

Impact of reactivity controlled compression ignition (RCCI) mode engine operation in diesel engine powered 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

H. AJHAY VENKATESAN (38150008)

JEEVA M (38150042)



**DEPARTMENT OF MECHANICAL ENGINEERING
SCHOOL OF MECHANICAL ENGINEERING**

SATHYABAMA

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

Accredited with Grade “A” by NAAC

JEPPIAAR NAGAR, RAJIV GANDHI SALAI, CHENNAI - 600 119

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DEPARTMENT OF MECHANICAL ENGINEERING

BONAFIDE CERTIFICATE

This is to certify that this Project Report is the bonafide work of H. Ajhay Venkatesan (38150008) and Jeeva M (38150042) who carried out the project entitled **"Impact of reactivity controlled compression ignition (RCCI) mode engine operation in diesel engine powered with B20 blend of waste cooking oil biodiesel"** under my / our supervision from to

Internal Guide

Dr. J. JAYAPRABAKAR, M.E., Ph.D.

Head of the Department

Dr. G. ARUNKUMAR, M.E., Ph.D.

Submitted for Viva voce Examination held on _____

Internal Examiner

External Examiner

DECLARATION

We, H. Ajhay Venkatesan (38150008) and Jeeva M (38150042) hereby declare that the Project Report entitled **"Impact of Reactivity Controlled Compression ignition (RCCI) mode engine operation in diesel engine powered with B20 blend 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.

DATE:

PLACE: CHENNAI

1. 
2. 

SIGNATURE OF CANDIDATE

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ABSTRACT

In the present study, the influence of RCCI (Reactivity controlled compression ignition) on performance, emission and combustion of a CRDI engine is experimentally studied. Fuel blend (20% biodiesel, 80% diesel and NaOH catalyst) is prepared. The prepared blend is tested for its properties according to American Society for Testing and Materials (ASTM) standards. The engine study was conducted by having 3 different kinds of injections of 10% Pen RCCI, 20% Pen RCCI and 30% Pen RCCI. The Brake Thermal Efficiency (BTE) is improved upon increasing the injection pressure. Due to this NO_x emissions were increased since higher injection pressures promoted better combustion. But the Specific Fuel Consumption (SFC) is less at higher injection. The CO_2 , Hydrocarbon emissions and smoke opacity values were increased at higher charge. The prepared blend can be used in a CI engine by pre-mixed ignition for improving the performance and combustion characteristics.

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LIST OF SYMBOLS AND ABBREVIATIONS

WCO	-	Waste cooking oil
B20	-	20% biodiesel and 80% diesel
RCCI	-	Reactivity controlled compression ignition
BSFC	-	Brake Specific Fuel Consumption
SFC	-	Specific fuel consumption
BTE	-	Brake thermal efficiency
VE	-	Volumetric efficiency
EGT	-	Exhaust gas temperature
CO	-	Carbon monoxide
CO ₂	-	Carbon dioxide
HC	-	Hydrocarbon
NO _X	-	Nitrogen Oxides
CP	-	Cylindrical pressure
HR	-	Heat release

CHAPTER 1

INTRODUCTION

1.1 INTRODUCTION OF BIO-DIESEL

Biodiesel fuel derived from plants or animals and consisting of long-chain fatty acid ester. It is typically made by chemically reacting lipids like fat, waste oil or another vegetable oil with an alcohol, producing a methyl, ethyl or propyl ester by the process of transesterification. Unlike the vegetables and waste cooking oils used in fuel converted diesel engines, biodiesel is a drop-in biofuels, meaning it is added with the existing diesel since most engines cannot run on pure Biodiesel without modification[20]. Biodiesel is fatty acid ethyl or methyl ester made from virgin or used waste cooking oils (both edible and nonedible) and animal fats. In India important sources for biodiesel are often nonedible oils obtained from plant species like *Jatropha curcas* (Ratanjyot), *Pongamia pinnata* (Karanj), *Alexandrian laurel* (Nagchampa), *Hevea brasiliensis* (Rubber), etc. Biodiesel contains no petroleum, but it is often blended at any level with petroleum diesel to make a biodiesel blend or can be utilized in its pure form. Just like petroleum diesel, biodiesel operates in compression ignition engine; which essentially require very little or no engine modifications because biodiesel has properties similar to petroleum diesel fuels and hence does not require separate infrastructure.

In conventional diesel engines use of biodiesel leads to substantial reduction of unburnt hydrocarbons, carbon monoxide gas and particulate matters. Biodiesel has almost no sulphur, no aromatics and has about 10 per cent built-in oxygen, which helps it to burn fully.

Biodiesel is up to 4 times faster than petroleum diesel and nontoxic. It has a high flash point. It has a mild, rather agreeable odour[9].

1.2 BACKGROUND ON BIODIESEL

Rudolph Diesel himself developed biodiesel in 1890, wherein pure vegetable canvases were utilized in diesel machines for husbandry, where petroleum diesel wasn't available. In 1900, one of the new diesel engines featured at the Paris Exposition was powered by peanut oil[11]. Ultramodern biodiesel energy is an outgrowth of exploration conducted in 1930s in Belgium, which is

made by converting waste cuisine canvas into composites called adipose acid methyl esters. In 1937, G.Chavanne was granted a Belgian patent for an ethyl ester of vegetable oil . In 1938, a passenger bus fueled with vegetable oil ethyl ester plied the route between Brussels and Louvain[24]. In the 1970s, the petroleum oil embargo caused many countries to look to vegetable oil as a possible fuel. The world “biodiesel” was probably first used in about 1984[8].

Process of trans-esterification was used to convert waste cuisine canvas into adipose acid alkyl ester and use as diesel energy relief with lower density of waste cuisine canvas. Biodiesel is the trade name of adipose acid methyl esters. Enterprises over terrain, energy security and use of agro products brought the use of waste cuisine canvas to the van.

Biodiesel is being used Worldwide now, due to enterprises over Global warming. The future of biodiesel lies in the world’s capability to produce renewable feedstock’s similar as waste cuisine canvas and fats to keep the cost of biodiesel competitive with petroleum.

Biodiesel is produced by a process called trans-esterification, in which colorful canvases are converted into methyl esters through a chemical response with methanol or ethanol in the presence of a catalyst, similar as sodium or potassium hydroxide. By- product of the trans-esterification process includes glycerol which needs to be removed from the finished product along with traces of the methanol or ethanol, un-reacted triglycerides and the catalyst.

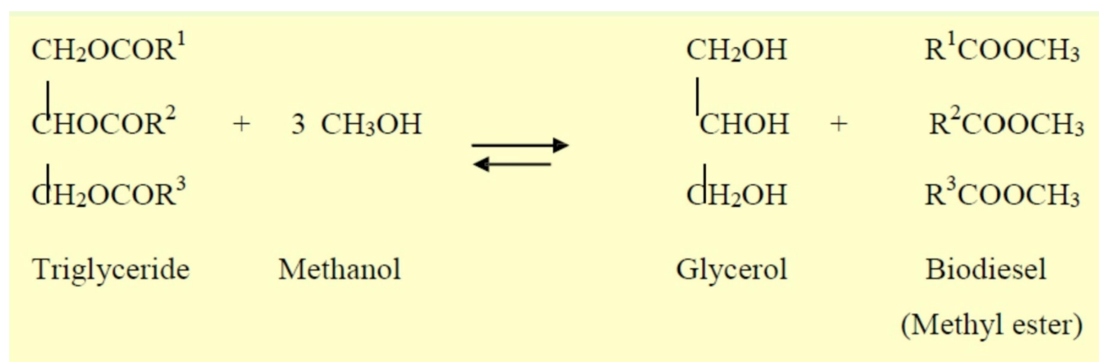


Fig.1.1 Transesterification reactions for biodiesel synthesis

1.3 GENERATIONS OF BIODIESEL

Biofuels exploration and development has led us to three different generations of biofuel. Each generation features a unique feedstock and its own potential benefits and draw backs. When we mention first generation biofuel, we are pertaining to biofuels from an existing row crop like corn ethanol or soy biodiesel. Second generation biofuels are derived from cellulosic biomass like perennial grasses. Third generation biofuels are to be made up of algae. There are three generations of biodiesel.

They are:

- First generation of biofuels
- Second generation of biofuels
- Third generation of biofuels

1.3.1 THE FIRST GENERATION OF BIOFUELS

First generation biofuels symbolize a step towards energy independence and weaning off reactionary powers for energy demands. These biofuels also support agricultural industriousness and pastoral communities through increased demand for crops. This 1st generation biofuels indeed have several disadvantages. They indeed have the eventuality to retain a negative impact on biodiversity and competition for water in some regions. They also only provides a small benefit over reactionary powers in felicitations to hothouse feasts since they still bear high amounts of energy to grow, collect, and process. Current product practices use reactionary powers for power. First generation biofuels also are a further decoration option than gasoline, making it economically insolvable.

1.3.2 THE SECOND GENERATION OF BIOFUELS

Alternate generation biofuels address numerous issues related to 1st generation biofuels. They don't contend between energies and food crops since they're available from distinct biomass. This leaves growers and policy makers with the hard decision of which crop to grow. Cellulosic sources that grow alongside food crops might be used for biomass, like sludge stover (leaves, stalk, and stem of sludge). Still, this is suitable to abate too numerous nutrients from the

soil and would wish to be replenished through toxin. also, the system to supply 2nd generation energies is more elaborate than 1st generation biofuels because it requires pretreating the biomass to release the trapped sugars. this needs further energy and accoutrements.

1.3.3 THE THIRD GENERATION OF BIOFUELS

Third generation biofuels are more energy thick than 1st and 2nd generation biofuels per area of crop. they are dressed as low- cost, high- energy, and fully renewable sources of energy. Algae are profitable therein it can grow in areas infelicitous for 1st and 2nd generation crops, which might relieve stress on water and pastoralist land used. It are frequently grown using sewage, wastewater, and saltwater, like abysses or swab lakes. due to this, there wouldn't be a demand to use water that might rather be used for mortal consumption.

In 1937, it had been a Belgian innovator, who first proposed using transesterification to convert vegetables canvas into carboxylic acid alkyl esters and use them as a diesel canvas relief. Waste vegetable canvas is also appertained to as vegetables canvas that has been cooking of the food and which isn't any longer employed in the farther food product. WCO is been collected in domestic, comercial and artificial, etc.

1.4 Engine Developments:

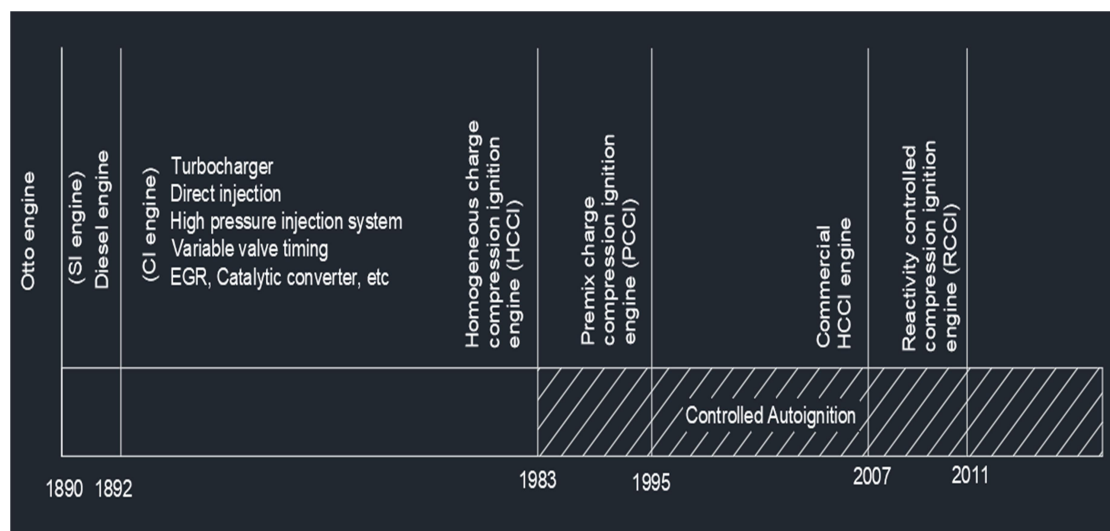


Fig.1.2 History of Engine developments

SI engine

Low emission
Better drivability
Low efficiency

CI engine

High efficiency
Low fuel consumption
Slow response
High emissions

HCCI engine

High efficiency
Low fuel consumption
Low emission
In-controllable

RCCI engine

High thermal efficiency
Low emissions
High degree controllability

1.4 PREPARATION OF BIODIESEL WITH WCO

Biodiesel blended in colorful proportions with petroleum-grounded diesel is used substantially as a transportation energy to power different vehicle machines. Biodiesel can be pumped, stored and burned just like petroleum diesel energy, and can be used pure, or in composites with petroleum diesel energy in any proportion.

1.5 RCCI (REACTIVITY CONTROLLED COMPRESSION IGNITION)

Reactivity controlled compression ignition(RCCI) is a combustion method for engine that uses in-cylinder fuel blending to generate minimal emissions and great thermal efficiency. The fundamental reason for RCCI's high efficiency is that the combustion heat has release has a great degree of controllability, allowing the thermodynamic efficiency to full optimized. RCCI is dual fuel engine combustion technology. The process involves preface of a low reactivity energy into the cylinder to produce a well mixed charge of low reactivity

energy, air and recirculated exhaust gas. The high reactivity fuel is injected before ignition of the premixed fuel occurs using single or dual injections directly into the combustion chamber. Lowered NO_x and PM emission reduced heat transfer losses increased fuel efficiency. Eliminates needs for costly after treatment system[27]

Machine testing were used in reactivity control compression ignition(RCCI) to reach extensive productive combustion upto 0% NO_x and PM[12]. In RCCI is a dual energy machine combustion technology. In which it uses at least two engines of different reactivity. Therefore, it leads to high thermal efficiency and low NO_x[13]. RCCI combustion are been operating over a wide range of machine loads from (4.6- 14.6 bar) with zero amount of NO_x, respectable pressure rise rate and high indicated effectiveness[7]. On RCCI combustion was focused on basic understanding of mixing and auto-ignition processes, at low load operating condition[3]. Totally we have done three types. Which contains Performance test, Emission test and Combustion test. And for each test we have taken five separate injections. The five injections are Diesel, B20, B20+10%Pentanol in RCCI, B20+20%Pentanol in RCCI and B20+30%Pentanol in RCCI.

CHAPTER 2

LITERATURE SURVEY

2.1 INTRODUCTION

A substantial amount research has been undergone into the production of various biodiesels, high performance waste cooking oil fuel properties and their performance in CRDI engine. Though many researchers have investigated various biodiesel blends with pentanol and Waste cooking oil based diesel, minimum number of literature reviews are available on pentanol blends as a substituent for CRDI engine. Numerous amount of research papers have been published in reputed National and International journals, among which performance, combustion and emission characteristics of varying injection pressure for diesel CRDI engine has been reviewed for this present work. Many of the journal mainly concentrated on biodiesel and its blending with diesel and pentanol in different proportions to optimize the blend. Increased injection pressures lead to smooth functioning of the engine. In our topic biodiesel we predominantly focus on reducing the percentage of NO_x. There are different methods to reduce the NO_x percentage and we have used RCCI method. While going through various literatures we have found different methods like EGR and Nano Particles and etc, to reduce the percentage of NO_x.

2.2 Waste Cooking Oil

A diesel test using waste cooking-oil biodiesel fuel was run to research engine performance. By adding 20% of waste cooking-oil biodiesel by volume, there were increase in specific fuel consumption and decrease in thermal efficiency for biodiesel blends compared to diesel fuel[1]. Biodiesel can be produced from many plants such as castor plant, palm tree, sunflower, soybean etc. There is also a growing interest to produce biodiesel from waste material, such as waste cooking oil and the use of waste cooking oil in the biodiesel is environmentally attractive[21]. In addition waste cooking oil also brings many disposal problems all around the world by polluting river water, choking of drainage, etc. So, use of WCO may usher in many benefits if it's used as a fuel source. Thus production of biodiesel from waste vegetable oil is one among the higher ways to utilize it efficiently and economically eliminating the disposal related problems. Waste cooking oil cannot be used directly in diesel engines as it has higher viscosity, free fatty acid and moisture content and these effects can be removed by transesterification of waste cooking oil[18]. Because of a high variety of waste Cooking oils and biodiesel fuels from various origins, it may not be always possible to fulfill the biodiesel standards. Biodiesel fuel having with different physical and chemical fuel properties, may affect fuel injection and combustion in diesel engine[4]. Biodiesel is superior to standard diesel in terms of its sulphur content, aromatic content and flash point. These advantages could be a key solution to reduce the problem of urban pollution since transport sector is an important contributor of the total gas emission[2]. Biodiesel, as an alternate fuel, has many merits. it's derived from a renewable, domestic resource, thereby relieving reliance on petroleum fuel imports. it's biodegradable and non-toxic. Compared to petroleum-based diesel, biodiesel contains a more favourable combustion emission profile, like low emissions of CO, particulate and unburned hydrocarbons[28]. Biodiesel can be described as carbon neutral' as this fuel does not produce carbon dioxide (CO₂). Biodiesel degrades rapidly in the environment and is non-toxic, moreover storing biodiesel is also very safe[23]. Alkali catalysts

utilized in transesterification is hydroxide or alkali methoxides. However, potassium hydroxide was considered as a best catalyst for transesterification of used waste cooking oils. In this study, the transesterification of WCO was carried out for a reaction temperature of up to 70°C [2]. People round the world use edible oils for cooking, after which the oil is discarded. the number of heat and water increases the hydrolysis of triglycerides and thus the percent of free acid (FFA) within the oil. The water and FFA content have a negative influence on the transesterification reaction. The WCO price is 2 to three times cheaper than vegetable oils, and it also reduces the worth of waste removal and treatment [25]. An alkali catalysis is required for transesterification process thanks to the presence of FFA in WCO. The WCO was heated up to 60 C in flat bottom flask in order to prevent evaporation of methanol from the solution [26].

2.2 Reactivity Controlled Compression Ignition

RCCI (reactivity controlled compression ignition) engines, which use the combined fueling strategies of conventional diesel and gasoline engines, have drawn much attention because of its high efficiency and low emissions [14]. The original idea of RCCI is to use gasoline and diesel to function low and high reactivity fuels, respectively. Some investigators turned their attention on applying preference and renewable energies to RCCI motors. For example, in the previous studies, natural gas, methanol, ethanol were used as the low reactivity fuel; meanwhile, diesel was still adopted as the high reactivity fuel [19][15]. The insufficiency of fossil energies put the gasoline at a disadvantage when used on RCCI. Further more, the gasoline contains polycyclic aromatic hydrocarbon (PAH), which is conducive to the formation of soot [10]. To solve the matter , researchers are trying to find other alternative fuels. Among them, alcohol fuels have gradually developed into potential low-activity fuels thanks to their oxidation and reproducibility for RCCI engines. In addition, alcohol energies have advanced vaporization idle heat and no PAH. These properties are believed to be beneficial in reducing NO_x and soot emissions from RCCI engines[29,5]. Reactivity-controlled compression ignition may be a dual-fuel partially premixed combustion concept, which uses port fuel injection system of a low-reactivity fuel (e.g. gasoline, gas and alcohol fuels) and direct injection of a high-reactivity fuel (e.g. diesel and biodiesel) with blending inside the combustion chamber to increase the combustion duration and to provide

phasing control[22]. For various fuel combinations, the engine research community has shown that running dual-fuel engines in RCCI mode, improves thermal efficiency and leads to ultra-low engine-out nitrous oxides and soot. However, stable RCCI combustion is restricted to a particular load range, counting on available hardware. At low loads, the combustion efficiency can drop significantly, whereas at high loads, the maximum in-cylinder pressure can easily exceed the engine design limit[17]. For high load operation, the problem is related to high peak in-cylinder pressures and pressure rise rates resulting from rapid RCCI combustion[16].

2.4 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 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 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 Reactivity Controlled Compression Ignition (RCCI) test in CRDI engine by 10%, 20% and 30% premixed charge injection.

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 various waste cooking oil in CRDI engines. Also to provide Reactivity Controlled Compression Ignition (RCCI) for the most efficient way of functioning of the diesel engine.

CHAPTER 4

MATERIALS AND METHODS

The process is classified into three phases:

- Preparation of biodiesel.
- A 4L B20 oil blend was prepared using 80% of diesel(3L) and 20% of biodiesel (1L of Waste cooking oil) also known as high performance fuel blend.
- Engine testing and analysis.

4.1 MATERIALS

- Methanol
- Diesel
- Waste Cooking oil
- NaOH (catalyst)

4.2 PRODUCTION OF BIO-DIESEL FROM WASTE COOKING OIL

In transesterification process we have taken preheated oil of 1.2litre around 60 degree room temperature. Added 180ml of methanol and 4.5g of sodium hydroxide catalyst. And then reaction is been rested for 90minutes. Then in the separation process the biodiesel is been transferred into the separating funnel to the layer separation and it's been rested for 2hours. Then it forms two layers as top layer is Bio-diesel and the bottom layers is glycerine. And the last step is washing the Bio-diesel. Where the water is being heated upto 70degrees. Then the final preparation of biodiesel in which the biodiesel is been heated at

110degrees continuously for the next 45minutes. Then the final product is been obtained from 1.2liters of waste cooking oil to 1litre of Bio-diesel.

Bio-Diesel Preparation Process



Fig 4.1 Preparation of bio-diesel

4.3 BLENDING

- Bio diesel used is B20 which is 20% bio diesel and 80% diesel.
- Quantity is 4L in which 3L is diesel and 1L is Waste cooking oil

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

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 4.2. density measurement

4.4.2 Viscosity measurement

The 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 4.3 viscosity measurement

4.4.3 Calorific value measurement

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.



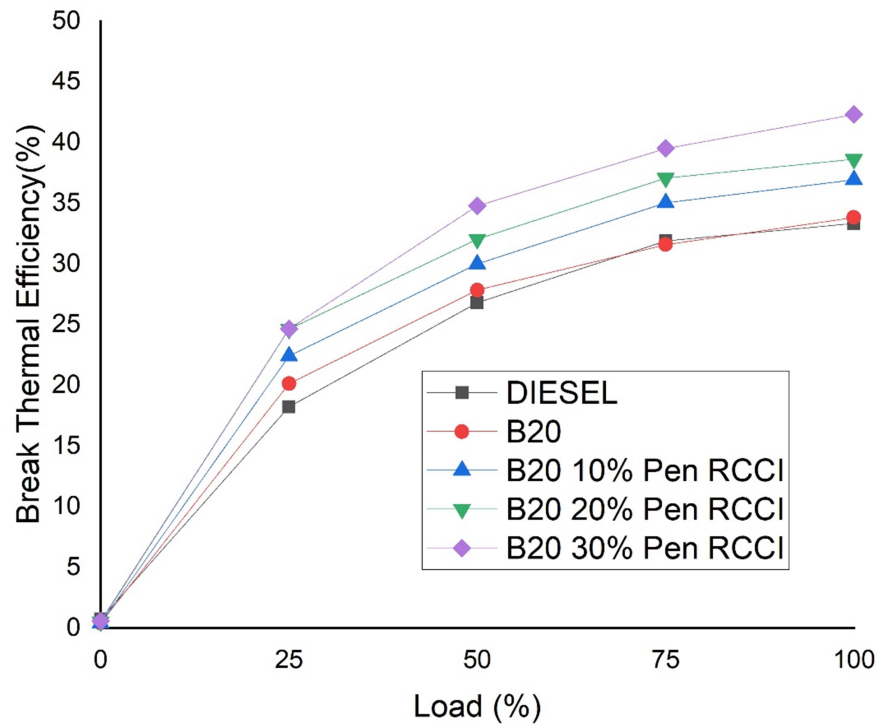
Fig 4.4 calorific value measurement

CHAPTER 5

RESULTS AND DISCUSSION

The production of biodiesel is optimized and evaluated by performing transesterification process. The transesterification process took place at 60-65°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. KOH 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 -1 °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- 7445.65 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 -8 °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.

5.2. PERFORMANCE GRAPHS



5.2.1 Brake thermal efficiency

Fig 5.1 break thermal efficiency

It was observed that for each machine cargo, there's a significant variation in BTE, as much as four points in BTE at certain loads. These are the effects of varying CRDI engine premixed ratio to vary at a given BMEP, depending on load[6].

Brake thermal efficiency will increase 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. It can be inferred from the graph that the B20-30% Pen RCCI has the highest

BTE followed by B20-20% Pen RCCI and B20-10% Pen RCCI diesel and B20-normal. It clearly shows that the 30% premixed charge has the highest BTE throughout the injection compare to the B20-20% Pen RCCI, B20-10% Pen RCCI, B20 and Diesel.

5.2.2 Volumetric efficiency

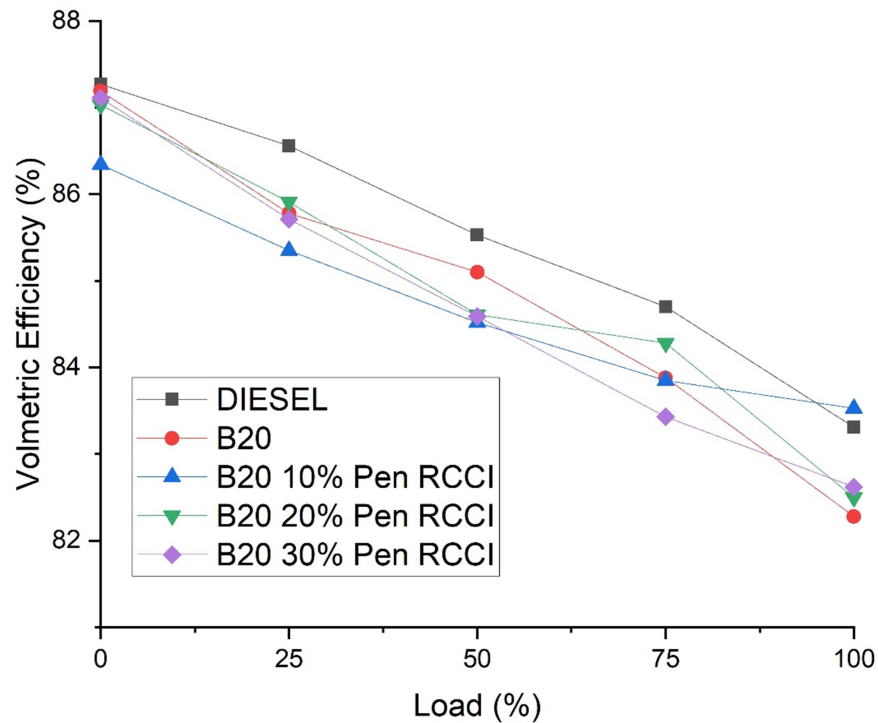


Fig 5.2 volumetric efficiency

Volumetric efficiency is the rate of volume of air smelled by the machine 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.

It can be inferred in the graph that diesel has the highest volumetric efficiency but by increasing the load we can see that volumetric efficiency is

decreasing at various conditions. B20-10% Pen RCCI has the highest volumetric efficiency at the maximum load.

5.2.3 Exhaust gas temperature

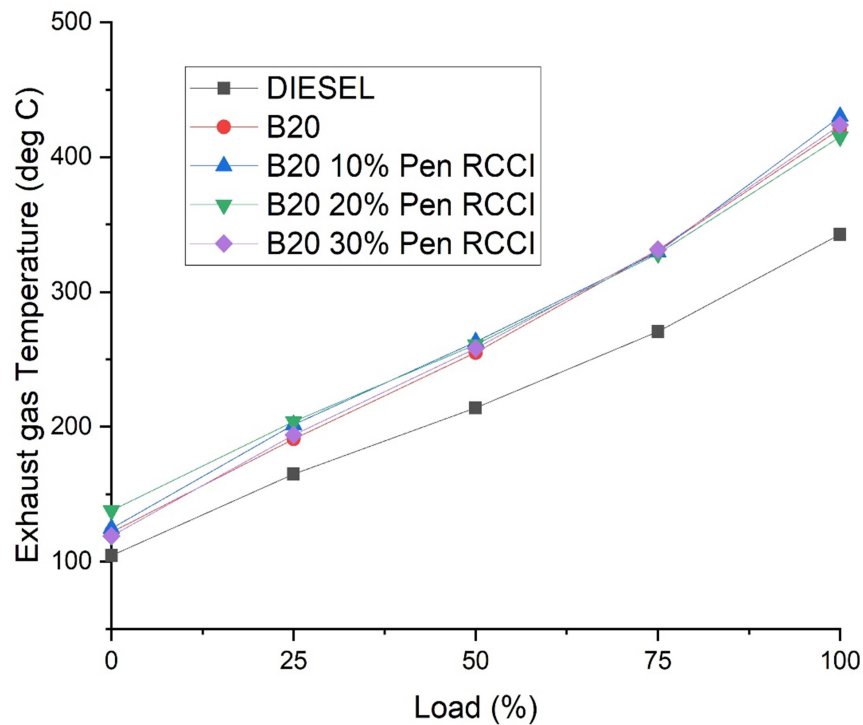


Fig 5.3 exhaust gas temperature.

An exhaust gas temperature is a meter used to monitor the exhaust gas temperature of an internal combustion engine in conjunction. The exhaust gas temperature either raises or reductions depending on the energy.

As shown in the graph exhaust gas temperature is getting increased by increase in loads, at the maximum load RB20 has the highest exhaust gas temperature compared to other fuels. At maximum load RB20-PM30% has the lowest exhaust temperature.

5.2.4 Specific fuel consumption

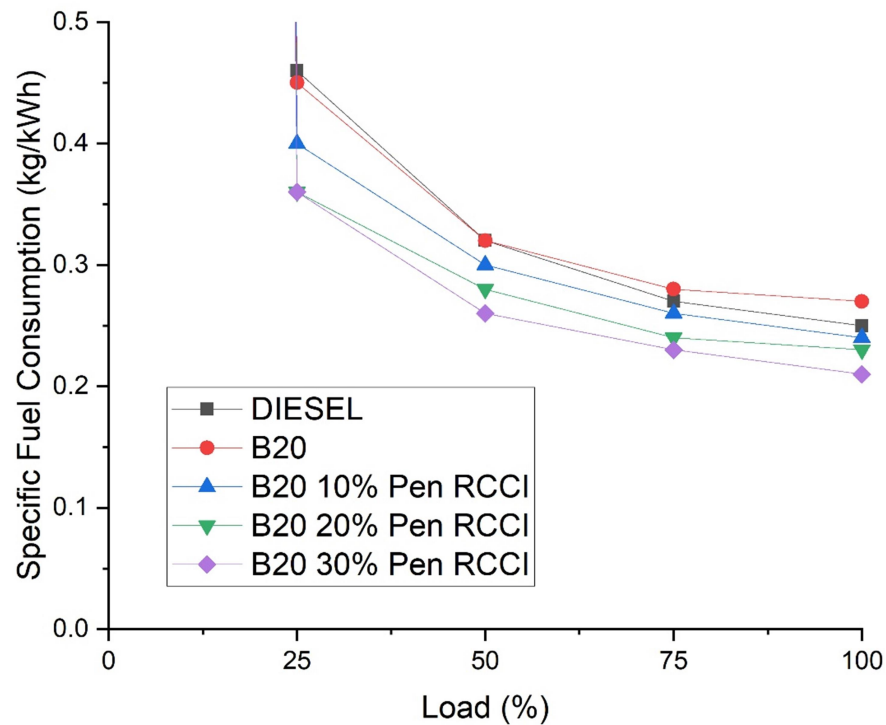


Fig 5.4 specific fuel consumption.

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 CRDI engines.

The graph shows the specific fuel consumption at different loads, As the load increases the specific fuel consumption decreases. In this B20-30% Pen RCCI has the lowest specific fuel consumption compared to B20-10% Pen RCCI, B20-20% Pen RCCI , diesel and B20.

5.3 EMISSION CHARACTERISTICS

5.3.1 Carbon monoxide

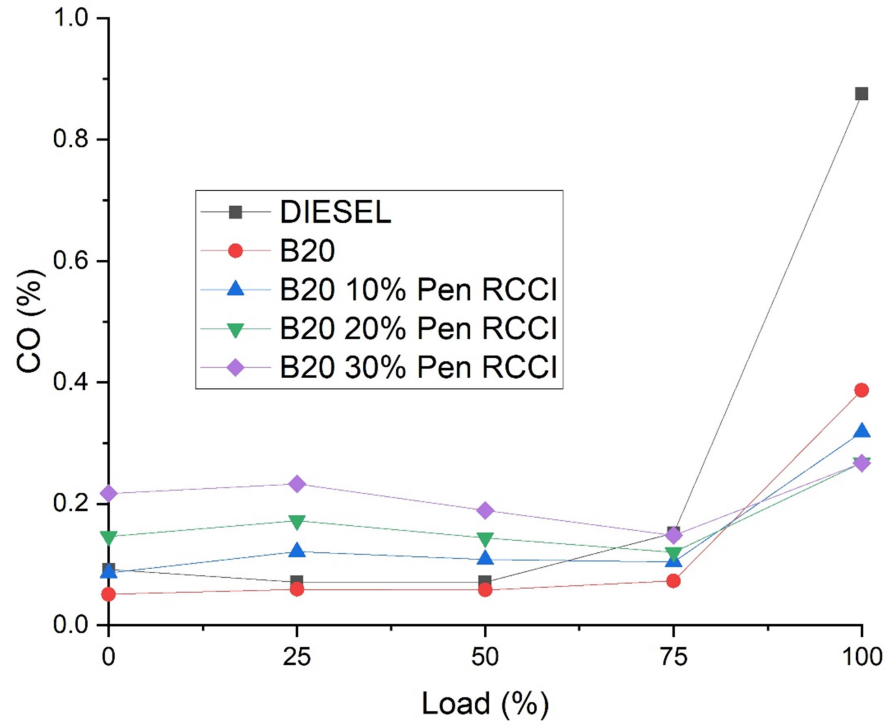


Fig 5.5 carbon monoxide

Carbon monoxide is the product of incomplete combustion in RCCI engine. It's produced by the partial oxidation of carbon containing composites. usually in combustion procedure carbon dioxide (CO₂) is formed after combustion.

In this graph the lowest CO emission is for diesel and B20 is approximately same. The highest CO emission is B30-30% Pen RCCI at certain load, but after the maximum load it is as low as diesel.

5.3.2 Carbon dioxide

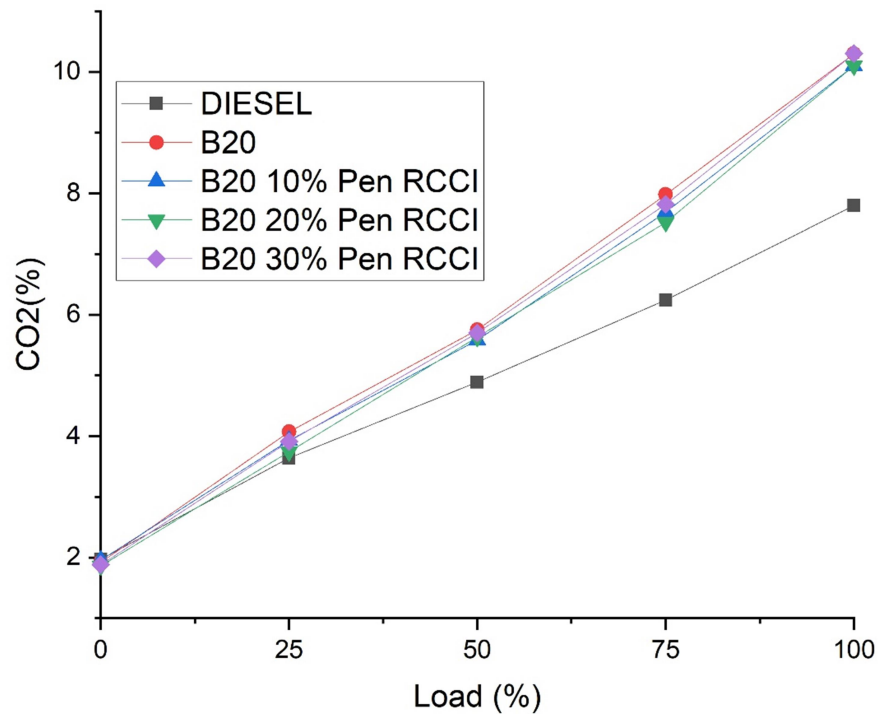


Fig 5.6 carbon dioxide

Gasoline contains carbon and hydrogen atoms. During combustion, the carbon (C) from the fuel combines with oxygen (O₂) from the air to produce carbon dioxide (CO₂).

In this graph B20-30% Pen RCCI has the lowest emission in the highest load and in the lowest load, B20 has the highest emission at highest load, but most fuels are almost same at the end.

5.3.3 Nitrogen oxide (NOx)

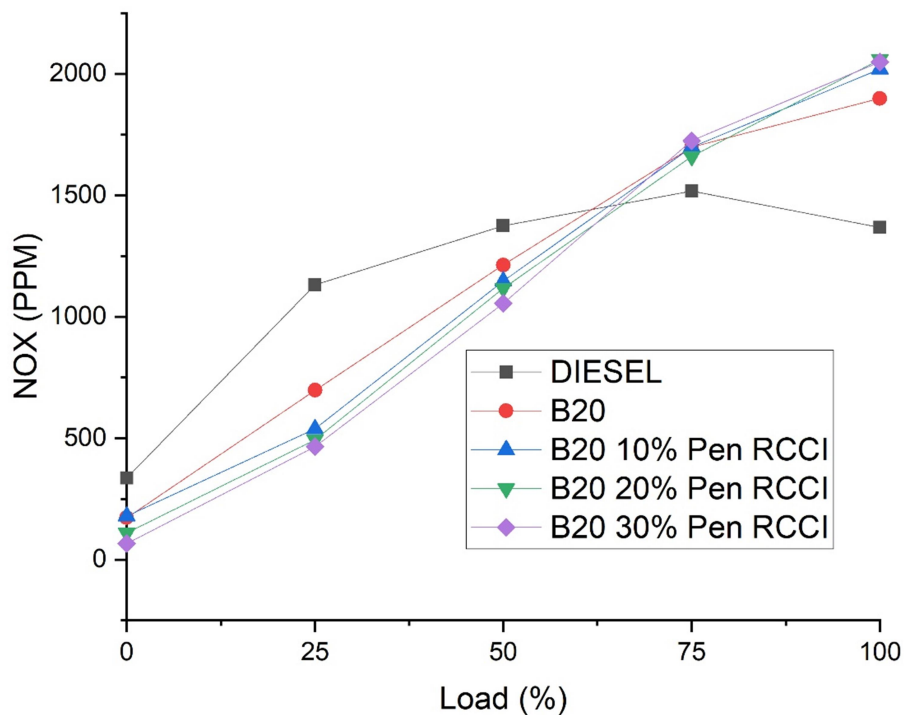


Fig 5.7 nitrogen oxide

CRDI engines operate at a higher temperature and pressure than petrol engines. These conditions leads to the production of NOx gases. Nitrogen Oxides are very poisonous, highly reactive gases. These gases evolved when fuel is burned at high temperatures. NOx 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 NOX at the lowest load and highest load, Highest emission is for B20-30% Pen RCCI load compared to B20, Diesel, B20-20% Pen RCCI and B20-10% Pen RCCI.

5.3.4 Hydrocarbon emission

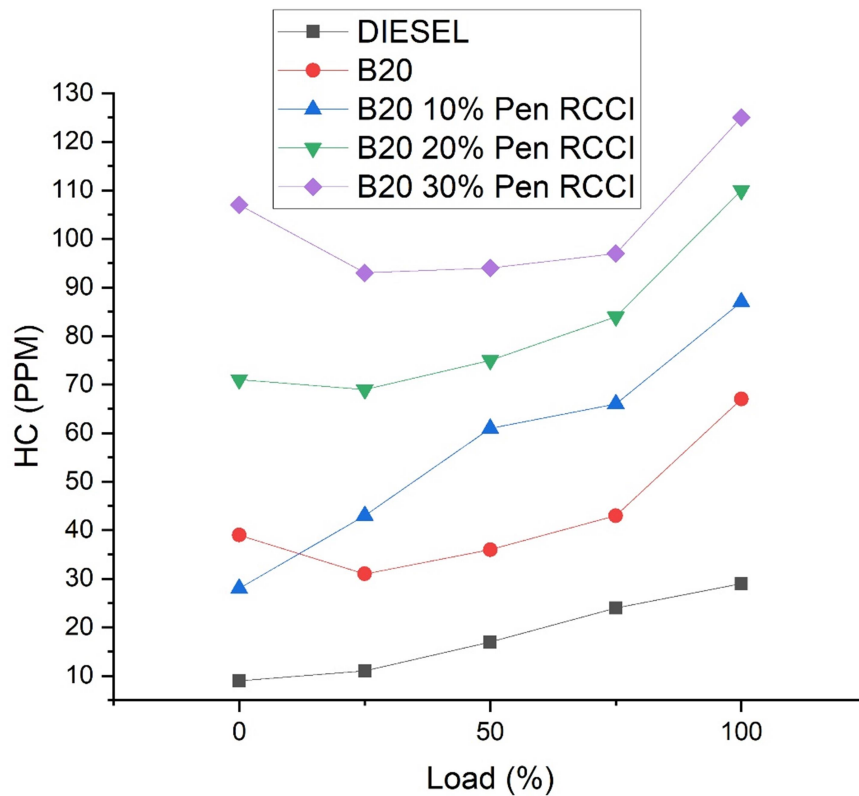


Fig 5.8 hydrocarbon emission

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.

In this graph B20-30% Pen RCCI has the highest HC emission value at the maximum load. DIESEL has the lowest emission value at both maximum & minimum loads.

5.3.5 Smoke opacity

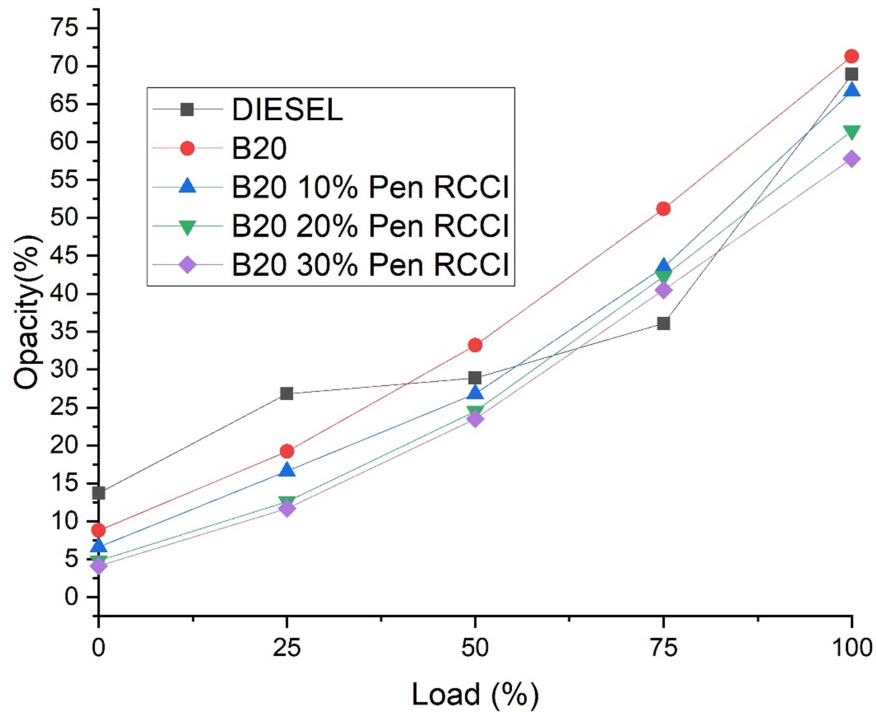


Fig 5.9 smoke opacity

In this 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 CRDI engine due to the fuel left on the cylinder walls.

In this graph, B20 has the highest opacity at both maximum & minimum loads, B20-30% Pen RCCI has the lowest opacity at the maximum load.

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 B20-30% Pen RCCI has lowest CP in lower loads. When the crank angle is increasing, the CP for B20-30% Pen RCCI is getting increased. At 0% load DIESEL has the highest CP and B20-30% Pen RCCI has lowest CP. At 25% load RB20-30% Pen RCCI has lowest CP and DIESEL has highest CP. Load at 50% load DIESEL has highest CP followed by B20 and B20-30% Pen RCCI has lowest CP. At 75% load B20-30% Pen RCCI has highest CP followed by B20-20% Pen RCCI and lowest is B20. At the highest load (100% load) B20-30% Pen RCCI has highest CP and DIESEL has lowest CP. So we can see that increase in crank angle is inversely proportional to cylindrical pressure.

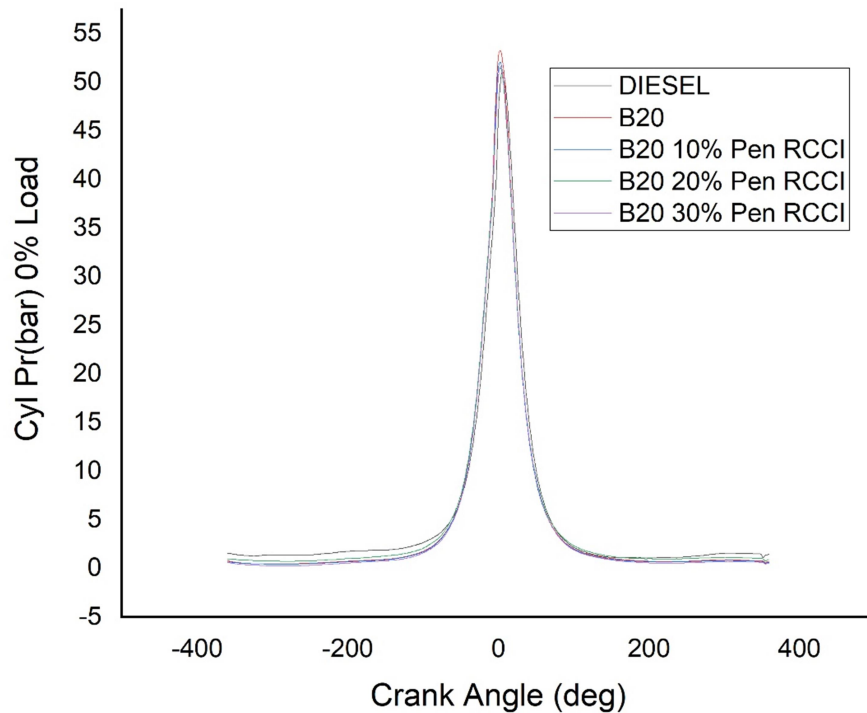


Fig 5.10 cylindrical pressure at 0% load

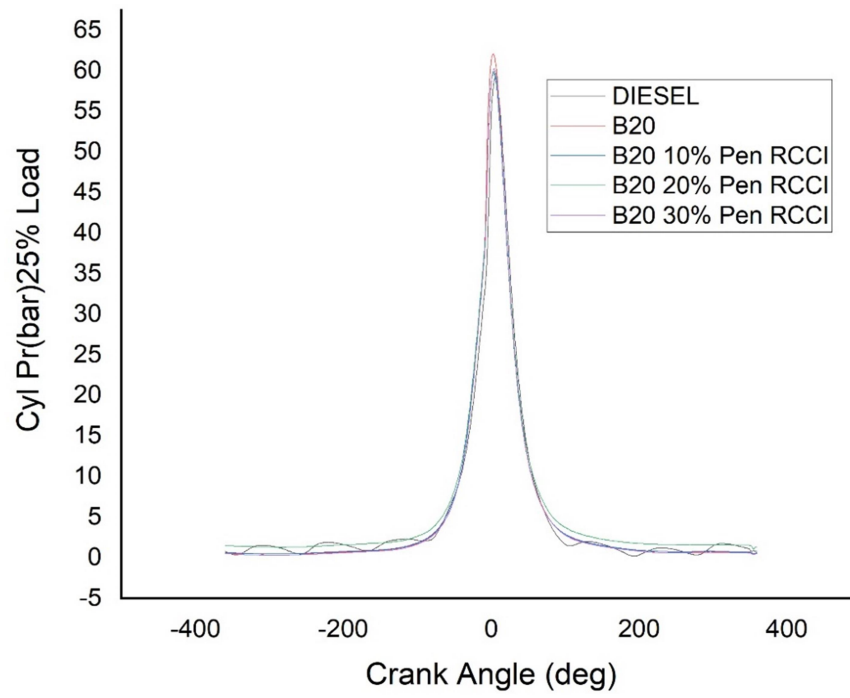


fig 5.11 cylindrical pressure at 25% load

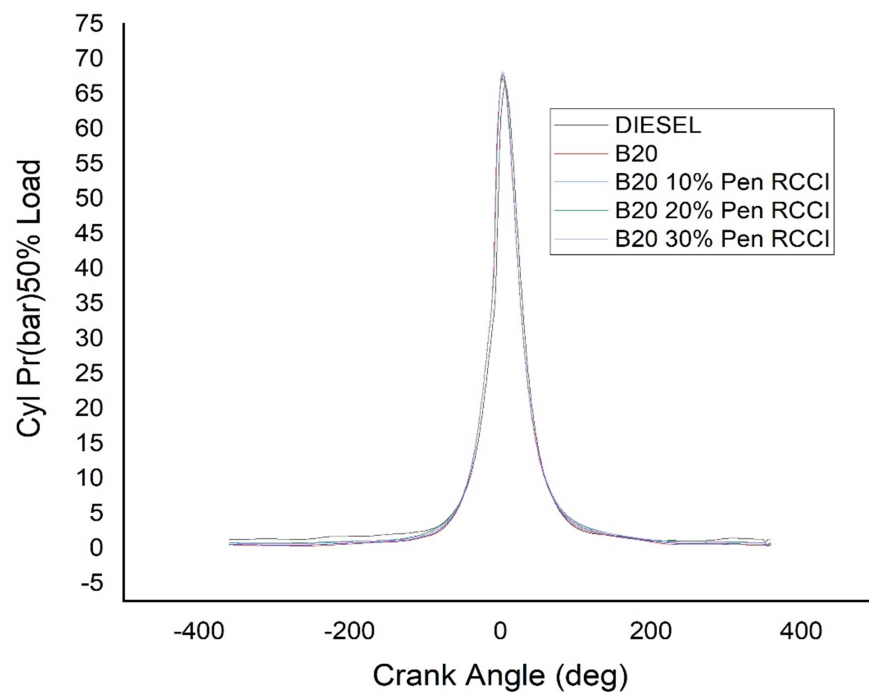


fig 5.12 cylindrical pressure at 50% load

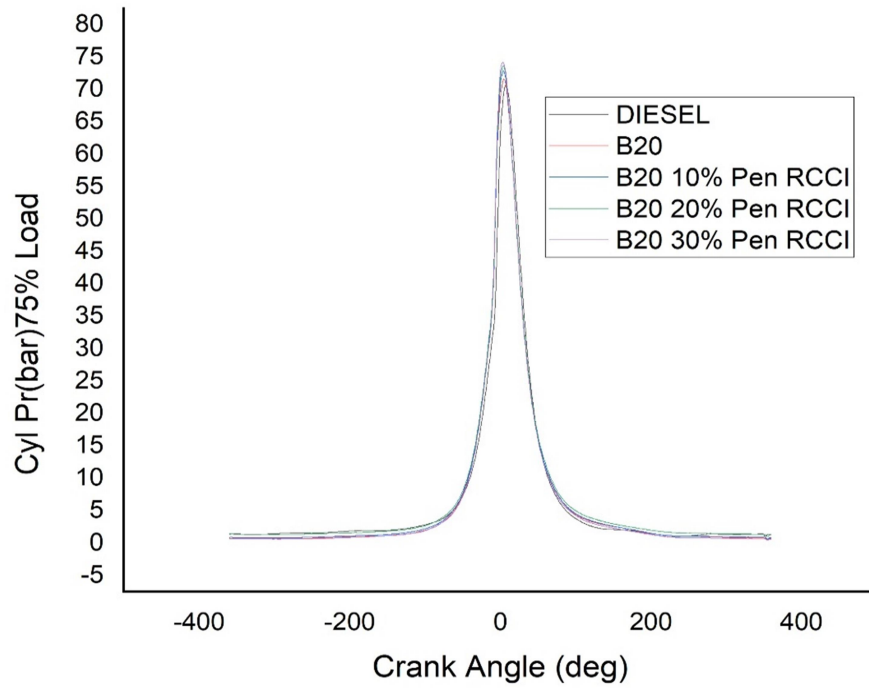


fig 5.13 cylindrical pressure at 75% load

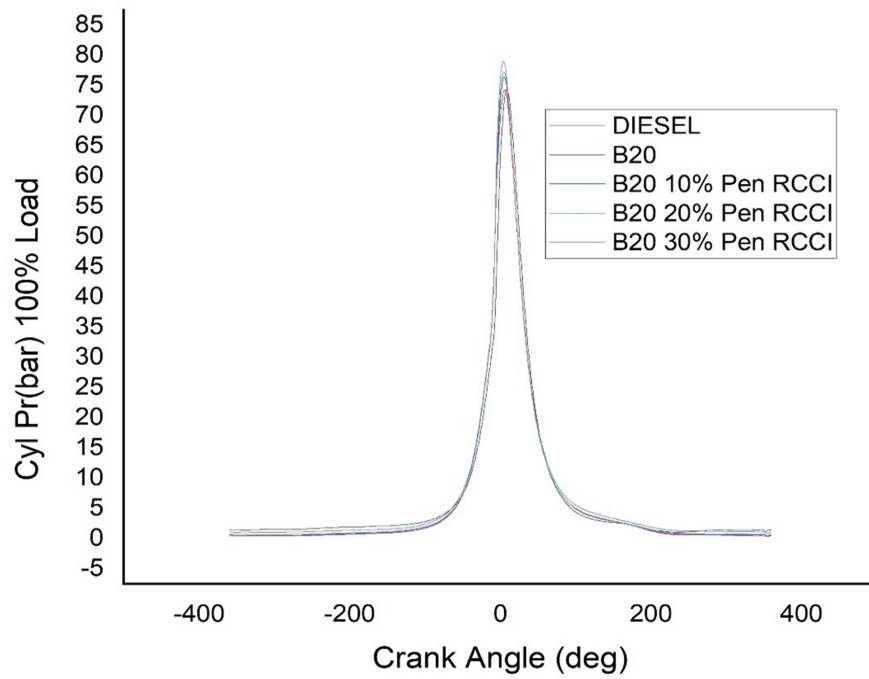


fig 5.14 cylindrical pressure at 100% load

5.4.2 Crank angle vs net HR J/Deg

The net heat release depends on the crank angle. As we can see that DIESEL has the highest net heat release in 0% load followed by B20-10% Pen RCCI and the lowest is B20. By increasing the load to 25% we can see the fluctuations of diesel at certain crank angles, B20 also has more fluctuations as diesel. B20 has highest net heat release, the lowest is DIESEL. At 50% load DIESEL has the highest net heat release followed by B20-20% Pen RCCI and DIESEL has the lowest net heat release, we can observe that DIESEL has more fluctuations in every load. At 75% load B20-20% Pen RCCI has highest net heat release followed by B20-20% Pen RCCI and DIESEL has the lowest heat release. At 100% load B20-30% Pen RCCI has highest net heat release followed by B20-20% Pen RCCI, at certain load B20-30% Pen RCCI net heat got decreased but finally the lowest net heat release is for DIESEL.

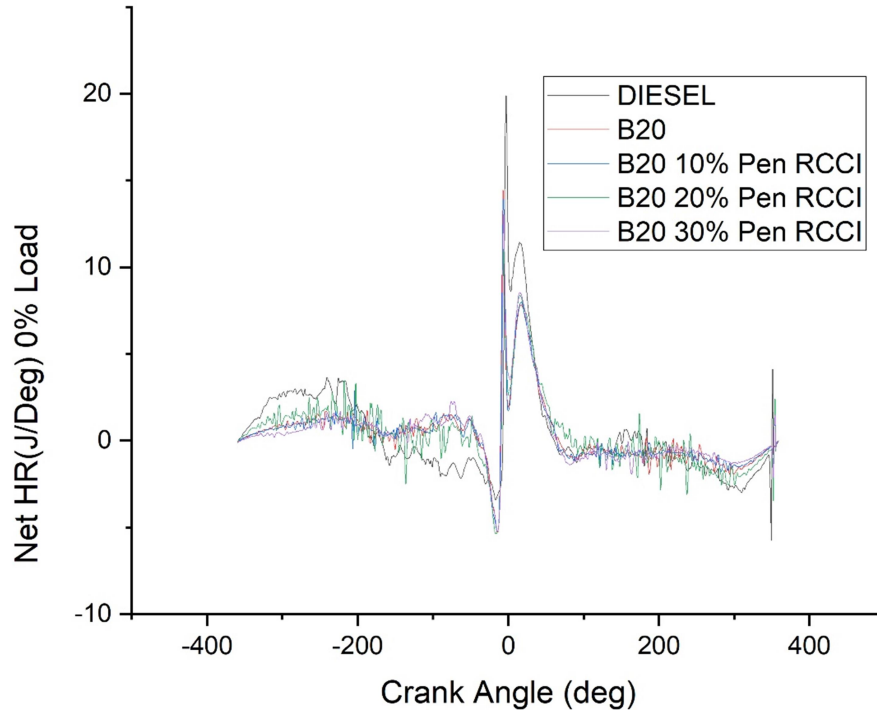


Fig 5.15 net heat release at 0% load

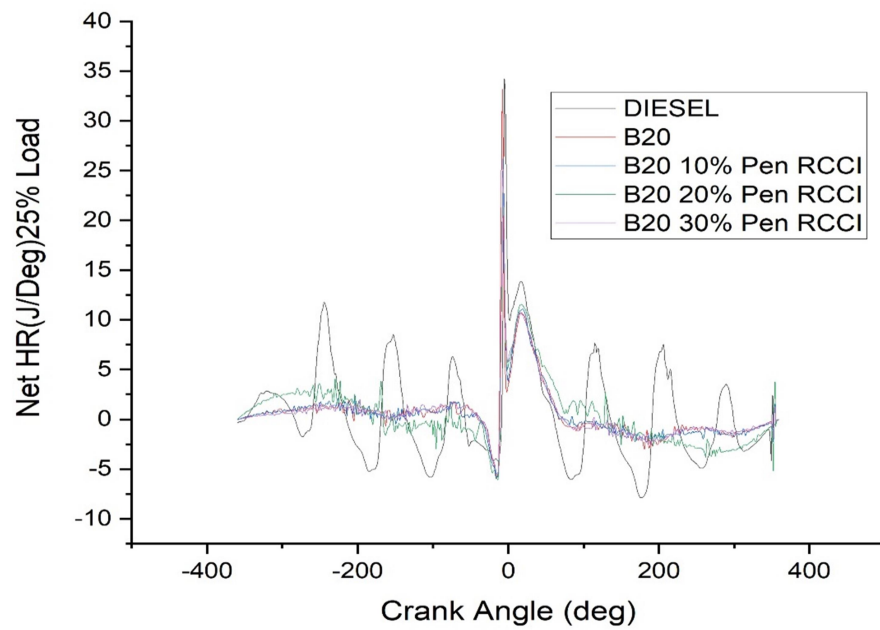


fig 5.16 net heat release at 25% load

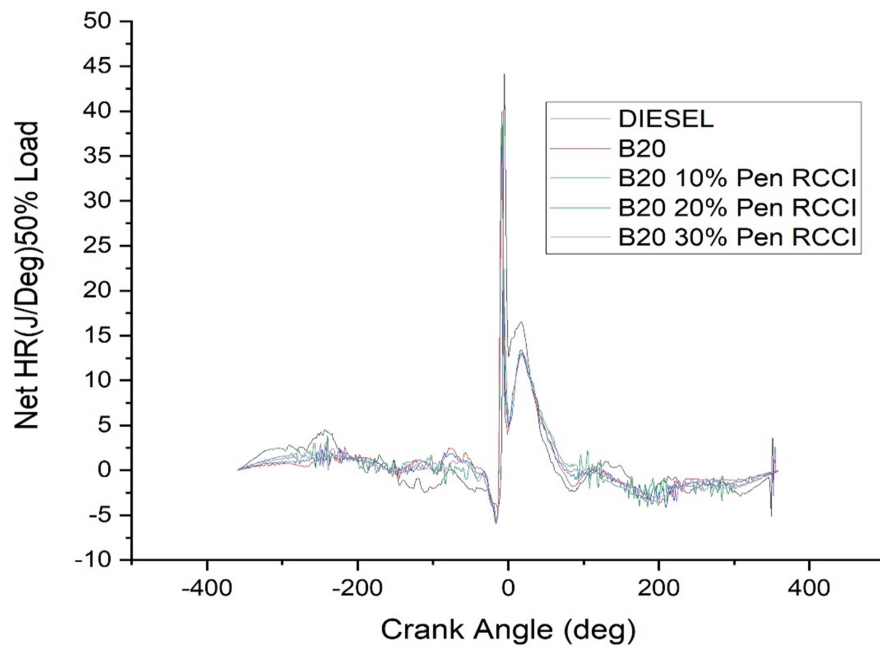


fig 5.17 net heat release at 50% load

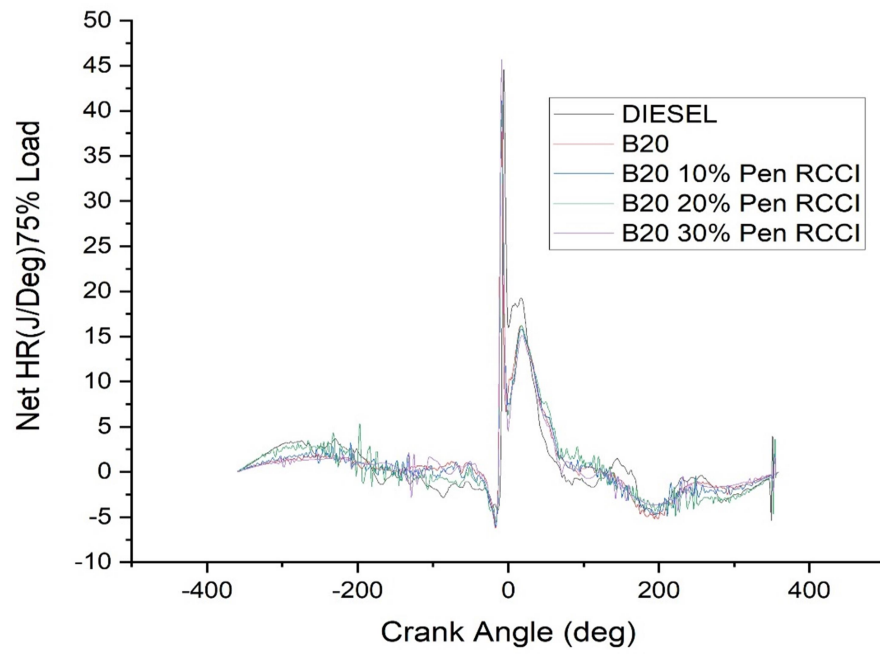


fig 5.18 net heat release at 75% load

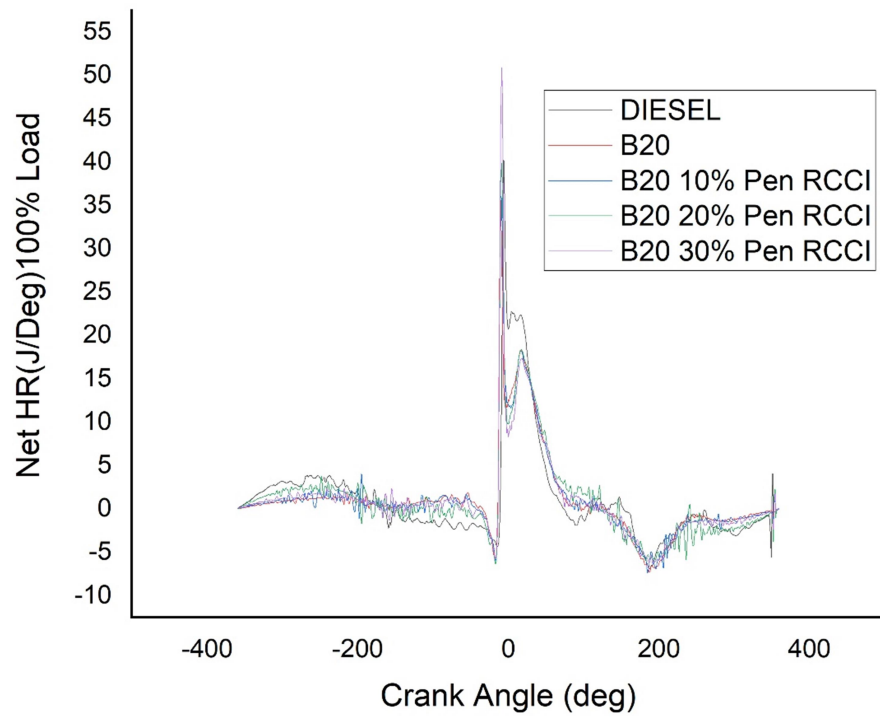


fig 5.19 net heat release at 100% load

CHAPTER 6

SUMMARY AND CONCLUSIONS

- The waste cooking oil of 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 charges at different loads.
- The brake thermal efficiency is found to be very high for B20-30% Pen RCCI.
- The volumetric efficiency is found to be very high for B20-10% Pen RCCI and low for DIESEL.
- B20-30% Pen RCCI has shown improvement in emission characteristics by lowering the carbon monoxide and carbon dioxide through out the different loads.
- NO_x emissions was lowest in case of diesel followed by B20-30% Pen RCCI.
- Hydrocarbon emission was highest in case of RB20-30%.

CHAPTER 7

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