

INVESTIGATION ON REDUCTION OF NO_x EMISSIONS USING HOT AND COLD EGR TECHNIQS IN CRDI DIESEL ENGINE

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

By

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INSTITUTE OF SCIENCE AND TECHNOLOGY

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BONAFIDE CERTIFICATE

This is to certify that this Project Report is the bonafide work of Abhisheik Kumar M (37150001) and Aravinthan S (37150016) who carried out the project entitled **"INVESTIGATION OF REDUCTION OF NOX EMISSIONS USING HOT AND COLD EGR METHOD IN CRDI ENGINE"** under my supervision from October 2020 to March 2021.

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DECLARATION

We, Abhisheik Kumar M (37150001) and Aravinthan S (37150016) hereby declare that the Project Report entitled **“INVESTIGATION OF REDUCTION OF NOX EMISSIONS USING HOT AND COLD EGR METHOD IN CRDI ENGINE”** done by us under the guidance of **Dr. J.JAYAPRABAKAR, M.E., Ph.D.** at Sathyabama Institute of Science and Technology, Chennai is submitted in partial fulfillment of the requirements for the award of Bachelor of Engineering degree in Mechanical Engineering.

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ABSTRACT

The study is conducted on the CI engine with a fuel blend consists of biodiesel, rice bran oil, and straight diesel along with varied combustion chambers the following conclusions are made. The present study which includes a high-performance diesel blend is prepared, with the constituents in the ratio of 80% diesel+20% rice bran oil. The blend is prepared as per the American Society for Testing and Materials (ASTM) standards. The properties are within the suggested limits. The experimentation conducted on a four stroke, single cylinder vertical water cooled diesel engine. Three types of combustion chambers (hemispherical, toroidal, reentrant) are tested along with b20 rice bran oil blend. The results are compared between within three combustion chambers. The performance characteristics stated the prepared blends shows slightly lesser performance values compared with diesel. The Brake Thermal Efficiency (BTE) is improved in hemispherical combustion chamber. As a penalty NO_x emissions were increased since B20 combustion chambers promoted better combustion. But the Specific Fuel Consumption (SFC) is less at toroidal and re entrant combustion chambers. The CO_2 Hydrocarbon emissions and smoke opacity values were increased in different combustion chambers. The prepared blend can be used in a CI engine by different combustion chambers for improving the performance and combustion characteristics.

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LIST OF SYMBOLS AND ABBREVIATIONS

SYMBOL	ABBREVIATIONS
B20	20% biodiesel and 80% diesel
ASTM	American Society for Testing and Materials
BDC	Bottom Dead Center
BSFC	Brake specific fuel consumption
BTE	Brake Thermal Efficiency
CO ₂	Carbon Dioxide
CO	Carbon Monoxide
CI	Combustion Ignition
CRDI	Common Rail Direct Injection
CNG	Compressed Natural Gas
CP	Cylindrical Pressure
EGR	Exhaust Gas Re circulation
EGT	Exhaust gas temperature
FAME	Fatty Acid Methyl Ester
HC	Hydro carbons
Net HR	Net Heat Release rate
NO _x	Oxides of nitrogen
SFC	Specific fuel Consumption
TDC	Top Dead Center

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CHAPTER 1

INTRODUCTION

1.1 DIESEL ENGINE

The diesel engine, named after Rudolf Diesel, is an internal combustion engine in which the fuel is ignited by the increased temperature of the air in the cylinder due to mechanical compression; it is thus referred to as a compression-ignition engine (CI engine). In contrast to engines that fire the air-fuel mixture with a spark plug, such as a diesel or gas turbine (using a fuel like natural gases or liquefied petroleum gas)

Diesel engines paintings with the aid of using compressing only the air. This will increase the air temperature inside the cylinder to one of these excessive diploma that atomised diesel gas injected into the combustion chamber ignites spontaneously. With the gas being injected into the air simply before combustion, the dispersion of the gas is uneven; that is referred to as a heterogeneous air-gas mixture. The torque a diesel engine produces is managed with the aid of using manipulating the air-gas ratio (λ); as opposed to throttling the consumption air, the diesel engine is based on changing the quantity of gas this is injected, and the air-gas ratio is normally excessive.

The IC engine is provided with fuels like petrol or diesel. It is likewise used to generate energy with small variety variety of tool with extra economically. Diesel engine are extra gas performance than any other. A diesel engine has high thermal performance, much less gas consumptions, reliability and better durability (Jayaprabakar et al 2017). So it is broadly utilized by many, it's also used to hold heavy loads, walking the locomotives, strength offering equipment. But on the subject of environment issues, we ought to discover exchange fuels. Alternate fuels which includes CNG, Hydrogen, biodiesels. Hydrogen fuels can also additionally deliver us grate discount in pollution. Internal engines are categorised into many types. According to Fuel, Petrol, CNG, diesel. And in line with association which

includes Inline, V, W, rotary, Wankel. It also rely upon the piston association. In inline kind engine pistons are arranged in unmarried direction.

V approach piston stocks a unmarried crankshaft they organized like V. In W kind engine 3 pistons are organized and stocks a unmarried crankshaft. These are very massive engine (**D. Samoilenko et al 2017**). There are sorts of strokes in engines particularly -stroke and 4-stroke. In 4 stroke Intake, combustion, electricity, exhaust take place. In diesel engine Fuel is added right into a engine as the piston reaches the pinnacle useless centre of the stroke. The gasoline is injected into a precombustion chamber or without delay into the piston-cylinder combustion chamber below excessive pressure. Diesel engines, except for compact, excessive-speed units, use direct injection. The diesel engine generates electricity with the aid of using burning gasoline pumped or sprayed into the cylinders compressed, warm air charge. The air must be heated to a temperature better than the ignition temperature of the injected gasoline

Due to its extremely high expansion ratio and intrinsic lean burn, which allows heat to be dissipated by excess air, the diesel engine has the best thermal efficiency (engine efficiency) of any practicable internal or external combustion engine. Since unburned fuel is not present during valve overlap, no fuel goes straight from the intake/injection to the exhaust, a slight performance loss is eliminated as compared to non-direct-injection gasoline engines. Low-speed diesel engines (such as those used in ships and other applications where total engine weight is less of a concern) can achieve up to 55 percent effective efficiencies.

Diesel engines are used in two-stroke and four-stroke cycles. Originally, they were intended to be a more effective alternative to stationary steam engines. They've been used in submarines and ships since the 1910s. Later applications included locomotives, trucks, construction machinery, and power plants. They were first seen in a few cars in the 1930s. Diesel engines have been used in larger on-road and off-road vehicles in the United States since the 1970s. Diesel cars account for half of newly registered cars in Europe, according to Konrad Reif. ²

The world's largest diesel engines put in service are 14-cylinder, two-stroke marine diesel engines;

In 1878, Rudolf Diesel, who became a scholar at the "Polytechnikum" in Munich, attended the lectures of Carl von Linde. Linde defined that steam engines are successful of changing simply 6– 10% of the warmth power into paintings, however that the Carnot cycle permits conversion of tons extra of the warmth power into paintings via isothermal alternate in condition. According to Diesel, this ignited the concept of making a notably efficient engine that might paintings at the Carnot cycle. Diesel became additionally uncovered to a hearthplace piston, a traditional hearthplace starter the use of rapid adiabatic compression ideas which Linde had obtained from Southeast Asia. After numerous years of running on his ideas, Diesel posted them in 1893 withinside the essay Theory and Construction of a Rational Heat Motor

Cycle of the diesel engine

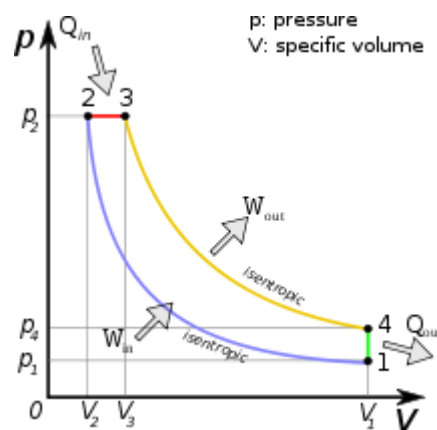


Fig: 1.1: Diesel cycle

P-V The perfect diesel cycle is depicted in this diagram. In a clockwise direction, the loop follows the numbers 1–4. The cylinder's volume is represented by the horizontal axis. The combustion in the diesel cycle happens at a nearly constant pressure. The work created for each cycle corresponds to the region inside the loop in this diagram. Diesel engine model, left side

The diesel internal combustion engine differs from the gasoline-powered Otto cycle in that it ignites the fuel with heavily compressed hot air rather than a spark plug (compression ignition rather than spark ignition).

In the diesel engine, most effective air is first of all added into the combustion chamber. The air is then compressed with a compression ratio usually among 15:1 and 23:1. This excessive compression reasons the temperature of the air to rise. At approximately the pinnacle of the compression stroke, gas is injected at once into the compressed air withinside the combustion chamber. This can be into a (usually toroidal) void withinside the pinnacle of the piston or a pre-chamber depending upon the layout of the engine. The gas injector guarantees that the gas is damaged down into small droplets, and that the gas is shipped evenly. The warmth of the compressed air vaporises gas from the floor of the droplets. The vapour is then ignited with the aid of using the warmth from the compressed air withinside the combustion chamber, the droplets maintain to vaporise from their surfaces and burn, getting smaller, till all of the gas withinside the droplets has been burnt. Combustion takes place at a notably regular stress at some point of the preliminary a part of the strength stroke. The begin of vaporisation reasons a put off earlier than ignition and the function diesel knocking sound because the vapour reaches ignition temperature and reasons an abrupt growth in stress above the piston (now no longer proven at the P-V indicator diagram). When combustion is whole the combustion gases amplify as the piston descends further; the excessive stress withinside the cylinder drives the piston downward, providing strength to the crankshaft.

A high compression ratio not only allows combustion to take place without the use of a separate ignition system, but it also significantly improves the engine's performance. The need to avoid pre-ignition, which can cause engine destruction, limits increasing the compression ratio in a spark-ignition engine where fuel and air are combined before entrance to the cylinder. Premature detonation is not an issue in a diesel engine because only air is compressed and fuel is not injected into the cylinder until just before top dead centre (TDC). As a result, compression ratios are much higher.

The p–V diagram is a simplified and idealised illustration of the occasions concerned in a diesel engine cycle, organized to demonstrate the similarity with a Carnot cycle. Starting at 1, the piston is at backside lifeless centre and each valves are closed on the begin of the compression stroke; the cylinder incorporates air at

atmospheric stress. Between 1 and a pair of the air is compressed adiabatically – this is with out warmth switch to or from the environment – through the growing piston. (This is most effective about actual due to the fact that there can be a few warmth trade with the cylinder walls.) During this compression, the extent is reduced, the stress and temperature each rise. At or barely earlier than 2 (TDC) gasoline is injected and burns withinside the compressed warm air. Chemical electricity is launched and this constitutes an injection of thermal electricity (warmth) into the compressed fueloline. Combustion and heating arise among 2 and three. In this c programming language the stress stays regular for the reason that piston descends, and the extent increases; the temperature rises attributable to the electricity of combustion. At three gasoline injection and combustion are complete, and the cylinder incorporates fueloline at a better temperature than at 2. Between three and four this warm fueloline expands, once more about adiabatically. Work is finished at the gadget to which the engine is connected. During this enlargement segment the extent of the fueloline rises, and its temperature and stress each fall. At four the exhaust valve opens, and the stress falls all of sudden to atmospheric (about). This is unresisted enlargement and no beneficial paintings is finished through it. Ideally the adiabatic enlargement have to continue, extending the road three–four to the proper till the stress falls to that of the surrounding air, however the lack of performance because of this unresisted enlargement is justified through the realistic problems concerned in improving it (the engine could ought to be a good deal larger). After the outlet of the exhaust valve, the exhaust stroke follows, however this (and the subsequent induction stroke) are now no longer proven at the diagram. If proven, they could be represented through a low-stress loop at the lowest of the diagram. At 1 it's miles assumed that the exhaust and induction strokes were completed, and the cylinder is once more stuffed with air. The piston- cylinder gadget absorbs electricity among 1 and a pair of – that is the paintings had to compress the air withinside the cylinder, and is furnished through mechanical kinetic electricity saved withinside the flywheel of the engine. Work output is finished through the piston-cylinder mixture among 2 and four. The distinction among those two increments of labor is the indicated paintings output in keeping with cycle, and is represented through the vicinity enclosed through the p – V loop. The adiabatic enlargement is in a better stress variety than that of the compression due to the fact the fueloline withinside the cylinder is warmer at some stage in enlargement than at

some stage in compression. It is because of this that the loop has a finite vicinity, and the net output of labor at some stage in a cycle is positive.

Efficiency

Due to its excessive compression ratio, the diesel engine has a excessive performance, and the shortage of a throttle valve means that the charge-change losses are pretty low, ensuing in a low specific gasoline consumption, in particular in medium and occasional load situations. This makes the diesel engine very economical. 135 Even alevn though diesel engines have a theoretical performance of 75%, 136 in exercise it's far tons decrease. In his 1893 essay Theory and Construction of a Rational Heat Motor, Rudolf Diesel describes that the powerful performance of the diesel engine could be in among 43.2% and 50.4% , or perhaps even greater. 137 Modern passenger vehicle diesel engines may have an powerful performance of as much as 43%, 138 even as engines in massive diesel trucks, and buses can obtain height efficiencies round 45%. 139 However, common performance over a using cycle is decrease than height performance. For example, it is probably 37% for an engine with a height performance of 44%. 140 The maximum diesel engine performance of as much as 55% is done via way of means of massive two-stroke watercraft diesel engines.

Major advantages

Diesel engines have several advantages over engines operating on other principles:

- The diesel engine has the highest effective efficiency of all combustion engines.
 - Diesel engines inject fuel directly into the combustion chamber, have no exhaust air constraints except air filters and intake plumbing, and no intake manifold vacuum to add parasitic load and pumping losses caused by pistons being forced downward toward intake system vacuum. For the same

purpose, cylinder loading with ambient air is assisted, and volumetric efficiency is improved. Although the fuel efficiency (mass burned per energy produced) of a diesel engine drops at lower loads, it doesn't drop quite as fast as that of a typical petrol or turbine engine.

Bus powered by biodiesel

Diesel engines can burn a wide range of fuels, including some fuel oils, which have benefits over gasoline. These benefits include:

- Low fuel costs, as fuel oils are relatively cheap
- Good lubrication properties
- High energy density
- Low risk of catching fire, as they do not form a flammable vapour
- Biodiesel is a readily synthesised, non-petroleum-based fuel that can be used directly in many diesel engines, while gasoline engines must either be modified to operate synthetic fuels or use them as an additive to gasoline (e.g., ethanol added to gasohol).
- Diesel engines have excellent exhaust emission characteristics. Carbon monoxide and hydrocarbons are present in trace concentrations in the exhaust. Diesel engines with direct injection produce almost the same amount of nitrogen oxides as Otto cycle engines. When operating at full load, swirl chamber and precombustion chamber injection engines emit nearly 50% fewer nitrogen oxides than Otto cycle engines. 142 Diesel engines produce ten times less pollution and carbon dioxide than Otto cycle engines (comparing the raw emissions without exhaust gas treatment).
- They don't have a high-voltage electrical ignition mechanism, but they're very reliable and respond well to wet conditions. The

lack of tubes, spark plug cables, and other radio frequency emitters also reduces a source of radio frequency pollution that can interfere with navigation and communication devices, which is particularly significant in maritime and aircraft applications, as well as radio telescope interference. (As a result, in areas of the American National Radio Quiet Zone, only diesel-powered cars are permitted.)

- Only the configuration and operating limitations of engine parts, such as friction, rpm, and load, restrict the ability of diesel engines to accept super- or turbocharging pressure. This is in contrast to diesel engines, which can detonate at higher pressures unless engine tuning and/or fuel octane changes are made to compensate.

Diesel engines rely upon the air/gas blending being achieved withinside the cylinder, 133 because of this that they want a gas injection system. The gas is injected immediately into the combustion chamber, which may be both a segmented combustion chamber, recognised as oblique injection (IDI), or an unsegmented combustion chamber, recognised as direct injection (DI). 147 The definition of the diesel engine is unique in requiring that the gas be brought immediately into the combustion, or pre-combustion chamber, as opposed to first of all into an outside manifold. For growing the gas pressure, diesel engines typically have an injection pump. There are numerous special styles of injection pumps and strategies for growing a nice air-gas mixture. Over the years many special injection strategies have been used. These may be defined because the following:

- Air blast, in which a blast of air blows the gasoline into the cylinder.
- Hydraulic injection / solid fuel, which involves forcing fuel into a spring-loaded valve / injector to create a flammable spray.

- A mechanical unit injector is one in which the injector is powered directly by a cam and the amount of fuel is controlled by a rack or lever.
- Mechanical injection in a standard rail, where fuel is injected at high pressure and operated mechanically.
- Common rail electronic injection, in which fuel is injected at high pressure and regulated electronically in a common rail.

1.2 CRDI DIESEL ENGINE

- In contrast to a low-pressure fuel pump feeding unit injectors, a common rail direct fuel injection system is designed around a high-pressure (over 2,000 bar or 200 MPa or 29,000 psi) fuel rail feeding solenoid valves (or pump nozzles). By injecting fuel as a greater number of smaller droplets, giving a much higher ratio of surface area to volume, high-pressure injection improves strength and fuel consumption over earlier lower-pressure fuel injection. This allows for better vaporisation from the surface of the fuel droplets, resulting in a more effective combination of atmospheric oxygen and vaporised fuel, resulting in a more total combustion.
- In diesel engines, common rail injection is commonly used. It also serves as the foundation for fuel direct injection systems used in gasoline engines.

1.3 BIODIESEL

In a nutshell, biodiesel is made up of long-chain fatty acid monoalkyl esters derived from green lipid sources such as vegetable oil or animal fat. Pure biodiesel that produces 100 percent biodiesel is referred to as B100. BXX refers to biodiesel mixes with petroleum diesel, where XX represents the biodiesel percentage, such as B80, which contains 80% biodiesel and 20% petroleum diesel (C.W. Mohd Noor 2018). Bio-diesel production is not new, since the concept of using vegetable oil as a fuel goes back to 1895. Rudolf Diesel produced the first vegetable-oil-powered diesel engine in 1900.

Groundnut oil was used to fuel the first turbine. In 1911, Rudolf Diesel believed that the diesel engine could operate on vegetable oil and that it would greatly help agricultural development in the countries where it was used. Vegetable oils as engine fuel can seem to be insignificant today. However, in the future, such oils could become as essential as petroleum.

There has been an increase in environmental awareness among the general population over the past few decades. As a result, people tend to switch to alternative fuels (**A. Murugesan 2007**). Biodiesel is a chemically produced green alternative fuel made from vegetable oils, animal fats, and greases. Transesterification transforms vegetable oils into fatty acid alkyl esters, which can be used as a low-viscosity diesel fuel alternative.

1.4 Types Of Emission

Many air emissions have been found to have a host of harmful consequences for human health and the environment. The following emissions are major contaminants of concern:

- Hydrocarbons (HC) - A elegance of burned or partly burned gasoline, hydrocarbons are toxins. Hydrocarbons are a main contributor to smog, which may be a main trouble in city areas. Prolonged publicity to hydrocarbon may cause to asthma, liver disease, lung disease, and cancer. The regulations regulating hydrocarbons vary depending on the type of engine and jurisdiction; in some circumstances, "non-methane hydrocarbons" are restricted, whereas "overall hydrocarbons" are regulated in others.. Technology for one software (to fulfill a non- methane hydrocarbon standard) might not be appropriate to be used in an software that has to fulfill a overall hydrocarbon standard. Methane isn't at once toxic, however is more tough to interrupt down in gasoline vent traces and a charcoal canister is supposed to acquire and comprise gasoline vapors and direction them both again to the gasoline tank or, after the engine is began out and warmed up, into the air consumption to be burned in the engine.

- Carbon monoxide (CO) - A product of incomplete combustion, inhaled carbon monoxide reduces the blood's capacity to hold oxygen; overexposure (carbon monoxide poisoning) can be fatal. (Carbon monoxide persistently binds to hemoglobin, the oxygen-carrying chemical in red blood cells, where oxygen (O₂) might quickly bind. The bonding of CO excludes O₂ and additionally reduces the capacity of the hemoglobin to launch already-bound oxygen, on each count rendering the red blood cells ineffective. Recovery is with the aid of using the gradual launch of pure CO and the body's manufacturing of latest hemoglobin—a healing process—so complete recuperation from mild to severe [but nonfatal] CO poisoning takes hours or days. Removing someone from a CO-poisoned surroundings to fresh air stops the damage however does now no longer yield spark off recuperation, not like the case where someone is eliminated from an asphyxiating surroundings [i.e. one deficient in oxygen]. Toxic results behind schedule with the aid of using days also are common.)
- NO_x - Generated when nitrogen in the air interacts with oxygen within the engine due to the high temperature and pressure. Smog and acid rain are caused by NO_x emissions. NO_x is the product of combining NO and NO₂. NO₂ is a highly reactive gas. When an engine operates at its most effective (i.e. hottest) running stage, NO_x generation increases, so there is a normal tradeoff between reliability and NO_x pollution control. The use of emulsion fuels is supposed to greatly minimise it. [2]
- Particulate matter – Soot or haze made up of micrometer-sized particles: Particulate matter has a number of harmful health consequences, including lung illness and cancer, to name a few. Cardiovascular disorder has been attributed to very fine particulate matter.
- Sulfur oxide (SO_x) - A common expression for sulphur oxides released from automobiles consuming sulfur-containing gasoline.

Sulfur oxide emissions from the tailpipe are reduced as fuel sulphur levels are reduced.

- VOCs (volatile organic compounds) - Organic compounds with a boiling point of less than or equal to 250 °C, such as chlorofluorocarbons (CFCs) and formaldehyde. Volatile organic compounds (VOCs) are a subset of hydrocarbons and are discussed separately due to their potential health risks.

1.5 NOx

NOx

NOx gases are commonly constructed from the response among nitrogen and oxygen during combustion of fuels, along with hydrocarbons, in air; specifically at excessive temperatures, along with in automobile engines. 123 In regions of excessive motor automobile traffic, along with in huge cities, the nitrogen oxides emitted may be a substantial supply of air pollution. NOx gases are also produced evidently by lightning.

It is normally meant to encompass nitrous oxide (N₂O),¹ although nitrous oxide is a reasonably inert oxide of nitrogen that has many uses as an oxidizer for rockets and automobile engines, an anesthetic, and a propellant for aerosol sprays and whipped cream. Nitrous oxide plays infrequently any function in air pollution, even though it may have a significant impact on the ozone layer,⁴ and is a significant greenhouse gas.

At room temperature, oxygen and nitrogen do not react due to energy constraints. At high temperatures, though, they undergo an endothermic reaction that produces different nitrogen oxides. Such temperatures can be found within an internal combustion engine or a power plant boiler, as well as normally in a lightning strike, when a combination of air and gasoline is burned.

In other words, the ratio of these two animals determines the amount of ozone in the atmosphere.

The time constant for NO mixing ratios of 10 parts per billion (ppb) is 40 minutes; for NO = 1 ppb, it is 4 minutes.

1.5.1 Formation of Smog

Photochemical smog is formed when NO_x and volatile organic compounds (VOCs) react in the presence of sunlight, and it is a major source of air pollution. Over the summer, as the incident solar radiation is stronger, the presence of photochemical smog increases. Hydrocarbons released by industry and transportation react rapidly with NO_x, causing an increase in ozone and peroxide compounds, especially peroxyacetyl nitrate (PAN). 8

Children, people with respiratory disorders like asthma, and people who work or exercise outdoors are particularly vulnerable to the negative effects of smog, which include lung tissue destruction and decreased lung capacity.

1.5.2 Formation of Nitric Acid and Acid Rain

NO₂ is further oxidized in the gas phase during daytime by reaction with OH

$$\text{NO}_2 + \text{OH} (+\text{M}) \rightarrow \text{HNO}_3 (+\text{M}),$$

where M denotes a 3rd molecule required to stabilize the addition product. Nitric acid (HNO₃) is highly soluble in liquid water in aerosol particles or cloud drops.

NO₂ also reacts with ozone to form nitrate radical

$$\text{NO}_2 + \text{O}_3 \rightarrow \text{NO}_3 + \text{O}_2.$$

During the daytime, NO₃ is quickly photolyzed back to NO₂, but at night it can react with a second NO₂ to form dinitrogen pentoxide.

$$\text{NO}_2 + \text{NO}_3 (+\text{M}) \rightarrow \text{N}_2\text{O}_5 (+\text{M}).$$

N₂O₅ react rapidly with liquid H₂O (in aerosol particles or cloud drops, but not in the gas phase) to form HNO₃,

$$\text{N}_2\text{O}_5 + \text{H}_2\text{O}(\text{liq}) \rightarrow 2 \text{HNO}_3(\text{aq})$$

They are believed to be the main routes for nitric acid formation in the atmosphere. 7:224–225 This nitric acid leads to acid rain or can settle in the soil,

where it produces nitrate, which is beneficial to plant growth. The reaction in the aqueous fluid.



is too slow to be of any significance in the atmosphere.^{7:336}

Because of the intense heating and cooling during a lightning bolt, nitric oxide is emitted during thunderstorms. This allows stable molecules like N₂ and O₂ to be converted into large quantities of NO, close to what happens during high-temperature fuel combustion. NO_x can be oxidised by lightning to create nitric acid (HNO₃), which can be precipitated as acid rain or accumulated on airborne objects. The amount of NO_x produced by lightning is dependent on the season and position. Over the summer months, lightning strikes more often over land above the equator in the inter-tropical convergence zone (ITCZ).

Ott et al.¹² calculated that each bolt of lightning in the mid-latitude and sub-tropical thunderstorm examined converted 7.0 kg (15 lb) of nitrogen into chemically reactive NO_x on average. They calculated that the cumulative amount of NO_x released by lightning per year is 8.6 million tonnes, based on 1.4 billion lightning flashes per year compounded by 7 kilogramme per lightning strike. NO_x emissions from fossil fuel burning, on the other hand, are estimated to be 28.5 million tonnes.

According to a new finding, cosmic rays and solar flares may have a direct impact on the frequency of lightning strikes that occur on Earth. As a result, space climate may be a big driver of NO_x created by lightning in atmosphere. Nitrogen oxides and other atmospheric constituents may be stratified vertically in the atmosphere.

Lightning-produced NO_x is usually detected at altitudes greater than 5 kilometres, whereas combustion and biogenic (soil) NO_x are typically found near the sources at surface elevations, according to Ott (where it can cause the most significant health effects).¹²

1.6 CONTROL OF NO_x

The protection of human health should be the top priority when developing a nitrogen oxides management policy. Peak nitrogen oxide exposures tend to have an effect on human health (NO_x). Nitrogen oxides are precursors to ozone (O₃) formation, which can affect human ecosystems and plants, in addition to actually harming human health. Finally, nitrogen oxides make a contribution to acid deposition, which damages flora and aquatic ecosystems. The quantity to which NO_x emissions damage human fitness relies upon on ground-level concentrations and the range of humans exposed. Source region can affect those parameters. Gases emitted in regions with meteorological, climatological, and topographical functions that want dispersion might be much less probably to pay attention close to the ground. However, a few meteorological situations, consisting of inversion, may also bring about drastically better ambient levels. Sources away from populace facilities will divulge fewer humans to dangerous pollutants. Plant siting is a vital characteristic in any air pollutants control strategy. However, due to the dispersion of nitrogen oxides that can make a contribution to ozone formation and acid deposition a long way from the source, counting on plant siting by myself isn't always a advocated strategy. The long-time period goal should be to lessen total emissions. Effective manipulate of NO_x emissions would require controls on both desk bound reassets and cellular delivery reassets. Each calls for extraordinary techniques. This tenet makes a speciality of manipulate techniques for desk bound reassets (often fossil-gasoline-fired electricity-producing plants). Limiting Emissions from Stationary Sources Nitrogen oxides are produced withinside the combustion process with the aid of using extraordinary mechanisms: (a) burning the nitrogen withinside the gasoline, often coal or heavy oil (gasoline NO_x); and (b) high-temperature oxidation of the molecular nitrogen withinside the air used for combustion (thermal NO_x). Formation of gasoline NO_x relies upon on combustion situations, consisting of oxygen awareness and blending patterns, and at the nitrogen content material of the gasoline. Formation of thermal NO_x relies upon on combustion temperature. Above 1,538o C (2,800o F), NO_x formation rises exponentially with growing temperature (Stultz and Kitto 1992). The relative contributions of gasoline NO_x and thermal NO_x to emissions from a specific plant depend upon the combustion situations, the kind of burner, and the kind of gasoline. Approaches for controlling

NO_x from desk bound reassets can cope with gasoline NO_x, thermal NO_x, or both. One manner of controlling NO_x emissions is to use low-nitrogen fuels. Another is to alter combustion situations to generate much less NO_x.

There are many way NO_x

1. Exhaust Gas Re circulation (EGR)
2. Selective Catalytic Reduction
3. Two Stage Turbocharger
4. High Scavenge Pressure and Compression Ratio
5. Water Injection and Water emulsion
6. Humid Air Method

NO_x can be removed using flue gas treatment methods such as selective catalytic reduction (SCR) processes. Coal and residual fuel oils containing organically bound nitrogen, according to some figures, account for more than half of global NO_x emissions. The nitrogen content in US coal varies between 0.5 and 2 percent, while residual fuel oil contains between 0.1 and 0.5 percent nitrogen. In certain cases, using low-nitrogen sources like natural gas would be the most cost-effective way to reduce NO_x emissions. Natural gas emits 60 percent less NO_x and almost no particulate matter or sulphur oxides than coal when used as a fuel.



Fig: 1.2: EGR

To minimise NO_x, we chose EGR in this project. A part of the exhaust gases from the engine were recycled to the scavenge room to mix with the air that will otherwise be supplied to the cylinder for combustion. This lowers the oxygen content of the air, reducing NO_x formation. There are two styles of EGR. EGR may be cold or humid. The engine receives a normal engine temperature from the hot EGR. A small amount of water is sprayed onto the exhaust gas by cold EGR. As a result, the temperature is lowered using this form. There is a significant reduction in NO_x emissions.

Carbon sprayed into the air at a temperature higher than the auto-ignition temperature of the fuel mixes with oxygen in the air and burns naturally. Diesel engines are also referred to as compression-ignition engines because combustion is started by air heated by friction rather than an electric spark. In a diesel engine, the combustion process is heterogeneous, which ensures that the fuel and air are not mixed before combustion starts.

As a result, complete combustion of the injected fuel requires rapid vaporisation and mixing of the fuel in the air (Charles Lafayette Proctor et al). It emits carbon monoxide, carbon dioxide, nitrogen oxides, and a variety of other

gases. Turbochargers are installed on the majority of diesel engines. A turbocharger is a forced induction device that increases the power and torque of an engine. It takes exhaust gas as an input and feeds the engine with fresh air.

1.7 PROBLEM OF NO_x EMISSION

Oxides of nitrogen (NO and NO₂), often abbreviated as NO_x, are among the air contaminants generated by gasoline and diesel engines. Nitrogen oxides have both overt and indirect negative impacts on human health due to the disruption they do to food crops and habitats. Since the 1960s, vehicle NO_x emissions have been limited.

Volkswagen was caught manipulating the efficiency of diesel cars' emissions control systems in 2015 in order to "beat" automotive checks that were meant to certify that a car met NO_x pollution levels. Since then, data has emerged that most, if not all, diesel producers in Europe, one of the world's largest car markets, have used legitimate or potentially illegal tactics to avoid vehicle emissions tests, and the scope of the resulting air pollution crisis has become clearer.

This card stack provides a summary of the issue, including how nitrogen oxides accumulate in vehicle exhaust, why they are dangerous, how they can be regulated in vehicles, and what barriers and alternatives there are to controlling them.

1.17.1 Solution

The first precedence in designing a strategy to govern nitrogen oxides is to guard human fitness. Human fitness impacts seem like associated with height exposures to nitrogen oxides (NO_x). In addition to probably negative human fitness, nitrogen oxides are precursors to ozone (O₃) formation, which could damage human fitness and plants. Finally, nitrogen oxides make contributions to acid deposition, which damages plants and aquatic ecosystems. The quantity to which NO_x emissions damage human fitness relies upon on ground-level concentrations and the variety of humans exposed. Source region can affect those parameters. Gases emitted in regions with meteorological, climatological, and topographical functions that choose dispersion might be much less probable to listen close to the ground.

However, a few meteorological situations, inclusive of inversion, can also additionally bring about appreciably better ambient levels. Sources farfar from population facilities will reveal fewer humans to dangerous pollutants. Plant siting is a important function in any air pollutants control strategy. However, because of the dispersion of nitrogen oxides which can make contributions to ozone formation and acid deposition a withinside the air used for combustion (thermal NO_x). Formation of gasoline NO_x relies upon on combustion situations, inclusive of oxygen awareness and blending patterns, and at the nitrogen content material of the gasoline. Formation of thermal NO_x relies upon on combustion long way from the source, counting on plant siting by myself isn't a endorsed strategy. The long-time period goal have to be to lessen overall emissions. Effective manipulate of NO_x emissions would require controls on both desk bound reassets and cellular shipping reassets. Each calls for exceptional techniques. This guiding principle makes a speciality of manipulate techniques for desk bound reassets (normally fossil-gasoline-fired electricity-producing plants). Limiting Emissions from Stationary Sources Nitrogen oxides are produced withinside the combustion process with the aid of using exceptional mechanisms: (a) burning the nitrogen withinside the gasoline, normally coal or heavy oil (gasoline NO_x); and (b) high-temperature oxidation of the molecular nitrogen temperature. Above 1,538o C (2,800o F), NO_x formation rises exponentially with growing temperature (Stultz and Kitto 1992). The relative contributions of gasoline NO_x and thermal NO_x to emissions from a specific plant rely upon the combustion situations, the kind of burner, and the kind of gasoline. Approaches for controlling NO_x from desk bound reassets can cope with gasoline NO_x, thermal NO_x, or both. One manner of controlling NO_x emissions is to apply low-nitrogen fuels. Another is to regulate combustion situations to generate much less NO_x. Flue fueloline remedy techniques, inclusive of selective catalytic reduction (SCR) processes, can dispose of NO_x.

CHAPTER 2

LITERATURE SURVEY

2.1 RICEBRAN AND BIO DIESEL

The world has for sometime witnessed growing concern over the environmental impact and/or exhaust of conventional fossil fuel energy sources¹. These issues have heightened the need for diversification, prompting worldwide investigations into new alternative fuel supplies for internal combustion (IC) engines. 2. Diesel engines, which are more powerful and durable than spark ignition (SI) engines, are commonly used on farms³ in India, as well as in heavy trucks, city transport buses, locomotives, electric generators, farm machinery, and unmanned aerial vehicles. Diesel fuel contains greater levels of aromatics and sulphur, all of which pollute the atmosphere. Biodiesel has similar properties to mineral diesel and can be used in traditional diesel engines without major modifications⁵. Direct transesterification of vegetable oils produces biodiesel, which is made when the resulting triglycerides react with a short-chain alcohol, typically methanol, in the presence of a catalyst. 6 The rough outer layers of cereal grain are known as bran, also known as miller's bran. It is made up of the aleurone and pericarp together. It is an essential component of whole grains, along with the germ, and is often prodded.

Bran can be found in rice, corn (maize), wheat, oats, barley, rye, and millet, among other cereal grains. Bran is not to be confused with chaff, which is a coarser scaly layer that surrounds the grain but does not form part of it and is indigestible to humans.

Bran contains large amounts of starch, calcium, vitamins, and dietary minerals, and is especially high in dietary fibre and essential fatty acids. It also contains phytic acid, an antinutrient that prevents nutrients from being absorbed.

Because of its high oil content, bran is prone to rancidification, which is why it is often isolated from the grain before storage or further processing. Bran is often heat-treated to extend its shelf life.

Rice bran is a byproduct of the rice milling process (the reduction of brown rice to white rice), and it provides a number of antioxidants that have health benefits. A significant portion of rice bran contains 12–13 percent oil and extremely unsaponifiable components (4.3 percent). Tocotrienols (a form of vitamin E), gamma-oryzanol, and beta-sitosterol are all constituents of this fraction, and they may all help to lower plasma levels of different lipid profile parameters. Rice bran also has a lot of dietary fibres in it (beta- glucan, pectin and gum). It also contains ferulic acid, which is a part of nonlignified cell walls' composition. However, some literature indicates that rice bran contains inorganic arsenic at high levels. According to one report, the levels are 20% higher than in polluted drinking water.

Bran is commonly used to enrich breads (particularly muffins) and breakfast cereals, especially for those looking to improve their dietary fibre intake. Bran can also be used for pickling (nukazuke), as in the Japanese tsukemono. Rice bran, in particular, has a wide range of applications in Japan, where it is known as nuka (糠; むか). Aside from pickling, the Japanese apply it to the water while cooking bamboo shoots and use it as a dishwashing liquid. It's known as jinda in Kitakyushu City and is used to stew fish like sardines.

Commercial ice blocks have rice bran attached to the surface to keep them from melting[citation needed]. Bran oil can also be extracted for use as a

cooking oil (such as rice bran oil) or for manufacturing uses (such as in the paint industry).

Wheat bran can be used as part of a blended ration with other inputs as a feed for poultry and other livestock. This group includes wheatings, a milling byproduct made up mainly of bran with a few bits of endosperm thrown in for good measure.

The BBC's TV show Gardeners' World discovered Bran to be the most effective slug deterrent. Feeder insects such as mealworms and waxworms use it as a substrate and food source. Since at least the 16th century, wheat bran has been used to tan leather.

2.2 CRDI ENGINE

The want for opportunity and renewable gasoline like BDF in vicinity of depleting diesel gasoline needs better IP because of their better viscosity. The traditional CI engine has the obstacle of gasoline IP which may be triumph over via way of means of using CRDI facility which injects gasoline at any CA, period and IP. Performance, emission and combustion traits examine on CRDI engine on rape seed oil methyl ester (ROME) and its combination with diesel confirmed decrease smoke, CO and HC emissions with better NO_x ranges attributable to higher air gasoline combination prevailed which caused entire combustion (Carlo et al., 2002). Better average blending of gasoline with air decreased ID with elevated gasoline droplet pace and reduced droplet size resulted at better gasoline IP. This caused better HRR and better in cylinder temperature which led to elevated engine out NO_x emissions (Lee and Park; 2002). The blending method of gasoline with air improved at better gasoline IP because of better rate temperature to be had at excessive load circumstance. Khandal et al. / CRDI Engine to Reduce NO_x 2 © 2018 via way of means of Author/s More flamable combination became shaped at some point of ID length due to the better PP at gasoline IP of 900 bar as compared to 800 bar. At the identical SOI, version of gasoline IP extensively altered the warmness launch profile, i.e., better gasoline IP caused in advance SOC and better as properly as narrower top warmness launch (Ye and Boehman, 2010; Labecki and Ganippa, 2012). A examine at the impact of injection parameters at the combustion and emission traits of CRDI engine fuelled with waste cooking oil revealed that HRR of BDF regularly

elevated with superior gasoline IT regardless of load circumstance. At excessive load, the ISFC became better and reached minimal whilst the IT became approximately 10°aTDC. The HC emissions of the BDF had been barely decrease than those of the diesel on the gasoline IP of 1600 bar, however NO_x emissions withinside the engine out fueloline had been discovered better. It became additionally stated that the CO emissions reduced with better gasoline IP at excessive load circumstance whilst gasoline IT became retarded (Joonsik et al., 2014). CRDI engine operated at a steady engine pace of 1800 rpm and special hundreds of 3.2 bar, 5.1 bar IMEP found out that the manage of combustion phasing and EGR of the gasoline/diesel fuels should yield emission decrease than CI engine and BTE better than common SI engine (Jiakun et al., 2015). The impact of 10%, 20% and 50% Karanja BDF (KOME) blends with diesel have been studied at the injection price, gasoline atomization, overall performance of a CRDI engine at a steady engine pace of 1500 rpm and at special IT. The outcomes confirmed that with decrease combination (20%) HC and CO emissions have been decreased in evaluation to mineral diesel. It became additionally reported that as much as B10, CRDI engines confirmed progressed BTE and decreased emissions with no alternate in hardware (Agarwal et al., 2015). The have a look at on CRDI engine confirmed that engine operation became feasible with as much as 75% swine lard methyl esters combination with diesel however with small lower in brake gasoline conversion efficiency and boom in BSFC (Mikulski et al., 2016). The diesel equal degrees of soot emission and 22% decrease NO_x emission have been found out with 30% RSO at IT of 3°bTDC and IP of 1200 bar (Labecki et al., 2012). Soybean BDF indicated faster ignition, decrease pre-combined spike and decrease PP while begin of energizing became among 2 to 6°bTDC. For rapeseed BDF with gasoline IT numerous from 10 to 5°bTDC the combustion technique came about closer to TDC ensuing in better BTE. More green usage of gasoline ensuing in higher atomization and the development or retardation in gasoline IT from the most useful fee is the motive for deterioration of BTE (Ye and Boehman, 2010; Monyem et al., 2001; Senatore et al., 2008). At better gasoline IP the BTE progressed because of green usage of gasoline due to higher atomization (Bakar et al., 2008). As the gasoline IP will increase from 800 bar to 900 bar the combustion phasing of BDF advances because of the discount of the ID thru higher air entrainment and blending. When the gasoline IP is accelerated ID reduced because of smaller SMD, shorter

cut up length, better dispersion and higher atomization of injected linolenic linseed oil methyl ester BDF (Puhan et al., 2009). Retarding the gasoline IT decreases the PP because of shorter ID ensuing in decrease top cylinder fueloline temperatures which ended in decrease NO_x concentration (Leung et al., 2006). The smoke emissions of BDF have been better than mineral diesel beneathneath the identical working conditions. This can be attributed to the presence of FFA withinside the BDF main to poor air-gasoline mixture. Smoke emissions of each fuels accelerated while the IT became retarded because of gradual and diffusion combustion segment because of decreased gasoline-air blending rate because of later injection (Sayin et al., 2009). The engine overall performance with bio gas-combined diesel fuels (combination range) become comparable to that beneathneath D100 gas. Use of BDF–diesel blends diminished the HC and CO emissions however confirmed better engine out NO_x. The smoke emissions have been decreased through 50% with using bio ethanol–diesel blends (Kim and Choi, 2009). The NO_x emissions substantially multiplied with growth in gas IP for the BDF and CO, HC, smoke emissions confirmed lowering fashion with better gas IP at better loads (Hwang et al., 2014; Armas et al., 2006). The quantity of gas brought at some stage in ID should be multiplied because of improved atomization of gas on the nozzle outlet with excessive IP which ends up in a greater disbursed vapour section and higher combustion which helps multiplied premixed HRR particularly at better load circumstance (Ozsezen et al., 2008; Can et al., 2004). It may be referred to that at exclusive gas IT (20°bTDC to 5°aTDC) the PP and the height HRR of the BDF are barely decrease than the ones of the diesel. The PP is multiplied because the gas IT become superior because of multiplied ID. More homogeneous gas-air combination is shaped which leads to a robust premixed combustion section main to a better PP (Narayana et al., 2016). From the exhaustive literature survey on CRDI engine, it is able to be referred to that usage of biodiesel, impact of CC form and nozzle holes at the overall performance has been scantily reported. Therefore the goal of this experimental have a look at particularly focusses on using biodiesels (BHO and BCO) derived from non-safe to eat oils and take a look at their suitability in CRDI engines along with use of injector with various quantity of holes and TRCC form. Initially the gas IT and IP for satisfactory BTE circumstance become received after which retaining most appropriate IT and IP, experiments have been performed

at the engine with injector having various quantity of holes. Finally conclusions have been drawn from the experimental have a look at

2.3 NO_x REDUCTION TECH

The first precedence in designing a approach to manipulate nitrogen oxides is to shield human fitness. Human fitness affects seem like associated with height exposures to nitrogen oxides (NO_x). In addition to doubtlessly negative human fitness, nitrogen oxides are precursors to ozone (O₃) formation, that could damage human fitness and plants. Finally, nitrogen oxides make a contribution to acid deposition, which damages plants and aquatic ecosystems. The quantity to which NO_x emissions damage human fitness relies upon on ground-stage concentrations and the variety of human beings exposed. Source vicinity can have an effect on those parameters. Gases emitted in regions with meteorological, climatological, and topographical functions that favor dispersion could be much less in all likelihood to pay attention close to the ground. However, some meteorological situations, together with inversion, may also bring about significantly better ambient levels. Sources farfar from populace facilities will disclose fewer human beings to dangerous pollutants. Plant siting is a crucial characteristic in any air pollutants control approach. However, because of the dispersion of nitrogen oxides which can make a contribution to ozone formation and acid deposition some distance from the source, counting on plant siting on my own isn't a advocated approach. The long-time period goal have to be to lessen overall emissions. Effective manipulate of NO_x emissions would require controls on each desk bound reassets and cellular transport reassets. Each calls for exceptional techniques. This tenet specializes in manipulate techniques for desk bound reassets (broadly speaking fossil-gasoline-fired electricity-producing plants). Limiting Emissions from Stationary Sources Nitrogen oxides are produced withinside the combustion procedure via way of means of exceptional mechanisms: (a) burning the nitrogen withinside the gasoline, broadly speaking coal or heavy oil (gasoline NO_x); and (b) high-temperature oxidation of the molecular nitrogen withinside the air used for combustion (thermal NO_x). Formation of gasoline NO_x relies upon on combustion situations, together with oxygen awareness and combining patterns, and on the nitrogen content material of the gasoline. Formation of thermal NO_x is based upon on combustion

temperature. Above 1,538o C (2,800o F), NOx formation rises exponentially with developing temperature (Stultz and Kitto 1992). The relative contributions of gas NOx and thermal NOx to emissions from a precise plant depend on the combustion situations, the form of burner, and the form of gas. Approaches for controlling NOx from table sure reassets can address gas NOx, thermal NOx, or each. One way of controlling NOx emissions is to use low-nitrogen fuels. Another is to adjust combustion situations to generate much less NOx. Flue fueloline treatment techniques, together with selective catalytic reduction (SCR) processes, can take away NOx.

The IC engine is provided with fuels like petrol or diesel. It is likewise used to generate power with small variety variety of tool with greater economically. Diesel engine are greater gasoline performance than any other. A diesel engine has excessive thermal performance, much less gasoline consumptions, reliability and better durability (**Jayaprabakar et al 2017**). So it's miles broadly utilized by many, it's also used to hold heavy loads, going for walks the locomotives, electricity presenting equipment. But while it comes to surroundings issues, we must locate exchange fuels. Alternate fuels inclusive of CNG, Hydrogen, biodiesels. Hydrogen fuels may also deliver us grate discount in pollution. Internal engines are categorised into many types. According to Fuel, Petrol, CNG, diesel. And in keeping with association inclusive of Inline, V, W, rotary, Wankel. It additionally rely upon the piston association. In inline kind engine pistons are organized in unmarried direction.

V manner piston stocks a unmarried crankshaft they organized like V. In W kind engine 3 pistons are organized and stocks a unmarried crankshaft. These are very large engine (**D. Samoilenko et al 2017**). There are styles of strokes in engines specifically -stroke and four-stroke. In four stroke Intake, combustion, strength, exhaust take place. In diesel engine Fuel is delivered right into a engine because the piston reaches the pinnacle lifeless centre of the stroke. The gasoline is injected right into a precombustion chamber or immediately into the piston-cylinder combustion chamber beneathneath excessive pressure. Diesel engines, with the exception of compact, excessive-pace units, use direct injection. The diesel engine generates strength via way of means of burning gasoline pumped or sprayed

into the cylinders compressed, warm air charge. The air need to be heated to a temperature better than the ignition temperature of the injected gasoline.

Carbon sprayed into air with a temperature more than the fuels auto-ignition temperature naturally interacts with oxygen withinside the air and burns. Since combustion is initiated through air heated through friction in place of an electric powered spark, diesel engines are often known as compression-ignition engines. The combustion system is heterogeneous system in diesel engine, this means that that the gasoline and air are now no longer blended till combustion begins.

As a result, rapid vaporisation and blending of the gasoline withinside the air is essential for entire combustion of the injected gasoline (Charles Lafayette Proctor et al). It releases a few emission gases along with co, co₂, NO_x and lots of gases. Most of the diesel engines are geared up with turbochargers. A turbocharger is a pressured induction mechanism that makes an engine generate extra strength and torque. It makes use of a exhaust fueloline as enter and sends sparkling air into the engine.

We all realize the CI engines are extensively used due to it excessive thermal performance and low renovation It runs on diesel gasoline that's a traditional fossil gasoline and is at the verge of extinction. Also exhaust fueloline (HC, CO, CO₂, NO_x etc) of diesel engine are very dangerous and fundamental supply of air pollutants for this reason contributing to international warming. Studies have observed that over 60% of the full air pollutants is due to engine exhaust. Engineers and scientists have carried out plenty of research and experiments to locating opportunity for diesel engine and powerful way to manage emission that's contributing to air pollutants. They observed that biodiesel as a gasoline can update diesel and additionally it may lessen the dangerous exhaust gases to considerable quantity. However, human beings are nonetheless operating in this area to discover the satisfactory opportunity for diesel gasoline. Biofuel (biodiesel) have ability to fulfill the developing strength call for for this international in sustainable manner. But it become observed that biodiesel gasoline has better NO_x emission than pure diesel operated engine.. A. Exhaust Gas Recirculation In EGR approach we recirculate the element of exhaust gases which aids in decreasing the NO_x

emission. Exhaust fueloline typically consists of of CO₂, NO_x and many others and aggregate has better unique warmth evaluate to atmospheric air, as a consequence recalculated exhaust fueloline displace clean air in combustion chamber and as a result, it enables to lessen oxygen to be had for combustion and additionally it boom the unique warmth of aggregate getting into the combustion chamber as a consequence decrease flame temperature. Fig. 1: Exhaust fueloline recirculation EGR is one of the maximum effective and budget friendly approach to lessen NO_x emission. EGR enables in growing the warmth ability, dilution of consumption price and ignition delay. Dilution concept says that, impact of EGR on NO_x is as a result of growing quantity of inert fueloline withinside the aggregate reduces the adiabatic flame temperature. EGR is a beneficial approach for decreasing NO_x formation. Exhaust includes CO₂, N₂ and water vapor mainly. When part of this exhaust fueloline is recirculated to the combustion cylinder, it acts as diluents. This additionally reduces the O₂ attention withinside the combustion chamber. The unique warmth of the EGR is an awful lot better than clean air as a result EGR will increase the warmth ability of the consumption rate.

2.4 EGR COLD & HOT

Cooled EGR will increase consumption density, thereby will increase volumetric performance of engine. At the equal time, the decreased temperature can in addition lessen NO_x emission, however HC emission and cycle-by- cycle versions are elevated as compared with that of warm EGR. Effects of HOT EGR. Dilution impact refers to the discount in oxygen furnished to the engine because of utility of EGR wherein as chemical impact is because of the participation of carbon dioxide, (gift withinside the EGR) withinside the combustion process. **EGR** systems divert some of the engine-out exhaust gas and mixes it back into the fresh intake air stream

CHAPTER 3

AIM AND SCOPE

3.1 AIM

- Investigate the Reduction Of NO_x Emission Using Hot And Cold EGR Methods In CRDI Engine
- To reduce the impure emissions present during the process
- To compare the emission results of our experiment(B20) to that of an emissions results of an CRDI diesel engine.
- To compare the performance of the prepared Fuel with and without EGR

3.2 SCOPE

Since fossil fuel emissions are growing every day and are non-renewable and detrimental to the climate, biodiesel can be seen as a renewable and environmentally friendly substitute. Rice bran oil is one the best method for both economically and environment. The blend of diesel, rice bran, methanol will change the emission levels

CHAPTER 4

MATERIALS AND METHODS

4.1 WORK PHASES

First we prepared Bio fuel by Transesterification at IRC Sathyabama Institute of Science and Technology A 5L B20 oil blend was prepared using 80% of diesel(4L) and 20% of biodiesel(1L of ricebran oil). The prepared oil blend is taken to Kanchipuram for engine testing which was successfully carried out and the results were obtained. Then the corresponding graphs were plotted according to the result obtained from engine testing. The graphs for performance, emission and combustion were plotted and the results were concluded.

4.2 MATERIALS REQUIRED

- Alcohol - Methanol
- Oil – Rice Bran oil
- Catalyst – NaOH (Sodium hydroxide)
- Diesel
- CRDI Engine with Cooled and Hot EGR

4.3 PREPARATION OF BIO FUELS

The rice bran oil is bought in shop. Then it is given to IRC in sathyabama institute of science and technology. They prepared the biofuels by using transesterification.

4.3.1 *Mixing of Catalyst to Alcohol*

The work uses sodium hydroxide pellets (Caustic soda) as a catalyst. The methanol must be mixed in these dry caustic balls. Using a magnetic stirrer, roughly 5 grammes (0.5 weight percent of rice bran oil) of NaOH pellets are combined with 182 ml of methanol (molar ratio of 1:6 to rice bran oil) for about 90 minutes. It was made certain that the dry NaOH pellets were properly combined with the methanol.

4.3.2 *Transesterification Process*

Transesterification is a reversible reaction in which fatty acids, alcohol, and a catalyst are combined together. As a catalyst, you can use either a solid base or a strong acid. Sodium or potassium methanolate was widely used on a large scale in industry. Raw biodiesel and raw glycerol are the end effects of the transesterification process. These raw materials are then cleaned in a subsequent phase. FAME (fatty acid methyl ester) biodiesel is generated when methanol is used as an alcohol. The developed distilled glycerol can be used in the food and cosmetics industries. In the oleochemical field, it's often used. It can minimise the viscosity of oils, rendering it more desirable for the processing of biodiesel than other processes. In the transesterification reaction, a fatty acid is replaced with an alcohol in the presence of a catalyst, resulting in esters.



Fig: 4.1: Transesterification

4.3.3 Separation Process

The reacted mixture is poured into the two flasks with openings and allowed to settle for 15 minutes. Glycerin collects at the bottom of the conical separator flask due to gravity and higher density, while methyl ester or biodiesel sits at the top. Using the opening valve at the foot, the glycerin can be quickly drained out. So the two layer is clearly identified and separated into glycerin and methyl ester.

4.4 PREPARATION OF HIGH PERFORMANCE BIODIESEL

For a B20 fuel, a blend 1 litre of biodiesel and 4 litres of diesel is used. The prepared 5L blend of fuel is injected in to the CRDI Engine. Then the CRDI Engine is allowed to run with this fuel. Then the CRDI is controlled using a ECU Software named NIRA. Then the Performance or the result is analysed through the Labview IC Engine Combustion Analysis. Then 4 set of readings are taken with pilot mass 20% and pilot mass 40% for Hot and cold EGR Respectively. If the exhaust gas enters the EGR directly it is Hot EGR and if it is passed through a coolant it is Cold EGR. The pressure at the CRDI Engine is 400 bar (5800 psi) throughout all the four test. There are seven sensors to sense the engine. We measure with different loads. Then the result is analyzed through the Software and the respective graphs are drawn using the software. The Engine test took place at SVE Engine test Centre, Kanchipuram.



Fig: 4.2: Mixing bio fuels with diesel

4.5 ENGINE TESTING

The testing is carried out in a single cylinder, four stroke diesel engine that is loaded using an eddy current style dynamometer. It is fitted with the necessary instruments for calculating combustion pressure and crank angle.



Fig: 4.3: CRDI Engine

4.5.1 Engine Details

Engine manufacturer - Kirloskar

Number of strokes - Four stroke

Number of cylinder - One

Type of injection - CRDI vertical

Type of cooling system - Water cooled

Table 4.1: Enginespecifiaction

RATED POWER	3.5 kw
RATED SPEED	1500 rpm
BORE DIA (D)	87.5 mm
STROKE (L)	110 mm
COMPRESSION RATIO	17:5:1
C.V OF FUEL FOR DIESEL	42,500 kj/kg
DENSITY OF DIESEL	840 kg/m ³



Fig: 4.4: Smokemeter

Smoke meter is used to measure the exhaust gas from engine. It measures only the black smoke. The smoke metre demonstrates the density of smoke, which means the degree of combustion efficiency. The smoke metre is made up of an optical instrument housed inside a measurement head with its own electrical control unit. The smoke meter consists of an optical unit mounted inside a measuring head which also has a separate electrical control unit.

4.5.2 *Components of Engine*

- Hydraulic dynamometer (engine loading)
- Panel box
- Airbox
- Fuel tank
- Manometer
- Fuel measuring unit
- Digital speed indicator
- Temperature indicator

4.6 **PROPERTY ANALYSIS**

Table 4.2 :Properties of D100

S.No	Parameters	Results
1	Acid Value	0.11 mg NaOH/g of oil
2	Density	0.845 g/cc
3	Kinematic Viscosity @ 40°C	0.84 cSt
4	Copper Strip Corrosion @ 60°C for 3hrs	1 a
5	Flash point by PMCC method	52 °C
6	Fire point by PMCC method	67 °C
7	Cloud Point	-5 °C
8	Pour Point	-12 °C
9	Moisture content	0.010 %
10	Calorific value	10143.916 Cal/g

Table 4.3 : Properties of RB100

S.No	Parameters	Results
1	Acid Value	1.3 mg NaOH/g of oil
2	Density	0.882 g/cc
3	Kinematic Viscosity @ 40°C	8.4 cSt
4	Copper Strip Corrosion @ 60°C for 3hrs	1 a
5	Flash point by PMCC method	221 °C
6	Fire point by PMCC method	234 °C
7	Cloud Point	2 °C
8	Pour Point	-10 °C
9	Moisture content	0.13 %
10	Calorific value	8642.63 Cal/g

Table 4.4 : Properties of RB20

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

Table 4.5 : Properties of Rice bran oil

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

CHAPTER 5

RESULTS

5.1 PERFORMANCE GRAPHS

Brake thermal efficiency, specific fuel consumption, and volumetric efficiency and exhaust gas temperature which are all the performance characteristics of the blended fuel are explained in this section.

5.1.1 *Brake Thermal Efficiency*

The break power of a heat engine as a function of the thermal inputs from the fuel is known as brake thermal efficiency. It's a measurement of how efficiently an engine transforms heat from a fuel into mechanical energy.. It is mainly affected by fuel properties such density and heating values.

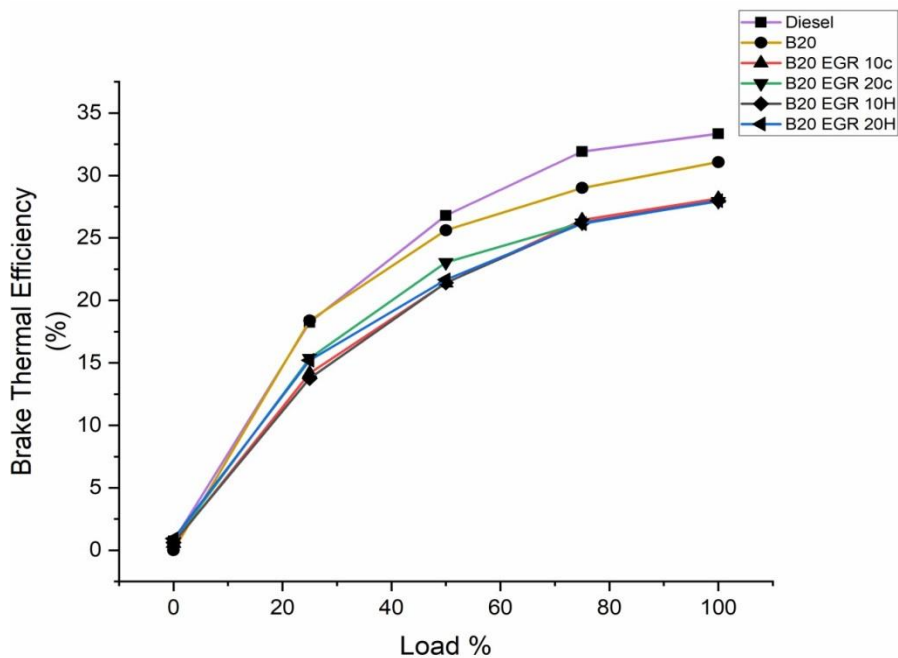


Fig: 5.1: Brake Thermal Efficiency

It is observed from the graph that variation in brake thermal efficiency against different loads. The graph is drawn between different loads in x-axis and Brake Thermal Efficiency in y-axis. It clearly shows from the above graph that the diesel has highest brake thermal efficiency and it is followed by B20, B20 EGR 10C, B20 EGR 20 C, B20 EGR 10H, B20 EGR 20H. But it is finally observed that B20 EGR 10C, B20 EGR 20 C, B20 EGR 10H, B20 EGR 20H has same brake thermal efficiency. Whereas diesel has highest brake thermal efficiency throughout the loading.

5.1.2 Volumetric Efficiency

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

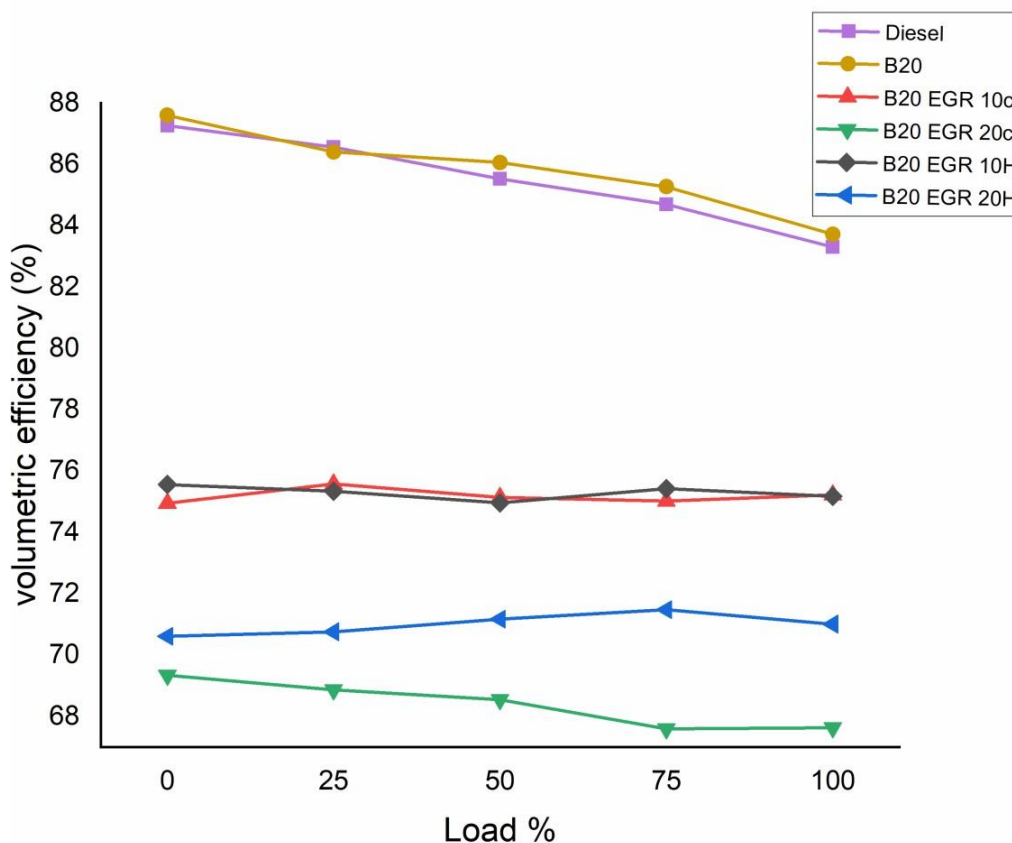


Fig: 5.2: Volumetric Efficiency

The above graph fig shows the variations in volumetric efficiency at different loads. The graph is drawn between different loads in x-axis and Volumetric efficiency in y-axis.

From the graph it shows B20 has a highest volumetric efficiency when compared to Diesel and other fuels. But B20 with EGR 20C has a lowest volumetric efficiency of all. Even from lower loads to higher loads, B20 shows the good result in terms of v volumetric efficiency.

5.1.3 Specific Fuel Consumption

It is amount of fuel consumed by a vehicle for each unit of power output. specific fuel consumption of an engine is the rate of fuel burnt to produce a unit of thrust. It is used to compare the efficiency of IC engines with shaft output. Lower the specific fuel consumption it will give higher mileage. The fuel property like heating value will vary the amount of specific fuel consumption value

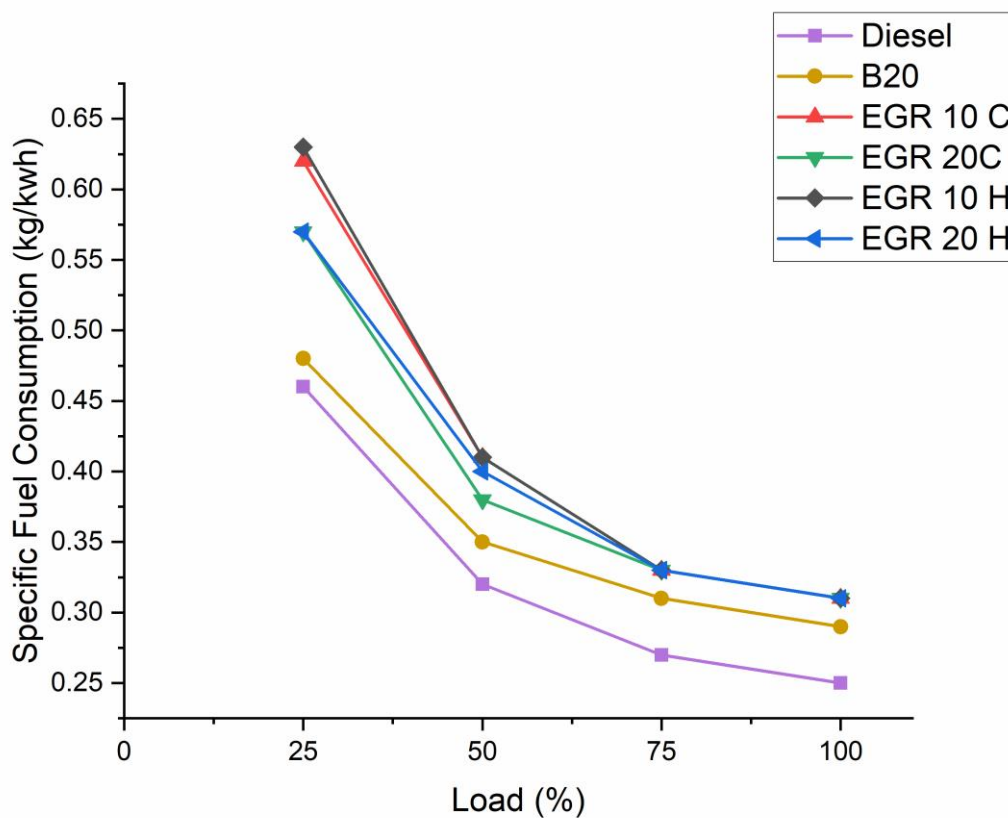


Fig: 5.3: Specific Fuel Consumption

With reference to the above graph fig , it shows the changes in specific fuel consumption against various loads. The graph is drawn between different loads in x- axis and specific fuel consumption in y-axis. It decreases with increase in loads. At 25% load EGR 10H has more specific fuel consumption than others. As the load increases it decreases with specific fuel consumption. Finally at 100% load EGR 10 C & 20C and EGR 10 H & 20 H shows the highest specific fuel consumption and they are similar to each other. But 100% load diesel shows the least specific fuel consumption.

5.1.4 Exhaust Gas Temperature

Exhaust Gas Temperature is a measurement of exhaust gas temperature. It measures gas at the manifold of the engine. For proper functioning of catalytic converter in an internal combustion engine, exhaust gas temperature (EGT) is needed. The Exhaust Gas Temperature varies from about 200 degrees Celsius to 500 degrees Celsius.

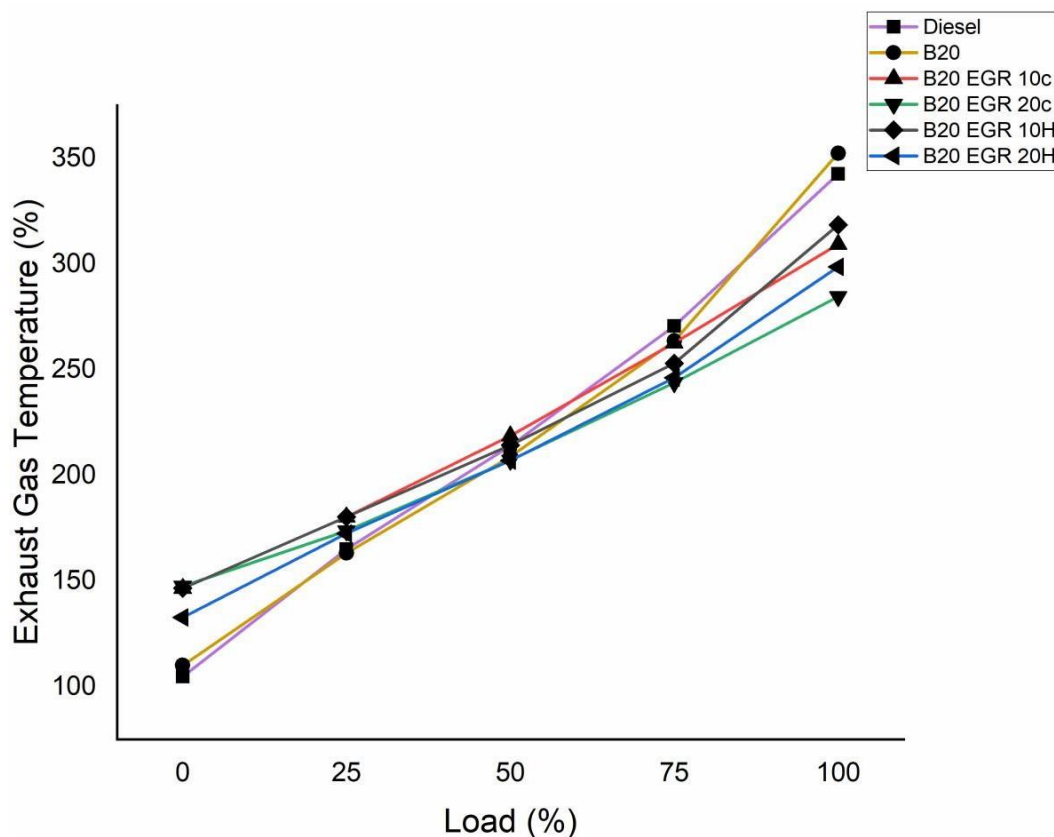


Fig: 5.4: Exhaust Gas Temperature

The above graph fig shows the exhaust gas temperature at various loads. The graph is drawn between different loads in x-axis and exhaust gas temperature in y-axis. The Exhaust gas temperature is increasing with increase in loads. B20 has more Exhaust Gas Temperature at higher loads where B20 with EGR 20 C has lowest Exhaust Gas Temperature at 100% load. But at 0% load it has the highest Exhaust Gas Temperature.

5.2 EMISSION CHARACTERISTICS

5.2.1 Carbon Monoxide (CO)

CO is transparent, tasteless gas. It is very harmful when it is inhaled in large amount. It is very harmful for every living being. Its is released when something is burned outside. It mainly caused due to vehicle emission, burning of fossil fuels. Breathing a high amount of CO reduces the amount of oxygen transmitted in a blood stream, may cause unconsciousness and death.

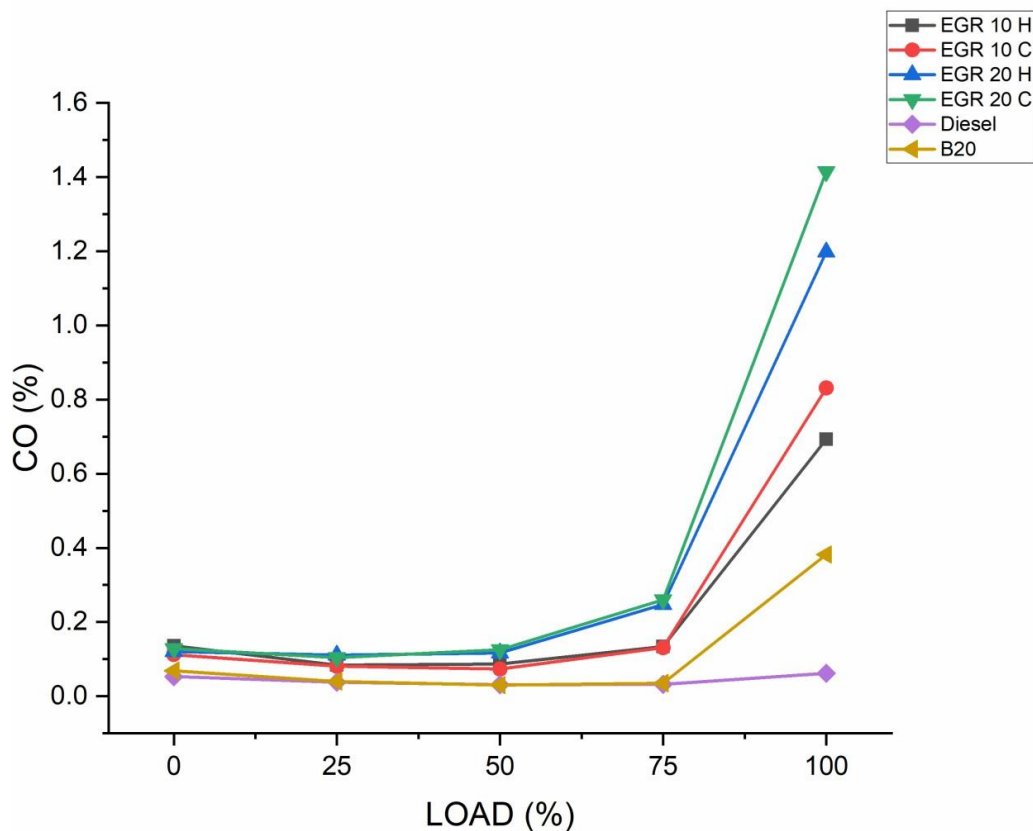


Fig: 5.5: Co

The above graph fig shows the Carbon monoxide emissions at various loads. The graph is drawn between the different loads in x-axis and the CO emissions in the y-axis. At 0% load diesel shows the least CO emission. CO emissions increases with increase loads.

As the load increase the EGR 20 C gives the maximum CO emission. But at higher loads diesel gives the minimum CO emission.

5.2.2 Carbon Dioxide (CO₂)

Carbon dioxide emissions are the primary driver of global climate change. It's widely recognised that to avoid the worst impacts of climate change, the world needs to urgently reduce emissions. The most human source of carbon dioxide emissions is from the combustion of fossil fuels, automobile emissions, etc. This may cause change in climate, some respiratory problems, air pollution.

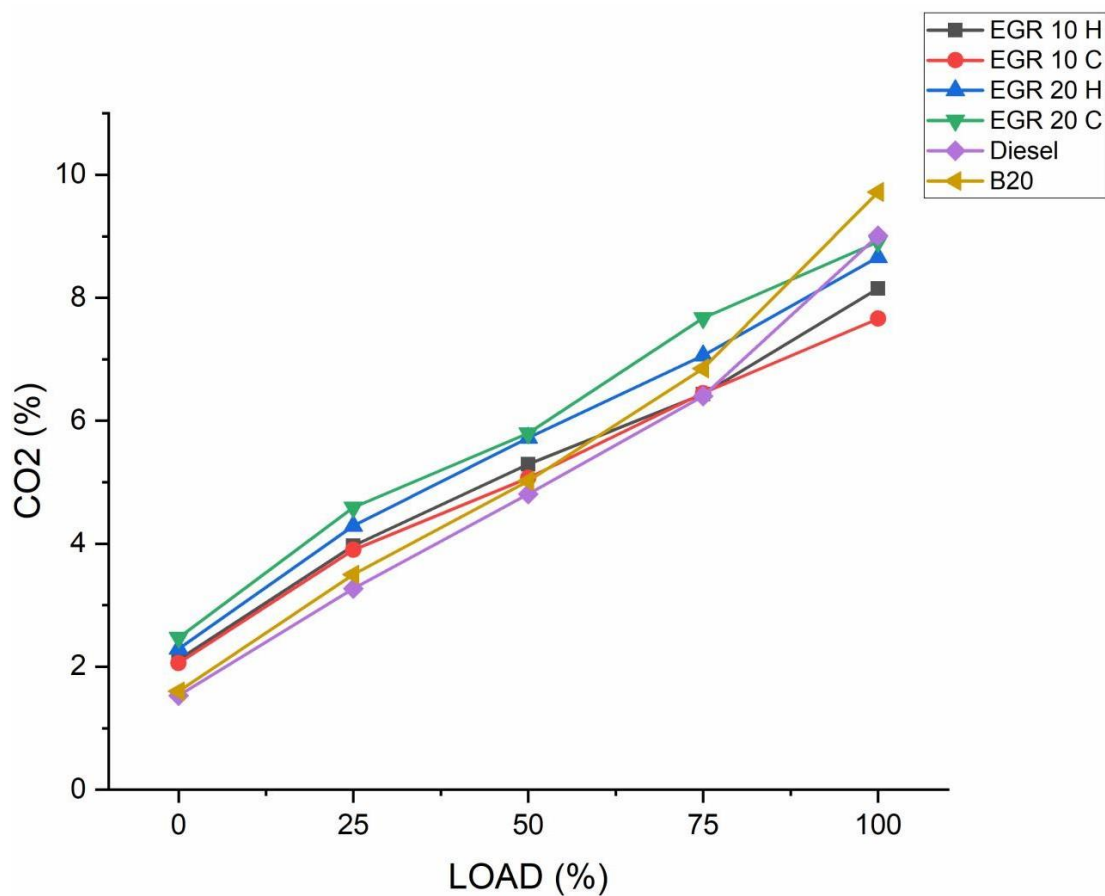


Fig: 5.6: Co₂

The above graph fig shows the Carbon monoxide emissions at various loads. The graph is drawn between the different loads in x-axis and the CO₂ emissions in the y-axis. The emission characteristic of carbon dioxide results are studied and discussed from obtaining the values from engine test. For pure diesel CO₂ is less when compared to other fuels. B20 has the highest CO₂ emission with high loads. It is followed by other fuels. whereas EGR 10 C has minimum emission at maximum loads.

5.2.3 Nitrogen Oxides (NOx)

Nitrogen Oxides are very poisonous, highly reactive gases. These gases evolved when fuel is burned at high temperatures. NO_x pollution is emitted by automobiles, trucks and various non-road vehicles (example construction equipment, boat). It looks like a brownish gas. It produces smog at summer days. It is very harmful to all living being, it may lead to death. The oxides of nitrogen like nitrogen dioxide and nitrogen oxide are together known as the NO_x emissions

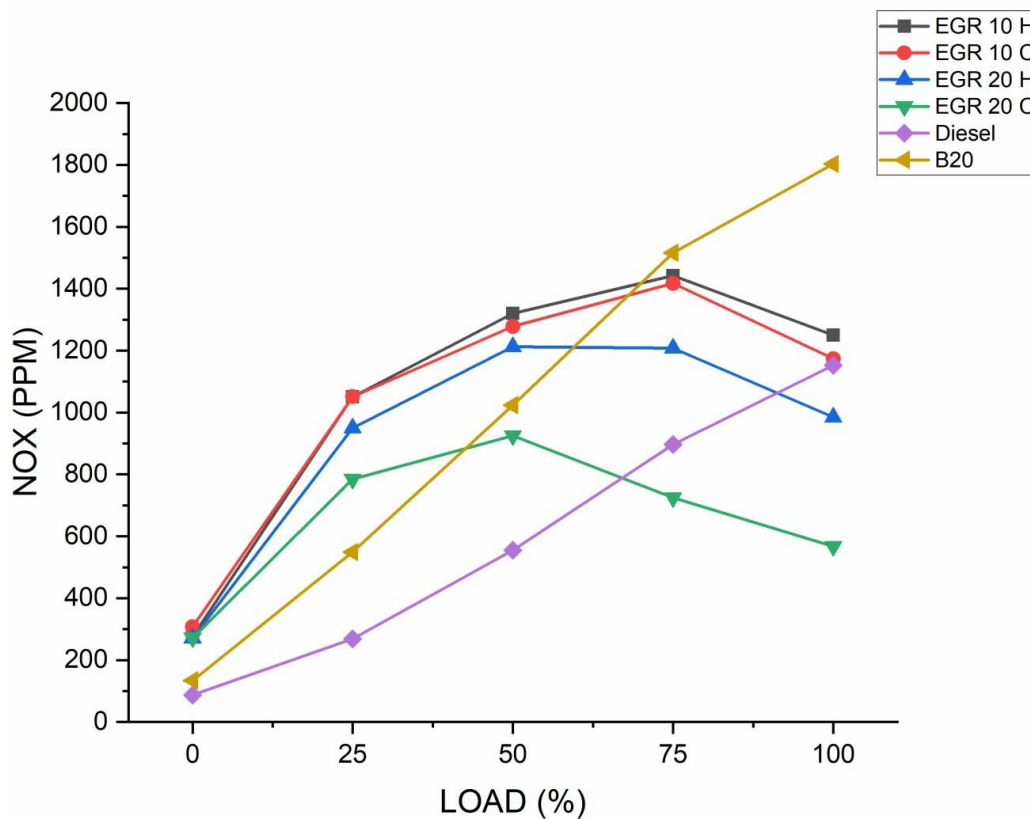


Fig: 5.7: NOx

The above graph fig shows the Nitrogen Oxides emissions at various loads. The graph is drawn between the different loads in x-axis and the NOx emissions in the y-axis. The emission characteristics of an ic engine are the NOx emissions which are the oxides of the nitrogen. At 0% load pure diesel has minimum NOx value, whereas B20 10 C has maximum value at 0% load. But EGR 20 C, 10H 20 H are similar to B20 10 C. At maximum load (100%) B20 contains maximum amount of NOx. And B20 and diesel are increases with increasing load. Where all EGR initially contains maximum NOx but when we increase loads it slightly decreases NOx level. EGR 20 C has a minimum amount of NOx.

5.2.4 Hydrocarbon Emission (HC)

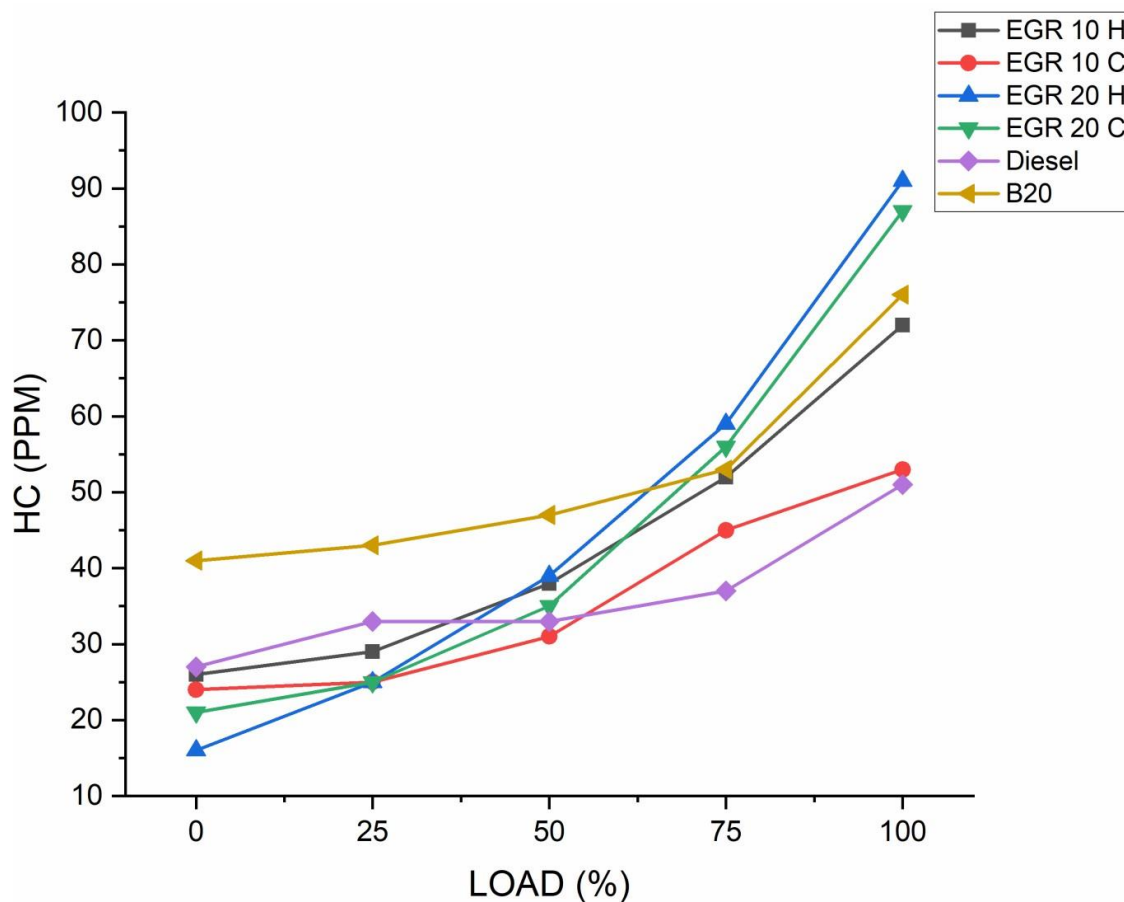


Fig: 5.8: HC

It is mainly due to incomplete combustion of fuel in the combustion chamber. It is simply a unburned fuel being pumped raw into the exhaust system. Mostly may cause ignition problem or internal engine failure and that reduces

compression. Because of poor ignition of fuel will release large of HC to atmosphere. It is very harmful to humans because HC deposits in RBC and may lead to death. It also affects other livings too. So, this is the to keep HC in low levels.

The above graph fig shows the Hydrocarbon emissions at various loads. The graph is drawn between the different loads in x-axis and the HC emissions in the y-axis. HC emission increases with increasing load. At 0% load B20 has highest value but at 100% load it moved to 3rdhighest HC emission. EGR 20 H became maximum HC emission value at 100% load, whereas diesel has lowest HC emission value.

5.2.5 Smoke Opacity

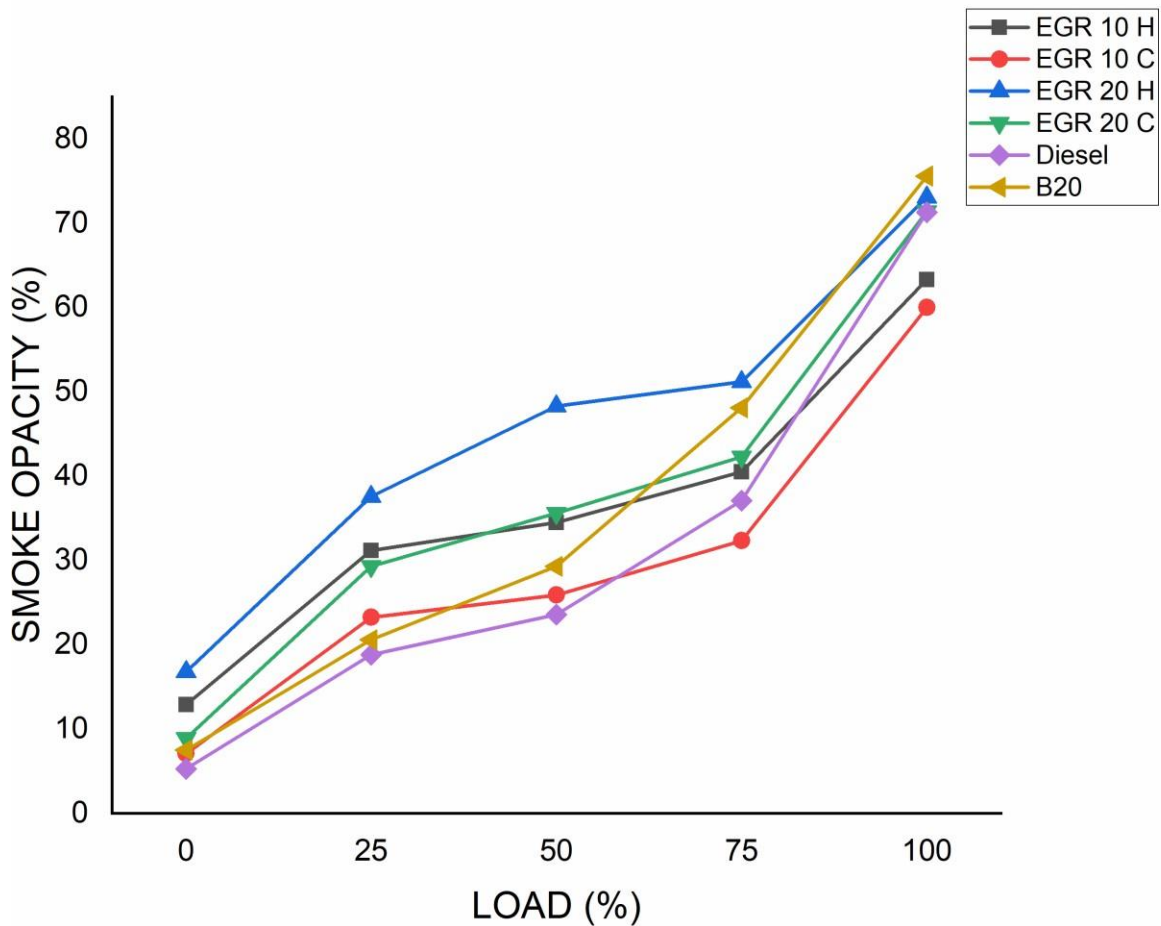


Fig 5.9 Smoke Opacity

It is a type of emission particles which produce due to the deposition of fuel on the cylinder wall. Smoke opacity is the degree to which smoke block lights and helps in the measuring of the smoke which comes out from the IC engine due to the fuel left on the cylinder walls. It has some particulate matters such as CO, CO₂, NOX, HC. It is harmful to health.

The above graph fig shows the Smoke opacity at various loads. The graph is drawn between the different loads in x-axis and the Smoke opacity in the y-axis. At 0% load pure form of diesel tends to have minimum Smoke opacity. And it is followed by B20, EGR 10 C, EGR 20 C, EGR 10 H, EGR 20 H. Finally B20 has a maximum Smoke opacity at maximum load whereas EGR 10 C has minimum amount of Smoke

5.3 CYLINDERPRESSURE

The cylinder pressure of an engine may be defined as the maximum pressure developed due to the combustion of fuel in which the chemical energy gets converted in to pressure energy. This will influence the engine power and also emissions.

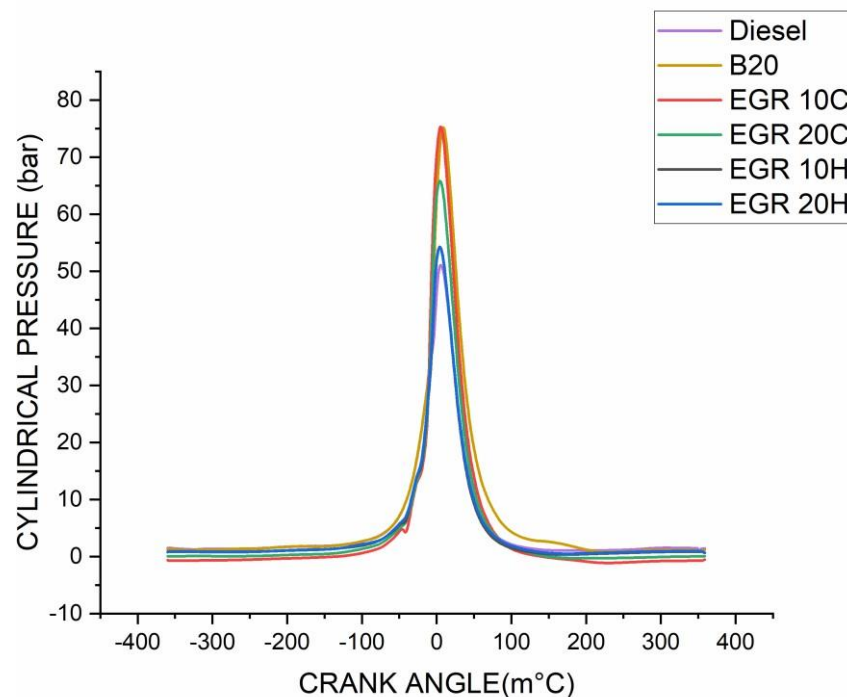


Fig: 5.10: Cylinder Pressure at 0% combustion

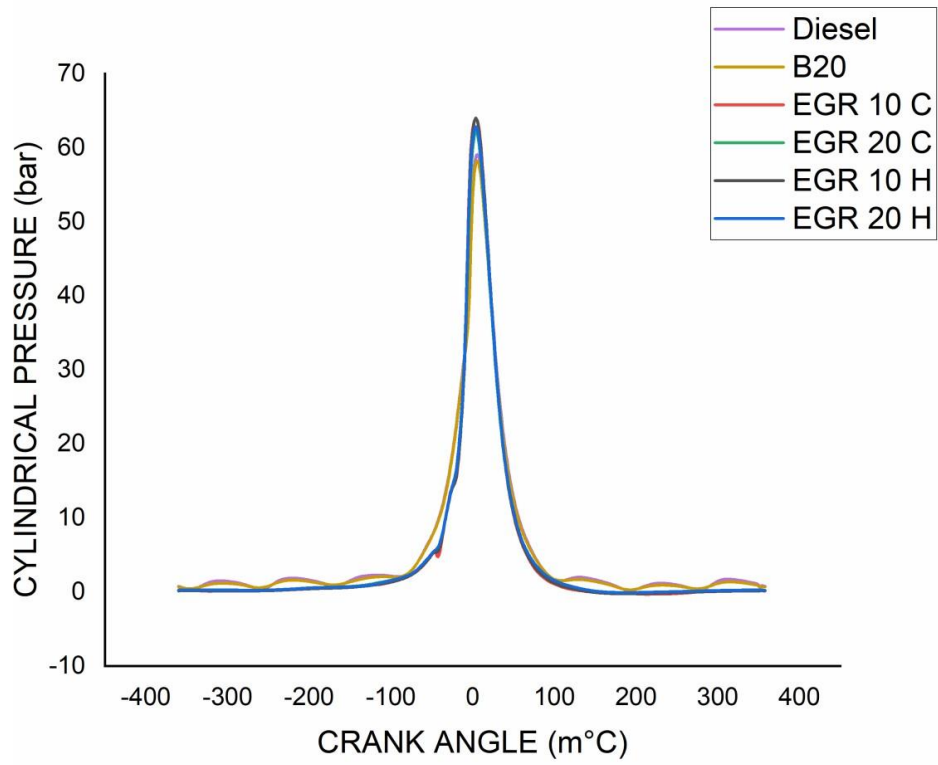


Fig: 5.11: Cylinder Pressure at 25 % Combustion

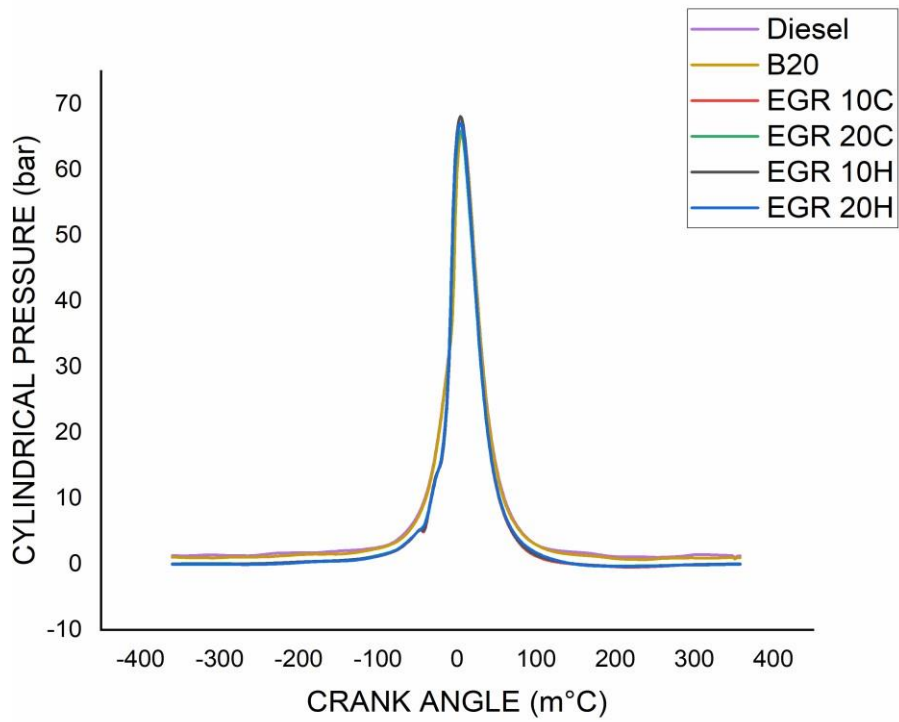


Fig: 5.12: Cylinder Pressure at 50% Combustion

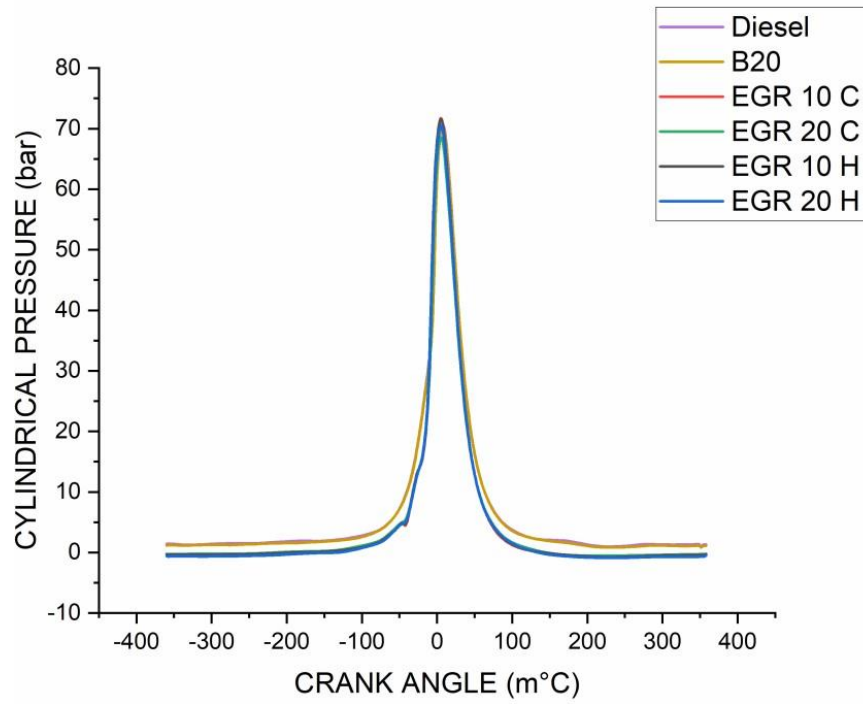


Fig. 5.13: Cylinder Pressure at 75% combustion

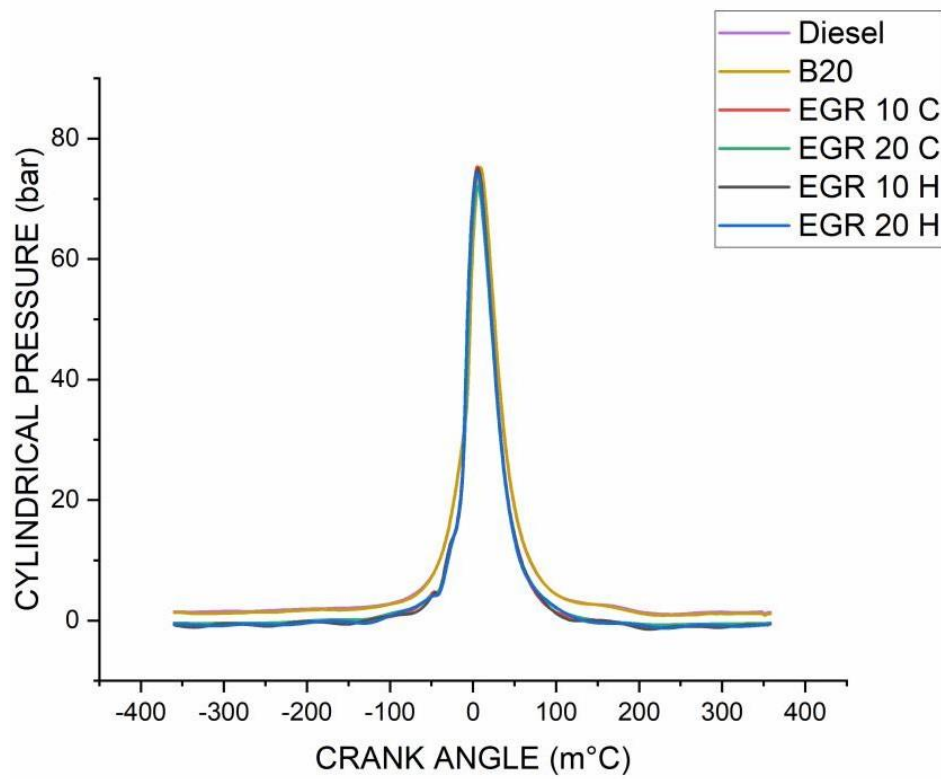


Fig. 5.14: Cylinder Pressure at 100% Combustion

The above graphs of combustion characteristics show the cylindrical pressure of the engine at various percentages of Combustion. From fig 5.3.1, fig 5.3.2, fig 5.3.3, fig 5.3.4, fig 5.3.5, we can clearly say that the cylinder pressure for all EGR conditions has increased when tested at 0% load. The cylinder pressure of all the other EGR conditions remains same for every load. Also we can study that the cylindrical pressure values for 100% combustion is higher than others.

5.4 NET HEAT RELEASE DURING COMBUSTION

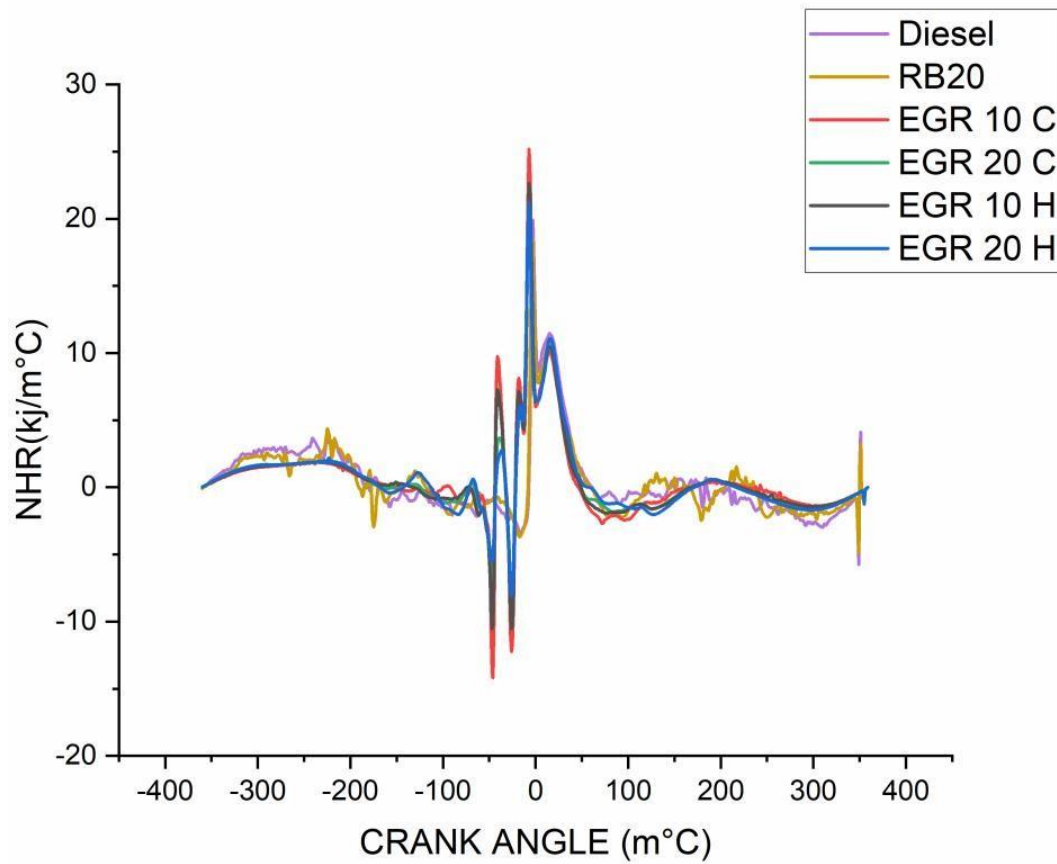


Fig: 5.15: NHR at 0% Load

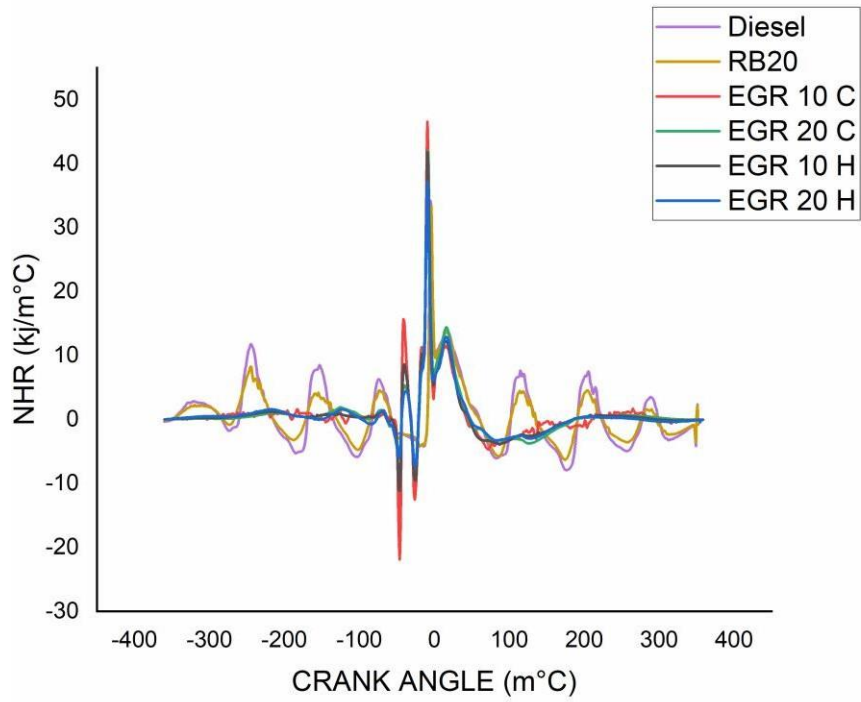


Fig: 5.16: NHR at 25% Load

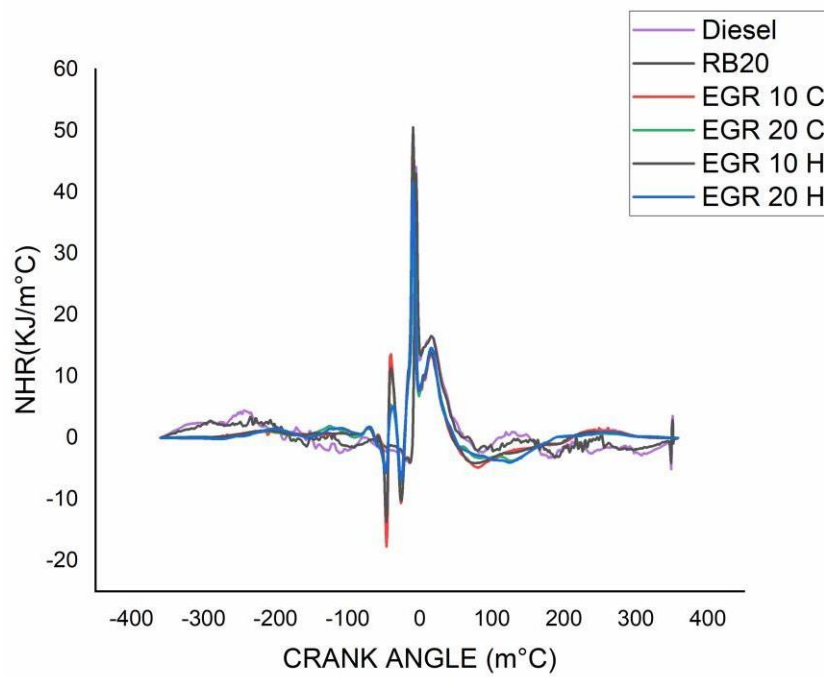


Fig: 5.17: NHR at 50%Load

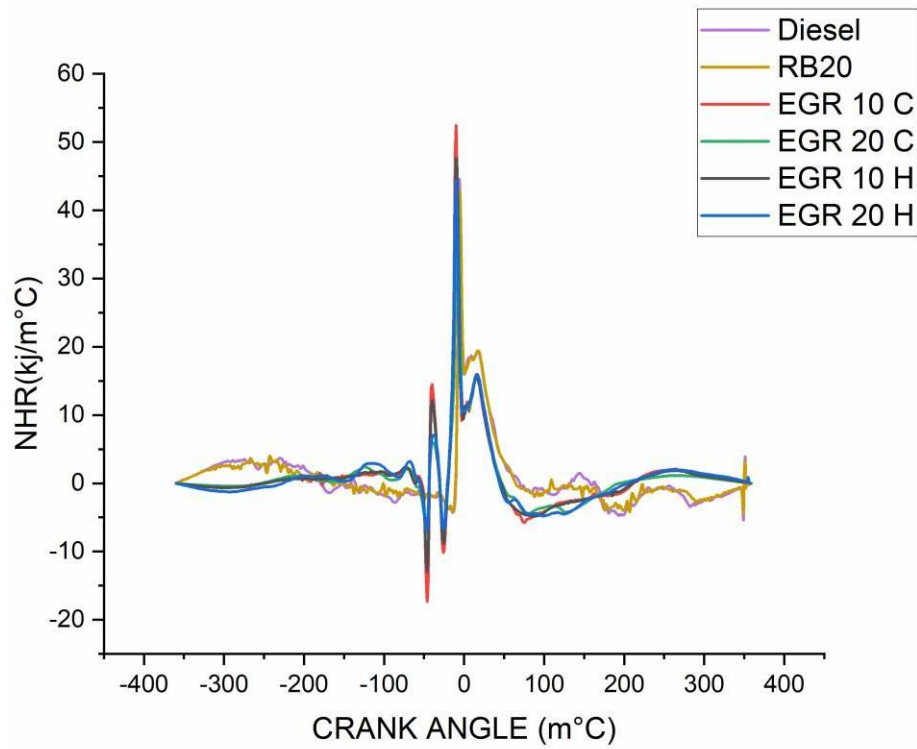


Fig: 5.18: NHR at 75% Load

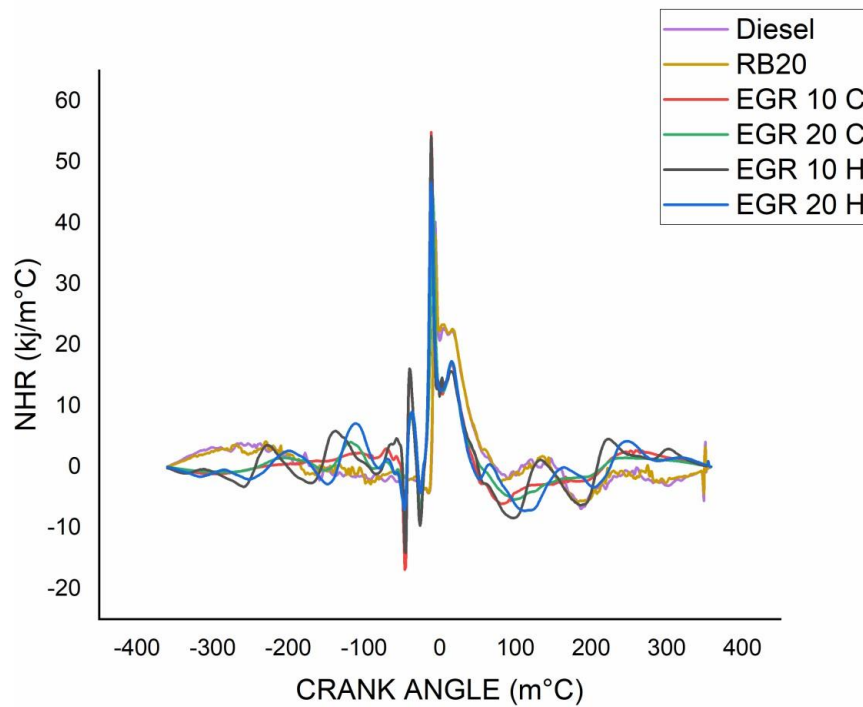


Fig: 5.19: NHR at 100 % Load

The above graphs show the net heat release of the engine during the combustion process at various loads. From the fig 5.4.1, fig 5.4.2, fig 5.4.3, fig 5.4.4, fig 5.4.5 when tested with 0% load EGR 10 C condition has higher net heat release compared to other conditions. At 25 % load the net heat release is almost similar to the 0% load. At 50% load, EGR 10 H has the higher net release compared to all the other conditions. Also the net heat release of RB20 is slightly higher than the Diesel. At 75% and 100 % load the EGR 10 irrespective of hot or cold conditions tends to be higher than the EGR 20H and EGR 20C. The net heat release of RB20 fuel is also slightly higher than the Diesel

CHAPTER 6

CONCLUSION

Though there are many advantages of EGR, however still has some limitation in terms of engine durability, lubrication contamination and causes wear to engine parts.

- In performance characteristics illustrates the diesel has high break thermal efficiency, compared to B20 with EGR. But all EGR shows low BTE in high load.
- The volumetric efficiency of the B20 has higher rate at higher load where EGR 20C has low rate.
- For specific fuel consumption for diesel has lower rate at 100% load but EGR 20H has high rate.
- The exhaust gas temperature B20 produces more gas at higher load, where EGR 20C has low gas.
- In co diesel produce less amount of co at higher loads where EGR 20 C produces more co.
- For NO_x EGR 20 C produces low NO_x rate at higher loads.
- CO₂ has B20 has high rate where EGR 10 C has low.
- HC emission has low in diesel where EGR 20H has more.
- There is more smoke opacity in B20 but EGR 10 C has low.
- For NHR we can conclude that EGR 10C condition has a higher value at all the load conditions. The graphs with respect to cylinder pressure except for 0% load EGR 20 H has the higher cylinder pressure value.

- This research is helps to develop the respond to dynamic mode of engine operation which could not possible with EGR technology.

From the experimental suggestion that the NO_x reduction without significant penalty on the brake thermal efficiency and also found intake pressure increases due to turbo charging effect

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