Department of Industrial Engineering

Ph.D. Course in Chemical Engineering

(XIV Cycle - New Series)

Thesis in Chemical Engineering

PROCESS OPTIMIZATION OF A LIGNOCELLULOSIC MULTI-PRODUCT BIOREFINERY

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Abstract

A methodology to reduce the complexity of the process optimization was applied to multiproduct biorefinery fed by lignocellulosic biomass. A process superstructure was built to consider alternative process pathways to levulinic acid, succinic acid and ethanol. A Mixed Integer Non-Linear Problem was obtained and transformed in a Mixed Integer Linear Problem by means of a discretization procedure of the non-linear variables. Rigorous design methods accounting for complete kinetics schemes for hydrolysis and fermentation reactors for the production of levulinic acid, succinic acid and ethanol were included in a biorefinery superstructure optimization. A discretization method was applied to obtain a MILP approximation of the resulting MINLP master problem. The optimal flowsheet of a biorefinery with hardwood feedstock, obtained by maximizing the Net Present Value, yields comparable biomass allocation to levulinic acid and succinic acid (more than 40% each) and the its balance to ethanol. A sensitivity analysis highlighted that the optimal flowsheet and the relevant technical and economic performances are significantly dependent on the economic scenario (chemical products selling price, discount rate) and on the plant scale. Finally, process optimization achieved by maximizing two different economic objective functions, Net Present Value and Internal Rate of Return, provided different optimal flowsheets and biomass allocation to chemical products. The effect of the change of the biomass type and composition on the plant was also considered. Results highlight that the composition of the biomass feedstock in terms of cellulose, hemicellulose and lignin has a significant effect on the biomass allocation to the three product production processes and on the relevant optimal flowsheet. Case studies with a combined use of different seasonal biomass types during the year were also studied to provide a methodology to find the optimal biorefinery flowsheet in real scenarios. In the season based scenario studied, product yield distribution and overall productivity of the plant varies during the different periods provided a constant biomass feed rate.