IOSR Journal of Mechanical and Civil Engineering (IOSR-JMCE)
e-ISSN: 2278-1684, p-ISSN: 2320-334X
PP 06-10
www.iosrjournals.org

Homogeneous Charge Compression Ignition Engine (New Concept of Pollution Free I.C. Engine)

Prof. Sanjay Harip
Department of Mechanical Engineering, Government Polytechnic, Ahmednagar, India.

ABSTRACT: *Homogenous charge Combustion ignition (HCCI) engines are being considered as an alternative to diesel engines. The HCCI concept involves premixing fuel and air prior to induction in to the cylinder (as is done in current spark- ignition engine) then igniting the fuel –air mixture through the compression process (as is done in current diesel engines) As per the report of united state congress (2005), The HCCI engines might be commercialized in light duty vehicles by 2012 and by 2015 as much as half million barrels of oil per day may be saved. Because of the need of reduce worldwide fuel consumption, greenhouse gas emissions, there is strong interest in HCCI worldwide. This paper describes the results & operation of a single cylinder KOEL engine in HCCI mode. This experiment represents the first step towards the development of engine based on HCCI concept.*

Keywords: *Auto ignition , PREDIC , activation energy.*

I. INTRODUCTION

In HCCI, A Homogenous mixture of air and fuel is compressed and ignited by the heat of compression HCCI combustion can be considered as a hybrid form between the Diesel and Otto combustion processes as it combines the homogenous mixture preparation of an Otto engine with the compression ignition of diesel engine. However, the combustion process is different. When heat and pressure of the mixture are high enough, the compressed homogenous charge ignites simultaneously at multiple spots in the combustion chamber, so there is neither a diffusion flame (as in a Diesel engine) nor a flame front traveling through a premixed charge, as in a spark ignition engine. Furthermore, the air-fuel mixture is often diluted with combustion products (i.e.), in order to limit the rate of combustion or to delay the start of ignition.

The HCCI combustion process has been known for a long time but except for some odd application, it has not been used for production engines. In the field of internal combustion engine research, however, it has gained considerable interest in the last decade, mainly because of the large reduction in NOx emissions it offers. Since the mixture is lean, diluted and homogenous, theoretically there is none of high temperature stoichiometric combustion zones that are essential for necessary for NOx formation and no fuel rich soot-forming zones. Whether these NOx and soot-forming zones are really absent depends on the actual homogeneity of the air fuel mixture. Numerous experiments have shown that the NOx and soot emissions are indeed drastically reduced and in some cases approach zero [2}

A combustion system that eliminates NOx formation is particularly attractive to engine manufacturers as NOx emissions are difficult to reduce with the exhaust gas after-treatment systems, when the engine is operated at lean (overall) air-fuel mixture. Lean operation makes throttling of the intake air unnecessary, which increases the efficiency. Since HCCI is also operated at lean air fuel mixtures, but avoids the need to reduce NOx emissions, the process offers considerable efficiency benefits over conventional Otto engines. Diesel engines are never throttled, so HCCI does not cause a significant increase in efficiency compared to conventional Diesels. HCCI is being developed for both Diesel and petrol based engines. The fuel used for Diesel based engines varies, but for obvious reasons a fuel with a high knock resistance is often chosen. However, more recently, various researchers have presented work in which they describe the use of diesel fuel for HCCI operation [3]. This type of operation, where diesel fuel is injected early in the compression stroke, is often referred to as **PREDIC** (**PRE**mixed lean **DI**esel Combustion). Although the combustion phasing and rate is more difficult to control. due to its low resistance to auto-ignition, using Diesel fuel has the advantage that it may be possible to combine low load HCCI operation with conventional Diesel operation at higher loads, using the same fuel and the injection system . The approaches to HCCI operation with diesel fuel vary. The fuel can be injected in the intake system or directly in to the cylinder during the compression stroke . The combustion of early injection and injection around TDC is reported to reduce NOx and soot levels, but they do not approach zero as they do with early injection of the entire fuel quantity. Control of combustion phasing and rate was accomplished in several different ways:

a) Variable Compassion ratio (Adjusting the compression Ratio)

b) By controlling Exhaust Gas Recirculation (EGR) rate
c) Injection Strategy
d) Combination of all above mechanisms

II. HCCI COMBUSTION PROCESS

The point of ignition is determined by the conditions in the cylinder during the compression stroke, so in order to influence the combustion phasing, the condition of the compressed gas must be altered. Diesel engines have a high compression ratio (16-22), which has to be lowered to reduce the pressure and temperature during compression. Another possibility to retard the start of ignition and lower the rate of heat release, which can be used in conjunction with a lowered compression ratio, is to use large amount of exhaust gas recirculation (EGR). EGR can be considered an inert gas that absorbs heat during the combustion, thus reducing the combustion rate.

The HCCI auto-ignition combustion process is chemically controlled. The Homogenous mixture is compressed until ignition occurs simultaneously at multiple spots across the combustion chamber. The influence of turbulence is limited as the mixture is already homogenous, so turbulence will not alter mixture composition, and there are no flame fronts or diffusion combustion to affect.

HCCI combustion can be divided into a low temperature and a high temperature reaction phase. The low temperature reaction start at approximately 700ºK and divided the process in to: initiation, chain propogation, degenerate branching and chain terminating stages. During the ignition steps, radicals are formed that react further with fuel molecule to form more radicals during chain propagating stage. During the branching step, molecules that were formed during the previous step spilt up in to two radicals. During the chain propagation step, Hydrogen peroxide (H_2O_2) is formed, which dissociates at temperature of around 1100ºK in to two OH radicals. This dissociation is considered to be important step as the reaction of the OH radicals with fuel molecules initiates the main combustion process [4].

The low temperature combustion process is temperature and pressure dependent [4], so altering the ambient condition during compression will affect the low temperature reaction, and thus the start of the high temperature combustion. The low temperature reaction is distinguished in figure 1.The High temperature reactions start at a temperature below 1100K,at which H_2O_2 decomposition starts, but it should be noted that the temperature curve represents average gas temperature , rather than the local temperature where the H_2O_2 decompositions occurs.

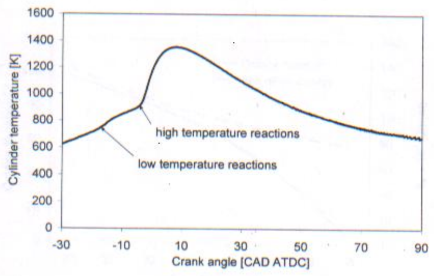

Fig. 1. Gas temperature for HCCI operation

The ignition quality of diesel fuel is defined its Cetane number. Where the Octane number used in conjunction with petrol increases to ignition, the cetane number increases with the ignitability of the fuel. The relationship between the apparent activation energy and the cetane number can be expressed as

$$E_A = (6890974)/ (CN +25) \qquad (1)$$

Equation shows that fuel with higher cetane numbers requires less activation energy, which in practice means lower temperatures in order to ignite. The relationship between cetane numbers, octane numbers and apparent activation energy. .

Diesel HCCI does not affect the fuel efficiency compared to conventional diesel, the main motivation for developing a diesel engine that can be operated in HCCI mode is to reduce NOx and soot emissions. Since the mixture in HCCI mode is homogenously distributed in the combustion chamber, there is no diffusion combustion with a rich and high temperature combustion zone. However, HC and CO emission, which are normally low for diesel engines, often strongly increase in HCCI modes. Typical reasons for this include misfiring, the short combustion duration, improper mixing (causing too rich or too lean),Fuel being trapped in crevices, spry interaction with the cylinder liner or piston, wall quenching, low gas temperature and high amount of EGR. The advantage of HC and CO emission over NOx and soot is that they can be removed with a relatively simple oxidation catalyst.

III. EXPERIMENT SETUP

The experiment was carried out with a single cylinder test engine configured as a Kirloskar Oil Engine with direct injection Diesel engine. The geometric compression ratio was lowered by modification to the piston and increasing the piston to head clearance as shown in the figure 2

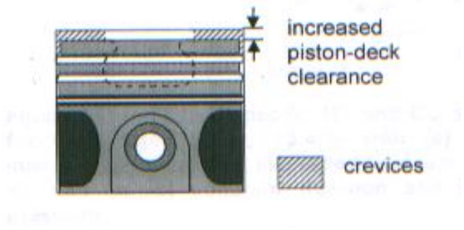

Fig. 2. Modified piston

Table No1 - Engine Specification

Engine Type	Kirlosker Oil Engine single cylinder
Bore	81 mm
Stroke	92.3 mm
Displacement	80 CC
Piston type	Toroidal bowl
Compression Ratio	17

Table No 2- Injection system Specification

Injection System	Bosch Common Rail
Injector type	Valve covered orifice
No. Of nozzle orifices	10
Nozzle Orifice diameter	0.11 mm
Included angle	60 deg

Table No.3 - Emission and Fuel Consumption measuring equipment

Fuel Flow Meter	Burette type
Smoke meter	SLP670, Ecophy make
HC,CO & PM meter	Neptune make
Nox meter	CLD70IELT , Ecophy make

Injector was fitted with a special ten- hole nozzle with an included angle of 60°. In addition the number of injector holes was from the regular five to ten, in order to reduce the droplet size and fuel penetration and thus improving the air/fuel mixing. The included angle was chosen to avoid interaction between the spray with the cylinder liner at the intended injection timing.

In order to operate the engine in HCCI mode. The fuel was injected in a series of five short injections, during the compression stroke, the start of the first injection being set at -90 CAD (90 Crank angle degree before top dead Center). The dwell time between the injection was set to 11 CAD i.e –90CAD,-79CAD,-68CAD,-57CAD,-46CADas shown in Fig No3.This for two reason to avoid interaction of the individual injections and to equalize the fuel rail pressure during the start of injection. The opening of the injector will perturb the rail pressure, which will then strongly fluctuate. For uniform injections, it is important to space the injections pulses at intervals such that the rail pressure during start of injection is the same for all injections.

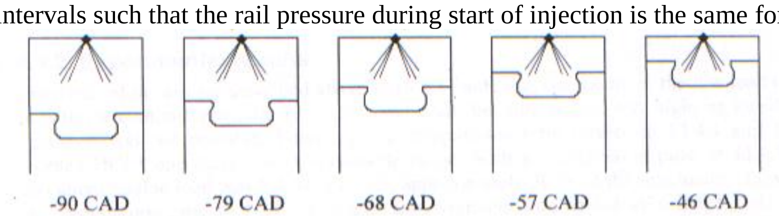

Fig. No.3.Schematic Representation of Injection process

The injection process schematically depicted in fig.3 initially compression ratio of 17 was used but the combustion rate proved to be difficult to control. Large amount of EGR were required to avoid knocking combustion. but excess EGR resulted misfiring[6].leaving a very small operating window for acceptable performance. The compression ratio therefore lowered later the compression ratio was further lowered to allow more variation in operating conditions by controlling the EGR valve. The EGR rate for all readings were adjusted so that the point at which 50% of the total heat was released coincided with TDC as closely as possible.. Advancing the heat released resulted in knock while retarding it resulted in misfire. The EGR was cooled down to the same temperature as the intake air.

IV. EXPERIMENTAL RESULTS AND DISCUSSIONS

The data recorded by various instruments shows that NOx and soot emissions approaches lower by a factor of 28. The measured value were highly scattered for the different engine load. But it should be noted the accuracy of the measuring instrument is limited to these values. The measured NOx concentration was all in 3 to 15 ppm range. The distribution of the fuel over the entire combustion chamber minimizes fuel-rich mixture, which causes soot and Nox emission. The reduced intake charge temperature, which also contributes to the low NOx emission.

The results show that the indicated specific fuel consumption is between 10% t0 15% lower than standard diesel engine, depending upon the load. But under low load conditions, the fuel consumptions increase dramatically. The lower thermal efficiency, due to lower compression ratio is partly responsible for this, but more important factor is the large increase in HC and CO emission is typical for HCCI. Typical reasons for high HC and CO emissions are; misfiring, short combustion duration, improper mixing (causing too rich or too lean mixture), fuel trapping in crevices, spray interaction with the cylinder liner or piston, low gas temperature and high amount of EGR.

V. CONCLUSIONS AND FUTURE WORK

A typical Common rail engine with reduced compression ratio was operated by starting the injection of diesel fuel early during the compression stroke. The combustion rate and phasing could be successfully controlled with the large amount of EGR .It was found that compared to conventional diesel operation, the NOx and soot emissions were reduced by 98% , while the HC and CO emissions increased dramatically. This increase in HC and CO emissions. The fuel consumption reduces to 10 to 15% than the standard diesel mode. HCCI engines have substantially lower emission of PM and NOx, which are the major impediments of CIDI, engines meeting future emission standards. Another advantage of HCCI combustion is its fuel flexibility. Gasoline is particularly well sited for HCCI operation. As per the report of united state congress (2005), The HCCI engines might be commercialized in light duty vehicles by 2010 and by 2015 as much as half million barrels of oil per day may be saved. Because of the need of reduce worldwide fuel consumption, greenhouse gas emissions, there is strong interest in HCCI worldwide. Future work will focus on reducing the HC and CO emissions by optimization the injection strategy and piston design as well as by retarding the start of ignition with a reduced effective compression ratio, in order to allow conventional diesel operation at varying load conditions.

VI. ACKNOWLEDGMENTS

The author would like to thank the following organizations and persons: The KMPL Engines Ltd., Ahmednagar Plant for Technical support and facilities and the technical staff of KMPL engines for their assistance in the preparation of the experimental set up.

REFERENCES

[1]Lida Normans and Yamasaki Yudi , "Combustion Technology for Homogeneous charge Compression Ignition engine" Massachusetts Institute of Technology Publication, 2003

[2]Su.W.Lin,Pei.Y " A Compound technology for HCCI Combustion in a DI Diesel Engine based on multi-plus injection" SAE paper, SAE 2005-01-1743, 2005

[3]Matson,.A., Diesael Particulate Matter Emission: Background, Characterization and Reduction Problem, Licentiate thesis ,Sweden, 2000

[4]Helmental Arjan,Denbratt Ignabat " HCCI Operation of a Common Rail Diesel Engine with early Injection of Conventional Diesel Engine" SAE paper 2005-01-1978, 2005

[5]Harip Sanjay, "Emission Control Technology for Automobile – The HCCI Technology", National Conference on Emerging Technologies and Applications-ETA-2006 at Saurashtra University, Rajkot, 2006

[6]Prof .Sanjay Harip, " The Homogenous Charge Compression Ignition (HCCI) Technology for Perfect Combustion and minimal emission" National Conference on State of The Art Technologies in Mechanical Engineering (STEM 2009), at PantNagar , Uttaranchl.

[7]Prof Sanjay Harip, ," an experimental Analysis of HCCI", National conference on Emerging Trends in Technology, VISION 2011, at Bharti vidyapith, Navi Mumbai on March 11, 2011.