Session 2633

The Virtual Classroom and Laboratory for Thermodynamics Education

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1. Introduction

Mechanical engineering technology (MET) students at the University of Arkansas at Little Rock (UALR) are using World Wide Web Course Tools (WebCT) and CyclePad software to enhance their understanding of the thermodynamic cycles employed in important technologies such as refrigeration equipment, automobile engines, and power plants. WebCT is a commercial, web-based software package for designing and delivering web-based education environments. CyclePad is a Windows-based interactive, intelligent learning environment for thermodynamics education developed by the Institute for the Learning Sciences at Northwestern University. WebCT allows instructors to create, without programming, sophisticated web-based classrooms that can help deliver and organize course content, assess student learning, facilitate communications, and provide access control. CyclePad allows students to design and analyze thermodynamic cycles in an articulate virtual laboratory, and to interact with a distributed artificial intelligence (AI) coaching system. CyclePad has been formally evaluated in the mechanical engineering programs at the United States Naval Academy (USNA) and Northwestern University, and in the MET program at UALR. One advantage of CyclePad is that it allows students to start analyzing cycles at the beginning of an introductory thermodynamics course in order to motivate the study of the individual processes that comprise a cycle. The approach taken by many thermodynamics textbooks, including those intended for engineering technology students, is to proceed in the opposite order, i.e., start with processes and synthesize cycles only after laying a theoretical foundation involving abstract concepts such as enthalpy and entropy. Many students, probably the vast majority of students, find these concepts very difficult to understand, but might be more interested in learning about them after seeing how thermodynamics has some important things to say about, say, the fuel efficiencies of the cars they drive.

2. The Synthetic Approach

Many thermodynamics textbooks introduce basic thermodynamic properties such as temperature and pressure, then discuss thermodynamic processes involving heat and work and introduce the

First Law. This is followed by the introduction of abstract thermodynamic properties such as enthalpy and entropy and an introduction of the Second Law. Engineering and engineering technology textbooks both take this approach. A typical first course ends here. Often, the Carnot cycle, on which no practical engine or refrigerator is based, is the only thermodynamic cycle that a student encounters, unless they take a second course in thermodynamics.

This approach is logical and allows students to learn about processes that are then synthesized to create cycles. However, this synthetic approach leaves many students in the dark about the importance and practicality of thermodynamics for more than a semester, and many students therefore take a dim view of the subject. While this approach is very logical, it is perhaps best appreciated by someone who has already mastered thermodynamics! Perhaps there is a better approach.

3. The Analytic Approach

A radical approach to the study of thermodynamics is to introduce practical thermodynamic cycles at the very beginning of the first (or only) course in thermodynamics, as early as the first week of classes. The cycles that model automobile engines, truck engines, airplane engines, power plants, and refrigerators provide powerful motivation for students to learn thermodynamics. Calculations of thermal efficiency and horsepower can be done, and sensitivity analyses can be performed to identify which parameters affect them and how they affect them.

These cycles can then be formally analyzed, i.e., broken into pieces, to introduce individual processes and motivate their detailed study. This analytic approach is admittedly messy; it immerses students into thermodynamics before they know much about it. But the synthetic approach is messy too, at least to students, because students fail to see the logic of that approach. The instructor knows where the synthetic path leads because she has been there already. The analytic approach, however, shows students the end of the path first, so they never have to question where they are going.

But how does one implement the analytic approach described above for cycles if students do not yet know how to do calculations for individual processes?

4. CyclePad[1,2] to the Rescue

CyclePad is a Windows-based interactive, intelligent learning environment for thermodynamics education developed by the Institute for the Learning Sciences at Northwestern University. CyclePad allows students to design and analyze thermodynamic cycles using a graphical user interface in an articulate virtual laboratory, and to interact with a distributed artificial intelligence (AI) coaching system. CyclePad has been formally evaluated[3] in the mechanical engineering programs at the United States Naval Academy (USNA) and Northwestern University, and in the MET program at UALR.

One advantage of CyclePad is that it allows students to start analyzing cycles at the beginning of an introductory thermodynamics course in order to motivate the study of the individual processes that comprise a cycle. One of the most important features of CyclePad is its sensitivity tool. After a cycle has been built and analyzed for a given set of conditions, the sensitivity tool permits a student to see how a parameter, e.g., thermal efficiency of an Otto cycle, is affected by varying another parameter, e.g., compression ratio. CyclePad recalculates the entire cycle many times, automatically, and displays a plot showing the functional relationship between the two parameters. Since students can easily spend more than an hour doing a single cycle analysis in full, in a spreadsheet or on paper, CyclePad permits students to experiment with cycle parameters and discover relationships that they never would have found otherwise because of time constraints and tedium.

Therefore, CyclePad serves as a virtual laboratory for studying the effects of different design decisions regarding thermodynamic cycles in ubiquitous use in personal and industrial machinery. For example, UALR does not have a gas turbine engine test facility, but CyclePad allows UALR MET students to study, in some detail, and rather quickly, how gas turbine engine efficiency is related to compression ratio, reheating, intercooling, and regeneration.

Moreover, CyclePad includes a library of standard cycles, such as Otto, Diesel, Brayton, Rankine, Vapor-Compression Refrigeration, etc., that beginning students can use. Thus, a student in the first week of class can learn to open one of the library cycles and do sensitivity analyses. As students learn more about the thermodynamics, they can use CyclePad to build more complicated cycles that are not found in the CyclePad library.

CyclePad also coaches students when difficulties arise, during both the cycle building stage, and the cycle analysis stage. Onboard coaching provides immediate feedback, for example, if a student makes an assumption about a cycle that contradicts a previously-made assumption. More sophisticated AI-based coaching is available via email communication with the CyclePad Guru[4], a TA agent located at Northwestern.

The instructor also uses CyclePad for in-class demonstrations of cycle analyses by projecting the computer display onto a screen. Students can make in-class presentations of their designs and analyses by the same method.

5. World Wide Web Course Tools (WebCT)[5]

UALR MET students also use a web-based course supplement to their thermodynamics course, created with WebCT. WebCT is a commercial, web-based software package for designing and delivering web-based education environments. It allows instructors to create, without programming, sophisticated web-based classrooms that can help deliver and organize course content, assess student learning, facilitate communications, and provide access control.

The virtual thermodynamics classroom created with WebCT serves many functions, but the biggest function is that it provides a focal point for the course that is available 24 hours a day, 7 days a week, unlike the physical classroom or the human instructor. The bulletin board and email facilities allow students to easily collaborate on computer laboratory assignments and term projects. The testing facility allows students to take automatically graded practice quizzes. The student presentation facility allows students to create web-based multimedia presentations[6] that can be shared with the instructor and classmates. The MET students at UALR work in small teams on a term project that involves the use of CyclePad in some way. The projects include a web-based multimedia presentation as well as an oral presentation at the end of the semester.

For a more detailed discussion of WebCT, please read the companion paper, *Using World Wide Web Course Tools for "Close" Learning*[6], elsewhere in these proceedings.

6. Conclusions

The combination of a WebCT virtual classroom and a CyclePad virtual laboratory can enrich a traditional lecture-based thermodynamics course in many powerful ways. They can also allow an instructor to teach thermodynamics with a radical analytical approach, instead of the traditional synthetic approach.

Bibliography

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