Study of biomass pyrolysis for hydrogen production: Impact of pyrolysis conditions on products yield

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Abstract:

Hydrogen production through lignocellulosic biomass pyro-gasification is a promising pathway for sustainable energy generation [1, 2]. This process involves two main steps: biomass pyrolysis, which produces char, followed by char gasification with steam to generate hydrogen. The characteristics of the char (yield and quality) play a crucial role in the efficiency of the gasification step and are strongly influenced by pyrolysis conditions, particularly temperature, heating rate, and residence time. Additionally, particle size impacts the homogeneity of the resulting char.

This study investigates the influence of these parameters on product characteristics by combining numerical simulations with experimental validation. Biomass particles from maritime pine wood pellets (Gascogne Bois) are pyrolyzed in a TGA/DSC 3+ from Mettler under different conditions (fixed or variable temperature, variable residence time). Thermogravimetric analysis (TGA), coupled with Differential Scanning Calorimetry (DSC), enables the identification of distinct stages in biomass pyrolysis by measuring mass loss as a function of temperature, thus providing key thermodynamic parameters of the reaction. The pyrolysis gas is analyzed using Gas Chromatography (GC) and Mass Spectrometry (MS), while the char is characterized by Infrared Spectroscopy (FTIR). This experimental approach provides insight into the kinetics of pine wood pyrolysis and allows for the prediction of product yields under varying conditions.

The pyrolysis process is simulated using the open-source software PATO, which models pyrolysis coupled with heat and mass transfer in porous media. The evolution of char properties and gas production is determined based on a pyrolysis reaction mechanism, which describes the process as a sequence of chemical reactions. Some mechanisms simplify biomass as a single homogeneous component undergoing a single global reaction, while others consider biomass as a mixture of distinct subcomponents (e.g., cellulose, hemicellulose, lignin), each decomposing through its own set of reactions. The model used in this study follows a more detailed approach, where multiple competing reactions occur simultaneously, influencing the final product distribution. One of the most widely used frameworks is the mechanism developed by Ranzi et al. [3], which decomposes biomass degradation into a series of competing reactions. This mechanism will be implemented in PATO and optimized to fit experimental data, providing a robust description of pine wood pyrolysis.

References

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