Oil fuel production through pyrolysis of reject plastic from paper industry using coal fly ash as catalyst

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Abstract. This study aims to obtain the best operating conditions including pyrolysis time and amount of catalyst in oil fuel production from reject plastic as raw material with coal fly ash as catalyst based on its yield and characteristics. Both reject plastic and coal fly ash are waste originating from a paper industry in Medan. This research was carried out in three steps: preparation of reject plastic and coal fly ash, oil fuel production and characterization (composition of coal fly ash and density, viscosity and heating value of oil fuel). The main components in the coal fly ash are SiO₂, C and Al₂O₃ that are 30.36%, 27.11% and 24.04% respectively. The yields of oil fuel are in the range of 14.18% - 26.58%. From 12 samples, 10 samples meet the standard density whereas 8 samples meet the standard viscosity for diesel fuel based on ASTM D-975. The best operating condition is achieved when using 15% catalyst with 2 h pyrolysis time that produce oil fuel with the highest heating value.

1. Introduction

Plastic is one of the world’s greatest industrial innovations, but the sheer scale of their production and poor disposal practices are resulting in growing adverse effects on human health and the environment. Global plastics production rose from 2 Mt to 380 Mt for this 50 year. Future plastics production is projected to double by 2035 and almost quadruple by 2050. Globally, it is estimated that only 9% of the 6300 Mt total of plastic waste generated was recycled [1]. Waste plastics disposal and excessive use of fossil fuels have caused environment concerns in the world. Both plastics and petroleum derived fuels are hydrocarbons that contain the elements of carbon and hydrogen. The difference between them is that plastic molecules have longer carbon chains than those in LPG, petrol and diesel fuels [2]. Therefore, an alternative way is needed to convert plastic waste into something more useful as fuel oil.

Energy has been the main vital of the economy and that within most sectors of a country. Energy demand has become a reference of country development. It has a critical impact on economic growth for many years. The more developed the country, the more energy is needed. Crude oil or petroleum is one of the most important energy resources in the world and supplied more than 40% of the total energy demand. The projection of the trend of gasoline imports will continue to increase while diesel imports will decline and will be discontinued in 2024, when B30 is pushed by the government [3].

The public's need for oil is increasing day by day, while oil and gas reserves are running low. Indonesia only has oil reserves of 3.7 billion barrels and this amount is only 0.2% of world oil reserves. Total oil production is 882 thousand barrels/day with consumption of 1.623 million barrels/day. It can be seen clearly that there is a gap between production and consumption [4]. It can be estimated that the reserves will run out in 10 years. One of the efforts to produce fuel is through the pyrolysis method by utilizing plastic waste as raw material.

In Medan, there is a company that produces recycled paper from used cardboard. From the recycling process, the company produces 16 tons of plastic waste per day which is a mixture of 98%
HDPE and 2% other types of plastic. In addition, the company also has a power plant with coal needs of 30 tons/day. This power plant produces coal fly ash of 5 tons/day [5] and would be utilized as a catalyst in converting plastic waste to fuel oil.

2. Methods

The raw materials used in this study are waste originating from plastics attached to used cardboard (called reject plastic) and coal fly ash waste generated by power plant from a paper industry in Medan. The reject plastic was cut into small pieces, while the catalyst is sieved with a 180/200 mesh sieve. The reject plastic is mixed with the catalyst and put in a pyrolysis reactor with nitrogen flow. The catalyst mass is 0%, 10%, 15% and 20% of reject plastic mass. The pyrolysis is carried out at 350 °C and maintained for 1.5, 2 and 2.5 h when the operating temperature is obtained.

The produced oil fuel is then characterized and compared to the characteristics of diesel fuel based on ASTM D-975 (Table 1). Whereas the composition of coal fly ash is analysed using EDX (Energy Dispersive X-Ray).

| Tabel 1. The characteristics of diesel fuel [6] |
|-----------------------------------------------|
| Characteristics                  | Value       |
| Heating Value (MJ/kg)              | 42.640      |
| Density @ 15 °C (g/cm³)            | 0.815 – 0.870 |
| Viscosity @ 40°C (mm²/s)           | 2 – 5       |

3. Results and Discussion

Composition of coal fly ash

The coal fly ash produced from the power plant in the paper industry mainly consists of SiO₂, C and Al₂O₃ as much 30.36%, 27.11% and 24.04% respectively. This result shows that the coal fly ash contains high amount of unburned carbon. Other oxides that contain in the coal fly ash are MgO (0.86%), SO₃ (1.16%), K₂O (0.63%), CaO (2.53%), TiO₂ (0.85%), FeO (11.09%) and CuO (1.35%).

Yield of Oil Fuel

The yield of oil fuel increases with the increasing pyrolysis time when no catalyst is added (Fig. 1). Meanwhile, the yield of oil fuel decreases with the increasing pyrolysis time at various amount of catalyst adding. The main function of the catalyst in the pyrolysis process is to break the long hydrocarbons chains into simpler compounds [7]. The obtained yields are higher as the amount of catalyst increases. This is due to more catalyst will increase the reaction rate and reduce the activation energy. The same trend is also exhibited in previous study [4].

In this study, the highest yield is obtained at the pyrolysis time of 1.5 h using 20% of coal fly ash as catalyst which is 26.58%. Meanwhile, the lowest yield of 14.18% is obtained when using 10% of coal fly ash with 2.5 h pyrolysis time.

Density of Oil Fuel

Figure 2 shows the tendency of density to fluctuate with increasing amount of catalyst and pyrolysis time. The obtained density ranged from 0.837 - 0.905 g/cm³. Based on ASTM D-975, the standard density for diesel fuel at temperatures of 15°C ranges from 0.815 to 0.879 g/cm³. According to the Decree of the Director General of Oil and Gas, the standard density for Industrial Fuel Oil (IFO) and Marine Fuel Oil (MFO) at a maximum temperature of 15°C is 0.991 g/cm³. Meantime, according to Pertamina, the standard density for premium and kerosene at a temperature of 15°C respectively ranged from 0.715 to 0.770 g/cm³ and a maximum of 0.835 g/cm³.
From the results of this study, it is found that only 2 samples that exceed the standard density for diesel fuel based on ASTM D-975, and all samples meet the standard for IFO and MFO. However, none of the samples can be categorized as premium or kerosene.

![Figure 1](image1.png)

**Figure 1.** Yield of oil fuel at different pyrolysis time and addition of coal fly ash catalyst

![Figure 2](image2.png)

**Figure 2.** Density of oil fuel at different pyrolysis time and addition of coal fly ash catalyst

**Viscosity of Oil Fuel**

In Figure 3, the viscosity values are also fluctuates with increasing amount of catalyst and pyrolysis time. The lower the viscosity value of a liquid, the more dilute it will be [8]. The obtained viscosity ranges from 1.873- 2.422 mm²/s. Based on ASTM D-975, the standard viscosity at 40 °C for diesel fuel ranges from 2-5 mm²/s.

There are 8 samples that meet the standard viscosity for diesel fuel based on ASTM D-975 whilst only 4 samples that have viscosity below the standard. All samples with pyrolysis time of 2.5 h have viscosity values in the range of that standard.
Figure 3. Viscosity of oil fuel at different pyrolysis time and addition of coal fly ash catalyst

Figure 4. Heating value of oil fuel at different pyrolysis time and addition of coal fly ash catalyst

Heating Value of Oil Fuel

Figure 4 shows the heating value of oil fuel at various amount of catalyst and pyrolysis time. The measured heating value on the bomb calorimeter is known as the High Heating Value (HHV). Based on ASTM D-975, the minimum standard heating value for diesel fuel is 42.64 MJ/kg, whereas according to the Decree of the Indonesian Director General of Oil and Gas, the standard heating value for Industrial Fuel Oil (IFO) is minimum of 41.870 MJ/kg. Based on the test results, only 1 sample that meet the standard for diesel fuel and IFO, i.e on the addition of 15% catalyst with a pyrolysis time of 2 h which is 58.08 MJ/kg.
4. Conclusion
1. Reject plastic can be converted to oil fuel through pyrolysis using coal fly ash as catalyst.
2. The yield of oil fuel from reject plastic is ranging from 14.18% to 26.58%.
3. Based on ASTM D-975 standard for diesel fuel:
   - there are 10 samples that meet the standard density which are in the range of 0.815 - 0.879 g/cm³.
   - there are 8 samples that meet the standard viscosity with values above 2.0 mm²/s.
   - there are only 1 sample that exceed the minimum heating value, i.e. 58.08 MJ/kg.
4. The best operating condition in this research is achieved with the utilization of 15% of coal fly ash as catalyst with a pyrolysis time of 2 h.

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