EXPERIMENTAL ANALYSIS OF HOMOGENEOUS CHARGE COMPRESSION IGNITION MODE COMBUSTION

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Abstract: The advent of stringent emission norms and depletion of fossil fuel resources led the engineers to work out new combustion technologies to substantially reduce harmful emission and to improve the overall efficiency of an IC Engine. Factors to be considered while designing a new combustion process are higher compression ratio, lean homogeneous air fuel mixture and complete combustion and instantaneous combustion, which leads to Homogeneous Charge Compression Ignition (HCCI). HCCI is a clean and efficient combustion process. In this paper an attempt is made to experimentally analyze the performance and emission characteristics of HCCI compression process taking place in Premixed Charge Compression Ignition (PCCI) mode assisted with Pilot Injection as combustion initiator.

Keywords: Analysis, Homogeneous Charge, Compression, Ignition.

1.0 INTRODUCTION:

Homogeneous Charge Compression Ignition (HCCI):

To minimize the magnitude of deviation from the ideal cycle and to comply with future emission norms the best features of SI and CI engine combustion can be coupled to obtain a LEAN BURNING HYBRID COMBUSTION MODE KNOWN AS HOMOGENOUS CHARGE COMPRESSION IGNITION in which the combustion takes place spontaneously and homogenously. It is a form of combustion process which capitalizes upon the advantages of higher compression ratio, lean homogenous air fuel mixture, lower combustion temperature and instantaneous combustion to achieve

- Higher thermal efficiency
- Higher fuel conversion efficiency
- Very low concentrations of pollution components
- High efficiency during part and full load operating conditions
- Low Specific fuel consumption
- Shorter combustion duration

In HCCI combustion well mixed fuel and oxidizer (typically air) are compressed to the point of auto-ignition controlled by means of a combustion initiator. As in other forms of combustion, this exothermic reaction releases chemical energy into a sensible form that can be translated by an engine into work and heat.

Since the HCCI combustion process employs homogeneous charge like that of a spark ignited engine and compression ignition like that of a diesel engine it inherits the best of petrol and diesel engine combustion process 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 density and temperature of the mixture are raised by compression until the entire mixture reacts spontaneously. Stratified charge compression ignition also relies on 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 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. 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 (NO_x) without after treatment catalytic converter. 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

HCCI engines have a long history, even though HCCI has not been as widely implemented as spark ignition or diesel injection. 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.

Since obtaining very lean homogenous mixture is hard, it becomes difficult to sustain HCCI mode over the operating range of varying speeds and loads, to effectively control the HCCI combustion over the operating range a modified form of homogenous charge compression ignition mode combustion known as PREMIXED CHARGE COMPRESSION IGNITION-DIRECT INJECTION (PREMIXED COMPRESSION IGNITION-DIRECT INJECTION) can be used. The major advantage of PCCI-DI mode combustion over that of HCCI mode combustion is that , after achieving homogenous charge PCCI-DI mode combustion employs a pilot injection as the combustion initiator there by establishing a effective control over the combustion in variable load and speed. Although all the inherit characteristics of HCCI mode combustion cannot be obtained in this mode of combustion, it still performs better than the conventional mode of combustion.

Variable Exhaust Gas Recirculation

Exhaust gas can be very hot if retained or re-inducted from the previous combustion cycle or cool if re-circulated through the intake as in conventional EGR systems. The exhaust has dual effects on HCCI combustion. It dilutes the fresh charge, delaying ignition and reducing the chemical energy and engine work. Hot combustion products conversely will increase the temperature of the gases in the cylinder and advance ignition.

2.0 VARIABLE VALVE TIMING:

Variable valve actuation (VVA) has been proven to extend the HCCI operating region by giving finer control over the temperature-pressure-time history within the combustion chamber. VVA can achieve this via two distinct methods:

1. Controlling the effective compression ratio: A variable duration VVA system on intake can control the point at which the intake valve closes. If this is retarded past bottom dead center (BDC), then the compression ratio will change, altering the in-cylinder pressure-time history prior to combustion.
2. Controlling the amount of hot exhaust gas retained in the combustion chamber: A VVA system can be used to control the amount of hot internal exhaust gas recirculation (EGR) within the combustion chamber. This can be achieved with several methods, including valve re-opening and changes in valve overlap. By balancing the percentage of cooled external EGR with the hot internal EGR generated by a VVA system, it may be possible to control the in-cylinder temperature.

Whilst electro-hydraulic and cam less VVA systems can be used to give a great deal of control over the valve event, the component for such systems is currently complicated and expensive.

Mechanical variable lift and duration systems, however, whilst still being more complex than a standard valve train, are far cheaper and less complicated. If the desired VVA characteristic is known, then it is relatively simple to configure such systems to achieve the necessary control over the valve lift curve.

3. 0 TRANSIENT STATE FUEL INDUCTION:

The way in which the combustion proceeds is greatly influenced by the IGNITION DELAY PERIOD. Ignition delay varies dynamically according to the in cylinder conditions. The non homogeneity of charge varies the ignition delay in such a way that it advances or postpones the combustion this in turn distributes the combustion over a period. In the meantime the fuel stays idly in the fuel line termed as RETENTION PERIOD .If we effectively utilize this period to interface the fuel with the in cylinder condition a part of pre flame reaction can be completed which reduces the ignition delay. The main purpose of our system is to establish a bridge which effectively interfaces the in-cylinder condition with the fuel there by establishing a more effective means to achieve sustainable combustion in a controlled fashion.

It is known that obtaining homogenous charge with uniform air fuel ratio is crucial to control the combustion; this system aims to obtain homogenous charge by induction the fuel in a transient state. Since only air and vapor can form perfectly homogenous mixture, in this system the fuel is injected in to the manifold at a temperature close to the flash point of the fuel being used in a stream of heated air being inducted the fuel instantly vaporizes and produces a homogenous charge. Given that the system is employed in direct injection diesel engine the in-cylinder swirl and squish motion of the air enhances the mixture formation. The heat energy required to heat the fuel and air can be obtained from the exhaust and the cooling water which are wasted.

3.0 EXPERIMENTAL SETUP:

The engine which we used for our testing purpose was a single cylinder DI engine (Agricultural type water cooled) which is fitted to a brake drum dynamometer. The engine specifications are, it is a Water-cooled, Vertical, 4 stroke cycle, direct injection, naturally aspirated. Gravity feed fuel system with efficient Paper element filter, Force Feed Lubrication to main and large end bearings and camshaft bush, Suitable for run- through or Thermosyphon cooling.

The fuel is heated by means of a 1000watts water bath provided with an electrical thermostat which enabled us to maintain the fuel at the desired temperature. The maximum fuel temperature that can be achieved using our set up is 75 deg c. In case of diesel we maintained the temperature at 55 deg c, and in case of bio-diesel we maintained the temperature at 75 deg c.

The air is heated by means of 800watts air heater placed in inlet manifold. The air temperature is maintained by means of a electrical thermostat to a maximum of about 80 deg c.

The fuel is injected in to manifold using an electronic fuel pump through a fuel injector mounted on the inlet manifold whose spray angle is 30 deg c, the fuel line pressure is maintained at 6 bars. The current rating of the fuel injection pump that we have used is 20 ampere and that of the fuel injector is 0.3 ampere.

5.0 DIESEL BIODIESEL PCCI-DI MODE COMBUSTION:

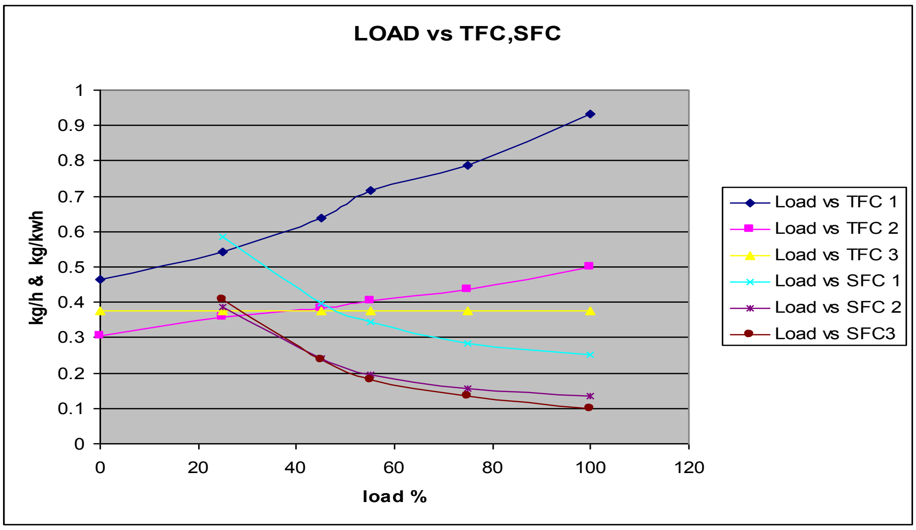

Figure.1

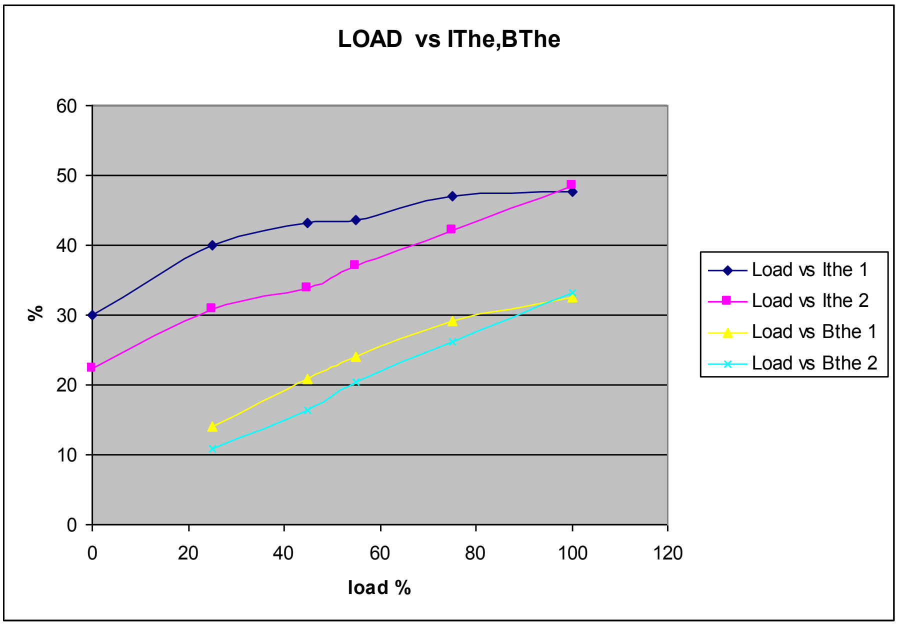

Figure.2

6.0 BIODIESEL PETROL PCCI-DI MODE COMBUSTION:

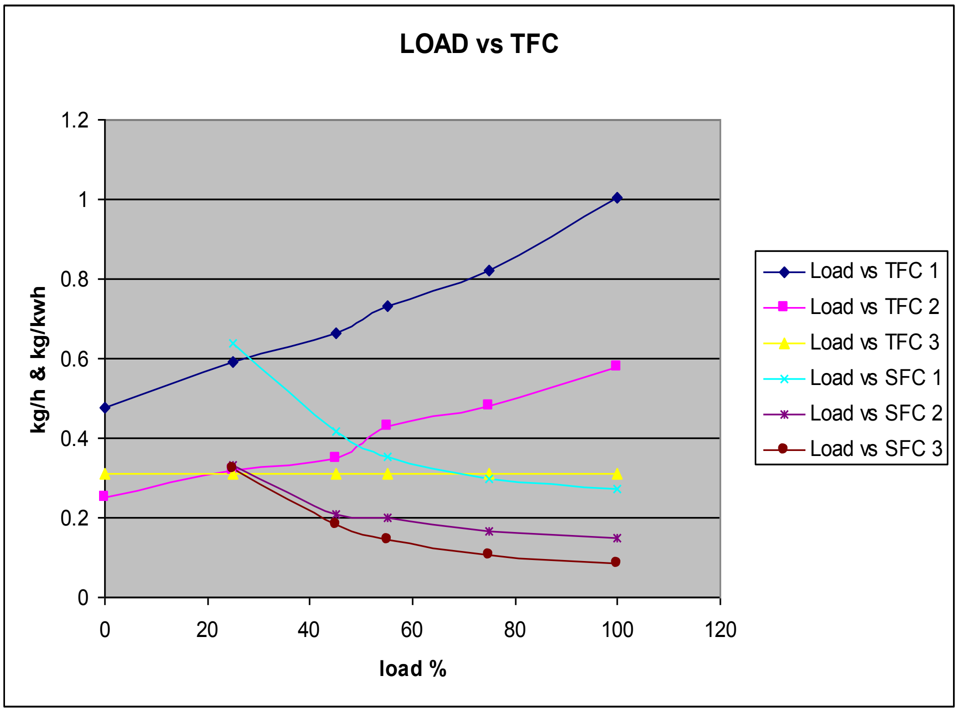

Figure.3

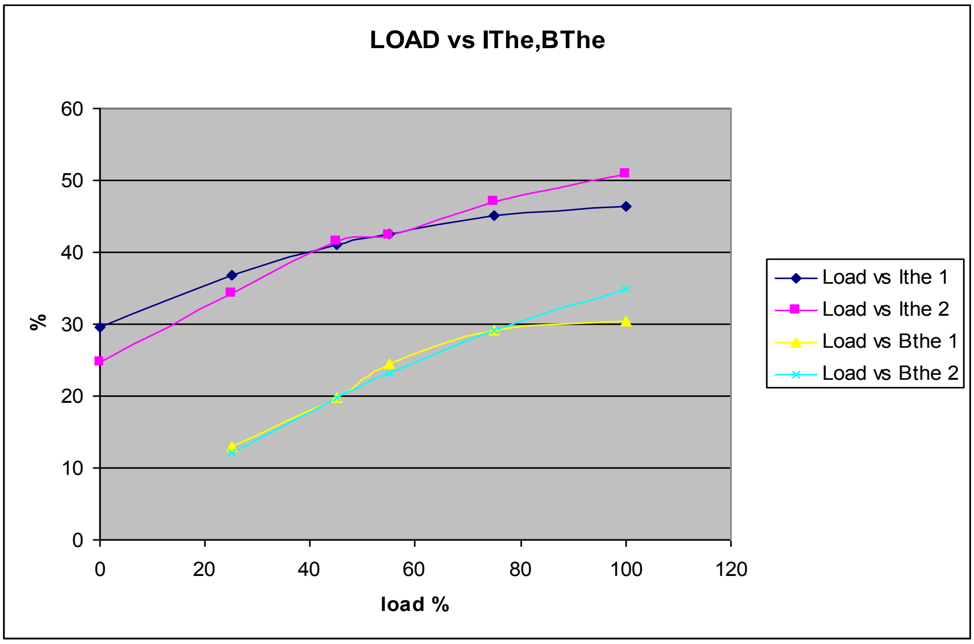

Figure.4

7.0 CONCLUSION:

Based on the above mentioned result we conclude that HCCI mode combustion process achieved by us in PCCI-DI mode is effectively increased the brake thermal efficiency and reduced the pollutant to a great extent.

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