Pyrolysis of Plastic Waste at High Temperature to Produce Fuel Oil

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Abstract: Thermal degradation of plastic polymers is becoming an increasingly important method for the conversion of plastic materials into valuable chemicals and oil products. In this work, virgin high-density polyethylene (HDPE) was chosen as a material for pyrolysis. A simple pyrolysis reactor system has been used to pyrolyse virgin HDPE with an objective to optimize the liquid product yield at a temperature range of 375°C to 450°C. The optimum temperature was 375°C which has a maximum yield of liquid exact 85.4 wt. % and perfect color of dark yellow was gained.

1. Introduction
Plastic materials comprise a steadily increasing proportion of the municipal and industrial waste going into landfill. Owing to the huge amount of plastic wastes and environmental pressures, recycling of plastics has become a predominant subject in today’s plastics industry. Development of technologies for reducing plastic waste, which are acceptable from the environmental standpoint and are cost-effective, has proven to be a difficult challenge because of the complexities inherent in the reuse of polymers. Establishing optimal processes for the reuse/recycling of plastic materials, thus, remains a worldwide challenge in the new century [1]. Plastic materials find applications in agriculture as well as in plastic packaging, which is a high-volume market owing to the many advantages of plastics over other traditional materials. However, such materials are also the most visible in the waste stream and have received a great deal of public criticism as solid materials have comparatively short life-cycles and usually are non-degradable. Thermal cracking, or pyrolysis, involves the degradation of the polymeric materials by heating in the absence of oxygen. The process is usually conducted at temperatures between 500°C and 800°C and results in the formation of a carbonized char and a volatile fraction that may be separated into condensable hydrocarbon oil and a non-condensable high calorific value gas. The proportion of each fraction and its precise composition depend primarily on the nature of the plastic waste and on process conditions as well [2]. In pyrolytic processes, a proportion of species generated directly from the initial degradation reaction are transformed into secondary products due to the occurrence of inter- and intra-molecular reactions. The extent and the nature of these reactions depend both on the reaction temperature and also on the residence of the products in the reaction zone, an aspect that is primarily affected by the reactor design.

In addition, reactor design also plays a fundamental role, as it has to overcome problems related to the low thermal conductivity and high viscosity of the molten polymers. Several types of reactors have been reported in the literature, the most frequent being fluidized bed reactors, batch reactors, and screw kiln reactors [3]. High-density polyethylene (HDPE) is the third-largest commodity plastic material in the world, after polyvinyl chloride and polypropylene in terms of volume. It is a thermoplastic material composed of carbon and hydrogen atoms joined together forming high-molecular-weight products [4].

2. Plastic Waste Impact

The modern plastics industry can trace its origins back to 1862 when Alexander Parkes unveiled Parkesine (cellulose-acetate plasticized with camphor) - the first man-made plastic [5]. Today, there are in excess of twenty different polymer types in common usage all with different properties and functionalities. Plastics have become an integral part of our lives. Their low density, strength, low cost, user friendly design and fabrication capabilities are the drivers to the steady growth in plastic consumption [6]. However, with a dramatic increase in the use of plastics over the last fifty years has come a major problem with its disposal. In sanitary landfill, polymers act essentially as inert materials and do not decompose readily, retarding the processes of settling and stabilisation of the refuse. An alternative to the landfilling of plastic waste must be sought. Packaging represents the single largest sector of plastics use in the IQ economy, with the majority comprising of polyethylene (PE) films (shrink wrap, sacks, industrial liners). Common uses include insulation, flooring, windows, pipes and fitted furniture, with polyvinyl chloride (PVC) utilized the most. In terms of volume, automotive vehicles contain a larger proportion of plastics than any other material, but
comprise only 10% of the total weight. The waste plastics from end-of-life vehicles (ELV), such as polypropylene battery cases and bumpers, are recycled under the ELV. The proportion of different types of polymers produced in the world from 1950 to 2015 shown in Figure 1. This amount of plastic produced after consumption will become a major burden if not recycled and benefit from the financial value of waste.

Figure 1 World plastic production 1950-2015 [7].

3. Experimental Work

Toward the start of each investigation the unfilled steel reactor and all void condenser and separator. Toward begin of an investigation, 24 g of the polymer (HDPE) was weighed and set into the steel reactor. The reaction tube was then shut with the highest point of the steel device, which fixed the base reactor tube with a nail. The steel mechanical assembly had an outlet of gases go to the condenser amid the trial and it likewise housed the thermocouple. The thermocouple was the sensor for the controller and it observed the temperature inside the responding solids. The gases were cooled by a mean of spiral condenser which it has an inlet of cold water counter current pass, out let of warm water to be recycled. The experiments had a range of temperature (375, 400, 425, 450°C) were reached, gas collected by elastic bag and liquid with flask.

4. Results and Discussion

The consistent pyrolysis of HDPE in a semi-batch reactor has been completed at (375, 400, 425 and 450°C). These temperatures are reasonable for abstaining from coking issues and achieving a most extreme yield of waxes (C_{21+}). Table 1 demonstrates the yield measure of the item portions got, which have been assembled into three distinct bumps: gas, liquid and wax. In light of the components revealed in the writing, polyolefin thermal cracking happens at these temperatures through two instruments [8]:

1. Random scission of the connections of liquefied macromolecules covering the sand particles to yield long chain hydrocarbons
2. Chain-end scission of oligomers to yield low sub-atomic weight products. The high warmth and mass exchange rate between stages in the reactor advances the principal component, with a high wax development rate.

<table>
<thead>
<tr>
<th>Temperature °C</th>
<th>Gases</th>
<th>Liquids</th>
<th>Residue</th>
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<tbody>
<tr>
<td>375</td>
<td>2.8</td>
<td>20.5</td>
<td>0.7</td>
</tr>
<tr>
<td>400</td>
<td>9.2</td>
<td>12.4</td>
<td>2.4</td>
</tr>
<tr>
<td>425</td>
<td>13.9</td>
<td>9.1</td>
<td>1.0</td>
</tr>
<tr>
<td>450</td>
<td>16.2</td>
<td>7.0</td>
<td>0.8</td>
</tr>
</tbody>
</table>

Three unique parts specifically condensable low thick liquid/high gooey liquid/wax like products, non-condensable gasses/volatiles and strong buildup were gotten amid pyrolysis. At various temperatures, the yield dissemination of various portions plainly contrasted and compressed in Figure 2. The condensable fraction (oil/wax) got at low temperature (375°C and 425 °C) was less thick and exceptionally unstable oil, though that got over 450 °C were gooey liquid or wax. The recuperation of condensable division was low (29.2 wt.% for high density polyethylene) at 450 °C and expanded to most elevated yield of 85.4wt.% at 375 °C then steadily diminished with further increment in temperature. The unstable parts expanded at high temperatures prompting low condensable. Also, the low liquid and high gaseous yield at higher temperature was because of the arrangement of more non condensable gaseous/unstable parts by thorough cracking. It became clear that to see thermal effects on the color of the liquid product. As can see in Figure 3 shows where the color change from light to dark color an indication of a heavy fractions like waxes.
5. PONA of produced oil obtained from Pyrolysis

Table 2 present the results of analysis was took at 375°C. The arrangement of the fluid items made expansive blend out of fluid extending from \( \text{C}_3 - \text{C}_{28} \) with olefin substance is almost no or no sum. The most extreme item was paraffin were they have a rate of 45.4 vol. %, these are 31.7 % for n-paraffin and 13.7% for i-paraffin, the oil composition show that the high productivity of breaking to be credited as low viscosity of oil known as blended fuel lamp oil cut.

<table>
<thead>
<tr>
<th>Hydrocarbon fraction</th>
<th>Volume percent %</th>
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<tbody>
<tr>
<td>n-paraffin</td>
<td>31.7</td>
</tr>
<tr>
<td>i-paraffin</td>
<td>13.7</td>
</tr>
<tr>
<td>Aromatics</td>
<td>25.5</td>
</tr>
<tr>
<td>Naphthenes</td>
<td>29.1</td>
</tr>
</tbody>
</table>

6. Conclusion

The pyrolysis of HDPE plastic has been considered as an effective way to convert waste plastics into environment friendly and useful hydrocarbon liquid products. Pyrolysis is a promising alternative for plastic wastes recycling. Poor quality mixed plastics can be converted into valuable liquids like automobile fuel. They might be an alternative source of chemicals for petrochemical processes. Additionally, rich gaseous products were generated, which can be used for power generation for the process and/or for external applications. The pyrolysis of plastic wastes has a significant influence in both products yields and reaction condition. The main purpose of using pyrolysis in this study is to improve the yield of liquid up to more than 80 percent. The study shows that the use of appropriate temperature can cause to achieve more desired conversion percent of the waste plastics into useful products, which are nuisance materials for the environment.

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References

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