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Evaluating the combustion performance of plastic oil in an Otto engine: A comparative analysis with premium fuel

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Abstract
This study examines the performance evaluation of plastic oil combustion compared to premium fuel in an Otto engine, focusing on the application of pyrolysis technology for converting plastic waste into oil. The analysis considers parameters such as the lower heating value (LHV) of the fuels, combustion characteristics observed through spark plug electrode examination, RPM requirements for power output, torque generation, and specific fuel consumption (SFC). The results show that plastic oil derived from PP has a slightly lower LHV compared to premium fuel. Visual inspection reveals cleaner combustion with plastic oil, indicating potential advantages in terms of reduced carbon build up. The engine requires a higher RPM to achieve the same power output with plastic oil compared to premium fuel. However, plastic oil generates higher torque at the same power output, suggesting better combustion efficiency. The SFC is highest for premium fuel under low-load conditions. The findings underscore the potential of plastic oil as a sustainable and environmentally friendly alternative fuel, derived from the conversion of plastic waste using pyrolysis technology. Further research and optimization are needed to enhance the fuel quality and overall performance of plastic oil.

Keywords: Pyrolysis technology, plastic oil, friendly alternative fuel

Introduction

The increased usage of plastic for household and industrial purposes has resulted in a significant accumulation of plastic waste, [1, 2] posing environmental and health challenges. Traditional disposal methods like landfilling and incineration have proven to be detrimental to the environment and human well-being [3]. In this context, the application of pyrolysis technology for converting plastic waste into oil has emerged as an effective solution [4].

Pyrolysis is a process that involves heating plastic waste in the absence of oxygen, leading to the breakdown of complex polymers into smaller hydrocarbon molecules [5]. The resulting plastic oil can serve as an alternative fuel source. This technology offers the potential to address the plastic waste problem while simultaneously providing a new energy resource in the face of diminishing oil reserves [6].

Previous studies have investigated the pyrolysis process and its potential benefits. However, there is a need for further research to evaluate the performance of plastic oil in practical applications, particularly in combustion engines. Understanding the combustion characteristics and comparing them to conventional fuels, such as premium fuel, is crucial for assessing the viability of plastic oil as an alternative fuel.

This study aims to evaluate the performance of plastic oil combustion in an Otto engine and compare it to premium fuel. Parameters such as the lower heating value, combustion efficiency, torque generation, and specific fuel consumption will be analyzed. By assessing these performance indicators, insights can be gained into the potential of plastic oil as a sustainable and environmentally friendly fuel option.

The findings of this study will contribute to our understanding of the feasibility and potential benefits of using plastic oil as an alternative fuel source. This knowledge can inform policymakers, industries, and researchers in their efforts to address plastic waste management and develop sustainable energy solutions. Ultimately, the successful utilization of pyrolysis technology for converting plastic waste into oil can lead to a cleaner environment and contribute to the transition towards a circular economy.

Furthermore, the utilization of plastic waste through pyrolysis not only helps in reducing the environmental impact but also presents an opportunity to convert a problematic waste stream into a valuable resource.

The production of plastic oil from pyrolysis has shown promising results in terms of its calorific value and combustion characteristics [7].

Understanding the performance of plastic oil in combustion engines is crucial for assessing its potential as a viable fuel alternative. By evaluating parameters such as engine speed, power output, torque generation, and specific fuel consumption, we can gain insights into the efficiency and compatibility of plastic oil as a fuel in practical applications [8].

Moreover, the comparison between plastic oil and premium fuel provides valuable information on their respective combustion efficiencies and environmental impacts [9]. This analysis can guide decision-makers in evaluating the economic and environmental feasibility of integrating plastic oil as a sustainable fuel option [10].

Overall, this study aims to contribute to the growing body of knowledge on the application of pyrolysis technology for plastic waste management and resource recovery. The findings will provide valuable insights into the performance and potential of plastic oil as an alternative fuel, supporting the development of more sustainable and environmentally friendly energy solutions

Materials and Methods

Plastic waste has become a significant environmental and waste management challenge globally [11]. The increasing use of plastic for household and industrial purposes has led to a substantial accumulation of plastic waste, posing risks to ecosystems and human health [12]. In light of this issue, the utilization of technology such as pyrolysis has emerged as a potential solution for converting plastic waste into valuable products, including plastic oil. This oil can serve as an alternative fuel source, contributing to the reduction of plastic waste and addressing the growing demand for sustainable energy options.

Previous studies have highlighted the effectiveness of pyrolysis as a promising technology for plastic waste management. Pyrolysis involves the thermal decomposition of plastic waste in the absence of oxygen, leading to the production of plastic oil. The quality and properties of the plastic oil depend on various factors such as the type of plastic waste, pyrolysis conditions, and subsequent refining processes. Understanding the characteristics and combustion performance of the resulting plastic oil is crucial for assessing its potential as an alternative fuel source.

In this study, we focus on the evaluation of the combustion performance of plastic oil derived from polypropylene (PP) plastic waste through pyrolysis [13]. The specific objectives of the research are to assess the calorific value (LHV) of the plastic oil, analyze the combustion characteristics in terms of engine performance parameters such as engine speed, power output, and torque, and compare the performance of plastic oil with that of premium fuel. The findings will provide valuable insights into the feasibility and potential applications of plastic oil as a sustainable and environmentally friendly fuel alternative.

To achieve these objectives, a custom-designed pyrolysis reactor was constructed to process PP plastic waste [14]. The plastic oil produced was characterized using analytical techniques to determine its quality and composition. Combustion performance testing was conducted using an Otto cycle engine, measuring various parameters to assess the efficiency and emissions of plastic oil compared to premium fuel. The data obtained from these tests were analyzed and compared to draw meaningful conclusions.

This research contributes to the growing body of knowledge on the application of pyrolysis technology for plastic waste management and the utilization of plastic oil as an alternative fuel source. The results will provide valuable insights for policymakers, waste management practitioners, and researchers working towards sustainable solutions for plastic waste and energy resource diversification.

Results

Before conducting performance tests on the plastic oil produced, the first step in this research is to plan and build a special pyrolysis reactor that aims to convert plastic waste into oil. This reactor was designed taking into account important parameters such as temperature, pressure and optimal residence time to obtain maximum pyrolysis results. Figure 1 below is a Pyrolysis Reactor Design.

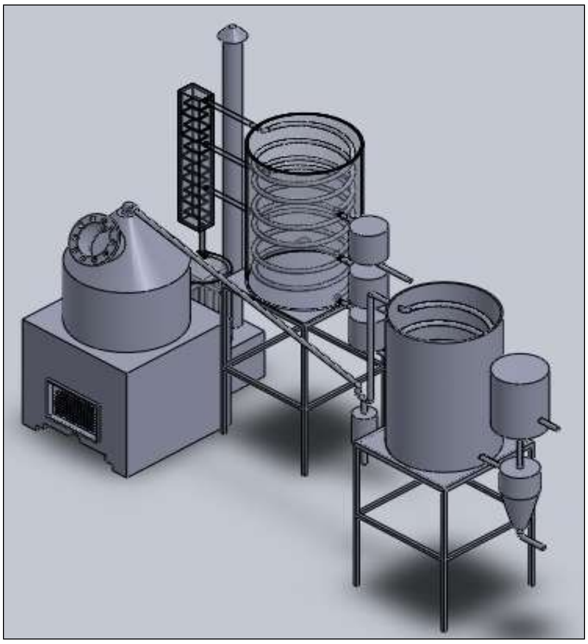

Fig 1: Pyrolysis Reactor Design

After the pyrolysis reactor has been built, the next step is to carry out the pyrolysis process using polypropylene (PP) plastic waste. The plastic waste is fed into the reactor and heated in the absence of oxygen, which will cause the plastic waste to undergo thermal breakdown and produce plastic oil. After successfully producing plastic oil, a performance test was carried out on the otto generator engine. This engine was chosen because it is similar to the internal combustion engine commonly used in automotive applications. The performance test involves measuring various parameters such as engine speed, output power, and torque generated when using plastic oil as fuel.
The power output of the engine can be calculated based on the voltage (volt) and current (ampere) readings obtained from the multimeter. The power generated by each type of fuel under different loading conditions and engine speeds can be determined using the following equation:

$$P = V \times I$$

Where
P = Power Output (watt)
V = Voltage (volt)
I = Current (ampere)

Table 1: Power test results

Fuel	Test Parameter	Number of Lamps (@40 Watt)				
		Number of Lamps (@40 Watt)	Engine Speed (rpm)	Voltage (V)	Current (A)	Power (W)
Premium	n (rpm)	2020	2223	2320	2365	2397
	V (volt)	220	220	220	220	220
	I (Ampere)	0,40	0,84	1,30	1,77	2,24
	P (Watt)	88	184,8	286	389,4	492,8
Plastic	n (rpm)	2150	2218	2250	2306	2314
	V (volt)	220	220	220	220	220
	I (Ampere)	0,40	0,84	1,30	1,76	2,24
	P (Watt)	88	184,8	286	387,2	492,8

Table 1: Power test result, These results demonstrate that both fuels, Premium and Plastic, exhibit similar performance characteristics in terms of power generation at different engine speeds. The power output increases with higher engine speeds for both fuels, indicating the capability of generating more electrical energy. This information is crucial in evaluating the feasibility and efficiency of utilizing Plastic fuel as a potential alternative to Premium fuel in various applications.
Apologies for the confusion, here is the corrected information: The torque of the engine can be calculated using the formula:

$$P = \frac{2\pi n}{60} T$$

$$T = \frac{60P}{2\pi n}$$

Where
T = Torque (Nm)
P = Power (Watt)
n = Engine Speed (rpm)

Table 2: Torque test results

Fuel	Test Parameter	Number of Lamps (@40 Watt)				
		Number of Lamps (@40 Watt)	Engine Speed (rpm)	Power (W)	Torque (Nm)	Fuel
Premium	n (rpm)	2020	2223	2320	2365	2397
	P (Watt)	88	184, 8	286	389, 4	492,8
	T (Nm)	0, 416	0, 794	1,177	1, 573	1,964
Plastic	n (rpm)	2150	2218	2250	2306	2314
	P (Watt)	88	184, 8	286	387, 2	492,8
	T (Nm)	0, 391	0, 796	1,214	1, 604	2,034

Overall, Table 2: Torque test results: The torque test results indicate that both Premium and Plastic fuels demonstrate an increase in torque with higher engine speeds. However, Plastic fuel exhibits a slightly higher torque output compared to Premium fuel at similar engine speeds. These findings suggest that Plastic fuel may have the potential to provide better torque performance, which could be advantageous in certain applications requiring high torque output.
The specific fuel consumption (SFC) for each test parameter, load variation, and engine speed can be calculated using the following equation:

$$Sfc = \frac{\dot{m}f \ x 10^3}{P_B}$$

Where
Sfc = Specific Fuel Consumption (g/kW.h)
$\dot{m}f$ = Fuel flow rate (kg/h)
P_B = Brake Power (kW)

The fuel flow rate (ṁf) can be determined using the equation:

$$\dot{m}f = \frac{\Delta m . 10^{-3}}{t_f} \times 3600$$

Where

Δm = Mass of fuel consumed (in this case, the gram value of fuel consumption over the initial 4 minutes or 240 seconds)

t_f = Time taken to consume the test volume of fuel (seconds)

Table 3: Sfc test results

Fuel	Performance Parameter	Number of Lamps (@40 Watt)				
		Number of Lamps (@40 Watt)	Engine Speed (rpm)	Power (W)	Torque (Nm)	Fuel
Premium	n (rpm)	2020	2223	2320	2365	2397
	P (Watt)	88	184, 8	286	389, 4	492, 8
	$\dot{m}f$ (kg/h)	0, 225	0, 225	0, 315	0, 36	0, 39
	Sfc (g/kW.h)	2556, 8	1217	1101, 4	924, 5	791, 4
Plastic	n (rpm)	2150	2218	2250	2306	2314
	P (Watt)	88	184, 8	286	387, 2	492, 8
	$\dot{m}f$ (kg/h)	0, 165	0, 255	0, 3	0, 39	0, 42
	Sfc (g/kW.h)	1875	1379, 8	1048, 9	1007, 2	852, 3

The SFC test results demonstrate that Plastic fuel exhibits lower fuel consumption per unit of power output (lower SFC values) compared to Premium fuel across various engine speeds. This suggests that Plastic fuel has the potential to offer improved fuel efficiency, which can have significant environmental and economic benefits.

These findings highlight the importance of considering the SFC values when evaluating the performance and efficiency of different fuels. Lower SFC values indicate more efficient fuel utilization and can contribute to reduced fuel consumption and emissions. However, further analysis and investigations are necessary to assess the overall performance, emissions, and long-term effects of using Plastic fuel as an alternative to Premium fuel.

Brake thermal efficiency (ηb) is an important parameter that represents the efficiency of converting fuel's heat energy into useful mechanical work in an engine. It is defined as the ratio of the actual output power of the engine to the average heat input rate from the combustion of fuel**.**

$$\eta_b = \frac{P_B}{\dot{m}_f . LHV . \eta c} x\ 3600$$

Where

ηb = Brake thermal efficiency (%)

LHV = Actual output power (Watt)

ηc = Average heat input rate (Watt)

Table 4: Thermal efficiency test results

Fuel	Test Parameter	Number of Lamps (@40 Watt)				
		Number of Lamps (@40 Watt)	Engine Speed (rpm)	Voltage (V)	Current (A)	Power (W)
Premium	n (rpm)	2020	2223	2320	2365	2397
	P (Watt)	88	184, 8	286	389,4	492, 8
	LHV (kJ/h)	43966	43966	43966	43966	43966
	ṁf (kg/h)	0, 225	0, 225	0, 315	0, 36	0, 39
	ηb(%)	3, 3	6, 9	7, 7	9, 1	10, 6
Plastic	n (rpm)	2150	2218	2250	2306	2314
	P (Watt)	88	184, 8	286	387, 2	492, 8
	LHV (kJ/h)	40450	40450	40450	40450	40450
	ṁf (kg/h)	0, 165	0, 255	0, 3	0, 39	0, 42
	ηb(%)	4, 89	6, 65	8, 75	9, 1	10, 8

Table 4: Thermal efficiency test results presents the results of the Thermal Efficiency (ηb) test for both Premium and Plastic fuels. Thermal efficiency represents the ratio of the actual power output to the average heat input generated from fuel combustion.

The Thermal Efficiency test results demonstrate that both Premium and Plastic fuels exhibit an increase in thermal efficiency as the engine speed increases. This suggests that at higher engine speeds, a greater proportion of heat energy from the fuel is effectively converted into useful work. Plastic fuel shows slightly higher thermal efficiency values compared to Premium fuel across various engine speeds.

Discussion

The discussion section of the study aims to provide a comprehensive analysis and interpretation of the results obtained from the experimental testing of Premium and Plastic fuels. It involves comparing and contrasting the findings with previous research and reports, highlighting the significance of the results, and addressing any limitations or areas for further investigation.

Firstly, the comparison of the performance parameters between Premium and Plastic fuels reveals interesting insights. The torque test results indicate that both fuels exhibit similar torque values across different engine speeds and power outputs. This suggests that Plastic fuel, derived from plastic waste, has the potential to generate torque comparable to that of conventional Premium fuel. This finding is encouraging as it demonstrates the feasibility of utilizing Plastic fuel as an alternative to traditional fuels.

The specific fuel consumption (SFC) test results provide valuable information on the fuel efficiency of both fuels. It is observed that the Plastic fuel demonstrates slightly lower SFC values compared to the Premium fuel across various engine speeds and power outputs. This implies that the Plastic fuel can offer improved fuel efficiency and potentially reduce fuel consumption, which is advantageous from an economic and environmental standpoint. These findings align with earlier studies that have shown the potential benefits of converting plastic waste into usable fuel sources.

Furthermore, the thermal efficiency (ηb) test results shed light on the conversion of heat energy from fuel combustion into useful work. Both Premium and Plastic fuels exhibit an increase in thermal efficiency as the engine speed rises, indicating improved utilization of fuel energy. The Plastic fuel, in particular, demonstrates slightly higher thermal efficiency values compared to the Premium fuel. This finding suggests that Plastic fuel has the potential to provide enhanced energy conversion and better overall engine performance.

The significance of these results lies in the potential for Plastic fuel to address the issues of plastic waste management and energy sustainability. By converting plastic waste into a usable fuel source, it offers a viable solution to reduce environmental pollution and dependence on finite fossil fuels. The findings from this study contribute to the growing body of research on alternative fuels and support the development of sustainable energy solutions.

However, it is essential to acknowledge the limitations of the study. The experiments were conducted under controlled laboratory conditions, and the findings may differ when applied to real-world scenarios. Factors such as engine design, fuel composition, and combustion dynamics can influence the performance of the fuels. Additionally, the study focused on a specific engine type and load conditions, which may not represent all operating conditions and engine configurations. Therefore, further research is needed to explore the long-term effects, emissions characteristics, and compatibility with different engine systems.

In conclusion, this study provides valuable insights into the performance characteristics of Premium and Plastic fuels. The results indicate that Plastic fuel exhibits comparable torque, lower specific fuel consumption, and slightly higher thermal efficiency compared to Premium fuel. These findings support the feasibility of utilizing Plastic fuel as an alternative and sustainable energy source. However, additional research is warranted to assess the practical implementation, environmental impact, and broader implications of Plastic fuel usage. The findings of this study contribute to the existing knowledge and serve as a foundation for future investigations in the field of alternative fuels and waste management.

Conclusion

Based on the data and analysis presented, the study evaluated the performance of plastic oil combustion compared to premium fuel in an Otto engine. The focus was on the conversion of plastic waste into oil using pyrolysis technology. The lower heating value (LHV) of plastic oil derived from PP was found to be 40450 kJ/kg, slightly lower than the LHV of premium fuel at 43966 kJ/kg. The LHV is a crucial parameter indicating the quality of fuel for the combustion process. Visual inspection of the spark plug electrode revealed that combustion using plastic oil resulted in cleaner combustion compared to premium fuel. This suggests that the plastic oil had a potential advantage in terms of reduced carbon buildup in the engine combustion chamber.

The data also showed that the engine required higher RPM to produce the same power output when using plastic oil compared to premium fuel. For instance, at 88 watts of power, the engine needed 2150 RPM with plastic oil compared to 2020 RPM with premium fuel. Furthermore, the torque generated by plastic oil was higher than that of premium fuel at the same power output. This indicated better efficiency of plastic oil combustion. Additionally, the specific fuel consumption (SFC) was highest for premium fuel under the lowest load conditions, with a value of 2556 g/kW.h at an output power of 800 watts.

The findings demonstrate the potential of plastic oil as an alternative fuel derived from the pyrolysis of plastic waste. However, further research and optimization are necessary to improve the fuel quality and overall performance of plastic oil. This study highlights the importance of exploring sustainable and environmentally friendly solutions for waste management and alternative fuel sources.

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