Pinch Analysis

A ground laying tool used by the LENI is Pinch Analysis. In the context of the LOVE project, it is applied in the analysis and in the optimization/integration of industrial processes and definition of waste heat, in the evaluation of accessibility/availability of waste heat, in the estimation of possible uses of the identified available waste heat and in the optimal integration of the waste heat recovery.

The method was developed by Bodo Linnhoff et al. [1] and is a way to systematically identify heat recovery possibilities within a process such that the overall energy consumption of the process is minimal (Minimum Energy Requirement (MER)). A detailed description of the method can be found in [2]. Shortly described, in a Pinch Analysis processing steps are analyzed in order to identify if they need heating or cooling to perform their function/transformation on the raw-material, pre- or side-product. It is important not to look at the technology needs but at the actual needs of the transformation step. For example, a heat exchanger might be designed to use pressurized steam in order to heat a pre-product from 60°C to 80°C. In this case the technology requirement (which the operator has to satisfy) is a certain amount of steam; the actual requirement of the transformation is a certain amount of heat, above 60°C to 80°C. From this analysis results a list of heating and cooling requirements, stating the temperatures and the quantities (enthalpies) of the needed heat streams. If heat has to be evacuated from a unit we talk about a hot stream because it can be used as a heat source. If a process unit needs heating we talk about a cold stream since it needs to be heated up (heat sink). Subsequently all hot and all cold streams are summed up to form the hot and cold composite curve, respectively. The construction of a hot composite curve is demonstrated in figure 1. It can be seen that the composite curve is steep if little heat is available in a temperature interval, and that it has a flat slope if much heat is available, e.g. in intervals with several streams.

Once the composite curves, including all hot and cold streams, are prepared they are used to identify the amount of heat that can be recovered within the process. In order to do so, a minimum temperature difference $\Delta T_{\text{min}}$ between hot and cold streams for a typical heat exchange is defined. $\Delta T_{\text{min}}$ depends on the heated and cooled materials and thermodynamic states as well as the available heat exchanger surface. Oftentimes, and thus also in this document if not mentioned otherwise, the corresponding $\frac{\Delta T_{\text{min}}}{2}$ is directly added or subtracted to or from the respective stream temperature, leading to a composite curve with corrected temperatures which show the available heat or needed cooling requirements of the process. In figure 2 (a) and (b) it is shown how the MER is identified by horizontally sliding the cold composite curve under the hot composite curve each with corrected temperatures until they touch. The point in which they touch is called Pinch Point. By recovering heat from the hot streams to heat up the cold streams, not only the need of a hot utility is diminished but also
the deployment of a cooling utility shrinks at the same time. *The choice of $\Delta T_{\text{min}}$ is hence a trade-off between the investment in heat exchanger surface and energy saving.* The use of computer models plays a crucial role since it allows for the identification of an optimum economic value if energy cost and investment in a Heat Exchanger Network (HEN) are well defined.

Another way to represent the process is the *Grand Composite Curve* (GCC). It shows the horizontal distance $\Delta Q$, between the hot and cold composite curve over the temperature (*figure 2 (c)*). Both diagrams, composite curves and grand composite curve, can be modified by replacing the temperature with the corresponding

$$\text{Carnot Factor} = 1 - \frac{T_{\text{amb}}}{T}$$

with the ambient temperature $T_{\text{amb}}$. Thus the thermal exergy is represented by the surface in the diagram (*figure 3 (d)*). *In order to optimize the exergetic efficiency of a process the surface between hot and cold curves has to be minimized.* The Pinch Analysis divides the process into two subsystems, above and below the pinch point. Above the pinch point, it is characterized by an overall necessity for heating. Below, there is an overall necessity for cooling. In consequence this means that no stream above the pinch point should be cooled by a cold utility but rather by internal heat exchange, and no stream below the pinch point should be heated by means of a hot utility but rather by heat recovery. Additionally no internal heat exchange should cross the pinch point (no stream below the pinch should be heated with a stream from above, in order to meet the MER. Further improvement of the thermal energy balance of a process is possible by integrating heat pumps, changing pressures in condensations or distillation columns or other measures. It is evident that the choice of the system boundaries heavily influences the analysis and in consequence the results. It is therefore very important to intelligently define those boundaries and not to confine the analysis to a subsystem; generally speaking the larger the analyzed process the more heat recovery possibilities are probable [1–3].

**FIG. 1** – Construction of a hot composite curve, individual streams from process analysis (left) and summed up to composite curve (right) [2].
FIG. 2 – Composite Curves with and without corrected Temperatures and Grand Composite Curves with Temperature and Carnot.
REFERENCES

