AC 2008-203: CAPSTONE COURSES FOR ENGINEERING TECHNOLOGY STUDENTS

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Capstone Courses for Applied Engineering Technology Students

Abstract

Drexel University's Goodwin College of Professional Studies has offered a co-op-based Applied Engineering Technology (AET) major since 2002. The program comprises three concentrations in Electrical, Mechanical, and Industrial Engineering Technology and provides an integrated educational experience directed toward developing the ability to apply the knowledge gained in the college to the solution of practical problems in the engineering technology field. The majority of courses are fully integrated with training and laboratory experience to provide students with a strong foundation of engineering practices and to stimulate students' interest by using a problem solving approach in state-of-the-art laboratories. Key factors in the development process included creation of the educational laboratories that can significantly contribute to the development of technologically literate students and workforce that could be in great demand not only in the tri-state area but also nationwide. Several laboratory- and project-based courses were developed and four of them, such as Nondestructive Evaluation of Materials, Programmable Logic Controllers, Measurements, and Robotics and Mechatronics, are described in this paper.

1. Introduction

The Applied Engineering Technology (AET) program at Drexel University was initiated as a response to job- and education-related issues expressed by government, academic institutions and industries across the nation. Since fall of 2002, Drexel has been offering its AET major in collaboration with the Delaware County Community College (DCCC) under a dual model, in which the students can pursue both AAS and BS degrees concurrently at DCCC facilities. In fall 2004, the AET major became available to the students at Drexel who intend to pursue the BS degree on a full- and part-time basis. The AET program's content provides an integrated educational experience directed toward developing the ability to apply the fundamental knowledge gained in Drexel's Goodwin College to the solution of practical problems in the engineering technology fields. The AET program clearly distinguishes itself from traditional engineering programs by applying a hands-on approach to the delivery of the courses. Over the past three years several state-of-the-art laboratories were developed. A key factor in this process is the creation of the educational laboratories that can significantly contribute to the development of technologically literate students and workforce that could be in great demand not only in the tri-state area but also nationwide.[1,2] The establishment of the state-of-the-art laboratories allows Drexel and its community college partners to develop training options for engineering technologists located in the region's key industries. Four capstone courses are described in this paper.

These courses complement the Senior Design Project capstone three-term, nine credit sequence and encourage students to apply their previous knowledge and experience in solving real-world engineering problems and develop skills in making professional presentations and writing technical reports. Experience gained by students during the laboratory sessions is often applied in their senior design projects and during their co-op cycles. For example, currently one of the senior design project teams is developing an automated thermocouple welder. Experience obtained by students in the Robotics and Mechatronics and Programmable Logic Controllers courses is being utilized during this senior design project. Another senior design project team is applying the knowledge and experience in ultrasound nondestructive testing (NDT) and robotics to develop an automatic scanning system for NDT applications. The newly developed courses "Energy Conversion" and "Microcontrollers" will follow the described model.

2. Description of the laboratories

2. 1. Nondestructive Testing Laboratory

Nondestructive testing (NDT) is one of the most powerful and cost effective techniques for quality and safety control of structures, parts, and products. NDT of materials and components is crucial to aerospace, naval, railroad, and other industries. The objective of the three-credit course that was developed is to introduce AET students to the engineering principles of ultrasound measurements by combining hands-on laboratory experience with lectures. Specifically, the students learn the engineering and physical principles of measurements of sound velocity in different materials, attenuation coefficients, directivity pattern of ultrasonic transducers, and the location and dimensions of heterogeneities in various materials, such as holes, cracks, cavities, etc. The work in the laboratory enhances the fundamentals taught in the classroom sessions. During the laboratory exercises students are introduced to tools, methodologies and techniques that may be useful to solving the problem. Finally, students carry out experiments and describe the results of the experiments in individual reports for each lab. After completion of all labs, each team is responsible for writing a final report that summarizes the current state in the area, describes the experimental techniques utilized, discusses the expected outcomes, provides data of the actual outcomes, and explains the reasons for the departures between the expected and the actual results. The team would analyze the data, draw conclusions, and suggest possible ways for improving the accuracy of their experiments. The team then presents its findings to the class as a whole. The experiments described below are presently carried out using the installed equipment (Figure 1)[3]:

- Measurements of the sound velocity in water
- Measurements of the sound velocity in other materials
- Directivity Pattern Measurements
- Measurements of the attenuation coefficient of the ultrasonic waves in Plexiglas
- Evaluation of homogeneity of various materials used in industrial applications
- Detection and localization of heterogeneities in the materials, such as flaws, cavities, layers, and holes
- Measurement of the dimensions of various parts and components, where conventional methods (such as rulers and calipers) cannot be applied
- Diagnostic evaluation of the structures of various materials by measuring the sound speed and attenuation

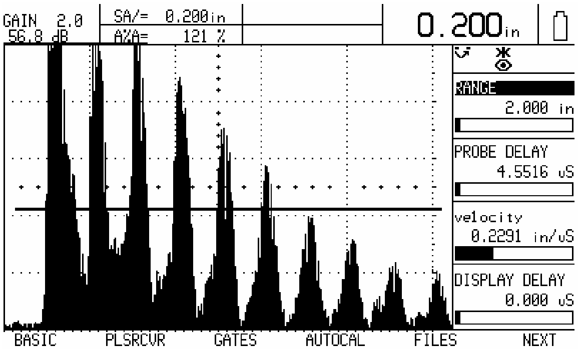
Figure 1. Automatic Flaw Detectors USN58L and USM 35X (from left to right).

During the laboratory sessions students are able to control NDE devices via computers allowing integration of the experiments with Internet-based automation technologies.

Specifically, the following experiments were carried out:

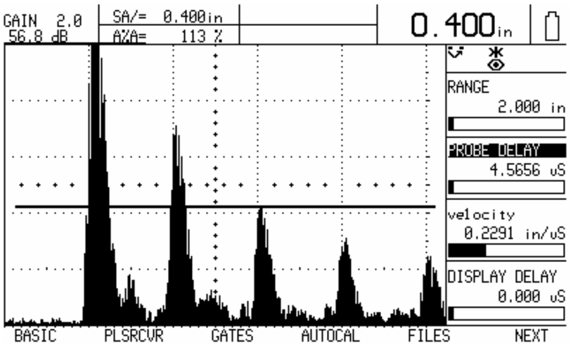
1. Calibration of the flaw detectors using **Straight-Beam** probes utilizing the instruments' **AUTO-CAL** feature (Figure 2-Figure 4).[4]

Figure 2. Calibration of the flaw detectors using a straight-beam probe.



GAIN 2.0 56.8 dB
SA/= 0.200in
A%A= 121 %
0.200in
RANGE 2.000 in
PROBE DELAY 4.5516 uS
velocity 0.2291 in/uS
DISPLAY DELAY 0.000 uS

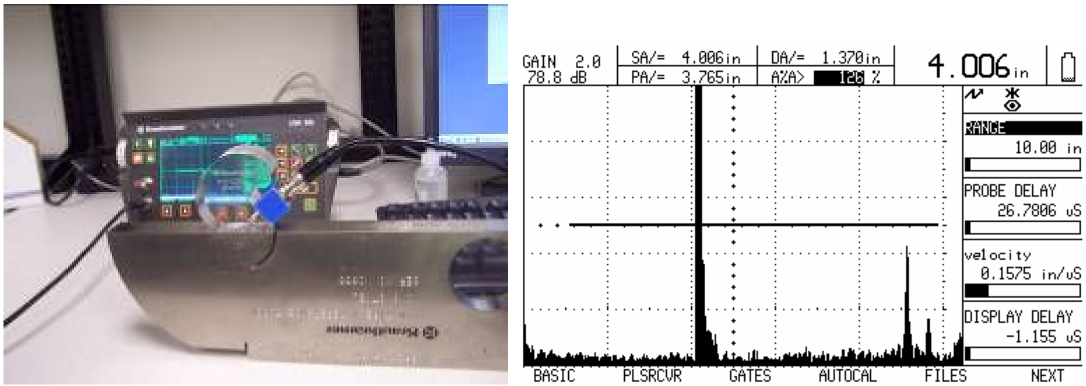
Figure 3. First calibration echo.



GAIN 2.0 56.8 dB
SA/= 0.400in
A%A= 113 %
0.400in
RANGE 2.000 in
PROBE DELAY 4.5656 uS
velocity 0.2291 in/uS
DISPLAY DELAY 0.000 uS

Figure 4. Second calibration echo.

2. Calibration procedure with the **Angle-Beam** probe for Wedge Angle Verification, Sound Path Distance Calibration, and Flaw Sensitivity Calibration using an IIW (International Institute of Welding) type 1 calibration block is presented below (Figure 5).



GAIN 2.0 78.8 dB
SA/= 4.006in
PA/= 3.765in
DA/= 1.370in
A%A> 126 %
4.006in
RANGE 10.00 in
PROBE DELAY 26.7806 uS
velocity 0.1575 in/uS
DISPLAY DELAY -1.155 uS

Figure 5. Calibration with the angle-beam probe for sound Distance and Flaw Sensitivity using an IIW calibration block.

2. 2. Robotics and Mechatronics Laboratory

An Internet-based approach for lab development and educational enhancement has been introduced at Drexel University.[5] The course, MET 205—Robotics & Mechatronics, has been developed and offered to the AET students since 2004. The course provides a requisite understanding of Internet based robotics/automation/machine vision for students to progress to an advanced level in the curriculum. The course also serves as a means for students to gain exposure to advanced industrial automation concepts before their senior design project. The course has an applied learning focus, offering flexibility to the students through an open laboratory philosophy. Since the concepts of Internet based robotics and mechatronics are best conveyed through application-based learning, the course is divided into two components: a classroom lecture component and an associative laboratory component. The course provides students with a comprehensive knowledge of Internet based manufacturing automation using industrial robots and other common machinery and components as shown in Figure 6. During the laboratory exercises the students have an opportunity to apply their knowledge by integrating several components together to develop an integrated solution to a manufacturing problem. To instill the team concept driven by industry needs the students are required to use a collaborative team approach in completing the exercises.

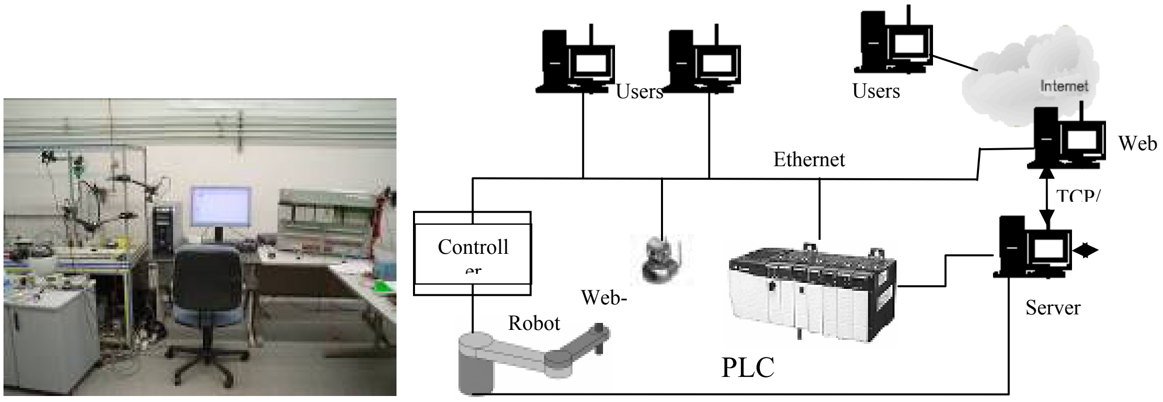


Figure 6. A workstation and its Web-based control architecture with a Yamaha robot, a computer, a controller, mechanical devices, and Allen Bradley PLC 1756 Series.

All the devices such as robot, web-camera, and Programmable Logic Controllers are connected to Ethernet. This reduces the wire maze needed to link every device and enables students to operate/control the equipment remotely. The controller of the robot (RCX40) can be connected to the Internet directly or to a computer using an RS 232C cable on COM 1 port. The software used for communication is VIP for Windows Version 1.6.0 developed by the Yamaha Co. Ltd. The experimental setup includes the following items: ROCKWELL RSLogix 5000, Yamaha SCARA robot, RCX40 robot controller with optional on-board Ethernet card, Yamaha I/O checker, DLink DCS-5300, and HP m1050e PCs. The system also consists of power supplies, DC motors, fans, buzzers, limit switches, relays, and lights. For viewing the workspace two D-Link webcams, which have Pan/Zoom/Tilt functions have been used as shown in Figure 7.

(a) (b) (c)

Figure 7. (a) Connection to the server, used for controlling the robot, is established using RDC and VIP Windows software (b) A robot control window, a machine vision system, and a web cam for a remote inspection, and (c) Two viewing windows and the robot control interface.

During the laboratory procedures, the students programmed, debugged, uploaded, and tested the robotic systems over the Internet. Students successfully implemented Internet applications to remotely operate the robot in the form of information interface as shown in Figure 8. The final 2 weeks were allocated to the specifically designed online robotic experiments. In addition, such online laboratories enable multiple institutions to share expensive laboratory resources, hence providing engineering and engineering technology students access to more sophisticated concepts and lab experiences.[6]

Figure 8. Students worked on the lab projects in the MET 205 Robotics and Mechatronics offered at Drexel University.

2. 3. Measurements and Thermodynamics Laboratory

Online education has intensified with the growth and extension of Internet technologies. Web-based educational environments may be more effective than conventional educational environments in a number of ways, particularly by facilitating communication among students. Student-oriented education can be achieved according to the learning ability and level of each student, because education is now possible whenever and wherever; at any time and any place.[7,8] Many Internet-based tools and educational programs limit student ability to understand engineering principles since they are mostly just visual-aid tools and do not simulate real time controlling and examining of operations. In the area of automation, the LabVIEW programming language provides the mechanism to remotely access controllable equipments through the Web.[9,10]

System Architecture

Experimental set-up of thermodynamic system consists of the following hardware components:

- Source of compressed air

- Pressure sensors
  Omega Dyne Inc; Model: PX209-200A5V
- Temperature sensors
  Omega Engineering Inc; Model: TX91A-K2
- Vortex Tube
- National Instrument-DAQ card
  16 inputs, 16 bits, 200KS/s, Multifunction I/O for USB
- Server
  Host Computer, IP Address: 144.118.69.219
- Client
  PC downloaded with LabVIEW Runtime Engine
- Network IP Camera
  Toshiba; Model: IK-WB21A
- Flow Sensor/Controller
  Mass Flow controller: FMA 5400/5500 Omega and control valve

Control Volume, Energy and Entropy using Vortex Tube

A vortex tube (Figure 9) is an instrument that separates a compressed gas supply into streams of gas at different temperature.[11,12] One stream is colder and the other is hotter than the temperature of the supply. The vortex tube has no moving parts. In this experiment with the help of vortex tube, the first and second laws of thermodynamics are supported. The *first law* states that the energy cannot be created or destroyed; rather the amount of energy lost in a steady state process cannot be greater than the amount of energy gained. The *second law* states that energy systems have a tendency to increase their entropy (heat transformation content) rather than decrease it. The *second law* is an expression of the fact that over time, differences in temperature, pressure, and density tend to even out in a physical system. Entropy is a measure of how far this even-out process has progressed.

Figure 9. Vortex tube.

Remote Operation and Data Acquisition for the Experiment.

To conduct the analysis, the volume flow rate of the gas supplying the vortex tube is controlled by distributing this flow to the hot and cold stream leaving the vortex tube. The temperature and pressure are also acquired before the vortex tube and in both streams after the vortex tube. Volume flow rates are acquired in both streams after the vortex tube. Thus the data acquisition collects three temperatures, three pressures and two volume flow rates, for a total of eight analog inputs. Control valves are digitally controlled from a LabVIEW program through the data acquisition card connected to a computer through a USB link.

In the LabVIEW program before data acquisition begins, the Set Increment box below the Save to File Switch is changed to set the time between measurements in seconds (See Figure 10 of the Display Panel).

When the LabVIEW program is initiated, data reading starts immediately. In the LabVIEW program, a display screen tracks the eight measured readings. Flow in each stream is controlled by moving markers with a mouse as shown below the digital display. On the right of the Display Panel the digital output of the measured readings are displayed. A mouse is used to turn the Save to File Switch to the ON position and data acquisition starts and is stopped by turning the switch to the OFF position. The computer that connects to the data acquisition system is linked to the Internet and any other computer so linked is able to operate the Display Panel.

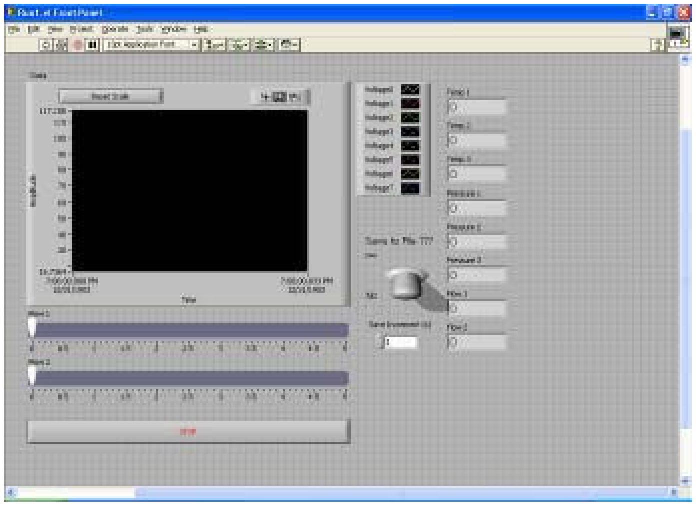


Figure 10. Front Panel using LabVIEW to measure thermodynamic parameters on Server side.

Cameras are provided with appropriate links so that students can see the physical system during operation.

The acquired measurements, using LabVIEW programming, are applied to thermodynamic equations to verify first and second laws of thermodynamics.

2. 4. Programmable Logic Controller Laboratory

Programmable Logic Controllers (PLCs) are becoming ubiquitous in the automation of a wide range of industrial processes where the cost of developing, reconfiguring, and maintaining the automation system is high compared to the total cost of the automation. Drexel's PLC course is aimed at introducing students to PLC architecture, components, ladder logic programming and debugging, hardware implementations, and safety issues. The four-credit course comprises about 50 percent lecture and 50 percent laboratory exercises. Eight laboratory exercises take the students from basic ladder logic relays and indicators through complex applications involving timers, counters, and interlocks.

The laboratory houses six PLC stations, which are based on the Amatrol Programmable Controller system[13] (Figure 11). The PLC employs SLC 500 series components in a seven-slot rack. The processor is an Allen-Bradley 1747-L514 SLC 5/01 Modular Processor[14] that provides a 4K instruction memory and up to 960 I/Os. DC I/O is provided by a 16-input 24V 1746-IB16 DC input module and a 16-output 0-50V 1746-OB16 DC output module. In addition, Amatrol 17200 Electropneumatic Application Panels and 17205 Motors Application Panels support a variety of motor- and solenoid-based experiments. Figure 11 shows the 17200 Electropneumatic Application Panel mounted above the PLC board. The hardware system was integrated by Allegheny Educational Systems with their Learning System.

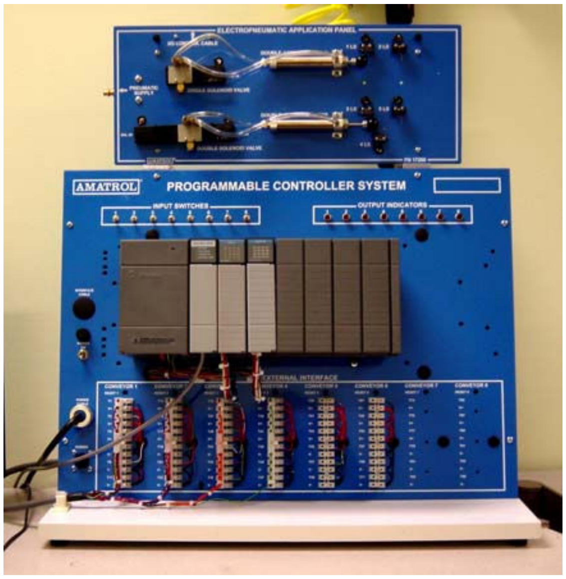
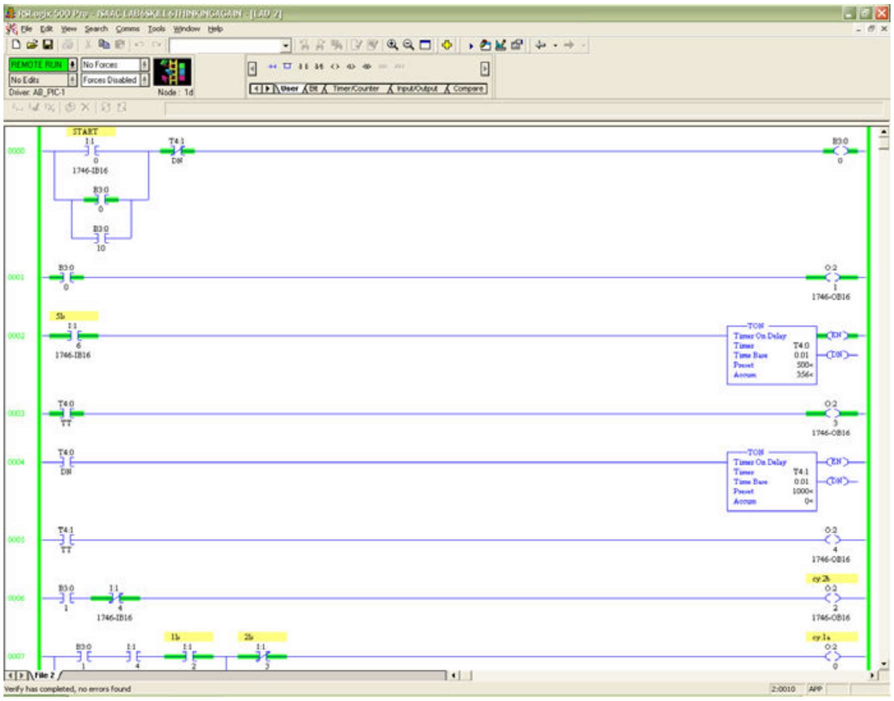


Figure 11. PLC workstation.

The PLC is programmed from a standard desktop computer via an RS232 PC port through a PIC converter to a DH 485 port on the processor module. Programming software includes the IEC-1131-compliant RSLogix 500 ladder logic programming package from Rockwell Automation.[15] A Screenshot of a typical PLC ladder logic program is shown in Figure 12.



Verify has completed, no errors found

Figure 12. Screenshot of a typical PLC ladder logic program taken from the RSLogix 500 software.

Students work in groups of two on projects emulating real-life industrial process and control problems. Some examples are automated positioning and drilling and motor control. A novel feature of the course involves the exams, which comprise both a written part and an in-lab component. The purpose is to distinguish between the performances of individuals within each group. An added benefit is that it encourages each group member to become familiar with all components of the laboratory equipment.

3. Summary

This paper described four laboratory- and project-based courses of the Applied Engineering Technology curriculum. Students enrolled in the Bachelor of Science in AET program are the main target audience. The students have access to the developed material in two modes: the traditional face-to-face classroom mode for those on Drexel's campus, and a real-time, Internet-based mode for those attending classes at remote locations, specifically students at community colleges partnering with Drexel. The developed instructional materials are also part of a wider initiative, including the development of novel teaching and learning strategies, the creation of new learning materials, and the implementation of effective assessment and evaluation techniques. An important objective of these laboratories is to improve the students' knowledge of data gathering, the identification of sources leading to erroneous measurements, and proficiency in communication skills. The described courses provide AET students with necessary knowledge and experience that was applied in their senior design projects and during their co-op cycles. The degree to which this objective is being met is currently being evaluated through course and co-op surveys.

The Senior Design Project is a three-term, nine credit course that engineering technology students take during their senior year. The senior design project is a capstone experience, in which students select a topic in consultation with their advisor according to a department's guideline and design and develop a working prototype. Specifically, during the 2007-2008 academic year, students utilize their knowledge and experience obtained in the described courses during their senior design projects related to the development of an automatic scanning system for NDT applications and automated thermocouple welder. The laboratory- and project-based instruction will help provide a strong background in Applied Engineering Technology to fill important roles in industry in the future. It will also stimulate and institutionalize innovative developments and will create a model for leveraging high-end instrumentation in undergraduate education.

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