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CASE STUDY

Advanced Fractionation of Waste Plastic Pyrolytic Oil in Refinery-Type Rectification Units

The study evaluates the integration of waste plastic pyrolytic oil into refinery-style distillation systems. Using CHEMCAD simulation software, multiple rectification configurations were analyzed, inspired by conventional crude oil atmospheric distillation units. The work is simulation-based and applicable to large-scale pyrolysis plants or standalone upgrading facilities.

CHALLENGE

Raw waste plastic pyrolytic oil produced from thermochemical recycling cannot be directly used as transportation or heating fuel due to its wide variability in composition and failure to meet standard fuel specifications. Conventional pyrolysis plants typically rely on simple condensation or basic distillation, which leads to broad boiling cuts, inconsistent quality, low cetane index, and unsuitable flash points. Additionally, direct processing of pyrolytic oil in standard crude oil refineries is problematic because pyrolytic oil has a significantly narrower boiling range and different chemical composition than fossil crude oil. The challenge was to determine whether refinery-type multi-stage rectification could be adapted to upgrade pyrolytic oil into fractions comparable to conventional fuels while maintaining operational feasibility.

Academic Research*

- **Business Type:** Chemical & Process Engineering / Waste Plastic Recycling
- **Project Type:** Process simulation and design of rectification units for upgrading plastic pyrolysis oil
- **Organization:** Warsaw University of Technology

SOLUTION

A simulation-driven approach was adopted using CHEMCAD process modeling software to evaluate advanced fractionation strategies. Three rectification configurations were studied:

1. A classic crude oil atmospheric distillation unit processing crude oil, pyrolytic oil, and a 90/10 crude–pyrolytic oil blend.
2. A simplified two-column rectification system adapted specifically for pyrolytic oil, reducing the number of side strippers.
3. A further simplified configuration eliminating additional strippers and pumparounds to reduce equipment complexity.

The designs were benchmarked against crude oil fractionation, focusing on boiling point distribution, density, flash point, and cetane index. Batch distillation simulations were also performed to compare distillation curves and evaluate fraction sharpness. The objective was to maximize similarity between pyrolytic oil fractions and conventional naphtha, kerosene, and diesel streams while minimizing plant complexity.

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RESULTS

The simulations demonstrated that direct processing of pure pyrolytic oil in a conventional crude oil distillation unit is not optimal due to mismatched boiling ranges. However, blending up to 10 mol% pyrolytic oil with crude oil did not significantly alter product yields or key fuel properties.

The modified rectification configurations (cases 2 and 3) successfully separated pyrolytic oil into four narrow boiling fractions. These fractions closely resembled refinery products:

- Light fraction similar to naphtha (≈50–180 °C)
- Middle fraction comparable to kerosene (≈180–280 °C)
- Heavy distillate aligned with diesel boiling range (≈280–340 °C)
- Bottom fraction suitable for further upgrading

Simplifying the column design did not materially degrade fraction quality. Case 3 achieved similar performance to case 2 with fewer unit operations, making it more attractive for industrial implementation.

TANGIBLE BENEFITS

- Enables production of higher-value fuel-range products from waste plastic pyrolysis oil
- Demonstrates feasibility of co-processing pyrolytic oil with crude oil at low blending ratios
- Provides refinery-compatible fractions that can potentially be hydrotreated alongside conventional streams
- Reduces reliance on landfilling or incineration of plastic waste
- Offers scalable upgrading pathways suitable for large pyrolysis plants or centralized upgrading hubs
- Simulation-based optimization minimizes development cost and technical risk prior to deployment

FIGURE 1 - CHEMCAD Model of the rectification plant-Case 1

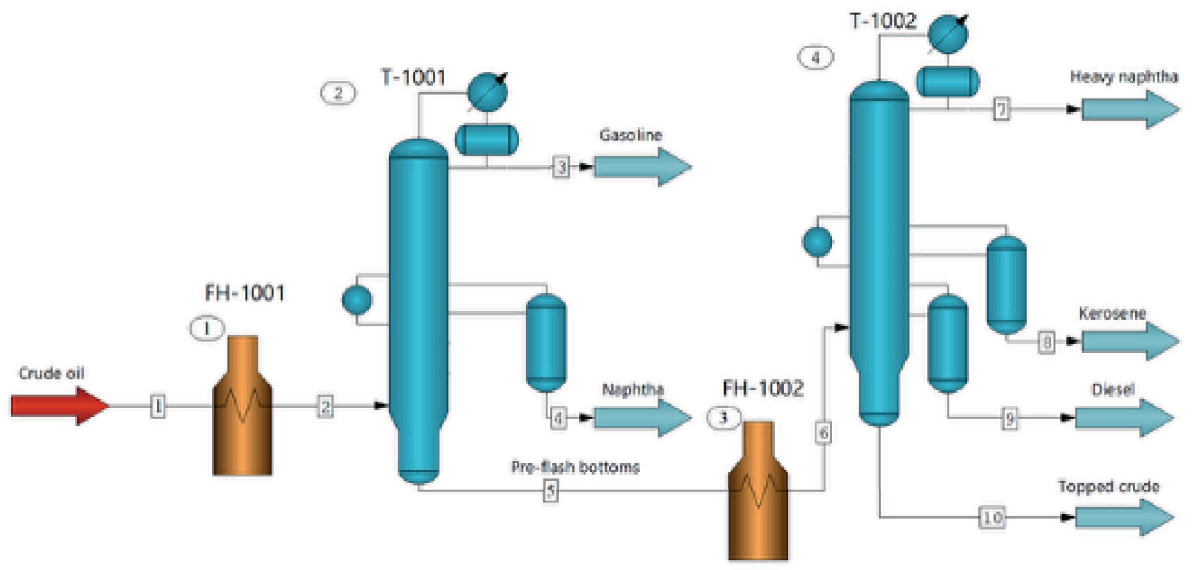

FIGURE 2 - CHEMCAD generated batch distillation profiles for crude and pyrolytic oil fractions