

EXPERIMENTAL INVESTIGATION ON RE-ENTRY PISTON HEADS

Submitted in partial fulfilment of the requirements for the award of

Bachelor of Engineering degree in
Mechanical Engineering

by

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(DEEMED TO BE UNIVERSITY)

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MARCH 2021



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BONAFIDE CERTIFICATE

This is to certify that this Project Report is the bonafide work of **CHANDAVOLU VENKATA SAI KIREETI (Reg. No.37150039)** who carried out the project entitled **"EXPERIMENTAL INVESTIGATION ON RE-ENTRY PISTON HEADS"** under our supervision from October 2019 to April 2020

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I, **CHANDAVOLU VENKATA SAI KIREETI (Reg. No.37150023)** hereby declare that the Project Report entitled “**EXPERIMENTAL INVESTIGATION ON RE-ENTRY PISTON HEADS**” is a record of an original work done by us under the guidance of **Dr. J. HEMANANDH M.E., Ph.D.**, at **SATHYABAMA INSTITUTE OF SCIENCE AND TECHNOLOGY** is submitted in partial fulfillment of the requirements for the award of Bachelor of Engineering degree in Mechanical Engineering.

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ACKNOWLEDGEMENT

I am pleased to acknowledge my sincere thanks to Board of management of **SATHYABAMA INSTITUTE OF SCIENCE AND TECHNOLOGY** for their kind encouragement in doing this project and for completing it successfully. I am grateful to them.

I convey my thanks to **Dr. S. PRAKASH, M.E., Ph.D., Dean, School of Mechanical Engineering** and **Dr. G. ARUN KUMAR, M.E., Ph.D., Head of the Department, Department of Mechanical Engineering** for providing me the necessary support and details at the right time during the progressive reviews.

I would like to express my sincere and deep sense of gratitude towards our Project Guide **Dr. J. HEMANANDH, M.E., PhD., Assistant Professor, Department of Mechanical Engineering** for his valuable guidance, suggestions and constant encouragement paved way for the successful completion of my project work.

I wish to express my thanks to all Teaching and Non-teaching staff members of the Department of **MECHANICAL ENGINEERING** who were helpful in many ways for the completion of the project.

ABSTRACT

As we are experiencing a shift from fossil fuels to alternate fuels. In this study, the effect of hydrogen addition to compression ignition (CI) as secondary fuel, with the blend of waste vegetable oil and biodiesel (WVOB) blend (B20) and (B30) on the engine performance and exhaust emissions was examined experimentally. In the tests, CI Engine set up under test is Kirloskar TV1 having power 3.75 kW @ 1500 rpm which is a 1 Cylinder, Four-stroke, Water Cooled, Diesel Engine, with Cylinder, 661.45 (cc) is used the outcome of the experiment. To increase efficiency and decrease emissions out of a CI engine. As global emissions are happening at an alarming rate some new changes have to be done to protect mother earth. Many new changes are coming in using different types of fuels and types of engines as well as shifting focus towards renewable energy such as solar and wind to reduce CO₂ emissions. The engine size as well as increasing the overall output of the engine as well as decreasing the emission.

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LIST OF ABBREVIATIONS

WVO	Waste Vegetable Oil
BV30	30% vegetable bio diesel and 70% pure diesel
BV20	20% vegetable bio diesel and 80% pure diesel
PD	100% pure diesel
RP	Re-entry Piston
LPM	Hydrogen flow rate litres/min
BSFC	Brake specific fuel consumption
BTE	Brake thermal Efficiency
HRR	Heat release rate
cSt	centistokes
CO	Carbon monoxide
CO ₂	Carbon dioxide
NO _x	Nitrogen dioxide
HC	Hydrocarbons

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CHAPTER 1

INTRODUCTION

1.1 BACKGROUND

We've long been aware of the problems that a shortage of fossil fuels can cause. For decades, excessive reliance on this energy source as the primary, if not only, energy carrier in transportation and power generation has raised concerns and prompted thorough research into alternative fuels. People became worried about low fossil fuel supplies after a forecast of peak oil supply was made. Despite the addition of several new variables to the metrics used to predict peak oil production, the majority of scientists and organisations agree that peak oil production will occur before 2020.

The environment is being threatened by global warming caused by greenhouse gas (GHG) emissions from fossil fuels. Today, 171,000 kg of coal, 116,000,000 L of gas, 186,000 L of oil is consumed every second [1]. It is suggested that the widespread use of biofuels rather than fossil fuels would contribute to a reduction in GHG emissions in our atmosphere, resulting in a reduction in global warming and global catastrophe [2]. Biodiesel, a biofuel made from waste vegetable oil, is a renewable energy source that is being overemphasized to meet rising transportation energy demand and reduce GHG emissions [3]. When recent studies in the field of renewable energy are considered, it is clear that an excessive amount of focus is placed on biodiesel, which has emerged as a viable alternative to petrochemicals or petroleum-based fuels [4]. Biodiesel is a clean and renewable fuel that is thought to help grow the agricultural economy while also reducing reliance on petroleum-derived fossil fuels. The interest in using biodiesel as an alternative fuel in compression ignition (CI) engines is increasing by the day [5] since it contains no sulphur or aromatics, is nontoxic, and biodegradable. Different organic resources, such as vegetable oils, animal fats, waste oils, and algae, can be used to make biodiesel. The characteristics of the biodiesel produced may differ depending on the feedstock and type of alcohol used in its production, which could lead to the occurrence of problems of different engine performance and emission values for each biodiesel engine. Generally, there is a decreasing tendency in PM, HC and CO emissions and there is an increasing tendency in NO_x emissions. The fact that biodiesel is more expensive than petroleum-based diesel fuel is an impediment to

its commercialization. The raw material cost (feedstock cost) is estimated to account for 70 to 85 percent of the overall biodiesel production cost [6]. If edible oils (nutritional source) are used as a feedstock in the production of biodiesel, the demand for agricultural land will rise in proportion to the demand for cooking oil. Using waste vegetable oils (WVO) instead of raw oils to make biodiesel is a good way to save money on raw materials. The main sources of WVO are made up of frying oil used for high-temperature cooking and edible fat found in kitchen waste. Every day, a large amount of WVO is produced in homes, restaurants, the food processing industry, and fast-food restaurants around the world. In the European Union alone, the potential WVO amount is estimated to be between 0.7 and 1.0 million tons per year. These wastes cause serious waste disposal issues, such as pollution of river water and drainage blockage. As a result, using these wastes as a raw material for biodiesel synthesis aids in the elimination and reduction of production costs [7]. In the literature, various studies were conducted on the testing of the biodiesel obtained from WVO in the CI engines [8]. It is understood from the literature, with the WVO biodiesel addition to the diesel fuel, generally, while a decrease occurs in the engine torque, the engine power and the brake thermal efficiency (BTE), an increase occurs in the brake specific fuel consumption (BSFC) and exhaust gas temperature (EGT). While an increase is seen in the CO₂ emissions, the NO_x, HC, CO and smoke emissions generally decrease. In addition, it was stated by Al-Dawody et al. [9] and Gadetal [10] found that using WVO biodiesel lowers in-cylinder pressures (CPs). To increase the efficiency and emissions of internal combustion engines, hydrogen should be added to traditional hydrocarbon-based fuels (ICE). Hydrogen is a clean-burning, non-toxic, odourless, organic, and recyclable alternative fuel that produces only water as a combustion product when combined with oxygen [11]. Since dangerous compounds such as hydrocarbon and carbon monoxide are not created when hydrogen is burned. As a consequence, it leads to the enhancement of air quality [4]. As compared to hydrocarbon-derived fuels, hydrogen has a number of advantages, including a faster flame, lower ignition energy, faster diffusion rate, a wider flammability limit, and a shorter quenching distance [12]. However, NO_x emissions increased while other emissions decreased when hydrogen was used in CI engines. According to Hamdan et al., hydrogen enrichment increases CPs slightly. Just a few studies on using hydrogen as a tertiary fuel in CI engines with diesel-biodiesel fuel blends were

included in the literature review. Furthermore, single-cylinder, lower-power test engines are typically used instead of the commercial CI engines that are widely used today. The aim of the research is to see how adding hydrogen to a commercial CI engine that runs on diesel-waste cooking oil biodiesel affects its efficiency and emission of a commercial CI engine, fuel with diesel-waste cooking oil biodiesel (B20) and (B30) fuel blends. The target is improving the performance and emissions of biodiesel fuel CI engine with hydrogen addition and determining the optimum hydrogen addition rate. Different engine loads (5.20kw) and constant engine speed were used in the experiments (1500 rpm). Hydrogen was applied to the intake air at a rate of 4 lpm by volume for each diesel and B20 and B30 ratio fuel test. Furthermore, because of their recent accessibility and affordability, fossil fuels now account for the majority of transportation fuel. According to a 2017 study by the International Energy Agency (IEA), fossil energy accounts for roughly 80% of total global commercial energy, with 98% of that going to transportation (de Almeida and Silva, 2009). This is due to rising global demand for and the number of vehicles, as well as strong economic growth in some countries, it is followed by large increases in energy consumption but apart from fuel security, there is another aspect that has prompted attempts to substitute all or part of the existing fossil fuels used in automobiles. This is because burning fossil fuels emits toxic gases (including CO₂) which are harmful to the population and have negative environmental consequences. CO₂ emissions from the burning of fossil fuels contribute greatly to global warming.

As a result, substituting renewable and other alternative fuels, such as gaseous and liquid fuels, for fossil fuels would increase clean fuel production and fuel stability. Furthermore, by developing engine technology to allow for the use of gaseous fuels, further fuel savings in transportation can be realised. When used in diesel engines, however, they have drawbacks in terms of performance and emissions when the engine is switched off. This is due to most gaseous fuels which have poor energy content and low cetane number (CN). To resolve the existing challenges, studies have been conducted with the aim of identifying alternative fuels, both gaseous and liquid fuels, that could be used to partially replace the traditional diesel fuels. It also considers the use of hydrogen as a gaseous fuel, which has a high energy content and can be used as an energy carrier.

1.2 HISTORY OF DIESEL ENGINES

After looking for a way to improve the Otto engine's efficiency, German engineer Rudolf Diesel came up with the idea for the engine that bears his name (the first four-stroke-cycle engine, built by the 19th-century German engineer Nikolaus Otto). Diesel discovered that if air could be heated to a temperature higher than the auto-ignition temperature of a given fuel, the electric ignition mechanism of a gasoline engine could be prevented during the compression stroke of a piston-cylinder system. In his patents from 1892 and 1893, Diesel suggested such a cycle. Initially, fuel substitutes such as powdered coal or liquid petroleum were suggested. After the experimental engine was killed by an explosion, Diesel turned to liquid petroleum to pump coal dust into the engine cylinder. He began pumping fuel into the engine with compressed air. Rudolf Diesel struggled at first to compress the fuel to the pressures needed for spray dispersion, disintegration, and droplet formation. As a result, the first diesel engine, which debuted in 1897, used compressed-air injection, in which the fuel was injected into the cylinder using compressed air. The poor penetration depth of the air/fuel mixture into the combustion chamber was an issue with this method due to the low pressure at the nozzle. As a result, higher injected fuel volumes (higher engine loads) and engine speeds were not ideal for this method of mixture forming.

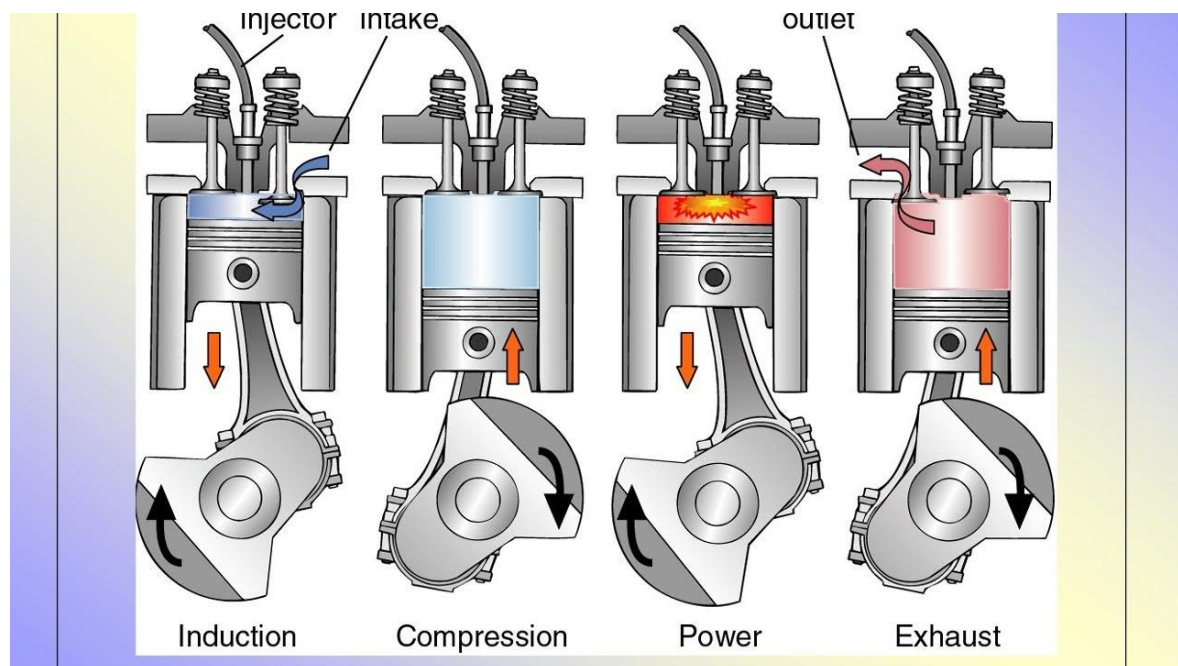
Direct injection (DI) and indirect injection (II) diesel engines are the two types (IDI). The combustion chamber in the former is fully encircled by the cylinder head and piston surfaces, and it usually takes the shape of a cavity or bowl in the piston crown. The combustion chamber is divided into two parts in the latter: one is a cavity in the piston shaped differently than in a direct injection engine, and the other is a pre-chamber connected to the cylinder by one or more passages. The pre-chamber is injected with petrol.

1.2.1 OPERATION OF A DIESEL ENGINE

Compression ignition (CI) engines have higher thermal efficiency in comparison with spark ignition (SI) engines. The CI engine was invented by Rudolf Diesel in 1882. One or more cylinders make up a diesel engine. The piston in each cylinder goes up and down, powered by the ignition of the air/fuel mixture. It was assigned the name "reciprocating-piston engine" because of this method of operation. The

connecting rod, also known as a conrod, transforms the piston's linear reciprocating motion into rotational movement on the crankshaft. A flywheel attached to the end of the crankshaft generally keeps the crankshaft rotating smoothly and reduces the unevenness created by the periodic existence of fuel combustion in the individual cylinders. Engine speed refers to the speed at which the crankshaft rotates. The diesel engine is a self-igniting engine that mixes fuel and air within the engine. Inside the combustion chamber, the air needed for combustion is extremely compressed. This causes the diesel fuel to spontaneously combust when pumped into the cylinder, resulting in high temperatures. As a result, the diesel engine's heat is used to liberate the chemical energy contained in the fuel and convert it to mechanical electricity (Bosch 2005). The engine has a four-stroke cycle. The basic operations of a conventional diesel engine are described below.

1.2.2 FOUR STROKE CYCLE OPERATION



- A] INDUCTION STROKE
- B] COMPRESSION STROKE
- C] POWER STROKE
- D] EXHAUST STROKE

1. Inlet-valve camshaft 2. Fuel injector 3. Inlet valve 4. Exhaust valve 5. Combustion chamber 6. Piston 7. Cylinder wall 8. Connecting rod 9. Crankshaft 10. Exhaust-valve camshaft

Fig. 1.1 OPERATION CYCLE OF FOUR STROKE DIESEL ENGINE

Inlet and exhaust valves regulate the intake of air and the expulsion of burning gases following combustion in a four-stroke diesel engine (Fig. 1.1). They open and close the inlet and exhaust valves of the cylinder. One or two valves can be present at each inlet and exhaust port.

- **Induction stroke:**

The piston travels downwards from Top Dead Center (TDC), raising the cylinder's capacity. The inlet valve is opened at the same time, and air is drawn into the cylinder without being restricted by a throttle valve. The cylinder potential is at its maximum when the piston hits Bottom Dead Center (BDC).

- **Compression Stroke:**

The inlet and exhaust valves have now been closed. The piston rises and compresses the air contained within the cylinder to the degree defined by the engine's compression ratio 25:1. The air is heated to temperatures of up to 900°C during the process. When the compression stroke is near completion, the fuel injection mechanism injects high-pressure fuel into the hot, compressed air with pressure up to 2000bar. The cylinder capacity is at its minimum as the piston hits top dead centre.

- **Ignition stroke:**

The ignition stroke starts after the ignition lag (a few degrees of crankshaft rotation) has occurred. Due to the heat of the compressed air in the combustion chamber, the finely atomized and readily combustible diesel fuel spontaneously ignites and burns. As a result, the cylinder charge heats up even more, and the cylinder pressure increases even more. The mass of fuel injected determines the amount of energy released during combustion. The piston is pushed downward by the pressure. The kinetic energy produced by combustion is thereby converted from the chemical energy released by combustion. The crankshaft drive transforms the kinetic energy of the piston into a turning force (torque) at the crankshaft.

- **Exhaust stroke:**

The exhaust valve opens fractionally until the piston hits bottom dead centre. The cylinder's thick, pressurized gases are ejected. As the piston rises again, the excess exhaust gases are forced out. The crankshaft has completed two revolutions after the exhaust stroke, and the four-stroke working cycle begins with the induction stroke.

1.2.3 VALVE TIMING in Diesel engines:

The inlet and exhaust camshafts have cams on them that open and shut the inlet and exhaust valves, respectively. A rocker-arm system transmits the action of the camshaft to the valves on engines with a single camshaft. Valve synchronization is the process of synchronizing the valves opening and closure with the rotation of the crankshaft. As a result, valve timing is expressed as a percentage of crankshaft rotation. The camshaft is driven by a toothed belt or chain the timing belt or timing chain, or sometimes by a set of gears, from the crankshaft. A full working cycle in a four-stroke engine takes two crankshaft revolutions. As a consequence, the camshaft rotates at half the usual speed. As a result, the crankshaft-to-camshaft transmission ratio is 2:1. The inlet and exhaust valves are opened progressively for a period of time during the transition from exhaust to induction stroke. This "valve overlap" aids in the "flushing out" of any leftover exhaust and cooling of the valves. Shown in Fig.1.2

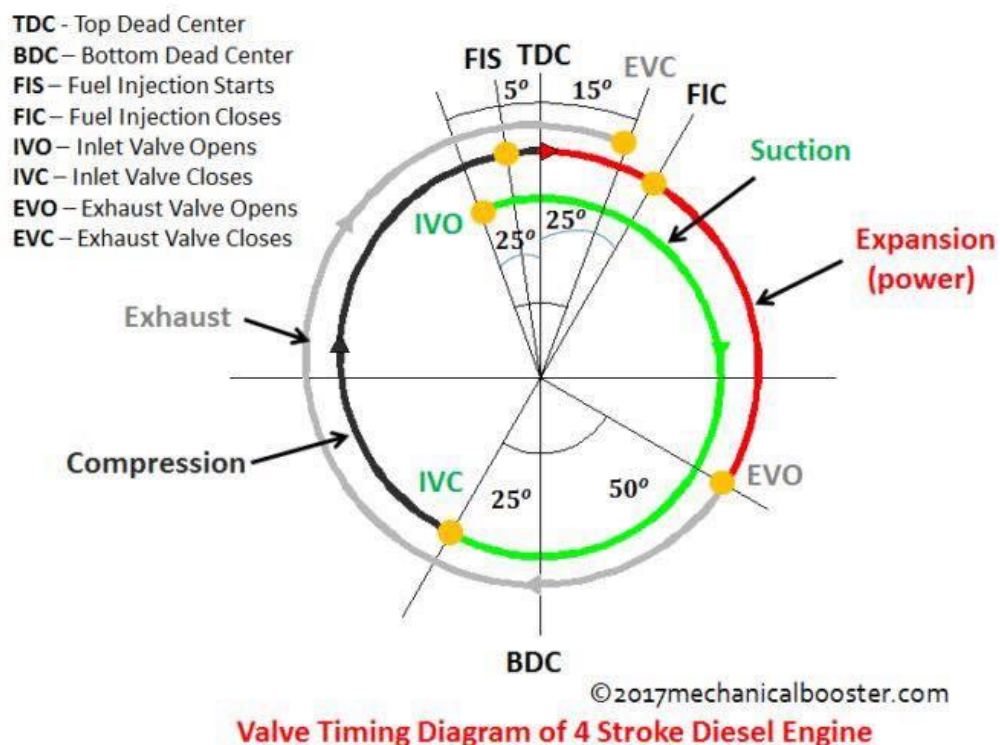


Fig.1.2: VALVE TIMING DIAGRAM FOR FOUR STROKE ENGINE

1.2.4 COMBUSTION IN CI ENGINES:

There are some fundamental variations in the combustion processes of SI and Ci engines. A homogeneous carburetted mixture of fuel vapour and air is

compressed in a certain proportion (6:1 to 10:1) in the SI engine, and the mixture is ignited by an electric spark just before the compression stroke ends. A single flame front advances through the air-fuel mixture after combustion. Only the air is compressed at a high compression ratio (16:1 to 20:1) in CI engines, resulting in a high temperature and pressure. Through one or more jets, fuel is injected into the highly compressed air in the combustion chamber. The fuel jet disintegrates into a fuel core encased in a shell of air and fuel particles. The combustion of fuel is atomized and vaporised. The atomization and vaporisation of the gasoline creates this spray envelope. The fuel particles are ripped from the core by the turbulence of the air in the combustion chamber passing over the jet. At some point in the spray envelope, a combination of air and fuel emerges, and oxidation begins.

1.2.5 COMBUSTION CHAMBERS IN CI ENGINES:

The most major aspect of the CI engine is the combustion chamber configuration, which ensures optimal fuel and air mixing in a short period of time. To do this, a structured air flow known as an air swirl is used to create a high velocity between the fuel droplets and the air. An injector with a single or several holes injects the fuel into the combustion chamber. The strength of the air swirl needed is decreased as the number of jets increases.

The CI engine combustion chambers are divided into two categories to achieve better air fuel mixing in a short period of time:

1.2.6 DIRECT INJECTION CHAMBERS:

An open combustion chamber is one in which the combustion room is effectively a single cavity with no restriction from one end of the chamber to the other and, as a result, no significant change of pressure between the chamber's parts during the combustion phase.

1.2.7 COMPONENTS OF A DIESEL ENGINE:

A diesel engine has such components and parts as engine body, crankshaft, connecting rod, piston, cylinder liner, heat exchanger, cylinder cover, high-pressure fuel pipe and alarm, connecting rod bolt, supercharger, turbocharger, fuel injection pump assembly, piston rings, cam shafts, chain connecting crankshaft and cam shaft.

1.2.8 HEMISPHERICAL CHAMBER:

In recent diesel engines, this configuration has been tried. This is a truncated cone with a 30° base angle, which is a variation of the cylindrical chamber. The swirl is created by covering approximately 180 degrees of the valve. The depth of the squish can also be modified.

1.2.9 RE-ENTRY CHAMBER:

Re-Entrant Combustion Chambers. Combustion chambers in modern direct injection diesel engines can be designated as either open or re-entrant. If the top opening of the bowl in the piston is smaller in diameter than the maximum bowl diameter, it is a re-entrant bowl. The concept behind this shape is to have a strong squish as well as air displacement inside the Re-entry chamber as shown in Fig.1.3, comparable to that of a smoke ring. Because of the powerful squish, the mask necessary on the inlet valve is limited, and oxygen is best used. For this kind of chamber, the spray cone angle is 150° to 160°.

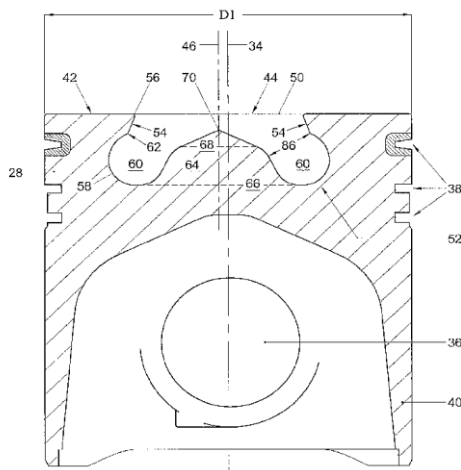


Fig. 3

Fig. 1.3 Re-entry Combustion Chambers in DI Engines

1.2.10 Key benefits of direct injection chambers:

The following are the key benefits of direct injection chambers:

- We don't combine the air and fuel until igniting the mixture in a DI diesel engine; instead, we inject the fuel into the already hot and compressed air, where it burns when it is injected, so the trick is bringing each molecule of fuel to its necessary molecules of air in a short period of time.

- The multi hole nozzle allows for fine atomization of air fuel mixture.

The following are some of the drawbacks of these combustion chambers:

- High fuel injection is needed, necessitating a complicated fuel injection pump design.
- The need for precise fuel metering by the injection system, particularly for small Engine.

1.2.11 PHASES IN COMBUSTION:

The combustion process takes place in four phases, namely ignition delay, premixed combustion, diffusion combustion and late combustion. This entire process can be understood from the heat release rate diagram shown in Fig:1.4 .

The ignition delay phase is delay in time between start of ignition and start of the combustion. This phase is mainly affected by fuel properties. In pre-mixed combustion phase more heat release rate is seen in the cylinder due to the combustion of air fuel mixture. The diffusion combustion phase is controlled by the speed at which fuel is available for combustion. The late combustion phase occurs during the expansion stroke and depends upon the unburnt fuel remaining in the cylinder. Heat released is low in this phase due to less air-fuel mixture in the chamber.

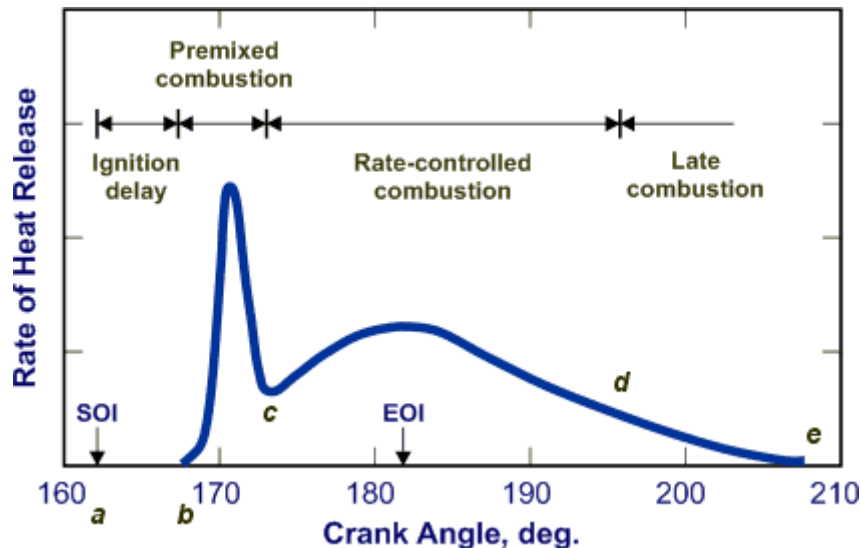


Fig. 1.4: phases of combustion in CI engine

1.2.12 DIESEL ENGINE EFFICIENCY AND PERFORMANCE:

Internal-combustion engines operate by adjusting the pressure and temperature of a working fuel (cylinder charge). The ratio of input energy (fuel) to usable work is the engine's effective performance. This is determined by the difference between the thermal efficiency of an optimal work process (Seiliger process) and the percentage losses of an actual process.

Seiliger process:

The Seiliger method can be used as a thermodynamic comparative process for reciprocating piston engines. This is shown below in Fig.1.5, It explains potentially beneficial work done in optimal circumstances. The following simplifications are assumed in this ideal process:

As a working medium, ideal gas. Gas with constant specific heat. No losses during gas exchange

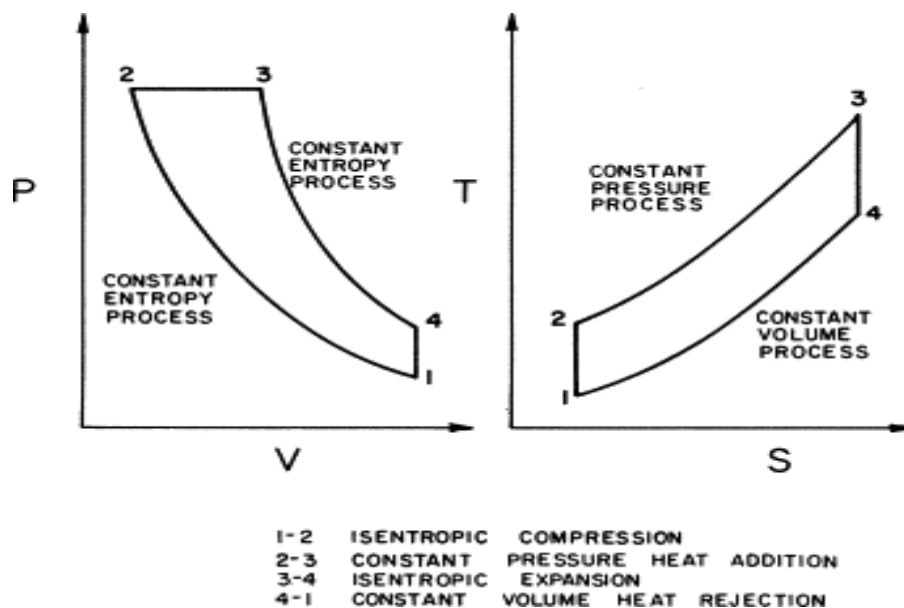


Fig. 1.5: Seiliger process in CI engines

Isentropic compression (1-2):

Pressure in the chamber rises as the volume of the gas decreases with isentropic compression (compression at constant entropy, i.e. without heat transfer).

Isochoric heat propagation (2-3):

The combination of air and gasoline begins to ignite. At a constant volume, heat amplification (q_{BV}) occurs (isochoric). Gas pressure grows as well.

Isobaric heat propagation (3-3):

If the piston travels downwards and the gas volume increases, further heat propagation (q_{Bp}) happens at steady pressure (isobaric).

Isentropic expansion (3-4):

There is no more heat transfer. As the volume increases, the pressure decreases.

1.2.13 DIESEL ENGINE EMISSIONS:

The diesel engine is a significant source of energy. It is commonly used in industrial and land transportation applications. Despite their efficiency, diesel engines have considerable disadvantages such as high NO_x and particulate emissions; this is also a major problem that requires serious consideration. In recent years, extensive study has been conducted to monitor these gases.

Diesel fuel, like most fossil fuels, is made up of carbon and hydrogen. In a perfect thermodynamic equilibrium, complete combustion of diesel fuel in engine combustion chambers will only produce CO₂ and H₂O. Many factors such as that of the air–fuel ratio, ignition timing, instability in the combustion chamber, combustion type, air–fuel concentration, combustion temperature, and so on render this unlikely, and a variety of dangerous products are generated during combustion like CO, HC, NO_x, and PM.

The estimated composition of diesel exhaust gas is depicted in the Fig.1.6. (Khair and Majewski 2006). In the case of diesel exhaust gas, pollutant emissions are less than 1%. At a pace of more than 50%, NO_x has the largest proportion of diesel pollutant emissions. PM emissions fall in second to NO_x emissions in terms of pollutant emissions. Since diesel engines are lean combustion engines with low CO and HC concentrations. Furthermore, depending on the requirements and nature of the gasoline, pollutant emissions can contain a small amount of SO₂. Diesel fuel contains sulphates, which allow it to form SO₂ emissions.

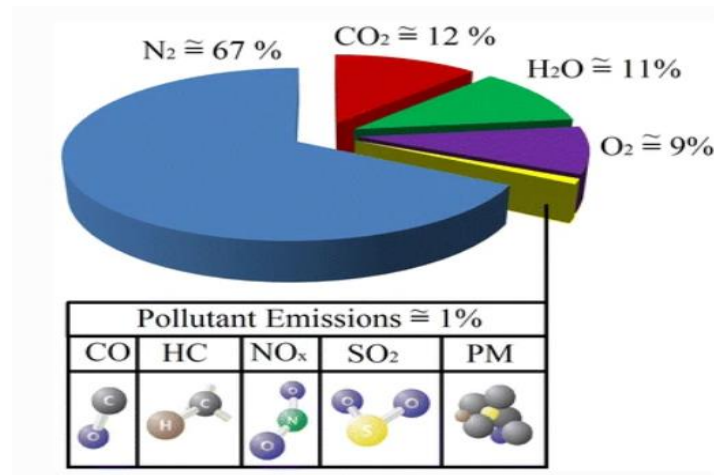


Fig. 1.6: Diesel engines Exhaust composition

Diesel fueled vehicles are one of the most important causes of the air quality deterioration. Engine speed and load, fuel physical and chemical properties, air-fuel ratio, injection timing, and combustion chamber design all influence the concentration of the harmful by products generated by the diesel combustion. Understanding the development and combustion processes of a diesel engine and exhaust emissions is crucial because it can lead to strategies for their regulation. The five major pollutant emissions (CO, HC, PM, NO_x and PM) from diesel engines are explained in this section.

1.2.14 Carbon Dioxide (CO₂)

Carbon dioxide is the most major greenhouse gas produced by human activities (CO₂). In 2018, CO₂ accounted for about 81.3 percent of all human-caused greenhouse gas emissions in the US. Carbon dioxide is found in the atmosphere as part of the Earth's carbon cycle. Human activities are changing the carbon cycle, both by adding more CO₂ to the environment and by impacting natural sinks' ability to extract and store CO₂, such as trees and soils.

Carbon dioxide is a significant by product of the burning of hydrocarbon fuels. It is one of the major greenhouse gas pollutants, with nitrous oxide, nitrogen, perfluorocarbons, sulphur, and hydrofluorocarbons. CO₂ is an obnoxious gas. CO₂ is still present in the atmosphere, albeit in very low concentrations. The level, on the other hand, has risen at an exponential pace over time. According to a survey conducted by the International Energy Agency, gross CO₂ emissions from fuel combustion were almost non-existent in the 1970s, but were projected to be 33.5 Gt CO₂ in 2019. Human actions have shifted the balance, and they can no longer

compensate for the forest's failure to consume CO₂. Massive global use of fossil fuels (natural gas, coal, and oil), exacerbated by emissions and the long lifetime of CO₂ in the atmosphere, has a detrimental impact on climate change and is a major issue for all nations. Some of the suggested solutions include the use of engine technology that provide better fuel conversion efficiency, the use of renewable energy, the use of low-carbon fuels, and, in the long run, the use of hydrogen.

1.2.15 HYDROCARBONS (HC)

Hydrocarbons are harmful to both the environment and human health. They, along with other pollutant emissions, contribute greatly to the production of ground-level ozone. Hydrocarbons are toxic and can cause cancer as well as irritate the respiratory system. The thousands of species of hydrocarbons include alkanes, alkenes, and aromatics.

If the temperature is above 600 °C and there is oxygen present in the exhaust, unburned hydrocarbons begin to react in the exhaust, so hydrocarbon emissions from the tailpipe can be slightly lower than hydrocarbons leaving the cylinder. Diesel engines produce very few hydrocarbon emissions. Light loads are a common source of diesel hydrocarbon emissions. The primary source of light-load hydrocarbon emissions is lean air–fuel mixing. In lean mixtures, flame speeds can be too low for combustion to complete during the power stroke, or combustion may not take place at all, resulting in high hydrocarbon emissions. The concentration level is attributed to misfire and a poor charge mixture due to a lack of adequate fuel and air mixing. HCs emissions can be caused by oil film layers, wall flame quenching, deposits and crevices in the combustion chamber, liquid fuel, and exhaust-valve leakage. Furthermore, the oil is commonly used as a lubricant. The oil thin film absorbs the fuel, preventing it from interfering with combustion and allowing it to leave the combustion chamber unburned. To reduce HCs emissions, some methods are used to increase mixing time and strength, such as adjusting fuel injection speed, increasing fuel injection pressure, and changing the piston head.

1.2.16 CARBON MONOXIDE (CO)

Carbon monoxide (CO) is an invisible gas that results from incomplete fuel combustion and is highly toxic to humans. When it is burned, it produces acids, which causes engine corrosion and smog. Hydrocarbons (HC). Due to incomplete

combustion, HCs escape from exhausts as unburned fuel. Carbon monoxide levels in combustion engine gasoline engines are extremely high. CO will escape from an exhaust leak before being transformed to non-toxic CO₂ in the catalytic converter.

1.2.17 NO_x EMISSIONS

The term NO_x refers to a group of compounds known as nitrogen oxides that are found in the exhaust of internal combustion engines. At engine-out settings, nitric oxide (NO) is typically the most abundant nitrogen oxide in DI diesel engine exhaust, accounting for more than 70-90 percent of total NO_x.

1.2.18 OPACITY:

Instruments that calculate the optical properties of diesel exhaust include smoke and smoke opacity metres. These instruments were developed to test visible black smoke emissions using physical phenomena such as light beam extinction by scattering and absorption.

1.3 ALTERNATIVE LIQUID AND GASEOUS FUELS:

1.3.1 ALTERNATE LIQUID FUELS:

The use of a "carbon-neutral" fuel is needed to reduce global CO₂ levels. In the other hand, declining oil supplies combined with a huge abundance of natural gas has promoted the use of another renewable fuel.

In addition, one of the most important aspects in the running of a dual-fuelled engine is the liquid or pilot fuel used. The type and volume of pilot fuel used have a direct effect on engine efficiency and emissions. Apart from engine operating conditions the selection of the pilot fuel is required to ensure a consistent ignition, well flame distribution, and the burning of air-gaseous fuel mixture in the combustion chamber, resulting in minimal cycle-to-cycle variance. This section discusses alternative pilot fuel (BIODIESEL) which can be used.

1.3.1.1 BIODIESEL:

Biodiesel is a fuel developed by the transesterification process. The raw material is transformed into a fuel that can power diesel engines by triggering a chemical reaction in vegetable oil, whether it comes from a specially-grown crop or

commercial waste. In this method, animal fats can also be used. Palm oil, sunflower oil, canola oil, soya oil, and jatropha oil are some of the most common biodiesel raw materials

1.3.1.2 USE OF BIODIESEL:

One of the most important benefits of biodiesel is that it can be used in existing engines, vehicles, and facilities with limited modifications. Biodiesel can be pumped, cooled, and burned in the same way as petroleum diesel fuel can, and it can be used in any proportion with petroleum diesel fuel.

Biodiesel and other biofuels will help countries reduce their dependence on imported fossil fuels, and biofuels emit less waste and net carbon emissions than fossil fuels, so governments around the world are promoting their use.

Owing to the widespread availability and low cost of petroleum diesel fuel, vegetable oil-based fuels have received less attention. During the oil shortages of the 1970s, there was a surge of interest in using vegetable oils to fuel diesel engines.

Unfortunately, since vegetable oil has a much higher viscosity than traditional diesel fuel, newer diesel engine designs cannot run on regular vegetable oils. Finding a way to reduce the viscosity of vegetable oils so that they could be burned properly in a diesel engine was critical. Pyrolysis, solvent mixing, and even emulsifying the fuel with water or alcohols have all been suggested as ways to achieve this goal, but none has proved to be effective. Biodiesel, on the other hand, has certain drawbacks that must be considered.

Some of the key properties that can affect engine performance and emissions are higher viscosity, lower heating value, and volatility. Furthermore, because of the high bulk modulus of compressibility, advanced fuel injection timing will result in increased NOX emissions. Reduced heating efficiency is to blame for the increased fuel consumption. Its high viscosity, on the other hand, improves engine lubricity and extends engine life.

Transesterification was introduced by a Belgian inventor in 1937 as a technique for converting vegetable oils into fatty acid alkyl esters and using them as a diesel fuel substitute. Transesterification is the process of breaking down a large molecule of vegetable oil into three smaller molecules that are less viscous and easier to burn in a diesel engine. In the development of modern biodiesel, which is made from fatty acid methyl esters, the transesterification reaction is critical.

1.3.1.3 Key advantages of biodiesel include:

- Biodiesel is an alternative fuel that can be used to operate any conventional unmodified diesel engine. Biodiesel can be used alone or mixed in any ratio with petroleum diesel.
- The life cycle production and use of biodiesel produces approximately 80 less carbon dioxide emissions, and almost 100% less sulfur dioxide than diesel fuel in diesel engines.
- Combustion of biodiesel alone provides over 90% reduction in total unburned hydrocarbons and 75-90% reduction in aromatic hydrocarbons.
- As compared to petroleum diesel fuel, biodiesel reduces particulates and carbon monoxide emissions significantly.
- Depending on the engine family and monitoring methods, biodiesel produces a small rise or decrease in nitrogen emissions.
- Biodiesel is safe to treat and transport since it biodegrades like sugar, is 10 times less poisonous than table salt, and has a high flashpoint of 110°C, as opposed to 45-55°C for petroleum diesel fuel.
- Biodiesel can be made from domestically produced renewable oil seed crops such as soybean, jatropha, cottonseed, rubber seed, and mustard seed.

1.3.1.4 The Energy and Emissions Footprint of Biodiesel:

In terms of greenhouse gas pollution, vehicles powered by biodiesel outperform vehicles powered by mineral oil. This is due to the offset produced by the CO₂ and CO which are absorbed by the oil-seed plant during its development.

1.3.2. Emissions of Greenhouse Gases:

According to scientists, carbon dioxide (CO₂) and carbon monoxide (CO) are two of the most significant greenhouse gases linked to global climate change. Biodiesel-fueled diesel engines produce the same amount of CO₂ as fossil-fuel-fueled diesel engines. The difference is that when oil-seed plants are grown for biodiesel, they absorb CO₂ from the atmosphere as they expand.

Diesel fuels are particularly concerned with particulate emissions from the vehicle's exhaust. These tiny particles are hazardous to one's health. Particle emissions can

be minimised by adding sulphur to the diesel and installing a catalytic converter in the exhaust system of the engine. Selected non-catalytic reduction (SNCR) technologies and exhaust gas recirculation (EGR) initiatives are two other recent innovations.

As compared to petrochemical-derived diesel, biodiesel can minimise particulate emissions by up to 50% with these steps in place. Biodiesel also has a higher cetane rating than standard diesel. The cetane number (CN) of a diesel fuel indicates the compression and combustion speed needed for ignition. A high CN, such as that used in biodiesel, ensures that the fuel will ignite more easily, the engine will run more smoothly, and particulate emissions will be reduced.

1.3.2.1 CHEMICAL PROPERTIES OF HYDROGEN:

- Hydrogen atoms are chemically very reactive. When a small amount of ignition energy in the form of spark is provided to the hydrogen-air mixtures, the molecules react with air in the atmosphere very actively and release significant amounts of heat and water vapor.
- At room temperatures these reactions are very slow, but is accelerated by catalysts such as platinum and spark. Very high temperatures (>5000 K) are needed to dissociate hydrogen molecules into atomic hydrogen completely, Hydrogen is considered an energy carrier to store and transmit energy from primary energy sources.
- The self ignition temperature of hydrogen is very high and best suited for Si engines. This temperature plays an important role in storage pressure of hydrogen because as pressure of the hydrogen inside the cylinder increases, temperature will also increase.
- The higher self ignition temperature of hydrogen allows the use of larger compression ratios without causing premature ignition.
- It is well known that as the compression ratio of the engine increases its thermal efficiency will also increase. Hydrogen can be ignited at its low ignition energy of 0.02 ml as compared to 0.24 ml for gasoline and 0.28 mi for methane at stoichiometric.

1.3.2.2 GASEOUS HYDROGEN:

Hydrogen is a renewable fuel that contains only water when burning in a fuel cell. Hydrogen is a gas that exists in nature. In comparison to Other Fuels Hydrogen, like gasoline or natural gas, is a chemical that must be treated carefully. When basic rules are followed, it can be used as safely as other traditional fuels. Colorless, odourless, and tasteless, hydrogen is non-toxic and non-poisonous. It's also non-corrosive, although it does lead certain metals to embrittle. Hydrogen is the smallest and lightest particle, and it exists as a gas in the atmosphere.

Hydrogen is 57 times lighter than fuel vapour and 14 times lighter than air. This means that if it's released into the open, it'll usually rise easily and scatter. In an outdoor environment, this is a significant safety benefit.

1.3.2.3 HYDROGEN COMBUSTION:

The lowest temperature at which a liquid can naturally combust without the presence of a flame or spark is called the auto-ignition temperature. Hydrogen and natural gas have very close auto-ignition temperatures. Both have auto-ignition temperatures of over 1000°F, which is far greater than the temperature at which gasoline vapour auto-ignites. Hydrogen has a pale blue flame that is almost undetectable in daytime, making it almost difficult to detect with the naked eye. Impurities in the hydrogen blaze, such as sodium from ocean air or other burning materials, can give it colour. For hydrogen systems, detection sensors are almost often installed to easily locate any leaks and reduce the risk of undetected fires. The hydrogen flame is almost transparent in comparison to the propane flame, but it can be seen with the thermal imaging camera in the foreground. Hydrogen fires can be seen in dark.

1.3.2.4 HYDROGEN GAS AS FUEL

Natural gas, nuclear power, coal, and renewable energy sources such as solar and wind power can all be used to generate hydrogen. Because of these characteristics, it is a good fuel for transportation and electricity generation. It can be used in a number of places, including cars, houses, portable electricity, and a variety of other items. Hydrogen fuel is now available in a range of forms. The most common methods today are natural gas reforming (a thermal process) and electrolysis. Other solutions include solar-powered and biological processes.

Hydrogen has a very high flammability spectrum as compared to other fuels (between 4 percent and 75 percent in air). The energy needed to start hydrogen combustion under ideal combustion conditions (a 29 percent hydrogen-to-air volume ratio) is much lower than that required for other common fuels (a small spark will ignite it). However, at low hydrogen concentrations in the air, the energy needed to start combustion is comparable to that of other fuels.

The reduction of primary energy resources (i.e., fossil fuels), and the emissions associated with fossil fuel burning, and the need to ensure energy resource sustainability have all promoted the usage of hydrogen as an alternate fuel for both transportation and power-train systems. Since hydrogen is the only fuel that does not contain carbon, its combustion produces no carbon-based emissions constituents, with the exception of traces required from lube oil combustion. The big issue with hydrogen combustion engines is NO_x emissions, which are caused by high temperatures during combustion. Several researchers have identified a trade-off between relative air/fuel ratio and NO_x emissions for homogeneous hydrogen combustion resulting from port injection or early direct injection.

Because of its properties, hydrogen is ideally suited for internal combustion applications, with high engine performance capacity and inherently low carbon-based emissions signatures. For production applications of advanced mixture forming concepts, further development of injection equipment would be needed. The lack of a fuel supply as well as adequate on-board storage density remain the major barriers to widespread hydrogen usage in transportation. Since hydrogen has a high-octane rating, it has been found to be a good replacement fuel for gasoline. In comparison to other gaseous or liquid fuels, hydrogen has a high LHV. However, as compared to liquid fuels, the energy density is much lower.

Hydrogen combustion at stoichiometric condition requires a significant amount of combustion air. For combustion, a mass-to-air ratio of about 34:1 is needed, which is much higher for diesel powered vehicles which is 14.6:1. Hydrogen-fueled engines can run at low equivalence ratios and hydrogen can burn in a lean mixture, allowing for stable combustion. As a consequence, low NO_x can be generated in this case. The hydrogen-fueled internal combustion engine, on the other hand, has the potential to emit NO_x at high engine load. This is due to hydrogen's low ignition capacity, which causes a hydrogen-air mixture to burn even in the presence of hot

spots or gases. This will lead to an earlier start of combustion, which increases the amount of heat produced while maintaining a high in-cylinder pressure/temperature. Another problem that can occur is premature ignition and backfire, which can result in engine knocking (White et al., 2006).

The use of hydrogen can also be used in dual-fuel systems. Hydrogen can be directly injected into the air intake. Through injecting hydrogen directly into the combustion chamber, the volumetric efficiency and therefore power density would increase. However, supplying hydrogen to a vehicle is also a technical challenge.

1.3.3 LIQUIFIED PETROLIUM GAS (LPG):

LPG is a subgroup of hydrocarbon-based gases extracted mainly from gas wells and as a by-product of crude oil refining. Butane and propane are the most important components of LPG (Masi, 2012). LPG-powered cars emit low quantity of pollution. (Johnson, 2003). LPG-powered cars have been found to lower emissions as comparison to gasoline-powered vehicles. The high hydrogen-carbon ratio and absence of aromatic hydrocarbons in LPG result in a decline in significant pollutants such as HC, CO, NOX, PM, and CO₂.

Aside from lowering emissions, LPG-powered engines are also low-maintenance, low-cost to operate, and have a high thermal performance. LPG is commonly used in SI engines owing to its high octane number but low cetane number. However, using LPG on CI engines has been desirable in order to increase both thermal performance and emissions. As compared to hydrogen (0.61 cm²/s), LPG has a lower diffusivity (0.12 cm²/s) (Lata et al., 2012). This property can cause a larger unburned air mixture region to develop, thus dissipating the available energy and potentially lowering thermal efficiency. It is expected that mixing LPG and hydrogen would boost the efficiency.

1.3.3.1 NATURAL GAS:

Methane, ethane, propane, butanes, pentanes, and other hydrocarbons are all present in natural gas. It is made up of dense deposits of decayed animals and plants that have been buried under the earth's crust for millions of years. Extreme heat and pressure transformed these fossils into black fuels, coals, and natural gases over time. Natural gas is collected from deep formations from a well, along

with other liquid hydrocarbons and non-hydrocarbons, and then refined before being transported through pipelines.

Compressed natural gas is usually contained in pressure cylinders on board a vehicle, with single steel cylinders being the most common in the past but now being replaced by many smaller composite cylinders. The gas is normally held at a pressure of 200–270 bar, and the extra cylinders add about 60 kg to the average vehicle's weight. Natural gas vehicles face difficulties in terms of vehicle range and fuel storage tank weight. A gaseous storage system running at 200 bar demands about four times the storage capacity and outweighs the fuel system by a factor of three at constant range. With a vehicle range of up to 600 km, lightweight components, increased storage pressures, and better engine efficiencies are projected to raise the volumetric ratio to 1:2.9 and the gravimetric ratio to 1:1.4.

The key reasons for renewed interest in natural gas in the world are energy stability and domestic demand, as well as the fact that natural gas is a clean-burning fuel. Natural gas has long been used for stationary power generation because of its high engine efficiency and low emissions. However, for light-duty applications, most natural gas vehicle applications depend on conversion from traditional gasoline engines, and for heavy-duty applications, diesel natural gas dual fuel applications. Both compressed natural gas and liquefied natural gas infrastructure would have a market share in terms of storage technology, since each is better adapted for specific applications.

1.4 DUAL FUEL BACKGROUND:

Cave and Helmore et al. are credited with developing the dual fuel engine in 1929 and 1930, respectively, when hydrogen fuel was used as a replacement fuel in diesel engines. Dual fuel, on the other hand, had drawbacks at the time, making it less common for commercialization. Mechanical performance, costly materials, large inefficiencies, and substantial knocking were among the difficulties. Where sufficient conditions for mixing and combustion are met, the use of different fuels with different flammability limits, both liquid and gaseous fuels, can result in improved engine-out emissions and efficiency.

The basic method of gaseous fuel induction is the fumigation of gaseous fuel in the intake manifold to blend with the intake air, which is one of the methods used to

inject gaseous fuels into the cylinder. This is a basic approach that is recommended for engines that do not have an electronically operated diesel injection unit. Emissions standards, which mandate strict requirements to be met for contaminants discharged into the atmosphere, have prompted the introduction of dual fuel technology in recent engines. The demand for dual fuel engines to save money on operations costs as compared to diesel engines is also driving growth. As a result, many diesel engines are upgraded to operate on gaseous fuels like natural gas, LPG, and hydrogen while retaining the benefits of diesel performance. These were chosen because they are economical and widespread. It has also been shown to improve diesel engines to produce less pollution.

1.4.1 DUAL FUEL ENGINE OPERATION:

A dual-fuel engine has the benefit of being able to run on both gas oil and natural gas, increasing energy supply security. Due to the extreme wide performance gap between a spark-ignition engine and a diesel engine, engine designers have been looking for a way to achieve the efficiency of a diesel engine in a natural gas-fired spark-ignition engine. This is where the dual-fuel engine, which has become the most common of these hybrids, got its start. Internal-combustion engines with reciprocating pistons can be used as dual-fuel engines, accepting both gaseous and liquid fuels. The combustion phase in a dual-fuel engine is often started with some liquid fuel. A dual-fuel engine is normally a modified diesel engine, as previously said. In Dual fuel engines, Hydrogen or natural gas is fumigated with air in the intake stream by a venturi located in the intake cavity. A Flow meter regulates the flow of hydrogen. The amount of hydrogen that enters the intake air stream is determined by the engine's load and rpm. To start combustion, the mixture is compressed and diesel fuel is injected at the end of the compression stroke. There are no improvements to the engine's internal workings or the diesel injection system. Hydrogen would replace some of the gasoline used to drive the engine, lowering diesel demand while maintaining the same power output.

1.4.2 ADVANTAGES AND APPLICATIONS OF DUAL FUEL:

The dual fuel hydrogen-diesel engine's key advantages are lower NO_x and PM emissions, as well as a lower fuel cost than diesel. If hydrogen is locally available, other potential benefits include improved thermal efficiency (load dependent) and

reduced fuel transportation impacts. Since the majority of the engine components will remain the same, the cost of maintenance will not increase as a result of the conversion. Since a significant amount of diesel is displaced by hydrogen, up to 70%, carbonization is reduced in the dual fuel engine. In a dual fuel hydrogen diesel engine, switching between diesel and hydrogen fuel modes can be done when the engine is operating without interrupting the engine's operation.

CHAPTER 2

LITERATURE REVIEW

Biodiesel's value as a sustainable and commercially feasible alternative to fossil diesel for use in compression ignition (CI) engines has prompted extensive research over the last two decades. This is mostly due to the scarcity of petroleum supplies and the public understanding of the environmental and health consequences of fossil diesel combustion.

[1] Ahmed NA, Ogunkunle O. A look at the latest global scenario for biodiesel adoption and combustion in diesel vehicles.

[2] Emine Kekilli evaluated hydrogen enrichment for biodiesel-diesel blends in a diesel engine.

[3] Mustafa Atakan Akara to investigate the efficiency and emission characteristics of a compression ignition engine. Biodiesel was made from used cooking oil and blended with pure diesel fuel in volume fractions of 0%, 10%, and 20%. Then, at various flow rates, pure hydrogen was added into the intake air. By evaluating power, torque, specific fuel consumption, CO, CO₂, and NO_x emissions, the effects of pure hydrogen on performance and emission characteristics were investigated. Experimental study revealed that waste oil biodiesel usage deteriorated performance and emission parameters except CO emissions 2018.

[4] Biodiesel production from WCO was investigated in this paper by Guanyi Chena.

[5] Yonghong Wang through experimental investigation of reaction conditions such as methanol/oil molar ratio, alkaline catalyst number, reaction time, and reaction temperature, all of which are thought to have a major impact on reaction conversion performance. Experiments using orthogonal analysis of parameters in a four-factor and three-level test were conducted to determine the optimum conditions for this transesterification process. The orthogonal test showed that the optimal experimental conditions were a 9:1 methanol/oil molar ratio, 1.0 wt% sodium hydroxide, a temperature of 50 °C. Verified experiments showed methanol/oil molar ratio 6:1 was more suitable in the process, and under that condition WCO conversion efficiency led to 89.8% and the physical and chemical properties of biodiesel sample satisfied the requirement of relevant international standards 2008. The optimum biodiesel conversion from waste cooking oil to biodiesel by transesterification method was investigated

[6] In the experiment conducted by Jatinder Kataria and S.K. Mohapatra in the current work. The optimum production of biodiesel was studied using base catalysed transesterification with various reactant proportions, such as the molar ratio of alcohol to oil and the mass ratio of catalyst to oil. 12:1 and 5% zinc doped calcium oxide were found to be the best conditions for base catalysed waste cooking oil transesterification. The generated biodiesel's calorific value, flash point, and density were investigated and compared to those of conventional diesel. The properties of the biodiesel and its blends (B20, B40, B60, B80, and B100) were comparable to those of diesel oil and ASTM biodiesel standards. The experiments were carried out on a CI engine with a variable engine load and a constant speed of 1500 rpm, a 200-bar injection pressure, and a compression ratio of 15:1 to 17.5. Among the performance parameters are brake thermal quality, brake specific energy consumption, and emissions parameters such as carbon monoxide (CO), hydrocarbon (HC), nitrogen oxides (NO_x), and smoke opacity varying with engine load (BP). Biodiesel made from waste cooking oil using a heterogeneous catalyst is suitable for use as a diesel oil blend and emi, according to the thermal efficiency of a diesel engine and emission parameters such as CO, HC, and NO_x on different biodiesel blends.

[7] In the study conducted by Mohamed F. Al-Dawody and Ali A. Jazie (Iraq 2018) .The methyl ester of waste cooking oil (MEWCO) was made from used cooking oils obtained from various restaurants and experimentally and theoretically tested. The suggested biodiesel is combined with original diesel fuel in various amounts (10%, 20%, and 100%) and tested on a constant speed diesel engine. The experiment looks at how the blending ratio affects efficiency and emission parameters under various load conditions.

[8] The experimental side is verified with simulation study done by Dieselrk software and it reveals that they are in good agreement. Since the heating value of the blended fuels has decreased as a result of rising MEWCO blends, the maximum pressure has decreased. On behalf of carbon emissions, both sides have announced promising reductions in nitrogen oxides (NO_x). The best compromise is a 20 percent MEWCO mixture, but anything higher than that results in a dramatic reduction in efficiency.

[9] In a research conducted by S. Verhelst and R. Sierens in 2001, the Laboratory of Transport Technology (University of Gent) adapted a GM=Crusader V8 SI engine

for hydrogen use in a city bus. The use of a sequential timed multi point injection method was decided upon. Ignition properties (smaller spark plug gap), injection pressure (dependent on the means of storage: compressed gas or liquid), lubricating oil consistency (a large amount of hydrogen is present in the crankcase due to higher blow-by volumes), and oxygen sensors are all associated with the use of hydrogen as a fuel in IC engines (very lean operating conditions). The advantages and disadvantages of a power regulation by changing the air to fuel ratio (as for diesel engines), as compared to throttle regulation (SI engines) are judged.

CHAPTER 3

AIM AND SCOPE OF PRESENT INVESTIGATION

3.1 AIM

Central aim of the study is to analyze the emissions and performance of Re-entry combustion chamber when using a dual fuel blend of biodiesel and Hydrogen at varying loads. The analysis aims to showcase the effect that injected Hydrogen has on cutting back of dangerous emissions and improving engine performance across all the loads. This in addition to the use of a custom created biodiesel blend explores the possibility of using such fuel in conventional diesel engines on a greater, more commercial scale.

3.2 SCOPE OF THE PROJECT

Our analysis, which looks at potential biodiesel substitutes, is shaped by this need for additional energy sources. The goal is to look into the power, durability, combustion, and nature of emissions of a dual fuel engine that uses WVO biodiesel as the primary fuel with Re-entry piston. As a supplementary fuel, hydrogen was pumped into the air intake. The biodiesel blends used in this analysis are WVO blended with diesel in volume fractions of 20% and 30% to produce BV20 and BV30, respectively. Performance and emissions standards of this fuel were tested in an effort to find the best possible outcomes

CHAPTER 4

EXPERIMENTAL MATERIALS AND METHODS

All the machinery used for the experimental investigation are described in this.

4.1 TEST ENGINE:

A Kirloskar TV1 experimental engine is used for our research shown below



Fig:4.1: Experimental engine setup

The test engine used was single cylinder direct injection and naturally aspirated 4 stroke diesel engine. Specifications of test are in Table 4.1. The dual fuel mode was adopted to a single cylinder diesel engine. Table lists the engine specifications. During the suction stroke, pilot fuel diesel was injected into the combustion chamber at 23° BTDC. At 4.5° BTDC, the inlet valve opened and closed at 35.5° ABDC. At 35.5° BBDC, the exhaust valve opened and closed at 4.5° ATDC. Via the intake, primary fuel (hydrogen) was mixed with air. The engine is provided with water cooled eddy current and used for loading the engine.

Table 4.1: Specifications of test engine used

Type	Single cylinder, four stroke, vertical Diesel engine
Bore	87.5 mm
Stroke Length	110 mm
Number of cylinders	1
Number of Valves	2
Swept volume	661cc
Compression ratio	17.5:1
Injection Pressure	200 Bar
Loading Device	Eddy current dynamo meter
Dynamometer Arm length	195 mm

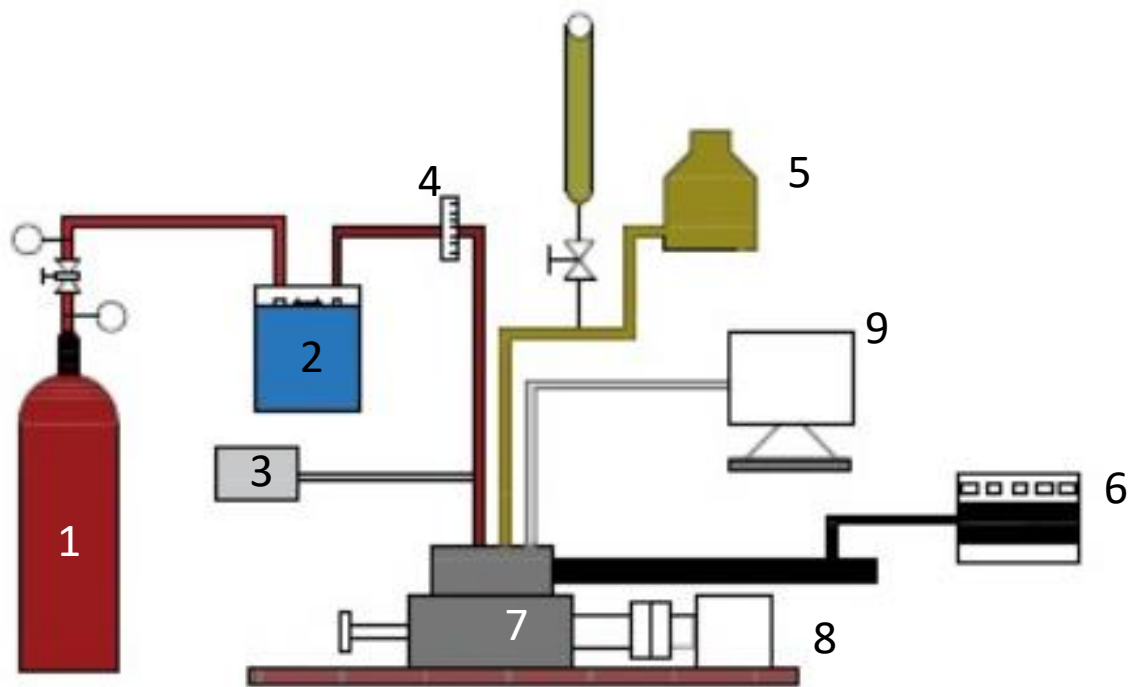
4.2 DUAL FUEL ENGINE SETUP:

The intake air manifold has been modified to enable the mixture of air and hydrogen into the combustion chamber while the diesel fuel is directly injected into the combustion chamber. A flow meter was equipped to control the amount of hydrogen into the combustion chamber. As shown in Figure 4.2.

4.3 Materials and methods:

In this experiment, we have used different biodiesel mixtures which consists of B20 and B30 fuel mixtures in which 20% is waste vegetable oil and 80% is diesel, likewise, 30% is waste vegetable oil and 70% is diesel, both the ratios of fuel were used at a time. To get data for efficiency and emission of the diesel engine during the experiment, we have inserted hydrogen in 4lpm at 1500 rpm which will help in CPs characteristic.

Fig:4.2 Figure shows the experimental setup of dual fuel engine



1.H₂ cylinder 2. Flame arrestor 3. Air Box 4. Flow meter 5. Diesel Tank 6. Five gas analyser & Smoke meter 7.Engine 8. Dynamometer 9. Data acquisition system

4.3 ENGINE INSTRUMENTATION:

The position of the crankshaft was recorded by using crank angle sensor (Kuebler – Germany). In cylinder pressure was measured using a pressure transducer mounted inside the cylinder head and connected to the data acquisition board via charge amplifier. IC Engine software was used to collect the combustion analysis data. The rate of heat release (ROHR), values of indicated mean effective pressure (IMEP), peak in-cylinder pressure, and percentage coefficient of variance of IMEP and other normal combustion parameters were among the results of the study of consecutive engine cycles (from a minimum of 200 cycles).

4.4 ENGINE OUT EMISSIONS MEASUREMENT:

An AVL Di-gas analyzer was used to measure the emissions. Carbon monoxide and carbon dioxide are measured in the analyzer using Non Dispersive Infrared (NDIR) sensor technology. Hydrocarbons are measured using Flame ionization detector. NO_x emissions are measured using the chemiluminescence detector. A temperature regulated heated line is used to send the engines emissions to the Di gas analyzer in order to avoid condensation.

4.5 FUELS:

By having a direct effect on the environment, food wastes contribute to a large portion of the overall global wastes generated. Indirectly, their production raises net economic costs of food production, freshwater use, fossil fuel use, and greenhouse gas pollution. One of the most common types of food waste is waste vegetable oils (WVO) generated by restaurants, caterers, and fast-food chains. Until recently, the majority of WVO was used to finance fuel in a variety of energy-intensive processes. The fuels used for the experimental research were Gaseous and liquid. The Gaseous fuel used is Hydrogen and the liquid fuels used are pure diesel and Waste vegetable oil blends that were transesterified to get waste vegetable oil biodiesel. And fuel blends were prepared for the experiment. The fuel blends were made by combining 20 percent WVO and 30 percent WVO with conventional diesel to get BV20 and BV30 biodiesel blends.

Table: 4.3 Properties of test fuels used

Properties	ASTM STANDARDS	EURO 6 STANDARD	Diesel	VB20	VB30	V100
Density (Kg/m ³) at 15°C	860-900	820-860	834.0	853	859	890
Kinematic viscosity @ 40°C in cSt	1.9-2.6	2-4.5	3.4270	2.360	2.360	3.580
Flash point °C	-	35	66	60	63	191
Fire point °C	130		-	70	72	202
Gross calorific value (kJ/kg)			42000	41193	40538	35960

Table 4.4: Properties of hydrogen gas

Molecular weight	2.01 kg/kmol
Density	0.0838 kg/m ³
Flash Point	585°C
Flame speed	270-325 cm/s
Octane Number	130
Cetane Number	-
F/A stoichiometric	34.3

4.5.1 TRANSESTERIFICATION:

In organic chemistry, transesterification is the process of combining the organic groups R of an ester with the organic group R of an alcohol. These reactions are frequently catalysed by an acid or base catalyst. Transesterification (alcoholysis) is the process of converting triacylglycerol lipids to alkyl esters without first isolating the free fatty acids. In 1853, several years before the first diesel engine was installed, the first transesterification of a vegetable oil was accomplished.

To study and obtain waste cooking oil from local sources and convert it into usable biodiesel is called process of transesterification. In this reaction, KOH (Potassium Hydroxide) is used as catalyst and CH₃OH (Methanol) as alcohol base [13]. 1% KOH by weight is added to Methanol in 6:1 molar ratio. At the same, waste vegetable

oil is heated to a temperature of 60°C and the earlier obtained catalyst and Methanol blend is added to this. The mixture is stirred moderately at a constant 60°C temperature for an hour. As the mixture cools down and rests for a day, two distinct layers separate themselves with the upper layer being biodiesel and the lower layer crude glycerol. Glycerol is carefully removed from this resultant solution. The top layer of methyl ester is washed with distilled water to remove any lingering traces of glycerol and then again washed with distilled water to remove possible traces of methanol. This mixture is heated at 110°C for an hour and filtered to obtain desired WVO biodiesel.

For the purpose of the study, WVO obtained from local sources was converted into usable biodiesel through the process of transesterification. The method of converting crude oil into its esters is known as transesterification. Waste vegetable oils triglycerides react with methanol as a catalyst to form methyl ester and glycerine as a by-product in this process. In this reaction, KOH (Potassium Hydroxide) is used as catalyst and CH₃OH (Methanol) as alcohol base. 1% KOH by weight is added to Methanol in 6:1 molar ratio. At the same, waste vegetable oil is heated to a temperature of 60°C and the earlier obtained catalyst and Methanol blend is added to this. The mixture is stirred moderately at a constant 60°C temperature for an hour.

After transesterification reaction the mixture was allowed to settle for 8-10 hours in a separating. The glycerol and the impurities are settled at the bottom funnel with the upper layer being biodiesel. Glycerol is carefully removed from this resultant solution. The top layer of methyl ester is washed with equal volume of hot distilled water until the wash water pH reached neutral to remove any lingering traces of glycerol and then washed with water to remove possible traces of methanol. This washed biodiesel was heated at 110°C for an hour and allowed to cool to the room temperature and filtered to obtain desired WVO biodiesel.

The obtained WVO biodiesel was combined with diesel to produce BV20 and BV30 blends.

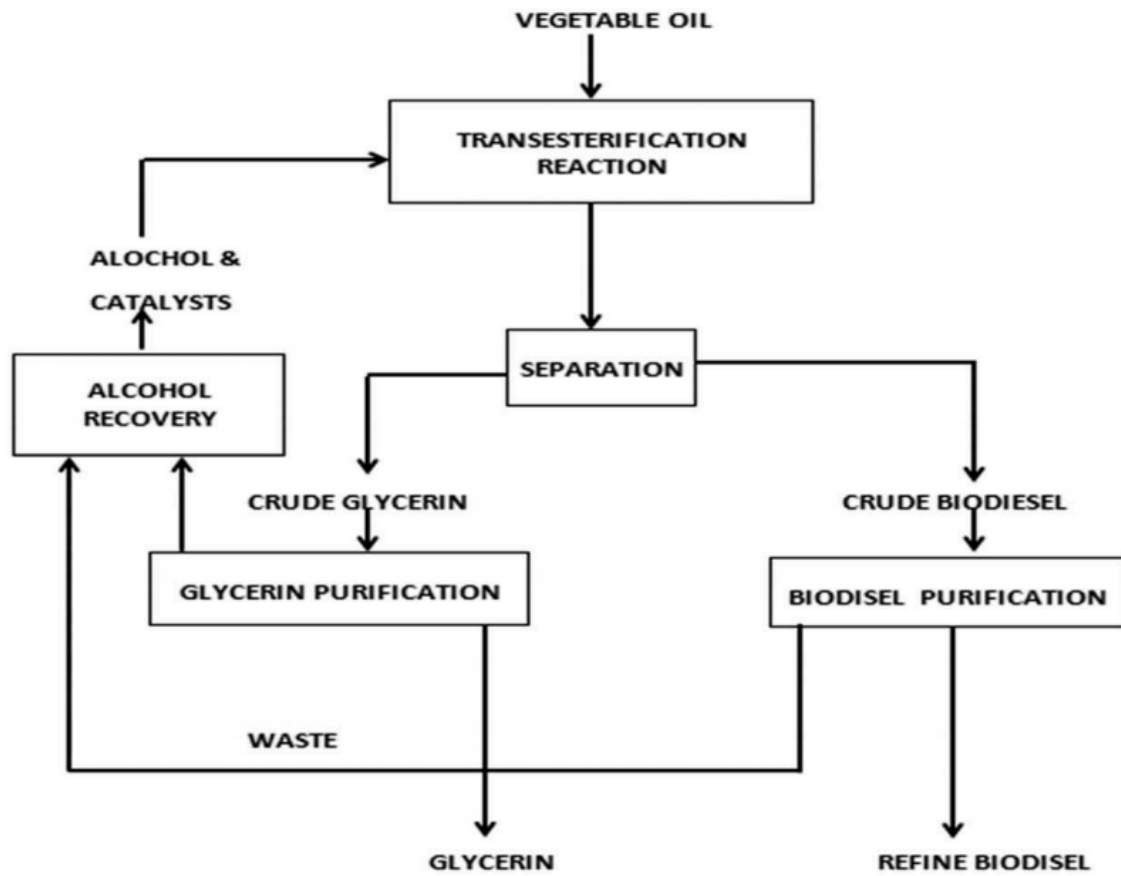


Fig. 4.5: Schematic process of Transesterification

CHAPTER 5

RESULTS AND DISCUSSION

5.1 EMISSIONS CHARACTERISTICS

Different emission parameters for Re-entry combustion chamber using both diesel and biodiesel blends BV20 and BV30 with 4lpm hydrogen were monitored and noted across varying loads. Below are the observed results –

5.1.1 Carbon dioxide (CO₂):

Emissions of Carbon dioxide are the primary source of climate change globally. In tests performed we obtained CO₂ as a result of complete combustion of carbon and oxygen present in petroleum-based fuels shown in Fig.5.1.1.CO₂ emissions increased as the engine load was increased for each test as seen in [15]. For pure diesel the CO₂ emissions were reduced with the addition of hydrogen while there was a significant reduction in the emissions for PD RP with hydrogen blend. When compared with pure diesel, BV30 biodiesel blend with 4lpm Hydrogen showed more CO₂ emissions. The reason for the reduction of CO₂ emissions is the lack of carbon that comes with the injection of 4lpm H₂, making the process cleaner and making the engine even more efficient.

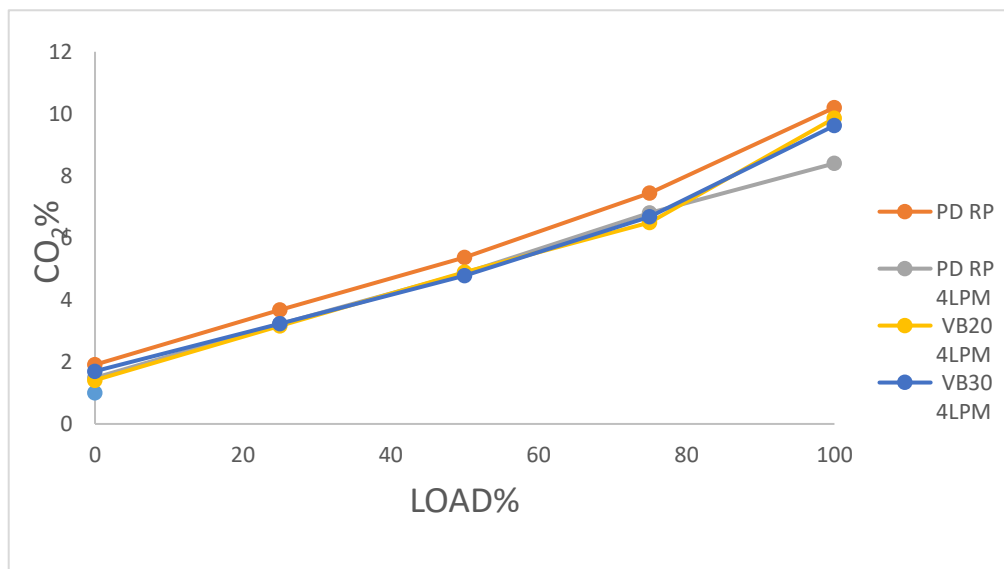


Fig.5.1 comparative analysis Carbon dioxide emissions with load

5.1.2 Carbon Monoxide (CO):

Carbon monoxide is among the most climate effecting pollutants. In our test's CO was produced from partial oxidation of carbon present in BV30 biodiesel during the combustion process. It was observed that CO emissions for BV20 and BV30 biodiesel blend with 4lpm hydrogen were lower in comparison to pure diesel as seen in [15]. As was seen in the case of Carbon dioxide emissions, the reason for reduced CO emissions is again attributed reduction of carbon created by the infusion of 4lpm Hydrogen. Yet, due to burning of lubrication oil, partial CO remains are seen lingering in engine exhaust as shown in Fig.5.1.2.

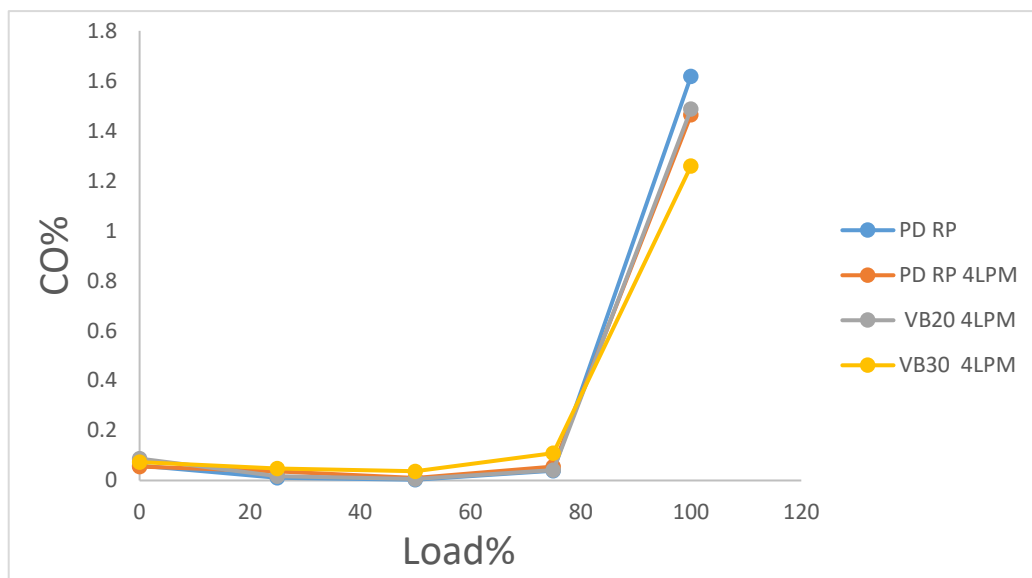


Fig.5.2 comparative analysis CO emissions versus Load

5.1.3 NO_x Emission:

NO_x is one of the most harmful emissions produced from CI engines. It contains 90-95% of NO and 5-10% NO₂. NO_x emissions occur as a result of higher combustion temperature, oxygen concentration in the combustion chamber and nitrogen being exposed to high temperature. NO_x emissions decreased with the use of BV30 biodiesel blend with 4lpm hydrogen when compared to pure diesel using 4lpm Hydrogen. With the increasing engine load for B20, more fuel was burned, leading to higher temperatures and subsequently increased NO_x emissions at 75 load whereas at maximum load with B30 mixture with hydrogen there is a high decline in the NO_x level compared to PD which in turn tells us that more use of waste cooking oil helps in the reduction of NO_x emissions showed in Fig.5.1.3.

Normally one tends to see that for smaller loads the NO_x emissions are comparatively less against greater loads because of the natural higher consumption. Similar results could be found in [16].

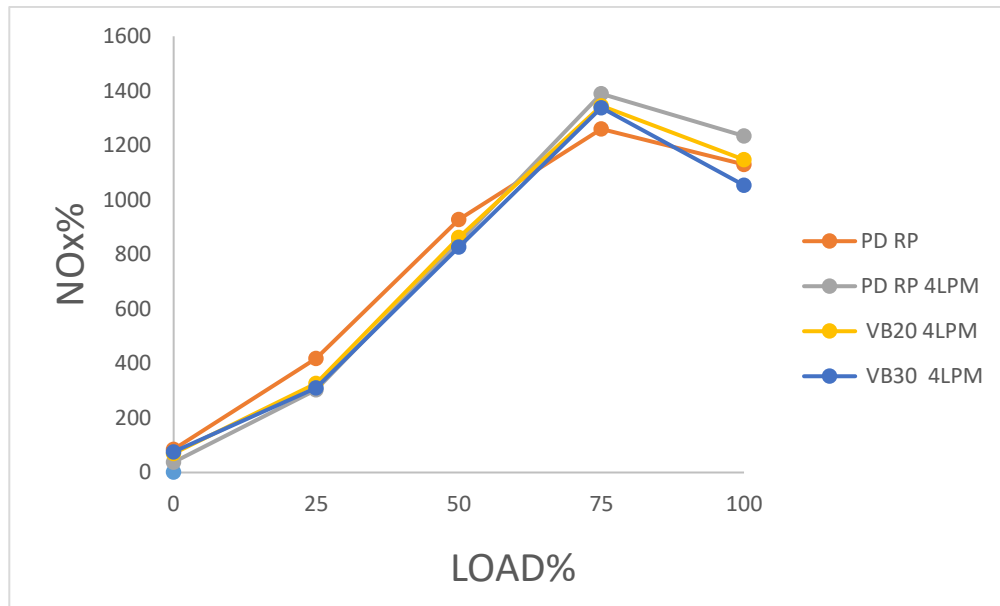


Fig.5.3 comparative analysis NO_x emissions versus Load

5.1.4 Hydrocarbon emissions:

Emissions of HC occur because of the incomplete combustion of the fuel. Hydrocarbon (HC) emissions are those gases which are generally not burned. Certain unburned fuel can remain in the combustion chamber and this fuel is ejected through the exhaust system, as the combustion process occurs rapidly. The effect of these gases can be seen in the Fig. 5.1.4. In examination it was seen that the HC emissions increased with the increasing engine load for all tests. HC emissions decreased with BV30 biodiesel with 4lpm Hydrogen tests compared to pure diesel.

In the literature, it was stated that the HC emissions can decrease with the hydrogen addition and the reason for this situation is explained as that the hydrogen does not include any carbon molecules [17]. As per study the HC emissions raised with a further increase of hydrogen. It was stated that this increase was most likely caused by the decrease of Oxygen in the cylinders. The availability of oxygen reduces when higher amounts of hydrogen is burned with biodiesel.

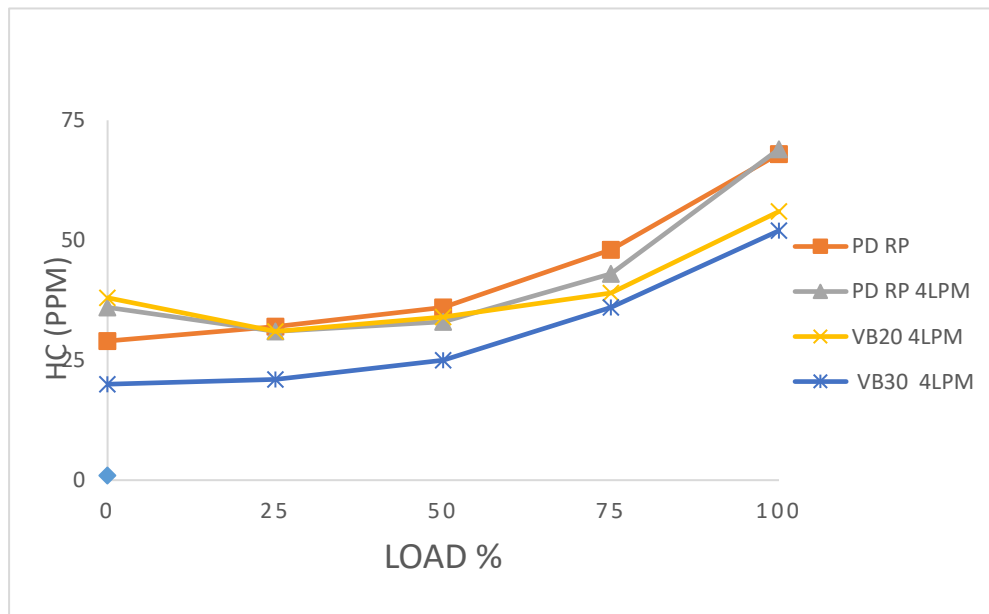


Fig.5.4. comparative analysis HC emissions versus Load

5.1.5 Smoke Emissions /OPACITY:

In any ICE, it is fuel that is not completely burnt which leaves a residual material in the form of smoke. It is also known as the formation of soot also known as opacity which is natural with the use of any hydrocarbon fuel in an ICE and in the case of pure diesel, the smoke emissions are relatively high as seen in [18]. The variation of smoke emissions of pure diesel when compared to the use of BV20 and BV30 can be seen in the Fig. 5.1.5. In the case of each load, BV20 with 4lpm H₂ and BV30 with 4lpm H₂ exhibited more emissions when they are compared to emissions produced by pure diesel.

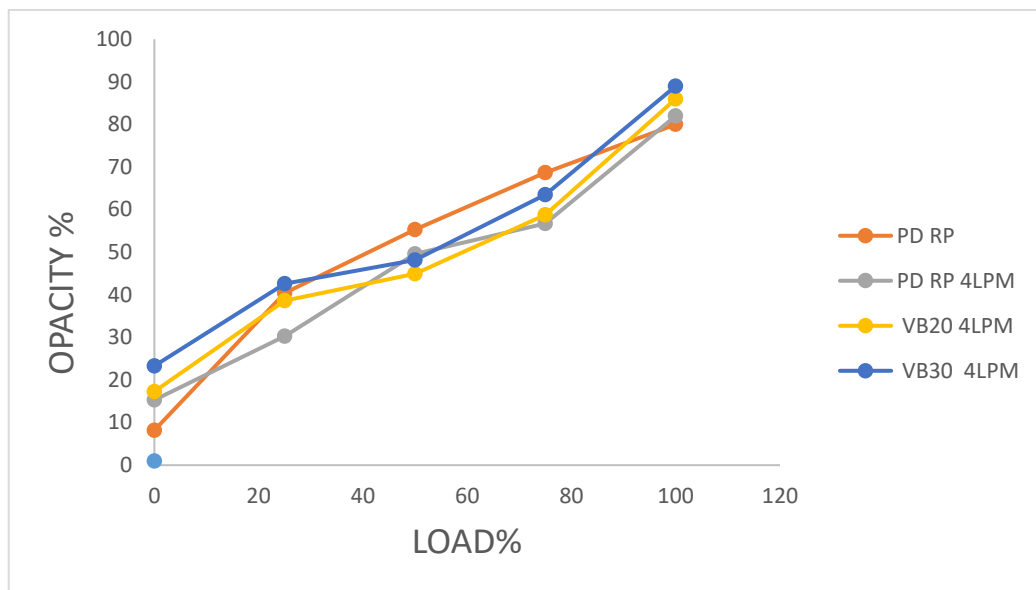


Fig.5.5 comparative analysis Opacity versus Load

5.2 ENGINE PERFORMANCE CHARACTERISTICS

Various engine performance parameters for a re-entry combustion chamber using both diesel and biodiesel blends BV20 and BV30 with 4lpm hydrogen were monitored and noted across different loads. Below are the observed results are as follows :-

5.2.1 BREAK SPECIFIC FUEL CONSUMPTION (BSFC):

BSFC is defined as proportion of mass fuel flow rate to engine power. BSFC depends on characteristics of a fuel. It is the measurement of engine effectiveness in the consumption of fuel [14]. Graph with variation of BSFC to different load conditions is given below. It is generally seen in studies related to BSFC that values obtained for pure diesel and other pure biodiesel blends tend to be close to one another. But an infusion of hydrogen to the fuel tends to reduce the BSFC values for both pure diesel and biodiesel blends across different loads. This reduction is far more significant for greater loads than it is for smaller ones. In our study, we have seen that BV30 with 4lpm hydrogen yields far less BSFC values when compared to pure biodiesel, as seen in Fig. 5.2.1.

In general, hydrogen addition reduces BSFC as hydrogen flame speed drastically improves mixture formation. This automatically increases in-cylinder temperature and pressure values; subsequently leading to a reduction of BSFC.

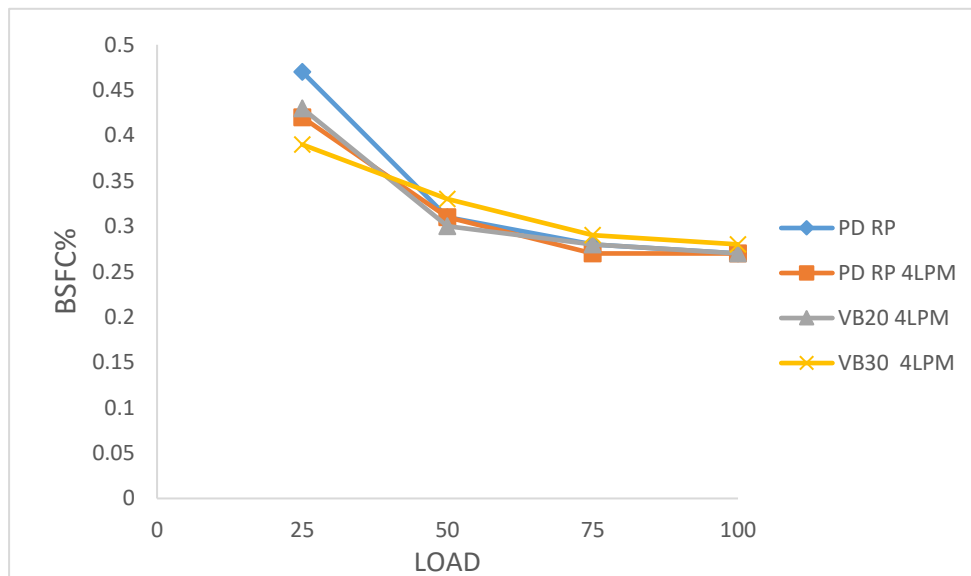


Fig.5.6 Brake specific fuel consumption

5.2.2 Brake Thermal Efficiency:

The overall amount of work that can be derived from used fuel is determined by the BTE. The BTE values obtained from engine tests are shown in Fig. 5.2.2. In a review of the literature, it was discovered that when biodiesel blends were used instead of straight diesel, the BTE of the engine decreased. The high viscosity and density of biodiesel are to blame for this decrease. In addition, low atomization and a longer ignition delay led to incomplete fuel combustion. In contrast to pure diesel, BTE increased in fuels with biodiesel blends in our research. In a review of the literature, it was discovered that experiments performed with and without the addition of hydrogen produced results that were remarkably similar. In this case in our study, highest amount of BTE was seen for BV30 enriched with hydrogen at 4lpm. Subsequent analysis of the data showed flame speed, high diffusivity, and lower quenching distance leading to complete combustion as the reason for this increase

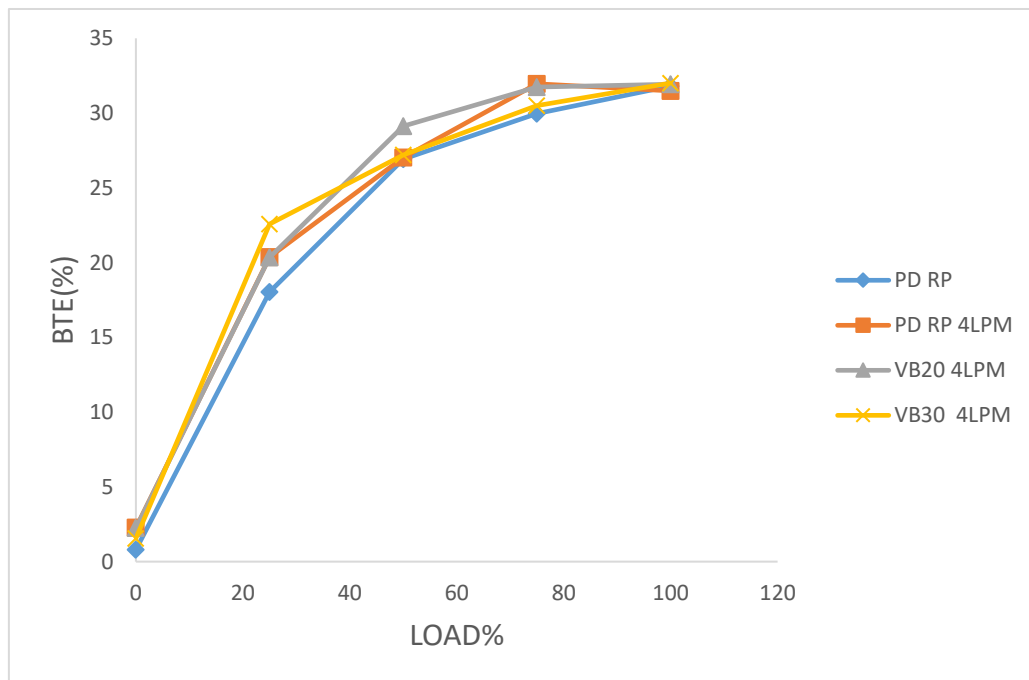


Fig.5.7 Variation of BTE with load

5.2.3 IN CYLINDER PRESSURE (P_{θ}):

One of the most important parameters used in analysis of combustion process is CP. CP curves show distribution of in-cylinder mechanical loads which occur as a result of combustion of fuel by crank angle. Pressure variations for different fuels on engine are shown below. In Fig. 5.2.3 it was seen that CP curve profiles are almost similar to each other for all fuel tests. But it tends to increase for PD with 4lpm Hydrogen owing to higher flame velocity. Abnormal combustion characteristics like high pressure raise rates were not seen. In pilot research it is seen that in tests performed with VB30 fuel, lower peak values were observed in comparison to pure PD with hydrogen. It is seen that when biodiesel is used, cylinders pressures are low. Another reason for the increase is the lower heating value of biodiesel when compared to diesel. In our study, cylinder pressure increased with the use of PD biodiesel with 4lpm Hydrogen.

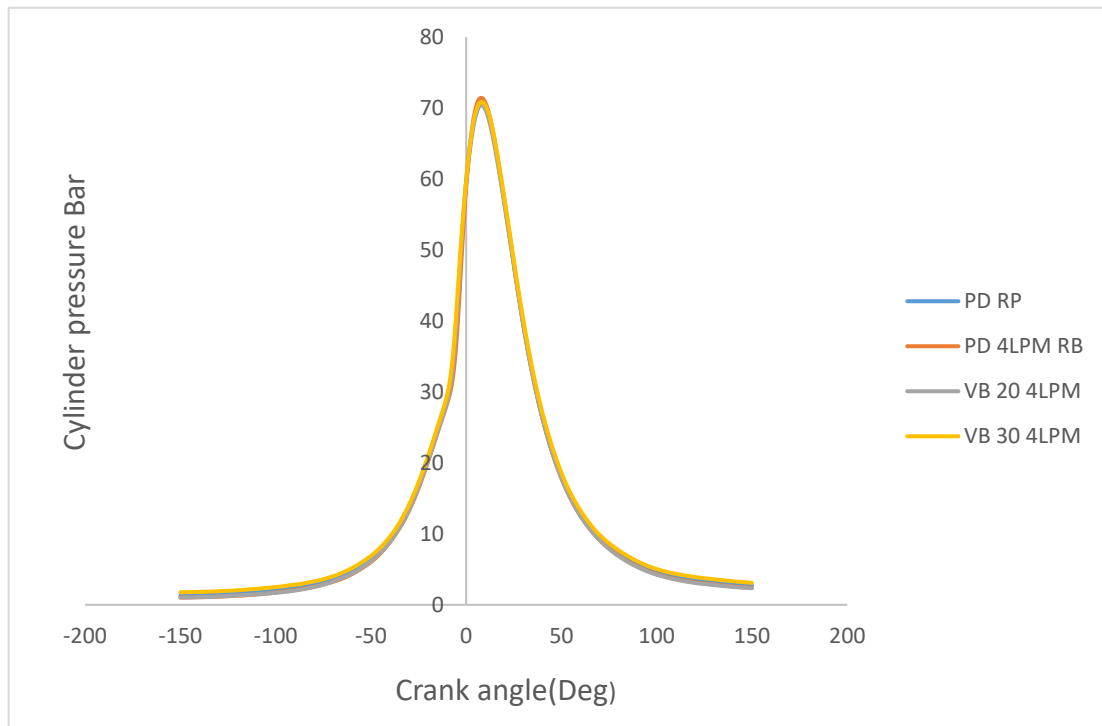


Fig.5.8 Variation cylinder pressure with crank angle

5.2.4 HEAT RELEASE RATE (HRR):

There are three stages in combustion process: Diffusion combustion, premixed combustion, and after burning combustion shown. It is these stages that collectively determine the heat release rate of a DI engine. Below Fig. 5.2.4. depicts HRR values of test engine with different fuel models. In literature survey, it was seen that HRR for biodiesel blends was less when compared to diesel in all the recorded values and graphs. This reduction is because of lower calorific value and shorter ignition delay of biodiesel blends when seen against pure diesel. But with the use of BV30 with 4lpm hydrogen, it was seen that HRR decreased in comparison to pure diesel and pure diesel with 4lpm hydrogen. This shift and decrease in the values of HRR is attributed to lower flame velocity and instantaneous combustion of hydrogen.

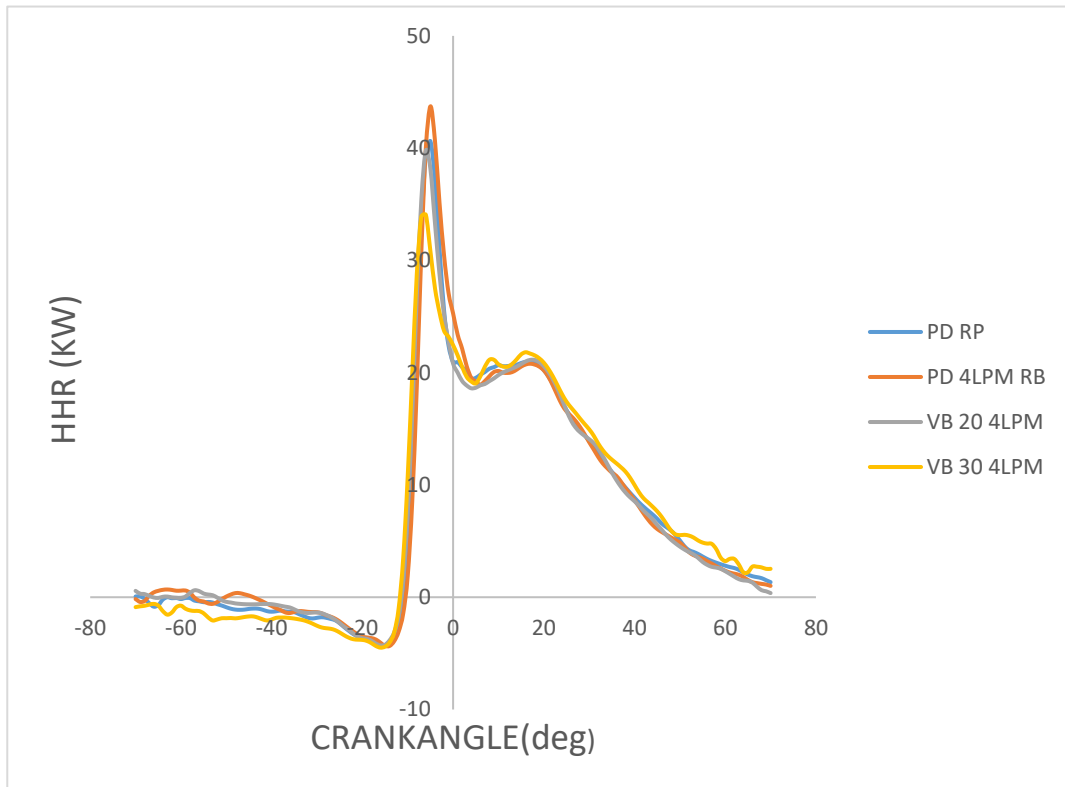


Fig.5.9 Variation of Heat Release Rate with crank angle

Chapter 6

SUMMARY AND CONCLUSIONS

6.1 SUMMARY

We are currently on the verge of a global energy crisis, which is being fueled by an over-reliance on fossil fuels for energy production. This not only accelerates the loss of natural resources, but also raises emission levels, resulting in a warmer environment with lower air quality. Although renewable energy sources are a part of the solution, alternative fuels that can be used in place of diesel and gasoline are another choice. Given the massive scale of commercial cooking operations and the massive amount of waste vegetable oil produced on a regular basis, converting this otherwise discarded material into a valuable source of energy might fill the current gap.

The aim of the research is to extend the application of WVO biodiesel by measuring its various emission and efficiency characteristics in a re-entry combustion chamber with hydrogen as a secondary fuel. This research looks at the realistic spectrum of fuels and aims to establish biodiesel blends that yield the best performance.

6.2 CONCLUSIONS

The project's aim was to determine the efficiency and emission properties of BV20 and BV30 biodiesel blends with 4 lpm hydrogen in a re-entry combustion chamber under various loads. The following are the results of a study on engine performance, power, and emissions for a re-entry piston using a biodiesel blend and a 4lpm hydrogen injection:

- It was observed that BTE for ICE decreased with the use of biodiesel blends when compared to pure diesel. But with the injection of 4lpm Hydrogen for BV30, there was an increase in the value of BTE. Highest amount of BTE was seen with BV30 enriched with hydrogen during the course of the study.
- It was seen in the study that the value of BSFC decreased marginally for smaller loads with an infusion of hydrogen but this value is much more significant at greater

loads. It is clear that BV30 with 4lpm hydrogen yields far less BSFC values when compared to pure diesel.

- In case of In-cylinder pressure and Heat Release Rate, with the addition of Hydrogen, the values increased in case of BV30 biodiesel blend in comparison to pure diesel and also pure diesel with 4lpm hydrogen. The shift in in-cylinder pressure is due to higher flame velocity of hydrogen that ends up in giving these increased values.

- Also observed in the study is the reduction in NO_x , CO, HC and soot emissions with the addition of 4lpm hydrogen to BV30 biodiesel blend when compared against pure diesel in the Re-entry piston. The reason attributed to this decrement is the absence of carbon that is generated with the infusion of 4lpm Hydrogen into the biodiesel blend.

It was seen during the course of the study that CO_2 emissions increased for biodiesel blends like BV30 when compared to pure diesel across the spectrum.

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ABSTRACT As we are experiencing a shift from fossil fuels to alternate fuels. In this study, the effect of hydrogen addition to compression ignition (CI) as secondary fuel, with the blend of waste vegetable oil and biodiesel (WVOB) blend (B20) and (B30) on the engine performance and exhaust emissions was examined experimentally. In the tests, CI Engine set up under test is Kirloskar TV1 having power 3.75 kW @ 1500 rpm which is a 1 Cylinder, Four-stroke, Water Cooled, Diesel Engine, with Cylinder, 661.45 (cc) is used the outcome of the experiment.

To increase efficiency and decrease emissions out of a CI engine. As global emissions are happening at an alarming rate some new changes have to be done to protect mother earth. Many new changes are coming in using different types of fuels and types of engines as well as shifting focus towards renewable energy such as solar and wind to reduce CO₂ emissions. The engine size as well as increasing the overall output of the engine as well as decreasing the emission.

The main gas involved in creating global warming is CO, in the following experiment performed involves the use of H₂ which majorly helps in reducing the CO value coming out of the engine. Hydrogen was added to the intake air at the flow rates of 4 lpm. CHAPTER-1 INTRODUCTION 1.1 BACKGROUND We've long been aware of the problems that a shortage of fossil fuels can cause.

For decades, excessive reliance on this energy source as the primary, if not only, energy carrier in transportation and power generation has raised concerns and prompted thorough research into alternative fuels. People became worried about low fossil fuel supplies after a forecast of peak oil supply was made. Despite the addition of several new variables to the metrics used to predict peak oil production, the majority of scientists and organisations agree that peak oil production will occur before 2020. The environment is being threatened by global warming caused by greenhouse gas (GHG) emissions from fossil fuels.

Today, 171,000 kg of coal, 116,000,000 L of gas, 186,000 L of oil is consumed every second [1]. It is suggested that the widespread use of biofuels rather than fossil fuels would contribute to a reduction in GHG emissions in our atmosphere, resulting in a reduction in global warming and global catastrophe [2].

Biodiesel, a biofuel made from waste vegetable oil, is a renewable energy source that is being overemphasized to meet rising transportation energy demand and reduce GHG emissions [3]. When recent studies in the field of renewable energy are considered, it is clear that an excessive amount of focus is placed on biodiesel, which has emerged as a viable alternative to petrochemicals or petroleum-based fuels [4].

Biodiesel is a clean and renewable fuel that is thought to help grow the agricultural economy while also reducing reliance on petroleum-derived fossil fuels. The interest in using biodiesel as an alternative fuel in compression ignition (CI) engines is increasing by the day [5] since it contains no sulphur or aromatics, is nontoxic, and biodegradable. Different organic resources, such as vegetable oils, animal fats, waste oils, and algae, can be used to make biodiesel.

The characteristics of the biodiesel produced may differ depending on the feedstock and type of alcohol used in its production, which could lead to the occurrence of problems of different engine performance and emission values for each biodiesel engine. Generally, there is a decreasing tendency in PM, HC and CO emissions and there is an increasing tendency in NO_x emissions.