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Process integration of near-neutral hemicellulose extraction in a Scandinavian kraft pulp mill – Consequences for the steam and Na/S balances

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ABSTRACT

While in a conventional kraft pulp mill, most of the hemicellulose and lignin fraction of the wood is burned in the recovery boiler to produce steam, in a biorefinery it can partially be used to produce added-value products. In this paper, the most important consequences of integrating a bioethanol production plant with a model pulp mill are presented in terms of steam and Na/S balances. The model mill represents an average Scandinavian hardwood kraft pulp mill, and the bioethanol plant is based on the "near-neutral" hemicellulose pre-extraction method. Regarding the steam balance, a comprehensive heat integration study is performed. Implementing hemicellulose extraction increases the net steam demand by 48 MW. However, process integration at the mill and the bioethanol plant individually leads to significant steam savings, and a corresponding net increase of steam by only 3 MW. Additional steam savings can be achieved if the total integration of the two processes (between the pulp mill and the bioethanol plant) is considered (3 MW), resulting in a biorefinery with no increase of steam demand. As regards the Na/S balance, it is shown that green liquor export from the mill to the bioethanol plant results in severe disruptions in the sodium and sulphur balance of the mill. Different attempts to solve this problem are discussed, but are very costly and/or negatively affect the water and steam balance of the mill.

1. Introduction

The Nordic pulp and paper industry is currently facing several challenges such as rising energy costs, strong competition from countries with significantly lower feedstock and production costs, and decreasing demand for some paper grades. Consequently, efforts have been made to increase the energy efficiency of mills and to diversify the mix of products.

Previous studies have shown that it should be possible to reduce the steam demand and/or to create a steam surplus in both chemical and mechanical pulp mills via process integration [1–6]. Excess heat at the mill facilitates the integration of biorefinery concepts, thus enabling additional products which can increase both the profitability and sustainability of mills. An overview of several biorefinery concepts in pulp mills has been presented previously [7,8], for example hemicellulose extraction to produce ethanol, lignin extraction to produce new chemicals or materials, and biomass gasification to produce transportation fuels. However, integration of biorefinery concepts is challenging since the steam production capacity at the mill is diminished as wood components are withdrawn from the pulp line. Moshkelani et al. [9] have developed a methodology to perform high levels of process integration and intensive energy efficiency, and concluded that the sustainability of biorefinery concepts depends upon the successful implementation of intensive energy integration and optimization measures.

As previously mentioned, large potentials for process integration in kraft pulp mills have been identified in earlier studies. The importance of process integration for different biorefineries has also been discussed by several authors; for example, Jönsson et al. [10] compared the profitability and carbon dioxide emissions of different technology pathways for using excess steam in a typical Scandinavian pulp mill. Garcia et al. [11] studied the consequences of integrating the organosolv process (for fractionating wood components) into a mill. Fornell et al. [12,13] studied the total conversion of a pulp mill into a bioethanol plant as well as the production of dimethyl ether (DME) by gasification of black liquor.

A biorefinery concept that continues to gain attention is lignocellulosic bioethanol production, as it may replace fossil fuels in the transport sector. According to Hämäläinen et al. [14], the increasing price of oil is the most important incentive for forest biorefineries in Scandinavia, North America and South America.

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