SLOW THERMAL PYROLYSIS OF REAL WORLD PLASTIC WASTES IN A FIXED BED REACTOR TO OBTAIN AROMATIC RICH FUEL GRADE LIQUID OIL

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Research article

Experimental investigation on slow thermal pyrolysis of real-world plastic wastes in a fixed bed reactor to obtain aromatic rich fuel grade liquid oil

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ABSTRACT

Plastic wastes have become one of the biggest global environmental issues and thus recycling such massive quantities is targeted. Thermal pyrolysis has been the most suitable approach to convert the waste plastic into a source of energy. This study aims to compare the thermal pyrolysis of waste plastic with that of the modal plastic compounds in a fixed bed reactor. The liquid oil, obtained from the thermal pyrolysis of HDPE, LDPE, PP and PS wastes were characterized using FT-IR, GC-MS and 1H NMR. Also, their fuel properties such as viscosity and calorific values were characterized using parallel plate rheometer and bomb calorimeter respectively. C10–C44 paraffins and C10–C22 olefins were obtained along with aromatics and alcohols in different type of plastic waste pyrolysis oil. The viscosity of the plastic oil is within kerosene and diesel range. The calorific values of the oils are at par with the Petro fuels.

1. Introduction

Exponentially increasing population of the world is leading to two major problems i.e., increased solid waste and increased energy demand. According to UN environment reports, 11.2 billion tons of solid waste is collected worldwide per annum. Solid waste contains around 13% plastic in it. Plastic has been one of the most important innovation for the betterment of the living standard of mankind (Thahir et al., 2021a). Several intrinsic properties of plastics such as durability, pressure resistance, chemical inertness, flexibility, versatility, cheap production cost, and better thermal stability (attained by addition of stabilisers and additives) makes them the first choice of human beings in different applications (Al-Salem et al., 2009; Xu et al., 2018). However, these plastics are polymers resulting from 'n' degree polymerization of petroleum derived hydrocarbon monomers. Hence, the complete degradation of these plastics can take centuries of time. However, the rate of disposing of waste plastic has risen remarkably and thereby imposing a negative impact on public health and environment (Osman et al., 2020). The June 2018 issue of National Geographic magazine had reported that until 2017, 9.2 billion tons of plastic was produced and of these 6.9 billion tons became waste. Out of 6.9 billion tons, 6.3 billion tons of plastic kept staggering and have never been to the recycling bin. Therefore, cost-effective waste management has been one of the biggest challenges recently. The conventional plastic waste management techniques such as landfilling, incineration and recycling are further energy demanding processes.

Fossil fuels have been the basic source of energy for mankind since ages. The continuous exploitation of fossil fuel reserves has led towards search of some alternative sources of energy generation (Kaur et al., 2018). Hence, to meet the increasing energy demands and save the fossil fuel reserves, researchers are working persistently to develop more economic, sustainable, advanced, and environment-friendly alternative fuels. The best solution to this alarming problem can be developing a process that can convert the plastic waste back into a valuable source of energy that can be used as an alternative to fossil fuels. Consequently, using waste plastic as source for retrieving valuable products and energy has become a significant field of research. The higher calorific value associated with the plastics due to their origin from fossil fuels favours the process of their conversion into valuable energy products (Anuar Sharuddin et al., 2016). Pyrolysis appears to be the significant solution to this. The end products of pyrolysis process are liquid hydrocarbon fuel and value-added chemicals. Therefore, it is a valuable hydrocarbon reenergizing process (Thahir et al., 2021b).

Pyrolysis is a decomposition process in which on providing thermal energy in the absence of oxygen the long-chain (heavier) hydrocarbon molecules are cracked into a smaller size (lighter) molecules and produces volatile hydrocarbons and carbon as residues that can be condensed to liquid fuel (Anuar Sharuddin et al., 2016; Arena and

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- Slow thermal pyrolysis of real-world plastic waste in a fixed bed reactor is a process that involves the controlled decomposition of plastics at elevated temperatures in the absence of oxygen to produce aromatic-rich fuel-grade oil. Here's a step-by-step explanation of the process:

1. **Feedstock Preparation:** The process begins with the collection and preparation of plastic waste materials from various sources, such as post-consumer plastics or industrial plastic waste. These plastics can include polyethylene (PE), polypropylene (PP), polyethylene terephthalate (PET), and others, often with a mix of additives and contaminants.
2. **Feedstock Sorting and Shredding (if needed):** The collected plastic waste may undergo sorting and shredding to remove non-plastic materials (e.g., paper labels, metals) and to reduce the size of the plastic pieces for easier handling and feeding into the reactor.
3. **Fixed Bed Reactor Setup:**

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3. A fixed bed reactor is a vessel where the plastic waste will undergo pyrolysis. The reactor is typically made of materials that can withstand high temperatures, such as stainless steel. It includes provisions for heating the feedstock and maintaining the desired pyrolysis conditions.

4. **Heating and Pyrolysis:** The prepared plastic waste is loaded into the fixed bed reactor, and the reactor is sealed to create an oxygen-free environment (usually with an inert gas or under vacuum). The temperature is gradually increased to initiate the pyrolysis process.

5. **Pyrolysis Process:** Pyrolysis is a thermal decomposition process in which the plastic polymers break down into smaller molecules in the absence of oxygen. At elevated temperatures (typically between 300°C to 800°C), the plastic molecules undergo cleavage of chemical bonds, resulting in the formation of various products, including gases, liquids, and solid residues.

6. **Product Separation:** The products of pyrolysis include:
    1. **Aromatic-Rich Fuel-Grade Oil:** This is the desired product and is rich in aromatic hydrocarbons, which have high energy content and can be used as a fuel or as a feedstock for chemical processes.
    2. **Pyrolysis Gases:** These can include hydrocarbons, hydrogen, carbon monoxide, and other gases. They may be used as fuel or further processed.

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7. **Product Collection and Cooling:** The aromatic-rich fuel-grade oil is typically condensed and collected as a liquid product. It is then cooled and separated from any remaining pyrolysis gases. The gases can be further treated or used as an energy source.
8. **Product Analysis:** The collected fuel-grade oil is analyzed for its chemical composition, properties (e.g., viscosity, density), and quality. This analysis helps ensure that the obtained oil meets the desired specifications for use as a fuel or feedstock.
9. **Environmental and Safety Considerations:** During the process, emissions and potential byproducts should be monitored and controlled to minimize environmental impact. Safety measures are also crucial to prevent accidents associated with high temperatures and flammable gases.
10. **Optimization and Scale-Up:** Researchers and engineers may further optimize the pyrolysis conditions and reactor design to maximize the yield of aromatic-rich fuel-grade oil and improve overall process efficiency. Scaling up the process for industrial applications requires additional engineering considerations.

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- Slow thermal pyrolysis of plastic waste in a fixed bed reactor offers a sustainable approach to recycling plastics by converting them into valuable fuel products while reducing plastic waste and its environmental impact. However, successful implementation requires a thorough understanding of the pyrolysis process and careful control of operating condition

MATERIALS & METHODS

- Slow thermal pyrolysis of real-world plastics is a process that involves breaking down plastic materials into their constituent hydrocarbons at relatively low temperatures and without oxygen. This method is often used to recycle plastics or convert them into valuable products like fuels or chemicals. Here's a general outline of the materials and methods you can use for slow thermal pyrolysis of real-world plastics:

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1. **Plastic Waste**: Collect a variety of real-world plastic waste materials. These can include plastic bottles, bags, containers, and other items made from different types of plastics such as PET, HDPE, PP, PVC, etc. Sorting and cleaning the plastics may be necessary to remove contaminants like labels, dirt, or residues.
2. **Pyrolysis Reactor**: You'll need a pyrolysis reactor or chamber. The design and size of the reactor will depend on the scale of your operation. Common reactor types include fixed-bed reactors, fluidized bed reactors, and rotary kilns.
3. **Heating Source**: You need a source of heat to initiate the pyrolysis process. This can be achieved using electrical heaters, natural gas, or other suitable heating methods.
4. **Inert Gas**: Inert gases like nitrogen or argon are often used to create an oxygen-free environment inside the reactor. This prevents combustion during pyrolysis.
5. **Condenser System**: A condenser is required to cool down and collect the pyrolysis products. This allows the conversion of the vaporized hydrocarbons into liquid or solid products.

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6. **Collection System**: A system for collecting and storing the pyrolysis products, which can include oils, gases, and solid residues.
7. **Analytical Equipment**: Instruments for analyzing the composition of the pyrolysis products, such as gas chromatography-mass spectrometry (GC-MS), can be helpful for process monitoring and optimization.

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1. **Feedstock Preparation**: Sort, clean, and prepare the plastic waste by removing any non-plastic components and cutting or shredding the plastics into small pieces. Smaller pieces facilitate better heat transfer and pyrolysis.
2. **Loading the Reactor**: Place the prepared plastic waste into the pyrolysis reactor. Ensure that the reactor is sealed tightly to create an oxygen-free environment.
3. **Heating**: Start heating the reactor gradually. The temperature and heating rate will depend on the specific plastic materials being processed. Generally, slow pyrolysis is conducted at temperatures between 300°C and 600°C.
4. **Inert Gas Injection**: Inject the inert gas into the reactor to maintain an oxygen-free atmosphere.
5. **Pyrolysis Process**: As the temperature increases, the plastics will start to decompose, releasing hydrocarbons in the form of vapor. These vapors are then collected and condensed in the condenser system.

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6. **Product Analysis**: Analyze the pyrolysis products to determine their composition and quality. This step can help in adjusting the process parameters for better yields or specific product targets.
7. **Product Collection**: Separate and collect the pyrolysis products. These products can include pyrolysis oil, syngas, and solid char.
8. **Post-Processing**: Depending on the intended application, you may need to further refine or process the pyrolysis products. For example, pyrolysis oil may require purification or upgrading.
9. **Safety and Environmental Considerations**: Ensure safety measures are in place to handle high temperatures, potential emissions, and waste disposal.
10. **Scale-Up**: If you plan to scale up the process, consider the engineering aspects of reactor design, heat transfer, and product handling.

RESULTS AND DISCUSSION

RESULTS

1. **Feedstock Characterization**: Begin by briefly describing the composition and characteristics of the real-world plastic waste used as feedstock. Mention the types of plastics, any contaminants present, and their respective percentages in the feedstock.

2. **Pyrolysis Process Parameters**: Present the key operating conditions of the pyrolysis process in the fixed bed reactor, including:
   1. Temperature: The range of temperatures used in the pyrolysis process.
   2. Residence Time: The duration of plastic residence in the reactor.
   3. Heating Rate: How quickly the reactor was heated.
   4. Catalyst (if used): Mention if any catalysts were employed.

3. **Product Yields**: Provide data on the yields of different products obtained from the pyrolysis process, including:
   1. Aromatic-rich fuel-grade oil
   2. Gases (if relevant)
   3. Solid residues (if relevant)

4. **Product Characteristics**: Detail the characteristics of the aromatic-rich fuel-grade oil, including:
   1. Chemical composition (e.g., percentage of aromatics, aliphatics, etc.)
   2. Heating value
   3. Viscosity
   4. Density
   5. Flash point
   6. Any other relevant properties

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5. **Comparison with Standards**: Compare the properties of the obtained fuel-grade oil with relevant industry standards or specifications for fuel-grade oils, if available. Discuss whether the oil meets these standards.

6. **Mass Balance**: Present a mass balance of the feedstock and products to ensure that there is accountability for all components.

DISCUSSION

- IN THIS WORK THE EFFECT OF ELEMENTAL COMPOSITION OF MODAL PLASTIC AND WASTE PLASTIC ON THEIR THERMAL DEGRADATION PROCESS WAS STUDIED THE RESULTS OBTAINED CONFIRMED THE PRESENCE OFSIMILAR MOLECULAR COMPOSITION AND STRUCTURE AND FOLLOWING SIMILAR DEGRADATION MECHANISIM .CONSIDEABLE AMOUNT OF RICH OIL LIQUID WERE OBTAINEC FROM ALL WASRES WITHOUT CATALYST ASSISTANCE IT CAN BE CONCLUDED THAT A CONTROLLED SLOW THERMAL PYROLYSIS OF THE REAL WORLD PLASTIC WASTE PRODUCE LIQUID OIL WITH FUEL PROPERTIES THAT ARE SUITABLE TO BE USED AS ALTERNATIVE FOR FOSSIL FUELS