ENLIGHTENING THERMODYNAMIC CONCEPTS IN THE LAB VIA HARDWARE AND SOFTWARE: THE CASE OF A HEAT PUMP CYCLE

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Abstract

On adapting to the European Higher Education Area (EHEA) whose essential parameters were established in the Bologna Declaration, new teaching techniques and strategies need to be adopted. In this frame, we discuss here an experience carried out in the Laboratory of Thermodynamics of an Engineering School.

Students perform a two-hour laboratory practice in which they first put to work a real heat pump and measure several variables of the cycle. This is done with a standard lab equipment, in which students can easily identify the throttle valve, compressor, evaporator and condenser. Then, they simulate the performance of the machine with a computer program that calculates thermodynamic properties, and they compare the results of the simulation with the real cycle they have seen before. The software, Ciclograf, has been developed specially for this purpose by the teachers of Thermodynamics who belong to the Educative Innovation Group "Thermodynamics Applied to Industrial Engineering" (TAII) of the Universidad Politécnica de Madrid (UPM).

In this way, it is expected that students will get better insight in the meaning of the thermodynamic balances and a clearer understanding of real cycles.

Finally, a satisfaction survey is passed to the students. The answers are clearly positive.

From the teacher point of view, the practical session doesn't consume too many resources, as it takes two teacher-hours per each 12 students, and just six computers and a laboratory heat pump (or similar equipment).

Keywords: Innovation, laboratory, thermodynamics.

1 INTRODUCTION

Spanish Universities are immersed in a process to adapt themselves to the European Higher Education Area [1]. This means a lot of challenges that must be faced with new strategies [2], that should be carefully studied and not improvised [3]. Traditional methods, even in cases when they have succeeded in the past, are not enough now.

In this paper we are going to describe an experience for the subject of Thermodynamics-II, given in the degrees of Industrial Engineering and Chemical Engineering at the Escuela Técnica Superior de Ingenieros Industriales (School of Industrial Engineering - ETSII) of the Universidad Politécnica de Madrid (UPM). This subject is imparted in the 4th semester of both degrees, with the same contents, teachers, evaluation and all of the other conditions, making up a total of about 400 new students per year. There is a compulsory laboratory practice for this subject, that should be limited, by agreement of the School Council, to a maximum duration of two hours, and that need to be done only once; so, the number of students that make the practice every year is fairly the same as the number of new students.

Contents of the subject include open systems, Rankine and cryogenic cycles and calculation of thermodynamic properties in multicomponent and reactive systems. It has been observed, from students opinion polls made in the past, that students often find this subject too abstract, so the laboratory seemed the perfect place to make a link between the reality of the systems they will find in industry and their abstract thermodynamic treatment and representation; it also looks like a good place to introduce them to the use of simulation tools. So, the main idea was to work with a real cycle, measuring some of the parameters of its performance, then simulate the same cycle with a computer program, and finally comparing the measured and calculated results.

2 DESIGN OF THE EXPERIENCE

As the number of students is quite big, they need to be distributed in groups. Each group should be of 10-12 students, so that they all can really see and manipulate the real cycle. It was considered that they can work on pairs at the computer, so that six computers were needed.

2.1 Real cycle

For the real cycle, we used a commercial lab unity, consisting on a heat pump/refrigeration cycle. It use water as fluid in the condenser, and can use water or air in the evaporator. Pressures, temperatures and flows at the significant points of the cycle can be easily measured, as well as power consumption. With these values, the efficiency of the cycle can be obtained through energy balances. Some operating parameters can be changed, so that the students can see how the efficiency changes accordingly.

2.2 Computer simulation

Having measured the flows, pressures and temperatures that define the thermodynamic cycle in the real equipment, the students proceed to simulate it in the computer. The program used for this is Ciclograf (formerly named Ciclowin), and it has been developed specially for this purpose by the teachers of Thermodynamics who belong to the Educative Innovation Group “Thermodynamics Applied to Industrial Engineering” (TAII) of the UPM, with financial support from UPM in the frame of the Educational Innovation Project “On-line interactive learning of thermodynamic cycles” [4].
The program uses an intuitive graphical interface, so that students get used to it in a few minutes, and are able to represent the cycle and introduce the needed variables and working fluid. Then, with just a click, they get the results, as for example in Fig. 1.

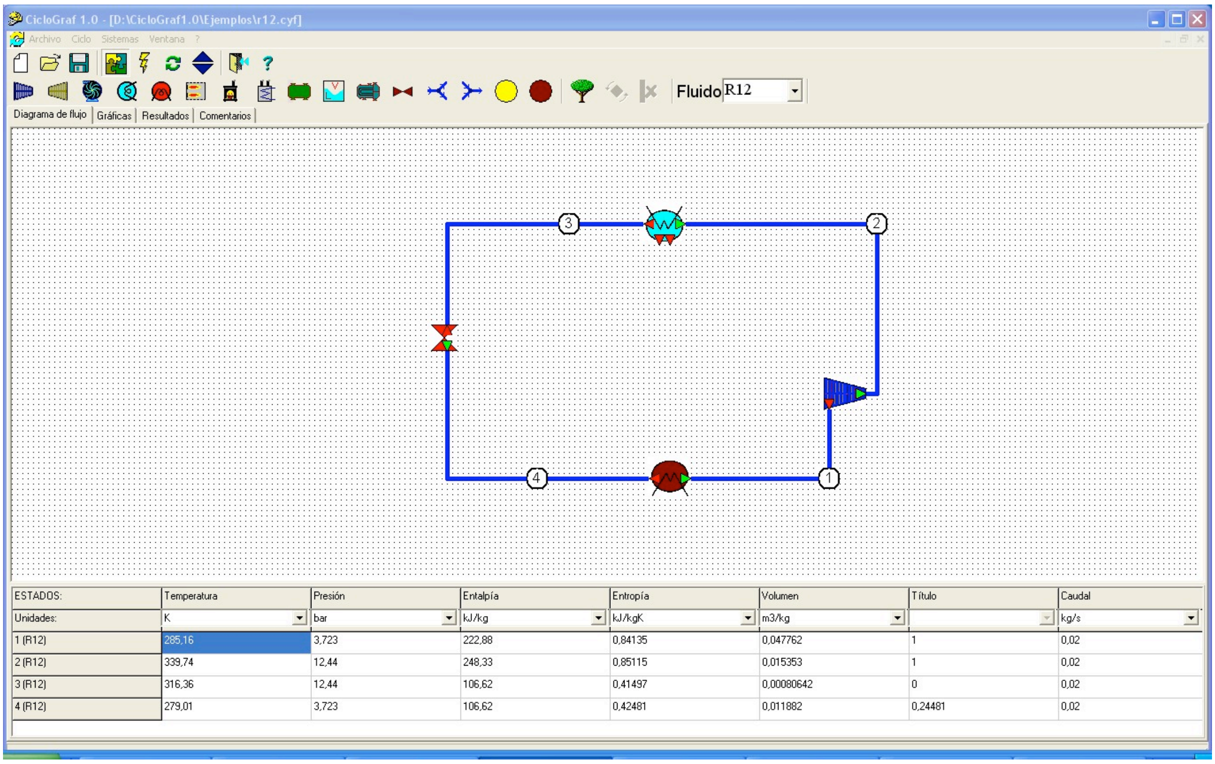


Fig. 1. Example screen of Ciclograf showing flow diagram and thermodynamic properties

At the same time, they get the T-s and h-s diagrams, and a summary of power and heat interchanged, and exergy destruction in the cycle, as it can be seen in Fig. 2 and Fig. 3

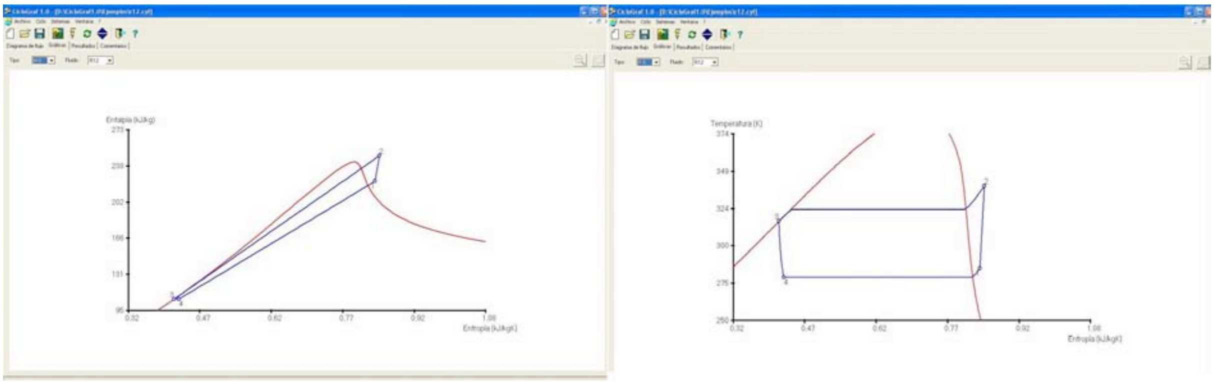
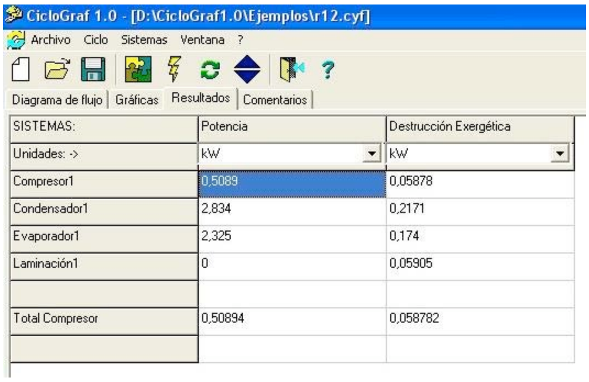


Fig. 2. The h-s and T-s diagrams for the example above in Ciclograf



SISTEMAS:	Potencia	Destrucción Exergética
Unidades: ->	kW	kW
Compresor1	0,5089	0,05878
Condensador1	2,834	0,2171
Evaporador1	2,325	0,174
Laminación1	0	0,05905
Total Compresor	0,50894	0,058782

Fig. 3. Summary of power and heat exchanges and exergy destruction

So, in very few minutes, students can see what would happen if the variables used to define the cycle should have taken different values; also, they can compare these results with those measured in the real equipment, and look for an explanation of the differences.

2.3 Organization

As the expected number of students was some 400, and groups should be of about 12 students, 34 groups were formed. Each group could attend the heat pump together, and then they make six pairs to work each pair with a computer. Computers didn't need to be last generation not too powerful, as the software demands few resources.

3 SATISFACTION SURVEY

A satisfaction survey was carried out, to get feedback from the students. A form was passed to the students just after finishing the laboratory session (except the first two days). Students were asked to evaluate from 1 to 10 his agreement with some statements (meaning: 1 not at all, 10 complete agreement), and also their global valuation of the practice and of the materials (also from 1: very bad, to 10: excellent). Students filled it voluntary and anonymously, so not all of them did it. Some of them left some questions blank; some others gave non-numerical answers, that were considered non-valid in any case. There were near 400 students that made the practice, and nearly 300 gave valid response to each question. Table 1 gives the statements, number of valid answers and mean value.

As can easily be seen, all considered aspects were well evaluated. The worst valuation was given to the written documentation (6.63), that was in fact incomplete at the moment. The following lowest mark, although it was not bad at all, was given to the duration of the practice (7.22). The real duration was about two hours, which is quite common for laboratory sessions at our School.

The highest mark was obtained by the theoretical introduction given. It is remarkable the agreement of students with the statements: they have learned something in the practice (8.24), and the practice fits the contents of the subject (8.17).

Table 1. Questions and answers of the satisfaction survey

Statement	*Answers*	*Mean*
The written documentation allows the understanding of the practice	251	6.63
The practice fits the program of the subject	277	8.17
The practice helps to understand the concepts developed in theory	279	7.83
The duration of the practice is appropriate	295	7.22
The realization of the practice contributes to the learning of the subject	291	7.65
Students participate actively in the practice	295	7.98
It is useful the realization of the practice	295	7.75
He/she has learned something in the practice	296	8.24
The theoretical introduction of the practice is helpful	295	8.50
General valuation of the practice	283	7.88
Valuation of the materials	279	7.53

4 CONCLUSIONS

From this experience we can conclude:

1- The need to present the theoretical concepts through experimentation with real elements. This allows the student to see the reality of these concepts, instead of seeing them as some kind of abstraction without connection with real world.

2- Practices in which the students can play an active role help them to get a clearer understanding of the theoretical concepts.

3- Practices with an experimental part and a simulation part, are a good tool to help students understand the models used in the subject.

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