Vidya Jyothi Institute of Technology (Autonomous)

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(Aziz Nagar, C.B.Post, Hyderabad -500075)

IV B. Tech II Semester Academic Calendar for the Academic year 2020-21

Department of Mechanical Engineering

Circular

MED/Major Projects/01

Dt: 05/04/2021

All the final year mechanical engineering students are informed that a project work has to be undertaken as partial fulfillment for the award of degree, in this connection you are required to form into groups with three to four members. Grouping is done voluntarily by yourself considering the domain of interest in mechanical engineering. Hence you are required to submit the group along with the domain/project topic so that faculty member can be allocated as supervisor/guide. Also you can speak to the faculty members in choosing them as supervisors for the project work undertaken. The submission of the group to **Mr. Prasad Kumar, Asst.Professor**, who is project coordinator on or before 20.04.2021

HoD
(Dr.G.Sreeram Reddy)

25	Ayaz khan B Kiran D Lalith Shashank kulkarny	17911A0359 17911A0361 17911A0373 18915A0326	Design and analysis of universal gearless power transmission mechanism	Dr V Phanindra bogu	VJIT	PO1,PO2,PO3,PO4,PO9,PO12
26	Syed salman kashif ahsan Sriram Vamshi S Manikanta Himanshu Yadav	17911A03A6 17911A03A4 17911A03A5 17911A0377	Buckling analysis of bio-metric structure Typha leaves	Dr V Phanindra bogu	VJIT	PO1,PO2,PO3,PO4,PO9,PO12,PSO 1
27	Ravi kumar Pavan Kumar B Manish chandra Mahesh	17911A0360 17911A0362 17911A0363 17911A0374	Experimental investization on wear behavoiur of kenaf-epoxy & kenaf-basalt-epoxy hybrid laminate	S Ramakrishna	VJIT	PO1,PO2,PO3,PO4,PO9,PO12
28	N Sripal Reddy V Sai kumar K Snehith Reddy M Abhilash Reddy	17911A0398 17911A03A8 17911A0390 17911A0391	Effect of basalt fiber on mechanical properties of kenaf fiber reinforced laminate	S Ramakrishna	VJIT	PO1,PO2,PO3,PO4,PO5,PO9,PO12
29	G Sai krishna B Harish J Laxman J Yogesh	18915A0316 18915A0317 18915A0321 18915A0322	Design of automatic solar tracking system	B Malathi	VJIT	PO1,PO2,PO3,PO4,PO9,PO12
30	J Pavan kumar J Praveen kumar J Naveen kumar K Prasanth Reddy	18915A0318 18915A0319 18915A0320 18915A0325	Mechanical properties of kenaf/basalt/epoxy composite laminates containing aluminium oxide	P Pavani	VJIT	PO1,PO2,PO3,PO4,PO9,PO12
31	G Shirisha G Shashivardhan Reddy N Nikhitha M Kavya	17911A0375 17911A0381 17911A0395 17911A0393	Expermental investigation of the influence of waste plstic oil biodiesel blends on CRDI automotive research engine eith open ECU ai different operating conditions	Dr.L Madan Anand kumar	VJIT	PO1,PO2,PO3,PO4,PO9,PO12,PSO 1
32	G Harish G Mahesh J Rathan Naik K Shiva	18915A0314 18915A0315 18915A0323 18915A0324	Analysis of refrigeration system for an automobile using exhaust heat recovery	B Malathi	CBIT	PO1,PO2,PO3,PO4,PO5,PO9,PO12

49	17911A0361	Design and analysis of Universal gearless power transmission mechanism.	11	13	15	39
50	17911A0362	Experimental investigations on wear behaviour of kenaf-epoxy & kenaf-basalt epoxy hybrid lamination.	10	12	14	36
51	17911A0363	Experimental investigations on wear behaviour of kenaf-epoxy & kenaf-basalt epoxy hybrid lamination.	10	11	14	35
52	17911A0365	Influence of angle ply orientation on impact strength of glass fibre Reinforced polyster composite laminates.	11	12	16	39
53	17911A0367	Fatigue analysis of notched super Austenitic stainless steel UN S31254.	10	13	15	38
54	17911A0368	Study on Natural convective heat transfer from two adjacent narrow plates.	11	13	15	39
55	17911A0369	Fabrication of Cryogenic grinding machine.	10	12	16	38
56	17911A0371	Investigation of mechanical properties of friction stir welding of Aluminium alloy 6063 using cerium powder.	11	12	14	37
57	17911A0372	Design and analysis of composite propeller shaft.	10	11	16	37
58	17911A0373	Design and analysis of Universal gearless power transmission mechanism.	10	11	14	35
59	17911A0374	Experimental investigations on wear behaviour of kenaf-epoxy & kenaf-basalt epoxy hybrid lamination.	11	13	14	38
60	17911A0375	Experimental investigations of influence of waste plastic oil biodiesel blends on CRDI automotive research engine with open ECU at different operating conditions.	11	12	15	38
61	17911A0376	Experimental investigations of influence of waste plastic oil biodiesel blends on CRDI automotive research engine with open ECU at different operating conditions.	11	11	15	37
62	17911A0377	Bucking analysis of Bio-mimetic structure Typha leaves.	12	13	14	39
63	17911A0380	Study on Natural convective heat transfer from two adjacent narrow plates.	11	13	15	39
64	17911A0381	Experimental investigations of influence of waste plastic oil biodiesel blends on CRDI automotive research engine with open ECU at different operating conditions.	12	13	16	41
65	17911A0382	Influence of angle ply orientation on impact strength of glass fibre Reinforced polyster composite laminates.	11	13	15	39
66	17911A0383	Influence of angle ply orientation on impact strength of glass fibre Reinforced polyster composite laminates.	10	13	16	39
67	17911A0384	Design and analysis of composite propeller shaft.	11	13	14	37
68	17911A0385	Development of white paint for combating global warming and reducing pressure on air conditioning technology.	10	12	15	37
69	17911A0387	Design and analysis of composite propeller shaft.	12	11	15	38
70	17911A0388	Fatigue analysis of notched super Austenitic stainless steel UN S31254.	12	13	14	39
71	17911A0389	Fabrication of Cryogenic grinding machine.	11	12	16	39
72	17911A0390	Effect of Basalt fiber on mechanical properties of Kenaf fiber reinforced laminate.	10	13	16	39
73	17911A0391	Effect of Basalt fiber on mechanical properties of Kenaf fiber reinforced laminate.	12	13	18	43
74	17911A0392	Fabrication of Cryogenic grinding machine.	12	11	17	40
75	17911A0393	Experimental investigations of influence of waste plastic oil biodiesel blends on CRDI automotive research engine with open ECU at different operating conditions.	12	13	16	41
76	17911A0394	Study on Natural convective heat transfer from two adjacent narrow plates.	10	12	16	38
77	17911A0395	Experimental investigations of influence of waste plastic oil biodiesel blends on CRDI automotive research engine with open ECU at different operating conditions.	11	12	16	39
78	17911A0396	Study on Natural convective heat transfer from two adjacent narrow plates.	0	0	0	0
79	17911A0397	Fabrication of Cryogenic grinding machine.	11	12	14	37
80	17911A0398	Effect of Basalt fiber on mechanical properties of Kenaf fiber reinforced laminate.	12	12	15	39
81	17911A0399	Deviation Analysis of a free form surface using reverse engineering approach.	10	11	16	37
82	7911A03A0	Influence of angle ply orientation on impact strength of glass fibre Reinforced polyster composite laminates.	10	12	15	37
83	17911A03A1	Development of white paint for combating global warming and reducing pressure on air conditioning technology.	11	11	16	38
84	17911A03A2	Development of white paint for combating global warming and reducing pressure on air conditioning technology.	12	11	15	38
85	17911A03A4	Bucking analysis of Bio-mimetic structure Typha leaves.	10	11	17	38
86	17911A03A5	Bucking analysis of Bio-mimetic structure Typha leaves.	11	10	15	36
87	17911A03A6	Bucking analysis of Bio-mimetic structure Typha leaves.	10	12	14	36
88	17911A03A7	Stress analysis of Notched super duplex stainless steel UNS S32760.	12	11	15	38
89	17911A03A8	Effect of Basalt fiber on mechanical properties of Kenaf fiber reinforced laminate.	10	12	16	38
90	17911A03B0	Influence of angle ply orientation on impact strength of glass fibre Reinforced polyster composite laminates.	11	11	15	37
91	17911A03B1	Fatigue analysis of notched super Austenitic stainless steel UN S31254.	10	11	16	37

A Project Report on

Experimental Investigation of the influence of waste plastic oil, Biodiesel Blends on CRDI Automotive Research Engine with open ECU at different operating conditions

Submitted in partial fulfillment of the requirement for the award of the degree of

BACHELOR OF TECHNOLOGY

in

MECHANICAL ENGINEERING

By

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Submitted to

DEPARTMENT OF MECHANICAL ENGINEERING

VIDYA JYOTHI INSTITUTE OF TECHNOLOGY

(An Autonomous Institution)

Approved by AICTE New Delhi & Permanently Affiliated to JNTUH, Accredited by NAAC & NBA,
An ISO 9001:2015 Certified Institution

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(2020-21)

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BONAFIDE CERTIFICATE

This is to certify that the project work entitled **"Experimental Investigation of the influence of waste plastic oil Biodiesel Blends on CRDI Automotive Research Engine with open ECU at different operating conditions"** is submitted by **G.Sirisha (17911A0375), G.Shashi Vardhan Reddy (17911A0381) , M.Kavya (17911A0393) and N. Nikhitha Reddy(17911A0395)** in the department of Mechanical Engineering in partial fulfillment of requirements for the award of degree of Bachelor of Technology in Mechanical Engineering for the academic year 2020-21. This work has been carried out under my guidance and has not been submitted the same for any university/institution for award of any Degree/Diploma.

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INTERNAL EXAMINER

EXTERNAL EXAMINER

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ABSTRACT

Petroleum based fuels play a vital role in rapid depletion of conventional energy sources along with increasing demand and also major contributors of air pollutants.

Biodiesels have come up as a very strong alternative for diesel fuel. Biodiesel is an alternative fuel to diesel engine that can replace or reduce the use of petroleum diesel. Biodiesel is derived Growing concern regarding energy resources and the environment has increased interest in the study of alternative sources of energy. To meet increasing energy requirements, there has been growing interest in alternative fuels like biodiesel to provide a suitable diesel oil substitute for internal combustion engines. Biodiesels offer a very promising alternative to diesel oil since they are renewable and have similar properties. Biodiesel is defined as a trans esterified renewable fuel derived from vegetable oils, animal fats, and waste cooking oils through transesterification process with properties similar or better than diesel fuel.

In the present work, Experiments were carried out to investigate the performance of waste plastic oil biodiesel blends on CRDi automotive research engine with open ECU at different operating conditions. The injection opening pressure was taken at 600bar and an injection timing of 15^{o}bTDC. The test were conducted by varying the engine speed (1500 – 3000rpm) at various loads. The effect of use of biodiesel fuel on engine power, fuel consumption and thermal efficiency are collected and analyzed with that of conventional diesel fuel. In the subsequent section, the engine emissions from biodiesel and diesel fuels are compared, paying special attention to the most significant emissions such as nitric oxides and particulate matter.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

ABBREVIATIONS

ECU	Electronic Control Unit
BTE	Brake Thermal Efficiency
BSFC	Brake specific fuel consumption
TDC	Top dead center
BDC	Bottom dead center
WPO	Waste plastic oil
CRDI	Common rail direct injection

CHAPTER I
INTRODUCTION

The large increase in number of automobiles in recent years has resulted in great demand for petroleum products. With crude oil reserves estimated to last only for few decades, there has been an active search for alternate fuels. The depletion of crude oil would cause a major impact on the transportation sector. The fossil fuels using in the internal combustion engines are nonrenewable and are high impact on a country's economy. Research reports say that the oil that is being drilled out of the earth would exhaust within few decades. This shows the world is the requirement of fuels that are renewable and can be indigenously produced in a country to save the economy.

The bio fuels are considered to be best of the renewable fuels and are can be produced indigenously. Bio-fuels are both gaseous fuels that which are called Bio gas and liquid fuels that which are termed as bio-diesels. Of the various alternate fuels under consideration, biodiesel, derived from vegetable oils, is the most promising alternative fuel to conventional diesel fuel

(derived from fossil fuels; hereafter just "diesel") due to the following reasons.

- Biodiesel can be used in existing engines without any modifications.
- Biodiesel is made entirely from vegetable sources; it does not contain any sulfur, aromatic hydrocarbons, metals or crude oil residues.
- Biodiesel is an oxygenated fuel; emissions of carbon monoxide and soot tend to be reduced compared to conventional diesel fuel.
- Unlike fossil fuels, the use of biodiesel does not contribute to global warming as CO_2 emitted is once again absorbed by the plants grown for vegetable oil/biodiesel production. Thus CO_2 balance is maintained.
- The Occupational Safety and Health Administration classify biodiesel as a nonflammable liquid.
- The use of biodiesel can extend the life of diesel engines because it is more lubricating than petroleum diesel fuel.
- Biodiesel is produced from renewable vegetable oils/animal fats and hence improves fuel or energy security and economy independence.

1.1 Bio-Fuels

1.1.1 Bio Gas

Biogas typically refers to a mixture of different gases produced by the breakdown of organic matter in the absence of oxygen. Biogas can be produced from raw materials such as agricultural waste, manure, municipal waste, plant material, sewage, green waste or food waste.

Biogas is a renewable energy source and, in many cases, exerts a very small carbon footprint.

Biogas can be produced by anaerobic digestion with anaerobic organisms, which digest material inside a closed system, or fermentation of biodegradable materials.

Biogas is primarily methane (CH_4) and carbon dioxide (CO_2) and may have small amounts of Hydrogen-Sulphide (H_2S), moisture and siloxanes. The gases methane, hydrogen, and carbon monoxide (CO) can be combusted or oxidized with oxygen. This energy release allows biogas to be used as a fuel; it can be used for any heating purpose, such as cooking. It can also be used in a gas engine to convert the energy in the gas into electricity and heat.

1.1.2 Biodiesel

Biodiesel is an alternative fuel similar to conventional or 'fossil' diesel. Biodiesel can be produced from straight vegetable oil, animal oil/fats, tallow and waste cooking oil. The process used to convert these oils to Biodiesel is called transesterification. This process is described in more detail below. The largest possible source of suitable oil comes from oil crops such as rapeseed, palm or soybean. In the UK rapeseed represents the greatest potential for biodiesel production. Most biodiesel produced at present is produced from waste vegetable oil sourced from restaurants, chip shops, industrial food producers such as Birdseye etc. Though oil straight from the agricultural industry represents the greatest potential source it is not being produced commercially simply because the raw oil is too expensive. After the cost of converting it to biodiesel has been added on it is simply too expensive to compete with fossil diesel. Waste vegetable oil can often be sourced for free or sourced already treated for a small price. (The waste oil must be treated before conversion to biodiesel to remove impurities). The result is Biodiesel produced from waste vegetable oil can compete with fossil diesel. More about the cost of biodiesel and how factors such as duty play an important role can be found here.

1.1.2.1 Benefits of Biodiesel

Biodiesel has many environmentally beneficial properties. The main benefit of biodiesel is that it can be described as 'carbon neutral'. This means that the fuel produces no net output of carbon in the form of carbon dioxide (CO_2). This effect occurs because when the oil crop grows it absorbs the same amount of CO_2 as is released when the fuel is combusted. In fact this is not completely accurate as CO_2 is released during the production of the fertilizer required to fertilize the fields in which the oil crops are grown. Fertilizer production is not the only source of pollution associated with the production of biodiesel, other sources include the esterification process, the solvent extraction of the oil, refining, drying and transporting. All these processes require an energy input either in the form of electricity or from a fuel, both of which will generally result in the release of greenhouse gases. To properly assess the impact of all these sources requires use of a technique called life cycle analysis. Our section on LCA looks closer at this analysis. Biodiesel is rapidly biodegradable and completely non-toxic, meaning spillages represent far less of a risk than fossil diesel spillages. Biodiesel has a higher flash point than fossil diesel and so is safer in the event of a crash.

The physical properties of the Biodiesel are as given below:

Table 1.1: Properties of Biodiesel

S. No	Biodiesel properties	Measured values	Units
1	Density at 20˚C	950	kg/m^3
2	Kinematic viscosity 40˚C	38.7	mm^2/s
3	Flash point (˚C)	150	˚C
4	Acid value	12.6	mgKOH/g
5	Saponificationvalue mgKOH/g	180	mgKOH/g
6	Moisture content	0.019	(%)w/w
7	Ash content	0.04	(%)w/w
8	Iodine value	90.6	I_2 g/100g
9	Free fatty acidic	5.28	%
10	Melting point	30.2	˚C

1.2.1. Waste Plastic Oil

The raw materials used in this study were from plastic waste, such as plastic waste bags collected from waste in Suranaree Subdistrict, Nakhon Ratchasima, Thailand. The composition of these plastics includes polyethylene (PE) and polystyrene (PS) and about 70% was contaminated organic matter. The waste plastics obtained from mechanical biological treatment (MBT) were processed into raw materials using an agglomerator, which processed the plastic into small pieces that could be continuously fed into the oil processing plant. The waste plastic oil was recycled using pyrolysis and did not undergo distillation.

The pyrolysis process involves the breakdown of large molecules into smaller molecules by chemically decomposing organic matter through heating in an oxygen-free environment. Waste plastic is processed to maintain a temperature of 300–350 ˚C inside the reactor, where the waste plastic is then vaporized and the outlet gas condensed through the condenser unit at this high temperature. The obtained liquid was taken as fuel, and this process happened constantly in converting the waste plastic back into usable oil. All gases from this process were treated before being released into the atmosphere. The exhaust gas was treated through scrubbers and chemical treatment for neutralization. From the pyrolysis process, the following output products were collected: Waste plastic oil (70%), gas (10%), and solid (20%), with values based on the weight of the input. The plastics yielded approximately 600 L per ton.

1. 3 Working of CI Engine

CI Engine

A CI engine is an engine in which the fuel charge is ignited by the heat of compression. The process of combustion in the CI engine is fundamentally different from that in a spark ignition engine. In a CI engine, air is let into the combustion chamber and compressed to a very high pressure.

1. 3. 1 Operating principle

The Diesel internal combustion engine differs from the gasoline powered Otto cycle by using highly compressed hot air to ignite the fuel rather than using a spark plug (compression ignition rather than spark ignition).

In the diesel engine, air is compressed, adiabatically with a compression ratio typically between 15 and 20. This compression raises the temperature to the ignition temperature of the fuel mixture which is formed by injecting fuel once the air is compressed.

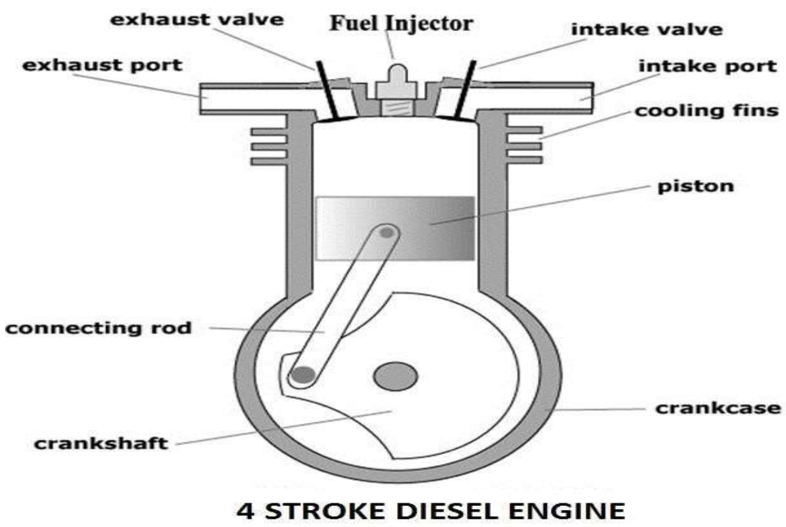


Fig 1.1 4 stroke diesel engine

Fig 1.2 diesel engine model, left side fig 1.3 diesel engine model, right side

1.3.2 Working of CI Engine

In the four-stroke engine the cycle of operations of the engine are completed in four strokes of the piston inside the cylinder. The four strokes of the four stroke engine are :suction of the fuel, compression of fuel, expansion or power stroke, and exhaust stroke. In 4- stroke engines the power is produced when piston performs expansion stroke. During four strokes of the engine two revolutions of the engine`s crankshaft are produced.

In the Diesel engine, only air is initially introduced into the combustion chamber. The air is then compressed with a compression ratio typically between 15:1 and 23:1. This high compression causes the temperature of the air to rise. At about the top of the compression stroke, fuel is injected directly into the compressed air in the combustion chamber. This may be into a (typically toroidal) void in the top of the piston or a pre-chamber depending upon the design of the engine. The fuel injector ensures that the fuel is broken down into small droplets, and that the fuel is distributed evenly. The heat of the compressed air vaporises fuel from the surface of the droplets. The vapour is then ignited by the heat from the compressed air in the combustion chamber, the droplets continue to vaporise from their surfaces and burn, getting smaller, until all the fuel in the droplets has been burnt. Combustion occurs at a substantially constant pressure during the initial part of the power stroke. The start of vaporisation causes a delay before ignition and the characteristic Diesel knocking sound as the vapour reaches ignition temperature and causes an abrupt increase in pressure above the piston. When combustion is complete the combustion gases expand as the piston descends further; the high pressure in the cylinder drives the piston downward, supplying power to the crankshaft.

As well as the high level of compression allowing combustion to take place without a separate ignition system, a high compression ratio greatly increases the engine's efficiency. Increasing the compression ratio in a spark-ignition engine where fuel and air are mixed before entry to the cylinder is limited by the need to prevent damaging pre-ignition. Since only air is compressed in a Diesel engine, and fuel is not introduced into the cylinder until shortly before top dead centre (TDC), premature detonation is not a problem and compression ratios are much higher.

1.3. 2. 1 The four–stroke diesel engine works on the following cycle:

1. Suction Stroke

In this stroke the piston moves from TDC to BDC (i.e. downward) and the suction of air takes place through the inlet valve.

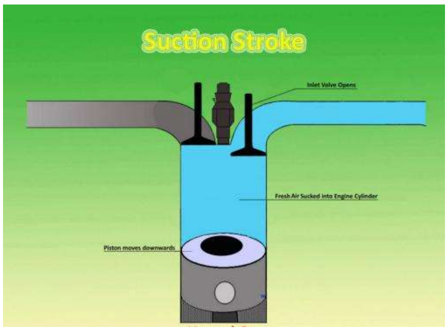


Fig 1. 4. Diesel suction stroke

2. Compression Stroke

This stroke compresses the air that is taken into the cylinder in the suction stroke. As the air gets compressed, the temperature of the air increases and reaches upto that level where the combustion of the diesel takes place.

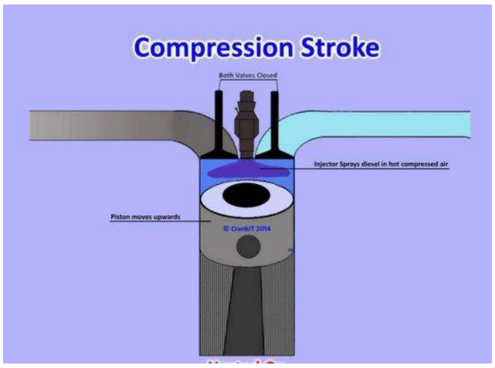


Fig. 1.5 Diesel compression stroke

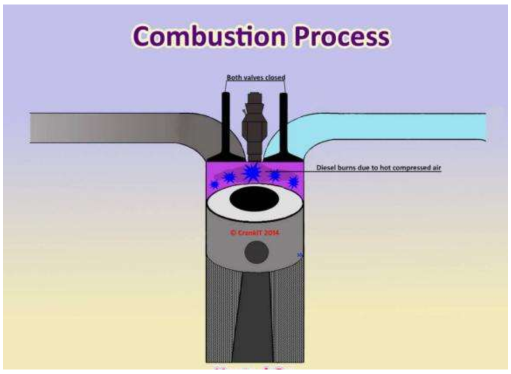


Fig. 1.6 Diesel engine combustion

3. Power Stroke

At just before the end of compression stroke, the injector injects the fuel into the cylinder. Due to the heat of the air, the ignition of the fuel begins and combustion takes place. Due to the combustion of the fuel, hot exhaust gases produced that puts a very high thrust force on the piston and it moves downward. The piston rotates the crankshaft with the help of connecting rod. It is called as power stroke because power is produced in this stroke.

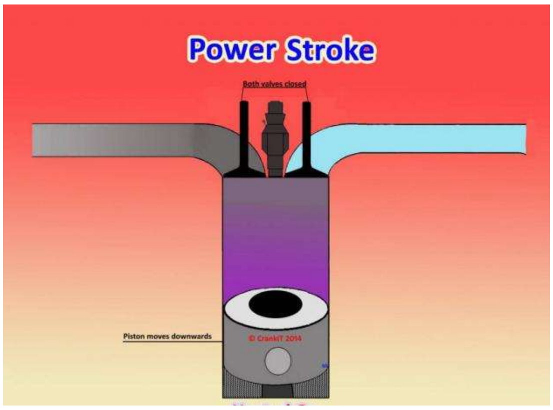


Fig. 1.7 Diesel power stroke

4. Exhaust Stroke

In this stroke the piston moves upward (i.e. BDC to TDC) and pushes the burnt gases out of the engine cylinder through exhaust valve.

After Exhaust stroke, again all the strokes repeats itself. In two stroke engine we get one power stroke in every single rotation of the crankshaft. But in four stroke engine, we get one power stroke, in every two rotation of the crankshaft.

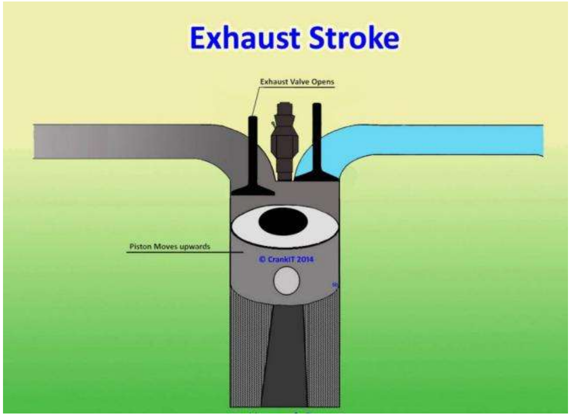


Fig.1.8 Diesel exhaust stroke

Table 1.2 CI Engine strokes details

S.no	Stroke	Inlet Valve	Exhaust valve	Operation performed
1.	Suction stroke	Open	Closed	Suction of air
2.	Compression stroke	Closed	Closed	Compression of air
3.	Power stroke	Closed	Closed	Fuel injection, ignition and combustion
4.	Exhaust stroke	Closed	Open	Escaping of burnt gases

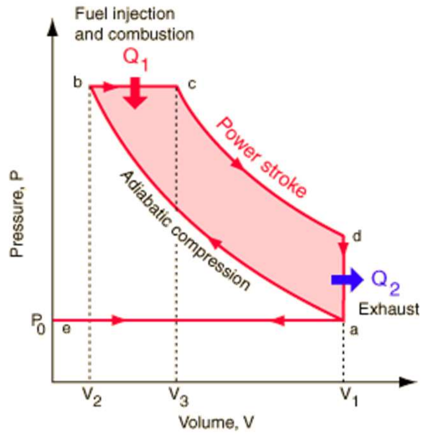


Fig. 1.9 Air standard diesel engine cycle

The p–V diagram is a simplified and idealised representation of the events involved in a Diesel engine cycle, arranged to illustrate the similarity with a Carnot cycle. Starting at 1, the piston is at bottom dead centre and both valves are closed at the start of the compression stroke; the cylinder contains air at atmospheric pressure. Between 1 and 2 the air is compressed adiabatically—that is without heat transfer to or from the environment—by the rising piston. (This is only approximately true since there will be some heat exchange with the Cylinder walls.) During this compression, the volume is reduced, the pressure and temperature both rise. At or slightly before 2 (TDC) fuel is injected and burns in the compressed hot air. Chemical energy is released and this constitutes an injection of thermal energy (heat) into the compressed gas. Combustion and heating occur between 2 and 3. In this interval the pressure remains constant since the piston descends, and the volume increases; the temperature rises as a consequence of the energy of combustion. At 3 fuel injection and combustion are complete, and the cylinder contains gas at a higher temperature than at 2. Between 3 and 4 this hot gas expands, again approximately adiabatically. Work is done on the system to which the engine is connected. During this expansion phase the volume of the gas rises, and its temperature and pressure both fall. At 4 the exhaust valve opens, and the pressure falls abruptly to atmospheric (approximately). This is un resisted expansion and no useful work is done by it. Ideally the adiabatic expansion should continue, extending the line 3–4 to the right until the pressure falls to that of the surrounding air, but the loss of efficiency caused by this un resisted expansion is justified by the practical difficulties involved in recovering it (the engine would have to be much larger). After the opening of the exhaust valve, the exhaust stroke follows, but this (and the following induction stroke) are not shown on the diagram. If shown, they would be represented by a low-pressure loop at the bottom of the diagram. At 1 it is assumed that the exhaust and induction strokes have been completed, and the cylinder is again filled with air. The piston-cylinder system absorbs energy between 1 and 2—this is the work needed to compress the air in the cylinder, and is provided by mechanical kinetic energy stored in the flywheel of the engine. Work output is done by the piston-cylinder combination between 2 and 4. The difference between these two increments of work is the indicated work output per cycle, and is represented by the area enclosed by the p–V loop. The adiabatic expansion is in a higher pressure range than that of the compression because the gas in the cylinder is hotter during expansion than during compression. It is for this reason that the loop has a finite area, and the net output of work during a cycle is positive.

The ideal air-standard cycle is modeled as a reversible adiabatic compression followed by a constant pressure combustion process, then an adiabatic expansion as a power stroke and an isovolumetric exhaust. A new air charge is taken in at the end of the exhaust, as indicated by the processes a-e-a on the diagram. Since the compression and power strokes of this idealized cycle are adiabatic, the efficiency can be calculated from the constant pressure and constant volume processes. The input and output energies and the efficiency can be calculated from the temperatures and specific heats:

1. 4 Dual-fuel diesel engines

So-called dual-fuel Diesel engines or gas Diesel engines burn two different types of fuel *simultaneously*, for instance, a gaseous fuel and Diesel engine fuel. The Diesel engine fuel auto-ignites due to compression ignition, and then ignites the gaseous fuel. Such engines do not require any type of spark ignition and operate similar to regular Diesel engines.

1.5 Efficiency

Due to its high compression ratio, the Diesel engine has a high efficiency, and the lack of a throttle valve means that the charge-exchange losses are fairly low, resulting in a low specific fuel consumption, especially in medium and low load situations. This makes the Diesel engine very economical. Even though Diesel engines have a theoretical efficiency of 75%, in practice it is much lower. In his 1893, Rudolf Diesel described that the effective efficiency of the Diesel engine would be in between 43.2 % and 50.4 %, or maybe even greater. Modern passenger car Diesel engines may have an effective efficiency of up to 43 %, whilst engines in large Diesel trucks, and buses can achieve peak efficiencies around 45%. However, average efficiency over a driving cycle is lower than peak efficiency. For example, it might be 37% for an engine with a peak efficiency of 44%. The highest Diesel engine efficiency of up to 55 % is achieved by large two-stroke watercraft Diesel engines.

1.6 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 the fuel directly into the combustion chamber, have no intake air restrictions apart from air filters and intake plumbing and have no intake manifold vacuum to add parasitic load and pumping losses resulting from the pistons being pulled downward against intake system vacuum. Cylinder filling with atmospheric air is aided and volumetric efficiency is increased for the same reason.
  - 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.

Fig. 1.10 Bus powered by biodiesel

Diesel engines can combust a huge variety of fuels, including several fuel oils, that have advantages over fuels such as petrol. These advantages 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

- Diesel engines have a very good exhaust-emission behaviour. The exhaust contains minimal amounts of carbon monoxide and hydrocarbons. Direct injected Diesel engines emit approximately as much nitrogen oxide as Otto cycle engines. Swirl chamber and pre-combustion chamber injected engines, however, emit approximately 50 % less nitrogen oxide than Otto cycle engines when running under full load. Compared with Otto cycle engines, Diesel engines emit 10 times less pollutants and 3 times less carbon dioxide.
- They have no high voltage electrical ignition system, resulting in high reliability and easy adaptation to damp environments. The absence of coils, spark plug wires, etc., also eliminates a source of radio frequency emissions which can interfere with navigation and communication equipment, which is especially important in marine and aircraft applications, and for preventing interference with radio telescopes.
- Diesel engines can accept super- or turbo-charging pressure without any natural limit, constrained only by the design and operating limits of engine components, such as pressure, speed and load. This is unlike petrol engines, which inevitably suffer detonation at higher pressure if engine tuning and/or fuel octane adjustments are not made to compensate.

1. 7 Problem Statement

In today's world, alternative fuels are needed more than ever. Ordinary powers, for example, coal, gaseous petrol, and non-renewable energy source, are continually being drained; be that as it may, the world's reliance on these powers is as yet developing. Moreover, the cost on remote powers is consistently expanding. For these reasons, the world is seeking after option fuel sources to decrease the reliance on traditional fills. One option fuel is biodiesel; biodiesel can be created from vegetable oil or creature fat and in this manner can be utilized to mitigate the remote fuel reliance. In arrange for biodiesel to be a reasonable option fuel source, a modern scale biodiesel generation process should be moved forward. Contrasted with current plans and petroleum product, the procedure must be cost aggressive. To alter the situation from pollutant free from the emissions from automotive vehicles researches needed to enhance the fuel combustions in a practical manner.

1. 8 Significance of Work

As on today need of Alternative fuels become mandatory research for economically growing countries like India. Day by day crude oil importing becoming a big task economically by checking the processing costs and taxation in up-growing countries. The increase of vehicles occupation and transportation needs the fuel consumption rate is very high. To balance the demand and supply researchers are needed to develop alternative to diesel and petrol for economical balance.

CHAPTER II

LITERATURE REVIEW

2.1 Historical Background

Developed in the 1890s by inventor Rudolph Diesel, the diesel engine has become the engine of choice for power, reliability, and high fuel economy, worldwide. Early experimenters on vegetable oil fuels included the French government and Dr. Diesel himself, who envisioned that pure vegetable oils could power early diesel engines for agriculture in remote areas of the world, where petroleum was not available at the time. Modern biodiesel fuel, which is made by converting vegetable oils into compounds called fatty acid methyl esters, has its roots in research conducted in the 1930s in Belgium, but today's biodiesel industry was not established in Europe until the late 1980s.

The diesel engine was developed out of a desire to improve upon inefficient, cumbersome and sometimes dangerous steam engines of the late 1800s. The diesel engine works on the principal of compression ignition, in which fuel is injected into the engine's cylinder after air has been compressed to a high pressure and temperature. As the fuel enters the cylinder it self-ignites and burns rapidly, forcing the piston back down and converting the chemical energy in the fuel into mechanical energy. Dr. Rudolph Diesel, for which the engine is named, holds the first patent for the compression ignition engine, issued in 1893. Diesel became known worldwide for his innovative engine which could use a variety of fuels.

2.2 Early Work

The early diesel engines had complex injection systems and were designed to run on many different fuels, from kerosene to coal dust. It was only a matter of time before someone recognized that, because of their high energy content, vegetable oils would make excellent fuel. The first public demonstration of vegetable oil based diesel fuel was at the 1900 World's Fair, when the French government commissioned the Otto Company to build a diesel engine to run on peanut oil. The French government was interested in vegetable oils as a domestic fuel for their African colonies. Rudolph

Diesel later did extensive work on vegetable oil fuels and became a leading proponent of such a concept, believing that farmers could benefit from providing their own fuel. However, it would take almost a century before such an idea became a widespread reality. Shortly after Dr. Diesel's death in 1913 petroleum became widely available in a variety of forms, including the class of fuel we know today as "diesel fuel". With petroleum being available and cheap, the diesel engine design was changed to match the properties of petroleum diesel fuel. The result was an engine which was fuel efficient and very powerful. For the next 80 years diesel engines would become the industry standard where power, economy and reliability are required.

2.3 Modern Engine, Modern Fuel:

Due to the widespread availability and low cost of petroleum diesel fuel, vegetable oil based fuels gained little attention, except in times of high oil prices and shortages. World War II and the oil crises of the 1970's saw brief interest in using vegetable oils to fuel diesel engines. Unfortunately, the newer diesel engine designs could not run on traditional vegetable oils, due to the much higher viscosity of vegetable oil compared to petroleum diesel fuel. A way was needed to lower the viscosity of vegetable oils to a point where they could be burned properly in the diesel engine. Many methods have been proposed to perform this task, including pyrolysis, blending with solvents, and even emulsifying the fuel with water or alcohols, none of which have provided a suitable solution. It was a Belgian inventor in 1937 who first proposed using transesterification to convert vegetable oils into fatty acid alkyl esters and use them as a diesel fuel replacement. The process of transesterification converts vegetable oil into three smaller molecules which are much less viscous and easy to burn in a diesel engine. The transesterification reaction is the basis for the production of modern biodiesel, which is the trade name for fatty acid methyl esters. In the early 1980s concerns over the environment, energy security, and agricultural overproduction once again brought the use of vegetable oils to the forefront, this time with transesterification as the preferred method of producing such fuel replacements.

In this chapter , a detailed survey of available literature is undertaken to review the different research achievements on split injection , biodiesel , waste plastic oil as an alternate fuel for C.I engine . in addition to this , properties of waste plastic oil and biodiesel , fuel formulation techniques , bio diesel production , common rail direct injection (CRDI) technique have been reviewed .

Yamane et al reported numerical and experimental results for biodiesel on the DI engine. They reported that the nozzle inlet pressure and nozzle needle pressure for biodiesel as well as gas oil at different fuel temperature. Among them, biodiesel shows higher value. They reported that the presence of soluble organic fraction is more, which causes poor mixing of air and fuel in the direct-injection engine

Rao et al studied the use of cooked oil as biodiesel experimentally. They produced the biodiesel by Transesterification process using alkaline catalysts. Performance characteristics and emissions are investigated and reported in detail. They found that though the peak pressure is higher for cooking oil, maximum heat release and rate of pressure rise is higher for diesel. Also, they reported that since the calorific value of cooking oil is lesser the thermal brake efficiency is lesser than diesel

Broatch et al investigated the influence of swirl on heat transfer in a diesel engine cylinder and they have reported 4–12% increase of heat transfer due to the increase of swirl at different operating conditions of the engine. Also, due to these heat transfer, the rates of evaporation, mixing and combustion also increase. Near Top Dead Centre (TDC), high turbulence is very desirable when ignition occurs for better combustion. It breaks up the fuel molecules, aids mixing fuel with air, and spreads the flame front much faster than that of a laminar flame

Bari and Saad They have created 11 guide vane models with different twist angles ranging in-between 3° and 60°. With CFD simulation they have simulated the in-cylinder air flow characteristics and compared with a base model (without guide vane). From simulations, it was found that to improve the air–fuel mixing to aid combustion, turbulent kinetic energy (TKE), swirling strength, vorticity and velocity were the important effective parameters. They have reported that 35° TA was the optimum angle for this type of guide vane. To validate their simulation results, they chose 5 models from simulations and fabricated those and installed them into the intake runner of a diesel-generator-set and ran the engine on biodiesel. From the experiment, it was also found that the 35° TA model performed the best compared to all others. The BSFC with the vane-angle of 35° model improved by 1.77% in comparison to the biodiesel-base (B-based) run. In the case of engine efficiency, vane angle of 35° displayed the highest improvement of 1.81% compared to B-based run. In the case of emission improvements, 35° vane angle was able to reduce 1.73% of CO2, 8.85% of CO and 7.49% of HC in comparison to B-based run.

Ellappan & Rajendran compared and reviewed the use of non-edible oil in low heat rejection engine for improving the thermal efficiency with reduced emission. It was concluded that the optimized biodiesel blend was 30% with diesel fuel as the thermal efficiency increased with reduced emission. The formation of *NOx* was higher due to higher oxygen content and shorter ignition delay.

Aydin made a comprehensive experimental investigation on a multi cylinder diesel engine by blending diesel using animal, vegetable and micro algae oil in the lower concentration of 10% to assess the thermal performance, combustion and emission characteristics. Results showed that the emissions such as *NOx*, CO_2 increased whereas, the other emission such as HC, CO and smoke opacity reduced using blends of biodiesel while compared to neat diesel. Results of thermal performance showed that the use of micro algae biodiesel exhibited higher thermal efficiency than vegetable and animal oil at lower load, whereas, at maximum engine load, the thermal efficiency was slightly higher using vegetable oil. Also, the BSFC and BTE of various biodiesel was lower than diesel fuel.

Karmakar et al has done an optimization of castor oil esterification using Taguchi L16 orthogonal array. The authors found out that 90.83% of oil was yielded by optimizing the methanol to oil molar ratio, reaction temperature, stirrer speed, catalyst concentration, time of reaction as 20:1, 50°C, 700 rpm, 1% w/w, 60 min, respectively. The Gas Chromatography analysis was performed for knowing the methyl esters compositional variance, and for optimization betterment, the ANOVA method was also performed. The authors also claim that methanol to oil ratio is the critical influencing parameter out of any other parameter.

Mahalingam et al produced biodiesel from rubber seed oil using methanol. The optimum blend chosen was B20 blended with alumina nanoparticles with different proportions of 10, 20, and 30 ppm. From the results, it is found that the engine thermal efficiency is increased, whereas the emission increased. For the biodiesel blend (B10), the specific fuel consumption has been reduced, and the NOx emission has been considerably increased.

Satishkumar et al has performed an engine experiment using Manilkara Zapota seed oil and its diesel blend on an unmodified diesel engine. Among the various blend, the author reported that the B50 blend is superior to other test fuels. B50 blend has the highest peak pressure, followed by B25 blend and diesel. It was concluded that the thermal efficiency of engine was improved by 17% while the BSFC of B50 blend was reduced by 14.34%. Similarly, there was a reduction of about 4.32 and 34.21% in the HC and CO emitted while compared to that of diesel fuel. There was an increase of about 38.91% in CO2 emitted using B50 blend as compared to neat diesel fuel. The author claims that due to high oxygen content, high pressure is obtained, and as the production of biodiesel goes beyond B50 blend viscosity plays a vital role, which results in reduced pressure.

Puhan et al conducted the performance tests on direct injection diesel engine at constant speed, operated on linseed oil methyl esters with varied injection pressure (200 bar, 220 bar and 240 bar). They concluded that 240 bar is the optimum injection pressure. Furthermore, at this optimum injection pressure the thermal efficiency was similar to that of diesel engine with decreased CO but increased NOx. The effect of injection pressure demonstrated improved brake specific fuel consumption for higher percentage biodiesel–diesel blends (such as B(20), B (50), and B(100)) and lower emissions of smoke capacity, unburnt hydrocarbon, CO but higher emissions of carbon dioxide and NOx

Lapuerta et al it was reported that soot produced by biodiesel-fueled engine oxidized at relatively lower temperatures compared to soot produced from the dieselfueled engine because of higher presence of oxygenated hydroxyl radicals. In most morphological studies, it was commonly concluded that the variations in fuel injection parameters effectively altered the nanostructure of soot and optimized fuel injection strategy resulted in lower soot graphitization with higher soot reactivity.

Suryawanshi and Deshpande reported a slightly higher BTE for Pongamia biodiesel blends compared to baseline mineral diesel. They also reported that retarding the start of injection (SoI) timings by 4 deg crank angle resulted in a minor improvement in BTE at part loads.

Kalargaris In a recent work, studied the effect of pyrolysis oil from polypropylene on the characteristics of combustion, exhaust emissions, and engine performance at different temperatures of the pyrolysis process in a diesel engine. The experiments showed that the pyrolysis oil promoted steady engine operation with a longer combustion duration, a lower engine performance, a higher NOx and HC, and lower CO emissions when compared with the engine operating on diesel fuel.

Venkatesan studied the combustion characteristics and the engine performance of a diesel engine fueled with WPO blends. The brake thermal efficiency (BTE) for the WPO blends was found to be slightly higher than that of the diesel fuel. The engine performance and combustion characteristics of the diesel engine were significantly affected by the physical and chemical properties of WPO. Furthermore, at the highest load conditions, WPO blends yield better results in comparison to diesel fuel with respect to peak pressure, the rate of pressure rise, in-cylinder pressure, and the rate of heat release. The use of WPO as an alternative fuel in diesel engines tends to result in an increase in BTE, NOx, and smoke emissions, while BSFC, CO, and HC emissions decrease with an increasing engine load.

CHAPTER III

METHODOLOGY

3.1 Introduction

The engine is single cylinder water cooled four stroke automotive diesel engine. Diesel fuel is injected directly into the combustion chamber with common-rail fuel injection equipment. The fuel parameters like fuel quantity, injection timing, number of injections, fuel pressure in the rail, etc. can be changed online with the help of an Open ECU. Open ECU based variation in above parameters simplifies the research by brining so many parameters in the preview of research. Above mentioned parameters can be optimized by single click of mouse at various RPM points to study their effect on Engine Efficiency, Ignition Delay and Emission etc. This can also be used for training of engineering students.

3.1.1 Technology

CRDi stands for Common Rail Direct Injection meaning, direct injection of the fuel into the cylinders of a diesel engine via a single, common line, called the common rail which is connected to all the fuel injectors. Whereas ordinary diesel direct fuel-injection systems have to build up pressure anew for each and every injection cycle, the new common rail (line) engines maintain constant pressure regardless of the injection sequence. This pressure then remains permanently available throughout the fuel line. The engine's electronic timing regulates injection pressure according to engine speed and load. The electronic control unit (ECU) modifies injection pressure precisely and as needed, based on data obtained from sensors on the cam and crankshafts. In other words, compression and injection occur independently of each other. This technique allows fuel to be injected as needed, saving fuel and lowering emissions. More accurately measured and timed mixture spray in the combustion chamber significantly reducing unburned fuel gives CRDi the potential to meet future emission guidelines such as BS4, BS6 et cetera. CRDi engines are now being used in almost all Mercedes-Benz, Toyota, Hyundai, Ford and many other diesel automobiles. Nowadays, common rail in Mahindra single and twin cylinders has been replaced with a Fuel Distribution

Block (FDB) and fuel pressure control is achieved with fuel feed pump speed control by ECU.

In a CRDi system, the Engine Control Unit (ECU) or Engine Control Module (ECM) plays an imperative role. The injection timing, quantity and pressure of injected fuel has a decisive influence on engine starting, idling, power and emissions. The engine ECU is programmed ("mapped") with relevant data to calculate the amount of fuel to be injected.

The driver requests the torque or engine speed requirements via accelerator pedal potentiometer thereby sending a signal to the engine ECU which then, depending on its mapping and data collected from various sensors, calculates in real time the quantity of fuel required, thus altering the injection duration. The ECU also can also be calibrated to enhance the engine performance, based on the environment in which the engine is being operated. The environmental compensations could be based on coolant temperature, charge air temperature, manifold air pressure, atmospheric pressure, exhaust gas temperature and many more. The ECU also offers various safety features like over-speed protection, low battery voltage cut-off et cetera. To put it in a nutshell, ECU acts as brain of the vehicle.

3.1.2 List of Items

Following are the items that are included in the package:

1. CRDi Engine – Diesel (1 Cyl., 4 stroke)
2. Open ECU – MCS1-i7
3. ECU Data File
4. ECU Calibration Software
5. Communication Cable
6. Wiring Harness
7. Combustion Analysis System
8. Water Eddy Current Dynamometer
9. Panel with necessary instrumentation
10. Cardan Shaft with safety guard
11. Test Bed (includes engine and dynamometer mountings, fuel feed and storage system, air filter and necessary water connections).

3.1.3 System Layout

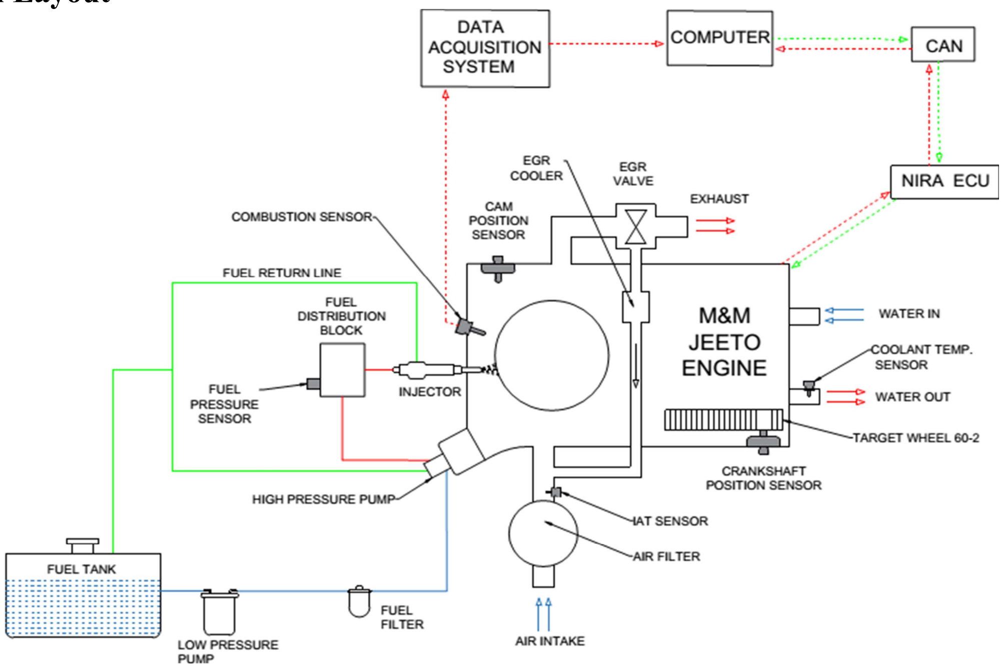


Fig. 3.1.: General illustratio of engine fuel system, ECU and data acquisition system

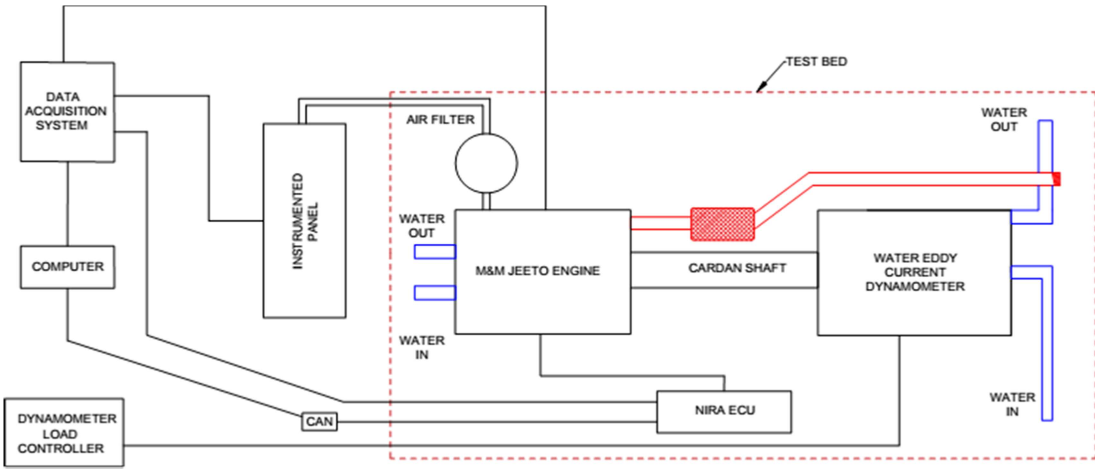


Fig. 3.2: General illustration of engine test setup

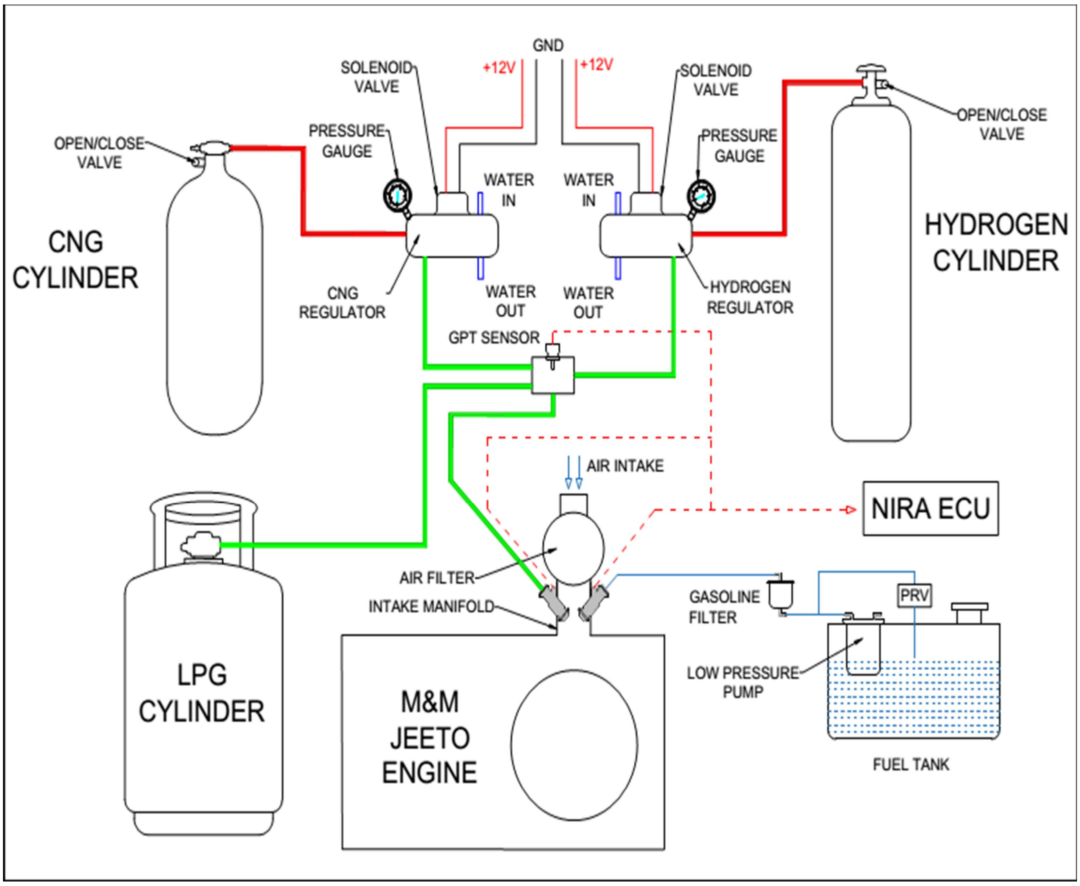


Fig. 3.3: General illustration of diesel secondary fuel injection system.

3.1.4 Salient Features

Following are the salient features of the equipment for flexibility in research:

1. Multispeed engine (1000-3000 RPM)
2. Open ECU for online change of fuel parameters
3. Injection Timing Control
4. Injection Pressure Control
5. Multiple Injections Feature (Pilot, Main and Post Injection)
6. Exhaust Gas Recirculation (EGR) Control with ECU
7. PC Based Calibration Software
8. Online Monitoring of engine parameters
9. Data logging feature in ECU Software
10. High Speed CAN Bus Communication
11. Water Cooled Eddy Current Dynamometer

12. Fuel Consumption and Air Flow Measurement
13. Constant Speed and Constant Torque Loading Feature (Optional)
14. Secondary Fuel Injection Feature of CNG/LPG/Hydrogen/Gasoline (Optional)
15. Secondary Fuel Software Control (Optional)
16. Combustion Analysis Software with High Speed Data Acquisition (Optional)

3.1.5 Use Cases (Some add-ons may be required)

Following are the use cases of the equipment:

1. Study the effect of various alternate fuels such as biodiesel, green diesel etc. on engine performance, combustion pressure, and fuel consumption and emission characteristics.
2. Study the effect of methanol, DME, Ethanol
3. Study of advanced combustion modes: HCCI and PCCI
4. Study the combustion properties of different fuels, determining knock index, Cetane Number etc.
5. Research work of M.Tech. /Ph.D. Thermal, IC Engines and Automobile Engg.
6. Lab experimentation for B.Tech. / B.E. / U.G. students.
7. Industry oriented training for engineering students.
8. Motorsports applications.

Fig.3.4: Different engine fuels could be tested with Open ECU

3.2 Detailed Specifications

3.2.1 Engine

The research engine specifications are as follows:

Table 3.1 Engine Specifications

Sr. No.	Description	Specifications
1.	Make	Mahindra and Mahindra
2.	Engine Capacity (cc)	625
3.	Number of cylinders	1
4.	Application	Automotive (Multi-speed)
5.	Number of Strokes	4
6.	Compression Ratio	18:1
7.	Bore (mm)	93.0 to 93.018
8.	Stroke Length (mm)	92
9.	Ignition	Compression Ignition
10.	Max. Power @ RPM	9 HP @ 3000 RPM
11.	Max. Torque @ RPM	30 NM @ 1800 RPM

3.2.2 Medhaavi ECU (MCS1-i7)

Fig. 3.2.1: Medhaavi ECU

Table 3.2 Medhaavi ECU Specifications

Sr. No.	Description	Specification
1	Operating Voltage	12v
2	No. of Connectors	02
3	No. of Pins	105 + 91 = 196
4	Type	Open (Configurable through PC based Software)
5	Analog Inputs	30
6	Digital Inputs	15
7	PWM Outputs	18
4	Relay Outputs	4 (Low Side)
5	H – Bridge	4
6	Injector Driver	Solenoid
7	Communication	CAN Bus

3.2.3 ECU Data File

In order the put the power ECU Hardware to use, a software file (x.I3D) will be supplied along with the ECU. The file will contain the below mentioned software logics, various maps, curves & variables which can be configured. The file could be opened in the PC based software (See section 2.4). At the start of project, the maps & curves will have base data to start the engine & will be further optimized during the course of project.

- Sensor data evaluation.
- Fuel mass calculation.
- Injection control (timing).
- Fuel pressure control.
- Engine synchronization (identification of TDCs).
- Main relay control.
- Engine speed control.
- Communication.

3.2.4 PC based ECU Control Software:

PC based calibration software is used to calibrate the ECU. It is also used to log data for subsequent analysis while the engine is running. By using it and applying your knowledge of engine tuning you can prepare for the calibration effort by entering certain parameters for your specific engine. This gives you a base calibration which will save you time later when you connect to ECU.
Calibration Software installs on a PC and connects to ECU via the USB base CAN converter dongle. (See Section 2.5). Main functions of the calibration software:

- Selection of measurement channels (RPM, Fuel, Pressure, & many more) for online monitoring.
- Selection of maps, curves, variables.
- Online (+offline) modification of maps.
- Recording of parameters for offline analysis.

- Calibration preparation + saving of file.
- Configuration of ECU software as per the engine.
- Sensor configuration.

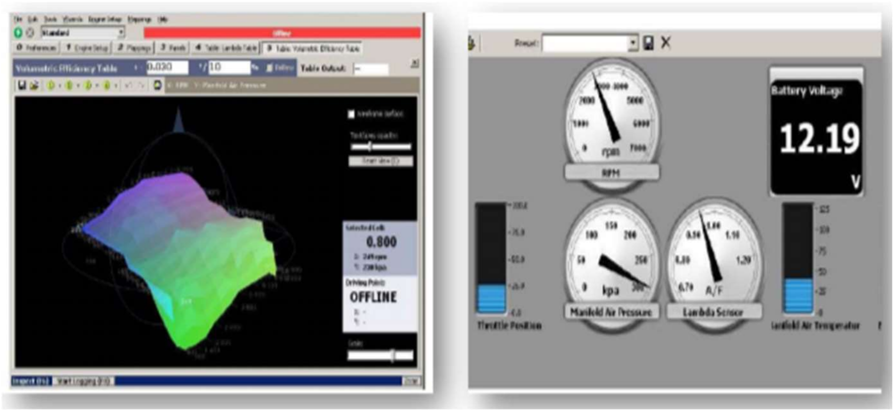


Fig. 3.2.2: Software Interface- Nira rk NAP Calibration Software

3.2.5 Communication Cable

Using this cable, PC based calibration software connects to ECU in order to facilitate data exchange.
This is a CAN dongle, one end of which connects to USB port of the laptop & other end connects to the CAN-H & CAN-L terminals of ECU communication port.

Major Features

• The Kvaser Leaf Light HS V2 is a high speed USB interface for CAN that offers lossfree transmission and reception of standard and extended CAN messages on the CAN bus.
• 8000 messages per second, each time stamped with 100 microsecond accuracy.
• Supports both 11-bit (CAN 2.0A) and 29-bit (CAN 2.0B active) identifiers.
• High-speed CAN connection (compliant with ISO 11898-2), up to 1 Mbit/s.
• Galvanic isolation, previously a more expensive option on Kvaser’s original Leaf Light, now comes as standard on the Leaf Light v2, enhancing protection from power surges or electrical shocks.
• Low current consumption (70 mA) reduces power drain from your laptop.

• Local buffering and pre-processing results in high performance and a reduction of time-critical tasks for the PC.

Fig. 3.2.3: Kvaser Leaf Light V2 CAN Cable

3.2.6 Wiring Harness

A set-up of Wiring Harness will be supplied which will be designed as per the test – bed requirements. The sensors & actuators will connect to the corresponding pins of ECU using wiring harness.

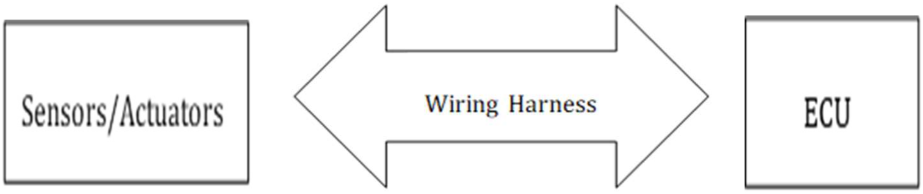


Fig. 3.2.4: A General Depiction of Automotive Wiring Harness

3.2.7 Engine Piston

The piston is the combustion bowl where the air and fuel mix and ignite due to compression temperature. To ensure compression, the piston needs to be sealed against the bore. At the same time it need lubrication

Two compression rings are used to ensure adequate compression.

An oil control ring is used to ensure that the oil film is controlled and does not escape to combustion chamber.

The material of the piston is Aluminium LM13 Dully treated with Alfin ring carrier

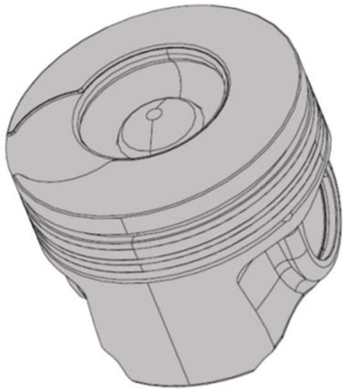


Fig. 3.2.5: Piston Geometry - Toroidal Combustion Bowl – M&M Jeeto

3.2.8 Valve Timing Data

Table 3.3: M&M Jeeto Engine Valve Timing Data

IVO	20.84° BTDC
IVC	260.16° ATDC
EVO	117° ATDC
EVC	38.6° ATDC
Valve Overlap	59.44°

3.2.9 Injector Specifications

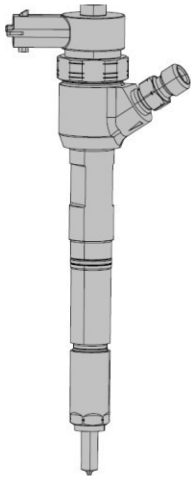


Fig. 3.2.6: Fuel Injector M&M Jeeto

It is an electro mechanical device, which is used to inject the fuel it to the combustion chamber. The quantity of fuel injected in the combustion chamber is controlled by an electronic control module.

Specifications:

• Nozzle Diameter : 145 micron
• No. of holes : 6
• Type : Solenoid

3.2.10 Water Cooled Eddy Current Dynamometer

Eddy Current Dynamometers are used for Testing Engines from 5HP to 1000HP capacity. The precision Strain Gauge type Load Cell are used for sensing the Torque developed by the Engines. Its rugged and rigid design ensured for long working life. This is achieved by electro less nickel plating to the most critical parts which are always in contact with cooling water.

STANDARD FEATURES:

1. High accuracy Strain Gauge Load Cell
2. Electro less Nickel plated water passages
3. Dry running is avoided by water flow switch.

4. Bi-directional operations
5. Low inertia of Rotor
6. Smooth running of Rotor
7. Rugged construction and Long Life Service
8. Compact design

Fig.3.2.7: Water Cooled Eddy Current Dynamometer TME-10

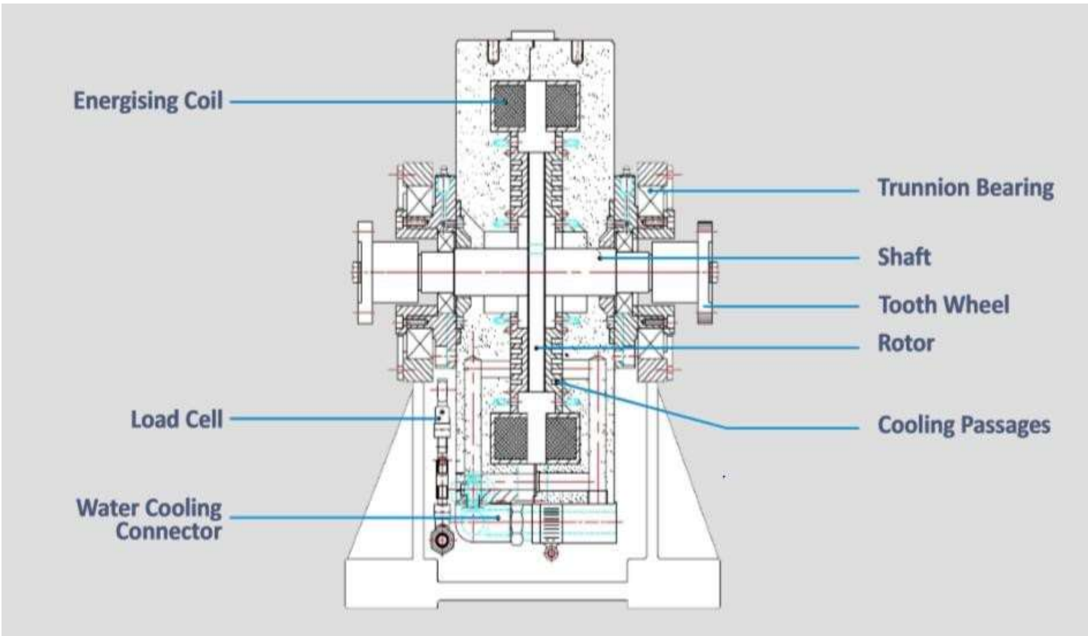


Fig. 3.2.8: General arrangement of Eddy Current Dynamometer

Table 3.4 Dynamometer Specifications

Sr. No.	Description	Specifications
1.	Maker	Technomech
2.	Model	TME-10
3.	Max. Power (in BHP)	10
4.	Supply Voltage (V AC)	250
5.	Max. Current (A)	5
6.	Energizing Coil Voltage (V)	45
7.	Min. Inlet Water Flow (LPM)	30
8.	Min. Inlet Water Supply Pressure (Kg/cm^2)	1
9.	Max. Inlet Water Temp. (°C)	35
10.	Approximate Weight (Kg)	130
11.	Water Inlet Size	3/4" BSP
12.	Water Outlet Size	3/4" BSP

3.2.11 MEUI Control Box

The Medhaavi Equipment User Interface (MEUI), table-top control box, is designed with the aim of making the engine research and experimentation work very efficient and timesaving. It is one of its kind, innovative, versatile, industrial standard and very userfriendly control box. It is equipped with following salient features:

1. In-built independent high-speed, NI-6210 based, data acquisition system with monitoring and data logging of highly-precise cylinder pressure, fuel/air consumption and load measurements along with USB 2.0 communication for PC software
2. In-built independent load controller compatible with eddy current dynamometers with dynamometer over-current protection
3. In-built ECU controls like Ignition switch, Start button, Battery Charging and APP and CAN communication for PC software
4. Combined in a single unit, versatile and ideal for environments with space constraints.
5. Easy to install with industry-grade aviation plugs and single 220V AC power cable.
6. Different indicators on front panel for main power supply, load control activation, dynamometer excitation indicator, APP indication, encoder TDC pulse indication, combustion pressure sensor open and short circuit indication helps in diagnosing faults quickly.
7. Engine shut-off feature in case main power supply is lost.
8. E-Stop feature for emergency engine shut-off.

Fig. 3.2.9: Medhaavi Equipment User Interface (MEUI) Control Box

3.3 Data Acquisition System

The data acquisition system consists of the following components:

• Combustion Analysis System

• Instrumented Panel for Fuel Consumption and Intake Air Flow Measurement

• Data Acquisition Software- EngineScan

3.3.1 Combustion Analysis

The main components of the engine combustion analysis system are as follows:

3.3.1.1Combustion Pressure Sensor with Cable

Nowadays sensors and measuring systems to analyse cylinder pressure and injection pressure are of great importance in the field of combustion engines. The sensor is precisely instrumented in the cylinder head. The sensor used in the system is frequency dynamic pressure sensor, structured with naturally piezoelectric, stable quartz sensing elements that are well-suited to measure rapidly-changing pressure over wide amplitude and frequency ranges. They feature micro-second response times and high resonant frequency. Solid-state construction, acceleration compensation, hermetically-sealed housings, and laser-welded flush diaphragms provide undistorted high frequency response and durability in adverse environmental conditions.

The high impedance measurement cable is used to transmit the electrical charge. Due to the relatively low electrical charge output of pressure sensors, the connection quality between the sensor and the charge amplifier is crucial.

Fig. 3.3.1: PCB 113B22 Combustion Pressure Sensor

3.3.1.2 Charge Amplifier and High Speed Data Acquisition Card

To allow effective signal processing the generated charge from combustion pressure sensor is converted to a voltage signal by means of a charge amplifier. The signal is then sent to the data acquisition unit.

The Medhaavi Data Acquisition System has been developed using National Instruments 6210 DAC. The NI-6210 data acquisition unit developed for combustion analysis performs following tasks:

• Monitors combustion activities of internal combustion engines
• Performs combustion analysis calculations
• Logs combustion activities and calculated values
• Graphically presents data and combustion activities
• Generates test reports for offline analysis
• Measure physical fuel consumption of engine during different test cycles and performs related calculation
• Measure engine intake air flow rate and performs related calculations

3.3.1.3 Crank Angle Measurement

The crankshaft angle mesurement for combustion analysis system is provided by rotary encoder Autonics E50S8. Rotary encoders electronically monitors the position of an engine crankshaft by converting shaft rotation into electronic pulses. The encoder's output pulses are counted and evaluated by a data acquisition unit to determine engine speed and TDC, which provides exceptional accuracy.

Fig. 3.3.2: Autonics E50S Encoder

3.3.2 Instrumented Panel for Fuel Consumption and Intake Air Flow Measurement

Medhaavi provides an instrumented panel as part of package which contains all the necessary components that are required to measure engine physical fuel consumption as well as intake air flow rate measurement. These parameters are extremely important to study the engine performance during different test cycles.

Fuel Consumption Measurement: The are major components that help in *fuel consumption measurement following*

Fuel Pressure Transmitter: The fuel pressure transmitter used is Dawyer 628 Series. The corrosion resistant 316L stainless steel wetted parts allow theSeries 628 transmitters to measure the pressure in a multitude of processes from hydraulic oils to chemicals.

Fig.3.3.3: A Dawyer 628 Series Piezoresistive Transmitter

Diesel Fuel Tank: A diesel fuel tank with capacity of 14.5L is mounted onto the panel to provide the hydraulic head for fuel flow.

Alternate Fuel Tank:: An alternative fuel tank, mounted alongside the diesel fuel tank, with capacity of 4 L helps in using alternative fuels like biodiesel. The fuel line is designed in such a way that ensures quick switching from diesel to any other fuel.

Burette: A 50ml glass burette is mounted on front of the panel. In case, to measure the fuel consumption physical reading from burette scale could also be considered to calculate fuel consumption.

Solenoid Valve: The solenoid valve used in the system is Uflow DAN14Z. The valve is of normally open type. The purpose of the solenoid valve is to shut-off the fuel supply from fuel tank for 30/60 seconds when command is given from Medhaavi_EngSoft1.0 to measure the fuel consumption.

Fig 3.3.4.: Uflow DAN14Z Solenoid Valve

Additionally, other necessary fittings and fabricated items are also the part of the fuel flow measurement system.

Intake Air Flow Measurement: The intake air flow measurement system comprise of HFM Type T-MAF Sensor. This sensor measures the engine intake air flow rate in Kg/hr. It works on Hot Film principle and gives digital output for air flow measurement, along with in-built NTC based ambient air temperature measurement. Its value can be recorded from ECU software by measurement variable, 'Air HFM1 Air Mass'. Its value can be further used to calculate volumetric efficiency and EGR flow rate.

Fig. 3.3.5: Bosch HFM-7

Apart from this, other necessary fittings and fabricated items are also the part of the air flow measurement system.

3.3.3 Data Acquisition Software- EngineScan

The EngineScan is a NI Labview based data acquisition system developed by Medhaavi after years of continuous research and experience in engine calibration, testing and combustion analysis systems. EngineScan is highly capable of performing sophisticated in-cylinder pressure analysis, measure fuel consumption, and air-flow, perform related calculations and generate test reports and data logs. EngineScan is an ideal solution for your engine test bed and complex research work.

3.3.3.1 Salient features of EngineScan:

- High-speed data acquisition upto 100 cycles.
- P-θ, P-V, RPR, LogP vs. LogV, MFB, HRR, CHRR, MGT plots.
- Fuel Consumption Measurement.

• Performance Report Generation for MS Excel.

• Brake Thermal Efficiency.

• Engine RPM measurement.

• Engine Load Measurement.

3.3.3.2 Getting familiar with EngineScan:

Please follow the following steps in order to use EngineScan:

1. Prior to starting the engine and getting online with ECU software, click on icon on desktop.

2. Now, EngineScan user interface will be displayed on the computer screen as shown below

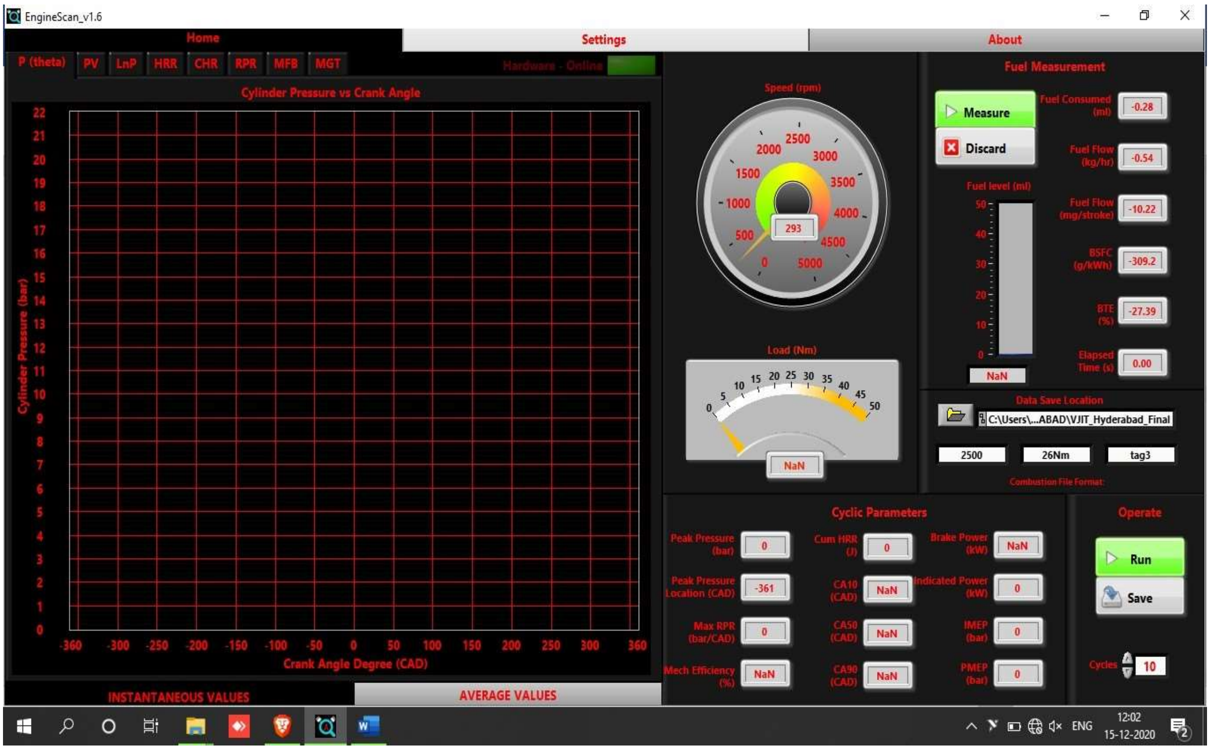


Fig. 3.3.6: User Interface- EngineScan

3. Select the folder location where the data logs will be saved. In case the user wants to add any tags in file name for identification purpose, three name tag boxes are given. See fig.4.8

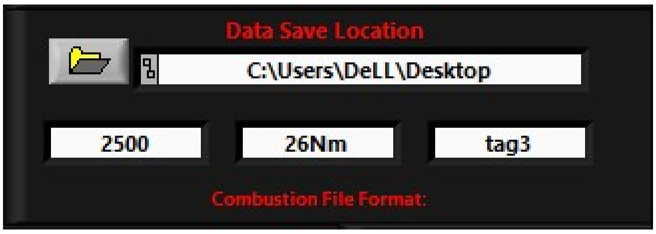


Fig. 3.3.7: Folder Location and name tag boxes.

4. Next, enter the number of cycles to be logged in ‘Cycles’ box in ‘Operate’ section at the lower right corner of software window.

5. Prior to start the experimentation on the engine, if the user wants to change the settings related to experimentation, click on the ‘Settings’ Tab:

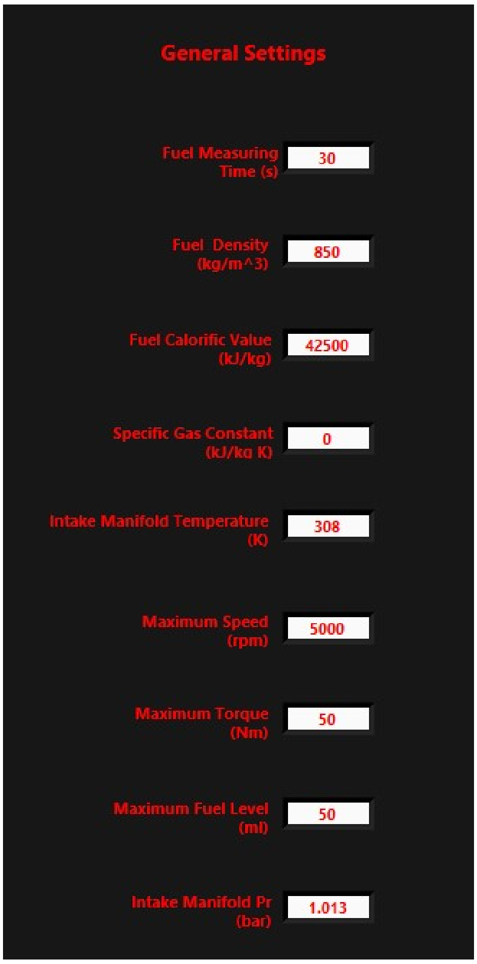


Fig. 3.3.8: User settings

6. Now, start the engine and click on green coloured ‘Run’ button in ‘Operate’ section at the lower right corner of the software window. The button will turn red and ‘Stop’ will be displayed. Same button will be used to stop the software.

Fig. 3.3.9: Run/Stop button

7. Now, the live data from the engine will be displayed in the software. The parameters like engine speed, load, P-θ, P-V, RPR, LogP vs. LogV, MFB, NHR, CHRR, MGT, Air Flow will become visible. In order to measure fuel consumption.

8. In order to start the fuel consumption measurement, click on 'Measure' button under 'Fuel Measurement' section. Once the test starts, the button will turn red from green and display 'Abort'. After the measurement is completed, all the data related to fuel measurement is displayed under 'Fuel Measurement' section boxes. In case, the results are not satisfactory, all the readings can be discarded using 'Discard' button. In case, the fuel measurement process is to be stopped in between, click on 'Abort' button.

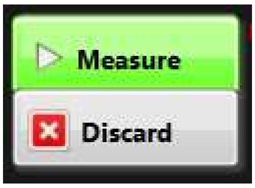


Fig. 3.3.10: Fuel Consumption Measure/Discard button

9. In order to save the data, click on 'Save' button under 'Operate' section. It will save the combustion data for the cycles entered in the 'Cycles' box as a new file at the selected folder location. Also, it will save the fuel consumption measurement results in a file named 'Performance Report'. Every time the data is saved, the combustion data will be saved in a new file, whereas the fuel data will be saved in the same file in different row each time.

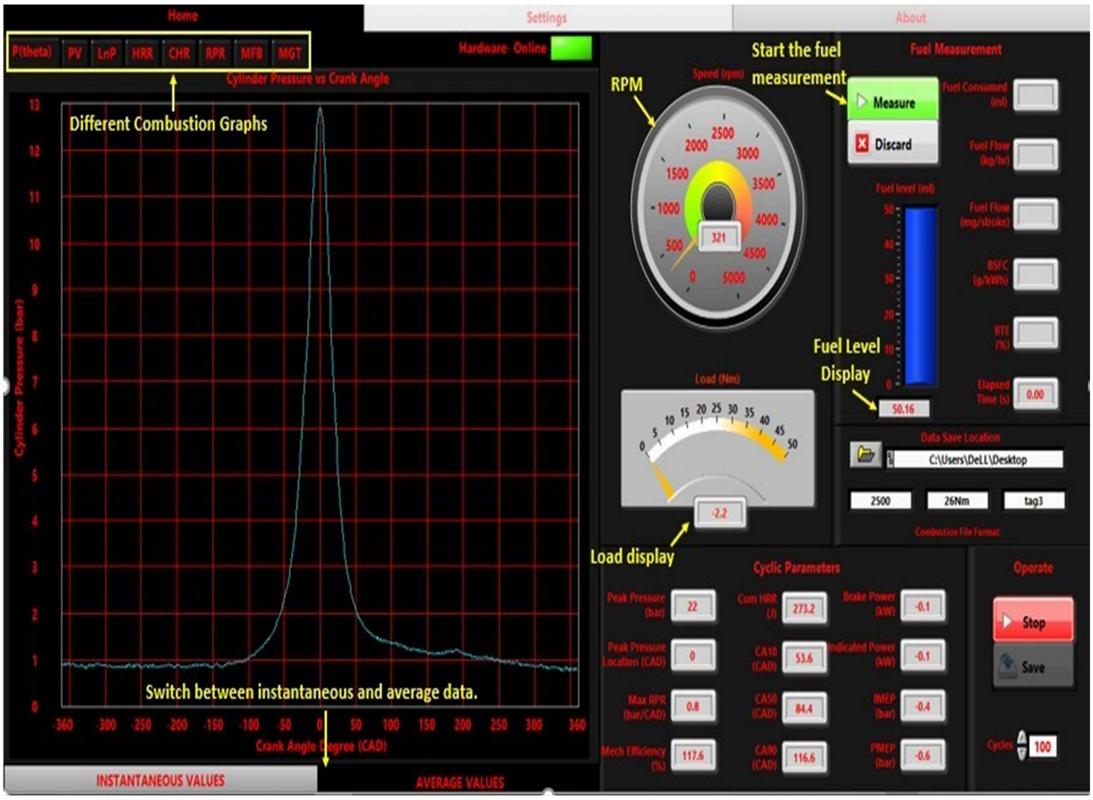


Fig. 3.3.11: EngineScan User Interface- Explained

3.4. Secondary Fuel System

With the growing strictness in diesel engine emission norms in India and to reduce the consumption of diesel, many new technologies are finding their way into the market. Secondary fuel injection with diesel is also one of these technologies currently in research.

Medhaavi is the leading provider of the electronic secondary fuel injection system integrated with CRDi technology. This technology has been developed after a long period of research on engines and ECU software algorithms. The secondary fuel injection covers following fuels- Compressed Natural Gas (CNG), Liquefied Petroleum Gas (LPG), Hydrogen and Gasoline. All these fuels could be possible to inject along with diesel and can be controlled electronically with software.

3.4.1 Components of CNG Sec. Fuel Injection System

Following are the general components of CNG secondary fuel injection system.

1. CNG Cylinder: Industrial grade CNG cylinders are provided as part of the package for storage of CNG for long periods of time and safely. The CNG cylinder has gas storage pressure of 200 bar.

Fig. 3.4.1: CNG Cylinder

2. Cylinder Cage/Stand: A fabricated cage for safe storage of CNG cylinders is provided.

Fig. 3.4.2: Cylinder Cage

3. CNG High Pressure Pipes: CNG high pressure pipes are the high-quality metal pipes for safe transfer of gas from cylinders to regulators.

Fig. 3.4.3: CNG High Pressure Pipe

4. CNG Pressure Regulator: The purpose of a CNG Pressure Regulator is to regulate the pressure of gas coming from cylinder. It also contains in-built solenoid valve for switching on/off the regulator. These pressure regulators also have provision for circulating hot water around them to prevent gas freezing in lines during cold weathers.

Fig. 3.4.4: CNG Pressure Regulator

5. CNG Pressure Gauge: The role of the pressure gauge is to measure the pressure regulator output pressure. The pressure gauge is integrated into the CNG pressure regulator.

Fig. 3.4.5: CNG Pressure Gauge

6. CNG Low Pressure Pipes:: CNG low pressure pipes are made up of high quality industrial rubber for carrying the gas from pressure regulator to the rail or injector.

Fig. 3.4.6: CNG Low Pressure Pipe

7. Gas Pressure and Temperature Sensor (Optional): Gas Pressure and Temperature sensor is used to monitor the gas line pressure and temperature in the ECU software.

Fig. 3.4.7: Sensata Gas Press. And Temp. Sensor

8. Gas Injector: These are specially designed injectors for port injection of CNG and hydrogen.

Fig. 3.4.8: Gas Injector

9. Flame Arrestor: The flame arrestor is the safety device used in the low pressure gas line in order to prevent any fire accident. Flame arrestor allows gas to pass through it but stops a flame in order to prevent a larger fire or explosion. An in-line type flame arrestor is provided in the package.

Fig. 3.4.9: In-Line Flame Arrestor

10. Engine Wiring Harness with Secondary Fuel Injection Provision: A special wiring harness is needed in order to control gas injector and monitoring the gas pressure and temperature in the ECU software.

Fig. 3.4.10: Wiring Harness with Secondary Fuel provision

11. Diesel-Dual Fuel Software: For controlling the secondary fuel injection from ECU, a special software with secondary injection algorithms is provided by Medhaavi.

3.4.2 Components of Gasoline Sec. Fuel Injection System

Following are the general components of Gasoline secondary fuel injection system:

1. Gasoline Tank: Sheet metal tank for gasoline storage with capacity of 15- 28 litres is provided in the secondary fuel injection package.

2. Fuel Pump: A low pressure fuel feed pump is fitted in the gasoline tank, which provides line pressure of 3.45 bar. The supply voltage for pump is 12 volts. The fuel pump has in-built mechanical pressure regulator

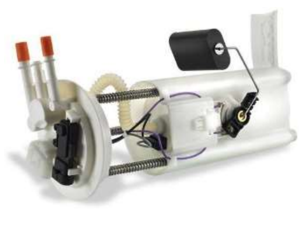


Fig. 3.4.11: Gasoline Fuel Pump

3. Fuel Filter: Fuel filter is mounted on the gasoline tank.

Fig. 3.4.12: Gasoline Fuel Filter

4. Gasoline Injector: The injector for gasoline injection is fitted in the inlet manifold of engine. The injector specifications are as follows:

Type: Saturated

Flow Rate: 224-232 cc/min.

No. of Holes: 4

Fig. 3.4.13: Gasoline Fuel Injector

3.5. OPERATING INSTRUCTIONS:

3.5.1 Basic Instructions:

Please follow the following steps in order to operate the engine test setup:

1. Turn on the 220V AC supply for MEUI table top control box and water pump.
2. Please make sure cooling water/coolant supply is available and water pump is running.
3. Connect the battery terminals.
4. Now, start the computer/laptop and display (if available).
5. Connect the USB 2.0 Cable and CAN Cable from MEUI front panel to your computer/laptop for getting online with Medhaavi_EngSoft 1.0 and Nira Rk ECU software.
6. Switch on the ignition from the selector switch provided on the MEUI front panel. The ECU will get online with the software. Also, get online with MES_1.0 software

for data acquisition. Both the software are independent and could be used individually also.

7. Now, crank the engine from the ‘Green’ push button and engine will start.

8. Before performing any kind of experiment on engine or loading the engine, always keep the engine on idle for 10-15 minutes for warm-up. This ensures best engine performance and life.

9. In order to load the engine, follow the instructions given below.

Fig. 3.5.1: MEUI control

3.5.2 Engine Loading Instructions:

1. Please make sure the 220V AC Supply to MEUI System and in-built load controller is turned on.

2. Before applying any load on the engine, make sure which mode the ECU data file is running.

• For manual mode, accelerate the engine up to desired RPM using the accelerator pedal and apply the load by following below instructions. In case, the engine RPM drops, depress the pedal more to keep engine at desired RPM. The accelerator pedal position and RPM can be seen in Medhaavi Open ECU software.

• For constant speed mode, accelerate the engine up to desired RPM using the accelerator pedal and apply the load by following below instructions. In this mode, engine speed will remain constant irrespective of the load. The accelerator pedal is used to give speed setpoint to ECU. The ECU tries to maintain the desired speed setpoint, until it reaches maximum injection quantity possible. The accelerator pedal position and RPM can be seen in Medhaavi Open ECU software.

3. Now, to apply the load, switch on the ‘Green’ Load/Unload button under load control section on MEUI front panel. This will activate the load controller. Now, the slide potentiometer with green light should be moved in order to increase the load. The potentiometer should be varied gradually and precise load value could be achieved.

4. To decrease the load, slide the potentiometer vertically downwards.

5. The in-built load controller applies direct load to the engine and load value being read by the load cell could be seen in the Medhaavi_Engsoft1.0.

Recommended engine operation: Following table gives values for maximum load that could be applied at specified RPMs. Operating the engine above maximum load values could result in engine failure, dynamometer failure and may lead to any lab accident.

RPM	LOAD (Nm)
1200	15
1500	20
1800	30
2000	30
2200	26
2500	24
3000	22

3.6 Safety Precautions:

3.6.1 Attire/Dress:

1. Always wear proper lab uniform.
2. Wear safety shoes
3. Wear gloves, when required.
4. Do not wear loose clothes while working near engine setup.

3.6.2 General Precautions:

1. Experimentation should be done in an attentive and disciplined manner to avoid any individual harm.

2. Never unduly interrupt the wiring harness and touch the electrical connections or live wires.

3. When running the engine, make sure to provide proper ventilation for exhaust gases in the lab.

4. Do not apply large load suddenly on the engine, it should be applied in small steps.

5. If working on higher engine speeds and loads, keep distance from rotating engine parts.

6. Necessary standards for storage/utilization of Gases (CNG/H2/LPG) should be followed. Gas leakage detection system to be deployed. The cylinders should be kept outside the test lab.

7. Keep safety equipment like fire extinguisher in working condition and in range while working on engine.

3.6.3 Repair Precautions

1. Before starting the operation, make sure to turn the ignition off and remove the battery connection. Remove the sensors' connectors and wiring harness if necessary.

2. Then, prepare tool stand, gauges, oils and parts for replacement

3. Remove Parts.

4. Place removed parts (if any) in a separate box to avoid mixing them up with new parts or contaminating new parts

CHAPTER IV

STUDY ON CONVERSION AND CHARACTERISTICS OF WASTE PLASTIC OIL

4.1 INTRODUCTION

The demand for fossil fuel has been increasing rapidly year by year demanding to find a suitable alternative fuel for diesel. Meanwhile the usage of plastic products has increased in a large manner; the disposal of these waste plastics directly affects the environment and burning of these products has lead to damage of the atmosphere. For the above reason it is very important to dispose of the plastic waste in a safe manner. In this chapter the conversion process of plastic waste into oil has been reported in detail. The characteristics of fuel have studied with the aid of FTIR and GC-MS test.

4.2 CONVERSION OF WASTE PLASTIC OIL

Pyrolysis is a thermal degradation process in the absence of oxygen, performed to obtain WPO by using as a catalyst (Silica- Alumina). The experimental layout of the pyrolysis process is shown in Figure 3.1 and Figure 3.2. Different sizes and shapes of waste plastics were collected and crushed with a shredder for ease of handling the process. Finely crushed waste plastics were fed into a reactor chamber. The reactor is also heated externally by an electrical domestic heater. The heater is made up of U shaped Nichrome wire and has 3kWh and 240V supply. The heating coil placed around the burning chamber is heated and maintained at a temperature range 320-5000C for 3-4 hours duration. The temperature inside the reactor was measured by a Cr - Al: K type thermocouple. The temperature and heating rate was controlled by an external PID (Proportional-Integral-Derivative) controller.

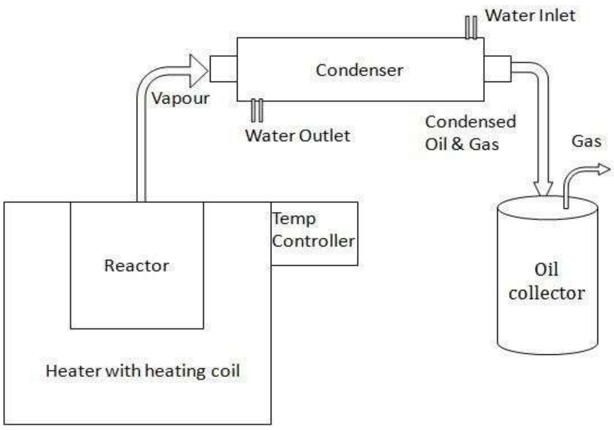


Figure 4.1 Experimental layout of pyrolysis process

Figure 4.2 Experimental setup of Pyrolysis process

Figure 4.3 Waste plastic oil

The high temperature, waste plastic becomes vaporized and passes through the condenser devices. The condenser has an 8mm ID and 10mm OD stainless steel pipe was used to connect the reactor. The condensable liquid products were collected in a

300mm length coil type stainless steel condenser. The temperature of the condenser is maintained at 25°C by circulating the water in the condenser. Due to the cold water present in the condenser, latent heat transfer occurs by condensing the waste plastic vapour as reported by Rajesh Guntur et al. (2011). The condensed waste plastic vapour is then stored in the oil collector in the form of plastic oil as shown in Figure 3.3. From the pyrolysis treatment the following output products were collected:
WPO – 75% to 90%, Gas – 5% to 20% and Residual coke – 5% to 10%.

4.3 PROPERTIES OF WASTE PLASTIC OIL

The physical and chemical properties of the WPO and diesel oil including the Gross calorific value, Cetane index, density, water content, kinematic viscosity, flash point and ash content is as shown in the **Table 3.1**.

4.3.1 Gross calorific value

The Gross Calorific Value of the fuel was determined in accordance with IS1448, P25 calorimeter was used. In this experiment, weighted oil samples are placed in a combustion bomb calorimeter and ignited by heating wires in oxygen enriched environment. The system automatically logs the temperature increase in the combustion bomb and calculates the temperature increasing rate and gross heating value of the weighed sample. The WPO and diesel have satisfactory heating values for fuel oils are 43388 kJ/kg and 42500 kJ/kg respectively. Brake thermal efficiency entirely depends upon calorific value of the fuel.

Sl.No	Properties	Protocol	Diesel	WPO
1.	Density(kg/m^3)	IS 1448, P 16	860	835
2.	Kinematic viscosity (cSt)	ASTM D 445	2.10	3.25
3.	Gross calorific value (kJ/kg)	IS 1448, P25	42500	43388
4.	Flash point ^{0}C	IS1448, P20	50	41
5.	Fire point ^{0}C		56	49
6.	Cloud point ^{0}C	ASTM D 97	-6	+ 6
7.	Cetane number	IS 1448, P9	50	48
8.	Water content (%)	ASTM D 95	0.05	0.12

Table 4.1 properties of diesel and WPO

4.3.2 Cetane index

The Cetane index (CCI) of the oils was calculated in accordance with IS1448, P8 by using the oil densities at 15^0C. Both pyrolysis oils show a greatly reduced CCI compared with diesel and biodiesel.

4.3.3 Density

The density of the oils was measured by an IS1448, P16 densitometer. Liquid samples are injected into a measuring cell and the device calculates the liquid density by measuring the light reflection from the liquid surface. It can be seen that of the WPO density is lower than conventional diesel are 835 and 860 respectively. Fuel density is directly related to the engine performance since the injection system works principally on a volume basis. However, an increase in fuel density leads to an advance in fuel injection timing and a greater spray cone angle as well as reduced fuel spray penetration in the cylinder by Yamane et al (2001). This may result in a poorer combustion and unstable engine operation.

4.3.4 Water content

The water content of the bio-oils was determined using a Mettler Toledo V30 Compact Volumetric Karl Fischer (KF) titrator in accordance with ASTM D95. The result was corrected to weight percent of the total sample. The water content of the remaining oil phase was measured as 0.05 wt. % in WPO and 0.12 wt. % in diesel. This could be considered as reasonable exist since it does not greatly reduce the oil heating values and does not lead to a further significant phase separation problem during oil storage. Furthermore, modest water content in the oils can reduce the combustion temperature in the cylinders and thereby reduce NOx emission.

4.3.5 Viscosity

Kinematic viscosity, which is the resistance to flow of a fluid under gravity, was measured in accordance with ASTM D445 with a Cannon– Fenske Routine glass capillary viscometer. During the test, fixed volume of oil samples are passed through the capillary of the viscometer under gravity at 40^0C. The sample travelling time is recorded. The kinematic viscosity is then the product of the viscometer calibration constant and the measured flow time. WPO has a very high value of 3.25 cSt compared with conventional diesel 2.10 cSt. Viscosity is considered beneficial in lubricating the fuel supply system and thus decreasing mechanical wear, however on the other hand it worsens the flow characteristics of the oil and its atomization quality which can cause incomplete combustion and engine power loss.

4.3.6 Flash point

Flash point was determined in accordance with IS1448, P20 by a Closed Cup apparatus. A test flame is directed to the pre-set location where the vaporized oil may be released at specified temperature intervals until the flash is detected. And have flash points, 41^0C for WPO oil and 50^0C for diesel. They may therefore be considered to have a high safety level in transportation and storage.

4.3.7 Ash content

Ash content of the oil was determined in accordance with ASTM D 5347. The carbonaceous solid samples produced from the Carbon Residue test were combusted in a muffle furnace at 775^0C. The remaining ash was cooled at room temperature and weighed and then expressed as a mass percentage of the original oil sample. These very high values are likely to correlate with fuel injector nozzle clogging and combustion chamber deposits which can affect combustion and overall engine performance. Ash content of the oils was measured as 0.012 wt. % for WPO and 0.01 wt. % for diesel.

4.4 GC-MS TEST FOR WASTE PLASTIC OIL

The GC-MS analysis of the liquid fuel sample obtained by catalytic pyrolysis of WPO was carried out to identify the compounds present in the fuel as shown in Figure 3.4 and is summarized in Table 3.2. The maximum peak areas of total ion chromatogram (TIC) of the compounds were Tridecane, Tetracosane, octadecane, pentacosane, 2-methyl octacosane, 4isopropyl-1, 3-cyclohexanedione, heptadecane, Nonadecane, 2,3,3,-trimethyl 1-hexane, hexadecane and Eicosane. The WPO contains longer hydrocarbon chains in molecular bonding as alkane and alkenes according to their carbon number which depicts the burning quality of fuel. No formation of highly toxic polyaromatic hydrocarbon chains was found, such as carcinogens, mutagens and teratogens in the WPO. But there is a smaller area of the fractional formation of benzene rings which may not be hazardous. However, the addition of emulsions with the plastic oil leads to the oxidation of alkane and alkenes

This reduces the formation of continuous hydrocarbon chains of WPO inside the combustion chamber by Rajesh Guntur et al. (2011).

CHAPTER V

RESULTS AND DISCISSION

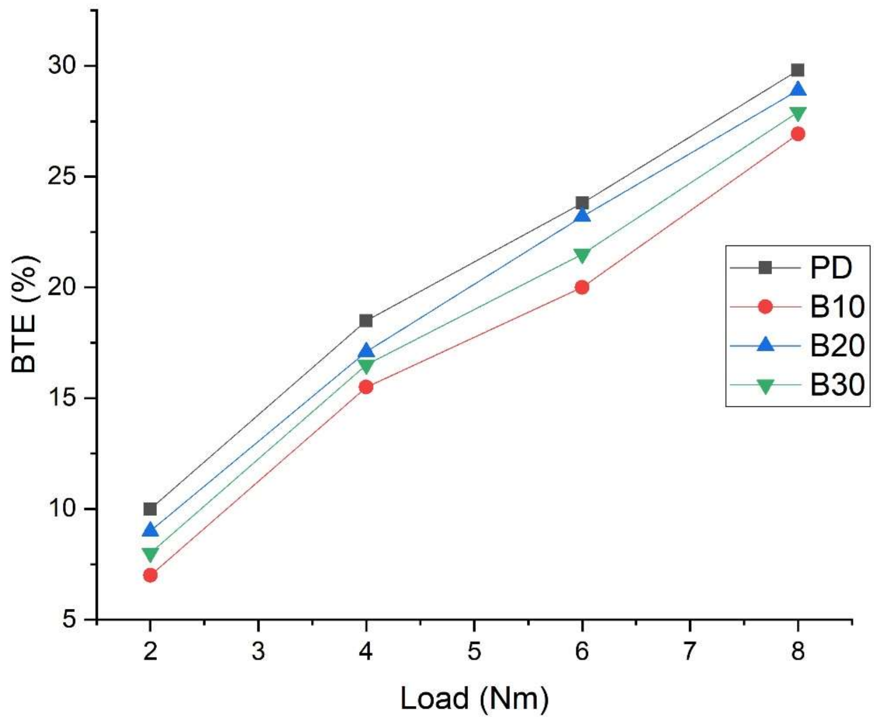
After going through all the experimental procedure and conducting numerous iterations as per the experimental methodology as mentioned in the chapter 3, significant results are drawn and presented that are exposed in the present chapter. The presentations of the results are done in a classified manner of steps for the better sympathetic of the behaviour of the Investigation engine at all experimental conditions. The Case wise presentation is given as;

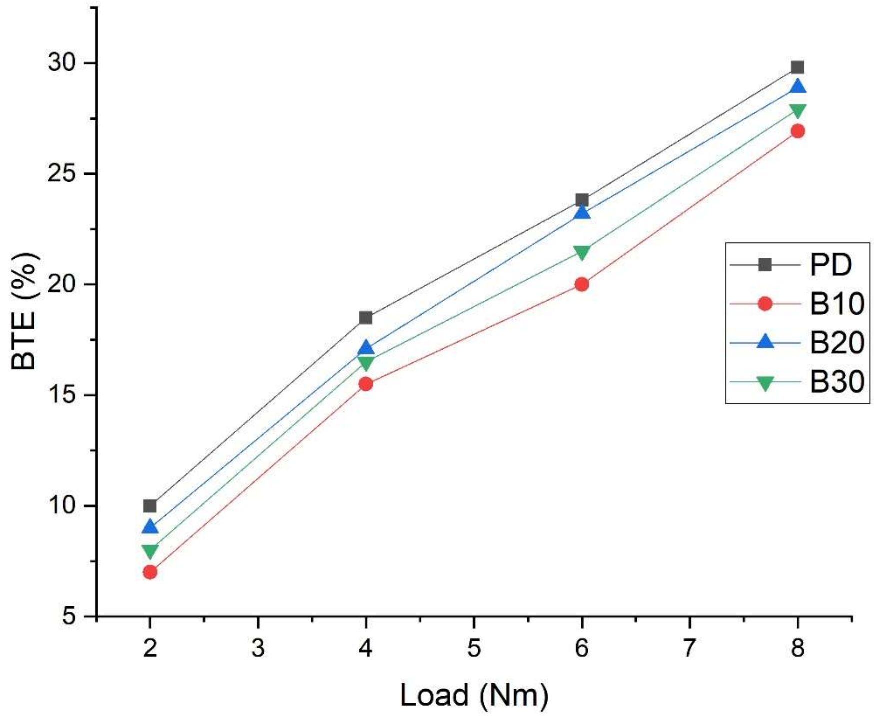
The main base of the experiment is the impact of split injection strategy on a CRDi automotive research engine with waste plastic oil biodiesel blend. Performance and combustion parameters are evaluated and presented in this chapter.

To investigate the effects of the number of injector holes on the performance of the CRDI engine, multi hole injectors were used. The injection of fuel was kept at the best BTE conditions, i.e., fuel IOP at 600 bar and injection timing at 15^o bTDC. In a CRDI, high-pressure fuel enters the nozzle, where it is sprayed into the engine cylinder as micro-fine droplets. The processes involved at the injector to perform injection happen at a very fast pace and are usually measured in milliseconds. In order to study the multiple or split injection effect on the WPO-fueled CRDI diesel engine, several multiple injection combinations were tried and out of them the optimized two, i.e., WPO by mass 40%-30%-30% (pilot, main, and post injections) and WPO 40-20-40, are only presented herein in the Results and discussion section. In this type of injection, the fuel WPO blends was injected at three injection timings of 20^o bTDC, TDC, and 5^oaTDC. The split injection 40-30-30 indicates the pilot-injection, main injection, and post injection percentages controlled by the ECU, which was connected to the engine by sensors. The fuel pressure control valve comprised a fuel-cooled solenoid valve. The valve opening was varied by its solenoid coil being pulse-width modulated at a frequency of 1 kHz. A particular split injection pattern was administered into the engine by varying the pulse width and frequency. By using software, data acquisition was done by the ECU and the sensor outputs were displayed on a computer monitor. The experiments were repeated six times and their averages were only considered for the result analysis. Uncertainty error analysis was carried out for the adequately acquired data.

5.1 Brake thermal efficiency.

It has been reported in the literature that multiple injections affect the BTE differently. Some researchers have reported no significant effect on BTE, while others have reported increased or decreased fuel consumption. If the pilot fuel injection happens too early, it forms too lean a mix to burn and the outcome will be a fuel consumption increase and reduced brake thermal efficiency. It is anticipated that late injections rejuvenate the combustion and further oxidation of PM and improve the fuel consumption





5.2 Brake specific fuel consumption

BSFC is another important parameter that determines the performance of any engine. It is the specific-quantity of fuel-used to generate a unit of power. The Graph 5.2 shows the BSFC for innumerable Blends of WPO & Diesel. Till the part loads of 25% and 50% the BSFC has been varying for different blends but starting from the higher loads 75% and at 100% loads the BSFC is seen almost same to that of diesel for blend B20.

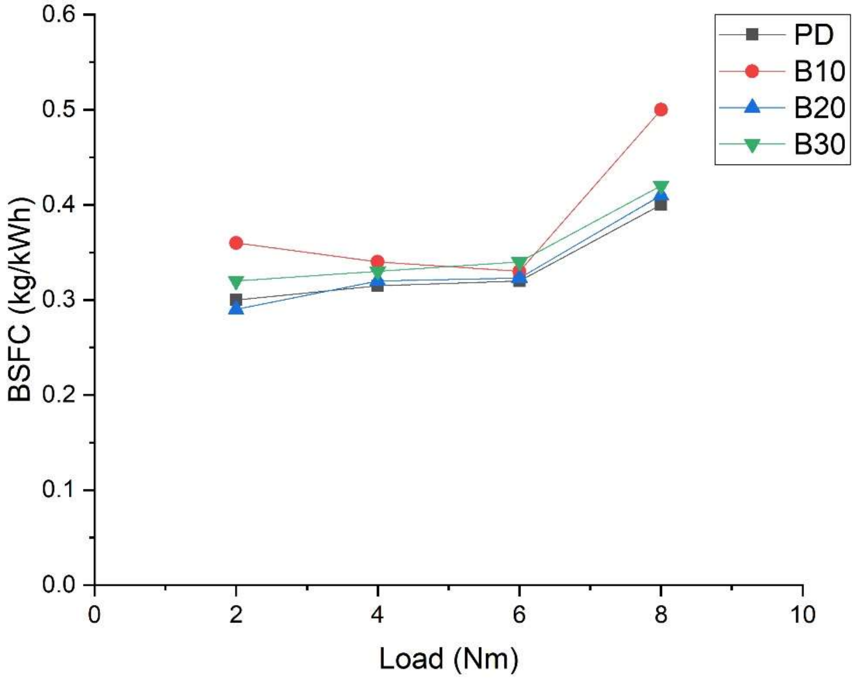


Fig 5.2 BSFC versus load with various blends.

5.3 Pressure versus crank angle

The fig 5.3 shows the graph which represents pressure versus crank angle with different biodiesel and diesel blends at different angles.

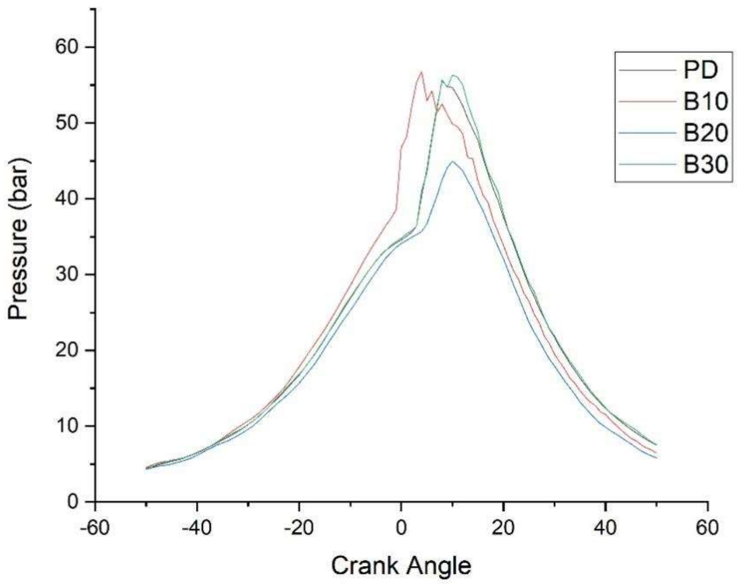


Fig 5.3 pressure versus crank angle with different blends.

5.4 HRR and crank angle degree.

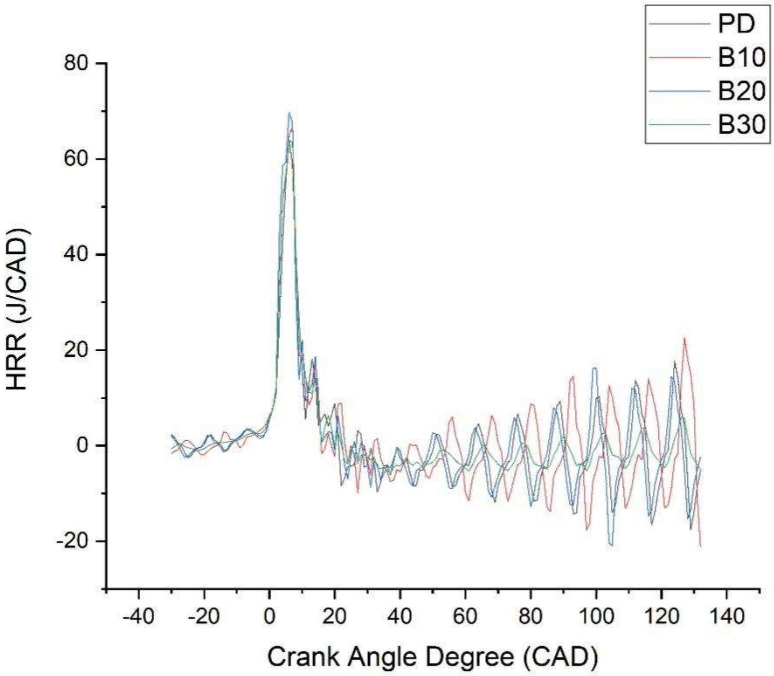


fig 5.4 HRR versus CRANK angle with different blends

5.5 MFB AND crank angle degree

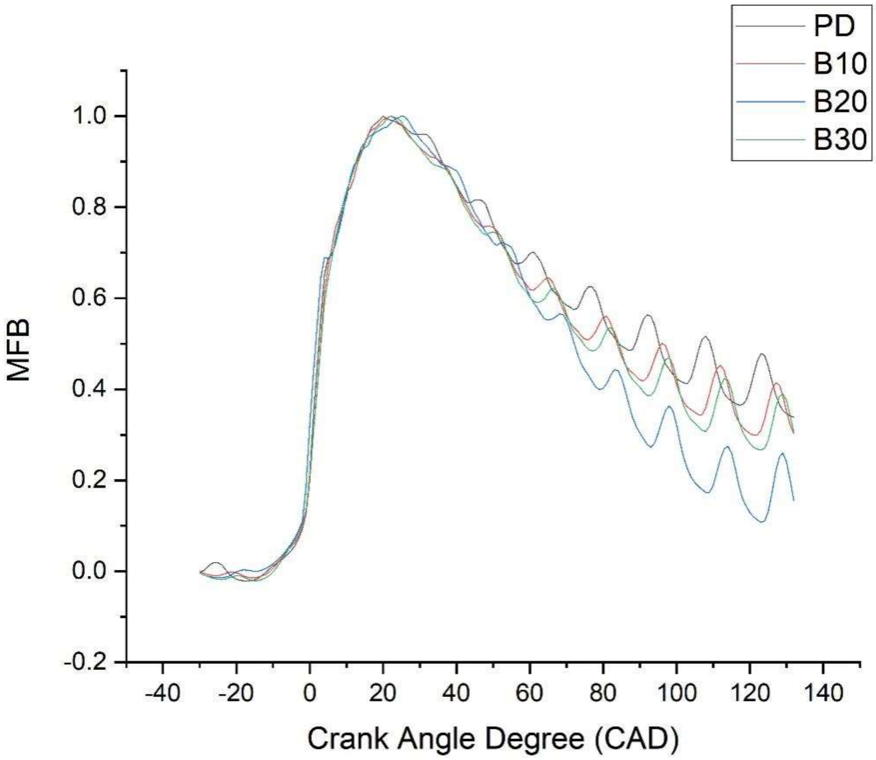


Fig 5.5 MFB versus crank angle degree

Mass faraction burnt is the ratio of the cumulative heat release to the total heat release . therefore if the mass fraction brunt is known as a function of crank angle , then the apparent heat release can be approximated .

CHAPTER VI
CONCLUSIONS

In this study, experimentation was conducted on single cylinder Automotive dual fuel research engine. Diesel and various blends of waste plastic oil and diesel were prepared and tested in engine. To Investigate the effect of operating conditions of engine on performance of diesel/biodiesel blends; tests were performed at no load, 25%, 50% and 75% load conditions by varying speed from 1500 to 3000 r/min at individual load. Following conclusions can be drawn from the series of experimentation performed.
Engine operating conditions have a significant effect on engine performance and combustion characteristics. It was observed that diesel/WPO blends show better results at higher loads as compared to lower load condition. Moreover, biodiesel blends show poor performance at lower loads and high speed conditions.

Due to high density, oxygen content and viscosity of WPO, the performance of engine gets improved. Therefore, all the tested blends B10, B20 and B30 show better performance and emission characteristics than conventional diesel.

Among all the blends, B20 shows maximum ITE and minimum BSFC.

The present analysis reveals that B20 can be utilized in an engine with the advantage of higher thermal efficiency. The engine fueled with B20 does not require any hardware modification.

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