Performance of Homogeneous Charge Compression Ignition Engine with Eucalyptus Oil

Prasad Chinnahulthi[1] , Jagadish Donepudi[2]

[1]*PG Scholar, Department of Mechanical Engineering, Narasraopeta Engineering College, Narasaraopet, Andhra Pradesh, India.*
[2]*Professor, Department of Mechanical Engineering, Narasraopeta Engineering College, Narasaraopet, Andhra Pradesh, India.*

Abstract - *Homogeneous charge compression ignition (HCCI) offers the potential for reduced Nitrous Oxide (NOx) emissions and improved fuel economy in internal combustion engines. In this engine the air and fuel are premixed and brought to reaction conditions during the compression stroke of an engine.*

The performance and emission tests are carried out on HCCI Engine to understand the parameters like brake specific fuel consumption, brake thermal efficiency and emissions of NOx, HC and smoke. The results showed that the performance deteriorated with HCCI mode of operation, however there has been significant reduction in combustion related emissions.

Conventional fuels such as petrol diesel are very important energy sources for this current era but the emission from conventional fuels and depletion of conventional fuels is propelling researchers to shift on biodiesel. In the current study pure eucalyptus oil is derived and transformed into biodiesel by transesterification process and blended with diesel the blend (B10) ratios were 90% Diesel and 10% Eucalyptus Oil the blended fuel is made to run in a single cylinder four stroke water cooled Homogeneous compression ignition engine. The performance characteristics like SFC, BP and BTH and for emission CO, HC and NOX in the exhaust gases was performed. After analyzing all the fuel blends for all the loading conditions (0,4,8,10 Kgs) of the engine the result showed that there was a significant reduction in HC and CO emission and decreased NOx emissions.

1.INTRODUCTION

The Internal Combustion Engine is the most wide-spread apparatus for transforming liquid and gaseous fuel to useful mechanical work. Reciprocating IC engine is certainly the best apparatus in some aspects compared to its counter parts. Still the processes of these IC engines are under development vowing to the commercialization for better place in the society.

The four stroke CI engine proved to be at its best since decades serving many fields of society. There is good support and investments for these technologies to promise the above said points. The improvements are related to engine combustion processes in terms of fuel saving or minimization of losses. However there are certain other possibilities of improvement of these engines in the basic design which involves the types of fuel injection, better intake of air and fuel air mixing etc. The engine redesign/modifications are also in the field due to strict restrictions of the emission regulations.

Over the past decade the demands are constantly rising towards engines which have fewer pollutant emissions, lower fuel consumption, improved power and lower costs. There are several alternatives being used to improve the engine out emissions. An alternative/modified combustion process 'homogeneous charged compression ignition' engine (HCCI) is being suggested by researchers in the place of existing CI engines.

The CI engine is good in using best compression ratio to yield good thermal efficiency, but owing to the diffusion flame it produces high amounts of nitrous oxide (NOx) emissions. In addition, high peak pressures and soot formation limits the CI engine to perform at its best.

It is more difficult with the NOx emissions because of the idea is to convert them into N2. This is very difficult to do in diesel exhaust gases because the high amount of oxygen present. De NOx catalysts exist but are in general very sensitive to sulfur, and most diesel engine fuels contain some amounts of sulfur. Technology that uses a reducing media, like urea or ammonia has also been tested but it then requires "refueling" in order to work properly. The SI engine uses a premix of fuel and air and it utilizes a spark plug (forced ignition) that sets of premixed turbulent flame combustion. This combustion principle makes it sensitive to self-ignition, "knocking", which can result in structural damage, mainly to the piston. This phenomenon limits the compression ratio of the SI engine, which in turn limits the thermal efficiency. The fuels for the SI engines have a certain degree of knocking resistance, measured by the octane number (ON) of the fuel.

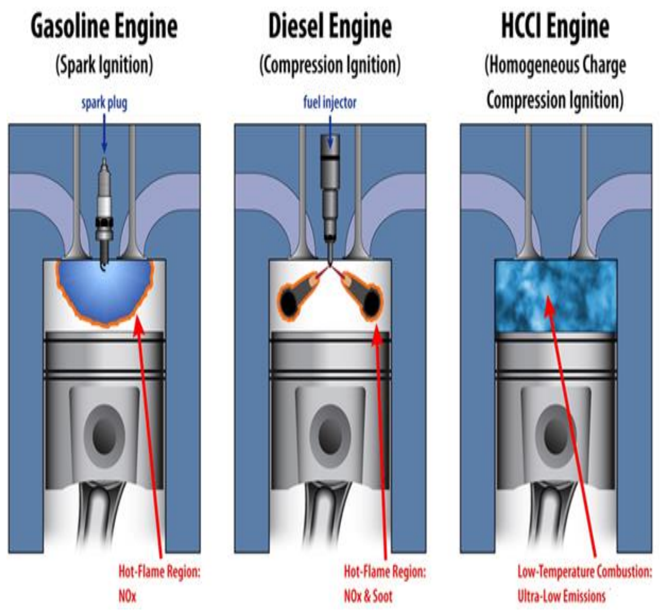
The SI engine has through the lower compression ratio a possibility to use higher rpm's in order to get high specific power because the pressures are limited, thus a more lightweight design can be used that allows higher rpm's. Load control is achieved by throttling which means that the inlet pressure, and hence the air mass flow through the engine, is controlled by a restriction, usually a butterfly valve. This forces the engine to work like a compressor at part load, which also reduces efficiency. In car applications, the major operating point of the engine is low to medium load, which means that the overall efficiency becomes quite low. For the diesel engine, it is almost the opposite situation. This has contributed to an increase of the number of diesel-propelled cars.

To overcome the shortcoming of diesel engine and SI engine there is a need to find a combination of the diesel engine and the spark ignited engine that only inherit the good properties of the diesel and SI engine i.e. efficiency like a diesel engine and exhaust emissions that are as clean as from the SI engine, or at least possible to after-treat to the same level. This is quite difficult and there have been very few attempts that have reached any commercial success. There are two concepts that are worth to be mentioned: lean burn Spark ignition engines with either homogeneous mixtures or stratified charge.

Emissions and fuel consumption are the two major worldwide environmental and energy challenges in the current century. Given the large number of vehicles manufactured worldwide, transportation is one of the largest sources of both gas emissions and fuel consumption in the world. One major solution to decrease emissions and fuel consumption in transportation is the use of cleaner fuels and more efficient combustion in engines.

HCCI engine is a type of combustion in which air and fuel are mixed homogeneously outside the engine cylinder and then compressed to the point of auto ignition level in compression stroke. The homogeneous charge compression ignition engine include the best features of conventional gasoline and diesel engine. The HCCI engine produces gasoline like soot emission while diesel like power efficiency.

- SI engines: spark ignition engine (gasoline engine).
- CI engines: compression ignition engine (diesel engine).



1.1 Homogeneous Charge Compression Ignition (HCCI) History

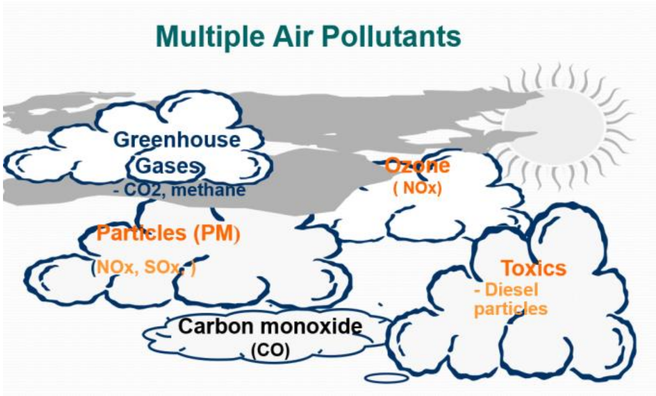
The first HCCI engines were two-stroke engines. The main concept of these investigations was to remove misfire and to stabilize the combustion process at part load. HCCI operation, when optimized, has been shown to provide efficient and steady operation. Honda used this combustion concept for motorcycles. In this case the HCCI Engine - Process was used to improve the stability of combustion and to decreasing the HC (Hydro Carbons) -emissions and fuel consumption at the part load (to ability of a system). High EGR rates of up to 80% were used. At higher loads and at full load, the motorcycle was driven as a conventional SI engine. Although being reported in numerous research papers as a new combustion concept for reciprocating internal combustion engines, HCCI also known as Controlled Auto-Ignition (CAI) has been around for over 100 years. The first patent refers to inventing a hot-bulb 2-stroke oil engine by Carl W. Weiss in 1897.

1.2 Emissions

Emission is one of the important reasons to inspiring the innovation of alternative fuel technology. It is the serious pollutants from gasoline and diesel engines. A large number of automobiles cause severe air pollution. Some exhaust pollutants get into the atmosphere from Cars, trucks and Industrial. they act as irritant, odorant and some are carcinogenic (to produce cancer). The different air pollutants are briefly described.

Engine emission standards regulate a common set of emissions universally agreed upon as having negative effects on air quality. In the gas phase, CO, HC, and NOX are regulated, with CO_2 not regulated by most legislation but still viewed as undesirable due to its classification as a greenhouse gas. Engine emissions are commonly normalized to engine output and presented in the form grams per brake horsepower hour (g/bhp) or grams per kilowatt hour (g/kW hr).

The two driving forces behind HCCI research are gaining higher efficiency and curtailing regulated emissions. In general CI engines have thermodynamic efficiencies 20% to 30% higher than a comparable output SI engine. This is a benefit of the high compression ratios and lean burn strategies allow by CI. Additionally CI engines eliminate the throttling losses characteristic of SI engines operating at part load. It is clear from the most elementary combustion chemistry reaction that an increase in efficiency translates directly to a decrease in CO_2 per unit power output.



1.2.1 Unburned Hydro Carbon (HC) Emissions

The HC emission is the result of oil film absorption, misfiring condition or incomplete combustion of hydrocarbon fuels, it is effect the human bodies. Rich mixture is not have enough oxygen to react with all the carbon and hydrogen, it leads to improve in HC emission. Overall equivalence ratio for CI engine is leaner in compared to internal combustion engine or gasoline engine. The hydrocarbon emission in compression ignition engine are less than gasoline engine. When hydrocarbon emission gets into the atmospheric air, they act as irritants and odorants.

1.2.2 Carbon monoxide (CO) emission

Reasons for higher CO emission are due to incomplete combustion of fuel, heterogeneousness of air fuel mixture and temperature rise inside the cylinder. Heavy fuel rich mixture leads to carbon monoxide emission during starting or when accelerating under load in the heavy duty vehicles. Not only is CO considered an unwanted emission (it is harmful), but it also represents lost chemical energy.

1.2.3 Oxides of nitrogen (NO_X)

The oxides of nitrogen depend upon available of oxygen and higher combustion temperature inside of the combustion chamber. NO_X reacts in the environmental gases to form ozone and is one of the major causes of photochemical smog. Development of cyanosis especially at lips, figure and toes, adverse changes in cell structure of lung wall is the long term health effects of oxides of nitrogen.

1.2.4 Particulate Matter

Particulates are fine solid or liquid particles which are emitted by the vehicles also, may be in solid or liquid phase. Solid particles emitted by automobile vehicles are largely made of carbonaceous matter (soot particles) consisting a small fraction of inanimate substances. Different type of liquid phase substances and other materials are also either adsorbed or absorbed on these particles. The cost of diesel is cheaper than gasoline and therefore in last decade people depended on diesel fuel. Diesel is the most harmful fuel for the reason that it emits ten times more particulate matter per mile than conventional internal combustion engines. Kinney, P. L. Showed in their study, that particulate matter (PM) dispersed through vehicle emissions and remains suspended at low levels.

1.3 Features of HCCI Combustion

- Unlike there is no throttling loss in SI engine, lean fuel operation and higher compression ratio. Therefore, HCCI gives higher power efficiency and best fuel economy.
- In HCCI combustion, fuel and air charge is homogeneously mixed, no accumulation of fuel in cylinder, it produces less or no soot.
- In HCCI combustion, start of combustion occurs when charge is automatically-ignited. It completely depends up on fuel characteristics, engine properties and atmospheric conditions.
- Since combustion starts immediately, there is no flame propagation shorter combustion duration and avoiding the knocking problem.
- In HCCI no more identification of fuel required. HCCI engine is a fuel flexible and adjustable engine which can be operated by low cetane fuel and several alternative fuels.
- Maximum temperature of cylinder decreases, because of overall cylinder combustion also decreases simultaneously and lower NOx emissions.
- By removing a higher pressure injector and other equipment lower cost of engine can be forecast.
- The HCCI engine can save 10- 30% fuel practically, while meeting current emission standards.

2. EXPERIMENTAL SET - UP

SPECIFICATIONS OF 5 H.P. KIRLOSKAR ENGINE (ROPE BRAKE DYNAMOMETER)

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 DIAMETE	:	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 Dynamometer

METHOD OF STARTING : Manual Cranking

METHOD OF COOLING PROVIDED : Water Cooling

The present experiments are conducted on a 5HP Vertical Cylinder single cylinder, water cooled engine of Kirloskar make. The compression ratio of engine is 16:1. Various Thermocouples are arranged at their respective positions to read the values of Exhaust gas temperature, Exhaust water temperature, water inlet temperatures. The amount of air inducted is measured by manometer connected to airbox. The time taken for 10cc fuel consumption measured by stopwatch. The proportions of exhaust gases are measured by inserting the probe into adjustment made in the exhaust manifold.

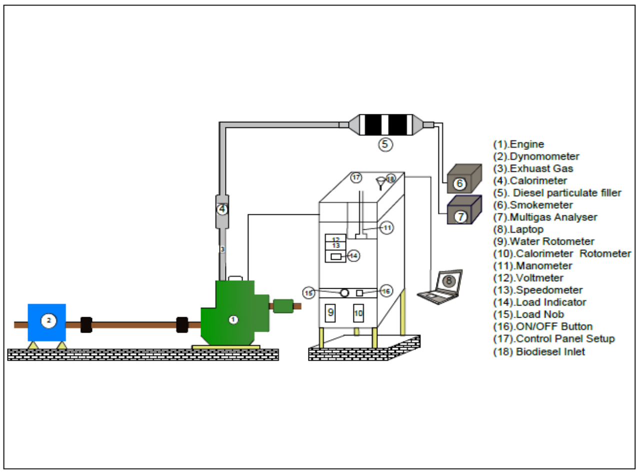


Fig. 3.1: Experimental Set-Up

2.1.Loading system:

The break drum Top end of the rope is connected to a spring balance and bottom end of the rope is connected to a weighing platform. The load to the engine can be varied by adding slotted weight provided on to the platform. Make sure the weight platform is above the base while the engine is loaded to do so use the handwheel provided on the loading frame.

2.2 Air Intake Measurement:

The suction side of the engine is attached to an air tank. The atmospheric air is drawn into the engine cylinder through the air tank. The manometer is provided to measure the pressure drop across an orifice provided intake pipe of the air tank. The pressure drop is used to calculate the volume of air drawn into the cylinder. (orifice diameter 20mm)

2.3 Fuel Measurement:

The fuel is supplied to the engine from main fuel tank through a graduated measuring fuel gauge burette.

2.4 Temperature Measurement:

A digital temperature indicator with selectors switch is provided on the panel to read the temperature in degree centigrade directly sensed by respective thermocouples located at different places on the test rig.

2.5 Experiment Procedure:

The various fuels that are used during investigation are diesel and HCCI engine.

To find the performance of any engine with any fuel, the following procedure is followed:

a. Measure the diameter of brake drum and diameter of rope with the inelastic thread and measure the length with the help of long scale.

b. The engine is provided with proper supply of cooling water and check the availability lubricating oil in the fuel tank by measuring the burette level.

c. There should be no load on the engine while starting, the decompression lever are relieved and by sufficient cranking and engage the decompression lever to get engine started.

d. The running engine is left the idle for some time to attain steady state conditions.

e. At this no-load condition, the following readings are noted: Time of starting time for 10cc fuel consumption.

1. Exhaust gas temperature.

2. Manometer reading.

3. Speed of the engine

f. Later the load is increased from no load to full load in steps of 20% and at every load the above-mentioned parameters are noted. The engine is made to run 10 minutes at every load before taking the above readings.g. Finally the load is completely removed and the engine is stopped by stopping the fuel supply.

3. TESTING ON HCCI ENGINE WITH ECALYPTUS OIL

The present test is conducted with eucalyptus oil on a 5HP Vertical Cylinder single cylinder, water cooled engine with HCCI set up. The time taken for 10cc fuel consumption measured by stopwatch. The proportions of exhaust gases are measured by inserting the probe into adjustment made in the exhaust manifold.

Table 1 : Observation Table

Load (Kg)	Speed (RPM)	Time taken for 10cc of fuel cons. (sec)	Manometer Diff. in (mm of Hg)	Emissions					
				HC	CO	CO_2	O_2	NOx	opacity
0	1500	20	15	21	0.02	0.04	20.52	1	79.2
4	1495	18	15	23	0.01	0.00	21.2	0	1.9
8	1490	16	15	25	0.02	0.00	21.25	0	0
10	1482	15	15	32	0.02	0.50	20.6	0	0

Table 2 : Performance Table

Brake ower (kW)	Mass of fuel Cons. (Kg/hr).	Specificfuel Cons. (Kg/kW hr)	Brake Thermal Efficiency (%).	Volumetric Efficiency (%).
0	1.476	0	0	44.2
1.142	1.64	1.436	5.89	44.4
2.77	1.84	0.660	12.75	44.53
2.83	1.968	0.695	12.18	46.2

4. TESTING ON HCCI ENGINE WITH ECALYPTUS OIL RESULTS

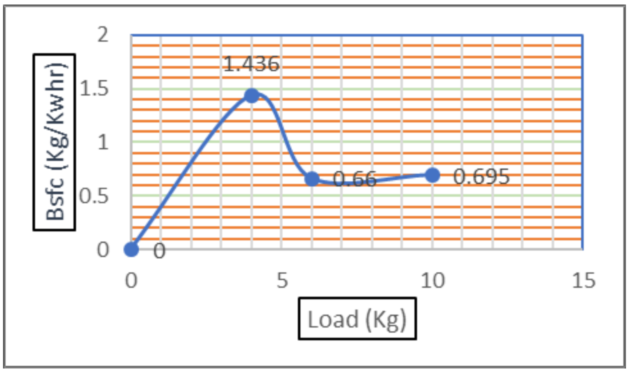


Chart -1: Load(kg) v/s Bsfc(kg/kwhr)

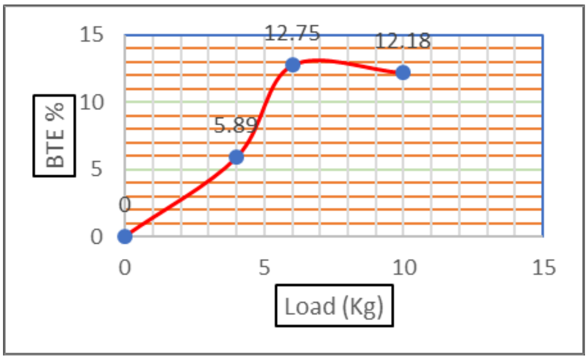


Chart -2: Load (kg) v/s Bte(%)

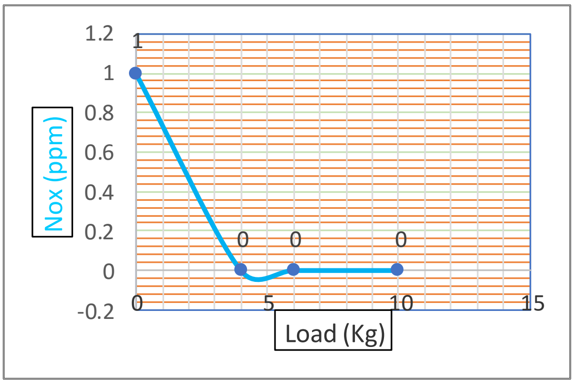


Chart -3: Load(kg) v/s Nox(ppm)

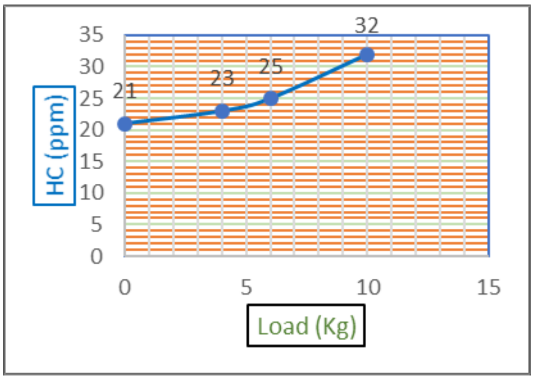


Chart -4: Load(kg) v/s HC (ppm)

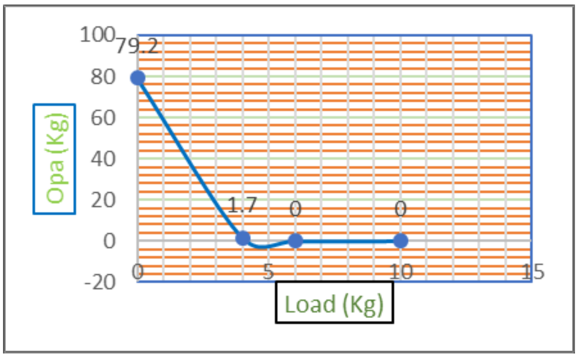


Chart -5: Load(kg) v/s Opa(%)

Chart -5 show that the load v/s brake specific fuel consumption the brake specific fuel consumption decreases with varying the load. Chart -5 show that the load v/s break thermal efficiency the break thermal efficiency increases then decreases with varying the load. The Chart -5 show that the load v/s nitrogen of oxide the nitrogen of oxide is decreases then increases with varying the load. Chart -5 show that the load v/s hydro carbons the hydro carbons decreases with varying the load. Chart -5 show that the load v/s opacity the opacity decreases with varying the load.

5. CONCLUSIONS

The various experiments are conducted on HCCI Engine.

1. The eucalyptus oil engine performance is very good compared to diesel.
2. The result showed that there was a significant reduction in HC and CO emission and decreased NOX emission.
3. The fuel efficiency is observed to be lower with HCCI engine owing to higher fuel consumptions when the fuel introduced in the intake pipe.
4. The emissions are less while the fuel introduced in the intake pipe (HCCI mode).
5. Hence the eucalyptus oil is more ecofriendly then diesel.

6. REFERENCES

[1] Shamla A. Mulane and S. D. Limaye., "Homogeneous Charge Compression Ignition (HCCI) Engine Technology-A Review," IJCET, no.4, pp. 160-163, 2016.

[2] Kaiser E.W., Yang J., Culp, T., Xu N., and Maricq, C., "Homogeneous Charge Compression Ignition Engine-out Emissions – does flame propagation occur in homogeneous compression ignition?", Int. J. of Engines Research, Vol. 3, No. 4, pp.184–295, 2003.

[3] Kahaaina, N., Simon, A.J., Caton, P.A., et al., "Use of dynamic valving to achieve residual-affected combustion", SAE paper 2001-01-0549, 2001.

[4] P.V.Ramana et.al, "Development of Alternative fuels for HCCI Engine Technology",IJEDR, no.3, pp-108-119, 2015.

[5] A. Dinesh, G. Surya, and K. Bhaskar., "Experimental investigation on HCCI engine with gasoline injection", National Conference On Recent Trends And Developments In Sustainable Green Technologies, no.7, pp. 293-296, 2015.

[6] Kalian, N., "Investigation of CAI and SI combustion in a 4-cylinder Direct Injection Gasoline Engine", PhD thesis, Sept., 2006.