Local Industry Involvement in the Support of Capstone Design Projects

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Abstract

This paper discusses why the involvement of the local industry and its sponsoring of senior design projects is crucial to the students to be exposed to quality and real life design problems. Also, examples of some of the projects that the local industry has supported will be presented.

I. Introduction

The students in the mechanical engineering program at Indiana University-Purdue University at Fort Wayne are required to complete a capstone senior design project. This is carried out during the two semesters of the senior year. In the first semester, basic conceptual designs are generated and then evaluated. The best conceptual design is then chosen 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. The projects are either in the solid or thermal areas of the mechanical engineering.

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. 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.

II. The Need for the Local Industry Involvement

The cost of constructing a prototype of the finished design is usually high. This is especially the case when the projects involve real life problems. For small undergraduate mechanical engineering programs with limited resources, such as ours, the high cost of building these projects tends to hamper the selection of quality capstone senior design projects. For example, the support of our department for the capstone senior design projects is $100 per student. With design teams of two or three students, this support amounts to $200 to $300 for each design project. This is hardly called an adequate support for good quality and practical senior design projects. This reality gave us two choices: one of them is to accept this situation; that is, select capstone senior design projects that fit within the budget stated above. This in turn affects the quality of these projects which may lead to problems with ABET regarding accreditation of our engineering program. The other choice is to do something about it by seeking external support for our capstone senior design projects.

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 is Navistar International Corp., Dana, General Electric, Franklin Electric, Othy, WarerFurnace International, Inc., Poly Hi Solidur-A Menasha Corporation, 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 these 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 quite good. 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, about two thirds of our capstone senior design projects are now supplied and sponsored by the local industry. 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 involvement of the local industry and its sponsoring of senior design projects is crucial to the students to be exposed to quality, practical, and real life design problems.

III. Design Process

The design process we follow in the capstone senior design projects is the one outlined by Jaluria [1]. The essential and basic features of this process are:

1. The problem statement:
   The formulation of the design problem 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.

2. Conceptual Design:
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.

3. Initial Design:
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.

4. 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.

5. Evaluation of different designs:
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 the Local Industry has supported in the last two years

Example #1: "Preheating System for the Extrusion Process of Ultra-High Molecular Weight Polyethylene," by Scott Allen and Jacqueline Kaluza [2].

The Poly Hi Solidur company, of Fort Wayne Indiana, wanted to increase the production rate of its Ultra-High Molecular Weight Polyethylene (UHMWP) rods over the current rate of 22 inches per hour. The polyethylene rods that Poly Hi produces are used in a variety of fields. These fields include a wide range of medical applications varying from uses in tools to uses as internal replacement body parts.

The method of fabricating the UHMWP is one in which a resin is deposited into a hopper which feeds a die that is electrically heated. The resin is then forced into the die by a hydraulic ram, giving the material the finished form of a solid cylindrical polyethylene rod.

It was believed that the production rate can be increased by preheating the UHMWP resin as it passes through the resin hopper and is introduced into the die, thereby reducing the processing time required for heating the resin within the mold and consequently increasing the production

rate of the cylindrical polyethylene rod.
The requirements of the sponsor company demand that the preheating system maintain the purity and integrity of the final product while increasing the overall process output. The maximum temperature of the preheater is limited by the material properties of the UHMWP resin. At excessive temperatures the resin powder becomes clumpy and sticks together which causes flow problems through the hopper into the die and discontinuities in the final product. In order to avoid this, the material should not be preheated to a temperature that exceeds 140ºC, as indicated by the distributer of the resin. The cost of the final design should not exceed $1000.

Description of the final design of the preheating system:

This system will preheat the resin in a cylindrical, insulated reservoir located externally from the ram extruder, as shown schematically in Fig. 1. This reservoir will have ceramic heating bands around the outside of the reservoir, which will provide heat to the resin and be monitored through the existing readout method employed by the company with the use of thermocouples. A motor with a stirring wand will compliment this method of heating by mixing the resin in such a way that uniform heating can be attained. The system will also have a nitrogen bubbler to provide an inert atmosphere for the preheated resin.

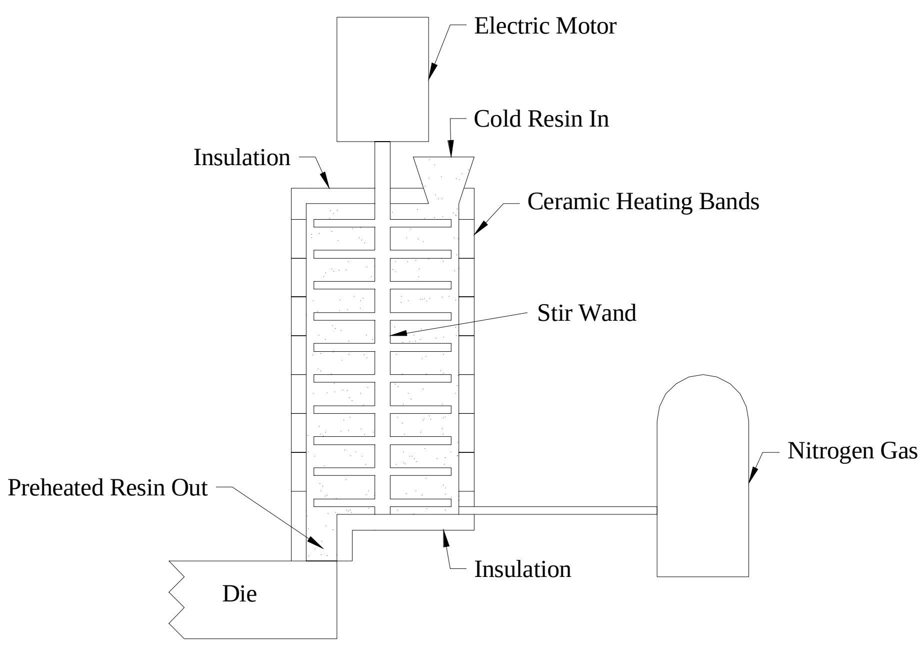

Figure 1: Preheating System

Once heated to the desired temperature, the resin will fall into the die as needed through an insulated tube from the bottom of the reservoir. New resin at room temperature will then fall through a supply tube into the top of the reservoir at the same rate. The concept behind having the resin fall into the reservoir at the same rate that it exits will allow it to remain full at all times. This should force extraneous air from the heating reservoir, and along with the nitrogen bubbler, prevent oxidation of the resin. The nitrogen bubbler will allow the environment within the reservoir to become more pure with time by forcing any remaining air from the reservoir. The motor mounted stirring wand will ensure that all of the resin is at the same desired temperature when it falls into the die.

It should be noted that this design project was successful. The preheater has increased the production rate by 18% to 26 inches per hour.

Example #2: "Industrial Zone Heating, Ventilation, and Filtration," by James Ham, David Mierau, and Matthew Rupert [3].

J & L Construction is a small, local construction company that is branching out into a new business venture. J & L Construction has asked that a heating, ventilation, and filtration system be developed for their new workshop, which contains cutting machinery for processing a new material used to make counter tops. They have asked that their processing center be kept at a minimum temperature of 75^{o}F, and to keep the total cost of the new heating, ventilation, and filtration systems as low as possible.

Description of the final design of the heating, ventilation, and filtration systems:

The final design of the heating system was based on a heating load of approximately 32000 Btu/h. This load was used to size both a unit heater and furnace. The unit heater was the recommended choice because of the small size of the heated space and the installation cost of the ducting incorporating with the furnace.

The final design of the filtration system consisted of a system of ducting, housing air flowing at a velocity of 4000 ft/min at a 6 inch diameter into a Cyclone Collector. The Cyclone Collector is a device, which separates dust particles from an air stream through centrifugal force. The clean air is then redistributed back into the building at a reduced velocity. A schematics of this device is shown in Fig. 2. The design operating point was determined to be 4.54 in. of H_2O of static pressure with a flow rate of 2100 cfm. This would require a 2 hp motor according to the manufacturer's data, providing a fan efficiency of 73%. The total installation cost for this system is approximately $3500.

The performance of the cyclone collector was evaluated in collecting solid surface material dust. Published date states that the cyclone collector should collect approximately 90% of sawdust. The experimentally determined value was 85%. It should be noted that a design change was incorporated to account for the dust traveling through the cyclone collector. It was the addition of filtering bags at the clean air return.

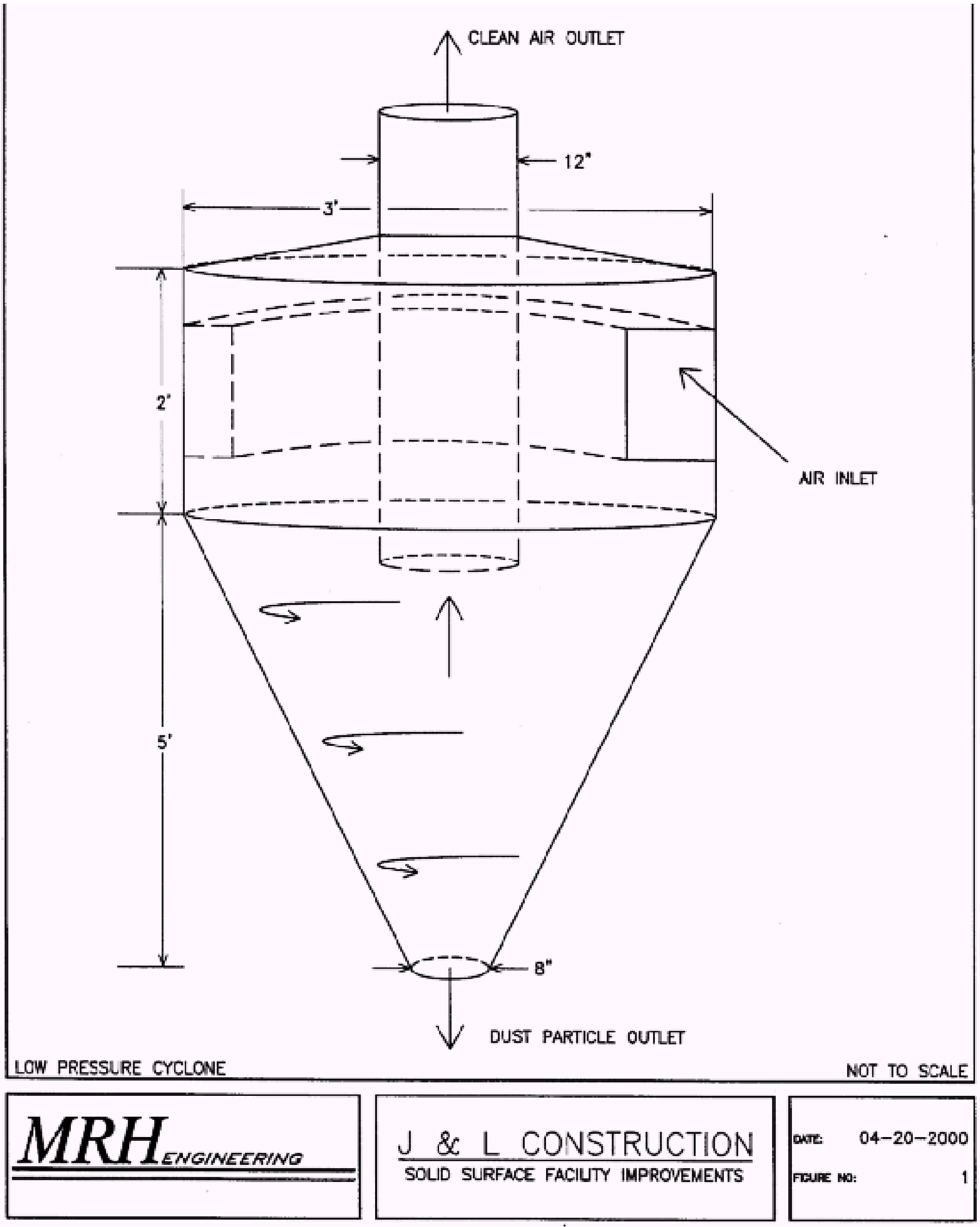

Figure 2: Cyclone Collector

Example #3: "Design of a Universal Light Axle Stand," by Sean Hoefer and Greg Maser [4].

The design of a universal axle stand is very important to the Light Axle Division of Dana Corporation, Fort Wayne, IN. Currently, due to the wide variety of axle models and their geometries, several different axle stands are used to fit the large variety of axle geometries. Thus, a great deal of floor space is required to house all the different axle stands, and valuable time is wasted switching from one stand to another in order for technicians to do their work. Therefore, The Samples and The Technical Service Departments believed that a significant amount of time and space can be saved if a universal axle stand existed.

Dana required that the axle stand be designed to hold most light axles. The axle stand was desired to have a mechanism to hold the pinion yoke in place at the 12 and 6 O'clock positions (pinion yoke facing the floor and ceiling). The axle stand was also desired to be portable and allow the axle arms to have a variable width. In addition, the axle stand height needed to be fixed and at a comfortable height for the technician and to hold a maximum axle weight of 800 lb.

Description of the final design of the universal axle stand:

The designed axle stand shown in Fig. 3 holds a straight beam axle by means of two tube rests. These tube rests have clamping mechanisms built in so that the rotation of the axle can be locked from rotation at any desired position by applying tension to the clamp by means of the T-bar. The figure shows the right clamping mechanism open while the left clamping mechanism remains closed to achieve the two desired lock positions. These positions are with the pinion pointing up or down. The tube rests can be adjusted vertically inside the column brackets by means of a lock pin in order to accommodate various technicians who prefer different working heights. The column brackets can translate back and forth on the rails on which they sit allowing the stand to accommodate the high percentage of axles required for the design. These column brackets can also be kept from translation by means of a friction handle. The rest of the stand is simply a frame composed of rails and end plates , either pinned or welded together. The wheels allow easy portability of the axle stand.

An independent carrier can be accommodated by means of the independent carrier adaptor assembly. With the cover plate removed from the independent carrier, the cover plate flange can be mounted to the adaptor by means of inserting a bolt first through the adaptor piece and then into the bolt hole in the axle housing itself for secure mounting. The independent carrier adapter mounts to the axle stand by taking the place of the tube rests. The independent carrier assembly, like the tube rests, can be adjusted vertically up and down to help ensure an ergonomic height for the operator. The total cost for parts only was approximately $4400.

Stress analysis was done for all parts theoretically and experimentally utilizing strain gages. The prototype stand was tested in everyday normal use and by means of strain gage instrumentation. Testing results indicate that the designed universal stand function well and worked trouble-free operation. It should be noted that this design has been patented.

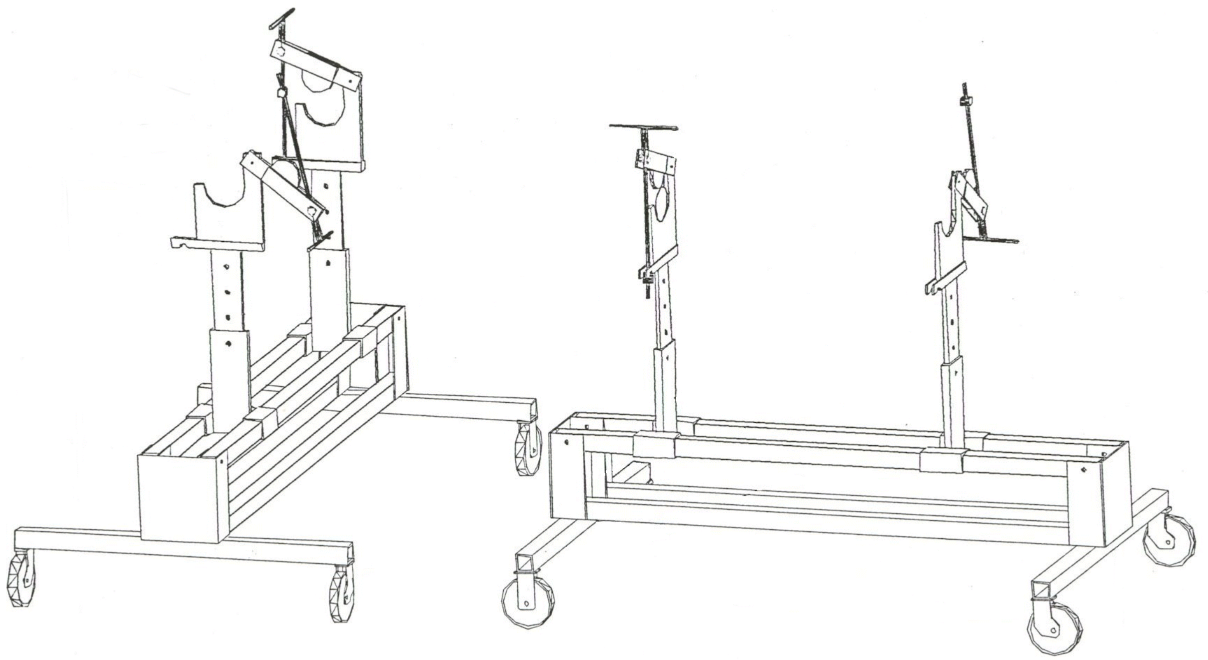

Figure 3: Universal Axle Stand

Example #4: "Improved Spinal Implant Locking Mechanism," by Jill Engel and Matt Withrow [5].

Othy, located in Warsaw Indiana, is an orthopedic instrumentation designer and supplier. The company manufactures instruments that are used for the implantation of orthopedic medical devices and the correction of orthopedic medical abnormalities. The objective of this design project was to design an improved spinal implant locking mechanism. The mechanism was to meet customer requirements as well as the design protocol of Othy.

In addition to minimizing the cost and the time to manufacture, the implant locking mechanism must satisfy the following requirements:

1. 10.6 : 1 mechanical advantage, with a minimum output force of 1000 lb.
2. Range of motion of 0.348" to 0.808".
3. Parallel motion.
4. Made of bio-compatible materials.
5. Maximum length of 22" to fit into sterilization tray.

6. Product life of two years or approximately 360 cycles.
7. Withstand repeated autoclave sterilization.
8. One hand grip.

Description of the final design of the locking mechanism:

The design process was an iterative one involving a loop of tasks. After the overall concept was chosen, force and stress calculations were done to be used as starting points for design. Using the results of those calculations, three-dimensional models were made of the device. As these models were created it was necessary to modify the concept. The calculations were then reapplied to test for function and strength. This calculation-model loop was done repeatedly until the design was optimized. The overall concept has a lever mechanism, shown in Fig. 4, that pushes on a rod, the rod pushes on two links that close a hinge-like mechanism. The mechanism has slightly grooved handles for ease of use. The pins are made of 455 SST condition H950 and the mechanism is made of 13-8 SST condition H950. Both materials have high yield strength, are bio-compatible, and can withstand repeated autoclave sterilization.

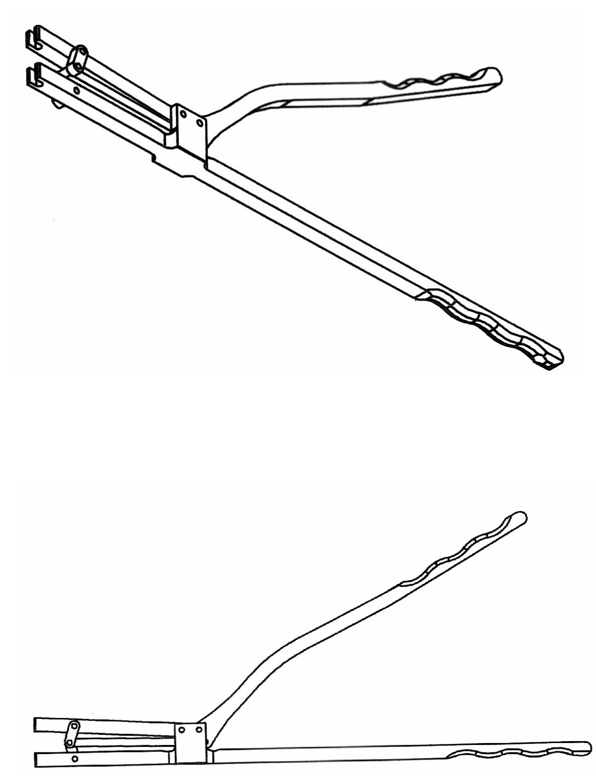

Figure 4: Spinal Implant Locking Mechanism

Electrical-resistant strain gages were used with a simulated maximum force to determine the actual stress at crucial locations on the mechanism. The functional test produced positive results as the mechanism was able to lock eighty seven percent of the implants successfully. The total cost of the prototype was $2500.

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