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Original Article

Evaluating Diesel Engine Performance with Blended Fuels from Low-Density Plastic Pyrolysis Oil: A Sustainable Approach to Diesel Engine Operation

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Abstract - *The present investigation discusses the evaluating diesel engine fueled by Low Density Plastic Pyrolysis Oil (LDPPO) made using a fast semi-batch catalytic pyrolysis employing Zeolite as a catalyst at a temperature of 550°C. Experiments involving the mixing of diesel fuel were carried out on a diesel engine, limited to single cylinder and LDPPO performance analysis- diesel blends in varying proportions like 10%, 20%, 30%, 40%, and 50% in volume proportions. The Brake Thermal Efficiency (BTE) has been noted to be closer to diesel, and the Brake Specific Fuel Consumption (BSFC) was lower for the 30% LDPPO mix than diesel and higher for other LDPPO mixtures. Carbon Monoxide (CO), Hydro Carbon (HC) and smoke were noted to be lower, and the Nitrogen Oxides (NO) were diminished for the LDPPO30 mix at peak load operations as similar towards the diesel. The analysis of Cylinder pressure and the study of Heat Release Rate (HRR) is more significant than diesel up to 30% LDPPO fuel mixture. According to the test findings, the 30% LDPPO-diesel combination is suitable for replacing diesel fuel without requiring any modifications.*

Keywords - *Low Density Plastic Pyrolysis Oil, Combustion, Performance, Diesel engine, Emission.*

1. Introduction

A continuous increase in energy consumption due to the increased number of automobiles on the road, the rapid depletion of petroleum resources, the highly volatile price of petroleum fuels, environmental emissions, disposal of waste drives, and stringent emission norms necessitates the research to search an alternate to the diesel oil Combustion Ignition (CI) engines [1, 2].

Due to its low production cost compared to other materials and ease of use in various applications, plastic consumption is increasing significantly year after year [3]. Plastic waste disposal has also increased, making it one of the most essential categories of municipal solid waste. Polyethylene represents the most extensively used plastic worldwide, with an estimated 80 million metric tons annually. Some typical applications are plastic bags, gadgets, oil bins, containers, and covering foil for wrapping [4].

Plastic waste is a significant problem among the various types of solid waste because it is non-biodegradable in the environment. Plastics have become an essential part of today's world because of their lighter weight, ruggedness, non-perishable nature, faster rate of manufacturing, design versatility, and raw material demand [5, 6]. Hydrocarbons make up the majority of plastics, which are derived from crude oil; however, they may also contain other additives like colourants, absorbents, and antioxidants [7]. Polyethene pyrolysis oil has only been studied in diesel engines with lower mixtures and positive outcomes at higher blends [8].

The analysis of an engine operating on raw plastic oil and its diesel blends, using plastic oil mix at 75% of rated power, resulted in higher BTE. They furthermore declared that Waste Plastic Oil (WPO) has a higher cylinder pressure and HRR rate than diesel [9]. Achieved higher levels of engine BTE and lower levels of BSFC while using Kaoline catalytic polypropylene oil; results indicated that 30%WPO blend performed well, but anything above 50% caused engine vibration [10].

According to reports, higher blend ratios and engine loads produce higher emissions than diesel. The performance of an engine with 5% High-Density Polyethylene (HDPE) plastic pyrolysis oil blend, the lower cetane number of HDPE plastic oil resulted in lower thermal efficiency. It caused more significant Carbon Dioxide (CO_2) and NO emissions than diesel [11]. They have examined the consequences of operating a double-cylinder engine with a 40% HDPE oil-diesel mixture. According to the findings, it generates greater NO, Unburned Hydrocarbons (UBHC) and CO and lesser CO and BTE at high engine loads [12].

The engine used 10% LDPE oil, and the results revealed lower BTE NO emissions and relatively high UBHC, CO, and CO_2 emissions [13]. Generated non-usage Waste Plastic Pyrolysis Oil (WPPO) and its lower mixtures are utilized to operate the engine, the results revealed that (WPPO) diminished the smoke levels and the BTE was higher compared to pure WPPO and diesel, but the CO and NO emission levels were relatively low [14]. The behaviours of the diesel engine were examined using WPO and its blends, and they came across that a 20% WPO-diesel blend boosted BTE while lowering BSFC but increased NO and HC emissions when contrasted with diesel [15].

Engine performance was evaluated using various proportions of WPO-diesel mixtures. Compared to diesel, the efficient WPO operation reduced BTE by 4%, and there was a significant rise in NO, CO, HC, and CO_2 emission levels with an increase in WPO in the mixtures. Under 80-90% of the engine's load condition, 60-70% WPO in diesel might provide the most outstanding performance and emissions [16].

Analysed an engine performance with WPO and its lower blends with 2.5% Di-Ethyl Ether (DEE) with various compression ratios, it was ascertained that the combination of DEE might accomplish diesel engine performance at higher Compression Ratio (CR) while compromising NO emissions [17]. WPO will reduce the engine Particulate Matter (PM) and NO emission levels. Results showed that the mixtures produced a low cylinder pressure and HRR and decreased NO and smoke levels. In the evaluation of diesel, the BTE of the engine was noted to be increased and also rise in HC and CO emissions for 30% WPO emulsified at final load [18].

The performance behaviours of an engine utilizing compression-ratio-dependent oil-diesel blend for use in transformers. The findings demonstrated that 30% WPO offers a substantial rise in BTE, fairly low smoke levels, and relatively high NO, and it is a sustainable booster for plastic oil [19]. The combined effects of Exhaust Gas Recirculation (EGR) higher BTE corresponded with lower fuel consumption at 21°CA when the properties of EGR and timing of booster with respect towards the efficiency of a DI engine operating on clean WPO has been studied.

The maximum NOx reduction was 52.4% under 30% EGR after Top Dead Centre (aTDC). Only at the earliest injection timing did EGR levels for WPO reduce smoke density by 20% [11]. Several studies have revealed that WPO has virtually identical characteristics to diesel. The 5%, 10%, 15%, and 20% diesel blends from waste polyethylene were tested on diesel engines at various speeds [20]. The findings showed that applying 5% WPO boosted power output while lowering CO emissions. Another element that affects the cetane ratio measures how well a fuel burns. WPO-produced vehicles had reduced torque and brake power due to a lower cetane number than diesel [21]. Using WPO in experiments with diesel engines produced a range of emission findings [10]. The outcomes presented that the pyrolysis temperature range significantly affects the features of the emissions as well as the quality of the oil produced.

Additionally, they revealed that incorporating a catalyst into the pyrolysis technique lengthens the reaction time and boosts WPO production. Diesel engines with various ratios were examined for the impact of kaoline catalyst in producing WPO [22]. The outcomes established that BTE stayed more advanced than diesel for all WPO combined up to 75% load.

The effects of WPO utilization as an alternative fuel in CI engines were investigated and generated more gaseous emissions, such as CO, NOx, and HC, than diesel, as well as increased BSFC and dropped BTE. Moreover, some quality has been experimented with using WPO purified through distillation. The results indicate that using distilled WPO as a mixture through diesel fuel can improve engine performance and emissions.

The combinations of Alumina nanoparticle blends found that alumina reduced BSFC while increasing peak pressure [23]. It has been found that a 50% distilled plastic pyrolysis oil mix considerably enhanced the BP brake power and BTE while lowering BSFC. Lower proportions of plastic oil with diesel resulted in lower energy consumption and higher thermal efficiency than straight waste plastic oil [24]. Regarding performance and emissions, pure plastic oil exceeded pure rice bran oil.

The effects of these nanoparticles on the efficiency and pollution levels of biodiesel-powered vehicles have been the subject of numerous scientific investigations. According to the study's authors, adding graphene oxide nanoparticles to Ailanthus altissima biodiesel blends increased performance and emission results. Engine performance was enhanced, and HC, CO, and NOx emissions stayed significantly reduced thanks to the incorporation of alumina nanoparticles into Rice bran oil methyl ester. When Al_2O_3 was added to diesel fuel, the engine ran far more efficiently and produced fewer hazardous emissions.

According to a comprehensive literature review, most researchers studied only up to 20% of WPO-diesel mixtures in engines, with only a few studies applying higher WPO mixtures and testing the diesel engine performance. Consequently, the research's primary goal is towards diesel engines' capabilities when operating under various operational situations while using 10–50% of Low-Density Polyethene (LDPE) plastic pyrolysis oil–diesel mixes. The outcomes were evaluated and related to the diesel fuel.

2. Materials and Methods

2.1. Plastic Oil Synthesis by Pyrolysis

Diesel was purchased from a retail store in Chennai that was owned and operated by Indian Oil Petroleum. The low-density waste plastic is pyrolyzed in a device designed for use in a laboratory to produce the WPO that will be used in this investigation. A variety of related factors, which include the kind of discarded plastic, the catalyst that was employed, the temperature of the reaction, and occasionally the reactor itself affects the chemical value related to the composition, value, and amount of the WPO produced by the pyrolysis process. When mixed waste plastics from MSW are pyrolyzed, the oil made more frequently contains long-chain hydrocarbons, and the impurities further complicate the molecular structure.

Long-term durability tests are necessary to determine how these impurities affect engine performance over time because they can lead to coke formation. Pyrolysis is a thermal decomposition method that employs a Zeolite as a catalyst to generate LDPE plastic oil in the lack of oxygen.

Low-density polyethene of uniform spherical shape was purchased in the chemical market in Chennai, and it is fed into a fast pyrolysis semi-batch reactor chamber. Three to four hours are spent maintaining a temperature between 400 and 600 degrees Celsius in the copper coil coiled around the burning chamber. A diagrammatic illustration which shows the pyrolysis apparatus in Figure 1.

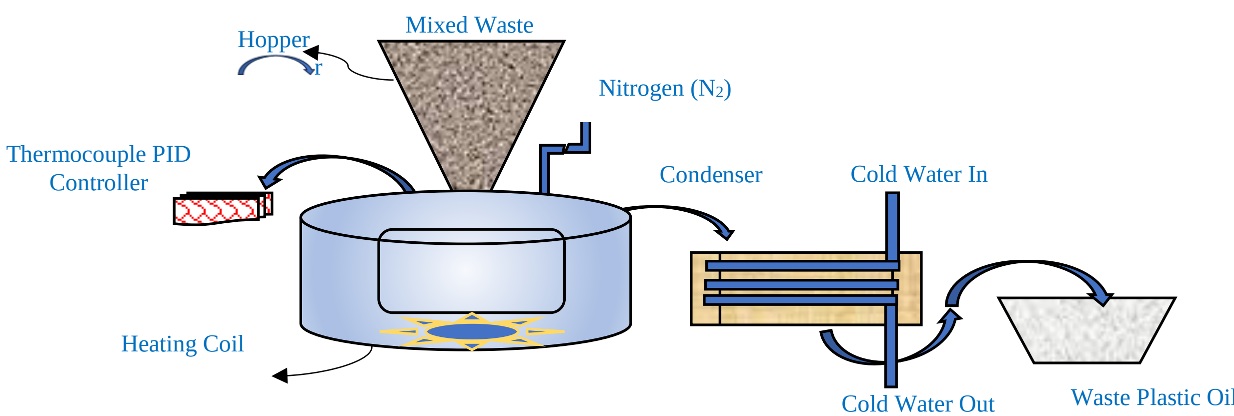

Fig. 1 Schematic view pyrolysis setup

Low-density polyethene plastic vaporizes and goes through the heat exchanger equipment at this high temperature. The condensation of the LDPE plastic steam results in latent heat transfer since the condenser is filled with cold water. The oil collector then collects the LDPE plastic vapour condensed as LDPE Plastic Pyrolysis Oil (LDPPO). During the pyrolysis process, the larger molecules break down into smaller ones. The following output products resulted from the pyrolysis treatment: LDPE plastic pyrolysis oil 60-70%, gas 20-30%, and residual coke 10-20%. The physio-chemical value of test fuels is shown in Table 1.

Table 1. Physio-chemical properties of LDPPO and diesel

Property	Diesel	LDPPO	ASTM Standard
Density at 15 °C (kg/m^3)	833	847.7	D1298
Calorific Value (J/kg)	42.9	40.3	D4809-95
Flash Point(°C)	52	41	D3828
Cetane Number	47	42	D376
Aromatic Contents (%)	29.5	65.5	D5186
Ash Contents (%)	<0.001	0.166	IP391

The pyrolysis reactors have three sections, as revealed in Figure 1: the key section, the secondary section, and the transformation section. Before entering the main chamber, the feedstock is broken down into smaller bits (1-2 cm2). Carbon dioxide purges the plastics in the two main sections of the fixed bed reactor to keep oxygen out. Since Carbon Dioxide (CO_2) is denser than air, it forces the air to rise to the highest point of the chamber when the feed travels down from the lower section to the upper one.

The conversion chamber, which is heated by burning natural gas, is where the fast pyrolysis occurs and where the plastics are transformed into char and gas at an average temperature of 900°C. The transformation chamber has gas and char, with separate exits that take up about 10% of the feed and are gathered for waste disposal. The pyrolysis oil gets disconnected after the gas passes through a condenser, where it is cooled.

The oil is filtered to a micron size to ensure that no deposits get transferred to the diesel engine's direct pipe and injection value. Composite plastics made mostly of polyamide and butadiene are the feedstock. Producing 1.6 litres of PPO typically requires 2 kilogrammes of waste plastic feedstock. As an outcome of the high temperature in the alteration slot, it contains a sizeable quantity of gaseous creation. The liquid phase accounts for 60–65% of the produced energy, while the gaseous phase accounts for 30-35% (PPO). Methane, hydrogen, nitrogen, carbon monoxide, and carbon dioxide are the primary components of the gas.

The gases remained examined utilizing gas chromatography with a detector for Thermal Conductivity (TCD) and Mass Spectrometry (MS). The formed gas's Lower Heating Value (LHV) (17.68 kJ/m^3) is low due to many inert gases in it. The value of natural gas is roughly half of the amount that it is now.

The oil produced is dark brown, almost black, and has an unpleasant odour. The most commonly used oil-producing compound was determined using the MS technique. The findings of the MS system displayed that the oil offers more than 50 extra hydrocarbon compounds, all of which are present in the oil, however, in smaller quantities than diesel. The carbon concentration of PPO is the same as diesel's, but the viscosity, fire point, and hydrogen value are all lower.

Carbon content, carbon value, oxygen value, total fragrant hydrocarbon value, and nitrogen value, on the other hand, all show considerable increases. PPO has a lower LHV than diesel but a greater LHV than most biodiesels, making it a promising fuel alternative. Concerning these characteristics, it would appear that the PPO would be used more often in stationary diesel engines for power generation and road transportation. Due to this, the current work's task was to focus on a fixed power group through a diesel engine.

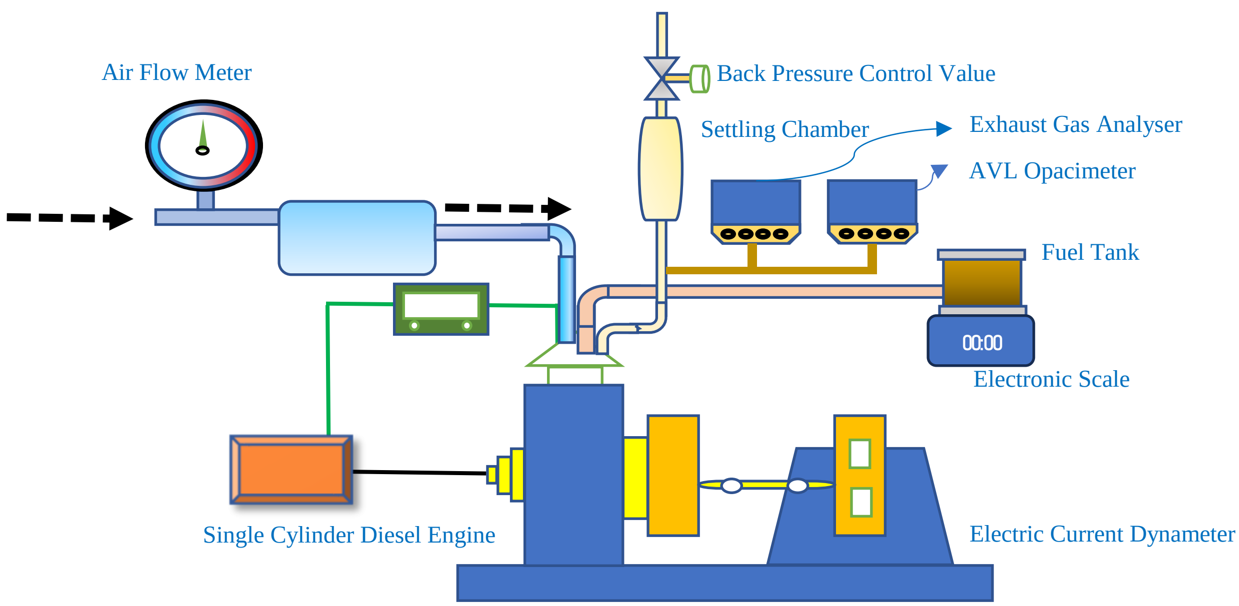

Fig. 2 Line diagram of the test engine configuration

2.2. Experimental Method

The experiment utilized a Kirloskar diesel engine of the vertical type, which was connected to an electromagnetic dynamometer to apply a load. The experimental engine's specs are listed in Table 2. Figure 2 is a line diagram depicting the testing engine's configuration. There would be two diesel fuel tanks and additional test fuels. A pressure sensor was fastened to the highest point of the cylinder head to gather information on the combustion process. The original angle was measured with the help of a TDC encoder.

An AVL-444 Di gas spectrometer was utilized to quantify CO, HC, and NO emissions, while an AVL-437C smoke metre was used to assess smoke density.

Once it ran smoothly, the engine switched from diesel fuel to plastic oil. Before using LDPE plastic oil-diesel blends, the fuel tank and, successively, the engine. The range, accuracy, and margins of error of the instruments are calculated per the procedure.

Table 2. Specifications of the test engine

Test Engine	Kirloskar, 4S
Cylinder	One
Bore	87.5 millimeter
Stroke	110 millimeter
Power	5.2 kilo Watt
Composition Ratio	17.5:1
Speed	1500 rpm
Fuel Injection Timing	23°b TDC
Injection Pressure	200 bars

2.3. Uncertainty Analysis

Visualisation, range, equipment, the atmosphere, and calibrating were utilised for estimating uncertainty and error analysis, which was then broken down into randomised and fixed errors based on the process's time. To get reliable outcomes, an uncertainty analysis must be conducted. Uncertainty in the engine system was determined using the root mean square technique, often known as the transmission of uncertainty technique. The formula was utilized to analyse the uncertainties of the engine performance parameters.

$$\varphi_R = \left[\left(\frac{\partial R}{\partial x_1}\varphi_1\right)^2 + \left(\frac{\partial R}{\partial x_2}\varphi_2\right)^2 + \cdots + \left(\frac{\partial R}{\partial x_n}\varphi_n\right)^2\right]^{\frac{1}{2}} \quad (1)$$

R is a function that relies on several independent variables, including x1, x2, x3, and xn. In addition, the value of R is well-defined as the overall proportion of uncertainty in the results, whereas φ1, φ2, φn are the uncertainties of the independent variable quantity (Holman 2012).

Table 3 summarizes the percentages of uncertainty for several quantities. An error examination was achieved using Taylor's theorem to validate the reliability of the examination outcomes. The overall sense of unpredictability is conveyed by,

The overall uncertainty can be expressed as the = Square root of [(BTE-1.0)2 + (BSFC - 1.0)2 + Emission (0.2)2 + (1)2 + (1)2 + (1.0)2+ (0.5)2+ (0.5)2] = ±2.35%.

Table 3. Uncertainties value

Parameters	Uncertainty Value
BTE	±1.0
BSFC	±1.0
CO	±0.2
HC	±1.0
NO	±1.0
Smoke	±1.0
Pressure Transducer	±0.5
Crank Angle Encoder	±0.5

3. Results and Discussion

Under various operating conditions, tests were shown on a mono-cylinder Direct-Ignition (DI) diesel engine and LDPPO diesel mixes. The measured values of performance and emissions are discussed in this section.

3.1. Cylinder Pressure

The change concerning the cylinder pressure with CA at 100 percent load can be witnessed in Figure 3. At full load, all LDPPO blends have pressure profiles similar to those of diesel. CP was observed to be slightly higher when LDPPO30 was used, but the difference was minimal. The results suggested that a low blending ratio up to LDPPO30 has a negligible effect on peak pressure at full engine load. Still, more excellent mixture ratios boost the peak pressure relatively at high engine load.

Lower viscosities and the cetane numbers of LDPPO30 blends will result in poor atomization and evaporation, increasing the premixed combustion. The peak pressure obtained for LDPPO10, LDPPO20, LDPPO30, LDPPO40, and LDPPO50 is 64.5 bar, 65.8 bar, 67.6 bar, 69.5 bar, and 70.9 bar, respectively, whereas for diesel, it is 67.1bar at maximum engine load. LDPPO30, LDPPO40, and LDPPO50 cylinder pressures are 0.5 bar, 2.4 bar, and 3.8 bar higher than diesel.

3.2. HRR

Figure 4 represents the HRR against CA for all the full-load fuels. It is seen that the higher LDPPO blends lead to a longer ignition delay, thereby increasing premixed combustion. The HRR of the LDPPO30, LDPPO40, and LDPPO50 is greater towards the diesel, possibly owing to a more extended delay period dominating the combustion process.

When the LDPPO ratio is boosted to peak output, the delay period and the premixed combustion phase increase significantly. Higher HRR for the LDPPO blends due to higher aromatic content present in the LDPPO, thereby increasing the adiabatic flame temperature of the combustion. Another factor contributing to the elevated HRR of LDPPO mixtures is the higher oxygen content (3.3 wt %) of LDPPO compared to diesel. The oxygen helps to improve the oxidation process by limiting the cylinder equivalence ratio. HRR obtained for LDPPO40, and LDPPO50 is 70.3 J/deg CA and 72.1 J/deg CA, respectively, whereas shows the diesel value of 61.5 J/deg CA at maximum engine load.

The engine was running with violent combustion when the higher blends of plastic oil were used, thereby increasing the HRR to 40% and 50% for LDPPO mixtures.

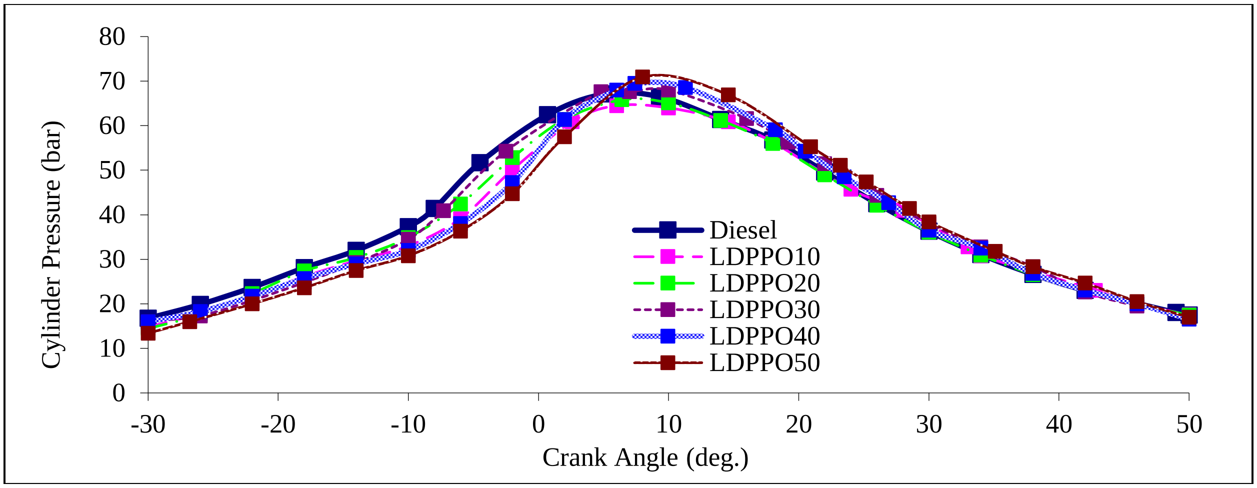

Fig. 3 Cylinder pressure against CA

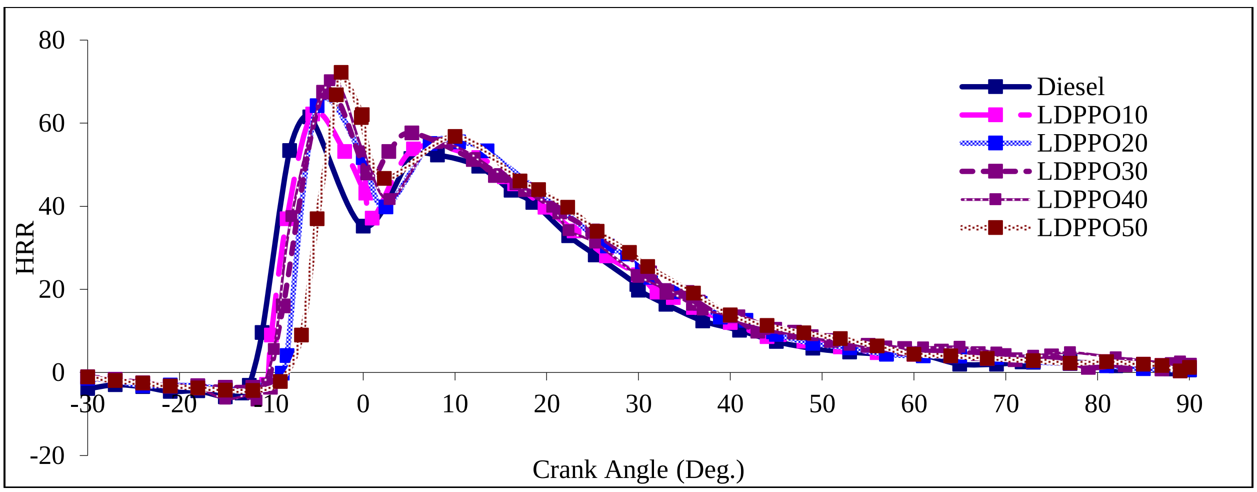

Fig. 4 HRR rate against CA

3.3. BTE

Figure 5 depicts differences in BTE with BP for diesel and LDPPO-diesel mixtures. BTE measures the amount of fuel that is transformed into mechanical work. It was found that the BTE of LDPPO blends was lowered compared to diesel. The BTE obtained for LDPPO10, LDPPO20, LDPPO30, LDPPO40, and LDPPO50 are 28.2%, 28.4%, 28.8%, 27.9%, and 27.2% correspondingly, and for diesel, it is 29.5% at peak load.

This could be because LDPPO-diesel combinations have a relatively lower calorific value than diesel. Lower BTE also demonstrates that the engine runs less effectively when LDPPO blends are used due to their greater aromatic components. Because of their lower viscosity and density, LDPPO10, LDPPO20, and LDPPO30 have a relatively high BTE than LDPPO40 and LDPPO50, resulting in enhanced combustion. BTE of LDPPO10, LDPPO20, and LDPPO30 is 1.0%, 0.8%, and 0.4% lesser than diesel.

3.4. BSFC

Figure 6 shows the BSFC against the BP for diesel and plastic oil blends. Replacing diesel with LDPPO blends increases the BSFC considerably under all operating conditions.

The graph clearly shows that although the load is increased, the BSFC lowers for each tested fuel, as predicted.

On the other hand, it is apparent that as the composition of LDPPO in the diesel blended fuel increases, the BSFC. BSFC obtained for LDPPO10, LDPPO20, LDPPO30, LDPPO40, and LDPPO50, which give higher BSFCs of 0.26 kg/kW-h, at full load 0.28 kg/kW-h, 0.27 kg/kW-h, 0.29 kg/kW-h and 0.3 kg/kW-h correspondingly, whereas, for diesel, it gives 0.25 kg/kW-h at peak load.

Because of the low energy content of plastic oil mixtures, the engine takes up more fuel, resulting in a rise in BSFC behaviour. This might be partially qualified to LDPPO's low energy content and high viscosity, eventually leading to poor combustion efficiency with higher BSFC. Compared to diesel, the BSFC of LDPPO blends increased by 4-12% at peak load.

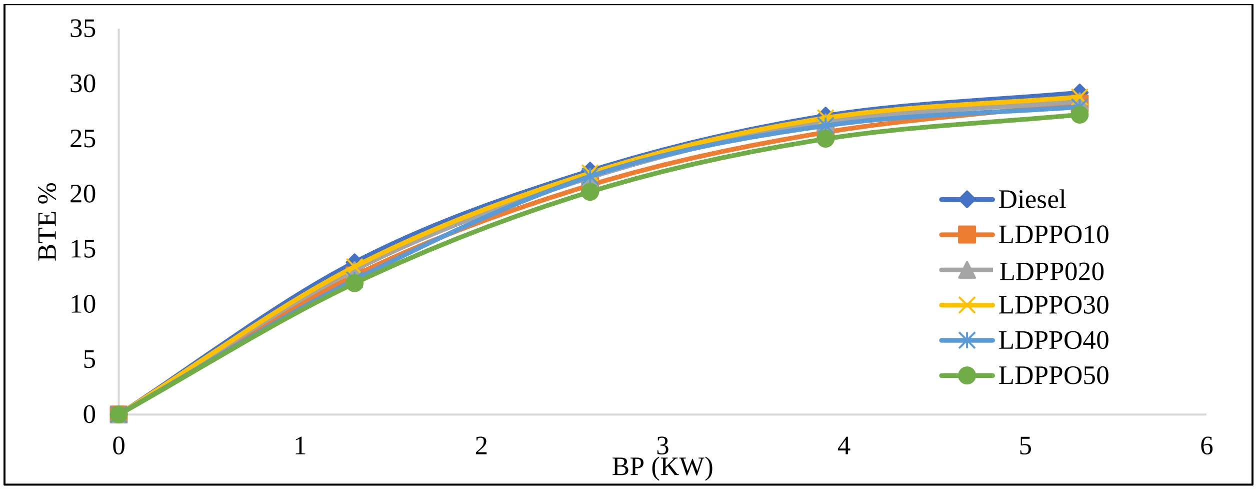

Fig. 5 Change of BTE with BP

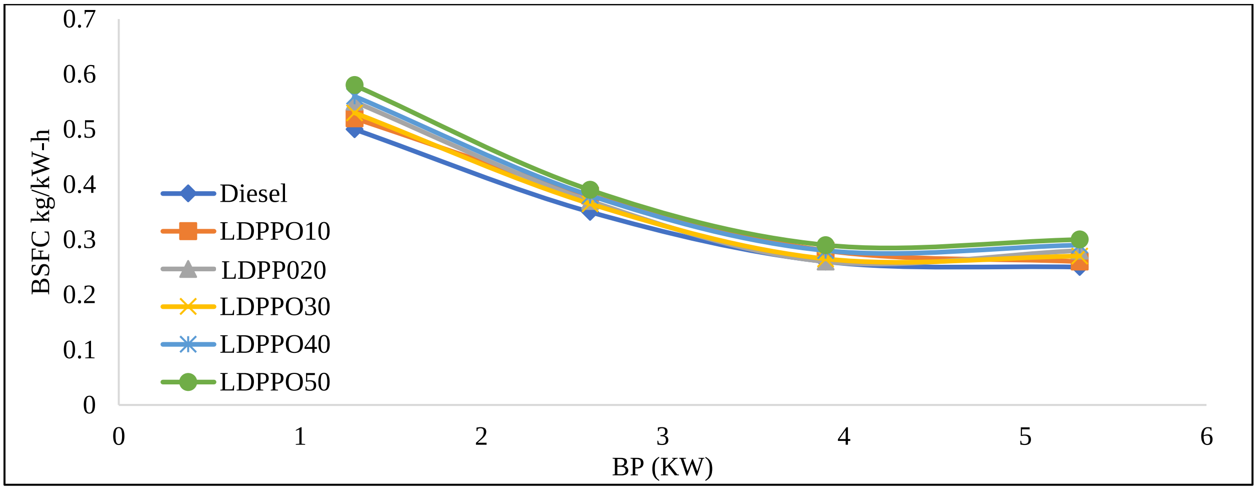

Fig. 6 Change of BSFC with BP

3.5. CO Emissions

Figure 7 illustrates the changes of CO with BP for all the test fuels. CO emission is an odourless and toxic gas product formed throughout combustion due to insufficient oxygen, poor air absorption, fuel-rich regions, and partial combustion.

Figure 7 shows that CO emissions drop significantly as the engine load keeps increasing, despite the type of fuel and its viscosity, which leads to poor mixture preparation and a lack of oxygen content in the fuel for combustion. When using LDPPO mixtures, the engine generates slightly more CO emissions than diesel at peak load. At peak power, the CO emissions obtained for LDPPO10, LDPPO20, LDPPO30, LDPPO40, and LDPPO50 is 0.13%, 0.14%, 0.15%, 0.16%, and 0.17%, respectively, whereas for diesel, it is 0.12%. The findings also demonstrate that the CO of plastic oil mixtures is greater than diesel, particularly at greater engine loads and as the mixture ratio increases. There is an increase in CO emissions for LDPPO10-30% is 8%-25%, whereas, for LDPPO40-50%, it varies from 33.3%-50% at maximum power conditions.

3.6. HC Emissions

Figure 8 explains the change of hydrocarbon emissions against BP for the verified fuels. The HC emission for diesel is considerably lower than LDPPO mixtures and tends to rise as the mixture ratio increases. Because of the greater aromatic content in plastic oil mixtures, HC emissions rise with increasing load for all mixtures compared to diesel fuel. HC obtained for LDPPO10, LDPPO20, LDPPO30, LDPPO40, and LDPPO50 are 42 ppm, 44 ppm, 46 ppm, 49 ppm and 53 ppm respectively, and for diesel is 36 ppm. HC emissions of up to LDPPO30 blends with diesel increased by 14-24 % compared to diesel, and it continued to rise with a rise in the proportion of LDPPO mixes.

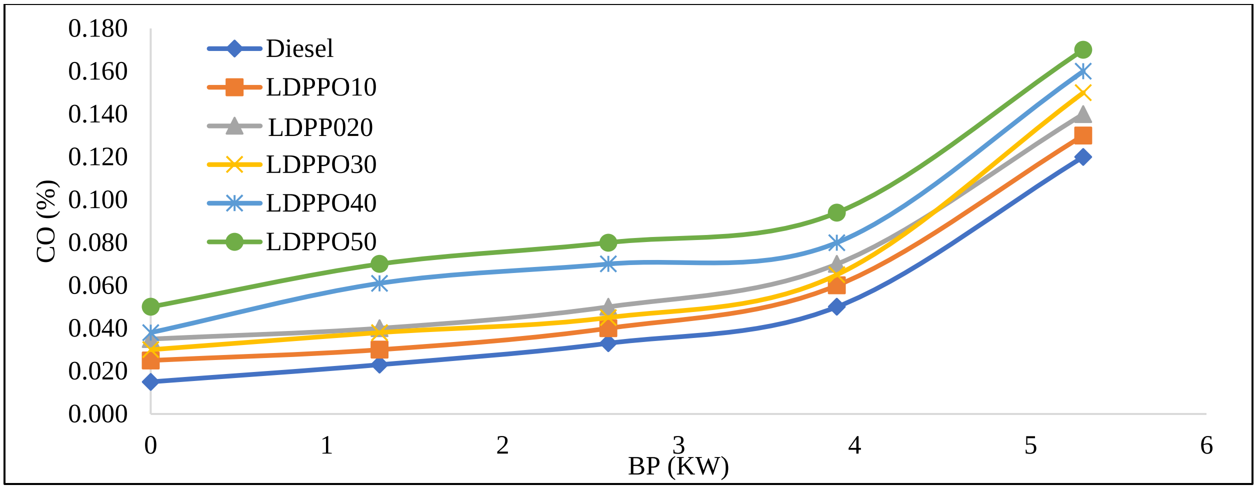

Fig. 7 Change of CO with BP

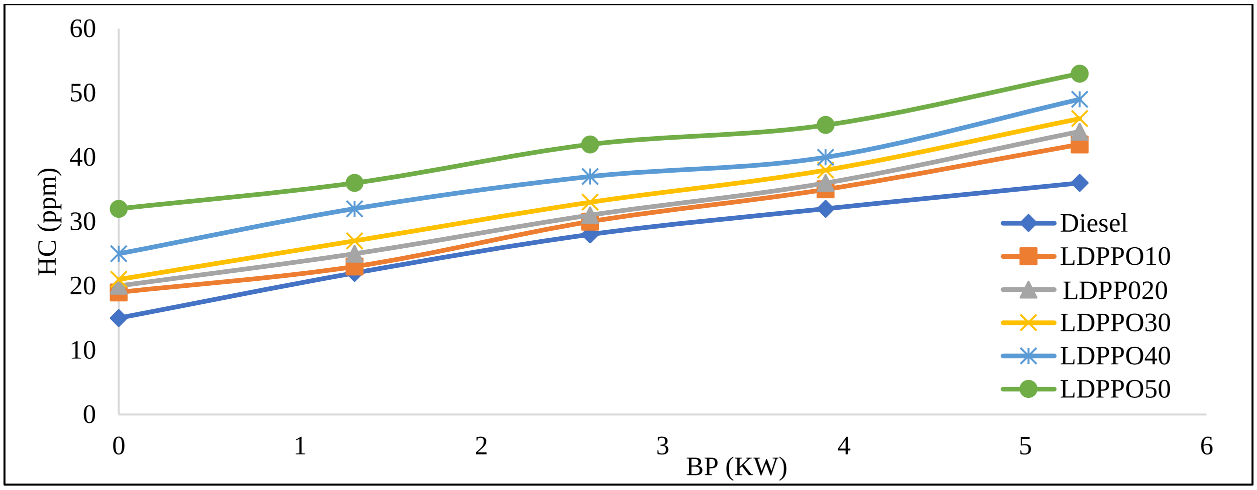

Fig. 8 Change of HC with BP

3.7. NO Emissions

The change in NO emission through BP for the test oils is shown in Figure 9. Because of the thermal effect of the fuel-burning technique, NO formation techniques exist in combustion theory.

NO formation in diesel engines is a thermal process caused by the raised temperature and high oxygen availability throughout combustion. According to the graph, the percentage of LDPPO mixtures increases NO emissions.

The shorter delay period results in a slight rise in peak combustion temperatures. An additional factor that might influence NO emissions is the excess O2 content of the fuel, which helps promote NO formation during burning via the thermal mechanism of the fuel. The NO emissions obtained for LDPPO blends are 836 ppm, 872 ppm, 956 ppm, 1010 ppm and 1064 ppm, respectively, related to the diesel is 824 ppm at full load. The NO emissions of LDPPO blends increased by 2-28 % compared to diesel.

3.8. Smoke Opacity

Smoke is formed in the engine combustion chamber due to the rich zone. Smoke emissions are produced all through the diffusive combustion phase due to insufficient burning fuel. Figure 10 signifies the change of smoke opacity through BP for all the fuel blends.

Smoke opacity varies from 5% to 36% for diesel; for LDPPO10, it varies from 6% to 40%; for LDPPO20, it varies from 7% to 44%; and for LDPPO30, it varies from 8% to 46%, whereas for LDPPO40 and LDPPO50 varies from 10%-48% and 14%- 52% respectively at rated power. At all loads, the smoke opacity is higher than diesel for all LDPPO blends. LDPPO blends had higher smoke levels than diesel values, showing higher viscosity and poor mixture formation.

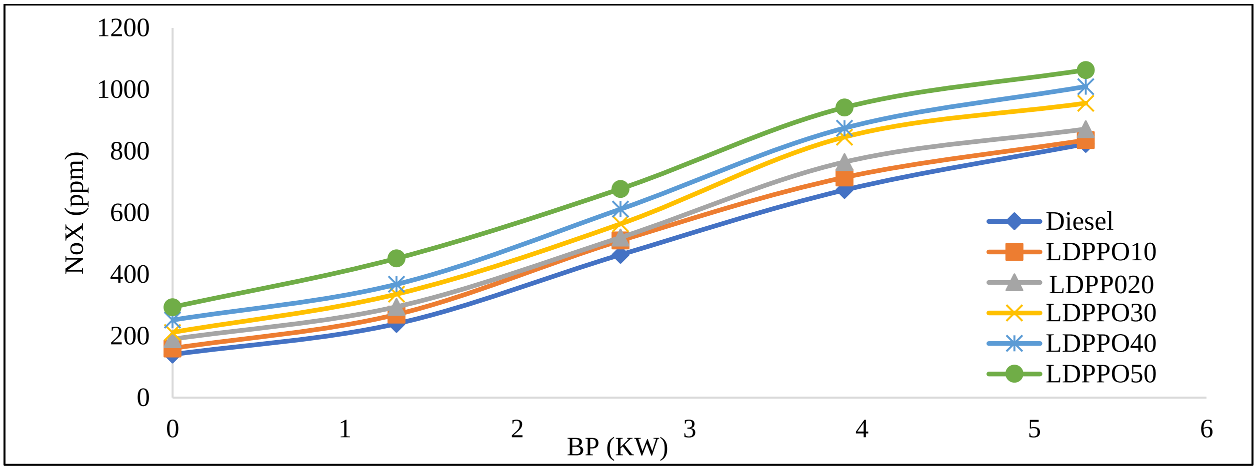

Fig. 9 Change of NO with BP

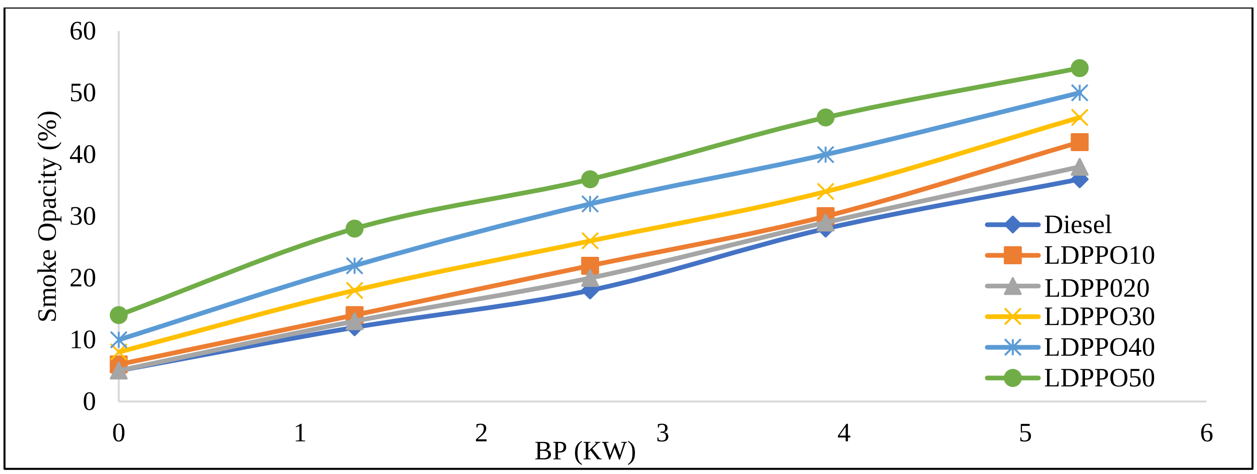

Fig. 10 Change of smoke with BP

4. Conclusion

This study focused on the performance related to the diesel engine using diesel, low-density polyethene plastic pyrolysis oil-diesel mixtures at various loads. The outcomes that followed were drawn as the consequence of these tests.

- LDPPO oil is the chosen fuel for a diesel engine as it requires no engine alterations and has properties similar to diesel fuel. Under maximal power conditions, increasing the proportion of LDPPO
- combined with diesel fuel resulted in lower peak pressure and an increase in heat transfer rate.
- Because it has a reduced calorific value, LDPPO-diesel blends have relatively lower brake thermal efficiencies than diesel fuel. LDPPO30 has a BTE of 28.8%, comparable to diesel fuel, and has a thermal efficiency of 29.2% at maximum power conditions.
- At all engine loads, the BSFC rises as the LDPPO mixture proportion decreases with increasing engine load. The HC emission of up to 30%LDPPO blends with diesel was improved by 14-24% compared to diesel, which is grown further higher blends.
- As the proportions of LDPPO rose with rising load, CO and HC emissions elevated. At maximum power conditions, CO emissions for LDPPO10-LDPPO30% increase by 8%-25%. While related to diesel, the HC emissions of up to 30% LDPPO mixes with diesel raised by 14-24%.
- At the peak of power, NO and smoke releases increased as the percentage of LDPPO in the diesel increased with the load. NO and smoke emissions increase by 2-16% and 4%-10%, respectively, for LDPPO10-LDPP30%.

Furthermore, based on the test results, a blend of 10%-30% LDPPO operating at full load is the best blend for achieving the highest levels of efficiency and pollutants in an unaltered diesel engine.

Acknowledgements

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