CONCEPTS OF STEAM RECOVERY FROM LC-REFINING BY INCREASED TEMPERATURE

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ABSTRACT

In a mechanical pulping process, (TMP) wood is refined to pulp in a process with very high wood utilization. However, the power demand in the process is high. Thus efficient energy recovery, especially steam recovery, is very important. In high consistency (HC) refining the pulp wood is refined at high temperature (140°C) and pressure. The high temperature makes it possible to recover process heat with usable steam properties.

One strategy to decrease the power consumption is to split the refining into two stages, one HC-stage and one low consistency (LC) refining stage. This kind of system is quite common today. One drawback with LC-refining is that it operates at a low temperature normally below 100°C. Hence, the steam recovery potential from conventional LC-refining is limited.

In this project, we analyse three concepts of steam recovery in LC-refining by increasing the temperature in the LC-stage. Two base cases: Conventional HC refining only and conventional HC/LC refining is compared with three steam recovery cases: Pulp/Pulp heat exchanging, Screw Press Dewatering combined with process water re-circulation and finally Pulp/Water Heat Exchanging.

The study shows that it is possible to recover steam from the LC-stage and, hence, increase the energy efficiency of a combined HC/LC refining system. The screw press case has the highest steam recovery potential of the HC/LC configurations. An initial economic estimate indicates that steam recovery in LC-refining is profitable compared to a conventional HC/LC-configuration.

Keywords: energy efficiency, steam recovery, mechanical pulping.

INTRODUCTION

Efficient use of energy is an important part of a mechanical pulp- and paper mill's competitive edge and in longer terms its viability. For example, in Sweden, the electricity share of the mill's direct costs can be more than 40% and exceeds that of pulp wood.

One way to reduce the electricity use is to combine HC- with LC refining optimized for mechanical pulping (1). There is well-proven technology for steam recovery from HC-refiners since many years. Steam recovery from LC-refining is not utilized due to the too low temperature utilized in the LC-stage. Hence, the benefit of the decreased power use is somewhat neutralized by decreased steam recovery when HC- and LC-refining are combined.

One strategy to reduce the effect of this drawback is to increase the temperature in the LC-stage. This approach has two advantages. Increased temperature will decrease the power demand in the refiner (2) and usable steam can be recovered from the process (3). Both aspects increase the energy efficiency of the LC-refining stage. In this work, we investigate the second advantage and determine if it is possible to increase the temperature in the LC-refining by re-circulation of heat within the process.

METHODS AND MATERIALS

This paper presents and analyses three different steam recovery configurations and compare the results with those of two conventional configurations. The configurations are described in detail in next section.

Industrial energy systems are often analysed with process integration methods, e.g. pinch analysis or optimization models (4, 5, 6). Normally, these methods presuppose a defined energy demand or temperature level. As this study focuses temperature change we apply a different approach. Each configuration is simulated with Matlab/Simulink. The models simulate detailed energy- and material balances in the system of concern. Figure 1 below indicates the level of detail of the simulations model. The figure shows the modelled units of a HC/LC-configuration where the steam is recovered in combination with dewatering in a pressurised screw press (see also figure 5).

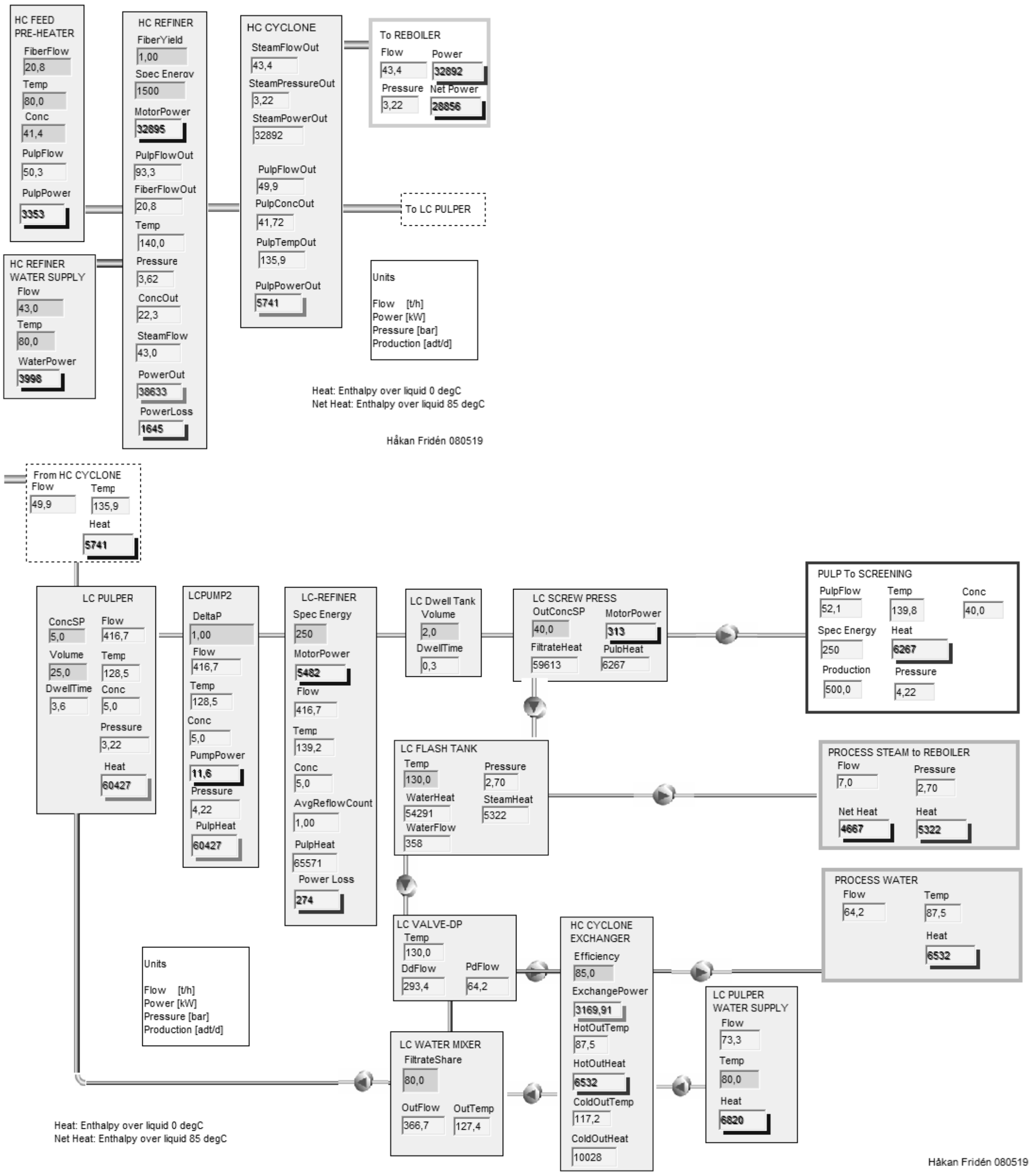

Figure 1: Indication of model detail level: HC and LC-stage in case B

The configurations, simulations models and results are validated through an interactive process in which a reference group with participants from SCA, Stora-Enso, Holmen Paper, Innventia (STFI-Packforsk) and Mid Sweden University followed the project. The reference group took active part in the design of the different configurations and reviewed the simulation models and the derived results.

RESULTS AND DISCUSSION

In this work, we present energy recovery potential in five separate cases. The first two configurations are reference cases (figure 2 and figure 3). The remaining three configurations are steam recovery cases (figure 4-6). Common to all cases, the pulp production is 500 adt./day. The HC-refiner is supplied with pre-heated wood chips and water of 80°C.

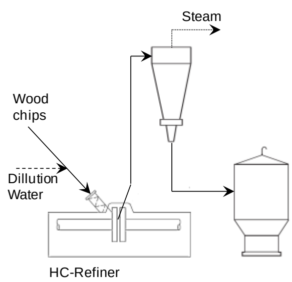

Figure 2: Zero alternative 1: Conventional HC-refining

As figure 2 show, the first reference case is a pure HC-refining system with steam recovery. Preheated 80°C wood chips and water are refined to pulp with 42% consistency. The specific power consumption is 1950 kWh/adt. This HC-refiner is actually included in all cases below. However, when the HC-refiner is used in combination with LC-refining, the specific power consumption in the HC-stage is decreased to 1500 kWh/adt.

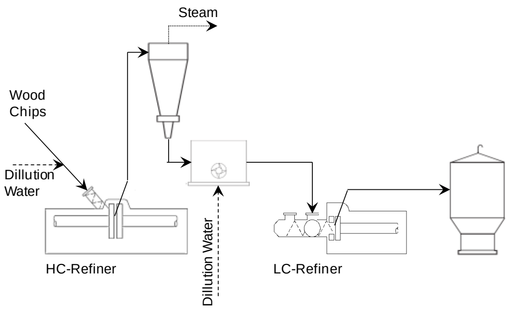

Figure 3: Zero alternative 2: Conventional HC/LC-refining

The second reference case, showed in figure 3, is a combined HC and LC refining system. A HC-stage using 1500 kWh electricity/adt is combined with a LC-stage that consume 250 kWh electricity/adt. Accordingly, the total specific power consumption is 1750 kWh/adt. The LC-refiner produces pulp with 5% consistency. Steam is recovered in the HC-stage but there is no steam recovery in the LC-stage

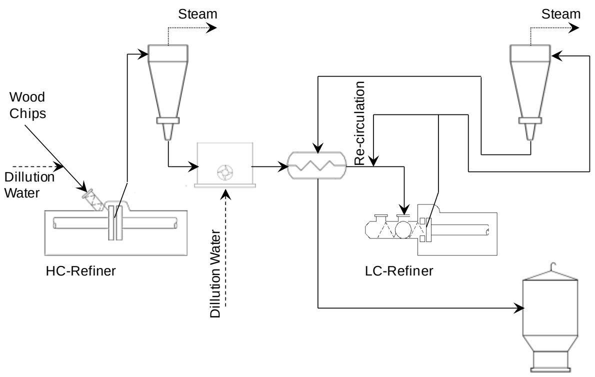

Figure 4: Case A: HC/LC-refining with pulp/pulp heat exchanging

In the three steam recovery cases, the LC-stage is pressurised and, compared to the reference case, the temperature in the LC-stage is increased. Hence, it is possible to recover low pressure steam from the HC-stage as well as the LC-stage. In all recovery cases, the pulp production is 500 adt/day. The consistency in the LC-refiner is 5%. The dwell time in the LC-stage is only about 4 minutes. The brightness of the pulp is most likely not affected by the increased temperature (7, 8)

Figure 4 above show the configuration of case A in which the incoming pulp to the LC-stage is pre-heated with heat from the outgoing pulp in a pulp/pulp heat exchanger.

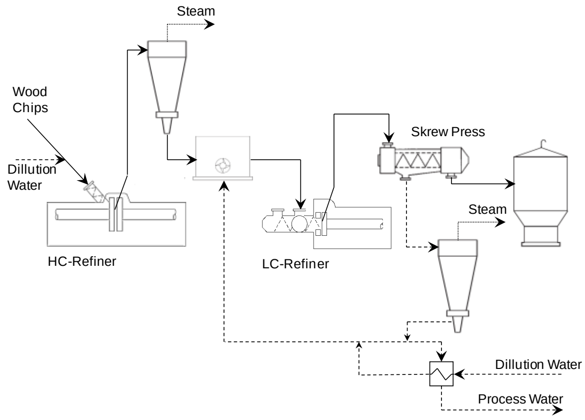

Figure 5: Case B: HC/LC-refining with pressurized screw press

Case B shown in figure 5 is one recovery case in which the pulp is dewatered in a pressurized screw press. This configuration is initially formulated by Münster (3). Steam is recovered from the pressate in a flash tank. Most of the remaining pressate is re-circulated into the process. However, 20% of the water is replaced with fresh dilution water. Like case A, the production is 500 adt/day. The consistency of the pulp after the screw press is 40%.

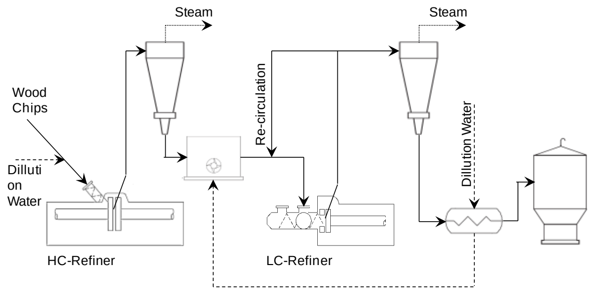

Figure 6: Case C: HC/LC-refining with pulp/water heat exchanging

In the last configuration, described by figure 6, steam is flashed from the pulp in a flash tank. The temperature in the LC-stage is maintained through heat exchanging with a pulp/water heat exchanger.

Specific steam recovery

The reference scenario Zero 1 shows the highest specific steam recovery (MW recovered steam per MW electric power consumption). This is due to the fact the HC-refiner operates with higher pressure and temperature than the conventional or pressurised LC-refiners defined in the other cases. Figure 7 below shows the steam recovery for each case.

The references cases show the best as well as the worst specific steam recovery potential. Due to the low temperature in the LC-stage of the Zero 2 case (approximately 98°C) it is not possible to recover steam of usable pressure. Hence, in this case all steam is recovered in the HC-stage. The LC-stage uses 250 kWh power per adt. pulp. With no steam recovery in the LC-stage, the specific steam recovery will decrease.

Comparing the three steam recovery alternatives A to C, the screw press scenario B shows the best specific steam recovery, approaching that of Zero 1. Case C have the second best recovery potential. Case A show a specific steam recovery just above that of Zero 2.

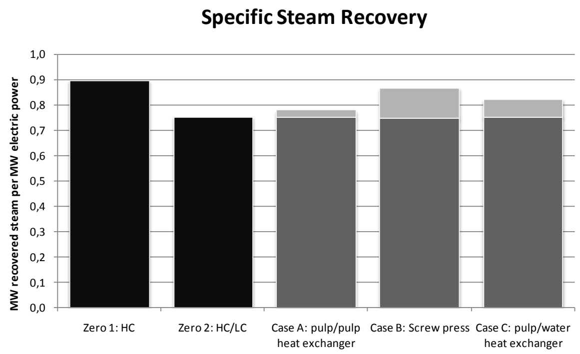

Figure 7: Specific steam recovery

One key issue that affects the recovery is the heat exchanger efficiency. In Case B, most of the pressate is recirculated and, hence, the heat in the pressate is brought back to the incoming pulp with minimal temperature losses; the only inefficiency occur in the water/water heat exchanger shown in figure 5. As a consequence, Case B has the highest temperature in the LC-stage.

The specific steam recovery of Case C is better than that of Case A. This is due to the assumed heat exchanger efficiency is higher in case C than case A, 85% and 80% respectively. Thus, the LC-temperature is higher in case C than case A.

Total electricity use and steam recovery

However, although the specific steam recovery give insights about the efficiency of the configurations, this key numbers give only minor indication of the total energy use and associated cost. The main reason for combining HC and LC refining is to reduce the power use. In this work the power used in the refiners decrease from 1950 kWh/adt. to 1750 kWh/adt. pulp, based on result from Engstrand et. al (9). Figure 8 below shows that the production of recovered steam will decrease as well.

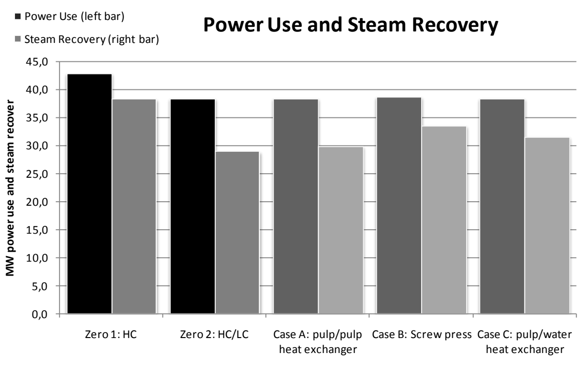

Figure 8: Total power use and steam production

Reference scenario Zero 1 shows the highest power consumption. This is due to the specific power use, as discussed above. All HC/LC cases show similar power use. The slight difference is due to differences in power drop in the recovery cases and the screw press power demand in case B.

The highest steam recovery is in case Zero 1; the power use as well as the specific steam recovery are higher compared to those of the other configurations. Among the recovery configurations, the screw press case B shows the highest steam recovery. This is due to the favourable specific steam recovery shown in figure 7.

Availability of heat exchangers and pressurized screw press

The heat exchangers proposed in case A and C must be able to handle pulp with 5% constancy on one or both sides of the heat exchanging surfaces. To our knowledge, no such heat exchangers are commercially available today. The pulp is a non-Newtonian fluid. If the velocity is slow, the flow regime of the pulp will be a plug flow. With higher velocity, the pulp will fluidize and it will behave like a fluid.

The head loss (Pa/m) is investigated by e.g. Duffy (10) and Hammarström (11). Heat exchanger design is described by Shah and Sekulic (12). The head loss of 1.5%-3.% pulp that flow in pipes (diameter 5.0 cm to 7.5 cm), having a velocity less than 1 m/s, varies between 1000-6000 Pa/m (11). If these estimates are true also for 5% pulp, the pressured drop in an ordinary spiral heat exchanger (12) can be as high as 5-10 bar. If so, the design pressure of the heat exchangers will be very high. Hence, there is a need for development of heat exchangers that can operate in these difficult conditions (13).

It seems possible to pressurize available screw press constructions (14). In comparison to the heat exchangers discussed above, the technological difficulties connected to pressurizing the screw press are assumed to be easier to handle. Thus, we think the technological risk associated to case B is lower than those associated to the heat exchanger cases A and C.

Economy

Within the framework of this study, it was not possible to make a precise economic evaluation of the different configurations. The profitability is determined by the electricity price and the value of the recovered steam together with the additional investment cost for the steam recovery equipment, e.g. heat exchangers or pressurized screw press.

As mentioned above, the proposed heat exchangers and screw press are not commercially available. Hence, it is not possible to make a solid estimate of the investments costs. However, assuming an electricity price of 39 EUR/MWh and a steam value of 18 EUR/MWh, a rough estimate indicates that all recovery cases are profitable event if the recovery equipments are several times more expansive than ordinary equipments available on the market today.

CONCLUSIONS

Table 1 below summarizes the main findings of the study. From an energy engineering perspective it is clear that it is possible to recover usable steam from LC-refining systems and, hence, further increase the energy efficiency of combined HC- and LC-refining.

TABLE 1: RESULT SUMMARY

Case	**Zero 1:**	**Zero 2**	**Case A**	**Case B**	**Case C**
Type	HC-stage only	HC+LC-stage	HC+LC-stage	HC+LC-stage	HC+LC-stage
Steam recovery concept	Steam recovery in HC stage	Steam recovery in HC-stage only	Steam recovery in both stages Pulp to pulp heat exchanging	Steam recovery in both stages. Screw Press dewatering and process water re-circulation	Steam recovery in both stages. Pulp to water heat exchanging
Production	500 adt pulp/day 42% cons.	500 adt pulp/day 5% cons.	500 adt pulp/day 5% cons.	500 adt pulp/day 40% cons.	500 adt pulp/day 5% cons.
Simulated Power demand (MW)	43	38	38	39	38
Steam recovery (MW)	38	29	30	34	31
Specific steam recovery	0,89	0,75	0,78	0,87	0,82
Steam recovery investment	Included in reference system	Included in reference system	Low	High	Low
Rough profitability estimate	-	-	Medium to high	Medium to high	High to very high
Technological risk	-	-	High	Low	High
Common to all cases: Input of wood chips, process water and dillution water are preheated to 80°C					

There are high uncertainties regarding technological performance and investment costs of the proposed heat exchangers and pressurized screw press. Continuing work in this context should involve development and pilot tests of heat exchangers and pressurized screw press as well as investigations of the aspects of electricity use and pulp quality in high temperature LC-refining.

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