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Effect of Reactor Temperature on the Characteristics of Alternative Fuel Produced from the Pyrolysis of Mixed Plastic Waste

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Abstract

Plastic waste is a type of waste that is difficult to decompose, and its quantity continues to increase, potentially causing environmental problems. One method that can be applied to reduce plastic waste is pyrolysis, a thermal decomposition process without oxygen that produces pyrolysis oil, which has the potential to be used as an alternative fuel. Reactor temperature is an important factor that influences the thermal decomposition process, thus affecting the characteristics of the resulting pyrolysis oil. This study aims to analyze the effect of reactor temperature on the characteristics of pyrolysis oil produced from mixed plastic waste. The study was conducted experimentally using 5 kg of mixed non-chlorinated plastic waste in each test, with reactor temperature variations of 300 °C, 320 °C, 340 °C, 360 °C, and 380 °C. Each temperature variation was tested once. The parameters analyzed included operating time, density, viscosity, and calorific value. The results showed that increasing the reactor temperature accelerated the operating time from 70 minutes at 300 °C to 50 minutes at 380 °C. The density of pyrolysis oil ranged from 745.18 to 785.15 kg/m³, with a viscosity of 4.793 to 5.891 cSt and a calorific value of 38.681 to 40.405 MJ/kg. At 380 °C, the highest calorific value of 40.405 MJ/kg was achieved, while the density and viscosity remained within ranges close to those of conventional fuels. Therefore, 380 °C exhibited the best pyrolysis oil characteristics among the temperature variations studied and has greater potential for development as an alternative fuel after further processing and purification.

Keywords: Plastic Waste, Pyrolysis, Reactor Temperature, Density, Calorific Value.

1. Introduction

Plastic waste is a growing environmental problem due to its inherent difficulty in decomposing naturally. The widespread use of plastic in various sectors has led to a continued increase in the amount of plastic waste each year, while the environment's ability to decompose it is very limited. The accumulation of plastic waste can damage soil, water, and ecosystems and has the potential to cause various negative impacts on health and the environment if not managed properly. Therefore, management efforts are needed that not only reduce the amount of plastic waste but also provide added value through its use as an alternative energy source.

In Padang Panjang City, waste production reaches approximately 50 tons per day, with an average generation of 0.8 kg per person per day, of which more than 10% is plastic waste [1]. This situation is exacerbated by the increasing generation of waste, which requires immediate management to prevent it from exceeding available management capacity [2]. Without proper management, the increasing volume of plastic waste will increase the burden on landfills (TPA), raise the risk of environmental pollution, and reduce environmental quality. Therefore, the application of technology that can reduce waste generation while producing products with economic value is necessary.

One technology with potential application is pyrolysis, the thermal decomposition of materials at high temperatures in the absence of or with very limited oxygen supply [3]–[5]. In this process, the polymer chains that make up plastic undergo cracking into lower molecular weight hydrocarbon compounds, producing pyrolysis oil, gas, and solid residue. Pyrolysis oil has the potential to be used as

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an alternative fuel because it contains hydrocarbon compounds with a relatively high calorific value. In addition to reducing the volume of plastic waste, pyrolysis technology also supports the development of more sustainable energy sources [6], [7].

The characteristics of pyrolysis oil are influenced by various factors, such as plastic type, particle size, heating rate, residence time, operating pressure, and reactor temperature. Among these factors, reactor temperature is the most influential parameter because it determines the rate of thermal decomposition and the distribution of the resulting hydrocarbon fractions. Temperatures that are too low can result in incomplete polymer cracking, producing pyrolysis oil with suboptimal characteristics. Conversely, excessively high temperatures can trigger secondary reactions in the pyrolysis vapor that alter the composition of the hydrocarbon compounds, thereby affecting the characteristics of the resulting pyrolysis oil. Therefore, reactor temperature control is an important aspect in obtaining pyrolysis oil with characteristics suitable for use as an alternative fuel [8], [9].

Several previous studies have examined the effect of temperature on the plastic pyrolysis process. Sharuddin et al. [8] in their review article, explained that temperature is one of the most influential operating parameters on the distribution of pyrolysis products because it determines the rate of polymer thermal degradation and the characteristics of the resulting pyrolysis oil. Williams and Slaney [9] studied the pyrolysis and liquefaction of several types of single and mixed plastics and showed that operating temperature affects the distribution of the hydrocarbons formed, thus changing the characteristics of the pyrolysis oil. Miandad et al. [10] also reported that plastic type and pyrolysis temperature affect the yield and quality of the resulting pyrolysis oil.

Subsequent research by Sharuddin et al. [11] showed that increasing reactor temperature can improve the quality of pyrolysis oil by changing the distribution of hydrocarbon fractions. Papari and Hawboldt [12] in their study of the thermal and catalytic pyrolysis of plastic waste, concluded that temperature is a critical factor determining the characteristics of pyrolysis products, including the physical properties of the resulting oil. Furthermore, Singh et al. [13] reported that increasing the temperature in the pyrolysis of mixed plastic waste resulted in changes in oil characteristics due to the increased intensity of the thermal cracking reaction. The results of this study indicate that reactor temperature is the main parameter that influences the quality of pyrolysis oil, so further studies are needed on mixed plastic waste with a controlled composition.

Although various studies have addressed the effect of temperature on the pyrolysis process, most still use a single type of plastic as the raw material, such as LDPE, HDPE, or PP, and focus more on the characteristics of pyrolysis oil or a specific product type. However, the plastic waste generated by the community is generally a mixture of various plastic types, each with different thermal degradation characteristics, resulting in a more complex hydrocarbon distribution and oil characteristics. Therefore, research on the pyrolysis of mixed plastic waste needs to be further developed to better represent the real-world conditions of plastic waste processing. The novelty of this study lies in the use of mixed non-chlorinated plastic waste consisting of HDPE, LDPE, PET, PP, and PS in equal compositions, and the evaluation of the effect of reactor temperature variations on the characteristics of pyrolysis oil based on density, viscosity, and calorific value. This approach provides a more representative picture of the characteristics of pyrolysis oil produced from mixed plastic waste compared to previous studies, which generally used a single type of plastic as the raw material.

Based on these conditions, this study aims to analyze the effect of reactor temperature variations on the characteristics of oil produced from pyrolysis of mixed plastic waste based on the parameters of density, viscosity, and calorific value. The results of this study are expected to serve as a reference in the development of pyrolysis technology for processing mixed plastic waste and to provide information on the effect of reactor temperature on the characteristics of pyrolysis oil as an alternative fuel. In addition, this study is expected to support efforts to utilise plastic waste at TPS-3R Bukit Surau, Padang Panjang City, through the application of pyrolysis technology as an alternative waste processing method that produces value-added products.

2. Method

This research is an experimental study that aims to analyze the effect of reactor temperature variations on the characteristics of oil produced from the pyrolysis of mixed plastic waste. The research was conducted at TPS-3R Bukit Surau, Padang Panjang City, West Sumatra. 5 kg of non-

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chlorinated mixed plastic waste was used as raw material in each test. The reactor temperature variations used were 300 °C, 320 °C, 340 °C, 360 °C, and 380 °C, while the operating pressure was kept constant at 1.2 bar. The test conditions at each reactor temperature variation are shown in Table 1.

Table 1. Test Conditions at Each Reactor Temperature Variation

No.	Reactor Temperature (°C)	Pressure (bar)	Plastic Mass (kg)	Plastic Type
1	300	1.2	5	HDPE, LDPE, PET, PP, PS
2	320	1.2	5	HDPE, LDPE, PET, PP, PS
3	340	1.2	5	HDPE, LDPE, PET, PP, PS
4	360	1.2	5	HDPE, LDPE, PET, PP, PS
5	380	1.2	5	HDPE, LDPE, PET, PP, PS

2.1 Materials and Equipment

The materials used in this study were mixed non-chlorinated plastic waste consisting of HDPE, LDPE, PET, PP, and PS, with a composition of 20% of the total mass of raw materials at show Table 2. The plastic waste was sorted, cleaned, and dried before the pyrolysis process to reduce the influence of contaminants on the test results. In each test, 5 kg of raw material was used. The main equipment used included a stainless steel pyrolysis reactor, a LPG burner as a heat source, a condenser to condense the pyrolysis vapor into oil, a pyrolysis oil container, a digital thermocouple to measure the reactor temperature, a pressure gauge to monitor the operating pressure, a digital densimeter to measure density, a digital viscometer to determine viscosity, and a bomb calorimeter to measure the calorific value of the pyrolysis oil.

Table 2. Composition of Non-Chlorinated Mixed Plastic Waste

Plastic Type	Composition (%)	Mass (kg)
HDPE	20	1.0
LDPE	20	1.0
PET	20	1.0
PP	20	1.0
PS	20	1.0
Total	100	5.0

2.2 Experimental Setup

The experimental setup in this study used a single stainless steel batch-type pyrolysis reactor equipped with a condensation system, product container, and temperature and pressure measuring instruments. The reactor was heated using a LPG burner as a heat source. The reactor temperature was measured using a K-type thermocouple installed at the bottom of the reactor, then connected to a temperature controller to monitor the process temperature in real time. The pyrolysis vapor was flowed to a condenser to be cooled and condensed into pyrolysis oil, which was then collected in a product container. The circuit diagram of the equipment used in this study is shown in Figure 1.

Figure 1 shows a schematic of the experimental setup used in this study. The system consists of a pyrolysis reactor heated using a gas burner and equipped with a pressure gauge to monitor pressure, and a thermocouple installed at the bottom of the reactor to measure temperature during the pyrolysis process. Mixed plastic waste is fed into the reactor through the plastic waste inlet, then heated to the test temperature. The pyrolysis vapor is then channeled to the condenser through a connecting pipe. Before entering the condenser, the vapor passes through a tar collection box, which serves to collect tar or heavy residue carried along with the vapor flow, so that only the vapor can continue to the condenser. In the copper coil condenser submerged in the cooling water tank, the vapor undergoes a condensation process into pyrolysis oil, which is then channeled to the oil storage vessel. Meanwhile, non-condensable gas is released through the gas outlet.

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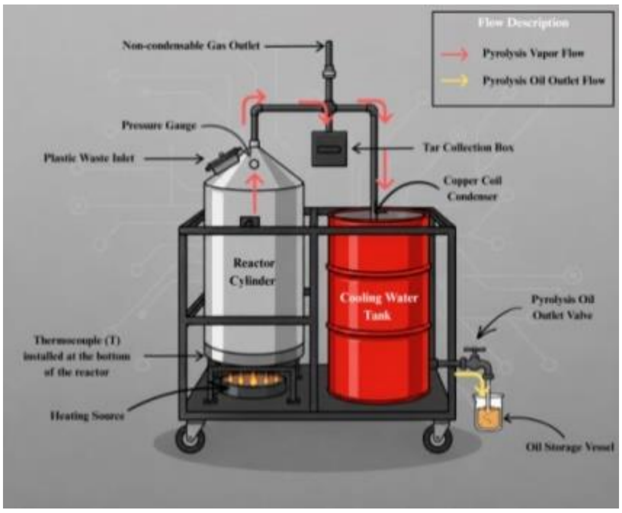

Figure 1. Experimental Setup of the Mixed Plastic Waste Pyrolysis System.

2.3 Pyrolysis Process

The pyrolysis process is carried out by inserting 5 kg of mixed non-chlorine plastic waste into the pyrolysis reactor; then, the reactor is tightly closed to minimize oxygen entry during the process. The reactor is heated using a liquid petroleum gas (LPG) burner until it reaches the test temperature, namely 300 °C, 320 °C, 340 °C, 360 °C, and 380 °C, while the operating pressure is maintained constant at 1.2 bar. During the heating process, the plastic waste undergoes thermal decomposition in the absence of oxygen so that the polymer chains break down into hydrocarbon compounds with lower molecular weights and produce pyrolysis vapor. The vapor is then flowed to a cooled condenser, so that it undergoes a condensation process and turns into pyrolysis oil. The condensed oil is then collected in a container and used as a sample for characteristic testing, including density, viscosity, and calorific value, to analyze the effect of variations in reactor temperature on the characteristics of pyrolysis oil [3], [8].

2.4 Density Testing

Density testing aims to determine the density of pyrolysis oil produced at each reactor temperature variation. Testing is carried out using a digital densimeter by measuring the density of oil samples at room temperature conditions according to the tool testing procedure. The density value describes the mass of oil in each unit volume and is used as one of the parameters to evaluate the physical characteristics of pyrolysis oil. The higher the density value, the greater the mass of oil contained in the same volume. Density is calculated based on the ratio between the mass and volume of oil, which is mathematically expressed in Equation (1) [14].

$$\rho = \frac{m}{V} \tag{1}$$

Note:

ρ = Density (kg/m³)
m = Mass of oil (kg)
V = Volume of oil (m³)

2.5 Viscosity Testing

Viscosity testing was conducted using a digital viscometer to determine the flow resistance of the pyrolysis oil produced at each reactor temperature variation. Prior to testing, the oil samples were heated to 40 °C, according to viscosity testing conditions, and then measured using a digital viscometer. Viscosity is a fluid property that indicates the level of resistance a fluid presents to flow due to internal friction between fluid layers [11]. The viscosity value obtained was used to evaluate the flow characteristics of the pyrolysis oil. A higher viscosity value indicates greater resistance to fluid flow, while a lower viscosity value indicates a more fluid-flowing oil. The viscosity test results were

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then used to analyze the effect of reactor temperature variations on the characteristics of the pyrolysis oil.

2.6 Calorific Value Testing

The calorific value of the pyrolysis oil was analyzed using a bomb calorimeter to determine the amount of heat energy produced during the combustion process. Calorific value is a key parameter in evaluating the quality of pyrolysis oil as an alternative fuel because it indicates the amount of energy released per unit mass of fuel. The higher the calorific value, the greater the energy produced, so the potential for its use as an alternative fuel is also better [13]. Tests were conducted on the pyrolysis oil produced at each reactor temperature variation, namely 300 °C, 320 °C, 340 °C, 360 °C, and 380 °C. The test results were then analyzed to determine the effect of reactor temperature on changes in the calorific value of pyrolysis oil and used as a basis for evaluating the quality of the fuel energy produced.

2.7 Data analysis

The test data were analyzed descriptively to evaluate the effect of reactor temperature variations on the characteristics of the pyrolysis oil produced. The parameters analyzed included operating time, density, viscosity, and calorific value at each reactor temperature variation, namely 300 °C, 320 °C, 340 °C, 360 °C, and 380 °C. All data were presented in tables and graphs to facilitate the identification of the trend of changes in each parameter due to temperature variations. Furthermore, the test results were compared and interpreted based on pyrolysis theory and previous research results to gain an understanding of the effect of reactor temperature on the quality of pyrolysis oil as an alternative fuel.

3. Result and Discussion

3.1 Mixed Plastic Waste Pyrolysis Results

The results of mixed plastic waste pyrolysis tests at various reactor temperatures of 300 °C, 320 °C, 340 °C, 360 °C, and 380 °C produced pyrolysis oil with different characteristics. The observed parameters included operating time, density, viscosity, and calorific value. The test results are presented in Table 3.

Table 3. Results of Pyrolysis Oil Tests at Various Reactor Temperatures

No.	Temperature (°C)	Operating Time (minutes)	Density (kg/m^3)	Viscosity (cSt)	Calorific Value (MJ/kg)
1	300	70	785.15	5.891	39.813
2	320	65	777.99	5.725	40.225
3	340	60	745.18	5.172	39.909
4	360	57	758.56	4.793	38.681
5	380	50	759.16	5.565	40.405

Based on Table 3, increasing reactor temperature affects the characteristics of the pyrolysis oil produced. The operating time tends to decrease with increasing reactor temperature, from 70 minutes at 300 °C to 50 minutes at 380 °C. The density of pyrolysis oil ranges from 745.18–785.15 kg/m^3, while the viscosity ranges from 4.793–5.891 cSt. The calorific value of pyrolysis oil ranges from 38.681 to 40.405 MJ/kg. These results indicate that variations in reactor temperature affect the physical and energy characteristics of pyrolysis oil. Further discussion on the effect of temperature on each parameter is presented in the next subsection.

3.2 Effect of Temperature on Density

Density is an important parameter in determining the characteristics of pyrolysis oil because it is related to the composition of hydrocarbons formed during the pyrolysis process. Changes in reactor temperature can affect the polymer chain cracking process, thus impacting the density of the resulting

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pyrolysis oil. The relationship between reactor temperature and pyrolysis oil density is shown in Figure 2.

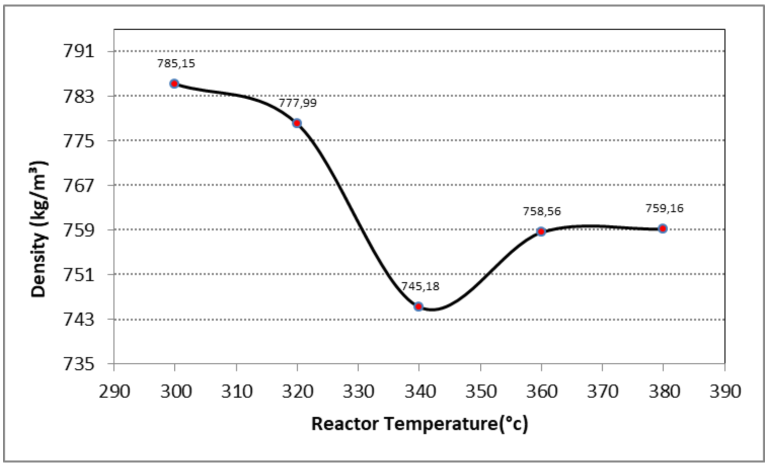

Figure 2. Effect of Reactor Temperature on Pyrolysis Oil Density

Based on Figure 2, the density of pyrolysis oil tends to decrease as the reactor temperature increases from 300 °C to 340 °C, namely from 785.15 kg/m³ to 745.18 kg/m³. This decrease indicates that increasing temperature enhances the intensity of thermal degradation of polymer chains (thermal cracking), resulting in lower molecular weight hydrocarbon fractions. According to [15], increasing temperature accelerates the thermal degradation process of plastics and increases the formation of volatile products, so that the characteristics of pyrolysis oil shift towards lighter fractions and its density decreases. This finding is supported by [16], who stated that temperature is one of the main operating parameters that determine the distribution of pyrolysis products. Increasing temperature will increase the intensity of polymer chain cleavage, resulting in lighter hydrocarbon fractions and affecting the physical characteristics of pyrolysis oil, including its density. Additionally, more effective heat transfer at higher temperatures improves the distribution of energy throughout the material, so that the pyrolysis process occurs more evenly [17]. The results of this study are also in line with [8], which states that temperature is an important operating parameter that significantly influences the distribution of pyrolysis products.

At temperatures of 360 °C and 380 °C, the density of pyrolysis oil increased again to 758.56 kg/m³ and 759.16 kg/m³, respectively. This indicates that the relationship between temperature and density is not always linear, [9] explained that the distribution of hydrocarbons from pyrolysis is influenced by the operating temperature and the degradation characteristics of each polymer type. In line with this, [16] explained that changes in temperature can alter the distribution of pyrolysis compounds, so that the characteristics of the resulting oil do not always change linearly with increasing temperature. In this study, all tests used the same raw material composition, namely a mixture of HDPE, LDPE, PET, PP, and PS, each amounting to 1 kg. Therefore, the increase in density at higher temperatures is suspected to be caused by changes in the distribution of hydrocarbon fractions due to thermal degradation mechanisms and secondary reactions (secondary cracking). These results show that the reactor temperature plays an important role in determining the density characteristics of the pyrolysis oil produced.

3.3 *Effect of Temperature on Viscosity*

Viscosity is one of the parameters used to evaluate the flow characteristics of pyrolysis oil. Changes in reactor temperature affect the hydrocarbon cracking process, which can lead to changes in the viscosity of the resulting oil. The relationship between reactor temperature and pyrolysis oil viscosity is shown in Figure 3.

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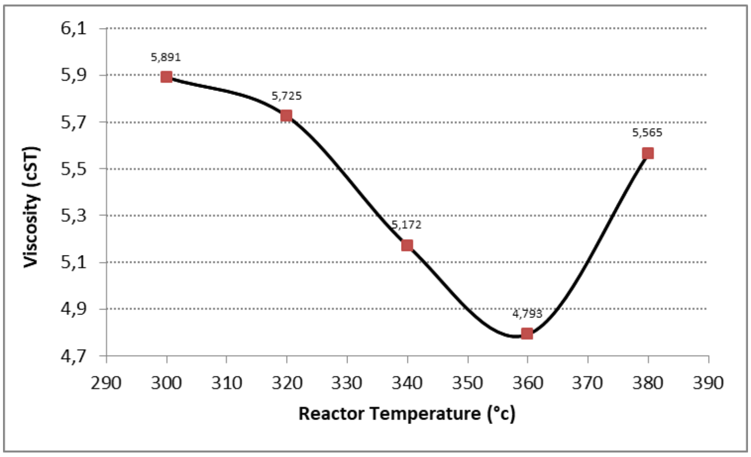

Figure 3. Effect of Reactor Temperature on Pyrolysis Oil Viscosity

The viscosity of pyrolysis oil at various reactor temperatures is shown in Figure 3. The viscosity value decreased from 5.891 cSt at 300 °C to 4.793 cSt at 360 °C, then increased to 5.565 cSt at 380 °C. The decrease in viscosity indicates that increasing the reactor temperature accelerates the thermal cracking process so that the polymer chains decompose into hydrocarbon compounds with lower molecular mass. Lighter hydrocarbon fractions have smaller intermolecular forces, so the oil flows more easily, and the viscosity value becomes lower [15]. In addition, more effective heat transfer at higher temperatures increases the distribution of energy throughout the material, so the pyrolysis process takes place more evenly [17]. This finding is supported by [8], which states that temperature is one of the main operating parameters that affect the distribution of pyrolysis products. [16] also explained that temperature changes affect the distribution of hydrocarbons produced by pyrolysis, thus changing the physical characteristics of the oil, including viscosity.

However, at a temperature of 380 °C, viscosity increased again. This condition indicates that the relationship between temperature and viscosity is not always linear. In this study, all tests used the same raw material composition, namely a mixture of HDPE, LDPE, PET, PP, and PS, each weighing 1 kg. Therefore, the increase in viscosity at higher temperatures is suspected to be caused by changes in the distribution of hydrocarbon fractions due to thermal degradation mechanisms and secondary reactions (secondary cracking). Furthermore, each type of plastic has different thermal degradation characteristics, resulting in different distributions of pyrolysis products at certain temperatures. These differences affect the composition of the hydrocarbon fractions formed and ultimately the viscosity of the pyrolysis oil. These results are consistent with [18], which shows that changes in process temperature cause changes in the composition of the resulting pyrolysis oil, thus altering its physical properties. Overall, the research results show that the characteristics of pyrolysis oil flow are influenced by the reactor temperature, thermal degradation mechanisms, the characteristics of each type of plastic, and the distribution of hydrocarbons formed during the pyrolysis process.

3.4 The Effect of Temperature on Calorific Value

Calorific value is an important parameter in determining the quality of pyrolysis oil as an alternative fuel because it indicates the amount of energy produced during the combustion process. Changes in reactor temperature can affect the composition of the hydrocarbons formed, thus affecting the calorific value of pyrolysis oil. The relationship between reactor temperature and the calorific value of pyrolysis oil is shown in Figure 4.

The calorific value of pyrolysis oil at various reactor temperatures is shown in Figure 4. The calorific value increased from 39.813 MJ/kg at 300°C to 40.225 MJ/kg at 320°C, then decreased to 39.909 MJ/kg at 340°C and 38.681 MJ/kg at 360°C, before increasing again to 40.405 MJ/kg at 380°C. The increase in calorific value at 320°C indicates that the thermal cracking process is more effective, resulting in hydrocarbon fractions with higher energy content [14]. This result is supported by [19], which explains that increasing temperature affects the composition of pyrolysis products from various types of plastics, thus changing the energy characteristics of the oil produced [20] also

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reported that temperature is the main factor determining the mechanism of plastic thermal degradation and the distribution of pyrolysis products.

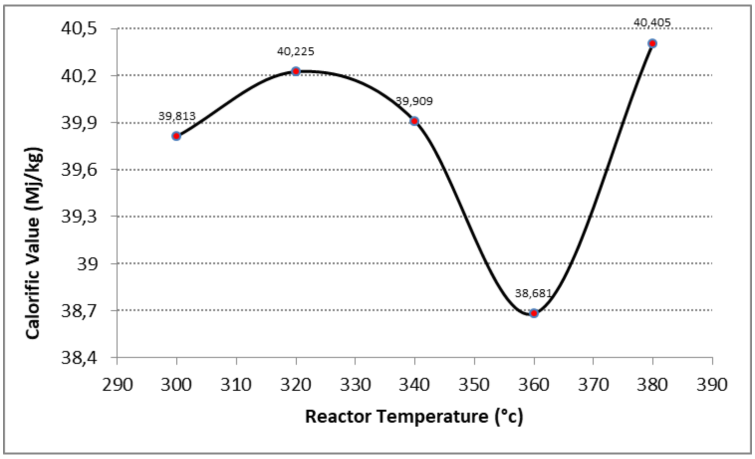

Figure 4. Effect of Reactor Temperature on Pyrolysis Oil Calorific Value

However, the decrease in calorific value at temperatures of 340 °C and 360 °C indicates that the relationship between reactor temperature and calorific value is not always linear. In this study, all tests used the same raw material composition, namely a mixture of HDPE, LDPE, PET, PP, and PS, each amounting to 1 kg. Therefore, changes in calorific value are thought to be caused by changes in the distribution of hydrocarbon fractions due to thermal degradation mechanisms and secondary reactions (secondary cracking). In addition, each type of plastic has different thermal degradation characteristics, resulting in hydrocarbon compounds with varying energy content at certain temperatures. These differences in characteristics affect the hydrocarbon composition of pyrolysis oil so that the resulting calorific value does not always increase with increasing temperature. These results are in line with [21], which states that changes in temperature affect the composition of pyrolysis products and the characteristics of the resulting oil, and [22], which shows that temperature and residence time affect the distribution of hydrocarbon fractions, thereby changing the quality of pyrolysis oil.

3.5 Comparison of Pyrolysis Oil Characteristics with Conventional Fuels

To determine the potential of pyrolysis oil as an alternative fuel, the characteristics of the pyrolysis oil obtained in this study were compared with those of conventional fuels based on the specifications of gasoline and diesel used as references. The parameters compared included density, viscosity, and calorific value, as presented in Table 4.

Table 4. Comparison of Pyrolysis Oil Characteristics with Conventional Fuel Specifications

Parameter	Pyrolysis Oil	Gasoline	Diesel Fuel	Reference
Density (kg/m^3)	745.18–785.15	715 – 770	815 – 860	ASTM D4052 [23], Pertamina Fuel Specifications [24]
Viscosity (cSt)	4.793–5.891	0.4 – 0.8	2.0 – 5.0	ASTM D445 [25], Speight (2014) [26]
Calorific Value (MJ/kg)	38.681–40.405	46 – 47	42 – 45	ASTM D240 [27], Heywood (2018) [28]

Based on Table 4, the density of the pyrolysis oil obtained ranged from 745.18 to 785.15 kg/m³. Most test results, particularly at temperatures of 340 °C, 360 °C, and 380 °C, were within or close to the density range of gasoline, while still lower than the density of diesel fuel. This indicates that the resulting pyrolysis oil has characteristics closer to gasoline based on density parameters. Meanwhile, the viscosity of the pyrolysis oil ranged from 4.793 to 5.891 cSt, thus remaining within

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the viscosity range of diesel fuel. This viscosity value indicates that the pyrolysis oil has flow characteristics within the viscosity range of diesel fuel, although higher than the viscosity of gasoline.

The calorific value of the pyrolysis oil ranged from 38.681 to 40.405 MJ/kg, which is still lower than the calorific value of gasoline and diesel fuel. However, increasing the reactor temperature tends to increase the calorific value of pyrolysis oil, with the highest value of 40.405 MJ/kg obtained at a temperature of 380 °C. At this temperature, the density of pyrolysis oil remains within the characteristic range of gasoline and its viscosity remains within the characteristic range of diesel. Therefore, the reactor temperature of 380 °C produces the best combination of pyrolysis oil characteristics among the temperature variations studied. These results indicate that pyrolysis oil from mixed plastic waste has the potential to be developed as an alternative fuel after undergoing further processing or purification.

4. Conclusion

Reactor temperature affects the characteristics of the pyrolysis oil produced, including operating time, density, viscosity, and calorific value. Increasing the reactor temperature accelerates the pyrolysis process, as indicated by the reduction in operating time from 70 minutes at 300 °C to 50 minutes at 380 °C. Among the tested conditions, a reactor temperature of 380 °C provided the best performance, producing pyrolysis oil with a density of 759.16 kg/m^3, a viscosity of 5.565 cSt, a calorific value of 40.405 MJ/kg, and the shortest operating time. The results of this study can be used as a reference for determining suitable operating conditions in the pyrolysis of mixed plastic waste to produce alternative fuels. Furthermore, these findings provide a basis for future research aimed at improving pyrolysis oil quality and supporting the development of more efficient and sustainable plastic waste management technologies.

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