

The effect of optimizing the operating parameters of the washers on the washers' efficiency and the overall economy of a mill

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ABSTRACT

The operation of the brown stock washing of a pulp mill's fiber line has a significant impact on the mill's energy economy, material efficiency and environmental emissions. With efficient and optimized washing, which is monitored by real-time concentration measurements, water consumption can be reduced, resulting in saved energy in the evaporation.

Optimizing the operation parameters of the washers affects the efficiency of the washer's operation and thus also the washing results. Even with a smaller amount of washing liquid, a sufficient carryover level of the pulp can be achieved for the following processes, if the washer works more efficiently. On the other hand, the dilution factor directly affects the load going to evaporation. Recently, the price of electricity in Europe has fluctuated strongly, and the energy economy of pulp mills has been viewed even more closely.

In this work, an on-line efficiency calculation based on total dissolved solids measurements was built for washers after cooking. The optimum driving mode for the washers was studied by experimenting with different feed and washing consistencies and monitoring the washer's operation with real-time TDS measurements.

The effects of air/gas on the washing performance were also studied.

INTRODUCTION

The motivation behind boosting fiberline efficiency, and especially brown stock washing performance, is economically and environmentally driven. Dissolved material should be removed efficiently, collect and sent to evaporation with an as high as possible solids content to increase steam and electricity production. Efficient washing improves the recovery of cooking chemicals (Na and S) and wood-based dissolved organic material. It also reduces the additional consumption of reagents in the subsequent bleaching stages (1). Since a washing filtrate from brown stock washing is finally introduced via an evaporation step into the recovery boiler, it influences the energy balance of chemical pulping. The higher the total solids content of a filtrate from the washing, the lower the steam consumption that is needed during black liquor evaporation. More water that goes to evaporation, the more steam that has to be used to drive it off. At the new pulp mills, new bioproducts also increase profitability. A balance must be found in the relationship between the price of current electricity and the price of pulp, chemicals and new products. Without effective washing, the economic viability of chemical pulp production is affected.

The parameters that affect the operation and determine the performance of a washing system can be divided into process conditions, such as dilution factor, feed and discharge consistencies, pH, temperature and entrained air, and equipment-specific parameters, such as a particular traveling speed, mechanical pressure or fluid pressure or vacuum (2,3). In this work we concentrated on the effect of feed and discharge consistencies and entrained air on the performance of washers. Washers like DD-washers, a high washing consistency is favorable in terms of washing efficiency, as long as it does not resist drainage of the wash water (4,5). Additionally, it has an influence on the electrical energy consumption and on the design of equipment. On the one hand, a low feed consistency means that large volumes of filtrate are pumped to dilution points before the washer, and consequently much electrical energy is required for pumping. The feed consistency also determines the amount of liquor that must be removed from the pulp suspension in the dewatering zone of the washing equipment, so it means the size of the dewatering zone and the filtrates tank and so the consistency has an influence on the capacity (2).

Air in the pulp retards its drainage. Hakamäki and Kovasin (6) found that the capacity of the test bed washers decreased 25 % when the pulp air content grew from 0 to 5 vol-%. According to Kurtz (7), free air which passes along with fibers could create permanent foam that blocks channels, and when it breaks, it flocculates impurities which are accumulated in the bubbles. In addition, very small air bubbles reduce drainage, because bubbles block the spaces between fibers and then make flow through a fiber net complicated. The dissolved air in wash filtrates could also cause bubbles, which complicates drainage even in ideal circumstances. Wang et al. (8) also state that small bubbles (<2mm) remain trapped in the pad on the washer drum. Recent studies (9–12) have shown that in Scandinavian softwood pulp mills, the average oxygen delignification bubble size is even smaller, about 0.1mm and in the hardwood mills about 0.5 mm. So, after O₂ delignification there could be small bubbles and dissolved air/gas, which is released when the pressure drops, and this can cause problems in washing again if the air/gas cannot be removed (13).

In this work, the performance of a washer, where the pulp is washed using a displacement operation, was studied using on-line process refractometers for monitoring. We have previously (3,5) published research results and it is presented in more detail in these articles.

MATERIALS AND METHODS

The consistency experiments for this study were carried out at a Scandinavian kraft pulp mill (A) which produces softwood pulp. In the fiber line (mainly Scots pine and Norway spruce), unbleached high-yield pulp is produced using batch cooking. The pulp is washed in two parallel lines, which both consist of a blow tank, a tramp material separator in the blow line, four-stage washers, refining, a screen room, two-stage washers, a vacuum filter, and a screw press. Production was about 700 a. d. metric tons/day during the research; the kappa target after the digester was 50. The measurement arrangements of the first four-stage washer in washing line 1, which was under investigation, are shown in Figure 1.

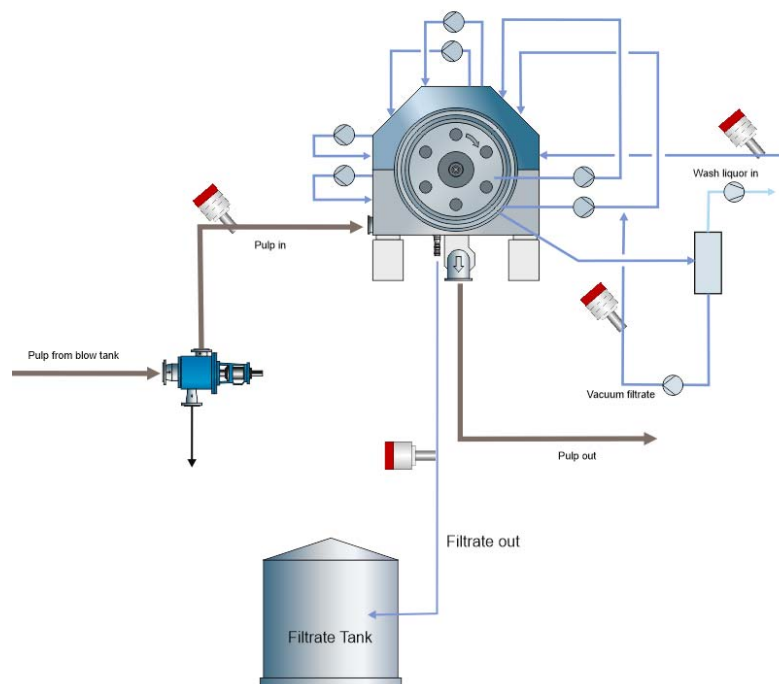


Figure 1. Measurement arrangements at the four-stage washer of the softwood pulp fiber line.

Individual measurements were also performed at another softwood mill B. In addition, at the swing mill (C), which produces hardwood (mainly *Betula pendula* and *Betula pubescens*) and softwood mainly (Scots pine and Norway spruce) measurement arrangements were built for the washers before and after the oxygen phase. Pulp fiber line C consists of a continuous digester with a high-heat wash in its lower section, two parallel washers after cooking and two parallel washers after the oxygen stage. The production target was about 3900 a. d. metric tons/day in softwood and 4500 a. d. metric tons/day in hardwood. Preliminary air/gas concentration measurements were made on the washers after the oxygen stage and the effects of air/gas concentration changes on the washers' operation were monitored. EchowiseTM gas concentration measurement and on-line bubble size imaging (12) were used for monitoring.

In the stepwise trials at Mill A, the feed and discharge consistencies were changed step by step. During the experiment, the concentration of TDS in the filtrate fraction of the washer's individual pulp/filtrate streams was monitored using on-line measurements. The measurement of TDS by process refractometers was used to create an on-line balance across the washing equipment. Real-time yield Y_{10} values were calculated from the balance sheet. The Y_{10} values are used in the results (Eq. 1). The idea of the Y_{10} value is to eliminate the influence of the feed consistency to the washer. The feed consistency is adjusted to 10 %. It is well-known that the feed consistency to a washer has an influence on the traditional wash yield. The Y_{10} value makes comparison of washers easier in terms of wash yields (14). The mill's data collection system was also utilized; the consistency and flowrate measurement results were used in the calculations.

$$Y_{C0,st} = 1 - \frac{L_{1,st}(x_{1,st} - y_2)}{L_{0,st}(x_{0,st} - y_2)} = 1 - \frac{L_1(x_1 - y_2)}{L_0(x_0 - y_1) + L_{0,st}(y_1 - y_2)} \quad (1)$$

$Y_{C0,st}$ = the wash yield at the standardized feed stock consistency

L_0 = the actual feed flow

L_1 = the actual discharge flow

$L_{0,st}$ = the standard feed flow

$L_{1,st}$ = the standard discharge flow from the washer

- all of these are presented as the ratio of the mass flow rate of liquid to the mass flow rate of bone-dry fiber

x_0 = the solute mass fraction in L_0

$x_{0,st}$ = the solute mass fraction in $L_{0,st}$

x_1 = the solute mass fraction in L_1

$x_{1,st}$ = the solute mass fraction in $L_{1,st}$

y_2 = the solute mass fraction in V_2 (wash liquid flow)

y_1 = the solute mass fraction in V_1 (actual filtrate flow)

The experimental data for the stepwise tests in Mill A are shown in Table I.

Table I. Mill experiments for Mill A

Test	Target of feed and discharge consistencies, %	Realized
0-level		5.0/12.7
1	4.4/10.5	4.6/10.5
2	5.0/10.5	5.0/10.5
3	4.7/11.75	4.8/11.75
4	4.4/13.00	4.8/13.00
5	5.0/13.00	5.0/13.00

RESULTS AND DISCUSSION

Stepwise trials

Feed and cake washing consistencies were changed during the test runs. It was noticed that the amounts of washing liquid and screw dilution were not standardized in relation to production. Thus, DF changed on a wide scale. It can be seen from Figure 2 that when DF is above zero, Y_{10} remains high. The results are like the longer monitoring period at mill B, in Figure 6. However, the changes in DF made it difficult to analyze the results.

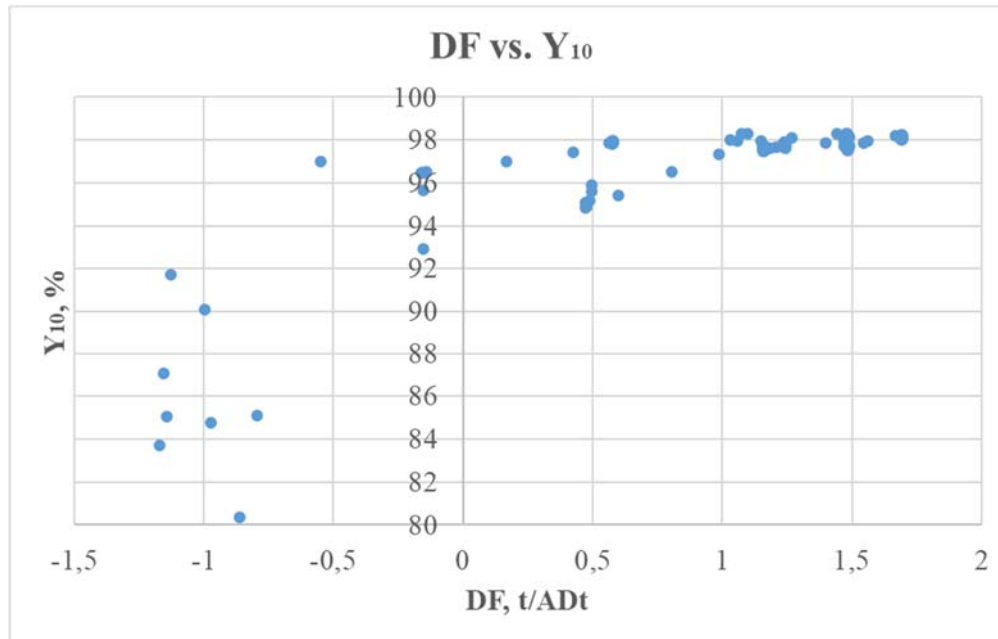


Figure 2. Effect of the dilution factor (DF) on the Y_{10} at Mill A.

By measuring the TDS content from pulp suspensions and washing liquor, it is possible to measure the washing results in real time. In addition, by measuring the three or four incoming/outgoing TDS streams to the washers together with the consistencies and flowrate measurements, it is possible to calculate the real-time effectiveness of the washer(s). Increasing the cake washing consistency from 10.5 % to 13.0 % improved the Y_{10} value from 95 % to 98 % at Mill A as can be seen in Figure 3. It is worth to mention that TDS content of the washed pulp was measured from the vacuum filtrate, which is higher than the TDS content in the washed pulp i.e. reported Y_{10} values are lower than real Y_{10} values. The low Y_{10} values with a cake washing consistency of 10.5% were due to the momentary low DF.

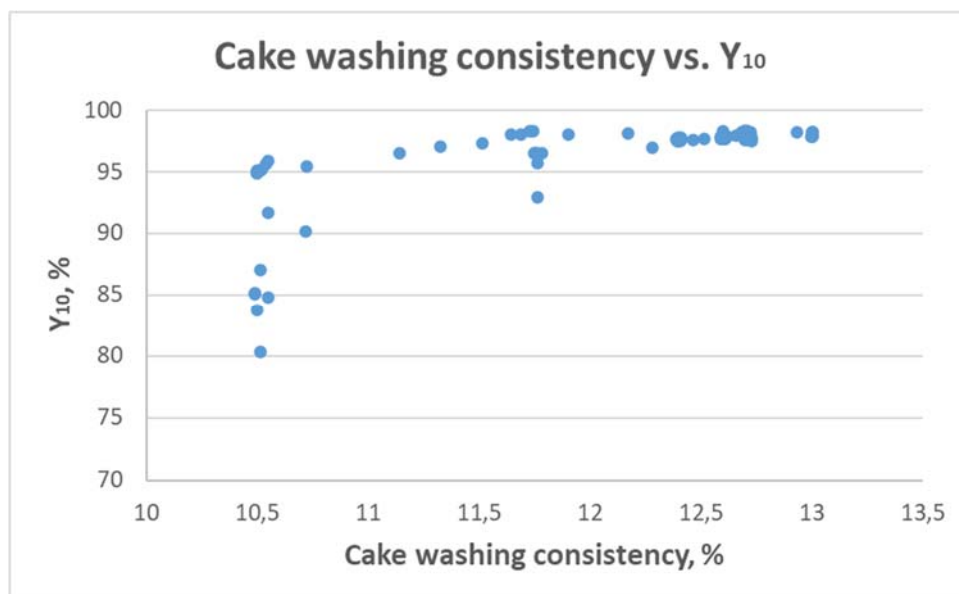


Figure 3. Effect of the cake washing consistency on Y_{10} value at mill A

Gas content/bubble size measurements

Figure 4 shows the rotation speed of the washer, the gas content of the post- O_2 washers' feed pulp and the production rate. It can be seen from the figure that the gas content for the washer varies greatly, normally 1 to 8 %. The measurements are sensitive to pressure changes, so the actual gas contents are slightly lower. Higher gas contents were observed when the temperature of the upper part of the second reactor in the oxygen stage was below 100 Celsius degrees and the suspension could not expand. The rotation speed of the washer follows the production and thus the effect of the gas on the drainage, at least with these gas mass fractions, is small. However, with the measurement, changes in the gas content entering the washer can be observed in real time, and the reasons for this can be searched.

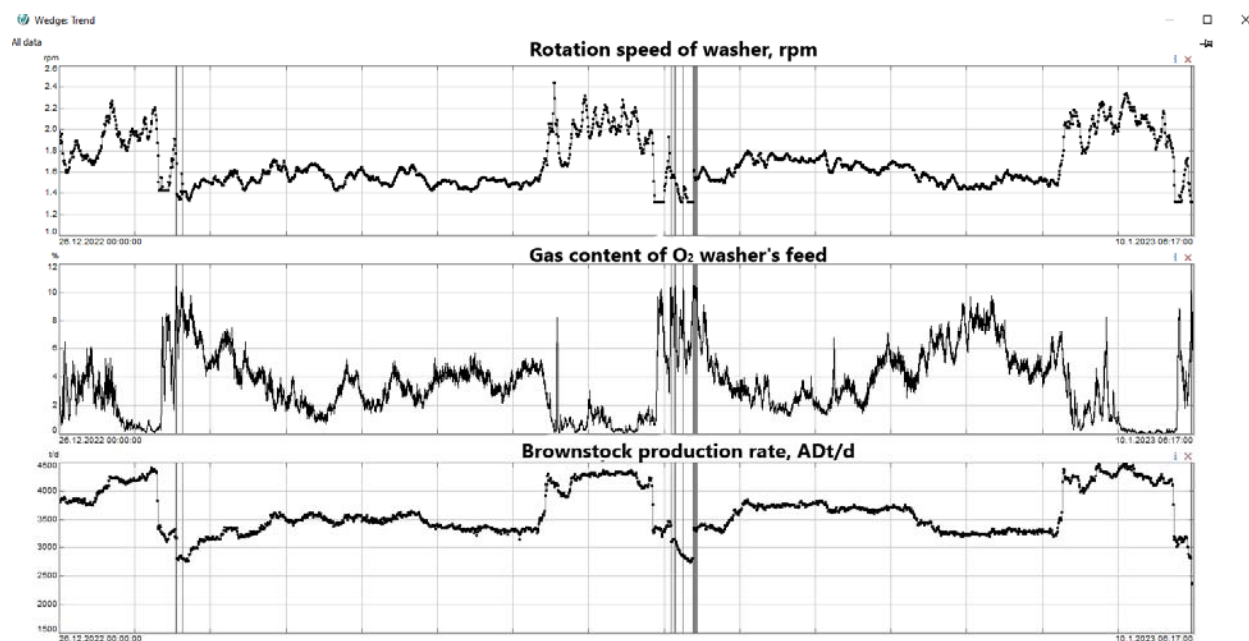


Figure 4. Gas content of post- O_2 washers' feed, rotation speed of washer and production at Mill C.

Figure 5 shows the gas content and temperature of the post-O₂ washers' feed pulp. It can be seen, when the temperature is lower, more gas goes into the washer.

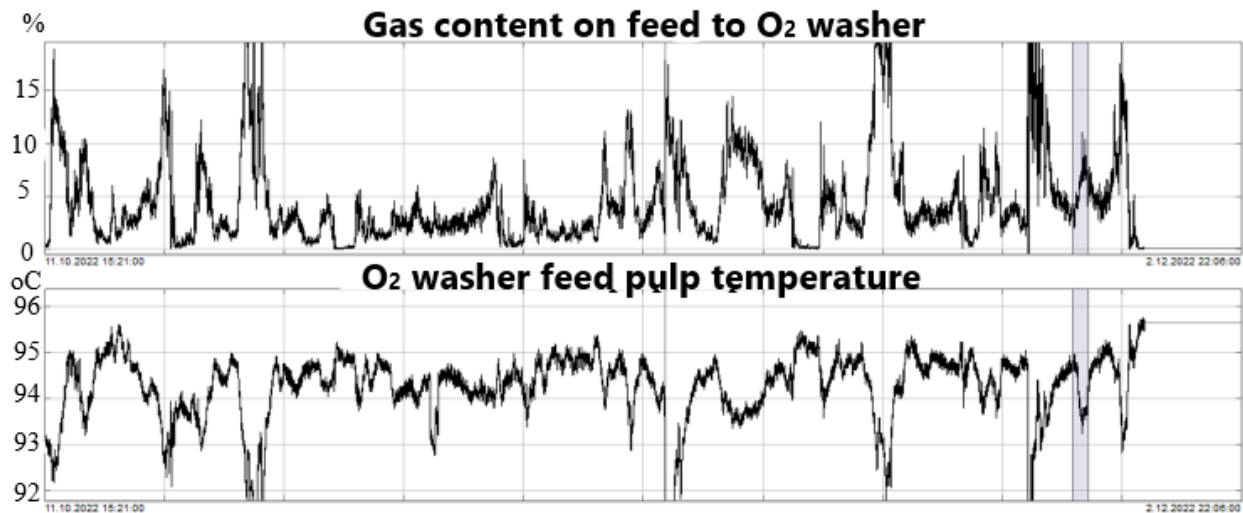


Figure 5. Gas content and temperature of O₂ washers' feed at Mill C.

CONCLUSIONS

The amount of dilution factor (DF) has a clear effect on the washing performance. The experimental results of the DF's effect on the displacement ratio are shown in **Figure 6**. Increasing the DF increases the displacement ratio and thus improves the washing results. On one hand, the results indicate that increasing the DF from 1 to 3 can slightly increase the displacement ratio (DR). On the other hand, when the DF decreases below unity, the DR of the washer decreases very quickly, yielding a low washer performance. The more effective the washing, the larger the change in DR when the DF is decreased. The DF should therefore be above unity to guarantee unimpeded washer performance. However, the use of a dilution factor above two is not feasible at the experimental mill, because the evaporation plant was a bottleneck. TDS measurements can be used to monitor DF, monitor the operation of the washer and whole fiber line. Since available DF is limited, it underlines necessity of efficient washing.

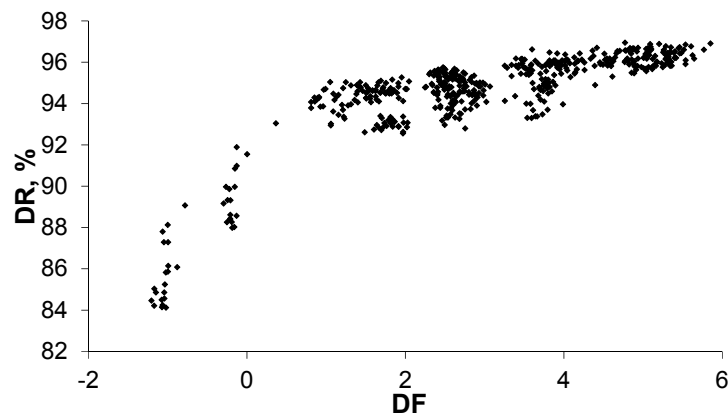


Figure 6. Effect of the dilution factor (DF) on the displacement ratio (DR) at Mill B.

By utilizing the measurement results from three/four refractometers plus the consistency and flowrate measurements, it was at least possible to create a measurement system which can calculate the effectiveness of a single washer accurately and in real time. The real-time measurement results for total dissolved solids (washable material) also enabled the determination of the correct real-time process conditions and the performance monitoring of the washers. This also gives an opportunity to optimize the amount of wash water and the results indicated that the water consumption had a great influence on the economy of the fiber line, such as evaporation and wash loss after a washing line

The results also showed that higher consistency during cake washing had a positive effect on the washing efficiency and the amount of air/gas in the pulp is possible to measure on-line.

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