ADAPTING A COURSE IN THERMODYNAMICS TO EHEA

López Paniagua, Á. Jiménez Álvaro, J. Rodríguez Martín, C. González Fernández, R. Nieto Carlier

Department of Energy and Fluid Mechanics, Escuela Técnica Superior de Ingenieros Industriales (ETSII), Universidad Politécnica de Madrid (UPM) (SPAIN)
ilopez@etsii.upm.es, a.jimenez@upm.es

Abstract

This paper will describe an experience carried out with an heterogeneous group of seven 1st and 4th year students of Industrial Engineering at Universidad Politécnica de Madrid, UPM (Technical University of Madrid). It consists in a collaborative project whose outcome will be the design of a practical laboratory session with a gas turbine for 2nd year students of Thermodynamics, and it will be included in the 2010-2011 course program, to contribute to progressively adapt it to the requirements, principles and guidelines of the European Higher Education Area (EHEA). The practical session is elaborated by students and for students, leading to a full student-centered activity for training and learning in Thermodynamics subjects, which take part in the first years of technical education for a degree in Industrial Engineering. The students have been encouraged to participate actively in the experience, and they all have shown a high level of involvement along the whole activity. The experience has been found to be of interest for both the students, in aspects as improved motivation, skills developing, new/reinforced learning; and also for the tutors, in particular a better understanding of the profile of the students before they begin the ordinary course in the subjects.

Keywords: Practical Session, Collaborative Project, Student Centered Activity, Thermodynamics Education, Engineering Education.

1 INTRODUCTION

This experience is an example of the work that the *Termodinámica Aplicada a la Ingeniería Industrial* (Thermodynamics Applied to Industrial Engineering) Group of Innovation in Education, GIE-TAII, is carrying out to adapt to the *Bologna Declaration* ideals. Previous efforts in this direction have been presented by GIE-TAII in order to improve student learning levels in the Thermodynamics subjects coursed at Escuela Técnica Superior de Ingenieros Industriales, ETSII (School of Industrial Engineers), focused in *e-learning* and PBL (Problem-Based Learning) methodologies [1]. In the present case, our purpose is to develop a completely student-centered activity, which would foster flexible, work-based learning and part-time study, directly in line with the *Leuven Communiqué of European Ministers Responsible for Higher Education* of April 2009. The Group also wanted the results of the activity to help the teaching of Thermodynamics in future years, by bringing it closer to the Bologna objectives. As a result of this activity, a practical laboratory-session for the 2nd year students with a gas turbine for use in aeronautics, will be designed.

1.1 Global activity plan

The full experience was planned in the following way:

1. First, this course (2009-2010), a selected group of students with grants for Academic Excellence in High School studies, design a laboratory experiment with gas turbine (1.38ECTS). It is a turbine used for aeronautical applications (single-sitter ultralight planes) instrumented for use in laboratory. The whole group of students is formed by two 4th year, seniors and five 1st year juniors. The original group is split for some activities in two teams, each coordinated by a senior member. Their work is then debated, put in common and tried in the actual gas turbine under the supervision of the tutoring teachers.
2. Second, the practical session manual resulting from this year's experience will become part of the Thermodynamics course (second year) from academic year 2010-2011, in the form of a practical session (0.12 ECTS).

1.2 Objectives

The 2009-2010 stage has as specific objectives:

1. Enhancing the education of the participants: They are given the chance to explore and work with an instrumented gas turbine similar to those found in industry.
2. Fostering development of personal competences: The participants are required to work in teams, debate technical and organizational issues, present their work to the teachers and seek for knowledge. The two senior students are given the chance to use their experience to guide and coordinate teams.
3. Grounding technical knowledge: The chance to explore and manipulate real equipment allows senior students to ground a wide collection of concepts acquired from the subject of Thermodynamics as well as in others. Junior students have the chance of grounding elementary notions such as energy, force, power, etc.
4. For tutoring teachers and the *GIE-TAII*: The experience will provide insight into the target students for 2nd year Thermodynamics, essential for developing student-centered teaching. The first results of the experience have shown: 1. The specific vocational interests with which students initiate engineering studies, 2. Their specific conceptual lacks and how they affect their practical reasoning, 3. The point of view from which they approach theoretical concepts.

The 2010-2011 stage will be directed to a much larger student population (approximately 550 per academic year). Thus it will serve mainly objectives 1 and 3. The GIE-TAII Group intends to enhance it with surveys in order to progress also in objective 4.

1.3 Equipment

The laboratory equipment use for this activity is a self contained small scale gas turbine engine system, designed to demonstrate the principles and characteristics of an aeronautical gas turbine engine. The engine is fully instrumented, with temperature and pressure sensors at each stage of the engine, allowing a full theoretical analysis of a gas turbine engine configured to provide thrust through a nozzle.

Fig. 1 is a schematic representation of the engine with a frontal duct and the position of the points where termocouples and pressure fittings allow measurements of temperature, static pressure and dynamic pressure. This sketch represents also the essential parts of the engine which are the centrifugal compressor, the annular combustion chamber, the axial turbine and the exit nozzle.

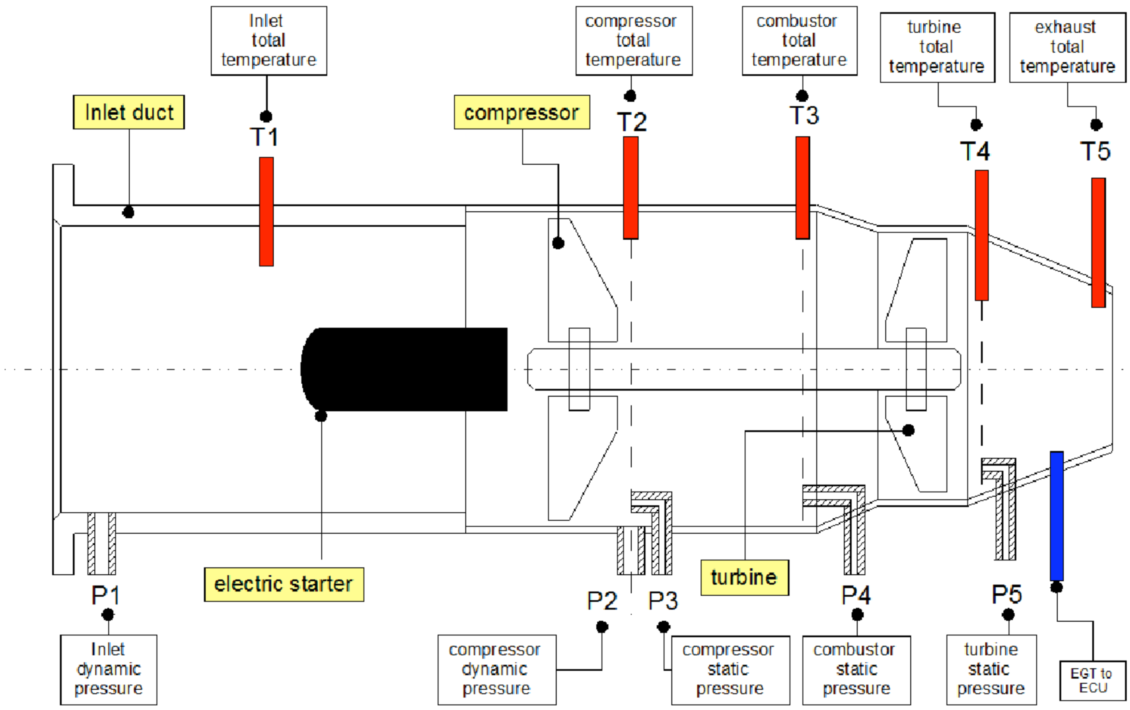

Figure 1. Section of the engine and position of the sensors

The gas turbine engine is controlled safely by a standard PC, through software provided by the manufacturer. This software includes extensive facilities to display the data from the sensors at real time, log this data and export it to conventional format for post processing.

2 METHODOLOGY

As it is stated above, the global activity is divided in two stages. In the present academic course, the first stage regarding the design on the practical session is going to take place, and up to date, it is about to be finished. The global work has been structured in the following sub-activities:

a. *Seminar session and global introduction to theoretical concepts (0.08 ECTS)*. It should be highlighted that the major part of the Academic Excellence granted students are in their first year at our School. They have not coursed any subject in Thermodynamics before, soy they have a lack in some conceptual knowledge. These previous session is needed to debate with them the very basic points like *"what is a gas turbine?"*, *"what kinds of gas turbine can we find?" "what parameters are used to describe how it works"*, *"what are its main components and what happens inside each of them", "what are the very basic thermodynamic magnitudes we use to analyze its behavior"*, *"instrumentation and physical information that can be measured inside the turbine", "notions on energetic conversions and energetic efficiency from both First and Second Laws point of view"*, etc.

b. *Startup procedure (0.02 ECTS).* In the following session, the startup sequence of operations is firstly described by the tutoring teachers, and the pages of the gas turbine user manual containing this information is also posted in a board next to the gas turbine position. Following, it was shown to the students a whole cycle of startup, data registration and exportation and switching off the gas turbine. The gas turbine is manipulated all the time by the teacher, and the students get familiarized with this procedure and with the device.

c. *Turbine handling (0.24 ECTS).* The students carry out several experiments with the gas turbine in order to learn how to control it. The turbine is now manipulated by the students, supervised by the teacher. Three experiments were performed. In the first one, it is registered and analyzed the behavior of the turbine during the transient states along startup and switch off and during the steady state achieved after the startup. The rotation speed along the whole cycle is plotted and the result is discussed. The second experiment consists in a comparison between the measured thrust obtained by the turbine with the guess derived from a theoretical simplified model, for different positions of the throttle (fuel admission valve). The third experiment consists in the reproduction of a *h-s* diagram of the main points in the schematic representation of the gas turbine. The students themselves get familiarized with the handling of the device, they deal with the data provided by the instrumentation, exporting and post-processing it, and also they experience the different possibilities and potentiality of the turbine.

d. *Experiment proposals elaboration (0.2 ECTS).* At this point, the students group is divided in two subgroups. Each of them is coordinated by a senior student of 4th year. Both subgroups are encouraged to design a new experiment, with the vocation of becoming a practical session for their classmates of 2nd year (ordinary course on Thermodynamics) based in their intuition and interests derived from the use of the turbine in the previous experiments, and also in a bibliographical review. The senior student is in a key position to organize the brainstorming proposals given by the junior students, as he/she has previously taken the ordinary Thermodynamics course in the 2nd year. This sub-activity takes place outside the laboratory. The estimated time for it is around 5 h.

    - *Debate (0.16 ECTS)*. Both proposals are discussed by the whole group and the teacher in a new session at laboratory. The group should debate and defend their own position, trying to persuade the rest about the interest of their proposal. The initial ideas should be clarified, redirected, fixed and put in order by the teacher. Many interesting theoretical explanations were done at this point, to guide the students intuitions towards something concrete. This discussion was really interesting and also very enriching for both, students and teachers. Finally, a general scheme for the practical session is arranged.

e. *Elaboration of a practical session outline (0.16 ECTS).* The students prepare a detailed outline for the practical session based in the conclusions of the previous discussions. This is a collaborative sub-activity carried out by the whole group outside the laboratory.

- *Execution of the practical session (0.08 ECTS).* The designed experiment is carried out in practical session according to the outline delivered by the students. Focus is put on the identification of lacks, faults and improvable points on the experiment design. All the experiment is supervised by the teacher.

- *Discussion (0.08 ECTS)*. The whole group debate the issues observed during the practical execution of the designed experiment. Also the obtained experimental results are discussed and analyzed, and the teacher gives a theoretical justification for them and and explanation about why they are expected. The recent experience of the seniors students in the preparation of the subjects is very interesting here for detecting the weakness of the experiment. The ideas for possible improvements are also discussed.

- *Elaboration of a final outline for a practical session (0.08 ECTS).* The students prepare a new detailed outline for the practical session including the improvements derived from the previous experience and from the later discussion. This sub-activity is also carried out by the whole group outside the laboratory.

- *Final execution of the designed practical session (0.08 ECTS).* The final designed experiment is carried out in practical session according to the final outline prepared by the students. Time needed for it is evaluated during the experiment.

f. *Individual report (0.16 ECTS).* Every student delivers a technical report about its participation in the activity. They should describe the most interesting points for them and the ones for their classmates that will take the practical session with the turbine designed by them, as they expect. They should

g. *Monitoring (0.04 ECTS)*. During the whole activity, teachers ask the pupils about educational aspects related to the development of the work. At the end of the activity, the students deliver an open structure report evaluating the learning process they have followed, motivational aspects and new interests derived from the experience. These reports and the feedback obtained by the teachers will be studied for obtaining conclusions on the educational value of the activity.

3 RESULTS

As of the writing of this paper, the activity is just concluded. Therefore, the results mentioned following are its first outcome, although future ones may eventually appear.

- Manual for a practical session with a gas turbine. The main outcome of the activity has been the design for a practical session in which topic and methodology have been developed students whose motivation, interests and educational level are comparable to the target pupils. The design has been tested for feasibility by the students themselves, and for technical coherence by the tutors.
- Brainstorming on topics of interest for the practical session. Brainstorming and debate sessions have yielded a series of ideas for other experiments with the turbine, interests and technical level of the pupils.
- Information on the educational aspects of the activity. The reports written by the pupils illustrating their perception of the educational aspects of the activity coincide in mentioning some points:
- Junior students have acquired descriptive technical knowledge about gas turbines (they will read Thermodynamics in second course)
- Both junior and senior students have acquired practical knowledge about sensors and use of laboratory equipment.
- The activity has required improving their capacities for teamwork in general, with specific mentioning to coordination.
- Senior students have grounded theoretical knowledge obtained in Thermodynamics and other related disciplines (internal combustion engines).
- All participants have valued positively their suggesting the topic and methodology for the session, and consider it will be positive for future students

4 CONCLUSIONS

The first conclusion that may be drawn from this activity is that the pupils have improved their generic competences and practical skills, in line with the objectives of the Bologna process, and their technical level. The seven participants in the experience have reported improving their generic competences as a result of the way in which the experience was planned, including debate and oral presentations. They also reported having increased their technical knowledge, in different ways depending on whether the student was a 4th year senior or a 1st year junior. This appreciation by the pupils is in accordance with the opinion of the tutors.

Secondly, the tutors have obtained a more accurate vision of the profile of pupils arriving to second year. Although their technical level was accurately valued through academic parameters and direct contact while teaching, this experience has thrown light on their general knowledge in engineering on one side and motivation on the other. Students arriving at second year show a disconnection between concepts learned in physics, such as energy, and their application in practice. This effect is more intense with concepts such as entropy, which have only appeared lightly in previous years and entail even higher abstraction. This makes that, at first, their interests in seeing the equipment focus more on the apparatus than in understanding its underlying physics. However, a small effort in triggering their imagination made their interest more profound. Finally, it was observed that the topics for the session that they proposed were in many cases out of the expectations of the tutors, for example measuring turbine performance in different ways from those usual in engineering.

In conclusion, we think that the activity has been very positive in many ways for the seven participants. We think that it will also be positive for the pupils who will carry it out from next year (it will be adapted by the teachers so that it can be carried out in practice), who will benefit from the point of view from which the practical session is designed, and from the doubts and reflections put forward by the participants. The activity clearly has made progress in the line of the Bologna process with the participants. This progress is expected to happen with pupils when the practical session is included in the regular course; nevertheless, it is expected that the higher number of pupils per session will limit the success of the activity.

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