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Influence of Process Parameters on Polyolefin Pyrolysis Through Experimental Investigation

Keywords: Pyrolysis, polyolefins, thermochemical recycling, comprehensive two-dimensional GC

Aim

To investigate the influence of feed composition, pyrolysis temperature, and residence time on the product distribution of polyolefin pyrolysis with a tandem micro-pyrolyzer facility.

Justification

Worldwide plastic generation is estimated to reach 398.9 million metric tons in 2024 and is expected to increase exponentially. Plastics are made from light olefins (ethylene, propylene, butene), which are produced from crude oil. Polyolefin plastics (high-density polyethylene, low-density polyethylene, polypropylene) constitute the majority of packaging plastic waste. Landfilling and incineration represent traditional approaches for plastic waste disposal; however, they are associated with various environmental drawbacks. Conventional mechanical recycling is a commonly employed method, yet it often results in down-cycling, yielding lower-quality products from polyolefin waste. Conversely, chemical recycling processes, such as pyrolysis, have garnered significant attention in recent years due to their capability to thermo-chemically convert plastic waste into pyrolysis oil, which can subsequently be further cracked into valuable platform chemicals (i.e. C2-C4 olefins). Pyrolysis encompasses a series of thermochemical reactions occurring within a moderate to high-temperature range (400°C-600°C) under an inert (oxygen-free) atmosphere. The thermal degradation of plastics during pyrolysis yields pyrolysis oil, non-condensable gases, and solid residues (char). Notably, the resultant gasoline-diesel range hydrocarbons offer promising alternatives to conventional fuels meanwhile naphtha fraction can be valorized in steam-crackers. The product distribution, however, is significantly influenced by pyrolysis conditions, including temperature and residence time of pyrolysis vapors within the reactor, alongside the composition of the feedstock.

The thesis aims to investigate the influence of pyrolysis temperature and residence time on thermal pyrolysis of various types of polyolefins including LDPE, HDPE, PP, and their mixtures with different compositions. Experiments will be performed by a tandem micro-pyrolyzer unit combined with comprehensive two-dimensional gas chromatography with a flame ionization detector and time-of-flight mass spectrometer (GC x GC-FID/TOF MS). This analytical facility enables online qualitative and quantitative analysis of pyrolysis products, facilitating the exploration of further insights into the decomposition mechanism and its relation with polymer types. As a result of these experiments, reference pyrolysis conditions can be determined for the catalytic experiments to be investigated in the future.

Program

1. Literature review on the thermal pyrolysis of polyolefins over different process parameters.
2. Performing feedstock characterization techniques to determine thermal (TGA/DTG, DSC) and physicochemical (proximate and ultimate analysis) properties.
3. Investigate the effect of different polyolefin feedstocks on pyrolysis products at various temperatures and carrier gas flows.
4. The on-line analysis of the pyrolysis products by using GC x GC-FID/TOF MS unit.