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Comparative Analysis of Emission Characteristics of Conventional and PCCI Engines

Ramajayam J
Assistant Professor,
Dept. of Mechanical,
Dhanalakshmi College of Engineering, Chennai,
Tamil Nadu, India

Pradeep Kumar A R
Professor,
Dept. of Mechanical,
Dhanalakshmi College of Engineering, Chennai,
Tamil Nadu, India

Sendilkumar R
Assistant Professor,
Dept. of Mechanical,
Dhanalakshmi College of Engineering, Chennai,
Tamil Nadu, India

Abstract

In this experimental investigation, a comparative study has been done between conventional engine and Pre-mixed Charge Combustion Ignition (PCCI) combustion technology. The experiments have been conducted with various test fuels with diesel as reference fuel. A single cylinder water cooled diesel engine has been used for this experimental work. After exhaustive experiments, it has been observed that the oxide of nitrogen emission (NO_x) was found to be very low PCCI combustion. Uunburnt hydrocarbon and carbon dioxide were also found to be reduced much. In addition to the emission characteristics, appreciable improvement in fuel economy was also reported.

Keywords: Pre-Mixed Charge Combustion Ignition (PCCI), No_x Emission, Fuel Economy.

Introduction

The role of internal combustion engine in automobile sector will exist for another two decades even-though electric vehicles are the new depute. The heavy vehicles such as truck, container vehicle, and tanker vehicle still need more power and reliability, which is possible in internal combustion engine. The stringent emission norms are the great challenge for the manufacturers of automotives. Hence the researchers are aggressively concentrating on various methods to reduce emission norms to meet the recent emission norms. The factors to be considered while designing the new combustion process are compression ratio, lean homogeneous air-fuel mixture, complete and instantaneous combustion process.

During combustion the engine not only generates useful power, but also emits considerable amount of pollutants such carbon monoxide (CO), carbon dioxide (CO_2), unburnt hydrocarbons (UBHC), oxides of nitrogen (NO_x) and particulate matter (PM). Reducing the exhaust emission is the greatest challenge infront of all researchers in the field of alternative fuel and engine modification.

In this research work, experiments have been carried out to analyze the performance and emission characteristics of a PCCI engine, assisted with Pilot Injection (PI). A quantum of experiments have been conducted in a modified single cylinder water cooled diesel engine by adopting a conceptual system of TSFI (Transient State Fuel Injection) with reference fuels diesel and gasoline. The test fuel used was bio-diesel.

Review of Literature

Lei et al [1] conducted experiments with PCCI engine along with EGC technology. The study focused on internal and cooled external EGR. The combustion and emission characteristics of diesel fuel have been studies in PCCI engine. The combination internal and external EGR played a vital role in improving the performance and emission characteristics of the PCCI engine. The authors have concluded that the experiments proved that the smoke emissions were found to be appreciably reduced. It was also observed that external EGR avoided the knock during combustion.

Ghassan et al [2] conducted factorial analysis with various bio-fuels such as fresh and waste vegetable oils and waste animal fat. Experiments have been conducted at various injection pressures in the range of 120, 140, 190, and 210 bar. In factorial analysis engine parameters such as combustion efficiency, mass fuel consumption and engine speed were analyzed by varying injection pressure and fuel type.

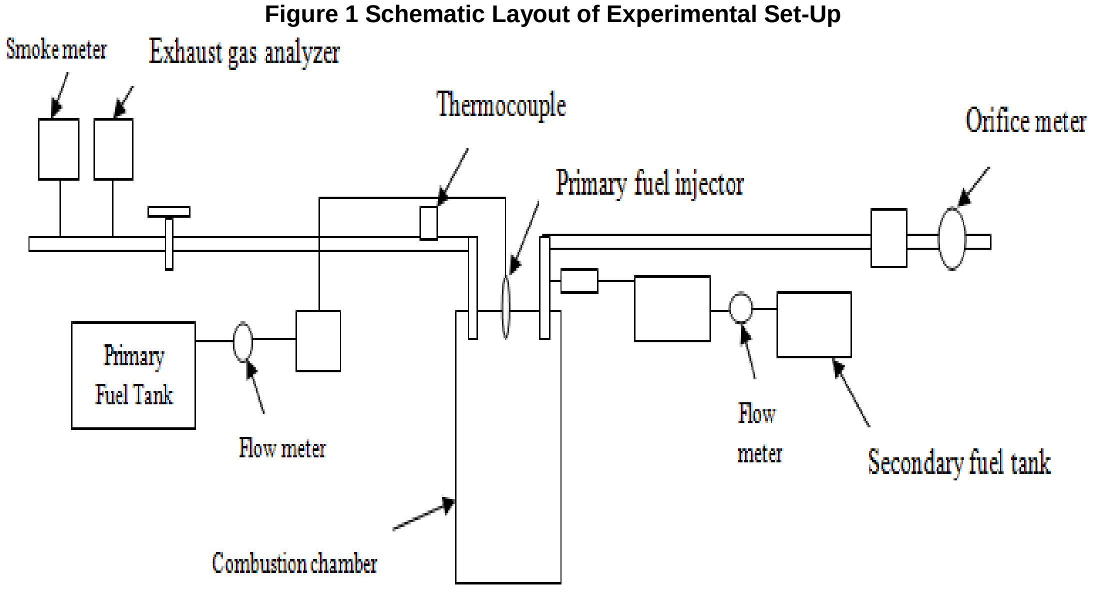
Francisco et al [3] conducted an analysis to estimate the quantity of hydrocarbon present in exhaust gas of diesel engine fueled with biodiesel blends. The study concluded that fuel blends are oxygenated hence hydrocarbon emissions were found to be lesser when compared to diesel fuel. However, oxides of nitrogen emission was found to be more when compared to diesel fuel.

Magnus et al [4] conducted experiment on low temperature combustion in PCCI engines. The researchers estimated the temperature required for combustion analytically as well as experimentally. The fuels such iso-octane, n-heptane, toluene and methyl cyclo-hexane have been tested. When the engine speed was 1200 rpm and compression ratio 18, the temperature required to convert CO into CO_2 was found to be 1500 K, before flame quenching. The authors have also concluded that the peak combustion temperature varies as per the fuel type and auto- ignition characteristics.

Deepak et al [5] conducted the experiments with vegetable oil in single cylinder four stroke diesel engines. The studies have been conducted with test fuels such as linseed, mahua, rice bran, Linseed Oil Methyl Ester (LOME). The reference fuel used was mineral diesel. The experiments concluded that straight vegetable oils had problems of durability and clogging of injector. The problems attributed to high viscosity of straight vegetable oil, when compared to LOME and mineral diesel. The authors have also concluded that the cost of using vegetable is almost equal to diesel fuel.

Experimental Set-Up

Figure 1 Schematic Layout of Experimental Set-Up



The experimental set-up has a single cylinder four stroke, water cooled, Direct Injection (DI) diesel engine. A primary fuel supply system, exhaust gas analyzer, thermostat air temperature control system and pilot injection system are the other major components of experimental set-up. A pilot injection has been attached to the air manifold for secondary fuel injection in PCCI mode of operation. Thermostat and heat arrangements have been fixed to the air manifold for preheating air, thereby to remove the moisture content. The fuels used in the experimental work, are diesel and bio-diesel. The secondary fuel is also heated by means of a 1 kW water bath attached with an electrical thermostat. The temperatures of 55^{o} C and 75^{o} C were maintained for diesel and biodiesel respectively. The intake air is preheated to a maximum temperature of 80^{o} C. An electric fuel pump is used to inject the secondary fuel through a pilot fuel injector. A flow rate of 7.2 ml/min is maintained.

Properties of Test Fuel and Reference Fuel

Table 1

Properties of Test and Reference Fuel

Properties	Diesel	Bio-diesel
Density, kg/m^3	829	873
Cetane number	49	43
Kinematic Viscosity, cSt	1.1	3.8
Flash Point, °C	53	118
Specific Gravity	0.84	0.86
Self Ignition Temperature, °C	261	271
Molecular Weight, g/mol	198	290

Table 1 shows the properties of reference fuel and test fuel. It is observed that biodiesel blends have almost similar properties of the reference fuel (Diesel) except in molecular weight with a large difference around 100 g/mol.

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Hence it is evident that biodiesel blend could be used as a fuel in PCCI engine.

Results and Discussion

Unburnt Hydrocarbon Emission

Figure 2 Load Vs Unburnt Hydrocarbon Emission

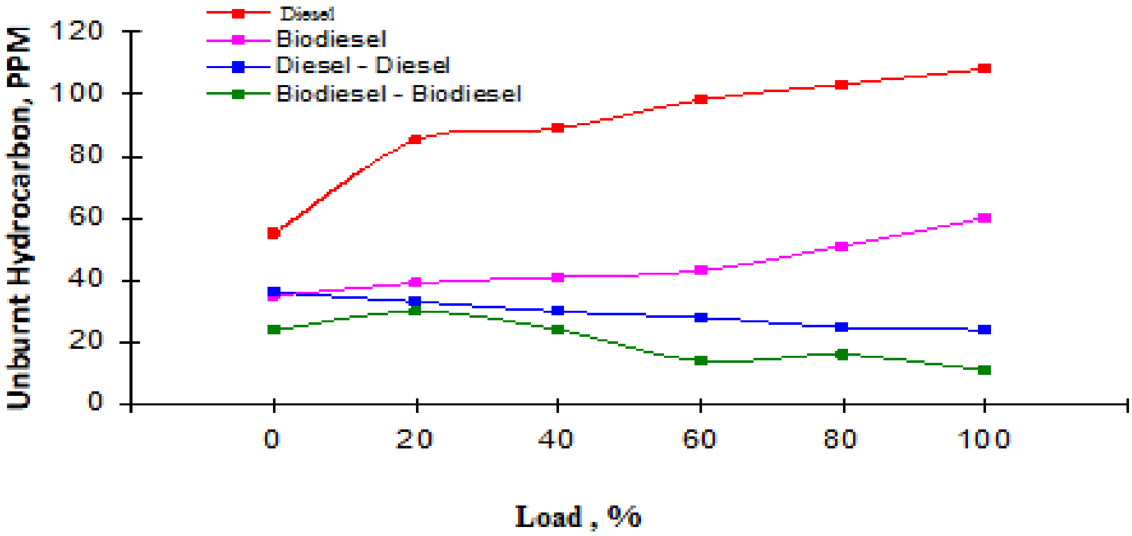

Figure 2 shows the graphical representation of unburnt hydrocarbon emission for test fuel and reference fuels. From the graph it is evident that unburnt hydrocarbon emission lesser than conventional mode of operation. In PCCI mode the biodiesel and biodiesel combination produced least of other combinations. For all the fuels, it is found that there was increase of unburnt hydrocarbon emission with the increasing load. The reason for reduced hydrocarbon emission is attributed to the complete combustion in PCCI mode than conventional mode of operation [6].

Carbon dioxide (CO_2) Emission

Figure 3 Load Vs Carbon dioxide emission

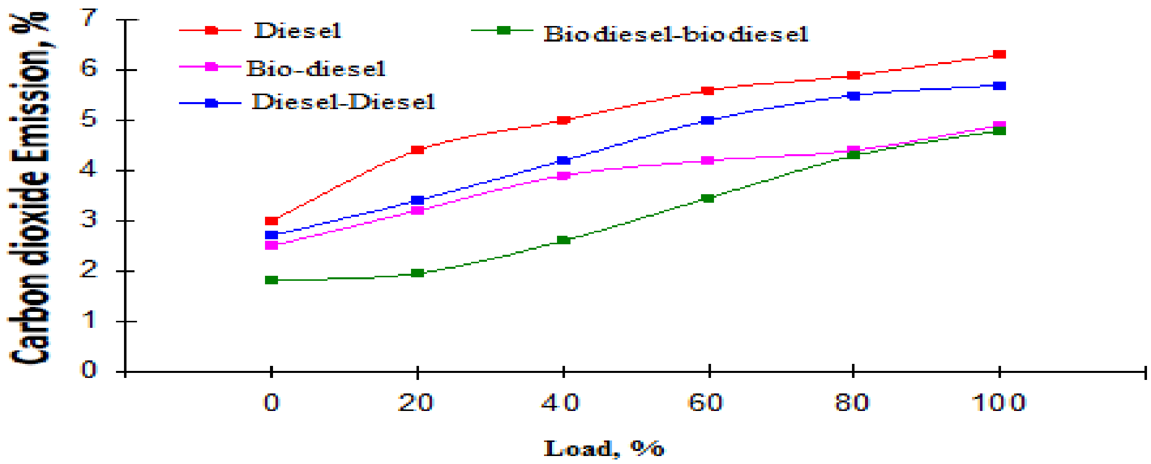

Figure 3 shows the graph between load and carbon dioxide emission. The biodiesel-biodiesel fuel combination in PCCI mode produced least carbon dioxide emission when compared to other fuels. The reason for this might be attributed complete combustion which is due to presence of higher oxygen content in the fuel. The oxidation process of biodiesel fuel was found to be better than hydrocarbon fuels [7].

Oxides of Nitrogen (NO_x) Emission

Presence of oxygen and availability of temperature at peak combustion is the reason for oxides of nitrogen emission. With all biodiesel blends, it is unavoidable to reduce the NOx emission, unless the operating temperature reduced. It has been tried upto some extent, but still it is not able to reduce much. However, oxides of nitrogen (NO_x) emission in PCCI mode operation is much lesser than conventional DI diesel engine [8].

Conclusion

In this experimental work, attractive features are reduced unburnt hydrocarbon emission, carbon dioxide emission and oxides of nitrogen emission in PCCI combustion mode. Though oxides of nitrogen of biodiesel fuel is higher than diesel fuel, it is lesser in PCCI mode of operation when compared to conventional engine. An appreciable fuel economy is another compliment PCCI combustion.

Scope for Future Work

The authors recommend that this work might be extended with gaseous fuels such as Liquefied Petroleum Gas (LPG), Compressed Natural Gas (CNG), biogas etc. The modified engine might help for better performance and oxides of nitrogen reduction.

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