PROJECT SYNOPSIS

ON

HOMOGENOUS CHARGE COMPRESSION IGNITION(HCCI) ENGINE

Submitted in Partial Fulfillment of requirements for the Award of Degree of Bachelor of Technology in Mechanical Engineering

Under the guidance of

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ABSTRACT

To protect the environment and to minimize the effect of pollution on human health, restrictions to follow towards the development of engines become more and more stringent. Now a days the challenges facing are mainly emissions (NOX and soot) and Fuel economy. One solution to this problem is design of the most fuel efficient engines by improving the technology and other is developing environmental friendly internal combustion engine so as to meet the future emission standards. Thus, the main goals of engine researchers to develop engines such as Hybrid vehicles, Fuel cells GDI engines HCCI engines with advanced design simulations by using efficient electronic and electrical devices. Homogeneous Charge Compression Ignition (HCCI) technology engine combustion has potentially highly efficient and to produce low emissions. HCCI engines, it also can have high efficiency as compression-ignition direct-injection (CIDI) engines (an advancement of existing diesel engine), and producing ultra-low oxides of nitrogen (NOx) and particulate matter (PM) emissions.

A homogeneous charge compression ignition (HCCI) engine is similar to a combination of conventional SI engine and diesel engine. Its fuel-air mixture is premixed, as in a conventional SI engine, while its combustion is initiated by self-ignition, which is like diesel engine. Hence it is the combination of the two most popularly used types of I.C engines: homogeneous charge spark ignition (gasoline engines) and stratified charge compression ignition (diesel engines). As in homogeneous charge spark ignition, the fuel and oxidizer are mixed together. However, rather than using an electric discharge to ignite a portion of the mixture, the concentration and temperature of the mixture are raised by compression until the entire mixture reacts spontaneously. Stratified charge compression ignition also relies on temperature increase and concentration resulting from compression, but combustion occurs at the boundary of fuel-air mixing, caused by an injection event, to initiate combustion.

The defining characteristic of HCCI is that the ignition occurs at several places at a time which makes the fuel/air mixture burn nearly simultaneously. There is no direct initiator of combustion. This makes the process inherently challenging to control. The unburned hydrocarbon and carbon monoxide emissions are still high (due to lower peak temperatures), as in gasoline engines, and must still be treated to meet automotive emission regulations.

Brief Introduction

An HCCI engine is a mix of both conventional spark-ignition and diesel compression ignition technology –

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

PROS & CONS of SI & CI:

Now the SI engines use fixed air/fuel ratio, therefore the engine load regulation is made possible only by governing the air mass flow into the combustion chamber. The throttle used for this purpose results in pumping losses and reduction in efficiency. It produces extremely low soot emissions because it uses premixed charge with stoichiometric fuel-air ratio (λ=1), but it also has lower thermal efficiency due to pumping loss and a lower compression ratio (generally in the range of 8 to 12), which is limited by knocking. Hence, SI engines with accurate control of air-fuel ratio and three way catalytic convertors are very clean power producing machines but their efficiency is limited because of throttling, knocking and the lean flammability limits.
In CI engines, only a fraction of the air and fuel is premixed and burns fast, whereas for the larger part of the fuel, the time scale of evaporation, diffusion etc. is more than the chemical time scale. Hence, the air-fuel mixture within the combustion chamber can be divided into two regions- the high fuel concentration regions and the high temperature flame regions. In the fuel rich regions, the rate of soot formation is high due to absence of oxygen (O2). Though, some soot may be oxidized with the increase in in-cylinder temperature. NOx is produced at high rates in the high temperature regions. In a traditional diesel engine, the cylinder temperature is about 2700 K. In the CI engines, there is less pumping loss and the higher efficiency due to higher compression ratio (generally in the range of 12 to 24). CI engines are very efficient power producing machines, but they have a constraint in the form of trade-off between oxides of nitrogen (NOx) and Particulate Matter (PM) emissions. Therefore, it is necessary to keep the maximum cylinder temperature low in order to minimize the NOx emission and also to promote better fuel-air mixing in order to reduce the smoke emissions.

THE AMALGAMATION OF SI & CI (HCCI):

On the other hand, HCCI is characterized by the fact that the fuel and air are mixed before combustion starts and the mixture auto-ignites as a result of the temperature increase in the compression stroke. The resulting spontaneous burn produces a flameless energy release in a large zone almost simultaneously -- very different than the spark/gasoline burn or the compression/diesel burn. The unburned hydrocarbon and carbon monoxide emissions are still high (due to lower peak temperatures), as in gasoline engines, and must still be treated to meet automotive emission regulations.

THE AUTOMOTIVE SCENE –

The homogeneous charge compression ignition (HCCI) engine has caught the attention of automotive and diesel engine manufacturers worldwide because of its potential to rival the high efficiency of diesel engines while keeping Ox and particulate emissions extremely low and the fact that HCCI engines can operate using a variety of fuels. However, researchers must overcome several technical barriers, such as controlling ignition timing, reducing unburned hydrocarbon and carbon monoxide emissions, extending operation to higher loads, and maintaining combustion stability through rapid transients.

NEW DIMENSIONS –

Previous research shows that three-way catalytic converter used in spark ignition (SI) engines could reduce most exhaust pollution, such as HC, CO and NOx, towards achieving exhaust standards but the catalytic converters would not reduce carbon dioxide (CO2), a major cause of global warming effect. Several researches on blends fuel or additives reached the improvements of engine efficiency and emission reduction, such as microalgae biodiesel, butanol, water, H2/O2 mixture, or plasma-enhanced combustion in diesel engines. HCCI has been demonstrated and known for quite some time, as it has a potential practical reality, and made as recent advent of electronic sensors and controls HCCI engine.

CRITERIA	**SI**	**CIDI**	**HCCI**
Fuel	gasoline-like fuel	diesel-like fuel	Flexible fuel
A/F Ratio λ	1	1.2 to 2.2	>1
Mixture preparation	PFI & GDI	DI	DI, PFI
Ignition	Spark ignition	Auto-ignition	Auto-ignition
Combustion Factor	Flame propagation	Mixing rate	Multipoint or spontaneous
Flame	Yes	Yes	No
Combustion temperature	High	Partially high	Relatively low

NOTE:

- HCCI combustion uses a higher compression ratio, lacks a threshold value and has a shorter combustion period and faster combustion rate. Thus, it nearly achieves constant volume combustion and a higher thermal efficiency because of lower combustion temperature and lower radiation loss.

- There is no flame front or flame spread or local regions of excessively high temperature and rich mixture, thereby reducing soot and NOx generation to a very low level.
- Variety of fuel types can be used in this mode of combustion.

Literature Review

HCCI is an alternative and attractive combustion mode for internal combustion engines that offers the potential for high diesel-like efficiencies and dramatic reduction in NOx and PM. HCCI occurs as the result of spontaneous auto-ignition at multiple points throughout the volume of the charge gas and each auto ignition may or may not produce a flame front. In order to control the energy release rate to acceptable levels the engine must be operated with high levels of dilution, exhaust or extra air, which results in significantly reduced pumping losses for SI engines and lower peak burned gas temperature. With appropriately higher compression ratio and less heat loss due to low combustion temperature; the thermal efficiency approaches the levels of CI engines. The low combustion temperature also dramatically reduces NOx emissions [Dickey et al., 1998]. Unlike conventional diesel combustion, the charge is well mixed, so PM emissions can be very low. With increasingly stringent emissions legislation, HCCI is the most promising candidate to solve the emissions problem.

However, some technical issues limit the application of HCCI and require development:

• Combustion phasing – both start of auto ignition and control of combustion rate – perhaps the greatest challenges;
• CO and UHC emissions, resulting from low combustion temperature, particularly at lower load conditions, and from crevices and boundary layer;
• Stability over required operating range;
• High load conditions: detonation and NOx emissions;
• Cold start;
• Transient operation (operating mode transition).

Various research projects are underway for resolving these major technical issues to make it as per the international automobile norms. A few have been listed below –

Lu et al [58] conducted experiments on four cylinder, four stroke, direct injection, diesel engine. One cylinder of the engine was reformed for operating with HCCI combustion using n-heptane as the baseline test fuel. Methanol, ethanol, iso-propanol were selected as suppression additives. The control of ignition timing of HCCI engine using n-heptane by port injection of reaction inhibitors was studied. The effectiveness of inhibition of HCCI combustion with various additives was compared under the same equal ratios of total fuel. The experimental results show that suppression effectiveness increases in the order of isopropanol < ethanol < methanol. But ethanol is the best additive when the operating ranges, indicated thermal efficiency and emissions are considered. The CO emissions strongly depend on the maximum combustion temperature, while HC emissions are mainly dominated by the mole ratio of ethanol to that of total fuel. The simulated results also confirmed the retarding of the ignition timing by ethanol addition to the fuel.

Santoso et al [60] conducted experiments on the single cylinder HCCI engine with electromagnetic variable valve timing (VVT) system. The compression ratio of engine was adjustable in the range of 10 to 16 by changing clearance volume of the cylinder. In the preliminary engine testing process sever knocking was encountered in both the HCCI and CI modes at high compression ratios while HCCI combustion was not sustainable at low compression ratios. The final compression ratio for all the results reported was compromised to be 12.3. The engine behaviours in the transition are illustrated with data obtained from a CI / HCCI dual mode engine which was controlled by an electromagnetic VVT system. Finally controlling the engine operating variables leads to achieve a smooth HCCI combustion at medium loads. The NOx and smoke emissions were reduced significantly for HCCI engine compared with conventional CI engine.

Anil Singh et al [66] conducted experiments on single cylinder engine in HCCI mode using hydrogen as fuel. The engine was a modified 435 cm3 single cylinder, air cooled, direct injection, compression ignition engine. The original diesel fuel injection system was removed and a hydrogen port fuel injection system was added. The piston was modified from the original re-entrant bowl piston to a dish shaped piston, while maintaining the original 21.2:1 compression ratio. The engine speed was maintained constant at 1800 RPM. From the experimental results, they found that the NOx and smoke emissions were reduced.

Zhang et al [67] investigated the effect of valve timing to inlet and exhaust valves of a HCCI engine. The HCCI combustion was achieved by varying the amount of trapped residuals through negative valve overlap on a Ricardo Hydra four-stroke port fuel injection engine fuelled with ethanol. The effect of ethanol on HCCI combustion and emission characteristics at different air-fuel ratios, speeds and valve timings were investigated.

Xingcai et al [68] conducted experiments on a four cylinder, four stroke, direct injection diesel engine. The test fuel diesel was injected in to the intake pipe at the location of approximately 0.35 m upstream to the inlet port by pintle nozzle. The injection timing was fixed at 2850 bTDC. Due to the delaying of the ignition timing by the ethanol addition, the indicated thermal efficiency of HCCI combustion increase [69-71]. Significant reduction of NOx and smoke emissions were observed. However, it was observed from the results that HC and CO emissions were increased.

Statement of the Problem

EMISSIONS:

HCCI operates on lean mixtures the peak temperatures are much lower than SI and diesels. The low peak temperature reduces the formation of NOx. However, the low peak temperatures also lead to incomplete burning of fuel, especially near combustion chamber walls. This leads to high carbon monoxide and hydrocarbon emissions. An oxidizing catalyst can remove the regulated species, because the exhaust is still oxygen-rich.

The system features lower-temperature combustion compared to ordinary gasoline engines, resulting in nearly no NOx emissions. It offers the highest potential heat efficiency among internal-combustion engine systems, leading to projections of major cuts in CO2 emissions. Current HCCI technology allows only a limited range of stable combustion, and expanding that is the challenge ahead.

EFFICIENCY:

HCCI combustion process is highly different from the combustion processes in the SI and CI engines. The reason is that HCCI lacks flame propagation. Hence this new engine concept has a superior potential for achieving high thermal efficiency when compared to the diesel engine having the efficiency which exceeds 40%.

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