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Environmental impact of waste plastic pyrolysis oil on insulated piston diesel engine with methoxyethyl acetate additive

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ABSTRACT

The energy recovery from waste plastics as a prospective fuel source helps to overcome the issues of waste plastic management and the growing fuel shortage. In this article, High-Density Polyethylene (HDPE) plastics are used to convert into waste plastic pyrolysis oil (WPPO) through the pyrolysis process. An experimental investigation is carried out to evaluate the effectiveness of WPPO in a Thermal Barrier Coated piston engine (TBC) with an oxygenated additive of Methoxyethyl acetate (MEA). The incremental ratio of WPPO to pure diesel with the addition MEA and its performance, combustion, and emission characteristics are studied in a direct injection single-cylinder low heat rejection diesel engine. MEA and the coated piston resulted in improved performance of WPPO. Brake-specific fuel consumption is reduced by up to 9% under various load situations. D70W20MEA10 shows carbon monoxide elimination of up to 15% under various load conditions and a hydrocarbon reduction of up to 16%. At half load, D70W20MEA10 produces about 3% less HSU of smoke.

KEYWORDS

Coated piston; diesel engine; methoxyethyl acetate; thermal barrier coating; waste plastic pyrolysis oil

1. Introduction

Due to fast industrialization and population growth, the energy crisis and environmental degradation have become significant global issues. Plastic bottles, bags, and other solid debris take a long time to disintegrate in nature. Landfilling, recycling, and burning plastic pose major health and environmental concerns to both individuals and the environment. Thus, plastic pollution must be eliminated to prevent further environmental harm (Patni et al. 2013). About 60% of the plastic could be recycled, while the remaining 40% was dumped in a landfill. Plastic garbage is difficult to

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manage and pollutes the environment since it is not biodegradable. Thermal recycling or burning of plastics is gaining popularity. Plastic garbage disposal offers significant energy saving and recovery possibilities (Shamsuyeva and Endres 2021). Plastic contains hydrocarbons, which are a clean burning, eco-friendly fuel. Pyrolysis is a method for recovering energy from waste polymers that is both ecologically and economically beneficial (Mangesh et al. 2017).

Gungor et al. (2015) examined waste plastic oil as a fuel in a multi-cylinder diesel engine. It is found that using pure WPPO has a considerable impact on thermal performance. The amounts of carbon monoxide and nitrogen oxides in the atmosphere have risen significantly. Kumar et al. (2016) investigated the efficiency and combustion characteristics of a diesel engine powered by recycled plastics. Hariram, Seralathan, and Raffiq (2017) compared the characteristics of plastic pyrolysis oil of pure diesel and the properties of mixed fuels, including ethanol, to determine which was more efficient. Singh et al. (2020) produced 100% plastic pyrolytic oil without using a catalyst and investigated the fuel's characteristics. It was discovered that utilizing 50% plastic oil blends resulted in a marginal loss of performance and a minimal increase in emissions when the engine is tested on plastic oil. Das et al. (2020) examined waste plastic oil blends produced from the Zeolite-A catalyst to determine their composition. The engine research showed enhanced brake thermal performance on 20% blends when the engine ran at full load.

A new technique for converting unsaturated molecules to saturated compounds was explored by Mangesh et al. (2020b), who used pyrolysis oil hydrogenation to accomplish this. Using hydrogenated polypropylene pyrolysis oil blended with diesel and examined the blend's combustion, performance, and emission characteristics. Ananthakumar, Jayabal, and Thirumal (2017) examined the diesel engine's performance utilizing plastic oil and diethyl ether fuel mixes. Overall, plastic oil mixes had a lower Brake Thermal Efficiency (BTE) than diesel, whereas fuel consumption had considerably reduced. Hydrocarbon (HC) and smoke emissions were comparable to diesel. Bridjesh et al. (2018) attempted to substitute diesel for half the quantity of WPPO and the additives diethyl ether and methoxyethyl acetate to reduce greenhouse gas emissions.

Similarly, a novel oxygenated diesel additive, 2-methoxyethyl acetate (MEA), may be utilized to reduce exhaust smoke. Several diesel blends with MEA of 10, 15, and 20% were investigated. Exhaust gas emissions are lowered by adding MEA to diesel. The engine's thermal efficiency rises by 2%, while smoke-produced drops by half with MEA15 (Yanfeng et al. 2007). In diesel engines, MEA works well with ether and ester radicals. Using MEA in a waste plastic fuel mix cuts smoke emissions significantly.

Reduced engine exhaust temperatures may have enhanced BTE by increasing oxygenated functional groups in plastic oil. Methoxyethyl acetate has a greater oxygen content than plastic fuel and burns entirely. It considerably decreases CO and unburned hydrocarbon emissions (Bridjesh et al. 2018). Compared to diesel, waste plastic test fuel enhanced thermal efficiency by 5%. The fuel evaporated quicker due to the higher self-ignition temperature of MEA than normal diesel. The unsaturated hydrocarbon in the test fuel burns more thoroughly and cleanly with more oxygen in MEA (Gnanamoorthi and Murugan 2019). Using 2-methoxyethyl acetate and *Jatropha* biodiesel improves both the fuel's performance and emissions. The increase in brake thermal efficiency is minimal. However, there is considerable improvement in reducing smoke density, hydrocarbon, and carbon dioxide compared to diesel, and only a negligible impact on reducing NO_x and CO (carbon monoxide) (Senthil et al. 2015).

An exhaustive study demonstrates that waste plastic fuel may be utilized alone or in binary blends with base diesel or oxygenated fuel, with or without engine modifications. Numerous efforts have been made to employ oxygenated additives with waste plastic fuel. It was found that adding additives to waste plastic fuel increases the physicochemical qualities of the blended fuel and significantly reduces pollutants. The current study examines waste plastic fuel's emission, and performance characteristics derived from HDPE pyrolysis in a single-cylinder thermal barrier coated piston diesel engine. The combination of methoxyethyl acetate as oxygenated additives with plastic fuel recovered from waste plastics was not attempted in thermal barrier coated piston diesel engine applications. In this investigation, 10% methoxyethyl acetate as oxygenated additives were blended with different ratios of waste plastic fuel as a ternary fuel to achieve better performance in the diesel engine. This research assesses the emission characteristics and performance of a single-cylinder thermal insulated piston diesel engine fueled with waste plastic fuel and oxygenated additives, and outcomes are assessed in terms of the environment's sustainability to satisfy societal needs.

2. Materials and method

The pyrolysis process is the most popular method when producing oil from waste plastics. HDPE is characterized by a high degree of crystalline structure and a long linear polymer chain. The pyrolysis process is used to thermally degrade the long-chain polymers of waste plastics into monomers, which are then recycled. In this process, at a high temperature in the absence of oxygen, catalytic pyrolysis transforms waste plastics into fuels as a recovered energy source. Mangesh et al. (2020a) investigated the

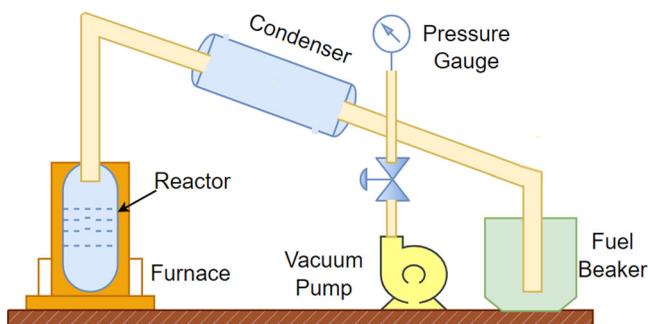


Figure 1. High Density Polymer's catalytic pyrolysis setup.

characteristics of four pyrolysis oils produced from a range of polymers, including high-density polythene, low-density polythene, polypropylene, and styrene, and found that they had similar properties.

The Zeolite catalyst was used to catalyze the waste plastic granule catalytic conversion in a semi-batch reactor. [Figure 1](#) depicts the reactor and furnace for the catalytic pyrolysis process of capacity 1.25 kW and operate at temperature 850 °C. A K-type thermocouple was used to set and maintain the temperature, controlled by a digital controller. Pyrolysis is a type of heat deterioration that happens in the absence of a vacuum, for that vacuum pump used. In the furnace, the material is heated to a maximum of 600 °C. The high-density waste polymer required a response time of 60 min, while it was transformed into pyrolysis oil at 450 °C. The waste high-density polymer produces 60% pyrolysis oil, wax formation 25% and 25% gas, coke formation through the catalytic pyrolysis reaction (Mangesh et al. 2020a). Waste plastic pyrolysis oil has various characteristics, which are listed in [Table 1](#). The fuel characteristics of WPPPO are highly similar to those of diesel fuel in many essential aspects.

The thermal barrier coating applied to the combustion chamber components improves combustion efficiency and keeps heat-resistant materials in the chamber. Heat shock during combustion requires high thermal expansion coefficient coating materials (Patnaik et al. 2017). Sivakumar and Senthil Kumar (2014) revealed that ceramic materials might have desired features such high thermal expansion, low thermal conductivity, and a stable phase structure at high combustion temperatures. Alumina or zirconia thermal barrier components stabilized with yttria are commonly employed in research (Ramalingam, Rajendran, and Ganesan 2016; Thibblin, Jonsson, and Olofsson 2018). It has been decided to integrate pistons as heat insulation into diesel engines to reduce heat loss during combustion further and, therefore, enhance their thermal performance. The use of oxygen-enriched combustion is one of the most successful methods for reducing exhaust gas emissions among these options. The presence of ester and ether radicals in

Table 1. Properties of waste plastic pyrolysis oil.

Sl.No	Properties	Diesel	WPPO	ASTM standards
1	Gross Calorific Value, Kcals/kg	10895	11124	ASTM D 240
2	Kinematic Viscosity at 40 °C, cSt	2.60	9.48	ASTM D 445
3	Density @15 °C , gm/ml	0.8374	0.7975	ASTM D 1298
4	Flash Point, °C	72	25	ASTM D 93
5	Fire Point, °C	82	34	–
6	Cetane Index	51	66	ASTM D 613

the oxygenated additives contributes to improving the combustion properties. The boiling point of MEA is much higher than the boiling point of diesel. The development of vapor blocks in the fuel system is prevented because of this action. This study used methoxyethyl acetate as oxygenated additives with WPPO.

2.1. Experimental details

With the help of a constant speed single-cylinder water-cooled direct injection diesel engine with a power output of 4.2 kW, the engine research could be carried out as shown in [Figure 2](#). The test engine was started using the hand-cranking technique, and the diesel engine was linked to an eddy current dynamometer to measure its performance. A dynamometer may manually load the engine from zero to the maximum load in increments ranging from 25 to 100%. The test engine was allowed to operate throughout the experiment under standard test circumstances, such as 210 bar injection pressure and injection timing of 21°bTDC. The engine runs at 1500 rpm and has a 17:1 compression ratio, which produces much power. The AVL di gas analyzer and the AVL Smoke Meter were used to examine the characteristics of exhaust pollution produced by the engine. The AVL software was used to evaluate the stability and emissions of the test engine under consideration. Experimentation details with critical instrumental parameters are tabulated in [Table 2](#).

Engine performance, combustion, and emission characteristics data were used to investigate the potential usage of WPPO in a thermal barrier-coated piston engine. Pure diesel fuel was used for the trial runs and base investigation. The WPPO blends D70W20MEA10 were created on a volume-based approach by combining 70% Diesel, 20% WPPO, and 10% MEA. For further experiments, D60W30MEA10 and D50W40MEA10 were produced with 30 and 40% WPPO volume, respectively, with 10% MEA. The assessment was carried out on a single-cylinder thermal barrier-coated piston diesel engine loaded at a 25% incremental load from 0 to 100% of its maximum capacity. Brake Thermal Efficiency (BTE), Specific fuel consumption (SFC), Exhaust Temperature, combustion parameters, heat release, and cylinder pressure are investigated. Hydrocarbons (HC),

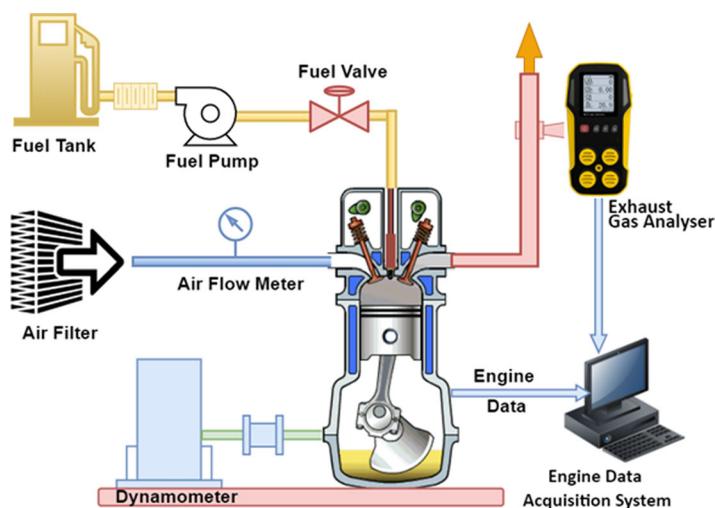


Figure 2. Single Cylinder DI Diesel Engine Experimental setup.

Table 2. Experimentation instruments details.

Measurement	Range	Accuracy	Uncertainty of data	Instrument
Load	–	+0.1 kg to –0.1 kg	± 1 %	Dynamometer
Speed	0–10000 rpm	± 10 rpm	± 0.50 %	Digital tachometer
Fuel quantity	0–50 cm ³	± 0.1 cm ³	± 1%	Burette Measurement
Hydro Carbon	0–15%	± 0.5%	± 0.25%	AVL exhaust gas analyzer, NDIR technique
Carbon Monoxide	0–20000 ppm	± 10 ppm	± 0.25%	AVL exhaust gas analyzer, NDIR technique
Nitrogen Oxides	0–5000 ppm	± 10 ppm	± 0.25%	AVL exhaust gas analyzer, NDIR technique
Smoke	0–100%	± 1%	± 1%	AVL smoke meter

nitrogen oxides (NO_x), CO, and smoke are among the exhaust gases produced by engines analyzed.

3. Results and discussion

3.1. Performance characteristics

3.1.1. Brake thermal efficiency

The brake thermal efficiency influenced the engine's power, as shown in Figure 3. BTE is defined by the ratio of brake engine power to fuel energy consumption that depends on calorific fuel values. The BTE of D100, D70W20MEA10, D60W30MEA10, and D50W40MEA10 were 27.2, 25.6, 24.8, and 24.1% at full load condition. For the BTE at maximum load condition, the brake thermal efficiency of D70W20MEA10 improved by about 2.5% more than D60W30MEA10. A high concentration of plastic oil in the blend shows lower BTE than diesel fuel because plastic oil has a greater concentration of aromatic compounds, thereby lowering the combustion rate. It can be attributed to the high aromatic component of plastic oil

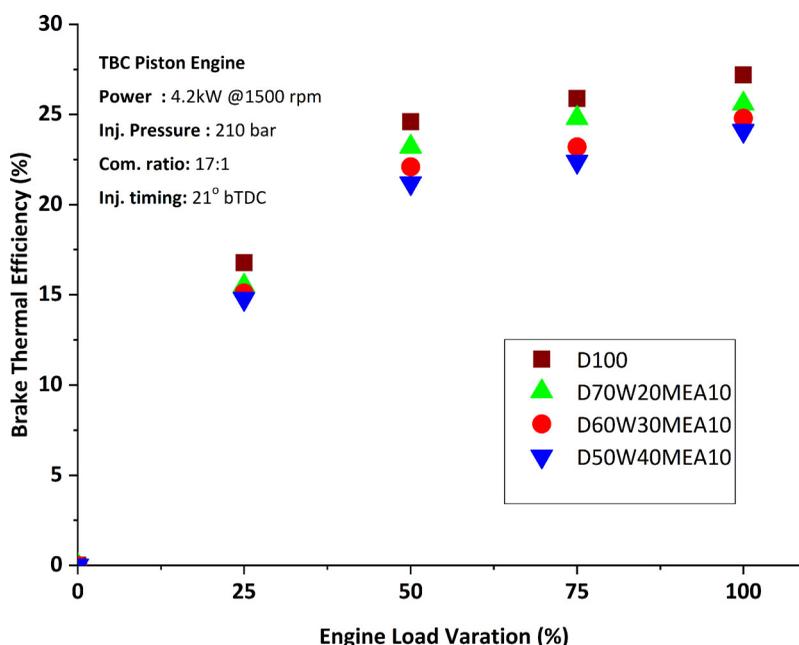


Figure 3. Evaluation of WPPO's brake thermal efficiency on engine load.

requiring more energy to break the chain. When used at maximum load, WPPO may provide up to an eighty percent improvement in thermal performance (Mani, Nagarajan, and Sampath 2011). MEA has a similar boiling point and self-igniting temperature to diesel. Due to increased WPPO spray atomization and quicker fuel vaporization, the plastic fuel reaction is overcome. Above all, MEA's higher ignition delay promotes improved fuel-air mixing, which improves WPPO mixes for closer BTE (Bridjesh et al. 2018). The TBC engine achieves increased thermal performance, better combustion efficiency, and consistent ignition timing due to enhanced vaporization and air-fuel atomization.

3.1.2. Specific fuel consumption

Each engine has a unique specific fuel consumption value that changes depending on the speed and loads applied to the engine. The magnitude of SFC for the fuels D100, D70W20MEA10, D60W30MEA10, and D50W40MEA10 were 0.298, 0.28, 0.32, and 0.36 g/kW h, respectively. When comparing D70W20MEA10 to D100 at different load levels, the SFC was decreased by about 2 to 9%, as shown in Figure 4. MEA blend allows faster fuel vaporization and greater spray atomization than plain diesel. However, a good fuel spray leads to improved combustion. The dual effect of high cetane rating and the coating on the combustion components exhibits a lower SFC rating than a standard diesel engine (Bridjesh et al. 2018). The quantity of WPPO in a blend grows as the amount of SFC in

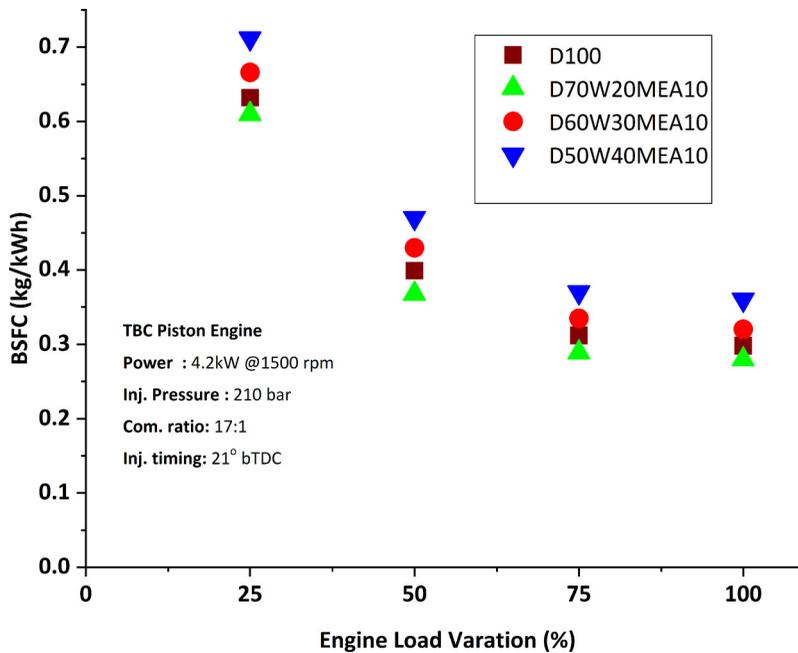


Figure 4. Evaluation of WPPO's specific fuel consumption on engine load.

the mix increases. It is due to the poor atomization of WPPO, which is caused by the increased viscosity and density of the substance. The SFC increment percentage is 7.3 and 20.2% for D60W30MEA10 and D50W40MEA10, respectively, as related to diesel fuel. The pooled effect of higher viscosity and lower magnitude of heating value for WPPO exhibits more fuel consumption.

3.1.3. Exhaust gas temperature

In Figure 5, the combustion temperature affects the exhaust gas temperature, and the exhaust gas temperature (EGT) increases with increasing load. Similar results were also found in previous related work (Musthafa 2017) at all load ranges. The exhaust gas temperature of WPPO and its blends was higher than that of diesel (Mani, Nagarajan, and Sampath 2011). When waste plastic oil is used as a fuel, incomplete combustion occurs due to the plastic oil's reduced volatility and greater viscosity. It could have resulted in a higher exhaust gas temperature. However, D70W20MEA10 produced closer EGT to D100. The value of EGT of D100, D70W20MEA10, D60W30MEA10, and D50W40MEA10 were 533, 548, 572, and 610 °C, respectively. Methyl ethyl acetate has a greater oxygen concentration (about 40% by weight) promotes more through burning than diesel. Consequently, the exhaust gas temperature of the test fuel D50W40MEA10 is elevated (Kalargaris, Tian, and Sai 2017). The increased

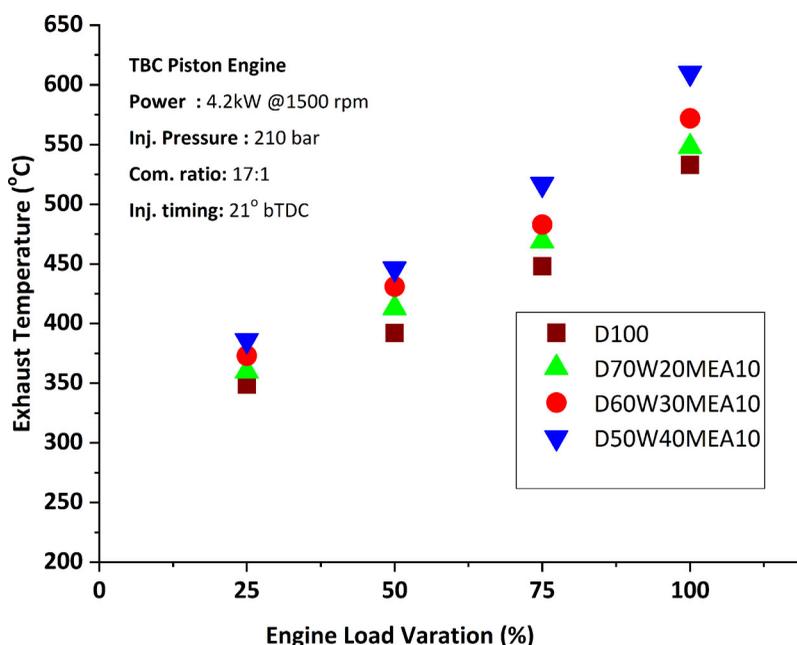


Figure 5. Evaluation of WPPO's exhaust temperature on engine load.

exhaust temperature was found due to a bit of quantity of gases undergoing combustion toward the conclusion of the expansion stroke.

3.2. Combustion analysis

3.2.1. Cylinder pressure

Figure 6 illustrates the variations of in-cylinder pressure (ICP) with respect to the crank angle of various WPPO blends and diesel. It could be noticed that the peak pressure of blends was found lower than regular diesel fuel at high load conditions. The magnitude of ICP for D100 and D70W20MEA10 were 64.2 and 61.4 bar, respectively. Compared with standard diesel, peak ICP of D70W20MEA10, D60W30MEA10, and D50W40MEA10 was decreased by 4.3, 9.5, and 11.2%, respectively. It was evident that the high combustion rate of diesel fuel, which enhance the post-combustion temperature, thereby increasing the cylinder pressure generation.

For D60W30MEA10 operation, the ICP was about 58.02 bar, and for D50W40MEA10, it was 56.9 bar. At rated speed conditions, higher waste plastic oil blends of D50W40MEA10 were shown 7.2% lower cylinder pressure than the lower waste plastic blend concentration (D70W20MEA10). The ICP depends on the amount of fuel burned in the primary combustion phase, which is controlled by the ignition delay period of fuel. The delay period is also influenced by the homogeneity of the A/F mixture (Gnanamoorthi and Jayaram 2019). The reduced cylinder pressure was

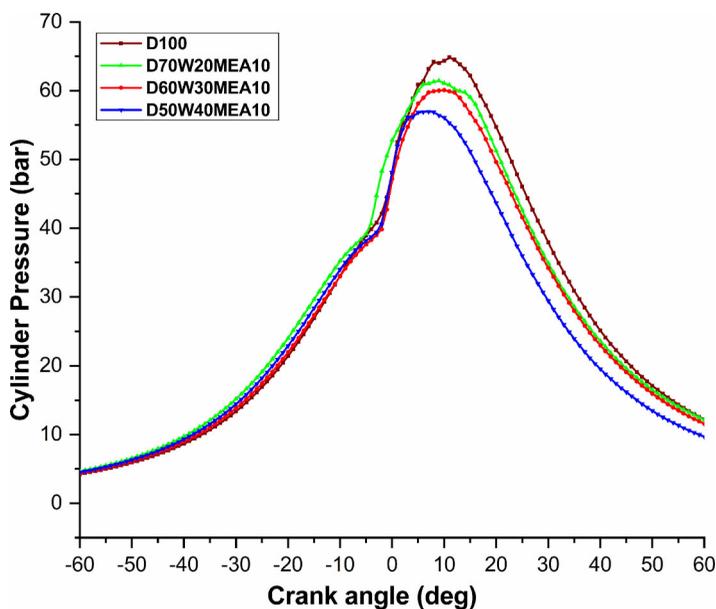


Figure 6. Difference of WPPO's cylinder pressure generation.

observed for waste plastic oil mixes due to inadequate atomization. High density and low volatility fuels may be affected by vaporization properties. The viscosity of waste plastic oil mixtures is greater than diesel fuel, reducing the combustion rate.

3.2.2. Heat release rate

The variation of heat release rate (HRR) for diesel fuels, D70W20MEA10, D60W30MEA10, and D50W40MEA10, is depicted in Figure 7. It was noticed from the figure that the HRR of plastic oil blends was lesser than that of diesel fuel. The maximum HRR was about $71.3 \text{ J}/^\circ\text{CA}$ for diesel, whereas it decreased by 6.6, 8.9, and 13.3% for diesel with plastic blends of 20, 30, and 40%, respectively. It was perhaps due to the lower energy value of blend that results in inferior combustion in the first phase of combustion. Moreover, a higher blend concentration of plastic oil drastically reduces the HRR. It could be attributed to the lower volatility. The heating value of plastic oil was highly accumulated in the cylinder, which burns in the secondary combustion phase and exhibits lower cylinder temperature (Sambandam, Venu, and Narayanaperumal 2020). The ignition delay duration is an important metric in combustion research. Because plastic oil has a higher cetane grade than diesel, it has a shorter delay period than diesel. The delay period is the time between fuel injection and combustion (SOC).

The result was found that all plastic blends were exhibited earlier SOC compared to diesel fuel. The maximum magnitude of HRR for plastic

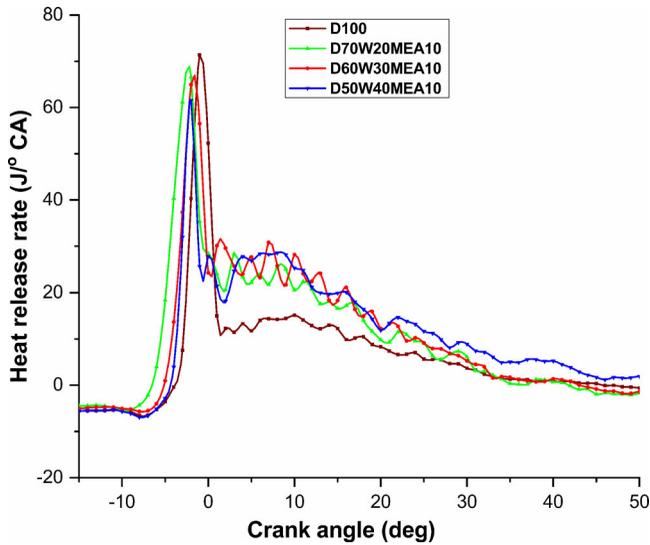


Figure 7. Difference of WPP0's heat release rate.

blends D70W20MEA10, D60W30MEA10, and D50W40MEA10 are 66.6, 64.9, and 61.8 J/°CA, respectively. All test fuels included primary and secondary combustion stages. Because plastic oil has a shorter delay time than diesel, the HRR of plastic blends is greater in the secondary phase of combustion than diesel. For premixed combustion, MEA's reduced latent heat value and enhanced volatility cause more fuel to collect in the combustion chamber, increasing the heat emitted by D50W40MEA10 (Gnanamoorthi and Murugan 2019). The secondary combustion phase increased with increasing plastic oil content. Low primary combustion was caused by excessive aromatic components and inadequate air use in blends.

3.3. Emission analysis

3.3.1. Carbon monoxide

The equivalence ratio proportions are vital in CO formation. Higher loads require more fuel, which reduces oxygen content and raises CO concentrations. Low CO emissions result from low equivalence ratio and high in-cylinder temperatures. The rich fuel combination caused considerable CO production at starting and full load. In Figure 8, D70W20MEA10 is found to have the lowest CO emissions of the tested fuels. It may be attributed to the presence of more oxygen molecules in MEA and the mixing of fuel and air with the proper spray atomization, which tends to reduce CO emissions. The significant rise in CO emissions greater than 50% load may be related to more fuel consumption, and the shorter period allowed the fuel to burn entirely. Sivakumar and Bridjesh (2019) found that waste plastic fuel-operated coated engines released about 0.25% less CO at maximum load than

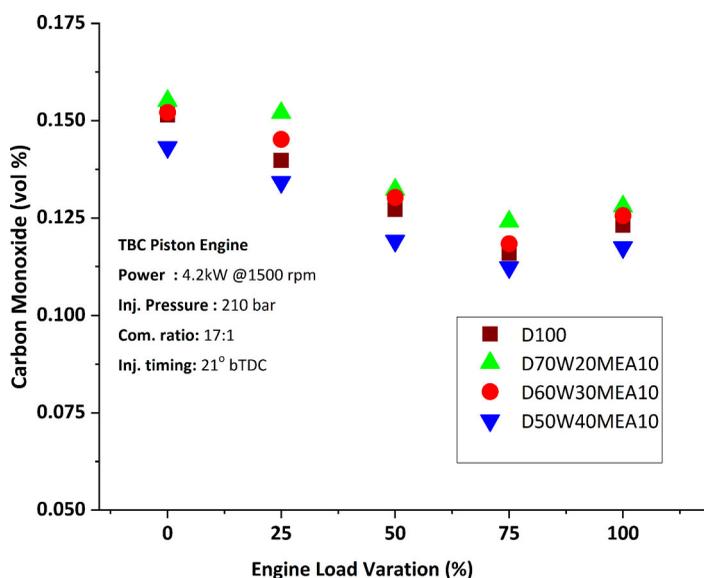


Figure 8. Evaluation of WPPO's carbon monoxide on engine load.

conventional engines because of better combustion due to TBC. WPPO includes about 4–5% oxygen, which aids in the complete burning of the fuel and leads to a higher reduction in carbon monoxide emissions (Aydin, Sayin, and Aydin 2015). The result of CO emission for the fuels D100, D70W20MEA10, D60W30MEA10, and D50W40MEA10 were 0.123, 0.128, 0.125, and 0.117% vol., respectively. TBC coatings enhance the combustion performance of WPPO mixes by allowing for high cylinder temperature, which results in a high oxidation rate of CO emissions. Additionally, the Inadequate O₂ content in WPPO promotes the CO into CO₂ conversion rate. Carbon monoxide emissions rise at full load due to the higher amount of fuel used in combustion with less oxygen presence.

3.3.2. Unburned hydrocarbons

The significant reason for the formation of hydrocarbon emission is lower vaporization, a slower oxidation rate, and the high rate of fuel consumption (Hariram et al. 2020). Figure 9 illustrates the variation of HC emission formation for different test fuels. D70W20MEA10 showed a remarkable reduction of HC emission about 7–16% under mid-load to full load conditions. Because MEA has a higher oxygen content, it may be essential to ignite the unsaturated hydrocarbons in order to burn entirely and cleanly. As a result, extra oxygen assists in the combustion process, lowering HC emissions. TBC engines emit less hydrocarbons than diesel engines, according to Sivakumar and Bridjesh (2019). The quantity of HC pollution reduces as WPPO content increases owing to full burning and more chemically

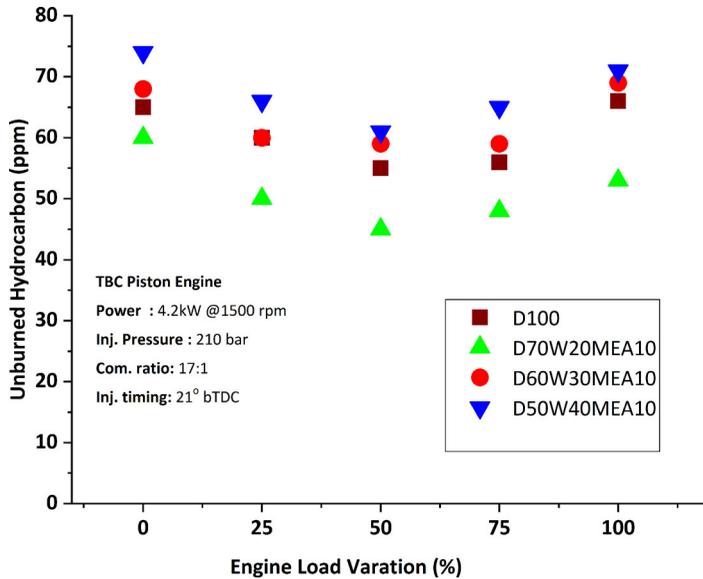


Figure 9. Evaluation of WPPO's unburned hydrocarbons on engine load.

reacted hydrocarbons. In such circumstances, the new particle deposited in crevice volume increases HC emissions (Damodharan et al. 2017). Additionally, the quenching effect leads to higher HC emissions due to the WPPO's low cetane number and decreased auto-ignition properties. HC emission for the fuels D100, D70W20MEA10, D60W30MEA10, and D50W40MEA10 were 66, 53, 69, and 71 ppm, respectively. Furthermore, unreactive hydrocarbons do not break down into saturated compounds during burning, resulting in exhaust fumes production instead (Singh et al. 2020). Because of unsaturated aromatic combinations in waste plastic, which promotes hydrocarbon emission, the indestructible essence of waste plastic is produced.

3.3.3. Nitrogen oxides

As shown in Figure 10, all tested fuels tend to increase the NO_x emission related to increasing the load range. The primary factor contributing to NO_x emission is the increased temperature within the cylinder and the overall peak temperature during the combustion cycle. It might be due to the lean mixture availability in the cylinder and maybe because of the increased energy density of MEA (Hoang and Pham 2019). Sivakumar and Bridjesh (2019) found elevated NO_x emissions coated engines with WPPO fuel blends. It was mainly due to higher combustion cylinder temperature because of thermal film-coated in the combustion chamber. NO_x development occurs only at the point of combustion temperature at elevated levels, as nitrogen readily reacts with O₂. Due to the more oxygen content in

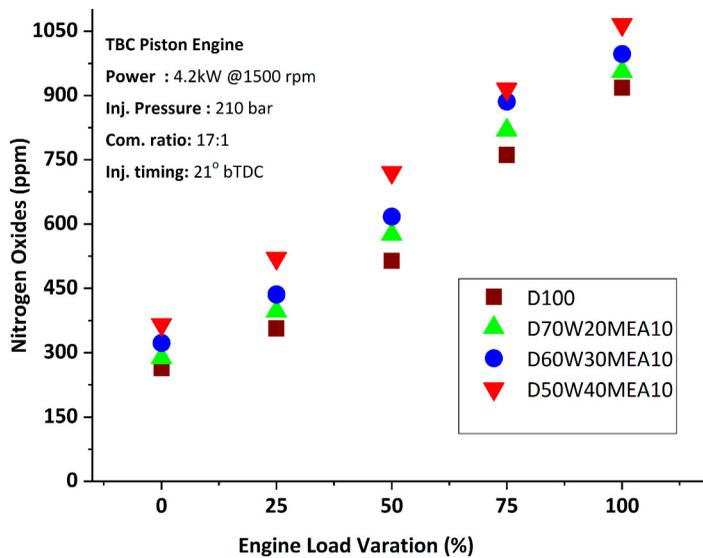


Figure 10. Evaluation of WPPO's nitrogen oxides on engine load.

MEA that plays a significant role in the formation of NO_x, The NO_x emission of diesel was raised from 264 and 918 ppm for the initial load to full load. Comparing waste plastic oil to pure diesel at maximum load, the NO_x emission was 25% higher (Mani, Nagarajan, and Sampath 2011). The higher temperature inside the cylinder and the overall peak temperature throughout the combustion cycle due to the lean fuel charge are the main component leading to NO_x emission during the combustion cycle (Hoang and Pham 2019). The magnitude of NO_x emission of D70W20MEA10, D60W30MEA10, and D50W40MEA10 were 956, 997, 1066 ppm, respectively. NO_x is generated by the reaction of oxygen and nitrogen. In a lean mixing scale, more NO_x is produced, leading in higher combustion temperatures. The Zeldovich process also regulates the kinetics of NO_x production. Oxygen concentration, combustion chamber temperature, surplus air coefficient, and combustion chamber residence time all affect NO_x generation (Nam Cao et al. 2020).

3.3.4. Smoke emission

In a CI engine, smoke is produced by secondary combustion. In the combustion region, the fuel-atomized droplets are broken into elementary carbon atoms, resulting in less smoke. WPPO's high aromatic content accidentally creates a fuel mix. As a result of incomplete combustion and excessive smoke emission, it impacts spray formation. Low atomization, high viscosity, and excessive fuel concentration all contribute to smoke generation. Figure 11 illustrates the difference in smoke formation with respect to various test fuel conditions. D100 emits less smoke than D70W20MEA10 and D70W20MEA10. The

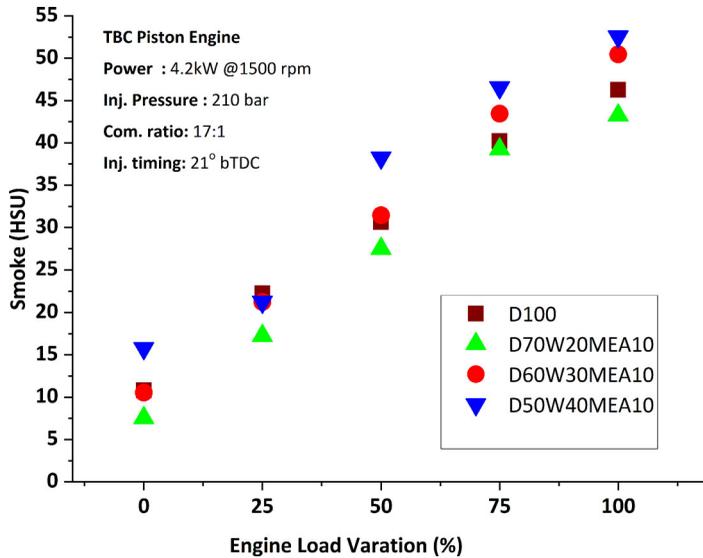


Figure 11. Evaluation of WPPO's Smoke on engine load.

peak value of smoke emission for D100, D70W20MEA10, D60W30MEA10, and D50W40MEA10 are 46.26, 43.25, 50.45, and 52.54 HSU, respectively. The D70W20MEA10 produces about 3% less HSU of smoke at half load. TBC engines produce less smoke than conventional diesel engines, as Sivakumar and Bridjesh (2019) noted. It might be because the combustion chamber is covered with low thermal conductivity materials. The waste plastic oil produced 40% more smoke than pure diesel when operated at full load (Mani, Nagarajan, and Sampath 2011). The presence of MEA-bound oxygen in locally abundant zones appears to help in combustion. WPPO produces far more smoke than diesel. WPPO fuel blends produce a lot of smoke due to their long burning time and slow flame spread rate. Incomplete combustion increased the amount of smoke created because of higher hydrocarbon burning (Nam Cao et al. 2020). The TBC approach works by raising the cylinder's temperature. The coated engine may enhance cylinder temperature and droplet combustion, reducing smoke.

4. Conclusion

Hydrocarbons, which are found in plastic, are an excellent energy source. Waste plastic may be turned into energy, which is the most challenging element of waste plastic recycling. Thermal barrier coating and oxygenated additives demonstrate the possibility of utilizing WPPO as an alternative fuel source by reducing exhaust pollution and improving engine efficiency and lower fuel consumption. The following observations were made about the WPPO blends produced by the TBC engine:

- The brake-specific fuel consumption of D70W20MEA10 falls by about 2–9%, depending on the load circumstances encountered. An MEA blend allows for faster fuel vaporization and greater spray atomization than pure diesel, and a good fuel spray leads to improved combustion.
- A high concentration of plastic oil in the blend shows lower BTE than diesel fuel because plastic oil has a greater concentration of aromatic compounds, thereby lowering the combustion rate. The brake thermal performance of the D70W20MEA10 improved at the maximum load.
- Under various load situations, D70W20MEA10 showed an increase in carbon monoxide removal of between 6 and 15%. TBC coatings enhance the combustion performance of WPPO mixes by allowing for a high cylinder temperature, which results in a high oxidation rate of CO emissions. MEA oxygen content improves CO reduction.
- D70W20MEA10 showed a higher decrease of hydrocarbons under various load situations ranging from 7 to 16%. Because of the increased concentration of oxygen in MEA, it may be necessary to ignite the unsaturated hydrocarbons in the fuel in order for it to burn more completely and cleanly.
- At rated speed conditions, higher waste plastic oil blends of D50W40MEA10 were shown to have 7.2% lower cylinder pressure than the lower waste plastic blend concentration. A higher blend concentration of plastic oil drastically reduces the heat release rate.
- The D70W20MEA10 produces about 3% less HSU of smoke at half load, and elevated NO_x emissions were found for the WPPO blends.

This study investigates the possibility of recovering energy from waste plastics as a potential option as a fuel source. According to the findings of this study, WPPO has the potential to be used as an alternative energy source for industrial engines, marine engines, and even railroad diesel engines.

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