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THE COMPARISON OF PROPERTIES OF PYROLYSIS OIL FROM POLYPROPELENE PLASTIC WASTE AT LOW HEATING RATE WITH INDONESIAN DIESEL OIL

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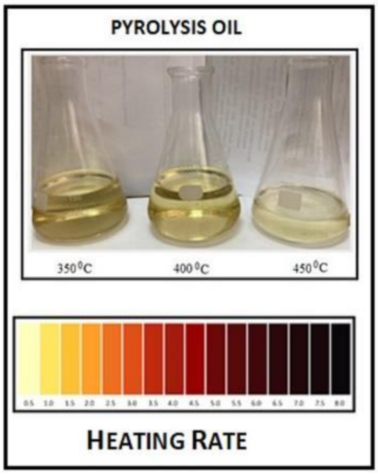
Graphical abstract



Abstract

Polypropylene plastic waste is naturally not easily degraded, causing a negative impact on the environment. The pirolisis method is one method that can overcome this problem, besides that there is added value in the form of oil from pirolisis. The current research aims to see the characteristics of oil from pirolisis of polypropylene plastic waste at low heating rates, namely at pirolisis temperatures of 350 0C, 400 0C and 450 0C. The characteristics tested are density by ASTM D-1298 method, kinematic viscosity by ASTM D-445 method, Flash point by ASTM D-93 method, Calorific value by ASTM D-240 method, Cetane number by ASTM D-613 method and color by ASTM D-1500 method. The characteristics of oil from pirolisis of Polypropylene plastic waste are then compared with the quality standards of diesel fuel based on Decree of the Director General of Oil and Gas No. 146.K/10/DJM/2020. The results showed that the characteristics of oil from pirolisis of polypropylene plastic waste were close to the quality standards of diesel fuel 48 with density in the range of 0.805-0.882, kinematic viscosity in the range of 2.05-2.28 Cts, 05-0.882, flash point in the range of 46.5 - 51.05 0C, calorific value in the range of 11480-12380 kcal/kg, Cetane number in the range of 44.8-47.05 and color of oil in scale No. 0.5.

Keywords: Polypropylen, Density, Kinematic Viscosity, Flash Point, Calorific Value,Cetane Number

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1. Introduction

Plastic is a polymer that is a derivative product of petroleum that has lightweight properties, is highly resistant to corrosion, is malleable so that it can be moulded into any shape, with appropriate additives, it is possible to vary its opacity, thickness, elasticity, and thermal properties. Therefore, plastics are widely used by humans for both household and industrial appliances (alhazmi et al., 2021).

The increase in plastic use to nearly 300 million tonnes is of course also followed by an increase in the amount of plastic waste which has a negative impact on the environment because in nature plastic is very difficult to decompose. So far, plastic waste has been handled with open dumping landfill and recycling systems. The recycling method is an effective method in overcoming the problem of plastic waste because in addition to reducing the negative impact of plastic waste on the environment, it also has economic benefits (Jha et al., 2021). Pyrolysis is a method of decomposing polymers into monomers by heating at temperatures between 350 ^{0}C and 900 ^{0}C in an oxygen-poor environment (Panda et al., 2010; Aswan et al., 2019) with the resulting solid residue, oil, combustible gas and impurities (Lewandowski et al., 2019).

There are several differences in the pyrolysis process, namely conventional pyrolysis (slow pyrolysis) takes place at temperatures of 550-900 ^{0}K with products in the form of solids, liquids, and gases (Harussani et al., 2020). For fast pyrolysis, it is associated with tar, at low temperatures (850-1250 ^{0}K) and/or gas at high temperatures (1050-1300 ^{0}K). Currently, the preferred technology is fast or flash pyrolysis at high temperatures with very short residence times. Fast pyrolysis (more precisely defined as thermolysis) is a process in which materials, such: as biomass or plastics are heated rapidly to high temperatures in the absence of oxygen (Siddiqui et al., 2009).

Fundamentally, there are various types of plastics depending on their chemical composition, including Polyethylene terephthalate (PET), High-density polyethylene (HDPE), Polyvinyl chloride (PVC), Low-density polyethylene (LDPE), Polypropylene (PP), Polystyrene (PS) and several other types whose percentage of use is very small. All types of plastic can be converted into oil except PVC which is not recommended for pyrolysis because it contains chlorine so that in the pyrolysis process it will release HCl and chlorine compounds which are corrosive and damaging to the environment (Sharuddin et al., 2016).

The chemical composition of plastics affects the working temperature of pyrolysis where for PET at 500 ^{0}C (Cepeliogullar et al., 2013), HDPE at 300-550 ^{0}C (Ahmad et al., 2015) where the pyrolysis reactor used is different for temperatures higher than 550 ^{0}C the pyrolysis results are dominated by the gas fraction (Mastral et al., 2002). For polypropylene plastic, the working temperature based on thermogravimetric starts to decompose at a temperature of 245 ^{0}C to 450 ^{0}C (Nisar et al., 2018).

The product of the plastic pyrolysis process is oil which has the characteristics of conventional fuels such as kerosene, petrol and diesel (Syamsiro, 2015) depending on the pyrolysed plastic raw material. Dewi (2017) stated that the oil from pyrolysis products of polystyrene plastic waste at heating temperature variations of 400 ^{0}C, 450 ^{0}C and 500 ^{0}C characteristics resembles gasoline while according to Liestiono et al. (2017) pyrolysis oil from LDPE plastic waste with heating rates of 2, 4, and 6 ^{0}C/minute characteristics resembles kerosene.

Therefore, researchers are interested in examining how the characteristics of pyrolysis oil with polypropylene plastic waste raw materials with low heating rates.

2. Material and Method

2.1. Material

This research was conducted on a fix bed type reactor with the dimensions of the reactor, plastic waste tube and annular fins can be seen in table 1, while the testing scheme of tools and instruments can be seen in figure 1.

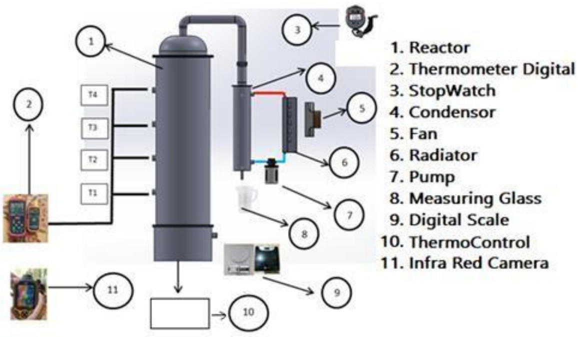

Figure 1: Research Scheme

The heater uses an LPG gas burner with a furnace diameter of 20 cm. Digital scales are used to measure the mass of plastic or residue mass with a maximum load of 10 kg and accuracy of 1 g. The heating rate is controlled using proportional integral derivative (PID) autonics type control. While the condenser with cooling coil type with radiator cooling with fan. A stopwatch is used as a timer with a precision of 1/100 second.

Table 1: Reactor and *annular fins s*pesifications

Spesification	Reactor	Plastic processing tube	Annular fins tube
High	1000 mm	1000 mm	1000 mm
Diameter of tube	320 mm	100 mm	25,4 mm
Diameter of annular fins			60 mm
Pitch			40 mm
Number of annular fins tube			6
Number of annular fins			24

2.2 Method

Polypropylene plastic waste was first cleaned and then dried in the sun, then chopped with a size of 2 x 2 cm2. Then put into a plastic waste tube with a weight of 1200 grams occupying up to a height of 90 cm from the bottom of the plastic waste tube. The reactor was heated to the planned pyrolysis temperatures of 350, 400 and 450 0C with a retention time of 200 minutes which is equivalent to heating rates of 2.24 0C/min, 2.37 0C/min and 2.430C/min. The pyrolysis vapour is cooled with a cooling coil type condenser, where the water that has been used to condense the vapour into pyrolytic oil is cooled in the radiator fan. The product in the form of oil is collected in a container which is then tested in the fuel test laboratory of the Industrial Research and Consultation Center with the characteristics tested are density by ASTM D-1298 method, viscosity by ASTM D-445 method, calorific value by ASTM D-240 method, Flash point by ASTM D-93 method, Cetane number by ASTM D-613 method and colour by ASTM D1500 method.

3. Result and Discussion

The accumulated pyrolysis oil test results are presented in Table 2 with diesel 48 (subsidised diesel) as a comparison. Pyrolysis oil from PP plastic material has a character that is close to diesel 48 from the five important parameters of diesel 48 as a fuel, namely, density, viscosity, calorific value, flash point and cetane number.

Table 2 oil test results

No	Properties	Variation of Pyrolysis Temperature			SK Dirjen Migas No. 146.K/10/DJM/2020
		350°C	400°C	450°C	Diesel 48
1	Densitas (kg/l) @ 15°C	0,805	0,813	0,882	0,815-0,87
2	Kinematic viscosity (Cst) @ 40°C	2,05	2,16	2,28	2-5
3	Flash Point (°C)	46,5	48,1	51,05	52
4	Calorific value (kkal/kg)	12380,5	12050,3	11480,6	-
5	Cetane Number	44,8	46,85	47,05	45-48
6	Colour	0,5	0,5	0,5	Maks No.3

Density

Density is an indication of the amount of substance contained in a unit volume, where density has a direct effect on engine performance characteristics. Engine performance characteristics such as cetane number and heating value are related to density (Tat et al., 2000). In addition, density also affects injector efficiency because as density increases, atomisation of the injected fuel becomes poorer (Ryan et al., 1984). On the other hand, diesel fuel injection systems measure fuel by volume. So, changes in fuel density will affect the engine output power due to the different mass of injected fuel (Bahadur et al., 1995; Demirbas et al., 2007). The results showed that pyrolysis temperature had an effect on oil density, where the increase in pyrolysis temperature increased the oil density, the same thing was also obtained by other researchers (Yan et al., 2015; Muhammad et al., 2015; Khan et al., 2016) in their research. This is related to the increase in pyrolysis temperature, the content of long hydrocarbon chain compounds in pyrolysis oil increases so that the force between hydrocarbon compound molecules also increases, causing the distance between molecules to get smaller, which in turn causes the density of the oil to increase (Sofana et al., 2022). Similarly, research conducted by Miandad et al. (2017) showed that the results of GC-MS conducted on polypropylene plastic pyrolysis oil contained various types of hydrocarbon fractions including alpha-methylstyrene, benzene, xylene, methylnaphthalene, phenanthrene, ethylbenzene, propylbenzene, naphthalene, biphenyl, 2-

phenylnapthalene. The test results show that the density of pyrolysis oil is close to the density of diesel 48 (see table 2) which has a range of 0.815-0.87.

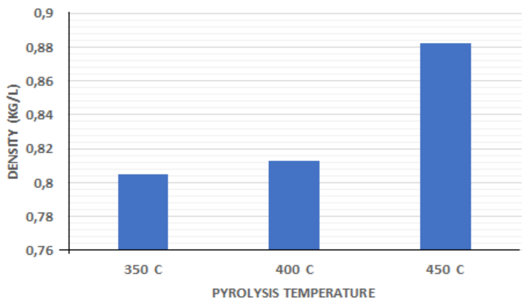

Figure 2: Effect of pyrolysis temperature on the density of polypropylene pyrolysis oil

Kinematic viscosity

Viscosity is a number that expresses the ability of a liquid fuel to flow. Viscosity plays an important role as a basic parameter of whether the fuel oil is easy to flow, pump, and ignite (Tate et al., 2016). Low viscosity causes leaks in the fuel system while too high viscosity causes poor atomisation of the fuel leading to incomplete combustion resulting in deposits in the combustion chamber, increased energy requirements to pump the fuel and impacts on the pump and injector combustion (Kinast, 2003). The test results are presented in Figure 3.

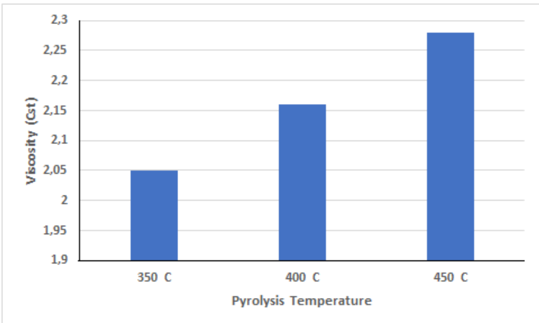

Figure 3: Effect of pyrolysis temperature on the viscosity of polypropylene pyrolysis oil

The viscosity of pyrolysis oil increases with increasing pyrolysis temperature, this is because viscosity is influenced by oil density, the higher the density of oil, the viscosity also increases. The viscosity value obtained from the research is the same as the viscosity value obtained by Singh et al. (2020), and when compared with the viscosity value of diesel 48, the viscosity value of the oil from pyrolysis of PP plastic waste is within the range of the viscosity value of diesel 48 (see table 2).

Flash Point

Flash point is the temperature at which the vapour above the fuel surface will burn rapidly (explode). Flash point indicates the ease with which a fuel burns. The higher the flash point, the harder the fuel is to burn and the lower the flash point, the easier the fuel is to burn. Although flash point does not affect combustion directly, it makes biodiesel safer in terms of storage, fuel handling and transport (De Caro et al., 2001).

The results showed that the flash point of the pyrolysed oil increased with increasing pyrolysis temperature, this is due to the increase in the length of the hydrocarbon chains formed with the increase in pyrolysis temperature as described in the previous explanation. The flash point value obtained from the study is close to the flash point value of diesel 48 (see table 2).

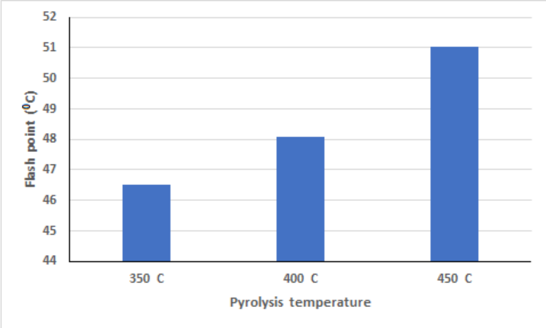

Figure 4: Effect of pyrolysis temperature on flash point of polypropylene pyrolysis oil

Calorific Value

The calorific value shows the amount of energy produced by a material per unit mass after complete combustion (Irzon, 2012). The calorific value of pyrolysis oil decreases with increasing pyrolysis temperature, this is because the calorific value is strongly influenced by the density and viscosity of the oil (Tat et al., 1999). The calorific value will decrease as the density of the oil increases, the same thing is also obtained by Elangovan et al. (2016).

The calorific value of the results of the study when compared to the calorific value of diesel 48 test results conducted by Yunianto (2021) of 11009.3 kcal/kg, it is suspected that the hydrocarbon chain produced by pyrolysis oil is higher than that of diesel 48.

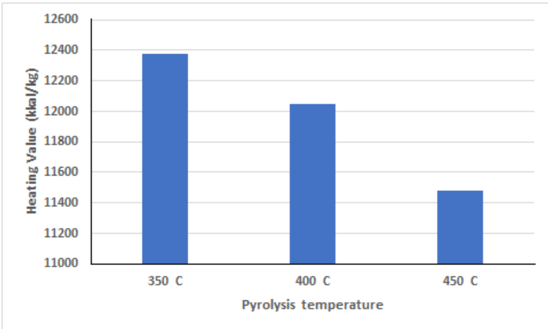

Figure 5: Effect of pyrolysis temperature on the Calorific Value of polypropylene pyrolysis oil

Cetane number

Cetane number is a relative measure of the time delay between the injection of fuel into the combustion chamber and the start of combustion. Fuels for compression ignition engines must be able to ignite automatically. If ignition does not occur immediately when fuel is injected into the cylinder, then fuel and air accumulate to such an extent that when ignition occurs, the rate of combustion is too fast. Rapid combustion results in a high rate of pressure rise which can result in engine knock that decreases efficiency and can damage the engine. Thus, the ability to assess the ignition quality of fuel compression ignition is important because without adequate fuel ignition quality (sufficiently high cetane number), the engine will be difficult to start and perform poorly (Murphy et al., 2004).

From the results of laboratory tests conducted, it shows that with the increase in pyrolysis temperature, the cetane number also increases, this is because the density of pyrolysis oil also increases as also obtained by Sivaramakrishnan et al. (2012). The cetene number of pyrolysis oil is within the range of cetane number of diesel oil 48 (see table 2).

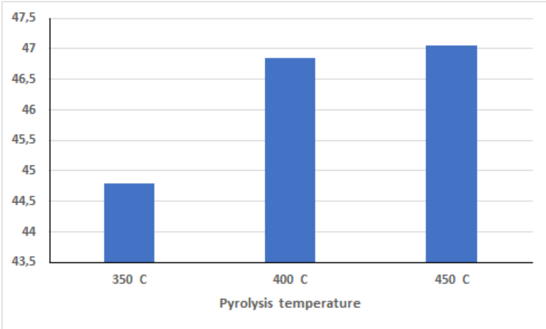

Figure 6: Effect of pyrolysis temperature on cetane number of polypropylene pyrolysis oil

Colour

Colour testing using ASTM D1500 with a scale image as below

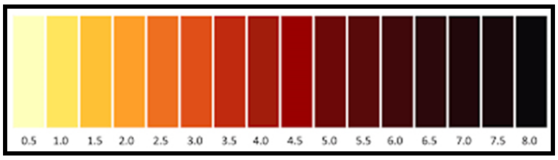

Figure 7: Colour scale ASTM D1500

The test results of the pyrolysis oil show that the colour of the pyrolysis oil is light brown with its density decreasing as the pyrolysis temperature increases, see Figure 8 with a colour scale of No.0.5. It is suspected that the colour formation of the oil is related to the composition of the pyrolysis oil. When compared with the quality standard of diesel oil 48 whose maximum colour scale is No.3, the colour of pyrolysis oil when compared with the colour scale falls within the quality standard (see table 2).

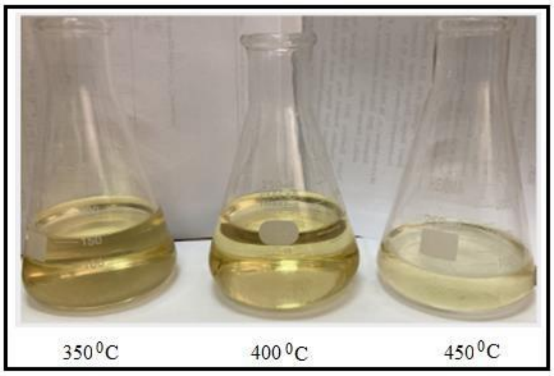

Figure 8: Effect of pyrolysis temperature on the colour of polypropylene pyrolysis oil

4. Conclusion

From the presentation of the results and discussion, it can be concluded that the characteristics of pyrolysis oil from polypropylene plastic waste at low heating rates have similar characteristics to diesel fuel 48 based on the quality standards of SK Dirjen No. 146.K/10/DJM/2020.

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