Improving Quality of Used Lubricant Oil as an Alternative Fuel Through the Pyrolysis Process

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Abstract. Handling the problem caused by hazardous waste and toxic (B3 waste) including used lubricating oil (ULO) of vehicles is very important because it hurts the environment and living things. In addition, exploration of energy sources continues to be carried out due to a decrease in the main energy source causing the energy crisis issue to get scarier. ULO is one of the energy sources that can be used as an alternative fuel through pyrolysis. This study aims to examine the pyrolysis process of ULO by controlling its temperature and heating rate to produce distillate gasoline-like fuel (GLF) and diesel-like fuel (DLF). The research method is a laboratory test where a certain amount of ULO is put into the pyrolysis reactor and then heated at a controlled temperature. Due to the influence of heat, ULO decomposes on several types of liquids named waste oil pyrolysis fuel (WOPF) similar to conventional fuels which can be identified by the color of the resulting liquid.

Keywords: Used lubricant oil, Pyrolysis

1 Introduction

Lubricating oil serves to protect engine components, both motor vehicle engines and industrial engines from wear and tear in addition to controlling the temperature in the combustion chamber [1]. Currently, lubricating oil is generally made from petroleum extraction which is added with additives to obtain lubricating oil characters according to standards. Used oil or called used lubricant oil (ULO) [2], or also called waste lubricant oil (WLO) [3] is waste from lubricating oil after use. Usually, this waste is considered worthless and is allowed to accumulate before being disposed of carelessly. This oil has a fairly long carbon chain between fractional derivatives of petroleum distillation. The number of carbon atoms is 12 (C_{12}) to 20 (C_{20}) in one molecule. This used oil can boil at temperatures above 300 ^{o}C.

Used oil generally contains harmful substances and metal particles [4]. If disposed of carelessly, the consequences caused are environmental pollution that is very dangerous and

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poses a threat to human life and other living things [5]. **Figure 1** shows a situation where beach water is polluted by waste oil that is disposed of carelessly.

Fig. 1. Public locations polluted with waste oil

Awareness of this threat has increased efforts to treat waste oil. Almost 20 years ago the handling of used oil by recycling was done to restore the quality of used oil so that it can be used again [6]. Burning directly for destruction is also the easiest solution, but the resulting air pollution will be a threat if the combustion process is not done properly [7]. However, burning used oil by mixing it with other fuel waste such as fuel oil can improve combustion performance [8]. Instead of having to burn directly, the pyrolysis process may be carried out as part of the waste oil recycling process.

A study 23 years ago studied the kinetics of changing used oil to pyrolysis oil experimentally and analyzed it through mathematical models. The results reported that the pyrolysis process in used oil provides a new paradigm for processing waste oil to be more useful [9]. The latest article in his review mentioned that used oil pyrolysis oil has very potential to be used as motor vehicle fuel by first upgrading or by mixing it with the main fuel [10].
Pyrolysis of used oil depends on important parameters such as temperature, operational pressure, and the catalyst used. Depending on the desired product, the pyrolysis process temperature becomes a key parameter. Demirbas et al., 2008 suggested that pyrolysis temperatures between 200 ^{o}C to 350 ^{o}C can produce gasoline equivalent oil [11]. However, when the temperature is raised to 600 ^{o}C, the resulting product is pyrolysis oil equivalent to diesel fuel [12]. High temperatures also increase the amount of product produced. As many as 65% pyrolysis oil products can be obtained at a temperature of 575 ^{o}C [13]. There are also findings of researchers who show that the influence of catalysts is not too significant in the production of pyrolysis oil [14]. Producing alternative fuels from used oil, in general, faces constraints on the energy needed. The higher the temperature needed, the greater the energy needed. The pyrolysis process of used oil at moderate temperatures is still rarely publicized and is still dominated by high temperatures.

This study focuses on the pyrolysis process at moderate temperature to increase the added value of ULO in gasoline and diesel-like fuel. This fuel can be used as an alternative fuel for

internal combustion engines or boiler fuel in industry. However, how ULO is processed to produce oil with levels equivalent to gasoline and diesel oil is an important question that must be answered through ways and processes that can be done.

2. Methodology

To answer the questions in this study experimental research methods. A total of a liter of used oil is fed into the pyrolizer. Slowly the reactor is heated using LPG fuel and the temperature is monitored using a thermometer. The test was carried out in the temperature range of 300-500 ^{o}C with a heating rate of 10-40 ^{o}C/min. After the target temperature is reached, heating continues for 10 minutes at that temperature. During heating, the pyrolysis steam flows into the condenser for the cooling process so that the pyrolysis steam turns into a liquid. The liquid is accommodated in the distillate tank every 5 minutes by opening the tap of the oil product. To get a quality product, the pyrolysis target temperature is changed to get a good product. Visually, a good pyrolysis product can be known from the color of the condensate produced.

2.1 Materials

In this study, the material used is used lubricating oil. This used oil was taken from a motorcycle repair shop close to the research site. There is no special treatment of used oil, only ordinary filtration is carried out to clean it from coarse material or other impurities. **Figure 2** shows the appearance of used oil received from a motorcycle repair shop.

Fig. 2. The appearance of used oil

2.2 Experiment diagram flow

Figure 3 is a diagram of the arrangement of equipment needed to conduct an experimental study of the distillation of used oil as an alternative fuel. The equipment used is very simple; a distillation tube, condenser, and collector tank.

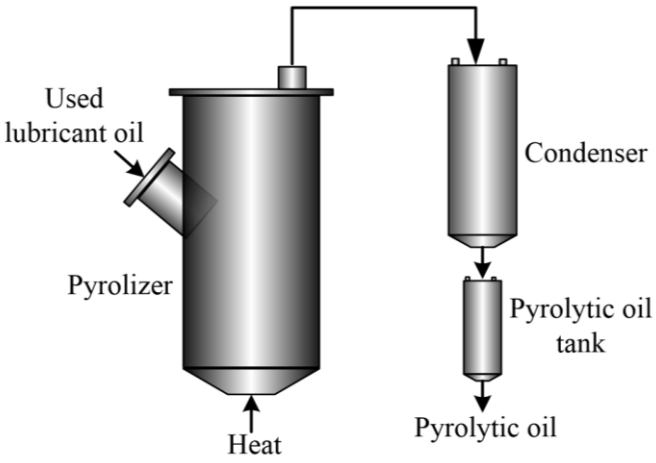

Fig. 3. Arrangement of research equipment

3. Result and Discussion

3.1 Temperature profile during the process

Figure 4 shows the temperature profile used during the test. The temperature range used is from 300 ^{o}C to 500 ^{o}C with a maintained temperature increase of 10 ^{o}C/min.

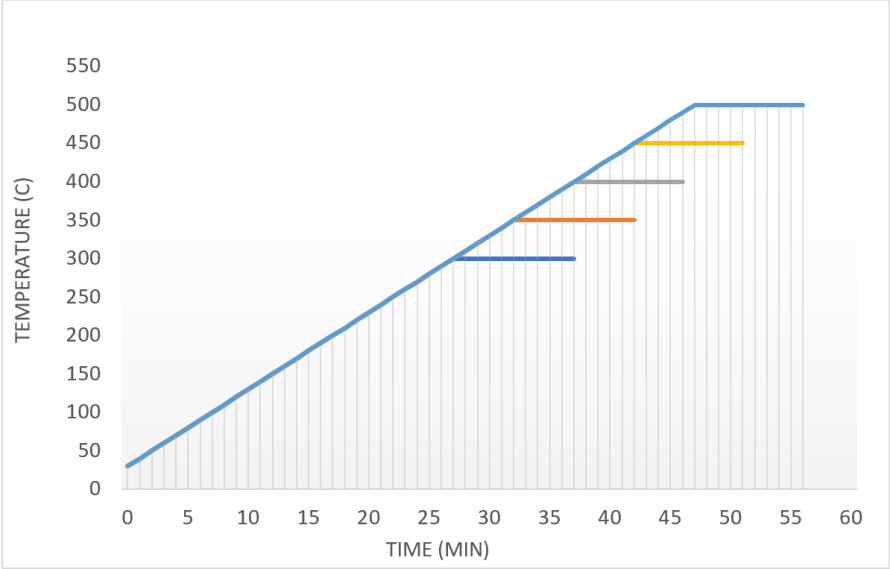

Fig. 4. Temperature profile during the pyrolysis process at a heating rate of 10 ^{o}C/min with different temperature targets

3.2 Pyrolytic product visualization

The results of the visual observation of ULO pyrolysis results can be seen through the resulting product visualization images as shown in **Figure 5**. Gasoline-like pyrolytic oil has a light color, while diesel-like pyrolytic oil has a slightly lighter color compared to the original dirty oil.

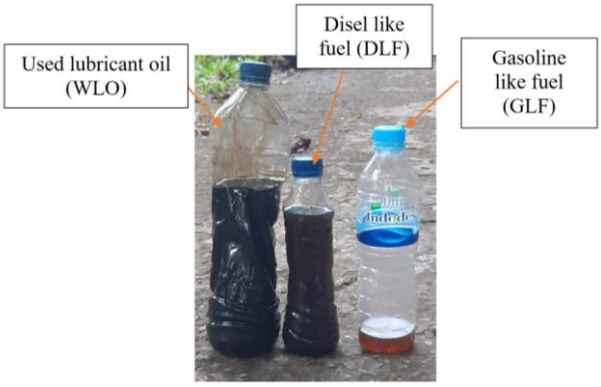

Fig. 5. The appearance of pyrolysis oil on heating 30 ^{o}C/min with a target temperature of about 450 ^{o}C/min

3.3 The influence of temperature on pyrolysis product

The temperature of the pyrolysis process affects the yield and quality of the pyrolitic produced. In general, the higher the pyrolysis temperature, it pyrolysis of organic materials or inorganic materials such as plastics, the more liquid is produced [15]. However, the optimal temperature limit for pyrolysis of spent lubricating oil ranges from 300°C to 500°C, depending on the type of lubricating oil and pyrolysis conditions [10]. If the pyrolysis temperature is too low, then the quantity of liquid produced will be little or even nothing. This is because the pyrolysis process requires enough temperature to trigger a chemical reaction that converts the raw materials into pyrolysis products. Meanwhile, if the pyrolysis temperature is too high, the liquid produced can be reduced because the temperature is too high can trigger further reactions that can break the carbon chains to be even shorter and result in the formation of gases that cannot be condensed. Therefore, pyrolysis temperature regulation should be done carefully and meticulously to obtain the optimal and high-quality liquid quantity.

From this study, it was obtained that the optimum temperature limit for the waste oil pyrolysis process is varied as shown in **Figure 6** to **Figure 8**. This is due to several factors, such as the type of used oil, the equipment available, and the parameters to be obtained. In general, the optimum temperature for used oil distillation in this study was between 350°C to 450°C. The results of this study are in line with the results of research conducted by Bhaskar et al. (2004) [6]. In this temperature range, most of the components in used oil can be well separated. However, the optimum temperature may vary depending on the type of used oil. For example, for used oil that contains a lot of impurities or water, a higher distillation temperature may be required. In addition, keep in mind that too high temperatures can cause oil degradation and produce compounds harmful to the environment and human health. Therefore, the regulation

of the distillation temperature must be done carefully, and pay attention to other factors such as distillation time and proper use of equipment.

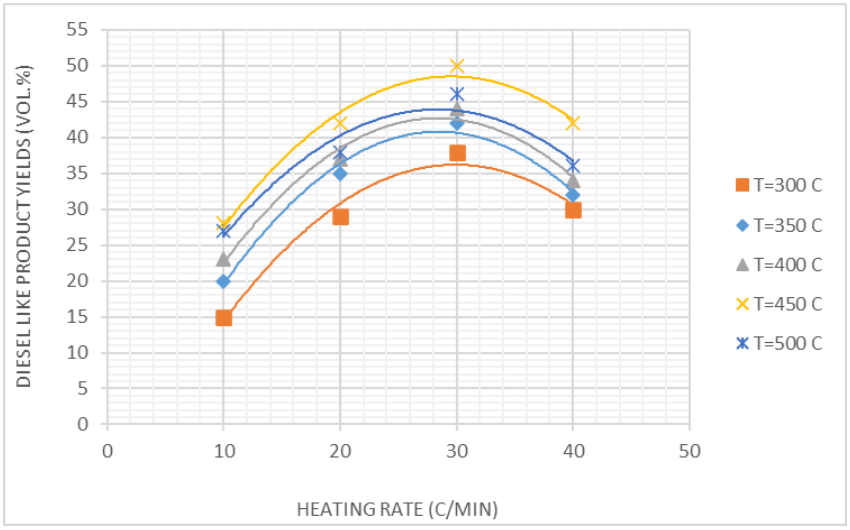

Fig. 6. The effect of temperature on diesel-like fuel product

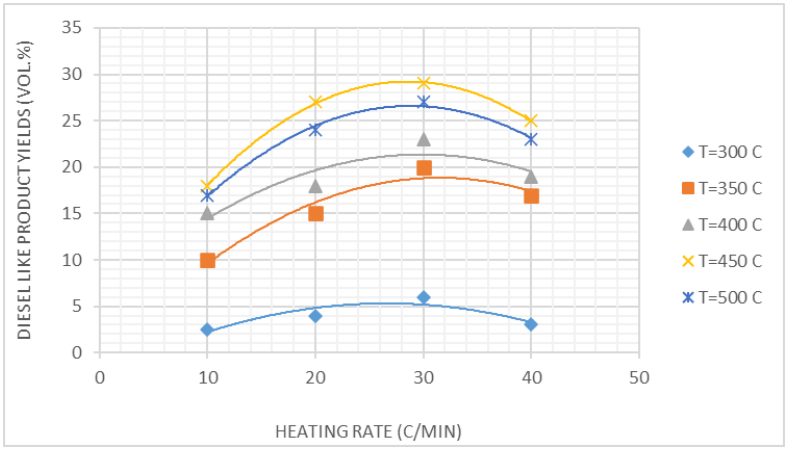

Fig. 7. The effect of temperature on gasoline-like fuel products

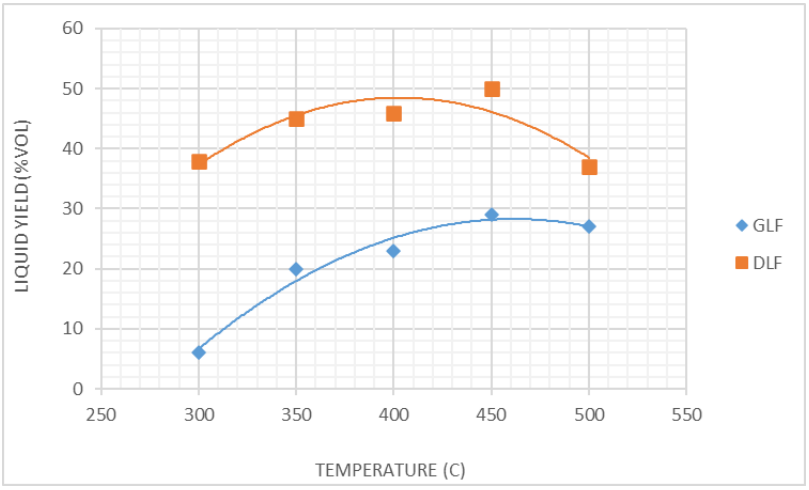

Fig. 8. The effect of temperature on oil products at a heating rate of 30 ^{o}C/min

The results showed that the used oil pyrolysis process can produce light hydrocarbon molecules to restore the quality of used oil so that it can be reused as a basic material for lubricating oil or fuels such as diesel-like fuel [12], [16], [17], petroleum, or gasoline-like fuel [11], [18].

4. Conclusion and Recommendation

Research on used oil with the intention of improving quality through pyrolysis has been carried out. In this study, temperature and heating rate are important factors in setting parameters to obtain optimal and high-quality distillation results. The optimum temperature limit for pyrolysis of used oil as an alternative fuel is between 300°C to 500°C, although it may vary depending on the type of scrap oil used and the equipment available. Too high temperatures can lead to oil degradation and produce compounds harmful to the environment and human health. This study shows that pyrolysis can improve the quality of spent oil as an alternative fuel, but the regulation of distillation parameters must be done carefully and systematically to obtain optimal results and be safe for the environment and human health. Distillation can also be a promising alternative to reduce the use of fossil fuels and reduce the environmental impact generated by waste oil

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