The Need of Capstone Senior Design Projects for Outside Support

Hosni I. Abu-Mulaweh
Department of Engineering
Indiana University-Purdue University at Fort Wayne
Fort Wayne, IN 46805, USA

Abstract

The students in the mechanical engineering program at Indiana University-Purdue University Fort Wayne are required to complete a capstone senior design project. Whenever it is possible, the students are exposed to real life design problem experience. However, most of the time, this is not achievable because of the cost of these types of projects is high. This paper discusses the need for outside support such as local and regional industry and professional societies such as the American Society of Heating, Refrigeration, and Air Conditioning Engineers (ASHRAE). The outside funding of capstone senior design projects is crucial in order for the students to be exposed to quality and practical real life design problems. Also, examples of some of the projects that the local industry and ASHRAE have supported will be presented in this paper.

I. Introduction

Capstone senior design project is a degree requirement in any respected engineering program. In some programs, the capstone senior design project is accomplished in one semester. Others devote two semesters to carry it out. At the author's institution, the capstone senior design project is accomplished during the senior year and it spans two semesters. In the first semester, the problem statement is formulated and basic conceptual designs are generated and then evaluated. The conceptual design that solves the problem best is then selected and a complete and detailed design is generated by the end of the first semester. In the second semester, a prototype of the finished design is built, tested and evaluated.

Whenever it is possible, the students are exposed to real life design problem experience by getting them involved and work on design projects provided and supported by the local industry and professional societies such as ASHRAE. Types of the design projects that the local industry is interested in include: completely new design to perform specific task(s), modify or improve existing design, and solving problems in some industrial operations. On the other hand, ASHRAE funds capstone senior design projects that involve an ASHRAE-related topic.

II. The Need for the Outside Support

The cost of constructing a prototype of finished design is usually high. This is especially true when the design projects deal with practical and real life problems. For small undergraduate engineering programs with limited resources, such as ours, the high cost of building these projects tends to cause a problem and hampers the selection of good quality capstone senior design projects. This problem becomes more pressing when the senior design projects are multi-disciplinary in order comply with the Accreditation Board for Engineering and Technology (ABET) accreditation criteria which require that graduates of engineering programs possess "an ability to function on multi-disciplinary teams" [1].

ASHRAE has a program called Undergraduate Senior Project Grant Program that provides funding (grants up to $5000.00) for undergraduate engineering senior design projects and technical school projects. These grants are made for the school for the support of the materials required for the project and not for funding school overhead costs, faculty or student salaries. These grants are provided to engineering, technical and architectural schools worldwide. By providing this type of funding, ASHRAE hopes to fill a need often found in undergraduate engineering and technical school programs. Their goal is to increase student knowledge, learning and awareness of the HVAC&R industry through the design and construction of senior design projects and to encourage students to pursue ASHRAE-related careers. Announcement of the Undergraduate Senior Project Grant Program is normally out by mid September of each year. Copies of the application form can be obtained from ASHRAE's Education Coordinator or from ASHRAE's web site (www.ashrae.org). The faculty member(s) and students of the design team are not required to be ASHRAE members. To apply for the grant, the faculty member needs to complete the application form on behalf of the students completing the senior design project. The application is normally due by December 1st of each year. It should be noted that capstone senior design projects that would result in some type of instructional experimental apparatus which can be used by future students, have more chance of being funded by this program.

The city of Fort Wayne is located in the heavily industrialized area of northern eastern Indiana. Examples of some of the industry that is located in this area are General Electric, Navistar International Corp., Dana, Franklin Electric, WarerFurnace International, Inc., and a large number of small engineering and manufacturing companies. Because of this we explored the involvement of the local and regional industry in sponsoring some of the capstone senior design projects. This was accomplished by writing to the companies in the area and by making plant visits to discuss the possibility of having the company supply and sponsor a project or a problem that they need to be solved. Also, a good percentage of our students work at these companies either full-time, part-time, or as co-op. The students were encouraged to explore the possibility of their employers supplying and sponsoring projects that needed to be done.

The perception of this idea by the local industry was very positive. Because they realized that this is a win-win situation. They get their design problems worked on and solved for free. They only need to pay for the parts and materials. On the other hand, this provides our mechanical engineering program with support for practical and real life design problems.

This approach was a success. On an average, three fourths (75%) of our capstone senior design projects are now sponsored by the local industry and ASHRAE. Also, this approach has improved the quality of the senior design projects. These projects are very practical and solve real life design problems. This is evident from the report of the most recent ABET visit where the reviewers deemed these projects to be of a very good quality and the mechanical engineering program was commended for outstanding design projects. This clearly shows that why the outside support, such as the local industry and ASHRAE, of senior design projects is crucial to the students to be exposed to quality, practical, and real life design problems.

III. The Design Process

The design process that the students follow in the capstone senior design projects is the one outlined by Bejan et al. [2] and Jaluria [3]. The first essential and basic feature of this process is the formulation of the problem statement. The formulation of the design problem statement involves determining the requirements of the system, the given parameters, the design variables, any limitations or constraints, and any additional considerations arising from safety, financial, environmental, or other concerns. The second step in the design process is the generation of conceptual designs employing the well known barinstorming technique. In this step, the configuration and main features of the system are given in general terms to indicate how the requirements and constraints of the given parameters will be achieved. The conceptual design may range from a new idea to available concepts applied to similar problems and modifications in existing systems. The selected conceptual design leads to an initial design which is specified in terms of the configuration of the system, the given quantities from the problem statement, and an appropriate selection of the design variables. Next is modeling and simulation of the system. Modeling involves simplifying and approximating the given system to allow a mathematical or numerical solution to be obtained. Material property data, experimental results, and information on the characteristics of various devices are also incorporated in the overall model to obtain realistic results from the simulation. The results from the simulation are used to determine if the design satisfies the requirements and constraints of the given problem.

IV. Examples of some of the Capstone Senior Design Projects that were funded by Outside Support in the last two years:

A) Projects funded by ASHRAE through Undergraduate Senior Project Grant Program:

Example #1: "A Refrigeration System for a Small Compartment," by Steven Juricak and Andrew Magner [4,5].

A refrigeration system instructional experimental apparatus, shown in Figure 1, was designed, developed and constructed for the undergraduate mechanical engineering laboratory at Indiana University-Purdue University Fort Wayne. The purpose of the instructional experimental apparatus is to demonstrate thermodynamics processes and systems which are fundamental to understanding the basic concepts of thermodynamics, such as the first and second laws of thermodynamics. In addition, this apparatus demonstrates a vapor compression refrigeration cycle. A number of thermodynamics experiments that can be performed in which the first and second law of thermodynamics are employed to determine the heat gained by the refrigerant in the evaporator, the heat rejected from the refrigerant in the condenser, and the isentropic efficiency of the compressor. The objective of these experiments is to assist the undergraduate mechanical engineering students in understanding the basic thermodynamics processes by utilizing real life applications. Such an apparatus would enhance and add another dimension to the teaching/learning process of the subject of thermodynamics. The students would be able to apply thermodynamics principles such as the first and second laws and others that they learned in the classroom lectures to real life application. This approach could make the subject of thermodynamics a more pleasant experience for the undergraduate mechanical engineering students. This project was completed by a senior design team with the assistance of an Undergraduate Senior Project Grant in the amount of $1775.00 from ASHRAE.

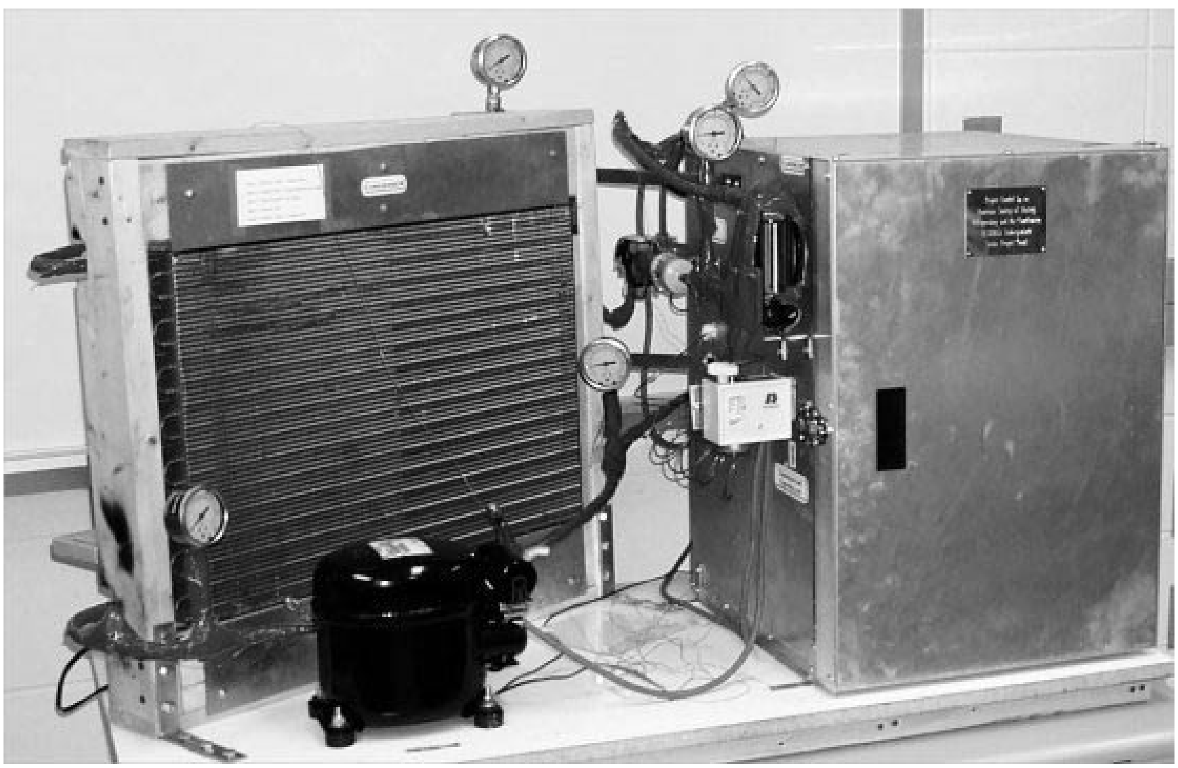

Figure 1: A Refrigeration System for a Small Compartment

Example #2: "Preheating Unit for Incoming Cold Water of a Residential Hot Water System," by Patrick Baugh and Aaron Rees [6].

A waste water heat recovery system instructional experimental apparatus, shown in Figure 2, was designed, developed, and constructed for the undergraduate mechanical engineering laboratory at Indiana University-Purdue University Fort Wayne. The purpose of this instructional experimental apparatus is to demonstrate heat transfer principles and heat recovery concepts. This experimental setup will help the undergraduate mechanical engineering students in understanding the basic heat transfer processes by utilizing real life applications such as waste water heat recovery system. This heat recovery system is a preheating unit for the incoming cold water of a residential hot water system. It is designed to recover some of the heat of the waste water going into the sewage system. This project was completed by a senior design team with the assistance of an Undergraduate Senior Project Grant in the amount of $1835.00 from ASHRAE.

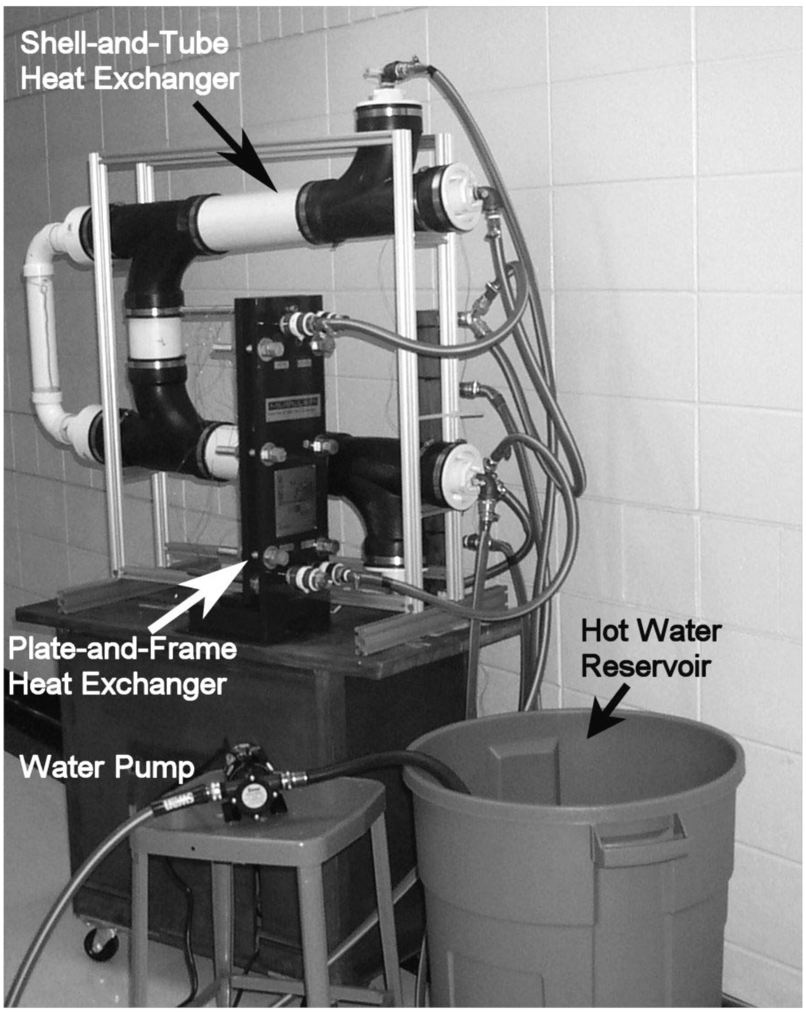

Figure 2: Heat Recovery System

B) Projects funded by Local Industry:

Example #1: "Heat Pump Water Heater," by Sanjoy Duttary, Htin Myin, and Kevin Noonan [7].

Hot water is a necessity in today's lifestyle. Hot water heaters come in various sizes and either gas fired or electric. The use of a heat pump water heater to supply hot water for residential and commercial usage is an efficient and energy conservative method. Water Furnace International Inc. located in Fort Wayne, Indiana, is a manufacturer of geothermal heating and cooling systems. Heat pump water heaters can be either water-source or air-source, and Water Furnace International wanted to develop an air-source heat pump water heater, so that they can enter this untapped market segment. The heat pump is simply an electrically powered mechanical device that transfers heat from a lower-temperature source to a higher-temperature environment, such as an air-conditioner. The basic design of the heat pump water heater system includes a compressor; a double walled vented coaxial heat exchanger, a thermal expansion device, an air-coil evaporator, and a water circulation pump. Figure 3 shows a picture of the heat pump water heater prototype that was designed, developed, and built. The total cost of designing, developing, and building the prototype was approximately $1600.00.

Figure 3: Heat Pump Water Heater

Example #2: "Maximizing the Efficiency of an Air-Oil Heat Exchanger," by Scott Braun and Clark Waterfall [8].

Many manufacturing facilities use large hydraulic systems to meet production requirements. Once these hydraulic systems are built, they can drive everything from cylinders to presses. Many hydraulic systems use oil as the fluid medium. This oil tends to warm as it cycled through the system driving machinery. A heat exchanger (see Figure 4) can be placed in the loop of the hydraulic system to remove the excess heat. When additional pieces of machinery are added to the system, the heat exchanger must be able to effectively cool the system, and in many instances, the old heat exchanger unit must be replaced by a larger unit that has a greater cooling capacity. These units are costly, and, for many small manufacturing facilities, physically consume too much space on the manufacturing floor. The old heat exchanger unit (the smaller) is typically discarded as it is no longer needed.

To resolve this problem, Neff Engineering Company of Fort Wayne, Indiana, has requested that a kit, or kits, be designed and developed which can be added to the existing heat exchanger to increase its efficiency by at least 35% in order to allow additional components to be added to the hydraulic system. The efficiency of the existing heat exchanger will increase by adding specified components (kit) to it which will enhance the rate of heat transfer from the hydraulic system to the air. The design team designed and developed several kits. The cost of these kits is in the range of $15.00 to $60.00. The total design and development cost of this project was approximately $650.00.

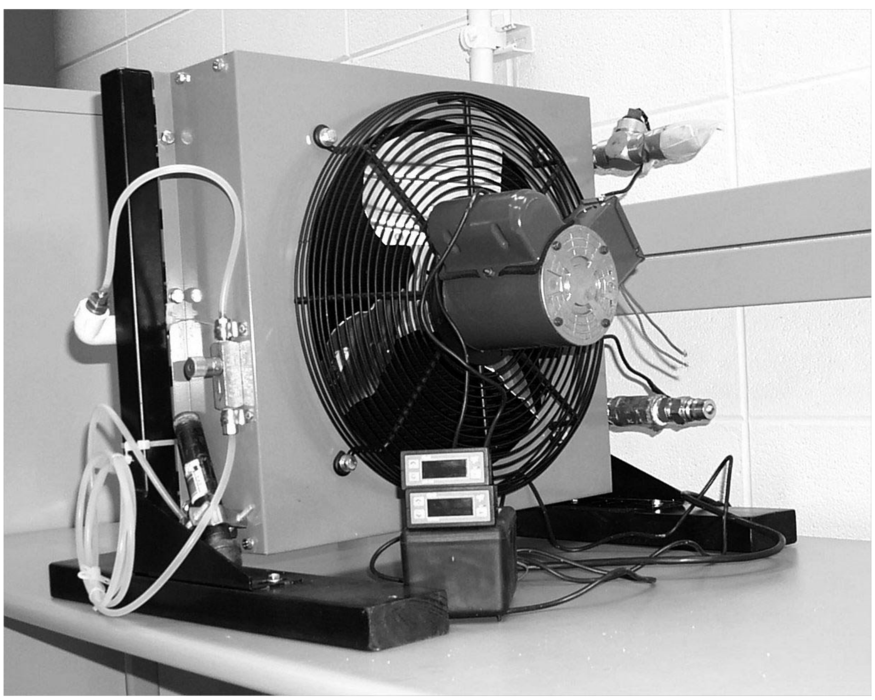

Figure 4: Heat Exchanger

Example #3: "Increasing the Capability of a Geothermal Heating/Air-Conditioning Unit Test Lab," by Robert Frye, Brandon Kelly, Kevin McGuire, and Aaron Winteregg [9].

This design project is a multi-disciplinary (mechanical and electrical engineering) project. The design team consists of two mechanical engineering students (Brandon Kelly and Kevin McGuire) and two electrical engineering students (Robert Frye and Winteregg).

Water Furnace International Inc. in Fort Wayne, Indiana wanted to increase the capacity of their test facility from 50 GPM to 100~150 GPM and to automate the control system. The test facility is used to determine the flow capacity, flow restrictions, and heat transfer of water-to-water cooling and heating units, in order to determine the heating or cooling capacity of newly designed high efficiency comfort systems for residential, institutional, and commercial applications. The current system was originally designed with a peak capacity of 8 tons. With the demand for larger units, the need came for a larger capacity test facility.

This fall 2002 semester, the design team has finished designing the system. In spring 2003 semester, they will build, test, and evaluate the system. The estimated cost of this project is about $20,000.00.

V. Conclusion

This paper shows that the outside support such as the local industry and professional societies for the capstone senior design projects is badly needed. This outside funding of capstone senior design projects allows the students to be exposed to quality, practical, and real life design problems. On an average, about three fourths of our capstone senior design projects are now sponsored by outside funding. In addition, this approach has improved the quality of the capstone senior design projects and made it possible to have multi-disciplinary design projects. Most of these projects are very practical and solve real life design problems.

Bibliography

1. ABET Engineering Accreditation Criteria, Criterion 3: Program Outcomes and Assessment. http://www.abet.org.
2. Bejan, A., Tsatsaronis, G., and Moran, M. (1996), "Thermal Design & Optimization ," *John Wiley & Sons, Inc*., New York.
3. Yogesh Jaluria (1998), "Design and Optimization of Thermal Systems," *McGraw-Hill*, New York.
4. Steven Juricak and Andrew Magner (2000/2001), "A refrigeration System for a Small Compartment," *Reports #1&2: Capstone Senior Design Project, Department of Engineering, Indiana-Purdue University*.
5. Abu-Mulaweh, H.I. (2002), "Portable Experimental Apparatus for Demonstrating Thermodynamics Principles," *Proceedings of the ASEE Annual Conference*, Montreal, Canada, CD-ROM, Session 1426.
6. Patrick Baugh and Aaron Rees (2001/2002), "Preheating Unit for Incoming Cold Water of a Residential Hot Water System," *Reports #1&2: Capstone Senior Design Project, Department of Engineering, Indiana-Purdue University*.
7. Sanjoy Duttary, Htin Myin, and Kevin Noonan (2000/2001), "Heat Pump Water Heater," *Reports #1&2: Capstone Senior Design Project, Department of Engineering, Indiana-Purdue University*.

8. Scott Braun and Clark Waterfall (2000/2001), "Maximizing the Efficiency of an Air-Oil Heat Exchanger," *Reports #1&2: Capstone Senior Design Project, Department of Engineering, Indiana-Purdue University*.
9. Robert Frye, Brandon Kelly, Kevin McGuire, and Aaron Winteregg (2002), "Increasing the Capability of a Geothermal Heating/Air-Conditioning Unit Test Lab," *Report #1: Capstone Senior Design Project, Department of Engineering, Indiana-Purdue University*.

HOSNI I. ABU-MULAWEH
Hosni I. Abu-Mulaweh is an Associate Professor of Mechanical Engineering at Indiana University-Purdue University, Fort Wayne, Indiana. He earned his B.S., M.S., and Ph.D. in Mechanical Engineering from the University of Missouri-Rolla, Rolla, Missouri. His areas of interest are Heat Transfer, Thermodynamics, and Fluid Mechanics.