HCCI COMBUSTION (HOMOGENEOUS CHARGE COMBUSTION IGNITION)

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Abstract: Engine is the heart of automobile. Engine is the device that coverts heat energy of the fuel into mechanical energy. HCCI stands on homogeneous charge compression ignition. HCCI engine is an advanced combustion engine. In a HCCI concept, the fuel and air is pre mixed and compresses till auto ignition. It is developed to increase the fuel efficiency and reduce the emissions such as NOx and HC without sacrificing the efficiency such as NOx and HC. In HCCI engine homogeneous mixture of air and fuel is the key feature. HCCI engines allow Lean mixture of air and fuel. Hence it helps to reduce the NOx emission because lean mixture is cooler and cooler combustion makes less NOx and wastes less energy heating up the engine. HCCI engine have several difficulties such as, control of auto ignition, it producing heat more and weak capability in cold start. After studying the literature survey on HCCI engine, research work needs to be done in this area because HCCI engine is the environment friendly combustion.

Introduction:

A word "Greenhouse effect" is worldwide issue since so many years before. It warms the earth's surface, unstable weather rising ocean levels. It leads the global climate change. It is because of CO2 and the emissions emits from the vehicles and industries. Although electric and hybrid cars hit the market but still IC engines are most important power plant in automobile sector.

Compression ignition (CI) and spark ignition (SI) engines are two basic technologies used in automobile sector. in SI engine, both air and fuel mixture enters into the combustion chamber in suction stroke but in CI engine only air enters into the combustion chamber in suction stroke. Si engine uses spark plug to ignite the mixture and diesel engine uses fuel injector to ignite. A comparison between petrol and diesel engines is petro engine is equipped with catalytic converter provides low emission but lack in efficiency. On the other hand diesel engine provides high energy and also produces high emissions of NOx.

In order to avoid these problems, researchers start researching on HCCI combustion.

HCCI engine, homogeneous mixture of fuel and air are compressed to the point of auto ignition. It neither has a spark plug like gasoline engine nor has a fuel injector like diesel engine. it gives the 30 % more efficiency than conventional gasoline SI engine. It allows the lean mixture. HCCI engine can operate on gasoline engine, diesel engine and most alternate fuels.

HCCI engine has been gaining more importance due to reduction of emission such as NOx and HC.

Historical outline of HCCI engine:

It was first discovered by Onishi in 1979 as an alternative way for two stroke engines. This is completely new type of combustion introduced the piston engines. The demerits of two stroke engines producing high residuals emissions at low and partial load and knocking effect when the engine is stopped. So Onishi and his co-workers devising a combustion mode that relied on both high levels of internal residuals and high initial charge temperature. After Onishi presentation the same combustion process was demonstrated at Toyota. It was discovered that HCCI combustion is well suited for two stroke engine at part load condition. It was proposed that combustion in HCCI engines is extremely smooth and less fuel consumption as well as low exhaust emission. In 1983 the first four

stroke engine in HCCI mode was tasted. And the experiments were performed with blends of paraffinic and aromatic fuels over the range of engine speed. This process was analyzed, by considering HCCI is mainly controlled by chemical kinetics. After research has been further extended in 1989. Experiments were done on the engine using conventional SI operation at high loads and HCCI at part loads. Experiments were made also on four stroke engine. The performance of the HCCI engine operated with blended gasoline and diesel fuel with combination of λ and EGR were examined. Experiments were performed on HCCI combustion process in order study the effect of turbulence in 2002. One of the smallest automakers planes to introduce HCCI engine in Mazda 3.

Difference among SI, CI and HCCI engines :

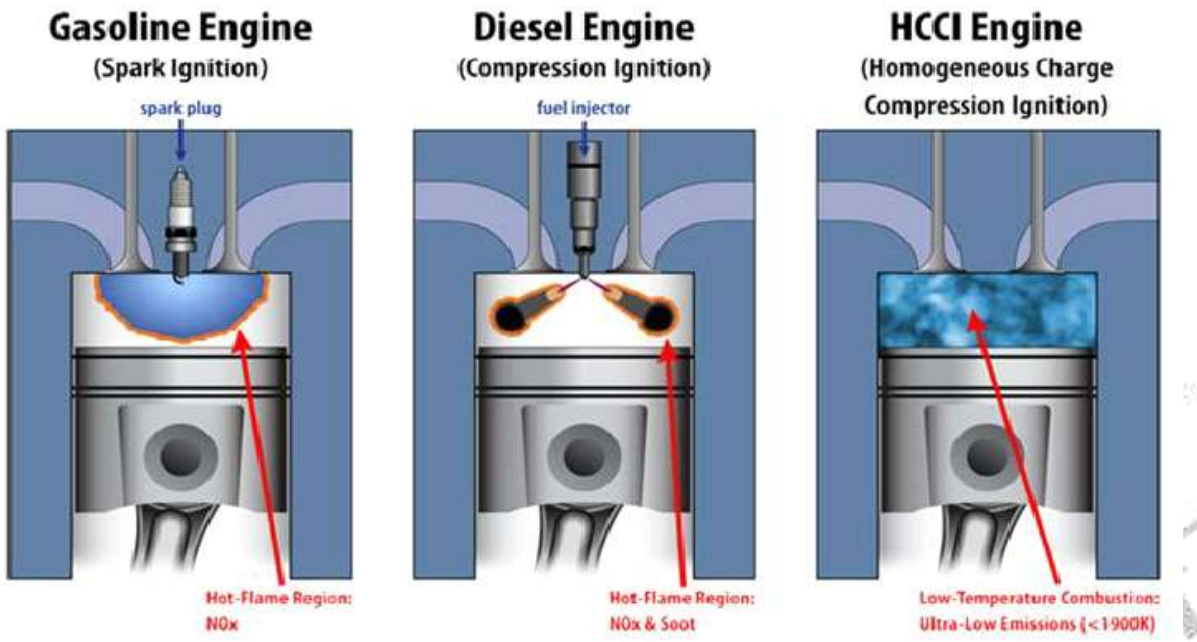

Figure 1: comparison among gasoline engine, diesel engine and Mazda HCCI

Figure 1 showing the differences among SI, CI and HCCI engines. SI engine have Spark plug to initiate the combustion, CI engines have fuel injector to inject fuel and combustion takes place in a compressed hot air region**.** HCCI engines have no spark plug and fuel injector and combustion starts spontaneously in multiple locations. In HCCI combustion, a homogeneous mixture of air and fuel is compressed until auto ignition occurs near the end of the compression stroke that is significantly faster than either CI or SI combustion

Comparison of traditional combustion modes and HCCI combustion.

	SI	DICI	HCCI
Fuel	Gasoline-like fuels	Diesel-like fuels	Flexible fuel
λ	≈1.0	=1.2–2.2	>1.0
Mixture preparation	PFI, GDI	DI	DI, PFI, and DI + PFI
Ignition	Spark ignition	Auto-ignition	Auto-ignition
Combustion form	Premixed	Diffusion	Premixed but dominated by chemical kinetics
Combustion rate limitation	Flame propogation	Mixing rate	Multipoint or spontaneous
Flame front	Y	Y	w/o
Combustion temperature	High	Partially high	Relatively low

Working principle of HCCI Combustion:

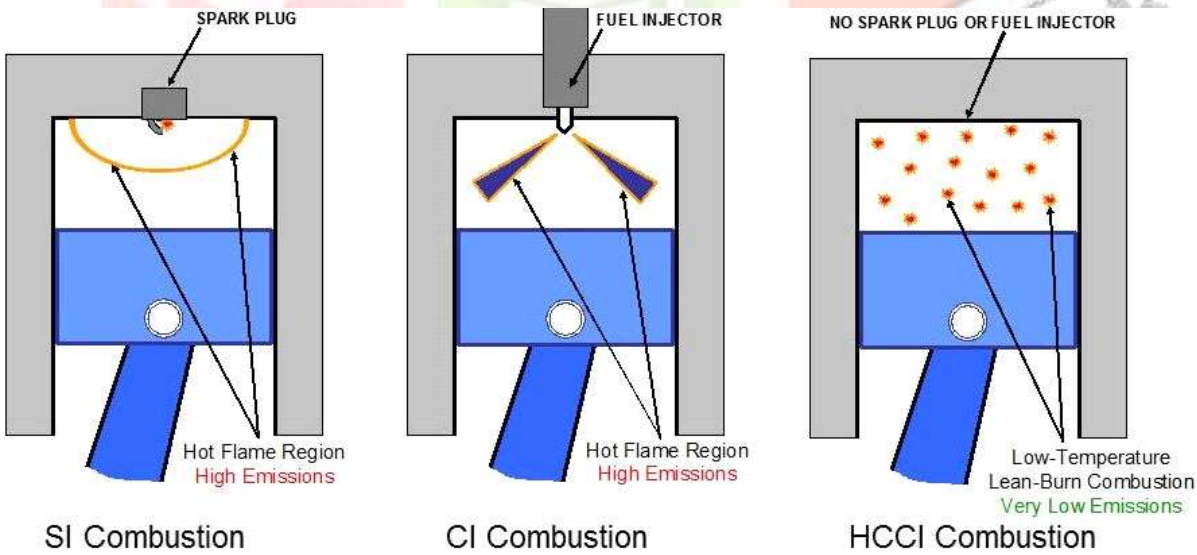

Figure 2: Showing the principle of SI, CI and HCCI

HCCI engine uses lean mixture, HCCI engine is different from other conventional combustion concepts such as CI and SI engines. It uses Homogeneous charge. During suction stroke, Homogeneous charge is drawn into the cylinder and in compression stroke homogeneous charge compressed to high pressure and temperature. During power stroke, the entire homogeneous charge gets burned simultaneously and producing power. In exhaust stroke, exhaust gases passing out from outlet valve. But before all of the exhaust valve can be evacuated, the exhaust valve gets closed early, trapping some of the latent combustion heat

HCCI experiments:

Figure 3: Volkswagen TDI converted to HCCI mode

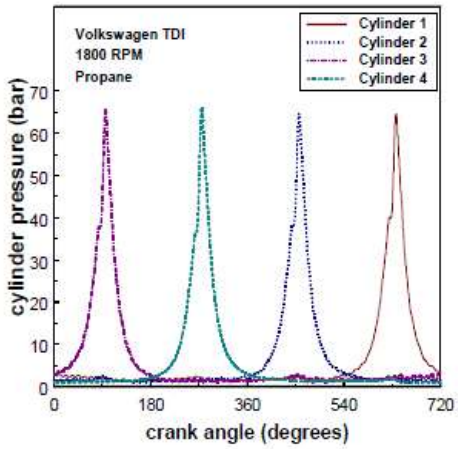

Figure 4: pressure traces for Volkswagen TDI 4 cylinder engine operating in HCCI mode

The various experiments being done on HCCI combustion. First experiment was done on CFR engine. CFR engine is a rugged engine and it has variable compression ratio. After conducting of experiments a very good results got with experimental and numerical results. Next experiments was done on 4 cylinder Volkswagen TDI engine operating in HCCI mode (fig 3) this cylinder has operated in multi cylinder HCCI mode since 1999(pressure traces shown in fig 4) working of HCCI engine in multi cylinder is more difficult than single cylinder because it is very sensitive to temperature. Temperature difference from one cylinder to other cylinder can cause colder cylinder to misfire and hotter cylinder to ignite early. Experiments were done to find out control strategy over a wide range of speed and load condition.

Figure 5 and 6 showing the results that have been found on TDI engine the experiments is conducted with propane fuel and monitored the engine performance, combustion process and emissions for variations in intake temperature and fuel flow rate.

Figure 5 showing the brake mean effective pressure (BMEP) versus intake manifold temperature. Ranges of BMEP from 0.8 bar to 3.3 bar. Idle means 0 bar BMEP operating point occurs at 0.34g/s fuel flow rate and an intake temperature about 130 °C and combustion efficiency at this idle point is about 75%. The emission of CO is very high that cant acceptable. At higher load operating points, lower intake temperature results in higher BMEP. The brake mean effective pressure obtained for 0.65, 0.72 and 0.83g/s conditions ranges from less than zero to 25% and maximum indicated thermal efficiency is 32%.

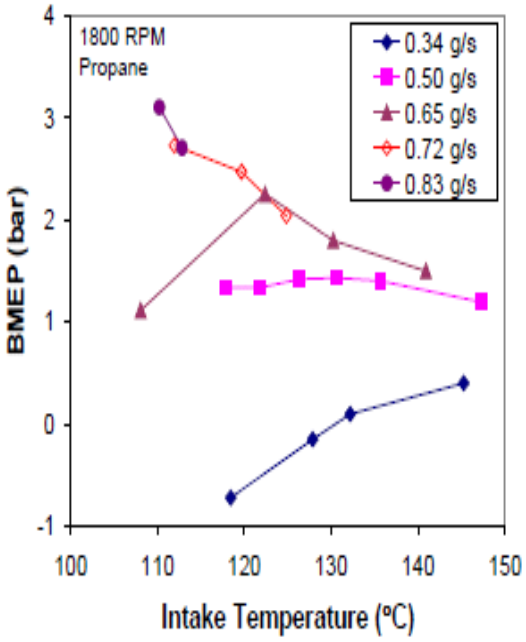

Fig (5)
BMEP vs. intake manifold temperature For Volkswagen TDI operating over wide range of intake temperature and fuel flow rate

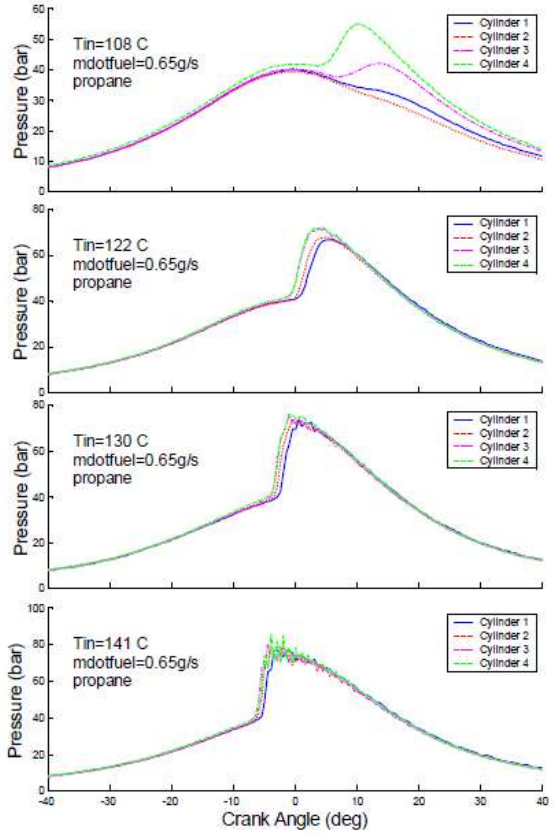

Fig (6)
Pressure traces for four different intake manifold Temperature at 0.65 fuel flow rate for the Volkswagen

Figure 6 showing the pressure traces for four different intake manifold temperatures at 0.65 fuel flow rate for propane fuel in HCCI mode. The lowest temperature operating point, 108ºC intake temperature operations can be seen to be inconsistent between the cylinders; operation around the lower limits is very tenuous. If slight change in cooing water temperature, oil temperature and compression ratio, intake manifold temperature could significant change in combustion process.

At highest temperature nearly 141ºC it shows little difference between cylinder pressure traces, combustion process happens in advance, and significant pressure oscillation observed.

After experiment was performed in caterpillar 3401 engine that has been converted to HCCI mode. Caterpillar engine used in heavy trucks. The pressure measurements of in-line cylinder allows direct comparison with HCT simulations of the start of the combustion, heat release rate, IMEP and also engine emission rate. Experiments were performed with a wide range of operating conditions with multiple fuels such as methane, propane and natural gas to analyze engine performance

MAZDA 3 HCCI: Japanese automaker Mazda motor will introduce HCCI at the end of 2018. That offers nearly 30% fuel efficiency by pressure. Charge will not ignite by spark plug. Mazda plans to introduce HCCI engine in the new Mazda 3.

Advantages of HCCI Combustion:

HCCI can operate on gasoline, diesel and other alternate fuels. HCCI combustion employs higher compression ratio and features shorter combustion duration and a fast combustion rate. It approximates constant volume process and hence archives maximum

thermal efficiency. It uses lean mixture hence it cools the combustion so cooler combustion produce less emissions and it wastes less energy. Spark ignition engines are fitted with three way catalyst and can be regarded as clean engine. But the problems occurs during part load condition. But at partial load efficiency becomes low because of pumping losses. And SI engines produces large amount of CO2 which is responsible for greenhouse effect.

Diesel engines are using in cars, trucks, heavy machineries and as well as in ship. CI engine is exactly opposite to SI engine. CI engine has no pump losses and thereby achieving high part load efficiency. But the diesel engines are struggling with emission like smoke, NOx and Hydrocarbons. Smoke is produced due to rich region of combustion area and NOx produced due to High temperature burned gas region.

But in comparison with SI and CI engine, HCCI engine has higher part load efficiency, low NOx emission; HCCI had excellent low fuel consumption.

But in HCCI, the control of combustion is more challenging than SI and CI engine

Conclusion:

This paper presents history, experiments done, comparison and advantages of HCCI combustion. HCCI engines are more efficient than SI and CI engines. Lower emissions of NOx and HC. HCCI combustion has fuel flexibility; it can operate by gasoline, diesel and other alternate fuel. But the control of HCCI combustion is basically more challenge than using spark plug and fuel injector to dictate ignition timing as in SI and CIDI engine. Apart from this HCCI engine have more benefits. It is help full for “Go Green” and 15 to 20% thermal efficiency can be achieved.

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