Effects of Wood Chip Characteristics on Refining Energy Consumption

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ABSTRACT

Wood chip is a main raw material of the pulp and paper industry, its characteristics such as wood species, basic and bulk densities, moisture content, freshness, bark content, size distribution etc., strongly influence TMP refining energy consumption for a given pulp quality and productivity. In the TMP process, these variations lead to change in the mass flow rate in the chips fed into the refiner. The mill's experience shows us, for a normal operating condition, 30% of disturbances of the pulping process caused by these variations.

The TMP is a large consumer of electrical energy. A disc refiner, powered by 10-30 MW electric motors, is used to convert wood chips to high quality papermaking fibers. In this paper an online chip characteristics measurement system CMS^E (Chip Management System Extended Version) will be used to monitor online chip characteristics and a DSS (Decision Support System) will be built up to help operator to optimise refining energy.

A laboratory pilot refining experiment will be performed in order to study the impact of the variations of chip qualities on energy consumption. The results will be validated by mill trials, and TMP energy savings will be demonstrated.

INTRODUCTION

In the TMP (Thermomechanical Pulping) process, wood chip is the raw material and its characteristics such as species, freshness, size, density and moisture content are important factors affecting pulp quality [1]. It is believed that variations in these characteristics can lead to large deviations in both the quality of the produced pulp as well as the energy used to obtain it. Since TMP process is used in 80% of the newsprint production worldwide, it is imperative to make sure that the energy spent to allow this production is done efficiently, not for cost reduction purposes alone but also for resource protection purposes. Table 1 shows the Jackson and Wild estimate of the energy consumption for a 500 BDMT/D single-line TMP mill at 2400 kWh/BDMT, which is typical for TMP from black spruce chips for newsprint production [2].

Table 1 - Steam and Electricity Consumption

	Steam (GJ/ADt)	*Electricity (kWh/ADt)*
Chip handling		40
Refiners		2160
Pumps, screens, agitators, blowers		240
Heat recovery	-5.5	10
Total consumption	-5.5	2450

At present, variations in specific energy consumption (SEC) to obtain a desired quality can be relatively high. Usually there is a range of desired quality values, CSF (Canadian Standard Freeness) values for example, in which the produced pulp must maintain itself to satisfy customer demand. In this range, the obtained CSF can sometimes be near the upper limit or the lower limit. When the value is near the lower limit of the desired range, this means more energy is needed to reach the desired quality. When it is near the upper limit, an optimal consumption of energy for an acceptable quality pulp is used. Figure 1 shows an example of the variation of SEC for a CSF = 135 mL. Obviously, if the SEC variation can be minimised, it is possible to produce a pulp with CSF = 145 ml or approach its limit 150 mL for the same refining energy consumption, or less energy for the same CSF (135 mL).

We believe that one of the reasons for these large variations lies in the fact that while the relations between the refining process and pulp quality [3, 4, 5] and between process and chip characteristics [6, 7, 8] have been exhaustively studied, the relations between chip characteristics and pulp quality have been somewhat undermined. The unavailability of reliable technology for online measurement of chip characteristics can be a major factor in the scarcity of research in this area. However, with the CMS^E [11, 12, 13, 14, 15, 16], this problem can be solved and appropriate study of the effect of chip characteristics on different areas of the pulping process may go further.

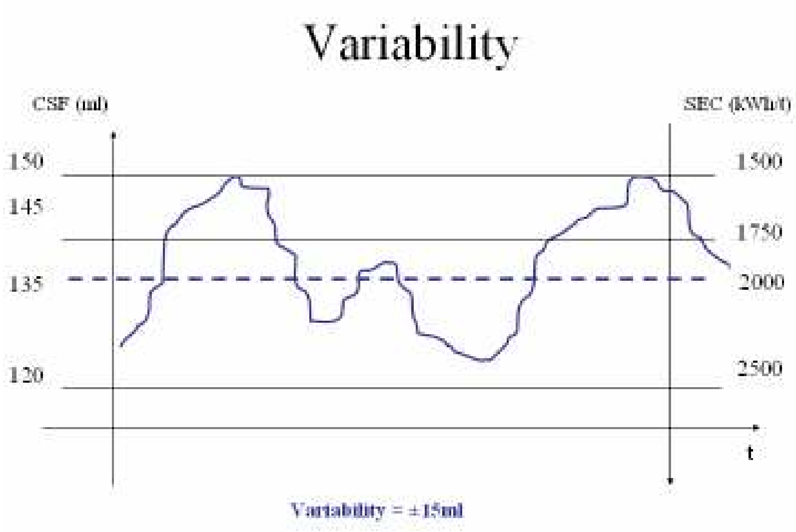

Figure 1 - Variability of SEC for a TMP process without feedback or predictive control

Specifically, the aim of the on-going study is threefold:

1. For a given pulp quality, study the effects of chip characteristics on refining SEC;
2. Use the these relations in a simulation in order to predict (predictive model) pulp quality from chip characteristics;
3. Minimize refining SEC by minimizing chip characteristic variability

At this time, the actual control strategies in the mills consist of feedback controllers on the feed screws to control primary motor load. Dilution for primary refiner is coupled with the feed screws. The variation of chip quality will act as a disturbance affecting the motor load because it is manipulated to control CSF of the pulp and can never be considered as an input of the control system.

EXPERIMENTAL

The method used to obtain the relations between chip characteristics and SEC for a given pulp quality will consist of chip quality evaluation, the pulping process and pulp quality evaluation

Chip quality evaluation is the first part of the employed methodology and basically represents the linking of the information found by the CMS^E to chip quality. The specific information having to be determined will be the following:

- ◊ chip freshness (luminance)
- ◊ wood species
- ◊ moisture content
- ◊ size distribution with regard to the width
- ◊ basic and bulk densities for each species

The pulping process will proceed such that the results will be useful to the associated mill. Therefore the priority will be to recreate the process conditions used at that mill. In particular, a 2 stage TMP process where the first stage is pressurized and the second is at atmospheric pressure will be used.

It is also important to mention that exhaustive laboratory tests at the pilot plant are going to be carried out in order to find the impacts of the wood chip characteristics on refining energy. These tests will explore different experimental values for chip properties (density, size, etc) that can not be tried in the context of a continuous mill production. Subsequently, mill trials will be performed to validate the laboratory results. The modelling and process control structure designs will be based on online mill measurements.

According to some Canadian mills' experience, variations in percentages of wood species have been proposed in the ranges seen in Table 2.

Table 2 - Mill variations in percentage of wood species

Wood species	*% of total mixture*
Black spruce	70%- 90%
Fir	0% - 15%
Pine	0% - 20%
Hardwood	0% - 10%

The experiments concerning pulp evaluation are subdivided into three categories, described in the following sections.

Wood species and density

The adopted strategy will be to explore the experimental space by using values that cover the species' respective ranges. Ideally, it would be best to use as little spruce as possible since it is the most costly species but its intrinsic properties being ideal for the TMP process, its absence would reduce the quality of the obtained pulp and would influence energy consumption. The typical mixture (mixture 1, Table 3) is the most representative of the one used at the mill so it reflects the normal conditions pretty accurately. Mixtures 2 and 3 verify the influence of maximum and minimum spruce presence respectively on energy consumption. Mixtures 4 and 5 provide information on proportions still representative of the typical mixture but in more or less amounts of fir.

Table 3 - Mixtures used in pilot trials

Wood species	*Mixture 1 (typical)*	*Mixture 2*	*Mixture 3*	*Mixture 4*	*Mixture 5*
Black spruce	80%	90%	70%	75%	85%
Fir	5%	10%	0%	15%	5%
Pine	10%	0%	20%	5%	5%
Hardwood	5%	0%	10%	5%	5%

These trials demonstrate the effect of species and the effect of density since basic density of each species as well as bulk density of the mixture will be different for each of the five mixtures. Emphasis will be put on obtaining a given CSF to be able to measure the impact of the wood species proportions on SEC.

Freshness and moisture content

Chip freshness is another important parameter in the TMP process. It plays a prominent role in determining bleaching agent consumption. However, its effect on the refining energy is unknown and must be studied.

It is also desired to verify the impact of moisture content on pulp quality and SEC. Previous results show that moisture content plays a role at that level, a high proportion of moisture conferring better resistance properties to the resulting paper [9]. In order to do this, the chips will be dried at two different levels from their natural state. The moisture content variation should be in the range of 36% – 48%. Special care will be given to make sure moisture content stays in this interval by controlling drying rate. The mixture used will be the typical mixture representative of normal mill operation (Table 4).

Table 4 - Typical mixture and aging criterion

Wood species	*Typical mixture*	*CRIQ's Luminance loss*	
		Trial 1	*Trial 2*
Black spruce	80%	3 points	6 points
Fir	5%		
Pine	10%		
Hardwood	5%		

Size distribution

It has been demonstrated that the needed SEC to obtain a pulp of CSF 500 mL decreases proportionally with chip size [6]; however chip size has no effect on SEC for pulps refined to CSF values of less than 500 mL. Therefore, smaller chips help decrease SEC but those of lengths lower than 5 mm will produce pulps that have weaker resistance properties. For a fixed SEC, a superior pulp quality (fibre length, adhesion) will be obtained with thicknesses between 4 and 8 mm [10] or lengths between around 16 and 22 mm. The need for SEC increases for a fixed CSF when thickness is higher than 6 mm or around a length of 19 mm..

Table 5 – Chip size distribution for pilot trials

Width (mm)	*Small (%)*	*Medium (%)*	*Large (%)*
<=5	1	1	1
5-9	24	12	4
10-15	40	30	25
16-28	32	45	65
>29	2	12	5

The categories of the smallest chips as well as the largest ones will be refined twice, again for experimental error verification purposes. The typical mixture (Table 4) represents the average size distribution and since it has been used in the previous refining procedures there is no need to refine it again here.

Once we have found the correlations between these specific chip characteristics and tested them at the pilot laboratory, a validation of these relations is necessary at the mill. The important thing to do first is to stabilize chip quality, mainly the bulk density of the mixtures. The way to accomplish this is to give a setpoint value to the feedback controllers assigned to the three species chip feeding screws (Figure 2). When the chip mixtures' characteristic values are becoming unacceptable, the screw speeds must adjust accordingly to stabilize the values, providing more or less of the necessary species to the mixture. A more detailed explanation of feedback control is provided in the Modelling and Optimization part of the paper.

Once the chip quality values are stabilized to appropriate values according to the relations found by the pilot test trials and the lab trials, prediction of the obtained pulp quality is carried out at the mill. Pilot trials and these mill trials will then be compared for detection of any deviation between the results.

MODELLING AND OPTIMISATION

After laboratory trial, the next step is the mill validation. The CMS^E has been installed in the mill, its online measurement information allows the relations between the needs in refining SEC and chip characteristics; in other words, for a given pulp quality, to study the impact of chip quality on refining energy. A primordial part of result analysis will be not only to carefully observe interactions between mean values obtained in the trials (CSF, SEC, chip characteristics) but also to study the effect of variability of each of those values (standard-deviation) on the variability of the other values. These found relations will then be used in a simulation in order to predict pulp quality based on chip characteristics.

The ultimate goal remains to be able to minimize SEC by minimizing chip quality variations. We will have to validate our results in laboratory and the associated mill will do so as well for observation of possible deviations, as discussed above.

We consider in this part that the trials for determination of relations between chip quality and pulp quality have been successful for different proportions of wood species and different chip conditions. Relations have been found and can be applied to a reasonable confidence interval.

The species proportions will be handled by screw speed control. A setpoint value controls each of the three screws. For example, if too much spruce is used according to the set point value of this species' needed value, the control will react by decreasing its screw speed to bring its presence to a normal percentage. With the relations found during pilot trials, two types of control will be applicable to the process described in Figure 2.

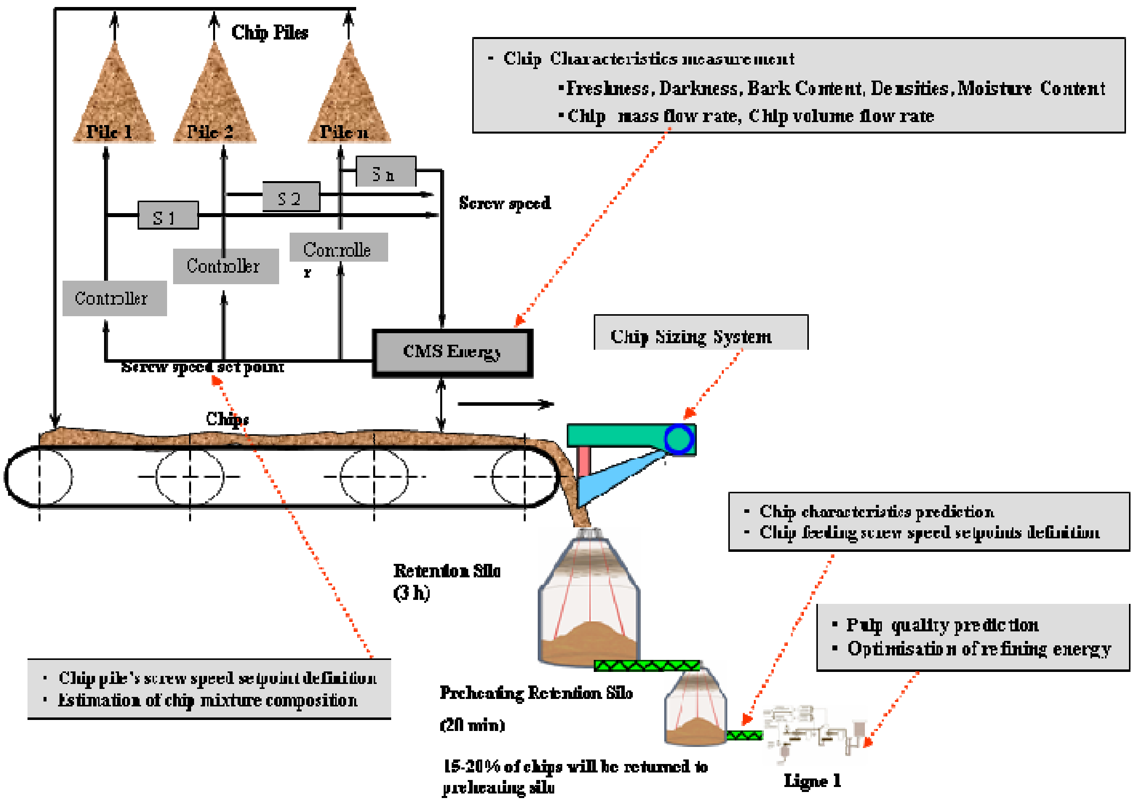

Figure 2 – Diagram of TMP process mill trial flow sheet

Feedback control

At the entrance point of the chips on the first conveyer, the CMS^E will disclose the passing mixture's characteristics: luminance, weight, volume (hence, density), moisture content, bark content. If these characteristics are not acceptable or they tend to show a tendency towards unacceptable values, it will be possible to immediately react.

Once this information is given, it is necessary to change the feed screw speeds' setpoints to reverse the negative tendency (ex. high density) by mixing new mixture proportions. The relations between chip quality and pulp quality will allow us to know for example that if more spruce and less pine are added, the bulk density will decrease and will stabilize in an acceptable range for this particular pulp production. This action will allow the properties correction of future lots that will pass under the CMS^E. However, the chips that have already passed under this scanning system but had inappropriate characteristics must be dealt with as well.

Predictive control

Operators assigned to the refining process notice the chip characteristic tendencies (simultaneously with the feedback control case) before the chips find themselves in the storage silos. This way, operators have time to take the necessary precautions and make the adjustments on the process (plate gap, dilution water, chip screw speed) to counter the negative tendencies signalled by the CMS^E that the characteristics were taking. To follow up on the previous example concerning bulk density, if this property is found to be too high when the chips have passed under the CMS^E, this value appears instantly on the refining line operator's screen. Therefore he has information on the trend taken by the chips and hence will know that at future time X (for example in 15 minutes), the chips being refined will have a density of Y value. He will then have to manipulate the process parameters to produce an acceptable quality pulp with density value Y that will be refined at time X. This operation can be realised by a MPC that will be discussed later.

Methodologies

Once the relations between chip quality and pulp quality have been validated, the first step is to build a model that estimates characteristics of the chips entering the primary refiner. This model is based on online mill chip characteristic measurements. In our study, CADSIM Plus from Aurel Systems Inc.is used as the simulation software for all modelling, simulation and optimization purposes. The model being built, the plan is to simulate the impact of chip characteristics on the primary refiner SEC.

The second step consists of developing a model for control of setpoint value definition. This model will use the relations between feed screw speed and chip characteristics. A simulation of the set points as a function of chip characteristic measurements and process operation parameters will be executed in CADSIM.

This step concerns prediction of pulp quality and encompasses one of the main goals of this study, which is to study the effect of chip characteristics on pulp quality. Using the relations found during the pilot trials and lab tests, a model for the mill pulp quality prediction is built. Simulation of values that explore the whole experimental space (Table 2) is carried out to verify the behaviour of the model. The last step is the optimization of the primary refiner SEC. This includes the study of the impact of chip characteristics and process operation parameters on refining energy for a given pulp quality and the development of a model to find the optimal operating parameters for primary refining. As shown in Figure 3, an SEC optimisation structure will be used for modelling.

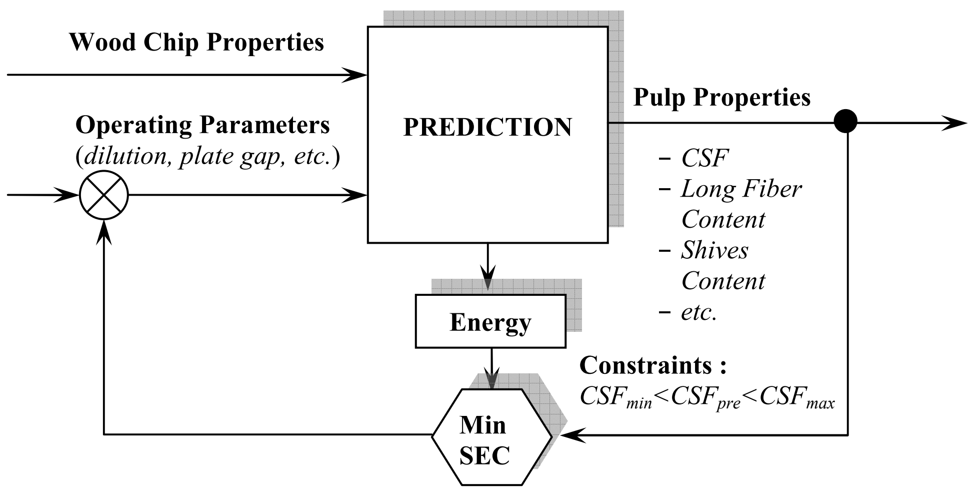

Figure 3 – SEC optimisation structure

This structure allows us to include constraints on the pulp properties (ex. a CSF value between 100 and 150). Therefore, with the initial chip property and process parameter entries, the model iterates to find the best final parameter values to obtain the lowest specific energy while satisfying the specified constraints. This model will be used to build the DSS system in order to help operators to minimize the SEC.

CONCLUSIONS

A laboratory pilot refining experiment will be carried out in order to study the effect of chip quality variations on energy consumption. The obtained results will be validated by mill trials and a DSS will be used to minimize energy consumption by reducing chip quality variations.

In order to accomplish this, relations between chip quality and pulp quality from the pilot trials will be used in a computer model that describes adequately the refining process. With these relations, we will be able to predict pulp quality based on chip characteristics. Simulation with online mill values will be carried out to test the robustness of the model. The optimization process of the primary refiner energy consumption will include study of the effect of chip characteristics and primary refiner operation parameters on refining energy, for a given pulp quality.

These trials will be started in spring 2007 and results will be obtained in the summer of 2007.

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