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EMISSION AND PERFORMANCE CHARACTERISTIC OF A PCCI-DI ENGINE FUELD WITH COTTON SEED OIL BIO-DIESEL BLENDS

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ABSTRACT

In this research work, experimental studies have been carried out on emission and performance characteristics of a pre-mixed charge compression ignition (PCCI) setup using cotton seed bio-diesel blends. Port fuel injection strategy is the basic concept of PCCI engine. Bio-diesel was used in PCCI engine for further reduction in emissions. Bio-diesel was produced by trans-esterification process. Cottonseed oil (CSO) was selected for biodiesel production. The experiment was conducted with PCCI setup using diesel-diesel, blends of bio-diesel with varying percentage from 10% to 30% by volume. The experiments were conducted in PCCI setup with bio-diesel blends and compared with conventional diesel mode of operation. The experimental results showed that there was decrease in carbon monoxide (CO), nitrogen-oxide (NO_x) and increased hydrocarbon (HC) emissions. There was a reduction in smoke emission and increase in brake specific fuel consumption (BSFC) with increase in blends of bio-diesel in PCCI modes.

Keywords: diesel engine, PCCI, cotton seed bio-diesel, emissions.

Nomenclature

CO	-Carbon monoxide
CO_2	-Carbon dioxide
HC	-Hydrocarbons
NO_X	-Nitrous oxides
PCCI	-Pre-mixed Charge Compression Ignition
BSFC	-Brake Specific Fuel Consumption
ppm	-parts per million

1. INTRODUCTION

Diesel engines are widely used for their efficiency as well as for low fuel consumption. These engines are widely used in transportation and power generation sectors for their fuel efficiency. But emissions from diesel engine include nitrogen oxides (NO_x), particulate matter (PM) and unburned hydrocarbons (HC) and to a small extent carbon monoxide (CO) which causes environmental pollution and number of health issues for living beings [1]. Simultaneous reduction of NOx and PM is one of the main challenges it faces. The stringent emission norms have been increasing for the regulation of emission from diesel engines [2]. To regulate the emissions standards various methods are introduced this include various after treatment systems and alternate mode of combustion are used. Some of the new combustion concepts are Homogeneous charge compression ignition (HCCI), Pre-mixed charge compression ignition (PCCI), Reactivity controlled compression ignition (RCCI) etc. are used in CI engines to reduce the pollution levels. Pre-mixed combustion in CI engine is used to reduce simultaneously NO_x and particulate emission [3]. The simplest method of achieving least NO_x and soot emissions is by HCCI combustion. But the controllability problem and the high pressure rates are required when compared over conventional diesel engine [4]. Hence studies for (PCCI) Pre-mixed charge compression ignition combustion engines were made. This combustion is between HCCI and conventional CI combustions. PCCI engine is a good alternative to existing engines due to its ability to reduce NO_x and soot formation. But high level of carbon-monoxide (CO) and unburned hydrocarbon (HC) emissions are produced [5-10]. In this engine a pre-mixed charge is prepared externally by injecting a small quantity of fuel in a vaporiser unit. The rest of the fuel is supplied from the main injection [11]. The combustion and emission factors are influenced by fuel properties and different fuels used as source of energy [12]. In the current study, premixing of the different blends of fuel takes place which is used as alternative for diesel. Increasing price and problems that are related to greenhouse gas emissions have been most important for the production of new source of energy. With the stringent emission norms that are proposed by the environmental protection agency (EPA) includes that the fuel burned should be cleaner and less toxic are preferred [13]. As there is a continuous increase in consumption of non-renewable fuels and limited fossil fuel resources availability, alternative fuels are considered. Bio-diesel is one of the best alternatives which are available from natural resources such as bio-mass, plant and animal feedstock. Bio-diesel is a renewable source of energy, is bio-degradable and non-toxic in nature. Bio-diesel are more advantageous when compared to that of conventional diesel [14]. The fuel chemical and physical properties play an important role for combustion, emission and performance of engine. Other properties such as droplet size and atomization and shorter ignition delay are also important causes for

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emissions and fuel combustion [15-16]. Cotton seed oil is a good option to make bio diesel because it is not used for edible purposes. Bio-diesel is produced by mixing methanol and sodium hydroxide (NAOH) as a catalyst and heating it at 60°C to 65°C [17-23]. This is formed by trans-esterification process where esters of long chain of fatty acids are converted from triglycerides such as oils and fats. The bio-diesel are termed as glyceride free fatty acid esters [24]. The emissions produced from bio-diesel are reported to have higher amount Nitrogen oxide when compared to that of conventional diesel engine, however bio-diesel has high oxygen content which reduces carbon-monoxide, hydro-carbons and particulate matter which increased brake specific fuel consumption (BSFC). [25-26].

The objective of the present study is to find performance and emission characteristic of PCCI engine fuelled with bio-diesel under different operating conditions of engine with and without PCCI setup. The experiment is to stabilise the emissions produced from the PCCI engine and from biodiesel. Several blends of biodiesel and diesel are used in a PCCI engine to analyse its emission characteristics.

2. EXPERIMENTAL SETUP AND PROCEDURE

The experiment was conducted on a single cylinder, 4-stroke, direct injection air cooled compression ignition engine with a bore of 86mm and a stroke of 63mm. The engine was coupled to an eddy current dynamometer. PCCI setup was done when a vaporiser unit was attached to the engine which acts as port fuel injection. The injection pressure of main injection was 180bar and for port fuel injection was 3.5bar.

The schematic representation of the experimental setup is shown in Figure-1.

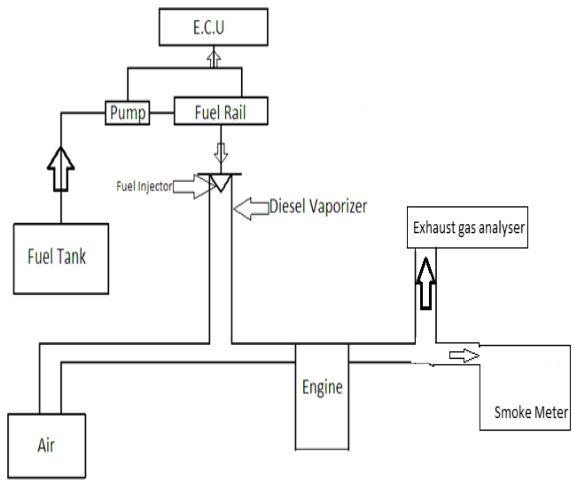

Figure-1. Schematic diagram of experimental setup.

The diesel was used for both main as well as port fuel injection. Cotton seed oil was considered as raw material for production of bio-diesel and was produced by transesterification process. Emission measurements were carried out usingMEXA-584LHoriba emission gas analyser which includes CO, NO, HC, CO_2emissions. AVL smoke meter was used to measure amount of smoke emitted from engine exhaust. The technical specifications of the engine are shown in Table-1.

Table-1. Specifications of engine.

Model	GL-400
Bore	86mm
Stroke	63mm
Displacement	395cm^3
Compression ratio	18:1
Max Engine output(kW @rpm)	5.5kW @ 3600 rpm
Dry weight	45kgs

The experiment was conducted on a 4-stroke diesel engine fitted with vaporiser unit at the inlet manifold which is used for port fuel injection and formed a PCCI setup. In vaporiser unit injected fuel quantity was controlled by ECU. The engine was coupled with eddy current dynamometer where speed was maintained at 2000rpm and torque varies from no load to 12Nm. Engine was made to run initially with diesel –diesel i.e., for main injection as well as for port injection.

Table-2. Properties of cotton seed oil.

Property	Cotton seed oil
Density(kg/m^3)	912
Calorific value(kJ/kg)	39500
Kinematic viscosity(Cs)	55.6
Flash point(°C)	205
Fire point(°C)	228

Bio-diesel was prepared using magnetic stove maintained between temperatures of 60°C to 65°C for about 2 hours and stirred at speed of 650rpm. The smoke opacity in the engine exhaust is measured by using smoke meter.

The cottonseed oil was used as a fuel in this experiment along with diesel. The cottonseed bio-diesel was produced by transestrification process using methanol and sodium hydroxide as a catalyst along with cottonseed oil at standard proportion. The blended percentage of bio-diesel in diesel is 10%, 20% and 30%. The properties of the cottonseed oil are shown in Table-2.

3. RESULTS AND DISCUSSIONS

3.1 CO Emissions

CO emissions are caused due to lack of oxygen and this affect the conversion of CO to CO_2.

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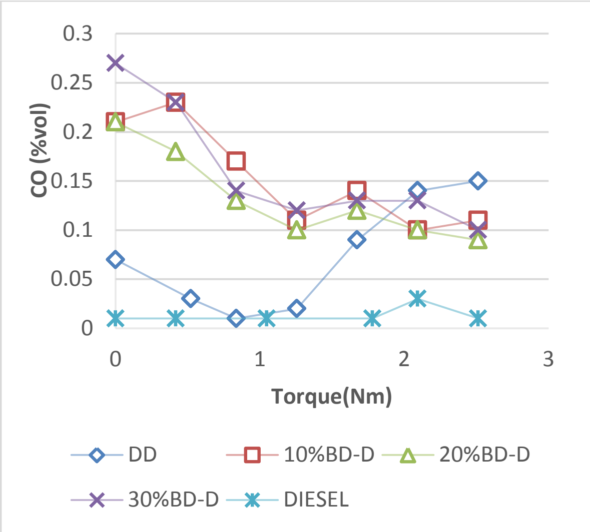

Figure-2. Variation of CO and Torque.

Figure-2 shows the comparison between torque versus CO for conventional and PCCI setup for combinations of bio-diesel, diesel blends. For bio-diesel alone the CO will be less because of presence of oxygen in molecular stage and for PCCI engine the CO formed will high due to low temperatures. It could be because of incomplete combustion due to lack of oxygen caused rich mixture. Figure-2 shows that when biodiesel was used in PCCI engine a decreasing trend of CO emission was observed which could be because of the presence of oxygen in the bio-diesel oxidised small quantity of CO at molar level into CO_2. It was observed that CO emissions was reduced in 20% bio-diesel blend with increase in torque from no load to 12 Nm when compared to that of other blends.

3.2 HC Emissions

HC emissions are caused due to incomplete combustion of fuel and the wall wetting characteristics of the fuel. Flame quenching and low temperature combustion are also probable causes for emitting more HC.

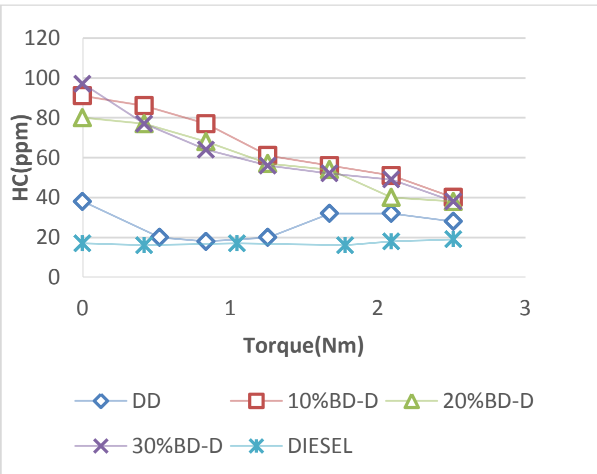

Figure-3. Variation of HC and Torque.

Figure-3 gives the variations in HC emissions with increase in percentage of biodiesel blend. In PCCI engine HC produced was found to be higher for biodiesel blends when compared with diesel which could be because of crevice and low temperature regions. As the torque increases from no load to 12Nm decreasing trend was observed because the unburned fuels tend to burn at higher loads. 20% bio-diesel blend was found to be less when compared to that of other blends.

3.3 NO_X Emissions

The formation of NO_X depends on the combustion chamber temperature. Increase in combustion chamber temperature causes increase in the NO_X emissions.

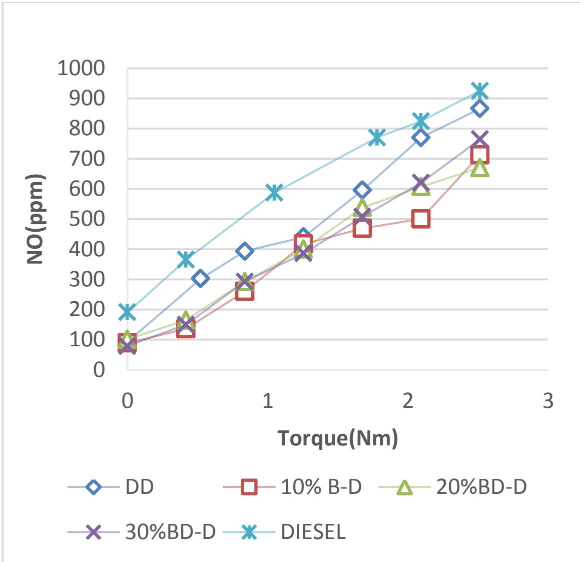

Figure-4. Variation of NO and Torque.

Figure-4 shows the variation of NO emissions for different fuel blends. In the case of diesel –diesel, (premixed-main injection)the NO emission was higher because of partially homogenised mixture reduces ignition delay and increases the heat release rate caused higher in-cylinder combustion temperature led to higher NO emissions. In PCCI mode of operation the NO values found to be less due to low temperature combustion process. It also could be because of lower heat release rate due to lesser calorific value of the blended fuel. When bio-diesel is used in PCCI engine there was a reduction in NO emission when compared to that of diesel in PCCI.

Smoke opacity

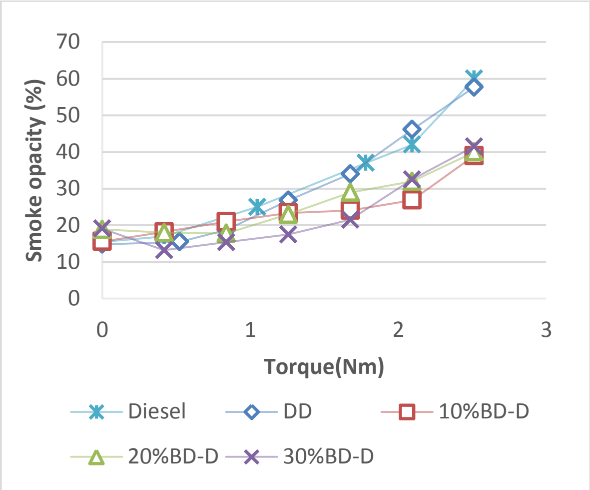

Figure-5. Variation of smoke opacity and torque.

Figure-5 shows the variation of smoke opacity with increasing load. Smoke formation primarily occurs in the fuel-rich zone in the injected spray regime. It is seen that bio-diesel reduces the smoke produced during the combustion. It could be due to complete combustion of the fuel caused by molecular oxygen content in the bio-diesel. This oxygen enables the complete combustion of the fuel ie, oxidises more number of hydro carbons and it was reflected in the Figure-3. The decreasing trend was observed for the increase in the bio-diesel percentage from 10 to 30 % by volume when compared to that of diesel-diesel mode of combustion.

3.3 Brake specific fuel consumption

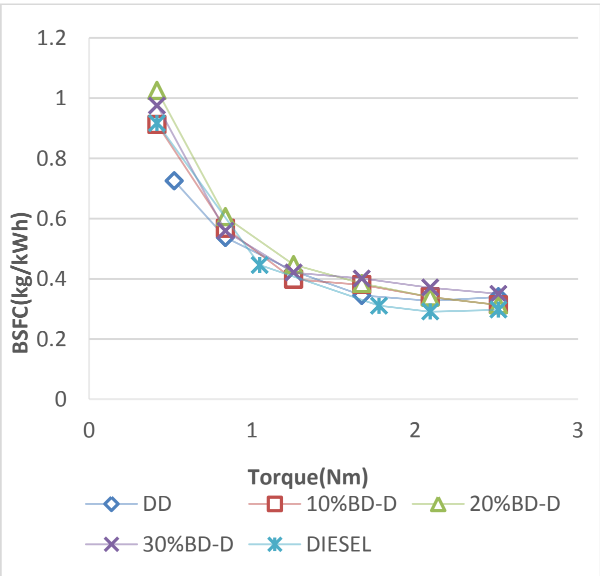

Figure-6. Variation of BSFC and Torque.

Figure-6 shows the amount of fuel consumed for each blend of fuel at different load conditions. In general as the load increases the BSFC was getting decreased. Bio-diesel-diesel modes consumed more amount of fuel compared to that of diesel due to its lesser calorific value when compared to diesel. As percentage of bio-diesel increased from 10% to 30% there is an increase in fuel consumption. It could also be because of wall wetting at the surface of premixing chamber due to pressure drop led to increased BSFC for the biodiesel-diesel modes

CONCLUSIONS

The following conclusions are drawn based on the experimental work done on a PCCI mode and conventional mode with and without premixed biodiesel.

1. With the use of cottonseed based bio-diesel in PCCI engine shows a decreasing trend in smoke when blend varies from 10% to 30% by volume in biodiesel-diesel modes.
2. The brake specific fuel consumption (BSFC) was increased with increase in bio-diesel blends from 10% to 30% due to wall wetting and low calorific value of the blended fuel.
3. CO and NO_x emissions were found less on 20% blend when compared to that of other blends. It was found that CO and NOx emissions were reduced about 28% and 16% respectively for maximum load conditions.
4. HC emissions were increased about 54% for 20% blend in the PCCI mode due to crevice and quenching effects.
5. It was concluded that 20%cottonseed bio-diesel-diesel PCCI mode was found to be optimum and observed stabilised control over emissions when compared with other bio-diesel blends PCCI mode of operations.

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