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Chemical process simulation for minimizing energy consumption in pulp mills

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ABSTRACT

Chemical process simulation has proven to be an effective tool for performing a systematic and global analysis of energy systems to identify routes for maximizing the process efficiency concerning to the heat recovery. This paper shows an application of computer simulations in a Brazilian pulp mill, using two strategies for minimizing the mill energy consumption. In the first one, the overall heat transfer coefficient has been predicted for each body of the multiple effect evaporators by using continuous on-line data from the industrial plant in the black liquor recover unit. By monitoring oscillations of this heat transfer coefficient, the suitable time for washing the evaporator heat transfer surfaces can be well determined, reducing the energy loss during black liquor evaporation. In the second strategy, the liquor combustion has been simulated as function of the black liquor solids concentration to analyze its effect on the recovery boiler efficiency improvement.

1. Introduction

Pulp and paper industries, one of the most important sectors in Brazil, require a high efficiency to produce the pulp. Therefore, one important goal of this sector is to minimize the energy consumption in the process. Note that there are several ways to find the most appropriate operating conditions for a specific pulp mill. One of them is the computer simulation, which is more economical and represents a useful tool for evaluating possible process alternatives (i.e. changes to new equipment and/or different operating conditions). Nowadays, there are several modeling and simulation software tools available. The most simulators used in pulp and paper industries are listed in Table 1 [1,2]. These software simulators are constituted of (i) modular units, representing the operations that occur in the pulp industry; (ii) executive program, responsible for administrating the modular units; and (iii) databases of physicochemical and thermodynamic properties of all components involved in the pulp process. In the present work, WinGEMS [3] has been chosen for predicting and simulating the specific changes in the overall process.

WinGEMS is a modular program designed to perform the mass and energy balance calculations. Calculations are grouped together in modules called blocks. The program has a wide selection of blocks, which perform specific process calculations. These blocks must be chosen and linked for creating the block diagram (flowchart), which should represent the specific industry.

Considering the complexity of the heat fluxes in the pulp industry plants, it is essential to evaluate different and specific operation condition alternatives to choose the best option for minimizing the energy consumption. This paper shows how to use this methodology as an efficient tool for industries.

To illustrate this use, two different scenarios have been tested as followed:

1.1. Case 1: Black liquor evaporation

The overall heat transfer coefficient has been predicted for each body of the multiple effect evaporators in the black liquor recovery unit, using continuous on-line data from the industrial plant [4]. With measurements on-line, the suitable time for washing the evaporator heat transfer surfaces can be well determined by monitoring continuously the predicted value of this heat transfer coefficient (including time oscillations).

1.2. Case 2: Black liquor boiler recovery

To analyze the effect of increasing the liquor solids concentration on the recovery boiler efficiency, the liquor combustion has been simulated as a function of the solids content in the liquor feeding this boiler [5].

2. Brief description of the pulp process

Pulp mills can be divided in two major processing lines: fiber and chemical recovery [6] (Fig. 1). The fiber processing line extends from the wood digester to the pulp bleaching section, passing by

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Table 1
Available simulators applied in the pulp and paper process [1,2]

Simulator	Institution or company
FlowCalc – flowsheet calculation	Simulation software
General energy material and balances system – GEMS;	Department of chemical engineering at university of Idaho and Pacific simulation
WinGEMS (GEMS version for Windows)	http://www.pacsim.com http://www.metsoautomation.com
Modulate analysis of pulp and paper systems – MAPPS	Institute of paper science and technology
Mass and energy balances – MASSBAL	SACDA Inc. (Systems analysis control and design activity) and Open Models Inc. http://www.openmodels.com
Advanced system goes process engineering – ASPEN PLUS	Aspen Technology, Inc. http://www.aspentech.com
CADSIM PLUS	Aurel Systems Inc. http://www.aurelsystems.com

the brown pulp washing step. The main goal of the fiber processing line is to remove lignin from wood and to achieve high brightness pulp in the end bleaching sequence. The chemical recovery cycle is necessary to make the pulping process economically feasible. The sub-product, extracted from pulping wood in the digester, called the black liquor, is concentrated by multi-effect evaporation system and burned in the recovery boiler where the combustion of organics provide energy to produce high pressure steam and to carry out the reduction reactions to recover Na_2S and Na_2CO_3. The inorganic product of the boiler recovery is used to regenerate the sodium hydroxide and sodium sulfide needed for pulping.

2.1. Evaporation

As shown in Fig. 2, the evaporation plant of a specific Brazilian mill, which has been chosen in this work, includes six effects, containing a total of eight falling film plate evaporators. In the first effect, which includes three evaporators (bodies), usually only two bodies are in normal operation while the other is being washed. This washing operation rotates regularly from body to body to provide the appropriate cleanness for all of them. From Fig. 2, it can be seen that the weak black liquor (with solids concentration about 15%) feeds the sixth, fifth and fourth effects. Then, the liquor flows countercurrently to vapor, finally leaving the first effect to expand in the flash tank where it attains the final solids concentration before entering into the storage tanks for strong liquor.

Scaling on black liquor evaporators is a serious problem, which must be overcame for improving the Kraft mill production [4]. This problem always occurs when the black liquor is concentrated at 48% of solids, above which the limit of solubility of sodium carbonate (Na_2CO_3) and sodium sulfate (Na_2SO_4) is attained. Then, Na_2CO_3 and Na_2SO_4 form the soluble double salt: burkeite ($2Na_2SO_4 \cdot Na_2CO_3$), which deposits on the equipment walls. The final evaporation stage occurs in the first effect and the liquor flow pattern in the first effect body is switched at regular intervals to ensure that the heating elements are continually washed with incoming weak black liquor. This should prevent the buildup of scaling on the heat transfer surfaces. However, the washing operation can become ineffective since it is normally carried out after fixed time periods, generally without any investigation on the real condition of evaporator surfaces. Thus, an excessive washing or a lack of washing may occur in such situation. This finding motivates the current work to analyze variations in the overall heat transfer coefficient (U) in order to define the time for washing. By specifying the washing time when the performance of the evaporator drops to a predetermined level (i.e. when the U-value decreases from a level stipulated by the statistical analysis), it is possible to minimize energy consumption and production losses.

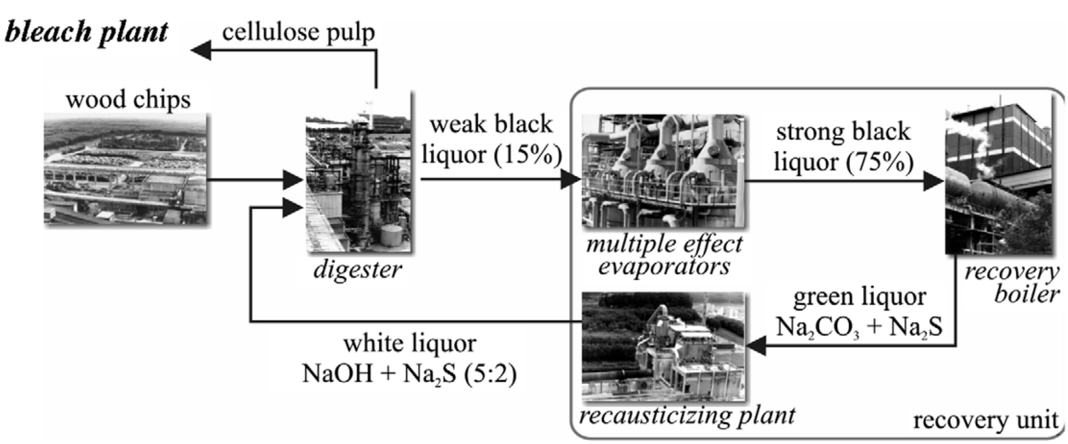

Fig. 1. Schematic representation of the pulp mill plant.

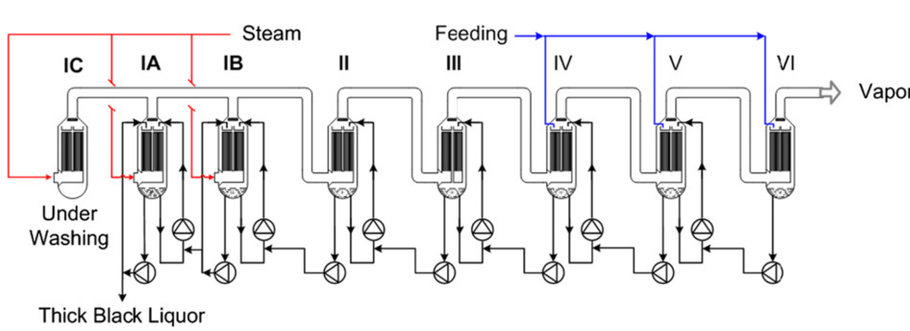

Fig. 2. Flowchart of the industrial evaporation unit of the Brazilian mill.