

COMPARATIVE ANALYSIS OF USING MAIN INJECTION SPLIT INJECTION PILOT INJECTION POST INJECTION IN CRDI ENGINE USING RICEBRAN METHYL ESTERS

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

By

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BONAFIDE CERTIFICATE

This is to certify that this Project Report is the bonafide work of Davis Lazar (37150045) and Habeebullah.M.A (37150069) who carried out the project entitled **“COMPARATIVE ANALYSIS OF USING MAIN INJECTION SPLIT INJECTION PILOT INJECTION POST INJECTION IN CRDI ENGINE USING RICEBRAN METHYL ESTERS”** under my supervision from October 2019 to April 2020.

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We, Davis Lazar (37150045) and Habeebullah.M.A (37150069) hereby declare that the Project Report entitled “**COMPARATIVE ANALYSIS OF USING MAIN INJECTION SPLIT INJECTION PILOT INJECTION POST INJECTION IN CRDI ENGINE USING RICEBRAN METHYL ESTERS**” 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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I am pleased to acknowledge my sincere thanks to Board of Management of **SATHYABAMA** for their kind encouragement in doing this project and for completing it successfully. I am grateful to them.

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ABSTRACT

Pilot and post injections are being used in modern diesel engines for improving engine performance in addition to meeting stringent emission norms. One of the main goal of this project is to reduce the impure contents such as, Carbon mono oxide, nitrogen oxides, hydro carbons & particulate matter. This goal is achieved by using transesterification In a diesel engine which is operated with a high performance of diesel blend. Aside from reducing the impure contents we will also get to compare the performance of the prepared blend an impact in a diesel engine when its being operated along with the high performance of blend diesel. The B20 blend diesel we use for this particular experiment constitute of several constituents. These constituents being, 80% diesel + 20% rice bran oil biodiesel (Transesterification process).

Biodiesel produced from different feedstocks is gaining global recognition as partial replacement for mineral diesel in compression ignition (CI) engines. In this study Ricebran methyl esters biodiesel blends were used for investigation of pilot injections, post injection, main injection, split injection pressures and injection timings on biodiesel blends. Comparative analysis of using Split injection Pilot injection Main injection Post injection in CRDI Engine using Ricebran methyl esters will be studied in the following stages. This paper reports an investigation of the use of biodiesel in a common rail direct injection (CRDI) engine. Experiments were carried out on a CRDI engine that is powered with diesel and biodiesel to investigate the effect of injectors with different numbers of holes on its performance.

We plan to obtain a suitable injection pressure for better output of the Engine.

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LIST OF SYMBOLS AND ABBEREVIATIONS

SYMBOLS	ABBEREVIATIONS
B20	20% biodiesel and 80% diesel
ASTM	American Society for Testing and Materials
BTDC	Before top dead centre
BSOF	Benzene Soluble Organic Fraction
BSFC	Brake specific fuel consumption
BTE	Brake Thermal Efficiency
CO ₂	Carbon Dioxide
CO	Carbon Monoxide
CRDI	Common rail direct injector
CP	Cylindrical Pressure
EDC	Electronic Diesel Control
EGR	Exhaust Gas Re circulation
FFA	Free Fatty Acid
FIP	Fuel Injection Pressure
HC	Hydro carbons
IDI	Indirect Diesel Injector
IC	Internal Combustion
KNN	K-nearest neighbor
NHR	Net Hear Release
NO _x	Oxides of nitrogen
PLS	Partial least squares classification
PM	Particulate matter
RDA	Regularized discriminant analysis
SI	Spark Ignition
SFC	Specific fuel Consumption
SOC	Start of Combustion
SOMI	Start of Main Injection
SVM	Support vector machines
TDC	Top dead centre

CHAPTER 1

INTRODUCTION

1.1 HISTORY AND BACKGROUND

Vickers spearheaded the utilization of the common rail injection in submarine motors. Vickers motors with common rail fuel framework were first utilized in 1916 in the G-class submarines. It comprised of four unclogger siphons to convey a pressing factor as much as 3,000 pounds for each square inch (210 bar; 21 MPa) each 90° of pivot to keep the fuel pressure satisfactorily steady in the rail. Fuel conveyance to singular chambers could be stopped by valves in the injector lines.¹ Doxford Engines utilized a typical rail framework in their went against cylinder marine motors from 1921 to 1980, where a multicylinder responding fuel siphon created a pressing factor around 600 bars (60 MPa; 8,700 psi), with the fuel being put away in aggregator bottles.² Pressure control was accomplished by a flexible siphon release stroke and "spill valve". Camshaft-worked mechanical planning valves were utilized to supply spring-stacked Brice/CAV/Lucas injectors, which when infused through the side of the chamber into the chamber framed between the cylinders. Early motors had pair of timing cams, one for forward running and one for toward the back. After that motors had two injectors for every chamber, and the last arrangement of steady pressing factor turbocharged motors was fitted with four injectors for each chamber. These frameworks were utilized for the injection of both diesel and hefty fuel oil (600cSt warmed to a temperature close to 130°C).

The common rail motors have been utilized in marine and train applications for quite a while. The Cooper-Bessemer GN-8 (around 1942) is an illustration of using pressurized water worked normal rail diesel motor, otherwise called an altered regular rail.

The common rail framework model for auto motors was created in the last part of the 1960s by Robert Huber of Switzerland, and the innovation was

additionally evolved by Dr. Marco Ganzer at the Swiss Federal Institute of Technology located in Zurich, later of Ganzer-Hydromag AG (est. 1995) in Oberägeri.

The main effective use in a creation vehicle started in Japan by the mid-1990s. Dr. Shohei Itoh and Masahiko Miyaki of the Denso Corporation, a Japanese car parts producer, built up the regular rail fuel framework for substantial vehicles and transformed it into down to earth use on their ECD-U normal rail framework mounted on the Hino Ranger truck and sold for general use in 1995. Denso claims the main business high-pressure basic rail framework in 1995.

Present day normal rail frameworks, albeit dealing with a similar standard, are represented by a motor control unit, which opens every injector electrically instead of precisely. This was widely prototyped during the 1990s with coordinated effort between Magneti Marelli, Centro Ricerche Fiat, and Elasis. After innovative work by the Fiat Group, the plan was gained by the German organization Robert Bosch GmbH for finish of advancement and refinement for large scale manufacturing. Looking back, the deal gave off an impression of being an essential mistake for Fiat, as the new innovation end up being profoundly productive. The organization had minimal decision yet to sell Bosch a permit, as it was in a poor monetary state at that point and did not have the assets to finish advancement on its own. In 1997, they expanded its utilization for traveler vehicles. The principal traveler vehicle to utilize the normal rail framework was the 1997 model Alfa Romeo 156 with a 2.4-L JTD engine, and later that very year, Mercedes-Benz presented it in their W202 model.

1.2 CI ENGINE & IT'S FUELS

The diesel motor, named after Rudolf Diesel, is an inside burning motor where start of the fuel is brought about by the raised temperature of the air in the chamber because of the mechanical pressure; subsequently, the diesel motor is a purported pressure start motor (CI motor). This differentiations with motors utilizing sparkle plug-start of the air-fuel combination, like a petroleum motor (gas motor) or a gas motor (utilizing a vaporous fuel like flammable gas or condensed oil gas).

Diesel motors work by packing just the air. This expands the air temperature inside the chamber to such a serious level that atomised diesel fuel infused into the burning chamber lights suddenly. With the fuel being infused into the air not long before ignition, the scattering of the fuel is lopsided; this is known as a heterogeneous air-fuel blend. The force a diesel motor produces is constrained by controlling the air-fuel proportion (λ); rather than choking the admission air, the diesel motor depends on changing the measure of fuel that is infused, and the air-fuel proportion is normally high.

The diesel motor has the most noteworthy warm effectiveness (motor proficiency) of any down to earth interior or outer ignition motor because of its exceptionally high extension proportion and inborn lean consume which empowers heat dissemination by the overabundance air. A little proficiency misfortune is moreover maintained a strategic distance from contrasted and non-direct-infusion gas motors since unburned fuel is absent during valve cover and in this manner no fuel goes straightforwardly from the admission/infusion to the fumes. Low-speed diesel motors (as utilized in ships and different applications where generally speaking motor weight is moderately insignificant) can arrive at viable efficiencies of up to 55%.

Diesel motors might be planned as either two-stroke or four-stroke cycles. They were initially utilized as a more productive trade for fixed steam motors. Since the 1910s, they have been utilized in submarines and ships. Use in trains, trucks, substantial hardware and power age plants followed later. During the 1930s, they gradually started to be utilized in a couple of autos. Since the 1970s, the utilization of diesel motors in bigger on-street and rough terrain vehicles in the US has expanded. As per Konrad Reif, the EU normal for diesel vehicles represents half of recently enrolled cars.

The world's biggest diesel motors put in help are 14-chamber, two-stroke marine diesel motors; they produce a pinnacle force of right around 100 MW each.

Diesel's idea



Fig: 1.1: Rudolf Diesel's 1893 patent on a rational heat motor

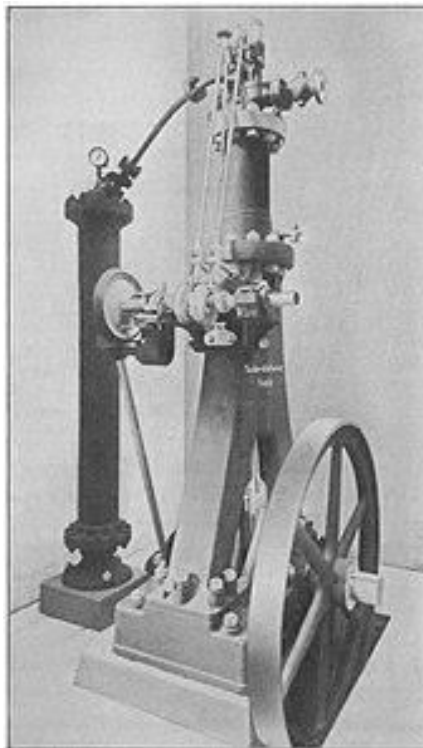


Fig: 1.2: Diesel's first experimental engine 1893

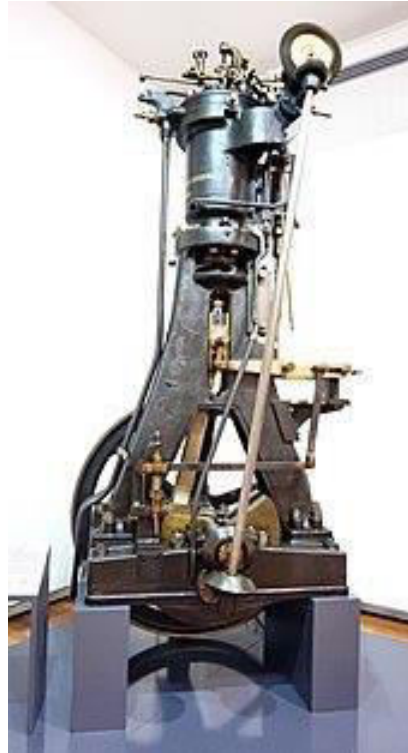


Fig: 1.3: Diesel's second prototype engine 1894

In 1878, Rudolf Diesel, who was an understudy at the "Polytechnikum" in Munich, went to the talks of Carl von Linde. Linde clarified that steam motors are equipped for changing over only 6–10% of the warmth energy into work, however that the Carnot cycle permits transformation of significantly more of the warmth energy into work by methods for isothermal change in condition. As indicated by Diesel, this lighted making an exceptionally proficient motor that could deal with the Carnot cycle. Diesel was likewise presented to a fire cylinder, a conventional fire starter utilizing quick adiabatic pressure standards which Linde had gained from Southeast Asia. After quite a while of chipping away at his thoughts, Diesel distributed them in 1893 in the paper Theory and Construction of the Rational Heat Motor.

Diesel was intensely censured for his exposition, yet just not many found the slip-up that he made; his judicious warmth engine should use a consistent temperature cycle (with isothermal pressure) that would require a lot more significant level of pressure than that required for pressure start. Diesel's thought was to pack the air so firmly that the temperature of the air would surpass that of burning.

By June 1893, Diesel had understood his unique cycle would not work and he embraced the consistent pressing factor cycle. Diesel portrays the cycle in his 1895 patent application. Notice that there could be not, at this point a notice of pressure temperatures surpassing the temperature of burning. Presently it is basically expressed that the pressure should be adequate to trigger start.

Diesel was assaulted and scrutinized throughout a time-frame of quite a long while. Pundits have guaranteed that Diesel never designed another engine and that the innovation of the diesel motor is misrepresentation. Otto Köhler and Emil Capitaine were two of the most unmistakable pundits of Diesel's time. Köhler had distributed an article in 1887, in which he depicts a motor like the motor Diesel portrays in his 1893 exposition. Köhler calculated that such a motor couldn't play out any work. Emil Capitaine had assembled an oil motor with sparkle tube start in the mid 1890s; he asserted contrary to what own might think is best, that his shine tube start motor worked a similar way Diesel's motor did. His cases were unwarranted and he lost a patent claim against Diesel. Different motors, like the Akroyd motor and the Brayton motor, additionally utilize a working cycle that is unique in relation to the diesel motor cycle. Friedrich Sass says that the diesel motor is Diesel's "own special work" and that any "Diesel fantasy" is "adulteration of history".

1.3 TYPES OF FUEL INJECTION

1.3.1 *Air-Blast Injection*

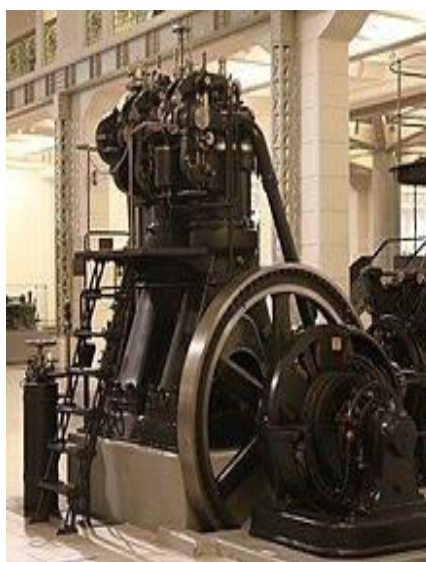


Fig: 1.4: Air-blast injection

Diesel's unique motor injected fuel with the help of compressed air, which atomised the fuel and constrained it into the motor through a nozzle (a comparative standard to an airborne splash). The nozzle opening was shut by a pin valve lifted by the camshaft to start the fuel injection before top dead centre (TDC). This is called an air-blast injection. Driving the blower utilized some force yet the efficiency was superior to the efficiency of some other combustion motor around then. Additionally, air-blast injection made motors hefty and didn't take into account fast burden changes making it unacceptable for street vehicles.

1.3.2 Indirect Injection

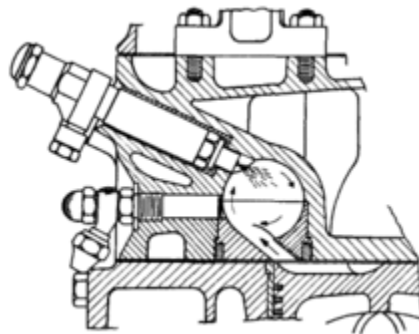


Fig: 1.5: Ricardo Comet indirect injection chamber

An indirect diesel injection framework (IDI) motor conveys fuel into a little chamber called a twirl chamber, precombustion chamber, pre-chamber or ante-chamber, which is associated with the chamber by a tight air section. For the most part the objective of the pre-chamber is to make expanded choppiness for better air/fuel blending. This framework likewise takes into account a smoother, calmer running motor, and on the grounds that fuel blending is helped by choppiness, injector pressures can be lower. Most IDI frameworks utilize a solitary hole injector. The pre-chamber has the impediment of bringing efficiency due down to expanded warmth misfortune to the motor's cooling framework, limiting the combustion consume, in this way lessening the efficiency by 5–10%. IDI motors are additionally more hard to begin and generally require the utilization of sparkle plugs. IDI motors might be less expensive to assemble however by and large require a higher compression proportion than the DI partner. IDI additionally makes it simpler to deliver smooth, calmer running motors with a basic mechanical

injection framework since accurate injection timing isn't as basic. Most present day auto motors are DI which have the advantages of more prominent efficiency and simpler beginning; be that as it may, IDI motors can in any case be found in the numerous ATV and little diesel applications. Indirect infused diesel motors use pintle-type fuel injectors.

1.3.3 Helix-Controlled Direct Injection

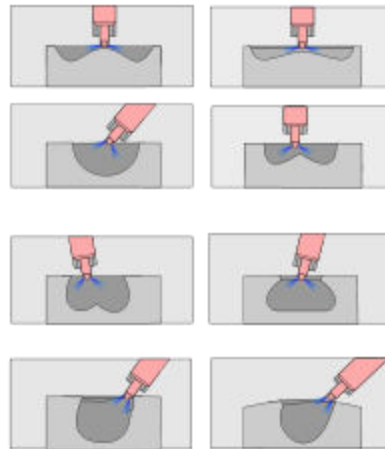


Fig: 1.6: Different types of piston bowls

Direct injection Diesel motors infuse fuel directly into the cylinder. Normally there is a combustion cup in the highest point of the cylinder where the fuel is splashed. Various strategies for injection can be utilized. Generally, a motor with helix-controlled technician direct injection has either an inline or a merchant injection siphon. For every motor cylinder, the relating unclogger in the fuel siphon apportions the right measure of fuel and decides the circumstance of every injection. These motors use injectors that are precise spring-stacked valves that open and close at a particular fuel pressure. Separate high-pressure fuel lines interface the fuel siphon with every cylinder. Fuel volume for each single combustion is constrained by a slanted depression in the unclogger which pivots a couple of degrees delivering the pressure and is constrained by a mechanical lead representative, comprising of loads turning at motor speed compelled by springs and a switch. The injectors are held open by the fuel pressure. On high velocity motors the unclogger siphons are all together. The length of fuel lines from the siphon to every injector is regularly something very similar for every cylinder to get

a similar pressure delay. Direct infused diesel motors for the most part use opening sort fuel injectors.

1.3.4 Common Rail Direct Injection

Common rail (CR) direct injection frameworks don't have the fuel metering, pressure-bringing and conveyance capacities up in a solitary unit, as on account of a Bosch wholesaler type pump, for instance. A high-pressure pump supplies the CR. The prerequisites of every chamber injector are provided from this common high pressing factor repository of fuel. An Electronic Diesel Control (EDC) controls both rail pressing factor and injections relying upon motor working conditions. The injectors of more established CR frameworks have solenoid-driven uncloggers for lifting the injection needle, while more current CR injectors use uncloggers driven by piezoelectric actuators, that have less moving mass and in this manner permit significantly more injections in an extremely brief timeframe. The injection pressing factor of current CR frameworks goes from 140 MPa to 270 MPa.

1.4 NEED FOR ALTERNATE FUELS

At some point, our sources for traditional fuel including petrol would be exhausted. Inferable from the way that these fuels are normally not sustainable, many individuals are concerned that daily would come when the interest for these powers would be more than the stockpile, setting off a significant world emergency. Non-preservationists additionally agree with the assessment that most of the oil fields (arranged in the Middle East) on the planet are related to issues – both political and financial. Deciding another strategy or arrangement as for finding various nations to make new energizes would lessen the distress and struggle to come about because of the world's reliance on fuel supply from the Middle East.

The utilization of elective energizes impressively diminishes hurtful fumes emanations (like carbon dioxide, carbon monoxide, particulate matter, and sulfur dioxide) just as ozone-creating discharges.

1.5 BIO DIESEL & IT'S NECESSITY

Biodiesel is a type of diesel fuel got from plants or creatures and comprising of long-chain unsaturated fat esters. It is commonly made by artificially responding lipids like animal fat, rice bran oil, soybean oil, or some other vegetable oil with alcohol, delivering a methyl, ethyl or propyl ester.

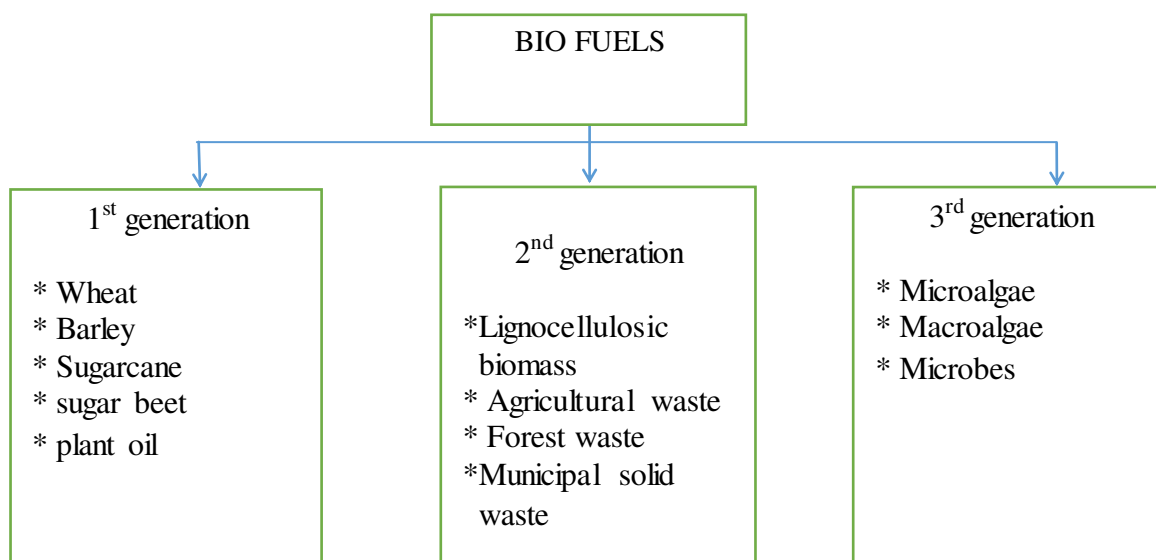


Fig:1.7: Generations of Biodiesel

Unlike the vegetable and waste oils used to fuel changed over diesel engine, biodiesel is a drop-in biofuel, which means it is viable with existing diesel motors and appropriation foundation. Biodiesel can be utilized alone or mixed with petrodiesel to any extent. Biodiesel mixes can likewise be utilized as warming oil.

The US National Biodiesel Board characterizes "biodiesel" as a mono-alkyl ester.

Blends of biodiesel and ordinary hydrocarbon-based diesel are most ordinarily disseminated for use in the retail diesel fuel commercial center. A significant part of the world uses a framework known as the "B" factor to express the measure of biodiesel in any fuel blend:

- 100% biodiesel is referred to as B100
- 20% biodiesel, 80% petrodiesel is referred to as B20

- 5% biodiesel, 95% petrodiesel is referred to as B5
- 2% biodiesel, 98% petrodiesel is referred to as B2

Lapuerta, Magín, et al. "Stability, lubricity, viscosity, and cold-flow properties of alcohol– diesel blends." ,The diesel and bio ethanol blend can be used as alternative as a renewable fraction in automobiles which will grow attention in economic and environmental advantages. The stability will increase when biodiesel is added to the diesel fuel and while adding the alcohols to the blend will loss lubricity of the fuel blend.

1.6 BIO DIESEL SOURCES & CLASSIFICATION

Biodiesel, a biofuel made primarily from oily plants and algae and to a lesser extent from other oily sources (such as waste cooking fat from restaurant deep-frying). Biodiesel, which has found greatest acceptance in Europe, is used in diesel engines and is usually blended with petroleum diesel fuel in various percentages. See *also* renewable energy.

Soybean and oil palm are common plants used in biodiesel production. The use of algae and cyanobacteria as sources for biodiesel holds promise but has been difficult to develop economically. Some algal species contain up to 40 percent lipids by weight, which can be converted into biodiesel or synthetic petroleum. Some estimates state that algae and cyanobacteria could yield between 10 and 100 times more fuel per unit area than plant-based biofuels.

Balabin et al. "Biodiesel classification by base stock type (vegetable oil) using near infrared spectroscopy data." classifies biodiesel according to different classification models.

Delvi, Mohamed Kafeel, et al. "Biodiesel production utilizing diverse sources, classification of oils and their esters, performance and emission characteristics: A research." classifies biodiesel:

Table 1.1 Classification of biodiesel samples by different multivariate methods: regularized discriminant analysis (RDA), partial least squares classification (PLS), K-nearest neighbor (KNN), and support vector machines (SVMs).

	RDA		PLS		KNN		SVM	
	N_{right}/N_0	E	N_{right}/N_0	E	N_{right}/N_0	E	N_{right}/N_0	E
Sunflower	33/44	25%	33/44	25%	38/44	14%	40/44	9%
Coconut	33/40	18%	35/40	13%	40/40	0%	39/40	3%
Palm	34/40	15%	34/40	15%	33/40	18%	35/40	13%
Rapeseed	60/65	8%	63/65	3%	64/65	2%	64/65	2%
Soy	37/40	8%	37/40	8%	35/40	13%	38/40	5%
Cottonseed	28/30	7%	28/30	7%	28/30	7%	30/30	0%
Castor	37/40	8%	38/40	5%	40/40	0%	40/40	0%
Jatropha	25/29	14%	27/29	7%	29/29	0%	29/29	0%
Linseed	25/35	29%	25/35	29%	31/35	11%	30/35	14%
Used frying oil	38/40	5%	40/40	0%	40/40	0%	40/40	0%
Total	350/403	13.2%	360/403	10.7%	378/403	6.2%	385/403	4.5%

Table 1.2 Physiochemical properties of universally used biodiesel feed stocks

Oil or Fats	Density 15 °C (kg/m ³)	Kinetic viscosity at 40°C (mm ² /s)	Cetane No (°C)	Flash Point (°C)	High heating value (MJ/kg)	Cloud point (°C)	Calorific value MJ/kg	Pour point (°C)	Iodine No (°C)	Acid (neutralization) value (mg KOH/g)
Canola	—	4.42	37.6	160	39.7	-3.3	—	-9	—	0.01
Soybean	913.8	4.039	37.9	254	39.6	0.9	39.76	—	128-143	0.266
Sunflower	880	4.439	49	160	39.6	3.4	—	—	—	0.027
Palm	864.42	4.5	54.6	135	—	16	—	15	54	0.24
Peanut	848	4.42	53.59	166	39.8	0	40.1	-8	67.45	0.28
Safflower	885.5	5.8	56	148	—	-5	38.122	—	—	—
Mesua	898	6.2	54	112	39.5	—	42.23	3	—	0.01
Rice Bran	872	4.811	51.6	430	—	—	41.38	269	—	0.48
Maclura	889	4.66	48	180	39.4	-5	—	-9	125	0.4
Cotton seeds	875.7	4.09	51.43	150	39.4	7	40.43	6	—	0.16
Jatropha	879.5	4.8	51.6	135	38.65	2.7	39.23	2	104	0.4
Neem	868	5.213	—	76	—	9	39.81	2	—	0.649
Karanja	931	6.13	55	95	—	7	43.42	3	—	0.42
Mahua	874	3.98	65	208	36.0	—	36.8	6	—	0.41
Linseed	874	3.752	52	160	39.3	-3.8	—	-15	—	0.058
Coconut	807.3	2.726	—	114.8	—	—	—	—	—	0.106
Rapeseed	882	4.43	54.4	170	37.4	-3.3	37	-12	—	—
Tobacco	888.5	4.23	51.6	165.4	—	—	—	—	136	0.3
Beef tallow	—	4.624	—	—	—	—	—	—	—	0.147
Roselle	880.1	4.588	—	130	—	—	—	-1	62	0.43
Okra	876	4.01	55.2	156	—	1.10	—	2.12	—	0.38
Rubber	—	5.81	—	130	—	4	36.5	-8	—	—
Coffee	—	4.852	—	160	—	0.2	—	—	—	0.076
Diesel	850	1.3-4.1	40-55	60-80	42	-20	42-46	-35	38.3	0.062
Calophyllum Inaphyllum	888.6	7.72	51.9	151	—	38	—	—	85	0.76

1.7 ENGINE MODIFICATION.

The CRDI engine blends the fuel in such a way that the engine performance will be improved with a slight change to engine timing, 2 or 3 degrees for a 100% blend. The use of advanced injection timing and increased injection pressure has been known to reduce NOx emissions. Thus a need for engine modification arises.

Szybist et al. "Behavior of a Diesel Injection System with Biodiesel Fuel." Investigated on correlations of injection timing and term were performed for diesel fuel and a scope of biodiesel mixes (B20 to B100). The fuel injector on a 4-stroke, single-chamber, four strength, air-cooled, direct injection diesel motor was situated in a splash chamber while the motor was motored and fuel was conveyed to the injector by the fuel siphon on the motor. Splash perception and measurement of infusion timing were acted in the shower chamber utilizing a motor videoscope, light lessening from a HeNe laser and fuel line pressure, and were synchronized to driving rod position. Movements in infusion timing were seen between the fuel mixes, adding up to a 1 wrench point (CA) degree distinction between diesel fuel and unadulterated biodiesel (B100). Burning investigations were likewise performed to perceive what the move in infusion timing meant for the circumstance of the ignition interaction. There was a development in start of up to 4 CA degrees with B100 which can be credited, at any rate to a limited extent, to the high level infusion timing.

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estimation. A PDA framework was likewise used to describe the conduct of the two energizes with the model injector spouts at surrounding conditions.

Beatrice, C., et al. "Diesel combustion control in common rail engines by new injection strategies." Investigated and found the enhancements of the solenoid injector and of the electronic control unit of the current common rail (CR) injection framework permit the utilization of different successive infusions. On account of this element this high level normal rail framework is equipped for performing up to five back to back injection in a single motor cycle, hence improving control of the burning interaction. Specifically, at some working conditions, enactment of a little infusion after the principle one permits residue delivered in the past phases of the ignition cycle to be oxidized without expanding nitrogen oxide emissions.

Gulzar, M., et al. "Oil filter modification for biodiesel-fueled engine: A pathway to lubricant sustainability and exhaust emissions reduction." In this research paper, two endurance tests were done to assess the novel methodology of solid base oil channel with palm biodiesel filled single-chamber diesel motor. The impacts of solid base channel on grease theology, cylinder ring/chamber wear misfortunes, motor execution and fumes emanations were researched. The aftereffects of long span motor testing showed that the solid base channel improved the ointment's physical and tribological attributes. Tribo-testing, utilizing high stroke responding test rig, demonstrated that the mechanical energy misfortunes because of cylinder ring-chamber association were decreased fundamentally. At last, the motor execution and fumes outflows examination for solid base channel testing showed an improvement in motor execution.

Wang, Wei-Guang, et al. "Emissions from nine heavy trucks fueled by diesel and biodiesel blend without engine modification." This paper depicts an investigation that thought about fumes emanations from being used weighty trucks powered with a biodiesel mix with those from trucks energized with petrol diesel. The biodiesel mix tried is a combination of 35% biodiesel and 65% oil diesel, a mix assigned as B35. The examination depends on the field test results from West Virginia University's Transportable Heavy Duty Chassis Dynamometer Emissions Testing Laboratory and supported by the U.S. Division of Energy. The weighty

trucks we tried performed well when the initially prepared pressure start motor (diesel motor) was energized with B35 with no motor changes. Efficiency (as far as gallon per mile) of the two fills was about something similar. The emanations test results have shown that the substantial trucks powered by B35 produced altogether lower particulate matter (PM) and tolerably lower carbon monoxide (CO) and hydrocarbon (HC) than similar trucks filled by no. 2 diesel (D2). Oxides of nitrogen (NO_x) emanations from B35 and D2, in any case, were by and large in a similar level. Discharges varieties from two diverse motor models and two driving cycles were additionally noticed.

Raheman, H et al. "Performance of diesel engine with biodiesel at varying compression ratio and ignition timing." The presentation of the Ricardo E6 motor utilizing biodiesel acquired from mahua oil (B100) and its mix with high velocity diesel at different pressure proportion (CR), injection timing, and motor stacking has been introduced in this paper. The brake explicit fuel utilization and fumes gas temperature expanded, though brake warm productivity diminished with an increment in the extent of biodiesel in the mixes at all pressure proportions and injection timings (35–45° before TDC) tried. Nonetheless, an opposite pattern for these boundaries was seen with expansion in the CR and progression of injection timing.

1.8 INJECTION TIMINGS AND TYPES

Fuel injection is the presentation of fuel in an inside burning motor, most regularly car motors, by the methods for an injector. All Diesel (pressure start) motors use fuel infusion, and numerous Otto (sparkle start) motors use fuel injection of some sort. The essential contrast among carburetion and fuel infusion is that fuel infusion atomizes the fuel through a little spout under high tension, while a carburetor depends on pull made by consumption air sped up through a Venturi cylinder to bring the fuel into the airstream.

The expression "fuel injection" is ambiguous and contains different particular frameworks with on a very basic level distinctive utilitarian standards. Regularly, the solitary thing in like manner all fuel injection frameworks have is the absence of carburetion. There are two primary practical standards of blend

development frameworks for inward ignition motors, inner combination arrangement and outside combination arrangement. A fuel injection framework that utilizes outside blend development is known as a complex infusion framework; there exist two kinds of complex injection frameworks: multi-point injection (port injection), and single-point injection (choke body injection). Inside blend arrangement frameworks can be isolated into direct, and roundabout injection frameworks. There exist a few distinct assortments of both immediate and circuitous injection frameworks, the most well-known inner blend arrangement fuel injection framework is the regular rail injection framework, an immediate injection framework. The term electronic fuel injection alludes to any fuel injection framework having a motor control unit.

The performance of diesel motors is intensely impacted by their injection framework plan. Truth be told, the most outstanding advances accomplished in diesel motors came about straightforwardly from unrivaled fuel injection framework plans. While the principle reason for the framework is to convey fuel to the chambers of a diesel motor, it is the means by which that fuel is conveyed that has the effect in motor execution, outflows, and commotion attributes.

Not at all like its sparkle lighted motor partner, the diesel fuel injection framework conveys fuel under incredibly high injection pressures. This suggests that the framework part plans and materials ought to be chosen to withstand higher burdens to perform for broadened spans that match the motor's sturdiness targets. More noteworthy assembling accuracy and tight resiliences are likewise needed for the framework to work proficiently. Notwithstanding costly materials and assembling costs, diesel injection frameworks are portrayed by more complex control necessities. Every one of these highlights amount to a framework whose cost may address however much 30% of the complete expense of the motor.

CHAPTER 2

LITERATURE SURVEY

2.1 RICE BRAN BIODIESEL

The world has for sometime witnessed growing concern over the environmental impact and/or exhaust of conventional fossil fuel energy sources . These concerns have highlighted the need for diversification and prompted research worldwide into potential alternative sources of fuel energy for internal combustion (IC) engines . In India, diesel engines, being more efficient and sturdier than spark ignition (SI) engines, are frequently used on farms , in heavy trucks, city transport buses, locomotives, electric generators, farm equipment, underground mine equipment, etc . Diesel used in diesel engines contains higher amounts of aromatics and sulphur, which cause environmental pollution. Properties of biodiesel are similar to mineral diesel and can be used in conventional diesel engines without significant modifications . Biodiesel is synthesized from direct transesterification of vegetable oils, where the corresponding triglycerides react with a short- chain alcohol, usually methanol in the presence of a catalyst.



Fig: 2.1: Rice bran

Zullaikah, Siti, et al. "A two-step acid-catalyzed process for the production of biodiesel from rice bran oil." *Bioresource technology*. A study was undertaken to examine the effect of temperature, moisture and storage time on the accumulation of free fatty acid in the rice bran. Rice bran stored at room temperature showed that most triacylglyceride was hydrolyzed and free fatty acid (FFA) content was raised up to 76% in six months.

Lin, Lin, et al. "Biodiesel production from crude rice bran oil and properties as fuel." This research investigated and successfully reported the production of bio-diesel by process of transesterification of crude rice bran oil (RBO). The method included three steps. Firstly, the definite quantity of RBO was reduced to below 1 mg KOH/g by a two-steps pretreatment process within the presence of a vitriol catalyst. Secondly, the merchandise prepared from the primary process was administered esterification with an alkaline catalyst. The influence of 4 variables on conversion efficiency to methyl ester, i.e., methanol/RBO molar ratio, catalyst amount, reaction temperature, and response time, was studied at this stage.

Chhabra, Mayank et al. "Performance evaluation of diesel engine using rice bran biodiesel." Investigated the utilization of biodiesel from non-eatable oil sources fills in as an option in contrast to this issue. The current examination centers around sway appraisal of rice wheat and unrefined rice grain biodiesel and its mixes with diesel on diesel engine performance. The test examination gives inside and out detail of the biodiesel production process, assessment of fuel properties and effect on motor execution. The examination likewise explores the improvement of the Compression ratio (CR) of a compression start engine fueled with mixes of biodiesel. To discover the ideal CR of the motor, tests were directed at various CRs going from 12 to 18. At that point the analyses were led utilizing B10, B20 and B40 blends of rough rice bran bio-diesel and diesel at CR of 12 and 14 and these outcomes were contrasted and the outcomes acquired when a similar motor was tried on conventional diesel fuel. Additionally the trial consequences of B10, B20 and B40 blends of rice wheat bio-diesel at CR 14 were examined and investigated. In light of the test examination the mixes of unrefined

rice grain bio-diesel can be utilized as fuel in diesel motor without making any alteration to the diesel motor.

Devarajan et al. "Emission analysis on the influence of ferrofluid on rice bran biodiesel." Investigated the expansion in NO_x emission is one of the significant disadvantages for utilizing biodiesel as an option for petrol diesel. A few examinations had been completed to decrease the NO_x emissions level in biodiesel. The current work is the consequence of an endeavor wherein ferrofluid is added to rice grain oil methyl ester in the method of dissecting its impacts on outflow attributes. Magnetite concentrate is exothermic and is known for its attributes of delivering abundant warmth at higher temperatures. Nanofluid utilizing magnetite was blended by responding Iron II (FeCl₂) and Iron III (FeCl₃) in a watery alkali answer for structure Magnetite Fe₃O₄ (Ferro liquid). Arrival of warmth by magnetite during the burning interaction would balance the customary constraints related with biodiesel, for example, expanded defer period, sub-par ignition rate and higher NO_x emanations and so on Investigations were directed with Rice Bran Oil Methyl Ester (RBOME) and Rice Bran Oil Methyl Ester with expansion of ferrofluid (RBOMEF) and are contrasted and oil diesel. RBOMEF was readied containing 97.7% biodiesel, 2% magnetite based ferrofluid and 0.3 % surfactant by volume was utilized in a Compression Ignition motor. The exploratory examination found an abatement in HC, CO and NO_x discharges of 10.8%, 9.1% and 8.49% individually.

Table 2.1 Fatty acids compositions of Rice bran oil

Fatty acids	Percentage	Method
C14:0 Myristic acid	0.8%	Gas-Liquid Chromatography
C16:0 Palmitic acid	21.6%	
C18:0 Stearic acid	2.8%	
C18:1 Oleic acid	37.5%	
C18:2 Linoleic acid	35.4%	
C18:3 α-Linolenic acid	1.9%	

Karthikeyan A., and Jayaprabakar J et al. "Energy and exergy analysis of compression ignition engine fuelled with rice bran biodiesel blends." Investigated successfully on a four-stroke single chamber, water-cooled pressure start (CI) motor combined with a vortex ebb and flow dynamometer. The rice grain oil biodiesel mixes of B10, B20, B30 and unadulterated diesel are tried for its exhibition in the motor. Energy and exergy investigation is completed for the biodiesel mixes and unadulterated diesel. The trial information were gathered utilizing consistent state tests which empower precise estimations of air, fuel and cooling water stream rates, motor burden and every one of the important temperatures. The presentation boundaries, energy and exergy efficiencies were figured for each fuel activity and contrasted and one another. The energy and exergy investigation has made to discover input accessibility, brake power accessibility, cooling water accessibility and fumes gas accessibility. From the exergy investigation, part of major exergy annihilation was found. Equilibriums of energy and exergy rates for the motor were additionally processed.

Prabhu, A., et al. "Experimental investigation of emission characteristics on ricebran biodiesel–alcohol blends in a diesel engine." The current investigation is intended to research and take a gander at impact of biodiesel–propanol and biodiesel–pentanol mixes on emanation attributes of a diesel motor. Examinations were driven on D100 (diesel), B100 (biodiesel), B50 (half biodiesel and half diesel), BPen20 (80% biodiesel and 20% pentanol), BPro20 (80% biodiesel and 20% propanol) at various motor burdens. As for discharge attributes, the effects on CO, HC, Nox and smoke outflows were examined. On considering all motor loads, the BPro20 and BPen20 mixes increment CO emanation by 31.8% and 40.9%, and HC discharge by 25.8% and 8.6%, individually, yet lessens NOx outflow by 14.1% and 8.9%, and smoke outflow by 17.7% and 6.7%, separately. As a rule, the BPro20 mix is further successful in diminishing smoke and NOx outflows while the BPen20 mix would provoke to less augmentation in HC discharges.

2.2 CRDI ENGINE

Common rail is a fuel infusion framework found in current diesel motors. Common rail frameworks give a degree of adaptability which can be abused for class driving emanation control, force and fuel utilization.

The diesel fuel in an electronically controlled motor is put away at variable pressing factor in a chamber or 'rail' associated with the motor's fuel injectors by means of individual lines, making it a 'common rail' to every one of the injectors. The pressing factor is constrained by a fuel pump yet it is the fuel injectors, working in corresponding with the fuel pump, that control the circumstance of the fuel infusion and the measure of fuel infused. Interestingly prior mechanical frameworks depend on the fuel pump for pressing factor, timing and amount.

In spite of gas motors, diesel motors needn't bother with a burning framework due to the inborn properties of diesel, the ignition interaction will consequently happen under certain tension and temperature toward the finish of the diesel cycle. Typically, this cycle requires a high pressure proportion of around 22: 1 for a non-turbocharged engine. Additionally, it is important to have a medium and weighty machine case and square to deal with high fire pressure. Thus, diesel motors are consistently bulkier than petroleum motors of same limit. From one perspective, high pressing factor and substantial cylinders maintain a strategic distance from diesel motors from pivoting at high paces like petroleum motors (In most diesel motors the greatest force stays under 4,500 rpm). CRDI represents Common Rail Direct Injection that implies, direct infusion of fuel into the chambers of a diesel motor through a solitary, basic line, called the normal rail which is associated with all the fuel injectors. Regular rail direct infusion is an immediate fuel infusion framework utilized for diesel motors. CRDI framework utilizes a particle sensor to give the continuous burning information for singular chamber. The normal rail upstream of the chambers goes about as a gatherer which circulates the fuel to the injectors at a steady pressing factor up to 1600 bar. A typical rail and injector is constrained by motor ECU (Electrical Control Unit) with many info sensors in HSDI (High Speed Direct Injection) diesel motor. The motor ECU assumes the main part in controlling the diesel motor. The framework design incorporates high pressing factor siphon, rail and lines, injector, ECU, and sensors. Hardware has significantly added to the advancement of inward ignition motor. This advancement has brought about diminishing ecological corruption, but then proceeding to help upgrades in execution.

Gangwar, Jitendra et al. "Composition and comparative toxicity of particulate matter emitted from a diesel and biodiesel fuelled CRDI engine." In the current investigation, parametric examinations were done using a CRDI (Common Rail Direct Injection) diesel motor worked at various burdens at two diverse motor rates (1800 and 2400 rpm), utilizing diesel and 20% biodiesel blends (B20) created from Karanja oil. An incomplete stream weakening passage was utilized to gather and quantify the mass of the essential particulates from diesel and biodiesel mix gathered on a 47 mm quartz substrate. The gathered PM (particulate matter) was exposed to synthetic investigations to survey the sum of Benzene Soluble Organic Fraction (BSOF) and follow metals utilizing Inductively Coupled Plasma-Optical Emission Spectrometer (ICP-OES). For both diesel and biodiesel, BSOF results showed diminishing levels with expanding motor burden. B20 showed higher BSOF when contrasted with those deliberate with diesel.

Kim, Hwanam,et al. "The effect of biodiesel and bioethanol blended diesel fuel on nanoparticles and exhaust emissions from CRDI diesel engine." Investigated and found the response qualities of nanoparticles on the impetus, and the fumes outflow attributes when a typical rail direct infusion (CRDI) diesel motor is run on biofuel-mixed diesel energizes. In this examination, the motor presentation, outflow qualities, and molecule size conveyance of a CRDI diesel motor that was furnished with a warm-up exhaust systems or a catalyzed particulate channel were inspected in an ECE (Economic Commission Europe) R49 test and an European fixed cycle test. The motor presentation under a biofuel-mixed diesel fuel was like that under D100 fuel, and the high fuel utilization was because of the brought down calorific worth that resulted from blending in with biofuels. The utilization of a biodiesel–diesel mix fuel decreased the all out hydrocarbon and carbon monoxide discharges yet expanded nitrogen oxide (NO_x) emanations because of the expanded oxygen content in the fuel. The smoke outflow was decreased by half with the utilization of the bioethanol–diesel mix. Emanation transformation efficiencies in the WCC and CPF under biofuel-mixed diesel energizes were like those under D100 fuel.

Yoon, Maru et al. "A method for combustion phasing control using cylinder pressure measurement in a CRDI diesel engine." Investigated and found

the start of combustion (SOC) in the combustion chamber has a significant impact upon all exhibitions of the motor. In this paper, chamber pressure was researched as a methods for the shut circle SOC control of a typical rail direct injection diesel motor. To recognize the SOC, the wrench point position where the distinction pressure became 10 bar was chosen as the pressing factor variable. Utilizing this pressing factor variable as a criticism variable, a versatile feedforward control was proposed. The feedforward regulator comprised of the outspread premise work organization and the input blunder learning strategy, which was utilized for the preparation of the organization. The proposed SOC control technique showed a far superior guideline execution than that of the direct input regulator. A further expansion of the system dependent on the individual chamber pressure criticism, the individual chamber SOC control technique, successfully diminished chamber by-chamber SOC variety in consistent and transient motor tasks.

Ganser et al. "Common rail injectors for 2000 bar and beyond." Investigated and found the high injection pressures are an absolute necessity in the present DI diesel motor fuel injection frameworks. The Common Rail injection framework, presented in large scale manufacturing around 2 1/2 years prior, will follow the pattern substantial for other fuel injection gear, which calls for ever higher pressing factors. A CR injector plan appropriate for injection pressing factors of 2000 bar or more is introduced in this paper. As indicated by this plan, injector models reasonable for traveler vehicle and heavy duty truck applications have been figured it out.

2.3 ENGINE MODIFICATION

The CRDI engine blends the fuel in such a way that the engine performance will be improved with a slight change to engine timing, 2 or 3 degrees for a 100% blend. The use of advanced injection timing and increased injection pressure has been known to reduce NOx emissions. Thus a need for engine modification arises.

Saravanan, C. G., et al. "Impact of fuel injection pressure on the engine characteristics of CRDI engine powered by pine oil biodiesel blend." This paper zeroed in on amplifying the pine oil biodiesel utilization in a diesel motor having

common rail direct injection (CRDI) framework with no motor adjustments. Pine oil got from pine tree saps, has shown great fuel properties, for example, lower consistency, streak point, limit and practically identical calorific worth to diesel. In this examination, the effect of high fuel infusion tension on the motor qualities of a diesel motor powered by 30% pine oil biodiesel blend (P30) was dissected. At standard 200 bar fuel infusion pressure, the brake thermal efficiency (BTE) of P30 biodiesel mix was diminished contrasted with sole diesel. To improve the usage and execution of the P30 mix, fuel infusion pressure expanded from 200 bar to 350 bar at a stage of 50 bar. The outcomes show that BTE and ignition qualities are improved with an expansion in infusion pressure.

Szybist et al. "Behavior of a Diesel Injection System with Biodiesel Fuel." Investigated on correlations of injection timing and term were performed for diesel fuel and a scope of biodiesel mixes (B20 to B100). The fuel injector on a 4-stroke, single-chamber, four strength, air-cooled, direct injection diesel motor was situated in a splash chamber while the motor was motored and fuel was conveyed to the injector by the fuel siphon on the motor. Splash perception and measurement of infusion timing were acted in the shower chamber utilizing a motor videoscope, light lessening from a HeNe laser and fuel line pressure, and were synchronized to driving rod position. Movements in infusion timing were seen between the fuel mixes, adding up to a 1 wrench point (CA) degree distinction between diesel fuel and unadulterated biodiesel (B100). Burning investigations were likewise performed to perceive what the move in infusion timing meant for the circumstance of the ignition interaction. There was a development in start of up to 4 CA degrees with B100 which can be credited, at any rate to a limited extent, to the high level infusion timing.

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worldwide shower information appropriate for tuning direct infusion frameworks to such powers and for mathematical codes approval. A scattering investigation among various planes was additionally performed, alongside the infusion rate estimation. A PDA framework was likewise used to describe the conduct of the two energizes with the model injector spouts at surrounding conditions.

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assigned as B35. The examination depends on the field test results from West Virginia University's Transportable Heavy Duty Chassis Dynamometer Emissions Testing Laboratory and supported by the U.S. Division of Energy. The weighty trucks we tried performed well when the initially prepared pressure start motor (diesel motor) was energized with B35 with no motor changes. Efficiency (as far as gallon per mile) of the two fills was about something similar. The emanations test results have shown that the substantial trucks powered by B35 produced altogether lower particulate matter (PM) and tolerably lower carbon monoxide (CO) and hydrocarbon (HC) than similar trucks filled by no. 2 diesel (D2). Oxides of nitrogen (NO_x) emanations from B35 and D2, in any case, were by and large in a similar level. Discharges varieties from two diverse motor models and two driving cycles were additionally noticed.

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2.4 INJECTION TIMINGS

The performance of diesel engines is heavily influenced by their injection system design. In fact, the most notable advances achieved in diesel engines resulted directly from superior fuel injection system designs. While the main purpose of the system is to deliver fuel to the cylinders of a diesel engine, it is how that fuel is delivered that makes the difference in engine performance, emissions, and noise characteristics.

Agarwal, Avinash Kumar, et al. "Effect of fuel injection pressure and injection timing on spray characteristics and particulate size–number distribution in a biodiesel fuelled common rail direct injection diesel engine." In this paper, impact of shifting fuel infusion pressing factors and infusion timings on particulate size number appropriation and splash qualities was explored in a solitary chamber, regular rail direct infusion (CRDI) pressure start (CI) Effect of infusion tension on shower attributes of biodiesel mixes and diesel. The features are Effect of infusion pressing factor and SOI timing on particulate discharges. Shower tip entrance was longer at higher fuel infusion pressures. Particulate size expanded with impeding SOI timings. Particulate number focus was most reduced for KOME10.

Khandal et al. "Effect of exhaust gas recirculation, fuel injection pressure and injection timing on the performance of common rail direct injection engine powered with honge biodiesel (BHO)." *Energy* 139 (2017): 828-841. The investigation successful highlights that Honge biodiesel was utilized for its plausibility concentrate in CRDI motor. TRCC shape upgraded air-fuel blending and improved ignition. Improved BTE and brought down Emissions were gotten at IP of 900 bar and IT of 10° BTDC. Work of EGR further diminished NOx discharges of CRDI motor. NOx outflow decreased by 36.9% with 15% EGR yet 21% is ideal.

Geng, Limin, et al. "Effects of injection timing and rail pressure on combustion characteristics and cyclic variations of a common rail DI engine fuelled with FT diesel synthesized from coal." The investigation successful highlights that expanding RP brings about higher BTE, though propelling IT first builds BTE and afterward diminishes it. Propelling IT initially abbreviates IDP and afterward draws out it, while it has the contrary impact on CD. At low loads, PPRR and PHRR of F-T diesel are 32.72% and 32.13% lower than that of diesel. Propelling infusion timing or expanding motor burdens can improve burning security. F-T diesel has lower cyclic varieties because of better unpredictability and higher fuel reactivity.

2.5 DIFFERENT INJECTIONS & INJECTION MASS

Fuel injection is the presentation of fuel in an inside burning motor, most regularly car motors, by the methods for an injector. All Diesel (pressure start) motors use fuel infusion, and numerous Otto (sparkle start) motors use fuel injection of some sort. The essential contrast among carburetion and fuel infusion is that fuel infusion atomizes the fuel through a little spout under high tension, while a carburetor depends on pull made by consumption air sped up through a Venturi cylinder to bring the fuel into the airstream.

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Dober, Gavin, et al. "The impact of injection strategies on emissions reduction and power output of future diesel engines." This paper successful investigates present Delphi's advancements in fuel injection techniques for light and medium obligation diesel motors that will follow future emission legislation, while giving higher force density and positive mileage.

Moreno, Carlos et al. "Influence of small pilot on main injection in a heavy-duty diesel engine." In this paper the variables affecting the impact of pilot-injection on principle injection burning were explored utilizing heat discharge

investigation in a substantial diesel motor fuelled with standard diesel fuel, and remembered the impact of those elements for motor execution and emanations. Blends of pilot injection boundaries for example pilot beginning of injection, pilot mass, pilot-primary injection partition, and rail pressure were read for different working conditions and burning stages. It was inferred that the impact of pilot-injection ignition on principle injection can be considered dependent on the period of pilot burning toward the beginning of fundamental injection. Four cases were distinguished: a) primary injection during the blending period of pilot injection; b) principle injection during the premixed period of pilot ignition; c) fundamental injection during the diffusive period of pilot burning and d) fundamental injection after pilot burning was finished. The impact of pilot injection was represented by the theoretical model of collaboration modes. This methodology has the benefit that the impact of every mode on the principle injection is free of the pilot injection boundaries. For burning control dependability and combination reasons, it is imperative to consider the change between the four diverse association modes as to differences in the chamber conditions, pilot infused mass and pilot injection ignition.

Babu, J. M., et al. "Analysis on the effect of pilot injection strategies on combustion and emission characteristics of palm-munja biodiesel/diesel blend on CRDI diesel engine." This paper investigates that the multiple injection procedure can upgrade the air/fuel blend, ignition and fumes emanation qualities by giving a limited quantity of fuel before the primary injection. Among a wide range of substitute energizes, biodiesel has arisen as an eco-accommodating fuel for the diesel motors. This paper is zeroing in on the impact of pilot injection techniques on diesel motor say timing (-30° BTDC to -50° BTDC) and by changing the fuel amount (5–15%). The exhibition, ignition and discharge qualities of Palm-munja biodiesel/diesel mix (B20) were researched on CRDI diesel motor. The experimentations were done on a steady speed by shifting burdens from 0 to 100%. The trial results show that as an expansion in pilot injection timing there is a decrease in the in-chamber pressure, while ash and NO_x emissions decline as the pilot injection timing increments. As the pilot injection fuel amount builds, the in-chamber pressing factor and NO_x emission increment, though sediment emanation diminishes.

Shayler, P. J., et al. "The influence of pilot and split-main injection parameters on diesel emissions and fuel consumption." The paper traces trial examinations of fuel injection methodologies which are conceivable utilizing high pressing factor common rail fuel injection frameworks. Methodologies utilizing a split main with a pilot injection have been investigated. The procedure factors were the proportion of the first to second piece of the main, the partition among these and the circumstance of the beginning of main injection. Fumes gas distribution rate was a fourth factor. Pilot injection amount and timing, and rail pressure were held consistent. The effect on emissions and specific fuel consumption is portrayed and the strategy for upgrading settings is illustrated. The control of fuel injection settings to best meet streamlining focuses for emissions and specific fuel consumption is portrayed. The advantages contrasted with results for improved single main injection are depicted, as are issues of technique power.

2.5.1 *Injection Mass*

İçingür, Y., & Altıparmak, D. (2003) has found that when the injection pressure was increased to 250bar the smoke emissions levels were observed to be low, it is because of the smaller drop size of the fuel injection (better atomization).

Kannan GR, Anand R. "Effect of injection pressure and injection timing on DI diesel engine fuelled with biodiesel from waste cooking oil." Has observed a remarkable increase in efficiency of performance, combustion and emission characteristics. They also found that the optimal injection pressure for diesel engine fueled with diestrol fuel is 240 bar.

Choi et al. "An experimental study on the effects of oxygenated fuel blends and multiple injection strategies on DI diesel engine emissions." This paper demonstrates that at high loads, split injection had an extra positive impact on sediment emissions when contrasted with single injections, yet the residue decreasing impact of the oxygenates was not as set apart as that seen with the single injection cases. This outcome demonstrates that the ash decrease because of the expansion of oxygenate to the fuel is best in rich ignition as split injections are known to be viable at inclining out the charge. Indeed, at low motor burdens

when the general blend is additionally inclined out, the oxygenated fills had just a slight impact on particulate emissions. Split injections were successful in diminishing particulate emissions at low loads especially at cutting edge fuel injection timings when in general temperatures would be relied upon to be higher.

CHAPTER 3

AIM AND SCOPE

3.1 AIM OF THE PROJECT

In this project we are going to Compare the analysis of using main, split, pilot , post injection in CRDI engine and find out the which one is best and also To compare the emission results of our experiment(B20) to that of the emission results of an CRDI diesel engine.

To compare the performance of the prepared Fuel with different types of fuel injection.

3.2 SCOPE OF THE PROJECT

- To investigate the effect and efficiency of different types of injection methods in an diesel engine operated with a high performance diesel blends.
- To achieve a maximum efficiency during injection of fuel present during the process.
- To compare the results of our experiment(high performance diesel blends) to that of an results of an normal diesel engine.
- To compare the performance of the prepared blend with and without main, post, split and pilot injection.
- Experiments will be carried out in a single cylinder CRDI research engine in multiple injection mode at 2000 bar fuel injection pressure (FIP) under varying start of pilot injection (SOPI) and start of main injection (SOMI) timings.

CHAPTER IV

MATERIALS AND EXPERIMENTAL METHOD

4.1 WORK PHASE

First we prepared Bio fuel by Transesterification at IRC Sathyabama Institute of Science and Technology. A 5L RB20 oil blend blend was prepared using 80% of pure diesel (4L) and 20% of bio-diesel (1L of rice-bran oil). The prepared oil blend was then taken to Kanchipuram for engine testing which was successfully carried out and the results were obtained and analyzed. Then the corresponding graphs were plotted according to the result obtained from engine testing using the Origin pro 2019 software. The graphs for performance, emission and combustion were plotted and the results were concluded.

4.2 MATERIALS USED

For the preparation of the blends alcohol, pure diesel, biodiesel, and oil are required. This procedure includes the usage of Rice-bran oil, similarly, methanol is used as the alcohol used in the transesterification process. the detailed experimental methodology proposed for the researched work is illustrated in the details of materials required, methods applied, specifications of the instruments used, working principles and the experimental procedures by which the research has been conducted are explained in this chapter.

- Alcohol - Methanol
- Oil – Rice Bran oil (1L)
- Catalyst – NaOH (Sodium hydroxide)
- Diesel (5L)
- CRDI Engine

4.3 METHODOLOGY



Fig: 4.1: Experimental Methodology

4.3.1 Transesterification Process

Transesterification is a reversible reaction in which the fatty acids, alcohol, and a catalyst are mixed together. As a catalyst, we can use either a solid base or a strong acid. Sodium hydroxide or potassium methanolate is 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 the formation of esters.



Fig: 4.2: Transesterification process

Table 4.1: Transesterification properties of ricebran 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 %

4.3.2 Process of Preparing Fuel Blends

The pure diesel gives more emissions and also it is biodegradable and non-renewable fossil fuel. The alternative biofuel is prepared by the transesterification process but that biofuel cannot use directly in the compression ignition engine. Thus the biofuel is blended with diesel and alcohol with some rice-bran oil because this blend will give best performance, combustion and emission characteristics according to many literature papers. So the diesel is taken from the Indian petrol bunk near Satyabhama institute of science and technology, the rice bran oil was also bought from oil shop in Chennai. 5 liters of three blends are prepared by adding 4 liters of diesel (80%), and 1 liter of rice bran oil biofuel (20%). the components are measured by using measuring jar and using funnel the

blends are prepared in a bottle. So totally 3 bottles of 5000ml each blends are prepared. This is prepared using rice bran oil which is not an edible oil. B20 is a common blend because it represents a good balance of cost, emissions, cold-weather performance, materials compatibility, and ability to act as a solvent. We used Rice bran oil, Methanol as alcohol, NaOH as catalyst for preparing the blend. The B20 blend was prepared in the IRC, Sathyabama Institute of Science and Technology, Chennai.



Fig: 4.3 : Separation of glycerin from Bio-diesel.



Fig: 4.4: Mixing of Catalyst with alcohol

Table 4.2: Properties of Blends

PROPERTIES	RB20	RB100	D100
DENSITY @20C,kg m ³	0.8524	0.882	0.845
Kinematic viscosity	1.69	8.4	0.84
Flashpoint,°C	153	221	52
Calorific value cal/g	9842.6+	8642.63	10143.916

4.4 ENGINE TESTING AND ANALYSIS

The experimental research was done in a single cylinder, four stroke diesel engine connected to an eddy current type dynamometer for loading. For the combustion pressure and crank angle measurements necessary instruments were provided.

Process

- Pure Diesel is termed as B0 or D100 and Pure Bio-diesel is termed as B100, for a B20 fuel, a blend 1 liter of bio-diesel and 4 liters of diesel is used.
- The prepared 5L blend of fuel is injected into 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 analyzed through the Lab view IC Engine Combustion Analysis.
- Then 4 set of readings are taken with pilot injection 20% and main injection 40% at pilot mass 10, 15, 20 and 25.
- 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

4.4.1 Engine Details.

The engine specifications that was used to carry out the various test are mentioned in the table

Table 4.3: Engine specifications

Cooling	Water-cooled engine
Model	Kirloskar TV1
No.of.Cylinders	1
Cubic Capacity (liter)	0.661
Rated Speed (rpm)	1500
Governing	Class "A2/B1"
Power	5.20KW
Power Rating	7 hp
Cylinder bore	87.50mm
Stroke length	110.00mm
Connecting rod length	234mm
Compression ratio	17.50
Swept volume	661.45cc
Over all dimensions	Width 2000*length2500*height1500mm.

4.4.2 Schematic Diagram of Engine



Fig: 4.5, Fig 4.6 and Fig 4.7 Testing engine

TEST RIG COMPONENTS

The test rig consists of a single-cylinder four-stroke diesel engine which is connected to the following components in the order specified below

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



Fig: 4.8: Smoke meter and Gas Analyzer

The fig 4.6 shows a gas analyzer and a smoke meter. The diesel exhaust smoke meters are also known as opacity meters which identify and measure the amount of light blocked in a sample of smoke given out by diesel engines. The smoke meter displays the smoke density giving the rate of the efficiency of the combustion. The smoke meter consists of an optical unit mounted inside a measuring head which also has a separate electrical control unit. The gas analyzers are of the principle that the absorption of light by the gas under test. The analyzer only needs to shine a beam of light via the unheated chamber then it is measured to understand how much, the specific wavelength was observed by the sample. The analyzer consists of an optical filter that cancels out all light leaving the wavelength that the selected gas molecule can observe. Other gas molecules will not absorb light at this particular wavelength, and they don't even affect the amount of light reaching the detector.

Table 4.4: Properties of diesel

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 4.5: Properties of rice-bran oil

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 4.6: Properties of rice-bran bio-fuel

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

CHAPTER 5

RESULTS AND DISCUSSION

5.1 PERFORMANCE GRAPHS

5.1.1 *Brake Thermal Efficiency*

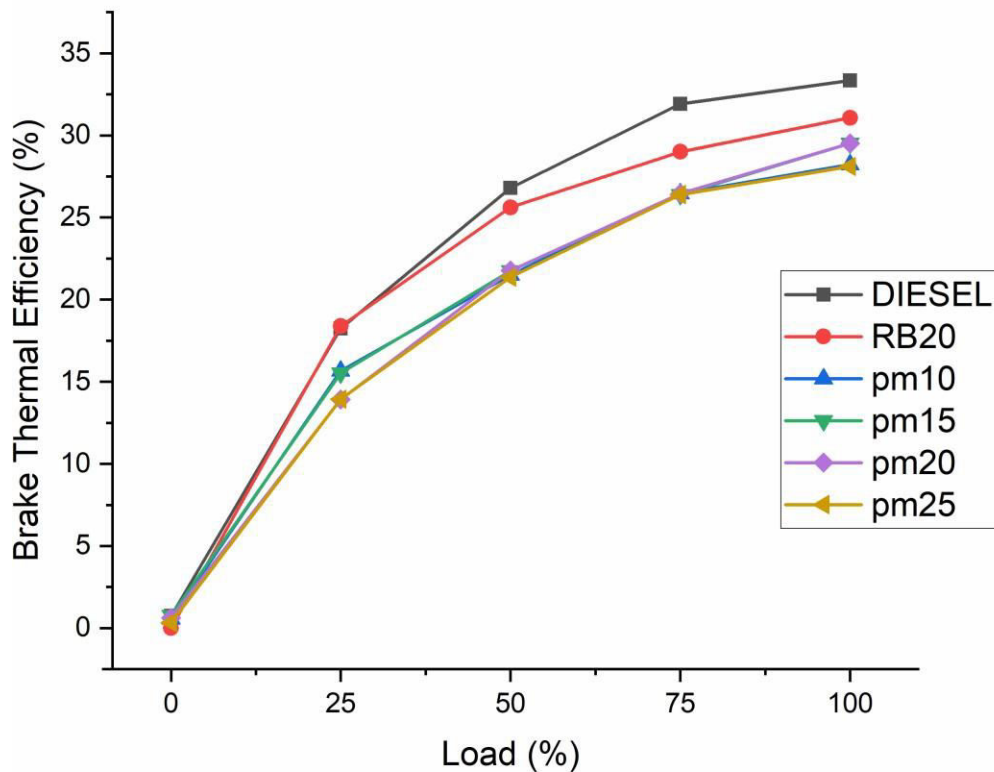


Fig: 5.1: Brake Thermal Efficiency

Brake Thermal Efficiency is referred as the break power of a heat engine as a function of the thermal input from the fuel. It is used to evaluate the potential of an engine to convert the heat from fuel into mechanical energy. The BTE is mainly affected by fuel properties such as density and heating values.

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 RB20, pm10, pm15, pm20, pm25. But it is finally observed that pm10, pm15, pm20, pm25 has same brake thermal efficiency. Whereas diesel has the highest brake thermal efficiency followed by RB20 throughout the entire loading.

5.1.2 Exhaust Gas Temperature

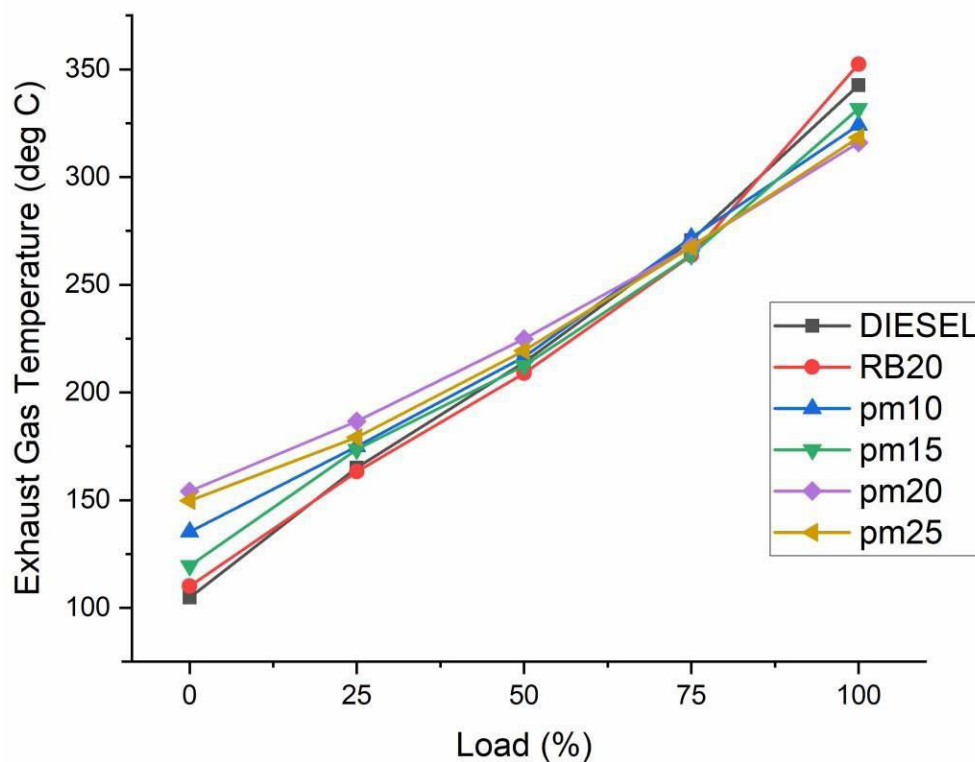


Fig: 5.2: Exhaust Gas Temperature

The exhaust gas temperature (EGT) is defined as the temperature of the gas at the exit of the turbine. An exhaust gas temperature gauge or sensor is a meter used to monitor the exhaust gas temperature of an internal combustion engine. It measures gas temperature at the manifold of the engine. For the proper

functioning of the catalytic converter in an internal combustion engine, exhaust gas temperature (EGT) is required.

The Exhaust Gas Temperature varies from about 200 degrees Celsius to 500 degrees Celsius. The above graph 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. It is observed that the Exhaust gas temperature is increasing with increase in loads. RB20 has more Exhaust Gas Temperature at higher loads where RB20 at 25% load has lowest Exhaust Gas Temperature.

5.1.3 Volumetric Efficiency

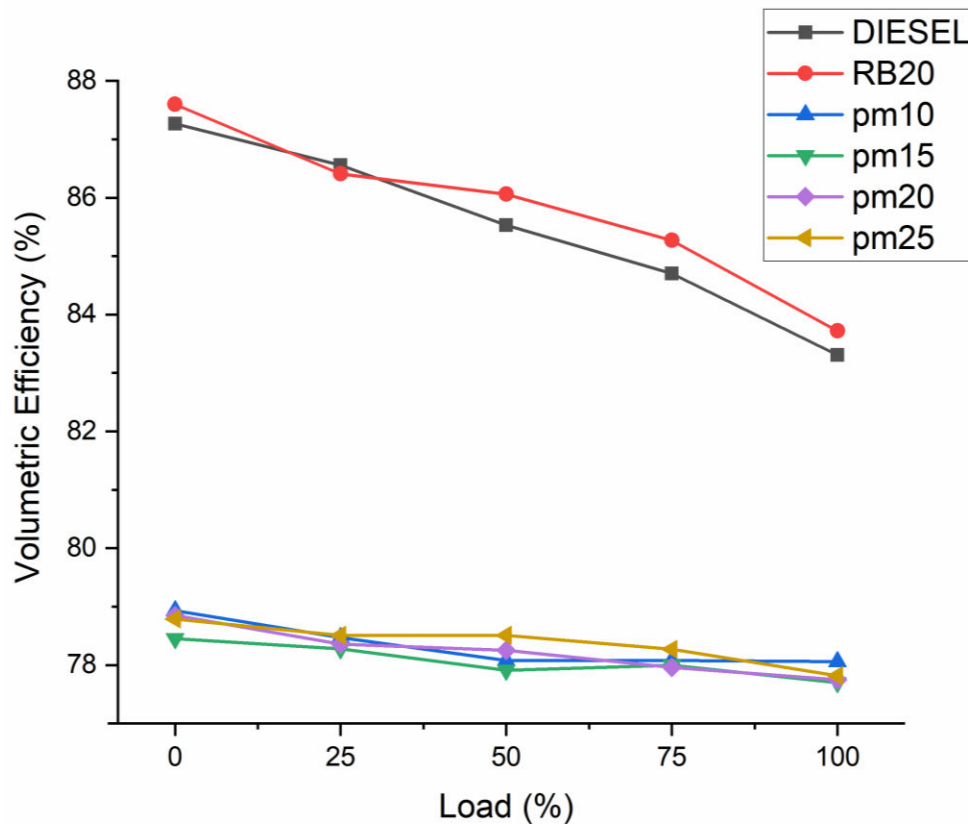


Fig: 5.3: Volumetric Efficiency

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

The above graph 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 RB20 has the highest volumetric efficiency when compared to Diesel and other fuels. It is observed that pm10, pm15, pm20, pm25 has the lowest volumetric efficiency at any given load. The RB20 shows good result concerning volumetric efficiency, even from lower loads to higher loads.

5.1.4 Specific Fuel Consumption

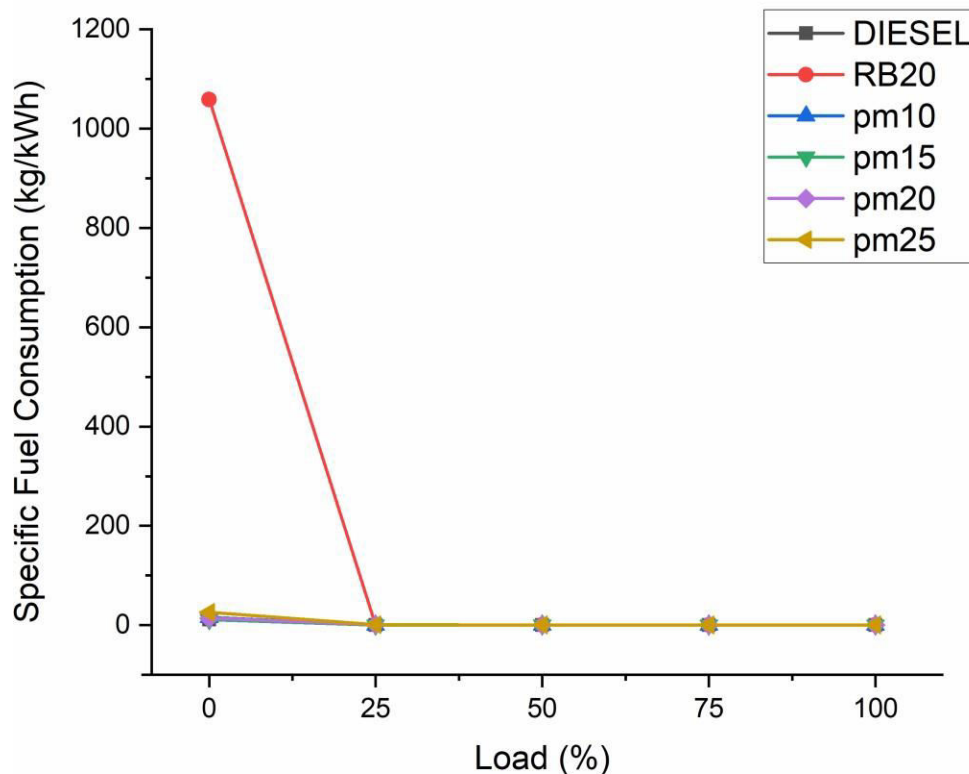


Fig: 5.4: Specific Fuel Consumption

Specific Fuel Consumption is defined as the amount of fuel that is consumed by a vehicle for each unit of power output. The Specific Fuel Consumption of an engine is the rate of fuel burnt to produce a unit of thrust. This is used to compare the efficiency of IC engines with shaft output. Lower the specific fuel consumption, higher mileage of the vehicle.

The fuel's property like heating value will vary the amount of specific fuel consumption value with reference to the above graph 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. The SFC decreases drastically with increase in loads. The RB20 at 0% load has more specific fuel consumption than others. As the load increases the specific fuel consumption falls almost to zero. Finally at 100% load diesel, RB20, pm10, pm15, pm20, pm25 values are at zero as they are similar to each other.

5.2 EMISSION CHARACTERISTICS

5.2.1 Carbon Monoxide (CO)

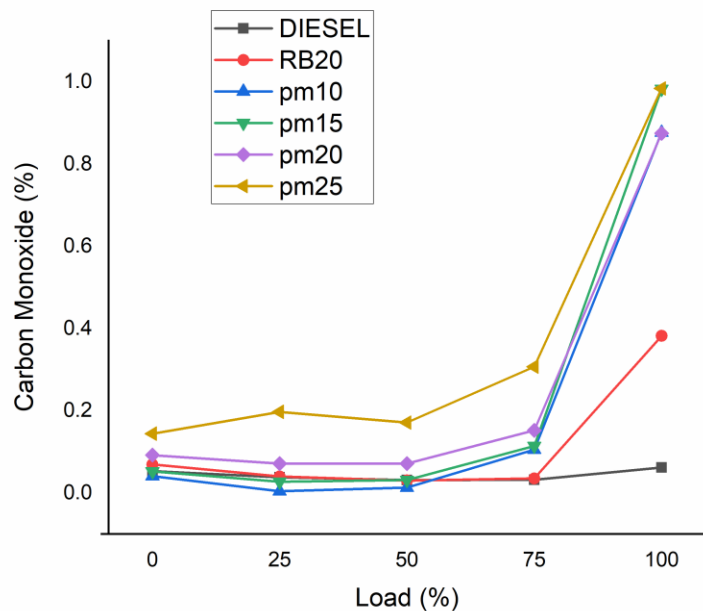


Fig: 5.5: Carbon Monoxide (CO)

CO is a colourless, odourless gas. When inhaled in large amounts, it is extremely dangerous. It is extremely dangerous to all living things. When something is burned outside, it is produced. It is primarily caused by automobile emissions and the burning of fossil fuels. CO poisoning decreases the amount of oxygen carried by the bloodstream, which can lead to unconsciousness and death. Carbon monoxide emissions at different loads are depicted in the graph above.

The graph depicts the various loads on the x-axis and CO emissions on the y-axis. Diesel, RB20, pm10, pm15, pm20, and pm25 have the lowest CO emissions from 0 to 75 percent load. Carbon Monoxide emissions increase gradually at higher loads. Throughout the graph pm25 shows the highest CO emission when compared to others. At 100% load the CO emission drastically increases.

5.2.2 Carbon Dioxide (CO₂)

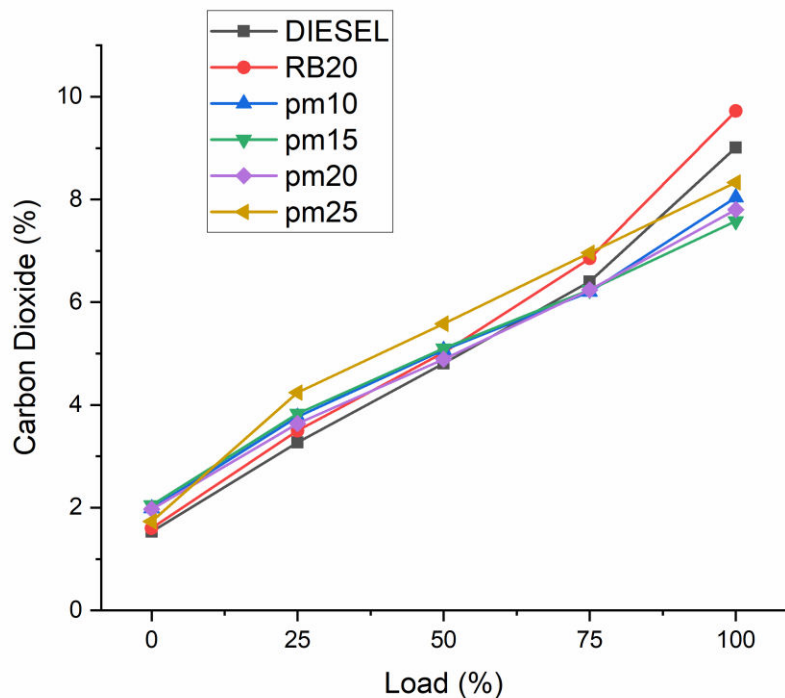


Fig: 5.6: Carbon Dioxide (CO₂)

Global climate change is mostly caused by carbon dioxide emissions. It is generally acknowledged that, in order to prevent the worst effects of climate change, the planet must reduce emissions as soon as possible. The combustion of fossil fuels, vehicle emissions, and other human-made sources of carbon dioxide emissions are the most common. This could result in climate change, respiratory problems, and air pollution. Carbon Dioxide emissions at different loads are depicted in the graph above.

The graph depicts the various loads on the x-axis and carbon dioxide emissions on the y-axis. From the values obtained from engine testing, the emission characteristics of carbon dioxide are analysed and discussed. Initially Diesel has less CO₂ emission when compared to other fuels. At higher loads, RB20 and diesel emit the most CO₂, while pm10, pm15, pm20, and pm25 emit the least CO₂.

5.2.3 Oxides of Nitrogen (NO_x)

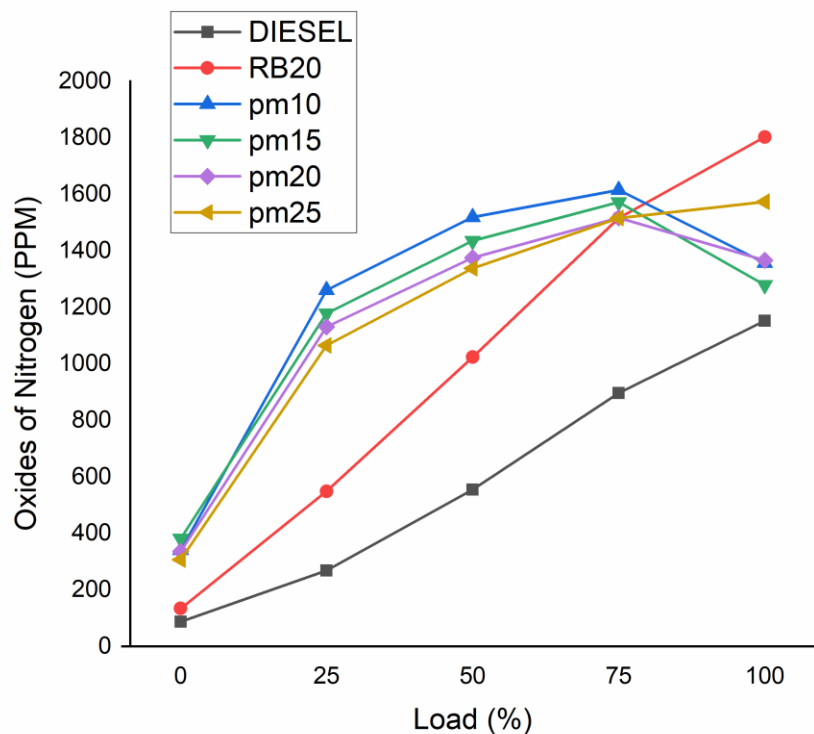


Fig: 5.7: Oxides of Nitrogen (NO_x)

Nitrogen oxides are highly reactive and toxic gases. When fuel is burned at high temperatures, these gases are produced. Automobiles, trucks, and other non-road vehicles all emit NO_x emissions (example construction equipment, boat). It appears to be a brownish gas. On hot summer days, it emits smog. It is extremely dangerous to all living things and can result in death. NO_x pollutants are made up of nitrogen oxides such as nitrogen dioxide and nitrogen oxide.

The graph above depicts the emissions of Nitrogen Oxides at different loads. The graph depicts the various loads on the x-axis and NO_x emissions on

the y-axis. NOx pollutants, also known as oxides of nitrogen, are one of an IC engine's pollution characteristics. Diesel and RB20 have the lowest NOx emission values at 0 % load, while RB20 has the highest value at 100% load. We can also notice that pm10, pm15, pm20, pm25 have a higher NOx emission value between the loads 0 to 100 percent load and then decline at maximum load (100%) whereas diesel and RB20 show a steady increase in NOx emission value. RB20 holds the most NOx emission when it is fully loaded (100%), With rising load RB20 and diesel emission value increases.

5.2.4 Hydrocarbon Emission (HC)

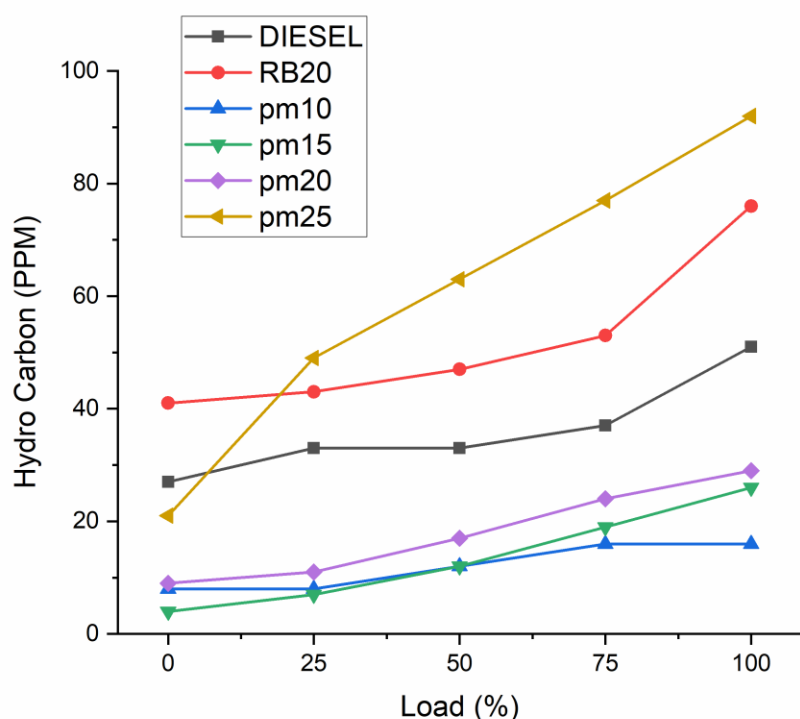


Fig: 5.8: Hydrocarbon Emission (HC)

The main source of Hydro Carbon is incomplete combustion of fuel in the combustion chamber. It has an impact on all mammals. As a result, it's critical to keep this emission as low as possible. It's simply un-burned fuel pumped directly into the exhaust system. Because of the poor ignition of the fuel, a large amount of HC is released into the atmosphere. It is extremely dangerous for

humans because inhaling this gas causes red blood cell depletion, that further leads to death.

The graph above depicts the hydrocarbon emissions at different loads. The graph is drawn between the various loads on the x-axis and the HC emissions on the y-axis. The amount of HC emission increases as the load increases. At 0% load RB20 has highest value but at 100% pm25 has the highest HC emission followed by RB20 and diesel. The Hydrocarbon emissions is drastically reduced with pm10, pm15 and pm20 respectively.

5.2.5 Smoke Opacity

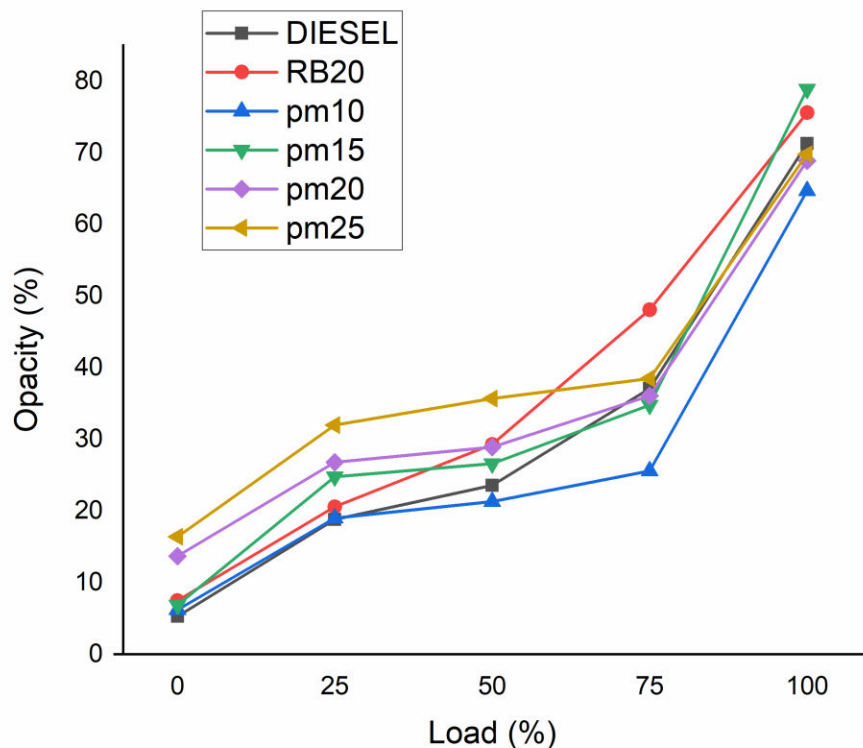


Fig: 5.9: Smoke Opacity

It is a type of emission particle formed as a result of fuel deposition on the cylinder wall. Opacity is the degree to which smoke blocks lights and aids in the measurement of smoke generated by the IC engine as a result of fuel left on the cylinder walls. It includes particulate matter such as CO, CO₂, NO_x, and HC. It is dangerous to one's health.

The graph above depicts the opacity of smoke at different loads. The graph is drawn between the various loads on the x-axis and the opacity on the y-axis. At zero percent load, pure diesel has the least smoke opacity, followed by pm10, pm15, RB20, pm20, and pm25. Finally, at 100% load, pm15 has the most smoke opacity, while pm10 has the least amount of smoke opacity.

5.3 CYLINDER PRESSURE

The cylinder pressure of an engine can be defined as the maximum pressure developed due to the combustion of the fuel in which the chemical energy gets converted into pressure energy. This would have an impact on engine power as well as emissions.

The combustion characteristics graph shown display the cylindrical pressure of the engine at different crank angles. We can clearly see from Figs. 1.1, 1.2, 1.3, 1.4, and 1.5 that the cylinder pressure has risen for all injection conditions when measured at 50% and 100% load. For all other injection conditions, the cylinder pressure remains constant regardless of load.

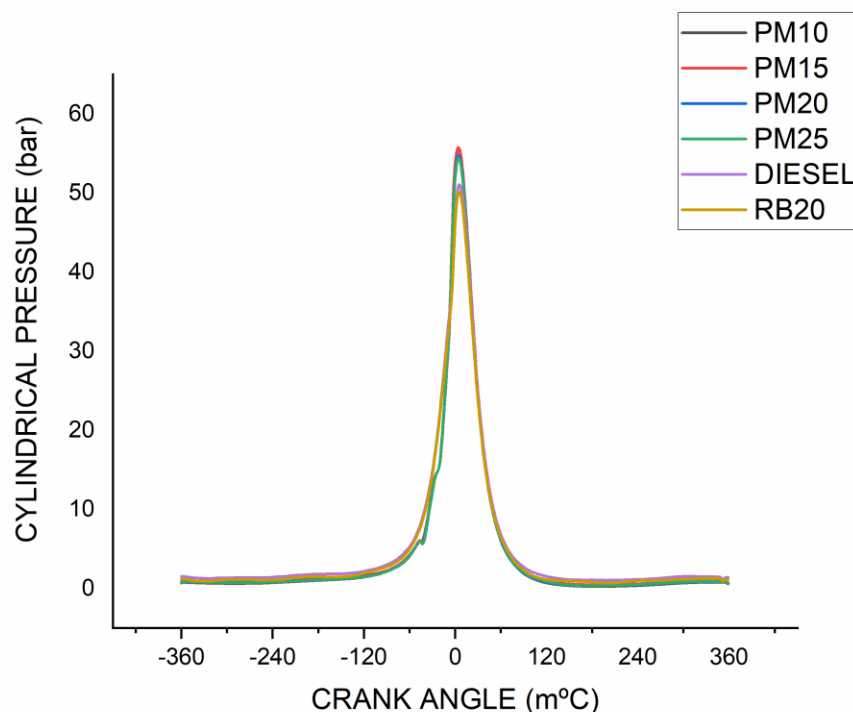


FIG: 5.10: Cylinder Pressure at 0% load

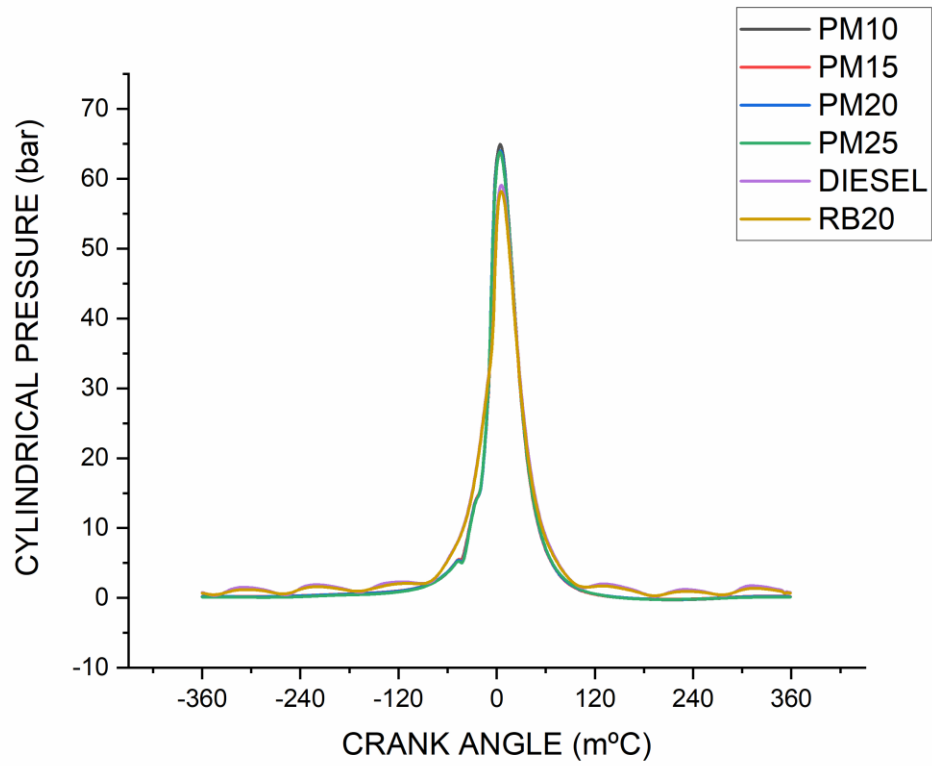


FIG: 5.11: Cylinder Pressure at 25% load

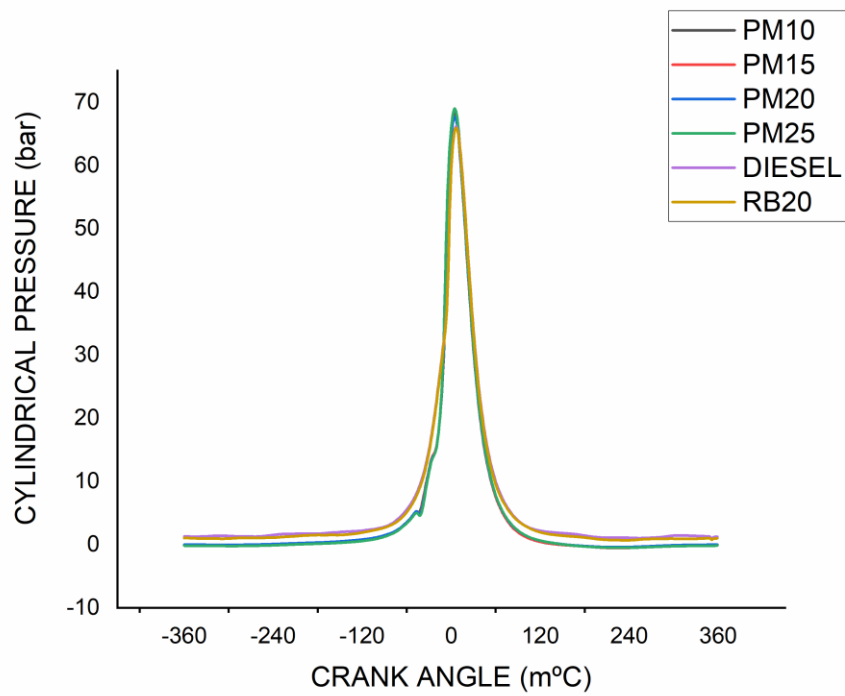


FIG: 5.12: Cylinder Pressure at 50% load

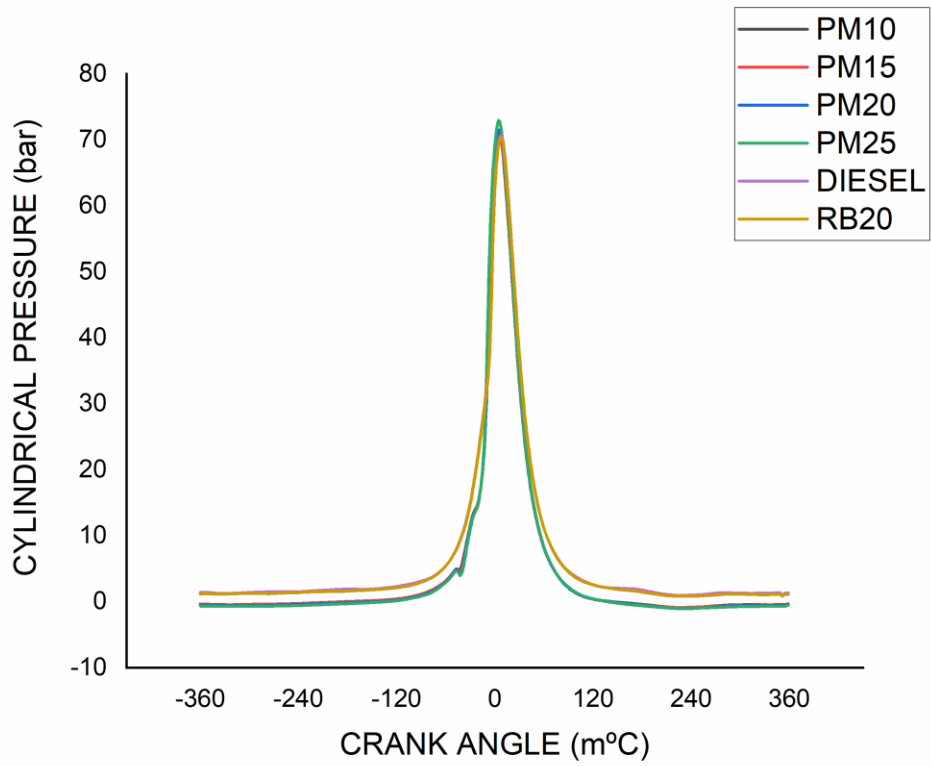


FIG: 5.13: Cylinder Pressure at 75% load

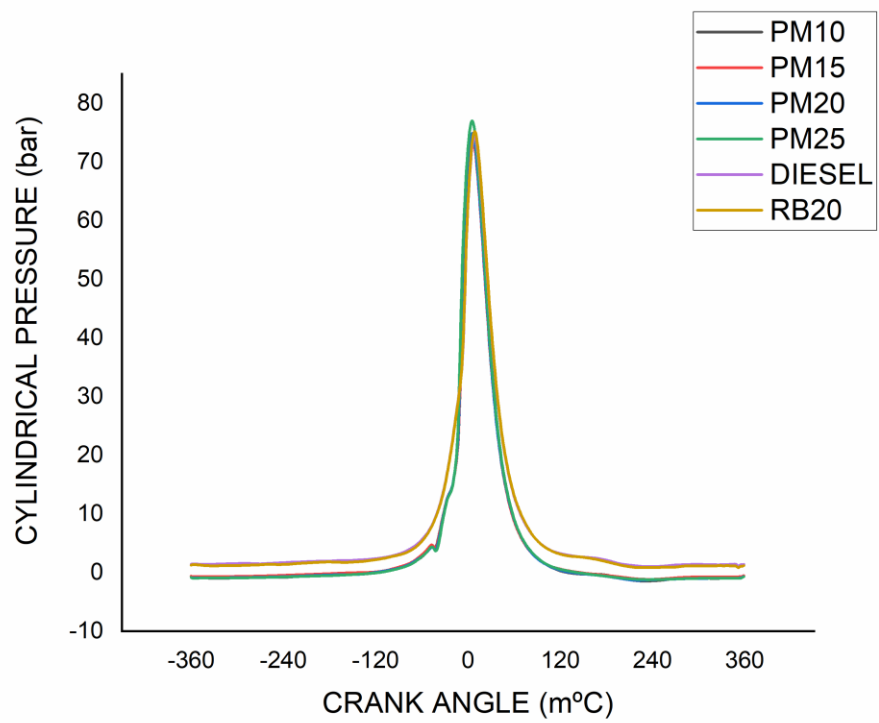


FIG: 5.14: Cylinder Pressure at 100% load

5.4 NET HEAT RELEASE DURING COMBUSTION:-

The graphs depict the net heat release of the engine during the combustion phase at different loads. From the fig 2.1, fig 2.2, fig 2.3, fig 2.4, fig 2.5 it can be studied that Net heat release is maximum when the crank angle is at 0 deg. At 0% load condition the net heat release is lower as compared to other conditions. At higher load conditions, pm25 has the highest net heat release rate whereas the RB20 consistently has the lowest NHR during combustion.

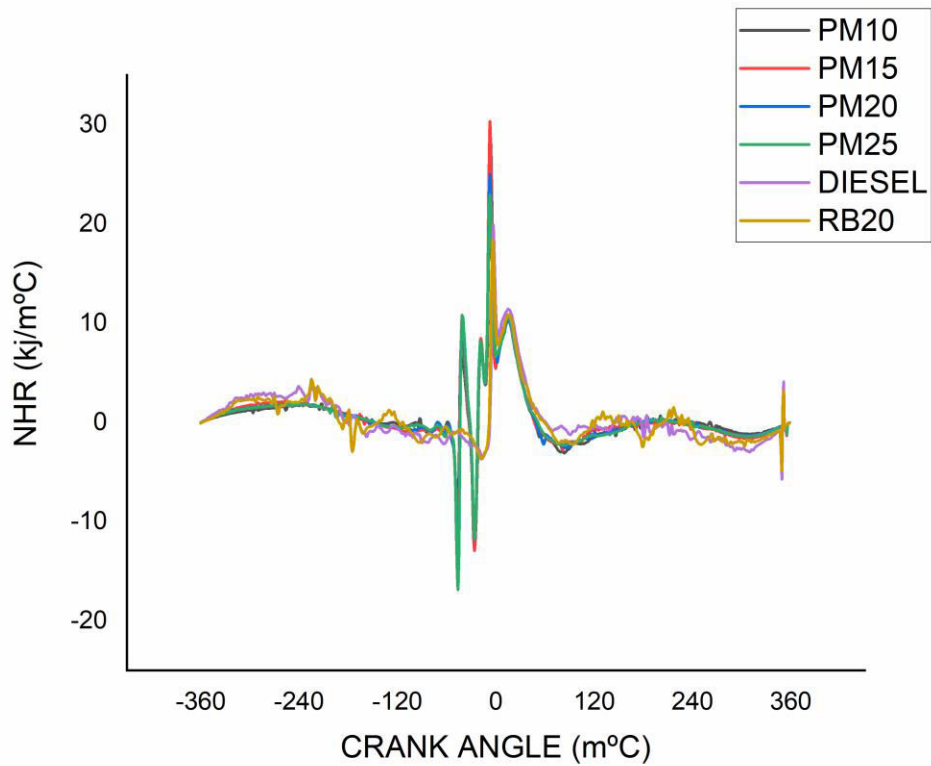


Fig: 5.15: NHR at 0% Load

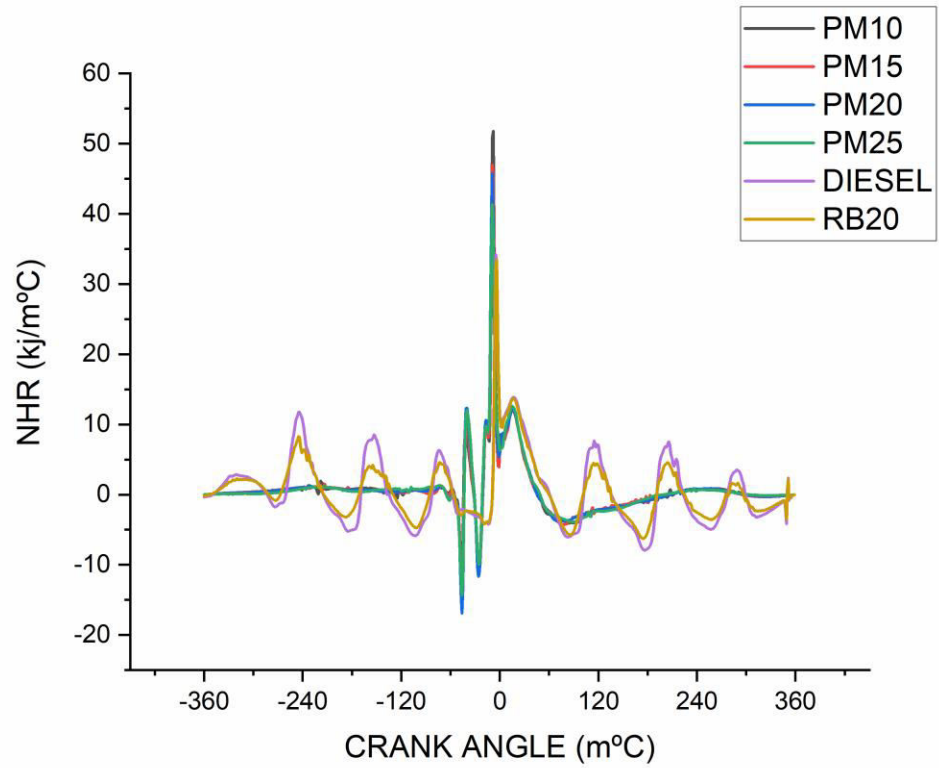


Fig: 5.16: NHR at 25% Load

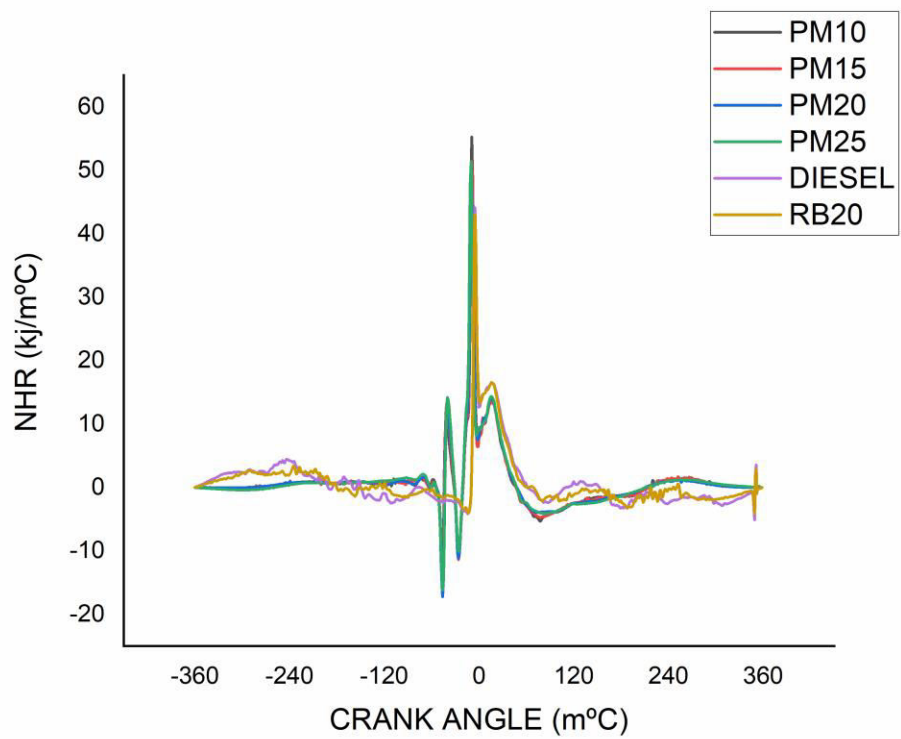


Fig: 5.17: NHR at 50% Load

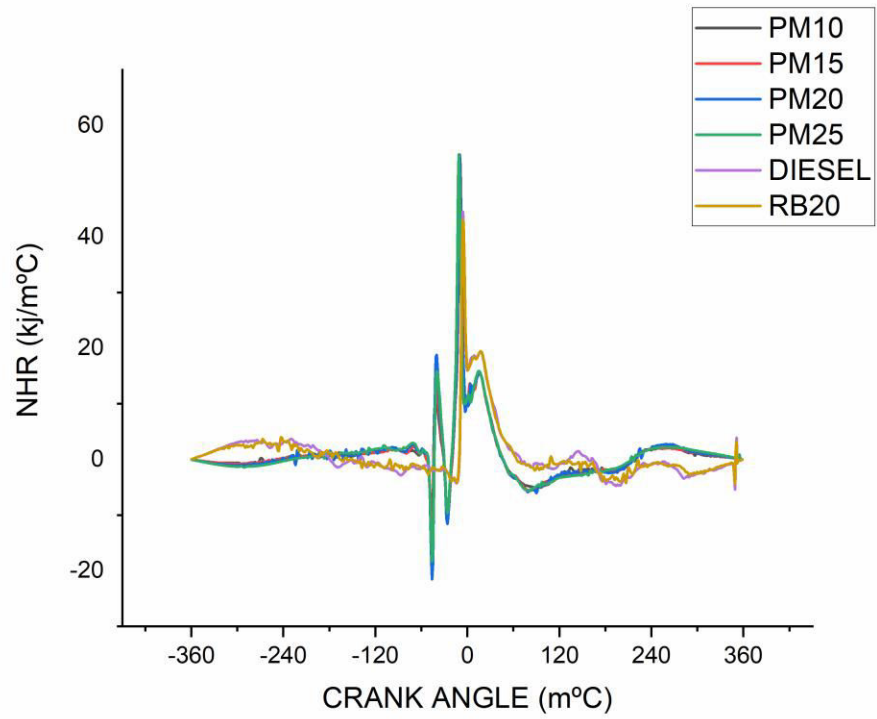


Fig: 5.18: NHR at 75% Load

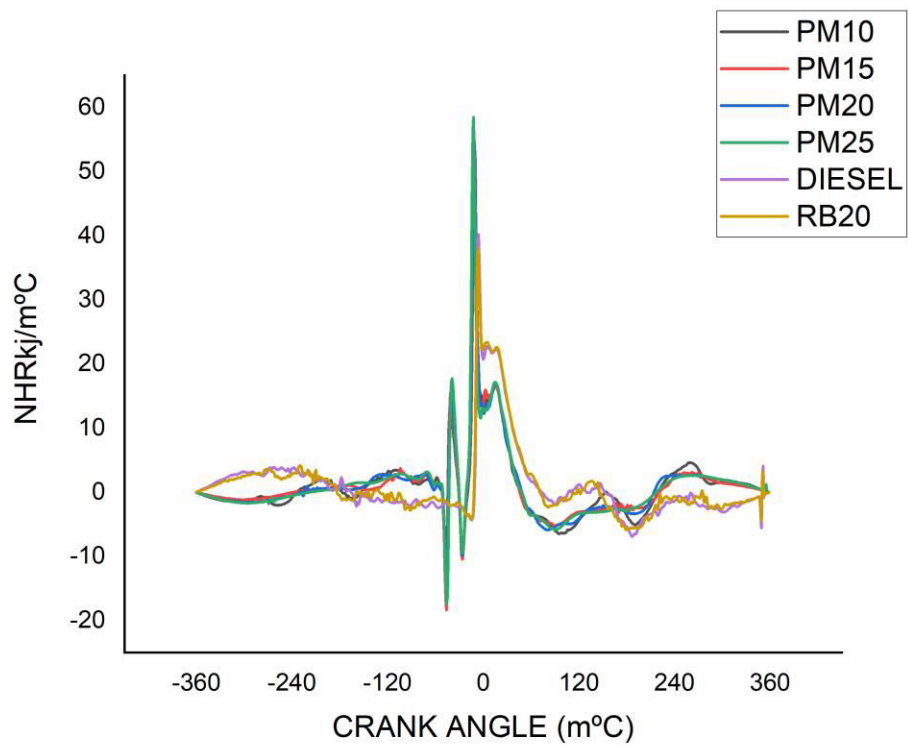


Fig: 5.19: NHR at 100% Load

CHAPTER 6

SUMMARY AND CONCLUSION

- Comparative analysis of using Main injection Split injection Pilot injection Post injection in CRDI Engine using Ricebran methyl esters was successfully completed and Performance, Emission and Combustion properties were evaluated.
- The high performance fuel blend was successfully prepared and tested for physical and chemical properties.
- The prepared high performance fuel blend is tested by varying injection pressures at different loads.
- The performance characteristics illustrates that the prepared Bio-diesel fuel blends have reduced brake thermal efficiency and volumetric efficiency as compared to RB20 and pure diesel. PM20 and PM25 produced the least exhaust gas temperature higher loads.
- The emission characteristics illustrates that the PM10, PM15, PM20, PM25 has shown substantial improvement in emission characteristics by lowering the carbon dioxide and hydrocarbon particulates through out the different loads, but is limited improvement in NO_x and carbon monoxide levels. PM10 shows the lowest smoke opacity emission rates.
- The combustion characteristics illustrates that the NHR and cylindrical pressure is increased for pm10 and pm25.
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