Senior Capstone Design and Build: Comparing Product Design and Manufacturing Equipment Design

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At Grand Valley State University the senior capstone designs have included many industry based projects. The projects are primarily design and build over a two semester course sequence. This paper summarizes the design process used for the 2009 projects and uses two case studies to highlight some of the differences between product design and manufacturing equipment design.

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Introduction

Grand Valley State University has been using a two semester design and build capstone project. The design and build approach addresses many of the concerns that employers have voiced with regards to recent graduates in engineering and technology.[1,2] This article is intended to highlight some of the differences between product design and manufacturing equipment design. Exploring and understanding these differences will enable further refinement of these types of capstone design projects. The first semester includes problem definition, specification generation and sign-off culminating with a design review and sign off. The second semester is primarily building, validating and troubleshooting the final product. Two types of projects are generally involved. Manufacturing equipment such as automated assembly, welding cells and automated test equipment. The second type of project is producing a prototype product suitable for the sponsor's needs. The requirements for these two types of project vary significantly. The manufacturing equipment typically have over designed load bearing frames. This is desirable in a manufacturing environment where unforeseen loading conditions may occur and a material savings of 10% may result in a failure costing several hours or days of production to be lost. Conversely a savings of 10% for a product may be well worth a tradeoff with regards to product life.

GVSU Capstone Process Stages[3]

The capstone experience at GVSU is a two semester sequence of courses. Typically the first semester is design and prototyping and the second semester is build and validation. The sequence and times are listed below:

(January- April)
Week 1 – Lectures start and student teams are assigned to projects.
Week 2 - Students are given clearance to visit sponsors based upon prepared questions.
Week 3 – Students prepare specifications and receive approval to present to sponsor.
Week 4 – Sponsors sign off on specifications.
Week 5 – Students submit design concepts and propose testing and prototyping plans.
Week 6-7 – Students receive formal concept approval from project sponsors.
Week 8-11 – Students perform detailed design work leading to submission of draft design proposal.
Week 12 – Students perform present design proposals to the faculty.
Week 13 – 15 Students present design proposals to sponsors for sign off.
(May-July)
Weeks 1-8 – Students order components, build parts, assemble systems, test and prepare for delivery.
Weeks 9-12 – Sponsors review projects and prepare for sign-offs.
Week 13-14 – Student teams resolve minor issues and prepare for senior project day and final project sign-off.
(August) Projects Delivered

Product Case Study

A wireless rechargeable dental mirror with a built in light source. The prototype is shown in figure 1.

The company sponsoring the project had defined the outside envelope. The light had to function for a full working day. In addition the tip of the mirror had to be easily changed and disposable. The charging base

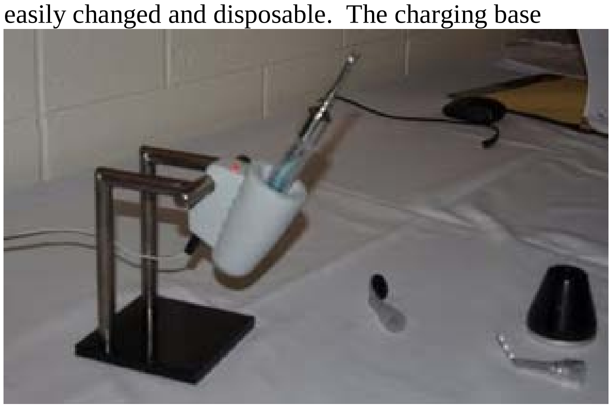

Figure 1. Dental Mirror Prototype

was less prescribed but had to be mountable to a standard cart. An expected production volume of several thousand assemblies per year was used for tooling projections. A team consisting of two product design and manufacturing (PDM), two electrical (EE) and one mechanical (ME) engineering students was assigned to this project. The internal design for the light and charging system was clearly the portion of the project to be lead by the EE students. The case and mounting base were handled by the PDM and ME students. Close communication between these two sides of the design team was required to create a robust functioning product. The time that the instrument was in use each day was critical. This drove battery size and charging rate. The students quantified this time by mounting a web cam to a table and pointed it at the mirror holder. Later the students reviewed the recording and noted the time used. The requirement that the tip had to be easily changed was difficult to quantify. How much time and force constitutes 'easily'? These values had to be researched and agreed to by the sponsor. A snap fit design was desired but proved difficult to implement because of the production processes that were expected to be used. This required some clever engineering from the students. The projected production volumes resulted in additional design constraints driven by costs of tooling versus piece cost. Communication between the EE, PDM and ME students proved to be a critical component. Several set-backs during the design were the result of poor communication and understanding of how their choices impacted the other disciplines. The EE students did not have the background knowledge at the beginning of the project to design a wireless charging device. They gained some through coursework and additional knowledge through their own research. The PDM and ME students had assumed that wireless charging was essentially a solved problem. Later after the circuit board, batteries and internal mountings were agreed to the students had to deal with the possibility of the product being dropped. This drove changes in the circuit board, coil, mounting points and housing requirements.

Test Equipment Case Study

Two test stands able to accept a range of pumps and quantify the flow rate. One of the finished test stands is shown in Figure 2.

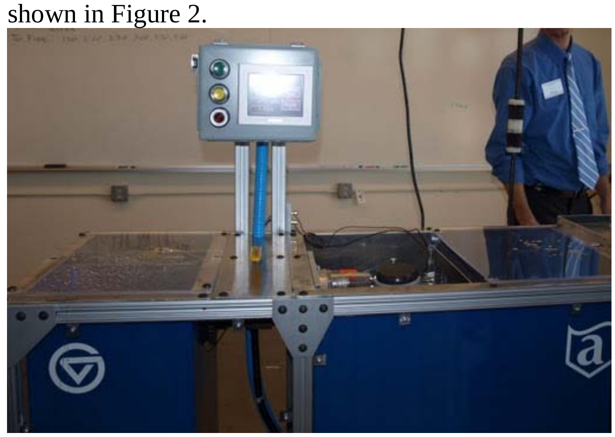

Figure 2. Pump Test Stand

The customer specified the time allowed for testing, floor space, accuracy, variable head pressure and what information was to be generated and stored.

A team consisting of four ME students and one PDM student was assigned to this project. The students initially researched flow meters that were commercially available. No flow meters were found that met the requirements and did not drive the project 30% or more over budget. After several rounds of brainstorming and minor prototyping the students decided to use an ultrasonic sensor to measure water level. This drove the need to design a chamber that reduced the ripples in the water caused by the pumps. The frame and water tanks were designed with a large factor of safety to insure a long useful life and no unexpected failures due to transport, minor abuse or other unknown loadings. Initial calculations and prototyping indicated that the separate components should perform the required functions. Building and integrating the components proved to be challenging. The human interface had several different screens and levels of control that were locked or accessible depending on the operator.

Discussion

The two projects presented share similar stages: specification, design and build. However there are several areas that the projects had significant differences.

Packaging: The dental mirror had a clearly defined envelope while the test stands had a floor space requirement. The dental mirror by necessity drove a compact an efficiently packaged design. For example during the design and prototyping phase both teams had changes to the electrical hardware that affected the mechanical portion. The test stands used a larger box and the problem was solved. The dental mirror involved internal mounting design changes and additional components.

Production volume: Several thousand dental mirrors versus two test stands. The dental mirror design concerned itself with assembly labor, piece cost and production tooling costs. The test stands had to be manufactured and assembled twice. It was not a concern if the process involved a student cutting and filing for several days as long as the equipment met the requirements.

Operating life: The dental mirror had a disposable single use component and the remainder of the product was expected to last for several years in an office environment. The test stands were expected to last for several thousand operations over a period of years in an industrial environment with minimal maintenance.

Operating environment: The dental mirror would be used in an office and be cleaned with an alcohol wipe. Worse case loading may involved being dropped on the floor. The test stands had to be resistant to industrial cleaners and solvents. Load cases may involve being 'nudged' by a forklift or used as a platform to step on.

Human Interface: The dental mirror was a hand-held product without adjustment. The test stands used a touch screen and hard wired safety switches. Programs were to be written to create the menus and store data as required by the customer.

Timeline: The test stand project followed the timing given earlier. However the dental mirror product lagged by as much as six weeks due to the increased amount of design time required. The team graduated on time because they did not require the eight weeks given in the process stages for build and test. Both teams finished within two weeks of each other.

Conclusions

A fundamental difference is the number products or machines that are expected to be produced. Several thousand for the product versus two for the test equipment drives many of the design decisions. This is not surprising as they are industry sponsored projects and the primary driver is economics.

The two teams finishing within two weeks of each other seems to suggest a similar amount of effort was required for both projects. Quantifying the amount of time students spend on the capstone project is being attempted at Grand Valley using a web based tracking system.

After gathering and analyzing additional data based on the 2009 -2010 capstone projects a revised timeline for capstone projects involving product design will be proposed for the 2010 – 2011 academic year. It is expected to add several weeks of design before the design sign off and compress the build and test sequence.

References

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