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Low-temperature transformation of biomass: challenge for chemical reaction engineering

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The global tendency towards the use of renewable sources is a big challenge not only for conceptual chemical technology, but to chemical engineering, too. We are shifting from relatively simple molecular structures appearing in crude oil and natural gas to the very complex ones in biomass. Molecules originating from biomass are, typically polyfunctional macromolecules. On the other hand, biomass is a well-organized entity, consisting mainly of cellulose, hemicelluloses and lignin. The sugar platform of a future biorefinery is based on bio-chemical conversion processes of biomass to sugar feedstocks, while the syngas, pyrolysis platform is based on thermo-chemical conversion processes of biomass to synthesis gas or pyrolysis oils for chemicals, materials and fuels.

There are still several problems to be solved to make the mild-temperature sugar platform working in practice. One of the key issues is the catalyst development. In order to obtain platform chemicals from cellulose and hemicellulose, the glycosidic bonds should be broken by hydrolysis. Several catalysts have been proposed, such as homogeneous mineral and organic acids, heterogenized acid catalysts on carbon support, cation exchange resins as well as enzymes. The hydrolysis kinetics of polysaccharides in the presence of several catalysts is considered, along with kinetic modelling of autocatalytic phenomena appearing in the hydrolysis of polysaccharides. A new kinetic model for the hydrolysis kinetics has been developed, taking into account the differences in the reactivities of the glycosidic bonds in the polymer chain.

From the mild-temperature hydrolysis process, valuable monomeric sugars are obtained: besides glucose, polyfunctional molecules, such as arabinose, galactose, mannose and xylose are obtained. These molecules can be used as such, or refined further, e.g. by hydrogenation, oxidation and isomerization. The process intensification approach starts with catalyst selection and optimization, kinetic studies, investigation of physical properties as well as mass and heat transfer phenomena. In general, it can be stated that the interaction of chemical reaction kinetics and internal mass transfer effects in the pores of solid catalysts plays a crucial role in the transformation of molecules from biomass. In many cases, catalyst deactivation interferes with kinetic and mass transfer phenomena.

Several examples of the application of continuous structured reactors on the transformation of sugars to value-added molecules are shown in the lecture. The approach covers the following possible aspects: from the optimization of catalyst nanoparticles to the design of structured elements, kinetic and mass transfer studies, mathematical modelling of individual catalyst particles and continuous reactors. A general research strategy will be presented: from reaction kinetics to reactor design.

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