

Characterization of the Volatile Fraction of Used Wind Turbine Blade Pyrolysis Oil by Two-Dimensional Gas Chromatography

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Abstract:

With the global expansion of the wind energy sector, developing sustainable solutions for the disposal of wind turbine blades (WTBs) has become increasingly critical. While most turbine components, such as concrete and steel, are easily recyclable, the blades present a greater challenge due to their complex composition including wood, resins, coatings, glass fibers, and unsaturated polyester matrices. Consequently, efficient recycling processes are needed to divert blades from landfills and recover valuable materials.

This study focuses on the volatile fraction generated through one of the most promising recycling methods, pyrolysis, analyzed using comprehensive two-dimensional gas chromatography (GC×GC) coupled with time-of-flight mass spectrometry (TOFMS) and flame ionization detection (FID). Two column configurations, normal (non-polar × mid-polar) and reverse (mid-polar × non-polar), were compared to improve separation and semi-quantification of chemical families, with particular emphasis on oxygenated compounds. Indeed, these molecules are of special interest because they can influence the macromolecular properties of recovered materials and act as catalyst inhibitors.

Both configurations revealed a predominance of aromatic compounds, along with smaller amounts of normal and iso-paraffins, naphthenes, and olefins. Over 800 compounds were detected, including approximately 80 oxygenated species such as ketones, aldehydes, esters, alcohols (including phenols), and carboxylic acids. The results underscore the complementary strengths of both chromatographic setups. This approach not only enables semi-quantification of key chemical classes, particularly oxygenated molecules, but also links these species to their origin within the unsaturated polyester resin. Such molecular-level insights into WTB pyrolysis oil are essential for advancing effective recycling strategies for composite materials.

Keywords: GC×GC, pyrolysis oil, wind turbine blades, oxygenated compounds, recycling, composites