Characterization of used oil distillate at various distillation temperatures as diesel fuel

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Abstract. Used oil is a hazardous and toxic waste. When this waste is disposed off into the environment, it harms the environmental. The conversion of used oil to diesel fuel candidates has been studied utilizing a simple distillation method. The distillation is carried out on used oil with a zeolite catalyst placed on a distillation tower. Distillation temperature variations of 360 °C, 380 °C, 400 °C are applied to used oil to produce fuel distillates. Tests were carried out on distillates in flashpoints using ASTM D93, Kinematic Viscosity using ASTM D445 and Cetane Index using ASTM D4737. The results of the calculated cetane index test showed the respective values of 48.44, 48.46 and 48.84. The viscosity at 40°C (mm²/sec) resulted in 1.57, 1.64, and 2.00. While the flashpoint value shows the number 27°C, the temperature variation does not affect the flashpoint value. The results of this test, when compared with Dirjen Migas Specification, the flashpoint value has not been fulfilled although with the addition of NaOH. A distillation temperature of 400°C only fulfils the minimum kinetic viscosity. In contrast, the Calculated cetane index has been fulfilled, with the largest value generated at a distillation temperature of 400°C.

Keywords: used oil, distillation, zeolite.

1. Introduction
Oil in general consists of 90% base oil and 10% additives. The Directorate General of Chemical, Pharmaceutical and Textile Industries of Indonesia (in Indonesian: Dirjen Migas) reports that oil production in one year reaches 908.36 million litres [1]. The increase in production volume will be directly proportional to the rise in the number of vehicles. Meanwhile, the ability of lubricant protection against friction between engine components will decrease with time of use. After the viscosity value has reduced to the minimum limit, it is classified as waste [2].

Used oil waste contains more unwanted pollutants such as polyaromatic hydrocarbon, heavy metals (copper, lead, iron, etc.) and sulfur [3]. Oil waste is categorized as hazardous and toxic waste (B3), negatively impacting environmental pollution. One litre of waste oil dumped into the environment will render 800,000 litres of water unusable and 5,000,000 tons of unfit water [4]. So, recycling is a solution to reduce the negative impact on the environment. The calorific value in used oil is high enough to have the potential as a fuel, but the impurity content is relatively high [2]. Therefore one of the recycling methods that can be applied to used oil is the pyrolysis technique.

Thermo-chemical methods for obtaining valuable products such as diesel fuels from waste oils [4–6] are known as pyrolysis. Tripathi et al.(2015) investigated pyrolysis of 300-800°C waste oil, with higher saturated hydrocarbons formed at temperatures of 350-400°C [7]. The addition of additives to used oil before pyrolysis has been carried out, including adding of H2SO4, NaOH [8], Na2CO3, CaO, and zeolite [4]. Askadiyta (2010) chose the optimal temperature to get the best quality in this study,
which was 490°C with zeolite and NaOH catalysts to distillate as much as 97.03% of used oil, Calculated Cetane Index 53.7, Kinematic Viscosity 5.807 mm²/s, and Flash Point 15.5 °C.

This paper will describe simple steps that can reduce the distillation temperature below 400°C, the cetane index value, and the kinetic viscosity that meet the Dirjen Migas Standard.

2. Material and Method
The materials used in this research were used car engine oil, zeolite and distillator. Used oil was filtered with a 200 mesh filter to ensure that no impurities are mixed in the used oil. It is known that used oil is highly viscous and contains plenty of sulfur, carbon soot, tiny metal particles and some gum-like materials. The oil that passes through the filter was heated at 110 °C to remove water in the used oil. Then the oil was ready to be put into the reactor tube. Zeolite catalyst functions as a filter and speeds up the separation reaction process. As much as 200 grams of zeolite were wrapped in wire mesh to form a cylinder according to the zeolite tube's size, then placed on the catalyst tower above the reactor.

![Catalyst tower](image1)

**Figure 1.** Catalyst tower

After the catalyst has been installed and the used oil preparation has been carried out, the next step is the distillation process. The distillation process begins by entering two litres of oil into the reactor tube. The used oil stove was then turned on, turning on the thermostat and setting the temperature to be reached. The distillation temperature used is 360 °C, 380 °C, 400 °C. The distillate that comes out of the distillator at a predetermined temperature was collected with a Beaker glass.

![Distillation reactor and distillate](image2)

**Figure 2.** (a) Distillation reactor, (b) distillate condensation process

The distillate was then characterized by flashpoint, kinetic viscosity and calculated cetane index (CCI). The flashpoint was determined following the ASTM D93 method with the Pensky Martens
Pash Point Tester. Kinetic viscosity at 40°C follows ASTM D445 with HK-265 Kinetic Viscosity Apparatus. Meanwhile, the CCI was determined by the ASTM D4737-10 method.

3. Results and Discussion
The physical condition of used oil before distillation is shown in Figure 2 (a), while the distillate results are shown in Figure 2 (b). It can be seen that there is a very significant colour change. This indicates that the impurities contained in the used oil have been appropriately separated. The flash point, viscosity, and CCI of sample testing with different distillation temperature treatments are presented in Table 1.

![Figure 3](a) Used oil, (b) distillation results

| Analite                  | Method      | Destillation Temperature (°C) | Dirjen Migas Spec* |
|--------------------------|-------------|------------------------------|--------------------|
| Flash Point PPMC, oC     | ASTM D93    | 27.00 27.00 27.00 27.00      | 52 Min 45 Max      |
| Viscosity at 400°C, mm²/sec | ASTM D445   | 2.16 1.57 1.64 2.00          | 2.00 4.5           |
| Calculated cetane Index  | ASTM D4737  | 53.48 48.44 48.86 48.65      | 45                 |

*specification guidelines-Dirjen Migas No. 28.K/10/DJM.T/2016
**used oil with NaOH addition

Based on Table 1, it can be seen that the flash points owned by each distillate have not changed. Even the minimum value based on Dirjen Migas specification has not been fulfilled. This flashpoint figure is higher when compared to the Asdikarya research results [9], which only got the highest flash point value of 15.5 even though it had used a higher distillation temperature and was given a pre-threat to the used oil sample. Whereas by heating above 500°C, only 26°C of flash points are produced. Increasing the flash point value can be done by adding additives to distillates such as Na₂CO₃, zeolite or CaO [10].

Kinetic viscosity has increased with increasing distillation temperature given. Although the increase is not significant, at a temperature of 400°C, it can meet the minimum Dirjen Migas specifications. In contrast, other treatments it did not meet the Dirjen Migas specification. Meanwhile, CCI used oil distillate pyrolyzed at various temperatures in this study has met the standards set by the Dirjen Migas. The change in distillation temperature did not significantly change the CCI value. The addition of NaOH to used oil can increase the viscosity value and even increase the CCI value.

4. Conclusion
The used oil has been successfully purified by the pyrolysis method with distillation temperatures of 360, 380, and 400 C. The characterization of flash point, viscosity, and calculated cetane index shows that without the addition of NaOH at the pre-treatment stage, the increase in viscosity and CCI values
were not significant. The addition of NaOH was able to increase CCI and viscosity, but did not change the flash point value.

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