2023 Annual Conference & Exposition
Baltimore Convention Center, MD | June 25 - 28, 2023
The Harbor of Engineering
Education for 130 Years
Paper ID #37975

Work in Progress: Introducing Process Simulators to Mechanical Engineering Seniors in a Thermofluids Course

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Abstract

This paper presents the authors' experience in introducing the Aspen Plus software to support students in understanding various types of thermofluid cycles for an undergraduate mechanical engineering thermofluids course. In most thermodynamics/thermofluids courses, students are asked to analyze thermofluid systems using a combination of steam tables or the ideal gas law equations. However, in industry, an engineer would be expected to use a process simulator to simulate thermofluid cycles. The main motivation of this project was to familiarize students with such software. Students were assigned to work in groups of two to analyze three different types of thermofluid cycles; Rankine cycles, gas power cycles, and refrigeration cycles. Each cycle was covered in an assignment. The assignment prompt was to analyze the cycles by hand using steam tables or ideal gas relationships and then to simulate the cycle using a commonly used process simulator, Aspen Plus. This allowed students to compare their hand-calculated answers with the Aspen simulation. Students were provided a comprehensive video tutorial in the beginning of the semester to explain how to use the software. After evaluating the assignments submitted by the students, it was found that students were proficient in the use of the software to analyze basic and complex thermofluid cycles. By integrating software that is commonly used in industry, students will be better prepared to design and analyze systems in the real world.

Introduction

One of the primary goals of engineering education is to prepare students for the current engineering workforce. Today's modern world is moving at breakneck speed, but progress and change in engineering education is not matching that same pace. Engineers constantly face workplace challenges such as rapid advancements in technology and the demands of changing workplaces [1]. This necessitates innovative pedagogical advances that encourages creativity, problem solving, and learning independence. Educators must customize their classes to assist students to excel in jobs available in today's market, but also jobs that might not yet exist. The desired end goal of educational advances is to spark learning desire and to create novel and innovative ideas to assist in solving the never-ending stream of incoming issues encountered in modern life [2] .

Thermofluids science is crucial in the industry sector as well as for the environment, and it contributes to the long-term sustainable development growth of our modern society. Thermofluids is making its way up the engineering supply chain, and the ability to perform multistage simulations all through the designing process is becoming standard practice for many companies [3]. Thermodynamics/Thermofluids is commonly taught using steam tables or steam curves [4,5]. However, this does not reflect the reality of the thermofluid system design process. One of the first attempts in introducing software into thermofluid system design through the use of C# [6]. Currently, there are code-based software that can be used for thermofluids analysis such as the Engineering Equation Solver, Interactive Thermodynamics, or PYroMat [4,5,7]; however, they would require students to learn how to code within these softwares. The extensive coding requirements of these softwares make it difficult to introduce them to undergraduate students. On the other hand, process simulators (e.g., Aspen Plus) are more of a drag-and-drop approach which is more intuitive to students.

The study was developed for a Thermal Fluids Design class (MEEN 421). This is a senior-level course in which students are taught how to analyze various thermofluid systems including modified Rankine cycles, Brayton cycles, and Refrigeration cycles. This course represents the final thermodynamics course for most students. As with most engineering courses, the analyses of such systems are assessed in homework and exams. However, these types of assessments do not translate well into their engineering career as they would not be expected to use a paper and pencil approach. The intention in assigning the project to was to introduce students to a process simulator which would replace or work in coordination with pen and paper results. The primary objective of this proposed work is to demonstrate the benefits of introducing systems to a modern process simulator that students could be expected to use in engineering industry jobs. The overreaching goal is to understand how to enrich mechanical engineering students' laboratory experience and to create new tools/methods to incorporate in the current thermofluid curriculum. These tools would ideally dampen the initial shock that most engineering students face when entering the workplace and help bridge engineering education and industry together.

Classroom Study

Engineering student should be given the opportunity to be entrenched in real-world problem-solving classroom environments. This study aims at providing students the opportunity to solve traditional thermofluids problems utilizing a novel approach. The main problem description provided to all students was to study different power cycles and compare the results that are found by hand with the ones generated from Aspen Plus. The students were asked to analyze thermofluid systems using the traditional approach (using steam tables/ideal gas law) and then to analyze the same systems using the process simulator. The project was assigned to students in groups of 2-3. The semester-long assignment was split into three assignments throughout the semester with two problems in each assignment. The assignments were split up into three topics: 1) Rankine cycles, 2) Brayton cycles, and 3) Refrigeration cycles. Each assignment had two problems: a simple system and a more complicated system. The intention was that the simpler system would help the students gain confidence and the required skills to assist them to move onto the complicated system. The students were to submit a memo for each assignment that covered how they solved the problems analytically and with the use of the process simulator.

A rubric was developed to assist students with the completion of their memo. The rubric used has been included in the appendix. There were five major sections that were focused on: 1) introduction, 2) problem statement, 3) hand solution, 4) simulation solution, and 5) conclusions. The introduction included background and a short literature review on the general cycle that the assignment covered. The problem statement was to include the problem statement itself and the information that students extract from the problem statement (the process was isentropic, the pressure at a given state, etc.). In the hand solution, students were to include the temperature-entropy diagram, equations used, key parameters of streams (temperature, pressure, etc.) and the solution. The Aspen solution section was to include the major steps used to develop the Aspen solution including specifying the components, blocks, streams, and the final results.
Because Aspen is largely used for chemical engineering processes, but there is limited material that is relevant to topics covered by this course. As a result, a video tutorial was created to introduce students to the basic functions of Aspen. The video was posted on Youtube so that students can access the video at anytime as well as to assist other mechanical engineering

students outside of our institution. In previous semesters, we did have a class session dedicated as a tutorial session however many students did not have the software and we did not feel that it was beneficial. In addition, Youtube allows the creation of chapters within a video so that students can skip to the chapter that they are interested in instead of scrambling through the video to look for a specific section. The tutorial was created using Microsoft Powerpoint and Aspen Plus for the actual tutorial material and Zoom was used to record the screen and the camera. The camera was included so that the instructor could be included to add a more "personable" touch.

Use of Process Simulators in Engineering Education

Process simulators have long been used in chemical engineering curriculum [8,9]. They are typically used in senior level design courses. There are limited studies about incorporating process simulators in a mechanical engineering course [10]. At final stage in their studies, students would understand the basics and theory of the different components used in a process. The process simulator does all of the calculations based on the flow diagram that is drawn by the student. A process simulator speeds up the analysis due to the simulation doing all the calculations instead of the student performing it by hand and referring to various steam tables, isentropic relations, and energy equations. Figure 1 shows the flow diagram of a simulation done in Aspen Plus.

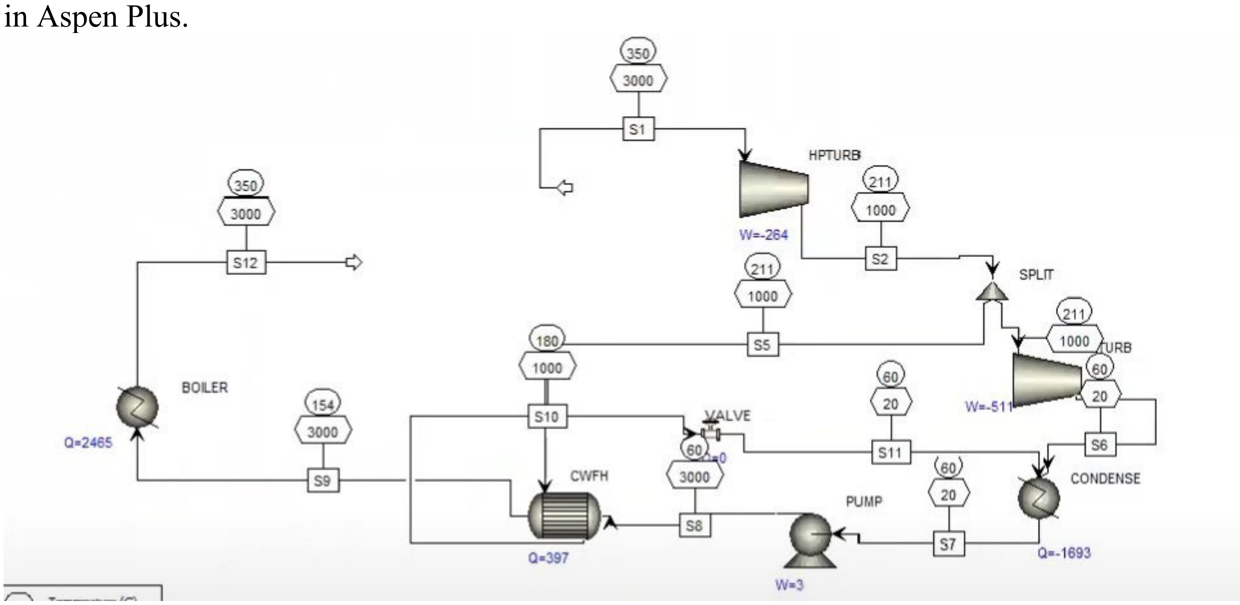

Figure 1- Example of flow diagram in Aspen Plus

Results

This project was assigned in the Fall 2022 semester. There were a total 17 students that completed the course. Students had an opportunity to improve their skills as there were three assignments spread across the semester. Based on the grading of the memos submitted, students were able to solve the assigned problems through both hand solution and using the process simulator. However, it seems that the specifics of what to use the process simulator for need to be better outlined in the assignment description. Some students used a combination of the steam tables with the process simulator. In the future, it will be emphasized that the solution for the process simulator should be done *only* using the software and without the use of the any equations or steam tables.

In future course offerings, a survey will be given to students before the assignments to evaluate what students know about process simulators, if they have ever used a process simulator, or if they know of any alternatives to pen-and-paper calculations. This would help inform the instructors of the background knowledge the students have coming into the course. Once the assignments are completed, another survey would be given to determine what the students have learnt about process simulators or if they felt that they have benefitted from the use of process simulators.

Summary and Conclusions

In summary, a project assignment was created to introduce mechanical engineering seniors to process simulators (specifically Aspen Plus). A tutorial was made for the students and no class time was spent in explaining how to use the software. Students submitted three assignments in which they were asked to analyze different types of thermofluid cycles using hand calculations and using the process simulator. In conclusion, students were introduced to a modern tool that is used in industry that allows them to apply their knowledge in thermofluids. The intent of the project is to prepare students for software they might use in industry. In future course offerings, a survey will be included to determine how students feel about the project and their introduction to process simulators.

The authors feel that this project did help introduce students to a modern process simulator that is used in industry so there is a plan to continue such a project in the next course offering.

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Appendix

Memo Evaluation Rubric

Introduction (10%)

- Introduce the general cycle that you are studying and its application to every day life.
- Include a short literature review on research that has been done on the general cycles

Problem Statement (10%)

- Introduce the problem statement and point out important features of the cycle that lead to the solution.

Solution (35%)

- Draw the T-s diagram of your assigned cycle
- Identify key relationships between different streams (energy balance, isentropic relations, etc.)
- Identify key parameters of all streams (temperature, pressure, enthalpy, entropy) as required and display them in a table.
- Introduce and explain equations used to solve the problem

Aspen Solution (35%)

- Identify all the key steps in solving the assigned problem:
    - Specifying components/Equation of State used
    - Specifying blocks and their input information o Specifying streams and their input information
    - Show the results of your simulation and compare with results from your hand solution

Conclusions (10%)

- Make your major conclusions based on the results from your Aspen Plus simulation and hand solution