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Catalytic Upgrading of Plastic Waste Pyrolysis Oils as Feed for Light Olefin Production

Aim

This master's thesis aims to investigate the upgrading of pyrolysis oils derived from circular feedstocks, with a focus on plastic waste. The research will evaluate strategies for removing critical contaminants, including halogens, nitrogen, sulfur, and metals, from polyolefin-based pyrolysis oil. Effective contaminant mitigation is required to support downstream chemical recycling, prevent catalyst deactivation, and limit the severity of subsequent upgrading operations such as hydrotreatment. Ultimately, the study seeks to determine the extent to which upgraded pyrolysis oil can serve as a viable feedstock for steam cracking, with particular emphasis on the production of light olefins.

Justification

The demand for plastics continues to rise, necessitating a shift from the current open-ended use to a more sustainable closed-loop approach. Despite this, only 10% of plastic is currently recycled globally, leaving the majority as waste, which ends up in landfills, is incinerated, or pollutes the environment. Thermochemical recycling of plastic waste to light olefins through consecutive pyrolysis and steam cracking of pyrolysis oils is a promising technology adopted by industry leaders such as Shell, BP, Total-Energies, SABIC, and ExxonMobil. However, the complex nature of pyrolysis oils, including contaminants, hinders their direct use in steam crackers. Hence, pyrolysis oils require thorough upgrading to produce naphtha-like feedstocks, necessitating a comprehensive understanding of the components that require treatment.

This thesis is motivated by the need to improve the upgrading of plastic-derived pyrolysis oils before their valorization via steam cracking. While hydrotreatment is effective for impurity removal, its reliance on hydrogen, high operating severity, and sensitivity to catalyst poisoning increases cost and complexity. Catalytic adsorption offers a complementary upgrading pathway that selectively captures problematic contaminants before hydrotreatment, thereby reducing catalyst deactivation risk and lowering hydrogen and processing demands. In this project, a systematic experimental study will be undertaken to evaluate catalytic adsorption as a pretreatment strategy for removing halogens, nitrogen, sulfur, and metals from pyrolysis oils. Bench-scale adsorption experiments will establish adsorbent performance and contaminant removal efficiencies. Analytical characterization will clarify interactions between contaminants and adsorbent and quantify improvements in oil quality relative to those required by steam cracking and hydrotreatment.

Program

- **Literature study:**
  - Valorization of waste-derived Py-oils.
  - Key contaminants in pyrolysis oil and their impact on the hydroprocessing and steam cracking.
  - Applicable upgrading and decontamination techniques for Py-oils.
  - Catalytic adsorption as a complementary upgrading technique for Py-oils
- **Experimental Phase:**
  - Utilization of GC × GC techniques for analyzing pyrolysis oil and the effluents of the adsorption trials.
  - Performance assessment of novel and benchmark adsorbents using a bench-scale adsorption setup.