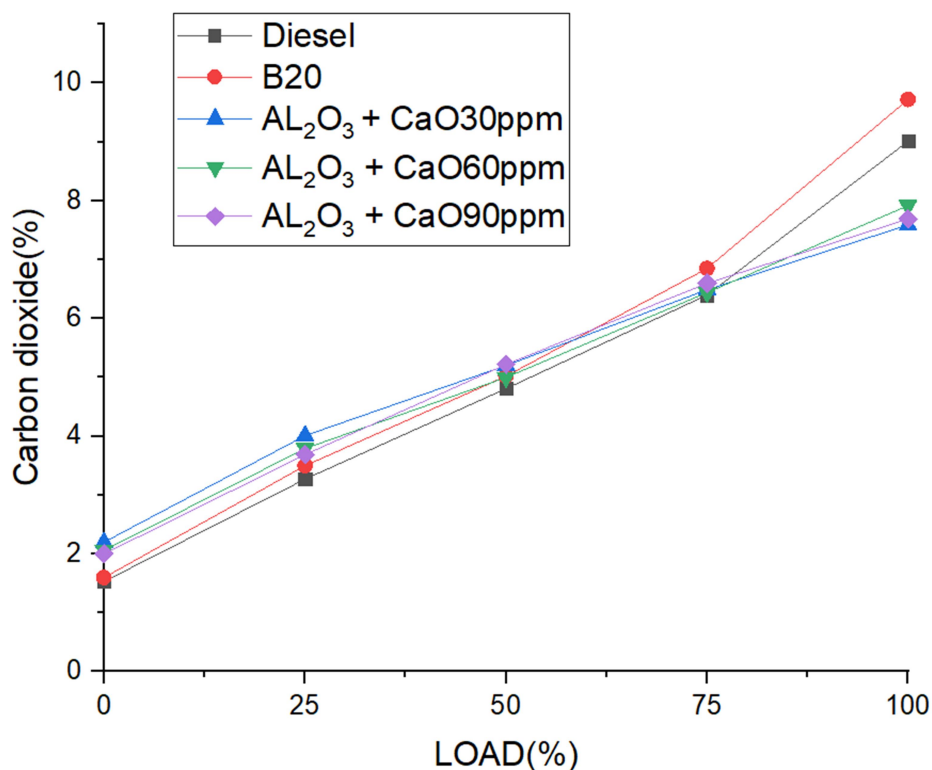


Fig 5.6 carbon dioxide

CO₂ emissions indicate that the air-fuel mixture has completely burned. It demonstrates that the oxygen supply for the fuel sprayed into the chamber was adequate. CO₂ is a basic greenhouse gas that, together with other exhaust gases, is discharged into the environment. CO₂ has little impact on the atmosphere because it is a gas that plants need to survive. Global climate change is mostly caused by carbon dioxide emissions. It is commonly acknowledged that, in order to avert the worst effects of climate change, the world must reduce emissions as soon as possible. In this graph, AL₂O₃ + CaO30ppm has the lowest emission at the maximum load, Diesel has the lowest emission at the lowest load, and B20 has the greatest emission at the lowest load.

5.3.3 Nitrogen oxide (NO_x)

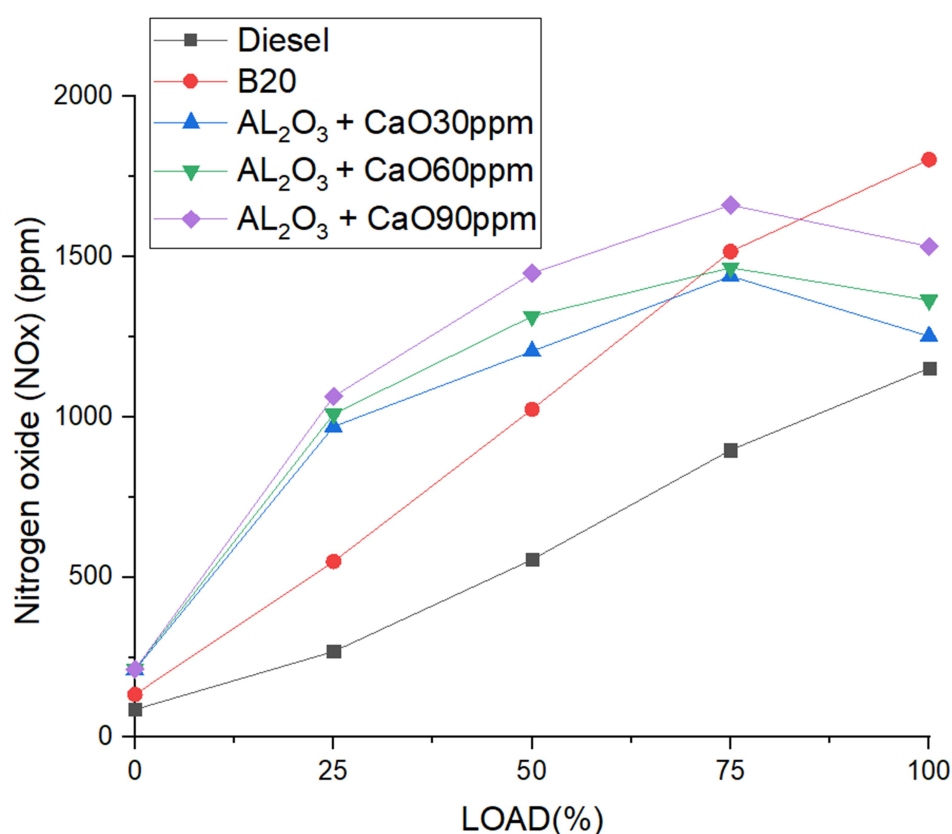


Fig 5.7 nitrogen oxide

Nitrogen Oxides are very poisonous, highly reactive gases. These gases evolved when fuel is burned at high temperatures. NO_x pollution is emitted by automobiles, trucks and various non-road vehicles (example construction equipment, boat). It looks like a brownish gas.

In this graph Diesel has the lowest emission of NO_x at the lowest load and B20 highest load, Highest emission is for AL₂O₃ + CaO30ppm load compared to other loads except at 100% load. Harish Venu, Venkataramanan Madhavan NO_x is reduced at the higher engine load conditions. This may be due to reduced combustion duration. Also, higher ignition delay

5.3.4 Hydrocarbon emission

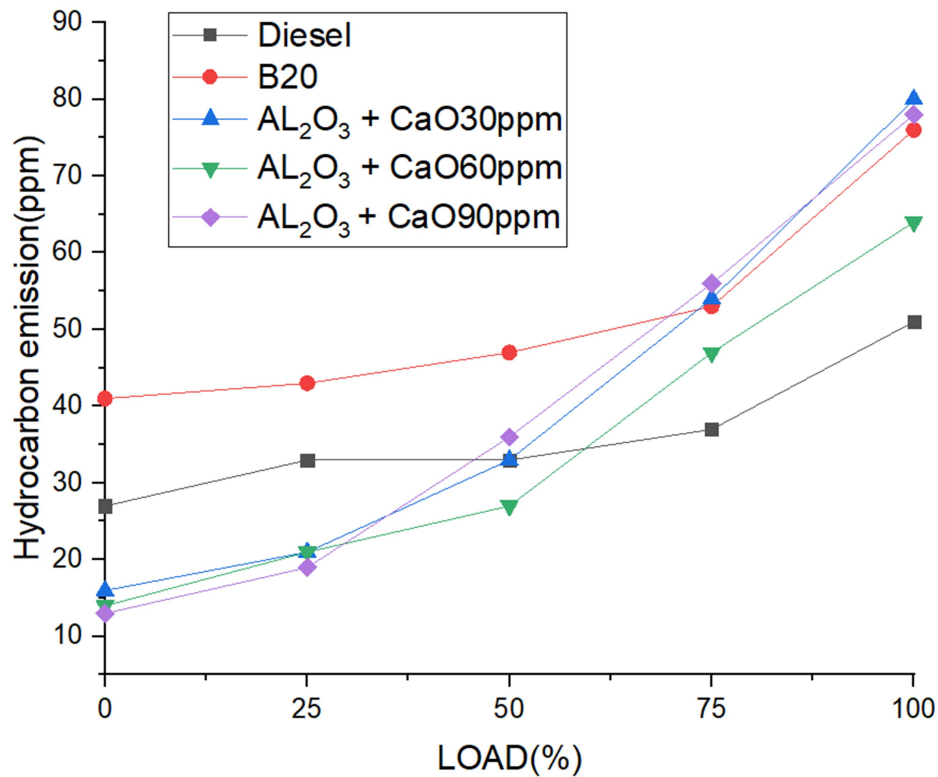


Fig 5.8 hydrocarbon emission

It is mainly due to incomplete combustion of fuel in the combustion chamber. It is simply a unburned fuel being pumped raw into the exhaust system. Mostly may

cause ignition problem or internal engine failure and that reduces compression. Because of poor ignition of fuel will release large of HC to atmosphere.

As shown in the graph $Al_2O_3 + CaO30ppm$ has the highest HC emission value at the maximum load and Diesel has the lowest emission at maximum loads. B20 has the lowest emission value at maximum load & $Al_2O_3 + CaO90ppm$ lowest load at minimum loads. C. Syed Aalam, C.G. Saravanan, M. Kannan the main reason for HC reduction at the lower loads could be accounted for optimum injection timing, injection pressure and presence of pure ethanol in BDE blend which favors better combustion followed by lowest HC emissions. When the IT is advanced to 27 deg BTDC HC emissions increases.

5.3.5 Smoke opacity

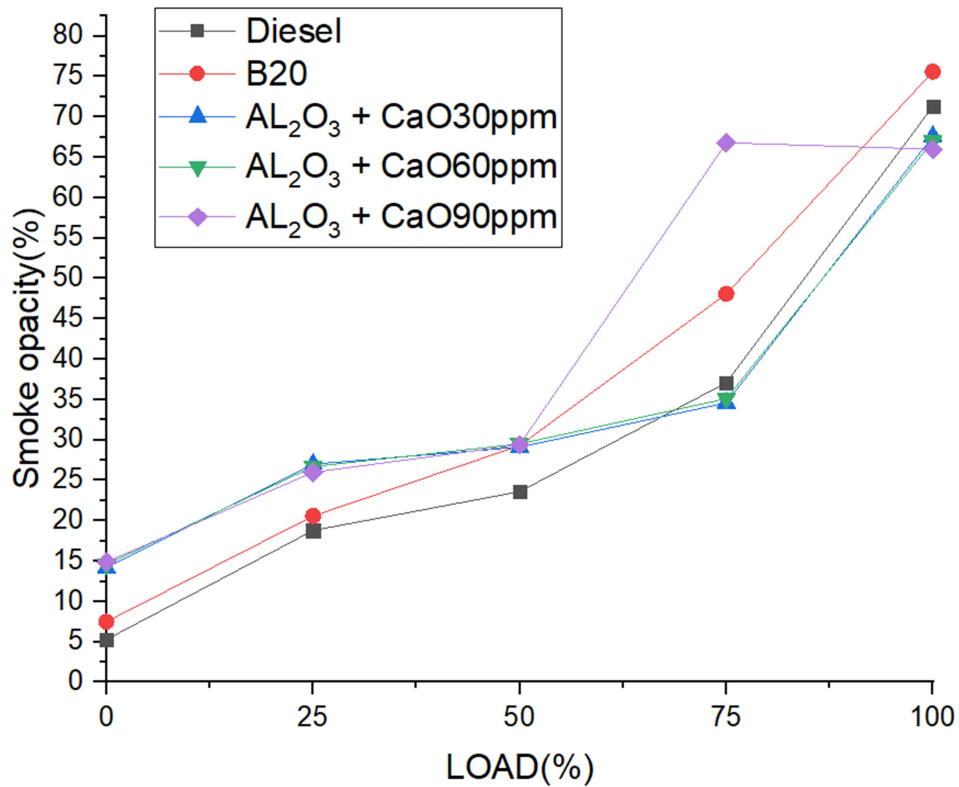


Fig 5.9 smoke opacity

It is a type of emission particles which produce due to the deposition of fuel on the cylinder wall. Smoke opacity is the degree to which smoke block lights and helps in the measuring of the smoke which comes out from the IC engine due to the fuel left on the cylinder walls. It has some particulate matters such as CO, CO₂, NO_x, HC. It is harmful to health as shown in the graph, B20 has the highest opacity at maximum & AL₂O₃ + CaO has the highest opacity minimum loads, AL₂O₃ + CaO90ppm has the lowest opacity at the maximum load Diesel has the lowest opacity at minimum load. C. Syed Aalam, C.G. Saravanan, M. Kannan the main reason for such a drastic smoke reduction at RET IT could be due to the longer ID, lower CD which enhances the vaporization of ethanol in BDE blend thereby promoting complete combustion followed by lowered smoke emissions.

5.4 COMBUSTION GRAPHS

5.4.1 Crank angle vs cylindrical pressure

The below graph represents crank angle and cylindrical pressure, we can see that the cylindrical pressure is more in diesel and B20 has highest CP at all loads. When the crank angle is increasing, the CP for AL₂O₃ + CaO is getting increased. At 0% load AL₂O₃ + CaO has the highest CP and DIESEL has lowest CP. At 25% load AL₂O₃ + CaO has highest CP and DIESEL has lowest CP. At 50% load DIESEL has lowest CP and AL₂O₃ + CaO has lowest CP. At 75% load AL₂O₃ + CaO90ppm has highest CP followed by B20 and lowest is B20. At the highest load (100% load) B20 has highest CP and AL₂O₃ + CaO30ppm has lowest CP. So we can see that increase in crank angle is inversely proportional to cylindrical pressure.

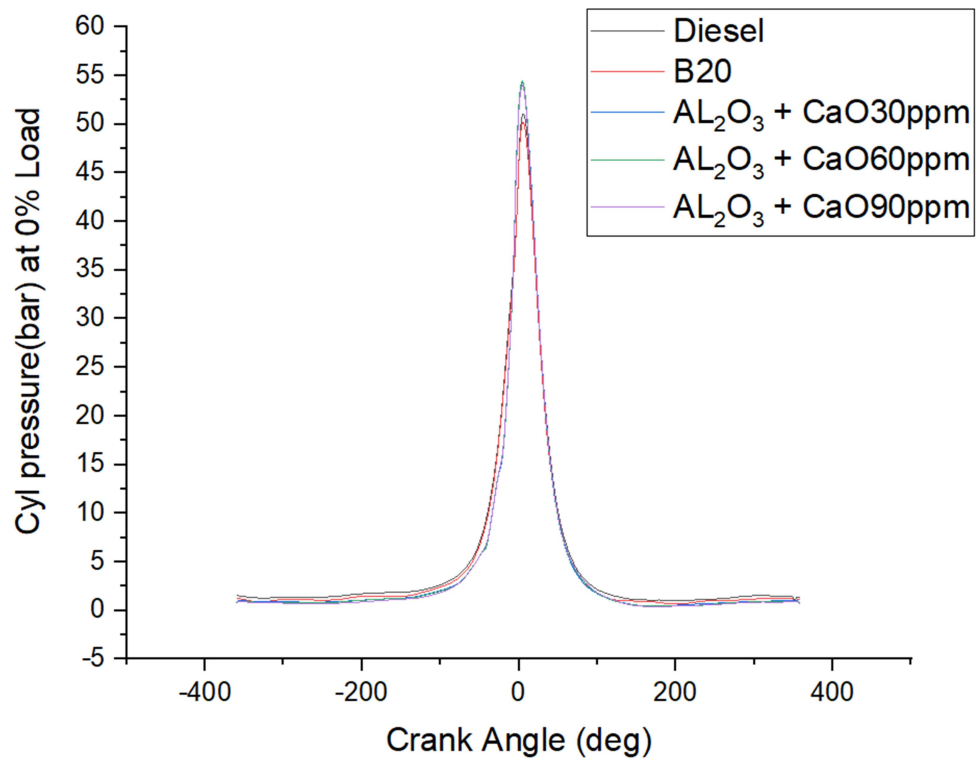


Fig 5.10 cylindrical pressure at 0% load

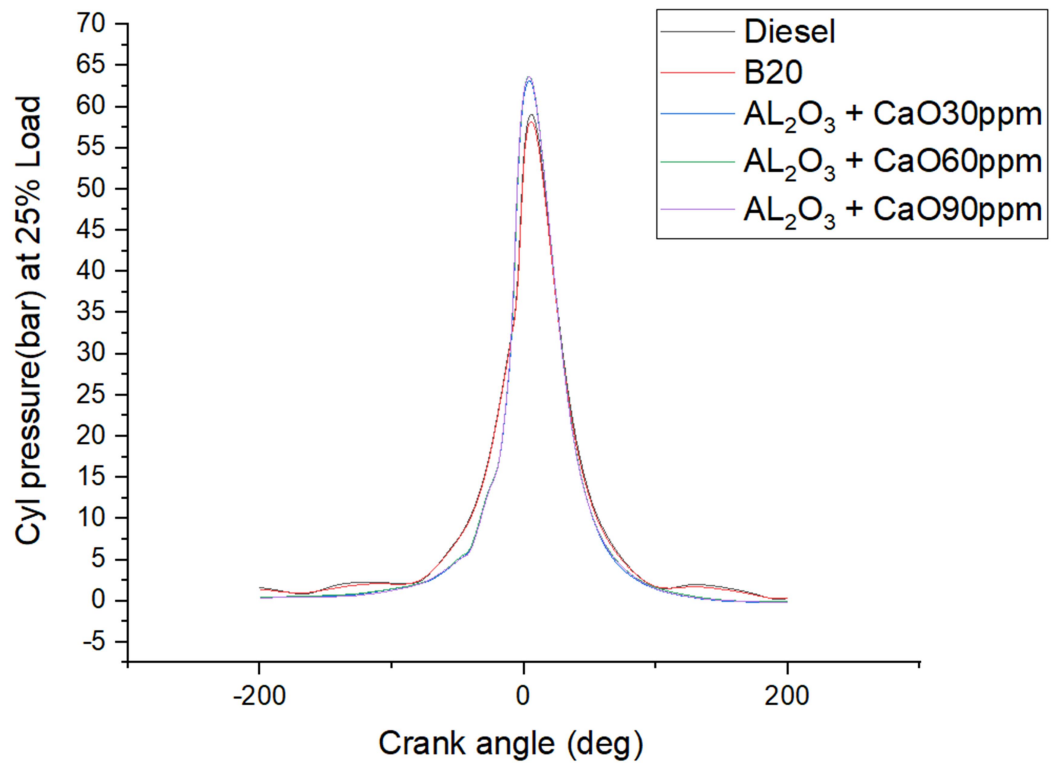


fig 5.11 cylindrical pressure at 25% load

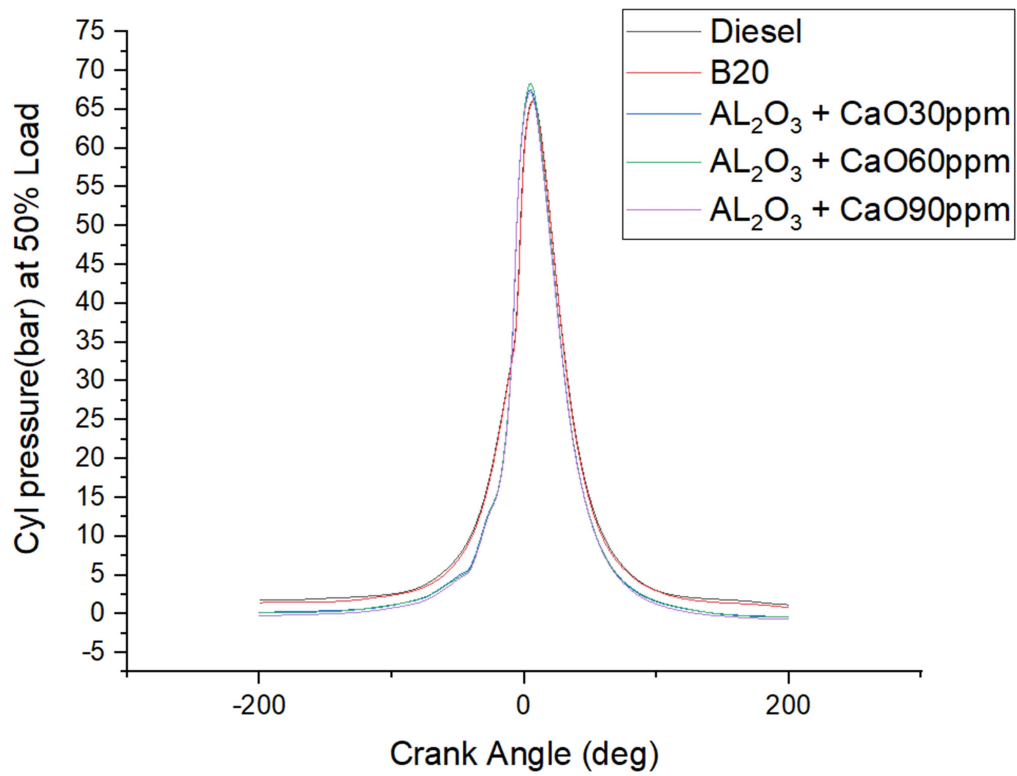


fig 5.12 cylindrical pressure at 50% load

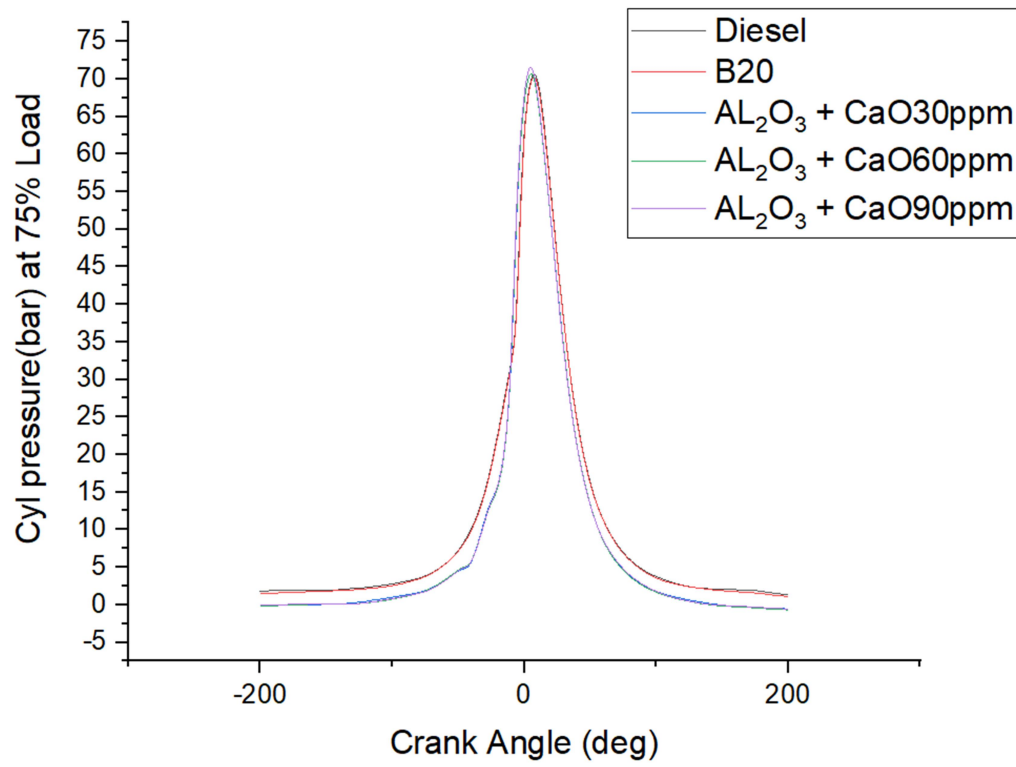


fig 5.13 cylindrical pressure at 75% load

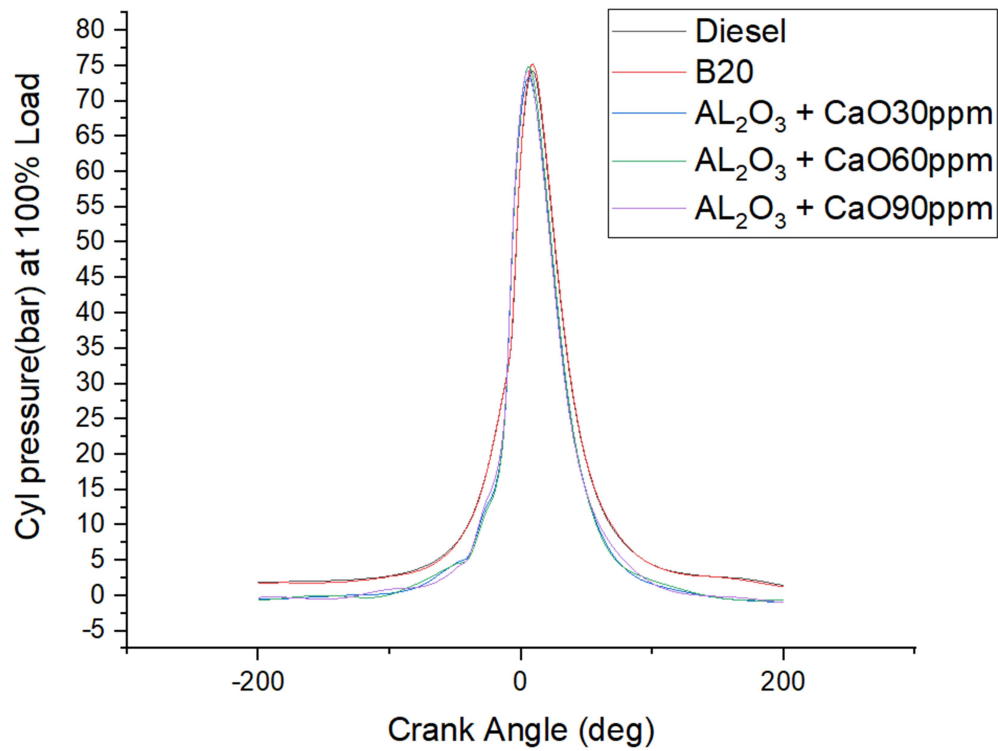


fig 5.14 cylindrical pressure at 100% load

5.4.2 Crank angle vs net HR dQ_n/dq

The net heat release depends on the crank angle. As we can see that AL₂O₃ + CaO60ppm has the highest net heat release in 0% load and the lowest is AL₂O₃ + CaO30ppm. By increasing the load to 25% we can see the fluctuations of diesel at certain crank angles, B20 also has more fluctuations as diesel. RB20 has highest net heat release, the lowest is DIESEL. At 50% load DIESEL has the highest net heat release and AL₂O₃ + CaO60ppm has the lowest net heat release. At 75% load AL₂O₃ + CaO90ppm has highest net heat release and B20 has the lowest heat release. At 100% load AL₂O₃ + CaO60ppm has highest net heat release followed by AL₂O₃ + CaO30ppm, finally the lowest net heat release is for B20.

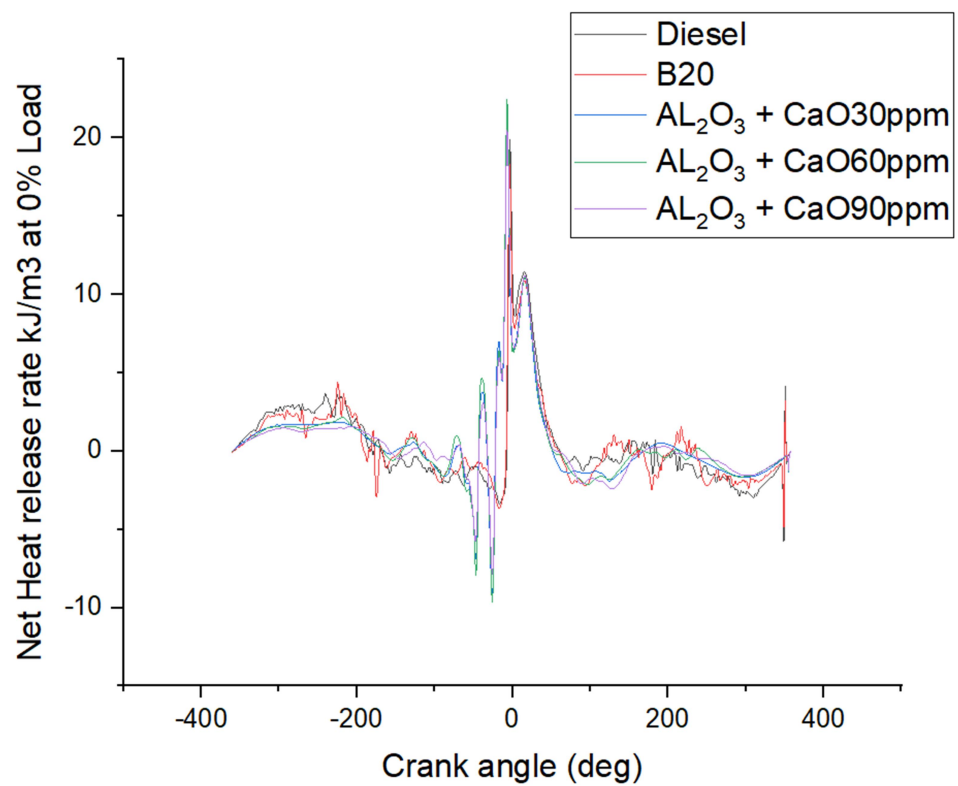


Fig 5.15 net heat release at 0% load

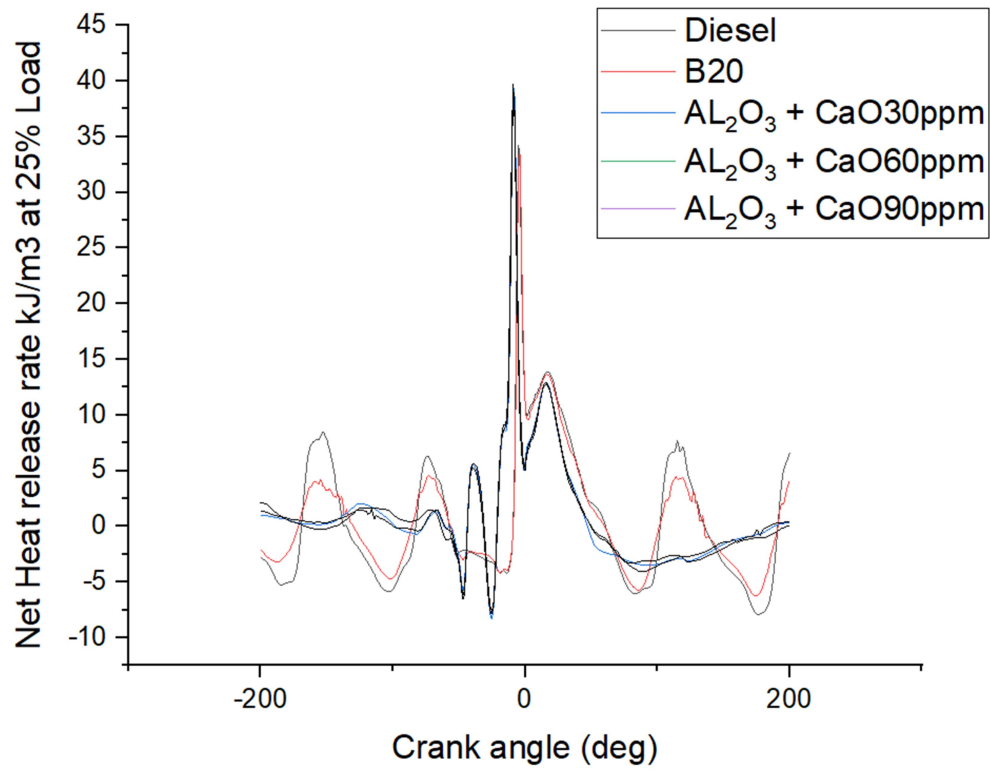


fig 5.16 net heat release at 25% load

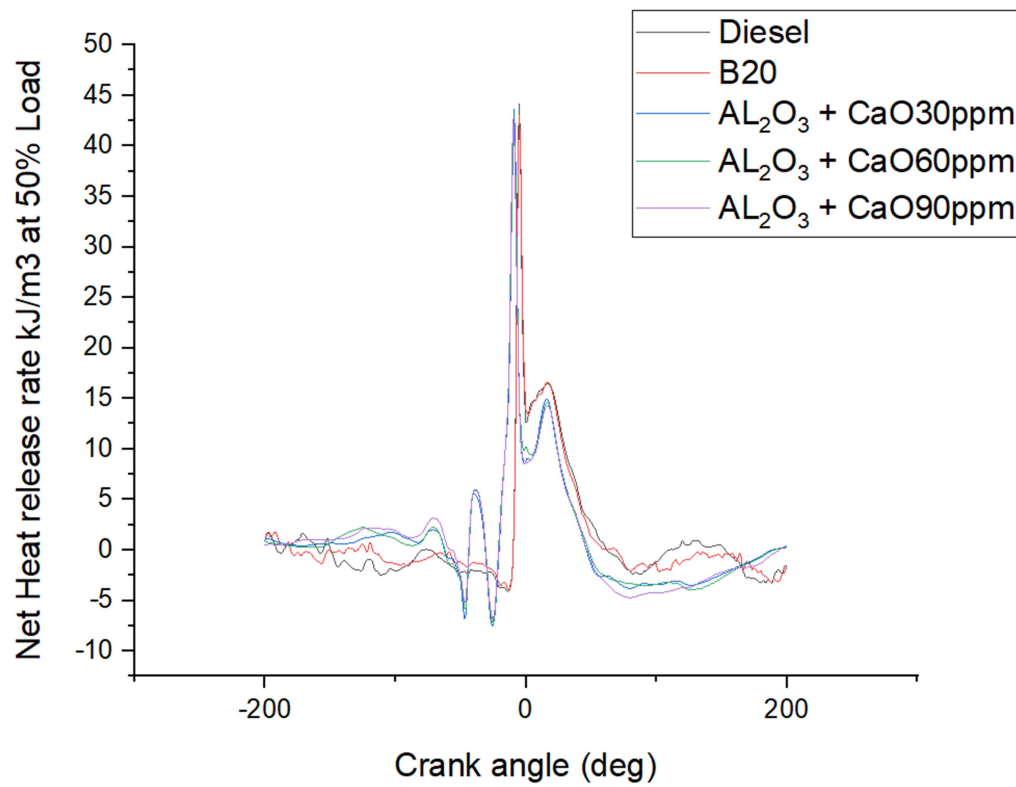


fig 5.17 net heat release at 50% load

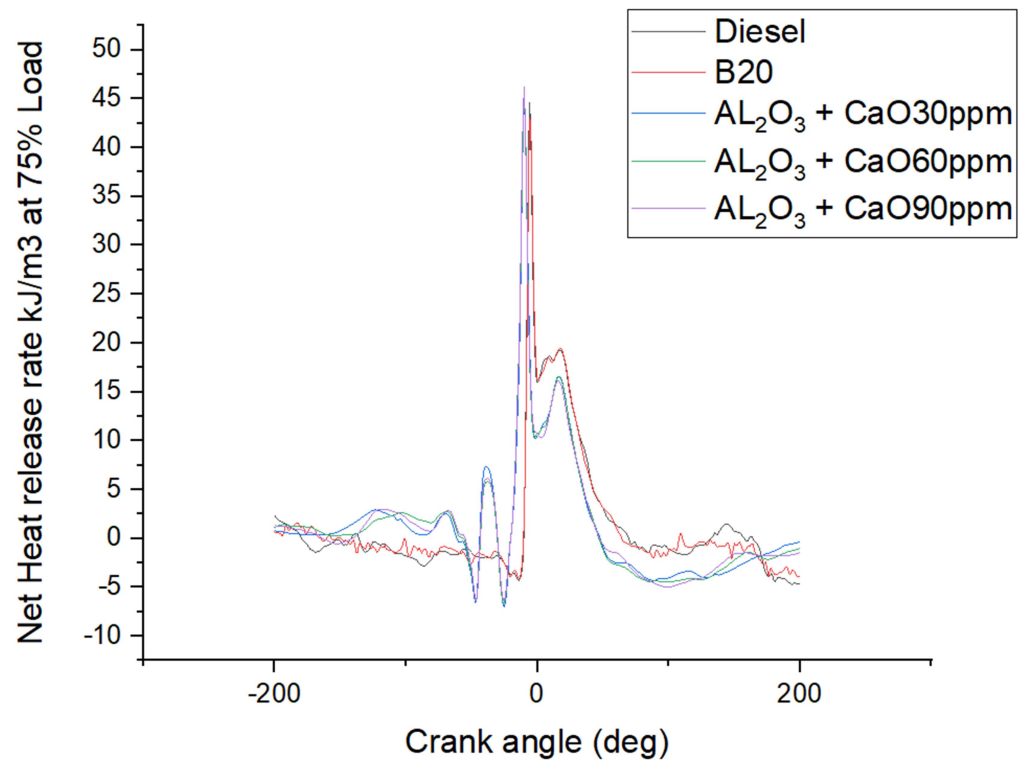


fig 5.18 net heat release at 75% load

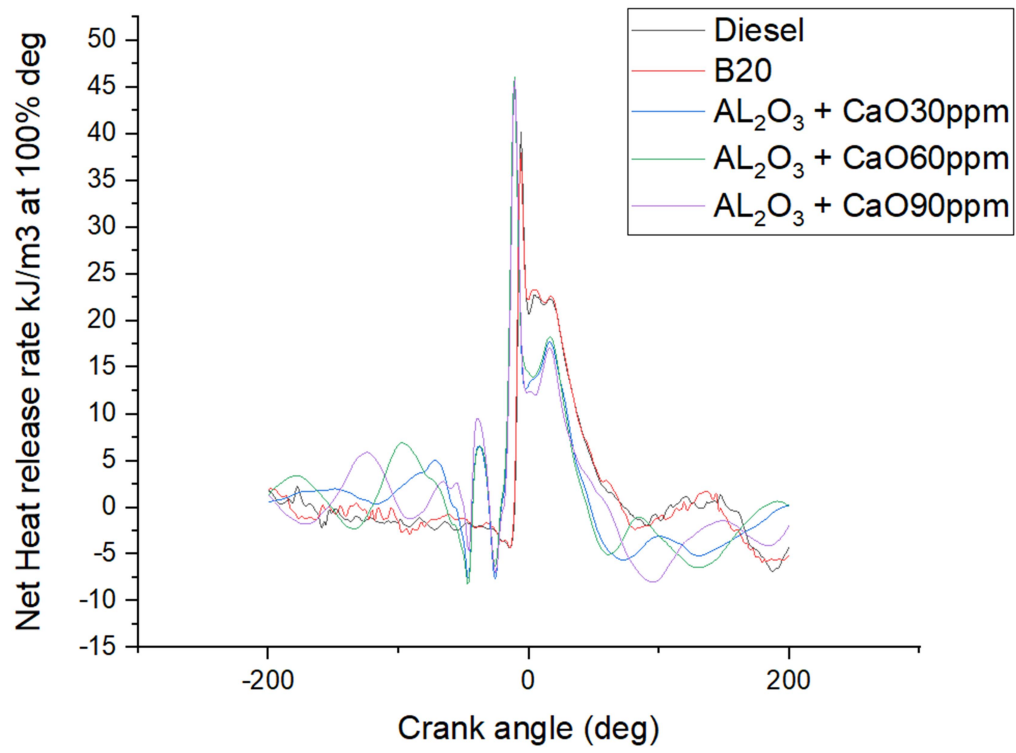


fig 5.19 net heat release at 100% load

CHAPTER 6

SUMMARY AND CONCLUSIONS

- The waste cooking oil biodiesel is prepared successfully according to the standards.
- The high performance blend was prepared and tested physical and chemical properties.
- The high performance fuel blend is tested at different premixed charges at different loads.
- The brake thermal efficiency is found to be very high for Diesel and low for $Al_2O_3 + CaO$
- The volumetric efficiency is found to be very high for Diesel and B20 and low for $Al_2O_3 + CaO$
- $Al_2O_3 + CaO$ has shown improvement in emission characteristics by lowering the carbon monoxide and carbon dioxide throughout the higher loads.
- NO_x emissions were lowest in case of diesel followed by $Al_2O_3 + CaO$
- Hydrocarbon emission was highest in case of $Al_2O_3 + CaO$ 30ppm

CHAPTER 7

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