Thermodynamics without trouble with Thermoptim®

Learning thermodynamics is almost always difficult, whatever the efforts made by instructors:
- this field calls upon basic concepts whose practical interest is far from being simple to illustrate, such as internal energy, enthalpy or entropy;
- calculations are almost always complex, at both formal and numerical levels, particularly for closed systems;
- even the simplest laws are strongly non-linear;
- industrials mainly use open systems and (T,s) or (h, log P) charts, whereas beginners work with the classical closed system (P,v) diagrams.

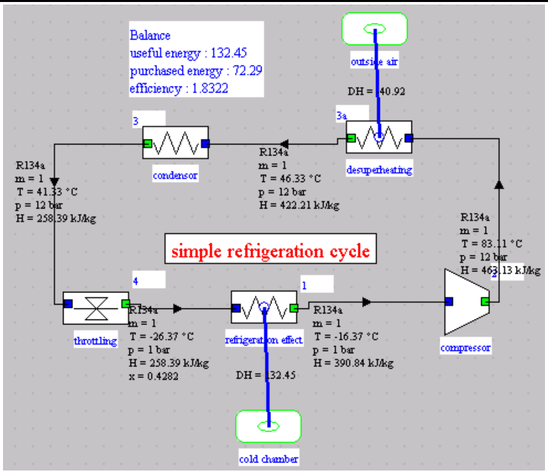

Figure 1 : Synoptic screen of a refrigeration cycle

The result is that students find it difficult to understand basic notions, and consider thermodynamics to be off-putting, in spite of the number of its important industrial applications and their impact on everyday life (car or aeronautics propulsion, electricity production, refrigeration...).

Thermoptim (www.thermoptim.org) is a software which allows students to learn thermodynamics without trouble: in parallel to or even before the presentation of the theorical bases, they can make very practical exercices on real machines applications, such as the study of a refrigerator or an electricity plant... As the students' knowledge is limited, this training must be as easy as possible. To motivate them, the results obtained must be realistic.

Thanks to its thermodynamic function libraries, Thermoptim allows one to graphically model simple or complex energy technologies without writing a single equation, and to get very accurate results which can be visually displayed in different ways. It is in particular possible to get rid of the very limitative hypothesis of the perfect gas, and to use real fluid models. The example in figures 1 and 2 shows the modeling of a refrigeration compression cycle working with R134a, a CFC substitute with an ozone depletion potential equal to zero.

Students can work on real life applications of the notions studied in class and thus understand their pratical interest. They concentrate their cognitive efforts on the qualitative analysis of the systems studied, the quantitative assesment being made by the software. It is worthwile proceeding this way because thermodynamics is much simpler at the qualitative level than at the quantitative one: students have no difficulty understanding and memorizing the design of the classical thermal machines, which include but a few basic components whose functionnalities are directly intuitive : compression and expansion devices, heat exchangers and combustion chambers (figure 3).

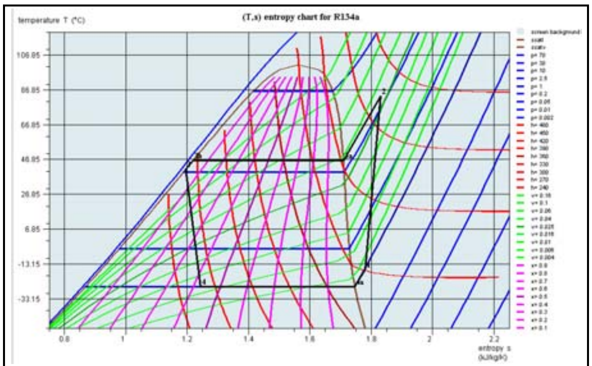

Figure 2 : Refrigeration cycle in an entropic chart

Moreover, the qualitative and visual representation of the architecture of these machines is largely independent of the way the components are calculated, i.e. of the hypotheses made for the quantitative assesment. Students thus see how a given element can be calculated more or less accurately depending on the mathematical tools they have at their disposal. Concretely, they understand that the perfect gas hypothesis allows one to carry out some approximative analytical calculations, whereas a modeling environment such as Thermoptim provides much more realistic results. The link between the theoretical bases presented in class and the industrial reality can therefore be better understood. Experience shows that students very rapidly master the basic functions of the software to be able to use it as an exploratory tool which enables them to better understand the concepts presented in class. They can plot the real cycles on the thermodynamic charts (T, s) or (h, log P) used by the professionals and see why and how they differ from the theoretical ones such as the Carnot cycle. Having access to the real properties of fluids, they can get rid of the usual hypotheses (which are unfortunately often caricatured) and build by themselves perfectly realistic models of thermal machines.

This novel instructional approach consists in illustrating the basic notions which are not intuitive at all by beginning by dealing with simple but realistic examples. At first students are attracted by the game aspect of the software. They get caught up and try to obtain results, which compels them to understand the screens which are displayed. Therefore, they acquire the basic thermodynamics vocabulary and assimilate rather quickly the main notions. In a second step, once the basic processes are well understood, they can study full cycles that they build graphically by assembling elementary components, learning intuitively how to model them.

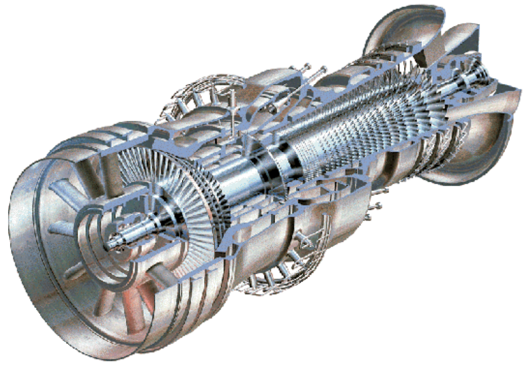

Figure 3 : Alstom Power GT24/26 gas turbine

Conclusive instructional experiences have been carried out since 1997 in the different cycles of about seventy higher education institutes in technician, engineer and university curricula, in France and abroad. The result is first an increased motivation for thermodynamics, leading to a fostered attention and participation in class as compared to classical approaches, and second a better assimilation of both theoretical notions and their practical implementation.

Thermoptim can thus be described as a kind of **virtual experimentation platform** allowing students to make connections between theory and practice by implementing the concepts studied in class, and to become initiated to the modeling of energy systems. In a way, it allows one to adopt for thermodynamics an approach similar to that commonly used for electronics and optics. Besides, its utilization is quite analog for students with the simulation software available in these disciplines.

To conclude, it is possible to introduce a more constructivistic instruction of thermodynamics, complementary to the classical analytical one. This shift of emphasis makes the assimilation of the field easier.

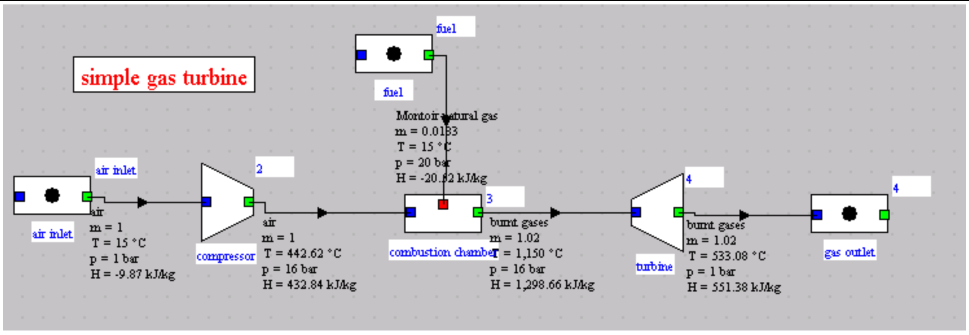

Figure 4 : Synoptic screen of a gas turbine in Thermoptim

Students work on small realistical projects which allow them to make connections between the theory and the applications, to investigate the influence of various parameters on the performances of the systems studied, and in particular to get a very good understanding of the design of the usual machines. They improve their understanding of the underlying physics, without having to devote too much time to the quantitative aspects or to resort to too simplistic hypotheses.

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

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