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A more effective way to upgrade pyrolysis oil

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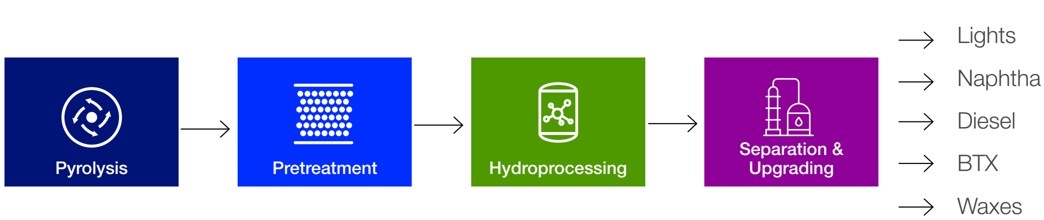
Plastics have become essential to everyday life. At the same time, pollution from plastic waste has become a pressing environmental issue. Demand for innovative plastic recycling solutions is being driven by legislation, consumer preference, and the industry itself. Novel plastics recycling processes, including innovative purification, and upgrading, are key to achieving a sustainable and truly circular industry. MaxFlux® hydroprocessing technology is an advanced process that enables efficient upgrading of plastic pyrolysis oils (PPO).

Circularity through advanced recycling and upgrading

Waste plastics have been primarily directed to landfills or are incinerated, with a smaller fraction being diverted to recycling. Influenced by the regulations to limit waste plastic and disposal into landfills, there is a growing need for sustainable recycling solutions.

One of the leading methods for chemical recycling of mixed plastics is pyrolysis. This chemical recycling process involves depolymerization of the plastic waste producing an oil, which after clean-up, can then be used again as a raw material in polymerization processes. The advantages of using pyrolysis to achieve the reduction of plastic waste is, that unlike mechanical processes, a true circularity without any inferior product qualities can be achieved. Plastic pyrolysis ensures that the quality of the recycled plastic derived from the PPO is as good as virgin plastic.

However, the pyrolysis oil recovered from mixed plastics will contain a broad range of impurities, such as halogens, sulfur, oxygen, or nitrogen, that must be removed prior to any further processing in downstream units Downstream units´, for example a naphtha cracker, will have strict impurity limits to ensure operational reliability and high product quality. Hydroprocessing is emerging as the primary pathway for upgrading PPO to a quality that cracker operators demand. However, hydrotreating (HDT) alone may not be sufficient as PPO contains various heteroatoms and unstable organic compounds such as diolefins that can be harmful to the hydrotreating (HDT) unit and catalyst. Thus, pretreating adsorbent, guard beds, and oil stabilization are usually required as well.



Depending on the destination of the upgraded PPO, either if it will ultimately be blended into fuels or used for petrochemicals, there will be stringent requirements to ensure compatibility with co-processed feeds and existing unit designs. Thus, the strategy to upgrade PPO typically requires a multi-faceted approach that is dependent on the impurities and application. Although effective, not all HDT processes are equal.

Hydrotreating pyrolysis oils

Historically, hydroprocessing technology has long been practiced in the refining industry for treating feedstocks such as distillates and light hydrocarbons. Even though hydroprocessing of waste PPO is an extension of this long-existing application, the operational challenges may be exacerbated. Composition of the plastic waste and the technology used to pyrolyze the plastic waste affect the pyrolysis oil quality, which in turn will impact upgrading efficiency. This uncertainty calls for solutions that are flexible, robust, and efficient.

In the conventional trickle-bed hydrotreating configuration, recycled hydrogen gas is mixed with make-up hydrogen and then the liquid feed. The mixture is heated and sent to the reactor inlet, where it is distributed across a catalyst bed. The reaction between the dissolved hydrogen and the reactive species occurs at the catalyst surface as additional hydrogen from the gas phase dissolves into the liquid to replace what was consumed. While it may be the most common HDT process, the trickle-bed reactor system is constrained by three issues: hydrogen diffusion, thermal management, and flow distribution.

MaxFlux technology is an improvement over traditional hydroprocessing that overcomes these challenging limitations by operating the reactors in a high liquid flux mode. The hydrogen is dissolved fully into the liquid at the reactor inlet. A portion of the reactor effluent is then recycled to be mixed with the fresh feed. This removes the mass transfer limitation, eliminating large volumes of hydrogen recycle gas, and taking out the gas recycle loop entirely from the process. This can be particularly advantageous in PPO hydroprocessing, where flexibility and robustness are paramount.

The MaxFlux advantage

In the MaxFlux reactor design, the high liquid flux ensures that the overall reaction is controlled by the intrinsic reaction rate without mass transfer limitations. In addition, the liquid volume absorbs more of the reaction exotherm compared to the trickle-bed design, where exotherms are typically managed by injection of additional quenching hydrogen between catalyst beds. This reduces the temperature rise across the reactor bed and eliminates the need for the aforementioned hydrogen quench. This lower temperature rise also minimizes over-cracking and undesirable side reactions, increasing the yield of desired products.

Innovative reactor internals have been designed to ensure complete mixing of hydrogen with the fresh feed and distribution across the catalyst bed. This design further eliminates the need for complicated feed internals, distribution trays, and quench zones. Hydrogen is delivered to the reactor more efficiently and the large liquid volume stabilizes temperature fluctuations. These features of MaxFlux provide significant capital and operating cost savings, less light ends make, and longer catalyst life.

A typical grassroots MaxFlux configuration for PPO is shown in Figure 1. The pyrolysis oil is first passed through adsorbent beds and a guard bed reactor to remove contaminants that are harmful to both the active HDT catalyst and the downstream cracker. Diolefin conversion is also typically included in one upstream of the main hydrotreating reactor. Reactor effluent recycle is mixed with the pyrolysis oil feed at the inlet of the guard bed reactor. The outlet of the guard bed is heated and sent to the inlet of the MaxFlux reactor. The HDT reactor may be comprised of one or more catalyst beds, with make-up hydrogen added between each bed to re-saturate the oil. The portion of the reactor effluent that is not recycled is then sent to the separation section of the unit. This could be a product stripper or fractionator as needed to achieve the design product yields and properties.

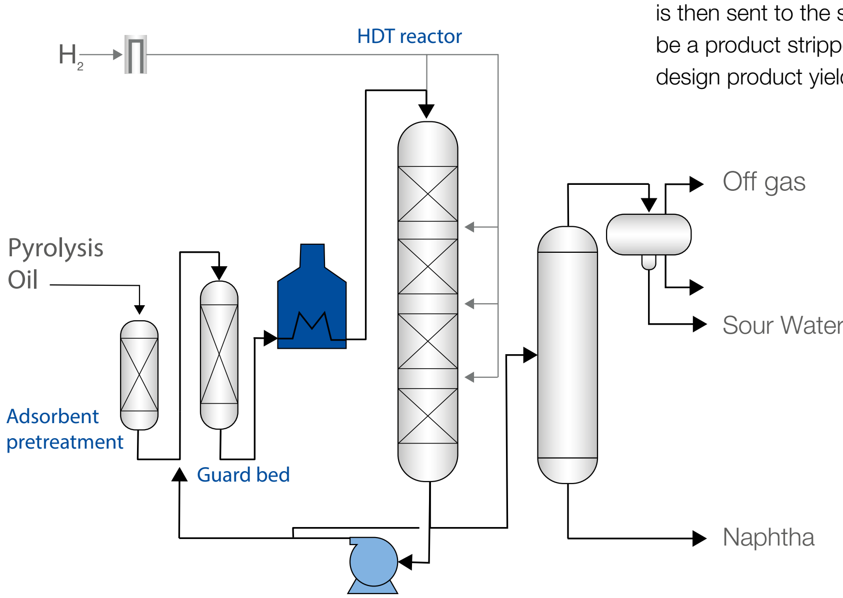


Figure 1. Basic MaxFlux design for plastic pyrolysis oil upgrading

Key advantages of MaxFlux technology:

- Lower total capital investment vs trickle bed technology
- Reduced operating expenses with lower electricity and fuel gas consumption.
- Improved mixing and distribution minimize over-cracking to undesired products
- Increased catalyst lifetime with reduced catalyst deactivation due to coking

Performance

The contaminants in waste PPO are the main drivers for corrosion, fouling and downstream catalyst poisoning in industrial steam cracking plants. These materials can be used only if they are upgraded, as the heteroatom impurities will exceed typical feedstock specifications for stable operation of a steam cracker. On the other hand, when choosing any upgrading technology and the correct sequence of decontamination steps, care must be taken because some of the contaminants present in the PPO can also be detrimental to these steps as well. At every decontamination step, constraints regarding permissible operating conditions and allowable contaminant levels, for example, must be considered. This typically results in somewhat complex designs.

A Basic Engineering Package (BEP) recently executed by Sulzer Clean Fuels and Chemicals Licensing division targeted upgrading 100 KTA of different PPOs with the characteristics shown in Table 1. The unit was designed to meet the steam cracker feed. Using a combination of pretreatment beds, both scavenger and active catalyst types, and MaxFlux hydrotreating, all the relevant contaminants are reduced to ultra-low levels (< 1 wppm), thus achieving the required product specifications.

Property	Typical PPO quality	Steam cracker feed spec	MaxFlux product quality
Nitrogen, ppmw	400 – 1,500	< 100	< 10
Sulfur, ppmw	30– 200	< 500	< 50
Silicon, ppmw	35– 50	< 1	< 1
Chlorine, ppmw	30 – 150	< 3	< 1
Oxygen, ppmw	2,800 – 5,000	< 100	< 1
Total Metals (excl. Si), ppmw	25 - 50	< 1	< 1
Total Olefins, wt%	45 – 55	< 2	< 1

Table 1. Performance of MaxFlux hydrotreating for plastic pyrolysis oil

Beyond achieving the required product specifications, the BEP work also resulted in a high degree of integration between the various process steps, which offered significant savings in terms of both capital and operational expenditure. Figure 2 below shows a simplified schematic for the optimized configuration:

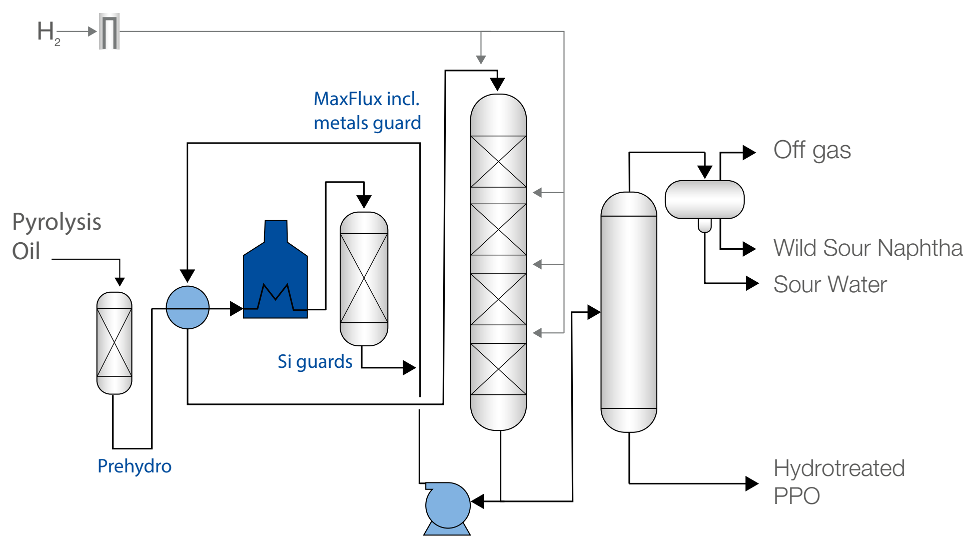


Figure 2. Customized MaxFlux design for plastic pyrolysis oil upgrading

Your Partner in Circularity

Each PPO is unique. It is critical to consider all characteristics of each PPO in order to successfully design a PPO upgrading unit. Sulzer, a global leader in supplying state-of-the-art process equipment, is using their expertise to deliver the most flexible process for upgrading pyrolysis oils into higher value products. With efficient contaminant removal, MaxFlux technology is the hydrotreating solution with lowest capital cost, operating cost, and carbon footprint. To learn more about the MaxFlux Technology and to receive a preliminary assessment of your feedstock, please contact us at www.sulzer.com.

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