The Thermoptim® software

Whereas the analysis of energy technologies and thermodynamics are generally considered as difficult fields, it is possible to greatly simplify matters by separating the overall system description, which is generally rather simple, from the study of the various components considered one by one.

The overall description is very useful at the qualitative level: it is visual and allows one to understand the role of each component in the whole system. On the instructional level, it is of basic importance to understand the design principles of these technologies. Once the overall structure of an engine or a refrigeration device is well understood, it is much easier to study its components one by one because one knows how each is included in the system and what its function is.

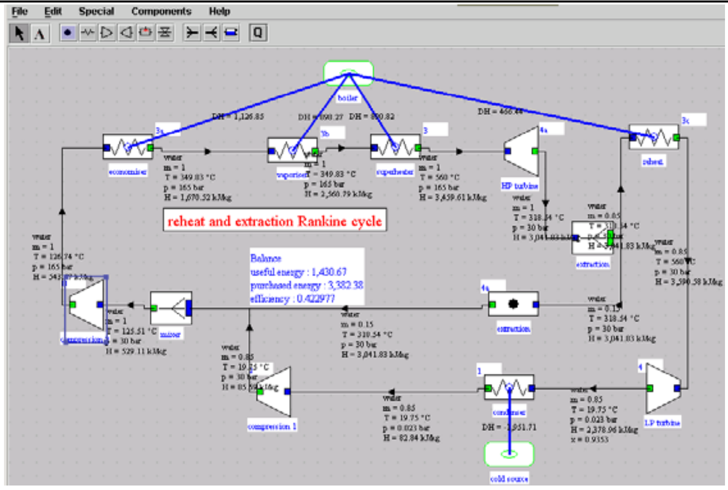

Figure 1 : Synoptic screen of a steam cycle

If one has access to an appropriate graphical environment such as that which is provided in Thermoptim, the internal structure of any system can be very easily described. The qualitative or diagrammatic representation which is obtained is full of engineering information that can subsequently be quantified by setting the numerical thermodynamic parameters of the various components. Thanks to this novel approach separating qualitative and quantitative aspects, Thermoptim's users are allowed to easily calculate even complex thermodynamic systems without writing an equation or programming a single line of code.

Initially Thermoptim has been developed to help solve problems encountered in teaching applied thermodynamics. Its present functionalities make it possible to use it for also solving much more complicated problems such as industrial schematic design (for instance it has been used for the system integration of cogeneration units or advanced electricity generation production plants involving several hundreds of components).

The Thermoptim software

The Thermoptim software (www.thermoptim.org) provides a modeling environment including four closely interconnected working elements : a diagram editor / synoptic screen (figure 1), a simulator, interactive charts (figure 2), and an optimization tool, allowing one to easily vary the whole set of characteristics of the system under investigation.

Since energy conversion technologies can be represented as an assembly of interconnected components, their system analysis can be based on a combination of a system design for the studied project, which allows one to bring to the fore its main functional elements and their interconnections, and a steady-state thermodynamic modeling of its various elements. To make these calculations one needs:
- each functional element represented by an appropriate Thermoptim basic type (substance, point, process, node, heat exchanger) which has its own characteristics and coupling variables ;
- the whole system model assembled from these types using an interactive interface ;
- the system simulation of the whole made possible thanks to an automatic recalculation engine which exploits the system properties that were implicitly described when the system was initially modeled.

Thermoptim has been developed to help solve some difficulties related to the learning and better understanding of applied thermodynamics. Its objectives are the following:
- motivate beginners by avoiding initial calculation difficulties while enabling them to study examples complex enough to represent real world cases (it is used in about 20 higher education institutes) ;

- provide advanced users with a powerful calculation environment allowing them to improve their productivity.

Applied thermodynamics is indeed a relatively complex science, the physical laws being very nonlinear. Thermodynamic fluids are either ideal gases or vapors. The first are relatively easy to model as compared to the second because they are governed by much more complex equations. These fluids undergo various transformations, themselves also nonlinear, from the simplest like compressions or expansions, to more complex ones leading to composition changes, such as combustion or moist gas condensations. According to the case, these processes have to be calculated in open or closed system, the equations being different.

Main functions of the software

Thermoptim allows one to calculate the complete state of different fluids (temperature, pressure, mass volume, enthalpy, internal energy, entropy, exergy and quality), for ideal gases and condensable vapors. These fluids can undergo various transformations or processes:
- compression and expansion, in open or closed systems. These can be adiabatic or polytropic, and are characterized by their isentropic or polytropic efficiency ;
- combustion, also in a closed or open system, at set pressure, volume or temperature. Fuel can be introduced into the combustion chamber separately from the oxidizer, or premixed. The dissociation of the carbon dioxide can be taken into account ;
- isenthalpic throttling ;
- heat exchanges with other fluids: the software is able to calculate the UA product or the overall heat transfer coefficient across the surface of a heat exchanger for the following configurations: counter flow, parallel flow, cross flow or (p-n) type.

Fluid networks are represented by nodes (mixers, dividers and separators), which conserve enthalpy and mass flow-rate. The other elements (compressors, turbines, combustion chambers, heat exchangers) can be easily connected into these networks.

Fluid mixtures can be made. These are considered to be ideal gases. Specifically, Thermoptim allows one to process water vapor / gas mixtures and provides six types of processes to study them (heating, cooling, humidification, supply conditions, desiccation).

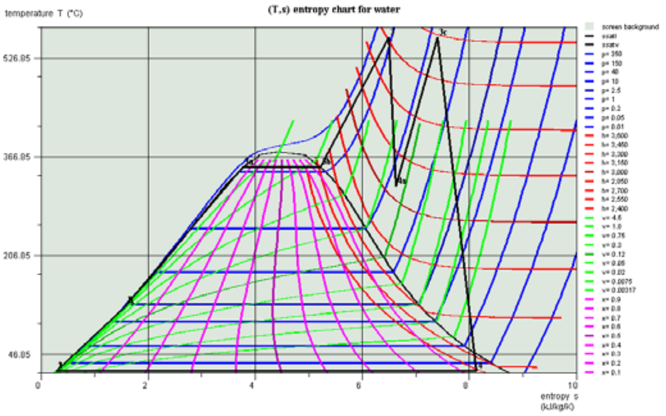

Figure 2 : Steam cycle in an entropic chart

The software possesses a database of thermophysical properties of substances most commonly used in applied thermodynamics. The whole set of elements composing the system studied is grouped as a project which can be handled thanks to appropriate interfaces.

GICQUEL R., Systèmes Energétiques, Tomes 1 et 2, Presses de l'Ecole des Mines de Paris, février et novembre 2001.

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