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Testing of Performance, Emission and Combustion Characteristics of a Diesel Engine Using Polymer Oil

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ABSTRACT

This paper describes an experimental study of using polymer oil obtained from the plastic waste as a fuel in diesel engine. In this study, the effects of using polymer oil on the engine performance, exhaust emissions and combustion characteristics have been experimentally investigated. In the present work, polymer oil are used in a single cylinder four stroke, water cooled diesel engine. The engine fuelled by the polymer oil is comparable with that fuelled by diesel. The experimental result showed that the carbon monoxide, carbon dioxide, Oxides of nitrogen and smoke were significantly increased. Unburned hydrocarbon, brake specific fuel consumption and brake thermal efficiency were found to have increased by using polymer oil

Keywords: Diesel, Polymer Oil, Plastic Waste, Engine Performance.

1. INTRODUCTION

Plastics are used on a daily basis throughout the world. Due to their relatively low cost, versatility, durability and obduracy to water, they are used in a wide range of products. Plastics are synthetic substances produced by chemical reactions. Almost all plastics are derived from petroleum. Plastics are polymers, very long chain molecules that consist of monomers, linked together by chemical bonds. The monomers of petrochemical plastics are inorganic substances and are non-biodegradable, Hence, this leads to the soil contamination and in long term, serves as a cause for severe environmental hazards such as degradation of soil fertility, pollution of surface and subsoil water. As per the survey conducted in India in the year 2000, nearly 6000 tonnes of plastic waste were produced on a daily basis and only 60% got recycled [1]. The remaining 40% could not be recycled.. Plastics are produced from petroleum derivatives and are composed primarily of hydrocarbons but also contain additives such as antioxidants, colorants, and other stabilizers. However, when plastic products are used and discarded, these additives are undesirable from an environmental point of view [2,-3]. Many of the industries have developed several processes to convert waste plastics into fuels [4]. Many researches involving thermal degradation of waste plastics into liquid fuel have been conducted. Thermal degradations are not only used for polymer but it is also used for aromatics and gas [5-6]. Furthermore, some researches have been also conducted using catalytic degradation and pyrolysis resulting in successful outcomes [7-8]. Panda, et.al [9] described that production of liquid fuel from plastic waste would be a better alternative as the calorific value of the plastics is comparable to that of fuels, around 40 MJ/kg. This option also reduces waste and conserves natural resources. It was also mentioned that mechanical recycling of plastic wastes is widely adopted method by different countries and the catalytic pyrolysis of plastic to fuel is gradually gaining momentum and being adopted in different countries recently due to its efficiency over other process in all respects. Walendziewski [10] carried out two series of waste plastic cracking. The first series of polymer cracking experiments was carried out in a glass reactor at atmospheric pressure and in a temperature range 350-420°C, the second one in autoclaves under hydrogen pressure (~3-5MPa) in temperature range 380-440°C. They also concluded that the application of catalyst results in lowering of polymers cracking temperature, density of obtained liquid and increased the gas fuel yield. Bertoli et al. [11], did studies on the performance, emission and combustion characteristics of a Light duty DI Diesel Engine with wood pyrolysis oil (WPO)which was blended with different percentage of oxygenated compounds. It was concluded that reliable operations were recorded with WPO–diglyme blends with WPO content up to 44.1% by weight. Nomajor trouble was observed on the critical components of the engine. S. Murugan et al.[12]. evaluated the performance and emission characteristics of a single cylinder direct injection diesel engine fuelled by 10, 30 and 50 percent blends of Tyre pyrolysis oil (TPO) with diesel fuel (DF). The combustion parameters such as heat release rate, cylinder peak pressure and maximum rate of pressure rise were also analyzed. Results showed that the brake thermal efficiency of the engine fuelled by TPODF blends increased with increase in blend concentration and higher than DF. NOx, HC,CO and Smoke emissions were found to be higher at higher loads due to high aromatic content and longer ignition delay. The cylinder peak pressure increased from 71.4 bar to 73.8 bar. The ignition delays were longer than DF. The polymer oil is derived from the plastic waste. The objective of the present study is to investigate the performance, the emission and the combustion characteristics of a diesel engine fuelled with polymer oil.

2. PLASTIC WASTE TO POLYMER OIL

Plastic waste material was converted into uniform size by the process of crushing, cutting and shredding in the feed system, for the purpose of handling and melting. This process of sizing and grading the waste was semi automatic. The graded feed was stored in a hopper before feeding into the reactor by a conveyor feeder. The dust and the other fine wastes collected from the cyclone filter are disposed through a vent with particle size monitoring system. The plastic waste was treated in a reactor along with a catalyst and maintained at a temperature of 275◦C–375◦ C at atmospheric pressure for about 3to 4 hours. The outlet gas from the pyrolysis process was condensed in a series of condensers and the liquid obtained was taken as fuel. The uncondensed gases were let out into the atmosphere. Properties of diesel, polymer oil are compared in Table.1.

3. EXPERIMENTAL SET UP

Tests were conducted on a single cylinder, four stroke, direct injection, water cooling kirlosakar diesel engine at an engine speed of 1500 rpm. The engine has a 800cc cylinder volume. The test engine specifications are given in Table2. The schematic arrangement of the experimental set up and photographic view are shown in figure (1) and (2).The test engine was directly coupled to an eddy current dynamometer for load measurement. Airflow meter was used to measure the airflow .The fuel measuring tube (burette) was used to measure the fuel flow rate. The pressure transducer was used to measure the cylinder pressure. It was fit onto the cylinder head with a charge amplifier. AVL di-gas analyzer was used to measure NOx /HC/CO/CO_2 emission in the exhaust gas. Exhaust gas temperature was measured with a thermo couple. AVL smoke meter was used to measure the smoke density in the exhaust. Combustion characteristic of the engine was measured by the AVL combustion analyzer.

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The fuels used in this study include diesel and polymer oil. Diesel was obtained from Indian Petroleum Corporation. Polymer oil are purchased from a commercial supplier.

Table1. Fuel properties of diesel, polymer oil and ethanol

Property	Diesel	Polymer oil
Gross calorific value (kJ/Kg)	46,500	45216
Density @30 ^{0}C in (g/cc)	0.840	0.7949
Kinematic viscosity,cst @40^{0}C	2.0	2.85
Cetane number	55	51
Flash point (^{0}C)	50	41
Fire point (^{0}C)	56	43
0xygen content (wt.%)	0	0

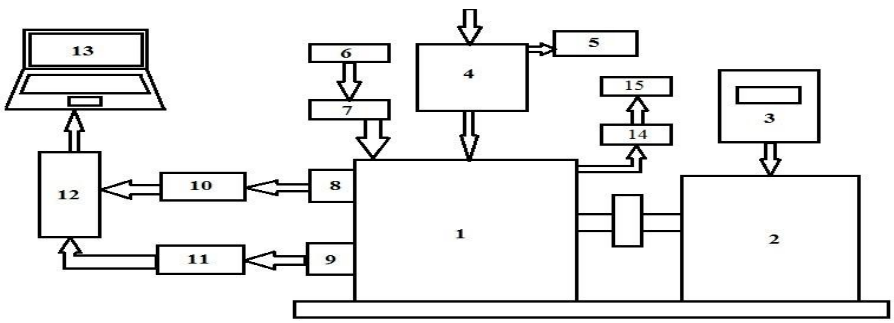

Fig 1. Experimental setup of the Test Engine

The nomenclature of the numbers are mentioned below

1. Diesel engine
2. Alternator
3. Dynamometer control
4. Air box
5. U-Tube manometer
6. Fuel tank
7. Fuel measurement flask
8. Pressure pickup
9. TDC position sensor
10. Charge amplifier
11. TDC amplifier circuit
12. A/D card
13. Personal computer
14. Exhaust gas analyser
15. AVL smoke meter

Figure 2: Photographic view of the Experimental set up.

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Table 2: Specifications for kirlosakar diesel engine

Parameter	Specification	Unit
Power	3.7	Kw
Speed	1500	RPM
Cylinder bore	0.08	m
Stroke	0.11	m
Number of cylinders	4	--
Number of strokes	4	--
Type of cooling	Water	--

4. RESULT AND DISCUSSION

The experiment was conducted in a standard diesel engine at an engine speed of 1500 rpm. A comparison of the engine performance, the emission and the combustion characteristics for the following combinations was made and the results were presented.

- Diesel fuel (DE)
- Polymer oil (PO)

4.1 Performance

4.1.1 Brake Thermal Efficiency

The brake thermal efficiency with the engine load of polymer oil is compared with the diesel as shown in Fig 3. It can be observed from the figure that the brake thermal efficiency of diesel is 28% and for the polymer oil is 27.25% .it is clear that the brake thermal efficiency of the polymer oil is lower than the diesel. Lower calorific value and higher viscosity are the due reasons for the lower brake thermal efficiency.. The exhaust gas temperature and the heat release rate are marginally higher for polymer oil compared to diesel [13]. This may result in higher heat losses and lower brake thermal efficiency in the case of polymer oil.

4.1.2 Brake Specific Fuel Consumption

Fig 4 shows the variation of the brake specific fuel consumption with load for the tested fuels. It can be observed from the figure that the brake specific fuel consumption has increased by using polymer oil compared to diesel.. Brake specific fuel consumption varies from 0.56kg/kWhr at 20% of load to 0.28kg/kWhr at full load for diesel and varies from 0.62kg/kWhr at 20% of load to 0.29kg/kWhr at full load for polymer oil.. The main reason for the increase of specific fuel consumption is due to lower calorific value of polymer oil than that of diesel.

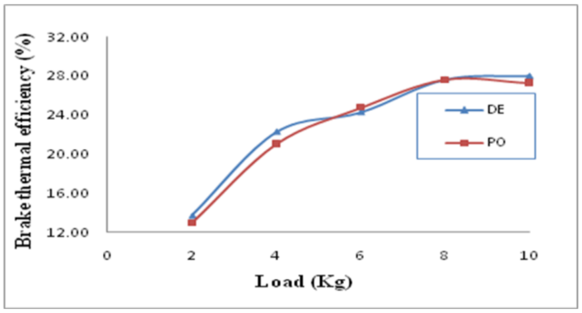

Figure 3.Variation of brake thermal efficiency with load

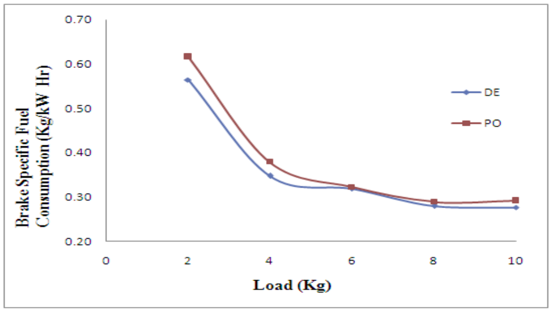

Figure 4. Variation of brake specific fuel consumption with load

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4.2 Emission

4.2.1 Carbon Monoxide

Carbon monoxide emission is mainly due to the lack of oxygen, poor air entrainment, mixture preparation and incomplete combustion during the combustion process [14,15]The variation of carbon monoxide with load is shown in Fig.5.CO emission is toxic and must be controlled. The concentration of CO emission varies from 0.07% at 20% of load to 0.09% at full load for diesel, It varies from0.07% at 20% of load to 0.14% at full load for polymer oil , The results show that the C0 emission of polymer oil is higher than the diesel at full load. The reason may be increased CO emission is incomplete combustion due to reduced in –cylinder temperatures, and higher fuel consumption at higher loads.

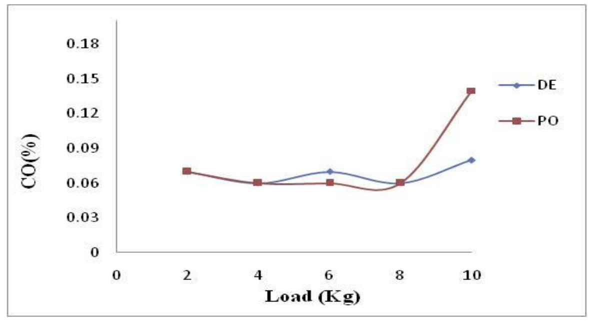

Figure 5. Variation of carbon monoxide with load

4.2.2 Unburned Hydrocarbon

The variation of unburned hydrocarbon with load for tested fuels is shown in Fig 6. Unburned hydrocarbons are produced when the fuels are incompletely burned. Unburned hydrocarbon varies from 32 ppm at 20% of load to 57ppm at full load for diesel. It varies from 49ppm at 20% of load to 91ppm at full load for polymer oil.. From the results, it can be noticed that the concentration of the hydrocarbon of polymer oil is marginally higher than the diesel. . This may be attributed to unsaturated hydrocarbons present in the polymer oil which are unbreakable during the combustion process [16, 17].

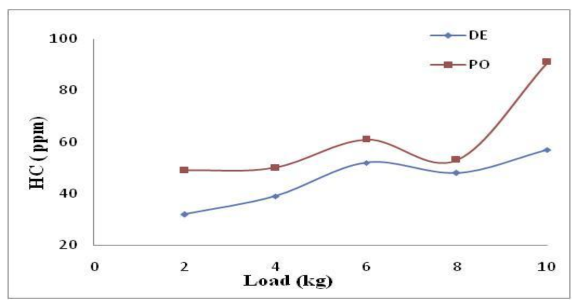

Figure 6. Variation of unburned hydrocarbon with load

4.2.3 Oxides of Nitrogen

The formation of NOx is mostly dependent on oxygen concentration and cylinder temperature.Fig7 shows the comparison of oxides of nitrogen with load for the tested fuels. It can be noticed that the NOx emission in the polymer oil is higher than the diesel. NOx varies from 129 ppm at 20% of load to 855 ppm at full load for diesel. and from 150 ppm at 20% of load to 904ppm at full load for polymer oil. The reason for increased NO_X in the polymer oil is higher combustion temperature and higher heat release rate.

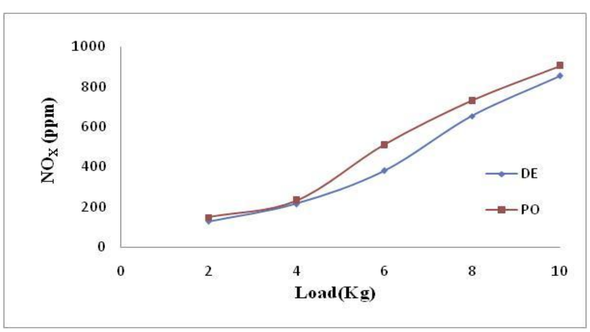

Figure 7. Variation of oxides of nitrogen with load

4.2.4. Smoke

Smoke opacity is indicative of dry soot emissions which is one of the main components of particulate matter (18). Fig 9 shows the comparison of smoke level with load. Smoke level varies from 1.7% at 20% load to 53.5% at full load for diesel, from 2% to 55.1% for polymer oil..It can be observed that the soot emitted by the polymer oil significantly higher than the corresponding neat diesel. This reason may be non-availability of homogeneous, charge inside the engine cylinder, reduced duration of combustion and rapid flame propagation may also be the reasons for higher smoke intensity [19].

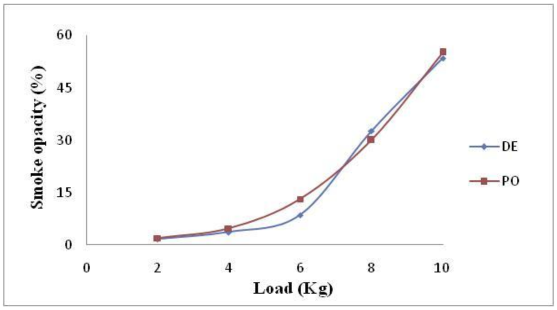

Figure 8. Variation of smoke with load

4.3 Combustion Parameters

4.3.1 Heat release rate

The comparison of heat release rate for diesel and polymer oil operation at full load is shown in Fig9.It can be observed that the maximum heat release rate of 40J/◦CA is recorded for diesel, while polymer oil records its maximum heat release rate of 41J/◦CA. polymer oil show the maximum heat release rate at full load compared to diesel. Heat released during the premixed combustion is higher for polymer oil than diesel due to higher ignition delay.

4.3.2Cylinder pressure-crank angle diagram

Fig 10 indicates the cylinder pressure with crank angle at full load for the fuels tested. The cylinder pressure obtained at full load indicates higher value for polymer oil compared to diesel and .It can also be seen that for diesel operation, the cylinder peak pressure is about 61 bar and for polymer oil, it is 63 bar . In a CI engine, the peak pressure depends on the combustion rate in the initial stages, which is influenced by the amount of fuel taking part in the uncontrolled combustion phase that is governed by the delay period (20-21).The increase in ignition delay of polymer oil results in a strong premixed burning phase and gives rise to the peak cylinder pressure.

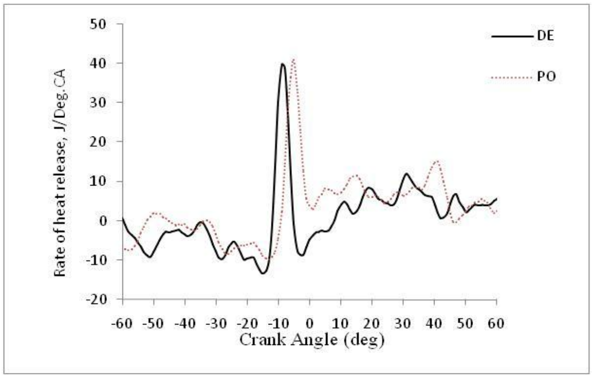

Figure 9. Variation of heat release rate with crank angle

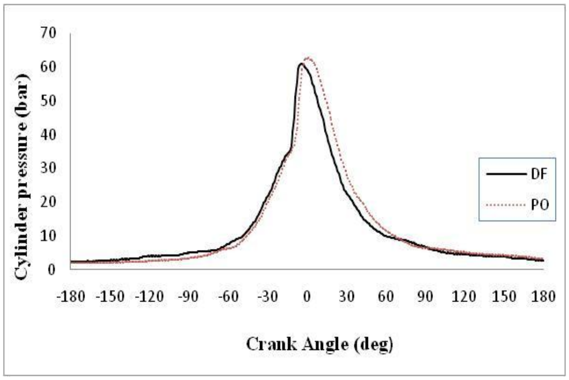

Figure 10. Variation of cylinder pressure with crank angle

5. CONCLUSION

The variations in the engine performance, the emission and the combustion parameters of a diesel engine have been investigated using polymer oil. Based on the experimental results, the following conclusions are drawn.

- Engine was able to run with 100% polymer oil
- Thermal efficiency is closer to the diesel fuel operation
- CO, CO_2 and HC emission are higher than the diesel fuel.
- Brake specific fuel and NOx emission is higher for polymer oil operation than that of diesel fuel operation.
- Smoke level higher in polymer oil compared to diesel operation.
- Heat release rate and the cylinder pressure obtained at full load indicate higher value for polymer oil compared to diesel.
- Polymer oil can be used alternate fuel to the diesel.

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