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I. Introduction

Senior or Capstone project courses are part of majority of the Engineering Technology Curriculum. This is partly because of the faculty's desire to assess student's ability to apply the knowledge acquired and, partly because of the mandate by the Accreditation Board for Engineering and Technology (ABET). A number of papers have been published on the topic of senior projects and the necessity for providing realistic engineering experience [1,2,3]. Looking at these publications, a common theme emerges which calls for making these projects relevant to industry [1]. This can be accomplished by greater industry involvement and redesigning the capstone course to meet the needs of industry. This paper discusses two frameworks under which this can be accomplished and presents two research projects that were completed as part of senior design project in the Mechanical Engineering Technology program at Old Dominion University.

II Industry Involvement

Industry involvement in senior projects is a key factor for a successful capstone course as identified by many authors [1,2]. Industry involvement can vary greatly in terms of focus, scope and company support. At one end this may involve only financial support, while on the other end the involvement may include both personnel and financial commitment.

III Innovative Research Projects

Innovative research projects can be offered under various organizational framework as discussed by the author in a previous paper [4]. While funding from industry, state or federal agencies , can certainly enhance the quality of senior research projects, unfunded student research projects can be equally gratifying in terms of quality of learning experience.

1. Funded Research Projects

Following is an example of funded research project done in the Automated Manufacturing Laboratory at Old Dominion University. This project was done with the help of two seniors participating in the project as part of their capstone course requirement. The two students were from the MET and EET programs and they worked on Mechanical Design and Electrical Controls respectively.

Case Study - Design & Fabrication of an Automated Battery Testing Machine [6].

An automated battery testing machine was designed and built. The machine is capable of testing approximately 50,000 batteries in an eight-hour shift. The batteries are fed through a vibratory feeder on to a moving chain conveyor. The conveyor takes the batteries through two testing stations. The first one performs an open circuit voltage test and the second station performs a high current test. Two programmable logic controllers control the motion of the conveyor with the help of several photo optic sensors and limit switches.

Functional Requirements - The functional requirements of the machine were specified by Rebatt. These included the following -

1. Automatic battery feeder to provide a continuous supply for the conveyor.
2. Batteries should be tested under load and no-load conditions.
3. Machine should separate good batteries from the bad ones based upon results of the two tests.

Design of Mechanical Components - Design of mechanical components consisted of four major tasks. First the machine had to be modified to handle AA size batteries. Second, an automatic battery feeder was designed to provide a continuous supply for the conveyor belt. Third, a feeder block was designed to place the batteries on the conveyor belt. Fourth, a take-up unit was designed to collect the good batteries.

a. Retrofitting for AA size

Retrofitting for size AA consisted of modifying the support blocks for batteries which are mounted on the chain conveyor belt. The new support block caps were designed such that the height of the batteries remained the same relative to the conveyor belt. This eliminated the need for modification to other mechanical components involved in material handling . Two hundred twenty support blocks were machined in the machine shop using high density polyethylene.

A nylon pressure plate applies vertical pressure on batteries as they enter the testing stations (figures 1). As batteries move under the pressure plate, they are horizontally positioned by two guiding plates before reaching the testing station.

b. Design of Battery Feeder

At least three conceptual designs were made for the battery feeder. The final design selected included a nylon hopper with rotary vanes in the center of the hopper (Figure 2). A prototype was made and tested satisfactorily. The center rotary vane was made out of a solid bar stock of high density polyethylene with one flute for aligning and transporting the batteries to the center of the hopper. An ac motor turned the vane at 18 rpm. This design provided approximately 55 batteries/minute and was later modified to include two inserts which increased the throughput to approximately 65 batteries/minute.

c. Battery Delivery Mechanism

The battery delivery mechanism consists of a nylon tube and a feeder block with a proximity sensor (figure 3). The nylon tube carries the batteries from the vibratory feeder to the feeder block. The feeder block is mounted such that it drops the batteries between two support caps. A second block with a proximity sensor centers the battery on the conveyor belt while providing the control signal to the controller to advance the conveyor to the next position. Figure 1 shows a picture of the feeder block.

d. Battery Collection

Batteries are dropped in a funnel at the end of the conveyor which channels them into a collection box.

Control System - A Programmable Logic Controller (PLC) based control system was designed to control the various functions of the equipment--including the motion of conveyor, testing of batteries, sensing part presence, actuating the pneumatic valves for ejecting bad batteries. Figure 4 illustrates the control panel layout. The control panel is mounted on the side of equipment for ease of operation (figure 5).

Testing Procedure - When the battery tester is powered on, the PLC takes a voltage calibration reading. This calibration is performed on both battery test stations. Once the calibration is completed, the tester is ready to run. After the run button is depressed, the tester checks to see if a battery is in position from the feeder. This can be overridden by closing the metal gate on the feeder. The tester knows when a battery is in position by use of a proximity sensor. This sensor detects when the battery has cleared the feeder and is in position on the line. The machine will now advance the line one index position as sensed by the position wheel. This process repeats until the stop button is pressed , or no new battery is sensed after a period of 10 seconds. As the machine is indexed, the battery approaches the first test station.

This station performs an open circuit voltage test. The test station has a proximity sensor to determine when a battery is entering the station. After the test station, there is a reject station. The reject station is turned on if a bad battery is detected. The reject station uses compressed air to blow the battery off the line. Following the reject station, there is another proximity sensor. This sensor will let the PLC know if the bad battery was indeed removed from the line. This procedure is repeated for the second test station on the line. This station performs a high current test of the battery. Its sensors operate the same as the first test station. Once batteries are indexed past the second test station's sensors, they have passed all tests and are considered good. They continue to index down the line and fall down the funnel located at the end of the tester.

Summary - The automated battery tester designed and fabricated for Rebatt Inc. tests approx 65 AA size batteries per minute. The equipment tests the batteries under loaded and no-load conditions and separates the bad batteries from the good ones. An automatic battery feeder provides a continuous supply of batteries for the conveyor belt. The equipment has been operational at the client's facility for more than a year. The total cost of the project was approximately $ 50,000 out of which the client's share was $20,000. Based upon three shift operation and displacement of five operators earning $6.00/hr, the payback period came out to be less than a year.

2. Unfunded Research Projects

Following project is an example of unfunded research work done in the Automated Manufacturing Laboratory at Old Dominion University by a group of senior students under the supervision of the author. The equipment used in the research was donated by the S. S. White Company.

Case Study - Effect of Various Parameters on the efficacy of Material Removal in Abrasive Jet Machining [7].

Abrasive Jet Machining (AJM) or Microabrasive Blasting (MB) is commonly used in industry for cutting, cleaning, abrading, drilling and etching applications in the manufacturing industry. The material removal rate in the AJM process is dependent on five key variables. 1. Air Pressure, 2. Abrasive Flow Rate, 3. Nozzle Size, 4. Abrasive Particle Size and 5. Nozzle Distance from Workpiece. While the process has been used for many years the effect of these variables and the interactions among these variables on Material Removal Rate is not understood very well. Effect of parameters like nozzle tip distance, abrasive flow rate and nozzle tip angle on the material removal rate was specifically studied during this project.

Abrasive Jet Machining has been used for hundred of years in various forms in a variety of finishing and surface preparation operations. However its application for machining parts is a relatively recent phenomena. There is very little published data available on AJM process. Most of the research work related to AJM has been done in-house by a handful of equipment manufacturers and only part of this data is available to general public.

The results of the study show that as nozzle tip distance increases, material removal rate (MRR) increases and then decreases (Figure 7). The abrasive jet tends to diverge as it moves away from the nozzle and the velocity of contained particles decreases. This decreases the material removal for larger values of nozzle tip distance. A similar effect was observed with respect to the other two parameters namely, abrasive flow rate (Figure 8). As abrasive flow rate increases, MRR increases due to increasing number of cutting points (particles). However, at large flow rate, the cutting process is hampered by inter-particle collisions and hence the decline in MRR.

IV. Summary

Innovation in capstone projects should not be limited by external funding. The above case studies indicate that properly designed unfunded senior projects can offer quality learning experience for students. Involvement of industry is a key factor for a successful capstone course.

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Alok K. Verma is Associate Professor and Director of the Automated Manufacturing Laboratory at Old Dominion University. He received his B.S. in Aeronautical Engineering from the Indian Institute of Technology, Kanpur in 1978 and MS in Engineering Mechanics from Old Dominion University in 1981. He joined the Mechanical Engineering Technology Department in 1981. His publications are in the areas of Fluid Dynamics, Advanced Manufacturing Processes, CAD/CAM, and Robotics. His current research interests are in the area of non-traditional manufacturing processes and process optimization. Alok Verma has co-edited the proceedings of the International Conference on CAD/CAM & Robotics for which he was the general chairman. He is active in ASME, ASEE and SME.

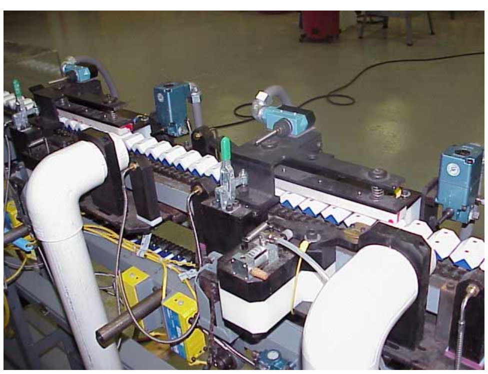

Figure 1

Figure 2

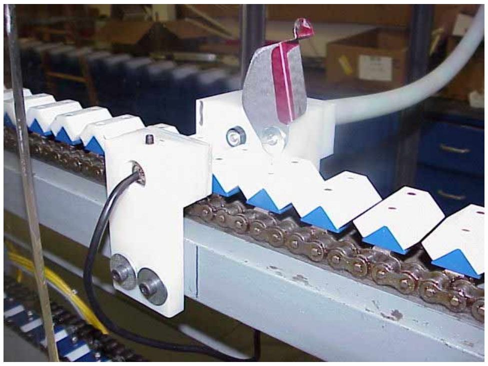

Figure 3

Figure 4

Figure 5

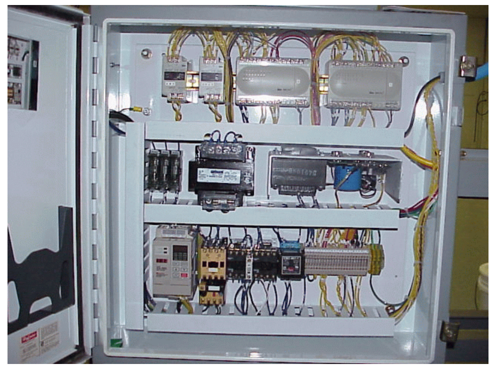

Figure 6

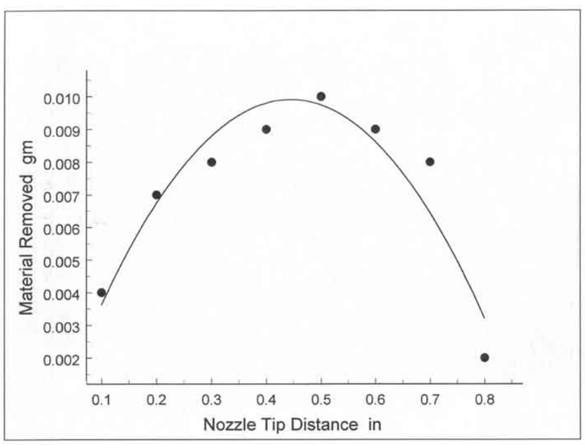

Figure 7

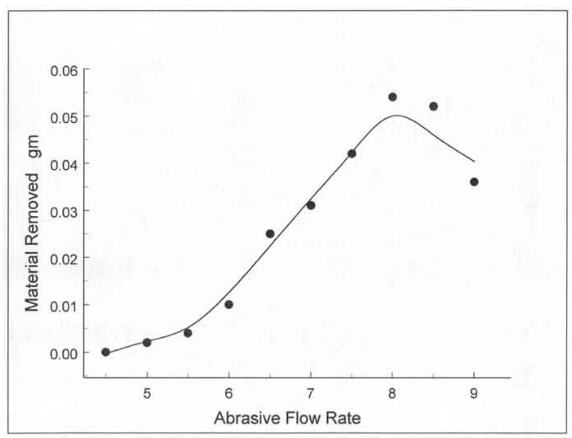

Figure 8