DEVELOPMENT OF AN UPSCALABLE RECYCLING PROCESS FOR POLYOLEFINS AND OTHER POST-CONSUMER PLASTIC FRACTIONS VIA SOLVENT-BASED DEPOLYMERIZATION

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Abstract

A concept for chemical recycling of post-consumer plastics in a refinery surrounding was designed in order to develop an economically feasible and technically viable solution for resource-efficient usage of hydrocarbon products.
Thermal, non-catalytic depolymerization at moderate temperatures and pressures is meant to produce valuable refinery feedstock with an outstanding C/H ratio at optimum operation costs.
Solvent-based polymer cracking in liquid-phase conditions realized in a tube reactor design should overcome process difficulties originating from high viscosity and low thermal conductivity of polymer melts and lead to a stable, robust and controllable process with constant and optimized product qualities.
To evaluate the conceived theoretical findings, a continuous bench-scale pilot plant was designed and built at the pilot plant facilities of OMV Refining and Marketing in Schwechat, Austria.
Polyethylene (PE), Polypropylene (PP), Polystyrene (PS) granulates and their mixtures were fed to the unit for studying the base depolymerization kinetics and process behaviors. In later test series, several pretreated post-consumer plastic fractions were used as feedstock to review the robustness of the process towards impurities and impact of compounding and additive materials.

Keywords: *chemical recycling, polyolefins, thermal cracking, solvent, refinery*

1. Introduction

Chemical recycling of pure and mixed plastics has undergone extensive research for decades.[1],[2] Decreasing available disposal volumes and political pressure towards reduction of landfilling, high crude oil and thus feedstock prices are nowadays economic and ecological incentives for the development of recycling technologies.
Major companies in chemical and oil and gas industry developed a range of different technologies. Complex, CAPEX-intense reactor designs, such as fluidized beds and rotary kilns were applied to overcome process difficulties originating from high viscosity and low thermal conductivity of polymer melts. High temperature applications and elaborated catalysts produced the favored products but also caused high operation costs. Simpler and more cost efficient designs led to poor and inconstant product qualities and low throughputs.
Early papers and articles written in the beginning 1990s have already described the challenge of making the technology cost effective. 20 years later, crude oil prices rose to about a five-fold, plastics world production increased by some 180% and landfill bans were put in place in various European countries.
This set of changed economic conditions can finally lead to the economic viability of depolymerization technologies.

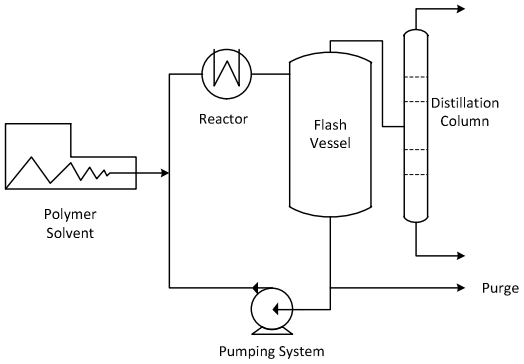
2. Materials and Methods

After intense literature studies and discontinuous laboratory tests a continuous bench-scale pilot plant was designed and constructed.
Compared to earlier works [3], the approach was to build a fully continuous plant, also for purge products.
The aim was to find process parameters for ideal cracking conditions into favourable products. Optimum reaction temperatures and system pressures for solvent-based liquid-phase cracking had to be developed and verified [4].
The tube reactor design provides plug flow conditions and thus distinct retention times, next to a high and through multiple heating zones variable ratio of heat transfer surface to the reaction volume.
Process data is used to set up simulation models in order to validate the economic and technical viability of the process and to allow scale-up approaches.
A moderate process temperature and pressure design favours energy efficient operation; the non-catalytic solvent based process avoids margins losses through catalyst regeneration or a spent catalyst application.
Target feedstock materials are fractions with polyolefin contents as those represent the majority in pre-treated (e.g. NIR-sorted) post-consumer recycling materials.
In order to study the base depolymerization kinetics and process behavior pure virgin polyolefin granulates and their mixtures are used as feed stock materials for the

first test series. Later, several pre-treated post-consumer plastics were fed to the unit to study the robustness of the process towards impurities and impact of compounding and additive materials.

3. Results and Discussion

Typical post-consumer plastic fractions are fed into the process using refinery heavy oil fractions as solvent and matrix liquid and cracked in a tube reactor. The obtained products are flashed from the residues and additive substances and distilled into typical refinery feedstock products. The remaining residues and solvent mixture is recycled in a pump around system.



The set of product analyses is adapted to typical testing parameters of refinery feedstock and products, such as:

- simulated TBP distillation
- PIONA analyses for naphtha fractions
- density and viscosities
- aromatics
- C/H ratio

An empirical and visual testing method for coke contents from polymer cracking in the purge material formation was developed.

Process temperatures and pressures are preferably below 500°C and 20 bar_g.

4. Conclusions

This new process can provide an economically viable solution for the chemical recycling of preferably polyolefins as feedstock for refineries.

The solvent-based technology enables an upscalable reactor design and controllability of reaction and flow conditions throughout the cracking unit.

The obtained process data could be used to set up simulation models in order to validate the economic and technical viability of the process and to allow scale-up approaches.

Economic considerations assuming an upscaling to a commercial size unit and its integration in an existing refinery are done.

The found conclusions were compared to state-of-the-art technologies.

References

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