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Increased thermal efficiency in Scandinavian integrated TMP and paper mills – analysing the potential for steam savings using the heat load model for pulp and paper

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In this paper the potential for steam savings and excess heat levels is analysed for four Scandinavian TMP mills using the Heat Load Model for Pulp and Paper (HLMPP). The results are compared with similar results from previous studies for two other TMP mills. Further, an analysis is made regarding the linkage between the steam consumption and temperature level of excess heat and mill specific characteristics such as e.g. production rate and fresh warm water usage. Based on the results and the analysis the potential for implementation of different biorefinery concepts is discussed. The results indicate that steam savings of 2-20 % can be found in Scandinavian TMP mills. The pinch temperature is rather low, around 0-70 °C for most of the studied TMP mills, compared to the pinch temperature usually found at kraft pulp mills (100-140 °C) and thus the potential utilization options for the excess heat is rather limited. The results also show that the level of heated fresh water is affecting both the steam consumption and the pinch temperature and thus also the potential for efficient integration of different biorefinery processes.

Abbreviations

CEPI	Confederation of European Paper Industries	News	Newsprint
DIP	De-inked pulp	PPI	Pulp and paper industry
GW	Ground wood (pulp)	RCF	Recycled fiber
GCC	Grand Composite Curve	SEC	Specific electricity consumption
HLMPP	Heat load model for pulp and paper	TD	Telephone Directory
MFC	Machine finished coated	TMP	Thermo-mechanical Pulp

1. Introduction

The pulp and paper industry (PPI) is currently in a transition situation – where it is no longer only producing pulp and/or paper but also producing additional products which can increase both the mill profitability and the overall mill energy-efficiency – thereby transforming mills into biorefineries. For the conversion of a mill into an energy-

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efficient biorefinery, it is an advantage if the mill has a surplus of steam and/or heat which can be utilized for thermal integration of the biorefinery processes, or a heating demand at such a temperature level so that it can be supplied with heat from the biorefinery processes. Earlier studies have shown large potentials for generating a steam surplus, and introducing different biorefinery concepts, in the chemical PPI (Axelsson, et al., 2006; Jönsson and Algehed, 2010; Marinova, et al., 2009). However, the potential for introduction of biorefinery concepts based on steam savings and excess heat levels in the mechanical PPI has previously not been studied. One way to reduce the process steam demand, and thereby generate a steam surplus, is to thermally integrate the processes – process integration. The potential for process integration is most commonly determined by Pinch Analysis. However, traditional Pinch Analysis requires an extensive amount of data and is therefore relatively time consuming. To be able to quickly screen the steam-saving potential for a number of mills the Heat Load Model for Pulp and Paper (HLMPP) can be used (Hakala et al., 2008). The HLMPP demands less input data and thus saves time. The HLMPP results are not as accurate as the results from a traditional Pinch Analysis but the accuracy proven so far is good enough for making pre-studies (aiming at identifying whether a Pinch analysis is worth performing or not) or screening potentials for a number of mills (Hakala, et al., 2008; Ruohonen, et al., 2009).

1.1 Aim

The aim of this paper is to analyse the potential for steam savings and identify excess heat levels for four Scandinavian TMP mills using the HLMPP. The aim is also to compare these results with similar results from previous studies for two other TMP mills in order to see if any general conclusions can be drawn. Furthermore, the aim is to analyse whether there is any linkage between the specific steam consumption and the temperature levels of excess heat and the mill specific characteristics such as e.g. production rate and fresh hot water usage. Finally, the paper also aims at discussing the potential for implementation of different biorefinery concepts for TMP mills based on the steam savings and temperature levels of excess heat identified.

1.2 Delimitations and system boundaries

The mills included in this paper have different characteristics and have been chosen in order to show the steam-saving potential for different types of TMP-based pulp and paper mills. The reason for choosing mills with TMP lines is that amongst the mechanical pulp and paper processes, TMP is the most promising process to convert to a biorefinery due to the possibility to recover steam from the high-pressure refiners. Seen to the European PPI, the absolute majority of the TMP production is located in Scandinavia (>70%), as is also a majority of the chemical pulp production. This is probably due to abundance of raw material and historically low electricity prices. Thus, the mills included in this study are all Scandinavian.

2. Method: The HLMPP Tool

The modeling tool used for identification of the steam-saving potential, Heat Load Model for Pulp and Paper (HLMPP), is a tool developed for estimating the potential for energy-efficiency through process integration (Hakala et al., 2008). The results gained from the HLMPP used in this paper are mainly the Grand Composite Curve (GCC) from which the theoretical steam-saving potential, pinch temperature and amount of excess heat can be determined. The HLMPP tool simulates the processes, based on both input data from the mills and type values pre-defined in the model, to get the complete stream data needed to estimate the potential for process integration. Hence, the HLMPP requires considerable less input data than a traditional Pinch Analysis. This time saving characteristic makes the HLMPP suitable for screening of saving potentials, as when doing a pre-study or a more aggregated study (as the study presented in this paper), or for quickly identify whether it is worth to go further with a full Pinch Analysis or not. However, since some parts of the processes are simulated based on reference values the stream data is not as correct as for a traditional Pinch Analysis and thus, a more thorough analysis should be done before any investment decisions are made. In previous studies the HLMPP tool has given results which correspond quite well to the results gained by detailed analysis for both pressurized ground wood (PGW) mills and for pulp and paper mills with TMP and DIP lines (Hakala et al., 2008; Ruohonen, et al., 2009).

3. The Studied System: Input Data for Included Mills

For the discussion presented in this paper, data and results for six mills – one model mill and five real mills – are used. An overview of the mills included in the study is given in Table 1. The data and HLMPP analysis for mills number 1-4 was gathered and performed for the study presented in this paper whereas the data and results for mills 5-6 are based on previous studies (Axelsson and Berntsson, 2005; Ruohonen et al., 2010). All of the mills are based mainly on TMP. As can be seen in the table, the mills range from rather small, 280 kt/year, to quite big, 780 kt/yr. From the table, it can also be noted that the consumption of heated fresh water also differs a lot between the studied mills. Apart from one mill, a state-of-the-art model mill, all of the mills studied produce steam in boilers to supplement the steam generated by the TMP heat recovery.

Table 1: Data for the four mills studied and two previously studied mills for comparison

	Mills analysed with the HLMPP for this paper				Previously studied mills	
	Mill 1	Mill 2	Mill 3	Mill 4	Mill 5	Mill 6
Paper production [kt/yr]	280	780	600	550	697	456
Paper quality	News/ MFC	News	News	SC	TD/news/ LWC	SC
Type of (virgin) pulp prod.	TMP	TMP	TMP	TMP/GW	TMP	TMP
TMP fibre content[I] [%]	94	64	63	48	53	58
Total steam demand [MW]	48	137	105	105	108	65
Steam from boilers [%]	29	47	53	42	32	0
Steam surplus [MW]	2[II]	-	-	-	-	21
Refining SEC [kWh/ADt]	2100/ 2250	1900/ 2000	1750/ 2200	2900	1900/ 2200	3050
Heated fresh water, divided for each PM [t/$t_{paper92}$]	7-12	3.7-6	8.5-11.2	6.5-22.5	7.5-10	4.7

[I]The rest is GW, DIP/RCF, filler or bought kraft pulp. [II]On a yearly average 2MW is vented; however, it is very intermittent.

4. Results

The main results are presented in Table 2 and Figures 1 and 2. As can be seen in Table 2, the potential for steam savings for the four mills studied ranges between 2-20%. These levels of steam-savings are comparable to the levels previously identified for TMP mills, see mill 5-6. However, as can be seen in the table, both the current steam use and the amount of theoretical steam savings identified vary a lot between the different mills. Furthermore, it can be seen that, in general, there is excess heat available but it has a rather low temperature. Only one mill has a pinch temperature >80 °C and that is a state-of-the-art model mill. Two of the mills have a pinch temperature of 0 °C. This indicates a high water usage and, hence, some of the fresh water, heated to a rather moderate temperature level, will be heated using external hot utility (steam). From Table 2, it can also be seen that most of the mills have a GCC with a rather "sharp nose". This indicates that implementation of a heat pump could be of interest since heat from below the pinch could be raised to a temperature above the pinch with a small temperature lift, saving additional 2-12 MW of steam for mill 1-3.

Table 2: Overview of main results in form of steam saving potentials and GCC curves for the mills analysed in this study and two previously studied mills for comparison.

	Mills analysed with the HLMPP for this paper				Previously studied mills	
	Mill 1	Mill 2	Mill 3	Mill 4	Mill 5	Mill 6
Original steam demand [MW]	48	137	105	105	108	65
Theoretical savings potential by solving pinch violations [MW]	9.7	2.9	5.1	20.7	8	3.4
Hot water >80°C available [MW]	0	0	0	0	0	4.0
Pinch temperature [°C]	65	72	65	0	0	117

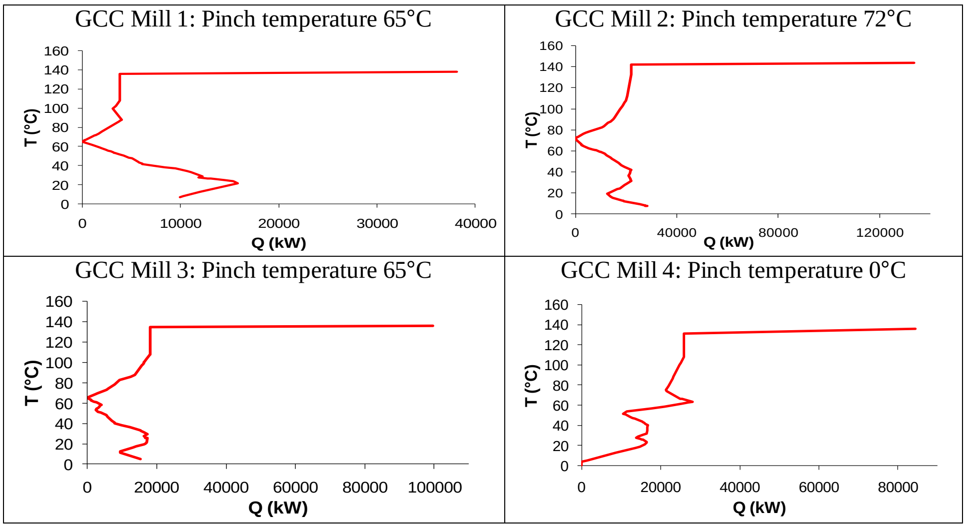

Figure 1: Grand composite curves for the mills analysed in this paper using the HLMPP

4.1 Correlation between warm water usage and steam consumption

To be able to draw some general conclusions regarding the steam use and the potential for steam savings, an analysis was done to try to identify any linkage between these parameters and other important process parameters. The parameters studied were: 1) technical age of equipment, 2) TMP share of pulp used, 3) daily production and 4) fresh warm water usage. For Parameters 1-3, no significant correlation was found, neither to the current steam consumption nor to the theoretical minimum steam consumption. A correlation was only found for the fresh warm water usage, as presented to the left in Figure 2. As can be seen to the right in the figure, the fresh water usage also affects the pinch temperature. A low fresh warm water usage gives a high pinch temperature and thus a more usable temperature of the excess heat available. Thus, it can be argued that for TMP mills to be able to increase their thermal energy-efficiency, and their potential for efficient integration of different biorefinery concepts, the mill should strive at lowering the warm water consumption. These results are in line with similar results from previous studies made on kraft pulp mills showing that a lower use of heated fresh water gives excess heat at higher temperatures and thus a larger potential for further process integration (Axelsson, et al., 2006; Wising, et al., 2005).

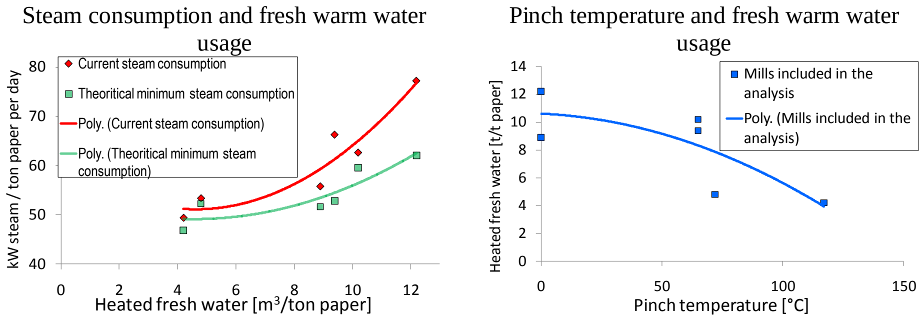

Figure 2: Linkage between fresh warm water consumption and steam use (left) and fresh warm water consumption and pinch temperature (right).

5. Concluding Discussion

The results show that, for TMP mills, the level of fresh water usage is affecting both the steam consumption and the pinch temperature and thus also the potential for efficient integration of different biorefinery processes. Looking at the amount of potential steam surplus, it can be concluded that the level of theoretical steam savings varies between the different TMP mills. For the mills in the study, the theoretical steam-saving potential varies between 2% and 20%. However, due to the GCCs quite “sharp” noses, most of the studied mills show promising potentials for further steam savings of up to 12 MW by installation of heat pumps. The pinch temperature, and thus the temperature of excess heat, is quite low for all the mills, ranging from 0-72 °C for all of the studied mills except for the model mill based on best available technology (which has a pinch temperature of 117 °C). However, it was shown that the pinch temperature is higher for the mills with a low fresh water usage. Thus, possible biorefinery applications for the excess heat are rare, at least if the mill has a high fresh water usage. However, due to the low pinch temperature, integration with e.g. a saw mill could be of interest since the

TMP mill could then use excess heat from the saw mill (which generally holds a temperature of ~75-90 °C) to supply part of the mill's heating demand and thereby further reduce its steam demand. All in all, from the levels of steam savings found, it can be concluded that the mechanical PPI has a potential for introduction of different biorefinery concepts based on utilization of this saved steam. However, since generally the steam savings do not lead to any net steam surplus at the mill and the excess heat has a rather low temperature there are not as many biorefinery concepts of interest for a TMP mill as for a Kraft pulp mill. However, due to the low pinch temperature, integration with new biorefinery processes where the TMP mill is the receiver of excess heat can be of interest.

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