Distillation of heavy hydrocarbons from waste plastic pyrolysis oil using ASTM D5236 vacuum Potstill method

Waheed Zeb[1*], Pieter Knockaert[1], Jung Suk Coene[1], Joël Hogie[1], Uros Kresovic[3], Kevin Van Geem[2], Steven De Meester[1]

[1] Laboratory for Circular Process Engineering (LCPE), Department of Green Chemistry and Technology, Faculty of Bioscience Engineering, Ghent University, B-8500 Kortrijk, Belgium
[2] Laboratory for Chemical Technology (LCT), Department of Materials, Textiles and Chemical Engineering, Faculty of Engineering & Architecture, Ghent University, B-9052 Zwijnaarde, Belgium
[3] Indaver N.V. Belgium, B-2800 Mechelen, Belgium

Keywords: Pot-still distillation, Pyrolysis oil, Slack waxes, Waste plastic,
[*]Presenting author email: waheed.zeb@UGent.be

1. Introduction

Thermal pyrolysis of waste plastic produces gases, liquid products (pyrolysis oil), and char particles, with pyrolysis oil being the main component. Pyrolysis oil is a complex mixture of hydrocarbons with a carbon distribution ranging from C_5 to C_{60} when processed under moderate conditions of 450 °C and 1 bar (Abbas-Abadi et al., 2022). One of the promising techniques to upgrade waste plastic pyrolysis oil is distillation to separate hydrocarbons based on the boiling range (Zeb et al., 2023). The C_5-C_{22} hydrocarbons are liquid products obtained by fractional distillation which are commonly used as fuels, such as gasoline and diesel, light and heavy naphtha as steam cracker feedstock, and short carbon chain olefins as feedstock for the preparation of chemicals (Lee et al., 2021). The C_{22+} hydrocarbons are heavy, solid at room temperature, and possess high melting points, commonly referred to as atmospheric distillation residue. The heavy hydrocarbons require high vacuum distillation to obtain slack waxes (Larrain., et al 2020). Slack waxes have many industrial applications, for example, wood protection, candle making, emulsions, etc (European Wax Federation, 2023). The C_5-C_{22} hydrocarbons (liquid products) are widely discussed in the literature (Ragaert et al., 2017). Yet, research on the distillation of C_{22+} heavy hydrocarbons is scarce. To valorize the C_{22+} hydrocarbons, it is crucial to study the distillation using the ASTM D5236 vacuum Potstill method.

2. Materials and methods

The waste HDPE pyrolysis oil investigated in this study was obtained from a Belgian plastic recycling company. The pyrolysis process was carried out at 450 °C and 1 bar. The distillation was conducted in a Potstill ASTM D5236 batch setup (BR Instruments USA), as shown in Fig.1. The setup consists of a boiling flask with a capacity of 5 L. The distillation column has two entrainment trays to prevent vapor and liquid mixing. The setup is also provided with a chiller to operate the condenser and a fraction collector to allow switching between fractions. The vacuum pump is capable of producing a high vacuum of 0.1 mbar accompanied by vacuum traps designed to capture vapors and prevent their exhaust. The temperature and pressure were recorded on the LabVIEW program. The distillation was performed according to the ASTM D5236.

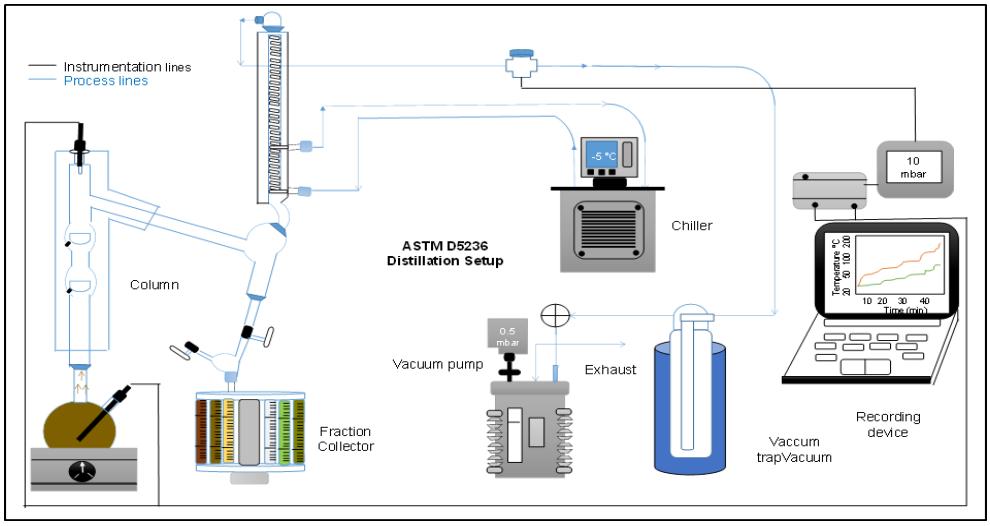

Fig. 1: High vacuum Potstill distillation setup

3. Results and discussion

Potstill distillation of HDPE pyrolysis oil separated light waxes (C_{23}-C_{29}) and heavy waxes (C29-C36). Fig.2 represents distillation yields for HDPE pyrolysis oil. It can be seen that HDPE pyrolysis oil produces 71.7 wt % liquid fraction from C_5-C_{22} hydrocarbons, while the solid residue was 22.8 wt% along with 6.2% losses during fractional distillation. The yield of light slack wax (C_{23}-C_{29}) was 6.7 wt%, and that of heavy slack wax (C_{29}-C_{36}) was 12.8 wt %. The C_{36+} residue was 1.9 wt%, including a minor loss of 1.3 wt%.

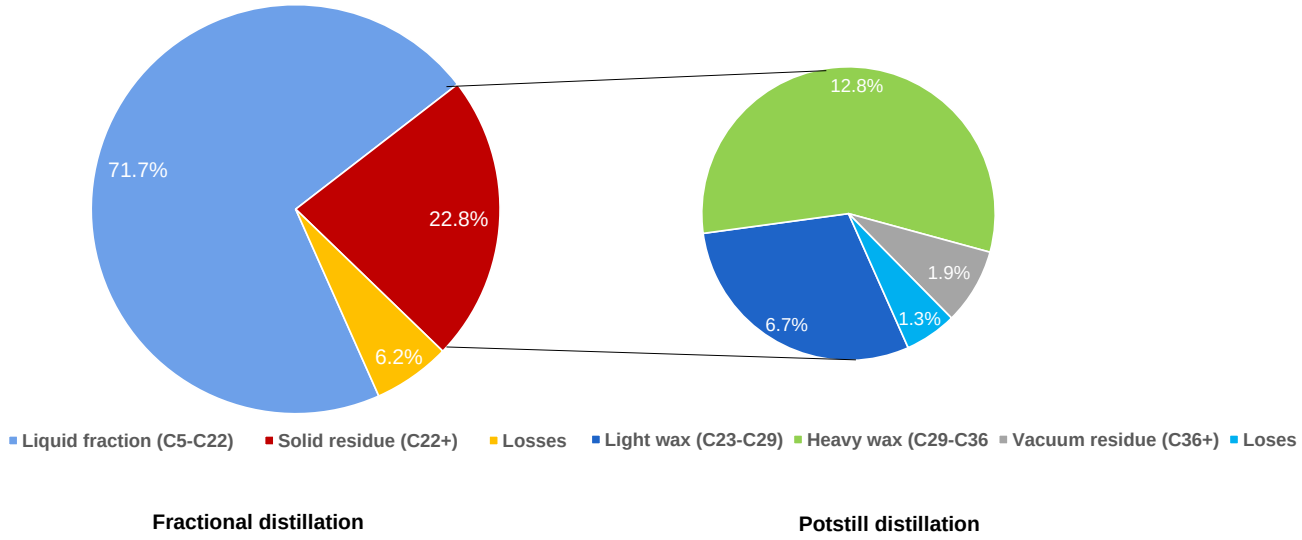

Fig. 2: Overall yield of HDPE pyrolysis oil distillations.

Slack wax applications are based on their physical properties and chemical composition. Thus, it is crucial to analyze melting point, density, viscosity, type of hydrocarbons, and chain length. This presentation will show how to produce slack waxes with narrow boiling from HDPE pyrolysis oil using the ASTM D5236 vacuum Potstill method. Furthermore, insights will be provided on yields and comparative properties of the initial oil, slack waxes, and reference industrial waxes.

4. Acknowledgment

This work was financially supported by the Catalisti-ICON project, “Plastics to Precious Chemicals (P2PC)”, Project code: HBC.2019.0003 funded by Flanders Innovation & Entrepreneurship (VLAIO) and Higher Education Commission of Pakistan (HEC) for scholarship under “HRDI-UESTPS/UETS” program.

References

Abbas-Abadi, Zayoud, A., Kusenberg, M., Roosen, M., Vermeire, F., Yazdani P., Waeyenberg, J.V., Eschenbacher A., Hernandez, F.J.A., Kuzmanović, M., Thi, H.D., Kresovic,U., Sels, B., Puyvelde,P.V., Meester, S.D., Saeys, M., Geem Kevin, M. V., (2022). Thermochemical recycling of end-of-life and virgin HDPE: A pilot-scale study. Journal of Analytical and Applied Pyrolysis., 166, 105614.

European Wax Federation. (2023). https://www.wax.org/about-us/applications.html, Accessed on 26/12/2023.

Lee, D., Nam, H., Wang, S., Kim, H., Kim, J. H., Won, Y., Lee, K.H. (2021). Characteristics of fractionated drop-in liquid fuel of plastic wastes from a commercial pyrolysis plant., Waste Management, 126, 411-422.

Larrain, M., Steven, V. Passel.,Gwenny, T., Kresovic, U., Alderweireldt, N., Moerman, E., Billen, P., (2020). Economic performance of pyrolysis of mixed plastic waste: Open-loop versus closed-loop recycling, Journal of cleaner production., 270, 122442.

Ragaert, K., Delva, L., Geem. K.V. (2017). Mechanical and chemical recycling of solid plastic waste, Waste Management., 69, 24-58.

Zeb, W., Roosen, M., Knockaert, P., Janssens, S., Withoeck,mD.,nKusenberg M., HogiemJ., Billen P., Tavernier S., Geem, K.M.V., Meester, S, D. (2023). Purification and characterisation of post-consumer plastic pyrolysis oil fractionated by vacuum distillation., Journal of cleaner production,416, 137881