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ENVIRONMENTAL EFFECT OF USING DIESEL ON WASTE PLASTIC OIL FUELED IN DI DIESEL ENGINE

P. Senthilkumar

Department of Mechanical Engineering, Loyola Institute of Technology, Chennai, Tamil Nadu, India

ABSTRACT

In the world, many countries are continually developing materials and methods for effective utilization of the alternative fuel resources available in their region. On the other hand waste plastic poses very serious ecological challenges because of their disposal problems in all over the world. The oil obtained by pyrolysis of waste plastics can be utilized as a fuel without any change in engine modifications, which results in an increase the emissions like carbon monoxide (CO) and oxides of nitrogen (NO_X) and unburned hydrocarbons (UBHC) compared with diesel. This paper deals with the blending of waste plastic oil (WPO) with diesel in two different constituents, namely WPO 90 % and diesel 10 % (PD10) and WPO 80 % and diesel 20 % (PD20). Diesel engine characteristics such as combustion, performance, and emission have been evaluated for different load conditions and compared with the results with that of diesel, WPO and its blends. The experimental results indicated that the brake thermal efficiency (BTE) of WPO-diesel blends at full load conditions is higher as compared to that of WPO. The BTE increased by about 1.31% with PD20 operation at full load compared to WPO. Exhaust gas temperature (EGT) decreased by 5^{o}C in PD20. NOx and UBHC emission was decreased with increase in the percentage of diesel in WPO blends. CO and Smoke emission decreased by 0.04 % and 2.1 % in the case of PD20 compared to WPO at full load condition respectively.

KEYWORDS: *Diesel Engine, Emission, Performance, Pyrolysis Process, Waste Plastic Oil*

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INTRODUCTION

Higher thermal efficiency and ease of handling are the reasons behind full acceptance of diesel for many industries like automobile, agricultural and power generation sectors. Meanwhile, in the past four decades, the demand for oilderived fuels had been enormously increased due to the augmentation of automotive vehicle usage, this tends to increase the economic value of the fossil fuel. Also, mounting of an air pollution caused by the burning of fossil fuels intensifies to search for alternative fuels for the internal combustion engines to ensuring energy security and solving environmental issues. Plastics have become an essential part of today's world due to their light weight, hardness, energy efficiency, coupled with a quicker rate of production and design flexibility. At the same time, waste plastics have created very serious environmental challenges due to their huge quantities and disposal problems. Pyrolysis process is a better method for converting waste plastics into plastic oil because of their advantages such as self-governing feedstock, least amount of waste produced, lowpressure operation and high conversion efficiency in the order of 80% **[1]**. Previous research works based on the WPO stated that the diesel engine can able run with sole WPO without any modifications. The emissions are CO, CO_2 and UBHC were marginally higher than that of the diesel. The fuel WPO releases higher cylinder pressure compared to diesel due to evaporation of WPO in the cylinder by absorbing the heat from the combustion chamber **[2].** The BTE at all load conditions were lower as compared to that of diesel, EGT, NOx and CO emission increases with an increase in engine load **[3]**. The aim of this work is to compare the performance, combustion, and emission characteristics of WPO -Diesel blends with WPO and diesel.

MATERIALS AND METHODS

Production of Waste Plastic Oil

Pyrolysis is a process of thermal degradation in the absence of oxygen, performed to acquire WPO by using a catalyst. Various sizes and shapes of waste plastics were collected and crushed with shredder for ease of handling the process. Finely crushed waste plastics were fed in a reactor chamber. The copper coil placed around the flaming chamber is heated and maintained at a temperature range of 320^0C-500^0C for 3-4 hours duration. At this high temperature, from the chamber waste plastic gets vaporized and passes through the condenser. Because of the cold water present in the condenser, by condensing the waste plastic vapor **[4].** The condensed vapor is then stored in the oil collector in the form of plastic oil. Pyrolysis process involves the breakdown of larger to smaller molecules. Pyrolysis treatment of this output products was collected: Waste Plastic Oil – 75% to 90% (a mixture of petrol, diesel, and kerosene), Gas – 5% to 20% and Residual coke – 5% to 10% **[5].**

Waste Plastic Oil-Diesel Blends Preparation

In this present study, PD10 and PD20 blends were prepared by 90%v of the WPO and 10%v of diesel and 80%v of the WPO and 20 %v of diesel respectively. The WPO was easily blended with diesel without using any substances. The properties of WPO and its blends compared with diesel are given in **Table 1.**

Table 1: Properties of Diesel, WPO and WPO Blend

Properties	Protocol	Diesel	WPO	PD 10	PD 20
Density@15^0C kg/m^3	IS1448,P16	860	835	838	840
Kinematic viscosity @40^0C (cSt)	ASTM D445	2.107	3.254	3.135	3.025
Flash point ^{0}C	IS1448,P20	50	41	42	44
Fire point ^{0}C	IS1448,P20	56	49	50	51
Gross calorific value (KJ/kg)	IS1448,P25	42500	43388	43300	43210
Cetane number	IS1448,P9	50	48	48.3	48.5

Experimental Setup

The experiments carried out on a single cylinder, air cooled, direct-injection (DI) diesel engine. AVL software was used for combustion data analysis and DAQ card placed in between the computer and the engine converts the recorded analog signal into a digital value. The AVL365C angle encoder was attached to the engine to measure the crank angle for various piston positions. The AVL-GH14D was used as a pressure transducer to indicate the pressure level in the combustion chamber. K-2 type thermocouple was used to measure the EGT. The test engine coupled with an electrical dynamometer to apply load on the engine. The engine was connected to the computer to record and analyze the output data of cylinder pressure and heat release rate was evaluated. AVL - Digas 444 exhaust gas analyzer was used to measure the engine emissions such as NOx, UBHC and CO. Smoke opacity of the exhaust gas was measured with the use of AVL 437 C smoke meter.

RESULTS AND DISCUSSIONS

Performance Characteristics

Brake Thermal Efficiency

The BTE variation with respect to load for diesel, WPO,and WPO blends is shown in **Figure 1**. BTE of diesel, WPO, and WPO-diesel blends increases with an increase in engine load. The figure shows that WPO blends have a higher BTE at all load conditions were compared to that of WPO. As the engine load increases the heat generated in the cylinder increases and hence the thermal efficiency increases. The BTE is 24.96% for diesel and 22.61% for WPO at full load; however, when the engine is filled with WPO-diesel blends such as PD10 and PD20 it gives marginally higher thermal efficiencies of 23.41% and 23.92% respectively at full load condition, compared to that of WPO.

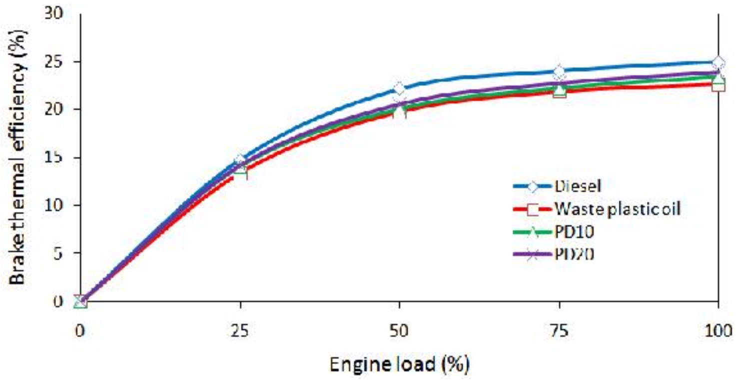

Figure 1: PD Variation of BTE vs Engine Load

This may be due to the fact that at full load condition the heat release rate is marginally higher and huge amount of heat is carried out by exhaust gas for WPO compared to diesel**.** This may result in lower BTE in the case of WPO **[6].**

Exhaust Gas Temperature

The variations of the EGT with respect to load for diesel, WPO, and WPO blends are as shown in **Figure 2.** All the graphs for all fuels are increasing from no load to full load.

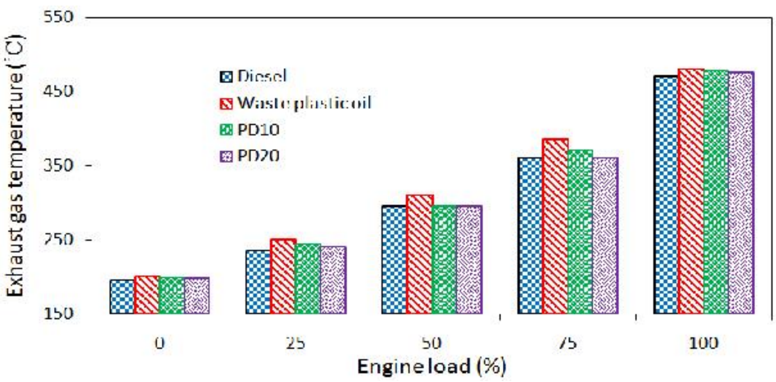

Figure 2: PD Variation of EGT vs Engine Load

The reason for the increase in EGT with engine load from the simple fact that more amount of fuel was required by the engine to generate the extra power needed to take up the additional loading **[7,8].** The EGT varies from 195^0 C at no load to 470^0C at full load for diesel whereas WPO varies from 200^0 C at no load to 480^0C at full load condition. In the case of WPO-diesel blends, it varies from 199^0 C to 478^0 C for PD10 and 198^0 C to 475^0 C for PD20, as the load increased from

0 to 4.7 kW. The EGT in the case of different blends is found to be marginally higher compared to diesel. As a result of increased combustion duration, a higher EGT is recorded in the plastic oil. The increased EGT could be due to the low thermal efficiencies of the engine.

At a lower thermal efficiency, less of the energy input in the fuel is converted into work, thereby increasing the exhaust temperature **[9].**

EMISSION CHARACTERISTICS

Unburnt Hydro Carbon

In a CI engine, UBHC emission is lesser than that of SI engine. The variation of UBHC with a load for testing fuels is shown in **Figure 3**. The UBHC increas with an increase in the load. The graphs show similar trend throughout the operation. UBHC varies from 21 ppm at no load to 29 ppm at full load for diesel and it varies from 33 ppm at no load to 48 ppm at full load for WPO. Similarly for PD10, it varies from 30 ppm at no load to 44 ppm at full load, for PD20 it varies from 28 ppm for no load to 39 ppm for full load. The fuel spray does not propagate deeper into the combustion chamber and the hydrocarbons remain along with the cylinder wall and the crevice volume **[10].**

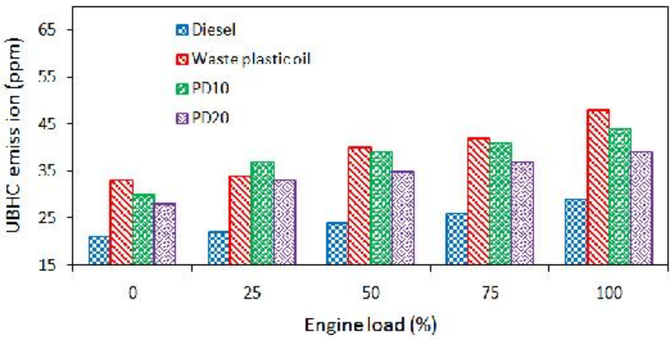

Figure 3: PD Variation of UBHC Emission vs Engine Load

Oxides of Nitrogen

In the formation of Nitrogen Oxides, the predominant factors are the air/fuel ratio and the environment temperature. When there is adequate burning the temperature rises and hence more free Oxygen atoms combine with Nitrogen, increases the formation rate of Nitrogen Oxide **[11]. Figure 4** shows the variation of NO_X with the load.

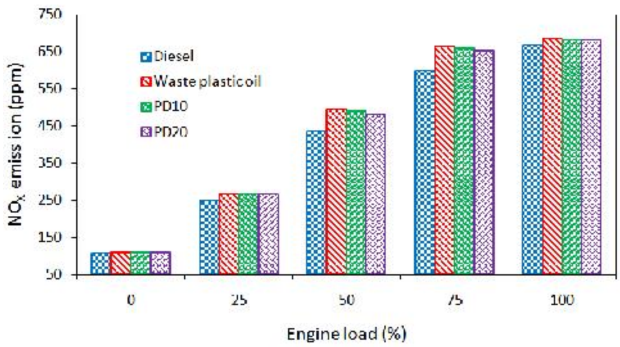

Figure 4: PD Variation of NO_X Emission vs Engine Load

It can be observed that the NO_X emission increases with the increase in the percentage of the WPO in blends. CI engines, all the time run with lean air fuel mixtures and produces higher NOx. It was also observed that the NO_X

emission increases with increase in load for all the blends. NO_X emission increases with the increase in load from 107 ppm at no load to 668 ppm at full load for diesel and from 110 ppm at low load to 685 ppm at full load for WPO. It varies from 110 ppm to 683 ppm for PD10 and 109 ppm to 681 ppm for PD20, from no load to full load conditions. The reason for increasing NO_X in WPO could be due to increased ignition delay, promotes premixed combustion and fuel has a ring structure tends to have a higher adiabatic flame in temperature which results in a higher heat release rate **[12, 13].**

Carbon Monoxide

CO emission is mainly due to the lack of oxygen, poor air entrainment and intermediate combustion during the combustion process. The variation of CO with load is shown in **Figure 5**.

The CO emission varies from 0.03% Vat no load to 0.22% by vol. at full load for diesel and from 0.05 % by vol. at no load to 0.26 % by vol at full load for WPO. For PD10, it varies from 0.04% by vol. at no load to 0.25% by vol. for a full load, for PD20 it is 0.04% by vol. at no load to 0.24 % by vol. at full load.

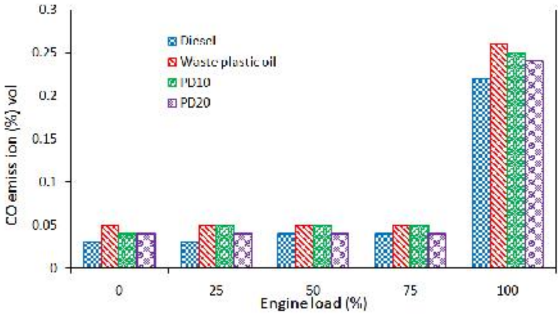

Figure 5: PD Variation of CO Emission vs Engine Load

The results showed CO emission of WPO as higher than diesel, especially at higher load. The reason behind the increased CO emission is intermediate the combustion due to the absence of oxygenated compounds in WPO **[14].** The drastic increase in CO emission at higher loads is due to higher fuel consumption. The results show that the CO emission of WPO-diesel fuel blends as higher, than that of diesel.

Smoke Opacity

The smoke is just a solid soot particle suspended in the exhaust gas. **Figure 6** shows the variation of smoke with a load for diesel and WPO blends. The trend seems to be increasing with increase in load for all tested fuels. Smoke varies from 5.5 % at no load to 51.1 % at full load for diesel, whereas for WPO it varies from 12.3% at no load to 55.2 % at full load. For PD10, it varies from 11.4% at no load to 54.2% at full load, from 10.8% at no load to 53.1 % at full load for PD20.Further reduction of WPO in the WPO blends decreases the smoke emission.

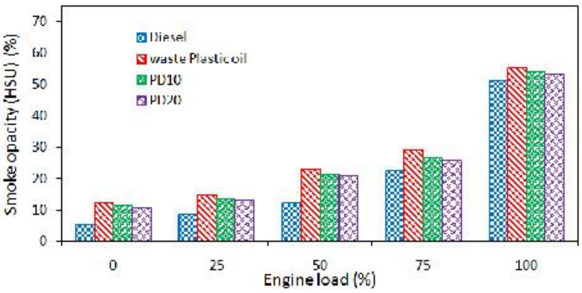

Figure 6: PD Variation of Smoke Opacity vs Engine Load

The smoke for WPO-diesel blends can be seen as higher than diesel. This could be due to the non-availability of homogeneous charge inside the engine cylinder. Lower combustion temperature reduced the duration of combustion and rapid flame propagation may also be the reasons for higher smoke intensity **[15, 16].** However, at higher load it ranges due to the non-availability of sufficient air because of the abnormal combustion, there is a visible white smoke emission.

CONCLUSIONS

In this study, the experiments were conducted using diesel, WPO obtained by pyrolysis of waste plastics and their blends under different loads to investigate the performance and emission characteristics of a compression ignition engine at varying load conditions, the following conclusions are drawn.

- The engine was able to run with 100% WPO and blends of WPO with diesel without any modifications.
- BTE at all load conditions is lower as compared to those of diesel due to the fact that at full load, the EGT and the heat release rate are marginally higher for WPO compared to diesel. EGT increases with an increase in engine load.
- The NO_X emission increase with increase in percentage of WPO in blends and decreases with an increase in the engine load.
- The UBHC emission is increasing with the increase in engine load and increases with increase in the percentage of the WPO in blends.
- The WPO shows the higher CO and the smoke emission compared to diesel and decreases with the increasing diesel in WPO blends.

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