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Experimental Investigation on Performance and emission characteristics of HCCI Engine fueled with diesel and Jatropha Bio-Diesel

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ABSTRACT

Pollution is a major issue worldwide. In that, pollution from automobile exhaust emission is the major concern due to HC, CO and NOx emission gives hazardous effect on environment. Current pollution and strict pollution norms reducing exhaust emissions and increasing the fuel economy of internal combustion engines. To overcome these issues a technology is needed to be developed and HCCI is such a technology, which is highly efficient as well as less polluting. HCCI is a hybrid of both spark ignition (SI) and compression ignition (CI) combustion concepts. It is also need of replacement of convectional fuel like petrol and diesel with alternative fuels. HCCI engine fueled with biodiesel can be address both issues with alternation of convectional fuel with alternative fuels. By HCCI, it can achieve both homogeneous charging with high compression ratio. Homogeneous charge reduces HC and carbon shoot emission while higher compression ratio gives higher thermal efficiency. Present work is focused on performance and emission characteristics of HCCI engine fueled with Jatropha biodiesel.

Introduction

Demand for petroleum products is increasing day-by-day however the resources are fairly limited. Also, there is increase in the environmental pollution specially pollution from the automotive/engine exhaust. Due to known hazardous effect of environment pollution and strict pollution norms reducing exhaust emissions and increasing the fuel economy of internal combustion engines have found global importance. Therefore, to overcome these issues a technology is needed to be developed and HCCI is such a technology, which is highly efficient as well as less polluting. HCCI is a hybrid of both spark ignition (SI) and compression ignition (CI) combustion concepts [1]. HCCI engines operates with the compression ignition of homogeneous charge formed by premixing air and fuel mixtures through early injection on to the hot surface of a heated chamber known to be the vaporizer. Engine is operated in the region of lower equivalence ratios to improve efficiency and reduce emissions. Due to the increase in vehicle population, the lean combustion technology is to be employed and it is mainly to be adapted in IC engines as these engines are widely in use [2]. The NOx emission can be reduced only by reducing the flame temperature of combustion and lean burn engines produce lower temperatures so that it reduces the formation of thermal oxides of nitrogen [3]. The excess air employed in lean burning results in a more complete combustion of the fuel which reduces both the hydrocarbon and carbon monoxide emissions [4].

HCCI also has some challenges during its effective adaption. The main challenge during use of HCCI is to overcome the lack of controls for the combustion process. Hence a complete electronic control system is needed in case for effective adaption of HCCI technique. HCCI operating points are unstable i.e., it is impossible to map an HCCI engine reliably. Some small changes in any engine parameter, for example, intake temperature, compression ratio or even coolant temperature, will have a large impact on the combustion timing. Thus, closed loop combustion control is necessary to guarantee correct combustion timing.

Bio-Diesel

Biodiesel which has combustion characteristics similar to diesel and biodiesel blends have shorter ignition delay, higher ignition temperature and pressure as well as peak heat release compared to diesel fuel. Moreover, the engine power output and brake power efficiency was found to be equivalent to diesel fuel. Biodiesel and diesel blends can reduce smoke opacity, particulate matters, un-burnt hydrocarbons, carbon dioxide and carbon monoxide emissions but nitrous monoxide emissions get slightly increased when used in a conventional engine.

Biodiesel HCCI is a new area of research because it combines advantages of both biodiesel and HCCI combustion. Main advantage of burning biodiesel in HCCI combustion mode is simultaneous reduction of NOx and soot, as well as reduction of fossil CO2 emissions. In HCCI mode, biodiesel combustion happens at significantly lower in-cylinder temperature, therefore it reduces NOx emissions. Biodiesel HCCI also enhances the fuel efficiency because of combustion of ultra-lean mixtures in HCCI.

Experimental setup and methodology

The engine used in the study was a vertical, single cylinder, water-cooled, four stroke diesel engine. The engine was coupled to an eddy current dynamometer to measure the engine output power. Burette was used to measure fuel consumption of diesel and weigh scale for measuring the amount of consumption in vaporizer system. Proximity sensor calibrated by digital tachometer is used to measure the speed of engine. The temperature was measured with the help of temperature sensor LM35. Exhaust gas analyzer is used for measuring HC (ppm), NO (ppm), CO (% by vol.), CO2 (%by vol.) and O2 (% by vol.).

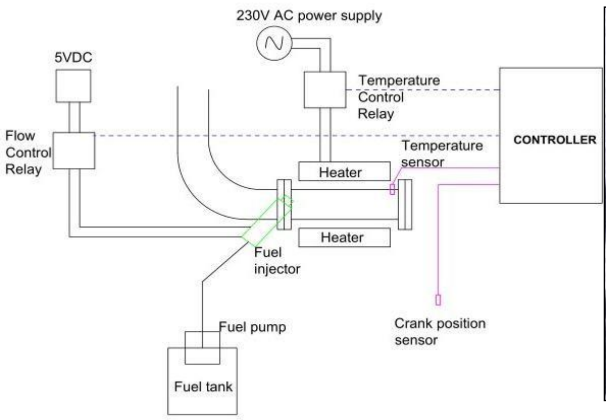
Figure 1:Experimental setup of HCCI engine testing

The experimental setup consists of engine, fuel vaporizer, fuel injection system, data acquisition system; and also, emission measurement system. The modifications are done near the engine intake system.

Table 1: Test engine specification

Engine	Kirloskar
Dynamometer	Eddy current, water cooled
Bore (mm)	87.5
Stroke (mm)	110
Displacement (cm^3)	661
Compression ratio	17.5:1
RPM	1500
H.P.	5.2

The fuel vaporizer connects with engine intake system. Vaporizer consists of a main vaporizing chamber made of copper tube. Copper is selected as material of construction (MOC) due to its high thermal conductivity. External surface of the main vaporizing chamber is covered by an electric band heater (ceramic) to generate enough heat for vaporization of fuel. For the fuel supply, the fuel injection system of the HCCI engine consists of a fuel pump, fuel tank, fuel injector and an injector control circuit. Fuel pump supplies the fuel from the tank to the fuel injector. Fuel injector operates on a 12 V TTL. When the receiver receives the optical rays passing through the window of the pulley and hence gives signal to the main injector to inject fuel for the defined time in to the vaporizer surface. The angle of injection can be varied by changing the position of the pulley window by rotating it and then fixing pulley with respect to TDC.



(a) Schematic diagram of fuel evaporator

(b) Photograph of fuel evaporator

Figure 2: Fuel evaporator of HCCI engine

Table 2: Technical Specifications of the Fuel Vaporizer

Heater power	500 W
Vaporizing chamber diameter	38 mm
Vaporizing chamber length	150 mm
Fuel injection pressure	5.0 bar

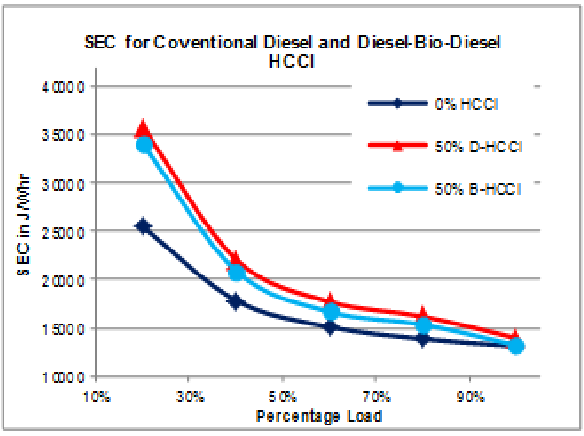
Table 3: Properties of Diesel and Jatropha Bio-Diesel

Fuel Property	Jatropha	Diesel
Density (gm/cc)	0.920	0.860
Boiling point, °C	124	188-343
Kinetic Viscosity, cst (@40°C)	5.043	2-4
Calorific Value, kJ/kg	39,570	42,000
Flash point, °C	143	55
Autoignition Temp. °C	210	316
Cetane number	32	51

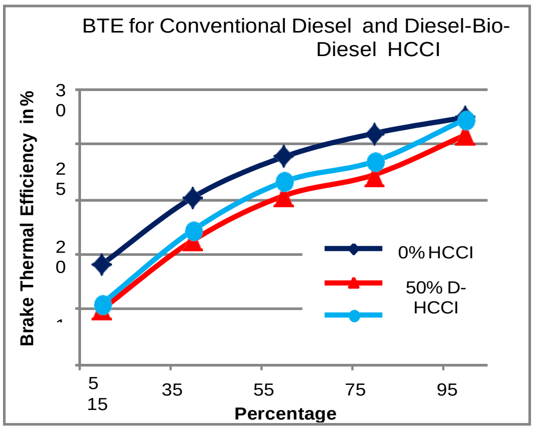
Results and discussion

The Observations plotted as graphs are as shown below in the figures and The consideration is about Conventional Diesel Engine and HCCI engine with 50% Diesel HCCI and also with 50% Bio-Diesel HCCI. The performance is analysed in terms of Brake Specific Fuel Consumption (BSEC), Brake Thermal Efficiency (BTE) and Volumetric Efficiency. The Brake Specific fuel consumtion is lower for Bio-diesel HCCI when compared to Diesel HCCI. Thus the BTE being higher for Bio-Diesel HCCI at lower loads when considerd only HCCI engine. But Bio-Diesel HCCI efficiency is lower than the conventional Diesel engine BTE at lower loads and then as load approaches the rated load, the BTE tends to be increase and reaches values higher than the conventional diesel BTE as seen in the figure 3.

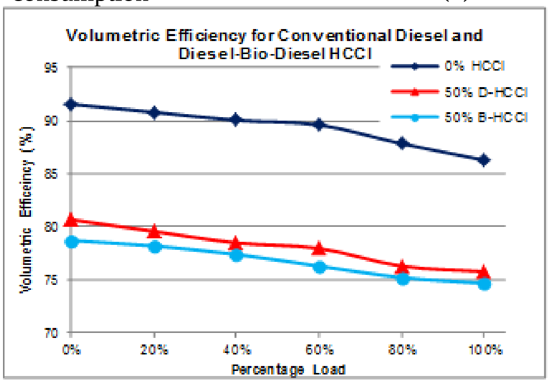
The volumetric efficiency of the HCCI engine is lower than the conventional engine due to the volume of air displaced by the fuel vapor during suction stroke of the HCCI engine.



(a) Specific energy consumption



(b) Brake thermal efficiency

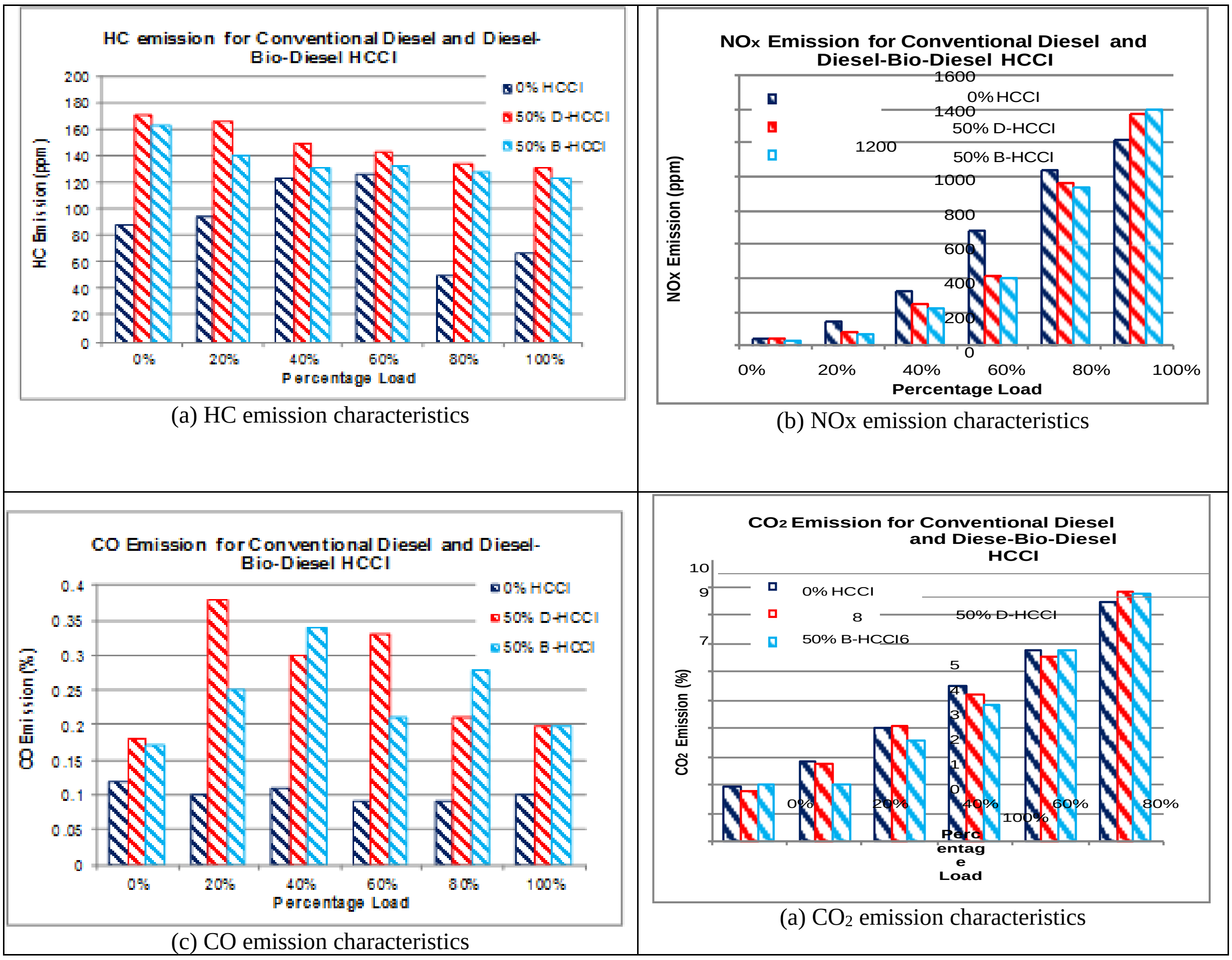


(c) Volumetric Efficiency

Figure 3: Performance characteristics of HCCI engine fuelled with Bio-diesel and Diesel

When emissions are considered, the HCCI engine produces higher HC emissions than the conventional diesel engine as shown in figure 4(a). As seen from the observation, the HC emission of HCCI engine is higher but the Bio-diesel HCCI has lower HC emission than that of the Diesel HCCI.

On the other hand, the NOx emission is lower for a HCCI engine than the conventional one. The NOx emission of Bio-Diesel HCCI is the lowest as seen in the figure 4(b).



(a) HC emission characteristics

(b) NOx emission characteristics

(c) CO emission characteristics

(a) CO_2 emission characteristics

Figure 2: Emission characteristics of HCCI engine fuelled with Bio-diesel and Diesel

When CO and CO_2 emissions are considered, the CO emission tends to increase and CO_2 emission tends to reduce a little with HCCI adaption as shown in figure 8 and 9. The CO_2 emission reduction is very low and hence shows that there is not much reduction in conversion of CO to CO_2. Thus, almost oxidation rate of CO to CO_2 does not vary much as seen in figure 9.

Conclusion

The Observations from the experiment involving conventional diesel engine and HCCCI engine with 50% Diesel HCCI and also 50% Bio-diesel HCCI leads to the following result and conclusion:

- The BSEC reduces with HCCI mode for when the set load is nearly at rated load condition. The lower BSEC occurs forBio-Diesel HCCI.
- The BTE is lower for HCCI engine at lower loads. At about the rated load condition, the Bio-Diesel HCCI BTE is the highest when compared to both Diesel HCCI and conventional Diesel HCCI.
- The emissions like NOx and soot is reduced with HCCI mode of operation and these emissions being least for Bio-Diesel HCCI.
- The HC and CO emission is higher with HCCI technique adaption. BUT when HCCI is considered, the Bio-Diesel HCCI provides lower HC and CO than the Diesel HCCI.

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