From Concepts to Design Realization: A Design Project

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Abstract

Machine design courses tend to focus primarily on machine component design. This is an essential part of the course because students must be able to design a wide variety of components for many different applications. However, students often do well in component design and analysis but struggle with open-ended design problems, i.e., they have a difficult time see the bigger picture. The goal of this effort was to help the students make the transition from component design to the design of machine systems.

To accomplish this, machine design students met with an entrepreneurship student to learn about a proposal to improve the ergonomics involved while removing dishes from a standard dishwasher. The goal was to develop a method for moving the lower dishwasher rack out and up so that it is at same height at the upper rack. A dishwasher with this capability could help a large number of people with disabilities or back pain. Based on the specifications provided, the machine design students work in teams of two to develop various designs. The students participated in an end-of-semester poster session and prizes were given for best technical and most innovative designs. The competition provided additional motivation for the students to their best to come up with the best design.

Introduction

Success of engineering education depends on the students’ ability to apply their learning to a real life problem with realization of a feasible product. The challenge educators face is how to integrate students’ learning into the bigger real picture. Specifically a class project should utilize most of the course topics towards real life problems. To achieve this objective, a machine design project was chosen from the ideas generated from another interdisciplinary class on entrepreneurship. One of the entrepreneurship students had identified a need for a dishwasher for elderly or physically handicapped persons. The entrepreneurship student had already analyzed the idea from a business perspective. The machine design students met with this student for specifications and constraints. The goal was to design a lower dishwasher rack that can be automatically brought out and elevated to a position that is higher than conventional dishwashers so that back strain and pain are reduced. The students came up with a wide variety of creative design proposals. Examples of the designs will be presented in this paper, along with discussion about the advantages and challenges of project. The students followed the design process from concept generation to design realization utilizing relevant learning modules from the course. They also participated in a poster competition with students from other project-based courses.
This project lead to the exploration of other project organizations, e.g., horizontal and vertical integration of project teams, including students from machine design, product design, and manufacturing processes course as described the Future Work section.

Background

Grand Valley State University (GVSU) is located in the west part of Michigan surrounded by many auto suppliers and furniture manufacturers. The School of Engineering has strong support from the local industries and we strive to keep our curriculum up-to-date, reflecting their needs. All of our senior design projects are sponsored and co-operative education is mandatory in for undergraduate engineering students.

One engineering faculty member is involved in The Center for Entrepreneurship at the Seidman College of Business at GVSU. This center serves to promote entrepreneurship. ENT 150 - Entrepreneurial Quest is offered as a part of that program. This course provides an overview of the breadth of activities typical of a new business owner and takes the student through the initial stages of creating a new product or service, market feasibility, and entering the marketplace.

A dishwasher product with “Amazing Raising” lower rack, originally conceived in this ENT 150 class during the winter semester of 2005, was chosen as the design project for EGR409. Students take this course after they have completed total three semesters of co-op as can be seen from the typical course sequence below.

Fall (Third Semester): EGR209 Statics and Solid Mechanics  
Summer: EGR290 Engineering Co-op I  
Winter: EGR390 Engineering Co-op II  
Summer (Sixth Semester): EGR309 Machine Design I  
Fall: EGR490 Engineering Co-op III  
Winter (Seventh Semester):  
   EGR409 Machine Design II  
   EGR485 Senior Project I  
Summer (Eighth Semester): EGR486 Senior Project II

Consequently, they have enough maturity to see the bigger picture and can appreciate the necessity of connecting the course project to real life problems.

Objectives

- To integrate student’s learning into a bigger real life picture.
- To increase the emphasis on the design of machine systems.
- To utilize most of the course topics towards real life problems.
- To allow students to collaborate with people with other specialties

Project Description

The project was intended to help people with back problems from, but not limited to injury, arthritis, and aging. Initially the following broad project statement was given to the students.

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Design a lower dishwasher rack that can be automatically brought out and elevated to a position that is higher than conventional dishwashers so that back strain and pain are reduced for people with physical disabilities.

For the initial phase of the project, the originator of the concept was invited to meet with EGR 409 students for a class discussion. The concept was explained and there was discussion about the concept of the product and its purpose. Information about the product uniqueness, customer research results, and the business side of the product such as target market, market potential, cost, etc. were also discussed. The originator goal was to develop a marketable design and then sell the product to a company that can manufacture and sell the product. Students were interacted frequently with the originator throughout the project.

A dish washer was provided in the workshop for measurements and packaging study. The students were required to deliver a solid model of their mechanism which can be packaged in the given wish washer. The components were designed based on packaging, strength and fatigue-life considerations. Throughout the semester students were given target deliverables such as packaging study, concept generation, design selection, subsystems identification, complete free body diagrams, force analysis and stress calculations. The final report was to be comprehensive.

At the end of the semester, the machine design students participated in a poster session with other project-based classes, and awards were provided for the best technical design and the most innovative design.

Outcome

Teams of two machine design students created a wide variety of designs ranging from innovative motor-driven mechanisms with excellent consumer appeal (Figure 1) to simple manual spring-driven designs (Figure 2) or manual vertical shaft lift mechanism (Figure 3). Some mechanisms moved the rack out and up simultaneously while others moved the rack out using gears on tracks with a separate mechanism to lift the rack. Figures 4-7 show other interesting examples. The first two designs (Figure 4 and 5) include a rack and pinion system to move the lower rack out of the dishwasher enclosure. After moving the lower rack out of the enclosure, these two designs raise the lower rack using an electric cylinder and four arms that raise the rack with spur gears, respectively. The design in Figure 6 uses a scissor mechanism to raise the rack in one fluid motion. The last design (shown in Figure 7) incorporates a four-bar linkage, wheel and track system, and is powered from below by a ball screw and electric motor. Altogether there were approximately 20 different designs last winter, but no prototypes were made.
Figure 1. Motor Driven Mechanism

Figure 2. Manual Spring Loaded Design

Figure 3. Manual Vertical Shaft Lift Mechanism

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Figure 4: Lower dishwasher rack lifted by an electric cylinder

Figure 5: Lower dishwasher rack lifted with four arms

Figure 6: Lower dishwasher rack lifted with scissor mechanism with rack and pinion housing

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Figure 7: Lower dishwasher rack lifted with a four-bar mechanism

Conclusions

This project allowed the students to collaborate with people with other specialties. In this case they interacted with the originator of the concept. They could also integrate their learning into a bigger real life picture by delivering concrete designs to satisfy a need that was recognized and confirmed by customer research. In addition to designing the necessary components, the students were able to work with the course instructors to design a machine *system* as compared to design simple machine components in isolation. The students were also able to apply most of the course topics toward a real life problem. The end of the semester poster presentation and competitions provided additional motivation for the students to do their best work.

Future Work

The future direction for the EGR409 course project is to increase the emphasis on the *design* and *manufacture* of mechanical *systems*. A strategy that includes vertical and horizontal integration of project team from various courses will be adopted. To aid in this effort, mechanical engineering, product design and manufacturing faculty are collaborating with faculty from Kettering University using their NSF funded model for the multidisciplinary integration of interdepartmental courses. Preparations began last summer and it included our faculty attending a seminar at Kettering University for training and obtaining sub-grant from their above mentioned NSF grant. The same dishwasher design project along with other projects will be offered to the students. The implementation the strategy will allow students to collaborate with people with other specialties and be introduced to integrated system design and manufacturing. It will also help them visualize the complete system and the big picture throughout the project.