

Experimental Investigation on a Compression Ignition Engine with Blends of Plastic Oil and Diesel as Fuel



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1 Introduction

As we all know, the carbon dioxide is a greenhouse gas and plays an important role in global warming. The fossil fuels are also ceasing at a rapid rate [1], and in future, there will be scarcity of fossil fuels. So in future to meet energy demand, we have to look over on developing new alternate sources of energy [2]. The plastic oil can be used to obtain energy [3, 4]. It can be obtained by pyrolysis, catalytic cracking, etc [5, 6]. The most commonly used process is the pyrolysis process. Pyrolysis occurs in presence of no oxygen. The plastic waste can be converted into liquid, gas and solid by pyrolysis technique. Pyrolysis plastic oil possesses similar properties as that of petroleum products so can be used in diesel engines [7, 8]. The objective of this research work was to determine whether the use of pyrolysis plastic oil as an alternative diesel engine fuel would be feasible or not and estimate the optimum operational conditions.

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2 Methods and Materials

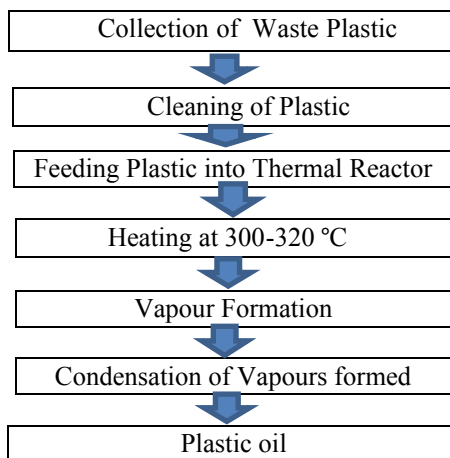
Pyrolysis Process

Pyrolysis is a technique of thermal degradation of matter in absence of oxygen. Conversion of waste plastic in oil is shown in Fig. 1. The gasses formed are condensed in condenser to obtain a hydrocarbon distillate, and the fluid is separated using refining to get the oil [9–11].

Comparison of properties of plastic oil and Diesel

#	Properties	Plastic oil	Diesel
1	Density(kg/m ³)	792	850
2	Ash content (%)	<1.02%wt	0.044
3	Calorific value(kJ/kg)	41,800	42,000
4	Kinematic viscosity @40C	2.15	3.04
5	Cetane number	51	55
6	Flash point °C	40	50
7	Fire point °C	45	56
8	Carbon residue (%)	0.01%wt	0.2
9	Pour point °C	-4	3-15
10	Sulphur content	<0.02	<0.034

Fig. 1 Conversion of waste plastic into oil through pyrolysis method



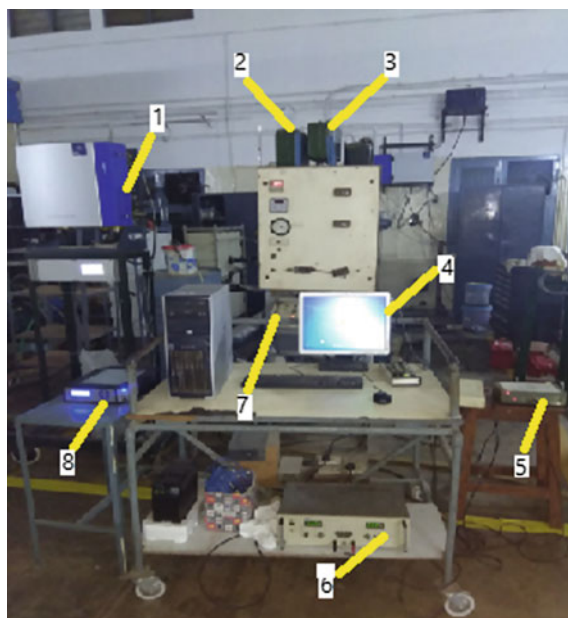


Fig. 2 Front view of experimental setup. 1 Smoke meter, 2 diesel tank, 3 blend tank, 4 DAQ, 5 pressure pick up, 6 voltage regulator, 7 dynamometer controller, and 8 DI GAS analyser

Test Engine

The technical specifications of the engine are given in Appendix A. The engine setup is shown in Fig. 2. The cylinder pressure was measured by a piezoelectric pressure transducer. Two fuel tanks were installed so that diesel and blends can be used separately for the experiments. The mechanical pump was plunger type. For each reading, pressure and TDC data were recorded by a piezoelectric transducer and a TDC sensor using data acquisition system (DDAS). Figure 2 shows front view of the setup used in this work. Cooling water pump was used to provide cooling to dynamometer and pressure pick up.

Performance, Emission and Combustion Data measurement devices

Appendix A Specifications of the engine

Type	Four stroke, naturally aspirated
Manufacturer	KIRLOSKAR TAFI
No. of cylinders	1
Bore × Stroke	87.5 mm × 110 mm
Connecting rod length	220 mm
Rated power	4.4 kw @ 1500 rpm

(continued)

(continued)

Type	Four stroke, naturally aspirated
Compression ratio	17.5: 1

3 Results and Discussion

Combustion characteristics

3.1 Effect of Blend Ratio and Operating Parameters on Peak in-Cylinder Pressure

The variation in peak pressure for various loads for blends is represented in Fig. 3. It was found that low blending ratios make little effect on maximum pressure irrespective of the operating conditions, but the peak pressure is increased for higher blending ratios. It may be due to lower viscosity and cetane number of plastic oil as compared to diesel [12]. The spray atomisation and evaporation of the fuel are improved due to lower viscosity of PPO [13], which increased the premixed combustion phase duration. The combustion was delayed because of low cetane number thus increased the premixed burning phase period.

Engine Performance Parameters

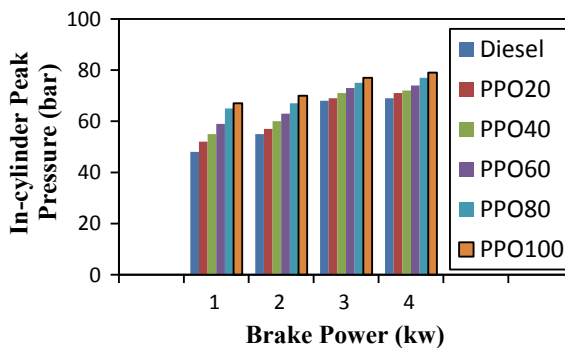


Fig. 3 Effect of blend ratio and operating parameters on maximum in-cylinder pressure

3.2 Effect of Blend Ratio and Brake Power on Brake Specific Fuel Consumption (BSFC) and Thermal Efficiency (BTE)

The variation of the BSFC and thermal efficiency for blends and diesel for various loading conditions is shown in Fig. 4a, b, respectively. Due to more fuel demanded, the BSFC for blends is increased for all operating conditions even with the lowest PPO proportions. The lower heating value of PPO fuel was the reason for this. The lower BTE in case of blends may be due to more aromatics contents present in PPO as more energy is needed to breakdown the aromatics bonds [14]. The high heat transfer losses occurred may be because of more burning temperature in case of blends.

3.3 Effect of Blend Ratio and Brake Power on Volumetric Efficiency

The variation of volumetric efficiency with brake power for blends and diesel at constant speed is plotted in Fig. 5. The decrease in volumetric efficiency with increasing the blend ratios as shown in Fig. 5 is due to availability of oxygen during combustion (Fig. 6).

Exhaust emissions

3.4 Effect of Blend Ratio and Operating Parameters on Nitrogen Oxides

The NO_x mechanisms occur in three different ways, the thermal, prompt and fuel bound NO mechanism [13–17]. The thermal mechanism plays a major role for the formation of NO_x because of the high combustion temperature and more O_2 availability. The longer ignition delay duration caused in large portion of premixed burning, thus more heat and combustion temperature obtained and hence the concentration of NO_x emissions increased parallelly as the proportion of blends increased. The more nitrogen availability in the fuel also aggravates the NO_x formation by fuel mechanism.

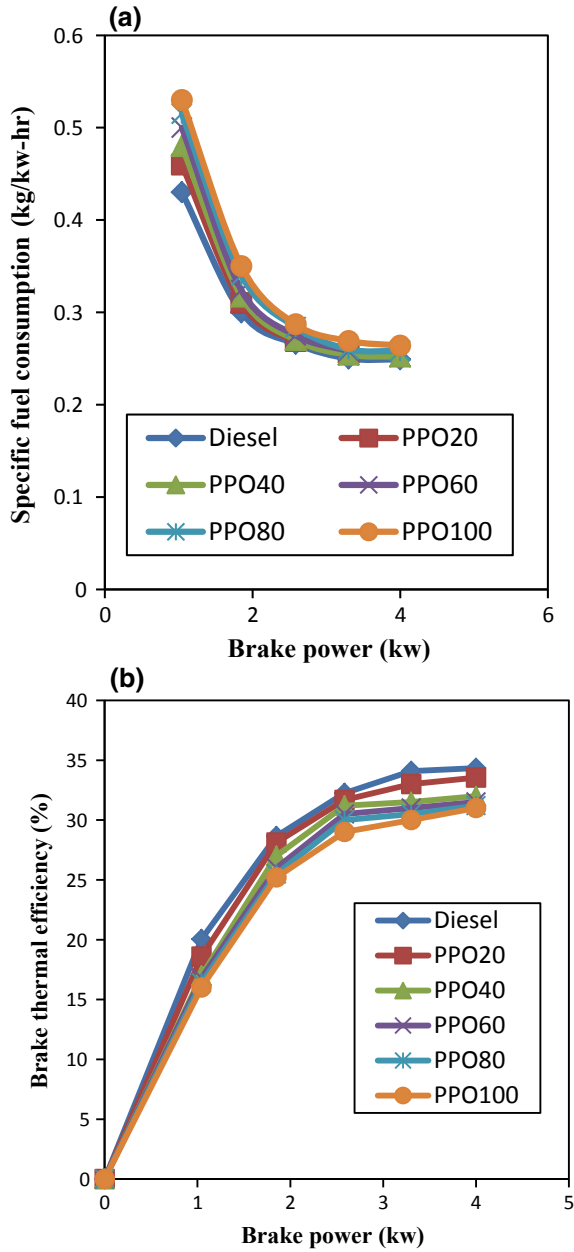


Fig. 4 a Effect of blend ratios and BP on BSFC at constant speed (1500 rpm) and **b** effect of the blend ratios and BP on BTE at constant speed

Fig. 5 Effect of blend ratio and BP on volumetric efficiency at constant speed (1500 rpm)

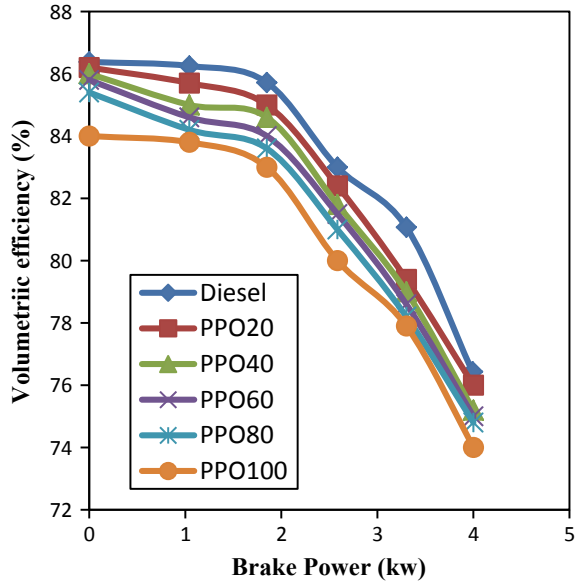
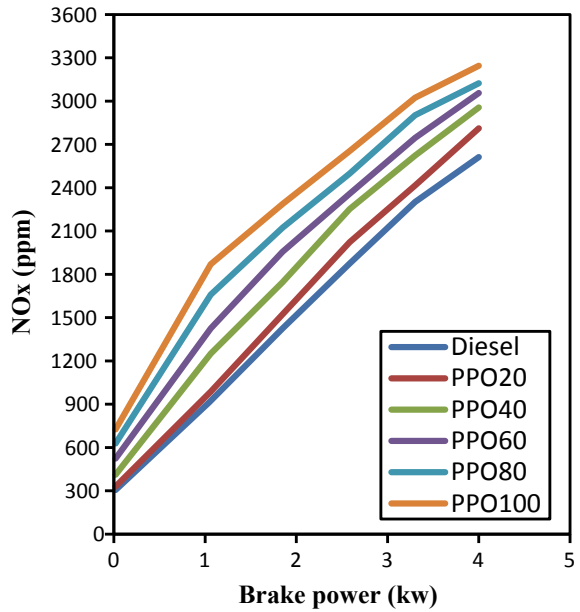


Fig. 6 Variation of NO_x with BP at constant speed (1500 rpm)



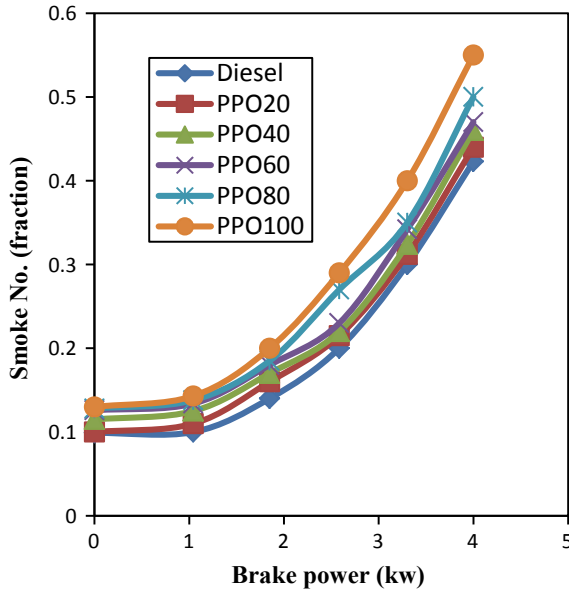


Fig. 7 Effect of brake power on smoke at constant speed (1500 rpm)

3.5 Effect of Blend Ratio and Operating Parameters on Smoke

Figure 7 shows the variation of smoke with brake power for different blends and diesel at constant speed. The smoke emitted is more in case of blends as compared to diesel as shown in Fig. 7. Increasing the proportion of pyrolysis plastic oil in blends with diesel increases the smoke as can be seen clearly from Fig. 7.

3.6 Effect of PPO Concentrations and Operating Parameters on Hydrocarbons

The variation of unburned HC emissions is shown in Fig. 8. The under-mixing or over-leaning (bulk-quenching) local zones and wall flame quenching mainly affect the HC emissions [15, 18, 19]. The HC emission in case of PPO blends is significantly more than that of diesel, and the HC emissions also increase with more proportions of PPO in blending ratios. For the same PPO blend, HC emissions decrease with load.

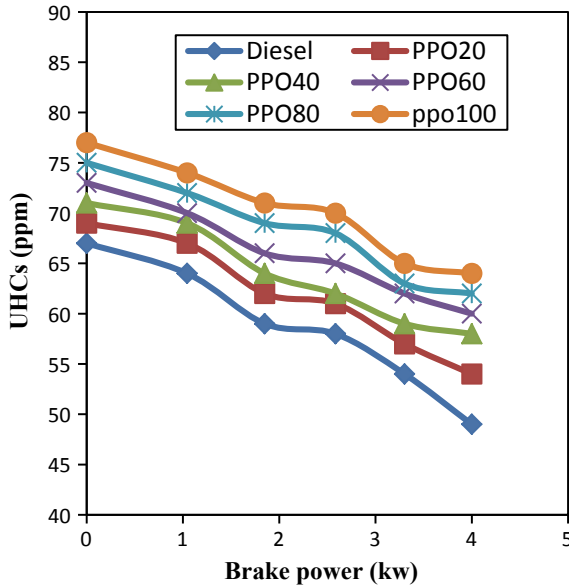


Fig. 8 Variation of HC with BP at constant speed (1500 rpm)

3.7 Effect of Blend Ratio and Operating Parameters on Carbon Dioxide

The carbon dioxide is emitted due to complete combustion of the carbon atoms. Since it is a greenhouse gas so CO₂ emissions should be reduced. The carbon dioxide emitted is more in case of PPO blends as can be seen clearly from Fig. 9. This has bad effect on the environment, nevertheless, this fuel is obtained from wastes which is also non bio-degradable and more CO₂ would be released in future.

3.8 Effect of Blend Ratio and Operating Parameters on Carbon Monoxide (CO)

The CO emissions are mainly formed due to incomplete burning of carbon contained in the fuel, and the CO is mainly affected by the mixture strength and temperature. The tests results show that the CO emissions decrease as load increases irrespective of the fuel as can be seen clearly from Fig. 10. In general, more quantity of plastic oil in blends produces more CO emissions. The incomplete burning at these operating parameters is more due to low cetane number of PPO.

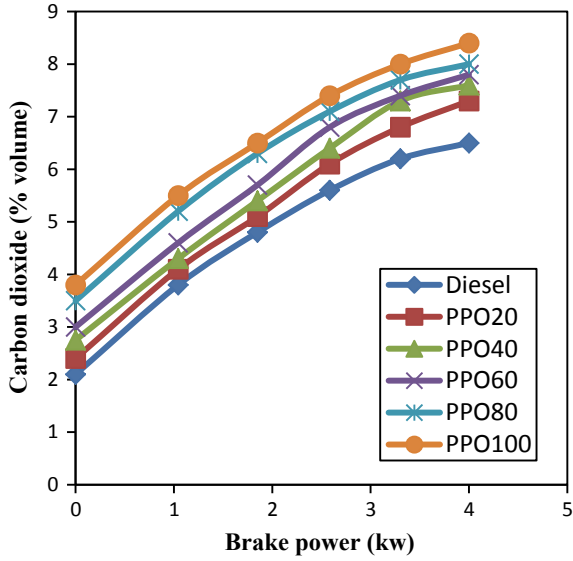


Fig. 9 Effect of blend ratio and BP on CO₂ at constant speed (1500 rpm)

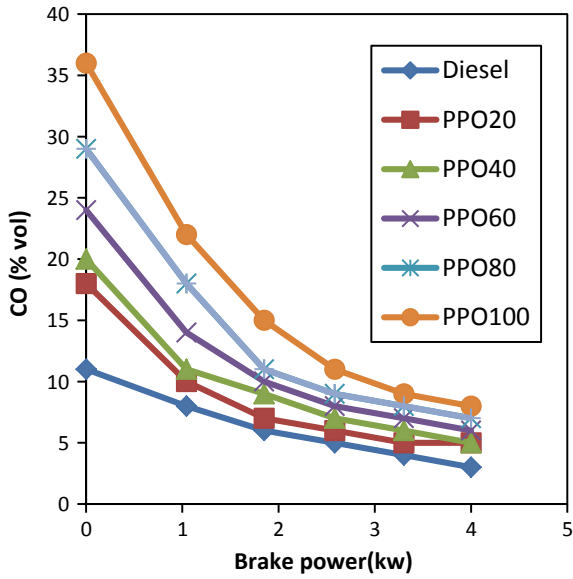
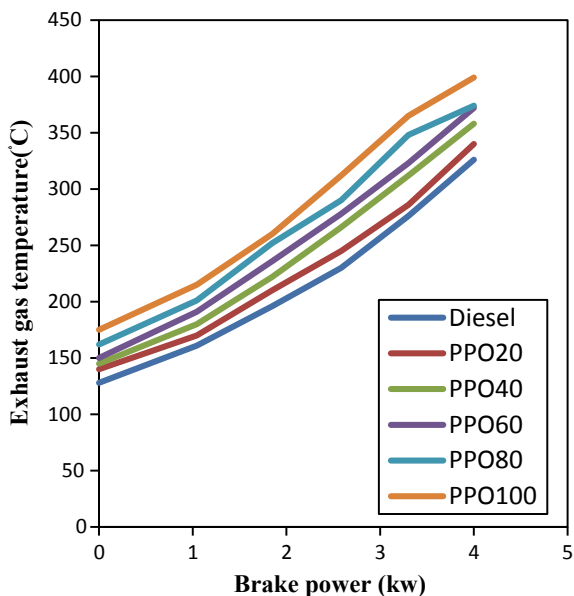


Fig. 10 Effect of blend ratios and BP on CO at constant speed (1500 rpm)

Fig. 11 Effect of BP on EGT at constant speed (1500 rpm)



3.9 The Variation in Exhaust Gas Temperature (EGT) with Different Blend Ratios and Operating Parameters

The EGT in case of blends are increased at all loads as compared to that of diesels as can be clearly seen from Fig. 11. If the quantity of plastic oil is increased in blends, then EGT is also increased. This variation in EGT can be explained by the longer ignition duration.

4 Conclusions

The following conclusions drawn about the emissions are:

- The NO_x emissions for plastic pyrolysis oil blends PPO20, PPO40, PPO60, PPO80 and PPO100 at 90% of full load are increased by 7.65, 13, 17, 23 and 24.2%, respectively, as compared to diesel while engine was running in constant speed (1500 rpm) mode.
- The UHC emissions for plastic pyrolysis oil blends PPO20, PPO40, PPO60, PPO80 and PPO100 at 90% of full load are decreased by 6.5, 17.4, 26, 30 and 39%, respectively, as compared to diesel while engine was running in constant speed (1500 rpm) mode.
- The CO_2 emissions for plastic pyrolysis oil blends PPO20, PPO40, PPO60, PPO80 and PPO100 at 90% of full load are increased by 12.3, 16.9, 20, 23 and 29.2%,

respectively, as compared to diesel while engine was running in constant speed (1500 rpm) mode.

- The CO emissions for plastic pyrolysis oil blends PPO20, PPO40, PPO60, PPO80 and PPO100 at 90% of full load are decreased by 6.5, 17.4, 26, 30.4 and 7.6%, respectively, as compared to diesel while engine was running in constant speed (1500 rpm) mode
- The smoke emissions for plastic pyrolysis oil blends PPO20, PPO40, PPO60, PPO80 and PPO100 at 90% of full load are increased by 4, 8.7, 11, 18 and 30%, respectively, as compared to diesel while engine was running in constant speed (1500 rpm) mode.

From the analysis and results data, it is found that the blends of 60–80% plastic oil operating at 80–90% engine loads could be utilised in CI engine such as diesel engine to attain the best engine performance and reduce exhaust emissions with some improvements such as cetane number injection timing and pressure.

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