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Thermal Pyrolysis of Plastic Waste: The Effect of Temperature and Heating Rate on the Yield of the Pyrolytic Oil

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ABSTRACT

The pyrolysis of plastic waste is a promising method for converting plastics into valuable products like fuels and chemicals. This study investigates the influence of temperature and heating rate on the pyrolysis process. Understanding these effects is crucial for optimizing the process and maximizing product yields. Most of the results indicates that higher temperatures lead to increased gas and lower liquid yields, while lower temperatures favor solid formation. Additionally, a higher heating rate generally results in higher gas yields.

Keywords: pyrolysis, plastic waste, waste to energy

1 Introduction

Plastic waste has become a significant problem for the environment, with global plastic waste generation reaching 400 million metric tons in 2022, up from almost 380 million metric tons in 2019 [1]. One of the promising methods for disposing of plastic waste is the production of liquid fuel from it, which not only helps reduce plastic waste but also utilizes its energy content. Pyrolysis involves the cracking of plastics at a temperature ranging between 350–900 °C [2,3] in the absence of oxygen, resulting in the production of liquid fuel, gas, and char [3,4]. The yield of liquid fuel, gas, and char depends on the type of plastic and the reaction conditions such as temperature and heating rate and other factors [5,6].

2 Experimental

The performance and efficiency of pyrolysis depends on many factors, given its controllability. In this presentation, two of these factors will be studied, namely temperature and heating rate, as parameters in the pyrolysis of LDPE, HDPE and PP.The studies mentioned here only include thermal cracking, where there is no catalyst involved and where the reaction takes place in a closed or semi-closed reactor (i.e., the products are evacuated continuously).

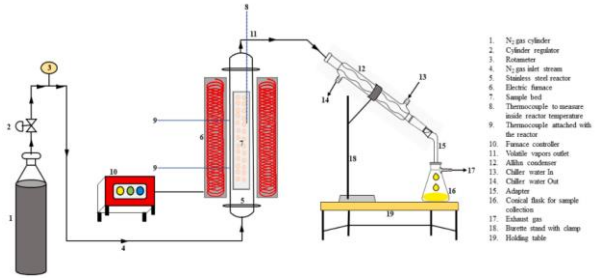

Figure 1: Thermal pyrolysis unit [5]

3 Results and Discussion

The pyrolysis of LDPE, HDPE, PP and other plastics produces a range of products, including gases, liquids, and solids, with the yield and composition of these products depending on the reaction conditions [3,5].Temperature stands out as a critical and extensively researched factor among all pyrolysis conditions [6]. It exerts a strong influence on both the yield and quality of plastic-derived oil [3].

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Table 1: *Thermal cracking of various plastics under certain conditions, and the resulting products*

Plastic	Temperature [°C]	Heating Rate [°C/min]	Reactor	Oil Yield [%wt]	Gas Yield [%wt]	Solid Yield [%wt]	Reference
Medical waste	500	20	Batch	52	43➔46	2➔5	[2]
HDPE 11.3% PP+ LDPE 85,5% Other materials 3.5%	410	10	Semi-Batch	69	28➔29	2➔3	[5]
PP waste	550	5	Semi-Batch	89,25	<10	<5	[7]
LDPE waste	>450	5	Semi-Batch	76,2	20	<5	[7]
LDPE waste	450	10	/	70,2	25➔28	<5	[8]
HDPE waste	450	15	Batch	16	8,7	62,3 [a]	[9]
LDPE waste	450	15	Batch	15,1	10,2	60,8 [a]	[9]
PP waste	450	15	Batch	21	7	61 [a]	[9]

Optimum oil yield was obtained at 350°C then decreased while char yield decreased until it became negligible with rising temperature. On the other hand, gas fraction rises with temperature [2]. The thermal pyrolysis of a mixed plastic waste containing LDPE, HDPE, and PP at 410°C showed a direct correlation between decreasing heating rate and increasing plastic oil yield. The yield rose from 43% at the fastest heating rate (28°C/min) to 59% at a moderate rate (19°C/min) and peaked at 69% with the slowest heating rate (10°C/min) [5]. A slight improvement in the yield of liquid fuel was observed with the increase in temperature. However, beyond 450 ◦C, a significant decrease in the yield of pyrolytic oil was observed [8].

4 Conclusions

The plastic oil yield rises with increasing temperature, but it declines when the temperature surpasses the plastic waste's end degradation temperature. After that and as the pyrolysis temperature increases, higher yields of gaseous products and reduced liquid yields are obtained [2,10]. As for the 2nd parameter, when the heating rate is low to moderate at a correspondingly low to moderate temperature, it encourages the primary pyrolysis reaction which leads to the production of pyrolytic oil, with relatively lower yields of gas and char. Conversely, when the heating rate is relatively higher at somewhat elevated temperatures, the secondary pyrolysis reaction becomes dominant, this secondary reaction favors gas production [3].

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