The need for outside support of capstone senior design projects

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

INTRODUCTION

Capstone senior design project is a degree requirement in any respected engineering programme. In some programmes, the capstone senior design project is accomplished in one semester, while others devote two semesters to carry it out. At the author's institution, Indiana University-Purdue University Fort Wayne (IPFW), Fort Wayne, USA, the capstone senior design project is accomplished during the senior year and spans two semesters. In the first semester, the problem statement is formulated and the 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, students are exposed to real life design problem experiences by getting them involved and working on design projects that are provided and supported by local industry and professional societies, such as the American Society of Heating, Refrigeration, and Air Conditioning Engineers (ASHRAE). The types of design projects that local industry is interested in include the following:

- Develop a completely new design to perform specific task(s);
- Modify or improve an existing design;
- Solving problems in some industrial operations.

On the other hand, ASHRAE funds capstone senior design projects that involve an ASHRAE-related topic.

THE NEED FOR OUTSIDE SUPPORT

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

ASHRAE has a programme called Undergraduate Senior Project Grant Programme, which provides funding (grants of up to $5,000.00) for undergraduate engineering senior design projects and technical school projects. These grants are made to 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 programmes. Their goal is to increase student knowledge, learning and awareness of the heating, ventilation, air-conditioning and refrigeration (HVAC&R) industry through the design and construction of senior design projects and to encourage students to pursue ASHRAE-related careers.

The announcement of the Undergraduate Senior Project Grant Programme 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). Faculty member(s) and students of the design team are not required to be ASHRAE members. To apply for the grant, a faculty member needs to complete the application form on behalf of the students completing the senior design project. The application is normally due by 1 December of each year. It should be noted that capstone senior design projects, which would result in some type of instructional experimental apparatus that can be used by future students, have a greater chance of being funded by this programme.

The city of Fort Wayne is located in the heavily industrialised 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, IPFW explored the involvement of the local and regional industry in sponsoring some of the capstone senior design projects. This was accomplished by writing to 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 IPFW students work at these companies, either full-time, part-time or as co-op. 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 local industry was very positive because they realised this to be a win-win situation. They get their design problems worked on and solved for free, and only need to pay for the parts and materials. On the other hand, this provides the mechanical engineering programme with support for practical and real life design problems.

This approach was a success. On average, three quarters (75%) of capstone senior design projects are now sponsored by 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 programme was commended for outstanding design projects. This clearly shows why outside support, such as the local industry and ASHRAE, of senior design projects is crucial so that students are exposed to quality, practical and real life design problems.

THE DESIGN PROCESS

The design process that students follow in the capstone senior design projects is the one outlined by Bejan et al and Jaluria [2][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 brainstorming 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 that 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 modelling and simulation of the system. Modelling 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.

SOME RECENT EXAMPLES OF CAPSTONE SENIOR DESIGN PROJECTS FUNDED BY OUTSIDE SUPPORT

Projects Funded by ASHRAE through the Undergraduate Senior Project Grant Programme

Example #1: A Refrigeration System for a Small Compartment, by Steven Juricak and Andrew Magner

A refrigeration system instructional experimental apparatus, shown in Figure 1, was designed, developed and constructed for the undergraduate mechanical engineering laboratory at IPFW [4][5]. 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 vapour compression refrigeration cycle.

Figure 1: A Refrigeration System for a Small Compartment.

A number of thermodynamics experiments 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 utilising real life applications. Such an apparatus would enhance and add another dimension to the teaching/learning process of the subject of thermodynamics. 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 applications. This approach could make the subject of thermodynamics a more pleasant experience for undergraduate mechanical engineering students. This project was completed by a senior design team with the assistance of an Undergraduate Senior Project Grant totalling $1,775.00 from ASHRAE.

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

A wastewater heat recovery system instructional experimental apparatus, as shown in Figure 2, was designed, developed and constructed for the undergraduate mechanical engineering laboratory at IPFW [6]. The purpose of this instructional experimental apparatus is to demonstrate heat transfer principles and heat recovery concepts. This experimental set-up helps undergraduate mechanical engineering students to understand basic heat transfer processes by utilising real life applications, such as a wastewater 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 wastewater going into the sewage system. This project was completed by a senior design team assisted by an ASHRAE Undergraduate Senior Project Grant that amounted to $1,835.00.

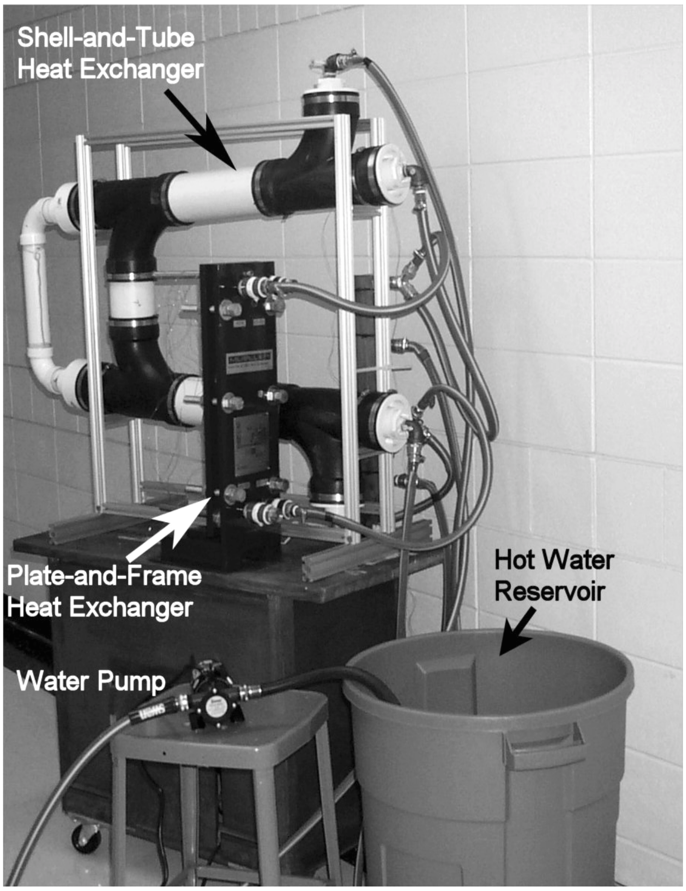

Figure 2: Heat recovery system.

Projects Funded by Local Industry

Example #1: Heat Pump Water Heater, by Sanjoy Duttary, Htin Myin, and Kevin Noonan

Hot water is a necessity in today's lifestyle. Hot water heaters come in various sizes and are 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 [7]. The total cost of designing, developing and building the prototype was approximately $1,600.00.

Figure 3: Heat pump water heater.

Example #2: Maximising the Efficiency of an Air-Oil Heat Exchanger, by Scott Braun and Clark Waterfall

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

Figure 4: Heat exchanger.

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.

In order to resolve this problem, Neff Engineering Company of Fort Wayne, USA, 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 [8]. 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.

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

The design project that focused on increasing the capability of a geothermal heating/air-conditioning unit test laboratory was a multidisciplinary (mechanical and electrical engineering) project. The design team consisted of two mechanical engineering students (Brandon Kelly and Kevin McGuire) and two electrical engineering students (Robert Frye and Aaron Winteregg) [9].

Water Furnace International Inc., in Fort Wayne, USA, 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. The total design and development cost of this project was approximately $20,000.00.

CONCLUSION

This article has shown that outside support, such as from local industry and professional societies, for the capstone senior design projects is badly needed. This outside funding of capstone senior design projects allows students to be exposed to quality, practical and real life design problems. On average, about three quarters of IPFW 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 multidisciplinary design projects. Most of these projects are very practical and solve real life design problems.

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