A SOFTWARE FOR ENERGY OPTIMISATION USING PINCH ANALYSIS

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ABSTRACT

Pinch Technology is a well-established procedure for the optimization of heat recovery in chemical process plants. The advent of Pinch Technology provides a comprehensive as well as systematic approach to maximise a plant's energy efficiency. Based on the 1st law principles, in some cases, the technique is amenable for use with commercial spreadsheets or even with hand calculations. Optimisation of medium and large scale oleochemical as well as petrochemical processes, however, could be significantly expedited through the use of a computer software. This paper describes the key features of the first Pinch Analysis software developed locally for energy optimization based on the Pinch Analysis principles. The software allows rapid construction of the composite and grand composite curves and the automatic optimal placement of utilities aimed at maximizing the energy efficiency. An interface for heat exchange network design that includes an enthalpy scale is an added advantage as it clearly shows the heat balances of heat-exchanging streams. This feature is missing in other Pinch Analysis software available in the global market.

Keywords: *Pinch Technology, Composite Curves, Grand Composite Curves, Retrofit, Utility Systems.*

THE BASIC *PINCH* PRINCIPLES

Pinch applications begin with a simple plot of process hot and cold streams enthalpy aggregate on a temperature vs. enthalpy diagram (shown in Fig. 1). The pair of "composite curves", provide profound insight for the design and retrofit of thermodynamically efficient systems. In essence, the curves give an overall picture of the process streams heat availability and requirement. The shaded region on the curves indicates the maximum possible heat recovery between the process streams. The overshoots of both hot and cold curves represent the minimum hot and cold utility requirements or the energy targets for the process. The point of closest approach between the hot and cold composites is referred to as the "pinch" which limits the process heat recovery. The pinch divides the process into two thermodynamically *separate systems*, each of which is in enthalpy balance with its relevant utility. It follows that the hot and cold utilities are the *only* required utilities for the process *above* and *below* the pinch respectively. In order to avoid excess utility consumption, the following rules must be observed at all times (Linnhoff, 1982).

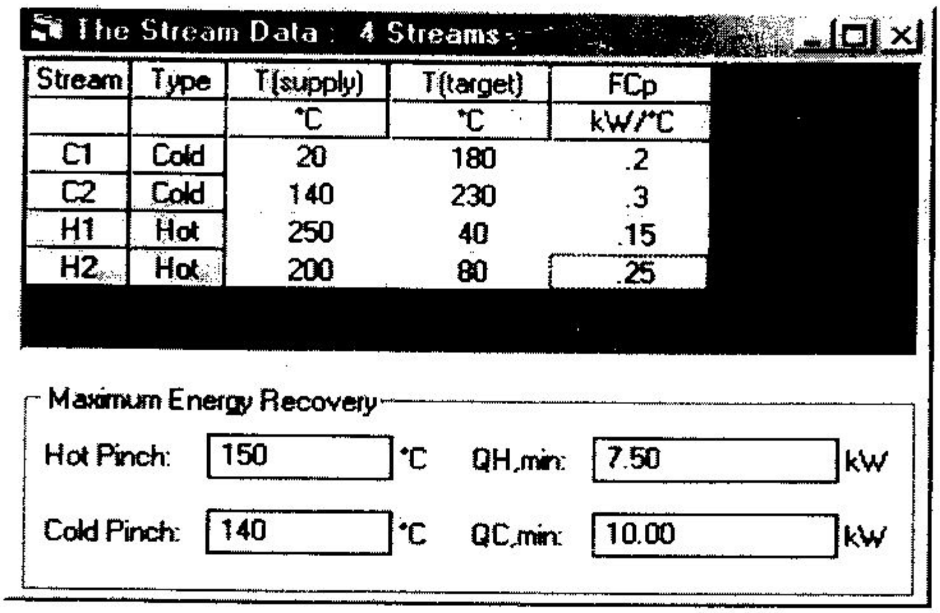
1. Keep the systems above and below the pinch independent from one another. Never allow heat to be transferred across the pinch.
2. Below the pinch, only cold utility is needed. Therefore, hot utility is irrelevant.
3. Above the pinch, only hot utility is needed. Therefore, cold utility is irrelevant.

The composite curves have proved useful in representing overall process streams heat quality and quantity, assessing the pinch situations and generating the energy targets. However, they give no clear indication of the appropriate utility level(s) especially in cases involving multiple utilities. For this purpose, knowledge of the different levels of process sources and sinks is needed.

The grand composite curves shown in figure 2 is a profile of the process sources and sinks. It is generated by plotting the horizontal (enthalpy) separation between the composite curves with built in ΔTmin. Using the grand composite curves as a tool, a designer is able to select the most appropriate utility or utility mix for a process. Optimum interface between process and utility systems can now be conveniently generated.

PROCESS STREAM DATA

The first step in performing an energy optimization study based on Pinch Analysis is to select the process streams having potential for heat exchange. The key information to be included for the analysis of heat exchange potential include the streams' starting temperatures (supply temperatures, T_S), streams' ending temperatures (target temperature, T_T) and heat capacity and flowrate. Streams' heat capacity and flowrate are usually lumped together and named *heat capacity flowrate*. Streams with heat surpluses and needed to be cooled are termed as a "hot stream" whereas those with heat deficits and needed to be heated are termed as "cold streams".


The Stream Data : 4 Streams

Stream	Type	T(supply)	T(target)	FCp
		°C	°C	kW/°C
C1	Cold	20	180	.2
C2	Cold	140	230	.3
H1	Hot	250	40	.15
H2	Hot	200	80	.25

Maximum Energy Recovery

Hot Pinch:	150	°C	QH,min:	7.50	kW
Cold Pinch:	140	°C	QC,min:	10.00	kW

Figure 1. Process Stream Data

The pinch software allows the required data to be entered directly into its stream data interface shown in Figure 1. Using the available information, the software will calculate the enthalpy content for each stream, ΔH, to give the streams' heat availability and requirement.The software uses the information from the process stream data to determine the cumulative hot and the cumulative cold streams' enthalpy for the process. Once these are established, the minimum utility targets for the process are determined via the composite curves or the problem table analysis approach to be described in the next sections.

THE COMPOSITE CURVES

The composite curves are plots generated by the software representing the "resultant" or cumulative hot and cold process streams on a temperature versus enthalpy diagram (see Figure 2). Constructed from process stream data, the curves provide a useful graphical representation of the quality and quantity of heat available and required for the process streams under study (Manan, 2000). For a fixed minimum approach temperature for heat exchange, ΔT_{min}, the composite curves give the minimum amount of hot and cold utility requirements for the process and the maximum amount of heat recoverable. The point of the minimum approach temperature is called the heat recovery "pinch". Figure 2 shows that the minimum utility requirements and the pinch temperatures are conveniently displayed on the software interface.

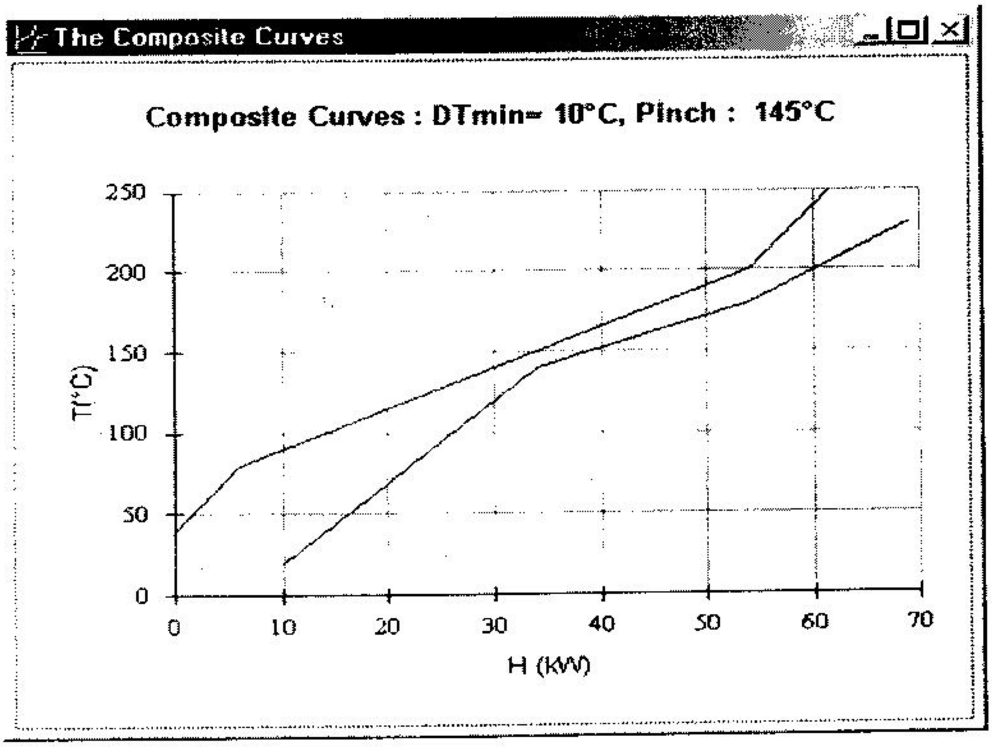


Figure 2. Process Composite Curves.

THE GRAND COMPOSITE CURVES (GCC)

The grand composite curves can be plotted from the enthalpy difference of the hot and cold composite curves at a given temperature. Essentially, this is the horizontal separation between the hot and cold composite curves. The grand composite curve is a profile of the process heat sources and sinks; separated by the process pinch, as shown in the Figure 3 below. The Grand composite provides an interface between the process and utility systems. It allows a designer to place relevant quantities of utilities at the appropriate temperature levels in a process.

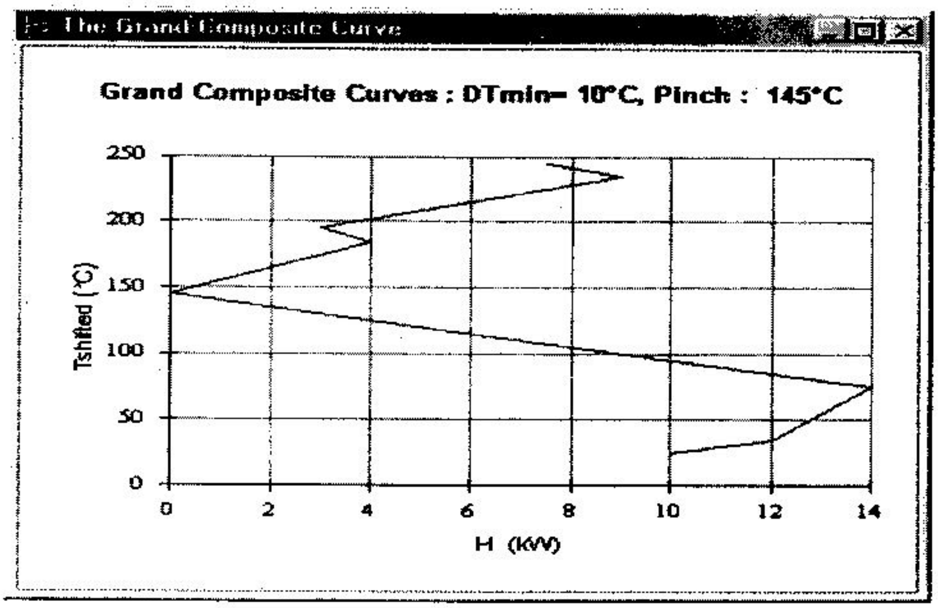


Figure 3. The Grand Composite Curves

Figure 4 shows the software dialog box for utility data entry. Any number of utilities can be entered for a process. Columns for utility costs are also provided for utility cost calculations and to enable the search for an optimum utility combination. This software automatically performs calculations for the optimum utility combination. The result of the optimal search is displayed in the balance grand composite curve shown in Figure 5.

Utilities	Type	T(in)	T(out)	Price	DH	Cost
		°C	°C	$/kW.yr	kW	$/yr
1	MP Steam	180	180	137.5	3	412.50
2	HP Steam	250	250	159.6	4.5	718.20
3	Cooling Water	25	35	80	10	800.00

Utilities Cost

Utilities	Sum DH(kW)	Sum cost($/yr)
Hot	7.5	1 130.70
Cold	10.	800.00

Figure 4. The Utility Data Dialog Box.

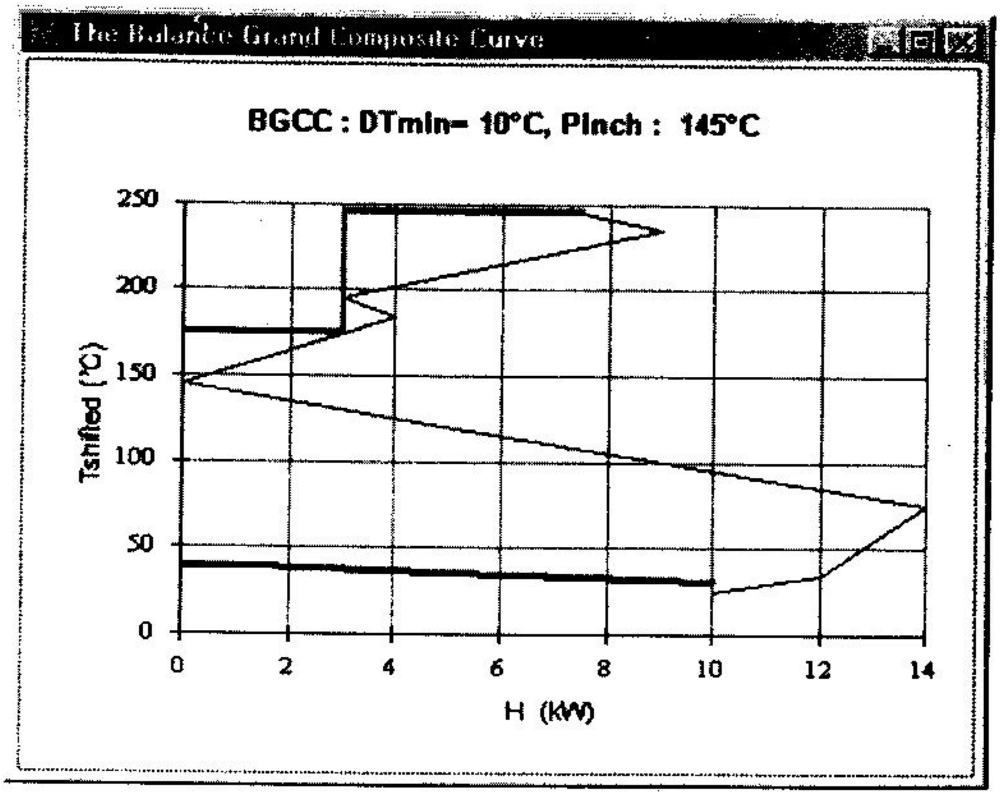


Figure 5. Balance Grand Composite Curve.

CONCLUSIONS

A software for optimization of process heat recovery that is based on the principles of Pinch Analysis has been developed. The software allows quick determination of the minimum process heating and cooling requirements, the heat recovery pinch and the optimization of utility loads and levels. Work on the design of heat recovery network to achieve the utility targets established is underway. With its user-friendly features and attractive graphical user-interface, the software can provide significant advantage for process designers and plant engineers alike.

REFERENCES

Linhoff, B., et al, "User Guide on Process Integration For the Efficient Use of Energy", IChemE, Rugby, 1982.

Manan, Z., Combining pinch and exergy analysis for process improvement- A cases study on an aromatics complex, Proceedings of 14th Symposium of Malaysian Chemical Engineers, Putrajaya, Malaysia, Oct. 30-31, (2000).