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Research Article

Sustainability improvement by utilizing polymer waste as an energy source for a diesel engine with alcohol additives

Padmanabhan SAMBANDAM[*1], Vinod Kumar THANGARAJ[2], Mahalingam SELVARAJ[3], Giridharan KRISHNAN[4], Ganesan SUBBIAH[5]

[1]*School of Mechanical and Construction, Vel Tech Rangarajan Dr. Sagunthala R & D Institute of Science and Technology, Chennai, India*
[2]*School of Mechanical Engineering, Vels Institute of Science, Technology & Advanced Studies (VISTAS), Chennai, India*
[3]*Department of Mechanical Engineering, Sona College of Technology, Salem, India*
[4]*Department of Mechanical Engineering, Easwari Engineering College, Chennai, India*
[5]*School of Mechanical Engineering, Sathyabama Institute of Science and Technology, Chennai, India*

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ABSTRACT

Energy and fossil fuel supplies have been threatened by the depletion of fossil fuels on a global scale, as well as by the constant rise in oil prices and the continual increase in environmental degradation. On the other hand, polymer waste has increased due to its usage in a daily lifestyle because of its cheap cost, ease of production, and adaptability. Indirectly, these polymer wastes are causing some major problems for the ecosystem and other living things. By transforming waste polymers into usable energy, can address for both the non-biodegradability of polymers and the need for an alternative fuel. This research paper aims to evaluate the performance of fuel produced by the pyrolysis of polyethylene polymer. Three distinct alcohol additive blends with polymer fuel were investigated in a single-cylinder direct injection diesel engine for their performance and emission characteristics. The engine efficiency of pentanol was found to be about 3.4% higher than that of base diesel, and with 7% better fuel consumption. Additionally, alcohol additives reduced CO emissions by 3.6%–3.8% and HC emissions by 3.5%–3.8%. The results were further analysed using the design of experiment tool, "Full Factorial Design" to determine the most optimal running condition with fuel consumption of 0.4508 kg/kWh, hydrocarbon of 49 ppm and carbon monoxide 0.265% at half load conditions.

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INTRODUCTION

Researchers are working around the clock to discover alternative sustainable energy sources that may address the difficulties that are occurring as a result of the depletion of non-renewable energy sources. However, a suitable waste management strategy is an additional key component of long-term success and development. Plastics are

***Corresponding author.**
*E-mail address: padmanabhan.ks@gmail.com

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one of the most extensively used materials on the planet, and while they are non-biodegradable in nature, they are being employed on a variety of fronts owing to the vast variety of applications, flexibility, and cost-effectiveness that they provide. Every day, people rely on plastic for a variety of functions [1].

Due to its great demand and economic feasibility, plastic trash recycling was also pushed. Recycling plastic trash into liquid fuel also has the additional advantages of conserving resources and reducing greenhouse gas emissions [2]. In addition to reducing strain on natural resources and coping with fast industrialization and economic expansion, energy recovery from waste plastics is seen as a potential option. It has already been done commercially in certain border and industrialised countries. Because of their high combustibility and abundance in nearby areas, waste plastics are considered highly competent resources for the extraction of petro-fuels. Waste plastics may be converted into fuel using a variety of methods, depending on the nature of the material [3].

The lower viscosity of alcohol as compared to diesel allows for more efficient atomization of the fuel injected into the cylinders and better mixing with the surrounding air when alcohol is combined with diesel. A significant amount of latent heat of evaporation exists in alcohol, which means that utilizing alcohol in a diesel engine by blending it with diesel or biodiesel fuel may improve the overall volume efficiency by cooling the alcohol during the intake and compression strokes [4]. The inclusion of propane resulted in lower smoke emissions than diesel and plastic oil, but greater HC (hydrocarbon) emissions than both. Plastic oil and diesel blends with 5% Propanol by volume beat their diesel equivalents in terms of NOx (Nitrogen Oxide) emissions. More propanol mixes produced more NOx than plastic oil and diesel. The thermal efficiency of the engine improved as the quantity of propanol in the blends increased [5].

A comparison between the performance and emissions of a municipal waste plastic oil-fuelled in diesel engine in this research. Adding nano-fluids to a municipal waste plastic oil mix improves brake thermal efficiency and reduces fuel consumption. The introduction of nano-fluids decreased hydrocarbon, carbon monoxide and increased NOx emissions compared to MPO20 [6]. The research work is aimed at developing a delayed timing engine with minimal heat rejection and a combustion chamber surface that has been partially stabilised zirconia ceramic-coated. The influence of fuel injection time on the performance of waste plastic oil in low heat rejection engines was investigated in order to get a complete understanding of the performance of waste plastic oil in low heat rejection engines. In the wake of the study, performance and emission metrics have significantly improved substantially [7]. Diesel and plastic oil were used to compare the performance of coated and uncoated engines. Performance has improved and specific fuel consumption has decreased as a result of this investigation. Diesel engines covered with zirconia had lower emissions, except for NOx, than diesel engines that were not coated with zirconia [8]. Exploring the effects of variable compression ratio diesel engine performance and emissions on variable parameters such as injection pressure and time. Various proportions of ethanol and diesel are mixed with plastic oils to make test fuels. The experimental analysis shows that P90D5E5 mix has the maximum thermal efficiency, increasing by 16 and 38% over pure diesel and pure plastic oil [9].

Three high-carbon alcohols were oxygenated and their effects on emissions and performance of a diesel engine were compared. For the greatest reduction of NOx and smoke emissions while utilising the least amount of fuel, a response surface methodology-based optimization was used [10]. The performance and emissions of a diesel engine utilising waste plastic oil generated by pyrolysis using Zeolite-A as a catalyst are being investigated. Using 20% plastic oil-diesel enhances thermal efficiency and decreases brake specific fuel consumption. The NOx and HC emissions are lower at low loads and increase with load [11].

Plastic oil blends, and its distilled derivatives may be used to power the engine without requiring modification. However, both raw plastic oil and distilled plastic oil had a significant negative impact on engine performance and emission levels. A greater density and viscosity, lower cetane number, higher sulphur content and acid value were all factors contributing to this [12].

When the load rises, the thermal efficiency improves and the fuel consumption decreases due to the greater concentration of plastic oil in the mix. High in-cylinder pressure is caused by plastic oil's high heat release and delayed ignition. Oxygenated chemicals in plastic oil also aid to reduce emissions from burning. Diesel engines may utilise up to 50% plastic oil in the mix with just a minor increase in CO emissions at higher loads [13]. The combustion and performance study of the engine and the pyrolysis oil may serve as a substitute for conventional fuel. The addition of pyrolysis oil does not result in outstanding performance like diesel fuel, as shown by combustion studies such as the fuel consumption and efficiency. Adding nanoparticles to them, on the other hand, improves their performance [14].

Thermal efficiency and emission quality improve with load, compression ratio, and waste plastic oil and ethanol in diesel. ANOVA and multivariate analysis determined the optimal engine load, compression ratio, and fuel blend, boosting performance and minimizing emissions. With a compression ratio of 18.1, and 20% WPO and 20% ethanol blended diesel, braking thermal efficiency and emissions were optimized [15]. The tertiary fuel mix

Table 1. Properties of polymer oil, ethanol, pentanol and methanol

Sl. No	Fuel property	Unit	Diesel	WPO20	Ethanol	Pentanol	Methanol
1	Density, at 15 °C	(g/m^3)	0.843	0.810	0.799	0.814	0.794
2	Viscosity, at 40 °C	(cSt)	2.45	2.52	1.10	2.88	0.68
3	Calorific valve	(MJ/kg)	42.31	40.12	28.18	34.65	20.10
4	Flash point	(°C)	61	38	16	49	14
5	Cetane index	–	54	51	8	20	5

contained three WPO concentrations and ethanol. Performance, emission, and Full Factorial Design analyzed the best running condition [16]. Optimization based on the design of experiments (DoE) was used with a three-factor full factorial experimental design was used to minimize emissions while maximizing fuel economy. CO, HC, and fuel efficiency surface contour plots determined to be statistically significant [17].

This study aims to investigate the effects of three different alcohols on Waste Polymer Oil (WPO) biodiesel blends at 20% and 60% with pure diesel. The performance and emissions analysis are carried out on a single-cylinder diesel engine under varying load conditions. The results of fuel consumption, emission of hydrocarbons, and carbon monoxide were optimized for engine load and type of alcohol by the design of the experiment tool.

MATERIALS AND METHODS

Cleaner and more efficient than traditional fossil fuels, biofuels made from plastics have a low sulphur concentration. Diesel fuel with a high sulphur content is now used in many developing nations. Liquid fuels may be made from plastic trash, which reduces white pollution while also helping to ease energy constraint. In comparison to fossil diesel, waste plastic oil has comparable features, such as a greater heating value [18].

Pyrolysis yield is influenced by several factors, including the kind of plastic used, the temperature and length of operation, the catalyst type used, and any additional materials added to enhance decomposition. The pyrolysis product from each form of recycled plastic relies on the temperature maintained during pyrolysis and the time it takes to decompose to produce the liquid and gaseous fuel from the material. Incorporating a wide variety of catalysts may help improve oil yield rates. Once again, how well the catalyst works is influenced by the aforementioned variables. Therefore, in order to extract the maximum amount of liquid oil possible, the proper catalyst and operating conditions must be used. A few substances may also speed up the breakdown process [19]. The properties of Polymer oil, Ethanol, Pentanol and Methanol are tabulated in Table 1.

An increase in biodiesel evaporation, a reduction in delay time, and an improvement in secondary atomization minimise emissions when nanoparticles are combined with biodiesel. The combustion process is also made more catalytic by the addition of these activities. The capacity to store energy inside nanoscale metal particles enhances a chemical process. Though it has a higher surface area to volume ratio, nanofluid has a greater ability to improve the pace at which oxygen and fuel react, resulting in a better combustion [6].

EXPERIMENTAL DETAILS

The plastic oil sample used in this investigation was made by pyrolyzing municipal plastic waste. The pyrolysis batch reactor heats the plastic to 600 °C. The heater used in the test was driven by NiCr-based electrical resistance. The liquid nitrogen trap is required because it distributes heat evenly and generates inert conditions for pyrolysis. Unsteady heat input from an autotransformer. The reactor lasted at 500 °C for three hours before cooling down. The pyrolysis evaporated product is collected in a container. The condensed bio-oil is subsequently refrigerated by an external cooling medium. After pyrolysis, the plastic char was separated [20].

Waste Polymer Oil biodiesel blends were tested in a single-cylinder, constant-speed direct-injection engine, as shown in Figure 1 [17]. Speed is maintained regardless of load and biodiesel mix percentages in the diesel engine. The engine was coupled to an eddy current dynamometer, which was used to alter the loads from 0% to 100%. For each of the testing blends, the load is increased by 25%, 50%, 75%, and 100%, according to the 4.4 kW power output of the engine.

An eddy current dynamometer, which monitors current flow, is used to adjust the engine loads manually. The airflow rate was measured using a calibrated orifice on an air drum, and the fuel flow rate was analyzed with a calibrated burette in this investigation. Two fuel tanks were employed for the fuel flow measurement; one was filled with pure diesel and the other with esterified biodiesel, and the fuel flow was recorded. AVL software was put on the test rig, allowing for the collection of various readings and outcomes while the machine was in operation. Table 2 represents the experimental measurements, instruments and its parameters.

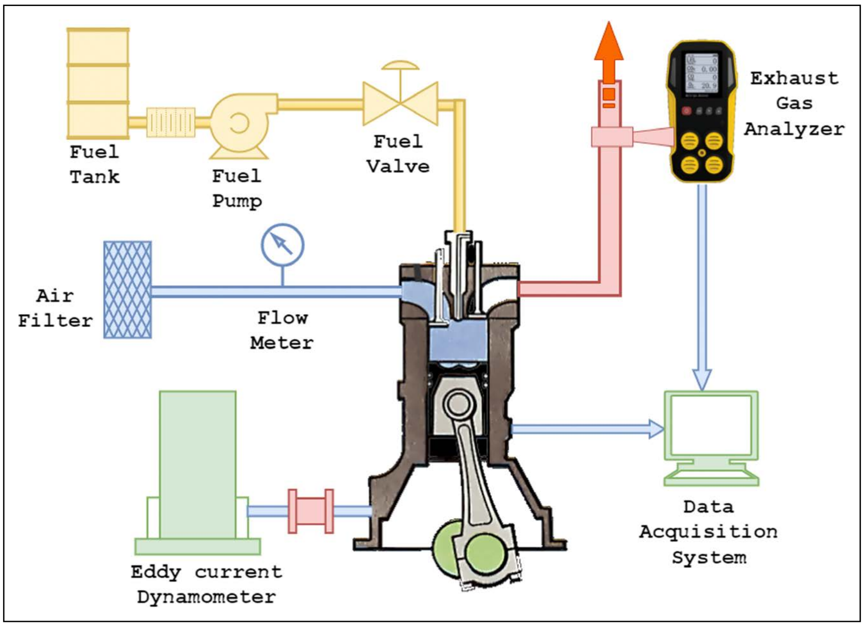

Figure 1. Experimental engine setup.

Table 2. Experimental instruments and its parameters

Sl. No	Measurement	Range	Accuracy	Instrument
1	Hydrocarbon	0 to 20000 ppm	± 10 ppm	AVL gas analyser
2	Carbon monoxide	0 to 15%	± 0.05%	AVL gas analyser
3	Nitrogen oxides	0 to 5000 ppm	± 10 ppm	AVL gas analyser
4	Engine load	–	+0.1 kg to −0.1 kg	Load cell
5	Crank speed	0–10000 rpm	± 10 rpm	Digital tachometer
6	Fuel quantity	0–50 cm^3	± 0.1 cm^3	Burette measurement

This study focuses on energy recovery from waste polymer oil as the alternative fuel source via the waste utilization approach. In this study, we used a novel mixture of shredded HDPE and LDPE in a ratio of 40:60 as the source of plastic oil extraction to use as plastic fuel. HDPE and LDPE testing needed a response time of 60 and 50 minutes, and the material was pyrolyzed into oil at 450 °C. LDPE pyrolysis products show a 60% oil yield, while HDPE pyrolysis products show a 50% oil yield, 25% wax formation, 25% gas formation, and coke formation.

Waste polymer oil obtained from the pyrolysis process of polyethylene polymer were blended with diesel at constant ratios of 20% on a volume basis, along with oxygenated additives of three different alcohols Ethanol, Pentanol and Methanol. The biodiesel fuel named WPO20E20, formed by the blends of 20% waste polymer oil biodiesel, 20% ethanol on a volume basis mixed with pure diesel of 60%. The fuel blends prepared as WPO20P20 (60% diesel + 20% WPO + 20% Pentanol), WPO20M20 (60% diesel + 20% WPO+ 20% Methanol) and WPO20 (80% diesel + 20% WPO).

RESULTS AND DISCUSSION

Brake Thermal Efficiency

The brake thermal efficiency of WPO20P20 was found to be about 3.4 % higher than that of pure diesel when tested under various load conditions (Fig. 2). Researchers found that the addition of low cetane number alcohols to blends increases the time it takes for the fuels to ignite because of the OH radicals' ability to remove hydrogen from the carbon position in most of the alcohols [5]. The efficiency of WPO over 20% has been shown to be negatively impacted. Because WPO has a greater calorific value than diesel, the WPO-diesel blend's calorific value is likewise higher than diesel. Addition of WPO to a diesel mix, however, may also cause viscosity and density increases as well as decreased heat release rates, which can have an impact on how well fuel is dispersed in the combustion process. This can lead to poorer thermal efficiency [11].

Brake Specific Fuel Consumption

By incorporating nanoparticles into the physical qualities of the fuel, as well as by providing an abundance of extra oxygen to complete the burning process, fuel consumption is re-

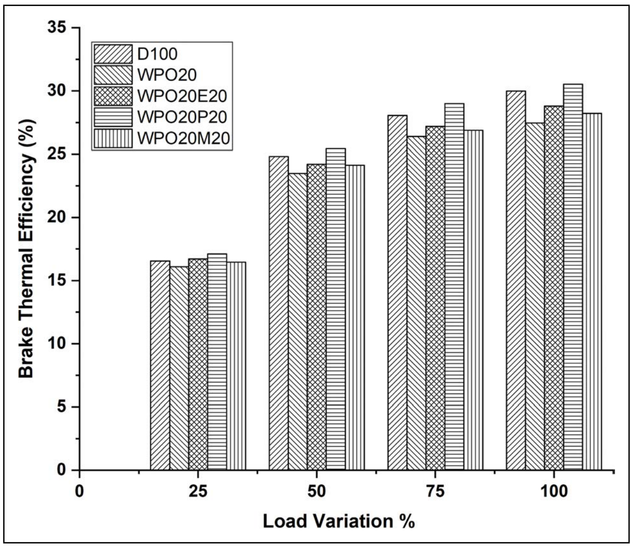

Figure 2. Variation of brake thermal efficiency on WPO.

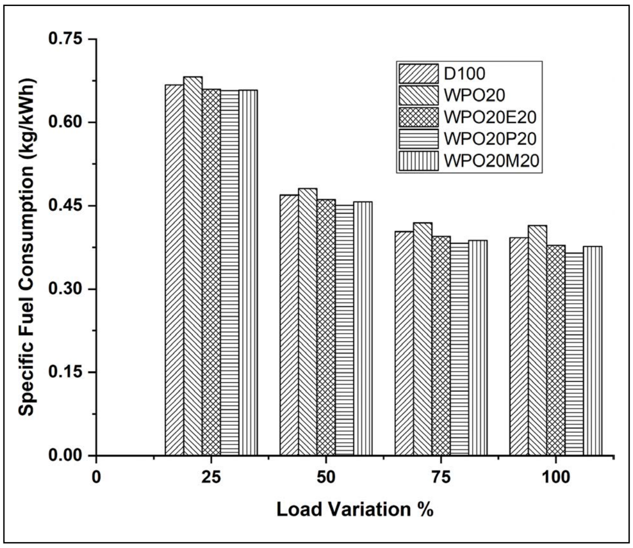

Figure 3. Variation of specific fuel consumption on WPO.

duced. There are less carbon deposits in the cylinder because of the nanoparticle treatment, which lowers the frictional power generated inside and lowers fuel consumption [6]. WPO20P20, WPO20M20 and WPO20E20 blends reached out maximum of 7%, 4% and 3.5% reduction in Specific Fuel Consumption (SFC) than diesel and WP20 blends reached out 2 to 5.5% increased fuel consumption than diesel as shown in Figure 3. As a consequence of the combustion being moved to a later stage due to a later injection timing, the pressure rises only during fast expansion, resulting in a lower effective pressure and a lower output. Combustion quality accounted for the majority of the disparity in fuel consumption across the mixes, even if the heating values were near [10].

Carbon Monoxide Emission

The blends of WPO20P20, WPO20M20 and WPO20E20 blends reached out maximum of 6.2%, 3.3% and 3.5% reduction in CO than diesel and WP20 blends reached out 2.7% increased carbon monoxide than diesel as shown in Figure 4 at various load conditions. It is due to the increased temperature of the gas that the amount of pre-mixed combustion is reduced. Because of this, the initial CO creation has been reduced in magnitude. Given its lower cetane number and greater aromatic content, WPO burns more slowly than gasoline and so burns for a shorter amount of time than gasoline [8]. High oxygen concentration means that WPO blends create fewer CO emissions than baseline fuels, which is why WPO blends have been found to be more environmentally friendly. In order to enhance combustion and reduce CO emissions, a lower viscosity and a greater latent heat of vaporisation of the mix are necessary [18].

Hydrocarbon Emission

During initial load operations, fuel with an excess of oxygen predominates inside the cylinder. This additional air decreases the quantity of fuel that travels through the chamber, resulting in a reduction in the amount of heat that is released. As a result, more fuel is likely to exit the chamber along with the exhaust [20].

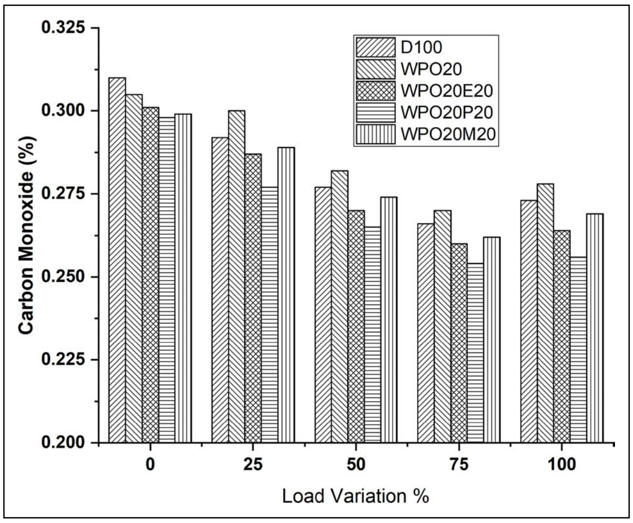

Figure 4. Variation of carbon monoxide emissions on WPO.

The blends of WPO20P20, WPO20M20 and WPO20E20 blends reached out maximum of 5.8%, 3.3% and 3.8% reduction in hydrocarbon than diesel. The greater viscosity of the WPO20 blends resulted in poor vaporization, spray penetration, and greater HC emissions as a result of the process. WP20 blends reached out 11% increased HC than diesel as shown in Figure 5 at various load conditions. High viscosity reduces vapour pressure and increases droplet generation, while it exacerbates incomplete combustion. Lower air-to-fuel ratio and temperature allow HC to escape into the exhaust at lower loads and temperatures. Increasing the WPO percent fraction in the mix increases emissions due to incomplete combustion and unreacted

Table 3. Analysis of variance of fuel consumption

Source	DF	Seq SS	Contribution	Adj SS	Adj MS	F-value	P-value
Model	4	0.128787	99.97%	0.128787	0.021465	998.57	0.001
Model	4	0.128787	99.97%	0.128787	0.021465	998.57	0.001
LOAD	2	0.026706	20.73%	0.026706	0.006676	310.60	0.003
Alcohol	2	0.102052	79.21%	0.001677	0.000839	39.02	0.025
Error	4	0.00121	0.06%	0.000043	0.000021		
Total	8	-0.12997	100.00%				

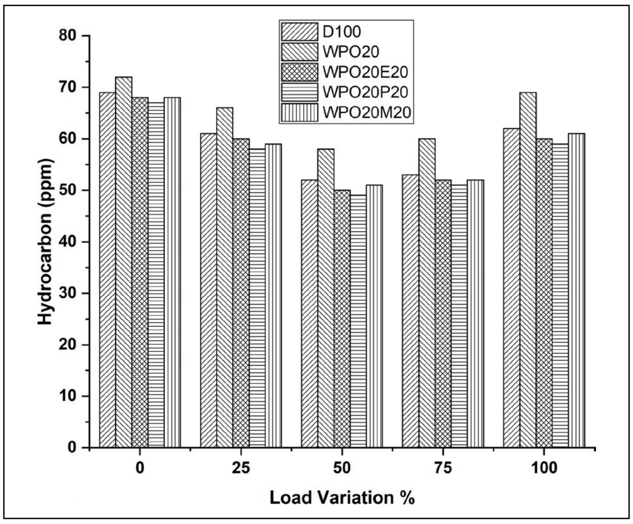

Figure 5. Variation of hydrocarbon emissions on WPO.

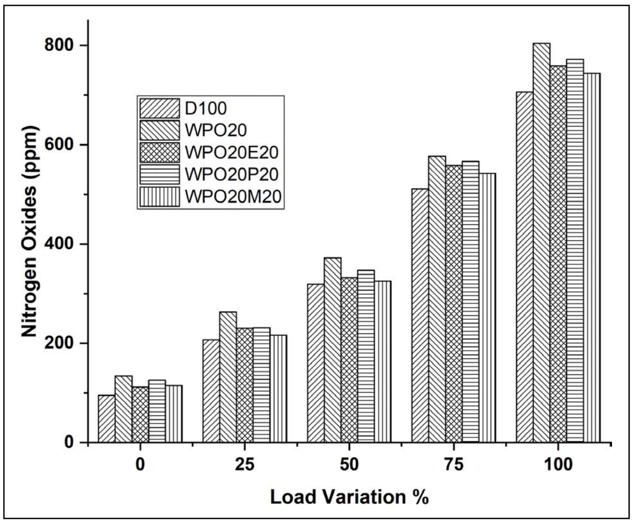

Figure 6. Variation of nitrogen oxides emissions on WPO.

hydrocarbons. PPO mixtures are connected to higher HC emissions for two reasons. Due to the lack of spreading, WPO mixes gather around walls and cracks, leaving them unburnt. Unsaturated hydrocarbons that do not burn and are ejected with the exhaust are the second major reason. Blends with high aromatic content emit more HC because they burn faster and ignite slower [13].

Nitrogen Oxide Emission

The premixed combustion phase of combustion has improved with the addition of greater alcohols to diesel, which aids in the reduction of soot emissions, as is evident. Certain instances of alcohol's evaporation enthalpy property have been claimed to have reduced NOx emissions concurrently owing to the cooling impact that occurs when alcohol evaporates [21]. As a consequence of the higher fuel use, increased engine load was blamed for the spike in NOx emissions. WPO20P20, WPO20M20 and WPO20E20 blends produce NOx at a rate of 10 %, 6 %, and 9% greater than diesel. WPO20 makes more than 15% than pure diesel. NOx emissions are produced as a consequence of a chemical interaction between oxygen and nitrogen molecules that does not occur in equilibrium in the high-temperature burned gas areas. Nitrogen dioxide and nitrogen monoxide (NO) are the primary components of NOx in tailpipe emissions. The generation of NOx is strongly reliant on the temperatures within the cylinder as well as the amount of oxygen present inside the cylinder [9].

Analysis of Variance of Fuel Consumption and Emissions

An experiment may be developed based on the results of the analysis. With varied loads and alcohol fuel mixes, the observed statistics have ramifications for fuel consumption and emissions.. In order to determine the experimental error, all potential interactions between variables may be divided into two categories using DOE. Using ANOVA tables, the researchers hope to reduce engine emissions and fuel consumption while increasing horsepower. Load variation and the kind of alcohol used are two important aspects to keep in mind while increasing efficiency and reducing expenses in this operation. Because it can handle fuel consumption variance to the extent of 99.97 percent, the model is appropriate. The model has an R-square of 99.97%, which means that it can accurately predict the response.

If the p-value is less than one, it's commonly believed that the null hypothesis must be rejected. If the p-value is less than 0.05 for the load and kind of alcohol, then the model is significant. Table 3 shows that load variation accounted for 20.73% of fuel consumption, whereas alcohol additive type

Table 4. Analysis of variance of emission

Source	DF	Seq SS	Contribution	Adj SS	Adj MS	F-value	P-value
Model	4	422.67	97.39%	422.67	105.667	37.29	0.002
Linear	4	422.67	97.39%	422.67	105.667	37.29	0.002
LOAD	2	144.67	33.33%	144.67	72.333	25.53	0.005
Alcohol	2	278.00	64.06%	278.00	139.000	49.06	0.002
Error	4	11.33	2.61%	11.33	2.833		
Total	8	434.00	100.00%				

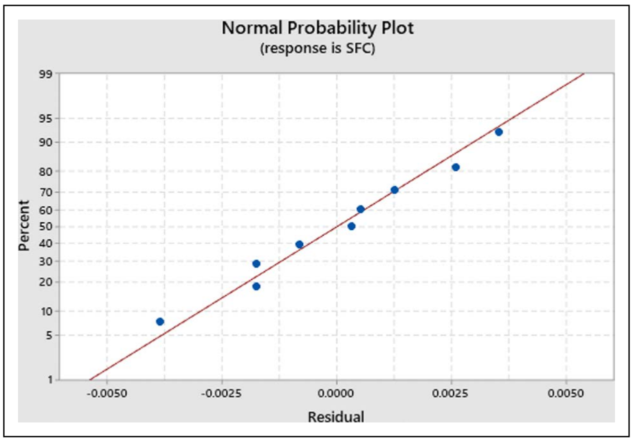

Figure 7. Normal probability of SFC.

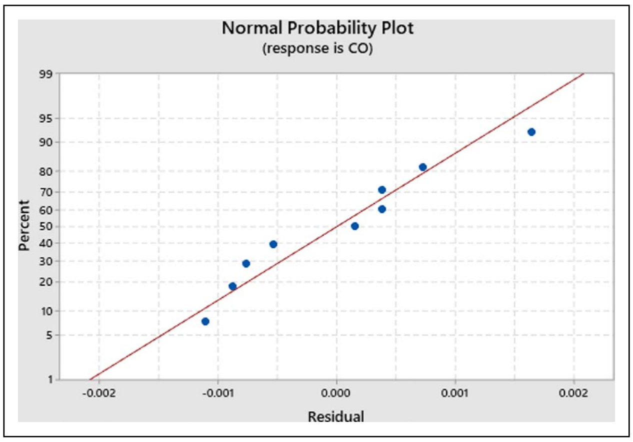

Figure 8. Normal probability of CO.

accounted for 792.1%. Additionally, the load fluctuation contributed 33.33% to emissions, while the kind of ethanol was responsible for 64.06%, as shown in Table 4.

The normal probability plot (Figures 7–9) demonstrates a normal distribution for the error terms. The residual displays have the same features as the original plot. To make acceptable assumptions, it should treat the expected and other factors as random and unstructured. Before evaluating the model, make sure the residual plot has an uneven pattern or is distributed. The normal probability plot displays the normal distribution of data and the response components. The residuals against fitted values show no change in variance. Figures 7–9 show the normal plot of residuals, which helps ensure that the residuals are normally distributed.

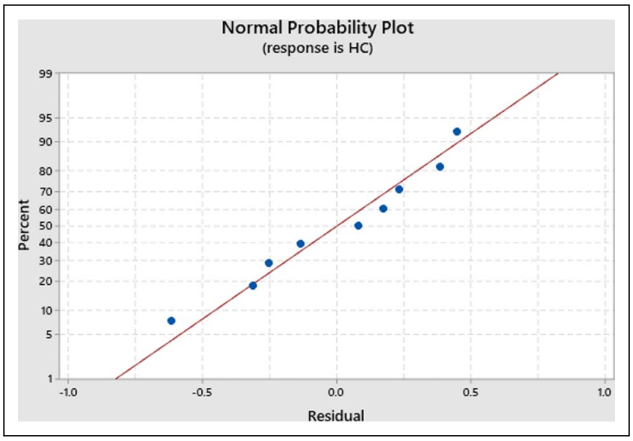

Figure 9. Normal probability of HC.

Response Optimization on Emission

Response optimization is an analytical approach that finds the optimal combination of input variable settings to maximise a single answer or a group of responses. For each variable input combination, the response optimizer function provides an optimal solution and an optimization graphic. It may be interactive. The plot's input variable values may be adjusted to obtain better optimization solutions.

Based on the response optimizer plot (Figure 10), it can be concluded that the pentanol ratio at half load condition is optimal for achieving low emission and effective fuel consumption values. As indicated in Table 5, the ideal circumstances for achieving this goal are when the engine is half loaded. Fuel consumption of 0.4508 kg/kWh, hydrocarbon of 49 ppm and carbon monoxide 0.265% are the optimum values. As depicted in Figure 10, the optimization plot reveals that the optimal load at WPO and alcohol mixes yields the lowest SFC, CO, and HC emissions at half-load conditions, with a composite desirability of 0.9285. Reducing the load will diminish all reactions. However, the impact on SFC emissions was negligible compared to CO and HC emissions. Consequently, when reducing the composite's desirability by diminishing engine

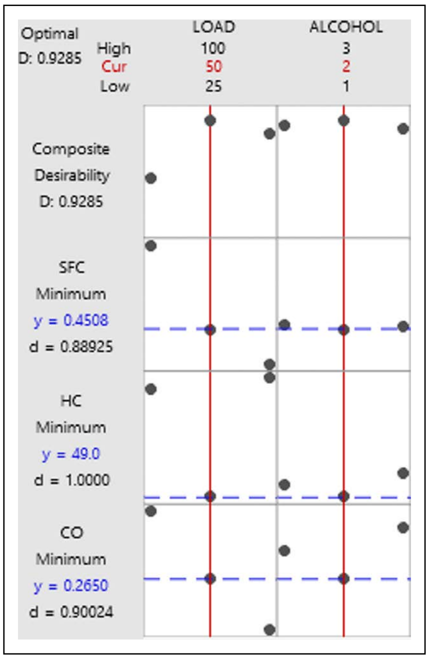

Figure 10. Optimized plot on load and alcohol.

load, the ideal values for engine load and alcohol blend in the experiment were in the half load. Increasing engine load will reduce SFC, HC, and CO emissions. This result recommends that researchers should experiment with a half-load and pentanol in order to improve engine performance.

Environmental Impact and Improvement of Bio-Economy

During the past decade, there has been a rise in investment in biofuels as sustainable alternatives to fossil fuels. These concerns have been brought about by the widespread environmental and health risks associated with the use of fossil fuels. For this reason, it is essential to properly manage the various components of the biofuel supply chain in order to successfully make the shift to a low-carbon and bio-economy. These components include the production of biomass feedstock, the logistics of transporting biomass, the production of biofuel in bio-refineries, and the distribution of biofuel to consumers [22].

A bio-economy requires the recycling of organic materials into valuable fuel and materials. Integration of recycling and bioconversion for enhanced process performance is also assessed. The goal of this work is to make it easier to recycle bio-waste for use in closed-loop systems. To commercialize and promote the use of alternative commodities, more research, market analysis, and funding are needed. To get the most out of the bio-waste, it's important to take a comprehensive, methodical approach that incorporates a wide variety of disciplines and makes use of data to refine, optimize, and introduce novel practices [23]. The circular bioeconomy can assist in solving global problems. By substituting petroleum as an industrial fuel, bioenergy and biomaterials production could reduce their environmental impact. The waste bio-refinery associated with the circular bio-economy may aid with carbon management and greenhouse gas emissions. By minimizing greenhouse gas emissions, implementing a waste bio-refinery circular bio-economy system exhibits a low carbon economy [24].

Table 5. Optimized results on emission and fuel consumption

Load	Alcohol	SFC Fit	HC Fit	CO Fit	Composite desirability
50	2	0.450811	49	0.265	0.928528

Water-soluble, biodegradable, and quickly evaporable, ethanol may have certain safety advantages over fossil fuels. Because it can be produced in nearly any nation, ethanol fuel is the most economical alternative to traditional sources of energy. Ethanol can be made from a variety of plants, including maize, and used as a fuel. However, E10 is the most common type of ethanol utilized, and depending on where you are in the world, it may make up as much as 15% of a blend. A high ethanol fuel mix, consisting of anything from 50 to 85% ethanol, is now in use in a number of nations, including the United States and Brazil [25, 26]. The simplicity of producing ethanol results in lower production costs than those of fossil fuels. Only carbon dioxide and water are released as by products when ethanol is burned as fuel. Carbon dioxide emissions are a little contributor to the environmental crisis. But it's thought that burning ethanol made from biomass like corn and sugar cane has little impact on atmospheric carbon levels. This is because carbon dioxide is taken in by the biomass during photosynthesis, and this may offset some of the carbon dioxide released during ethanol combustion. The three main foci of the circular economy are the feedstock, the production process, and the distribution of the final product. The company never gave the proper amount of thought to the product's legacy. Not much thought has gone into how the product will be maintained once its expected lifespan has ended [23, 24, 27].

The amount of ethanol blended with gasoline in India reached 10.16 percent in 2022, greatly exceeding the country's target. Additionally, the nation has pledged to achieving a 20 percent blending rate by 2025. Similar to the successful E20 ethanol blending project in India may save the government $4 billion per year in 2020–21, when the country's net petroleum imports will be 185 Mt at $551 billion, when the country's net petroleum imports will be $551 billion [28, 29]. Prices for traditional fuels are higher, but ethanol has a lower impact on the environment. Having the ability to convert vehicles to run on E20 is both a necessity and an opportunity because of the increased availability of farmland, the rising output of food grain and sugarcane, and the widespread availability of these products. Two-wheeled vehicles reduced their CO emissions by as much as half compared to four-wheeled cars, and four-wheeled vehicles reduced their emissions by as much as thirty percent. Ethanol and gasoline together can reduce hydrocarbon emissions by about 20% [30].

The primary objective of this research was to find a way to recover energy from waste polymer while also decreasing harmful emissions from a diesel engine. The blood's ability to carry oxygen to and from tissues is compromised by carbon monoxide, making it dangerous to human health. When blood comes into contact with carbon monoxide, haemoglobin is quickly oxidized into carboxyhemoglobin. Saturation of haemoglobin with oxygen is inhibited by the presence of carbon monoxide in the lungs. It has also been shown that this hydrocarbon reduces the production of white blood cells, suppresses the immune system, and makes the body more vulnerable to infection. There's also the fact that different stages of a plant's life cycle are vulnerable to different pollutant levels in terms of phototoxicity. [31, 32].

CONCLUSION

As a potential alternative fuel source, waste polymer are examined in this research. Alcohol has a higher oxygen content, ensuring a more uniform distribution of fuel and air during combustion. More oxygen may be found in alcohol, which is also less costly. The energy industry might benefit from the use of waste polymer oil as a diesel alternative. In order to increase the thermal efficiency of polymer blends, the addition of alcohol to waste polymer fuel boosted its combustion. Additions of pentanol to WPO blends increase efficiency by 3.4% and decrease fuel consumption by 7.4% when compared to diesel. In the same manner, the use of alcohol additions may lower hazardous emissions by up to 6%. It has been shown that the optimum potential engine condition under load and fuel mix may be improved via the use of Design of Experiments. The results of response optimization have also been analysed using response optimization. Researchers found that while driving at half-load, pentanol mixed diesel consumes the most fuel and emits the least pollution.

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DATA AVAILABILITY STATEMENT

The authors confirm that the data that supports the findings of this study are available within the article. Raw data that support the finding of this study are available from the corresponding author, upon reasonable request.

CONFLICT OF INTEREST

The authors declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

ETHICS

There are no ethical issues with the publication of this manuscript.

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