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Opportunities For Process Integrated Evaporation In A Eucalyptus Pulp Mill And Comparison With A Softwood Mill Study

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Significant energy savings can be made in the pulp and paper industry by implementing process-integrated evaporation (PIvap). The concept of PIvap has been evaluated for a Eucalyptus mill producing bleached kraft market pulp in Portugal and the results were compared to the ones from an earlier model mill study of a soft wood mill. In the eucalyptus mill there were, theoretically, 0.86 GJ/ADt of excess heat suitable for a PIvap besides the 2.6 GJ/ADt of pinch violations. The pinch violations could be transferred to excess heat, but some pinch violations were cost effective to solve. A suggestion where 1.1 GJ/ADt of pinch violations are solved and 1.6 GJ/ADt of excess heat are extracted is presented. If the excess heat is used in a 7 effect PIvap with integrated stripper and increased dry solids content, steam savings of 2.7 GJ/ADt could be made in the evaporation plant. Together with the pinch violations and opportunities for improved soot blowing, the total steam savings from the suggested measures were 4.5 GJ/ADt or 35%. The amount of steam savings and associated costs were similar to the ones in the soft-wood model-mill. Hence, no significant differences could be found for the opportunities to implement PIvap in the hardwood mill compared to in the soft wood mill. The existence of a pre-evaporation plant, however, showed to hinder introduction of PIvap, since a pre-evaporation plant uses excess heat, and uses it ineffectively compared to a PIvap. Hence, the pre-evaporation has been removed in the suggestion for integration presented here.

1. Introduction

With increasing concerns about fossil CO_2 emissions and increasing energy prices, energy savings in energy intensive industry becomes more and more relevant. One industry with potential for considerable energy savings is the pulp and paper production. In a kraft pulp mill, the evaporation plant stands for about 30% of the energy demand. Hence, savings in this process unit are of major interest. Significant energy savings in the evaporation plant can be made if a process-integrated evaporation is introduced. Process-integrated evaporation (PIvap) utilizes excess heat from the process to reduce the live steam demand; the concept is further described in *Section 3*.

In a recent study done at our department, the opportunity for PIvap was explored for a model mill (Axelsson et al. 2006). The model mill was a computer model of a market pulp mill producing bleached kraft pulp from softwood. Description of the softwood mill and the results of the study are presented in *Section 2* and *5*, respectively.

In the present paper the concept of PIvap is explored in a real mill: a eucalyptus mill in Portugal. The eucalyptus mill is, in contrast to the model mill, a hardwood mill. The purpose of this study was to evaluate the tools for finding excess heat used in the model mill study in a real mill environment and also investigate if there are any differences in opportunities for PIvap in a hardwood mill compared to in a softwood mill.

2. Description of the eucalyptus mill and comparison with the softwood mill

The studied mill is a market pulp mill producing bleached kraft pulp from eucalyptus hardwood. Key data for the mill can be found in Table I, more information about the mill can be found in Laaksometsä et al. (2007). The evaporation plant of the eucalyptus mill is old and is working with 5 effects steam economy. The evaporation plant of the softwood model mill in model mill study had a similar steam economy. The model mill was designed to be a typical Scandinavian mill concerning technical level and resource utilization. The soft wood mill also produces bleached kraft pulp and, as can be seen in Table 1, key data for the two mills are similar. One major difference is that the eucalyptus mill is a hardwood mill implying higher digester yield and, hence, it has lower specific steam demand.

3. Process Integrated Evaporation (PIvap)

In PIvap excess heat from the process is used to reduce the steam demand in the evaporation plant. PIvap is both a technology oriented (unconventional design) and system oriented (process integration) new concept. In this section the concept of PIvap is explained in brief, more about the concept can be found in Algehed (2002). The concept of PIvap is also discussed in Crips et al. (1996) and Xiao and Smith (2001). The introduction of PIvap implies new conditions for evaporation. To be able to accurately account for this, a simulation model has been developed at our department Olsson (2007).

Table I: Key data of the eucalyptus mill and the model mill

	Eucalyptus	**Model**	
Production	300 000	327 000	Adt/year
Digester yield	56	46	%
Steam consumption	12.7	16.6	GJ/ADt
Hot and warm water	13.4	13.5	tonne/ADt
Water, total	34	27	tonne/ADt
Evaporation plant			
- steam economy	5	5.5	effects
- DS in heavy liquor	69	73	%
- integrated stripper	no	no	
- pre-evaporation	yes	no	

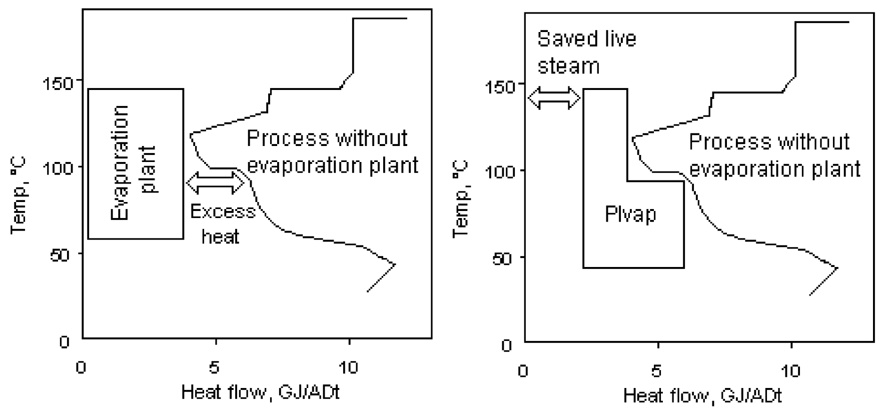

Figure 1: The concept of process-integrated evaporation (PIvap). Left: background/foreground curve where a conventional evaporation plant comprises the foreground, while the background is composed of a GCC of the rest of the process. The amount of excess heat suitable for PIvap is indicated with an arrow. Right: By rebuilding the evaporation plant, the excess heat can be used for evaporation. Consequently, live steam is saved.

Excess heat of high temperature (above 80°C) can be used in a process-integrated evaporation plant (PIvap) to reduce the live steam-demand. To find the amount of excess heat in the process, a Grand Composite Curve (GCC) of the stream data can be utilized. The GCC shows the net heating demand as a function of the temperature above the pinch, and the net cooling demand as a function of the temperature below the pinch. Cooling demand of high temperature is here considered as excess heat, see Figure 1. By rebuilding the evaporation plant, the excess heat can be used in the effects that work with the corresponding temperatures, as shown in the background/foreground curve in Figure 1. In reality, this means that excess heat from the process, such as flash steam at 100°C, is fed to an effect in the middle of the evaporation train. The excess heat can be of better use if it is used in more effects. This can be accomplished by adding effects at the end of the evaporation train, which is possible if the temperature of the surface condenser is decreased to 40°C. It is not conventional to have such low condensate temperatures in evaporation of black liquor, but technically it should not be a problem according to Olausson 2005.

Generally, the amount of excess heat decreases if pinch violations are solved. Hence, there is a trade off situation between solving pinch violations and implementing PIvap.

3. Steam saving opportunities

An energy system analysis done previously on the eucalyptus mill revealed that, theoretically, there were 2.7 GJ/ADt of pinch violations and 0.86 GJ/ADt of high temperature excess heat (Laaksometsä et al. 2007); see Figure 2.

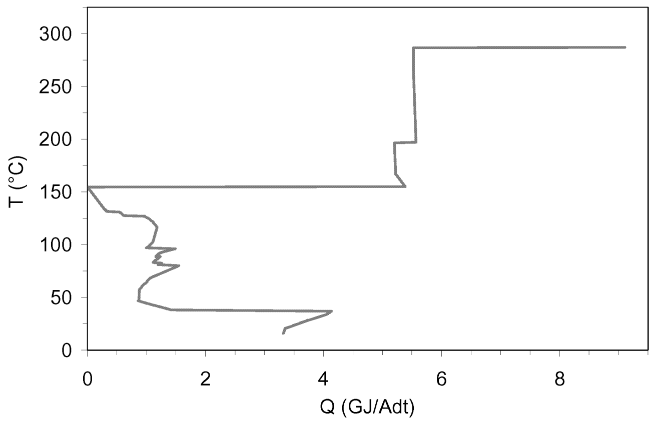

Figure 2: Grand Composite Curve of the Eucalyptus mill with a ΔTmin of 5 K and without stripper. There are 0.86 GJ/ADt of excess heat besides the 2.7 GJ/ADt of pinch violations. The pinch violations can bee transferred to excess heat.

If the pinch violations were not solved, the amount of excess heat for PIvap could be increased, which is in accordance with experience from other studies (eg Axelsson et al. 2006). Some pinch violations, however, were cost effective to solve. Our suggestion was to solve 1.1 MW of pinch violations and extract 1.6 GJ/ADt of excess heat to be used in the evaporation plant. A major part of the excess heat came from the black liquor flash; see Table 2. Today this heat is used in a 3-stage pre-evaporation plant. The heat would be used in more stages in a PIvap. By replacing the current evaporation system (pre-evaporation and 5 effect evaporation plant) with a 7 effect PIvap, the steam saving would be 1.5 GJ/ADt. If a new evaporation plant is installed, there is also an opportunity to integrate the stripper and increase the dry solid content from 69 to 74% giving more high pressure steam. With this, the total steam saving would be 2.7 GJ/AD in the evaporation. Adding the pinch violations and an opportunity to improve the soot blowing, the total steam saving would be 4.5 GJ/ADt in the eucalyptus mill; see Table 3. The total cost for this was 9 M€ if part of the old evaporation plant could be used corresponding to a value of 7.7 M€ (Axelsson et al. 2006).

4. Comparison with the model mill

The theoretical potential for steam saving was higher in eucalyptus mill: the theoretical pinch violations plus the theoretical amount of excess heat were 3.5 GJ/ADt in the eucalyptus mill and 2.1 GJ/ADt in the model mill.

Table II: Sources of excess heat in the eucalyptus plant

Sources of excess heat	GJ/ADt	MW
Condensate tank vent	0.05	0.53
Black liquor flash	1.28	13.6
Hot water from flue gas recovery	0.28	3.0
Total	**1.6**	**17**

Table III: Steam saving opportunities and associated costs in the eucalyptus mill as well as in the softwood model mill.

	Savings		Investment cost	
Eucalyptus mill	GJ/ADt	MW	M€	€/kW
Solving pinch violations	1.1	12	2.1	175
Improved Soot blowing	0.59	6.3	0.08	13
Extract excess heat[a]	(1.6)	(17)	2.9	-
Evaporation plant upgrade	2.7	29	3.9	134
Total	**4.5**	**47**	**9.0**	**189**
Softwood mill				
Solving pinch violations	0.7	8.0	1.3	161
Extract excess heat[a]	(1.6)	(19)	1.0	-
Evaporation plant upgrade	3.2	37	7.0	190
Total	**3.9**	**45**	**9.3**	**207**

[a] Amount and cost of extracted excess heat only, steam savings are included in the row "Evaporation plant upgrade".

As can be seen in Table III, the steam savings from the suggested measures were almost the same in both mills. So was the associated costs were similar if the value of the old evaporation plant was assumed to be the same in both cases; see Table III. However, the measures to solve pinch violations, and some of the sources of excess heat differed.

The fact that the eucalyptus mill is a hardwood mill did not give any significant implication on the opportunities for PIvap. Another factor that, though, had a great implication on the opportunities for PIvap was the existence of a pre-evaporation plant. The eucalyptus mill had a pre-evaporation plant in the original configuration using black liquor flash steam for evaporation in three steps. The flash steam would be used in more effects and, hence, more effectively in a PIvap. Using the flash steam in a PIvap instead of a pre-evaporator is a more efficient solution provided that most of the hot and warm water can be produced without using the condenser of the pre-evaporation plant. Theoretically this was possible in the eucalyptus mill, hence we assumed that the pre-evaporation plant was removed for the implementation of PIvap. In practice, 25% of the hot water had to be heated with steam in order not to make the new hot and warm water system too complex. The steam amount needed for water heating was 0.23 GJ/ADt, which is less than the steam saving from using the black liquor flash in the PIvap. If the hot water demand could be decreased, the steam would not be needed and the prospects for PIvap would improve. In connection to this it should be stated that the eucalyptus mill has plans to reduce the hot water demand.

5. Conclusions

The conclusions from the evaluation of process-integrated evaporation (PIvap) in the eucalyptus mill and comparison with the soft wood model mill study are as follows.

- The tools for finding excess heat used in the model mill studies were applicable also for a real mill.

- The amount of excess heat, steams saving potential with PIvap and investment costs in the eucalyptus mill were similar to the ones in the model mill study.
- As in the softwood mill, there were good opportunities for process-integrated evaporation in the eucalyptus mill.
- Pre-evaporation plant is a hinder for installing a PIvap since that a pre-evaporator uses excess heat. In the pre-evaporation the excess heat is used ineffectively, especially if the water usage is low.

7. Acknowledgement

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