A Project Report on

EXPERIMENTAL INVESTIGATION OF LEMON GRASS OIL IN HCCI ENGINE

Submitted in partial fulfillment of the requirements for the award of the Degree of

Bachelor of Technology
in
Mechanical Engineering

By

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ADITYA ENGINEERING COLLEGE

(An Autonomous Institution)

(Approved by AICTE, New Delhi, Affiliated to JNTUK Kakinada, Accredited by NAAC with 'A' Grade)

Aditya Nagar, ADB Road, Surampalem

2019 – 2023

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Aditya Nagar, ADB Road, Surampalem
2019--2023

DEPARTMENT OF MECHANICAL ENGINEERING

CERTIFICATE

This is to certify that the project report entitled **"Experimental Investigation of lemon grass oil in HCCI Engine"** being submitted by

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in partial fulfillment for the award of the Degree of Bachelor of Technology in Mechanical Engineering to the **Jawaharlal Nehru Technological University, Kakinada** is a record of bonafied work carried out by them at Aditya Engineering College.

The results embodied in this Project report have not been submitted to any other University or Institute for the award of any degree or diploma.

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This is to certify that **Mr.ERUDOYINAVIKAS (19A91A0369), Mr. MEDISETTI DURGA PRASAD (19A91A0393), Mr. VASIREDDY SAI SURYA MANOHAR (19A91A03B2) U.G Students of Mechanical Engineering Department ADITYA ENGINEERING COLLEGE, surampalem.** Has carried out experimental work at **Sri Venkateswara Engineering Consultancy Services, Kanchipuram - 631502.** The experiments were conducted on Experimental investigation on Single Cylinder Water Cooled Diesel Engine which is equipped With National Instruments Data Acquisition System and Eddy current Dynamometer AVL Smoke meter 437C and AVL Digas 444N Analyzer, using **EXPERIMENTAL INVESTIGATION OF LEMON GRASS OIL IN HCCI ENGINE** were obtained for various loads at constant speed of 1500 rpm.

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To emerge as a premier institute for quality technical education and innovation.

Mission:

M1: Provide learner centric technical education towards academic excellence

M2: Train on technology through collaborations

M3: Promote innovative research & development

M4: Involve industry institute interaction for societal needs

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Vision:

To be a preferred knowledge hub in Mechanical Engineering towards critical thinking, quality research and innovation.

Mission:

M1: Provide infrastructure for design and development of modern-day solutions

M2: Impart leadership, critical thinking and innovation to address the societal needs.

M3: Collaborate with industry, academia, & R&D organizations for excellence in teaching, research and consultancy services

K.L.K

Head of the Department

Head of the Department
Mechanical Engineering
Aditya Engineering College
Surampalem

PROGRAM EDUCATIONAL OBJECTIVES (PEOs)

Graduate of the Program will

PEO 1: Model and analyse complex engineering systems

PEO 2: Use professional Knowledge to solve real-time engineering challenges for societal development

PEO 3: Demonstrate interpersonal skills in the chosen area of profession for lifelong learning.

PROGRAM OUTCOMES (POs)

After Successful Completion of the program, the graduates will able to

PO 1: Engineering knowledge: Apply the knowledge of mathematics, science, engineering fundamentals, and an engineering specialization to the solution of complex engineering problems.

PO 2: Problem analysis: Identify, formulate, review research literature, and analyze complex engineering problems reaching substantiated conclusions using first principles of mathematics, natural sciences, and engineering sciences.

PO 3: Design/development of solutions: Design solutions for complex engineering problems and design system components or processes that meet the specified needs with appropriate consideration for the public health and safety, and the cultural, societal, and environmental considerations.

PO 4: Conduct investigations of complex problems: Use research-based knowledge and research methods including design of experiments, analysis and interpretation of data, and synthesis of the information to provide valid conclusions.

PO 5: Modern tool usage: Create, select, and apply appropriate techniques, resources, and modern engineering and IT tools including prediction and modeling to complex engineering activities with an understanding of the limitations.

PO 6: The engineer and society: Apply reasoning informed by the contextual knowledge to assess societal, health, safety, legal and cultural issues and the consequent responsibilities relevant to the professional engineering practice.

PO 7: **Environment and Sustainability:** Understand the impact of the professional engineering solutions in societal and environmental contexts, and demonstrate the knowledge of, and need for sustainable development.

PO 8: **Ethics:** Apply ethical principles and commit to professional ethics and responsibilities and norms of the engineering practice.

PO 9: **Individual and team work:** Function effectively as an individual, and as a member or leader in diverse teams, and in multidisciplinary settings.

PO 10: **Communication:** Communicate effectively on complex engineering activities with the engineering community and with society at large, such as, being able to comprehend and write effective reports and design documentation, make effective presentations, and give and receive clear instructions.

PO 11: **Project management and finance:** Demonstrate knowledge and understanding of the engineering and management principles and apply these to one's own work, as a member and leader in a team, to manage projects and in multidisciplinary environments.

PO 12: **Life-long learning**: Recognize the need for, and have the preparation and ability to engage in independent and life-long learning in the broadest context of technological change.

PROGRAM SPECIFIC OUTCOMES (PSOs)

After Successful Completion of the program, the graduates will able to

PSO1: Apply techniques in design, analysis and fabrication of high end automotive solutions

PSO2: Demonstrate essential skills to analyze the thermal, fluid systems and processes.

K.L.Ka

Head of the Department

Head of the Department
Mechanical Engineering
Aditya Engineering College
Surampalem

ABSTRACT

Homogeneous Charge Compression Ignition (HCCI) is the new approach to get high brake thermal efficiency and to minimize NOx emissions and smoke. By using this we can get higher rate of homogeneous A/F mixture as compared to compression ignition (CI) engine. One of the advantages of HCCI engine to operate with a wide range of fuels including gasoline, biodiesels and Hydrogen. The lemongrass oil was produced by Steam distillation method. The lemon grass was tested in some laboratory techniques like GC-MS, FTIR and UV-Vis machines. The lemon grass oil is blended with diesel fuel with various proportions like B20 + 3 LPM H_2, B20 + 6 LPM H_2, B20 + 9 LPM H_2. In the current research the use of lemon grass oil mixed with diesel and these results are compared with base reading. The use of biofuels was considered as to reduce pollutant emissions like NOx, CO, HC and smoke**.**

Key words: HCCI engine, NOx, CO, HC, FTIR, SEM, GCMS, UV-Vis

COURSE OUTCOMES

PROJECT PART 1

Regulation: AR19	L	T	P	C
Course Code: 191ME7P04	0	0	0	2

CO1	Identify the problem by applying acquired engineering knowledge.
CO2	Analyse the data from literature survey carried out.
CO3	Explain the objective of the project work identified
CO4	Build a team and assign the project modules.
CO5	Prepare project proposal and present in a report form effectively.

PROJECT PART 2

Regulation: AR19	L	T	P	C
Course Code: 191ME8P05	0	0	0	7

CO6	Apply design methodology to execute the project work considering societal, legal, and health frameworks.
CO7	Develop a schedule plan and fix timelines to execute the project tasks.
CO8	Investigate the optimal methods to carry out project work as a team member and as an individual.
CO9	Integrate the project activities to complete within timeline in the light of professional ethics and environmental sustainability.
CO10	Use modern tools and techniques to conclude the project work and report the results.

CO-PO MAPPING

PROJECT PART-I 191ME7P04														
CO/PO	**PO1**	**PO2**	**PO3**	**PO4**	**PO5**	**PO6**	**PO7**	**PO8**	**PO9**	**PO10**	**PO11**	**PO12**	**PSO1**	**PSO2**
CO1	3	2										1		2
CO2	2	3										2		2
CO3		3								2				
CO4									2					
CO5								1		3	2	3		
PROJECT PART-II 191ME8P05														
CO/PO	**PO1**	**PO2**	**PO3**	**PO4**	**PO5**	**PO6**	**PO7**	**PO8**	**PO9**	**PO10**	**PO11**	**PO12**	**PSO1**	**PSO2**
CO6	1	2	2			1		2				2		2
CO7		2									3	2		
CO8		2		3					3			2		2
CO9		2				2	2	2				1		2
CO10					3					3		2		2

CONTENTS

LIST OF FIGURES

LIST OF TABLES

CHAPTER 1

INTRODUCTION

1.0 GENERAL

Nowadays, automotive industries are facing different challenges like environmental issues and increasing fuel prices. Along with the quantity of energy produced there is also a huge demand for cleaner energy sources due to increasing environmental concerns. These problems had given a chance for new combustion techniques and fuels. The severe emission regulations have forced us to select the HCCI engine because of the many advantages when compared to SI & CI engines such as it offers higher thermal efficiency than the SI engine and less emission than CI engine. It has a high compression ratio like CI engine and premixing of fuel & air takes place before combustion starts like in SI engine. HCCI engine runs on lean fuel mixture which results in clean combustion at low temperature reducing NOx & soot.

There are some drawbacks related to HCCI engines like ignition timing control, cold start problems, difficulties in terms of homogenous charge preparation etc., However different studies have provided many remedies like air intake temperature modulation, techniques for charge preparation, variable compression ratio etc., There are several parameters that can influence the performance and emission characteristics of an engine. In this study we are going to find out the performance and emission characteristics of HCCI engine using lemon grass oil biodiesel B20 (20% lemon grass oil biodiesel + 80% diesel) in various proportions like B20 + 3 LPM H2 , B20 + 6 LPM H2, B20 + 9 LPM H2 .

1.1 ENGINE

An engine is a machine that converts one form of energy into mechanical energy, creating motion in the process. The engines can run on a variety of different fuels, in which gasoline and diesel are the most notable ones. However, there do exist 2 some alternative fuel types such as biofuels and natural gas. In thermodynamic terms, engines are generally referred to as heat engines, which produce macroscopic motion from heat. The heat in this case comes from the combustion of fuel in the engine.

1.2 CLASSIFICATION OF ENGINES

The engines are classified into many types such as

1. External combustion engines [EC Engines]
2. Internal combustion engines [IC Engines]

1.2.1 External Combustion Engine

In external combustion engines the combustion takes place outside the engine. External combustion engines are not efficient and the loss of thermal energy is high, so internal combustion engines are highly employed even though they are highly complex.

Example: Steam engine, Stirling Engine

1.2.2 Internal Combustion Engines

In internal combustion engines the combustion takes place inside the engine. The internal combustion engines are more efficient when compared to external combustion engines and are most widely used in automobiles.

Example: Diesel Engine, Petrol Engine

1.3 CLASSIFICATION OF INTERNAL COMBUSTION ENGINE

The Internal Combustion Engine (I.C. Engine) is mainly classified into two categories.

They are,

1. Based on number of strokes
   - Four-Stroke Engine
   - Two-Stroke Engine
2. Based on type of ignition
   - Spark Ignition Engine (S.I. Engine)
   - Compression Ignition Engine (C.I Engine)

1.4 BASED ON NUMBER OF STROKES

The internal combustion engines can be further classified into two categories based on the number of strokes. They are,

1.4.1 Four-Stroke Engine

The four-stroke (also four-cycle) engine is an internal combustion (IC) engine in which the piston completes four separate strokes during one rotation of the crankshaft.

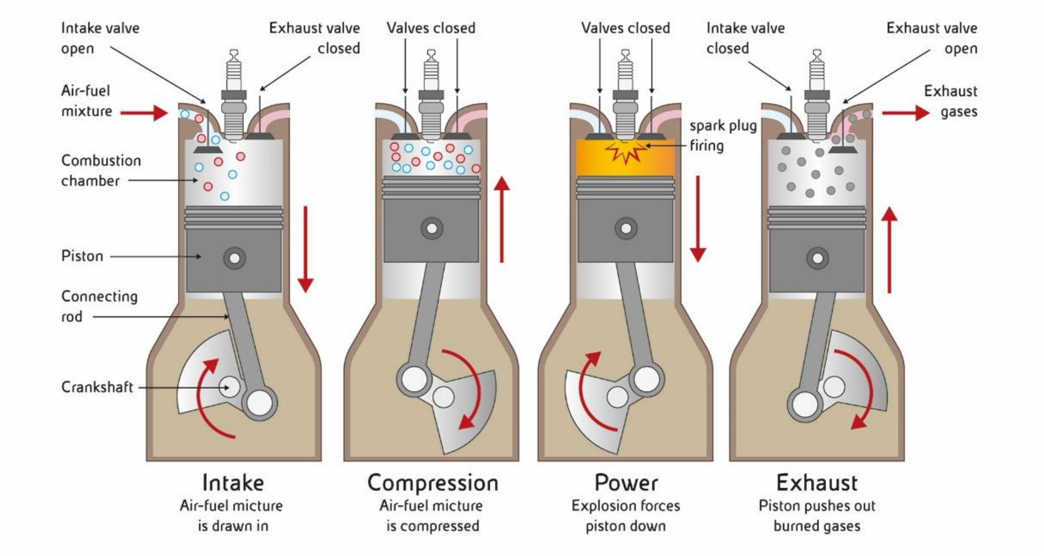

Fig 1.1: Four Stroke Engine

1.4.2 Two Stroke Engine

A two-stroke engine is a type of internal combustion engine that completes two strokes during a single rotation of the crankshaft.

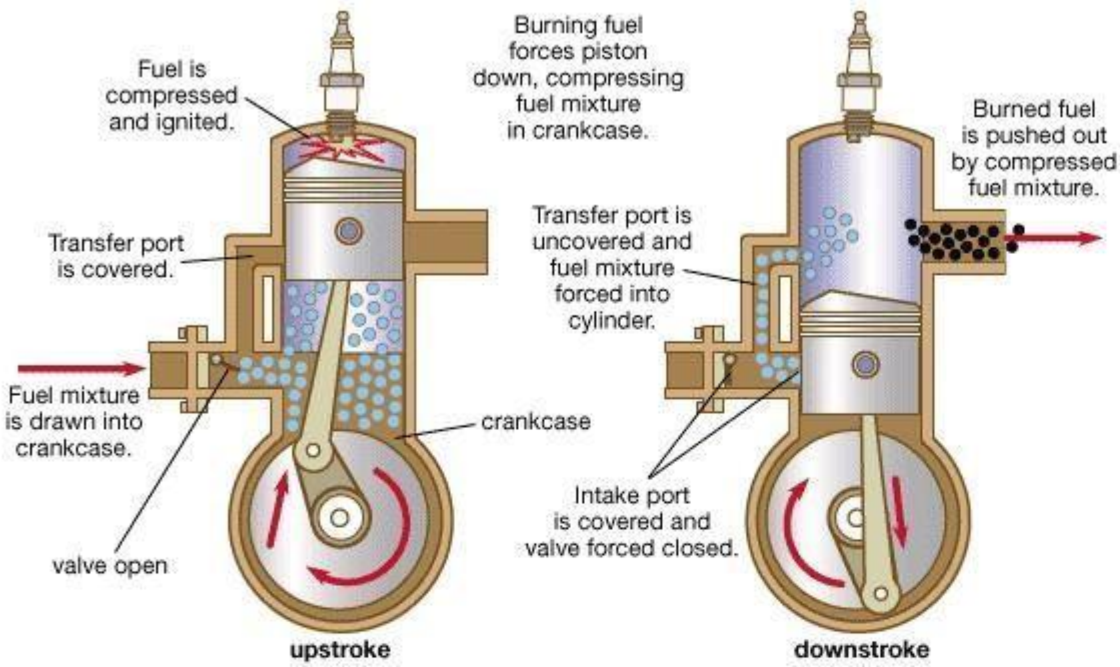

Fig 1.2: Two Stroke Engine

1.5 BASED ON TYPE OF IGNITION

The internal combustion engines can be further classified into two categories based on the type of ignition. They are,

1.5.1 Spark Ignition Engine (SI engine)

A petrol engine or gasoline engine is an internal combustion engine with spark-ignition, designed to run on petrol (gasoline) and similar volatile fuels. In petrol engines pre-mixed air fuel mixture is taken through the inlet and then compressed and ignited with the help of spark plug. The energy released due to combustion of fuel makes the piston reciprocate and provides mechanical energy.

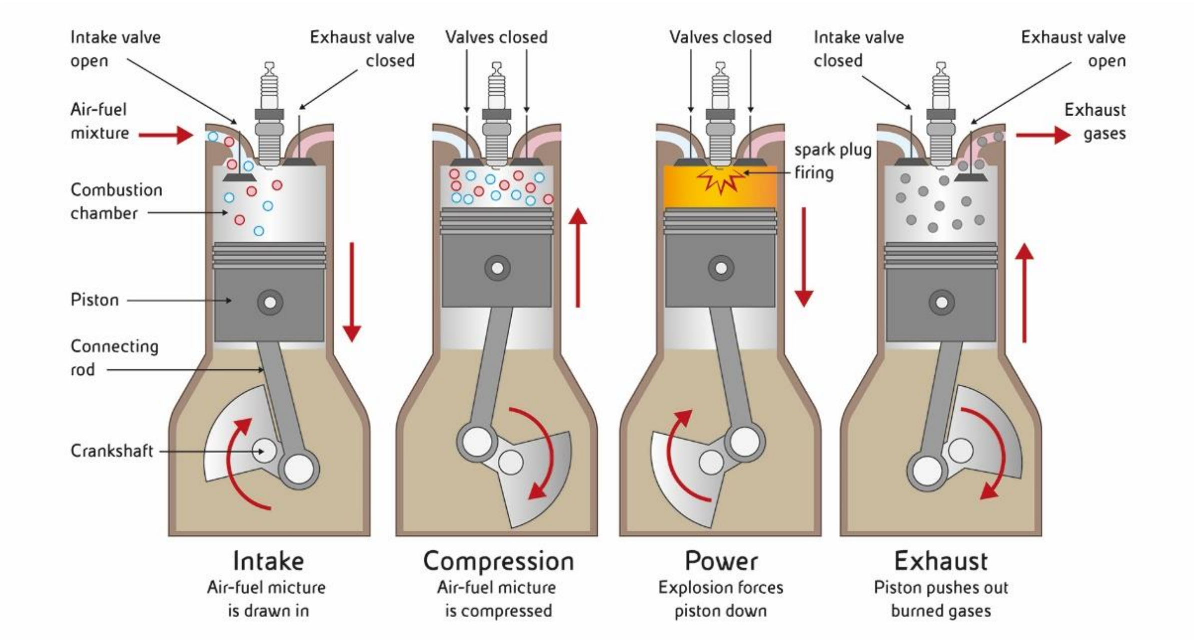

Fig 1.3: Working cycles of SI engine

1.5.2 Compression Ignition Engine (CI engine)

A diesel engine is also an internal-combustion engine in which air is compressed to a sufficiently high temperature to ignite diesel fuel injected into the cylinder. Unlike petrol engines, diesel engines do not require the use of spark plug to ignite the air fuel mixture. Instead, it uses a high compression ratio to ignite the mixture.

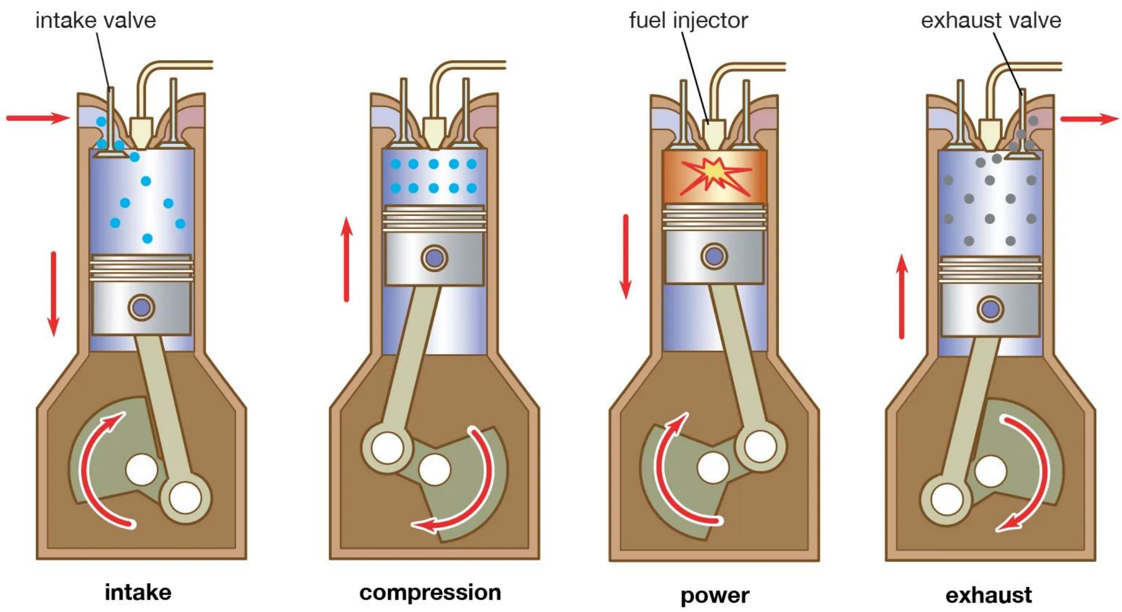

Fig 1.4: Working cycles of CI engine

1.6 BASIC COMPONENTS OF AN IC ENGINE

The basic components of an IC engine are as follows

- Cylinder
- Engine Block
- Piston
- Inlet Manifold
- Exhaust Manifold
- Inlet & Exhaust valves
- Connecting Rod
- Crankshaft
- Piston Rings
- Gudgeon Pin
- Camshaft
- Cams
- Fly Wheel
- Injector

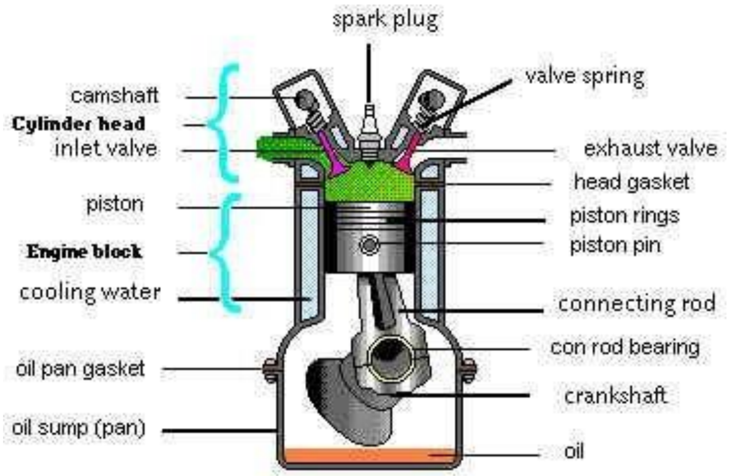

Fig 1.5: Schematic diagram of the SI engine

1.6.1 Engine Block

The engine block acts as the main supporting frame for the various components of the engine. It contains the cylinder, piston and other components of the engine. The engine block is also called a cylinder block.

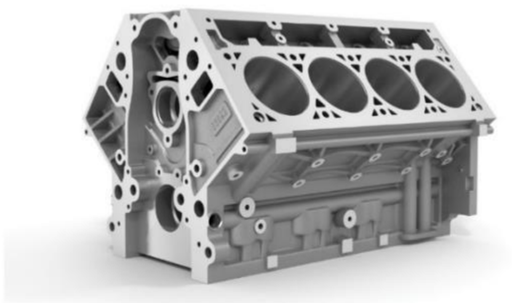

Fig 1.6: Engine Block

1.6.2 Cylinder

A cylinder is an important component of the engine and engine block. It is a cylindrical space which allows the piston to move in a specific motion. An engine blockcan act directly as a cylinder or liners can be used in the block which acts as cylinder.

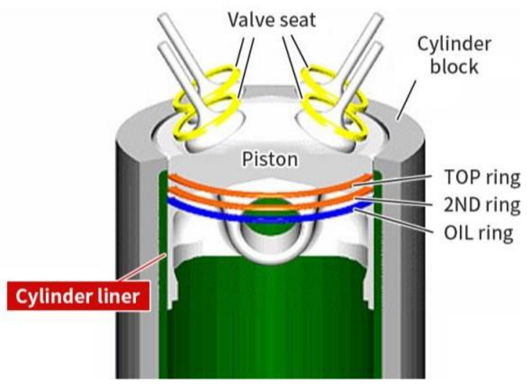

Fig 1.7: schematic diagram of engine cylinder

1.6.3 Piston

It is a cylindrical component fitted into the cylinder perfectly and provides a gas tight space with the piston rings and lubricant. It is the first component in transmitting the engine power by reciprocating up and down between TDC and BDC.

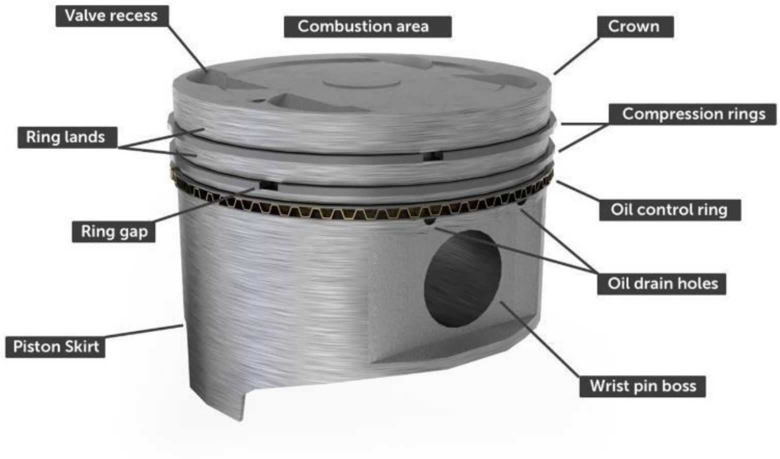

Fig 1.8: Piston of an engine

1.6.4 Piston Rings

Piston rings are fitted around the slots of the piston which provides a tight seal between the piston and the cylinder preventing the leakage of combustion gases.

Fig 1.9: Piston of an engine along with piston ring

1.6.5 Gudgeon Pin

It is a pin that connects the piston to the small end of the connecting rod.

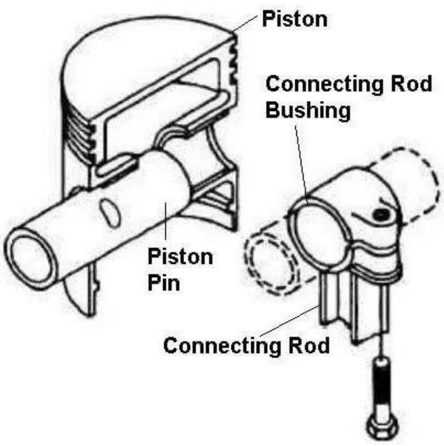

Fig 1.10: Schematic diagram of Gudgeon pin

1.6.6 Connecting Rod

The connecting rod connects the piston and the crankshaft. The two ends of the connecting rod are called as small end and big end. The small end is connected to the piston by gudgeon pin and the big end is connected to the crankshaft by crankpin.

Fig 1.11: Engine connecting rod

1.6.7 Crankshaft

It converts the reciprocating motion of the piston into a rotary motion at the output shaft. The crankshaft is enclosed in a crankcase.

Fig 1.12: Engine crankshaft

1.6.8 Inlet Manifold

It is the pipe which connects to the inlet valve of the engine through which air orair-fuel mixture is drawn into the cylinder.

Fig 1.13: Inlet manifold of an engine

1.6.9 Exhaust manifold

It is the pipe which connects to the exhaust valve of the engine through which the exhaust gases are expelled out from the engine after combustion.

Fig 1.14: Exhaust manifold of an engine

1.6.10 Inlet and Exhaust Valves

The inlet valve controls the flow of charge into the engine and the exhaust valve controls the flow of exhaust gases out of the engine. The inlet and exhaust valves are present at the cylinder head and are operated with the help of cams.

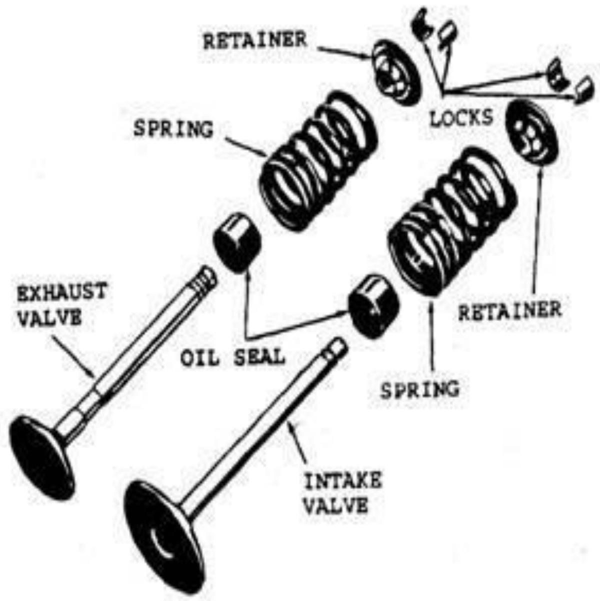

Fig 1.15: Schematic diagram of engine inlet and exhaust valves

1.6.11 Cams

Cam is an integral part of the camshaft which is designed to open the valves atcorrect timing intervals.

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1.6.12 Camshaft

The camshaft controls the opening and closing of the valves. The camshaft isdriven with the crankshaft through timing gears.

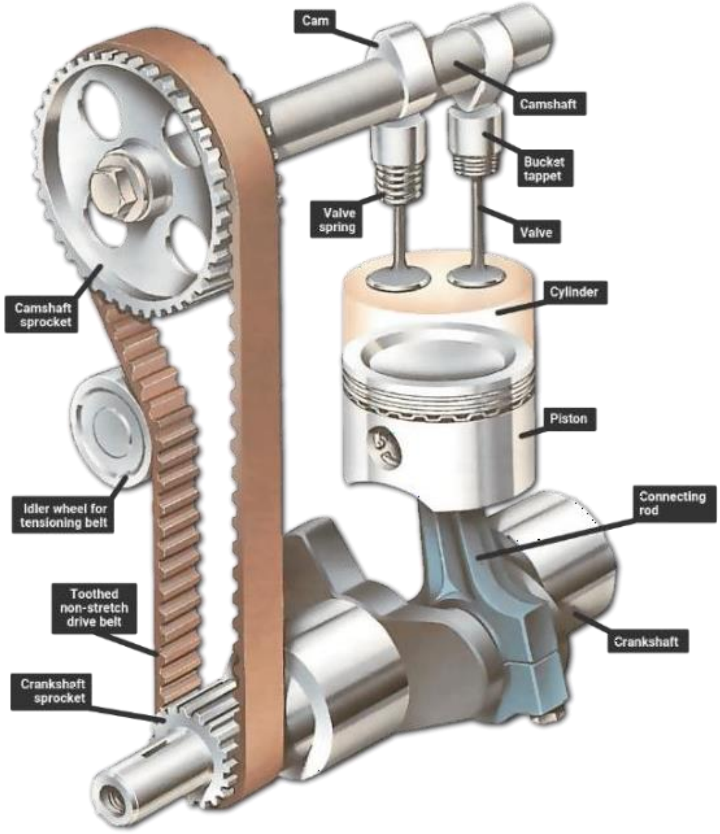

Fig 1.16: schematic diagram of valve operating mechanism

1.6.13Spark Plug

It is a very important component in spark ignition engines (petrol engines) usedto initiate the combustion of air fuel mixture.

Fig 1.17: Sparkplug of an engine

1.6.14 Fly Wheel

A flywheel is a heavy wheel that is attached to a rotating shaft to smooth out delivery of power from the engine. The inertia of the flywheel opposes and moderates' fluctuations in the speed of the engine and stores the excess energy for intermittent use.

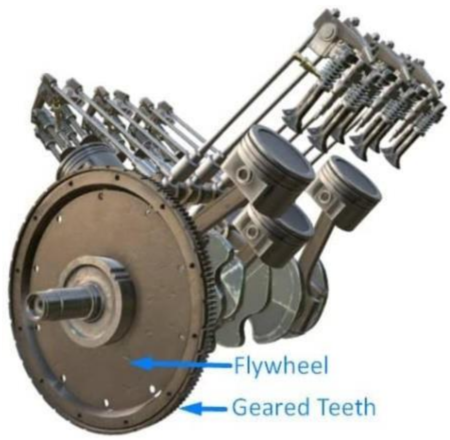

Fig 1.18: Engine Flywheel

1.6.15 Injector

Injectors are usually used in compression ignition engines. It sprays the fuel intocombustion chamber at the end of compression stroke. It is fitted on cylinder head.

Fig 1.19 Injector

1.7 THE NEED FOR ALTERNATIVE ADVANCED ENGINES

Even though the C.I. engines and the S.I. engines are the most widely used engines at present the rise in environmental concerns demands the use of alternative engines and fuels that emit less pollution. The C.I. and S.I. engines emit a lot of CO, UBHC and particularly high quantities of NOx emissions. There are several engine technologies developed to reduce the emissions from the engine in which one of them isHomogeneous Charge Compression Ignition (HCCI) Engine.

1.8 HOMOGENEOUS CHARGE COMPRESSION IGNITION (HCCI) ENGINE

- Homogeneous Charge Compression Ignition (HCCI) is a form of internal combustion in which well-mixed fuel and oxidiser (typically air) are compressed to the point of auto-ignition. As in other forms of combustion, this exothermic reaction releases energy that can be transformed in an engine into work and heat.
- In recent times crude oil depletion and emission norms are the main challenges to automotive industries.
- In order to overcome the challenge, Homogeneous charge compression ignition HCCI engine is the one of the best advanced combustion methods to reduce engine emissions
- By using HCCI engine gives hybrid thermal efficiency like CI engine and low Oxides of Nitrogen (NOx) and soot emissions like SI engine
- it is operated on lean homogeneous air-fuel mixture which reduces NOx and soot emissions
- Homogeneous Charge Compression Ignition (HCCI) is a form of internal combustion in which well-mixed fuel and oxidizer are compressed to the point of auto-ignition.
- The homogenous charge is drawn in to cylinder during suction and compressed to high enough temperature to achieve spontaneous ignition of charge.
- The Combustion process is quite different in HCCI engine when compared to C.I and S.I engines. It does not have the diffusion flame like in C.I engine and flame front like in S.I engine. Instead, the charge burns simultaneously

at several points.

- As the whole mixture burns simultaneously and there is no flame propagation, the combustion temperature can be controlled to less than 700 degrees Centigrade and thus NOx formation is avoided.
- Since the charge is homogeneous there will be no unburnt gases remaining in the exhaust.

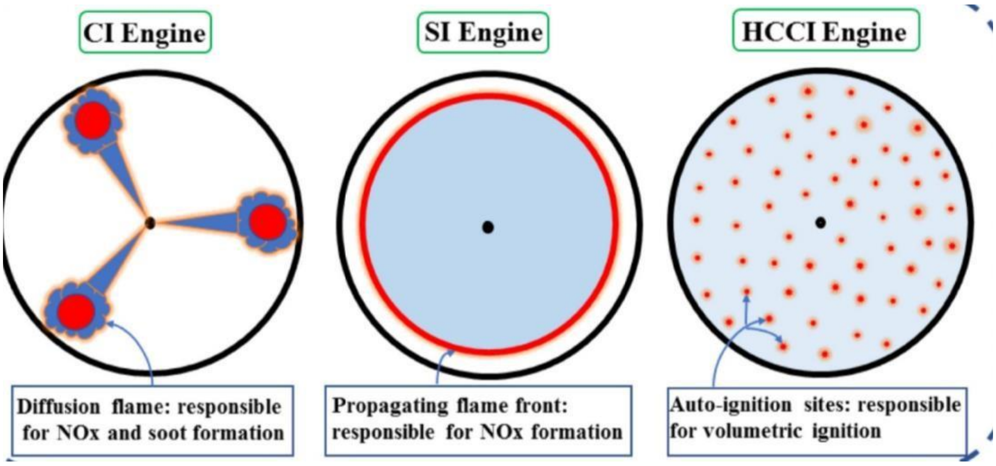

Fig 1.20: Combustion process in C.I, S.I, HCCI engine

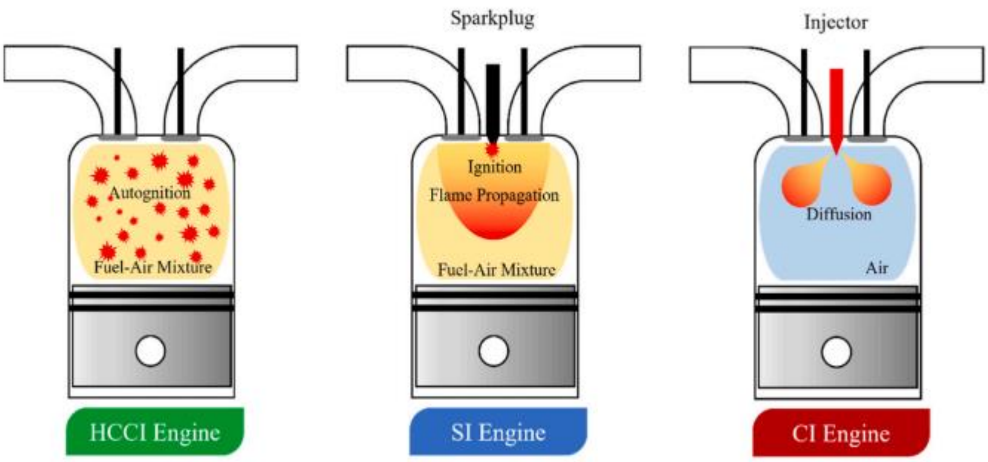

Fig 1.21: Differences between ignition process of SI, CI and HCCI engine

S.no	Engine parameters	Specifications
1	Number of cylinders	1
2	No. of strokes	4
3	Rated Power	5.2 kW
4	Cylinder diameter	87.5mm
5	Stroke length	110mm
6	Compression ratio	17.5:1
7	Orifice diameter	20mm
8	Dynamometer arm length	185mm

Table 1.1: HCCI engine specifications

1.8.1 Advantages of HCCI engine

- Ultra-low NOx emissions because there is no propagating flame frontand the burning is both locally and globally lean.
- Extremely low PM emissions because the mixture is homogenous.
- Homogeneous Charge Compression Ignition (HCCI) engines have the potential of producing a high thermal efficiency with extremely low PM and NOx emissions.

1.8.2 Disadvantages of HCCI engine

- HCCI operation at high loads is difficult.
- Cold starting problem.
- Start of combustion is difficult to control because there is no direct ignition source such as a spark plug or fuel injection timing.
- Controlling how rapidly the energy is released is also a problem. For this reason, significant EGR dilution is needed.
- CO and UHC emissions are also high at light loads.

1.9 Biodiesel

Biodiesel is a type of alternative fuel made from renewable sources such as vegetable oils, animal fats, or recycled cooking grease. It is a cleaner-burning and more environmentally-friendly alternative to petroleum-based diesel fuel, as it emits lower levels of greenhouse gases and other harmful pollutants

Biodiesel can be used in diesel engines without any modifications or in blends with petroleum diesel, with varying percentages of biodiesel and petroleum diesel. The most common blend is B20, which contains 20% biodiesel and 80% petroleum diesel. Biodiesel is also biodegradable, making it a more sustainable fuel option.

Fig 1.22 Biodiesel

1.10 Benefits of biodiesel for engines

Biodiesel may not be able to entirely substitute diesel fuel from fossil fuel, yet it can assist the achievement of a balanced energy usage. One of the benefits of using biodiesel is that it can be used in the existing engines without major modification. Certain changes, however, should be made for old vehicles whose fuel lines contain natural rubber. They should be changed since biodiesel will cause rubber fuel lines to crack. On the other hand, for modern car equipped with DPF, a dilution of fuel or oil may occur in the fuel system. Another advantage of using biodiesel is its superior lubricity. It is known that diesel engines depend on how good the fuel provide lubrication to the fuel injection system. Therefore, the use of diesel-biodiesel blends can improve their overall's lubricity. Also, since nowadays diesel fuel contains less Sulphur, its lubricity can be deteriorated as the compounds that used to provide lubrication have disappeared. This could shorten the lifespan of engine's fuel injection system

1.11 Challenges with biodiesel

Two important factors should be taken into consideration when using biodiesel in internal combustion engines. Biodiesel is known for its high viscosity and low volatilities. These two properties can cause long term problems on engine performance. Higher viscosity affects the fuel droplet size, fuel penetration in the cylinder and causes poor atomization qualities which thus affecting the combustion quality. Much effort has been done to improve engine performance, combustion and emission behaviors using biodiesel. The diesel-biodiesel blends can reduce the PM, CO, THC, SO2 and PAH emissions from diesel engines. NOx emissions, however, were found to be higher with biodiesel use [93]. High level NOx emissions of biodiesel can be a huge challenge when more stringent emission regulations are imposed in the coming years. To reduce NOx emissions, EGR is frequently employed. However, the use of EGR also leads to PM. To solve the trade-off relationship between NOx and PM, emulsified biodiesel is often used. It is oxygenated and water-containing solvent additives to reduce both NOx and PM and can be used without engine modifications with little impact on engine performance. However, fuel emulsions with high water contents can severely affect the injection systems due to their low lubricity. Another solution to reduce NOx is by using alcohol additives. Alcohol has higher vaporization heat which can result in a cooling thus reducing NO formation. Ethanol was previously investigated but due to its low solubility in diesel, as well as low lubricity, CN, energy density and heating value, butanol is more preferred. Both ethanol and butanol can be produced by fermentation of ABE from biomass feedstock. The final products are acetone (22–33%), butanol (62–74%) and ethanol (1–6%), being butanol the major component. In general, the addition of butanol into diesel-biodiesel blends. Results in Engineering 17 (2023) 100916 7 compression-ignition engines have reduced the soot emissions and increased the HC emissions. In terms of fuel consumption, CO and NOx emissions, however, contradictory results were reported. While some studies showed that butanol addition in diesel-biodiesel blends increased the engine fuel consumption, others showed the opposite trend. This conflicting result may be resulted from many factors such as fuel type, butanol percentage, engine specification and operating conditions. Ibrahim investigated and compared the effects of butanol-diesel-biodiesel blends in which butanol was added into B0, B100 and B50 on diesel engine performance, combustion characteristics, NO emissions and engine stability. The results showed that the optimum blends were the B50 where the maximum engine thermal efficiency increased by 6.5% and the lowest engine brake specific fuel consumption decreased by 5% compared to the diesel fuel.

The NO emission increased slightly with the use of oxygenated fuel and as the engine load increased, NO emission increased significantly. The combustion duration also increased with increasing the engine load. It was concluded that changing fuel type had negligible effect on the combustion start timing and engine stability. Few studies can be found on the use of butanol/vegetable oil/diesel fuel blends in diesel engines. Furthermore, studies concerning the use of butanol and non-edible biodiesels feedstock such as microalgae are also limited. Since microalgae can synthesize high amount of lipids, it is considered as the source of renewable biodiesel that can meet the global demand for transport fuels. microalgae biodiesel, butanol and diesel blends to investigate its performance and emissions on diesel engine. The results showed that even though butanol addition reduced the torque and brake power slightly, it improved the CO, NOx and smoke opacity emissions. Considering its problems when used in conventional diesel engines, biodiesel can be implemented in advanced combustion engine such as HCCI. HCCI operates on a premixed charge of fuel and air as in gasoline engine, yet the combustion occurs due to compression as in diesel engine. Therefore, both PM and NOx emissions could be reduced simultaneously while maintaining the efficiency of diesel engines. In addition, economic aspect become also the main challenge in biodiesel production. Reduction of cost production can be achieved through improving productivity of the technologies to increase yield, reducing capital investment cost and reducing the feedstock price. However, the overall cost-benefit ratio of employing biofuels is significantly higher. Biofuels have the potential to become less expensive in the future, given their rising demand.

To reduce biofuel cost, the fuel characteristics must also be upgraded, which can be accomplished by introducing nanoparticles. The economic assessment is critical decision for commercial-scale biodiesel production from feedstock. The total investment cost (fixed and running capital investment) to produce biodiesel vary depending on a number of factors, such as the technology selected, type of catalyst, the plant capacity, raw material type and feedstock price. However, the feedstock price is the most significant factor in biodiesel production, which covers about 80% of the total biodiesel production cost. Besides, the catalyst price is also influenced biodiesel production. Moreover, the utilization of low-cost materials, such as biomass waste-derived catalysts would minimize biodiesel production and support the sustainability ecosystem.

CHAPTER 2

LITERATURE SURVEY

- **Mofijur et al.** [1] reviewed the performance and emission aspect of the HCCI engine. The summary they drawn is that the HCCI engine offers relatively faster combustion than the CI engine and higher brake thermal efficiency. They observed that various alternative fuels and renewable fuels can be effectively used in HCCI combustion but cautioned about the charge preparation, phase control, cold start, etc. As a clean burning fuel, the craze for hydrogen as a fuel is attracting broader attention. The hydrogen market will compound in the near future as investors are welcoming the policy recommended technological breakthrough.
- **Gharehghani** [2] experimentally investigated the HCCI engine load limit for three different fuels i.e. natural gas, ethanol and methanol. The results showed that natural gas was the best fuel at high load HCCI combustion for high inlet temperature, whereas methanol and ethanol was suitable fuels at low load HCCI combustion and low inlet temperature condition.
- **Ngang and Ngayihi Abbe** [3] to investigate the engine performance for varying fraction of LPG under different torque. This study reveals that increase in LPG fraction improved engine performance in terms of efficiency, power and engine torque as well as reduced NOX and HC emissions. Several studies focus on the use of alcohol-based fuels in DF-HCCI engine or RCCI engine. In DF-HCCI engine, chemical properties and molecular formula of alcohol-based fuel impact HCCI engine combustion control and exhaust emission control. High octane number and low cetane number alcohol-based fuels are preferable for DF-HCCI engine or RCCI engine. Because alcohol-based fuels have inherent oxygen content, it leads to better combustion and fewer emissions. Furthermore, alcohol has high latent heat of vaporization (LHV) than gasoline which assists absorption of combustion chamber temperature.
- **M.A. Asokan** [4] reviewed on the Emission and performance behaviour of blends of diesel/lemongrass oil in DI diesel engine. The use of lemongrass oil and optimization of the oil production process that increases the yield and production

cost considerably decreases. The objective of this research is to explore the emission and performance behavior of diesel engine fueled with lemongrass oil (LGO). LGO was extracted by steam distillation process and various lemon grass oil blends were prepared and tested in a diesel engine. Compare to different blends, 20% lemongrass oil with diesel shows better performance on par with the operation of diesel fuel regarding BTE and exhaust emission. The BTE of B20 is 30.07% and diesel is 33.78%. Alongside the B20 emits 1758 ppm of NOx, though diesel emits 1855 ppm and LGO (B100) emits 1714 ppm of NOx. The smoke emission of B20 is 65% and diesel is 85.5%. This research proves that the lemongrass oil is good quality and can be used to substitute the fossil-based diesel.

- **S. Ganesan** [5] reviewed on the main objective of this study is to determine the engine performance and emission characteristics of Diesel engine using lemon Grass oil as a Base oil with MgO as a Nano catalyst. The experiment was conducted in a single cylinder with 4.4 KW Kirloskar research engine with varying the brake power from 1.5 to 4.5 KW from the investigation it was observed that the reduction of 10.5% in HC emissions and about 17% reduction in the emissions CO for the B20 blend with a decrease of 2.7% in NOx emission at full load.
- **Tri W.B. Riyadi** [6] Biodiesel for HCCI engine: Prospects and challenges of sustainability biodiesel for energy transition. Biodiesel use in homogeneous charge compression ignition (HCCI) engines has the potential to improve engine performance and combustion characteristics, while at the same time reducing harmful emissions. Diesel engines have the dilemma of PM and NOx trade-off. HCCI engine emerges as a new combustion mode to reduce such trade-off, while at the same time maintaining the superiority of diesel over gasoline engine with better fuel economy and engine performance. HCCI engine is a promising technology employing the premixed combustion to ensure the homogeneous and lean mixture under autoignition event. However, controlling its combustion phasing remains a major challenge. Also, HCCI engine suffers from high HC and CO emissions. To control its combustion timing and reduce high emissions from HCCI engine, fuel is one of the important parameters. The use of biodiesel fuel can achieve that goal. This study aims to review the effect of biodiesel addition in HCCI

engine. Insights into the prospect of biodiesel for HCCI engine were provided. Also, the challenges of fuel and engine aspect were discussed with potential solutions for future improvement. By playing around with several parametric variables such as inlet air temperature, exhaust gas ratio and injection pressure, HCCI engine fueled with biodiesel fuel could improve the engine performance and combustion characteristics, while at the same time reducing harmful pollutants such as CO, HC, NOx and smoke emissions.

- **Singh et al.** [7] studied the influence of biodiesel content on HCCI engine combustion, performance, and emission characteristics. Experiments were carried out in a modified two-cylinder engine with one cylinder operating in HCCI mode and the other in normal CI mode. Fuel vaporization and mixture formation were done with the help of an external apparatus. Different EGR settings (0%, 15%, and 30%) were used to manage HCCI combustion. Because biodiesel has a lower rate of heat release (RoHR) than diesel, the combustion outcomes for biodiesel HCCI were shown to be more stable compared to diesel HCCI. When the biodiesel content in the test fuel was increased, it resulted in a decrease in power output and a rise in specific fuel consumption. Due to the slower evaporation rate of biodiesel, a slight increase in CO, HC, and smoke emissions was noted as the biodiesel concentration increased. The use of biodiesel blends resulted in a considerable reduction in NOx emissions.
- **Swami et al**. [8] studied biogas/diesel powered HCCI combustion. Usually, using biogas reduces the thermal efficiency of both SI and CI engines. However, they found that in the HCCI mode, the thermal efficiency near to Diesel engine values can be achieved. At all times, the NOx range was obtained to be within 21 20 ppm and the smoke value was less than 0.1 BSU. The best energy to weight ratio was 50%. HC levels were extremely high and were reduced when the charge temperature was increased.
- **Ramkumar et al.** [9] investigated Tamanu Methyl Ether in HCCI engine at different inlet air temperature (100 ◦C–140 ◦C) and injection pressure (10 bar–14 bar). This study found that the most optimum inlet air temperature and injection pressure were at 120 ◦C and 12 bar. At this operating condition, the BTE of HCCI

engine reached comparable result with that of traditional diesel engine with fewer NOx and smoke being reported.

- **Moulali et al.** [10] varied the inlet intake air temperature from 100 ◦C to 140 ◦C, but they use Micro Algae biodiesel and equipped the engine with EGR having ratio of 0%, 10%, 20% and 30%. It was also found that the optimum inlet air temperature for this study was at 120 ◦C and % of EGR. Higher inlet air temperature may have improved the combustion, slightly reduced CO and HC, and significantly decreased NOx emissions. However, as the inlet air temperature and EGR were increased, more emissions were produced. It was also found that higher load would resulted in knocking, thus increasing heat release rate.
- **Puskar et al**. [11] developed a method to reduce NOx emissions of biodiesel on HCCI combustion modified from marine diesel engine. Various biodiesel ratios (0%, 50%, 80% and 100%) were mixed with Ultra Low Sulphur Diesel Fuel ULSDF. The experiments were carried out at different engine speeds and loads. The results showed that higher biodiesel content gave higher in-cylinder pressure, while the heat generation speed was found to be lower. Also, shortened ignition delay and faster combustion speed were observed with higher biodiesel percentage. Furthermore, higher NOx emissions were reported as the engine speed and load increased, but significant reduction of NOx was observed with higher biodiesel percentage.
- **Leo and Arivazhagan** [12] used WCO biodiesel/diesel blend in HCCI engine as the direct injected fuel, while gasoline was used as the premixed fuel. It was found that the WCO biodiesel blends in HCCI engine gave NOx and HC reduction by 11% and 6.67%, respectively compared to conventional direct injection diesel engine. Furthermore, ANN modelling was conducted to predict its performance and emission characteristics. It was found that the proposed ANN model developed in this study could predict the output variables with decent accuracy with the R value ranging from 0.994635 to 0.999571 and R2 from 0.995236 to 0.999143. To optimize the operating parameters, multi-objective optimization using RSM was adapted. The result indicated the optimum operating condition was achieved for WCO biodiesel at part load condition.

2.1 PROBLEM STATEMENT

- Global warming and air pollution are major consequences of our current society.
- The world’s vehicle population is growing rapidly, the automotive industry’s growth rate in India is one of the highest in the world.
- In recent times crude oil depletion and emission norms are the main challenges to automotive industries. In upcoming days crude oil may going to extinct.
- Various combustion techniques have been used to reduce engine emissions and alternative fuels have been tried as replacement for crude oil in IC engine.

CHAPTER 3

METERIALS AND METHODS

3.1 MATERIALS USED

- Lemon grass oil biodiesel
- Ferrous titanium trioxide and silicon dioxide nanoparticles
- Hydrogen gas

3.2 LEMON GRASS OIL BIODIESEL

Lemongrass has a fast-growing nature and is suitable for Indian climatic conditions. It is generally extracted by a steam distillation process; it contains around 75% of Citral. The chemical compositions of lemongrass oil are citral, farnesol, nerol, citronellal, and geranyl acetate. The pure lemongrass oil was used for the blending with diesel without any transesterification process. We have chosen lemon grass oil biodiesel to carry out our experiment on HCCI engine. To prepare lemon grass oil we first need to extract the oil from lemon grass by using steam distillation process.

3.2.1 Lemon grass oil extraction:

- The process of extraction of lemongrass oil involves steam distillation process (Fig. 3.2). The main chamber has water in it which gets heated. The water is then converted to steam and made to pass over the second chamber consisting of lemongrass.
- The steam then goes to 3rd chamber and gets cooled down and gets collected in the 4th chamber. Due to difference in densities the lemongrass oil and water gets separated i.e. the lemongrass oil gets collected in the top layer and the water in bottom layer.
- The lemongrass oil along with some impurities is smoothly drained out from the 4th chamber (collecting tank) and then the oil is mixed with lesser amount of ether. Further this mixture of ether + oil is placed over a bath of water and then heated, so that the hated water bath makes the ether to vaporize and leaving the pure lemongrass oil in the water bath. Alongside this also will moves out the

volatile substance left behind in the lemongrass oil. Finally, by using a filter paper (40 mm) the solid suspended particles are also removed from the oil thus confirming the abstraction of anhydrous lemongrass oil. To get various proportions (B20, B30 and B40) the lemongrass oil was mixed with diesel.

- The thermal as well as physical properties as per ASTM standards were examined and specified in Table 3.1. LGO density is 15.3% more than diesel and the CV of diesel is more by 15.2% than LGO which means that LGO needs to be injected more quantity. Also, the kinematic viscosity of LGO has more than diesel. flash point is 50 ^{0}C. So, in terms of safety aspect the LGO is a better fuel to diesel in terms of storage and handling.

Fig 3.1: Lemon grass

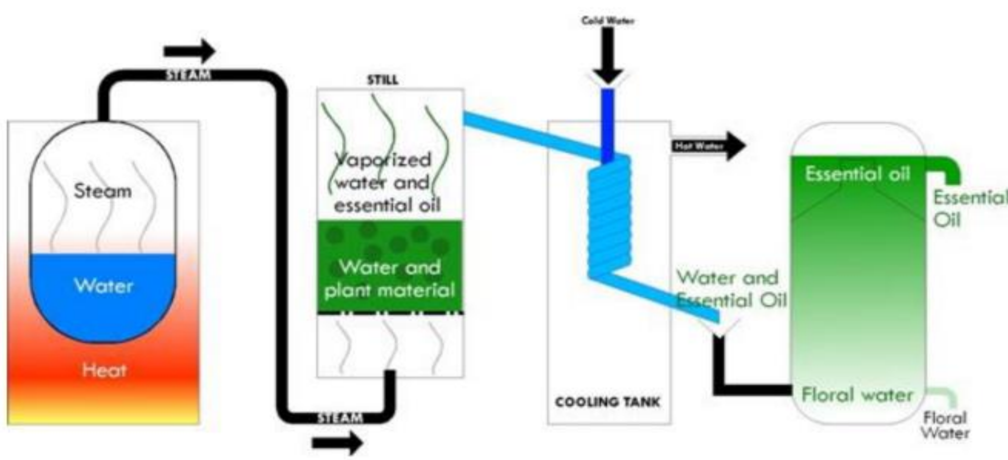

Fig 3.2: Lemon grass oil preparation (steam distillation process)

TABLE 3.1 Properties of lemon grass oil

Properties	diesel	B20 blend
Density (kg/m^3)	830	866
Calorific value (kJ/kg K)	43,962	41,319
Flash point (^{0}C)	52	59
Fire point (^{0}C)	58	64

3.3 Ferrous titanium trioxide and silicon dioxide nanoparticle

Ferrous titanium trioxide and Silicon dioxide (SiO_2) nanoparticles have been studied for their potential applications in biodiesel production. One of the key applications of SiO_2 nanoparticles in biodiesel production is as a catalyst in the transesterification reaction, which is a chemical reaction that converts vegetable oils or animal fats into biodiesel.

$FeTiO_3$ & SiO_2 nanoparticles can improve the efficiency and selectivity of the transesterification reaction by increasing the surface area of the catalyst and providing more active sites for the reaction to occur. In addition, SiO_2 nanoparticles can also improve the stability of the catalyst, leading to longer catalyst lifetimes and improved catalytic performance.

$FeTiO_3$ & SiO2 nanoparticles can also be used as adsorbents to remove impurities from the biodiesel, such as residual catalysts or other contaminants. This can improve the purity and quality of the biodiesel, making it suitable for use as a fuel.

It is important to note that the use of SiO2 nanoparticles in biodiesel production is still an active area of research, and more studies are needed to fully understand their potential benefits and risks.

3.3.1 Blend Preparation

To prepare lemon grass biodiesel blend B20 (20% lemon grass oil + 80% diesel) required quantities of lemon grass oil and diesel is taken in the container and placed on the magnetic stirrer and switched on. The Stir magnet will rotate inside the container which helps in thorough mixing of lemon grass and diesel.

Fig 3.3: Blend preparation

3.3.2 Blend Preparation for oil preparation

- 3drop of biodiesel into 1mg of nanoparticle.
- Mix it thoroughly with glass rod.
- Take 5ml ethanol.
- Add the above mixture into ethanol.
- Sonicated the ethanol mixture for dissolve by 5min.
- Check the transparency of the mixture sample.

3.4 HYDROGEN GAS

Hydrogen(H2) is added because it increases power output and fuel conversion efficiency and also improves Combustion stability. The hydrogen gas cylinder along with pressure 26 regulator, Dry flame arrester, Wet flame arrester and flowmeter are used during the experiment to inject the hydrogen gas into the engine.

Fig 3.4: Hydrogen gas cylinder with wet flame arrester

Fig 3.5: Flowmeter

CHAPTER 4

EXPERIMENTATION DETAILS

4.1 TESTS PERFORMED ON THE SAMPLE:

- The following tests were performed by the Equipment in SRM university, Chennai.
    1. Fourier Transform Infrared Spectroscopy (FTIR)
    2. Gas Chromatography – Mass Spectrometry (GCMS)
    3. Ultra-Violet – Visible Spectroscopy (UV-Vis)

4.1.1 Fourier Transform Infrared Spectroscopy (FTIR):

FTIR shows the Fourier Transform Infrared spectroscopy of neat lemongrass oil, which detects various characteristic functional groups present in the oil. The chemical bond will stretch, contract and absorb infrared radiation in a particular wavelength range during the interaction of an infrared light with the oil.

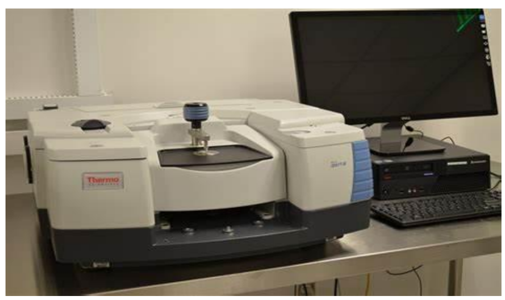

Fig 4.1: FTIR machine

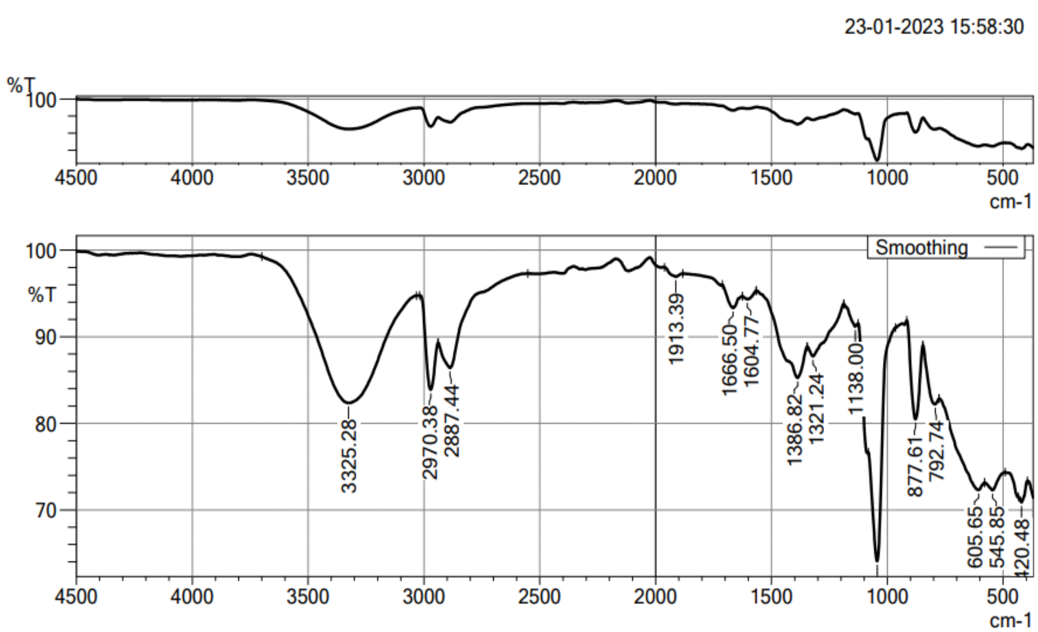

Fig 4.2: FTIR graph

FTIR spectra were recorded using a series FTIR spectroscopy to produce the IR spectra of the given oil sample. The FTIR spectrum has absorption bands in the region 4500-500 cm. The peak absorption of OH group indicated that phenolic compounds appeared at a frequency of 2887 cm.

The remaining peaks is CH, C=O, COOH etc.… but as for experimental purpose. We required OH group only.

4.1.2 Gas Chromatography – Mass Spectrometry (GCMS):

The GCMS instrument and the tests can be used as an analytical tool to quantify

Fig 4.3 GCMS

the chemical components present in the bunker fuels. The tests are usually done as per ASTM 7845 – Standard Test Method for Determination of Chemical Species in Lemon grass Oil by Multidimensional Gas Chromatography – Mass Spectrometry.

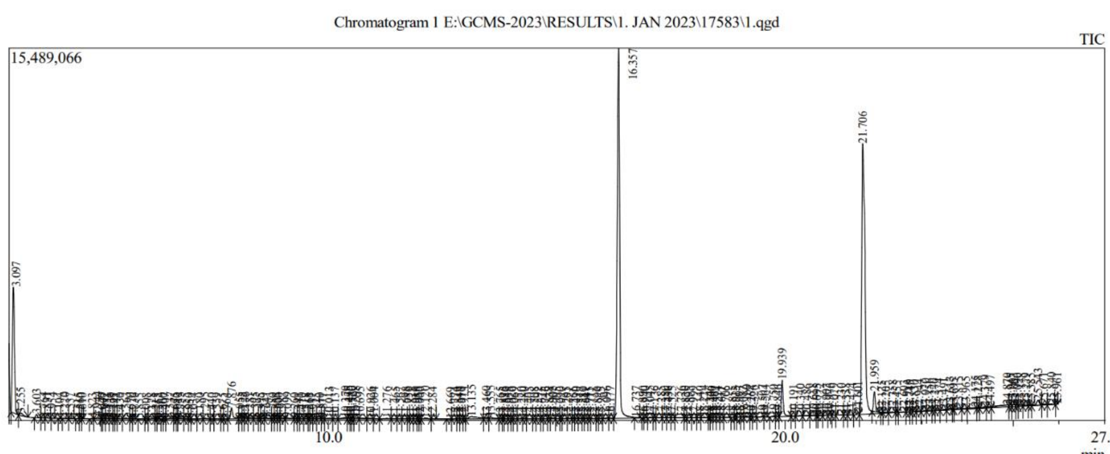

Fig 4.4 : GC – MS graph

- From these three graphs we observed on X-axis time in minutes and on Y-axis spectrum.

- Based on these graphs, there are totally 208 chemical compounds is observed in the oil sample. Each sample has different chemical name and properties.
- According to the graph we have noticed three major peaks at 3.097, 16.357 and 21.706 reaction timings. These three are ETHANE, 1,1-DIETHOXY, 1,2-BENZENEDICARBOXYLIC ACID and 9,12-Octadecadienoic acid (Z,Z)-, methyl ester.

4.1.3 Ultra-Violet – Visible Spectroscopy (UV-Vis)

UV-Vis Spectroscopy (or Spectrophotometry) is a quantitative technique used to measure how much a chemical substance absorbs light. This is done by measuring the intensity of light that passes through a sample with respect to the intensity of light through a reference sample or blank.

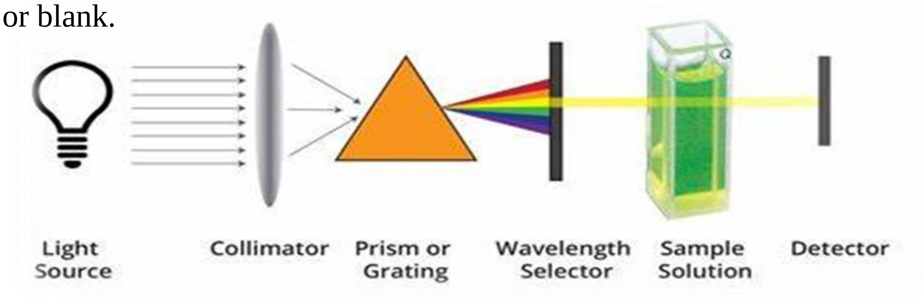

Fig 4.5: UV VIs

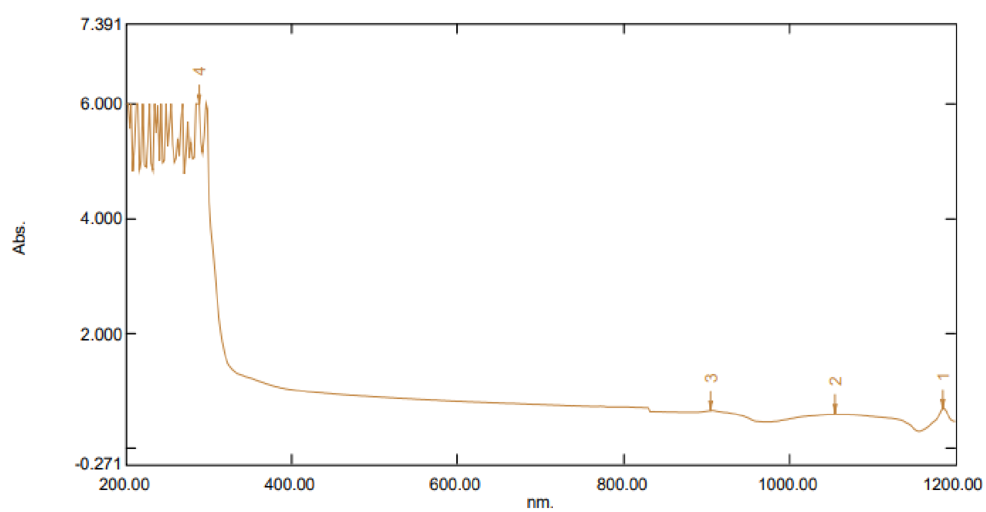

Fig 4.6: UV-VIs graph

- The graph on X- axis wavelength (nm) and on Y- axis absorbance (%). The graph is shown here from 200 to 1200 nm.

- Due to Nano particles the graph is at peak stage from 200 to 300 nm (That region should called as UV- region)
- From 300 nm to 800 nm the graph is decreased the region is called visible region. After 800 nm, it is Infrared region.

4.2 EXPERIMENTAL SETUP OF HCCI ENGINE

The experimental setup of HCCI engine is as shown below. Here, two separate fuels were used to operate the HCCI engine in which the primary tank is filled with primary fuel and secondary tank is filled with secondary fuel. The primary fuel tank was filled with the Lemon grass oil B20 (20% Lemon grass biodiesel + 80% diesel). The primary fuel is injected directly into the inlet manifold.

The fuel injector was controlled through an electronic control unit. An infrared indicator was utilized to signal the ECU for injector opening. The secondary fuel hydrogen gas was separately inducted with the help of flowmeter along with atmospheric air into the inlet manifold. And experiment is carried out by varying secondary fuel Hydrogen at variable rates like 3lpm, 6lpm and 9lpm.

A gas analyzer is used to measure the exhaust gases, it is connected with exhaust manifold to measure exhaust emission such as HC, CO, NOx, and CO2. The smoke meter is used to measure the smoke opacity which is also connected with exhaust manifold.

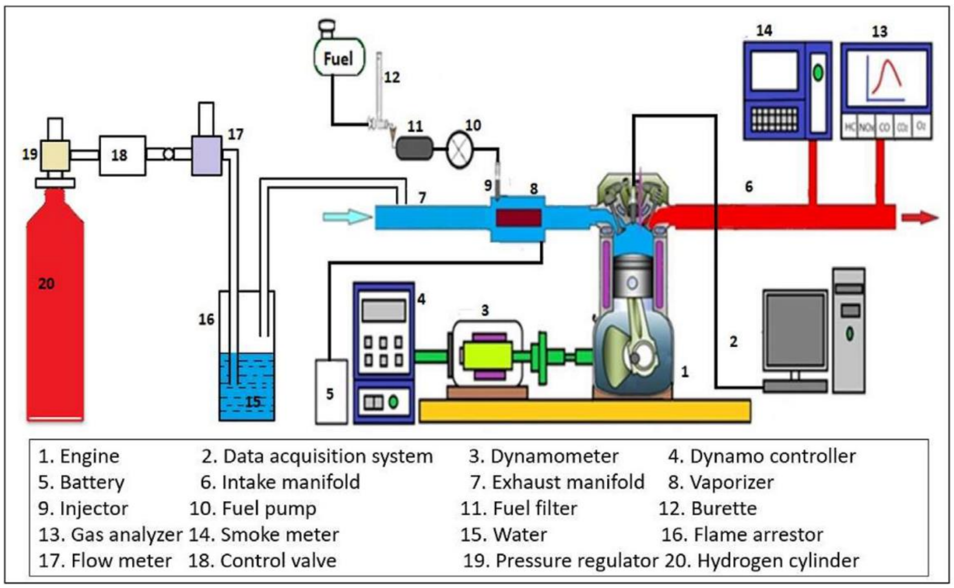

Fig 4.7: Experimental setup of HCCI engine

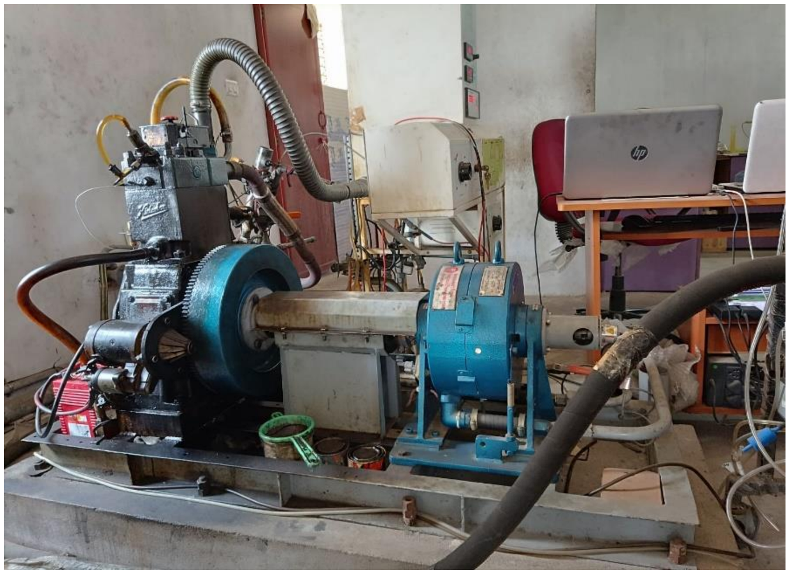

Fig 4.8: HCCI engine

4.3 ENGINE SPECIFICATIONS

S.no	Engine parameters	Specifications
1	Number of cylinders	1
2	No. of strokes	4
3	Rated Power	5.2 kW
4	Cylinder diameter	87.5mm
5	Stroke length	110mm
6	Compression ratio	17.5:1
7	Orifice diameter	20mm
8	Dynamometer arm length	185mm

Table 4.1 Engine specifications

4.4 GAS ANALYSER & SMOKEMETER SPECIFICATIONS

In the experimentation we have used the AVL 444-N gas analyzer to measure emissions and AVL 437C smoke meter. The specifications of the gas analyzer and smoke meter are listed in the figure below.

Fig 4.9: AVL gas analyzer

Fig 4.10: AVL 437C Smoke meter

Fig 4.11: Smoke meter readings

Model of the Gas analyzer	AVL 444 di-gas analyser	Accuracy
Pollutant	Range	
CO_2	0-10 % volume	0.01
HC	0-20000 HC	± 10 ppm
NO_x	0-5000 ppm	± 10 ppm
Smoke meter	AVL 437 Smoke meter	
Smoke intensity	0-100 opacity in %	± 1% full scale reading

Fig 4.12: Specifications of gas analyzer and smoke meter

4.5 EXPERIMENTAL PROCEDURE

- The lemon grass B20 biodiesel poured into the primary fuel tank.
- The hydrogen cylinder is connected to the inlet manifold with pressure regulator, Dry flame arrester, wet flame arrester and flowmeter in between as shown in fig 3.6 & 3.7.
- The flowmeter is adjusted to attain constant flow of 3 lpm of H2 gas.
- The gas analyzer and smoke meter are connected to the exhaust manifold.
- Since we are performing our experiment by varying the flow of hydrogen in liters per minute, we first keep 3lpm H2 and fix it to engine

- The engine is turned on and experiments are carried out by applying different loads on the engine (0 ,25, 50, 75 and 100KW).
- The performance and emission characteristics will be displayed in the computer with the help of dynamometer, gas analyzer and smoke meter at each respective load. We have to note down the time for 10cc of fuel consumption at respective loads.
    - After the experiment is performed on various loads the engine is turned off.

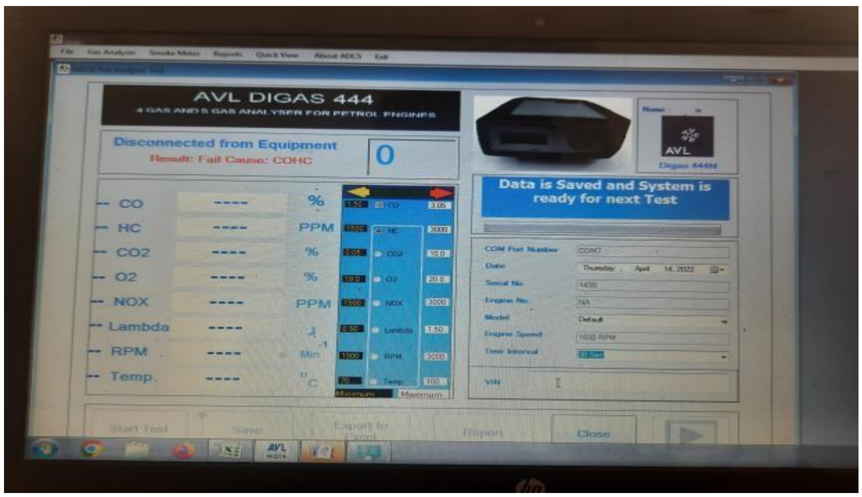

Fig 4.13 Gas analyzer software

Now the flow of the hydrogen is increased to 6 lpm and perform the same experiment. Next increased the flow of Hydrogen to 9 lpm. Results are noted and obtained in Excel format.

Fig. 4.14: Making note at Workspace

CHAPTER 5

RESULTS AND DISCUSSION

5.1 PERFORMANCE PARAMETERS

5.1.1 Brake Specific Fuel Consumption (BSFC)

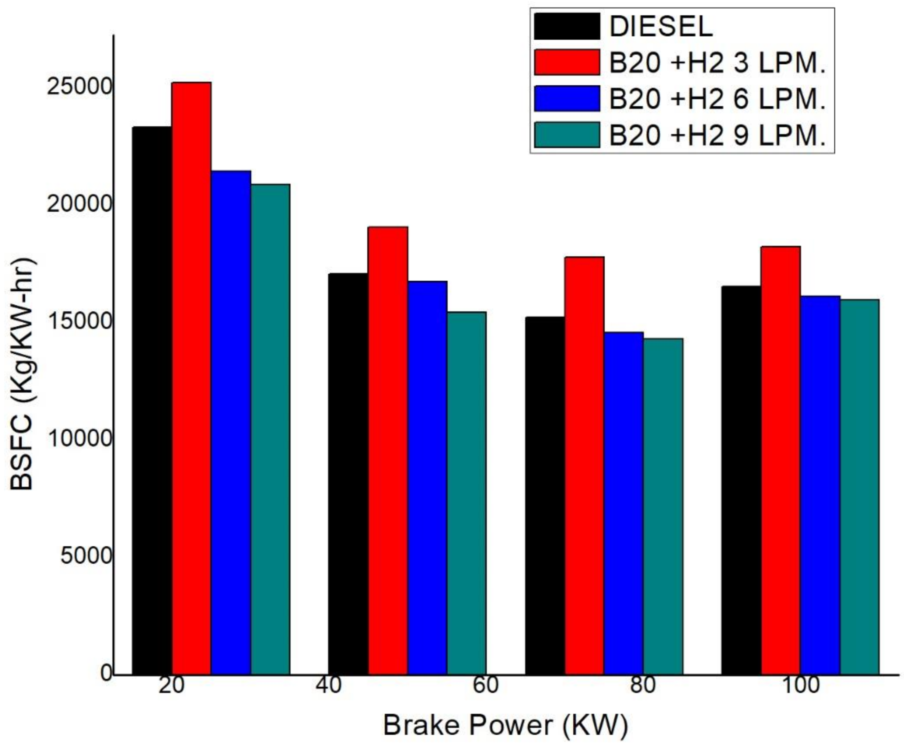

Fig 5.1 Graph for BSFC

Fig 5.1 represents the variation of Break Specific Fuel Consumption (BSFC) for lemon grass oil B20 blend for different flow of hydrogen at various loading conditions. We know that BSFC means the amount of fuel consumed per unit of break power developed per hour. The graph shows that the LGO B20 has high BSFC than diesel when operated at 3 LPM H2 at all loads. The LGO B20 H2 6 LPM and LGO B20 H2 9 LPM has less BSFC compared to remaining at all loads because of proper atomization and mixing of fuel air mixture before start of combustion. The decreasing BSFC percentage of LGO B20 + 6 LPM and LGO B20+ H2 9 LPM is 2.54% and 3.36% when compared to base fuel.

5.1.2 Break Thermal Efficiency (BTE)

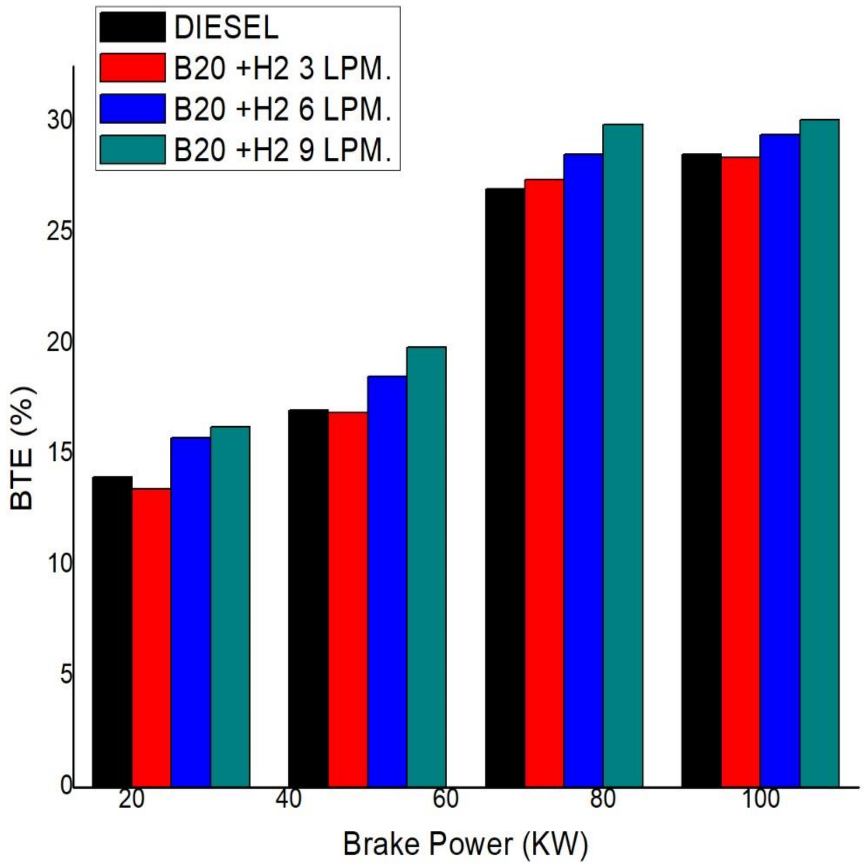

Fig 5.2 Graph for BTE

Fig 5.2 represents the variation of Break Thermal Efficiency (BTE) for lemon grass oil B20 blend for different lpm of H2 at various loading conditions. We know that BTE is nothing but the ratio of break power obtained from the engine to the amount of energy supplied. From the graph we can see that LGO B20 +H2 6 LPM and LGO B20 + H2 9LPM exhibits high BTE compared to remaining at all loads because of due to better combustion and air fuel mixture take place properly results in increased BTE. The LGO B20 H2 6 LPM exhibits higher BTE only at higher loads and the LGO B20 +H2 3 LPM has lower BTE compared to diesel at all loads. The increasing percentage of BTE for LGO B20+ H2 6LPM and LGO B20+ H2 9LPM is 3.18% and 5.53%, due to some oxygen content available in the biodiesel it makes proper combustion take places.

5.2 EMISSION PARAMETERS:

5.2.1 Carbon Monoxide (CO):

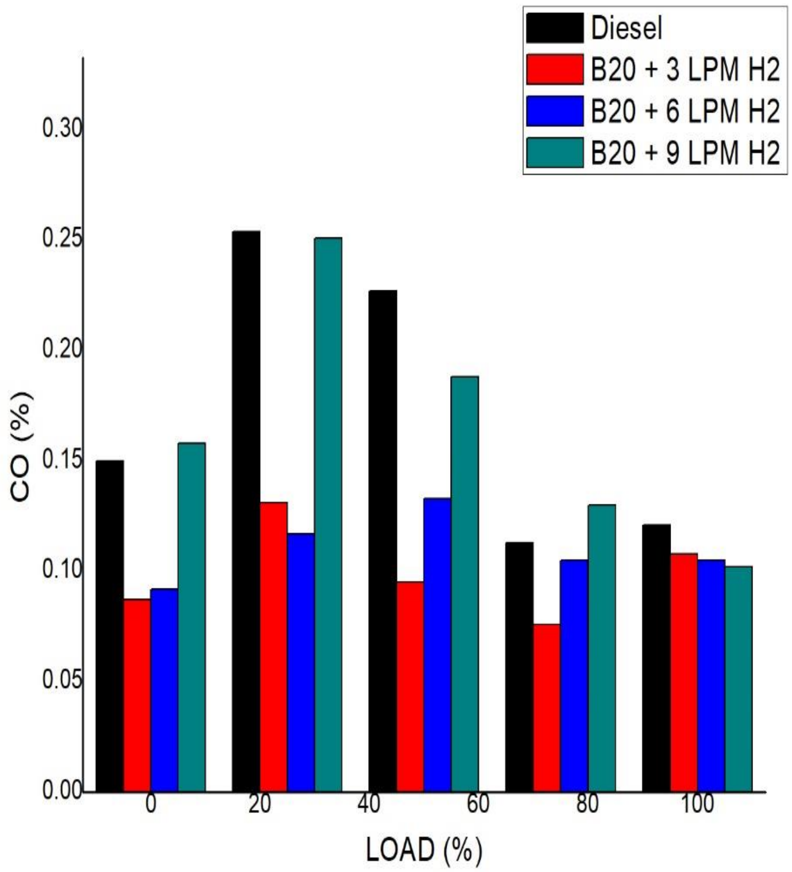

Fig.5.3 Graph for CO emissions

Fig 5.3 represents the variation of CO emission (Vol %) for lemon grass oil B20 blend for different injection pressures at various loading conditions. We know that CO emission takes place due to incomplete combustion of fuel either due to rich air fuel mixture or due to low flame temperature. From the graph we can see that Diesel has high CO emissions compared to remaining at all loads and the LGO B20 has low CO emission because higher injection pressures result in fine atomization which leads to efficient combustion which results in lower CO emissions. The percentage of reduction in CO for the lemon grass oil is 33.33%. due to atomization of the fuel while going for more injection pressure the level of CO is decrease when compared with other fuel blends.

5.2.2 Nitrogen Oxides (NOx)

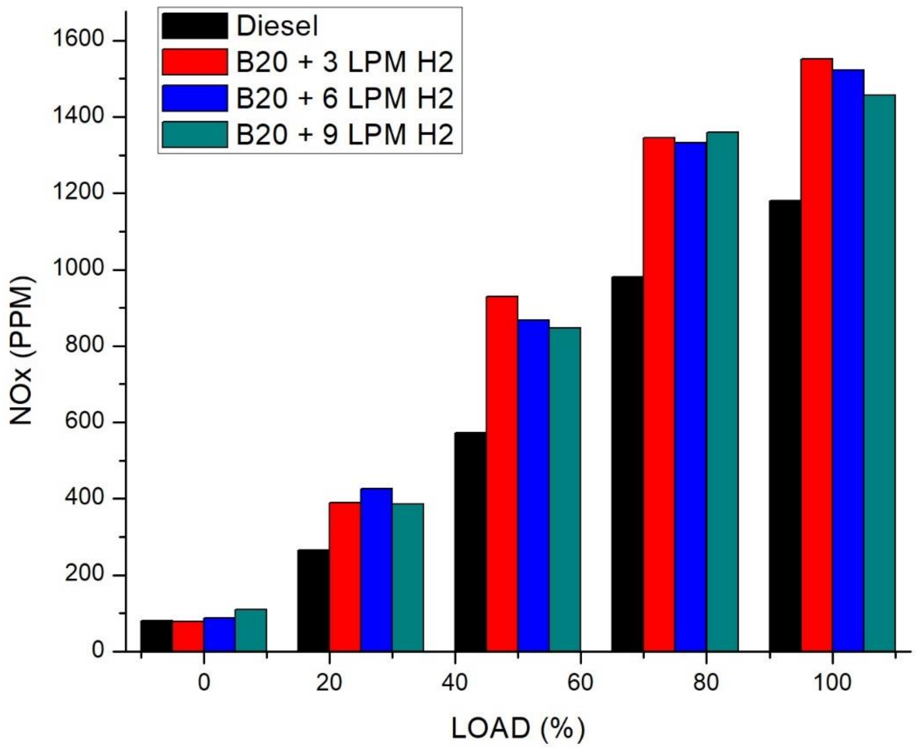

Fig 5.4 Graph for NOx emissions

Fig 5.4 represents the variation of Nitrogen Oxides (NOx) for sapota B20 blend for different injection pressures at various loading conditions. The NOx formation occurs when combustion takes place at high temperatures. The diesel has high NOx emission particularly at higher loads due to diffusion flame travelling during combustion in CI engine which results in increased temperature in the engine which leads to formation of NOx. The LGO B20 operated at different flowrates have some more NOx emissions because there will be diffusion flame propagation like in CI engine instead the combustion takes place at multiple points simultaneously which results in low temperature combustion. The LGO B20 H2 3 LPM has relatively somewhat higher NOx emission because of its fine particle size which results in low temperature combustion. The percentage of increased NOx for the when compared to base fuel is 6.84%, 16.7 % and 5.7%, due to availability of oxygen content in the fuel higher the NOx emission is closely higher than compared with other fuel.

5.2.3 Hydro Carbons (HC)

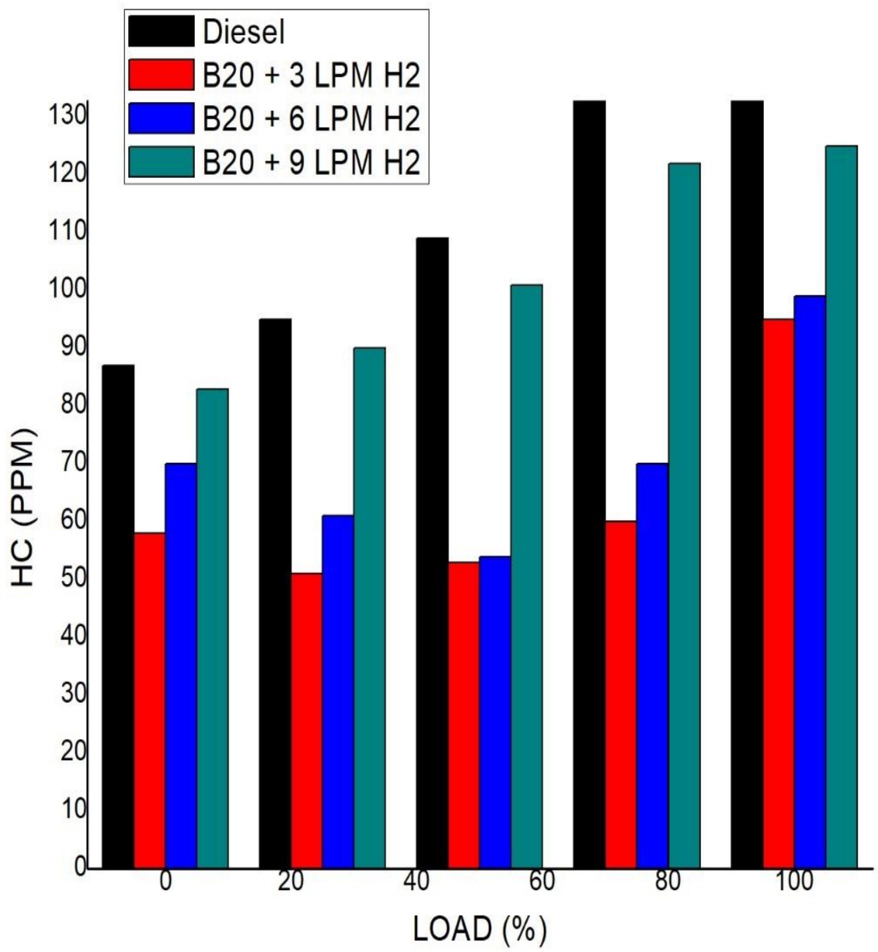

Fig. 5.5 Graph for HC emissions

Fig 5.5 represents the variation of Hydro Carbons (HC) for lemon grass oil B20 blend for different flow rates of H_2. The Hydro Carbons can be from fuel droplets or from products after combustion. The diesel has higher HC emissions and the HC emissions increases as the load increases for both diesel and sapota blend at all injection pressures. The LGO B20 +H2 3 LPM exhibits low HC emissions compared to remaining because the high flowrates ensure that there is good amount of homogeneity which eliminates large fuel droplets from forming that will result in forming of HC emissions. The percentage reduction of LGO B20 + H_2 3LPM, LGO B20 + H_2 6LPM and LGO B20 + H_2 9LPM is 12.3%, 5.16% and 15.46% compared to base fuel.

5.2.4 Smoke

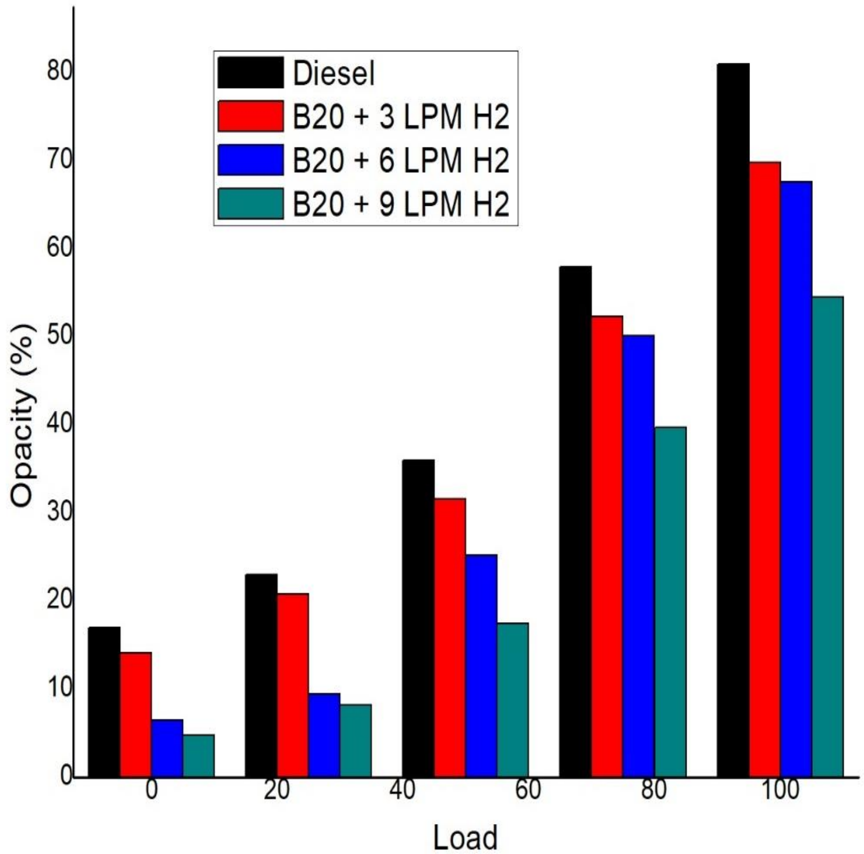

Fig. 5.6: Smoke Opacity

Smoke is an important aspect while discussing emissions. Figure 5.6 focused on the behaviour of smoke for several fuel samples. According to the results, diesel operation discharges more amounts of smoke emissions when compared to the LGO blends. LGO B20 gives a maximum reduction of smoke compared to the other fuel samples. LGO B20 showed 21.02% lower smoke percentage of diesel.

5.3 COMBUSTION PARAMETERS

5.3.1 In-Cylinder Pressure

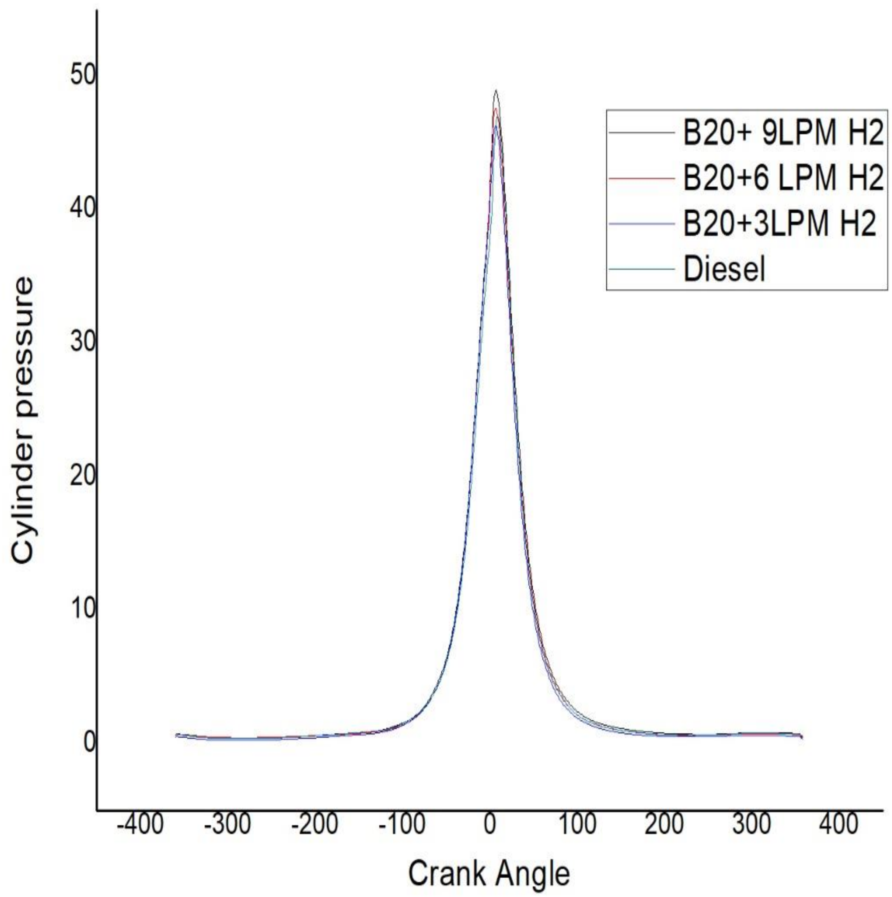

Fig 5.7 Graph for In-Cylinder pressure

Fig. 5.7 shows the graph of In-Cylinder pressure by the usage of base fuel and different blends. The in-cylinder pressure is increased the HRR also increased. Due to increase the combustion temperature the in-cylinder pressure is increased. From the figure, by the usage of the LGO B20 +H_2 9 LPM produced higher pressure rise in the cylinder which helps in achieving the high performance and hence leading to the better efficiencies when compared with the base fuel and other blends. Also, higher the in-cylinder pressure rises, the less work the engine has to do to suck the intake air and fuel.

5.3.2 Heat Release Rate

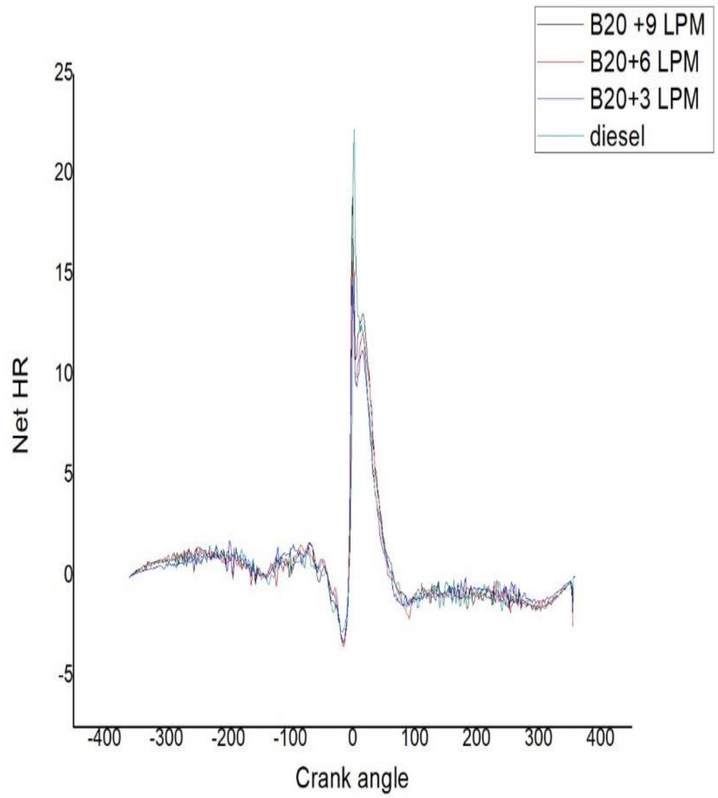

Fig 5.8 Graph for Net Heat Release

Fig. 5.8 shows the graph of HRR of different blends at all the load conditions. Heat release rate is the rate at which fire releases energy, this is also known as power. It is the driving force in the terms of fire. Hence, the production of undesirable effects of fire and its products also elevates with the increased HRR. This means that toxic gases, smoke and other types of fire hazards increase in parallel with the HRR. The in-cylinder pressure is increasing automatically the heat release rate also increased. All the fuel blend of HRR having nearby diesel value. It is clearly observed LGO B20+H_2 9LPM produce highest HRR when compared with other fuel blends.

CHAPTER 6

CONCLUSION

The following conclusions are drawn by conducting the experiment to study the effect of varying injection pressure on performance and emission characteristics of Homogeneous Charge Compression Ignition (HCCI) engine operated by using biodiesel (20% lemon grass oil biodiesel + 80% diesel) and hydrogen gas.

- It is observed that the LGO B20 has high BSFC than diesel when operated at 3 LPM H2 at all loads. The LGO B20 H2 6 LPM and LGO B20 H2 9 LPM has less BSFC compared to remaining at all loads because of proper atomization and mixing of fuel air mixture before start of combustion. The decreasing BSFC percentage of LGO B20 + 6 LPM and LGO B20+ H2 9 LPM is 2.54% and 3.36% when compared to base fuel.
- It is found lemon grass oil B20 blend for different lpm of H2 at various loading conditions. We know that BTE is nothing but the ratio of break power obtained from the engine to the amount of energy supplied. From the graph we can see that LGO B20 +H2 6 LPM and LGO B20 + H2 9LPM exhibits high BTE compared to remaining at all loads because of due to better combustion and air fuel mixture take place properly results in increased BTE. The LGO B20 H2 6 LPM exhibits higher BTE only at higher loads and the LGO B20 +H2 3 LPM has lower BTE compared to diesel at all loads. The increasing percentage of BTE for LGO B20+ H2 6LPM and LGO B20+ H2 9LPM is 3.18% and 5.53%, due to some oxygen content available in the biodiesel it makes proper combustion takes place.
- It is observed that the variation of CO emission (Vol %) for lemon grass oil B20 blend for different injection pressures at various loading conditions. We know that CO emission takes place due to incomplete combustion of fuel either due to rich air fuel mixture or due to low flame temperature. From the graph we can see that Diesel has high CO emissions compared to remaining at all loads and the LGO B20 has low CO emission because higher injection pressures result in fine atomization which leads to efficient combustion which results in lower CO emissions. The percentage of reduction in CO for the lemon grass oil is 33.33%. due to atomization of the fuel

while going for more injection pressure the level of CO is decrease when compared with other fuel blends.

- It is observed that the variation of Nitrogen Oxides (NOx) for sapota B20 blend for different injection pressures at various loading conditions. The NOx formation occurs when combustion takes place at high temperatures. The diesel has high NOx emission particularly at higher loads due to diffusion flame travelling during combustion in CI engine which results in increased temperature in the engine which leads to formation of NOx. The LGO B20 operated at different flowrates have some more NOx emissions because there will be diffusion flame propagation like in CI engine instead the combustion takes place at multiple points simultaneously which results in low temperature combustion. The LGO B20 H2 3 LPM has relatively somewhat higher NOx emission because of its fine particle size which results in low temperature combustion. The percentage of increased NOx for the when compared to base fuel is 6.84%, 16.7 % and 5.7%, due to availability of oxygen content in the fuel higher the NOx emission is closely higher than compared with other fuel.
- the variation of Hydro Carbons (HC) for lemon grass oil B20 blend for different flow rates of H_2. The Hydro Carbons can be from fuel droplets or from products after combustion. The diesel has higher HC emissions and the HC emissions increases as the load increases for both diesel and sapota blend at all injection pressures. The LGO B20 +H2 3 LPM exhibits low HC emissions compared to remaining because the high flowrates ensure that there is good amount of homogeneity which eliminates large fuel droplets from forming that will result in forming of HC emissions. The percentage reduction of LGO B20 + H_2 3LPM, LGO B20 + H_2 6LPM and LGO B20 + H_2 9LPM is 12.3%, 5.16% and 15.46% compared to base fuel.

CHAPTER 7

FUTURE SCOPE AND STUDY

The future scope of lemon grass oil blend in a Homogeneous Charge Compression Ignition (HCCI) engine holds significant potential due to its favorable properties as a renewable and sustainable fuel source. HCCI engines are known for their high thermal efficiency and low emissions, making them a promising technology for reducing greenhouse gas emissions and air pollution from transportation. Here are some potential areas of future development and application for lemon grass oil blend in HCCI engines:

- Engine Performance and Emissions: Future research can focus on optimizing the blend composition, engine parameters, and combustion strategies to further improve the performance and emissions characteristics of lemon grass oil blend in HCCI engines. This can include studying the impact of different blend ratios, fuel injection strategies, and engine operating conditions on combustion efficiency, emissions, and engine durability.
- Environmental Benefits: The use of lemon grass oil blend in HCCI engines can potentially lead to reduced emissions of greenhouse gases, NOx, and HC compared to conventional fossil fuels. This can contribute to mitigating climate change, improving air quality, and reducing the environmental impact of transportation.

In conclusion, the future scope of lemon grass oil blend in HCCI engines holds promise as a renewable and sustainable fuel source with potential environmental, economic, and social benefits. Further research and development efforts are needed to optimize its performance, emissions, and overall viability as a viable alternative for transportation and renewable energy production.

CHAPTER 8

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Academic Year: **2022-23**

Project Title: **Experimental Investigation of Lemon grass oil in HCCI Engine**

Type of Project: **Research Oriented**

Project Guide: **Mrs. Anjani Devi Sanipina**

PROGRAM OUTCOMES			
PO1	Engineering knowledge	PO7	Environment and sustainability
PO2	Problem analysis	PO8	Ethics
PO3	Design/development of solutions	PO9	Individual and team work
PO4	Conduct investigations of complex problems	PO10	Communication
PO5	Modern tool usage	PO11	Project management and finance
PO6	The engineer and society	PO12	Lifelong learning

PROGRAM SPECIFIC OUTCOMES	
PSO1	Apply techniques in design, analysis and fabrication of high-end automotive solutions
PSO2	Demonstrate essential skills to analyze the thermal, fluid systems and processes

CONCLUSION STATEMENTS

S. No	Description	Attained COs	Attained POs/PSOs
1	Explanation about the different type of engines and need for biodiesel.	CO1	PO1
2	Referred the standard journal papers and identified the problem.	CO2, CO3	PO2, PO12
3	Explained about Lemon grass oil properties and extraction process.	CO4, CO6	PO3
4	Prepared the blend and carried out characterization techniques (FTIR, UV, GCMS) on Lemon grass oil.	CO6, CO7, CO8	PO4, PO5
5	Conducted experimentation on HCCI engine to provide valid conclusions for this project.	CO8	PO4, PO5, PO7, PO8
6	Concluded the findings and analysed the results.	CO9	PO2, PO4, PO6, PSO2
7	Acknowledged the various authors findings by way of references.	CO2	PO8
8	Able to prepare a thesis and presented to a panel of experts	CO5, CO10	PO9, PO10 PO11

Signature of the Team members

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