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Analysis of an operating TMP mill using advanced composite curves and Heat Load Model for Pulp and Paper

Pekka Ruohonen*[1], Juha Hakala[2] and Pekka Ahtila[3]
[1] Pöyry Finland Oy, Performance and Measurement Services
Department of Energy Technology, Aalto University School of Science and Technology
[2] VTT Technical Research Centre of Finland
[3] Aalto University School of Science and Technology, Department of Energy Technology
Tekniikantie 4 A, P.O.Box 93, FI-02151, Espoo, Finland
pekka.ruohonen@poyry.com

In this study an operating thermo mechanical pulp and paper mill (TMP) is analyzed using advanced composite curves. The use of advanced composite curves is a relatively novel method developed in Chalmers University by Nordman and Berntsson. It is a graphical pinch based approach that takes into account the existing heat exchanger network and the utilities used. With this information provided it is possible to predict order of magnitude of the cost associated to retrofit certain part of the heat exchanger network. The method also reveals the possibilities to integrate heat pumps into the system. The mill is modelled using the Heat Load Model for Pulp and Paper (HLMPP). The mill used as an example in this study is a European mill, producing paper on three paper machines. The mill has three pulp lines; two TMP lines and one DIP line. The study also covers debarking and waste water treatment plants. The analysis shows a potential for improvement. The technical economical possibilities of achieving this potential are discussed.

1. Introduction

In the Nordic countries, and especially in Finland, a larger share of paper production consumes mechanical pulp than anywhere else in the world. Therefore, it is important to study what possibilities an operating plant with Thermo Mechanical Pulping (TMP) has for a cost-effective heat exchanger network retrofit. We assume that the improvement potential is significant, although not as large as in other types of integrated mills: Kraft pulp or Pressurized Ground Wood (PGW) pulp.

Pinch-based process integration methods are used in this paper. Pinch analysis (Linnhoff et al., 1994) is a well-known and widely used process integration method. The idea is to convert information on all the heating and cooling needs of the process into targets for hot and cold utility consumption.

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The use of advanced composite curves is a fairly new method developed in Chalmers University by Nordman and Berntsson (2009a) based on earlier work by Nordman and Berntsson (2001) and Wallin (1996). It is a graphical pinch-based approach that takes into account the existing heat exchanger network and the utilities actually used at the mill. With this information it is possible to predict the retrofit-related costs of a certain part of the heat exchanger network. The method also reveals the possibilities to integrate heat pumps into the system when considering different amounts of heat exchanger network retrofit. The method has been used previously in two case studies concerning chemical pulping (Nordman and Berntsson, 2009b), one study considering Pressurized Ground Wood (PGW) mill (Ruohonen and Ahtila, 2010) and one study considering a simulated TMP mill (Ruohonen and Ahtila, 2009).
Advanced composite curves have not previously been used to analyse an operating thermo mechanical pulp and paper mill. In this study, the possibilities of making a cost-effective heat exchanger retrofit in an operating thermo mechanical pulp and paper mill are analysed using advanced composite curves.

2. Methodology

Advanced composite curves (Nordman and Berntsson 2009a) are a pinch-based method that is developed especially for retrofit situations. The advanced curves take into account the existing heat exchanger network at the mill. Therefore, it is possible to estimate with good precision how costly it will be to improve the heat exchanger network.
There are four curves above pinch and four curves below. The curves above are:

- Hot Utility Curve (HUC), which shows the hot utilities currently used at the mill.
- Actual Heat Load Curve (AHLC), which shows what the hot utilities are used for.
- Extreme Heat Load Curve (EHLC), which shows how the hot utilities would be used if the current amount of hot utilities was used to heat streams at temperature levels as high as possible. This would be the solution that traditional pinch gives using a ΔT_{min} that results in the current amount of hot utilities used.
- Theoretical Heat Load Curve (THLC), which shows the thermodynamic possibilities to use the hot utilities to heat streams at temperature levels as low as possible, when a minimum temperature difference for the heat exchangers ($\Delta T_{min,\ HX}$) is used. The minimum temperature difference for the heat exchangers should be as small as the smallest reasonable value for a new heat exchanger. A temperature difference of 5 K is usually used.

The corresponding curves below pinch are:

- Cold Utility Curve (CUC)
- Actual Cooling load Curve (ACLC)
- Extreme Cooling Load Curve (ECLC)
- Theoretical Cooling Load Curve (TCLC)

The EHLC and THLC show the limits for temperature levels of possible heat exchange in the heat exchanger network. Therefore AHLC should always be between them. If AHLC is close to THLC, it means that the design is originally poor, heaters are placed on low temperature levels and thus more heat exchanger area is installed than would be necessary. In a retrofit case this is usually beneficial because this area might be useful when located somewhere else, and replacing heaters placed low usually requires a smaller number of matches to be changed. Therefore AHLC lying close to THLC is an indication of a relatively cost-effective retrofit and AHLC lying close to EHLC is an indication of a relatively expensive retrofit. A more comprehensive description of the method can be found in (Nordman and Berntsson, 2009a).

3. The Example Mill

The mill used as an example in this study is a European mill that produces paper on three paper machines. The mill has three pulp lines; two TMP lines and one DIP line. The study covers also debarking and waste water treatment.

The mill is modelled using the Heat Load Model for Pulp and Paper (HLMPP). Case mill theoretical minimum consumptions of both hot and cold utilities are calculated, and these are compared against true utilities consumption figures. HLMPP is a generic tool for screening energy reduction potential in pulp and paper industry with reasonable effort and with sufficient data accuracy. The goal of the model is to convert the mill data into heating and cooling requirements of the process, and thus lot of process details have been left out. In the model, several sources for wood fibre and several paper machines for different paper products and drying section setups can be applied. The model parameters are adjusted to the mill in question. The tool has been proven to work on a suitable accuracy level in previous studies (Hakala et al., 2008, Ruohonen et al., 2009 and Hippinen et al., 2009).

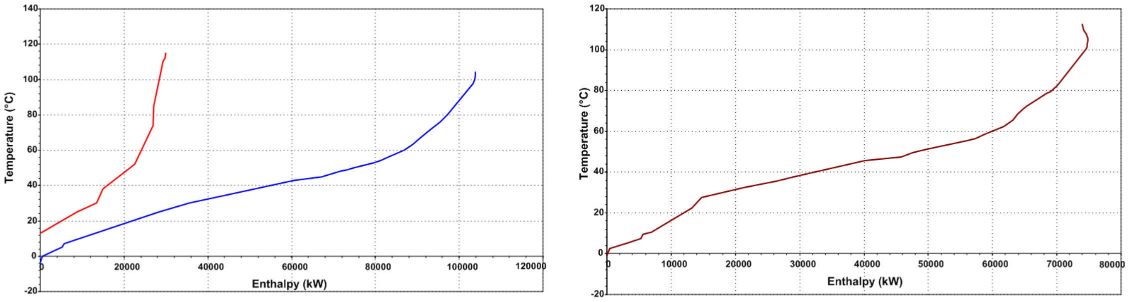
4. Results and Discussion

The analysis covers all the heating and cooling needs of the plant, except the steam used at the paper machines, which cannot be influenced by changes in the heat exchanger network. Three cases, all having different degrees of freedom are considered. The first two cases are done first treating the paper machine heat recovery as a utility and then taking it into the analysis as hot streams. The former case is marked “A” and the latter “B” in the results. Based on the results of these two cases, it was discovered that a third case is needed. This case, marked “C” is similar to case B, except that the preheating and steaming of chips a the TMP plant is decided to be done using steam.

4.1 Winter

On winter period the outdoor temperature is -3.5 °C and the temperature of incoming water is 7 °C. The composite curves and the grand composite curve for case winter A are shown in Figure 1. The pinch temperature is so low, -1 °C, that no external cooling is needed. Actually, the cooling demand is zero when the ΔT_{min} is 13 K or smaller. Then all heat available at the mill is utilized and there is no room for improvement by decreasing the ΔT_{min}, e. g. the process is “unpinched” below ΔT_{min} of 13 K. The demand curves for case A are shown in Figure 2.

The analysis shows that all heat recovery that is used currently, is needed also theoretically. Therefore it is included in the next analysis (case B) as a hot stream. Also, when treating the paper machine heat recovery as hot streams, the current utility consumption corresponds to a ΔT_{min} of 25 K. The advanced composite curves of cases B and C are shown in Figure 4. The curves on the cold side are similar for all of the cases A to C.



(a) (b)

Figure 1: (a) Composite curves, winter A, ΔT_{min} 5 K. (b) Grand composite curve, winter A, ΔT_{min} 5 K

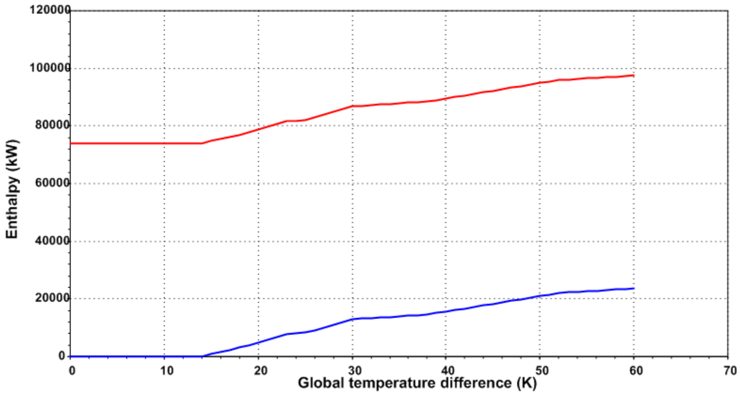
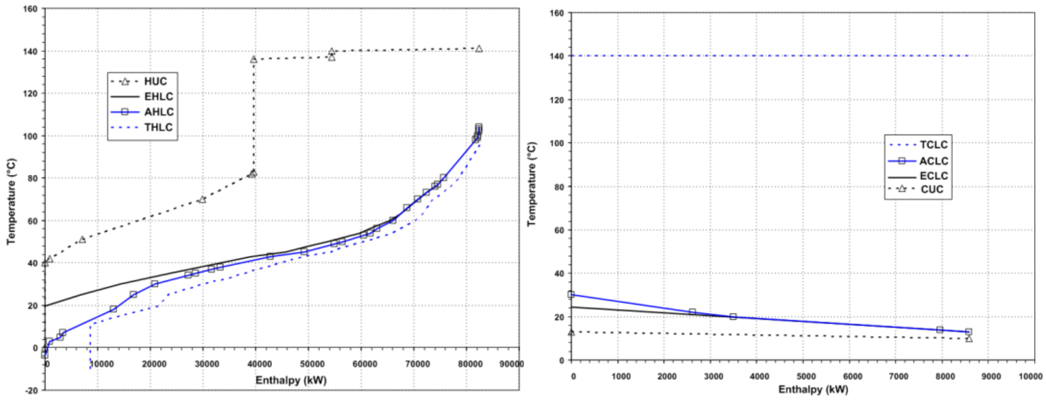


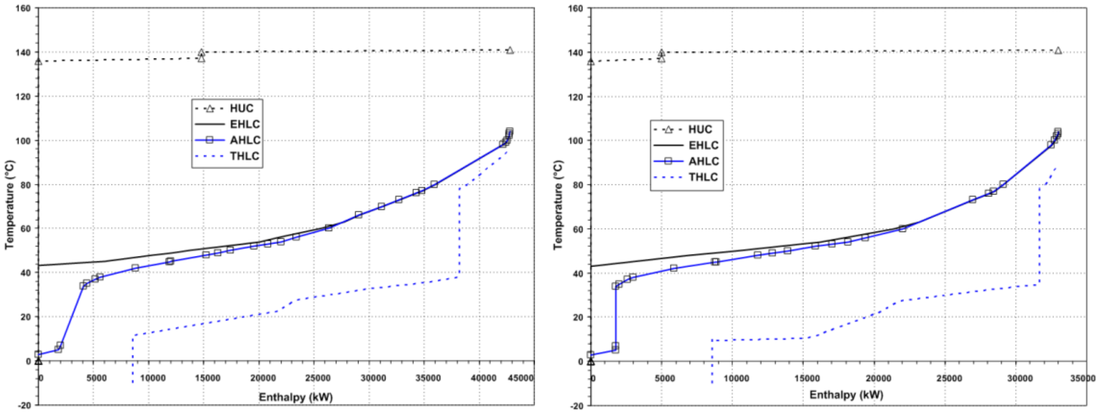
Figure 2: Demand curves, winter A.

The current utility consumption corresponds to a ΔT_{min} of 25 K. The advanced composite curves are drawn using this value. The curves are shown in Figure 3.



(a) (b)

Figure 3: (a) HUC, EHLC, AHLC and THLC, (b) CUC, ECLC, ACLC and TCLC, all curves are for case winter A



(a) (b)

Figure 4: HUC, EHLC, AHLC and THLC, (a) winter B, (b) winter C.

The analysis suggests that replacing the steam heating of chips at the TMP plant would be a relatively cost effective way to reduce overall energy consumption. However, this was not seen as a technically feasible solution. Therefore a third analysis has been carried out, treating the chips heating by steam as a mandatory solution. This is presented as Case C.

Also, when both treating the paper machine heat recovery as hot streams and deciding to leave the use of steam in chips preheating as it is, the current utility consumption corresponds to a ΔT_{min} of 25 K. The analysis shows that 8.5 MW can theoretically be saved by changes in the heat exchanger network. The analysis suggests that the steam uses at the debarking could be relatively cost effective to replace compared to other possibilities.

4.2 Summer

On summer period the temperature of outside air is 10 °C and the temperature of the incoming water is 17 °C.

Opposite to the winter case, there are cooling demands even when the ΔT_{min} is reduced to zero. This causes a greater theoretical improvement potential on summer than winter time, which is quite rare. When drawing the advanced composite curves a ΔT_{min} of 23 K corresponds to the current utility consumption. The analysis shows that on summer time there is theoretically an improvement potential of 9.0 MW, of which none is expected to be especially cost effective.

5. Conclusions

In this paper an operating TMP mill is analyzed using the advanced composite curves. The analysis has been carried out for two periods, winter and summer. The main differences are the temperatures of incoming water and air. For both periods, three cases are presented. The cases describe the process with different degrees of freedom. Case A takes into the analysis only the mandatory heating and cooling requirements of the mill and leaves the choice of utilities completely open. In Case B, paper machine heat recovery is added as hot streams. Case B suggests that the steam use in heating of chips at the TMP plant should be relatively cost effective to replace by process heat recovery. However, this was not seen as a technically feasible solution. Therefore, a third case (Case C) is presented, where the steam use at the chips heating is left as it is.

The analysis shows a theoretical improvement potential of 8.5 MW on winter and 9.0 MW on summer time.

Based on the results from the different cases (A to C) it is possible to show the importance of first having no preset limitations and taking more technical restrictions into the account when the analysis goes further.

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