ORIGINAL RESEARCH PAPER

Engineering

EXHAUST EMISSION ANALYSIS OF CI ENGINE USING VARIOUS BLENDS OF PPO-DIESEL

KEY WORDS: Compression ignition engine, Plastic pyrolysis oil, Nitrogen oxide, Carbon monoxide, Carbon dioxide, Hydro carbon.

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ABSTRACT

Plastic pyrolysis oil blended with diesel was tested in a single cylinder diesel engine in an experimental study. Waste plastic is used to make plastic pyrolysis oil. Various blends of PPO-DIESEL are tested for engine exhaust emission at various loads in this study. Nitrogen oxide (NOx), carbon monoxide (CO), carbon dioxide (CO2), and hydro carbon (HC) are all measured in engine exhaust emissions. According to the results, D80PPO20 blend is best compared to other fuels for NOx, CO in all blends has no difference at full load, D60PPO40 blend is best compared to other fuels for CO2, and D80PPO20 blend is best compared to other fuels for HC. PPO-DIESEL blends can be used without modification in CI engines.

I. INTRODUCTION

Diesel engine, a source of mechanical power tremendously dominating since many decades by imparting its valuable and useful effect in different sectors like agriculture, industries, and automobiles etc. As a result of heavy industrialization and the advancement of automotive industries around the world, there is an urgent need to find alternative fuels or switch to environmentally friendly fuels, as natural resources of conventional fuels such as diesel, gasoline, and natural gas are depleting at an alarming rate. These traditional fuels are hazardous to the environment because they emit harmful gases such as carbon monoxide, carbon dioxide, and nitrogen oxides (NO_x) [1]. In this viewpoint, impressive consideration has been drawn toward the generation of biodiesel as an immediate substitute or a mixing choice with non-renewable energy source to build its execution productivity [2]. There are a variety of feedstocks available on the market that can be used to replace fuel in CI engines, including edible and non-edible oils, animal fats, agriculture waste, and household byproducts, among others. These sources are environmentally friendly and produce less pollution. Cooking oil as a fuel has become more expensive in comparison to conventional petroleum fuels, and carbon deposits around the nozzle mouth and piston have become critical issues. Non-cooking oils have a higher viscosity than conventional and petroleum fuels, but they are less expensive and it can be reduced by blending. We all know that fossil fuels are depleting day by day, and that one day these fossil fuels will be completely depleted. So, in based on the above mentioned conflict, the alternative fuel, i.e. Plastic pyrolysis oil, can be used in CI Engines since they are intended to run effectively with diesel fuel only. To use plastic pyrolysis oil in a CI Engine, it must be blended with diesel fuel.

II. LITERATURE SURVEY

The effect of different alternative fuel blend ratios on engine exhaust emission was investigated. Experiments with various alternative fuels for CI engines have been presented to various researchers. It has been determined that biodiesel made from a variety of vegetable and non-vegetable oils, such as Jatropha oil, Palm seed oil, Waste plastic oil, and others, can be used as an alternative fuel for CI engines.

Kumar et al (2012) studied about the utilization of JBD with different fuel injection pressure angles in indirect injection (IDI) diesel engine and in their research paper Brake thermal efficiency improves as the fuel injection pressure is increased for the Jatropha blend with diesel at full load. As the fuel injection pressure increases the brake thermal efficiency decreases for diesel at full load. In case of Jatropha blend the NO_x emission is decreasing. Jatropha Blend can be used in the diesel engines in the form of fuel emulsions along with some ignition improver add**ition [5]. Maulik et al (2014) stud**ied about performance and emission analysis of diesel engine using palm seed oil and diesel blend. The purpose of their study showed the comparison of performance and emission characteristics of diesel engine using diesel and biodiesel as palm seed oil with various proportions by volume (B10, B20, and B30). The result of their experiment showed that 30% blend of palm seed oil found best blend compare to the other blend and B30 blend NO_x reduced compare to other blend [6]. Harsh et al (2016) studied about performance investigation of the single cylinder diesel engine fueled with the palm biodiesel-diesel blend. They performed experiment for five loads, i.e. 1,3,5,7 and 9 using Diesel, Palm biodiesel- diesel blends i.e. diesel, P10, P20, P40, P60, P80 and pure Palm biodiesel with load variation of 1kg load to 9kg load and compared with base cases. The result showed that Palm biodiesel increased the specific fuel consumption also increased and brake thermal efficiency slightly decreased in the P40 blend the fuel consumption is nearest to the diesel fuel **[7]**.

Mani et al (2010) investigated a DI diesel engine with waste plastic oil and exhaust gas recirculation in an experimental study. They conducted the research to see how cooled exhaust gas recirculation (EGR) affected the performance of a four-stroke, single-cylinder, direct-injection (DI) diesel engine running on 100 percent waste plastic oil. When using waste plastic oil without an EGR system, the results showed higher nitrogen oxide emissions. When the engine was run with cooled EGR, NO_x emissions were reduced. Based on significant reductions in NO_x emissions, minimum possible smoke, CO, and HC emissions, and comparable brake thermal efficiency, the EGR level was optimised at 20%. At all loads, smoke emissions of waste plastic oil were higher **[11]**. **Poompipatpong et al (2014)** studied about the effect of diesel-waste plastic oil blends on engine performance characteristics. The objective of the research was to present results of the performance (torque, power, thermal efficiency and specific fuel consumption in a heavy duty diesel engine when fueled with diesel-waste plastic pyrolysis oil (WPO) blends in full load condition. Three mixing ratios WPO25, WPO50 and WPO75 were used as fuel at a wide range of engine speeds and the results were compared to those of diesel (WPO0). They concluded that the increase of mixing ratio to WPO 75% greatly decreases engine output torque and power approximately by 23.79%. Consequently, specific fuel consumption can be increased by 31.22%, while thermal efficiency can be reduced by 5.97% [12]. Kaimal et al (2016) studied about combustion characteristics of DI diesel engine using waste plastic oil and its blends. Fuel used were PO (25%), PO (50%) and PO (75%) blends. The study gave conclusion that among all blends PO (25%) showed better emission characteristics and thermal efficiency with lower BSEC (brake specific energy consumption. With a slight improvement in the fuel quality, PO (25%) can be considered as an effective replacement for diesel in CI engines without any alterations [15]. Thamilarasan et al (2021) studied about investigation of plastic pyrolysis oil performance on CI engine blended with magnesium oxide nanoparticle using Taguchi method. The study gave conclusion that the plastic oil combination was the most dominant with its 10% rating [20].

III. PLASTIC PYROLYSIS OIL

Pyrolysis is a thermochemical decomposition of organic material at elevated temperatures in the absence of oxygen (or any halogen). It involves the simultaneous change of chemical composition and physical phase, and is irreversible. The word is coined from the Greek-derived elements pyro "fire" and lysis "separating". Pyrolysis differs from other high-temperature processes like combustion and hydrolysis in that it usually does not involve reactions with oxygen, water, or any other reagents. In practice, it is not possible to achieve a completely oxygen-free atmosphere. Because some oxygen is present in any pyrolysis system, a small amount of oxidation occurs. Bio-oil is produced via pyrolysis, a process in which biomass is rapidly heated to 450–500°C in an oxygen-free environment and then quenched, yielding a mix of liquid fuel (pyrolysis oil), gases, and solid char [29].

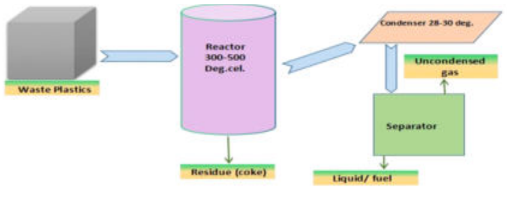

Figure 1: The Schematic Diagram of Plastic Pyrolysis Oil Process.

The steps involved in conversion of plastic waste into liquid fuel are shown in fig. 1 & description is given below:

- Take plastic waste from dump yard/storage and clean it.
- After cleaning, it is feeded in the reactor.
- Reactor is continuously heated by gas stove about at 300–500°C temperature.
- The vapour created due to high temperature in reactor is passed to condenser through pipe. Condenser contains cooling coil which is bounded by water in condenser. The vapour comes from reactor is condense in condenser.
- In separator, these condensed vapour comes in liquid form and other uncondensed gases. Separator leave out these uncondensed gases and gives liquid. This liquid is the plastic pyrolysis oil.
- Plastic pyrolysis oil and diesel are used for this research work were tested in certified laboratory for its properties and test results are stated below in given table 1.

Table 1: Properties of Diesel and Plastic Pyrolysis Oil.

Properties	Diesel	Plastic pyrolysis oil
Density: in kg/m^3	838	730
Calorific value: in kJ/kg	45500	44248

IV. EXPERIMENTAL METHODOLOGY

The steps involved in experimental methodology are given in below figure 2;

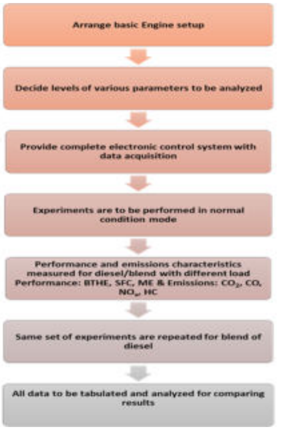

Figure 2: Figure shows the methodology of the experiment.

I. EXPERIMENTAL SETUP

The set up consists of single cylinder, four stroke, water cooled computerized research engine in which loading has been provided by eddy current dynamometer. The set-up consisting of air box, two fuel tanks for duel fuel test, transmitters for air and fuel flow measurements, fuel measuring unit, manometer, process indicator and hardware interface. Rota meter is used for calorimeter water and cooling water flow measurement. A battery, starter and battery charger have been provided for engine electric start arrangement. Various sensors and instruments are integrated with data acquisition system for online measurement of load, air and fuel flow and different temperatures. The setup enables the evaluation of thermal performance and emission constituents of an engine. Thermal performance parameters include brake power, frictional power, brake thermal efficiency, indicated thermal efficiency, mechanical efficiency, volumetric efficiency, specific fuel consumption, A/F ratio, heat balance etc. Lab view based engine performance analysis software package "Engine soft" has been provided for on line performance evaluation. Front view of experimental setup is in below figure 3:

Figure 3: Front View of Experimental Setup

Specification of test engine is given in below table 2:

Table 2: Specifications of Test Engine

Parameter	Specification
Engine	single cylinder, four stroke water cooled diesel Engine
Bore and stroke	87.5 mm by 110 mm
CR range	12 to 18
Dynamometer	Eddy current type
Temperature sensor	RTD type PT100
Load sensor	Load cell, range 0-50 kg
Load Indicator	Digital, range 0-50 kg
Digital voltmeter	Range 0-20V
Rota meter	Engine cooling 40-400 LPH, Calorimeter 25-250 LPH

The constituents of the exhaust gas like CO, HC and NOx are measured with exhaust gas analyzer. An instrument used to analyze the chemical composition of the exhaust gas released by a reciprocating engine is called exhaust gas analyzer. A gas analyzer is used for analysis of the pollutants within the exhaust gas. This gas analyzer is connected to the engine exhaust pipe. This instrument is employed to measure the necessary pollutants i.e. carbon monoxide gas (CO), NOx, unburnt Hydrocarbons (HC) etc. Figure 4 shows the exhaust gas analyzer which is used for measuring CO, CO2, NOX, O2 and HC Emissions. The specifications / working range of this gas analyzer is shown in Table 3.

Figure 4: Exhaust Gas Analyzer

Table 3: Exhaust Gas Analyzer Specifications

Constituent	Specified Range	Accuracy Vol.	Accuracy %	Resolution
CO	0-10% ±	0.06 ±	3%	0.01%
HC	0-20000 PPM	± 12 PPM	± 55%	1 PPM
CO2	0-20%	± 0.4%	± 4.0%	0.1%
O2	0-21%	± 0.1%	± 3%	0.01%
NOX	0-5000 PPM	25 PPM	± 5%	1 PPM

Where,
CO = Carbon monoxide % volume measured.
CO_2 = Carbon dioxide % volume measured.
HC = Hydrocarbon ppm measured
O_2 = Oxygen % volume measured
NOx = Nitrogen oxide ppm measured

VI. RESULTS AND DISCUSSIONS

Calculated engine exhaust emission parameters from the experiments performed for each of the blend ratio i.e. D100PPO0 (100% Diesel – 0% Plastic Pyrolysis Oil), D90PPO10 (90% Diesel – 10% Plastic Pyrolysis Oil), D80PPO20 (80% Diesel – 20% Plastic Pyrolysis Oil), D70PPO30 (70% Diesel – 30% Plastic Pyrolysis Oil), D60PPO40 (60% Diesel – 40% Plastic Pyrolysis Oil), D50PPO50 (50% Diesel – 50% Plastic Pyrolysis Oil) with change in load in each blend from 25%, 50%, 75%, and 100%. From obtained results following discussion has been drawn.

A. NOx (Nitrogen Oxide)

Figure 5 shows the variation of NOx for test fuel at different load condition. It is clearly shows that NOx for all fuel increased continuously for no load to full load condition. And for 20% of blend NOx reduced up to 904ppm lower than diesel fuel. And into 10% & 30% & 40% & 50% of blend NOx reduced up to 950 & 924 & 940 & 938 ppm respectively.

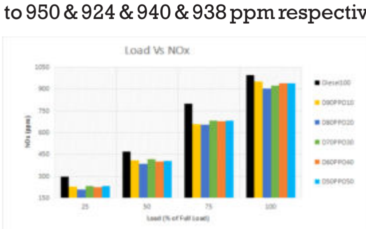

Figure 5: Variation of NOx for Test Fuel at different Load

From figure 5 it shows that the NOx in the D80PPO20 blend reduced than other fuel at lower to full load condition.

B. CO (Carbon Monoxide)

Figure 6 shows the variation of a Carbon Monoxide for test fuel at different load condition. It is clearly shows that CO by %volume for all fuel reduced continuously for no load to full load condition. And diesel has CO higher at no load with 0.04 %volume which is higher among other blends.

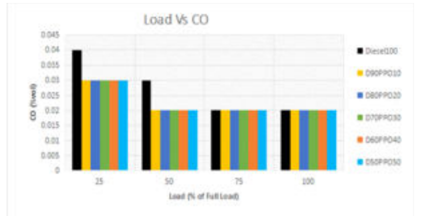

Figure 6: Variation of Carbon Monoxide (CO) for Test Fuel at different Load

At full load all blend and pure diesel have similar CO 0.02 %volume. So from figure 6 it shows that the CO in the all blends and diesel has no much difference at full load condition.

A. CO_2 (Carbon Dioxide)

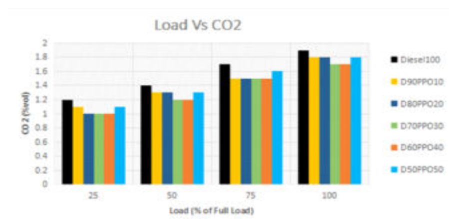

Figure 7: Variation of Carbon Dioxide (CO2) for Test Fuel at different Load

Figure 7 shows the variation of a Carbon Dioxide for test fuel at different load condition. It is clearly shows that CO2 by %volume for diesel fuel increased continuously for no load to full load condition. And for 40% of blend CO2 by %volume increased but lower than diesel fuel and other all blends. And into 10% & 20% & 30% & 50% of blend CO2 increased up to 1.8 & 1.8 & 1.75 & 1.8% by volume respectively at full load. From figure 7 it shows that the CO2 in the D60PPO40 blend reduced than other fuel at zero to full load condition.

D. HC (Hydro Carbon)

Figure 8 shows the variation of Hydro Carbon for test fuel at different load condition. It shows that HC for all fuel increased continuously for no load to full load condition and Diesel has very high compare to other test fuel.

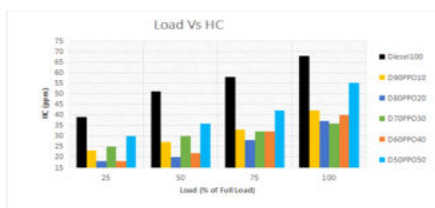

Figure 8: Variation of Hydro Carbon (HC) for Test Fuel at different Load

At full load condition diesel & 10% & 20% & 30% & 40% & 50% blend got HC 68 & 42 & 37 & 36 & 40 & 55 ppm respectively. From figure 8 it clearly shows that the HC in the D80PPO20 blend reduced than other fuel at zero to full load condition.

VII. Conclusion

Based on the results and discussions, the following conclusion can be drawn.

- Plastic pyrolysis oil & diesel blend directly used in engine without modification in the engine.
- As the Plastic pyrolysis oil % increased by volume than the exhaust emission is to be reduced.
- NOx in the D80PPO20 blend reduced than other fuel at lower to full load condition.
- CO in the all blends and diesel has no much difference at full load condition.
- CO_2 in the D60PPO40 blend reduced than other fuel at zero to full load condition.
- HC in the D80PPO20 blend reduced than other fuel at zero to full load condition.

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