Monitoring carryover at the brownstock washers

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Abstract: Brownstock-washing efficiency affects bleach plant chemical consumption as well as the load to the chemical recovery area. We investigated the effects of the dilution factor on mill operating costs with the aid of spreadsheet calculations to identify the optimum dilution factor. A study of one mill's washing operation showed that increasing the dilution factor on the last brownstock washer from 2.3 to 4.2 yields a saving of about $1 million/yr for a 700-tpd kraft pulp mill.

Brownstock washers are used to recover cooking chemicals from the product pulp. They constitute an important operation in the kraft chemical-recovery system as optimization of washer performance affects both the financial and environmental success of a pulp mill. Minimization of carryover to the bleach plant reduces both bleaching chemical costs and organic material in the bleach plant effluent. Brownstock washing efficiency is usually measured by measuring soda or saltcake loss or the COD carryover into the bleach plant. The operating target for saltcake carryover in most kraft mills is 5 to 15 kg of washable saltcake per tonne of pulp from the last brownstock washing stage to the bleach plant, regardless of whether or not the mill operates an oxygen delignification reactor. The correlation between black liquor solids (BLS) loss and saltcake losses in a conventional mill is 1.5 to 1.75 kg BLS/kg of saltcake loss from the brownstock washers [1]. This relationship is reduced to 1.0 to 1.25 kg BLS/kg saltcake following an oxygen stage [1].

Targets for washing efficiency are generally based on saltcake losses rather than on carryover of dissolved organics, even though the detrimental effects of organic carryover on viscosity, delignification efficiency, chemical consumption and organochlorine formation in the bleach plant are well recognized [2]. This practice is historical. It continues because simple, robust sensors are not available to monitor the carryover of dissolved organics [3]. A means to monitor such variables as TOC or COD, carried in the filtrate leaving with the pulp mat from a washer, or some other parameter that would predict bleach plant chemical consumption, is necessary for effective wash control in modern mills with generally good washing efficiency. To address environmental impacts, BOD5, COD, and colour are the important parameters to consider or monitor. From a bleaching chemical demand perspective, COD, BLS and soda loss are most important. From a chemical recovery perspective, BLS and soda loss are most important. The last two variables can be measured indirectly using the conductivity of the filtrate carried with the washed pulp stock. Conductivity can, therefore, be used to control brownstock washer efficiency. Conductivity is a simple, quick test to perform manually. It can also be measured in real time with an in-line sensor, and the collected data stored and analyzed in the mill's control system.

Several researchers have simulated the dynamic behaviour of a brownstock-washing system in order to develop automatic process control strategies that minimize the carryover of dissolved organics and inorganics to the bleach plant [4-7]. Implementation of a multi-variable control strategy for filtrate tank level control on a series of brownstock washers improved the cleanliness of the washed pulp and reduced variations in carryover [8]. This strategy was implemented using cascade feed-forward controllers on shower flows to eliminate interactions between filtrate tanks and new tuning rules for shower and tank level controllers [8]. The new tuning rules for the PI controllers were particularly successful in eliminating process oscillations and improving process stability.

For effective washing control, it is necessary to analyse the filtrate carried in the washed pulp mat in order to eliminate the long lag times associated with seal tanks. A simple filtrate sampler inserted below the repulping screw has been used to obtain filtrate samples [3], but it has also been found to be inadequate when washed pulp discharge consistencies are higher than 10-12%. We have identified, therefore, a commercial sampler capable of handling high-consistency pulp (up to 15%), while still extracting a representative filtrate sample from the pulp mat.

This report looks at the economic impacts that brownstock washing has on the other areas of the mill using a case study for one mill. The approach and analyses used are based on a paper by Compton [9].

MILL DATA

FOR CASE STUDY

The procedure outlined in the paper by Compton [9] was incorporated into a spreadsheet program that performed all the calculations and produced the necessary graphs to determine the optimum dilution factor for the brownstock washers. Compton’s method analyses the effects of varying the shower water flowrate on the last brownstock washer to determine the economic effects on mill operations. The amount of shower water applied on the last washer is used to calcu-
late the amount of steam required to raise the filtrate temperature and for evaporation in the multiple effect evaporators. From a curve of washing efficiency versus dilution factor, one can determine black liquor solids lost to bleach plant sewers. The loss of black liquor solids to the bleach plant is then used to calculate the amount of chemicals required for make-up and the saltcake make-up cost is, therefore, negligible.

The case study mill’s brown fibreline consists of a chip bin, Kamyr digester, atmospheric diffuser, knotters, two brownstock drum washers, an open screen room and a brown decker. The flow of wash liquor is counter-current to the pulp stream, starting at the brown decker with a mixture of fresh hot water and condensate. Filtrate from this decker is used on showers of the last brownstock washer and so on to the first brownstock drum washer, and then to the atmospheric diffuser. The computer model determined that the case study mill is currently operating the last brownstock washer at a dilution factor of about 2.3.

**RESULTS, DISCUSSION**

**Effect of Increasing the Dilution Factor:**

—**Costs:** Changing the dilution factor not only affects brownstock washer efficiency, but also has a major impact on evaporator loading. For a mill that has additional evaporator capacity, the cost of increasing the dilution factor is equivalent to the cost of additional steam required at the evaporators and a slight increase in pumping horsepower [9]. Dilution factor is the weight of wash liquor applied minus the weight of liquor leaving with the pulp mat divided by the weight of pulp and is based on the shower liquor flow rate and discharge mat consistency (kg water/kg pulp) [10]. Figure 1 shows the evaporation steam costs versus dilution factor for the case study mill. Two assumptions were made in developing this curve. First, the digester blow consistency was set equal to the pulp discharge consistency for the last brownstock washer. We also assumed that the evaporator system had extra capacity. If there is no extra capacity at the evaporators, then evaporation capacity can be increased by adding external heaters, evaporator bodies, or reconfiguring the bodies to operate with lower steam economies [9]. These modifications all have capital and/or operating costs associated with them.

For a counter-current washing system, increasing the shower flow rate on the last washer will increase the hydraulic flow of filtrate throughout the washing line, thereby increasing the electric power requirements for the filtrate pumps at each stage of washing.

Shower water temperature influences brownstock-washing efficiency, which increases as the water/filtrate temperature increases. However, the temperature must not be so high as to cause the filtrate to flash in the washer’s drop leg. The maximum operating temperature is normally between 70 and 80°C for drum washers [9]. The temperature of the incoming pulp and the shower on the last stage of washing, and the heat loss from the washers and filtrate tanks, determines the operating temperature of the washer line. One way of optimizing the washing operation is to control the shower water temperature. The case study mill currently operates its showers at 55°C. Figure 2 shows the cost associated with heating the shower water from 15 to 55°C as a function of the dilution factor used in the brownstock washing line.

Increasing the shower water temperature will lower its viscosity and enable greater diffusion into the sheet for better washing [10]. At temperatures above 60°C, hemicellulose becomes soft, opening the fibre structure and improving the flow of washing liquor through the pulp mat [12]. Low wash water temperatures, and those above 77°C, generally result in poor washing [13]. Mill experience has shown that the optimum wash water temperature is typically close to 70°C [14]. The increase in washing efficiency and savings in bleach plant chemicals that would result from an increase in shower water temperature can, however, only be estimated by a mill trial, as there are no known calculations to determine how washing efficiency varies with increasing shower water temperature.

—**Benefits:** On the positive side, increasing the dilution factor decreases the amount of black liquor solids lost to the bleach plant sewer, thereby reducing chemical make-up costs and organic loading on the effluent-treatment system. Additional savings result from decreased black liquor solids losses because these solids are kept within the chemical recovery system and now become fuel, which is used in the recovery boiler to generate steam. Pulp mills require a specific amount of steam to operate. The required amount of steam is generated by the recovery and power boilers. Returning black liquor solids to the recovery system decreases the demand for hog fuel by the power boiler. Figure 3 shows the equivalent fuel savings for hog fuel that result from returning more black liquor solids to the recovery system as a function of the brownstock washer dilution factor.
Decreasing the discharge of black liquor solids decreases the load on the effluent-treatment system. Saving in waste treatment costs can, thus, be achieved when there is a decrease in the concentration of black liquor solids discharged from the mill to the effluent-treatment system, Fig. 4. The calculated savings are based on the predicted reduction in required nutrient chemicals. A reduction in black liquor losses may also affect the number of aerators operating in the lagoon. As this is site-specific, no allowance for a reduction in aeration horsepower has been incorporated in this analysis.

The brownstock-washing efficiency has a major impact on operating costs for a bleached mill as it affects the consumption of oxygen in the delignification system, chlorine dioxide in the first bleaching stage and caustic in the second stage [9, 15]. The cost of the case study mill’s bleaching chemicals per tonne of pulp varies as a function of the dilution factor, Fig. 5.

**Over-all Cost / Benefit Analysis:** Figure 6 is reproduced from the Compton paper [9]. This graph can be developed for a specific mill by obtaining a pulp sample from the vat of the last brown washer. In the lab, the pulp sample is washed with various amounts of water (simulating varying dilution factor), and the amount of remaining saltcake and black liquor solids in the resulting washed pulp mat is measured. Alternately, the data for the graph can be obtained from the mill’s washer by varying the shower flow rate. The shape of the curve in Fig. 6 greatly influences the over-all economics and the final optimum dilution factor. The calculated effects of varying the dilution factor on chemical makeup, hog fuel (or equivalent fuel value of black liquor), effluent treatment and bleaching chemical costs are directly affected by this figure.

The various costs and benefits that result from varying the dilution factor (as illustrated in Figs. 1 to 5) are summed and plotted in Fig. 7, disregarding any impact that improved brownstock washing might have on the aeration requirements in the effluent treatment system. Operating the brownstock washers at the optimum point for the brownstock washers at this mill is with a dilution factor of about 4. There is very little to gain with higher dilution factors. The case mill is currently operating at about 2.3. Compton [9] and Korhonen [13] calculated similar optimum operating values, 4.5 and 4.0, respectively for bleached kraft mills.

Figure 8 shows the incremental savings per oven-dry tonne of pulp in the case study mill as a function of the dilution factor. Maximum savings are achieved at a dilution factor of 4.4, which produces over-all savings of $5 per oven-dry tonne of pulp when compared to current operations at a dilution factor of 2.3. Maintaining a dilution factor above 4 would be satisfactory, as there is very little to gain at higher dilution factors. However, in order to operate at the optimum dilution factor, the current evaporator system must be able to handle the extra evaporation load and weak black liquor flow.

**Economics of Brownstock Washing Control:** Brownstock washing is operated to supply the bleach plant with clean pulp and to separate the cooking chemicals from the pulp, while minimizing the amount of wash water used. At most mills, the last brownstock washer typically operates with a fixed shower flow rate, while the incoming pulp mass flow rate, as well as the amount of black liquor solids carried with it, can vary. Simply controlling the shower flow rate with pulp production provides a significant improvement towards minimizing mill operating costs. The measurement of filtrate conductivity provides the operator with an indication of the cleanliness of the pulp mat, and allows for a bet-
ter or more elaborate control strategy for the brownstock-washing system and additional benefits relative to filtrate tank level control [8]. Installation of a simple filtrate sampler and a flow controller would enable a mill to optimize the shower flow rate and minimize the carryover of black liquor solids to the bleach plant.

A Canadian mill has successfully tested such a system. Use of a filtrate sampler could also help the mill avoid possible over-use of shower water, thereby minimizing the volumetric flow of weak black liquor to the evaporators and maximizing black liquor density. Trials at another Canadian mill have also shown that the conductivity of the filtrate carried with the pulp mat can be used to minimize defoamer use. Based on the $5/odt of pulp savings estimated for the case study mill, a filtrate sampler, conductivity sensor and a control package should pay for itself in less than one month.

Washing control might also be applied beneficially to bleach plant washing stages such as D0; it might be possible to monitor the washing efficiency of this stage by measuring the UV absorbance of the filtrate from the pulp mat and use that measurement to minimize COD load to subsequent stages [15, 16]. This technique might also be extended to monitor the purity of contaminated condensates used for pulp washing and the COD and colour loading resulting from the severing of extraction stage filtrates [16].

**CONCLUSIONS**

Brownstock-washing efficiency has significant impacts on a kraft mill’s operating costs, as it affects bleaching chemical costs, the loading on multiple effect evaporators and effluent treatment system, and chemical make-up costs. The effect of the brownstock dilution factor on mill operating costs was investigated using a laboratory-developed washing curve, mill operating data and a series of spreadsheet calculations. Calculations based on the case study mill data, indicate that increasing the dilution factor on the last stage of brownstock washing from 2.3 to 4.2 would yield over-all savings of $5/odt or about $1 million/year for a 700-tpd kraft pulp mill. A complete brownstock washing control package would, therefore, have an expected payback period of less than one month. Operating a washing system at its optimum dilution factor will minimize operating costs, but it is only practical if the resulting volume of black liquor can be handled at the evaporators and pulp cleanliness meets the mill’s specifications.

**LITERATURE**


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**Résumé:** L’efficacité du lavage de la pâte brune a une incidence sur la consommation de produits chimiques à l’atelier de blanchiment ainsi que sur la charge à la zone de récupération des produits chimiques. Nous avons évalué les effets du facteur de dilution sur le coût d’exploitation de l’usine à l’aide d’un tableur, afin de déterminer le facteur optimal pour la dilution. L’étude des opérations de lavage d’une usine a indiqué que l’accroissement du facteur de dilution de 2,3 à 4,2 à la dernière pile laveuse de pâte brune permet d’économiser d’environ 1 million $ pour une usine produisant 700 tonnes de pâte kraft par jour.


**Keywords:** UNBLEACHED PULPS, KRAFT PULPS, ENTRAINMENT, WASHERS, MONITORING, DILUTION, EFFICIENCY, OPTIMIZATION, ENERGY CONSERVATION, CHEMICAL CONSUMPTION, BLEACH PLANTS, COST CONTROL, PROCESS CONTROL.