

**INFLUENCE OF VARIOUS COMBUSTION GEOMETRY
PROFILES ON THE PERFORMANCE OF DIESEL ENGINE
FUELLED WITH MICRO ALGAE AND COTTON SEED OIL**

Submitted in partial fulfilment of the requirements for the award of

Bachelor of Engineering degree in
Mechanical Engineering

By

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DEPARTMENT OF MECHANICAL ENGINEERING

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INSTITUTE OF SCIENCE AND TECHNOLOGY

(DEEMED TO BE UNIVERSITY)

Accredited with grade "A" by NAAC

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BONAFIDE CERTIFICATE

This is to certify that this Project Report is the Bonafide work of DINESH S (39150036) and BALAJI B (39150016) and who carried out the project entitled **"INFLUENCE OF VARIOUS COMBUSTION GEOMETRY PROFILES ON THE PERFORMANCE OF DIESEL ENGINE FUELLED WITH MICRO ALGAE AND COTTON SEED OIL"** under our supervision from December 2022 to April 2023.

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ABSTRACT

The investigation is done on the CI engine with a fuel blend consisting of straight diesel and Bi-fuel (Micro algae (90%) and Cotton Seed oil (10%)) together with different combustion chambers, the conclusions are as follows. The composition of the current research, which includes a bi-fuel diesel mix, is 80% diesel + 20% bi-fuel (Micro algae, 90%) + Cotton Seed Oil, 10%). The mixture is made in accordance with ATCC (American Type Culture Cultivation) guidelines. The characteristics fall within the advised ranges. A 4-stroke, one-cylinder, water-cooled diesel engine was used for the testing. The B20 Bi-fuel (Micro algae (90%) and Cotton Seed oil (10%)) is evaluated together with three different combustion chamber designs (Hemispherical, Toroidal, and Re-Entrant). Three combustion chambers are used to compare the findings. The hemispherical combustion chamber improves the brake thermal efficiency (BTE). Since B20 combustion chambers encouraged improved combustion, the result was an increase in NO_x emissions. But the hemispheric shape of the brake specific fuel consumption is smaller. In various combustion chambers, the CO₂ hydrocarbon emissions and smoke opacity values increase. Different combustion chambers in a CI engine can employ the produced mix to enhance performance and combustion characteristics. Overall Hemispherical Combustion chamber as performed better in all the parameters.

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LIST OF SYMBOLS AND ABBREVIATIONS

SYMBOL	ABBREVIATION
CI	Compression Ignition
CO ₂	Carbon di Oxide
B20	20%Biodiesel and 80%diesel
NO _x	Oxides of Nitrogen
WCOME	Waste Cooking Oil Methyl Ester
Rpm	Revolution Per Minute
HC	Hydrocarbon
PM	Particulate Matter
BTE	Brake Thermal Efficiency
BSFC	Brake Specific Fuel Consumption
TiO ₂	Titanium di Oxide
SiO ₂	Oxide of Silicon
ATCC	American Type Culture Cultivation
PBR	Photo Bioreactor
CC	Cubic Centimeter
Hp	Horsepower
KW	Kilowatt
C	Hemispherical
T	Toroidal
R	Re-entrant
CC	Combustion Chamber

CHAPTER 1

INTRODUCTION

1.1 HISTORY AND BACKGROUND

The first internal-combustion engine was created in the 19th century as a result of engineers' determination to find an alternative to steam power engines and appropriate scientific knowledge of the thermodynamics principles. The propellant is consumed internally in an internal combustion engine; the cannon shown is an early example of a single-stroke engine, and several individuals have tried using gunpowder to power a single piston in a cylinder. The main issue was the lack of an appropriate fuel for this process, and another issue was the difficulty of rapidly and easily repeating the ignition of the fuel in a confined environment. The first issue was addressed in the mid-nineteenth century with the introduction of municipal gas sources, but the second proved more difficult to solve due to the difficulty in maintaining equally distributed ignition. In 1878, the German engineer Nikolaus August Otto improved this design. The most prevalent application for CI engines in cars is transit. The benefits of CI engines include excellent fuel efficiency, decreased emissions, increased reliability, and decreased upkeep. Fig 1.1 represents the various sources of emission around the world. Here it shows clearly transportation is the major source of pollution, to overcome Finding an affordable, non-edible, and sustainable substitute fuel is necessary to address these kinds of problems.

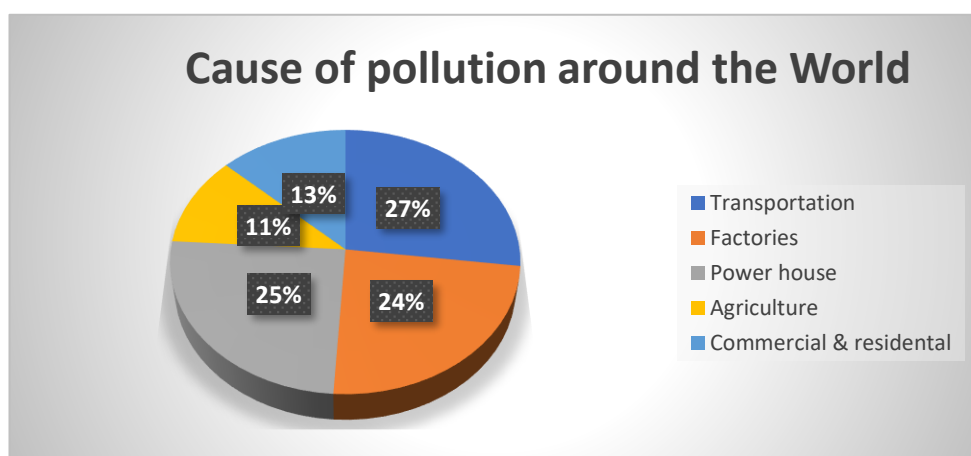


Fig:1.1: Causes for Pollution

There are numerous alternative fuels that can either fully or partly supplant diesel gasoline. Diesel substitutes that show promise include biofuels. When "Rudolf Christian Karl Diesel" created the compression ignition (C.I.) engine in the 1890s, the annals of bio diesel officially started. Rudolf debuted the diesel engine at the Paris world fair in 1898, and it was powered by groundnut oil. (Vegetable oil). From 2007 through 2020, an estimated 4.1 billion metric tons of CO₂ will be emitted into the atmosphere. Additionally, an additional 8.6 billion metric tons of CO₂ are anticipated to be emitted into the atmosphere between 2020 and 2035. [1]

Due to supply constraints and their effects on climate change through GHG (greenhouse gas) emissions into the atmosphere, excessive use of fossil fuels is considered as being unsustainable. Microalgae suggest alternative renewable sustainable energy sources since they have a high potential for producing large amounts of biomass, which could subsequently be used to manufacture various third-generation biofuels on a large scale. Microalgae accumulate lipids, particularly TAG (triacylglycerols), which may be converted into biodiesel, bioethanol, and bio methanol. Microalgae converts solar energy into carbon storage products.(J. P. Maity,J. Bundschuh 2014)[2]

the usage of algae for over fifty years as a feedstock for food, fuel, and energy. The concept of creating methane gas from microalgae was proposed in the early 1950s. But this concept didn't truly take off until the energy crisis of 1970s, when projects to produce gaseous fuels were launched. (Methane with hydrogen). Scientist (Nazia Hossain, T. M. I.Mahlia 2019) [10] conducted latest development in microalgae fuels added with nano additives that biofuel is receiving a lot of notice as an alternative fuel due to its ability to combine with gasoline for a maximum of 85% without requiring any engine modifications. Consequently, scholars and activists are constantly evaluating the viability of various options for biofuel. Microalgae have been tested as a possible feedstock for biodiesel production in the modern period because of their high energy content, accelerated growth rate, accessible culture methods, and noteworthy ability to fix CO₂ and contribute oxygen to the atmosphere.

Through a chemical procedure, veggie oils, animal fats, Algae and greases are converted into biodiesel, a sustainable alternative fuel. Rudolph Diesel invented biodiesel in 1890 by using only purified vegetable fuels in diesel engines. This was carried out in locations where it was difficult to obtain fuel. Modern biodiesel fuel was developed as a result of research carried out in Belgium in the 1930s. It is made by converting organic oils into compounds that are called fatty acid, methyl esters. Vegetable oils are trans esterified into fatty acid alkyl esters, which are used to substitute diesel gasoline with vegetable oils that have a reduced viscosity. Vegetable oils have become more popular as a result of worries about the climate, energy security, and the use of agricultural goods.

1.1.1 Advantages of Biodiesel

1. Efficient Fuel

Compared to fossil gasoline, biofuel is comparatively less flammable because it is produced from natural resources. It has a lot superior moisturizing quality. Compared to conventional gasoline, it produces less damaging carbon emissions. A variety of elements can be used to make biofuels. Utilizing them has a much greater total cost-benefit ratio.

2. Renewable

Utilizing them is efficient in nature since the majority of the sources for biofuels, such as dung, Algae, Switch grass, Soybean products waste from plants and organisms, are continuous and unlikely to run out very soon. Additionally, these crops can be replanted repeatedly, unlike the majority of fossil fuels, which will eventually expire and go up in smoke. Due to the demand for sustainable fuels, renewables are now being produced from a variety of sources, including organic fats and oils. Due to environmental and financial concerns, the usage of biofuel is becoming.

3. Greenhouse Gases

Studies show that biofuels can reduce carbon dioxide emission by as much as 65 percent. When fossil fuels are burnt, a significant amount of carbon dioxide, a warming gas, is released into the atmosphere. Because of these greenhouses gas'

capacity to absorb sunlight, the planet heats. Burning coal and petrol also increases temperatures and adds to global warming. People utilize biofuels all throughout the world to reduce the impact of greenhouse gas emissions.

Because it strikes a reasonable mix between material compatibility, low weather operability, efficiency, emission benefits, and prices, B20 is the most used biodiesel blend in the United States. Because some of the CO₂ released during the burning of biofuels returns to the environment where it was originally fixed by photosynthesis, compared to fossil fuels, they can produce fewer greenhouse gases overall. (C. Bessou, F. Ferchaud 2011) [3].

1.2 BIODIESEL HISTORY

The method used in the 1800s to create gasoline from biomass material is essentially the same method used today. The background of biodiesel is less technical and more political and commercial. Early in the 20th century, gasoline-powered cars were first made available. The amount of crude oil that oil companies had to process to supply gasoline resulted in an excess of distillate, which is a great fuel for diesel engines and much less costly than veggie oils. On the other hand, the always looked for new outlets for their goods. As a result, efforts to use veggie oils as fuel have persisted [2].

(S. Jaichandar and K. Annamalai 2011) in their research ,have been conducted on the performance, combustion, and emission of compression ignition (CI) engines. [11].

1.2.1 REQUIREMENT OF THE BIODIESEL

The alternative fuel known as biodiesel is produced by processing from biological sources such used cooking oil, animal fats, and edible and inedible oils. In certain places, biodiesel is also utilized to generate energy in engines and turbines in addition to being a fuel for transportation. (M. Rouhany & H. Montgomery 2019) [30].

O. Singh says that The EPA's mandatory Tier I and Tier II health impacts testing under the Clean Air Act was successfully completed by biodiesel in 2000, making it the sole alternative fuel in the nation. These independent experiments

unequivocally shown that biodiesel significantly reduces almost all permitted emissions and that it poses no risk to human health. Because biodiesel has no Sulphur or aromatics, it significantly reduces the number of unburned hydrocarbons, carbon monoxide, and particulate matter when used in a standard diesel engine. According to U.S. Department of Energy research, compared to petroleum diesel, carbon dioxide emissions were reduced by 78.5% during the manufacture and usage of biodiesel. Additionally, biodiesel has a favorable energy balance [33].

(H. K. Rashedul, H. H. Masjuki 2014) found that the performance of the engine must be compared to that of normal diesel, biodiesel is mostly manufactured for use in diesel engines. The primary application of biodiesel is to lower emissions, and it also has a variety of other benefits, such as not being explosive, flammable, poisonous, or biodegradable. There are some drawbacks in addition to these advantages. Some biodiesels emit NO_x, which is extremely detrimental to the environment, and have very poor flow characteristics at low temperatures. The use of biodiesel can be one way to take into account economic concerns when the cost of conventional fuel is high, it has an adverse impact on the environment, damages the ozone layer, and results in serious accidents. Because it is so difficult for the poorer nations to purchase these conventional fuels, it is necessary to employ biofuels, which are inexpensive and don't hurt the environment. This necessitates the usage of biodiesel.[29]

1.3 THE SOURCES OF BIODIESEL AND ITS CLASSIFICATION

The desire to reduce the usage of non-renewable fossil fuels has prompted extensive research into alternate fossil fuel sources. There are two categories of biofuels: primary sources and secondary sources. Firewood, wood chips, pellets, animal waste, agricultural and forest leftovers and landfill gas are the main sources of biofuels. The main feedstocks used currently are listed on the below table.1.1:

Table: 1.1: Main Feedstocks for Producing Biodiesel

Feed Stock Types	Source
Edible Oils	Sorghum, Wheat, Africanoil palm, Safflower, Ricebran oil, Soybeans, Barley, Sesame, Coconut, Canola, Sunflower, Rapeseed, Groundnut, Corn.
Nonedible oil	Cotton seed, Jatroph, Pongamia, Karanja, Cumaru, Cynara cardunculus, Neem, Nagchampa, Passionseed, Salmonoil, Croton megalocarpus, Pachiraglabra, Aleuritesmoluccana, Nagchampa, Passion seed, Mahua, Coffee ground, Abutilon muticum.
Animal Fats	Fish oil, Beef tallow, Chicken fat Poultry fat, Pork lard
Other sources	Algae (Cyanobacteria), Bacteria, Terpenes, Poplar, Switchgrass, Fungi, Miscanthus, Latexes, Microalgae (Chlorella Vulgaris, Nano Chlorosis). [5]

Algae have the world's quickest vegetative growth. Algae are grown industrially in open water bodies, photobioreactors, and closed systems. An important source of biomass is algae. Algae will eventually be a competitive biofuel source. Certain algae species may respond better to certain fuel types than others. Algae may be grown almost anywhere, including on sewage or in salt water, and it doesn't require fertile soil to produce food crops. Algal growth itself requires less energy than does its processing. Algae can replace oil-based fuels as a more effective and risk-free alternative. One of the plants with the fastest rates of development is algae, which are about 50% oil by weight. (A. Demirbas & M. F. Demirbas 2010) [6].

Algal fuels have a number of distinctive qualities, including the ability to be cultivated with minimal impact on freshwater resources, the ability to be produced utilizing wastewater and the ocean, and the ability to biodegrade and be largely innocuous to the environment if spilled. Due to their high manufacturing and capital expenses, algae are more expensive per unit of mass. (M. Paul Abishek, J. Patel 2014) [27].

1.4. METHOD FOR MAKING BIODIESEL

There are several methods for making biodiesel. Typically, transesterification and esterification, a chemical reaction between vegetable oils and short-chain alcohols are used to create biodiesel. (Like methanol or ethanol). Either a base catalyst or an acid catalyst is necessary for the manufacture of biodiesel. Because of its quicker reaction time and lower price, base type catalysts are the most often utilized. Though there is promise for large-scale biodiesel production from algae farms on non-arable land, prior research has not been idle to show an economically viable method that could be scaled to a commercial enterprise. (B. J. Gallagher 2011) [8]. The process of making biodiesel involves three main phases, namely:

1.4.1 LIPID EXTRACTION

Triacylglycerol, which is how lipids are held inside cells, must be broken down or weakened in order to release the lipids. Lipid recovery from diverse organic sources may be accomplished using a variety of lipid extraction techniques. 90% of the energy used to produce biodiesel is used to extract lipids from biomass; therefore, choosing an effective extraction procedure is crucial. Since solvents must be used for lipid extraction and then recovered from the extracted lipids, the separation of lipids or oil in cells of microalgae is an expensive and energy-intensive process. (M. Mubarak, A. Shaija 2016) [23]

1.4.2 TRANSESTERIFICATION

Triglycerides are often found in animal or plant-based oils. These triglycerides form glycerol and ethyl esters (biodiesel) when they interact with alcohols like ethanol or methanol. (byproduct). The majority of biodiesel is created utilizing the base-catalyzed transesterification method, which is a cost-effective way

to convert vegetable oils. Biodiesel production is cost-effective since virgin oils need modest temperatures and pressures to be produced. The transesterification reaction with alcohol, given by the general equation in Fig. 1a, is made up of a series of reversible processes. The conversion of triglycerides to diglycerides is the initial step. (K. Nantha Gopal, A. Pal 2014)[25]

1.5 DETAILS ABOUT BLENDS

(P. Saxena, S. Jawale 2012) in research, when combined with diesel fuel, biodiesel is used as a fuel. (Fossil fuel). Any proportion of biodiesel can be used in the mixture. Most diesel equipment may be operated with no changes or just minor ones using biodiesel mixes of 2% to 20%. For instance, the blend "B20" denotes the presence of 20 volume percent biodiesel. There is a need for the creation of appropriate models for the prediction of various properties of the blends since the properties of the blend fluctuate depending on how much fuel is blended with the biodiesel.[31]

(S. K. Nayak and P. C. Mishra 2019) on their research that Through the transesterification method, waste cooking oil methyl ester, also known as WCOME, has been converted into biodiesel. Experimental testing has been done to determine the impact of various fuel mixes combining both conventional diesel fuel and manufactured WCOME on the performance of diesel engines. The study investigated how the WCOME blending ratio affected the combination of biodiesel and diesel fuel's viscosity and susceptibility to soot. Engine mechanical and environmental characteristics recorded at engine rated speed (1500 rpm) and various engine loads have all been used to represent engine performance in terms of in-cylinder pressure data. The primary findings of this experiment demonstrated that the position and magnitude of the in-cylinder peak pressure are mostly influenced by the biodiesel mixing ratio and engine load.[26] Biodiesel is created by trans esterifying the parent oil or fat with an alcohol, often methanol, in the presence of a catalyst, typically a strong base like sodium or potassium hydroxide, or, preferably and more frequently, alkoxides. As a result, the resultant product may include not only the intended alkyl ester product, but also unreacted starting material, residual alcohol, and residual catalyst. G. Knothe [19]. Algal oil was touted as the ideal substitute for diesel fuel since it entirely decreased hydrocarbon

emissions when combined with diesel fuel at a 20% ratio. (R. Ganesan, S. Manigandan) [9]. It is clear from the benefits and physiochemical characteristics of algal biodiesel that it and its blends represent a potential alternative fuel for diesel engines. (B. N. Kale, S. D. Patle 2021)[21].

1.6. COMBUSTION CHAMBER

The region of the cylinder where the combination of air and fuel ignites is known as a combustion chamber. The fuel/air combination is compressed by the piston and ignited when it comes into touch with the spark plug, which causes the mixture to burn and force energy out of the combustion chamber. The process of mixing fuel and air, or the development of the flame in the combustion chamber, governs diesel combustion in theory T. Kamimoto & H. Kobayashi [15]. The Cylinder houses many of the important components of an Internal Combustion Engine including combination is applied directly to one or more engine components (the top of the piston, for example, in a column engine). (Often in the form of a rotating output shaft). This contrasts with an external combustion engine where the combustion only takes place in the component of the engine that transforms gas pressure. The geometry and layout of the combustion chamber have a significant impact on the combustion system inside the motor barrel. By modifying the geometry of the combustion chamber, the current study investigates the performance, outflow, and light characteristics of a turbocharged single diesel cylinder motor driven by biodiesel. In DI diesel engines, optimizing the fuel spray coupled with the geometry of the combustion chamber and the in-cylinder air flow is the key to efficient fuel/air mixture production and combustion. (X. Li, Y. Chen 2018) [20].

Different Types of Combustion Chamber:

1. Hemispherical Piston
2. Toroidal Piston
3. Re-Entrant Piston

1.6.1 HEMISPHERICAL PISTON BOWL

An internal combustion engine with a reciprocating cylinder design and a domed cylinder head is said to have a hemispheric combustion chamber. Hemi engines are those with hemispheric chamber designs. Small squish is also produced by hemispherical. However, it is possible to change the depth to diameter ratio to get any desired squish for improved performance (Jaichandar2014)[12].

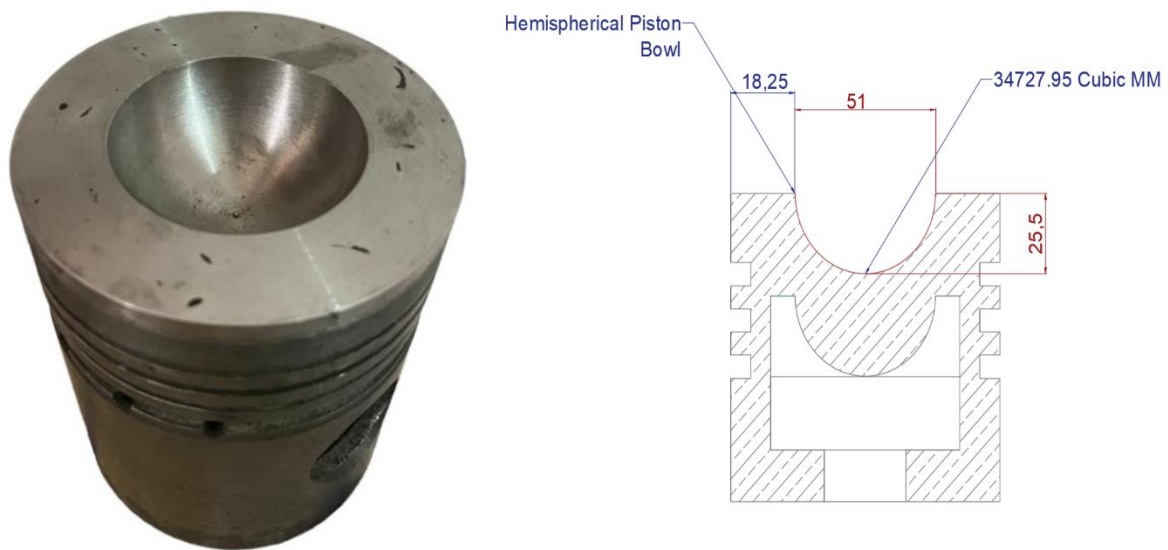


Fig: 1.2: Hemispherical piston bowl geometry

1.6.2 TOROIDAL PISTON BOWL

With a side injection, a toroidal combustion chamber shape is observed for an opposed piston engine. In one configuration, fuel is repeatedly pumped into each injector to create fuel clouds that are substantially separated from one another. Toroidal combustion chambers provide an innovative squish along with swirl movement of the air that facilitates speedy disappearance of extremely atomized fuel, facilitating total burning. (S. K. Nayak2019) [18].

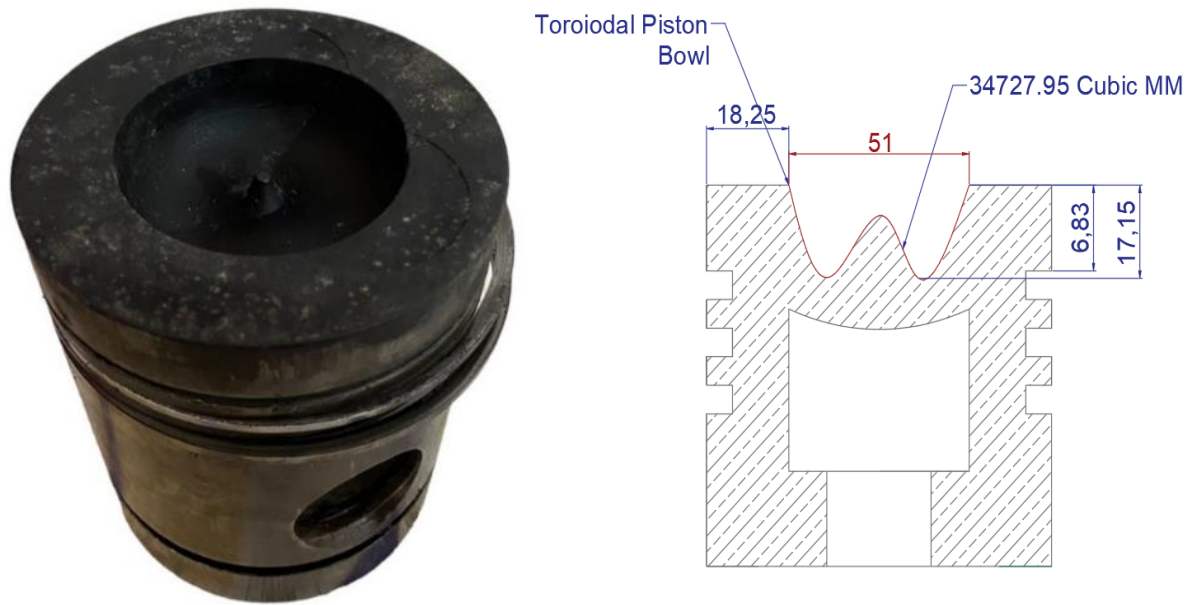


Fig: 1.3: Toroidal piston bowl geometry

1.6.3 RE ENTRANT PISTON BOWL

To create a combustion chamber type that minimizes the creation of smoke, NO_x, and particles by a distorted lip-generated flux in the cavity port that allows the fuel injection mist to cross in a laminar form. Fuel is initially directed downward into the bowl in a re-entrant combustion chamber before moving to the middle of the bowl. (B. Yan, H. Wang 2017) [38]

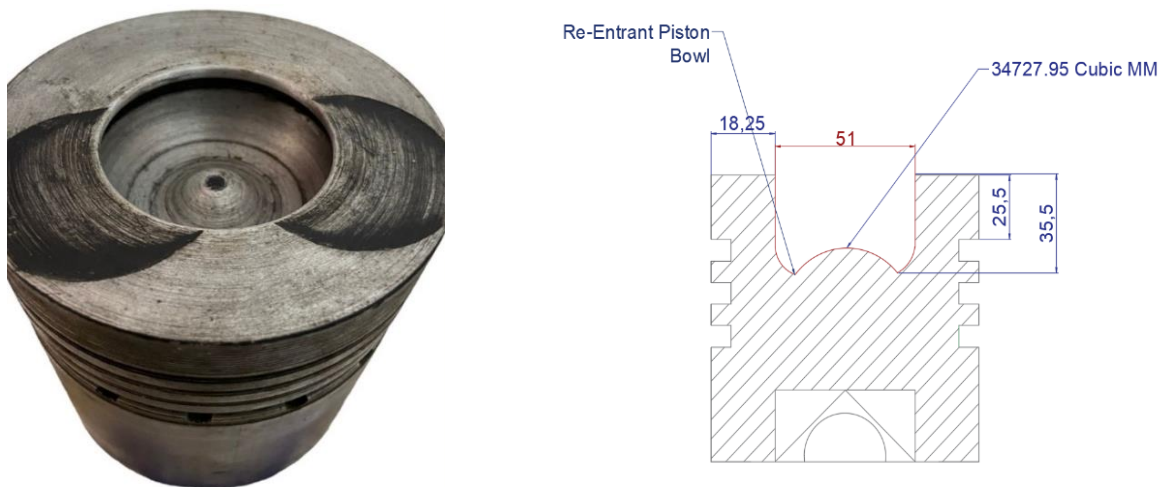


Fig: 1.4: Re-entrant piston bowl geometry

CHAPTER 2

LITERATURE SURVEY

2.1 INTRODUCTION

Numerous studies on the generation of biofuels, their characteristics, and their effectiveness in diesel engines have previously been conducted. Even though there have been several studies on the production of biodiesel from rice bran oil, there have been relatively few studies on the effects of using microalgae oil biodiesel blends in internal combustion engines on their performance, combustion, and emission characteristics. Many research articles were cited by us. Even though this fuel has been the subject of numerous studies, most of them have focused on different combinations of combustion chamber geometries in an effort to improve performance indicators like volumetric efficiency, specific fuel consumption, exhaust gas temperatures, and emissions of carbon monoxide (CO), NO_x, HC, and smoke.

2.2. CI ENGINE IMPACT OF COMBUSTION CHAMBER SHAPES

(Avinash Kumar, Rupesh Kumar Tripathi 2020) according to their research, the 10% and 20% biodiesel blends were created. Fatty acid content has a substantial impact on obliques. In terms of chemical and physical properties, were identical to diesel oil. The performance parameters and exhaust emissions of a diesel engine running on diesel fuel and biodiesel blends were investigated. In compared to B20 and diesel fuels, biodiesel blend B50 demonstrated lower specific fuel consumption, higher exhaust gas temperature, and higher thermal efficiency. When compared to B20 and diesel fuels, B50 exhibited reduced petrol emissions. The synthesis of high-quality biodiesel from the microalgae *S. oblique* and its effective and environmentally safe use in conventional diesel engines could be concluded.2020[22].

(G. Tüccar, T. Özgür 2017) in their research the commercially available fuels were tested to evaluate the effects of the fuel blends on the performance and exhaust emissions of a diesel engine. Measurements were made of engine performance indicators and exhaust gas pollutants such nitrogen oxides, carbon

monoxide, and smoke opacity. The findings demonstrated that while butanol addition resulted in a modest loss in torque and brake power values, the engine's emission values were enhanced. So, a particularly promising ingredient for diesel-microalgae biodiesel mixes is butanol.[27]

(R. Piloto-Rodríguez, Y. Sánchez-Borroto 2016), researchers they discovered that algal biofuels may be less hazardous to the environment and food supply than crop biofuels. The strain, growing technique, culture conditions, and chemical composition all have an impact on manufacturing costs as well as engine output and exhaust gas emissions. The goal of this paper is to perform a critical examination of the impacts of using biofuels derived from (micro)algae to power diesel engines. The number of articles reporting on diesel engine performance is vastly outnumbered by those reporting on algae culture, oil extraction, and biodiesel production. The articles that have been written in this field are analyzed in this essay. Torque and power output are commonly claimed to have reduced. Pure biodiesel and a range of blends up to B50 have both been tested. B20 appears to perform the best when compared to diesel fuel. While the use of various strains of biofuels can reduce a number of pollutants, a spike in NO_x is frequently observed and is connected to greater combustion chamber temperatures. Significant CO₂ and NO_x reductions are achieved when emulsions are used instead of blends or direct biodiesel. However, the few papers on engine testing have errors or omit critical facts about the experiments. The evaluation of biodiesel derived from algae or microalgae is an unexplored subject, and as this review demonstrates, some reference articles from today contain contradictory results or behaviors that haven't been extensively researched.[28].

2.3 THE INFLUENCE OF VARIOUS TECHNOLOGIES ON THE COMBUSTION AND EMISSIONS OF THE CI ENGINE

(J. E *et al.* 2017) in his research found that Due to the scarcity of fossil fuels and combustion emissions, Jiaqiang Ea, Minhhieu Pham researched how crucial it is to have innovative, renewable, and cleaner fuels. Biodiesel has long been used as a potential fuel and replacement. There are several different types of oil that may be used to make biodiesel, including waste oil, animal fat, and vegetable oils. The

performance and emissions parameters, such as BTE, BSFC, and brake power, are nearly maintained when biodiesel is used as diesel engine fuel because hydrocarbon (HC), carbon monoxide (CO), and particulate matter (P Material) are significantly decreased. (PM). Diesel engines may also run on biodiesel as a fuel source. However, higher NO_x levels are seen. The hassle associated with using biodiesel or other biofuels has decreased in recent years.[7].

2.4 EFFECTS OF MICROALGAE IN A C.I. ENGINE

(N. Krishania, U. Rajak 2020) researchers found that Jatropha, type pyrolysis oil, and spirulina microalgae biodiesel diesel engine with a rated power of 3.5 kW at 1500 rpm. exhaust emission characteristics. With varying engine loads, the engine was run at a constant CR of 17.5. Brake thermal efficiency (BTE), fuel consumption, exhaust temperature, Sauter mean diameter, and smoke comparison characteristics, there have been presentations on emissions, particulate matter (PM), nitrogen oxides (NO_x), and carbon dioxide (CO₂). The secondary mixes (JMETPO20, SP20) significantly reduced smoke, PM, and NO_x emissions while also improving CO₂ emissions from the diesel engine. As a consequence, 20% mixes were shown to reduce smoke, PM, and NO_x emissions.[18].

(S. Karthikeyan and A. Prathima 2017) on their research they found that, A sustainable fuel source that might take the place of biodiesel is algal oil made from microalgae. Microalgae are produced utilising sunlight, water, carbon dioxide, and other nutrients through the process of photosynthesis. Oil was mechanically extracted from the Botryococcus braunii algae species. algal oil was transesterified with ethanol and a base catalyst to produce biodiesel. algal oil was used to create the samples B20 for each methyl ester separately, Additionally, without any engine modifications, the performance and emission characteristics of those blend samples have been studied using experimentally measured quantities such as density, viscosity, calorific value, etc. According to the experimental findings, using biodiesel blends with nano additions in diesel engines has led to significant improvements in performance characteristics and a decrease in exhaust emissions.[16]

2.5 SUMMARY OF LITERATURE REVIEW

A large body of literature has been carefully examined and evaluated, and the findings have been gathered from it. Numerous methodological facts are included in the current research, and the results are based on those facts. The findings, conclusions, and recommendations are as follows:

- Biodiesel made from sustainable sources like Algae, animal fats and plant seeds may function as an alternative fuel in C.I. engines without requiring any modifications.
- Alternative biofuels should be made from inexpensive feedstock and renewable resources, such as microalgae, to replace the destructive fossil fuels.
- The ideal blend is B20, which contains 80% diesel and 20% biodiesel and significantly decreases CO, HC, and NOX emissions when compared to diesel fuels.
- When biodiesel is added to diesel fuel, performance attributes like brake thermal efficiency decline and specific fuel consumption rise, but the pollution levels are greatly reduced.

We learn through studying a variety of writings that a great deal of research has previously been done on biodiesel mixes. But relatively little study has been done on the various combustion chamber geometries. Therefore, the performance, combustion, and emission characteristics of the various mixes are the main focus of this study.

CHAPTER 3

AIM AND SCOPE

3.1 AIM OF THE PROJECT

- To produce biodiesel from Microalgae.
- To understand the combustion chambers when feed with a bio diesel blend.
- To study the performance and emission characteristics of the biodiesel blend in a diesel engine along with combustion chambers.
- To compare a diesel engine's performance and emission characteristics while it is operated with various combustion chamber configurations.

3.2 SCOPE

The combustion chamber geometry is a technique for reducing emissions that allows most kinds of diesel engines to emit significantly fewer emissions. The use of biodiesel, a renewable and environmentally favourable alternative fuel source, is possible because fossil fuel emissions are rising daily and because they are non-renewable and detrimental to the environment. The greatest option in terms of economics and the environment is biodiesel made from microalgae and cotton seed oil. The accuracy of the engine properties will be improved by the combination of diesel, microalgae, and cotton seed oil. By incorporating various combustion chambers into the Microalgae Blend, this study offers an answer for how a compression ignition engine performs.

CHAPTER 4

MATERIALS AND METHODS

The process is classified into five phases:

- Preparation of biodiesel.
- Different Combustion Chambers testing and analysis.

4.1. MATERIALS

For the preparation of the blend Alcohol, diesel, ATCC 616 medium salts, Distilled water and cotton seed oil are needed to make the mixtures. Similar to how methanol is used as the process's alcohol, algae are used as the oil in this specific procedure. The specific materials needed, methods used, instrument specifications, operating principles, and experimental procedures by which the research was conducted are all explained in this chapter. The detailed experimental methodology proposed for the researched work is illustrated in Fig. 4.1.

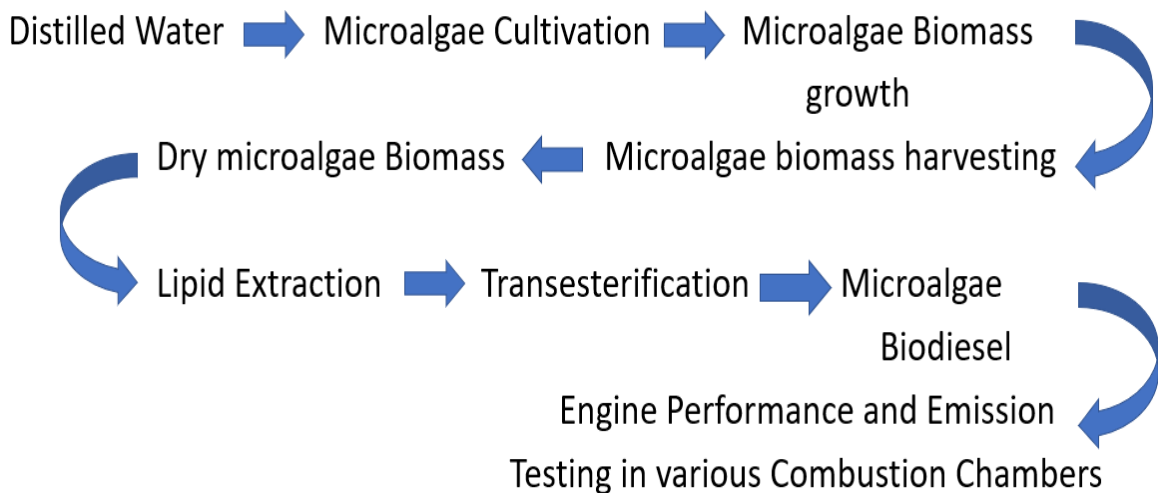


Fig: 4.1: Flow chart of biodiesel preparation

4.2 THE BIODIESEL PRODUCTION FROM MICROALGAE

Microalgae oil, cotton seed oil, and diesel are gathered. This part describes the complete biodiesel preparation procedure.

4.2.1 MICROALGAE CULTIVATION

ATCC (American Type Culture Cultivation) medium 616 ions are mixed with purified water in proportion to the amount of water present. The medium-added water is then heated for 30 minutes before being moved into a glass receptacle for cooling. The nano or chlorella particles are introduced to the medium-added water after cooling. These spores are put to the medium-added water to grow microalgae. Furthermore, the farmed microalgae grow into microalgae biomass.

4.2.2 ATCC MEDIUM 616

The Salt Mixture used for producing Green Microalgae Cultivation is listed below in the given fig.4.2.

American Type Culture Collection MEDIUM 616	TRACE METAL MIX
NaNO ₃ (Sodium Nitrate)	H ₂ BO ₃ (Dihydrogen borate)
K ₂ HPO ₄ (Dipotassium phosphate)	MnCl ₂ ·4H ₂ O(Manganese chloride)
MgSO ₄ ·7H ₂ O(magnesium sulphate heptahydrate)	ZnSO ₄ ·7H ₂ O(Zinc sulphate heptahydrate)
CaCl ₂ ·2H ₂ O(Calcium chloride dihydrate)	NaMoO ₄ ·2H ₂ O(Sodium molybdate dihydrate)
Citric Acid	CuSO ₄ ·5H ₂ O(Copper Sulphate)
Ferric ammonium citrate	Co(NO ₃) ₂ ·6H ₂ O(Cobalt nitrate hexahydrate)
EDTA(disodium salt) or edetic acid	Distilled water
Na ₂ CO ₃ (sodium carbonate)	

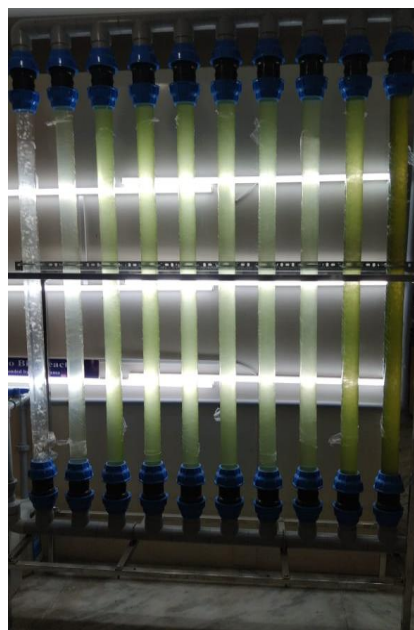
Fig: 4.2: ATCC medium

4.2.3 PHOTO BIOREACTOR

A photobioreactor is a type of bioreactor used to cultivate phototrophs such as microalgae in a closed system that prohibits direct material interaction between the culture and its surroundings. Any cultivation device intended for cultivating photoautotrophic organisms with the use of either natural or artificial light sources for photosynthesis is referred to as a photobioreactor (PBR). The system produces a single strain, contamination-free microalgae culture as a result of the system's supply of a closed, tightly controlled atmosphere for the culture's development. The microalgae were cultivated in the photobioreactor for 2-3 weeks with constant air delivery and artificial light sourcing.



Fig: 4.3: Photo Bioreactor



***Fig: 4.4: Bioreactor in
Microalgae growth***

4.2.4 FILTRATION

The Cultivated Nano Chlorosis Micro Algae is further Filtered by means of filter paper. The filtered algae are allowed to get dry. Afterwards, they all have been scrapped from the filter paper for further process.



Fig: 4.5: Filtered Nano Chlorosis

4.2.5 LIPID EXTRACTION

The process of extracting lipids from moist algal material involves disrupting the algal cell walls in the fluid in which the microalgae were grown. These methods are classified as organic solvent based or solvent free. The sample matrix is kept in intimate contact with the extraction solvent thanks to the Soxhlet extraction process. In order to prepare for various chromatographic techniques, this approach is used to separate and concentrate organics that are either scarcely or completely soluble in water.



Fig:4.6: Lipid Extraction

4.2.6 DISTILLATION PROCESS

A liquid is transformed into a vapour during the distillation process, and the vapour is then condensed back into a liquid state. A technique for carrying out chemical reactions and isolating the reaction mixtures in a single column called distillation.[37].

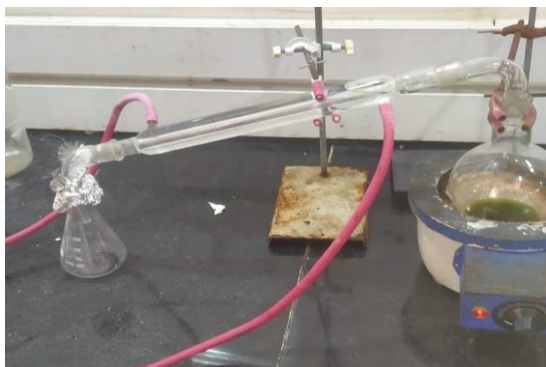


Fig: 4.7: Distillation Process

4.2.7 TRANSESTERIFICATION

Transesterification is the reaction of fat or oil with alcohol to produce esters and glycerol. A catalyst is used to increase the pace and output of the reaction. Due to the reversibility of the reaction, excess alcohol is used to move the balance to the product side. The process of swapping the organic group R'' of an ester with the organic group R' of an alcohol is known as transesterification. The presence of an acid or basic catalyst frequently catalyses these processes. It is a reaction in which oil (tri glycerides) interacts with methanol in the presence of a sodium hydroxide catalyst, producing methyl ester (biodiesel) and glycerin.

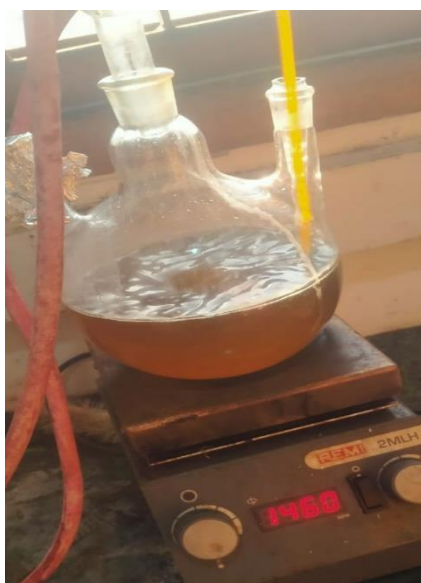


Fig: 4.8: Transesterification Process

4.2.8 GLYCERINE SEPARATION

The reacted combination is transferred into the two opening flasks and allowed to settle for about 15 minutes. Glycerine settles at the bottom of the flask due to gravity and greater density, while methyl ester or biodiesel remains at the top of the conical divider flask. The glycerine can be readily drained out by using the bottom opening number. Because the two layers are distinct, we can readily separate the glycerine from the methyl ester.



Fig: 4.9: Glycerine Separation

4.3 PREPARING FUEL BLENDS

Because pure diesel emits more pollutants and is a non-renewable non-biodegradable fossil fuel. The transesterification method is used to produce alternative microalgae oil, but this biodiesel cannot be used directly in a compression ignition engine. As a result, biodiesel is mixed with cotton seed oil and gasoline. As a result, the diesel is obtained from the fuel station. Cotton seed oil was purchased from an oil store in Chennai. 1500ml of three mixes are made by combining diesel (80%), microalgae oil, and cotton seed oil biofuel (20%). The components are weighed in a measuring jar, and the blends are made in a bottle using a funnel.

Table: 4.1: Properties of Blend

PROPERTIES	B20
DENSITY (kg / m³)	873
Kinematic viscosity	4.746
Specific Gravity	0.8508
Calorific value (kj/kg)	40100
Calorific value (cal/g)	9,570.40

4.4 ENGINE TESTING AND ANALYSIS

The engine study is carried out in a single cylinder, four stroke diesel engine that is loaded using an eddy current type dynamometer. The required tools are supplied for measuring combustion pressure and crank angle.

4.4.1 ENGINE DETAILS

The engine specs utilized to conduct the different tests are listed in the table.

Table: 4.2: Engine Specification

Engine Model	Kirloskar TV1
No of Cylinders	1
No of Strokes	4
CC (liter)	0.661
RPM	1500
Power	5.20KW
Power Rating	7 hp
Bore(mm)	87.50
Stroke (mm)	110.00
Connecting rod (mm)	234
CR	17.50
Swept volume	661.45cc
Cooling type	Water cooled
Over all dimensions	Width 2000*length2500*height1500mm.
Dynamometer	Eddy current type water cooled
Software	Engine Soft

The symbolic Image of Engine shown below in Fig 4.8. and Fig 4.9.

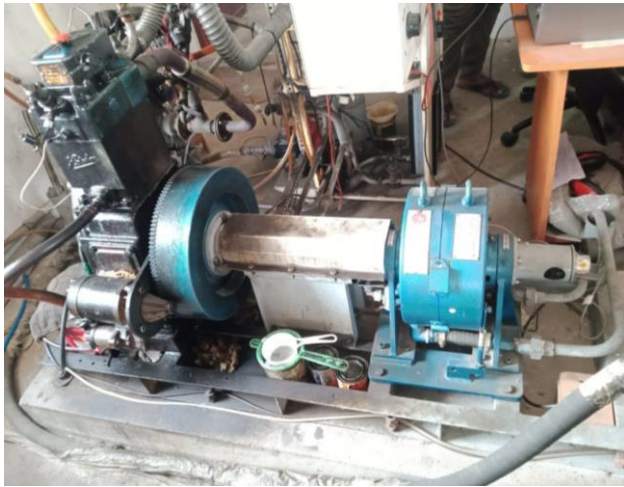


Fig:4.10: Engine Front view



Fig :4.11: Engine Back view

4.4.2 ENGINE TEST RIG COMPONENTS

The Engine test rig is done on a single-cylinder four-stroke diesel engine that is linked to the following components in the following order:

1. Eddy Current dynamometer (engine loading)
2. Panel box
3. AVL Smoke meter
4. Gas Analyzer
5. Airbox
6. Fuel tank
7. Manometer
8. Fuel measuring unit
9. Digital speed indicator
10. Temperature indicator



Fig:4.12: Smoke Meter



Fig:4.13: Gas Analyzer

The Fig 4.10 and 4.11 Shows the image of a smoke meter and a gas analyzer. The term "diesel exhaust smoke meters" refers to devices that measure opacity, or how much light is blocked by a sample of smoke produced by diesel engines. The smoke meter shows the smoke density, which indicates the rate of combustion efficiency. The optical unit for the smoke meter is housed inside the measuring head, which also contains an electrical control unit of its own. The theory behind gas analyzers is that they measure how much light the gas being tested absorbs. To determine how much of a given wavelength was detected by the sample, the analyzer just has to shoot a beam of light through the unheated chamber. An optical filter in the analyzer eliminates any light outside the wavelength that the chosen gas molecule can see. The amount of light that reaches the detector is unaffected by the presence of other gas molecules, which won't absorb light at this specific wavelength.

CHAPTER 5

RESULTS AND DISCUSSION

Experiments on the engine powered by microalgae diesel mix and a B20 blend were carried out in accordance with the aims and technique specified, and the findings are provided in this chapter. A standard engine was also tested for the same conditions (using the same diesel blend) for comparison purposes. Graphs are used to illustrate and discuss the outcomes of the investigations. Among the performance parameters are exhaust gas temperature, volumetric efficiency, specific fuel consumption, and brake thermal efficiency. The cylinder pressure and heat release rate are used to determine the engine's combustion type. Among the emission characteristics are carbon monoxide, unburned hydrocarbons, NOX, smoke opacity, and carbon dioxide.

5.1 PERFORMANCE PARAMETERS

This section explains the performance aspects of blended fuel such as brake thermal efficiency, specific fuel consumption, volumetric efficiency, and exhaust gas temperature.

5.1.1 BRAKE THERMAL EFFICIENCY

The term brake thermal efficiency (BTE) refers to an engine's capacity to transfer the heat energy produced by the diesel fuel during combustion into mechanical energy. Fuel qualities such as heating value and density have a considerable impact on brake thermal efficiency numbers.

The preceding graph clearly shows that during zero load circumstances, brake thermal efficiency is poor, and when load increases better brake thermal efficiency is reached. BTE increases as engine load increased. The BTE is lower for a B20 Re-Entrant and higher for a Hemispherical. This might be due to greater mixture formation of B20 and air as a result of better air movement in Hemispherical, which leads to better biodiesel combustion and hence raises the BTE(S. Jaichandar, P. Senthil Kumar, and K. Annamalai 2012 [13]) Here in this image C denotes

Hemispherical Combustion Chamber, R for Re-Entrant Combustion Chamber and T for Toroidal Combustion Chamber.

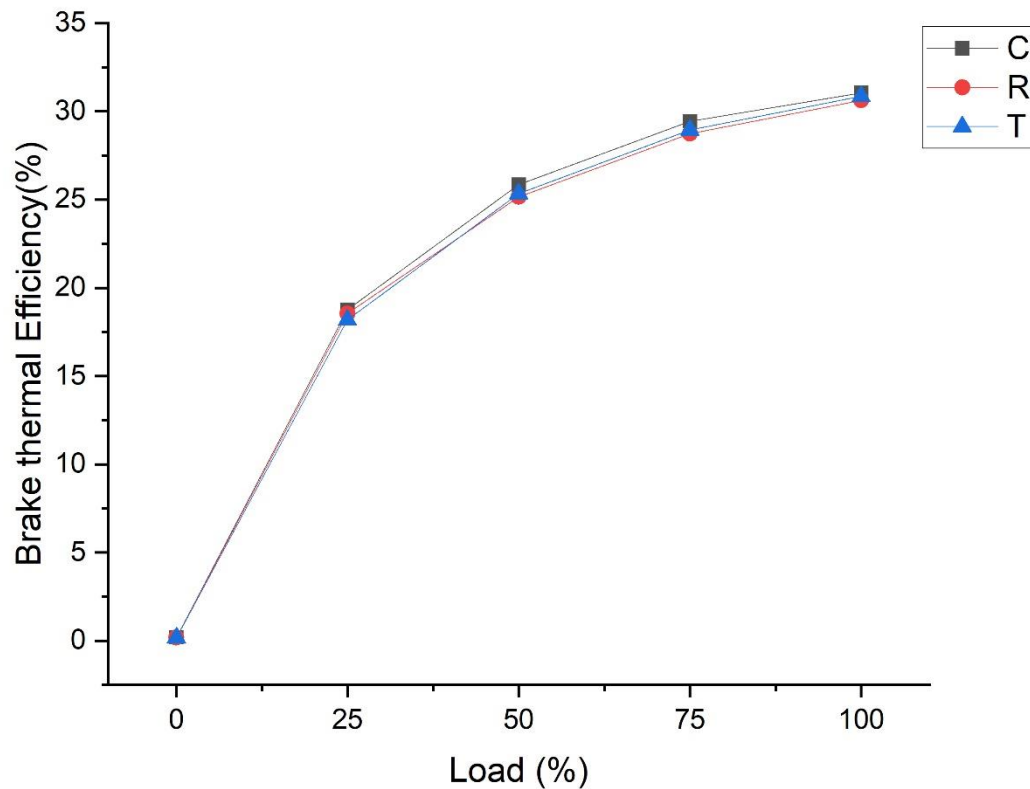


Fig: 5.1: Brake Thermal Efficiency

5.1.2 VOLUMETRIC EFFICIENCY

The ratio of a piston or plunger's displaced fluid volume to its swept volume is known as volumetric efficiency. The volumetric efficiency of the engine is generally affected by both the ambient and operating conditions.

Here in the below graph shows that:

The volumetric efficiency decreases as the load increases. It might be attributed to greater gas temperatures, as well as a rise in the temperature of the input valve and combustion chamber walls. This characteristic reduces the density of induced air, resulting in a decline in volumetric efficiency. In the case of Toroidal, at the end of the compression stroke, the whole air-fuel mixture combination is

trapped in the cylinder and promptly ignited. Toroidal, on the other hand, has somewhat greater volumetric efficiency when compared to other combustion chamber designs. Because squish motion is better in Toroidal than in other geometries, greater air movement in the CC leads to improved combustion(Varun, P. Singh, S. K. Tiwari 2017 [35]).

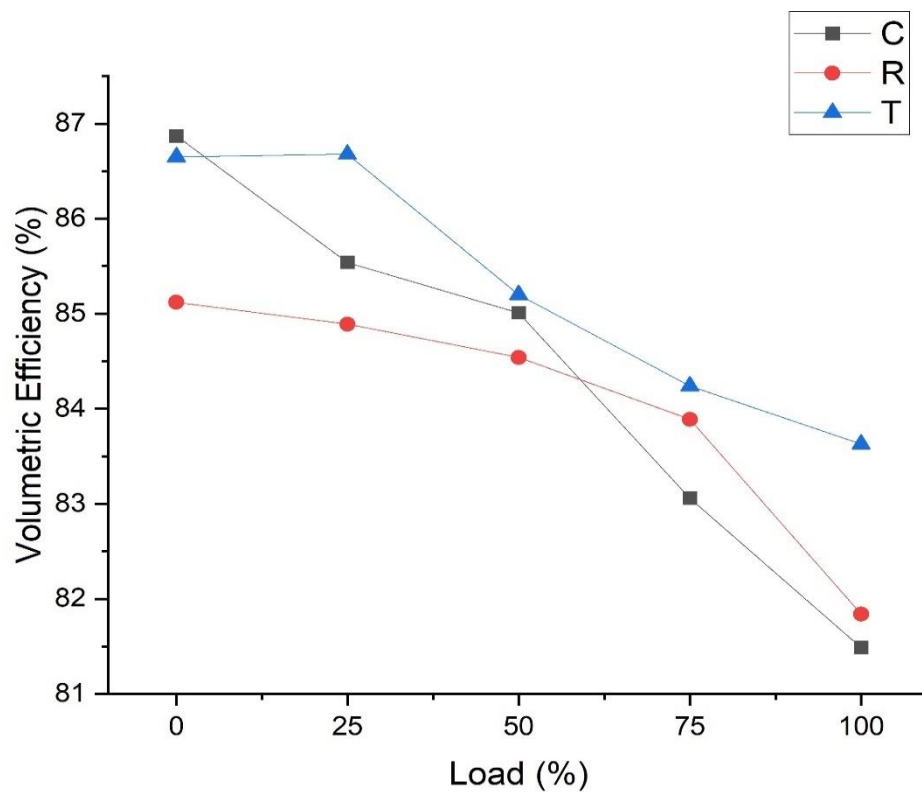


Fig: 5.2: Volumetric Efficiency

5.1.3 BRAKE SPECIFIC FUEL CONSUMPTION

Any prime mover that uses fuel and generates rotational, or shaft, power is measured by the brake-specific fuel consumption (BSFC). The most frequent application of it is to contrast shaft output with internal combustion engine efficiency. It is the ratio of fuel use to power output. It is believed that when load increases, BSFC for all test fuels with combustion chambers exhibits a falling curve due to improved combustion due to increasing in-cylinder charge temperature. However, at maximum loading, the BSFC for all fuels with combustion chambers rises. The BSFC for Hemispherical is lower and greater for Toroidal and Re-Entrant. Inefficient

fuel mixture, which leads to inefficient combustion, may account for the greater specific fuel consumption for re-entrant combustion chamber(S. Jaichandar and K. Annamalai 2012 [14]).

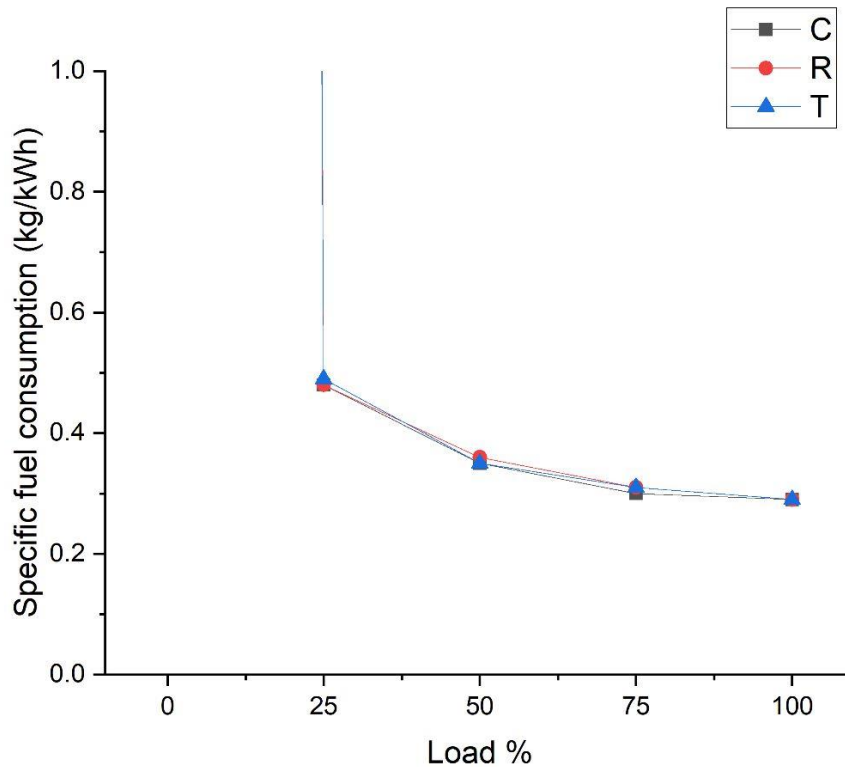


Fig: 5.3: Brake Specific Fuel Consumption

5.1.4 EXHAUST GAS TEMPERATURE

The temperature of the exhaust gases at the exhaust manifold is measured as the "exhaust gas temperature." It is possible to control the fuel/air mixture entering the engine because the temperature of the exhaust gas varies with the fuel/air mixture entering the cylinders. The graph below depicts the temperature of the exhaust gas under various loads. The graph indicates that when the load increases and combustion occur, the exhaust gas temperature rises. The rise in exhaust gas temperature is exactly proportional to the increase in load. The graph indicates that the exhaust gas temperature of a re-entrant piston at 75% load is much greater than that of another piston. The increased availability was caused by the developed combustion chamber temperature. With increasing loads, an increase in exhaust gas temperature was seen as part of the fuel oxidation occurred

in the regulated combustion zone and portion occurred after burning region(V. Karthickeyan2019[17]).

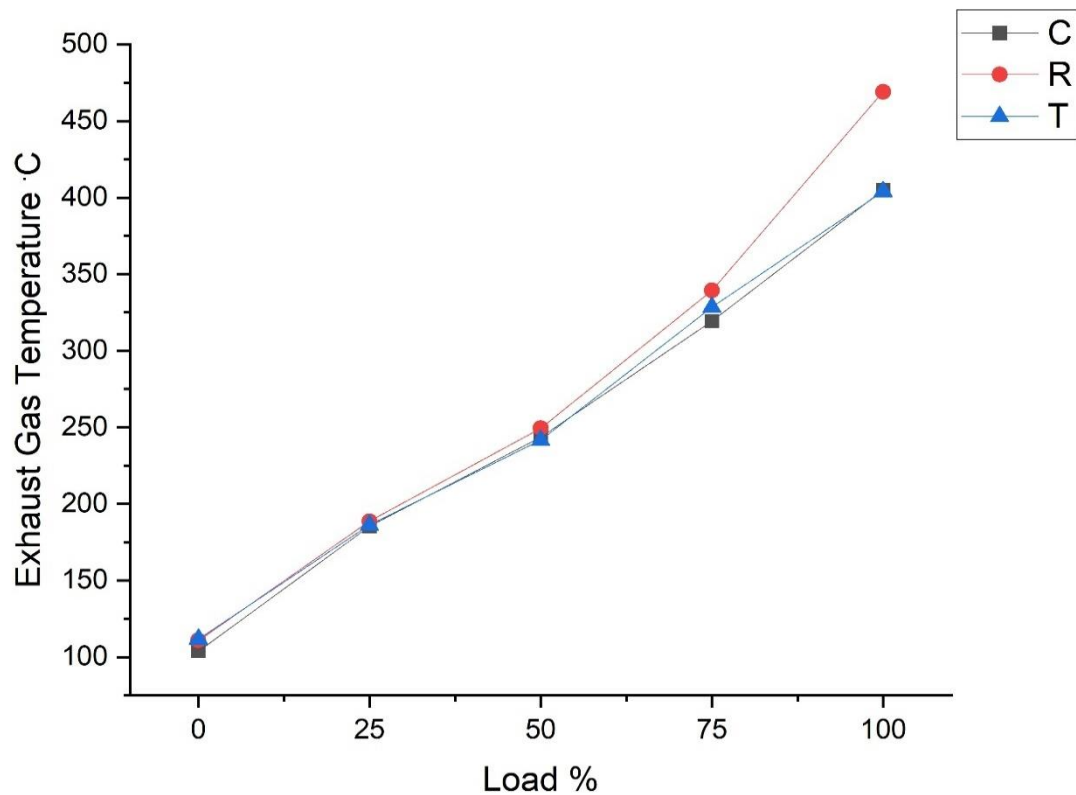


Fig: 5.4: Exhaust Gas Temperature

5.2 EMISSION CHARACTERISTICS

This section studies and discusses emission features such as CO emissions, CO₂ emissions, NO_x emissions, HC emissions, and smoke emissions findings by producing graphs for all emission levels at different loads.

5.2.1 CO EMISSION

Carbon monoxide (CO) is a poisonous, colorless, odorless, and tasteless atmospheric contaminant that pollutes the environment. It occurs as a result of a lack of oxygen. Carbon monoxide is emitted as a result of inefficient air-fuel mixture mixing, insufficient oxygen delivery, and lower oxygen concentration.

The emission characteristic, carbon monoxide (CO emissions) findings are analyzed and discussed based on engine testing data, as illustrated in fig 5.5. The graph depicts the relationship between the variable loads on the x-axis and the CO emissions on the y-axis. However, a larger percentage of biodiesel prevents more CO emissions.

From Fig. 5.5, it was discovered that CO emissions increase as engine load increased. Due to more fuel molecules being present in the combustion chamber with greater loads, oxygen concentration falls. When compared to other combustion chambers, Hemispherical emits less CO. The CO emission increased to 1.8% in the Re-Entrant. The B20 blend may increase CO₂ emissions, but it reduces air toxics and cancer-causing compounds, possibly due to an increased heat release rate during the pre-mixed phase of combustion. the oxygen content decreases, resulting in higher CO₂ emissions.(V. Chandrasekaran, M. Arthanarisamy 2016 [4]).

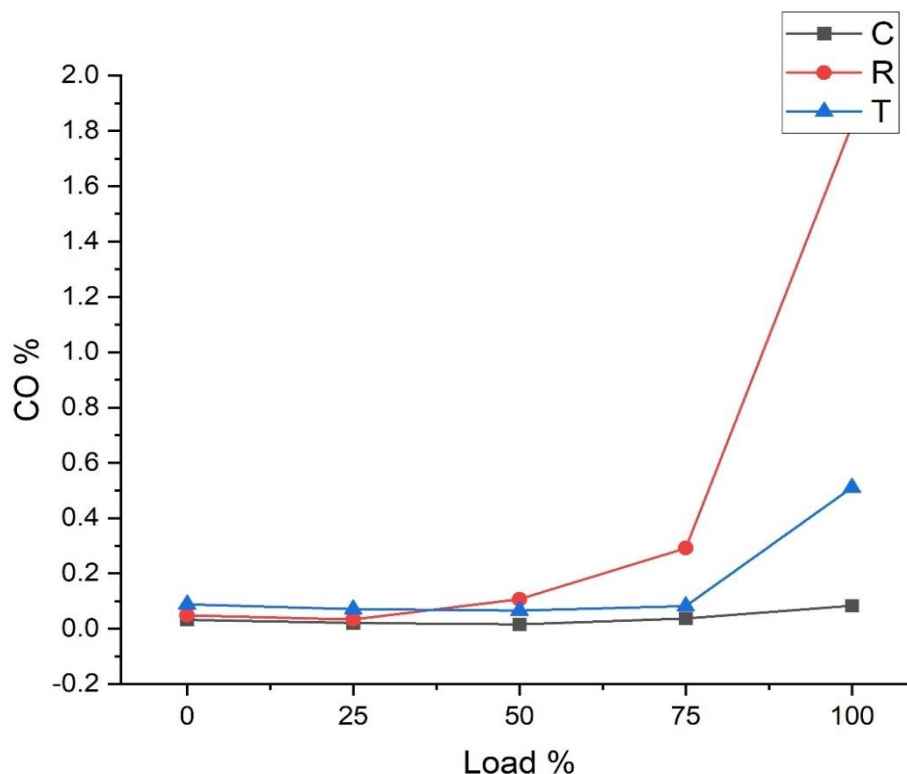


Fig: 5.5: CO Emission

5.2.2 CARBON DIOXIDE EMISSIONS

The release of CO₂ indicates that the air-fuel combination has burned completely. It demonstrates that there was enough oxygen available to support the fuel that was shot into the chamber. One of the main greenhouse gases, CO₂, is one of the exhaust gases that are emitted into the environment. Fuel combustion that is not complete results in the production of carbon monoxide. Because there is no oxygen molecule 1 in the chain of petroleum fuels, carbon monoxide may be produced readily. Biodiesel burns more completely than fossil diesel because it contains oxygen in its structure, which results in significantly lower carbon monoxide emissions.[24].

The carbon dioxide emission with increasing loads is seen in Figure 5.6. The graph demonstrates that the re-entrant piston's carbon dioxide emission at 75% load is significantly greater than that of other pistons operating at the same load. As engine loads increased, CO₂ emissions also climbed. When compared to other combustion chambers, Toroidal emits less CO₂.

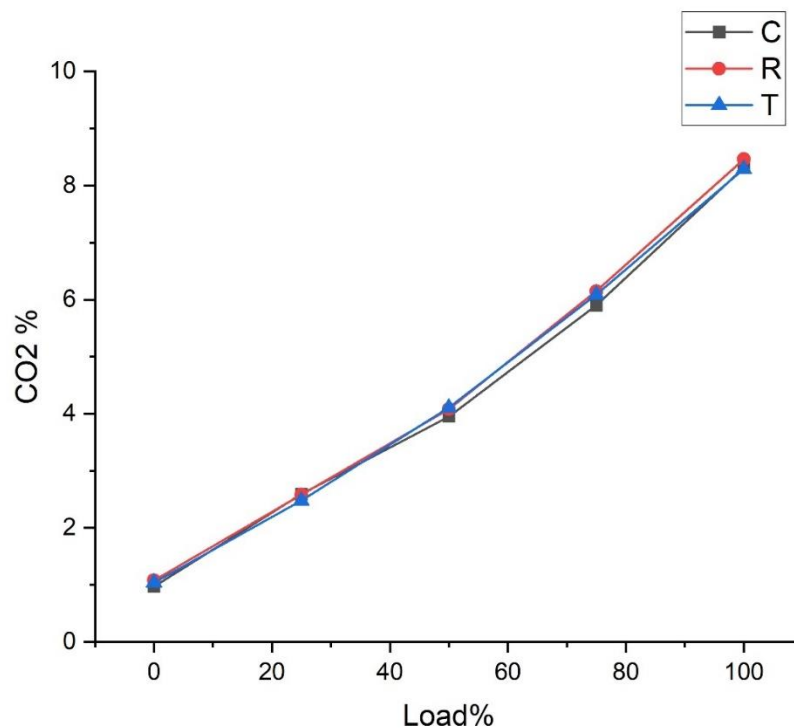


Fig: 5.6: Carbon Di Oxide Emission

5.2.3 NITROGEN OXIDE EMISSION:

The causes of NOX generation in CI engines include high flame temperatures and lengthy retention times. Biodiesel mixes have a higher oxygen content than regular diesel. When the engine's air-fuel combination is extremely lean, high NOX emissions may be produced. The discharge of nitrogen oxide emissions into the environment may be caused by a fuel system leak or an issue with the vehicle's oxygen sensor.

Figure 5.7 in the following graph displays the NOx emission values under various loads. The graph demonstrates that under greater loads Hemispherical as more NOX than Re-entrant, NOX emissions are noticeably higher. Due to improved swirl and squish action and somewhat improved combustion as a result of homogenous mixing, air demand may have increased. As engine loads rose, the NOX emission also increased.

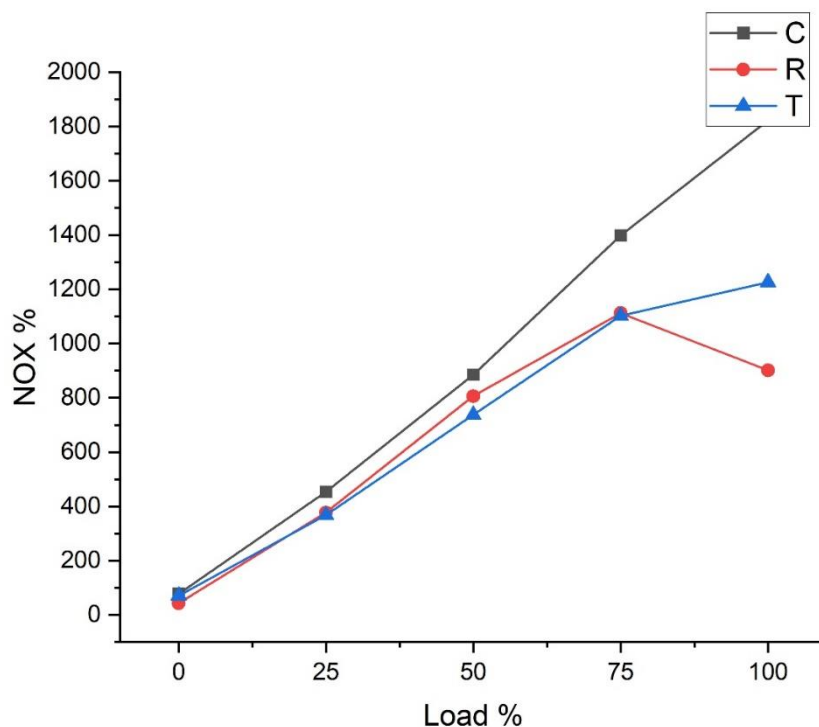


Fig: 5.7: Nitrogen Oxide Emission

5.2.4 HYDROCARBON EMISSION

The fuel in the combustion chamber is not completely burned, which results in hydrocarbon emissions. High levels of hydrocarbons will be released into the environment as a result of the fuel's poor igniting. The very rich and lean mixes produced during combustion are what cause the hydrocarbons to develop. Beyond the lean flammability restrictions, excessive air-fuel mixing will also result in the release of hydrocarbon gas into the environment, which pollutes the atmosphere. Compared to biodiesel fuel mixes, commercially available diesel or petrol diesel releases a lot more HC. Hydrocarbons that are released when fuel is burnt in an engine. Unburned fuel emissions from combustor are caused by unburned fuel "avoiding" the flame zones. S. H. Yoon & C. S. Lee 2011 [39].

Figure 5.8 depicts the rise in load-related hydrocarbon emissions. This section examines and discusses the findings about the HC emissions from the engine testing from fig. 5.8. The graph is created by plotting the HC emissions on the y-axis and the various loads on the x-axis. The graph demonstrates that the HC emission with greater in Toroidal when load is significantly larger, and hemispherical as a less HC emission at higher loads. As engine loads increase, the HC emission rises.

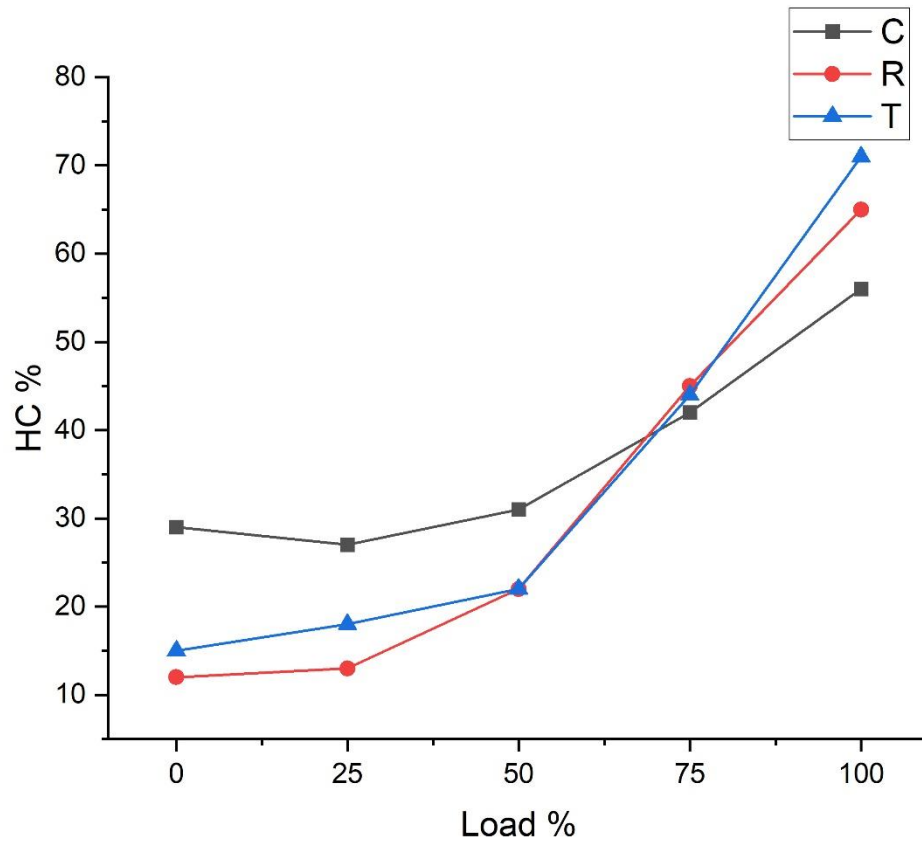


Fig: 5.8: Hydrocarbon Emission

5.2.5 SMOKE OPACITY

This kind of emission particles that will result from the accumulation of fuel on the cylinder's walls. As a result of the gasoline that has been left on the cylinder walls, the internal combustion engine produces smoke that may be measured by the opacity of smoke block lights. If the engines are broken down or not maintained properly, too much smoke will come out. The atmosphere and people will both be affected by these emissions that are released into the atmosphere.

This section studies and discusses the outcomes of the emission parameter known as smoke opacity. The fluctuation of smoke opacity in percent against loads for the B20 fuel with various combustion chambers is shown in Fig. 5.9. the bar graph with smoke percentage on the y-axis and various loads on the x-axis. Hemispherical has a lower level of smoke opacity than conventional combustion chamber pistons. With an increase in loads, the smoke's opacity

increases somewhat. In comparison to diesel at the same load, the smoke opacity of the B20 Re-entrant is greater at higher loads.

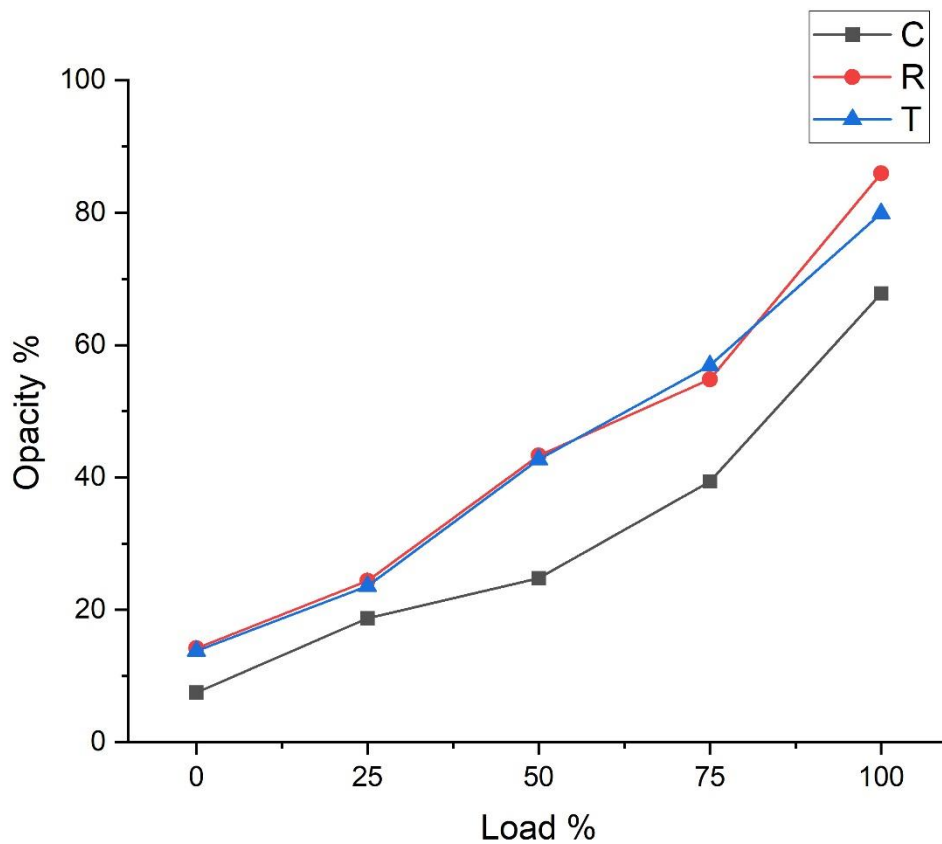


Fig 5.9: Smoke Opacity

5.3 COMBUSTION CHARACTERISTICS

In this part, the combustion properties of the blends, such as net heat release rate, cylindrical pressure, and change in pressure owing to change in heat, are described. Graphs are also generated and analyzed.

5.3.1 CYLINDER PRESSURE

The combustion parameter which pushes the piston in the cylinder to produce power. The engines peak cylinder pressure can be stated as the combustion of fuel and air inside the cylinder takes place, the maximum pressure developed in which the chemical energy will converter into the pressure energy. The combustion characteristics such as net heat release rate, cylindrical pressure, and change in pressure due to chance in heat of the blends are explained in this section The results of the engine test's combustion parameter and cylinder pressure analysis and discussion are shown in fig. to fig. The graph is shown with the crank angle in the x-axis and the cylinder pressure in the y-axis for various loads, including 0%, 25%, 50%, 75%, and 100%. In all, 5 graphs are therefore concurrently drawn for each load. When compared to other B20 combustion chambers, the toroidal piston chamber's cylindrical pressure is lower under all engine loads. In all loads, the toroidal chamber is slightly higher than re-entrant chamber. The peak pressure rise was decreased because the biodiesel and its mixes' ignition delays were shorter than those of diesel.

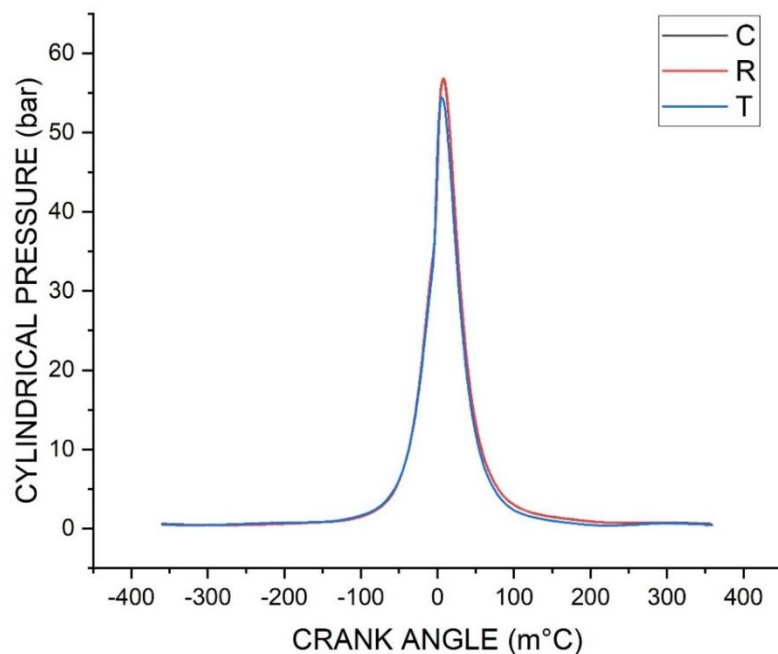


Fig: 5.10: Cylindrical Pressure at 25% Load

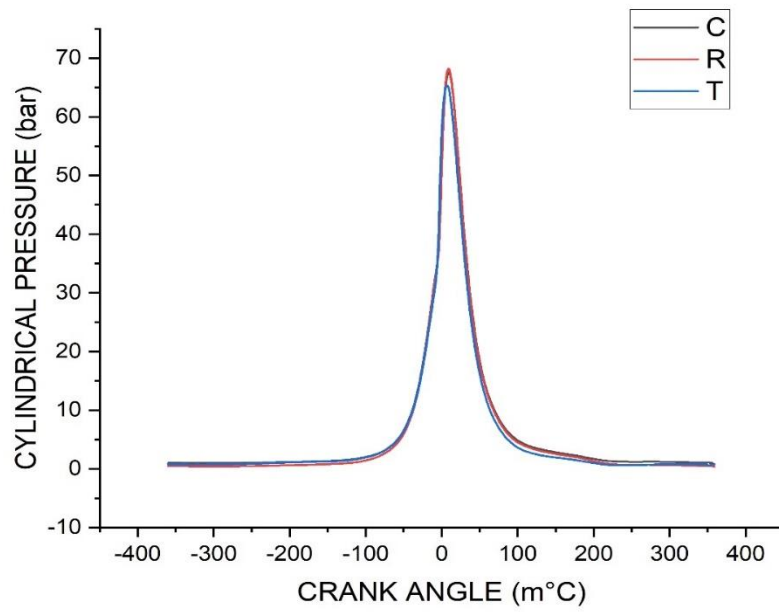


Fig: 5.11: Cylindrical Pressure at 50% Load

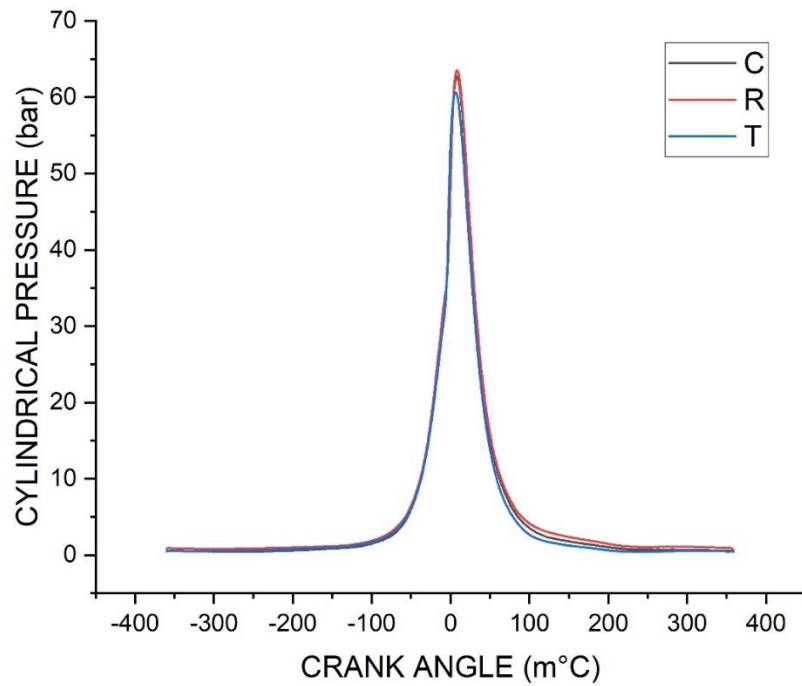


Fig: 5.12: Cylindrical Pressure at 75% Load

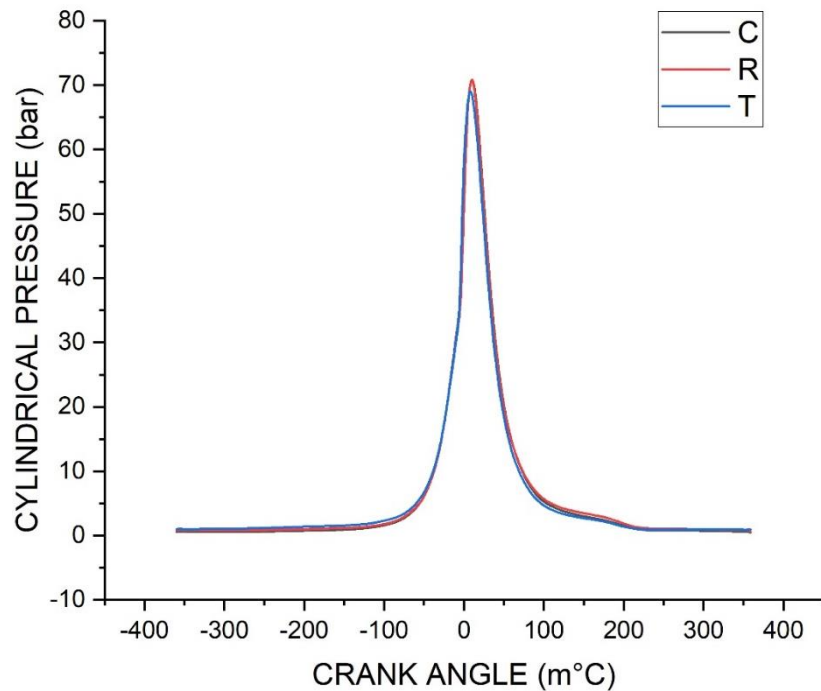


Fig: 5.13: Cylindrical Pressure at 100% Load

5.3.2 HEAT RELEASE RATE

The movement of the piston in an internal combustion engine causes the fuel and air inside the engine's cylinder to burn. The heat release rate is the rate at which heat is released from the cylinder during combustion. By heating the working medium, the heat may also be employed to increase its internal energy and be beneficial for carrying out tasks inside the shaft. Some heat may be lost as a result of the cooling water passing through the cylinder's walls and head. Figures 5.15 to 5.19 display the findings of the combustion characteristic known as net heat release rate. The graphs showing the relationship between crank angle (on the x-axis) and heat release rate (on the y-axis) for various loads, including 0%, 25%, 50%, 75%, and 100%. As we examine the graphs, we see that the heat release rates for all angles are nearly identical and exhibit an uneven pattern. The heat release rate for all blends continues to decrease as the crank angle increases in an inconsistent manner, with one blend's rate rising at one load while the others are falling.

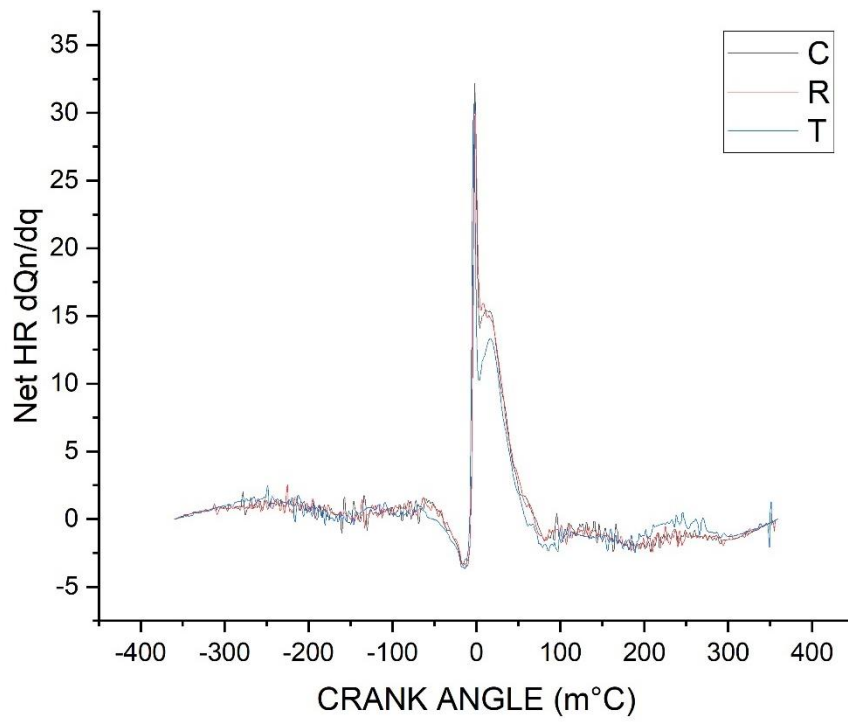


Fig: 5.14: Heat Release Rate at 25% Load

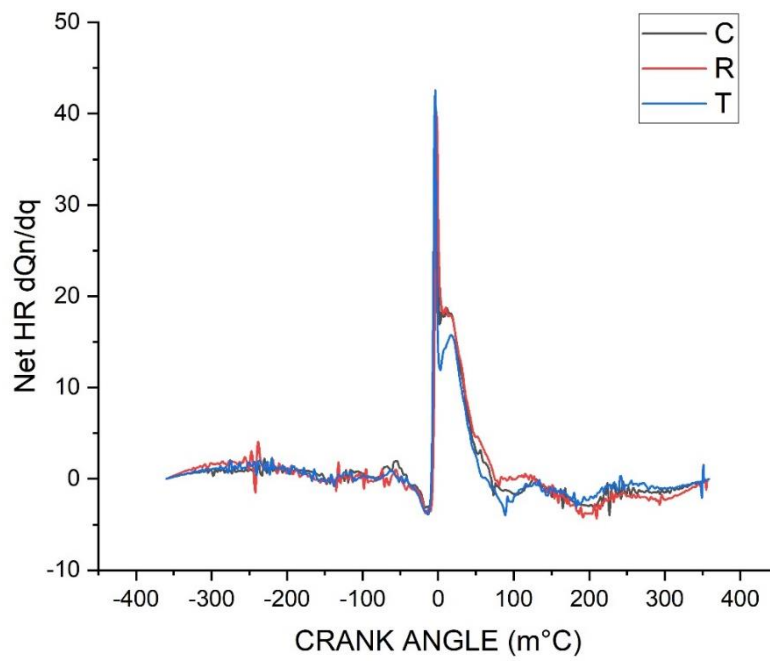


Fig: 5.15: Heat Release Rate at 50% Load

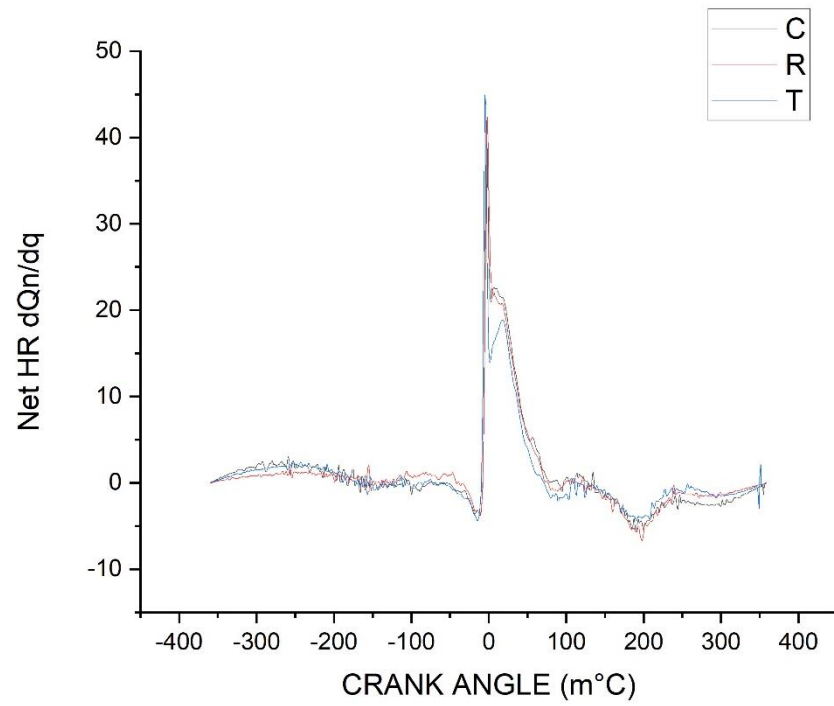


Fig: 5.16: Heat Release Rate at 75% Load

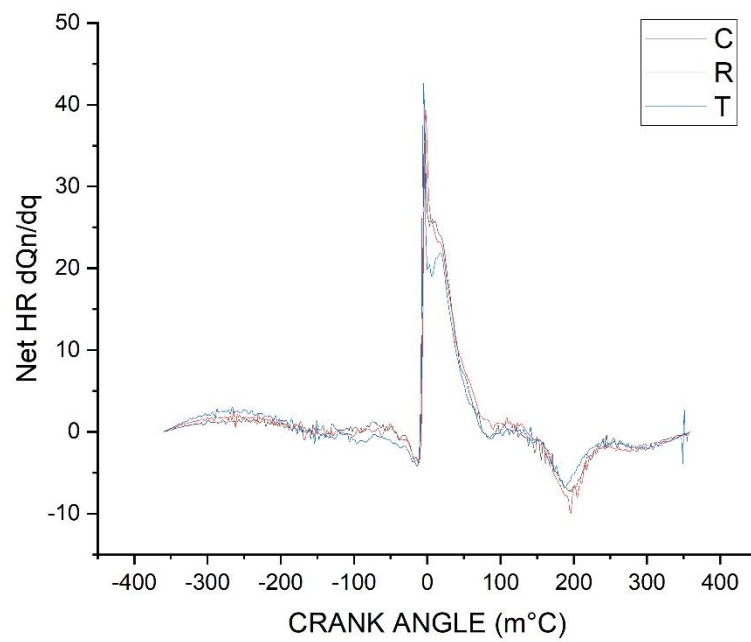


Fig: 5.17: Heat Release Rate at 100% Load

5.3.3 Log V Vs Log P

Boyle's Law states that in addition to the temperature of a given volume of confined gas remaining constant, its pressure and volume are also constant. where k is a constant, V is the gas's volume, and P is its pressure.

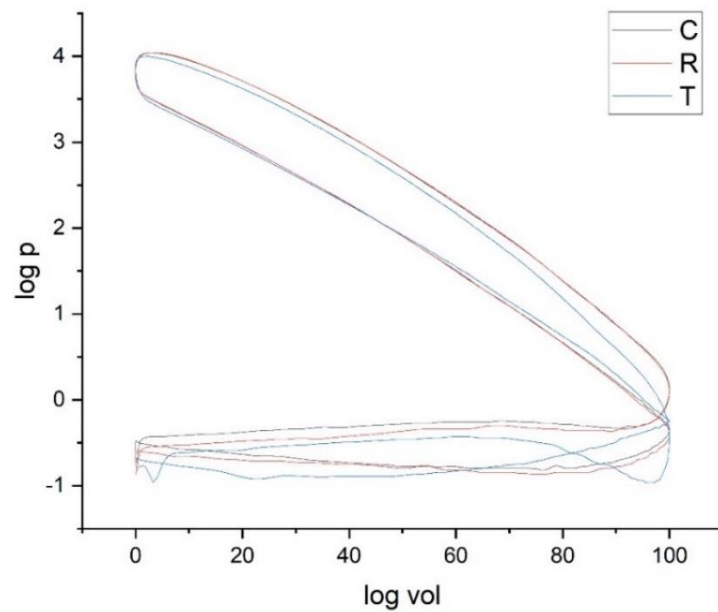


Fig: 5.18: Log V Vs Log P at 25% Load

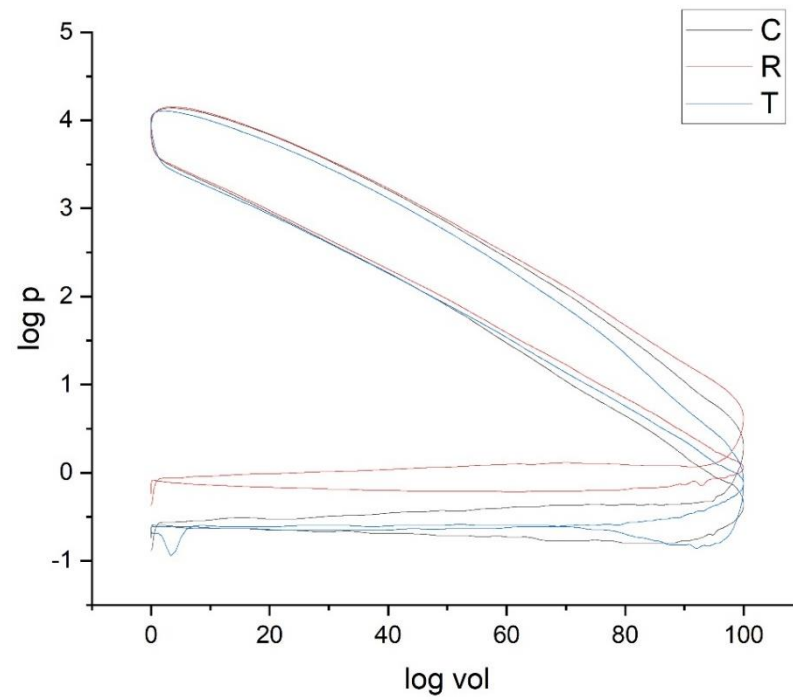


Fig: 5.19: Log V Vs Log P at 50% Load

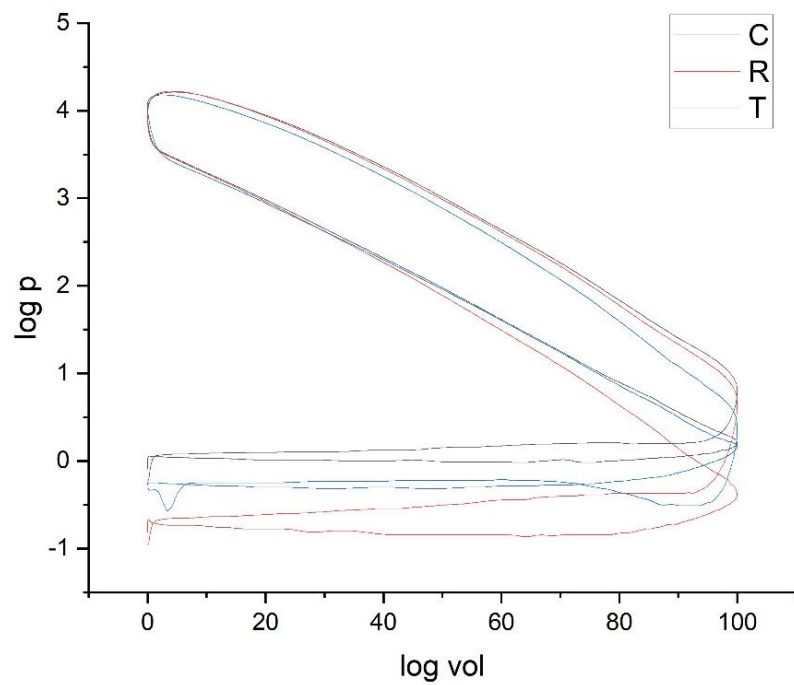


Fig: 5.20: Log V Vs Log P at 75% Load

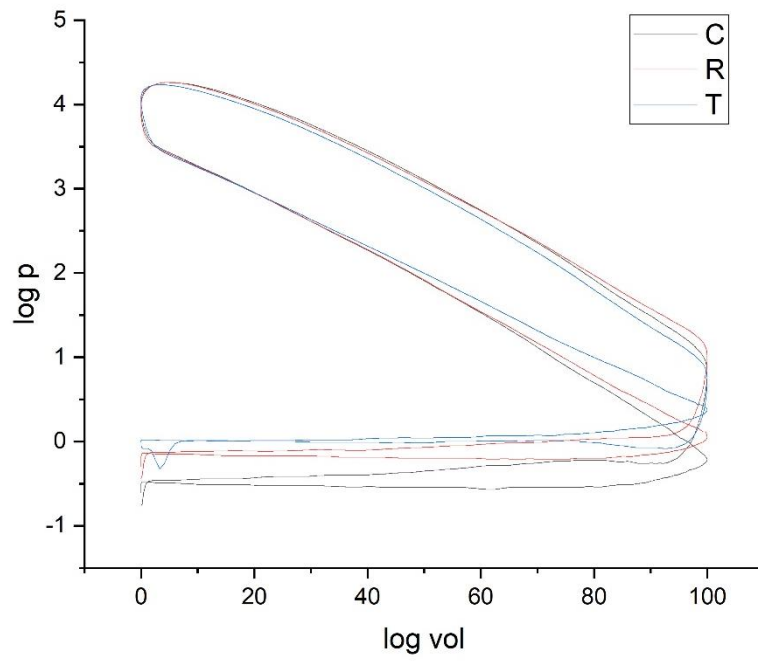


Fig: 5.21: Log V Vs Log P at 100% Load

CHAPTER 6

SUMMARY AND CONCLUSION

- Microalgae oil and cotton seed oil biodiesel are effectively made in accordance with the guidelines.
- The B20 fuel mixture is tested under various loads and in various combustion chambers.
- The hemispherical combustion chamber is proven to have a very high brake thermal efficiency.
- The volumetric efficiency is found to be very high for the Toroidal combustion chamber and low for Hemispherical combustion chamber.
- NO_x emissions were lowest in the case of Re-entrant followed by Toroidal.
- In the case of the re-entrant combustion chamber, the hydrocarbon emission was greatest.
- Hemispherical has a lower level of smoke opacity than conventional combustion chamber pistons.
- The Toroidal piston chamber's cylindrical pressure is lower under all engine loads.

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APPENDIX

PLAGARISM PERCENTAGE:

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CHAPTER 1 INTRODUCTION

1.1 HISTORY AND BACKGROUND

The first internal-combustion engine was created in the 19th century as a result of engineers' determination to find an alternative to steam power engines and appropriate scientific knowledge of the thermodynamics principles. The propellant is consumed internally in an internal combustion engine; the cannon shown is an early example of a single-stroke engine, and several individuals have tried using gunpowder to power a single piston in a cylinder. The main issue was the lack of an appropriate fuel for this process, and another issue was the difficulty of rapidly and easily repeating the ignition of the fuel in a confined environment. The first issue was addressed in the mid-nineteenth century with the introduction of municipal gas sources, but the second proved more difficult to solve due to the difficulty in maintaining equally distributed ignition. In 1878, the German engineer Nikolaus August Otto improved this design. The most prevalent application for CI engines in cars is transit. The benefits of CI engines include excellent fuel efficiency, decreased emissions, increased reliability, and decreased upkeep. Fig 1.1 represents the various sources of emission around the world. Here it shows clearly transportation is the major source of pollution, to overcome Finding an affordable, non-edible, and sustainable substitute fuel is necessary to address these kinds of problems.

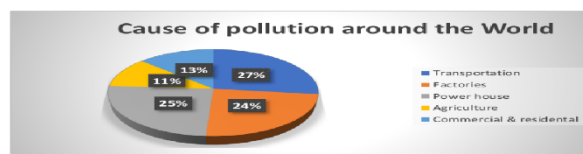


Fig:1.1: Causes for Pollution

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