

EXPERIMENTAL INVESTIGATION ON TOROIDAL PISTON HEADS USING BIODIESEL WITH HYDROGEN

Submitted in partial fulfillment of the requirements for the award of

Bachelor of Engineering degree in
Mechanical Engineering

by

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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 **AVIDI SAI HARSHITH (Reg. No. 37150023)** and **CHUKKA HARSHVARDHAN REDDY (Reg.No. 37150042)** who carried out the project entitled “**EXPERIMENTAL INVESTIGATION ON TOROIDAL PISTON HEADS**” under our supervision from December 2020 to April 2021

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ABSTRACT

The search for alternative fuel sources is one that is both urgent and imperative. Finding alternative options that improve efficiency while cutting back on emissions not only reduces over reliance on conventional fuel but also improves the overall air quality by cutting back on dangerous emissions. Global carbon emissions and resource depletion is moving focus away from fossil fuels. This has led to this frantic search ranging from wind and solar to biofuel and more. It is this necessity for additional energy sources that has shaped our study, which looks at possible biodiesel alternatives. The objective is to investigate the efficiency, performance, combustion and nature of emissions of dual fuel engine with Waste Vegetable Oil (WVO) biodiesel as primary fuel. To this, Hydrogen was injected into the air intake as secondary fuel.

The biodiesel blends used for the current study are WVO blended with diesel in the volume fraction of 20% and 30% to produce BV20 and BV30 fuels respectively. Hydrogen was injected along with air at a flow rate of 4lpm. The process of Transesterification was used to convert the acquired WVO into useful biodiesel that was used to create the biodiesel blends. The performance and emission results of this biodiesel blend used in Toroidal combustion chamber were observed and noted.

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LIST OF ABBREVIATIONS

WVO	waste vegetable oil
BV30	30% bio diesel and 70% pure diesel
BV20	20% bio diesel and 80% pure diesel
PD	100% pure diesel
TP	Toroidal Piston
4 LPM	Hydrogen flow rate liters/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

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CHAPTER-1

INTRODUCTION

1.1 BACKGROUND

For a long time, we have been aware of the issues posed by a lack of fossil fuels. For decades, a high over-dependence on this energy source as the primary, if not only, energy carrier in transportation and power generation has raised questions and prompted comprehensive studies into alternative fuels. When a prediction of peak oil supply was launched, people began to be concerned about low fossil fuel supplies. Despite the fact that many additional aspects have been added to the metrics used to forecast peak oil output, most science and organizations believe that peak oil production will occur before 2020.

Moreover, because of their recent ease of accessibility and affordability, fossil fuels now account for the majority of transportation fuel. In a 2017 survey, the International Energy Agency (IEA) stated that fossil energy accounts for about 80 percent of total world commercial energy, with 98 percent of it being used for transportation (de Almeida and Silva, 2009)[17]. This is a result of increasing global demand for and number of cars, as well as high economic growth in certain countries, which is accompanied by a significant rise 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) that are harmful to the population and have negative environmental consequences. CO₂ emissions from the burning of fossil fuels contribute greatly to global warming.

As an effect, the replacement of fossil fuels for renewable and other alternative fuels, including gaseous and liquid fuels, will increase clean fuel production and fuel stability. Besides that, further fuel savings in transportation can be increased by improving engine technology to allow for the use of gaseous fuels. However, their use in diesel engines has disadvantages in terms of engine output and emissions when the engine is turned off, (2007). This is due to most gaseous fuels' poor energy content and low cetane number (CN).

To overcome the above challenges, research has been conducted with the goal of examining certain alternative fuels, gaseous and liquid fuels, that could be

used to replace part of the conventional fuels used in diesel engines. It also looks at the potential of using hydrogen as a gaseous fuel, which has strong energy carrier resource with a high energy quality.

1.2 HISTORY OF DIESEL ENGINES

After looking for a way to improve the Otto engine's performance, German engineer Rudolf Diesel came up with the idea for the engine that bears his name (the primary four-stroke-cycle motor, built by the 19th-century German design Nikolaus Otto). Diesel found that the electric start component of a gasoline engine could be avoided in the event that discuss may well be warmed to a temperature higher than the auto-ignition temperature of a given fuel amid the compression stroke of a piston-cylinder gadget. In his patents from 1892 and 1893, Diesel suggested such a cycle. Initially, powdered coal or liquid petroleum is suggested as fuel alternatives. Powdered coal, a by-product of the Saar coal mines, was used as a readily available fuel by Diesel. Compressed discuss was planning to be utilized to include coal clean into the motor barrel, but directing the rate of coal infusion demonstrated troublesome, so Diesel turned to liquid petroleum after the exploratory engine was demolished by an impact. With compressed discuss, he begun to infuse fuel into the motor. At first Rudolf Diesel was incapable to compress the fuel to the weights required for shower scattering, deterioration, and bead shaping. As a result, the primary diesel motor, which was presented in 1897, utilized compressed-air infusion, in which the fuel was presented into the barrel with the help of compressed discuss. The destitute entrance profundity of the air/fuel blend into the combustion chamber was an issue with this strategy due to the moo weight at the spout. As a result, higher infused fuel volumes (higher motor loads) and motor speeds were not perfect for this strategy of blend shaping. Diesel motors are of two sorts. They are Coordinate infusion (DI) and Backhanded infusion (IDI). The combustion chamber of the previous is completely encompassed by the barrel head and cylinder surfaces, and it regularly takes the shape of a empty or bowl within the cylinder crown. The combustion chamber within the latter is separated into two parts: one could be a depth within the cylinder, which is molded in an unexpected way than in a coordinate infusion motor, and the

other could be a pre-chamber, which is joined to the barrel by one or more sections. The pre-chamber is where the diesel is pumped.

1.2.1 DIESEL ENGINE OPERATION

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 results in high temperatures, which cause the diesel fuel to spontaneously combust when injected into the cylinder. As a result, the heat produced by the diesel engine is used to release the chemical energy stored in the fuel and transform it to mechanical power (Bosch 2005). The engine operates on 4 stroke cycle. The conventional diesel engine basic operations are explained below.

1.2.2 FOUR STROKE CYCLE OPERATION

Inlet and exhaust valves regulate the intake of air and the expulsion of burning gases following combustion in a four-stroke diesel engine (Fig. 2). They open and close the inlet and exhaust ports of the cylinder. One or two valves can be present at each inlet and exhaust port.

A] Induction stroke:

The piston (6) travels downwards from Top Dead Centre (TDC), raising the cylinder's capacity. The inlet valve (3) is opened at the same time, and air is drawn into the cylinder without being restricted by a throttle valve. The cylinder potential ($V_h + V_c$) is at its maximum when the piston hits Bottom Dead Centre (BDC).

B] Compression Stroke:

The inlet and exhaust valves have presently been closed. The cylinder rises and compresses the discuss contained within the barrel to the degree characterized by the engine's compression proportion (which can extend from 6: 1 in large-scale motors to 24: 1 in automobile motors).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 (as much as 2,000 bar in modern engines). The cylinder capacity is at its minimum as the piston hits top dead centre (compression volume, V_c).

C] 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.

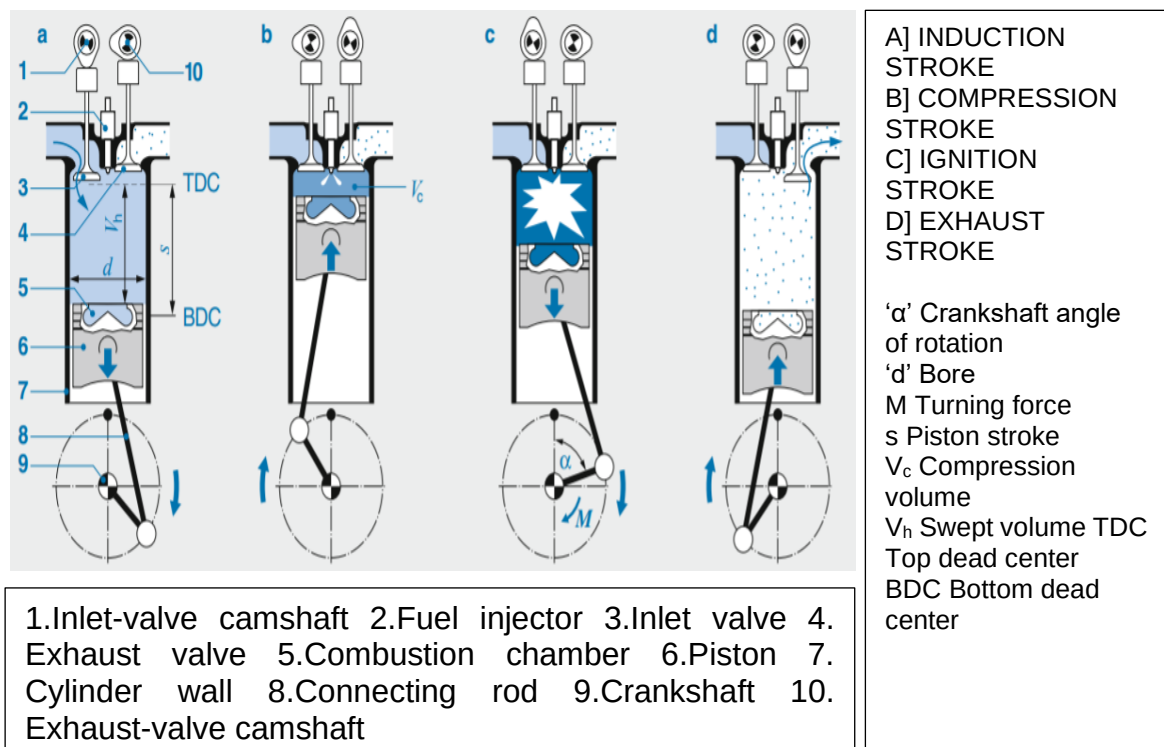


Fig1.1. OPERATION CYCLE OF FOUR STROKE DIESEL ENGINE

D] 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.

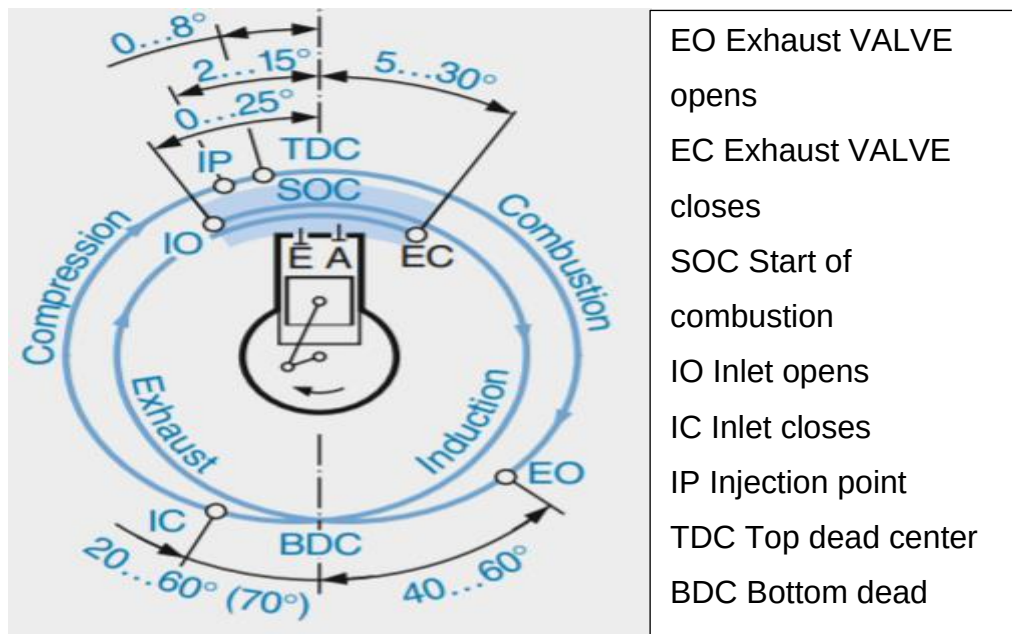


Fig:1.2 :VALVE TIMING DIAGRAM FOR FOUR STROKE ENGINE

1.2.4 COMBUSTION IN CI ENGINES

There are a few essential varieties within the combustion forms of SI and CI motors. Within the SI motor, a homogeneous carburetted blend of fuel vapor and discuss is compressed in a specific extent (6:1 to 10:1), and the blend is lighted by an electric start at one arrange some time recently the conclusion of the compression stroke. After combustion, a single fire front progresses over the air-fuel blend. Be that as it may, in CI motors, as it were the discuss is compressed at a tall compression proportion (16:1 to 20:1), coming about in a tall temperature and weight. Fuel is pumped into the intensely compressed discuss within the combustion chamber through one or more planes. The fuel fly deteriorates into a fuel center encompassed by an discuss and fuel molecule shower shell. The atomization and vaporization of the gasoline makes this shower envelope. The fuel particles are tore from the center by the turbulence of the discuss within the combustion of chamber passing over the fly. At a few point within the shower envelope, a combination of discuss and fuel rises, and oxidation starts.

1.2.4.1 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.

1.2.4.1.1 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.

The following are few details of combustion chamber designs:

SHALLOW DEPTH COMBUSTION CHAMBER

The depth of the cavity given in the piston in a shallow depth chamber is very limited. This chamber is typically used for massive engines that operate at low speeds. The squish is marginal due to the large cavity diameter.

CYLINDRICAL CHAMBER

A cylindrical chamber's depth to diameter ratio, on the other hand, can be adjusted to achieve the desired squish for improved efficiency.

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.

TOROIDAL CHAMBER

The concept behind this shape is to have a strong squish as well as air displacement inside the toroidal chamber, 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°.

1.2.4.1.2 Key benefits of direct injection chambers:

The following are the key benefits of direct injection chambers:

2. There are no cold-starting issues.
3. The multi hole nozzle allows for fine atomization.

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

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

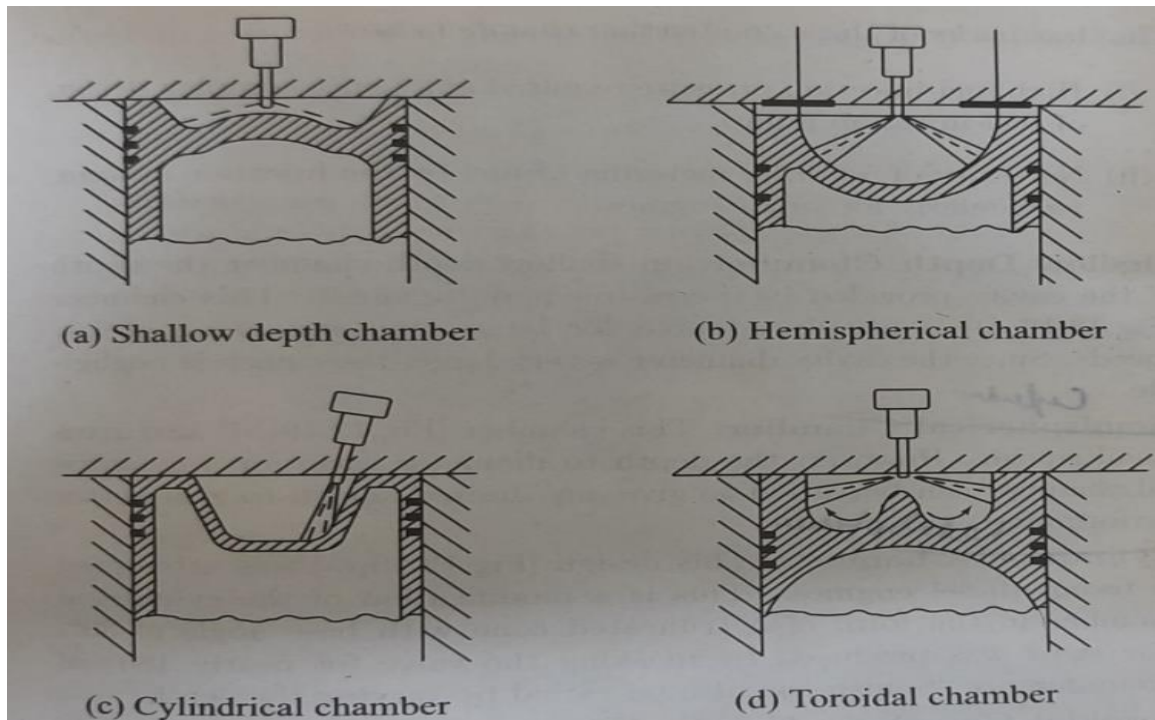


Fig: 1.3 Different type of Combustion Chambers in DI Engines

1.2.4.2 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.

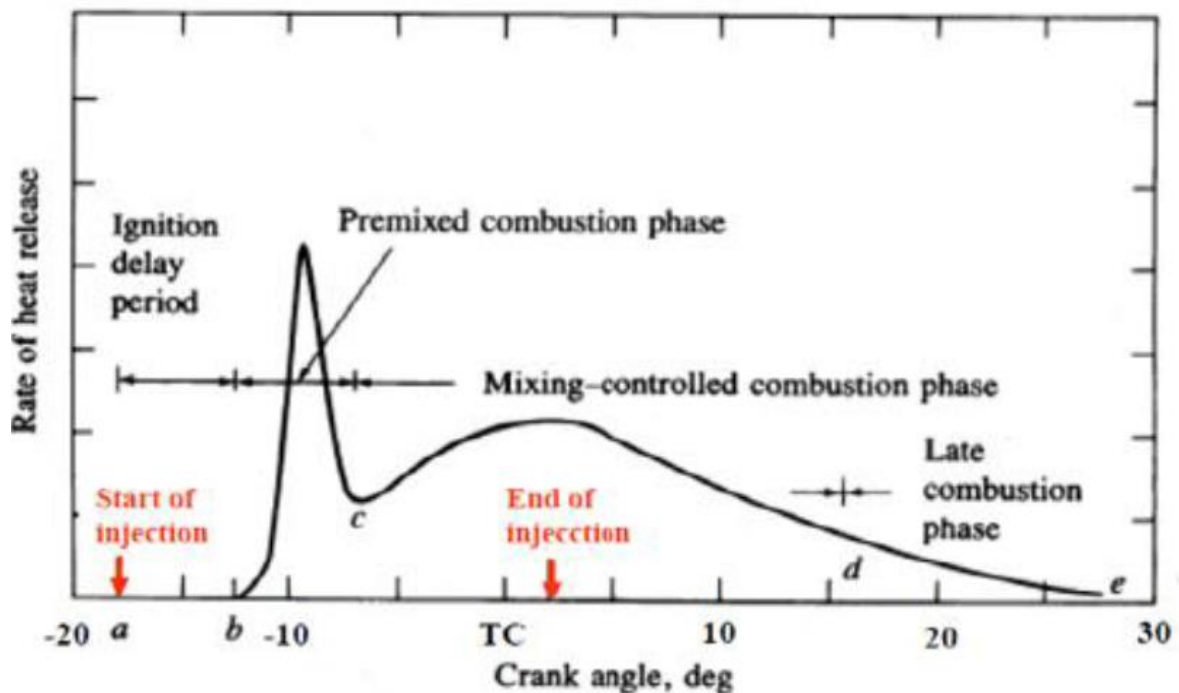


Fig: 1.4 : phases of combustion in CI engine

1.2.5 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 thermal efficiency of an optimal work process (Seliger process) and the percentage losses of an actual process.

Seliger process:

The Seliger method can be used as a thermodynamic comparative process for reciprocating piston engines. It explains potentially beneficial work done in optimal circumstances. As Shown in Fig.1.5 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

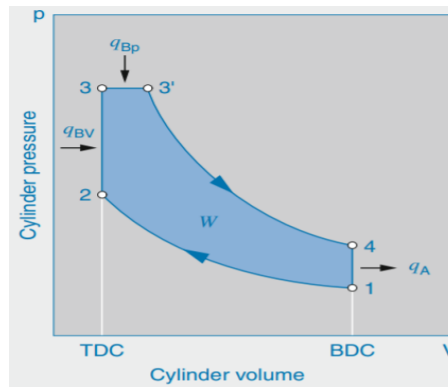


Fig: 1.5: Seliger process in CI engines

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.

1.2.6 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. (Prasad and Bella 2010)[19]. 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 Figure 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.

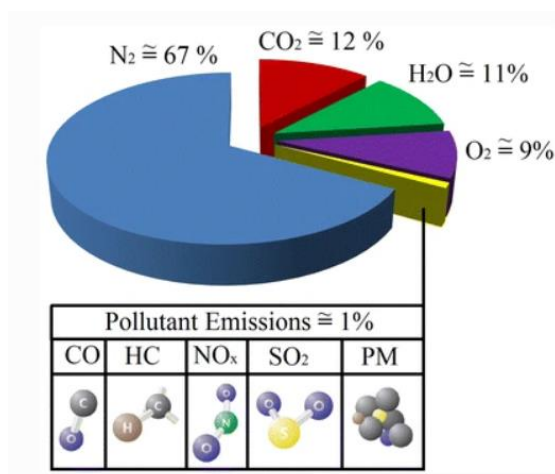


Fig: 1.6 : Diesel engines Exhaust composition

Diesel fuelled 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.

1.2.6.1 Carbon Dioxide (CO₂):

The main greenhouse gas produced from human activities is carbon dioxide (CO₂). CO₂ accounted for around 81.3 percent of all human-caused greenhouse gas emissions in the United States in 2018. As part of the Earth's carbon cycle, carbon dioxide is actually present in the atmosphere. Human actions are altering the carbon cycle, both by contributing more CO₂ to the environment and by

affecting natural sinks' capacity to extract and store CO₂ from the atmosphere, such as trees and soils.

The major outcome of the hydrocarbon fuel combustion is carbon dioxide. With nitrous oxide, methane, perfluorocarbons, sulphur, and hydrofluorocarbons, it is one of the main green house gas emissions(Kaewmai et al., 2012)[20]. CO₂ is still found in atmosphere, however in very small concentrations. But the level has risen at an exponential rate over time. According to international Energy agency survey, gross CO₂ emissions from the fuel combustion was almost negligible in 70's, but were calculated to be 33.5Gt CO₂ in 2019. Human practices have changed the equilibrium and are no longer able to substitute for the forests capacity to absorb CO₂. Massive use of fossil energy (natural gas, coal, and oil) on a global scale, compounded by pollution and the long lifespan of CO₂ in the environment, has a negative effect on climate change and is a major problem for all nations (IEA, 2011). 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.

1.2.6.2 HYDROCARBONS (HC):

Hydrocarbons are hazardous for the atmosphere and for human well-being. They contribute significantly to the formation of ground-level ozone, along with other pollutant pollutants. Hydrocarbons are harmful and can irritate the respiratory system as well as cause cancer. Alkanes, alkenes, and aromatics are just a handful of the thousands of species of hydrocarbons (Hiroyuki et al. 2011)[21].

Unburned hydrocarbons proceed to respond within the deplete on the off chance that the temperature is over 600 °C and oxygen show, so hydrocarbon emanations from the tailpipe may be altogether lower than the hydrocarbons clearing out the barrel. Hydro carbon emissions from diesel engines are typically minimal. Diesel hydrocarbon emissions are often caused by light loads. Lean air–fuel mixing is the primary cause of light-load hydrocarbon pollution. Flame speeds in lean mixtures can be too low for combustion to complete during the power stroke, or combustion may not occur at all, resulting in high hydrocarbon emissions (Zheng et al. 2008). Misfire and low charge mixture are attributed to the concentration level due to lack of proper fuel and air mixing. Oil film layers, wall flame quenching, deposits and crevices in the combustion chamber, liquid fuel, and exhaust-valve leakage are all

possible causes of HCs emissions. Furthermore, the oil often used lubricate the piston rings and cylinder liner may lead to the emission of HCs. The oil thin film consumes fuel, stopping it from interfering in the combustion process and allowing it to escape unburned from the combustion chamber. To minimize HCs emissions, some methods such as adjusting fuel injection speed, increasing fuel injection pressure, and changing the piston head are used to improve mixing time and intensity.

1.2.6.3 CARBON MONOXIDE (CO):

Carbon monoxide is a non-corrosive, odourless, tasteless, and colourless substance that is toxic to humans. CO in the air when inhaled and taken into the bloodstream by humans. It binds to haemoglobin and prevents it from carrying oxygen. As a consequence, focus is hindered, reflexes are slowed, and confusion occurs (Walsh 2011). It is a by-product of incomplete burning of carbon-containing fuels. This concentration is mostly determined by the air/fuel combination, and it is greatest in rich mixtures where the excess-air factor (λ) is less than 1.0. (Wu et al. 2004). Over-mixing and under-mixing between air and fuel are the two major causes of CO forming in diesel engines (Bagal et al., 2009) [22].

To attain an adequate degree of pollution control, several attempts have been made. Improvements in engine configuration and working conditions, such as the use of fuel injection timing, combustion chamber design, and combustion cavity diameter to achieve uniform air-fuel mixing, as well as the use of oxygenated diesel fuels, are among them (Chen and Iwashina, 2009, Lapuerta et al., 2008a).

1.2.6.4 NO_x EMISSIONS:

Three techniques can be used to explain the possibility of NO_x production in the combustion chamber i.e, Thermal NO_x, NO_x formation from the fuel, Fenimore NO_x formation. While the contribution of the first process is considered to be the most important, of all three NO_x formation mechanisms (Ban-Weiss et al., 2007). The combustion chamber is initially filled with air, which is mostly made up of oxygen and nitrogen. To combust the fuel, diesel engines use extremely compressed hot air. At that point the fuel is sprayed straightforwardly into the compressed discuss within the combustion chamber at the conclusion of the

compression stroke. The nitrogen within the air does not respond with the oxygen within the combustion chamber and is expelled from the motor within the same way. Be that as it may, tall temperatures within the barrels over 1,600 °C permit nitrogen to respond with oxygen, coming about in NO_x emanations lead to add up to NO_x contamination

The amount of NO_x emitted is determined by the cylinder's maximum temperature, oxygen concentrations, and heating rate. For a 100 °C rise in combustion temperature, the volume of NO_x produced increases by two-thirds (Lee et al. 2013) [23]. As a result, the temperature and oxygen concentration in the combustion are the most important factors in NO_x production. Both NO and NO₂ are toxic, but NO₂ is five times more toxic than NO and is a direct source of human lung disease. Nitrogen oxides (NO) and nitrogen dioxide (NO₂) are key items for nitrogen oxides. NO accounts for 85–95% of NO_x emissions. In the atmosphere, it is eventually transformed to NO₂. Despite the fact that NO and NO₂ are grouped together as NO_x, there are some important variations between the two contaminants.

Because of the adverse effects of NO_x, some NO_x limiting systems for internal combustion engines have been introduced to reduce emissions. less excess air, de nitrogenation of the fuel, ignition or injection timing improvement to reduce residence time at high in-cylinder temperature, catalytic combustion or after treatment system, including the use of selective catalytic reduction (SCR), and premixed or homogeneous intake charge operation. Since NO_x emissions are strongly linked to high in-cylinder temperatures, a diluted intake charge from either air or exhaust gas re-circulation (EGR) will significantly reduce emissions.

1.2.6.5 PARTICULATE MATTER (PM):

Particulate Matter (PM) is a common engine-out pollution from diesel engines, Diesel engines emit much more particulate matter (six to ten times more) than gasoline engines. Soot, soluble organic fraction (SOF), and inorganic fraction (IF) are the three principal components of diesel particle pollutants. Soot, which appears as black smoke, accounts for more than half of all PM emissions. When engine loads are low and exhaust temperatures are low, SOF values are too high

(Sarvi et al. 2011; Tighe et al. 2012) [24,25]. A non-homogeneous combustion mechanism in the cylinder is responsible for this. The majority of particulates are caused by insufficient combustion of hydrocarbons in gasoline and lube oil. The aromatic content of the fuel also adds to the amount of PM that is released. As a result, a fuel with a low aromatic content can help to reduce PM levels.

PM formation can be regulated by modifying in-cylinder conditions by dual fuel combustion and changing fuel properties by the use of oxygenated and free-aromatic fuels.

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 made by the transesterification process. The raw material is transformed into a fuel that can power diesel engines by triggering a chemical reaction in a vegetable oil, whether it comes from a specially-grown crop or commercial waste. In this process, animal fats can also be used. Palm oil, sunflower oil, canola oil, soya oil, and jatropha oil are some of the most popular biodiesel raw materials.

1.3.1.2 USE OF BIODIESEL:

Biodiesel and other biofuels may help countries offset their reliance on imported fossil fuels, and biofuels also contain less air pollution and net carbon

emissions than fossil fuels, so governments all over the world are encouraging their use.

Vegetable oil-based fuels have received less recognition due to the widespread supply and low cost of petroleum diesel fuel. During 1970s oil shortages, there was a brief increase of interest in using vegetable oils to power diesel engines.

Unfortunately, owing to the much higher viscosity of vegetable oil relative to conventional diesel fuel, newer diesel engine designs do not work on standard vegetable oils. It was important to find a way to reduce the viscosity of vegetable oils so that they could be burnt properly in a diesel engine. Many approaches have been proposed to accomplish this goal, including pyrolysis, solvent mixing, and even emulsifying the fuel with water or alcohols, but none have proven to be effective. Biodiesel, on the other hand, has certain drawbacks that must be considered.

Higher viscosity, lower heating value, and volatility are some of the main properties that can influence engine efficiency and pollution. Besides that, the high bulk modulus of compressibility can result in advanced fuel injection timing, which can result in increased NOX emissions. The increased fuel consumption is due to the reduced heating efficiency. However, because of its high viscosity, it increases engine lubricity and also engine life (Shahid and Jamal, 2008, Boehman et al., 2005)

In 1937, a Belgian innovator presented utilizing transesterification to change over vegetable oils into greasy corrosive alkyl esters and utilize them as a substitute for diesel fuel. Transesterification could be a strategy that breaks down vegetable oil into three littler atoms that are less thick and less demanding to burn in a diesel motor. Present day biodiesel is made from greasy corrosive methyl esters, and the transesterification response is the key to its preparing.

1.3.1.3 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 absorbed by the oil-seed plant during its development.

1.3.1.3.1 Emissions of Greenhouse Gases:

Carbon dioxide (CO₂) is one of the primary greenhouse gases related to global climate change, according to scientists. Biodiesel-fueled engines emit CO₂ in the same manner as fossil-fuel-fueled diesel engines do. The distinction is that when oil-seed plants are cultivated for biodiesel, they extract CO₂ from the air as they rise. The degree to which a biofuel is carbon-neutral is calculated by a complex measurement of the whole method of manufacturing and consuming the fuel.

1.3.1.3.2 POLLUTION

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 minimized 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 re-circulation (EGR) initiatives are two other recent innovations.

As compared to petrochemical-derived diesel, biodiesel can minimize 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 CI ENGINES GASEOUS FUELS

1.3.2.1 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. Colourless, odourless, and tasteless, hydrogen is non-toxic and non-poisonous. It's also non-corrosive, although it does lead certain metals to em-brittle. 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.

1.3.2.1.1 HYDROGEN COMBUSTION

The least temperature at which a fluid can actually combust without the nearness of a fire or start is called the auto-ignition temperature. Hydrogen and characteristic gas have exceptionally near auto-ignition temperatures. Both have auto-ignition temperatures of over 1000°F, which is distant more noteworthy than the temperature at which gasoline vapor 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.

1.3.2.1.2 HYDROGEN GAS AS FUEL

Hydrogen can be made from a range of domestic fuels, including natural gas, nuclear power, coal, and alternative energy sources such as solar and wind power. These features make it a suitable fuel for transportation and electricity production. It can be found in automobiles, homes, portable electricity, and a variety of other applications. Hydrogen fuel can now be produced in a number of ways. Natural gas reforming (a thermal process) and electrolysis are the most used approaches today. Solar-powered and biological processes are two other options. In comparison to other fuels, hydrogen has a very high flammability spectrum (between 4% and 75% 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 (Fig. 16). 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-fuelled 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-fuelled 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.

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.

1.3.2.2 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. LPG-powered cars emit low quantity of pollution. 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) [26]. 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.

1.3.2.3 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 United States 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

Reduced NO_x and PM emissions, as well as fuel cost lower than diesel, are the main benefits of the dual fuel hydrogen-diesel engine. Other possible benefits include improved thermal performance (load dependent) and decreased fuel transportation impacts if Hydrogen is locally usable. The cost of servicing will not grow as a result of the conversion because the rest of the engine components will remain the same. Carbonization is minimized in the dual fuel engine because a large volume of diesel is displaced by hydrogen, up to 70%. Transitioning between diesel and hydrogen fuel modes in a dual fuel hydrogen diesel engine can be achieved while the engine is running without interrupting the necessary engine load. If Hydrogen is not available, the control valve is closed, and the engine runs on diesel fuel like a traditional diesel engine

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] A. Refaat and N. K. Attia (2018). in a study said that the surrender rate gotten employing a 6:1 methanol/oil molar proportion, 1% potassium hydroxide as catalyst, and a temperature of 65°C for one hour. Underneath culminate conditions, the abandon rate gotten from misuse vegetable oil was comparable to that gotten from smooth vegetable oil, which come to 96.15 %.

[2] Madhu Agarwal and Garima Chauhan (2012), said within the ponder that utilizing potassium hydroxide (KOH) as a homogeneous catalyst At the ideal response conditions of response temperature 70 °C, response time 2 h, catalyst concentration 5%, catalyst stacking 15% wt%, and methanol to oil molar proportion 9:1, a surrender of 96.8% greasy corrosive methyl ester (Notoriety) was gotten with heterogeneous catalyst, whereas 98.2% surrender was gotten with homogeneous KOH catalyst at the ideal response conditions of response temperature 70 °C, response time 2 h, catalyst concentration KOH stacked on an alumina catalyst given a reasonable surrender for up to three cycles.

[3] S.T. Keera and S.M.El Sabagh(2011) For Reaction time (1–3 h), catalyst concentration (0.5–1.5 w/wt percent), and oil-to-methanol molar ratio (1:3–1:9) factors studied. The best yield percentage of waste vegetable oil obtained using a 6:1 methanol/oil molar ratio, sodium hydroxide as catalyst (1%) and a 60 °C temperature for 1 hour.

[4] In the study conducted by Murat Kadir Yesilyurt (2019) showed that the waste vegetable oil Biodiesel fuel reduced engine torque, braking speed, CO, UHC, and smoke opacity, but improved BSFC, EGT, NO_x, and CO₂ emissions. Increased injection pressure, on the other hand, resulted in up to 210 bar increases in engine torques, braking forces, and brake thermal efficiencies. As the findings were

analysed, the optimal fuel injection pressure for WCOB and fuel blends was discovered to be 210 bar.

[5] Whereas K.A. Abed, A.K. El Morsi (2018) said Waste cooking-oil biodiesel blends had better thermal efficiencies than diesel oil. Biodiesel blends had higher specific fuel consumption than diesel fuel. When comparing biodiesel blends to diesel oil, higher exhaust gas temperatures were observed. CO₂ emissions were higher for waste cooking-oil biodiesel blends than for diesel oil. Biodiesel blends had lower CO, smoke opacity, and HC emissions than diesel fuel. Biodiesel blends had higher NO_x emissions than diesel fuel.

[6] It was seen in study by Qing shu and jixian Gao(2010) that waste vegetable oil with high levels of free fatty acids (FFAs). When employing a 16:8 molar proportion of methanol to oil and 0.2% wt of catalyst to oil, the most extreme change of triglyceride and FFA was 80.5 wt. percent and 94.8 wt. percent after 4.5 hours at 220°C. additionally by

[7] Suleyman Simsek and Samet Uslu that with the utilize of AFBD100 and VEBD100 powers, the brake warm productivity (BTHE) esteem diminished whereas the brake particular fuel utilization (BSFC) expanded. When dissected in terms of debilitate emanation comes about, the decrease of carbon monoxide (CO), hydrocarbon (HC) and smoke emanations compared to D100 was decided by the utilize of AFBD100 and VEBD100 powers, whereas an increment in nitrogen oxide (NO_x) and carbon dioxide (CO₂) outflows occurred.

[8] Mustafa Atakan Akar et.al(2018) found that The addition of hydrogen to research fuel waste vegetable oil improved efficiency and emission metrics while increasing NO_x emissions. When test fuels were enriched with hydrogen gas, brake thermal efficiency and basic fuel consumption increased.

Hydrogen incorporation decreased CO and CO₂ emissions due to the lack of carbon atoms in the chemical composition of hydrogen fuel, but elevated cylinder temperature caused a rise in NO_x emissions.

[9] Reikia Bouguess and Lyes Tarabet(2020) in a study conducted on engine performance and emission characteristics using biogas and hydrogen findings show that biogas enriched with 20% hydrogen causes a 20% reduction of methane content in overall exhaust emissions, as well as an increase in engine performance. The levels of unburned hydrocarbon (UHC) and carbon monoxide (CO) emissions are reduced by up to 25% and 30%, respectively. When the equivalence ratio is

improved, UHC and CO emissions are reduced by up to 28 percent and 30 percent, respectively, when the engine is loaded at 60 percent.

[10] M channappagoudra et.al,(2018) found that engine operating on a 20% blend of dairy scum oil biodiesel, the hemispherical piston bowl geometry (HPBG) of an existing diesel engine was changed to toroidal piston bowl geometry (TPBG). In reaction to the engine adjustment, the experimental findings showed improved brake thermal efficiency and heat release rate of 5.5 % and 17.24 %, respectively, while brake specific fuel consumption, HC emission, and CO emission were reduced by 8.75 percent, 15 percent, and 14.47 percent, respectively. Improved fuel atomization, decreased fuel droplet size, increased cylinder temperature, improved squish and swirl, and other advantages of using the TPBG may all be attributed to it.

[11] In study conducted by prabhakar rao et.al, (2016) on effect of piston bowl geometry on the performance and emissions of DI diesel engine, The TCC piston bowl geometry created a stronger air–fuel mixture within the cylinder, resulting in a more homogeneous charge. Furthermore, by adjusting the depth of the bowl. The case with a 1.26 mm reduction in bowl depth from the baseline (TCC) specification has the highest emissions and efficiency characteristics of all the cases.

[12] U S Jyothi et.al,(2020) concludes that in the case of Toroidal piston geometry, the minimum particle diameter is slightly larger than hemispheric form at the end of the injection cycle at 365.250 CA. With hydrogen supplementation, it is further lowered to a desirable level of around 6%. This is due to the addition of hydrogen to the carbon material, which aids the combustion process by raising the cylinder temperature. If the injection advances from 341.50 CA to 365.250 CA with hydrogen supplement, the overall particle diameter increases with respect to bowl geometries in hemispherical, toroidal, and re-entrant toroidal forms, respectively, as opposed to neat diesel alone.

[13] Rahul Banerjee et.al, (2012) found that comparison to diesel operation, 20 % cooled EGR beneath hydrogen enhancement detailed a decrease of 9.2 % and 12.3 % in NO_x emanations at 60 % and 80 % stack, separately, whereas holding a diminishment of 4.6 % and 1.9 % in brake particular vitality utilization, as well as a 10 % and 8.33 % proportionate diminish in brake particular vitality utilization. CO emanations were diminished by 26.6 % and 20.0 %, individually, whereas CO₂ outflows were decreased by 24.5 % and 29.1 %, whereas brake

warm execution was moved forward by 4.8 % and 2 %, and essential fuel utilization (SFC) was decreased by 23.3 % and 18.95 %.

[14] Hendrick Maxil Zárate Rocha et al.(2017), revealed that as hydrogen concentrations increased, the Brake special fuel consumption decreased. Similarly, as the hydrogen concentration was increased, CO₂, CO, and HC emissions reduced proportionately. The rise in the average temperature within the cylinder, on the other hand, increased nitrogen oxide (NO_x) emissions. The peak pressure and heat release rate within the cylinder both increased, and the ignition delay was decreased as the hydrogen content increased.

[15] Hayder A.Alrazena and A.R.Abu Talib(2016) In their review overall conclusion is that the air–fuel ratio, engine speed, and engine load all play a role in the performance and emissions of hydrogen-enhanced diesel engines.

When including hydrogen to an motor, the brake warm effectiveness (BTE), brake control yield (BPO), brake cruel successful weight (BMEP), and particular vitality utilization (SEC) are all influenced by the engine's working conditions. It's too learned that expanding the rate of hydrogen decreases outflows, coming about in lower levels of unburned hydrocarbon (HC), carbon monoxide (CO), carbon dioxide (CO₂), particulate matter (PM), and smoke. Be that as it may, when H₂ is improved, nitrogen oxide (NO_x) levels rise, but this rise can be directed by different strategies.

[16] N. Saravanan and G. Nagarajan said in a study that hydrogen induction to the diesel engine Using the carburation procedure, specific energy intake, NO_x emissions, and exhaust gas temperature rose by 6%, 8%, and 14 percent, respectively, while brake thermal efficiency and smoke level decreased by 5% and 8%, respectively, as compared to baseline diesel. Also said that while using Timed port injection technique the brake specific energy consumption, temperature of the exhaust gas, and the amount of smoke emitted were all decreased by 15%, 45 percent, and 18 percent, respectively. In comparison to standard diesel, brake warm productivity and NO_x made strides by 17% and 34%, individually. As compared to pattern diesel, outflows such as HC, CO, and CO₂ are exceptionally moo in both carburation and TPI procedures.

CHAPTER 3

AIM AND SCOPE OF PRESENT INVESTIGATION

3.1 AIM

Central aim of the study is to analyze the emissions and performance of Toroidal 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

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. 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. The dual fuel mode was adopted to a single cylinders 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.

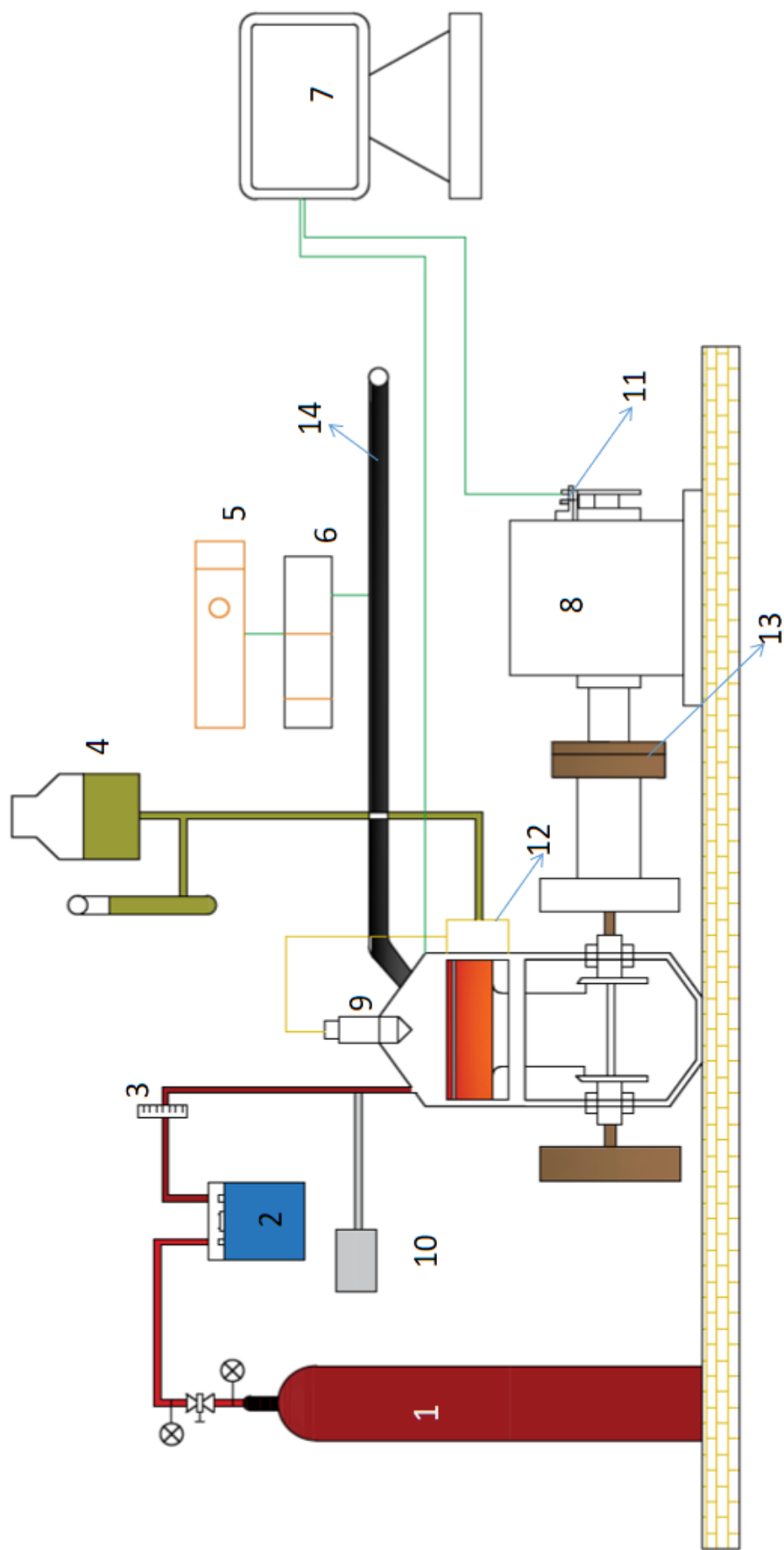
Table 4.1: Specifications of test engine used

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 DUEL FUEL ENGINE SETUP:

The admissions discuss complex has been altered to empower the blend of discuss and hydrogen into the combustion chamber whereas the diesel fuel is specifically infused into the combustion chamber. A stream meter was prepared to control the sum of hydrogen into the combustion chamber.

Figure shows the experimental setup of dual fuel engine



1. H_2 cylinder 2. Flame Arrestor 3. Flow meter 4. Diesel Tank 5. Five Gas Analyser 6. Smoke Analyser
7. Computer 8. Eddy Current Dynamometer 9. Fuel injector 10. Intake Air Box 11. Angle Encoder
12. Fuel pump 13. Coupling 14. Exhaust gas Outlet

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. ICEngine 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.

The properties of both liquid and gaseous fuels are mentioned in the table below

Table 4.2: properties of waste vegetable oil compared with ASTM and Euro standards

Properties	ASTM Standards	Euro 6 standards	Diesel	VB20	VB30	V 100
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 4.3: 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. An acid or base catalyst is commonly used to catalyse these reactions. The modification of triacylglycerol lipids to alkyl esters by alcohols without first isolating the free fatty acids is known as transesterification (alcoholysis) (May, 2004). The first

transesterification of a vegetable oil was achieved in 1853, several years before the first diesel engine was built.

The well-known chemical mechanism for converting triglycerides to methyl esters is transesterification. Owing to its high viscosity and acid value, oil derived from vegetable or animal fats is not ideal for use in unmodified diesel engines. These problems can be solved by transforming it to methyl esters, which have fuel properties comparable to diesel. Vegetable oils are triglycerides, and are made up of three greasy corrosive chains that are covalently connected to a glycerol spine by an ester linkage. Vegetable oil is promptly transesterified utilizing basic methanolic arrangements to create fatty corrosive methyl esters within the C12–C22 range, i.e. biodiesel, comparative to rough oil breaking to create diesel fuel.

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 glycerin 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.

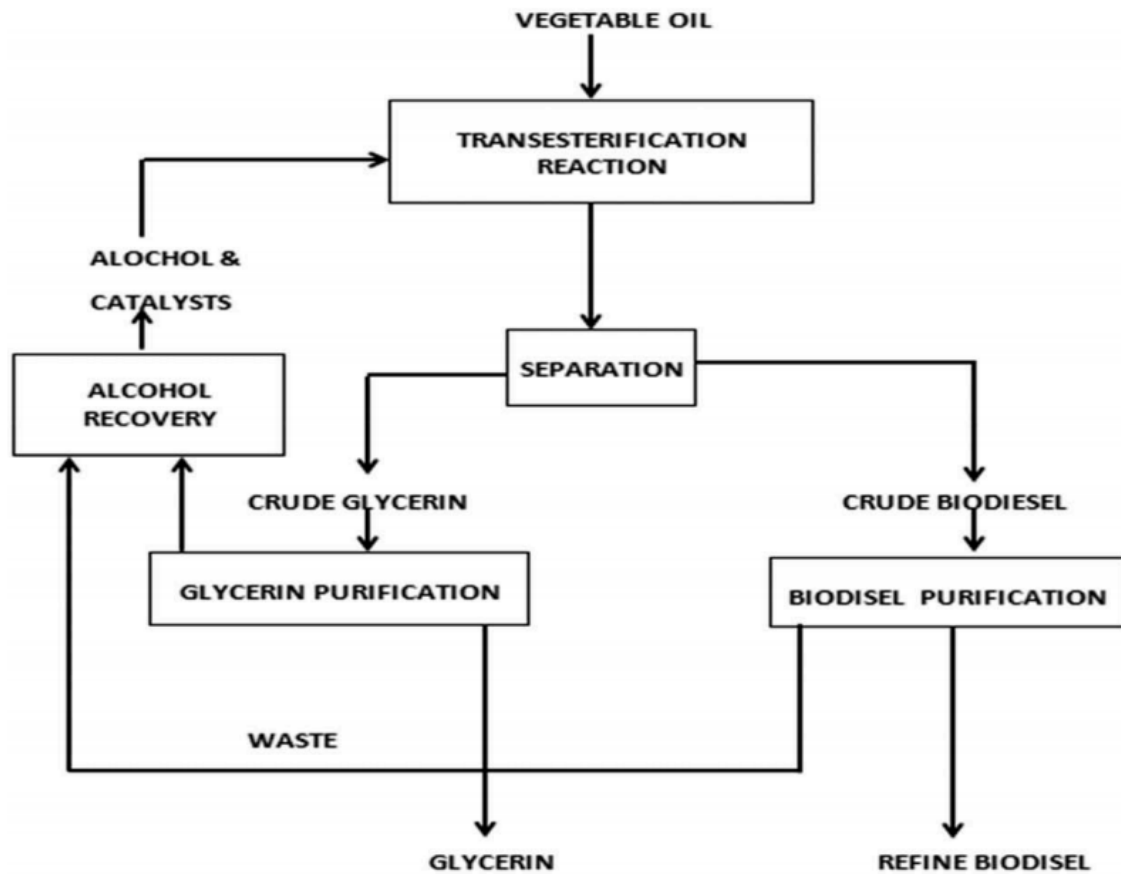


Fig: 4.3: Schematic process of Transesterification

CHAPTER 5

RESULTS AND DISCUSSION

5.1 EMISSIONS CHARACTERISTICS

Different emission parameters for Toroidal 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):

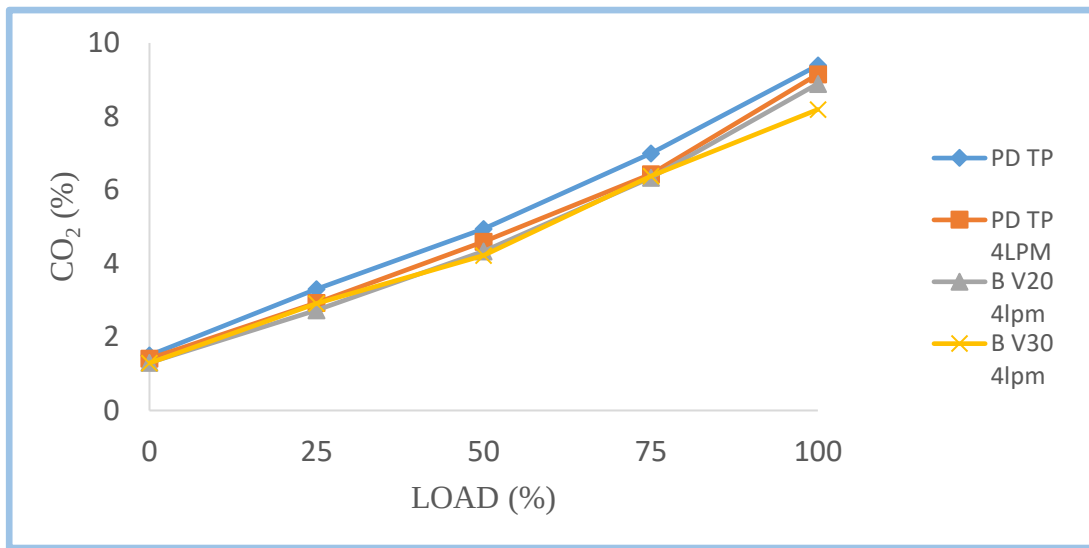


Fig: 5.1 comparative analysis of CO₂ emission vs load

In tests performed we obtained CO₂ as a result of complete combustion of carbon and oxygen present in petroleum-based fuels. The effects of hydrogen addition on CO₂ emission are given in the Fig.5.1 CO₂ emissions increased as the engine load was increased for each test.

It is seen in Fig that CO₂ emissions decreased with the addition of hydrogen to biodiesel blends. For pure diesel and BV20 biodiesel blend, the CO₂ emissions were reduced with the addition of hydrogen while there was a significant reduction in the emissions for BV30 biodiesel blend. When compared with pure diesel, BV30 biodiesel blend with 4lpm Hydrogen showed far less 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 far cleaner.

5.1.2 HYDROCARBONS (HC):

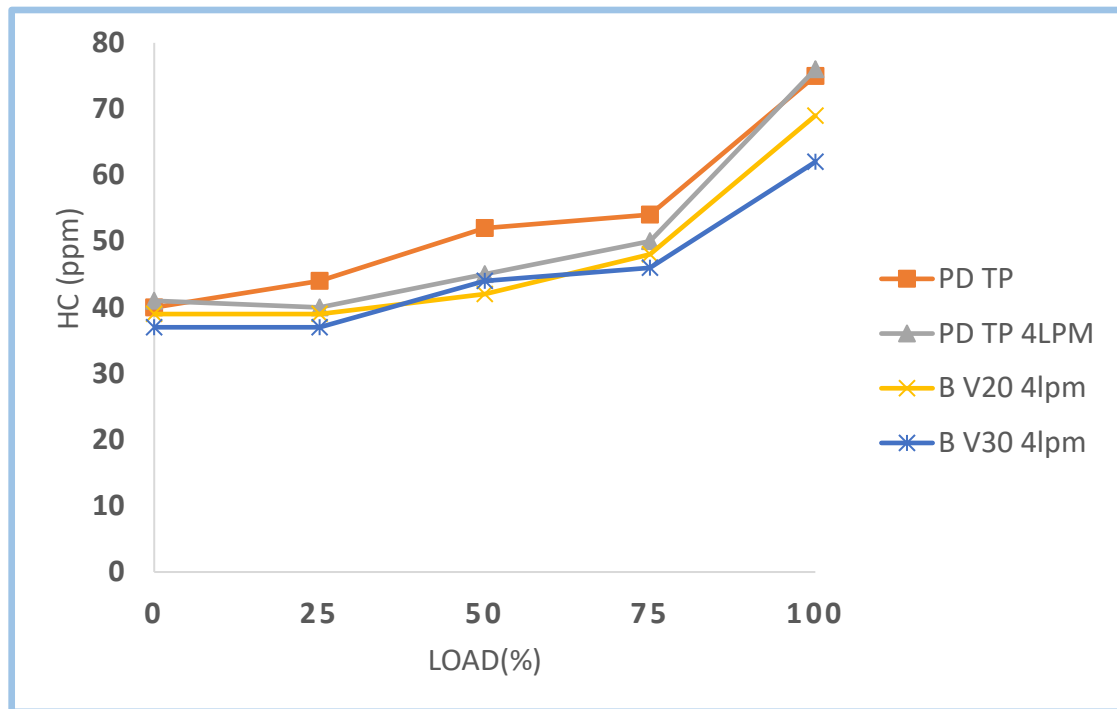


Fig: 5.2 comparative analysis of HC emissions vs Load

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.5.2. 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. On analysis, the reason for the decrease was seen to be the lack of Carbon that is created by the infusion of Hydrogen during the combustion process.

5.1.3 CARBON MONOXIDE (CO):

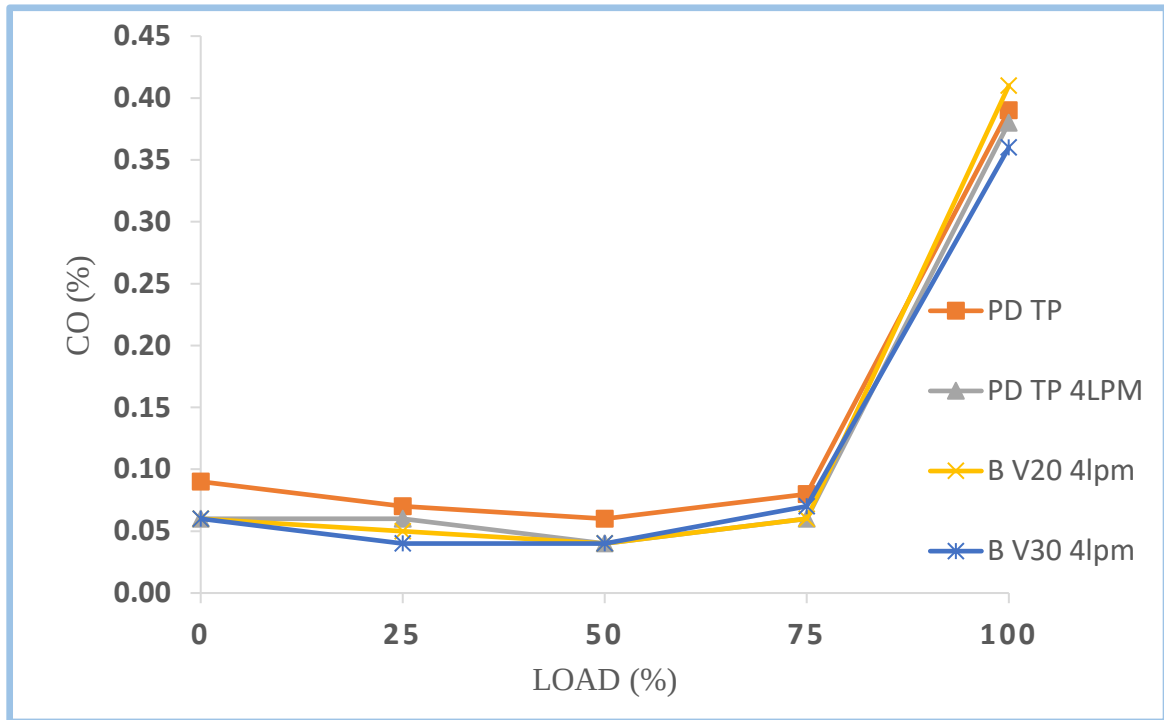


Fig: 5.3: comparative analysis of CO emissions vs Load

In our tests CO was produced from partial oxidation of carbon present in BV30 biodiesel during the combustion process. It was observed from the Fig.5.3 that CO emissions for BV20 and BV30 biodiesel blend with 4lpm Hydrogen were lower in comparison to pure diesel. 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.

5.1.4 NITROGEN OXIDE EMISSIONS(NO_x):

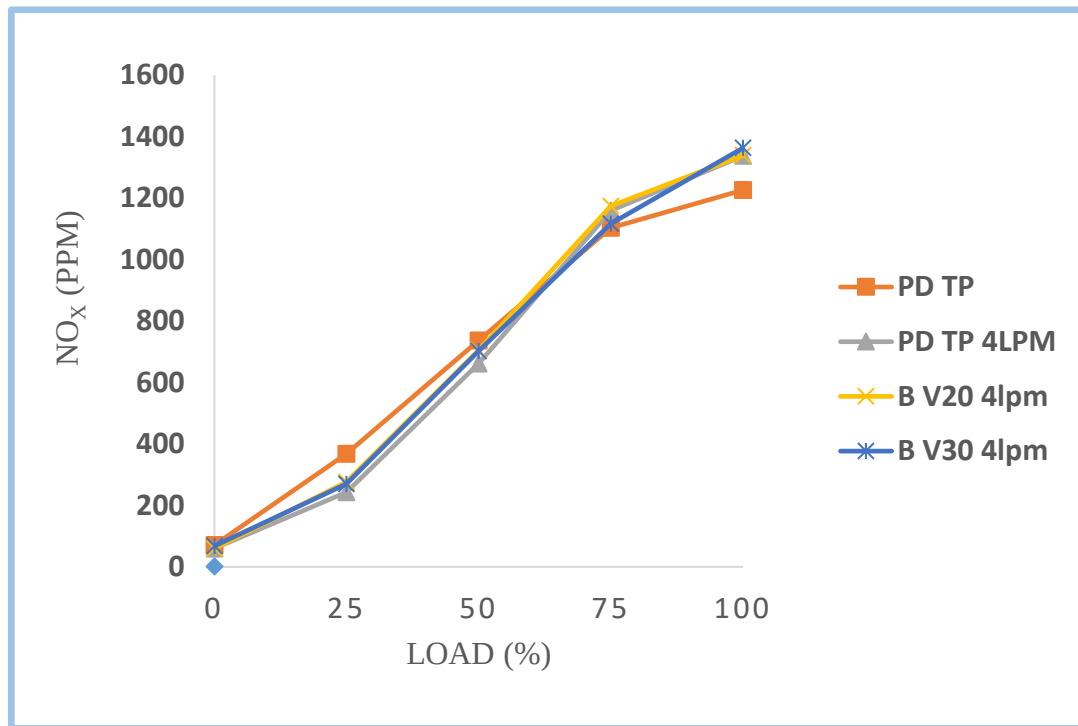


Fig: 5.4 comparative analysis of NO_x Emissions vs Load

NO_x emissions occur as a result of higher combustion temperature, oxygen concentration in the combustion chamber and nitrogen being exposed to high temperature. From Fig.5.4, it is seen that NO_x emissions increase with the use of BV30 biodiesel blend with 4lpm hydrogen when compared to pure diesel using 4lpm Hydrogen. With the increasing engine load, more fuel was burned, leading to higher temperatures and subsequently increased NO_x emissions.

5.1.5 SOOT EMISSIONS:

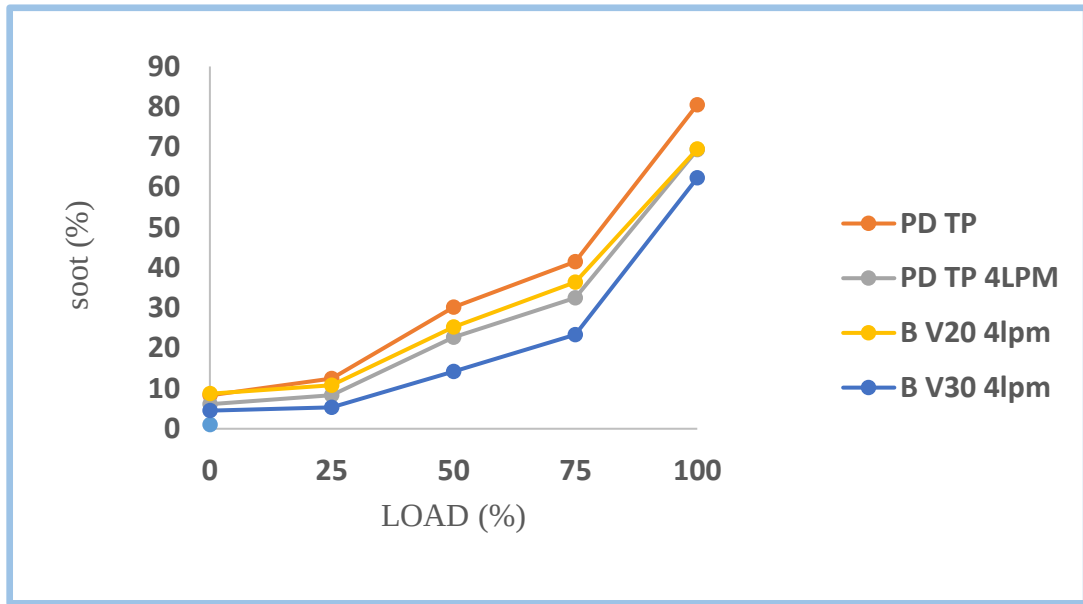


Fig: 5.5 comparative analysis of Soot emission vs Load

Formation of soot 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. The variation of smoke emissions of pure diesel when compared to the use of BV20 and BV30 can be seen in the Fig.5.5.

In the case of each load, BV20 with 4lpm H₂ and BV30 with 4lpm H₂ exhibited far less some emissions when they are compared to emissions produced by pure diesel. This is explained by the fact that biodiesel with 4lpm H₂ contains fewer hydrocarbon molecules and this produces less soot. The decrease in emissions continues with the enrichment of air with H₂ across varying loads. On the other hand, as the load increases, the smoke emissions also increase in a linear manner. This increment is attributed to the increase in consumption of fuel with greater engine load.

5.2 ENGINE PERFORMANCE CHARACTERISTICS

Various engine performance parameters for Toroidal 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 -

5.2.1 BREAK SPECIFIC FUEL CONSUMPTION (BSFC):

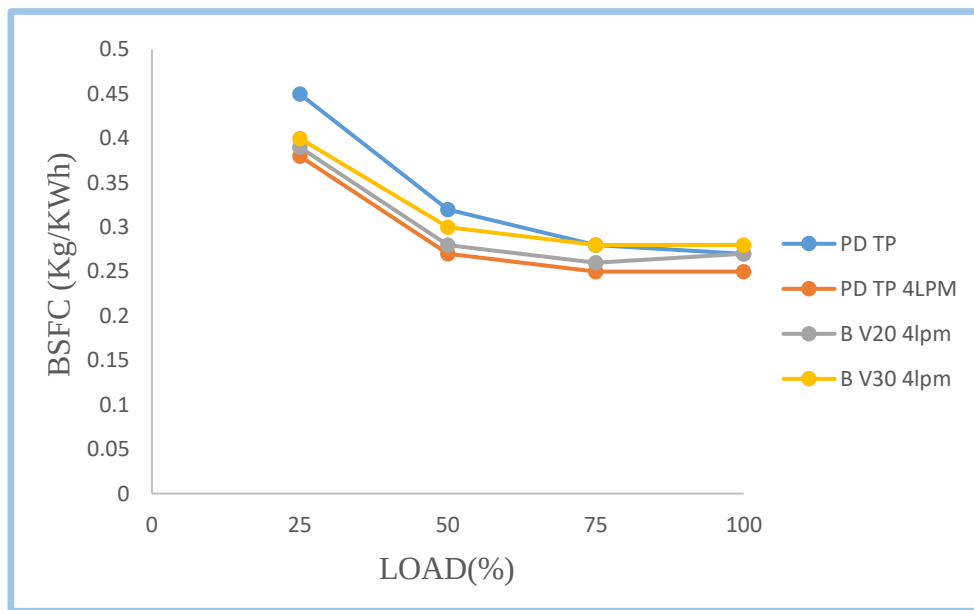


Fig 5.6: comparative analysis of BSFC variation with load

BSFC depends on characteristics of a fuel. It is a measurement of engine effectiveness in the consumption of fuel. Graph with variation of BSFC to different load conditions can be seen above. It is generally seen in studies that BSFC 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 Figure 5.6 above.

5.2.2 BREAK THERMAL EFFICIENCY (BTE):

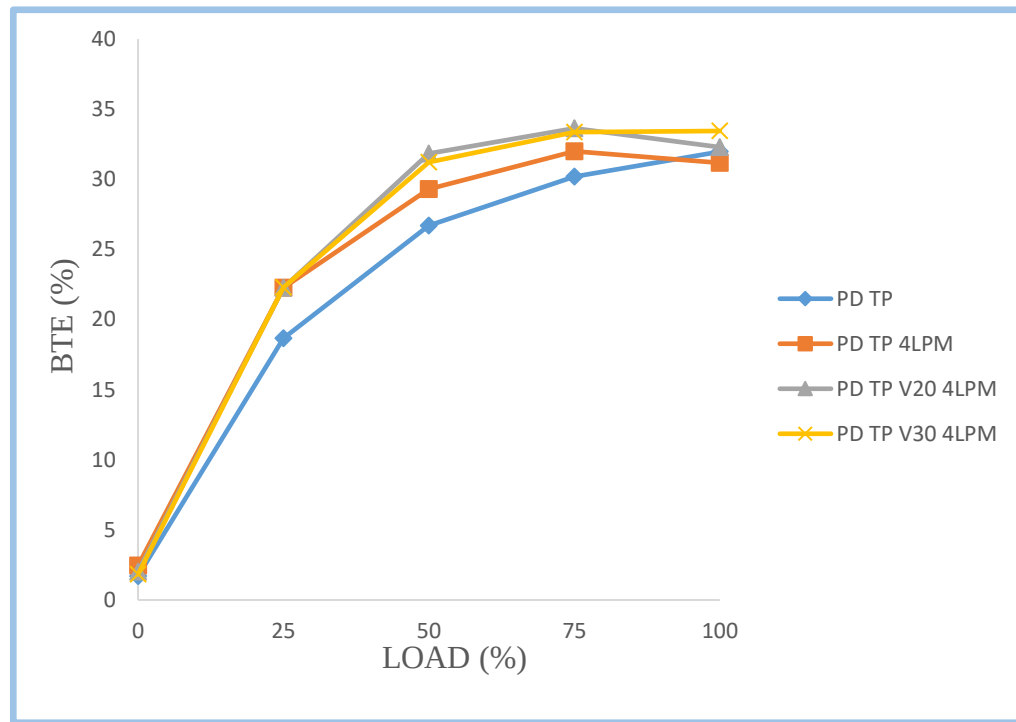


Fig: 5.7 comparative analysis of BTE with Load

In our study, BTE increased in fuels with biodiesel blends in comparison to pure diesel. From the above Fig.5.7, 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.

5.2.3 IN CYLINDER PRESSURE (P_0):

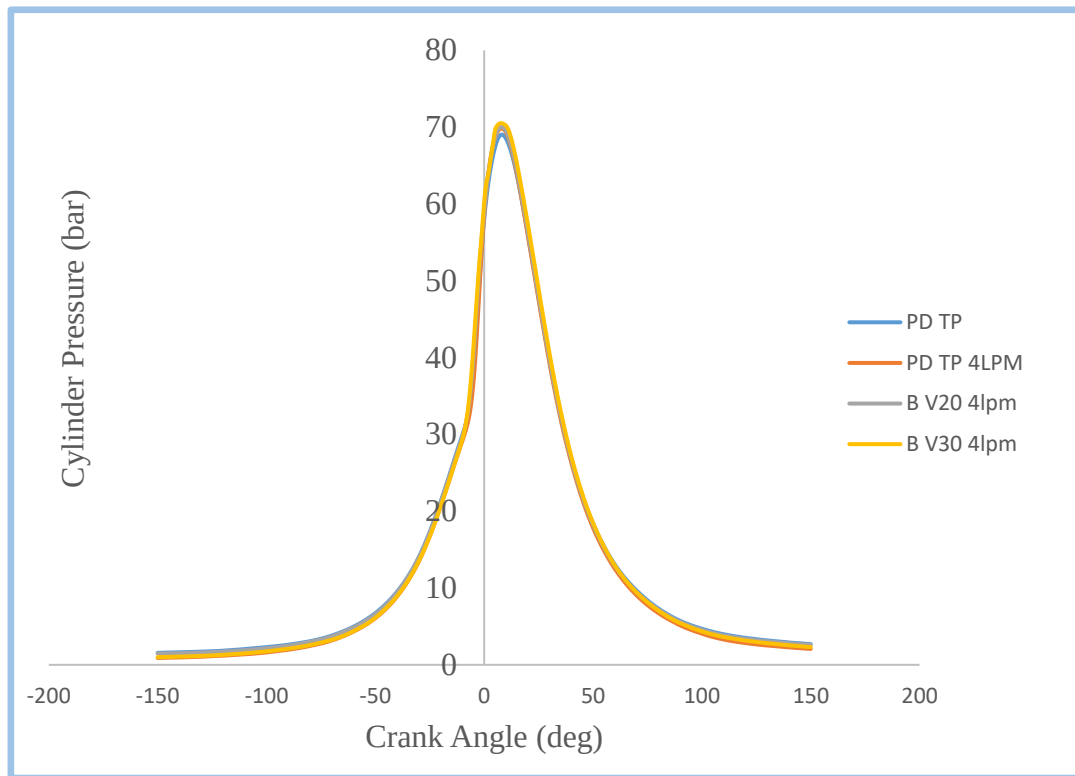


Fig: 5.8 comparative analysis of cylinder pressure with Crank Angle

Pressure variations for different fuels on engine are shown below. In Fig.5.8 it was seen that CP curve profiles are almost similar to each other for all fuel tests. But it tends to increase for BV30 with 4lpm Hydrogen owing to higher flame velocity. Abnormal combustion characteristics like high pressure raise rates were not seen.

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 BV30 biodiesel with 4lpm Hydrogen.

5.2.4 HEAT RELEASE RATE (HRR):

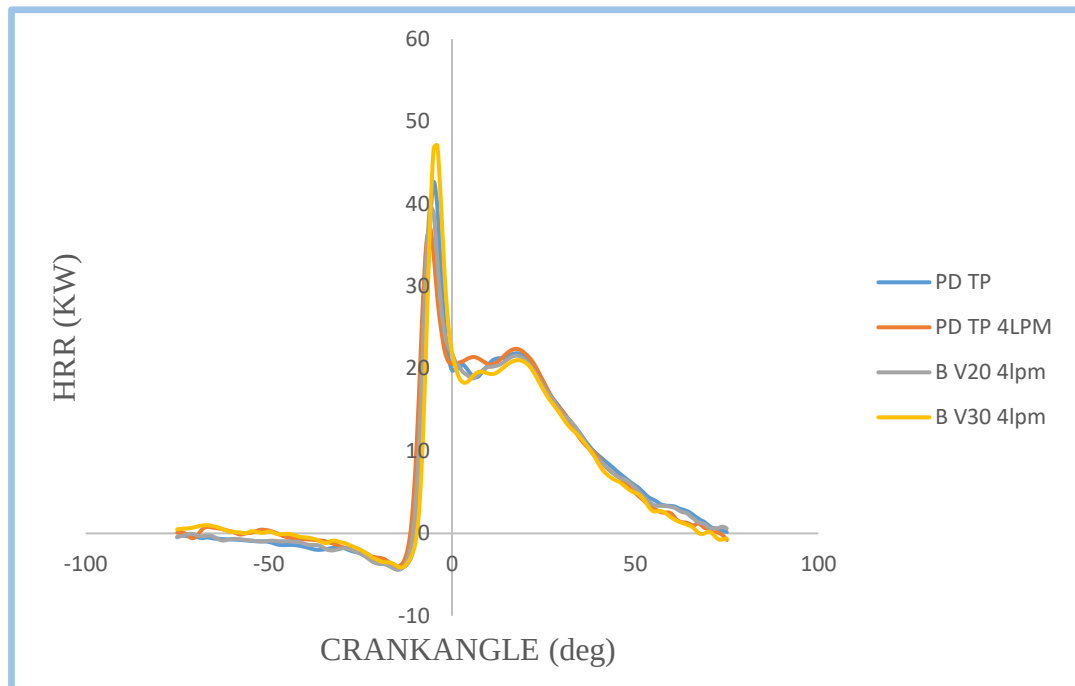


Fig: 5.9 Heat Release Rate variation with Crank Angle

The Figure.5.9 above depicts HRR values of test engine with different fuel models. With the use of BV30 with 4lpm hydrogen, it was seen that HRR increased in comparison to pure diesel and also pure diesel with 4lpm hydrogen. This shift and increase in the values of HRR is attributed to higher flame velocity and instantaneous combustion of hydrogen.

Chapter 6

SUMMARY AND CONCLUSIONS

6.1 SUMMARY

We are currently headed towards a global energy crisis that is being driven by over-reliance on fossil fuels for generation of energy. This not only leads to quicker exhaustion of natural resources but also tends to drive up pollutants, creating a warmer world with poorer air quality. While renewable energy sources provide a part of the solution, alternative fuels that can replace diesel and petrol offer another answer to this conundrum. Considering the vast scale of commercial cooking enterprises and the amount of waste vegetable oil that it produces on a regular basis, turning this otherwise discarded material into a valuable source of energy can fill the current void.

6.2 CONCLUSIONS

The aim of the project was to understand the performance and emission properties of BV20 and BV30 biodiesel blends with 4lpm hydrogen in toroidal combustion chamber across varying loads. The study performed on engine performance, efficiency and emissions for toroidal piston using biodiesel blend along with an injection of 4lpm hydrogen were seen as follows:

- Also observed in the study is the reduction in CO₂, CO, HC and soot emissions with the addition of 4lpm hydrogen to BV30 biodiesel blend when compared against pure diesel in the Toroidal 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 NO_x emissions increased for biodiesel blends like BV30 when compared to pure diesel across the spectrum. These emissions were increased further with the introduction of Hydrogen to the biodiesel fuel blend.

- 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.

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ABSTRACT The search for alternative fuel sources is one that is both urgent and imperative. Finding alternative options that improve efficiency while cutting back on emissions not only reduces over reliance on conventional fuel but also improves the overall air quality by cutting back on dangerous emissions. Global carbon emissions and resource depletion is moving focus away from fossil fuels. This has led to this frantic search ranging from wind and solar to biofuel and more.

It is this necessity for additional energy sources that has shaped our study, which looks at possible biodiesel alternatives. The objective is to investigate the efficiency, performance, combustion and nature of emissions of dual fuel engine with Waste Vegetable Oil (WVO) biodiesel as primary fuel. To this, Hydrogen was injected into the air intake as secondary fuel. The biodiesel blends used for the current study are WVO blended with diesel in the volume fraction of 20% and 30% to produce BV20 and BV30 fuels respectively. Hydrogen was injected along with air at a flow rate of 4lpm.

The process of Transesterification was used to convert the acquired WVO into useful biodiesel that was used to create the biodiesel blends. The performance and emission results of this biodiesel blend used in Toroidal combustion chamber were observed and noted. CHAPTER-1 INTRODUCTION 1.1 BACKGROUND For a long time, we have been aware of the issues posed by a lack of fossil fuels. For decades, a high over-dependence on this energy source as the primary, if not only, energy carrier in transportation and power generation has raised questions and prompted comprehensive studies into alternative fuels.

When a prediction of peak oil supply was launched, people began to be concerned about low fossil fuel supplies. Despite the fact that many additional aspects have been added to the metrics used to forecast peak oil output, most science and organizations believe that peak oil production will occur before 2020. Moreover, because of their recent ease of accessibility and affordability, fossil fuels now account for the majority of transportation fuel.

In a 2017 survey, the International Energy Agency (IEA) stated that fossil energy

accounts for about 80 percent of total world commercial energy, with 98 percent of it being used for transportation (de Almeida and Silva, 2009). This is a result of increasing global demand for and number of cars, as well as high economic growth in certain countries, which is accompanied by a significant rise 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) that are harmful to the population and have negative environmental consequences. CO₂ emissions from the burning of fossil fuels contribute greatly to global warming. As an effect, the replacement of fossil fuels for renewable and other alternative fuels, including gaseous and liquid fuels, will increase clean fuel production and fuel stability. Besides that, further fuel savings in transportation can be increased by improving engine technology to allow for the use of gaseous fuels.

However, their use in diesel engines has disadvantages in terms of engine output and emissions when the engine is turned off, (2007). This is due to most gaseous fuels' poor energy content and low cetane number (CN). To overcome the above challenges, research has been conducted with the goal of examining certain alternative fuels, gaseous and liquid fuels, that could be used to replace part of the conventional fuels used in diesel engines. It also looks at the potential of using hydrogen as a gaseous fuel, which has strong energy carrier resource with a high energy quality. 1.2

HISTORY OF DIESEL ENGINES After looking for a way to improve the Otto engine's performance, German engineer Rudolf Diesel came up with the idea for the engine that bears his name (the primary four-stroke-cycle motor, built by the 19th-century German design Nikolaus Otto). Diesel found that the electric start component of a gasoline engine could be avoided in the event that discuss may well be warmed to a temperature higher than the auto-ignition temperature of a given fuel amid the compression stroke of a piston-cylinder gadget. In his patents from 1892 and 1893, Diesel suggested such a cycle. Initially, powdered coal or liquid petroleum is suggested as fuel alternatives. Powdered coal, a by-product of the Saar coal mines, was used as a readily available fuel by Diesel.