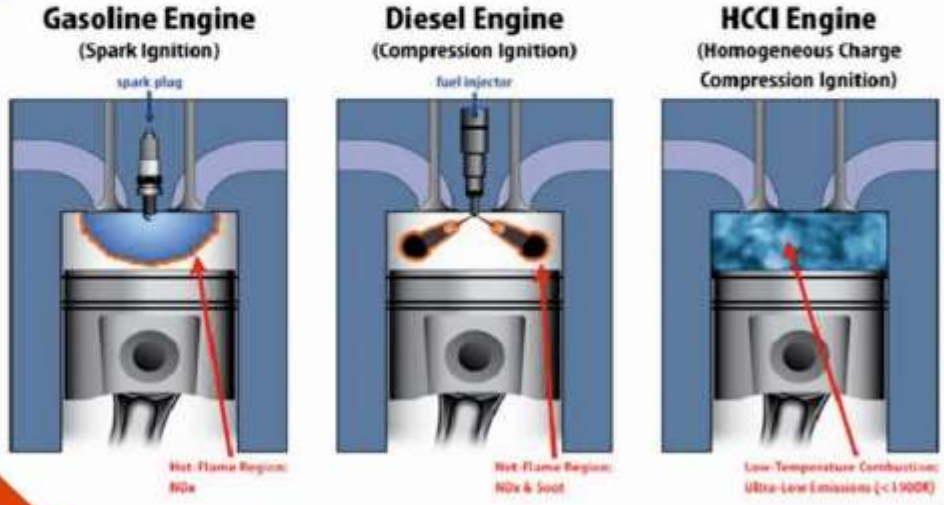

A TEXT BOOK OF HCCI ENGINES (RESEARCH ORIENTED)

Dr. A. Renuka Prasad

Dr. Rakesh Bhandari

Dr. D. Jagadish

Kripa Drishti Publications, Pune.

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PREFACE

The internal combustion engine has been the most successful device in delivering benefits to the different communities of the world. Reciprocating the IC engine is certainly the best apparatus in some aspects compared to its counterparts. Still, the processes of these IC engines are seeking developments vowing to the commercialization for a better place in the society. The progress has been well related to engine combustion processes in terms of fuel-saving or minimization of losses. However, there are certainly other possibilities for improvement of these engines concerning the basic design which involves the types of fuel injection, better intake of air, fuel-air mixing, etc. The engine redesign or modifications are also a field of interest due to strict restrictions by the emission legislation.

The internal combustion engines release harmful emissions into the atmosphere. The harmful emissions are major causes of smog formation, global warming, and environmental pollution. Transportation of vehicles such as heavy trucks, buses, and trains generates a large number of emissions that are oxides of nitrogen, particulate matters, hydrocarbons, and carbon monoxide. It contaminates the fresh air in the atmosphere, the air gets polluted and pollution is increasing every day along with the development (or) manufacture of the vehicles. The developing countries are facing the major issue is increasing environmental pollution. The metropolitan cities in INDIA, such as Bombay, Calcutta, Kanpur, Madras, and Delhi are facing smog formation, especially in the winter season.

Homogeneous Charge Compression Ignition (HCCI) technique is a promising technology for future generations. Applying the HCCI concept, reduce the harmful emissions generated from the Automobiles. This concept gives high efficiency to the internal combustion engines. It is the reasonability of good alternative technology for the spark ignition and conventional ignition engines. Homogeneous Charged Compression Ignition technology is an alternative technology for internal combustion engines. In this technique, the mixture is entered into the cylinder through the inlet of the engine. Homogeneous Charged Compression Ignition technology decreases (or) reduces the exhaust emissions from the automobiles and industries and also reduces the consumption of fuel. This technique is also better in terms of efficiency. This technique can be applied to small as well as large scale applications.

The Homogeneous Charge Compression Ignition technique can be applied to both Spark Ignition and Diesel Compression engines. The HCCI technique is most widely used in the Diesel Compression Ignition engines. The Homogeneous Charge Compression Ignition (HCCI) technique reduces the Emissions like hydrocarbons, carbon monoxide, oxides of nitrogen, and Particulate Matter. It also increases the combustion rate and efficiency of the engine. The different modes of experiments were performed on the engine testing. In the first mode, Diesel engine, No Turbocharge and No HCCI, in the second mode, Diesel engine, Turbocharge and

No HCCI and in the Third mode, Diesel engine, Turbocharge and HCCI and in final testing No Diesel engine, No Turbocharge and HCCI only used.

The performance results show that HCCI based engines working at different load conditions and improve the performance of the engine and increase combustion efficiency. In HCCI type engines, the combustion starts at lower temperatures, and combustion phenomena occur at different points in the cylinder. The HCCI technology mode engine generates a small number of exhaust emissions. The performance and released emissions depend on the quality and quantity of homogeneous mixture. The fuel consumption reduces with the Turbocharging mode of the engine. The brake thermal efficiency increases slightly with the HCCI mode of the engine. The oxide of nitrogen emission reduces with the HCCI mode only and unburned hydrocarbons emissions also reduce with the Turbocharging mode. And opacity or smoke emissions reduce with the HCCI mode of charging.

Experiments were performed on a 4-stroke single cylinder homogenous charge compression ignition engine. The basics of HCCI has been obtained by introducing fuel flow in the air intake pipe in different proportions viz. 25%, 50% and 75% of total fuel. The performance results show that emissions of NOx have been significantly reduced with fuel induction in a suction pipe through the fuel consumption is little higher with the selected fuel injection options compared with the conventional injection method. Thermal efficiency is observed to be low with fuel injection at the intake pipe. HC and smoke emissions increases with load and the reduction in emissions of NOx are significant as73%, 76%, 73% with 25%, 50%, 75% proportions respectively.

Biodiesel is the most favorable alternative fuel for Fossil fuels. The fossil fuels are Gasoline and Diesel etc. The Diesel used in vehicles develops a large number of hydrocarbons, oxides of nitrogen, Particulate Matters, and carbon dioxide emissions. These emissions are harmful to our health and environment. The Homogeneous Charge Compression Ignition (HCCI) technology is a new combustion concept and is alternate to the CI engines; it generates fewer amounts of exhaust emissions and higher efficiency. The HCCI combustion depends upon the quality of homogeneous mixture (fuel and air). Experiments were performed on a 4-stroke single-cylinder HCCI engine with Eucalyptus Biodiesel. The test was used to find the Performance and Emissions Characteristics of the HCCI engine.

The Eucalyptus biodiesel is blended with Diesel. The percentages are 90% of Diesel and 10% of Eucalyptus oil. The performance results show that Eucalyptus biodiesel gives cleaner smoke and more transparent compared to Diesel and also fuel efficiency is observed to be lower with the HCCI engine results in higher fuel consumption when the fuel introduced in the intake pipe. The emissions of NOx are significantly reduced with Eucalyptus oil blended with diesel.

Avvaru Renuka Prasad

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First and foremost I express my deep sense of gratitude to the Lords **Shri Venkateswara, Lords Shri Eswara and Goddess Shri Avula Maremma** for his blessings and mercies which enabled me to reach this stage a complete my studies without any interruptions.

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I would also like to express my thanks to my Dearest ***wife Veera Prathyusha*** and my dear ***son Guru Maremma Yodha.*** I am grateful to her persisting encouragement in completing my book successfully. I am thankful to her everlasting patience and support thought work.

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The success of this study comes through the invaluable help, guidance and contribution of faculties, friends and well wishers.

(Dr. A. Renuka Prasad)

Dedicated to

My Parents

Late. Sri. Avvaru Narayana & Sri. Vijaya Lakshmi.

INDEX

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Chapter 1

Introduction

1.1 Introduction:

Internal Combustion engines play a vital role in society. Most of the research works performed on engine modification for reducing the emissions and enhance the performance of the engine. Because increase the day to day demand and the requirement for society. The environmental pollution 35% is controlled in the World due to reducing the emissions from the internal combustion engines.

Engines may be classified as two types: Internal Combustion and Spark Ignition engines. Most of the IC engines are used for transport applications. Present, the entire world depends upon the transportation of food, materials and industrial applications etc. The alternative or another technique is homogeneous charged compression ignition technology is suggested that researchers in the replacement of the Internal combustion process. It enhances the Thermal efficiency, mileage of the engine and fewer amounts of emissions is released from the automobiles.

The crude oils such as Petrol and Diesel applications are increased and these oils are exhausted for the next generations. Most of the researchers or scientists find the Biodiesel is the major solvable resource instead of crude oils. The vehicles are released with harmful gases, so the air is polluted.

The various types of vegetables are used for producing the biodiesels. A large amount of biodiesel production is in balancing the economy of countries. Therefore, lesser amounts of biodiesels are produced. The production of biodiesels is affecting the food corps. Non-edible oils are the major solution for this crisis. Compared to all biodiesels, Eucalyptus oil gives better results and available throughout the year.

HCCI technology enhances the Thermal efficiency compared to Internal Combustion type engine. It is the best alternative technique for the next generations. In this technique, the homogeneous mixture is entered into the inlet of the engine. The Homogeneous mixture

contains fuel and air. At the time of the compression process, the mixture is compressed, the pressure and temperatures are increases. The phenomena of combustion take place inside the cylinder. The combustion efficiency is high compared to the IC engines. HCCI technique produces higher efficiencies.

The emissions are oxides of nitrogen, soot or PM, carbon monoxide and hydrocarbons are the main factors of polluting the environment. The combustion in internal combustion engines releases harmful gases.

This type of gases generates the number of troubles in the environment like global warming and health diseases for the human's life. Different techniques are applied for decreasing the harmful emissions through the tailpipe.

1.2 Internal Combustion Engine:

An internal combustion engine may be defined as a device; the principle operation of the engine is to convert chemical energy to thermal energy.

Engines may be classified into two types, the fuel-burning process at the inside cylinder is called Internal combustion and burning of fuel at outside cylinder called the External combustion type engines. The oil enters in a cylinder through the inlet, fuel combine with the air, starts ignition in the cylinder. Jet and Petrol fuel vehicles are the internal combustion type. The Internal combustion process simple, less weight, space, and oil consumption is better than the external combustion process.

They also classified, according to the basic design, cycle operation, number of strokes, type of fuel, supply system of fuel, type of ignition, and cooling and cylinder arrangement. In the Internal Combustion, process piston performs four strokes or two revolutions of the crankshaft.

At the time of suction only fresh air is entered (or) admitted to the cylinder and closes another valve. In compression, the air is compressed due to the movement of the piston from TDP to BDC. The inlet and exhaust valves are closed.

In a power stroke, the oil is entering into a cylinder. The sufficient conditions are generated at compression for igniting fuel in the cylinder and heat releases in this process. In this process, both valves are closed. In the exhaust process, the exhaust emissions are released in the atmosphere through the tailpipe. In this process, the inlet valve closes and the exhaust valve opened. The internal combustion type vehicles are greater weight because withstanding the pressures and produce high thermal efficiency. These are made with cast iron, aluminum alloys etc.

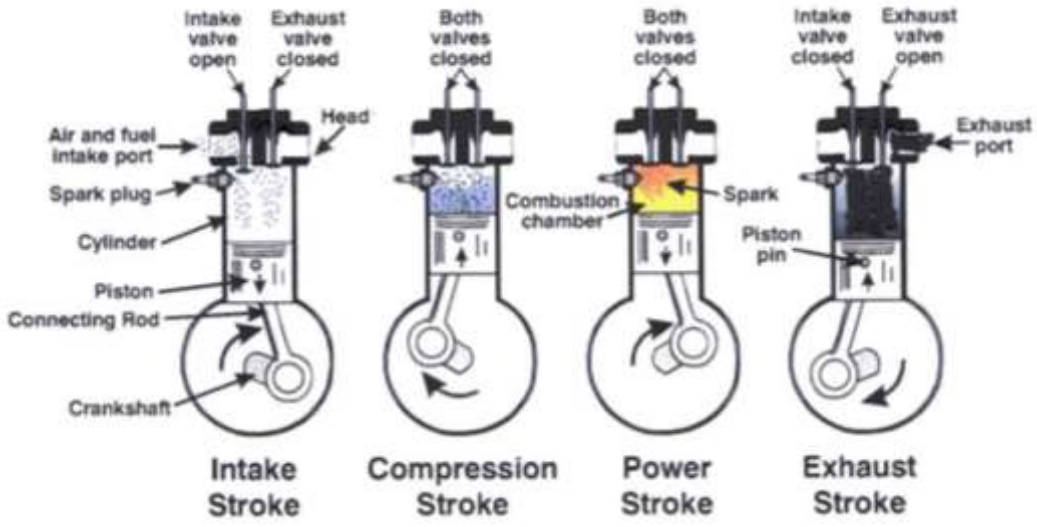

Figure 1.1: Operation in Internal Combustion

The internal combustion type vehicles released more harmful emissions into the atmosphere. The harmful gases and fuel consumptions are main issues (or) challenges in the present century. Road transport vehicles such as heavy and medium type trucks, cars, and trains are generated exhaust gases are oxides of nitrogen, particulate matters, hydrocarbons, and carbon monoxide.

It contaminated the air in the atmosphere. The developing countries facing major issue increases the pollution in the atmosphere. The metropolitan cities in INDIA, such as Bombay, Calcutta, Kanpur, Madras, and Delhi facing Smog formation in the winter season.

The car developed in the atmosphere half Kg Pollutants in a single day. So, calculate the cars in a single day, how much pollutants are generated in the atmosphere, approximately tons of pollutants are entered in the environment.

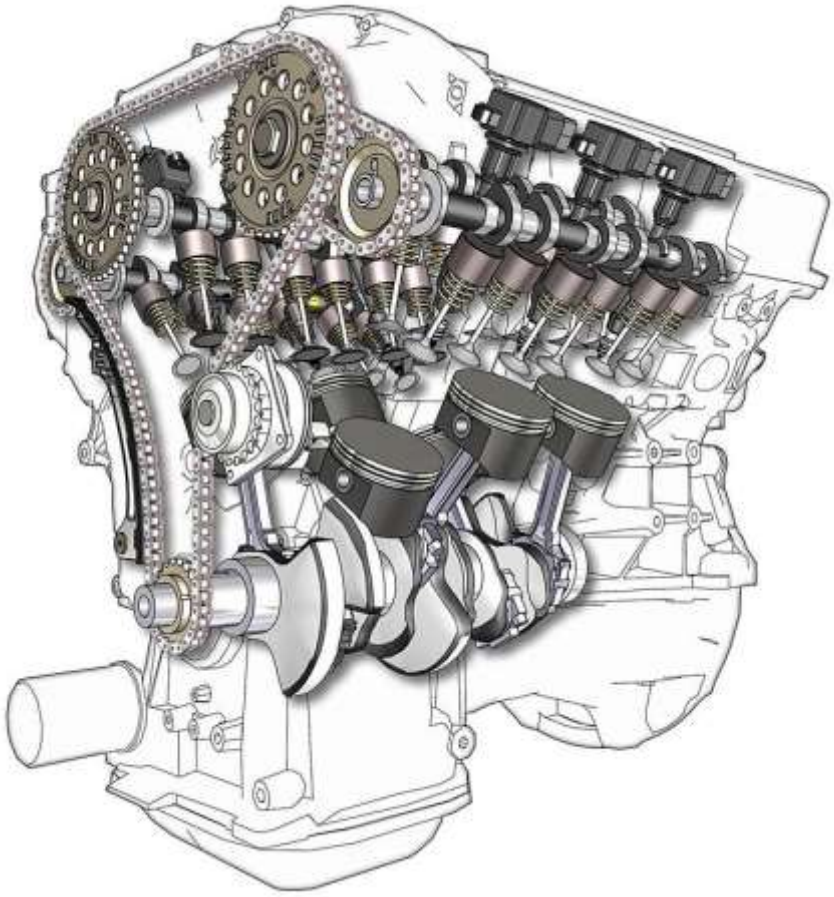

Figure 1.2: 6V Internal Combustion Engine

The harmful emissions are released mainly for two reasons. They are an insufficient mixture in the combustion chamber of the cylinder and cooling the combustion chamber surfaces. The insufficient mixture entered the cylinder, so combustion is difficult or incomplete. So, the larger amounts of exhaust gases are released. HCCI technique is a promising technology for the next generations. Applying the HCCI technique, reduce the harmful gases from the vehicles, and decrease oil consumption. It gives higher efficiency and the best alternative technology for the SI and IC combustion type process.

1.3 History of HCCI Technology:

The HCCI technique can also be used for two-stroke engines. By using this technique misfire inside the engine cylinder can be avoided. This technique is optimized to achieve a mixture that can be burned efficiently in the cylinder. Other techniques are Controlled Auto-Ignition and Activated Radical Combustion that determines and enhances the performance. The ARC technique has been employed by Honda automobile company efficiently on the vehicles. The HCCI reduces exhaust emissions and enhances the stability in the combustion process. By using this concept fuel consumption is reduced substantially. In 1897, the scientist Carl W. had got patent on two-stroke engines. In 1930's Nikolai et.al explored the use of such engines for the operation of automobiles. Hua Zhao explained the mechanism of chemical kinetics and controlling the fuel burning in the cylinder. In the 1970's Gussak et.al developed CAI techniques. Thring et.al. Developed the HCCI technique in 1989 as a part of his research work. His research work was aimed at finding the effect of Exhaust Gas Recirculation (EGR) and air-fuel ratio on the HCCI engine. In the 1990s the huge research work was done on HCCI. Many researchers concluded that HCCI technique reduces the exhaust gases.

The Homogeneous Charged Compression Ignition technique can be performed on various fuels and along with those which has fewer octane numbers. These technology vehicles provide higher efficiencies. It releases low values of NOx, PM, HC, and CO emissions. This technology can be used for automobiles with Diesel, petrol, and biodiesels.

1.4 Fundamentals of HCCI:

HCCI technology can be applied both to SI and internal combustion type engines. The main difference lies in the way fuel is introduced in the cylinder. In Internal combustion type engine, fuel and air are entered at different stages. In the HCCI technique, both fuel and air enter indirectly during suction stroke.

The fuel and air are compressed in the compression stroke and ignites automatically in the expansion. It gives better performance and good characteristics for both SI and CI type engines.

The combustion starts in the combustion chamber at several points at the same time. So, the lesser amount of exhaust gases is generated. Vehicles based on this technique release lesser value of NOx and particulate matters.

HCCI technology works with petrol, diesel, various biodiesels, and also on alternative gaseous fuels. Figure 1.3 shows the comparison of SI, CI, and HCCI combustions. The HCCI engine combustion depends on the quality of the homogeneous mixture.

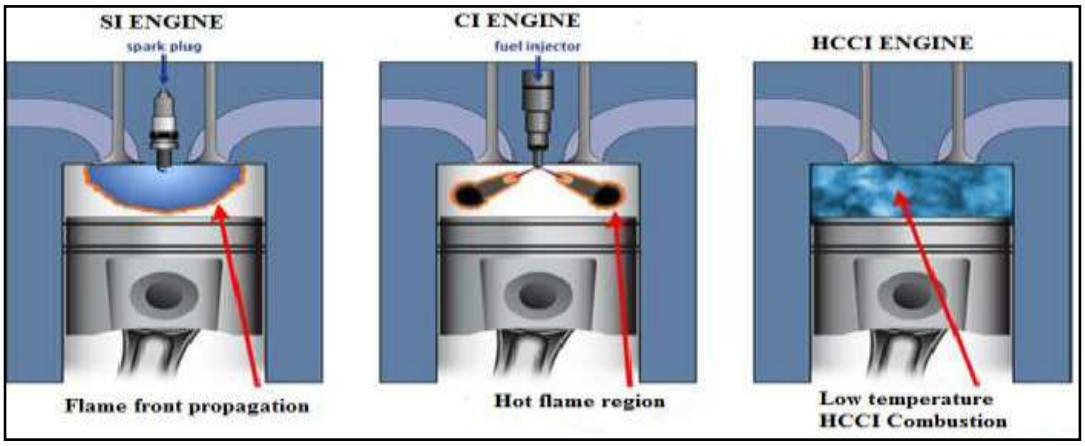

Figure 1.3: Comparison of SI, CI and HCCI combustion

The Homogeneous mixture can be prepared in two ways, externally and internally. In an internal mixture preparation method, a homogeneous mixture can be prepared inside of the engine, with some required modification in the cylinder head.

The Internal preparation method has been applied in the present work. In the external preparation technique, a huge amount of fuel-air mixture can be prepared before combustion in a cylinder.

Table1.1: Conventional CI and HCCI.

Parameters	**CI**	**HCCI**
Efficiency	Higher	Equally High
Emissions	High	Less

Parameters	**CI**	**HCCI**
Ignition Temp.	1500^0C to1780^0C	1200^0C to1500^0C
Ignition Period	Maximum	minimum
Mixture	Heterogeneous mixture	Homogeneous mixture

The mixture can be introduced in the cylinder by the internal preparation method. The lean homogeneous mixture burns simultaneously in the entire volume of the cylinder at end of the compression. The fuel ignites automatically inside the cylinder.

The combustion takes place inside the cylinder at more than one place at a time. Therefore, less amount of exhaust emissions are released. The Homogeneous Charge Compression Ignition engines may have an operating efficiency of 40%.

The combustion starts at lower temperatures inside the cylinder, so less (or) zero level amount of oxides of nitrogen emissions are released to the atmosphere.

When the premixed mixture enters into the cylinder rate of combustion increases. Therefore, a lesser amount of particulate is released.

1.5 Features of HCCI Engine:

- In the HCCI technique throttling losses are reduced and a higher compression ratio can be achieved. It produces more power with higher efficiency and reduces fuel consumption.
- It operates at lean fuel-air concentrations; it gives less amount of soot in the atmosphere.
- The fuel burning in the cylinder depends upon the concentrations of fuel and air.
- This technique does not have a phenomenon of flame propagation and it also avoids the knocking.
- It can also run with fuel having less value of cetane numbers and different alternative fuels.
- Combustion starts at low temperatures, generates fewer amounts of emissions such as oxides of nitrogen etc.
- It can save 15-30% of fuel compared to internal combustion engines.

1.6 Emissions from Tail Pipe:

In a suction stroke, the fuel and air are introduced in the cylinder. The fuel and air are compressed in the compression stroke by the piston accelerated from BDC to TDC.

At the time of power stroke, the fuel and air get ignited and produce heat, the waste emissions are released from the tailpipe.

From, the exhaust pipe the emissions are released in the atmosphere. These are the main causes of environmental pollution.

The exhaust emissions are carbon dioxide, carbon monoxide, hydrocarbons, oxides of nitrogen, and particulate matters.

1.6.1 CO_2, CO, and UHC:

The unburned hydrocarbon gases are released from the vehicles, because of improper combustion of fuels in a cylinder.

These are harmful pollutants in the atmosphere. At different operating conditions the HC patterns have different shapes.

UHC emissions affect the engine parts. The engine components are the combustion chamber, stroke length, the diameter of the bore. Engine performance also depends a lot on the compression ratio.

When the engine misfires, a large number of unburned hydrocarbons are released into the atmosphere. In the environment, they create health problems.

The Carbon monoxide gases are released from the automobiles.

The reasons are an in-sufficient mixture, improper rate of combustion, and also insufficient time for operation in the combustion chamber.

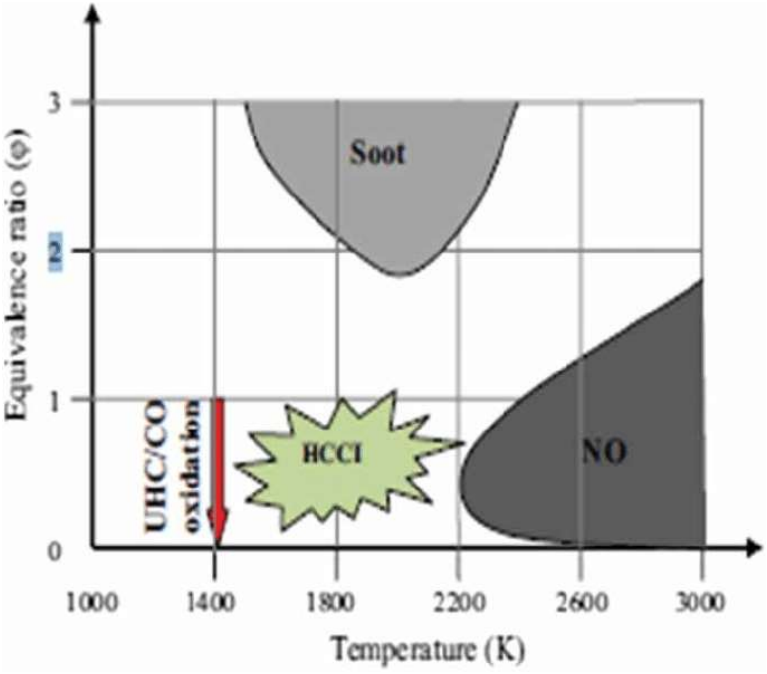

Figure 1.4: Reduction of Emissions in HCCI Combustion

Presently, we are introducing the heterogeneous mixture inside the cylinder, so a large amount of carbon monoxide emissions gets released from the vehicles.

Replacing the heterogeneous mixture by homogeneous mixture produces good results in the automobiles and a lesser amount of gases are released.

1.6.2 NOx and Particulate Matter:

These emissions releases to the atmosphere from the automobiles and industries. It mainly consists of nitrogen dioxide. We know that a large amount of heat is released by the reaction between nitrogen and oxygen. The NOx formation always depends on the inside cylinder temperatures and insufficient oxygen in the cylinder.

The NOx gases directly react with the ozone, so is highly detrimental to the atmosphere. When the ozone layer is damaged, it increases the earth's temperature and also affects the lungs of the human body. The vehicles release the PM gases which are very harmful to the humans and environment.

The reasons are an insufficient mixture, improper rate of combustion, and also insufficient time for operation in the combustion chamber. These are harmful to breathing and create several issues in the atmosphere. The size of PM varies from 0.02 to 0.06µm.

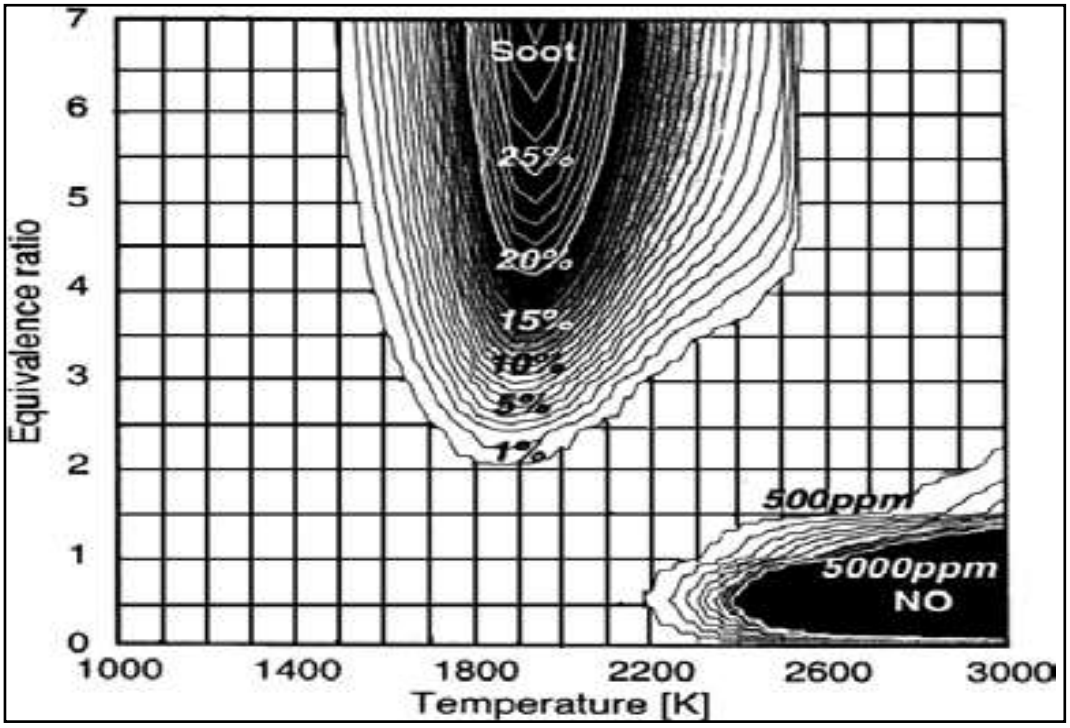

Figure 1.5: Generation of NOx and Soot Emissions

1.7 Effects of Air Pollution:

1.7.1 Global Warming:

The exhaust emissions such as CO_2, CO, HC, and NO_X, etc. are the main causes of global warming. It increases the temperature of the earth and environmental pollution. It affects the ozone layer, sun rays are directly entered into the earth's surface. These emissions are released from automobiles such as cars, busses, and transport vehicles. Figure 1.6 shows the effect of global warming on earth surfaces. It changes the climate conditions and atmospheric patterns. The main problems are associated with human skin diseases, enhance crop failures, sudden earth disorders like a tsunami, and earthquakes.

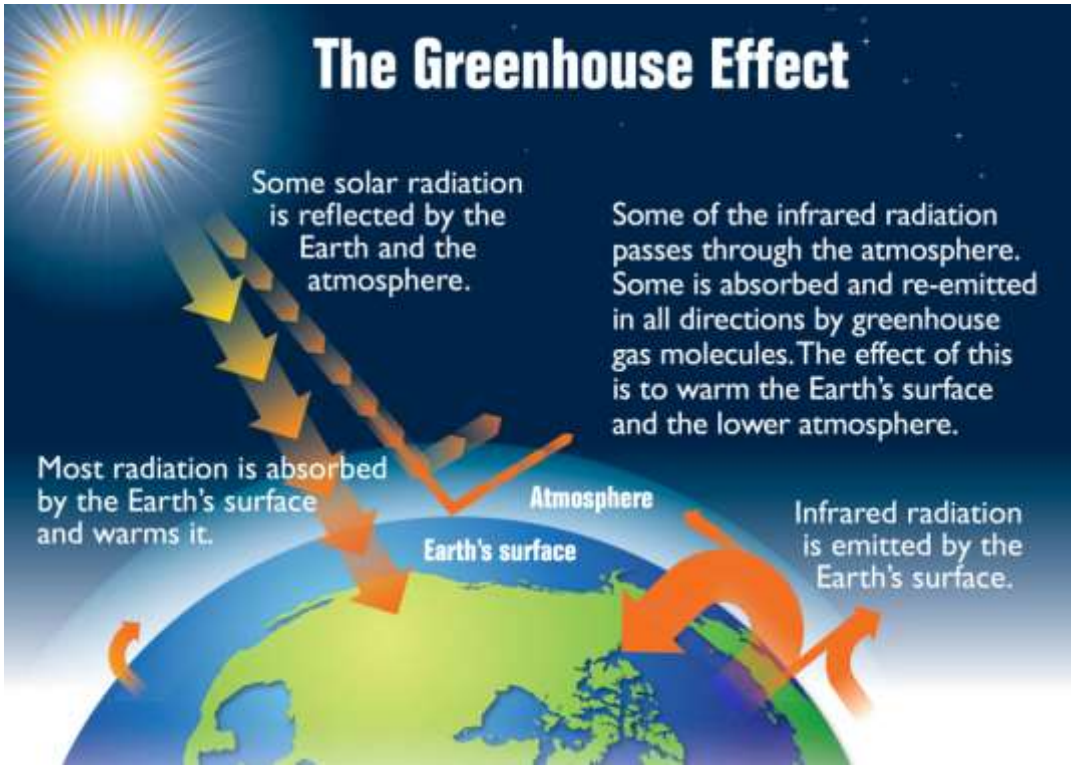

Figure 1.6: Effect of Global warming

1.7.2 Acid Rain:

The high rate of NO_X emissions is released into the atmosphere from the automobiles. The reasons are an in-sufficient mixture, improper rate of combustion, and also insufficient time for operation in the combustion chamber.

The NOx and sulfur dioxide reacts with the water contents in the atmosphere. Therefore acid rain formed in the atmosphere.

The acid rain is contaminated with the freshwater and wells, smash the forest area, collapse the constructing buildings. Figure 1.7 shows the formation of acid rain.

It damages the heart and lungs of the human body. It increases environmental pollution in the environment.

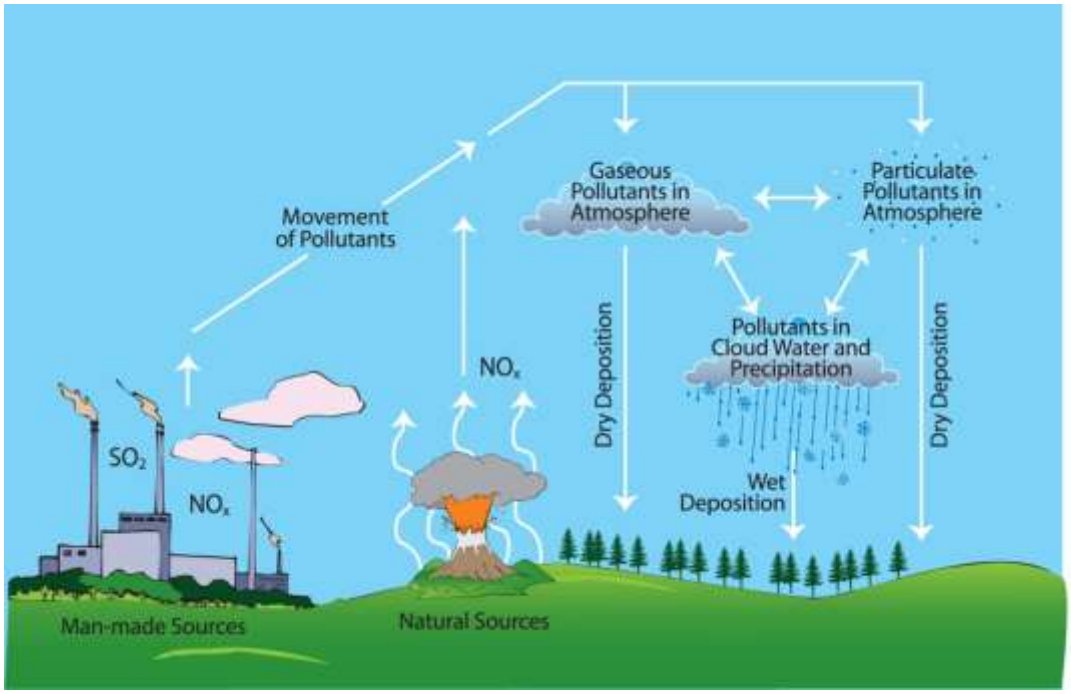

Figure 1.7: Formation of Acid Rain

1.7.3 Smog:

It is formed by the reaction between the unburned hydrocarbons and NOx in the environment. It is one of the major air pollutants. It consists of several organic and inorganic compounds. It is very toxic.

It increases the pollution in the atmosphere and also increases the road accidents of the vehicles. Developed and developing countries are facing serious problems because of the increased formation of smog. The main causes are exhaust emissions from the automobiles and industries that release harmful emissions.

1.7.4 Health Hazards:

The harmful health hazards are generated from exhaust gases of automobiles. These gases directly or indirectly affect human health. The health hazards are short term and long term. Health hazards along with possible reasons are shown in Table 1.2.

Table 1.2: Effects of health hazards due to Air Pollutants

Sr. No.	Air Pollutants	Short-term human health problems	Long term human health problems
1	Ozone defect	Cough, eye and chest problems.	emphysema
2	Oxidants	Eye and chest problems.	Failure of Lung and respiratory system.
3	Sulfates	Asthma disease.	The decrease in lung system.
4	Carbon monoxide	The problem in Headache, dizziness.	Brain, vomiting, changes in pulmonary function and cardiac and death.
5	Oxides of nitrogen	The effects are the same as Ozone with higher concentration.	Increase of cyanosis at various parts of the body.

1.8 Objectives and Methodology:

The Following objectives are:

- To design a Homogeneous Charged Compression Ignition Engine (HCCI), which works with both Diesel and Bio-fuels.
- To study the Performance and Emission Characteristics of the HCCI engine.
- To conduct a test on the HCCI engine with Eucalyptus Biodiesel.

1.8.1 Methodology:

- Modification of existing CI engine to the HCCI Engine. In the present research work, the following modifications are done in the existing CI engine are to change the fuel injection system, inside cylinder and cylinder head for HCCI mode. We construct a converter conversion of conventional diesel technique to the Homogeneous Charged Compression Ignition technique.

- Conducting experiments with HCCI concepts. A total of three experiments are conducted with the HCCI concept in the present work. The fuel introducing in the air intake pipe with different proportions 25%, 50%, and 75% of total fuel. Second, the different modes of tests performed on the HCCI mode engine. And finally, conduct the experiment with Eucalyptus oil blended with diesel.
- Performance and Emission tests on the HCCI engine with different fuels with selected modes of operation. The performance parameters specific fuel consumption, brake thermal efficiency are calculated with varying the load and performance parameters hydrocarbons, NOx, and PM are measured with exhaust gas analyzer and smoke (or) opacity measured with a smoke meter.

1.9 Structure of the present Thesis:

The structure of the present thesis, Chapter 1 discusses the Introduction of HCCI and Internal Combustion technology, exhaust gases, and pollution in the atmosphere. Chapter 2 describes the literature review of HCCI technology, combustion analysis, and homogeneous mixture preparation methods.

Chapter 3 describes the overview of HCCI engines, challenges, and advantages of HCCI technology. Chapter 4 gives details of the properties of the Eucalyptus oil, emissions, and limitations of alternative fuels. Chapter 5 & 6 describes the experimental setup, results, and discussions of the research work.

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Chapter 2

Literature Review

2.1 HCCI Technology Engines:

Gangeya Srinivasu Goteti et.al, (2017) [2] says Homogeneous charge compression ignition has the better efficiency and gives the lesser amount of exhaust emissions oxides of nitrogen and particulate matters, also usage of oxygenated fuels in Homogeneous charge compression ignition technology engines generated unburned hydrocarbons and carbon monoxide.

A HCCI technology engine are more suitable technique for next decades or generation to produce gases for good atmosphere and also investigates the effects of various fuels, fuel burns in cylinder and generated exhaust gases.

Mrs. C. M. Meenakshi et.al. (2017) [10] says Homogeneous Charge Compression Ignition (HCCI) technique or concept reduces the both oxides of nitrogen and particulate matter emissions at a same time. Biodiesel has the best alternative fuels for diesel type, because of similar characteristics are obtained and HOR suitable for high value of compression ratio.

To vary blend of chicken fat biodiesel in the present experiment, to find the performance and emission characteristics of Homogeneous charge compression ignition technology.

The specification of the engine intake manifold is 110mm and fuel entered at before Top Dead Centre with a 23^0 for the combustion. Moreover, investigates at various fuels and biodiesel blends to record the performance characteristics.

Fridhi Hadia et.al. (2016) [6] analysis the parameters such as value of compression ratio, time of injection, rate of combustion and exhaust gases of the characteristics numerically. In this experiment or test, two types of fuels are used Isooctane (IC8H18) and ethanol (C2H5OH).

The fuel burn timing depends upon the compression ratio value and enhances values of the parameters temperature and pressure. The water vapor injection is decreased 40% of the maximum temperature and lower value of combustion. So, small amount of oxides of nitrogen can be released.

Syed Yaser HUssaini et.al. (2016) [7] says the HCCI technique is a new concept, it gives the better thermal efficiency and control the problem of generating higher amounts emissions NOx and soot in the environment. The preparation of fuel air concentration is the main task in HCCI technology. To get the mixture of fuel and air, petrol used as fuel in this test or experiment. The mixture introducing the cylinder through carburetor, controlled by throttling losses, the especially intake manifold, it arrange to the cylinder head.

Some experiments conducted on Homogeneous charge compression ignition engine, observe the combustion in the test engine. The oxides of nitrogen and soot are compared to base engine reduced 78%.

Mohammadreza Nazemi et.al, (2015) [3] uses for the in-house exhaust gas flow model for GT-POWER and CHEMKIN-PRO software. The values are determined or investigates the single cylinder HCCI technology for validated the model.

This model estimated the values of burning fuel, mean effective pressure is 0.3 bar, crank angle degree value is 1.1 are investigated. The values of variable valve timing of HCCI technology affects are analyzed and using a new technique for the Homogeneous charge compression ignition engine cycle.

Miqdam T Chaichan et.al, (2015) [4] finds the Homogeneous charge compression ignition technology are reduce the NOx exhaust gases with low combustion temperature in the cylinder by the exhaust gas recirculation method. It can also be reduced the particulate matter values using the premixed fuel air mixture for combustion in the cylinder.

By the test results the values are achieved by increase the basic specific fuel consumption (BSFC) about 17%, also reduces the value of brake thermal efficiency is 20.88%. The engine is operating with advanced injection timing method and also 50% EGR value give the reverse outcomes.

Prof. Sanjay Harip et.al. (2014) [8] finds the HCCI technology considered as the alternative technology for diesel vehicles. The HCCI technique contains a premixing mixture, introducing to the cylinder and compressed together and start the combustion in the cylinder.

The Homogeneous charge compression ignition engine vehicles or automobiles are entered on the roads in 2012 and 2015 and also the half million barrels of fuel saved per day. Due to reduce the rate of fuel consumption, greenhouse gas emissions, also more interest on Homogeneous charge compression ignition technology in worldwide.

Anku Kumar Singh et.al. (2014) [9] investigates the HCCI technology applied for petrol, diesel and gaseous fuel type automobiles. HCCI is a new advanced technology. The Homogeneous charge compression ignition technology has the combined characteristics of gasoline and diesel type vehicles.

Such as SI type, mixture finely mixed and reduced or minimizes the particulate emissions. It gives higher efficiency than Compression Ignition Direct Ignition. The fuel burning is different than the Compression Ignition type, the combustion starts somewhere in the cylinder volumetrically entire cylinder.

Medhat Elkelway et.al, (2014) [1] investigate the homogeneous mixture preparation technique of external formation method for diesel fuel and worked with Homogeneous charge compression ignition combustion exhaust emission characteristics. Depends upon the performance of the automobiles and exhaust emissions of the injection temperature of fuel at operating conditions of the engine. The optimal pressure range 150– 200 bars of pressure. The temperature of fuel is 175^0C – 200^0C.

Mingfa Yao et.al. (2009) [5] says Homogeneous charge compression ignition technology are the considerable technology, because it can produce lesser amount of oxides of nitrogen and soot emissions and gives higher efficiencies. The researchers conducted on HCCI technology to control the combustion in the cylinder. First, numerical answer for the observation and powerful tool to determine the HCCI combustion. They discussed or explained various models applied to HCCI technology.

Second, HCCI technology also be applied on different oils. Burning of fuel and range of operation can be investigated by using the variety of characteristics. Third, analyzed the fuel air ratio preparation and applied on HCCI technology.

Fourth type optical diagnostics can be applied on HCCI technology. The key to burning of fuel, the proportions of degree of fuel air mixture and EGR also concept to achieve the rate of combustion.

2.2 HCCI Combustion:

Mr. Dhruval S. Patel et.al. (2017) [11] gives Homogeneous charge compression ignition combustion gives high efficiency, less amount of fuel consumption and small amount of NOx and PM exhaust emissions. The alternative are methane with hydrogen, methane with syngas to enhance the performance, decreasing the pollution in the environment, increase the rate of heat release.

Ethanol used for HCCI technology. Thermal efficiency always depends upon the temperature of homogeneous mixture. Using the hydrogen or natural gas as fueled in Homogeneous charge compression ignition engines, reduce the oxides of nitrogen, particulate matters and carbon monoxide emissions, fuel consumption and enhanced the efficiency from 13% to 16%.

Aravind. I. Garagad (2016) [20] says to get the higher reductions of NOx. The HCCI technologies are more suitable. To achieve in HCCI technology with homogeneous mixture and rich amount of exhaust gas recirculation value. The advantage of HCCI technology is fuel burning, SI or conventional type with dual type. Remove the wall impingements of fuels, get the good emissions and lower fuel consumption.

Khashayar Ebrahimi et.al. (2016) [18] says HCCI technology given small amount of oxides of nitrogen and soot. The fuel burn starts in HCCI technology with high temperature. The values of HCCI technology give the lesser amount of NOx and slightly higher hydrocarbon and carbon monoxide. It gives the high thermal efficiency at the high combustion efficiency values. It is suitable for control the fuel burning time in cylinder.

S. Gowthaman et.al. (2015) [19] investigates the HCCI technique on diesel type. Determine the performance characteristics of HCCI technique. It can be operated at different inlet temperature and pressures and find the performance and emission characteristics of HCCI technique.

The temperature and pressures are 40^0C and 70^0C and 3 to 5 bar respectively. The efficiency shows the accessible of conventional diesel type. At the 5 bar pressure and 60^0C inlet temperature gives the lesser amount of NOx and PM exhaust gases.

Giuseppe Genchi et.al. (2015) [17] studies on a HCCI technology. In this experiment natural gas and gasoline are fuels. The test conducted on CFR model. Changes the proportion values of two fuels. The result of this test gives the best or increase thermal efficiency is similar to spark ignition engine operations and also reduce the oxides of nitrogen formation in the environment.

Dr. P. M. Diaz et.al. (2013) [16] investigates the CNG for HCCI technology with exhaust gas recirculation method or technique. Compressed Natural Gas is the best alternative fuel. For CNG fueled HCCI technology starts combustion in the cylinder. In HCCI technique, simulate the multi zone CNG fueled. To enhance the exhaust gas recirculation value, enhances the fuel burn.

R. Senthil Kumar et.al. (2013) [14] gives Homogeneous charge compression ignition combustion gives high efficiency, less amount of fuel consumption and small amount of NOx and PM exhaust emissions. The alternative are methane with hydrogen, methane with gas to enhance the performance, decreasing the pollution in the environment, increase the rate of heat release.

Ethanol used for HCCI technology. Thermal efficiency always depends upon the temperature of homogeneous mixture. Using the hydrogen or natural gas as fueled in Homogeneous charge compression ignition engines, reduce the oxides of nitrogen, particulate matters and carbon monoxide emissions.

P. M. Diaz et.al. (2013) [12] analysis the properties of Compressed Natural Gas in HCCI technology, use maximum values of CR ratio. It gives large amount of heat, the

homogeneous mixture must be lean with Exhaust Gas Recirculation avoiding the knocking. Chemical kinetics determines the ignition.

The Homogeneous charge compression ignition technology has the characteristics of gasoline and diesel. Such as SI, reduced or minimizes the particulate emissions. The multi zone engine model are reasonably well with the various parameters. He Ma et.al. (2011) [15] says the HCCI technique is a new concept, it gives the better thermal efficiency and control the problem of generating higher amounts emissions NOx and soot in the environment. The preparation of fuel air concentration is the main task in HCCI technology. To get the mixture of fuel and air, petrol used as fuel in this test or experiment.

The mixture introducing the cylinder through carburetor, controlled by throttling losses, the especially intake manifold, it arrange to the cylinder head. Some experiments conducted on Homogeneous charge compression ignition engine, observe the combustion in the test engine. M. Ghazikhani et.al. (2009) [13] studies on the behavior of the homogeneous mixture or premixed, values of equivalence ratio, exhaust emissions carbon monoxide, hydrocarbons of Homogeneous charged compression ignition engine.

The experiment conducted on a single cylinder diesel, the CR is 17.5. To control the inlet change temperature using a heater fitted at inlet. Combustion depends upon the temperature inside cylinder. At the temperature inside cylinder is 110^0C to 155^0C experiments are conducted.

2.3 Effects of EGR on HCCI:

Ali Alqahtani (2015) [27] have given compare to Ricardo WAVE and AVL BOOST simulation software. For both SIGDI and homogeneous charged compression ignition engines obtaining the maximum efficiency and reduce the exhaust emissions from the engine. It gives the experimentally analyze the spark ignition and homogeneous charged compression ignition engines, single cylinder, 4 valve, gasoline engines with varying the engine speed or different configuration and determine the most suitable ideal set-up for the experimental engines. With the help of suitable set-up, minimize the long delays, engine designed and tested at operating conditions with respect to combustion phrasing.

M. Nazoktabar et.al. (2014) [29] studies control of combustion or auto ignition timing and power generation is the major challenge in HCCI technology. They developed a new concept for combustion control and power generation for Homogeneous charged compression ignition engine at any operating conditions.

A single zone thermodynamic fixed to the kinematic mechanism for first grade fuels or reference fuels affect the parameters are combustion starts in cylinder, mean effective pressure of Homogeneous charged compression ignition operating cycle. The crank angle changes the 50% of fuel mass in cylinder and adjusting the mean effective pressure data.

B. Bahri ET. al. (2013) [31] conducted experiment on Homogeneous charged compression ignition engine with blend of ethanol and diethyl ether. It can also be means of Stochastic Reactor Model (SRM). To calculate the gas flow in the engine 1D CFD code is applicable. To compare the obtained values with caterpillar CAT3401 single cylinder diesel engine, modified to Homogeneous charged compression ignition engine.

The exhaust emissions carbon dioxide, unburned hydrocarbons, carbon monoxide are operated with crank angle rate of heat release 50%. The small amount of exhaust emissions oxides of nitrogen and particulate emissions are obtained.

Suyin Gan et.al. (2011) [22] Says HCCI technology possess larger reductions in NOx and PM emissions. Some gases are slightly higher than conventional diesel type, HCCI technology is an alternative technology for conventional type process.

The affecting the HCCI technology operations are homogeneous mixture, injector parameters are pressure, piston dimensions, supercharging and turbo charging, exhaust gas recirculation and EGR values.

Hoon Kiat Ng et.al. (2011) [25] investigate the homogeneous mixture preparation technique of external formation method for diesel fuel and worked with Homogeneous charge compression ignition combustion exhaust emission characteristics. Depends upon the performance of the automobiles and exhaust emissions of the injection temperature of fuel at operating conditions of the engine.

The optimal pressure range 150– 200 bars of pressure. The temperature of fuel is 175^0C – 200^0C.

S. Voglsam et.al. (2011) [28] says the HCCI technique is a new concept, it gives the better thermal efficiency and control the problem of generating higher amounts emissions NOx and soot in the environment. The preparation of fuel air concentration is the main task in HCCI technology.

To get the mixture of fuel and air, petrol used as fuel in this test or experiment. The mixture introducing the cylinder through carburetor, controlled by throttling losses, the especially intake manifold, it arrange to the cylinder head. Some experiments conducted on Homogeneous charge compression ignition engine, observe the combustion in the test engine. The oxides of nitrogen and soot are compared to base engine reduced 78%.

Sunil Kumar Pandey et.al. (2011) [21] studies on Homogeneous charged compression ignition engine mode with heavy duty fuel, multi cylinder engine. In performance parameters are ignition pressure, rate of fuel consumption, achieved maximum pressure and combustion rate.

The experiment conducted on a single cylinder diesel, the CR is 17.5. To control the inlet change temperature using a heater fitted at inlet. Combustion depends upon the temperature inside cylinder. At the temperature inside cylinder is 110^0C to 155^0C experiments are conducted. The Homogeneous charged compression ignition can be operated with load of 25% and 0 to 60% of exhaust gas recirculation value.

Nick J. Killingsworth et.al. (2009) [30] analysis the properties of Compressed Natural Gas in HCCI technology, use maximum values of CR ratio. It gives large amount of heat, the homogeneous mixture must be lean with Exhaust Gas Recirculation avoiding the knocking. Chemical kinetics determines the ignition.

The Homogeneous charge compression ignition technology has the characteristics of gasoline and diesel. Such as SI, reduced or minimizes the particulate emissions. The multi zone engine model is reasonably well with the various parameters.

D. Ganesh et.al. (2009) [23] Conducted the experiment on HCCI technology with the fuel vaporizer. In this test, the diesel with air, forms a homogeneous mixture and entered into the cylinder through suction stroke. To control auto ignition timing and exhaust gas recirculation values are adopted. The results are reducing the oxides of nitrogen value 95% and smoke or soot value 83%.

Faming Sun et.al. (2005) [26] studies on the alternative fuels or sustainable bio-fuels are overcome the drawbacks or difficulties operation of the Homogeneous charge compression ignition technology engine combustion process. HCCI combustion, affecting the parameters performance of the vehicle, released amount of exhaust gas is analyzed. HCCI technology produces the NOx, UHC, CO and PM matters. Bellanca et.al. (2004) [24] explains the kinetic models validated and developed for auto ignition and laminar combustion process.

Homogeneous charged compression ignition engines can be operated with the homogeneous mixture ratio is greater than 2.0 also with the higher values of Exhaust Gas Recirculation. These operating conditions not suitable for availability of kinetic models, so further research is needed or necessary.

2.4 Alternative Fuels HCCI Engine:

S. Venkateswarlu et.al. (2017) [39] says the HCCI technique is a new concept, it gives the better thermal efficiency and control the problem of generating higher amounts emissions NOx and soot in the environment. The preparation of fuel air concentration is the main task in HCCI technology. To get the mixture of fuel and air, petrol used as fuel in this test or experiment.

The mixture introducing the cylinder through carburetor, controlled by throttling losses, the especially intake manifold, it arrange to the cylinder head. Some experiments conducted on Homogeneous charge compression ignition engine, observe the combustion in the test engine. The oxides of nitrogen and soot are compared to base engine reduced 78%.

J. A. Jeffrey et.al. (2016) [38] finds the Homogeneous charge compression ignition technology are reduce the NOx exhaust gases with low combustion temperature in the

cylinder by the exhaust gas recirculation method. It can also be reduced the particulate matter values using the premixed fuel air mixture for combustion in the cylinder.

By the test results the values are achieved by increase the basic specific fuel consumption (BSFC) about 17%, also reduces the value of brake thermal efficiency is 20.88%. The engine is operating with advanced injection timing method and also 50% EGR value give the reverse outcomes.

Puneet Verma et.al. (2015) [35] studies control of combustion or auto ignition timing and power generation is the major challenge in HCCI technology. They developed a new concept for combustion control and power generation for Homogeneous charged compression ignition engine at any operating conditions.

A single zone thermodynamic fixed to the kinematic mechanism for first grade fuels or reference fuels affect the parameters are combustion starts in cylinder, mean effective pressure of Homogeneous charged compression ignition operating cycle. The crank angle changes the 50% of fuel mass in cylinder and adjusting the mean effective pressure data.

N.S Senthur et.al. (2014) [36] says Homogeneous charge compression ignition has the both SI and IC concept characteristics. It can be operated with gasoline, diesel, gaseous and different alternative fuels.

The exhaust emissions of the automobile are increased greenhouse gases and depletion of ozone layer in the atmosphere, so more research necessary for clean combustion process in automobiles and also less amount of fuel consumption and higher efficiency. P. V. Ramana et.al. (2013) [34] finds the numerical solution for engines to controls the development for reduces significant the operating time, it gives information for understanding the system operations.

Based on different or various models like homogeneous charged compression ignition technology engine model, the virtual engine simulator can be used for control and development of design of a homogeneous charged compression ignition model, gives the alternative solutions, the homogeneous charged compression ignition engine gives the benefit high exhaust gas recirculation rate and control pollution in the atmosphere.

Lyes Tarabet et.al. (2012) [37] conducts experiments CNG as fuel with HCCI technology and also analyzed the single zone of zero dimensional HCCI technique. According to experimental or investigated results, the value of compression ratio is 11, the percentage of fuel additives are 0.13% and equivalence ratio value 0.5 are the optimum conditions of the combustion of compressed natural gas fueled Homogeneous charge compression ignition technology engines and ignition time is 9ms.

Tamilvendhan D et.al. (2011) [40] conducted experiment on Homogeneous charged compression ignition engine with blend of ethanol and diethyl ether. It can also be means of Stochastic Reactor Model (SRM). To calculate the gas flow in the engine 1D CFD code is applicable.

To compare the obtained values with caterpillar CAT3401 single cylinder diesel engine, modified to Homogeneous charged compression ignition engine. The exhaust emissions carbon dioxide, unburned hydrocarbons, carbon monoxide are operated with crank angle rate of heat release 50%. The small amount of exhaust emissions oxides of nitrogen and particulate emissions are obtained.

A Delorme et.al. (2010) [32] explains the kinetic models validated and developed for auto ignition and laminar combustion process. Homogeneous charged compression ignition engines can be operated with the homogeneous mixture ratio is greater than 2.0 also with the higher values of Exhaust Gas Recirculation. These operating conditions not suitable for availability of kinetic models, so further research are needed or necessary.

Krzysztof Motyl ET. al. (2003) [33] have given compare to Ricardo WAVE and AVL BOOST simulation software. For both SIGDI and homogeneous charged compression ignition engines obtaining the maximum efficiency and reduce the exhaust emissions from the engine.

It gives the experimentally analyze the SI and HCCI technology, single cylinder, 4 valve, gasoline with varying the engine speed or different configuration and determine the most suitable ideal set-up for the experimental engines. With the help of suitable set-up, minimize the long delays, designed and tested at operating conditions.

2.5 HCCI Injection:

Fridhi Hadia et.al. (2016) [41] have given compare to Ricardo WAVE and AVL BOOST simulation software. For both SIGDI and homogeneous charged compression ignition engines obtaining the maximum efficiency and reduce the exhaust emissions from the engine. It gives the experimentally analyze the SI and HCCI technology, single cylinder, 4 valve, gasoline with varying the engine speed or different configuration and determine the most suitable ideal set-up for the experimental engines.

With the help of suitable set-up, minimize the long delays, designed and tested at operating conditions. Gang Li et.al. (2016) [42] studies control of combustion or auto ignition timing and power generation is the major challenge in HCCI technology. They developed a new concept for combustion control and power generation for Homogeneous charged compression ignition engine at any operating conditions.

A single zone thermodynamic fixed to the kinematic mechanism for first grade fuels or reference fuels affect the parameters are combustion starts in cylinder, mean effective pressure of Homogeneous charged compression ignition operating cycle. The crank angle changes the 50% of fuel mass in cylinder and adjusting the mean effective pressure data.

S. Krishnamani et.al. (2016) [43] finds the numerical solution for engines to controls the development for reduces significant the operating time, it gives information for understanding the system operations.

Based on different or various models like homogeneous charged compression ignition technology engine model, the virtual engine simulator can be used for control and development of design of a homogeneous charged compression ignition model, gives the alternative solutions, the homogeneous charged compression ignition engine gives the benefit high exhaust gas recirculation rate and control pollution in the atmosphere.

N. R. Banapurmath et.al. (2014) [48] conducts experiments CNG as fuel with HCCI technology and also analyzed the single zone of zero dimensional HCCI technique. According to experimental or investigated results, the value of compression ratio is 11, the percentage of fuel additives are 0.13% and equivalence ratio value 0.5 are the optimum

conditions of the combustion of compressed natural gas fueled Homogeneous charge compression ignition technology engines and ignition time is 9ms.

N. Austin et.al. (2013) [45] analysis the properties of Compressed Natural Gas in HCCI technology, use maximum values of CR ratio. It gives large amount of heat, the homogeneous mixture must be lean with Exhaust Gas Recirculation avoiding the knocking. Chemical kinetics determines the ignition.

The Homogeneous charge compression ignition technology has the characteristics of gasoline and diesel. Such as SI, reduced or minimizes the particulate emissions. The multi zone engine model is reasonably well with the various parameters.

Muralitharan N et.al. (2011) [47] says investigate the homogeneous mixture preparation technique of external formation method for diesel fuel and worked with Homogeneous charge compression ignition combustion exhaust emission characteristics. Depends upon the performance of the automobiles and exhaust emissions of the injection temperature of fuel at operating conditions of the engine. The optimal pressure range 150– 200 bars of pressure. The temperature of fuel is 175^0C – 200^0C. M. Ghazikhani et.al. (2009) [49] says Homogeneous charge compression ignition technology are the considerable technology, because it can produce lesser amount of oxides of nitrogen and soot emissions and gives higher efficiencies. The researchers conducted on HCCI technology to control the combustion in the cylinder. First, numerical answer for the observation and powerful tool to determine the HCCI combustion. They discussed or explained various models applied to HCCI technology.

T Bancha ET. al. (2009) [50] finds the numerical solution for engines to controls the development for reduces significant the operating time, it gives information for understanding the system operations. Based on different or various models like homogeneous charged compression ignition technology engine model, the virtual engine simulator can be used for control and development of design of a homogeneous charged compression ignition model, gives the alternative solutions, the homogeneous charged compression ignition engine gives the benefit high exhaust gas recirculation rate and control pollution in the atmosphere.

Xiang Chen et.al. (2005) [46] finds the HCCI technology considered as the alternative technology for diesel vehicles. The HCCI technique contains a premixing mixture, introducing to the cylinder and compressed together and start the combustion in the cylinder.

The Homogeneous charge compression ignition engine vehicles or automobiles are entered on the roads in 2012 and 2015 and also the half million barrels of fuel saved per day. Due to reduce the rate of fuel consumption, greenhouse gas emissions, also more interest on Homogeneous charge compression ignition technology in worldwide.

D. Ayyappan (2004) [44] explains the kinetic models validated and developed for auto ignition and laminar combustion process. Homogeneous charged compression ignition engines can be operated with the homogeneous mixture ratio is greater than 2.0 also with the higher values of Exhaust Gas Recirculation.

These operating conditions not suitable for availability of kinetic models, so further research are needed or necessary.

2.6 Mixture Preparation:

Seyfi et.al, (2017) [55] gives overview of HCCI technology. In this technology spark plug or injector not necessary for combustion in the engine cylinder. With auto ignition, the fuel burns starts in number of points or areas in the cylinder.

The challenges in the operation of HCCI technology are cold start capability, auto fuel burn temperature control, fuel and air preparation, controlling the unburned hydrocarbons and carbon monoxide emissions. More developments needed for overcome these challenges and getting good efficiency and low level exhaust gases.

Fridhi Hadia et.al. (2016) [51] studies control of combustion or auto ignition timing and power generation is the major challenge in HCCI technology. They developed a new concept for combustion control and power generation for Homogeneous charged compression ignition engine at any operating conditions. A single zone thermodynamic fixed to the kinematic mechanism for first grade fuels or reference fuels affect the

parameters are combustion starts in cylinder, mean effective pressure of Homogeneous charged compression ignition operating cycle. The crank angle changes the 50% of fuel mass in cylinder and adjusting the mean effective pressure data.

B. Bahri et.al. (2016) [52] analysis the properties of Compressed Natural Gas in HCCI technology, use maximum values of CR ratio. It gives large amount of heat, the homogeneous mixture must be lean with Exhaust Gas Recirculation avoiding the knocking. Chemical kinetics determines the ignition. The Homogeneous charge compression ignition technology has the characteristics of gasoline and diesel. Such as SI, reduced or minimizes the particulate emissions. The multi zone engine model is reasonably well with the various parameters.

H. Hanafi ET. Al, (2016) [53] says HCCI an alternative technique for combustion process. Homogeneous charge compression ignition is a cleaner and gives more efficiency the other combustion techniques. The lesser amount of NOx and PM are released in the atmosphere. It has drawbacks or disadvantages are control of ignition timing, cold start problem and rate of heat for operation of the automobiles.

Ayyapan et.al, (2016) [57] conducts experiments CNG as fuel with HCCI technology and also analyzed the single zone of zero dimensional HCCI technique. According to experimental or investigated results, the value of compression ratio is 11, the percentage of fuel additives are 0.13% and equivalence ratio value 0.5 are the optimum conditions of the combustion of compressed natural gas fueled Homogeneous charge compression ignition technology engines and ignition time is 9ms.

K. Srinivas et.al, (2015) [58] studies on the alternative fuels or sustainable bio-fuels are overcome the drawbacks or difficulties operation of the Homogeneous charge compression ignition technology engine combustion process. HCCI combustion, affecting the parameters performance of the vehicle, released amount of exhaust gas is analyzed. HCCI technology produces the NOx, UHC, CO and PM matters.

Akhilendra Pratap Singh et.al, (2012) [59] investigates the influence of Homogeneous charge compression ignition technology compression ratio and combustion parameters are

evaluated. Change of TY1100 single cylinder engine with dimethyl ether as the fuel. The dimethyl ether fuel gives the work stable HCCI technology and gives lesser amount of NOx and smoke less combustion of the cylinder, with the both compression ratio values of 10.7 and 14. The combustion determined by the proportions of fuel air mixture. The starts of combustion mainly depends on the quality of mixture, history of temperature and pressure in the cylinder and also difficult to maintain or control the ignition timing at various speeds and loads.

Avinash Kumar Agarwal et.al, (2012) [56] says Homogeneous charge compression ignition has the both SI and IC concept characteristics. It can be operated with gasoline, diesel, gaseous and different alternative fuels. The exhaust emissions of the automobile are increased greenhouse gases and depletion of ozone layer in the atmosphere, so more research necessary for clean combustion process in automobiles and also less amount of fuel consumption and higher efficiency. S.M. Aceves et.al, (2004) [54] given the Homogeneous Charge Compression Ignition technology are highly efficient than other technology process and gives small amount of emissions are NOx and PM matters. Homogeneous charge compression ignition brings higher efficiency than compression ignition direct ignition. Homogeneous charge compression ignition technique can be operated at different fuels.

2.7 Fuels Used In HCCI Engine:

Bhaskar et.al, (2017) [60] gives the injection timing is the most effective method to control the combustion phrasing in a Homogeneous charge compression ignition technology engines. Injection timing affects the value of fuel air mixture, auto ignition and rate of heat release. The pressure enhances, because change of injection timing.

Dhruval et.al. (2017) [66] says Homogeneous charge compression ignition has the both SI and IC concept characteristics. It can be operated with gasoline, diesel, gaseous and different alternative fuels. The exhaust emissions of the automobile are increased greenhouse gases and depletion of ozone layer in the atmosphere, so more research necessary for clean combustion process in automobiles and also less amount of fuel consumption and higher efficiency.

Rakesh Kumar et.al, (2016) [61] investigated the HCCI technology generate high thermal efficiency and less amount of NOx and PM gases are generated. The Homogeneous charge compression ignition technology operated for various fuels.

The blend of different alternative fuels can be used both SI and CI type vehicles. Homogeneous charge compression ignition technology combustion achieved with parameters of control the temperature and pressure, correct proportions of fuel and air mixture and starts combustion starts volumetrically entire cylinder.

A. Dinesh ET. al. (2015) [68] analysis the properties of Compressed Natural Gas as fueled in Homogeneous charge compression ignition engines, use maximum values of compression ratio and intake air heating. It gives higher values of heat release, the fuel air mixture must be lean with Exhaust Gas Recirculation avoiding the knocking values. Chemical kinetics controls the ignition timing.

The Homogeneous charge compression ignition technology engine has the combined characteristics of gasoline and diesel fuel type engines. Such as spark ignition, the fuel and air finely mixed and reduced or minimizes the particulate emissions. The multi zone engine model are reasonably well with the various parameters.

SAW YOU MON et.al. (2015) [64] Says the numerical solution for engines to controls the development for reduces significant the operating time, it gives information for understanding the system operations.

Based on different or various models like homogeneous charged compression ignition technology engine model, the virtual engine simulator can be used for control and development of design of a homogeneous charged compression ignition model, gives the alternative solutions, the homogeneous charged compression ignition engine gives the benefit high exhaust gas recirculation rate and control pollution in the atmosphere.

Praveen Kumar et.al, (2014) [62] finds the lean homogenous blend is efficiently introduced into the cylinder, without throttling losses, combustion starts in the combustion volumetrically entire in the cylinder, not needed to flame.

This technique helps to reduce the soot and enhance the thermal efficiency. Homogeneous charge compression ignition petrol as fuel introduced into the cylinder, through manifold. The effect of fuel air ratio on the burn of fuel, performance, exhaust emissions generated to the atmosphere and characteristics of HCCI technology.

Alexandros G et.al. (2013) [63] finds the HCCI technology is a suitable promising technology for diesel vehicles to produce high thermal efficiency and small amount of oxides of nitrogen and particulate matters. HCCI technique applied on two cylinder diesel as fuel engine. The mode of operation is one cylinder in HCCI mode of operation and another cylinder conventional type mode.

The degree of fuel air mixture is the key to control the combustion or auto ignition in HCCI engines. The major problem is making a homogeneous mixture in correct proportions. The unburned hydrocarbons and carbon monoxide slightly higher the CI engine. Applied EGR technique, enhances the rate of combustion and gases in the cylinder.

P. M. Diaz et.al. (2012) [67] finds the numerical solution for engines to controls the development for reduces significant the operating time, it gives information for understanding the system operations. Based on different or various models like homogeneous charged compression ignition technology engine model, the virtual engine simulator can be used for control and development of design of a homogeneous charged compression ignition model, gives the alternative solutions, the homogeneous charged compression ignition engine gives the benefit high exhaust gas recirculation rate and control pollution in the atmosphere.

S. Mosbach et.al. (2006) [65] compare to Ricardo WAVE and AVL BOOST simulation software. For both SIGDI and homogeneous charged compression ignition engines obtaining the maximum efficiency and reduce the exhaust emissions from the engine. It gives the experimentally analyze the SI and HCCI technology, single cylinder, 4 valve, gasoline with varying the engine speed or different configuration and determine the most suitable ideal set-up for the experimental engines. With the help of suitable set-up, minimize the long delays, designed and tested at operating conditions.

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Chapter 3

Homogeneous Charge Compression Ignition Engines

3.1 Overview of HCCI Engine:

The internal combustion engine has been the most successful device in delivering benefits to the different communities of the world. Reciprocating the IC engine is certainly the best apparatus in some aspects compared to its counterparts. Still, the processes of these IC engines are seeking developments vowing to the commercialization for a better place in the society.

The 4-stroke compression ignition engine (CI) is crucial for decades proving its role in society. The progress is related to engine combustion processes in terms of fuel-saving or minimization of losses. However, there are certainly other possibilities for improvement of these engines concerning the basic design which involves the types of fuel injection, better intake of air, fuel-air mixing, etc. The engine redesign or modifications are also in the field due to strict restrictions by the emission legislation.

Today, we are commonly operating two types of concepts IC and SI. The difference between Spark Ignition and Internal Combustion type, the gasoline consists of a catalytic converter; it gives low exhaust gases and acquired less efficiency. But, IC type performance higher efficiency, it releases a rich amount of NOx and PM matters. Comparing these two concepts, HCCI technology gives higher efficiencies and releases fewer amounts of gases.

Homogeneous Charged Compression Ignition technology is an alternative technology for internal combustion engines. In this technique mixture entered inside cylinder through the inlet of the engine. Homogeneous Charged Compression Ignition technology decreases (or) reduces the exhausted emissions from the automobiles and industries and also reduces the consumption of fuel. This technique is better and gives more efficiency. This technique applied to small to large scale applications.

3.2 Homogeneous Mixture Preparation Methods:

Homogeneous mixture preparation technique aims to reduce the exhaust gases from the engine cylinder such as oxides of nitrogen, carbon monoxide, carbon dioxide, unburned hydrocarbons, and particulate matters. The inner cylinder temperature depends upon the degree of a homogeneous mixture.

The Homogeneous mixture prepared in two methods, externally and internally. In the internal preparation method, the mixing of fuel and air entered inside the cylinder through a suction stroke. A slight modification occurs at the engine inlet. Finally, a homogeneous mixture can be prepared internally.

In the external homogeneous mixture preparation, arrange the injector at the head intake manifold replacing the direct ignition concept. In this technique, during suction, the fuel enters the fresh air. In this method, a large amount of mixture prepared, before starts combustion in the cylinder.

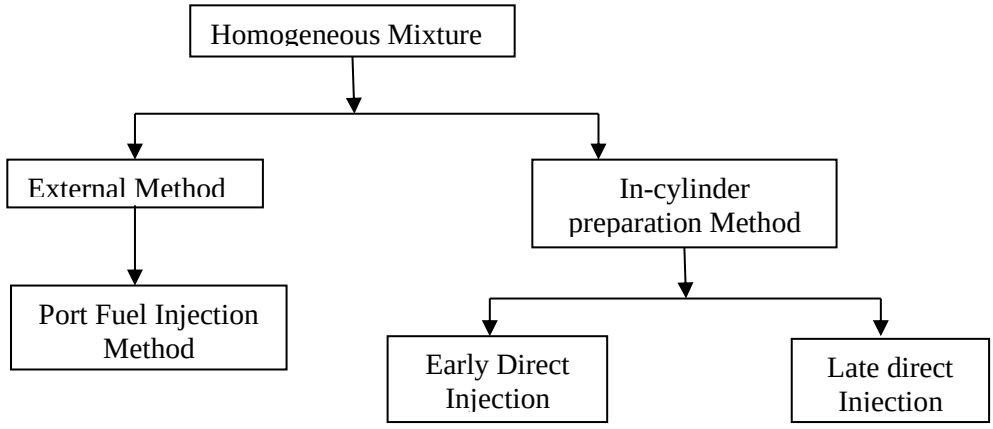

Figure 3.1: Homogeneous Mixture Preparation Methods.

3.2.1 External Homogeneous Mixture Preparation Method:

In the external homogeneous mixture preparation, arrange the injector at the head intake manifold replacing the direct ignition concept. In this technique, during suction, the fuel enters the fresh air. In this method, a large amount of mixture prepared, before starts

combustion in the cylinder. In this method, more mixing time is available than other preparation methods before the start of combustion in the cylinder. This method is highly suitable for gasoline and alcohol fuels.

Another process of external preparation is the port fuel injection method. The high volatile diesel is suitable for this method. In this technique, the large quantity of mixture prepared, before the combustion in the cylinder. The exhaust gases NOx, PM, and HC are reduced.

3.2.2 Port Fuel Injection Method:

It is the simplest method compared to other mixture preparation techniques. In this method, the injector is fitted at the inlet. This arrangement is arranged nearer to the inlet of the engine. The advantage of this method enhances the volumetric efficiency.

The exhaust gases are unburned hydrocarbons and carbon monoxide gases are reduced. During suction homogeneous mixture introduced to the cylinder through the inlet. In this method, at the time of ignition in the cylinder, the injection of fuel cannot be influenced. This method is suitable for part-load operation.

3.2.3 In-Cylinder Preparation Method:

This preparation method enhances engine performance and reduces the value of exhausting emissions from the engines. The port fuel injection method had drawbacks in mixture preparation. To overcome the drawbacks of the port fuel injection method, this method is efficiently introduced.

This method can be divided into early direct injection and late direct injection for obtaining the homogeneous mixture. The early injection method set during the compression stroke and late injection set to after Top Dead Center.

At the high pressures, the homogeneous mixture is easily formed. The number of nozzles to increase the pressures, a large amount of mixture is prepared.

3.2.4 Early Injection Method:

The fuel ignites in HCCI technology depend on injection timing. This method is mostly used for HCCI technology. It allows an ignition delay, with a low temperature of the mixture compared to conventional type and direct injection. The mixture introduced in the cylinder through suction, and then the mixture is compressed at compression in the cylinder. A piezoelectric sensor used for controlling the high pressures. The performance and emission characteristics depend upon the injection timing. The fuel economy, maintenance, and vibrations controlled by this method. The mixture can be injected during the suction; it can be divided the number of parts and starts burning after TDC. This technique is also known as premixed lean combustion.

3.2.5 Late Injection Method:

For a higher fuel economy and fewer exhaust emissions depends on the quality of the homogeneous mixture. This method, the fuel-burning starts before Top Dead Centre of the piston cylinder. The temperature and density decrease because of late injection. The cylinder conditions are favorable for fuel burning in HCCI technology. Suppose, the performance is high, the maximum temperature reduces, achieved a lesser amount of oxides of nitrogen. The soot also reduces because the ignition delay is prolonged and gives more time for preparation.

3.3 Combustion in HCCI Engine:

HCCI technology is the best alternative technology for combustion, performance, and efficiencies. The exhausted emissions such as oxides of nitrogen, hydrocarbons, carbon monoxide, and particulate matters are significantly reduced exhaust emissions. The combustion in HCCI technology engines occurs at volumetrically entire engine cylinder compressed by the piston. The HCCI technology possess better features than SI and CI type. The fuel and air incorrect proportions enter into the inside cylinder is known as homogeneous combustion. HCCI technology starts combustion at lower temperatures and releases a lesser amount of exhaust gases. The HCCI combustion process is shown in Figure 3.2.

STROKE 1 STROKE 2 STROKE 3 STROKE 4

(Air+Fuel) Exhaust

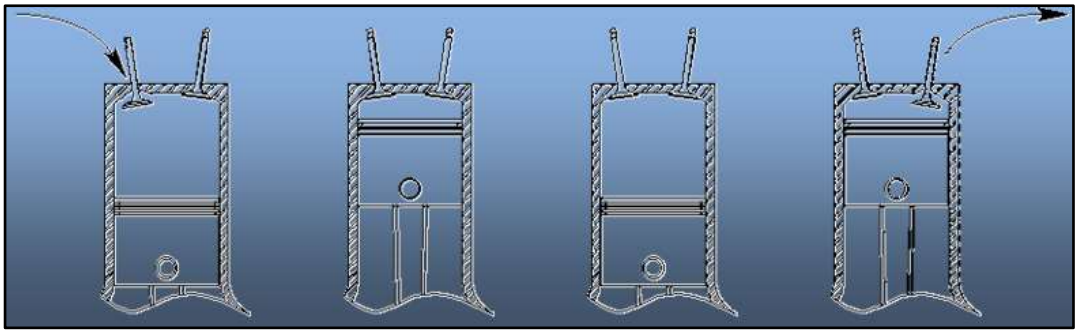

Figure 3.2: HCCI Combustion Process.

Homogeneous Charged Compression Ignition means the air and fuel mixed homogeneously inside cylinder and ignition starts automatically at the end of the compression stroke by the piston at higher pressure and temperature.

In HCCI technology principal operations are:

a. The mixture preparation enhances the combustion and improves the performance.
b. The combustion starts in the cylinder at the end of the compression stroke. The combustion spread entire in the cylinder simultaneously.
c. It produces a larger amount of heat, reduces the exhausted emissions.

This technology is also applied for SI type engines. This technique also suitable for different fuels, better performance, and enhance combustion.

The combustion takes place somewhere in the cylinder, because of heat losses at the cylinder walls. The amount of heat release depends upon the temperature and pressure parameters. In Homogeneous Charge Compression Ignition technology performs four strokes of the piston cylinder. At the time of suction, a homogeneous mixture entered (or) admitted into the cylinder and exhaust valve is closed. In compression, the homogeneous mixture is compressed by the piston movement.

The inlet and exhaust valves both are closed. Third stroke, expansion (or) power stroke heat releases in the cylinder. The sufficient pressure and temperature are generated at the end of the compression stroke compressed together to start ignition in the engine cylinder.

The power produced and both valves are closed in this process. In the exhaust, the exhaust emissions are released through the exhaust pipe. In exhaust stroke inlet valve closes and the exhaust valve opened. These engines are made with high metals like cast iron, aluminum alloys, etc.

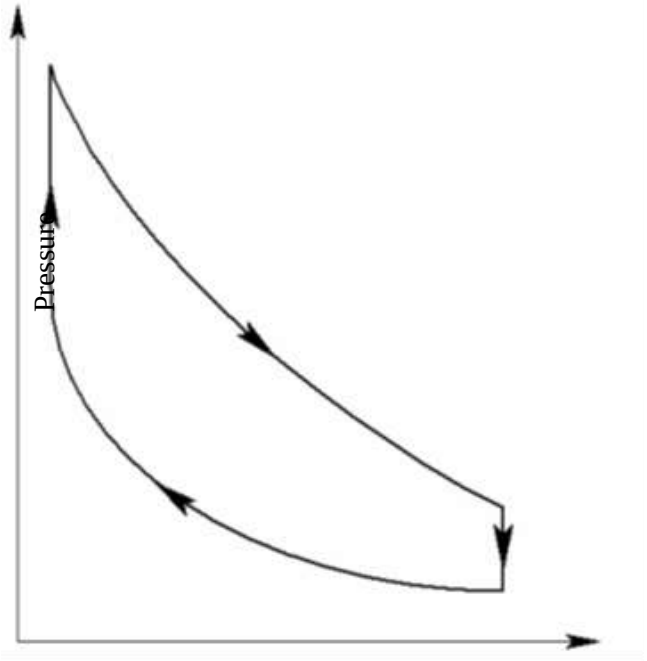

Figure 3.3: P-V diagram of the ideal HCCI cycle.

The Homogeneous Charged Compression Ignition engines according to gas power cycles, having both characteristics of the Otto cycle and Diesel cycle.

The P – V diagram of HCCI technology as shown in figure 3.3. It begins with an adiabatic and reversible compression process as shown in figure states 1 to 2. It consists of two reversible adiabatic and two constant pressure processes.

The Homogeneous Charge Compression Ignition technology combustion utilizes higher compression values and heat addition.

Table 3.1: Combustion Process at different concepts.

S. No	HCCI	Compression-Ignition	Spark Ignition
1	Ignition Automatically	Ignition Automatically	Ignition with spark
2	Un-throttled	Un-throttled	Throttled
3	Premixed Volumetric burning	Premixed diffusive burning	Premixed burning
4	No flame Propagation	Flame propagation	Flame propagation
5	Port and Direct Injection	Swirl with direct injection	Port injection
6	Lean / dilute stoichiometry	Variable Stoichiometry	Stoichiometric

3.4 Compression Ratio (CR):

It is the most important factor in the fuel ignition process and controlling the rate of combustion in the cylinder. It may be defined as the ratio of the total cylinder volume to the clearance volume.

HCCI technology is better compared to other methods to control the rate of combustion. If the CR value is low, the ignition extends in the cylinder.

The HCCI cycle increases the compression ratio value. Figure 3.4 shows the effect of compression ratio and efficiency.

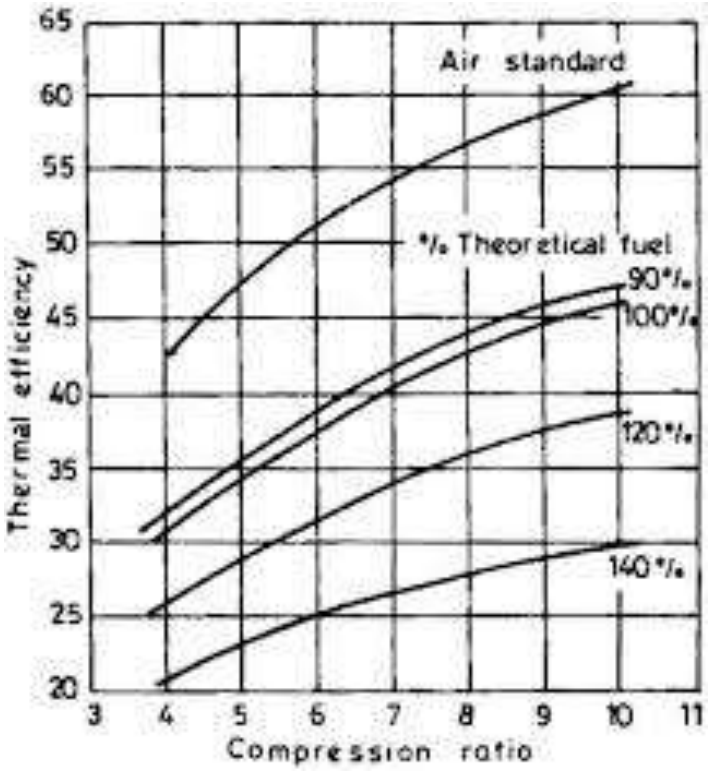

Figure 3.4: Compression ratio Vs efficiency.

3.5 Air-Fuel Ratio (A/F):

The HCCI technology operated at different speeds and loads with a lean homogeneous mixture. The fuel ignition in HCCI technology depends on the ratio of the mixture.

The correct proportions of air-fuel, reduce the emissions, and enhance the flame speed. The engine.

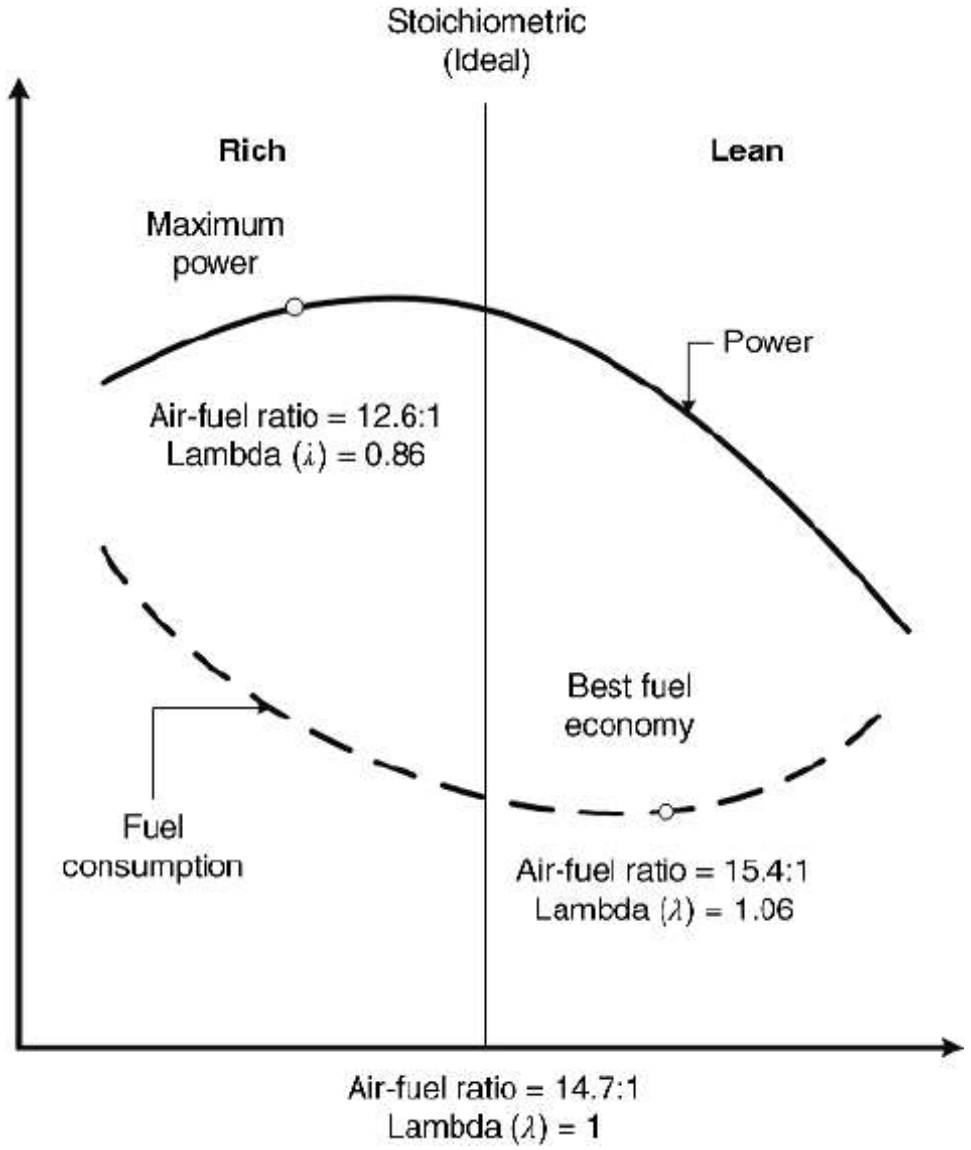

Figure 3.5: Fuel mixture Vs efficiency of the engine.

Combustion, maximum power, maximum temperature, maximum pressure, exhaust temperature in the cylinder, and mean effective pressure are affected by the air-fuel.

If the value increases, the large amounts of emissions are generated.

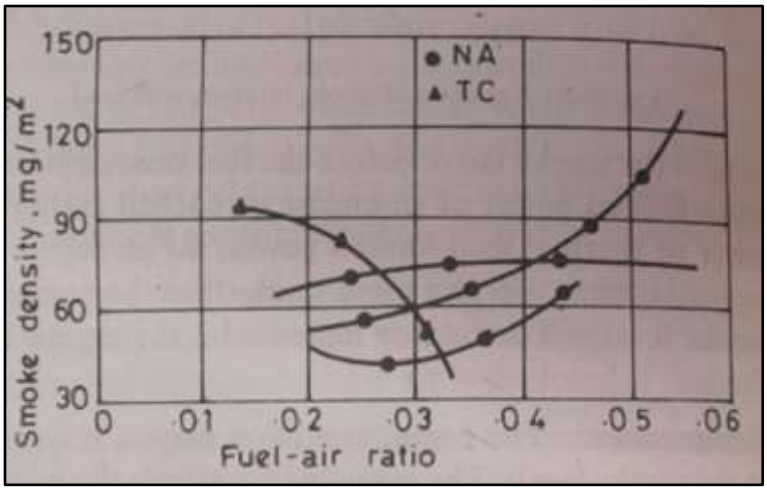

Figure 3.6: Fuel air ratio Vs smoke density.

3.6 Exhaust Gas recirculation (EGR):

In this process reuse the waste emissions released from the engine. These emissions are mixed with fresh air introducing in the cylinder. The parameters pressure and temperature depend on the value of EGR. It enhances performance and efficiency compared to other methods. Because of waste gases mixed with fresh air, reduces the ignition delay. The Exhaust Gas Recirculation reduces the percentage of O_2 in the combustion chamber.

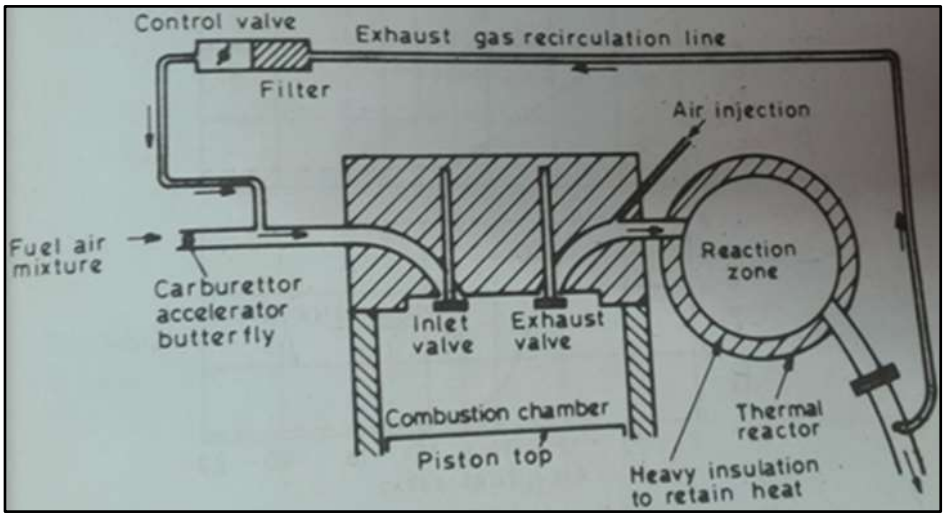

Figure 3.7: Exhaust Gas Recirculation process.

This technology is also applied for SI and Compression ignition type engines. This technique also suitable for different fuels and better performance and enhance combustion.

The combustion takes place somewhere at the cylinder, because of heat losses at the cylinder walls. The amount of heat release depends upon temperature and pressure. Exhaust Gas Recirculation consists of high specific heat.

So, increase the performance and efficiency of the engine. Automatically, decrease the temperature at the same value of heat release in the combustion chamber.

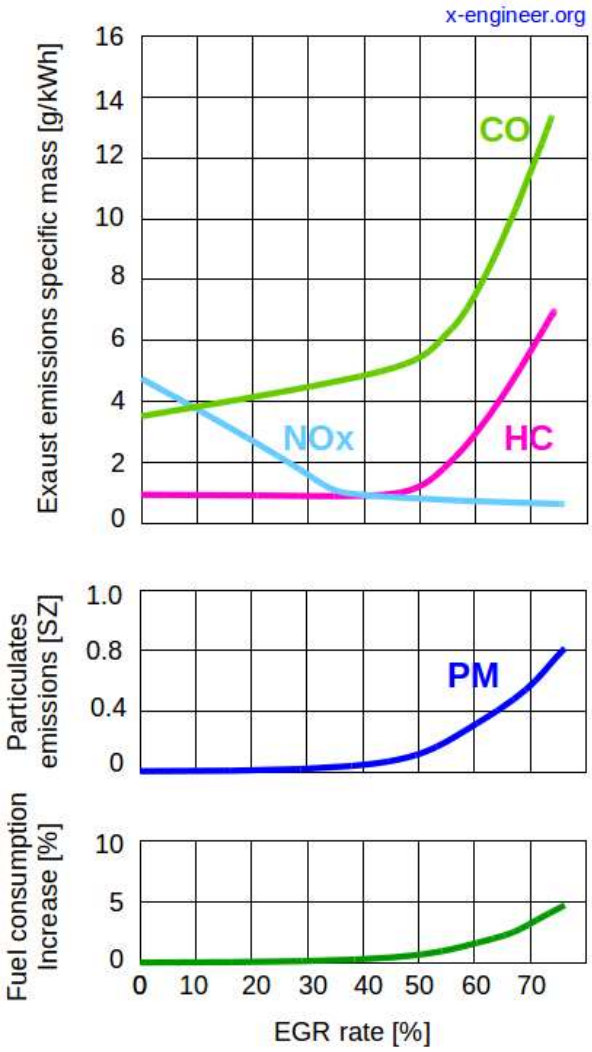

Figure 3.8: Effect of emissions with EGR.

3.7 Challenges and Solutions of HCCI:

At the operation of HCCI technology finding the difficulties are uncontrolled the combustion, preparation of the mixture, heavier noise and pressure, ignition at various loads, and speeds.

The HCCI technology fuel ignites with sufficient temperature, desirable pressure, and correct proportions of the mixture start combustion at somewhere in the cylinder. The rate of combustion depends on the ignition of fuel.

The ignition phenomenon is a difficult task in HCCI technology operation. The mixture enhances combustion and performance.

The HCCI technology another challenge is the cold starting problem. To overcome this challenge applied the glow plugs for spark type ignition and fine injectors for diesel type.

The effect of the cold-start problem reduces the compressed heat and finally decreases the inside heat of the cylinder. Adding different fuel additives varies CR values, reduces the cold starting problem. The emissions are oxides of nitrogen (NOx) and particulate matters (PM) are reduces. The hydrocarbons and carbon monoxide emissions are generated larger amounts of enters the atmosphere.

To minimize the hydrocarbon and carbon monoxide, require the devices. The device catalyst converter is reducing the gases from vehicles. These devices are less expensive, durable, and simple.

In HCCI technology control of auto-ignition phenomena is difficult compared to other techniques. The homogeneous mixtures find the rate of combustion of the engine. To change the value of CR adjusted by plunger located nearer to the cylinder head. It is also suitable for diesel and petrol engines.

To change the induction temperature is one of the best methods to control the ignition. This technique resistance heater is used to change the induction temperature and it shows the low engine operation.

Nowadays develops new technology is the Fast Thermal Management technique. This technique enhances the pressure ratio in the cylinder. It controls the movement of intake valve positions. After the bottom dead center, the valve changes the volume and changes the compression ratio.

3.8 Advantages and Disadvantages of HCCI:

The Homogeneous Charge Compression Ignition technology engines significantly reduce the exhaust emissions oxides of nitrogen and particulate matter. The combustion starts in HCCI engines, with sufficient or lean homogeneous mixture. The fuel consumption also reduces and savings 15% of fuel economy.

The combustion starts at a lower temperature, enhances the cleaner combustion rate, and generates lower emissions. The Homogeneous Charged Compression Ignition technology achieved higher efficiency.

Homogeneous Charged Compression Ignition technology operated at different fuels. Greenhouse gas emissions are reduced and controlled environmental pollution. The main reasons are good fuel burning and removing the throttling, higher compression ratios, and shorter duration of burning fuel with no flame.

The lean homogenous mixture results in less amount of exhaust gases and enhances the performance.

Start fuel burning at lower temperatures and reduces harmful exhaust emissions.

- Increase efficiency with a variety of compression ratio values.
- Particulate Matter filter is not required, because release a small number of particulate matters.
- Fuel consumption reduces at the same operating conditions.
- Throttling losses are reduced.
- Abnormal pressure and noise damage the performance.
- Difficult to maintain ignition phenomena.
- These are operating at low load and speed.

3.9 Developments of HCCI Engine:

HCCI technology enhances vehicle density. Catalyst technique suitable for reduces the hydrocarbons and carbon monoxide and permanent device for automobiles to reduce exhaust gases. To minimize the hydrocarbon and carbon monoxide emissions require these types of devices. The device catalyst converter is reducing the emissions from transport vehicles. These devices are less expensive, durable, and simple.

The time of combustion is controlled by different parameters such as pressure and temperature. The last 15 years onwards research conducts on Homogeneous Charged Compression Ignition technology engines. First General Motors manufactures a prototype engine Ecote 2.0 liter with supercharging and turbocharging. Scientists develop a GM 3.6 liter, 6 valves engine, but it consumes high fuel.

Volkswagen develops a Homogeneous Charged Compression Ignition engine in 2012, shows better performance and driving stability. It develops a 266 Horse Power. It also develops a VW group 2.0 liter prototype engine. It operates in two Concepts such as combined combustion system and gasoline compression ignition. This motor starts a six-speed manual type for conventional and VW's start dual-clutch manual type vehicles.

The DSG manufactures develops a 7 speed more powerful with Volkswagen in 2012. Mazda's manufactures in laboratory conduct tests on HCCI technology. Mazda develops a 1.4 liter turbocharged instead of a 2.0-liter type vehicle. In 2007 Mercedes Benz develops prototype engine F700 concept controlled and auto-ignition.

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Chapter 4

Eucalyptus Biodiesel

4.1 Introduction:

The important fossil fuels are Diesel and Gasoline is reducing and exhausted, because of day to day requirements and increasing the applications of crude oils in the world. Biodiesels are suitable instead of fossil fuels and its deuce fossil fuel requirements. Petrol and diesel vehicles release a large number of harmful gases. Therefore, the fresh air is contaminated in the atmosphere (or) air gets polluted. Scientists find several alternative sources for the fossil fuel crisis. It is the best alternative source for the future generation.

These are produced from a variety of vegetables. From an economic point of view, more biodiesel production is affecting the food corps. To overcome this problem vegetable oils replacing with non-edible oils.

Karanji, Pongamia, eucalyptus oil and jatropha etc. Eucalyptus oil produces (or) generates a lesser amount of emissions. It is cheaper, easily available, and has a high cetane number. The availability of eucalyptus oil is more in INDIA.

4.2 Requirement of Biodiesel

Nowadays, the important pollutants are CO, UHC, CO_2, NOx, and soot exhausted from the automobiles. These exhausted emissions (or) pollutants are created global warming, environmental pollution, and health problems for humans and damage the ozone layer.

These pollutants contain a large number of compounds such as organic and Inorganic, which develops smog in the atmosphere. The exhausted emissions increase pollution in the environment. The incomplete combustion of fuel in the engine cylinder, a large amount of emissions is released. By using the Biodiesel decrease the incomplete combustion percentage in the cylinder. So, reduce the pollution levels in the atmosphere.

Fig 4.1 explains the production of petroleum products in INDIA. It shows that the different percentages of petroleum products.

The light diesel oil is 0.3%, fuel oil 11%, Petroleum coke 2%, others are 8%, and liquefied petroleum gas 4%, motor gasoline 13.7%, Naptha 9%, kerosene 4%, aviation turbine fuel 5% and high-speed diesel oil 41% are distributed of oils. Above all products, production is high compared to diesel.

4.2.1 Consumption of Fossil Fuels:

From the Observation, petroleum products are rich because these are limitedly available in the environment. The pollution is increased due to incomplete combustion in automobiles and increases the number of automobiles.

For day to day to develop the transportation vehicles increases, a large amount of petroleum (or) diesel fuels are used. Our country INDIA imports nearly 80% of crude oils are imported from other countries every year.

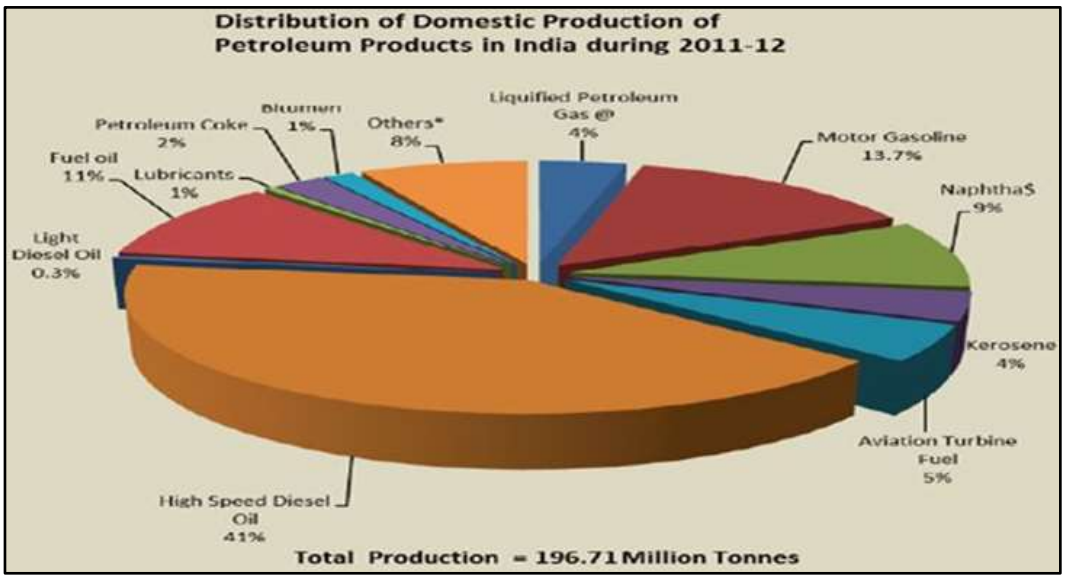

Figure 4.1: Petroleum products production.

Petroleum, diesel, crude oil, LPG, and CNG are fossil fuels. Natural gas consists of methane and a small amount of propane and butane.

The percentage of hydrocarbons in petroleum products is high. These types of vehicles are more suitable for Spark Ignition engines. The Diesel fuels are more suitable for Compression Ignition engines.

All fossil fuels are exhausted in future generations. Therefore, more research needed and conducts on alternative fuels.

4.2.2 Emissions from the Cylinder:

In a Suction stroke, the fuel and air mixture is introduced in the engine cylinder. In the Compression, the mixture is compressed by the piston moves from TDC to BDC. At the power stroke, fuel and air mixture burned and develops heat.

Then the exhaust emissions are exhausted from the tail (or) exhaust pipe. From, the exhaust pipe the emissions are entered into the atmosphere.

The exhaust emissions are carbon dioxide, carbon monoxide, hydrocarbons, oxides of nitrogen, and particulate matters. These are the main causes of environmental pollution.

4.2.3 Hydrocarbon (HC):

These are developed incomplete combustion of fuel in the cylinder. These are harmful pollutants in the atmosphere. They have different shapes and damage the cylinder components.

The engine components are the combustion chamber, stroke length, diameter of the bore, and also affect the compression ratio.

The engine is misfiring a large number of unburned hydrocarbons are released into the atmosphere. They create long term and short term health problems.

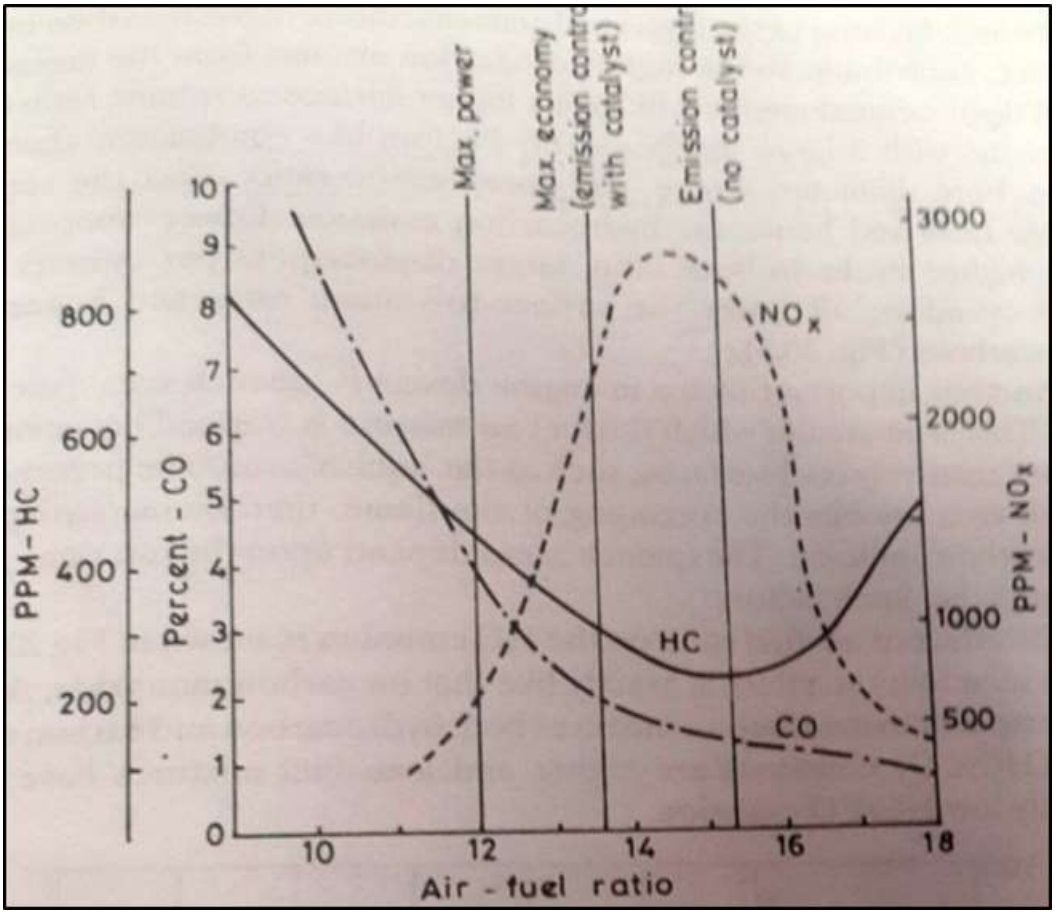

Figure 4.2: Fuel versus Hydrocarbons.

4.2.4 Carbon Monoxide:

Carbon monoxide is exhausted from the combustion chamber of the engine. The incomplete combustion occurred inside the cylinder large amount of CO emissions are released. Because of insufficient fuel and air mixture inside the cylinder.

Presently, we are introducing the heterogeneous mixture in the cylinder, so the high amounts of carbon monoxide emissions are released. By replacing the instead of a heterogeneous mixture, the homogeneous mixture produces less amount of CO emissions.

Automatically, the fewer amounts of emissions are exhausted from the exhaust pipe.

4.2.5 Oxides of Nitrogen:

The Oxides of nitrogen emission is the most harmful emissions released from the automobiles. It mainly consists of nitric oxide. We know that higher temperatures are released, the reaction between the oxygen and nitrogen.

The main reason is inside temperatures and insufficient oxygen available in the cylinder. It directly reacts with the ozone layer, it increases the earth's temperature and permanent health problems are created.

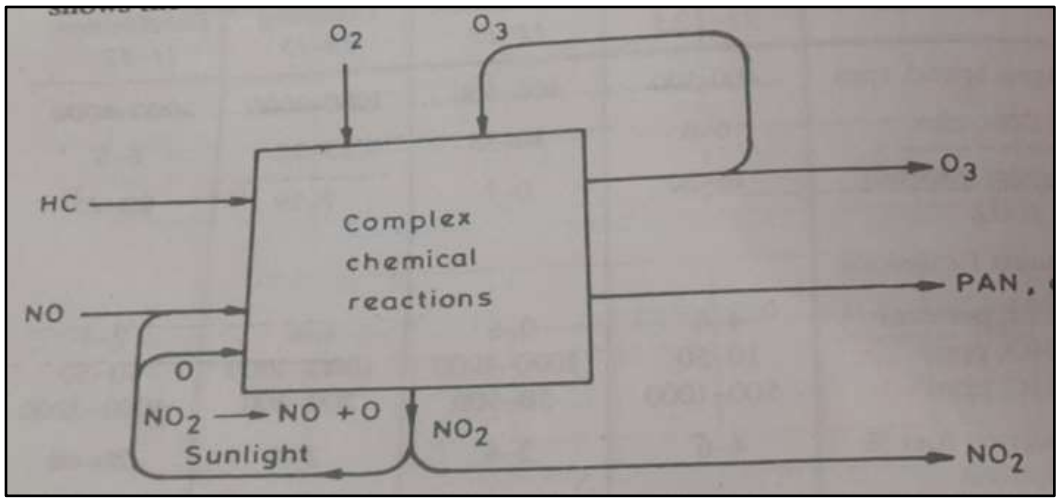

Figure 4.3: Formation of Smog developed.

4.2.6 Particulate Matters:

The Particulate Matter emissions are harmfully exhausted from the cylinder. They developed because of incomplete combustion of fuel in the cylinder.

These emissions are more harmful to human breathing and create a number of health issues in the atmosphere. It consists of Organic and Inorganic compounds.

These compounds contain high molecular masses. The Particulate Matter emissions size varies from 0.02 to 0.06µ.

4.3 Biodiesel Properties:

It is the alternative fuel for fossil fuels. It cannot be directly introducing into the cylinder; it must be blended with diesel. These are extracted from the eucalyptus seeds with mechanical types of equipment and different processes. The fatty acids are removed from the Eucalyptus seeds.

The storage and Transportation of seeds are not a complexity, because they are nontoxic and nonflammable. It has a high Cetane Number. Because of cetane number improves the ignition ability of the fuel. The emissions are carbon dioxide, carbon monoxide, hydrocarbons, oxides of nitrogen, and particulate matters are reduces.

The 100% pure Eucalyptus oils are not suitable for engine operations and automobile applications. These fuels must be blended with other petroleum fuels.

The Researchers and Scientists determine these oils are must be mixed with different ratios with diesel fuel, gives the best results than the use of 100% pure biodiesels on the engines.

The Transesterification process is suitable for the production of biodiesels. The various properties of biodiesels are discussed below.

4.3.1 Density:

The performance of the engine always depends upon the density of the fuel. The density of the fuel is high, the fuel consumption increases inside the cylinder.

The density is low; the effect of ignition delay occurred inside the cylinder. It may define as mass per unit volume. It may also be defined as the ratio of the fluid mass to fluid volume. It can be written as

Density (ρ) = $\frac{mass}{volume}$

= $\frac{m}{v}$

The fluid temperature inside the cylinder is high, the density of the fuel decreases. The temperature is inversely proportional to the density. The pressure depends on the density of the fluid. The biodiesel fuel density is always higher than diesel fuels.

Some of the researchers find the lower density of the fuels and generates the less quantity of oxides of nitrogen emissions.

4.3.2 Flash Point:

It is the most important fuel property. With the help of Flashpoint determines (or) find the type of fuel. Whether it is Petrol, Kerosene, crude oil, and Diesel, etc., the ignition inside the engine cylinder depends on the flashpoint. At some point in temperature fuel burns starts is known as Flashpoint. All fuels must have a flashpoint.

We conduct the experiment at the time of the container is closed, the point is called a closed flashpoint. At the conducting test, the container is open is called open flashpoint. The flashpoints of the Diesel and Petroleum are 50^0C and 80^0C respectively.

The flashpoint of the biodiesel is 120^0C. So the transportation and storage of biodiesel are non-complexity compared to other fuels, such as Petrol and Diesel, etc.

4.3.3 Cetane Number:

Eucalyptus oil has a high Cetane Number. Because of high cetane number improves the efficiency of the engine. The emissions are carbon dioxide, carbon monoxide, hydrocarbons, oxides of nitrogen, and particulate matters.

The 100% eucalyptus oils are not suitable for engine operations and automobile applications. These fuels must be blended with other petroleum fuels.

The Researchers and Scientists determine the oils are must be mixed with different ratios, it shows the best results than the use of 100% pure biodiesels.

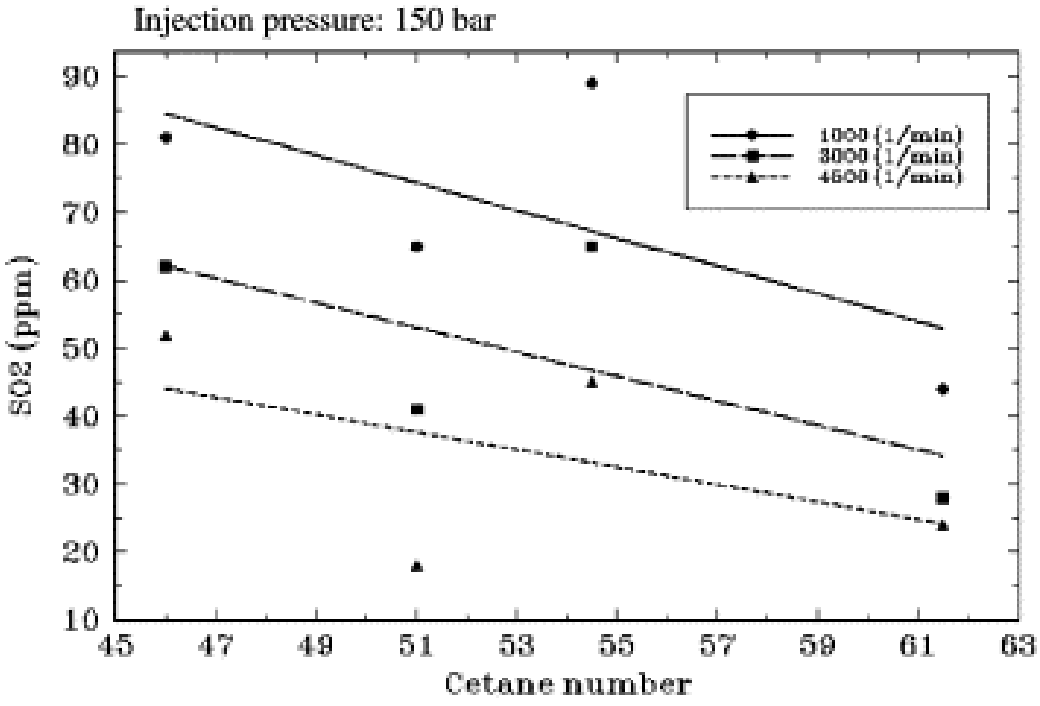

Figure 4.4: Cetane number versus pressure level.

4.3.4 Heating Value:

It is also known as Heat of combustion in the engine. It may be defined as the heat released at the time of fuel burnt in the cylinder.

The fuel consumption rate is affected by the Heating value property of fuel. When the heating value increases the fuel consumption decreases.

The Diesel fuel heating value is 13% higher than that of biodiesel reason is the density of biodiesel is high.

4.4 History of Eucalyptus Oil:

In 1790 at Nandi hills planted a eucalyptus tree by Tippu sultan. The Nandi hills in INDIA nearer to Mysore in Karnataka state. From the Australia seeds and different species of Eucalyptuses are imported.

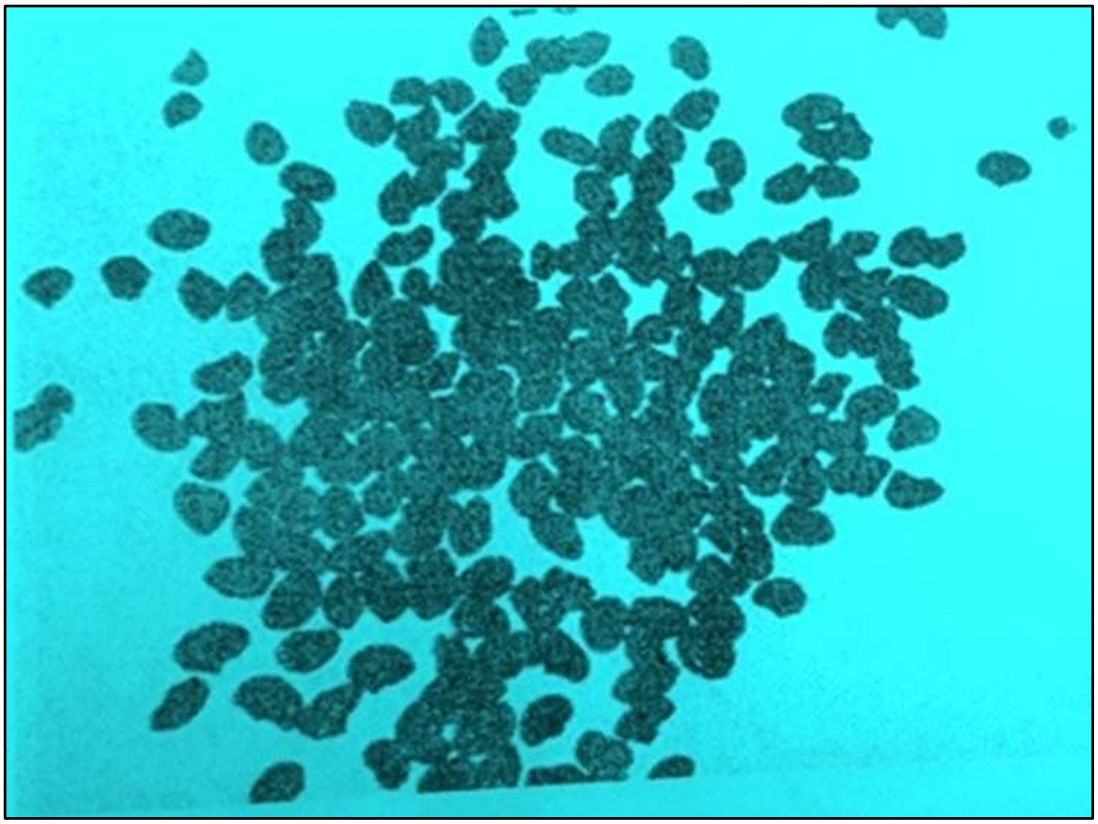

Figure 4.5: Eucalyptus seeds.

In Tamilnadu, regular plantation started in 1843 to 1856 for the demands and needs of firewood.

The trees are planted in different parts of the country from small villages to urban areas. The eucalyptus leaves are used for ayurvedic applications.

Figure 4.5 shows the eucalyptus seeds. The eucalyptus oil also extracted from leaves with different harvesting processes and mechanical types of machinery.

Eucalyptus crebra, Eucalyptus camaldulensis, Eucalyptus tereticornis, E.tereticornis, Eupleres major, Eucalyptus citridora, Eucalyptus polyanthuses, and Eucalyptus intermedia different species are found in 1954.

Table 4.1: Eucalyptus Oil properties.

S. No	Parameters	Diesel	Eucalyptus oil
1	Density	800-840	880-900
2	Molecular weight	190-230	270-300
3	Boiling Point	160-320	160-180
4	Viscosity	2.3	2.9
5	Flash Point	56	91
6	Cetane number	44	51

Eucalyptus oil produced from eucalyptus seeds followed the different processes, with the help of mechanical equipment eucalyptus seeds are extracted. The seeds contain 60% of cineole content. The features of the eucalyptus tree are fast-growing, stand with high winds and different weather conditions.

The important property of Eucalyptus tree fire is hardy. According to the state forest department, 1,000,000 ha plantation is over and 600 million types of seeds planted at various suitable lands. These are planted near hill areas. The capability growing is 12m height with 3 years.

4.4 Advantages:

The following advantages are:

- No engine modification is needed.
- It is eco-friendly, non-flammable, and nontoxic.
- Transportation and storage of the eucalyptus are easy.
- Eucalyptus reduces the emissions exhausted from the cylinder.
- It has low sulfur and aromatic content.
- Eucalyptus has a higher cetane rating because it gives more energy.
- It is a better solvent than standard diesel.

4.5 Disadvantages:

The following disadvantages are as follows:

- It gives higher fuel consumption and low thermal efficiency.
- The blending of eucalyptus oil with another fuel affects the carbon residue stored at the piston rings.
- Some problems occur at injector knocking and compatibility.
- It having oxygen is high.
- The lubricating oil is frequently changed.
- Fuel mixture improperly burned because of eucalyptus oil having high viscosity value.

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Chapter 5

Experimental Setup

5.1 Introduction:

The present experiments are conducted on a 5HP Vertical Cylinder, single-cylinder, water-cooled Kirloskar make the engine. The compression ratio is 16:1.

Various Thermocouples are used and fitted at their respective positions to read the temperature, water temperature, inlet temperatures.

The air inducted to the air box, with the help of a manometer amount of air measured. The time is measured with a stopwatch for 10cc of fuel consumption.

The exhaust gases carbon monoxide, carbon dioxide, hydrocarbons, and oxides of nitrogen and particulate matters measured with the help of an exhaust gas analyzer.

- **Specifications of 5 H.P. Kirloskar Engine:**

MAKE	:	KIRLOSKAR
BORE	:	80 mm
STROKE	:	110 mm
SPEED	:	1500 RPM
BRAKE HORSE POWER	:	5 H.P.
NUMBER OF CYLINDERS	:	1
COMPRESSION RATIO	:	16.5:1
ORIFICE DIAMETER	:	20.46 mm
COEFFICIENT OF DISCHARGE	:	0.6
EFFECTIVE DIAMETER OF BRAKE DRUM	:	15.3 cm
TYPE OF IGNITION	:	Compression ignition
METHOD OF LOADING	:	Rope Brake
METHOD OF STARTING	:	Manual Cranking
METHOD OF COOLING PROVIDED	:	Water Cooling

5.2 Experiment Setup:

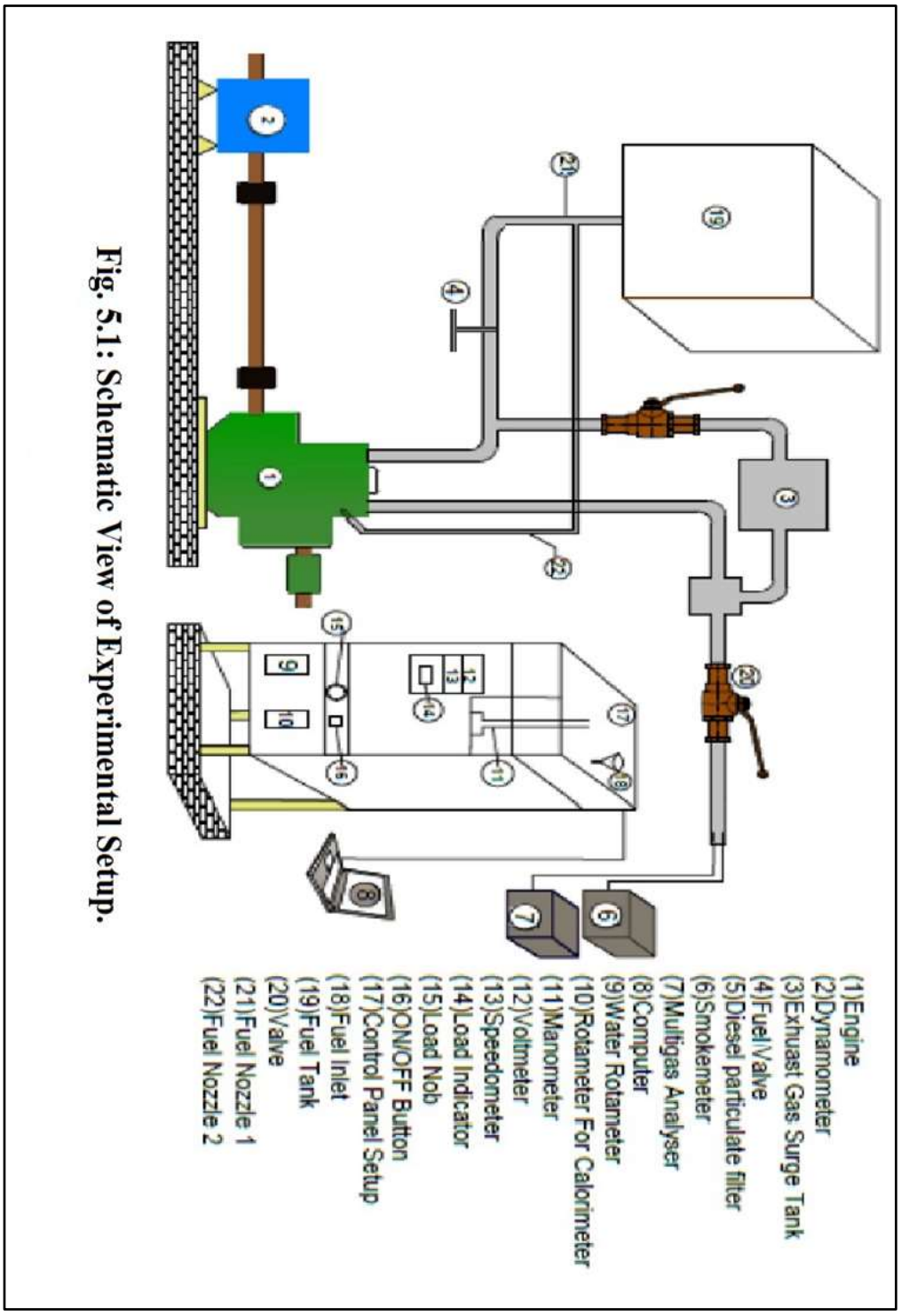
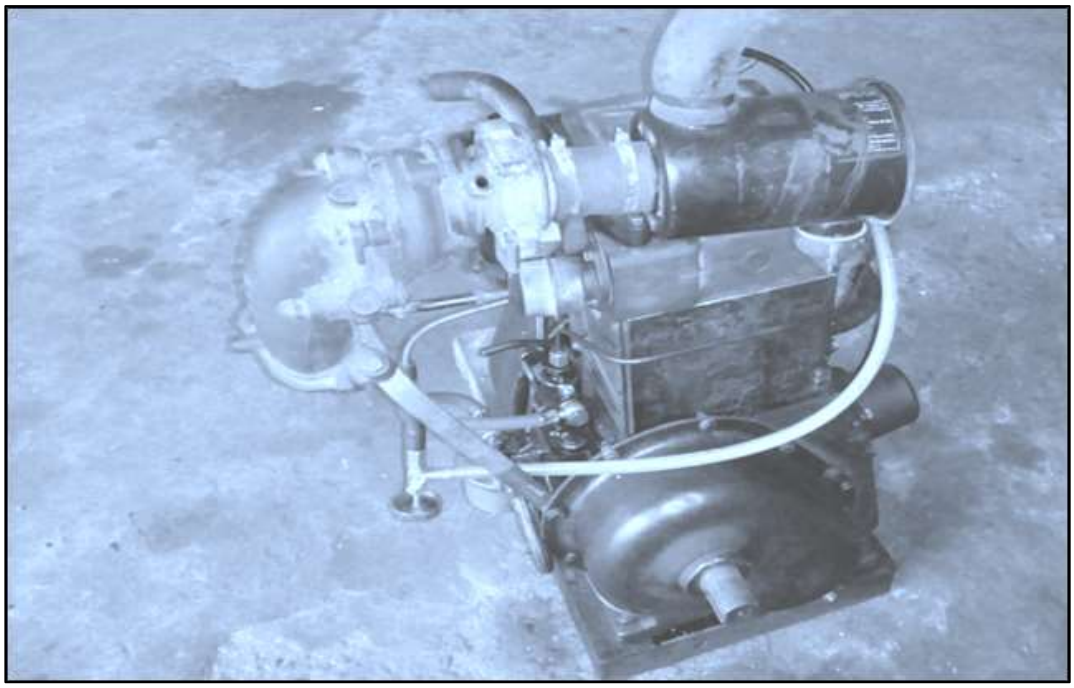


Fig. 5.1: Schematic View of Experimental Setup.

Figure 5.1: Schematic View of Experimental Setup

Experimental Setup


by PowerDirect



5.3 Modification Needed For HCCI Technology:

For achieving the HCCI technology mode of the engine, it required some modifications for the present research work. The modifications are to change the injection system, inside cylinder and head for HCCI mode. At the inlet of the engine, we prepared a hole for inserted the fuel pipe, the pipe has injected the fuel into the cylinder. And, also makes holes inside the cylinder head for igniting the fuel. So, fuel enters through the inlet of the engine. Finally, the homogeneous mixture is prepared inside the cylinder. We prepared a converter conversion of conventional diesel technique to the Homogeneous Charged Compression Ignition technique. Figure 5.2 shows the converter conversion of conventional diesel technique to the Homogeneous Charged Compression Ignition technique. This converter

consists of Air inlet, Centrifugal type fan and turbo type blower. These blowers are used to prepare a homogeneous mixture inside the cylinder. The Homogeneous mixture is entered into the engine. This converter is connected (or) attached to the inlet. The engine as usual, then the engine stops slowly with the off/on the lever, then fuel pipe is attached to the fuel injector with another fuel tank, then the engine runs with HCCI mode. Therefore, the HCCI technology generates a lesser amount of emissions and increases the rate of combustion.

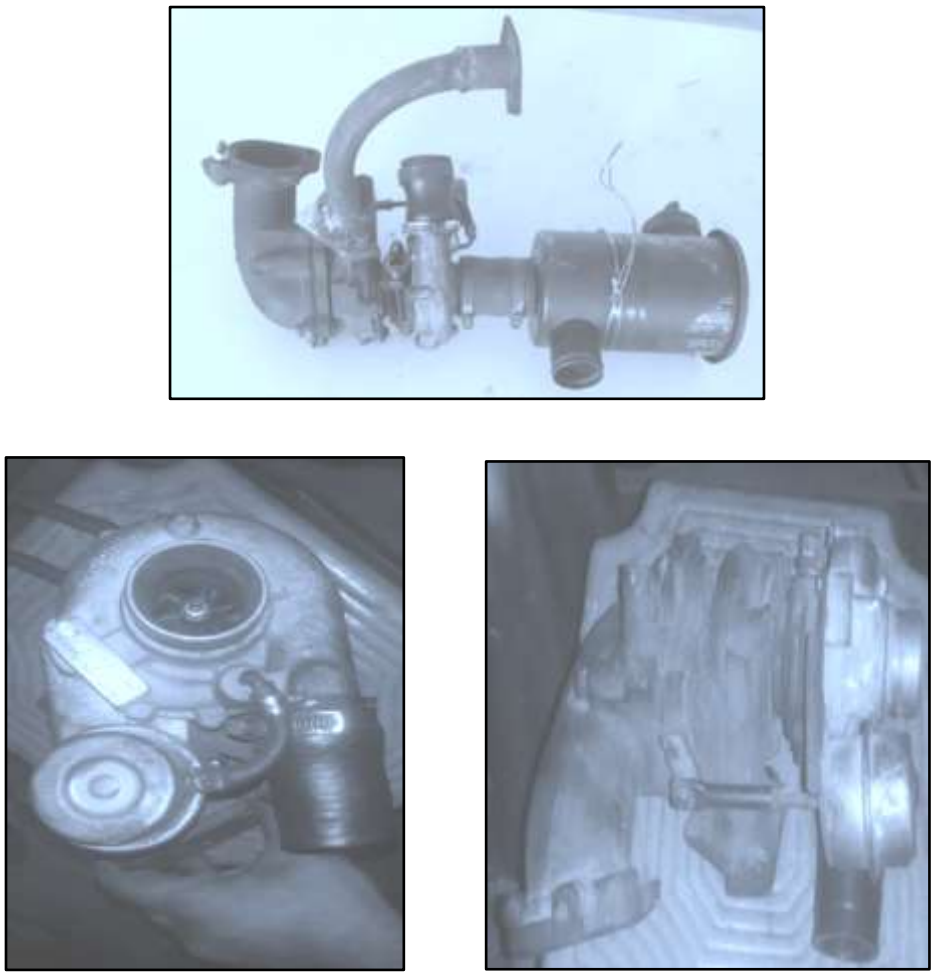


Figure 5.2: shows the converter from CI to HCCI.

5.4 In-Cylinder System:

The Homogeneous mixture prepared either internally or externally. In the External preparation method, construct a small mixing chamber, nearer to inlet and air is entering the

mixing chamber with the help of blower, the homogeneous mixture is prepared. Figure 5.3 shows the modifications done in the cylinder. In the internal preparation method, the mixture can be prepared at the inside cylinder. In this research work, we are prepared homogeneous mixture internally, so modifications occur at the inside of the cylinder head. Figure 5.4 shows the changes in the cylinder head.

Figure 5.3: Inside Cylinder.

Figure 5.4: Changes inside the cylinder head.

5.5 Fuel Injection:

In this research work, the fuel is injected directly through the engine inlet. The valve arrangement, kept nearer to the inlet pipe to control the fuel flow.

Figure 5.5 shows the fuel enters through the engine inlet and cylinder with a valve arrangement. By using the valve arrangement, the following tests are conducted.

The aim is to have premixed fuel to some extent at the inlet of the induction pipe since there are some problems like over fuel consumption and pre-ignition if the fuel is allowed only in the inlet pipe.

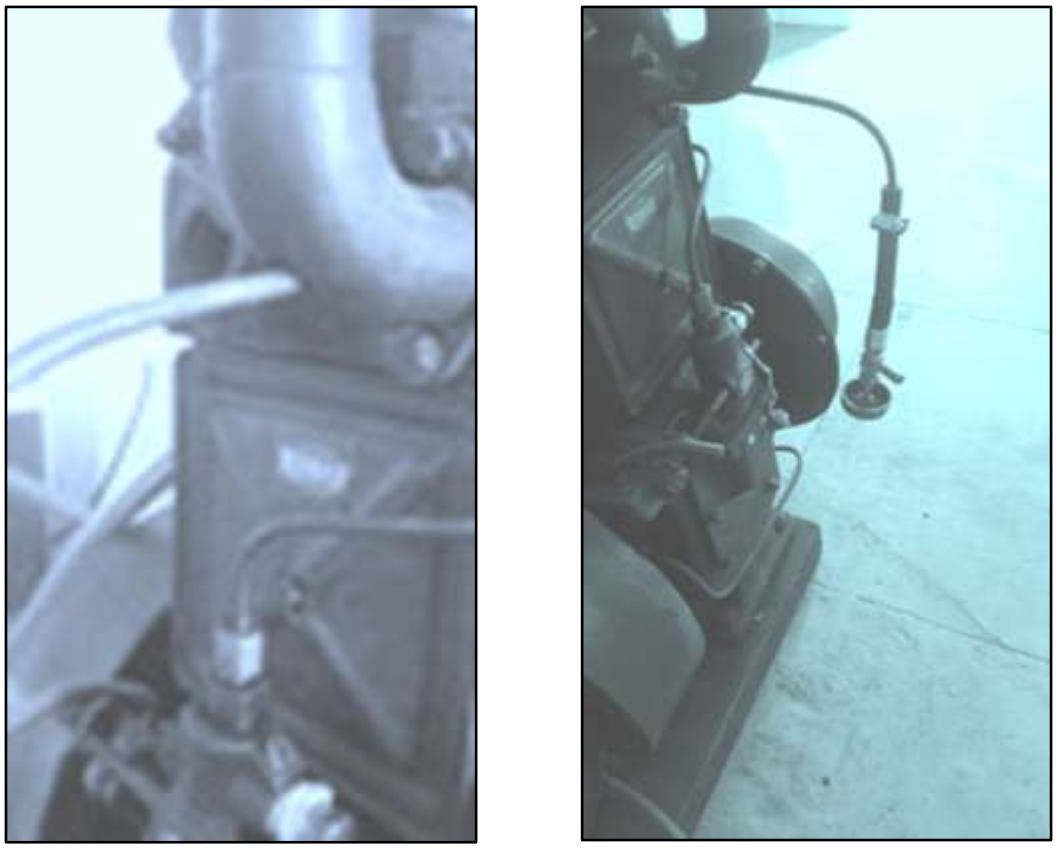


Figure 5.5: Fuel-Injected Engine Inlet.

5.6 Experimental Procedure:

After all modifications of the engine, it works HCCI technique mode. The homogeneous mixture can be entered into the engine cylinder through the inlet of the engine. Measure the fuel enters into the engine with the help of a stopwatch. It has been initially maintained that 25% of fuel to be injected at induction pipe, later it has been varied as 50% and 75%. The fuel is mixed with air to prepare a homogeneous mixture. The EGR arrangement is made to send 10% of exhaust gas into the engine suction pipe for EGR mode.

The performance parameters considered are brake specific fuel consumption and thermal efficiency, which were calculated using a load, fuel consumption. The emission parameters observed were HC, CO, NOx, Smoke, and these values were taken after the engine has attained steady-state conditions.

Then determine the performance and emissions of the engine with Diesel. The HCCI mode of engine, taking the reading of time taken for 10cc of fuel consumption by using a stopwatch and Manometer difference with the U-tube manometer with varying the engine loads.

Then, we determined the performance and emission characteristics with Eucalyptus biodiesel followed by the same experimental procedure. The 10 percent of Eucalyptus oil blended with 90 percent of diesel. The brake thermal efficiency, volumetric efficiency, and fuel consumption, hydrocarbons, carbon monoxide, oxides of nitrogen, and particulate matters are analyzed.

Then, four modes of experiments conducted on the HCCI mode engine. In the first mode, test with Diesel engine, No HCCI and No Turbocharge. In this mode, there are no modifications in the test engine. In the second mode, test with Diesel engine, No HCCI and Turbocharge. In this test, the exhaust pipe is connected to the engine inlet. In the Third mode, test with no Diesel engine, HCCI and Turbocharge, in this test, the exhaust pipe is connected to the engine inlet, and the fuel injection system will be changed. A final mode test with No Diesel engine, HCCI and No Turbocharge. In this mode, fuel injection system changes and engines operate at HCCI technique mode.

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Chapter 6

Results and Discussions

6.1 Experimental Investigations on the Engine with Different Proportions of Fuel:

The following tests performed on the selected single cylinder engine. And the procedure for test has been varying the loads as 4 kg, 8 kg and 10 kg. The test parameters were measured after engine reached steady state condition.

Test 1: 100% fuel injection in the cylinder (D).

Test 2: 25% of fuel in the induction pipe and 75% in the main cylinder (DH25).

Test 3: 50 % of fuel in the induction pipe and 75% in the main cylinder (DH50).

Test 4: 75% of fuel in the induction pipe and 25% in the main cylinder (DH75).

Test 5: 10% of Exhaust Gas Recirculation (EGR) with 100% fuel injection in the engine (EGR-10).

6.1.1 Load on Brake Specific Fuel Consumption:

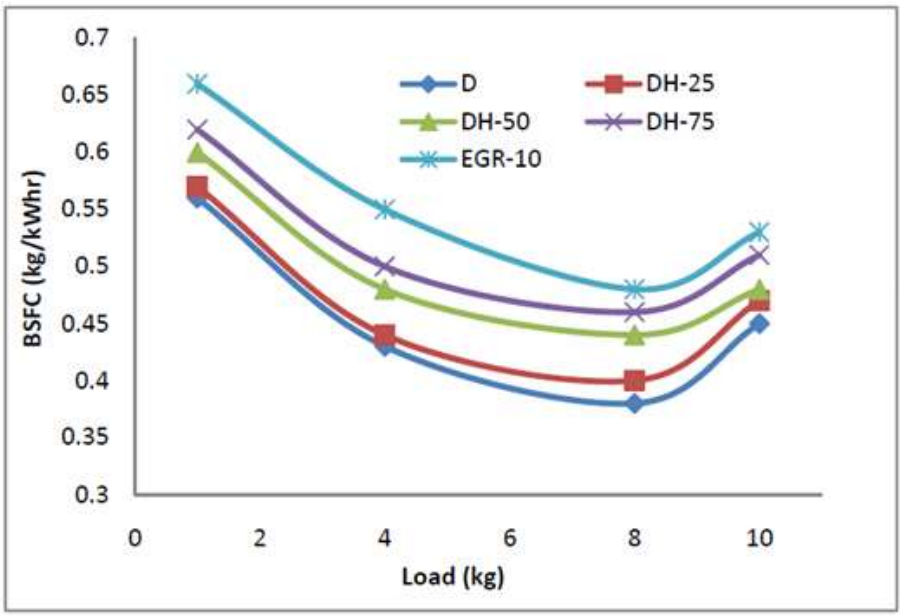

Figure 6.1: Load Vs Brake Specific Fuel Consumption

Figure 6.1 shows the graph of brake specific fuel consumption versus the load, it is observed that the engine has followed the trend higher fuel consumptions are observed with EGR and other higher values are for the injection amount at inlet pipe. Fig.6.2 shows the graph of load verses brake thermal efficiency and it can be seen that in the induction pipe result in increased the fuel consumption.

6.1.2 Load on Brake Thermal Efficiency:

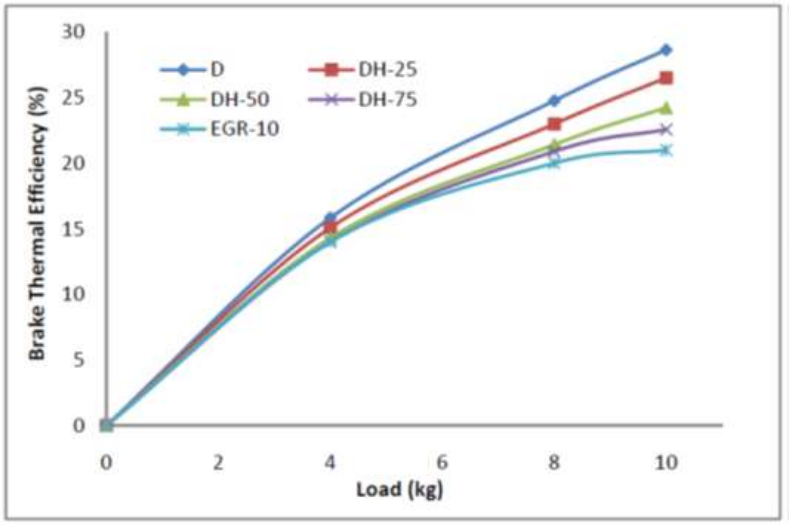

Figure 6.2: Load Vs Brake Thermal Efficiency.

6.1.3 Load on Oxides of Nitrogen in Exhaust:

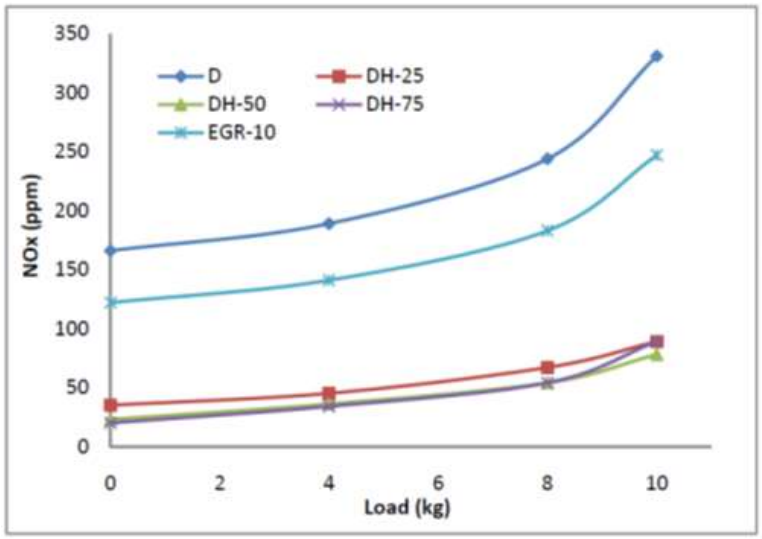

Figure 6.3: Load Vs Oxides of Nitrogen.

Fig.6.3 is drawn between oxides of nitrogen verses load it is observed that the EGR has contributions in minimizes emissions to certain extent, a significant amount of NOx emissions is noticed with injection in the induction pipe. The reason is charge homogenization.

6.1.4 Load on Hydrocarbons in exhaust:

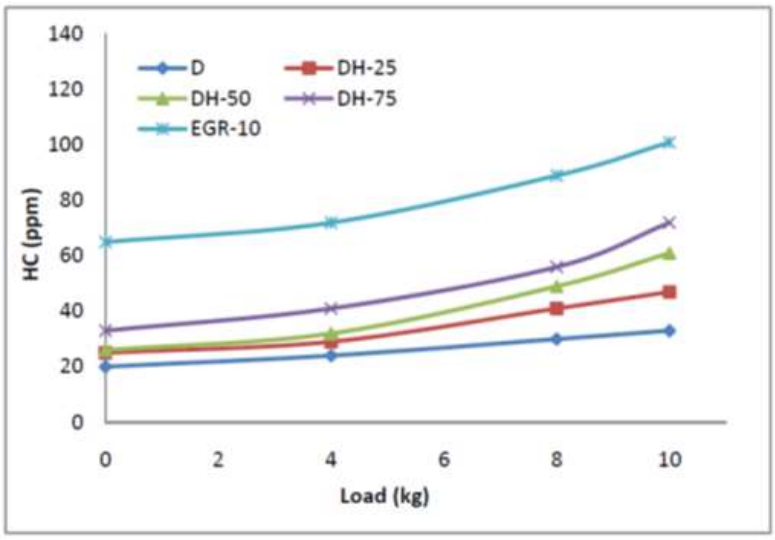

Figure 6.4: Load Vs Hydro Carbons.

6.1.5 Load on Opacity:

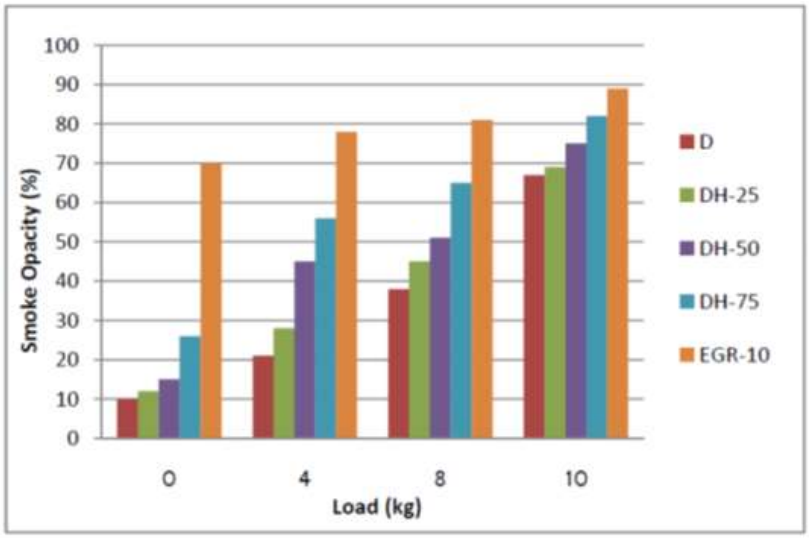

Figure 6.5: Load Vs Opacity.

Fig. 6.4 is between HC emissions and load variation; it is evident that load increases the emissions by reducing the quality of combustion. The load versus opacity is shown in Fig.6.5 and the smoke enhances with load as well with indirect injection.

6.2 Experimental Investigations on the HCCI Engine with Eucalyptus Biodiesel:

The Experiments are conducted on a HCCI technology with value of compression ratio is 17.5:1 and develops a 200bar pressure. The fuel consumption and brake thermal efficiency are determined. The emissions HC, CO, CO_2, NO_x and PM are analyzed.

6.2.1 Effect of Fuel Consumption with Load:

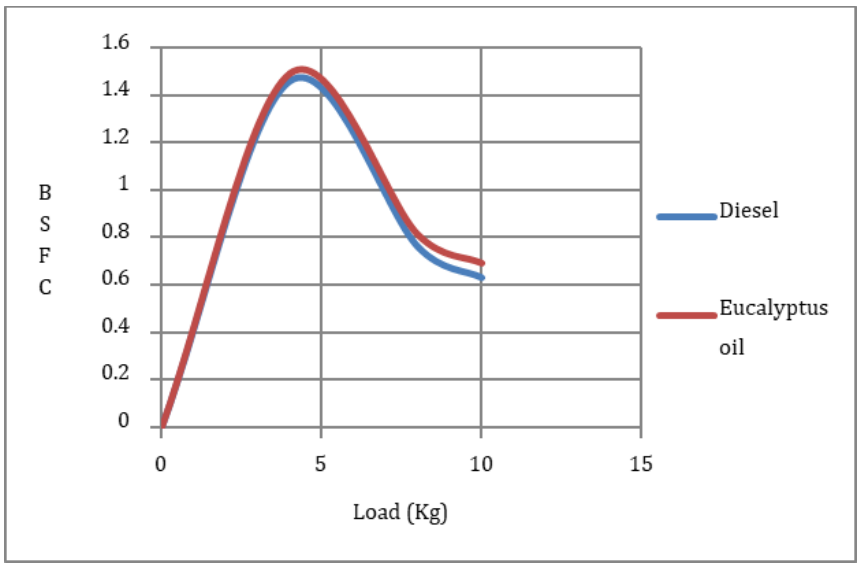

Figure 6.6: Load v/s Brake Specific Fuel Consumption.

Fig. 6.6 shows graph of the fuel consumption verses load. The graph shows specific fuel consumption increase with varying load. Because, the Eucalyptus oil having low calorific value.

Fig.6.7 shows brake thermal efficiency verses load. The fuel consumption is inversely proportional to thermal efficiency. The B10 eucalyptus oil thermal efficiency is lower than the thermal efficiency of diesel.

Fig. 6.8 explains the graph of oxides of nitrogen verse load. It shows that oxides of nitrogen of B10 Eucalyptus oil are lower than the diesel at all load conditions. Fig. 6.9 shows the hydro carbons verses load. The diesel fuel gases are higher than B10 eucalyptus oil.

Fig. 6.10 shows the graph of carbon monoxide verses load. It shows that CO emissions are higher than B10 eucalyptus oil.

6.2.2 Effect of Brake Thermal Efficiency with Load:

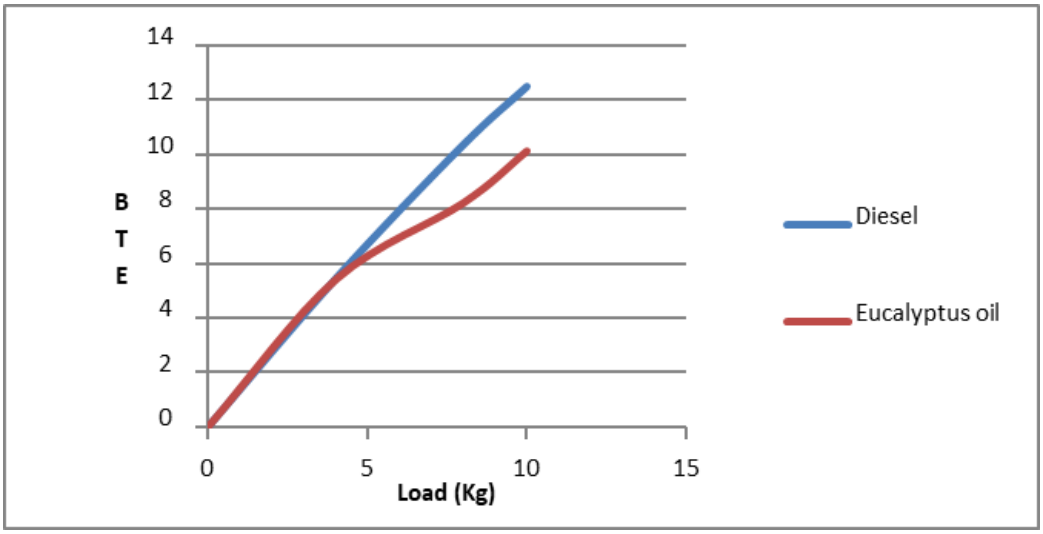

Figure 6.7: Load v/s Brake Thermal Efficiency.

6.2.3 Effect of Oxides of Nitrogen in Exhaust with Load:

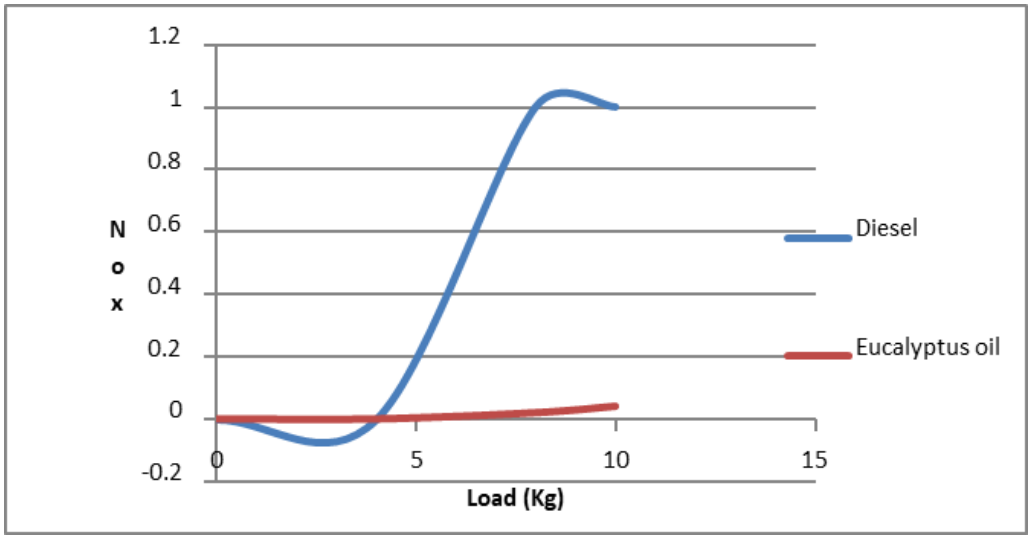

Figure 6.8: Load v/s Oxides of Nitrogen.

6.2.4 Effect of Hydrocarbons in Exhaust with Load:

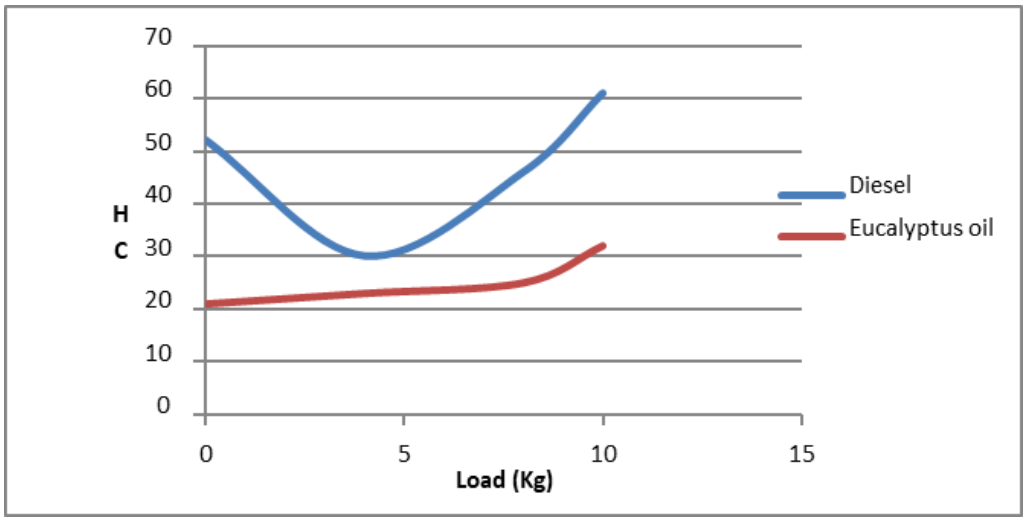

Figure 6.9: Load v/s Hydrocarbons.

6.2.5 Effect of Carbon Monoxide in Exhaust with Load:

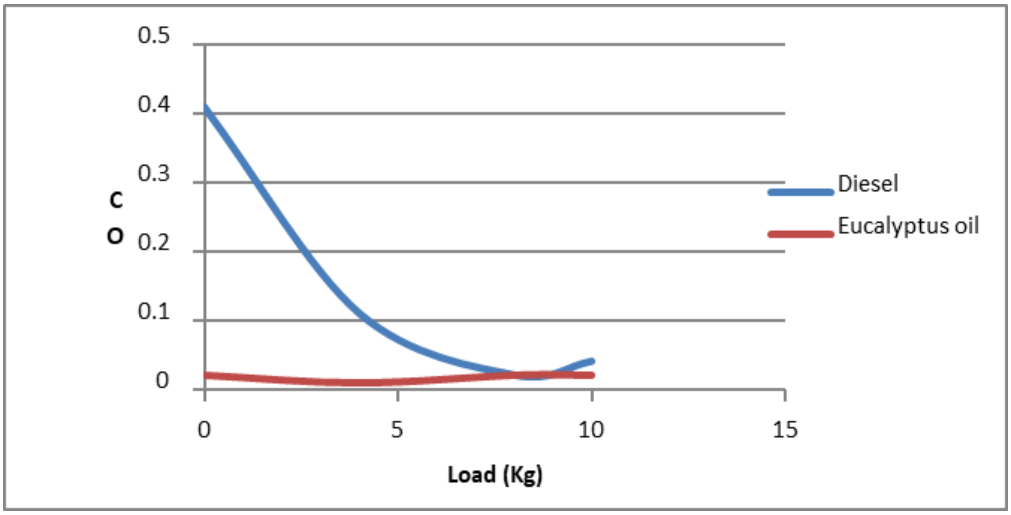

Figure 6.10: Load v/s Carbon Monoxide.

6.3 Experimental Investigations on the Engine with Different Modes of Tests:

Conducted experiments on a HCCI technology with value of compression ratio is 16.5:1 and develops a 200bar pressure. The fuel consumption and brake thermal efficiency are determined. The emissions HC, CO, CO_2, NO_x and PM are analyzed.

The Performance characteristics of internal combustion and Homogeneous Charged Compression Ignition technology with varying the speed at loads from min. load to maximum loads. The different modes of tests conducted on HCCI technology.

The following four tests are conducted on the HCCI engine.

Mode 1: Test with Diesel engine, No HCCI, No Turbo charge.

Mode 2: Test with Diesel engine, No HCCI and Turbo charge.

Mode 3: Test with No Diesel engine, HCCI and Turbo charge.

Mode 4: Test with HCCI, No Diesel and No Turbo charge.

6.3.1 Effect of Fuel Consumption with Load:

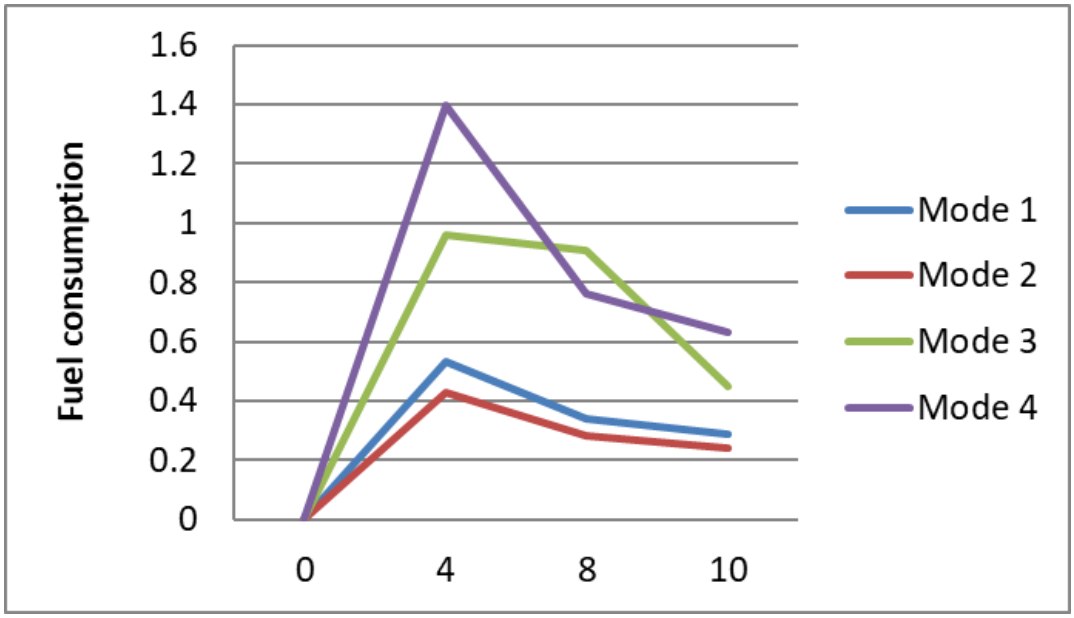

Figure 6.11: Load Vs Basic Specific Fuel Consumption.

Fig.6.11 shows the graph of basic specific fuel consumption versus the load, it is observed that the engine has followed the trend higher fuel consumptions are observed. Fig.6.12 shows the graph of load verses brake thermal efficiency and it can be seen that mode 2 in increased the brake thermal efficiency.

6.3.2 Effect of Brake Thermal Efficiency with Load:

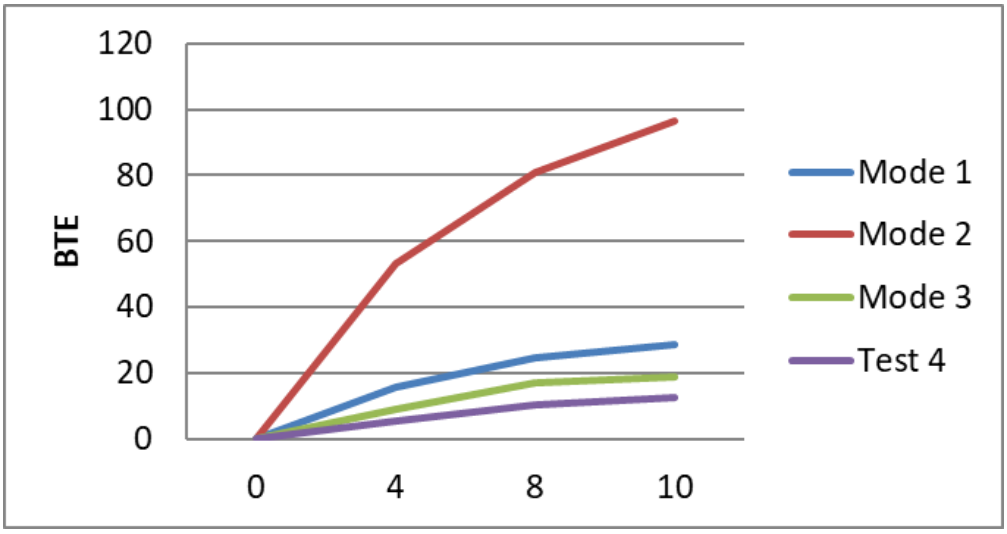

Figure 6.12: Load Vs Brake Thermal Efficiency.

6.3.3 Effect of Oxides of Nitrogen with Load:

Fig.6.13 is drawn between oxides of nitrogen verses load it is observed that the significant amount of NOx emissions is reduced in mode 4.

The reason is starts combustion in cylinder at more than one area.

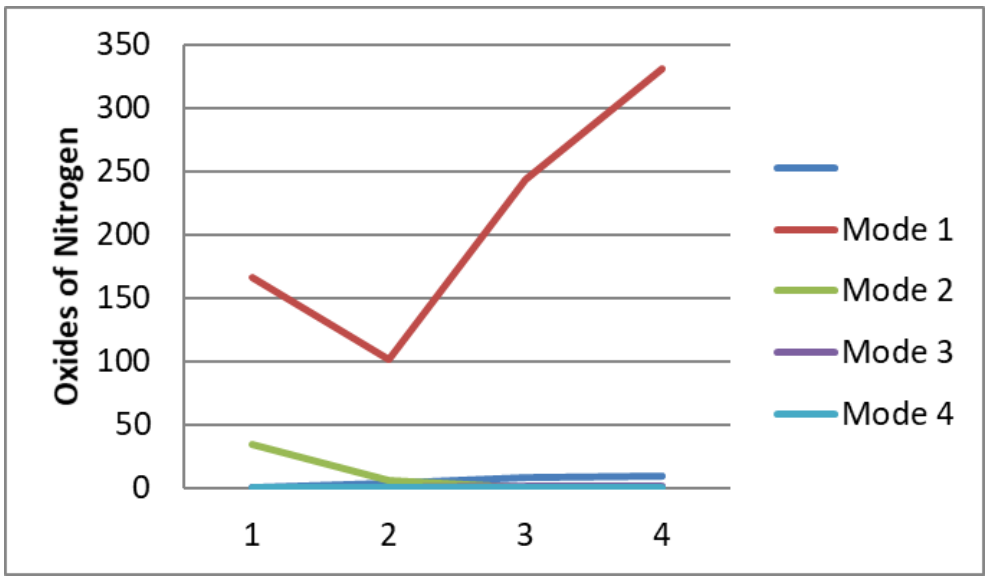

Figure 6.13: Load Vs Oxides of Nitrogen.

6.3.4 Effect of Hydro Carbons with Load:

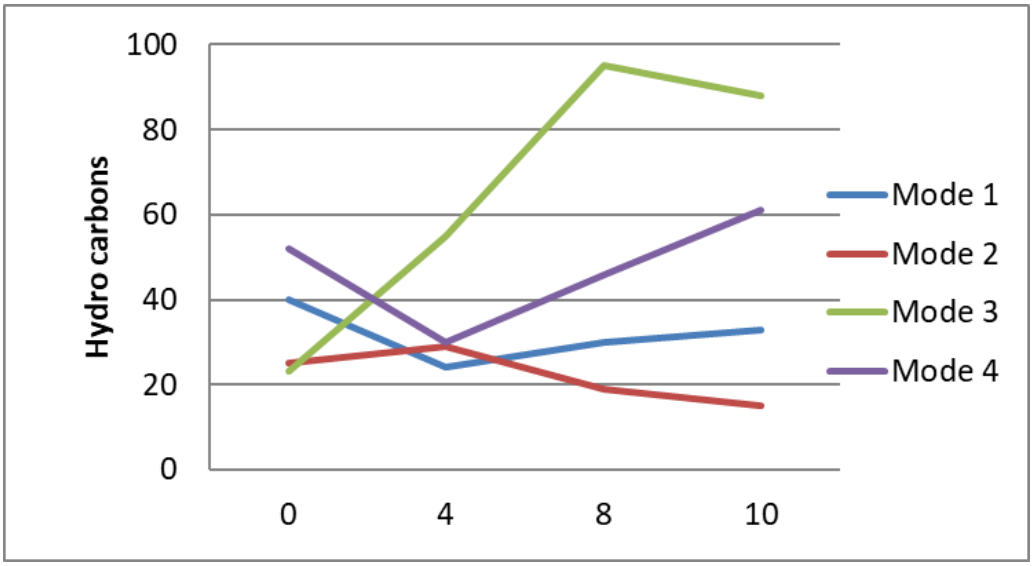

Figure 6.14: Load Vs Hydro Carbons.

6.3.5 Effect of Opacity with Load:

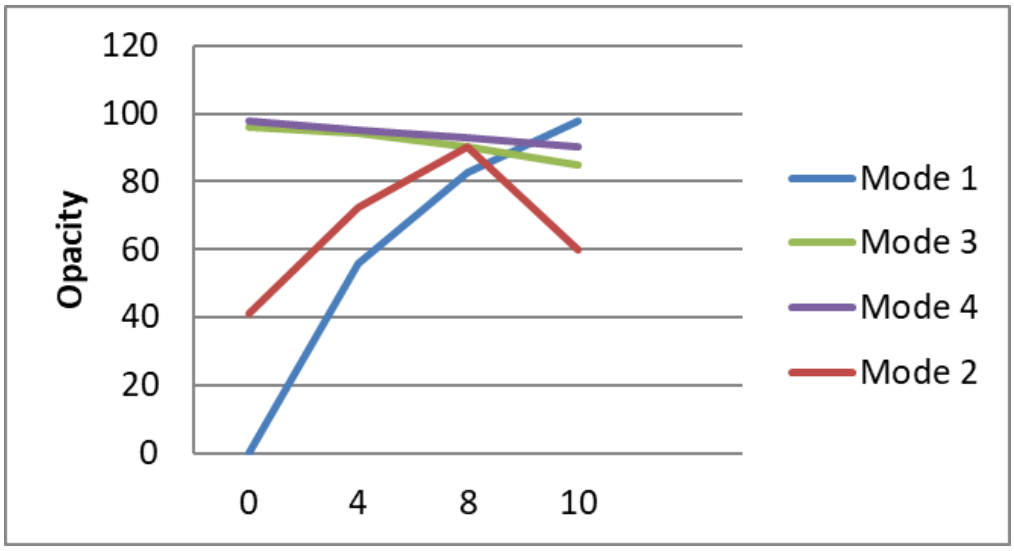

Figure 6.15: Load Vs Opacity.

Fig. 6.14 is between HC emissions and load variation; it is evident that load increases the emissions by reducing the quality of combustion. The load versus opacity is shown in Fig.6.15 and the smoke enhances with load.

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Chapter 7

Conclusion and Future Scope

7.1 Conclusion:

HCCI technology is the best alternative technology for IC engines. With the help of HCCI technique reduces the exhaust emissions from the vehicles or automobiles. So, it can minimize the environmental pollution in the country. The HCCI technology engines are better than the Compression Ignition type engines. The emissions of NOx and PM matters are significantly reduced; improve the rate of combustion and thermal efficiency of the engine. The Homogeneous Charged Compression Ignition technology also suitable for alternative fuels and it shows better performance. HCCI technology type engines are also suitable for Turbocharging and different types of operations. Homogeneous Charged Compression Ignition means the air and fuel mixed homogeneously inside cylinder and ignition starts automatically at the end of the compression stroke by the piston at higher pressure and temperature. In HCCI technology principal operations are: (a) the mixture preparation enhances the combustion and improves the performance. (b) The combustion starts in the cylinder at the end of the compression stroke. The combustion spread entire in the cylinder simultaneously. (c) It produces a larger amount of heat, reduces the exhausted emissions. The experiments are conducted on a 4-stroke constant speed diesel engine by using fuel injection at the inlet pipe in a step to proceed for HCCI. The various modes of tests conducted on HCCI technology. The following performance and exhaust gas characteristics are observed.

- The HCCI technology gives better thermal efficiency than compression ignition engines with the consumption of fewer fuels.
- The emissions of NOx have been significantly reduced with fuel induction in the suction pipe and it is better than the EGR system.
- The fuel consumption is a little higher with the selected fuel injection options compared with the conventional injection method.
- Thermal efficiency is observed to be low with fuel injection at the intake pipe.

- The optimal circulate of fuel injection points with better methods of premixing of air and fuel, this technology design is possible.
- The fuel-injected in the intake pipe to convert as a prototype of HCCI technology and the performance tests conducted.
- The efficiency finds to be lesser with HCCI technology given to higher fuel consumption.
- The Eucalyptus biodiesel produces cleaner and transparent smoke compared to Diesel.
- Over 1,000,000 hectares Eucalyptus trees planted in India.
- The fuel efficiency is low with the HCCI engine give high fuel consumption when the fuel enters into the intake pipe.
- The emissions of NOx are significantly reduced this type of fuel injection method.

7.2 Future Scope:

- To conduct the same experiments on the Double cylinder 5 H.P Kirloskar engine. One cylinder operating in CI mode and another cylinder operating in HCCI mode.
- To conduct the tests on HCCI mode with change the piston crown material such as Aluminum and copper etc. and analyze the exhaust emissions.
- In HCCI technology engines insulating the cylinder wall with ceramic thermal coating and finds the percentages of exhaust emissions from the exhaust pipe.
- In HCCI technology engines conducting the experiment with different fuels and with different blends of fuels.

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