Journal of Basic and Applied Engineering Research
Print ISSN: 2350-0077; Online ISSN: 2350-0255; Volume 1, Number 4; October, 2014 pp. 16-20

http://www.krishisanskriti.org/jbaer.html

Experimental Investigation of HCCI Engine with Ethanol Manifold Injection

Aswin R.[1], Karthick Sundar R.[2], Aravindraj S.[3], Bhaskar K.[4]

[1,2]*Department of Automobile Engineering*
Rajalakshmi Engineering College, Thandalam, Chennai, India

Abstract: **In this work the homogeneous charge compression ignition engine with manifold ethanol injection and diesel in the in-cylinder injection were selected as fuels and test conducted in a single cylinder constant speed diesel engine.HCCI combustion incorporates the advantages of both spark ignition engines and compression ignition engines. The effect of pre mixed ratio and injection timing were studied to determine the performance, emission and combustion characteristics of HCCI engine.In cylinder pressure crank angle diagram was obtained using AVL piezo electric pressure transducer and AVL crank angle decoder. The combustion parameters like peak pressure, combustion duration, heat release rate, cumulative heat release rate, mass burn fraction were obtained using AVL indi-module software. Existing inlet manifold of the engine was modified to accommodate the PFI injector to supply the secondary fuel. Secondary fuel is supplied from secondary fuel tank by low pressure pump. Electronic control unit was designed to control the start of injection, injection timing and quantity of fuel supplied in the inlet manifold. HCCI mode of operation reduced the NO_X and soot emission due to homogeneous mixture.**

Keywords: **Homogeneous charge compression ignition engine, manifold ethanol injection, combustion characteristics, NO_X and soot emission**

1. INTRODUCTION

Homogeneous charge compression ignition (HCCI) is a form of internal combustion in which well –mixed fuel and oxidizer are compressed to the point of auto-ignition. As in other forms of combustion, this exothermic reaction releases chemical energy into a sensible form that can be transformed in an engine into work and heat.

HCCI has characteristics of the two most popular form of combustion used in SI engines: homogeneous charge spark ignition and CI engines: stratified charge compression ignition. As in homogeneous charge SI engines, the fuel and oxidizer are mixed together. However, rather than using an electric discharge to ignite a portion of the mixture, the density and temperature of the charge is raised by compression until the entire mixture reacts spontaneously. Stratified charge compression ignition also relies on the temperature and density increase resulting from compression , but combustion occurs at the boundary of fuel-air mixing, caused by an injection event, to initiate combustion.

The defining characteristics of HCCI engine is that the ignition occurs at several places at a time which makes the fuel/air mixture burn nearly spontaneously. There is no direct initiator of combustion. This makes the process inherently challenging to control. However, with advances in microprocessors and a physical understanding of the ignition process, HCCI can be controlled to achieve gasoline engine-like emissions along with diesel engine like efficiency. In fact,HCCI engines have been shown to achieve extremely low levels of nitrogen oxide emissions without an after treatment catalytic converter. The unburnt hydrocarbon emissions and carbon monoxide emissions are still high, as in gasoline engines, and must still be treated to meet automotive emission regulations.

Recent research has shown that the use of two fuels with different reactivity can help solve some of the difficulties of controlling the HCCI ignition and burn rates. Reactivity controlled compression ignition has been provided to demonstrate highly efficient, low emissions operation over wide load and speed ranges.

HCCI engines have long history, even though HCCI has not been widely used. It is essentially an Otto combustion cycle. In fact HCCI was popular before electronic spark ignition was used. One example is the hot bulb engine which used a hot vaporization chamber to help mix fuel with air. The extra heat combined with compression induced the conditions for combustion to occur. Another example is the diesel model aircraft engine.

2. CONTROL OF HCCI ENGINE

The controlling of HCCI engine is a major hurdle to more widespread commercialization. HCCI is more difficult to control than other popular modern combustion engines, such as spark ignition and compression ignition engines. In a typical gasoline engine, a spark is used to ignite the pre-mixed fuel and air. In diesel engines, combustion begins when the fuel is injected into compressed air. In both cases, the timing of combustion is explicitly controlled. In an HCCI engine, however, the homogeneous mixture of fuel and air is compressed and the combustion begins whenever the appropriate conditions are reached. This means that there is no well defined combustion initiator that can be controlled. Engine can be designed such that the ignition conditions occur at a desirable timing. To achieve a dynamic operation in an HCCI engine , the control system must change the condition that initiates combustion. Thus the engine must control either the compression ratio, inducted gas temperature , inducted gas pressure, fuel-air ratio, or the quantity of retained or re-inducted exhaust. The control method adopted in our experiment is pre-mixed charge compression ignition(PCCI).

Compression ignition direct injection combustion (CIDI) is well established means of controlling ignition timing and heat release rate and is adopted in diesel engines combustion. Pre mixed charge compression ignition is a compromise between achieving athe control of CIDI combustion but with the exhaust gas emissions of HCCI, specifically soot. On a fundamental level, this means that the heat release rate is controlled preparing the combustible mixture in such a way that combustion occurs over a longer time duration and is less prone to knocking. This is done by timing the injection event such that the combustible mixture has a wider range of air-fuel ratios at the point of ignition, thus ignition occurs in different regions of combustion chamber at different times-slowing the heat release rate.

Furthermore this mixture is prepared such that when combustion occurs, there are fewer rich pockets thus reducing the tendency of soot formation. The adoption of high EGR and adoption of diesel fuels with a greater resistance to ignition enables longer mixing times prior to ignition and thus fewer rich pockets thus resulting in the possibility of both lower soot emissions and NO_X.

3. NECESSITY OF HCCI ENGINE

In recent years, a lot of attention has been focused on air pollution caused by automotive engines. Diesel engines have been particularly targeted for their production of oxides of nitrogen and smoke emissions. NO_X is formed at high rates when temperatures are high, whereas smoke is formed in fuel rich regions within the combustion chamber. Hence, it is essential to keep the peak cylinder temperature low in order to minimize NO_X emissions and also to allow for better fuel air mixing thereby reducing smoke emissions. In the HCCI engines, the combustion process is modified so that combustion occurs under lean mixture conditions which lower the local combustion temperature. The absence of high local combustion temperature and a rich fuel-air mixture during combustion process makes simultaneous reduction of NO_X and particulate matter(PM) emissions possible.

Methodology of HCCI

The test engine used was a single cylinder, air cooled agricultural CI engine (Kirloskar) which was modified to operate in HCCI mode. The engine test bench was equipped with

- Electronic control unit (ECU) to control manifold fuel injector(MFI)
- Data acquisition system and crank angle encoder
- Pressure transducer
- Battery
- Fuel pump for secondary fuel injection
- Pressure gauge with control valve
- AVL 5 gas analyser for emission analysis
- AVL Hartridge smoke meter for smoke analysis

4. OBJECTIVE OF THE EXPERIMENT

The objective of this study is to investigate the combustion and emission characteristics of HCCI concept and the effects of premixed ratio and direct injection timing. Normal ethanol was chosen as a premixed fuel because of its excellent ignition ability. The commercial diesel fuel was injected near the top dead centre(TDC) as a complementation under the condition of misfire or knock to expand the engine operating range.

The engine experiments were conducted over a load range from 0 to 100% while the engine speed was fixed at 1500 rpm. This work also examined the engine performance difference between conventional CIDI and HCCI and then provided suggestions for the optimum operation region of HCCI. The main objectives of this experiment is to compare the emission of diesel and mixture of diesel and ethanol emissions, to compare the pressure developed in a normal diesel engine and ethanol injected diesel engine. Both the above ethanol injections are taken at a retardation difference of three degrees and to evaluate its performance.

5. FUEL SELECTED FOR OUR EXPERIMENT

Ethanol or ethyl alcohol can be produced by the fermentation of carbohydrates which occurs naturally and abundant in some plants like sugarcane and fron starchy materials like corn and potatoes. It is considered to be a potential transportation alternative fuel. Ethanol is a very good candidate as an engine fuel as it is a liquid and has several physical and combustion properties similar to gasoline. It has a octane rating that allows ethanol engines to have much higher compression ratios, increasing the thermal efficiency. Almost any source of starch is a potential candidate for ethanol production.

Ethanol is a volatile, flammable, colorless liquid that has a strong odour. It burns with a smokeless blue flame that is not always visible in normal light. The physical properties of ethanol stem primarily from the presence of its hydroxyl group and the shortness of its carbon chain. Ethanol's hydroxyl group is able to participate in hydrogen bonding, rendering it more viscous and lessvolatile that less polar organic compounds of similar molecular weight.

Mixture of ethanol and water that contain more than 50% ethanol are flammable and easily ignited. Combustion of ethanol forms carbon dioxide and water. The combustion reaction is as follows,

$C_2H_5OH + 3O_2 \rightarrow 2CO_2 + 3H_2O$

6. EXPERIMENTAL SETUP

The research engine was based on a single cylinder, direct injection and four stroke naturally aspirated diesel engine. The main engine specifications are listed in Table 1. An electronically controlled port injection system was employed to inject ethanol in the intake manifold at the location of approximately 0.35 m parallel the stream to the inlet port and the diesel fuel was directly injected into the cylinder near the top dead center with the mechanical injection pump. The cylinder pressure was measured using a pressure transducer (Kirloskar model TAF-1).

The charge output from this transducer was converted to amplified voltage using an amplifier and was recorded at 0.25^0CA resolution with the sampling signals from the shaft encoder. According to the in-cylinder gas pressure averaged from 50 consecutive cycles for each operating point, the heat release rate can be calculated by zero emission combustion model. The exhaust gas composition CO, UHC and NO_X emissions were measured by gas analyser(AVL DiGas 2200). Also the equivalence ratio could be obtained from the analyzer. The smoke opacity was measured by a smoke meter(AVL 415).

S.No	Specification	Range
1	Model	Kirloskar TAF1 model ,4 stroke single cylinder air cooled
2	Rated power	4.4Kw
3	Rated speed	1500rpm
4	Bore	87.5mm
5	Stroke	110mm
6	Compression ratio	17.5:1

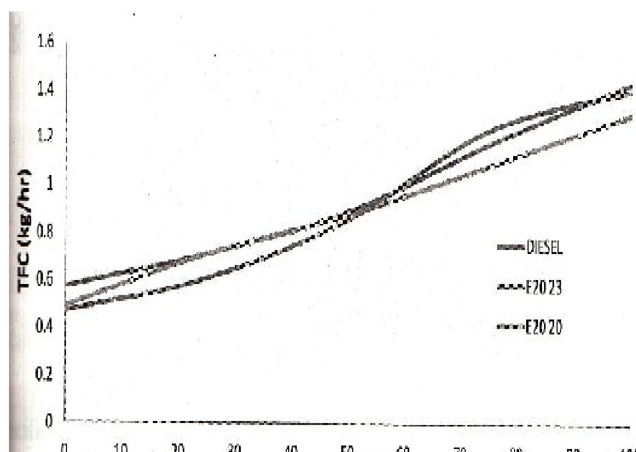
7. EXPERIMENTAL PROCEDURE

The combustion and emission characteristics of normal diesel engine with load and without load has been studied and tabulated. The pressure versus crank angle diagram for diesel engine, motoring curve has been drawn using a special software. Then the setup for HCCI ethanol manifold injection is fitted with the engine to reduce NO_X emissions. ECU monitors the control, flow injection timing, injection duration of ethanol into the manifold. E20 is the secondary fuel used for this experiment. The combustion characteristics and emissions for various load conditions in HCCI ethanol manifold injection can be studied and these values are compared with normal diesel engine. Retardation of three degrees in the injection timing can be done and the same experiment is repeated. The graph is compared with that of the normal diesel engine.

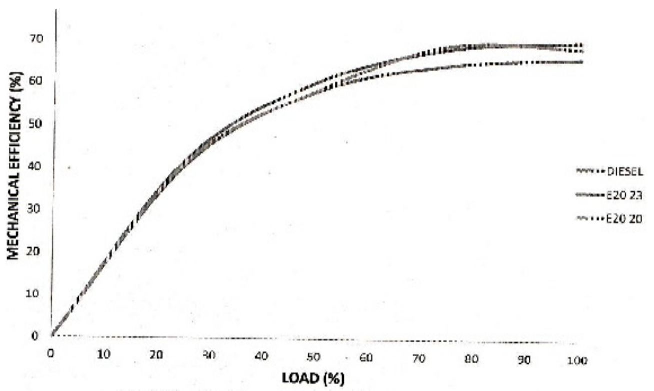
8. RESULTS AND DISCUSSION

The following sections describe the results of diesel and HCCI combustion mixture. The CI and HCCI performance , emission and combustion characteristics were investigated

8.1: Total fuel consumption: normally a diesel fuel consumes less fuel than HCCI engine until it reaches 50% loading condition . when the engine begins to operate at high load conditions the fuel consumption steeply increases for diesel fuel. For E20 23 the total fuel consumption gradually increases with respect to load. There is no significant difference in the fuel consumption,. Comparing the diesel and ethanol injected HCCI engine.

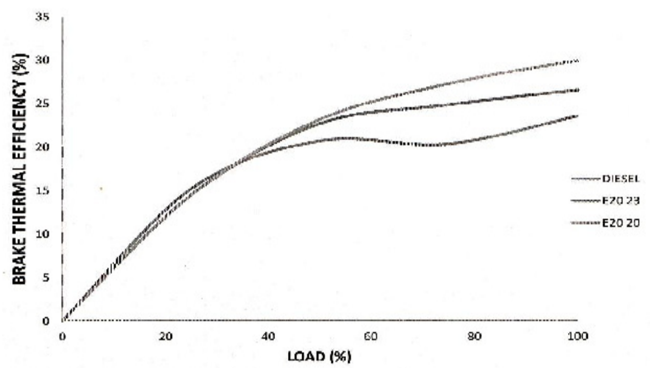


8.2: Mechanical efficiency :Ethanol has higher octane number than gasoline so it leads to rapid combustion than diesel. Since ethanol injection produces more brake power with respective indicated power implying reduction in friction loss owing to its higher octane number



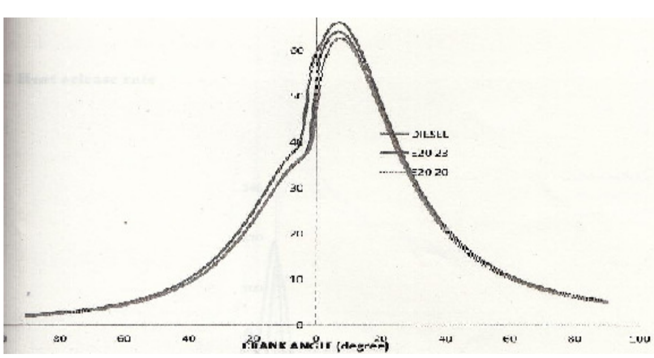
8.3: Brake thermal efficiency:

Brake thermal efficiency is the ratio of energy in brake power to input fuel energy. Here brake thermal efficiency is higher for ethanol compared to diesel. Octane number of ethanol is higher and so the power produced is higher, so the fuel consumption is lower.



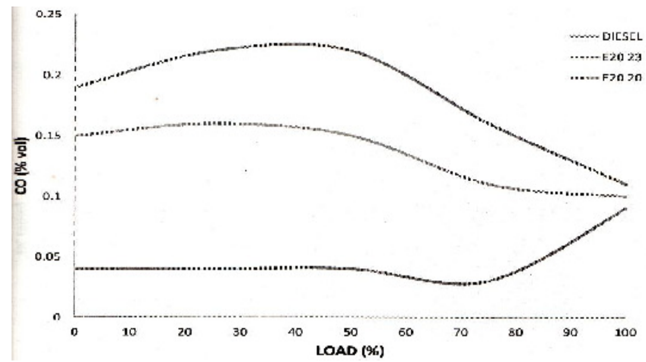
p-Ø diagram at 100% load:

The pressure developed with respect to crank angle has no significant difference between diesel and ethanol injected HCCI engine. But at low load condition diesel engine develops higher pressure compared to ethanol injected HCCI engine.



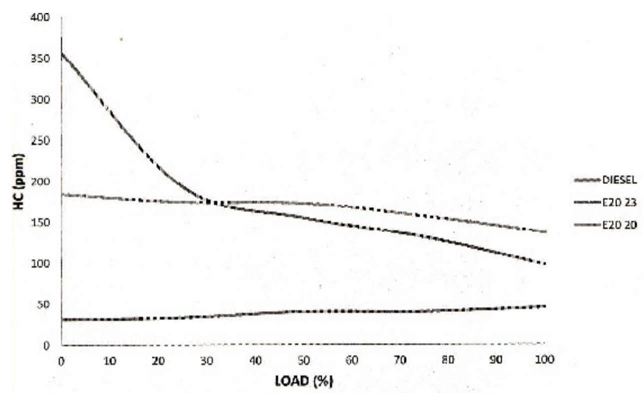
IX. Comparison of CI and HCCI Engine Emissions CO Emissions:

In low load condition the mixture of air and ethanol is rich, so in ethanol injection it produces more CO emissions at no load condition. But at full load condition air and ethanol injection reduces CO emissions, since there is less carbon in ethanol.



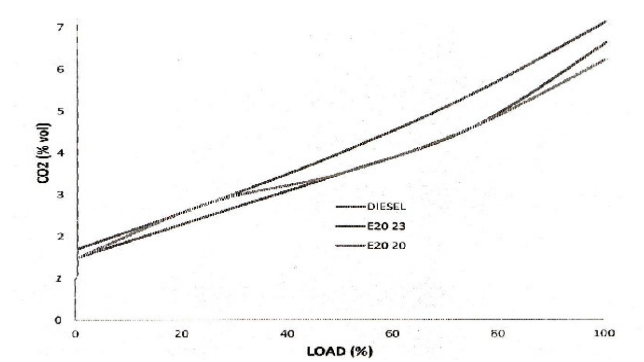
Hydrocarbon emissions:

HC emission is higher as like to CO emissions. This also can be attributed to the fact that ethanol has higher octane number like gasoline. So the low load conditions HC emissions are higher in ethanol injected HCCI engines when retarding the main injection of HC emission.



CO_2 Emissions:

CO_2 emissions decrease when the ethanol injected HCCI engine than the diesel engine, but not at significant difference.



Oxides of Nitrogen(NO_X):

Normally, diesel engine NO_X emissions are high and increase gradually with load. But in ethanol injected HCCI engine the NO_X emissions are reduced than diesel engines, because ethanol controls the combustion temperature. The difference between ethanol injected HCCI engine and diesel engine , the NO_Xemissions is around 200ppm.

9. CONCLUSION

Ethanol injected HCCI engine operates at better performance than the conventional diesel engine. SFC,TFC decrease considerably in ethanol injected HCCI engine. Mechanical efficiency and brake thermal efficiency also increases in ethanol injected HCCI engine than conventional diesel engines.NO_X emissions decrease first at low premixed ratios and exhibit a trend of increase at higher premixed ratios. Generally the NO_X of HCCI combustion could be dramatically reduced in comparison with diesel engine. The change of CO with premixed ratio is mainly depending on whether the premixed ratio exceeds the critical value.

REFERENCE

[1] Goran Haraldsson et.al. ,HCCI closed-loop combustion control using fast thermal management, SAE 2004-01-0943.

[2] Thomas W.Ryan III et.al. ,HCCI in a variable compression ratio engine-effect of engine variable, SAE2004-01-1971.

[3] Nebojsa Milovanovic et.al. ,SI-HCCI-SI mode of transition at different engine operating condition, SAE2005-01-0156.