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## COMPUTERIZED EDUCATIONAL PROGRAM IN TURBOMACHINERY

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### ABSTRACT

The recent astonishing progress in computerized sciences have given birth to multimedia, an electronic revolution sometimes compared to the Industrial Revolution of the 19<sup>th</sup> century. The application of multimedia to education is one of the pre-eminent challenges of the future for academic and industrial institutions. It will certainly dramatically increase both teaching and learning capabilities.

Turbomachines traditionally belong to a scientific field of high technology. Education in the field of turbomachinery is however today principally performed in a traditional way, via lectures, calculation exercises and laboratory experiments. The use of multimedia technology opens up possibilities, which did not previously exist, to perform systematic parameter studies and calculations in undergraduate education, so that the students are able to get a taste of the physical variables that govern the phenomena lectured.

A "Multimedia Educational Package" within the sector Turbomachinery has been developed. This tool, available on CD-ROM and partially on Internet, mainly focuses at present on Thermodynamic Cycles, Turbomachines and Measuring Techniques in Thermal Engineering.

Interactivity is the key concept of the program. The knowledge assimilated by the user is assessed via multiple choice questions with guided answers. Various aspects of the developed model are also integrated in a Turbomachinery Graduate Curriculum.

Numerous tests have already been carried out during lectures, with a positive response from the students. Both students and teachers profoundly believe that, if combined with traditional education, this multimedia tool will enhance not only the knowledge of students, but also their interest in this field. As far as the authors are aware this is the most comprehensive multimedia educational package for turbomachines which presently exists. Figure 1 shows the introductory interface of this package and Fig. 2 an example of a simulation of velocity triangles in the "Turbomachines City".

### INTRODUCTION

Since the early-90s, the planet has been on the threshold of a revolution in information technology. It is principally due to the fusion of two previously distinct fields: telecommunication and computers. The Internet has become a worldwide network whose growth is now unquestionable. It is more than just a fashion accessory as it reveals a need for these new communication means.

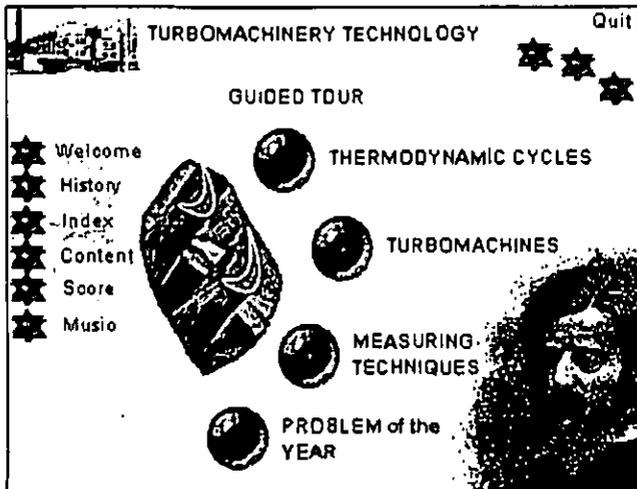


Figure 1. Main Menu

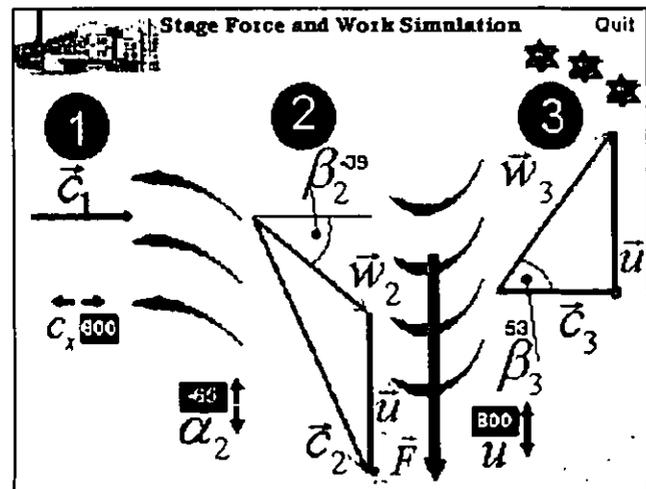


Figure 2. Axial Turbine Velocity Triangles and Work.

In this respect, multimedia, which can be defined as a combination of media, mainly text, picture, graph, sound and video, appears nowadays as a major tool in information distribution.

The XXth century has been incredibly rich in terms of these innovation processes. Imagine if one of our ancestors from the late 1890s were to be suddenly plunged into our contemporary world! He would lose all his bearings. However, there is one place where he would still feel at home: the classroom. Indeed, strangely enough, teaching methods have hardly changed over the last hundred years.

The Division of Heat and Power Technology at the Royal Institute of Technology, Stockholm, Sweden, has started to make use of this new multimedia technology within the scope of a "Multimedia Educational Package" focusing on Turbomachinery Technology. The major objective of this Multimedia Package is to improve education in the field of Heat and Power Technology not by replacing traditional ways of dispensing the knowledge, but by complementing these.

Thus, this paper presents the pedagogical advantages of multimedia and how its application to education in the field of Gas Turbine Technology will enhance both teaching and learning efficiencies. This first step should convince people that multimedia is able to face the challenge of improving the traditional pedagogical ways. Then, the physical contents of the "Multimedia Package", related to Gas Turbine Technology, are introduced. Thereafter, the tools which have been established in order to communicate the knowledge and know-how are analyzed. The evaluation of the "Multimedia Package" is finally considered.

## BACKGROUND

Cheap and reliable energy with easy access is of significant importance for the development of any country and for its ability to compete with foreign countries in almost all domains of science and technology, as well as for inhabitants to enjoy a high standard of living. Education in the energy field is thus an important aspect all over the world. Nowadays, 90% of the world's electricity production is carried out in thermal power plants. In this application, a Gas Turbine can be a major part of the thermodynamic cycle.

Education in the field of turbomachines is today principally performed in the traditional way. However, a significant amount of computer based products have been developed the last few years within various industries. For instance, the "International Gas Turbine Institute" has developed, in collaboration with Dr. Wilson and Dr. Korakianitis, at MIT, a PC-based "Home Study Course" in two volumes [1985], [1990], in which a simple program has been established that allows for calculation of thermodynamic processes. At the Swiss Federal Institute of Technology, Lausanne, Dr. Böls has developed a Macintosh-based, with graphical and digital input/output, computer program for interactive lecturing for design and calculation of a turbomachine. These "classical" programs calculate certain phenomena and can be used in this respect during lectures. Although these developments are of significant interest, they are often complicated to use and can not easily be employed by undergraduate students for educational purposes.

## OBJECTIVES

Multimedia Education must fulfill two main objectives: it must improve the pedagogical quality of teaching when used by teachers in a

classroom and it must increase learning speed and quality when used by the student at home. Therefore, using multimedia in the learning process is a way to decrease the gap between entertainment and school; "learning by playing" at school or "playing by learning" at home, the difference can be minimized. One could very well imagine that in the future students will learn the course basics at home, and then come to the classroom in order to discuss the misleading points with the teacher, as well as further advanced topics on the taught material. The teacher would then not be the person who dispenses knowledge, but the person who manages the interaction between students and information.

In any case, multimedia educational software cannot be a substitute for a teacher; contacts between students and their professors are of paramount importance, and computers are not supposed to replace this basic need. It must not be confused with long-distance training. Multimedia complements traditional education and makes it easier to communicate between professors and students. Moreover, it should be mentioned that a key aspect of this project is to make the software package user-friendly and attractive to the students. This undoubtedly enhances their motivation. It must however clearly be stated that the objective is not to develop a product that competes with existing commercial software packages (such as "ASPEN Plus" or others), nor to develop routines that can take care of a majority of phenomena in the Gas Turbine process. The goal is also not to develop a multimedia show. Instead the chief aim is to develop a well structured base as an educational tool that illustrates quite a few representative basic phenomena of the traditional thermodynamic and turbomachine processes that help the students to acquire a physical insight to some of the problems encountered in the field, and thus acquire the critical thinking that is necessary to evaluate various parts of a proposed design.

At this point, one could ask what are the advantages of using this multimedia technology as a complement to traditional education.

## ADVANTAGES OF MULTIMEDIA EDUCATION

Multimedia complements traditional material such as books. It enriches pedagogy by mixing different media. Good multimedia educational software simultaneously stimulates different senses, resulting in better assimilation and memory. Each student reacts differently in these two processes; for instance, some appreciate visual memory, others oral memory.

Ideal educational software could be compared to a supra-intelligent teacher, able to identify the needs of each of the students. Such a tool is very hard to establish as it can be compared to an Artificial Intelligence tool. Nonetheless, there is one aspect which enables the user to judge a large part of the multimedia software's quality: "interactivity". Interactivity is the major contribution brought by this new technology, as it introduces, to some extent, intelligence within the computer. Indeed, interactivity can be defined as an intelligent agent within the computer able to communicate with the user. Three successive steps can be distinguished:

- checking: this intelligent agent follows the navigation of the user inside the package. For example, a "history" of the user's navigation can be established;

- analyzing: this intelligent agent analyzes the student's assimilation through assessment techniques. Answers to questions and exercises are evaluated.
- guiding: from the previous mentioned analysis, the program can advise, encourage and motivate the student.

Moreover, multimedia educational software can bring support to the teacher in terms of availability. Whereas the teachers have their working hours during which they have to share their time among the classroom's students, the computer is always available depending on its user's willingness.

Convinced by the tremendous advantages which could result from the application of multimedia education to the field of Turbomachinery Technology, the Division of Heat and Power Technology, has computerized some aspects of its Undergraduate and Graduate Curriculum. A complete multimedia tool has thus been established.

In the present paper, only a few of the possibilities available in the program will be shown.

## **TURBOMACHINERY CONTENTS**

Several aspects of the Undergraduate and Graduate Curriculum of the Division of Heat and Power Technology have been developed within the "Multimedia Educational Package". The ones shown here are Thermodynamic Cycles, Turbomachines and Measuring Techniques in Thermal Engineering. These contents are organized in three vertical levels with an analogy to courses, lectures and chapters. The highest level is referred to as "City"; the second as "House"; the last, as "Room". Most of the information is concentrated in the "rooms".

Figure 1 represents the "Main Menu". Here, the three different "cities", "Thermodynamic Cycles", "Turbomachines" and "Measuring Techniques" are accessible as well as the "Problem of the Year". Besides, the user can start with a presentation of this package with a "Guided Tour".

### **The "City" of Thermodynamic Cycles**

The first "city" deals with Thermodynamic Cycles and their application to Power Generation and Propulsion. The Steam Cycles "house" studies the basic Carnot Cycle in an introduction "room". This is a somewhat simple cycle, but its understanding is a key component to the progression within the house. Then, in a second "room", the student is invited to learn about the Rankine Cycle. Improved Rankine Cycles are presented in other "rooms": Superheat and Reheat Cycles.

The Gas Turbine Cycles are the subject of the next "house". The Simple Gas Turbine Cycle is introduced in the first "room" and then improved in the following "rooms" by means of Regeneration, Intercooling and Reheating. The combination of the Steam and Gas Turbine Cycles, the so-called Combined Cycle is dealt with in the third "house". Finally, the Propulsion "house" focuses on turbo-jet, turbo-fan, both with and without afterburners, and the ram-jet concepts.

Figure 3 shows an example of a Simple Gas Turbine simulation. The opportunity to modify the combustion chamber outlet temperature, the turbine and compressor efficiencies is given. Thus, the Simple Gas Turbine Cycle is plotted and the cycle specific work output and

efficiency are calculated. The results are plotted in the right part of Fig. 3 in such a way that differences towards previous calculations are highlighted to the student. In many cases questions appear to guide the student towards the aim of the parametric study. Similar simulations exist for all the cycles in the program.

### **The "City" of Turbomachines**

The "city" of "Turbomachines" consists of three main topics: Axial Turbine, Axial Compressor and Aeroelasticity.

After a brief introduction into the Turbomachinery Basic Thermodynamics and Fluid Mechanics "house", where the basic equations such as the Continuity Equation, the First and Second Laws of Thermodynamics, Newton's Second Law are introduced, the Axial Turbine "house" includes the two-dimensional assumptions and nomenclature, the stage velocity triangles and stage thermodynamics. The design parameters such as degree of reaction or flow coefficient, and the stage losses and efficiency are finally presented. The Axial Compressor "house" recalls some of the major aspects dealt with in the Axial Turbine "house". However, more emphasis is put on limitation phenomena such as surge and stall. At last, the Aeroelasticity "house" focuses on blade and disc vibrations, Campbell diagram, rotor-stator interaction and flutter analysis [Fransson, 1993].

Figure 2 illustrates an Axial Turbine Stage Force and Work simulation. There, it is possible to change axial velocity, rotational speed and outlet stator absolute flow angle. The velocity triangles are plotted, the camber line and a new generic blade shape are displayed. The force on the rotor blades, the specific work, static temperatures and stage expansion are also calculated and plotted. Parametric changes are highlighted much in the same way as the interactive cycle simulations previously mentioned.

### **The "City" of Measuring Techniques**

One of the major problems of the engineering curriculum in the future may be the lack of experimental evidence where the students themselves may perform simple experiments as validation and comparison against numerical studies. The Division of Heat and Power Technology is actively involved in building up some simple but relevant experiments as laboratory exercises. Therefore, the Measuring Techniques "house" allows the student to learn about these laboratory experiments. Furthermore, they can simulate the real laboratory exercise. Once these computerized pre-laboratory experiments have been understood, the real laboratory experiments can be performed. For instance, two computerized pre-laboratory experiments on "Schlieren Flow Visualization" and "Determination of Losses in a Linear Cascade" have so far been introduced in the educational program.

Figure 4 displays the Schlieren Flow Visualization main interface. Here, the students simulate the real system, first by dragging and dropping some objects used in this visualization method in the right order. Then, they have to position these objects at the right location on the screen before proceeding further. The light rays are plotted and guide the students step-by-step through the simulation. Wrong positions or wrong elements are indicated and the results of this wrong decision is indicated. However, the student must still find the right answer. Once the whole pre-laboratory simulation has been performed,

pre-lab questions are asked. The answers to these are automatically stored and interactively sent to the teacher who then knows the student knowledge before the student is let into the "real experimental lab exercise". In the case of the Schlieren, also the "Focusing Schlieren Method" is performed in an identical way.

In a similar way as for an experimental laboratory exercise, a complete "Simulation of a Heat and Power Plant" exists in the "Multimedia Package". Here the final laboratory is performed on workstations, interactively simulating a Heat and Power Plant in Västerås, Sweden.

## TRANSFER OF KNOWLEDGE

In order to provide intuitive access to the contents and allow the user to experience the contents as intended, several multimedia concepts such as interfaces, buttons, user-friendliness, attractiveness needed to be created so that teachers and students would feel eager to use the "Multimedia Package" as often as possible.

The main menu (Fig. 1) gives access not only to the three cities, but also to introductory features such as the Curriculum of the Division of Heat and Power Technology, and a Guided Tour. The latter allows the newcomer to familiarize himself or herself with the "City", "House" and "Rooms" concepts as well as with the different options available in the toolbar located at the bottom of the screen. This toolbar consists of three main buttons: "Map", "Index" and "Feedback".

The "Map" (Fig. 5) enables the user to navigate anywhere in the program. This "Map" is accessible everywhere in the package and allows the user not only to have an overview of all the program's contents, but also to provide in a fast way the information required.

The "Index" (Fig. 6) is split into three categories: "Keywords", "Scientists", and "Dictionary". The "Keywords" section provides definitions for common words in the field of Heat and Power Technology whereas the "Scientists" section acquaints the user with the researchers who brought major improvements to Thermodynamic Cycles and Turbomachines.

A multilingual dictionary gives translations in English, French, German and Swedish to words related to Heat and Power Technology. For instance, if you know a German word but not its English equivalent, this dictionary will give you the translation.

The "Feedback" (Fig. 7) allows the user to express comments, ideas and criticisms which were highly appreciated during the development of the program. Computerized note-taking is also possible by students or teachers while navigating throughout the software.

The second level interface (Fig. 8) corresponding to a "city" consists of a screen divided into two areas. The main area is devoted to the display of the house icons and titles. The second area is a place where both a presentation and a history of the "city" can be reached. The historical information consists of a chronology of events which led to the development of the subject studied in the "city".

The "houses" can be accessed from this second level interface. Figure 9 shows an example of a "house" where the different "rooms" are accessible.

As previously mentioned, "rooms" are locations in the "Multimedia Package" where most of the pedagogical information is conveyed to the student. Every "room" includes an animated slide show, one or several simulations and a "Quiz".

The slide show is an animated sequence of multimedia elements. This dynamic show presents in detail the major physical concepts that should be understood by the students. These concepts are explicitly introduced in the first pages of the slide show, together with references, prerequisites and objectives required for the study of that specific "room". This is very important in so far as the student must know what should be learnt from a "room" in order to be able to appreciate his or her own understanding. Nomenclature, assumptions and equations are also provided in the slide show.

Then, the physical phenomena are explained via simulations. Those are the core tools of the learning process. A simulation is a mathematical model built on the basis of physical equations. The user is able to change the parameters which influence the behavior of the studied phenomenon. In every simulation, a "guide" sends messages so that the user does not feel lost, especially the first time the simulation is tried out. Nevertheless, these messages do not prevent the user from making mistakes. Moreover, information is always available under the form of hypertext. Hypertext is additional media that the package provides when the user clicks on a text in order to obtain more information.

In the slide show, simulations are followed by a short summary of the theoretical concepts to be remembered. Besides, each slide show ends with a summary repeating the main aspects to recall.

Figure 10 illustrates one of the first slides of the slide show focusing on the "Stage velocity Triangles".

After the investigation of the slide show and simulations, the students have the possibility to evaluate the knowledge assimilated through multiple choice questions: the "Quiz". The "Quiz" is illustrated in Fig. 11.

Animated slide shows, simulations and to a lesser extent, the "Quiz", are also likely to be used during lectures in the classroom. They will enable the teacher to illustrate the influence of main parameters on physical phenomena.

## EVALUATION

The correct evaluation of the quality of education is one of the main problems in any new teaching development. Therefore, a careful approach had to be established in order to estimate the overall effectiveness of the "Multimedia Package". At this stage of the development, few results can be presented as the program has only been tested by teachers and students at the Division of Heat and Power Technology. Nevertheless, major tools have been developed and

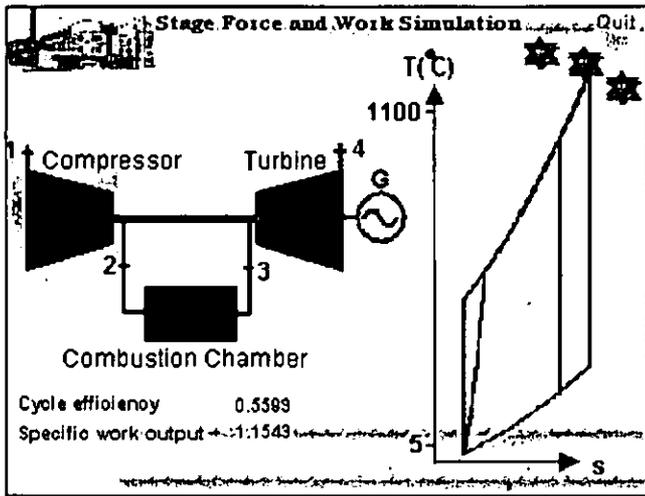


Figure 3. Gas Turbine Cycle Simulation.

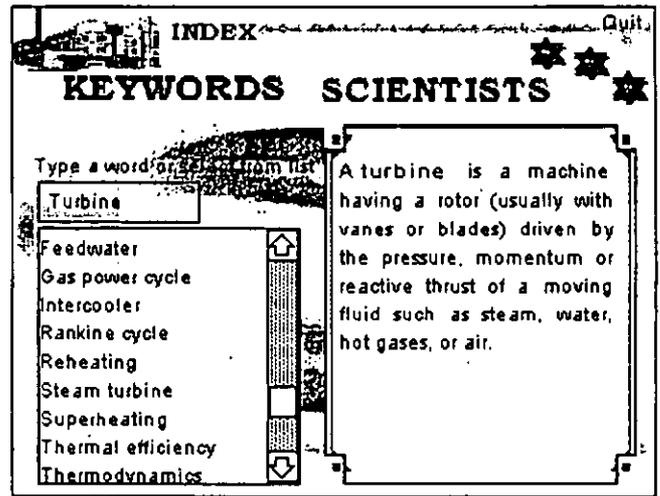


Figure 6. Index

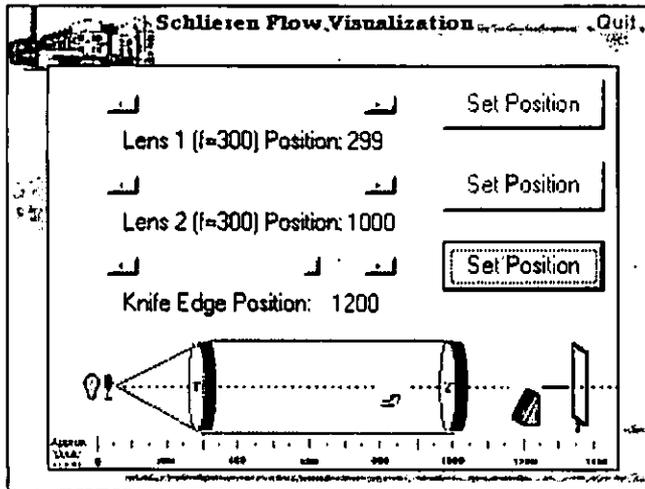


Figure 4. Schlieren Flow Visualization Simulation.

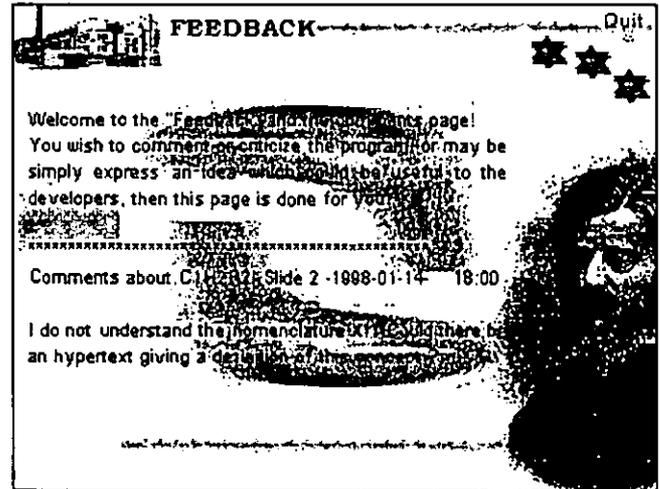


Figure 7. Feedback

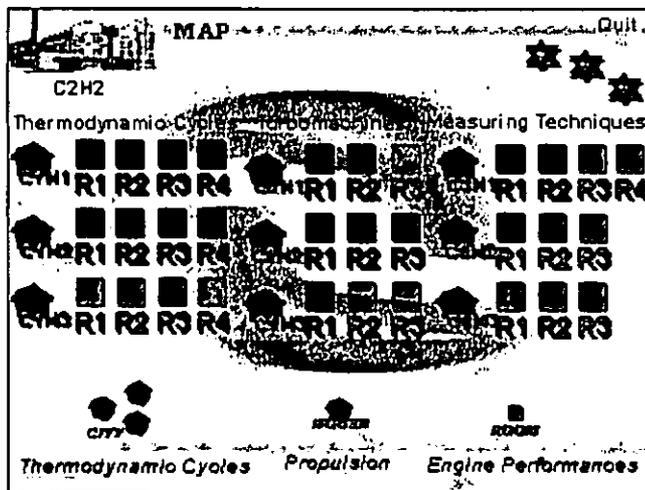


Figure 5. Navigation Map

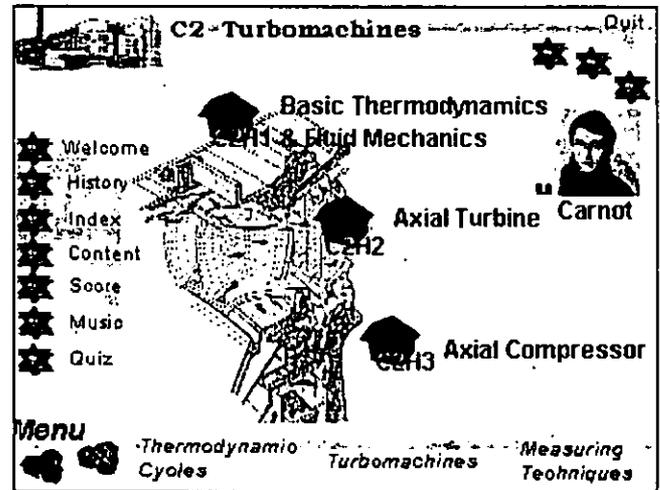


Figure 8. Second Level: the "Turbomachines City"

should allow a larger scale evaluation in the near future. This evaluation should give results about the comparison between traditional education and multimedia supported education.

In such an evaluation procedure, the first crucial step consists in determining the students' progress.

### **Evaluation of the students**

In order to evaluate the students' learning progress, three main tools have been achieved: the "Quiz", the "Problem of the Year" and the "Exam".

#### **The "Quiz"**

The "Quiz" is accessible everywhere in the program. As previously mentioned, the student is admitted to a series of multiple choice questions specific to the studied topic. Answers are analyzed and a few indications are displayed: obviously the right and wrong answers, but also some comments clarifying the "whys" and "hows". From this "Quiz", the assimilated and non-assimilated knowledge can be identified. The student's score, calculated upon the right and wrong answers, is stored in a database. This database is accessible anywhere in the program. There, the student is able to consult the different results obtained in the corresponding parts. The teachers have access to all the students' databases. Thus, they are able to follow the students' progress all year long.

#### **The "Problem of the Year"**

The "Problem of the Year" is a problem-based learning activity. Every new year, the students will be introduced to the Curriculum at the Division of Heat and Power Technology with this "Problem of the Year". In order to solve it, the students need to learn most of the knowledge taught in the different courses. At the end of the year, they will have acquired substantial knowledge in order to find a suitable solution. "The Problem of the Year" is thus included in the "Multimedia Package". This year, a Gas Turbine design was selected. The students must carry out the design of the Gas Turbine Thermodynamic Cycle for a jet engine. Thereafter, they design the axial compressor and axial turbine. However, the design of the combustion chamber is not considered yet in the "Multimedia Package". Computerized calculation exercises will help the students to solve the problem. Figure 12 shows an example of Axial Turbine Design exercise.

These exercises mainly involve choices of equations and design parameters. At some points during the exercise, a "guide" comments on the choices made by the student, who is thus encouraged to improve the design. They involve the full knowledge that should have been acquired throughout the "Multimedia Package". They also tests the student's ability to deal with real engineering methods.

#### **The "Exam"**

A computerized examination has been developed within the "Multimedia Package". It mainly consists of multiple choice questions and computerized typed comments and answers. This examination should motivate the students to make use of the "Multimedia Package" during the study-time at the Division of Heat and Power Technology. The "Exam" will also count in the overall evaluation of the student.

The evaluation of the students' progress is half way towards the overall evaluation of the "Multimedia Package" pedagogical efficiency.

### **Evaluation of the package**

Continuously during the development phase, the strengths and weaknesses of the program have to be determined. A constant feedback from teachers and students is necessary during this phase.

Several tests, on a small scale level, have already been carried out, with success. Teachers at the Division of Heat and Power Technology have used the "Multimedia Package's" slide shows and simulations during lectures focusing on Thermodynamics Cycles and Turbomachinery. Moreover, a few students have tested the program as a stand alone educational tool. The response was still positive, although a lot of criticisms were expressed. From these first tests, improvements were carried out.

One step further in this evaluation process has been foreseen: larger scale tests will be performed with all students starting a curriculum at the Division of Heat and Power Technology. Besides, the "Multimedia Package" should be tested at other academic institutions whose curriculums also deal with Gas Turbine Technology. Contacts in that respect have already been established with the Swiss Federal Institute of Technology, Lausanne, where the program has been released.

When these tests are finally achieved, the previously mentioned database, together with statistical techniques, should be a tremendous tool in order to precisely determine the true effectiveness of Multimedia Supported Education.

### **CONCLUSIONS**

The Division of Heat and Power Technology at the Royal Institute of Technology, Stockholm, Sweden, has established a "Multimedia Educational Package" focusing on Gas Turbine Technology. This tool presents basic and advanced physical Turbomachinery theory by animated slide shows and simulations. In the slide show, multimedia educational performances reach a peak: pictures, texts, spoken commentary, videos and visual animation convey the information to the student by means of several senses. On the other hand, a higher level of interactivity is achieved with the simulations, where the student is free to modify the physical model over a large range of values. Finally, assessments are carried out through the "Quiz", "Problem of the Year" and "Exam". The "Lecture Notes" are also available at some points in the package.

This "Multimedia Educational Tool" is used both by the teacher during lectures in the classroom, and by the students, at school and home, in front of a computer. Teachers and students at the Division of Heat and Power Technology are deeply convinced that education is further enhanced when combining traditional pedagogical methods with this "Multimedia Package". However, a careful evaluation of the "Multimedia Educational Package" needs to be carried out.

Education in the field of Gas Turbine Technology will be enhanced by the contribution of this Multimedia tool, provided that other academic and industrial institutions use it. One could thus imagine how the Gas Turbine world would evolve with better educated engineers. It is hard to predict the future; undoubtedly though, it seems

probable that computers and associated multimedia packages will play an ever-increasing part in the teaching process for the many advantages they procure.

### FUTURE WORK

The teachers in the Division of Heat and Power Technology are convinced that the "Computerized Educational Program in Turbomachinery" tool under development will be a valuable contribution to education worldwide. It is believed that teachers and students at universities outside of Sweden will have an interest in specific parts of the program. The future developments include:

- Propulsion
- Cogeneration
- Environmental considerations

### ACKNOWLEDGEMENT

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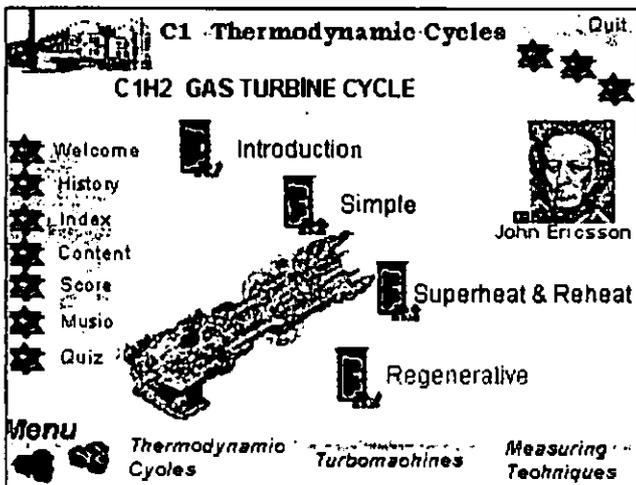


Figure 9. Third Level: "The Gas Turbine Cycle House"

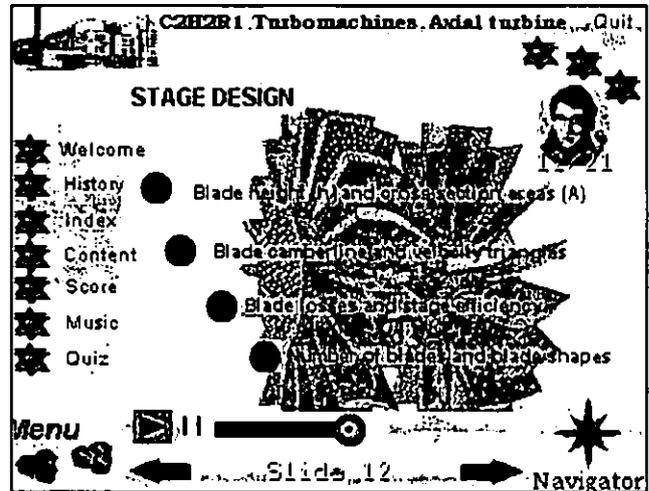


Figure 10. Slide Show: "The Stage Velocity Triangles"

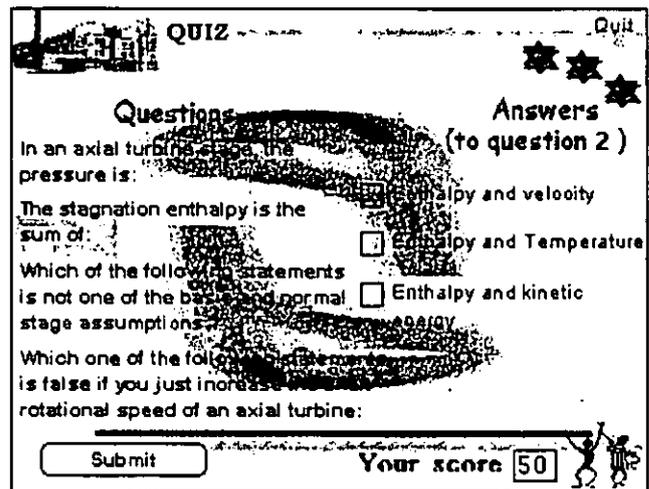


Figure 11. The "Quiz".

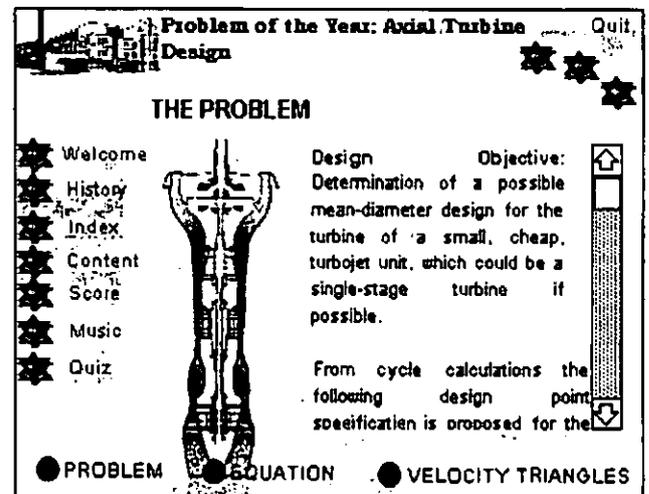


Figure 12. The "Problem of the Year": Axial Turbine Design.

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