Indian Journal of Science and Technology, *Vol 9(45), DOI: 10.17485/ijst/2016/v9i45/104611, December 2016*
ISSN (Print) : 0974-6846
ISSN (Online) : 0974-5645

Performance and Emission Characteristics of CRDI Engine Working on Plastic Oil

Ravi Shanker Shukla[1], A. S. Divakar Shetty[2*] and A. J. Antony[3]

[1,2]Department of Mechanical Engineering, Amrita School of Engineering, Bengaluru, Amrita Vishwa Vidyapeetham, Amrita University, Bengaluru – 560035, Karnataka, India; divakarshettyas@gmail.com
[3]Department of Mechanical Engineering, P. A College of Engineering Mudipu, Mangalore – 574153, Karnataka, India.

Abstract

This research work is carried out to evaluate the effect of using diesel plastic oil blends in a CRDI diesel engine. This paper shows the potential of utilizing waste plastic oil extracted by pyrolysis of waste plastic as an alternative fuel for diesel engine. The plastic is not an ingredient component in environment due to the adhesive bond between their elements. The oil that can be removed from waste plastic contaminant is like inexhaustible energy resource. The plastic oil facilitate to reduce the obligation of fossil fuel as well as it can be used as an alternative fuel in engine without changing description of the engine as it can also be used in pure form or blended form. In this study the diesel engine is fuelled with plastic oil, diesel blends. The performance and emission characteristics is evaluated. The blends PO10,PO20 and PO30 are prepared on mass basis. The experimental results inferring that, thermal efficiency of all blends gradually decreases compare to diesel at all loading condition. CO emission is decreasing considerably with increasing the percentage of plastic oil in blends, NO_X emission and CO_2 emission is increasing slightly with increase in blends percentage and loads.

Keywords: CRDI, Plastic Oil, Pyrolysis Process Waste Plastics

1. Introduction

The plastic is a material consisting of wide range of synthetic organic compounds. The plastic has become essential in our day to day life because of is attractive ability like very light weight, less costly and easy to carry. In1860 the plastic had invented but it is used in the last 30 years. The production of plastic has continued to rise each and every year. According to the global production of plastic the consumption of plastic is 5 million tonnes in 1950 and 260 million tonnes in 2009[1]. The consumption of plastic is increasing day by day and in 2013 it has been recorded to 299 million tonnes According to the new study the global production of plastic has come up to 302 million tonnes in 2015. According to the report of central pollution control board (CPCB) it is found that the Polyvinyl(PVC) Industry growth is 16-18% per year. In the year of 2000 the plastic consumption in India was reported to be 3 million tonnes and in 2007 it is increased up to 8.5 million tonnes. The Indian government is planning to increase the plastic consumption approximately 20 kg per person in 2022. Whereas the maximum consumption of plastic in Europe is 90 kg per capita and in America it is 60 kg per capita. Basically plastic are made long hydrocarbon chain and manufacture from petroleum product it contains poly vinyl chloride, Polypropylene and high density polyethylene[5,6,7]. In actual land filling is not a solution for waste plastic because land filling plastic produces harmful gases like carbon dioxide, nitride of oxygen, and greenhouse gases. This gases affects

**Author for correspondence*

the environment and increases the global warming. Due to the fast growth of automobile industry the consumption of oil increases so it is required to find out alternative fuel for diesel engine[3, 4].

Pyrolysis method is one of the best technique to utilize waste plastic in to the energy[10]. In this study, an attempt is made to determine alternative fuel which is having same or similar properties of fossil fuel. The waste plastic oil it can be used in CRDI engine as an alternative fuel with pure and different blending ratio[14]. The oil production from the waste plastic has major role in the recent year can be used at various scale and study[13,16].The required temperature is generally 450 to 700 degree centigrade but it is very difficult to maintain the temperature during the reaction[11]. For the better output of the pyrolysis process the catalyst like calcium oxide (CaO) Silica (SiO_2) alumina(Al_2O_3) and zeolite can be used as it help to increase the reaction rate and reduced the temperature requirement for the reaction[2,12].

2. Methods and Materials

2.1 Materials Characterization And Preparation Of Plastic Oil.

The waste plastic material like water bottle, plastic cover, milk cover is collected from Amrita plastic recycle centre Bangalore. These collected wastes are cut into small pieces of around 1cm^2. The pyrolysis chamber is fabricated using mild steal material as it withstand high temperature. Coal burning is used as a heating source to maintain the temperature of the reactor 550-750°C with blower arrangement. The required coal is collected from Vinayak coal suppliers S.P road Bangalore. To condense the condensable gases which is coming out from the reactor, concentric tube and shell and tube type heat exchangers are used with the constant circulation of water. There is one vertical pipe provided at the reactor to remove non condensable gases. A silicon gasket is used to prevent the leakage from the reactor. The raw plastic oil which is coming out from the other end of the heat exchanger is collected and purified before it used for preparation of the blends. A reactor and coal burning setup is used for pyrolysis process.

For the cooling of high temperature gas which is coming out from the reactor outlet two different types of heat exchanger have been used. One is parallel flow concentric heat exchanger and second is multiple channel flow heat exchanger. In purification process 100g of KOH is mixed properly with one litre of water and equal proportion of plastic oil is added. The mixture is kept for 2-3 hours in a conical flask as shown in Figure(3). As the heavy particles with water will settle at bottom portion of the flask and pure plastic oil settle at the upper level because of density difference. Then the water with heavy particles are removed at the bottom section of the flask. The blends of 10%, 20% and 30% are prepared on the mass basis.

Figure 1. Coal burning setup

Figure 2. Waste plastic material

Figure 3. Purification setup

2.2 Experimental Setup Crdi Engine and Experimental Details

The specification of the engine is shown in Table 1. For loading the engine brake drum rope dynamometer is used. The engine is operated at different loads at constant speed of 1500rpm. The water circulation to the engine head and exhaust gas calorimeter is provided through rota meter. The fuel consumption was measured with the help of burette and stopwatch. The time required for 10g of fuel consumption was taken and mass flow rate for the same is calculated. With the help of thermocouples at the different points the temperatures are measured. The engine is connected U-tube manometer to measure the flow rate of air to the engine. A five gas analyser was used to measure the CO, CO_2 and NO_x. Initially the engine was run by using neat diesel as fuel at all load conditions. In the second step the fuel tank was completely cleaned and blend having 10% of plastic oil is filled. The test was conducted at all load conditions and emission values were taken. The same procedure is repeated for other two blends by loading the engine as previous cases. The performance and emission characteristics are showing decreasing trend with increasing blends percentage. But PO20 and PO30 are showing almost similar variation in case of NO_X

Table 1.

Engine specification:	
Type	-4-stroke, single cylinder diesel engine.
Make	- kirloskar AV-1
Rated power	-3.7 KW, 1500 RPM
Bore and stroke length	- 85mm x 110mm
Compression ratio	-16.5:1.
Dynamometer	- Rope brake dynamometer.
Diameter of brake drum	-0.36m

3. Results And Discussions

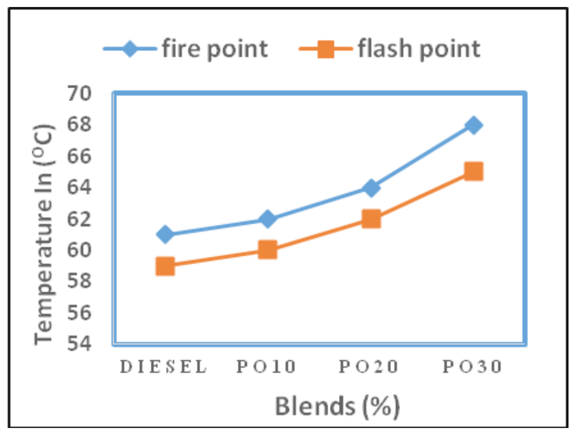

Figure 4. Variation of flash and fire point with blends percentage

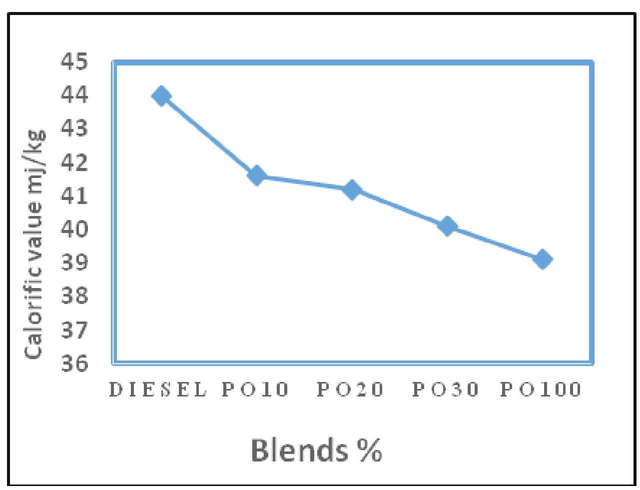

Figure 5. Variation of calorific value with blends percentage

The Figure 4 shows that the comparison between fire point and flash point with increase in blends percentage. It shows that the flash and fire points are increasing with increasing the plastic oil quantity in the blends compared with pure diesel. This increment in the flash and fire point is due to higher viscosity and density of the plastic oil is higher than diesel also plastic oil is less volatile. The increase in flash point is only 1% for PO10 and it 10% increase for PO30.

The variation of calorific value for the different plastic oil-diesel blends is elaborated in the Figure 5 the calorific value of the plastic oil is low as it has lesser cetane number. By increasing the quantity of plastic oil in the blends showing decreasing trend in calorific value. This is because of lesser calorific value of plastic oil compared to diesel. The PO shows 5.7% decrease and for PO30 it is 12.5% reduction.

4. Engine Performance

4.1 Brake Specific Fuel Consumption (BSFC)

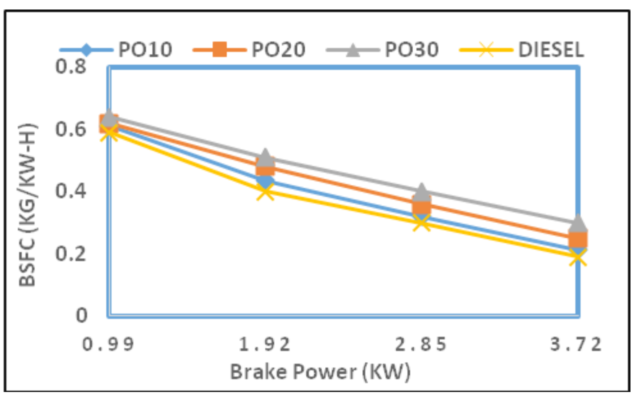

Figure 6. Variation of BSFC with BP at 1500 rpm

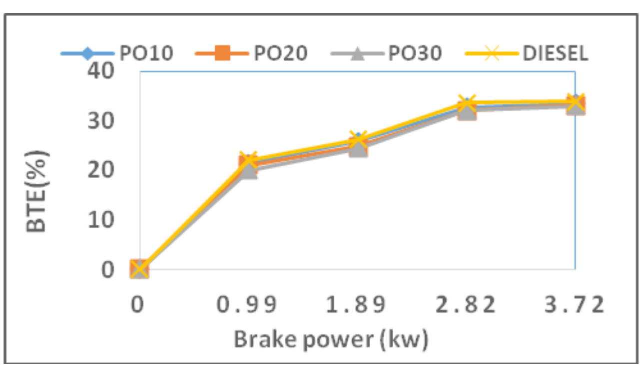

Figure 7. Relation between BTE with BP at 1500 rpm

The BSFC v/s BP shows the decrease in fuel consumption at higher loads. However the fuel consumption follows increasing trend by increasing the plastic oil quantity in the blends. The reason for getting higher fuel consumption is less calorific value of plastic oil. At the same load rich mixture has to be supplied compared to diesel. The efficiency is decreasing by 12% for PO10, 31% for PO20 and 48% for PO30.

4.2 Brake Thermal Efficiency

The variation of BTE with respect to brake power is shown in Figure 8. BTE is decreasing by increasing the blend percentage because of increasing in fuel consumption. The reason is plastic oil has lower calorific value and at the higher loads large amount of heat release makes increased heat loss. At the full load running under diesel gives 29% BTE and it is slightly decreasing for PO10, PO20, and PO30.

4.3 Exhaust Temperature

The exhaust gas temperature is increasing by increasing the BP. The exhaust gas temperature is about 140°Cat zero load and 240°C at full load for pure diesel. In case of PO10 the exhaust temperature showing less in the beginning and it increased to 268°C. The temperature is increasing by increasing the blend percentages. This is due to lower thermal efficiency as the work done will be less and heat release is more. The one more reason is of having high oxygen content plastic oil has constituents having higher boiling point increases the exhaust temperature.

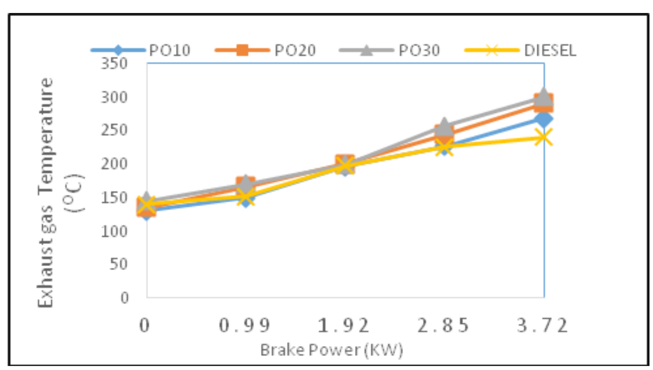

Figure 8. Variation of exhaust temperature with BP at 1500 rpm

5. Emissions Test

5.1 Carbon Monoxide

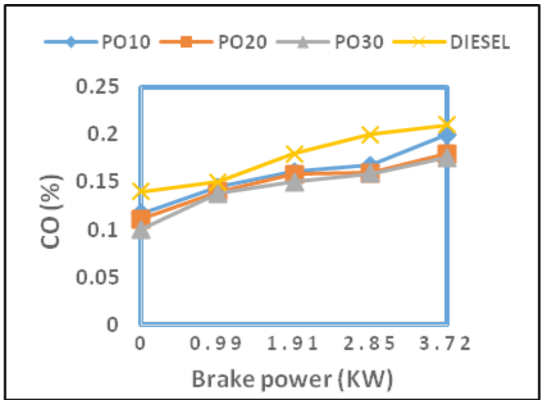

Figure 9. Varition of carbon monoxide with BP at 1500 rpm

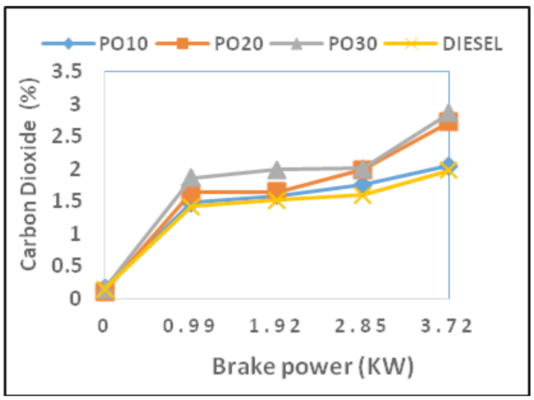

Figure 10. Variation of Carbon dioxide with BP at 1500 rpm

The Figure 9. shows that carbon monoxide incresses with increase in brake power. The PO10 varies from 0.117 % to 0.21%, for PO20 is varies from 0.111% to 0.18% and PO30 it is varies from 0.1% to 0.17%. The CO emmision is depend on the air fuel ratio. The CO is varies from 0.14% to 0.21% for diesel.The blends shows at full load decrease of 5% for PO10, 16% for PO20 and 19% for PO30. The reason is present of oxygenated hydrocarbon present in the plastic oil.

5.2 Carbon Dioxide

The variation in CO_2 with respect to BP shows increasing trend in figure as the plastic oil is higher oxygenated fuel. The PO10 varies from 0.17% to 2.05%, for PO20 is varies from 0.11% to 2.72% and PO30 is varies from 0.15% to 2.86%. The reason for increasing $CO_2$is using the same compression ratio and A/F ratio for plastic oil-diesel blends as the plastic oil shows less calorific value and lesser higher flash and fire pints. This may lead to improper combustion in the engine.

5.3 Oxides of Nitrogen

The Figure 11. shows that variation of oxide of nitrogen is directly proportional to the brake power. The NO_X is depend on the so many parameter like (temperature of combustion chamber, Air -fuel ratio, Time for combustion of fuel, etc). The oxide of nitrogen rises with increase blends percentage. NO_X varies from 85ppm to 290ppm for diesel oil. From 101ppm to 170ppm for plastic oil 10%. And PO20 and PO30 the oxide of nitrogen it is slightly high as compare to diesel and PO10. The reason for increasing NO_X may be due to the higher temperature at higher loads.

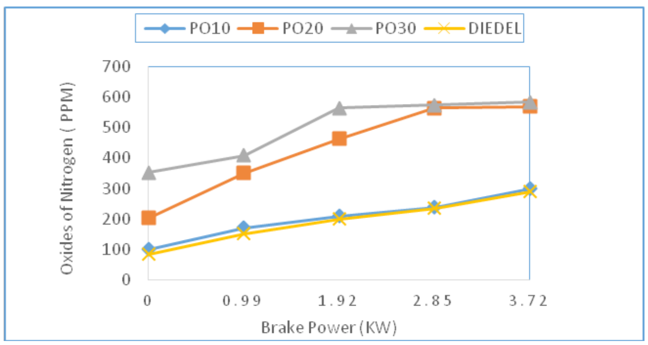

Figure 11. Variation of oxide of nitrogen with BP at 1500 rpm.

6. Conclusions

In this work the plastic oil is extracted from the dry plastic wastes by pyrolysis method. This provide us an alternative fuel which is having almost similar properties as fossil fuel,an efficient substitute to the fossil fuel being used in energy sector. The flash and fire points are increased, calorific value as shown little lesser values for the blends. By blending the pyrolysis oil with the diesel oil the engine performance was found to be acceptable by comparing the performance of engine working on neat diesel. The brake specific fuel consumption is more as compare to diesel fuel. And brake thermal efficiency is slightly reducing by increasing plastic oil quantity in blend.

The blends of plastic oil- diesel is influenced significantly on CO, CO_2, NO_X and exhaust gas temperature. The CO is decreased by increasing the blend percentage and CO_2 is increasing. The NO_X as well as exhaust gas temperature increasing significantly for PO20 and PO30. By observing the acceptable properties of plastic oil- diesel blends the plastic fuel can be used in the pure form also with little modifications to the engine.

7. Reference

1. Muthaa N H, Patel M and Premnath V **Plastics materials flow analysis for worldResources.**Conservation and Recycling**.** 2010; **47:** 222–244.
2. Adrados A, I **. Pyrolysis of plastic packaging waste: A comparison of plastic residuals from material recovery facilities with simulated plastic waste.** 2007.
3. Usta N 2005**An experimental study on performance and exhaust emissions of a diesel engine fuelled with tobacco seed oil methyl ester**. Energy Convers Management. 2005;**46:**2373–86.
4. Prakash R, Singh RK, Murugan S. 2013 **Experimental investigation on a diesel engine fueled with bio-oil derived from waste wood-biodiesel emulsions** Energy convers management. 2013; **30:**320–85.
5. Flamid SH, Amin MB, Maadhah AG **Handbook of polymer degradation New York: Marcel decker** 1992.
6. Williams PT, Williams EA. **Interaction of plastic in mixed plastic pyrolysis. Energy fuels.** 1990;**13:**88–99**.**
7. Sachin kumar, Prakash R, Murugan S and Singh R K . **Performance and emission analysis of blends of waste plastic oil obtained by catalytic pyrolysis of waste HDPE with diesel engine in a CI engine**Energy Conversion and Management. 2013; **74:** 323–31**.**
8. Sharmaa Brajandra k, Moserb Bryan R, Vermillionb Karl E, Dolly Kenneth M, Rajagopalana Nandakishore. **Production, characterization and fuel properties of alternative diesel from pyrolysis of waste plastic grocery bags.**Fuel Process Technology **.** 2014; **122:**79–90.
9. Xuea Yuan, Zhoub Shuai, Browna Robert C, Kelkara Atul, Baia Xianglan. **Fast pyrolysis of biomass and waste plastic in a fluidized bed reactor.** 2015; **156**(15):40–6.
10. Chartier Y 2013.**Safe Management of Wastes from Health-Care Activities, 2nd edition,World Health Organization.** Geneva,Switzerland. 2013.
11. Frigo Stefano, Puccini Monica, VitoloSandra. **Liquid fuel production waste tyre pyrolysis and it is utilization in a diesel engine fuel.** 2014 **;**116 : 399–408**.**
12. Syamsiro Mochamad, Saptoadi Harwin, Norsujianto Tinton, Noviasri Putri, Cheng Shuo **Fuel of production from municipal plastic waste in sequential pyrolysis and catalytic reforming reactors.**Energy proc. 2007; **47:**180–8.
13. Park JW, Kim JH, Seo G2002.**The effect of pore shape on the catalytic performanceof zeolites in the liquid-phase degradation of HDPE.**Polym Degrad Stabil. **2002;76:495–501.**
14. Panda AK, Singh RK, Mishra DK2012.**Thermo-catalytic degradation of thermocol waste to value added liquid products. Asian J Chem.2012; 24:5539–42.**
15. Vinod kotebavi, Divakara shetty and Debjyoti sahu. **Performance and emission characteristics of a CI Engine run on waste cooking oil-diesel blends.** Pollution Research.2016; 35(1):, 159–166 .
16. Panda AK, Singh RK. **Catalytic performances of kaoline and silica alumina in the thermal degradation of polypropylene.** J Fuel Chem Technol 2011;39:198–202.