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Plastic Waste Conversion to Oil Through the Pyrolysis Process

Abdurrahman Adel Jalabi[1], Naira Mohamed [2], Ahmed Waleed[2], Bahaa M. Kamel[3,*], A.M. Abdulaziz[1] and Shady Ali[2]

[1] *Department of Mechanical power Engineering, faculty of Engineering, Ain Shams University, Cairo 11566, Egypt*
[2]*Department of Mechatronics Engineering, Canadian International College, 5Th Settlement, Cairo 11835, Egypt*
[3,*]*Mechanical Engineering Department, National Research Centre, 12622 Giza, Egypt*

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ABSTRACT

More than ever, the globe is currently dealing with a serious problem of plastic garbage. Only 15% of the 400 million tonnes of plastic generated annually at this time are recycled, despite the fact that global plastic production is still rising. Even though recycling rates have been rising steadily over the past 30 years, the rate of global plastic production is much higher, which means that more and more plastic is finding its way into landfills, oceans, dump sites, and finally the environment, where it causes severe environmental pollution and the extinction of some important species, all of which harms the ecosystem Better solutions for plastic waste's final disposition are required to supplement existing recycling efforts and assist us to manage the issue. A smart and profitable answer to the plastic waste problem has been discovered after examining the recycling options. Pyrolysis plastics are chemically disassembled into their constituent parts during pyrolysis. The main outputs are a crude oil-like liquid that may be burned as fuel and other feedstock that can be employed in a variety of novel chemical reactions to create a closed-loop system. The experimental results on the pyrolysis of thermoplastic polymers are discussed in this paper as was found that the physical properties of the pyrolysis oil can be similar to some used petroleum fuels like diesel, kerosene, gasoline, and other used oil. After testing the viscosity and density and flash point for two different samples with different conditions it is found that different conditions can create different results which will enable us to control the quality of the produced. The results of viscosity were found to be 1.43 and 1.51 cSt and density with results of 0.8381 and 0.8675 g/cc and the flash points were -20 and 4 °C.

1. Introduction and Literature review

1.1. Global plastic waste

Plastic has become a major global problem which overwhelming the world [1]. With the increase in population plastic production increases. As realized that plastic waste is a great problem that threats our existence. The world is trying now to reduce plastic waste and plastic production. During the study, on the huge increase of plastic waste, it was found that half of all plastic ever manufactured has been made in the last 15 years [2]. The production of plastic has reached over 400 million tons annually and it's predicted to be doubled in 2050 if there is no control on this problem [3]; [4], Every year millions of tons of plastic waste are disposed of in the ocean and millions were landfilled causing the death of millions of animals from different species [5].

About 700 different species, including endangered ones, are found to be affected by plastics waste [6]

1.2. Recycling of plastic

Plastic contains additives that give them the ability to be stronger more durable and flexible. That's why plastic can take over 400 years to be degraded. Knowing this leads to realizing the need for recycling. There are some traditional methods of recycling and reusing plastics [7]. However, this can't be used with all plastic waste conditions, and even the recycled plastics eventually become endurable and are left to burn or be landfilled. Because of all that mentioned above, therefore pyrolysis can be an excellent solution to his global problem. Simply we can say

* Bahaa M. Kamel, Mechanical Engineering Department, National Research Centre, Cairo, Egypt, +201227004606, bahaa2004eg@yahoo.com

that pyrolysis is a process of accelerating the degradation or decomposition of plastic [8], which returns it to its initial components [9].

Plastics are durable, lightweight, and inexpensive materials. They can easily be molded into multiple products which find use in many applications. Every year, more than 420 million tons of plastics are manufactured across the globe [10].

2. Materials and Experiment:

2.1. Process specifications

The used plastic for this study was plastic waste from our daily usage of plastics like bottles, plastic tanks, plastic plates, cups,… etc. it was a mixture of (HDPE, PE, PP, and PS) [11] and mixed with catalyst ZSM-5 zeolite [12]; [13]. Waste plastics were cleaned with detergent and water to remove any unwanted materials like mud and oil. cleaned waste plastics were dried and cut into small particles in the range of 0.5 to 2 inches by using shredders [14].

Figure 1 shredded plastic

2.2. Process setup

The reactor utilized in this technique to produce oil from plastic was an externally heated batch feed fixed bed pyrolysis reactor operating at a laboratory scale. The machine setup is shown in Figure 3 [15]. The temperature controller, temperature sensor, heating coil, heat insulator, water cooling tank, condenser, storage tank, valve, and gas outlet are the fundamental components of the pyrolysis chamber [16]. The stainless steel reactor's functional length and diameter are 63 cm and 20.6 cm, respectively. Nichrome wire heating coils are used to electrically heat the reactor to more than 500°C [17]. It is crucial to be aware that the stainless steel chamber's wall contained a (thermocouple) temperature sensor that was used to monitor the temperature [18].

As a result, compared to a traditional system, the temperature measurement may appear to be lower. Additionally, a nitrogen inlet was employed in the chamber to generate an inert environment and maintain a constant temperature inside the reactor chamber [19].

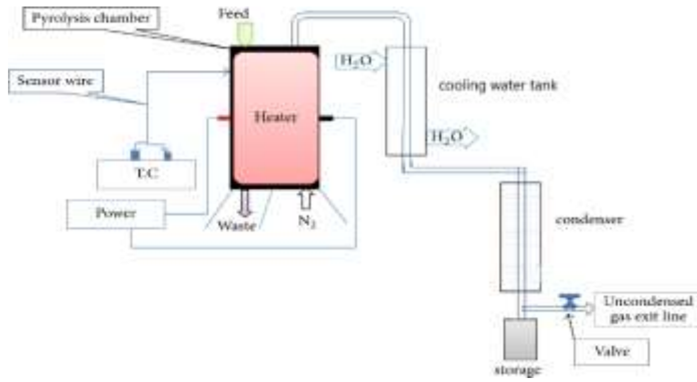

Figure 2 pyrolysis process

Figure 3 pyrolysis machine

There was no output in the low-temperature range. however, the process started to provide an output at a temperature range between 350°C and 500°C inside the reactor chamber for about 2:30 hrs. [20]; [21]. The vapor produced by pyrolysis was transferred through a pipe towards a condenser. The pipes pass through the water tank to cool the condensed bio-oil to be stored in a storage tank. The left-out gas was disposed to the atmosphere and the char residue was collected manually from the reactor after the process completion [22].

Figure 4 Waste plastic oil

3. Results and discussion:

3.1. Samples analysis

After preparing the samples it is needed to analyze them to understand and compare their physical properties with the existing used oils to know the value and the applications that can be used for this oil.

This oil is supposed to be used as a fuel or for a flammable purpose therefore, it will be analyzed with testing methods for fuel properties.

With the help of Egyptians Petroleum Research Institution and National Research Centre to analyze our samples in their laboratories.

Table 1: Testing methods for fuel properties measurement

Properties	Test methods
Density	ASTMD
Kinematic viscosity	ASTM D 445
Flash point	ASTM D 93
Pour point	ASTM D 97
Carbon residue	ASTM D 189-65

Sample1. 3:1 ratio of Plastic (1.5 Kilo) to catalyst (0.5 kilos) at 350-400 Celsius that yielde to 1.2 liters of liquid oil.

Table 2: Characteristics of waste plastic pyrolysis oil (WPPO1)

Properties	Results
Density at 15.56°C (g/cc)	0.8381
Viscosity at 40°C (c)	1.43
Flashpoint (°C)	4
Initial boiling point(°C)	84

Sample2. 10:1 ratio of Plastic (4 Kilo) to catalyst (0.4 kilos) at 400-520 Celsius that yield to 1.8 liters of liquid oil.

Table 3: Characteristics of waste plastic pyrolysis oil (WPPO2)

Properties	Results
Density at 15.56°C (g/cc)	0.8675
Viscosity at 40°C (cSt)	1.51
Flashpoint (°C)	-20
Initial boiling point(°C)	94

3.2. Effect of Distillation Temperature on Crude WPPO

The lighter and heavier hydrocarbon fractions contained in the pyrolysis oil are separated using distillation [23]; [24]. As shown in Figure 5, the percentage of distillation increased evenly as the temperature increased in WPPO1 during the distillation process, which took place between 110°C and 290°C. As indicated in Figure 6, only about 10.0% of the distilled WPPO2 was produced at a temperature of 130°C during the operation of the distillation in WPPO2. However, the percentage of WPPO2 steadily rose, from 10% at 130°C to 84.5% at 340°C [25].

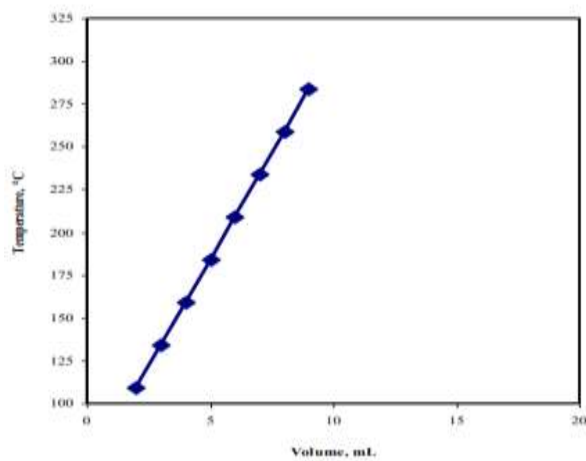

Figure 5 D86 of WPPO1

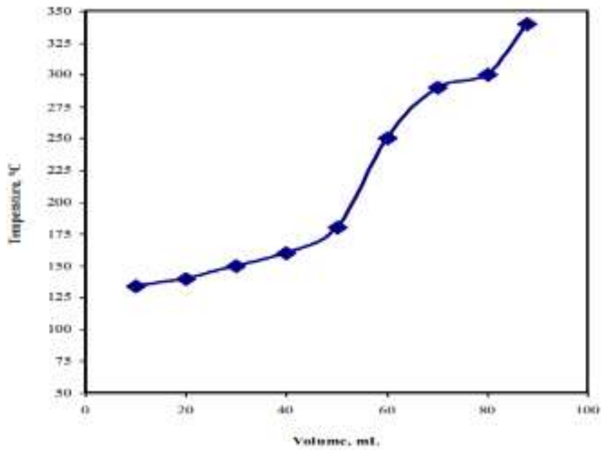

Figure 6 D86 of WPPO2

3.3. Viscosity

Different input, pyrolysis process parameters, temperature, and other factors affect viscosity. The fuel consumption, engine temperature, and engine load all increase as viscosity increases. However, extreme friction may develop if the viscosity of the oil is too excessive. At a temperature of 40°C, the viscosity is determined using the IP-50 approach. Figure 7 demonstrates that: at a pyrolysis temperature of 350–400°C, the viscosity of (WPPO1) was 1.43 cSt, which was lower than kerosene and lower than diesel [26]. While (WPPO2) had a viscosity of 1.51 cSt at a pyrolysis temperature of 400-550°C, which was comparable to kerosene and less viscous than diesel [27].

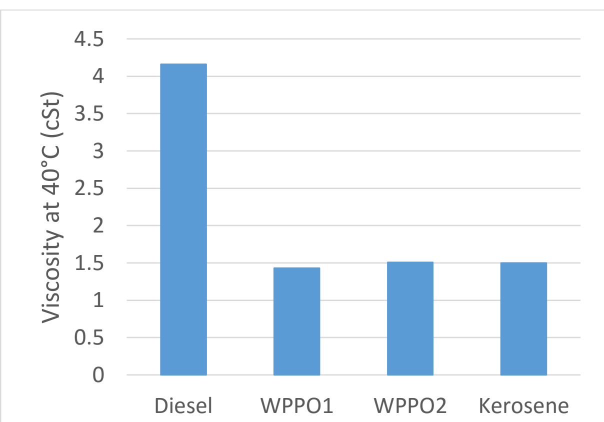

Figure 7 viscosity comparison

3.4. Density

The density of fuel oil is a crucial characteristic. Less fuel will be consumed if the fuel density is high. However, oil with a lesser density will use more fuel, potentially damaging the engine. Having said that, it is not optimal for fuel oil to have a density that is too low or too high. Figure 8 makes it obvious that WPPO1 and WPPO2 have densities of 0.8381 g/cc and 0.8675 g/cc, respectively, which are comparable to those of kerosene, diesel, and gas oil. Therefore, plastic pyrolysis process oil may be used in place of standard fuels like gas, kerosene, and diesel [28].

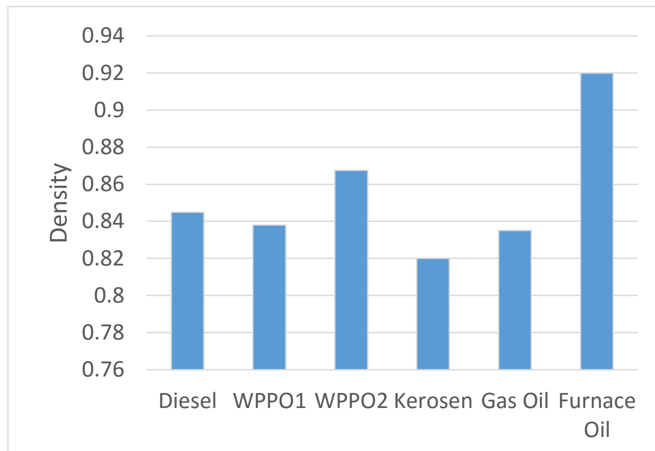

Figure 8 density comparison

3.5. Flash point

The oil's flash point is the lowest temperature at which it can evaporate and combine with air to ignite. It is employed to identify all fuels' fire risks. The ASTM D 93 technique was used to measure the flash point of WPPO. WPPO1's flash point was approximately 4°C, while WPPO2's was approximately -20°C. A fuel with a low flash point contains a high concentration of volatile substances, which represents a great safety risk when managing and transporting the fuel. Diesel and kerosene are easier to manage since their flash points are greater than WPPO (Figure 9). The flash point of WPPO will be raised by removing lighter components such as (gasoline/naphtha), and the fuel's quality will improve.

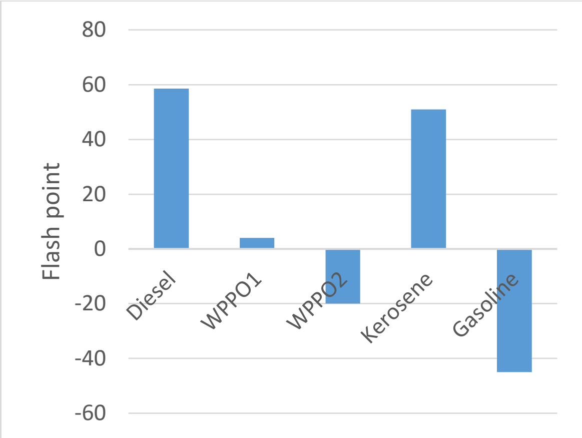

Figure 9 flash point comparison

4. Conclusion

The pyrolysis process is an effective solution to get rid of plastic waste and it also leads to the production of fuel oil in an environmentally friendly way which can achieve good profits. In this study pyrolysis process of waste, and plastic was carried out with a catalyst (ZSM-5 zeolite). It is also found that mixing different kinds of plastics can yield a mixture of oil and gas with a small amount of char (carbon black) with different properties. The higher the temperature and longer reaction times increase the gas yield and decrease the production of biochar. The oil produced through this technique is quite highly combustible and has a wide range of uses. The liquid produced by this technique has a low boiling range and a significantly higher volume. When fuel-like fluids are distilled it indicates that at higher temperatures and longer time rates, the lighter fractions are obtained. After the addition of several other petroleum products, the physical qualities of the produced fuel can be modified to provide extremely effective fuel or furnace oil.

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