A MECHANICAL ENGINEERING 2000 LABORATORY

Charles Knight and Gary McDonald
The University of Tennessee at Chattanooga

ABSTRACT

This paper presents an overview of our upgraded Senior Mechanical Engineering 2000 Laboratory. The paper defines the criterion for a mechanical engineering 2000 laboratory and discusses our experiences in developing our upgraded senior laboratory, and presents the use of modern data acquisition and computers in the laboratory. A discussion is presented concerning the management of this laboratory by the two instructors, and an update on evaluation and accountability of the lab work performed by the student teams is presented. The recognition that the laboratory has received is noted as well as the plans to develop some feasible access to it using the World Wide Web and Internet. A new laboratory experiment recently added to this lab is discussed along with the role that group design projects have on the future development of the senior laboratory.

WHAT IS A MECHANICAL ENGINEERING 2000 LABORATORY?

A mechanical engineering 2000 laboratory is a laboratory that can be used to teach basic, traditional mechanical engineering fundamentals, teamwork skills, and computer utilization skills, utilizing modern computer data acquisition, data analysis, and oral and written presentation throughout the lab. This represents a major challenge for the faculty who develop and teach such labs and the student who is exposed to many new electronic sensors and various types of newly developed instrumentation. Students who experience such a modern laboratory develop a better appreciation and understanding of their engineering fundamentals. In the modern 2000 laboratory setting, more intriguing experimental and analytical tasks can be completed without the computations and time constraints that usually limit the ultimate expectations of the student's learning experience.

THE UNIVERSITY OF TENNESSEE AT CHATTANOOGA EXPERIENCE

The renovation of our senior level mechanical engineering laboratory and the related changes to the senior level curriculum were completed at UTC during a three year period (1993-1996). Two years were needed to revise the curriculum while one year of intense effort by the authors was required to create the new two hour credit lab (1 hour lecture plus a 3 hour lab weekly). Older laboratory systems were modernized through installation of modern electronic instrumentation for performing measurements of flow rate, temperature, pressure, speed, torque, displacement, velocity, acceleration, strain, psychrometric conditions, and combustion products. A detail presentation of the UTC senior 2000 laboratory course, equipment and experiments has been made [1]. In this paper, we are updating the advances in the laboratory experiences and changes in managing the senior laboratory.

At UTC, we chose to renovate existing laboratory equipment by upgrading sensors and purchasing and installing Pentium type computers with data acquisition hardware boards and LabVIEW data acquisition software instead of purchasing modern state-of-the-art experimental equipment with built-in instrumentation and computer data acquisition in order to reduce costs. The renovation process required the faculty and staff to learn new skills necessary for operation, maintenance, and ongoing development of the new laboratory. A lecture-oriented faculty member usually does not have the experience required to teach and provide ongoing development of the new 2000 laboratory. The UTC experience has found that faculty must take intensive short course training in computer data acquisition to develop skills required for becoming a contributing team teacher in the new laboratory. At UTC, such training is provided through university funded faculty developmental grants. UTC faculty who were responsible for the development of the new lab are the faculty who teach the new lab.

The new mechanical engineering 2000 laboratory would have cost about $350,000 to purchase while UTC has spent less than $120,000 in developing the lab, with only about $60,000 being new money spent solely for computer software-hardware and various other types of instrumentation and sensors.

RECOGNITION FOR THE MECHANICAL ENGINEERING 2000 LABORATORY

The faculty responsible for developing the mechanical engineering 2000 laboratory were recently selected by National Instrument to develop "MODEL" courseware that will be used nationwide in promoting utilization of computer data acquisition, data analysis, and oral and written presentations in the university engineering laboratory. National Instruments developed the LabVIEW data acquisition software and hardware boards used in our senior laboratory. New external funding by the University of Chattanooga Foundation and the UTC Center of Excellence for Computer Applications has been provided. This will provide for the new 2000 lab to be fully developed and put on the Internet - World Wide Web where UTC distance learning students as well as any Internet user will be able to complete the laboratory course without having to come on campus. A UTC chemical engineering professor, Dr. Jim Henry, has pioneered this effort by providing real-time access to his Control Systems and Chemical Processes laboratories through a web page [2]. From the web page, a user can access each of the Controls and Chemical Processes laboratory experiments and run each experiment and retrieve data on-line. This is the same experience that campus students have in the laboratory. In the senior mechanical engineering laboratory, we will determine which experiments would be feasible to allow on-line access using the methods that were developed for the Control and Chemical Processes Laboratories. The possibility of offering both laboratory and lecture courses by use of the World Wide Web represents exciting challenges for engineering education.

FEEDBACK FROM TEACHING THE 2000 LABORATORY

The two faculty involved in team teaching the new laboratory had considered operating as many as five different labs concurrently with three of less students at each workstation. One faculty member taught the mechanics labs while the other member taught the thermal labs. After attempting to do this for two semesters, the two faculty members concluded that they could only support four workstations concurrently. This required that we increase the maximum number of students to four per workstation to produce adequate student credit hours for committing two faculty members to the teaching of the lab. The team teaching effort has worked well with each faculty member teaching different components of the lecture portion of the laboratory course with many demonstrations being used to illustrate basic data acquisition and instrumentation fundamentals.

During the first offering of the new 2000 laboratory, the instructor assigned each student a task to be completed during the experimental and final report preparation phases. We found that the students had difficulty in the assembly of report components from their group and in meeting the submittal date for the group-developed final report. This semester we have assigned a manager who is ultimately responsible for insuring that the student members contribute. This manager grades the performance of his contributing members, and the manager's awarded grade is used in assigning each student's grade for the final report in that group. The assigned responsibilities are rotated with each experiment so each group member will have the opportunity to serve as manager. Other group members are assigned tasks related to data acquisition, theory and procedures, and data analysis

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The UTC experience found that some groups would sacrifice a small point reduction for being late in submitting their final report. This semester we initiated a performance penalty of 15 points reduction per week for all late reports. This has insured that the students work muchharder to meet the formal two week time allocated for developing the final report.

The first year that the lab was offered we found several students who chose frequently not to attend the lecture portion of the new course. We now penalize the student 5 percent on their final course average for any lecture or laboratory experiment they do not attend. This has insured that no students by choice fail to attend the lecture or laboratory session.

DEVELOPMENTS IN THE UTC SENIOR MECHANICAL ENGINEERING LABORATORY

Since the last presentation on the development of this laboratory, a new experiment has been developed that is based upon the material presented in our kinematics and dynamics of machinery and machine design class. This experiment uses a 3.5 horsepower Briggs and Stratton

(B & S) lawnmower engine to study the piston, connecting rod, and crankshaft mechanism and the cam-follower mechanism.

The B & S engine was modified by removing the cylinder head, carburetor, and ignition system. A pulley was put onto the output of the crankshaft of the B & S engine with a belt connecting the pulley to an electric motor. An LVDT (linear variable displacement transformer) was used to measure the displacement of the piston, and another LVDT was used to measure the displacement of the intake valve. Two LabVIEW virtual instruments (VI's) were written: one for the piston and the other for the valve motion. In both VI's, the measured displacement is plotted versus time. Then using the differentiation sub-VI in LabVIEW, the velocity versus time and acceleration versus time diagrams are produced. Also, the maximum and minimum values for displacement, velocity, and acceleration are shown on each LabVIEW front panel.

A second B & S engine identical to the instrumented engine has cut-away sections which show all functional internal parts of the engine. A crank handle was attached to the crankshaft of the cut-away engine so the motion of all internal parts can be viewed as the crankshaft is rotated. A third B & S engine was totally disassembled and used for display and study of each engine component.

Once the experimental results are produced by data acquisition for a crankshaft speed, the students prepare a TK Solver or Maple V model of the piston displacement, velocity, and acceleration versus time using the equations for an inline slider crank mechanism. The model results are compared with experimental results for the piston motion.

Also, the students prepare a TK Solver or Maple V model for the cam-follower mechanism. By observing the cam shape and the experimental output for the cam motion, the students choose an appropriate cam shape for rise and return from the following follower motion types: cycloidal, parabolic, simple harmonic or combinations of these motion types. The model displacement, velocity, and acceleration results are compared to the experimental results obtained for the cam motion.

It should be noted that the specifications for the B & S engine were not available to the student or the instructor. Some of our more inquisitive students have searched the Internet for the B & S 3.5 horsepower engine specifications.

This laboratory tries to show the practical applications to the many kinematic and dynamic models taught in a traditional machine analysis and design class.

DESIGN PROJECTS IN THE SENIOR MECHANICAL ENGINEERING LABORATORY

Since the Fall 1996 when the first section of this new laboratory was taught, a three to four week design project has been a part of the laboratory. It represents 15% of the student's grade and is performed in groups assigned by the instructors. To give the student an experience in the development process of an experiment, the design project was introduced. These projects use either existing laboratory devices or new apparatuses to develop an experimental program to bring these devices to data acquisition. In the laboratory, the student see the end results of endless trials to get an experiment debugged using the various electronic sensors, signal conditioners, and DAQ boards with an error-free LabVIEW virtual instrument being the product.

Two different projects have been completed during the past year. The first project was related to renovating an old, blow-down supersonic wind tunnel with electronic pressure sensors and thermocouples being added to support data acquisition. A LabVIEW application that computed test section Mach number and speed using compressible flow fundamentals and test pressures and temperatures was developed. The renovated tunnel system worked well with steady-state test section flow being shown to exist for about five seconds during the total testing period of about fifteen seconds. Using the Bourbon pressure gages and temperature dials used in the older system, the period of steady-state operation was very difficult to determine due to the transient nature of the system.

The second project was related to the design and construction of an aluminum planar truss that was cantilever supported in a frame. The truss used roll-pins to attach the aluminum members to aluminum plates forming the classic gusset joints. Each member has a strain gage bonded to both sides to measure tension or compression due to the applied load. In the first semester, the truss was designed and fabricated in the engineering shop and analyzed using basic statics. The strain gages were added and wired. In the second semester, another group obtained the appropriate data acquisition devices and generated a LabVIEW virtual instrument for the truss project. This group also tested the truss using a conventional strain gage indicator to record strain gage output before connecting the gages to the strain gage data acquisition system. The data acquisition system was then used in obtaining the loading in each member of the truss, with the loading values being compared using basic statics. This year's projects being planned will retrofit existing fluid mechanics and mechanics of materials experiments with modern electronic sensors that will support data acquisition.

CLOSURE

The UTC experience has found that a mechanical engineering 2000 laboratory is an effective way to prepare the engineering student for the real world of mechanical engineering. It is our recommendation that other engineering schools begin to develop their own engineering 2000 laboratory.

REFERENCES

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CHARLES V. KNIGHT

Charles V. Knight received B.S., M.S., and Ph.D. degrees in mechanical engineering from The University of Tennessee at Knoxville. Dr. Knight has been a member of The University of Tennessee at Chattanooga faculty since 1979, having taught at The University of Tennessee campuses in Nashville and Knoxville ten years previously. His teaching interests are associated with fluid mechanics and thermal sciences. He completed six years of research for Tennessee Valley Authority associated with combustion and exhaust gas emissions and indoor air quality influences for wood burning heaters and boilers. More recently Dr. Knight has been responsible for mechanical engineering curriculum revisions and lab development at UTC. Dr. Knight is a registered Professional Engineer.

GARY H. McDONALD

Gary H. McDonald is currently a UC Foundation Associate Professor of Engineering in the Mechanical Engineering (Mechanics) at The University of Tennessee at Chattanooga. His teaching responsibilities include statics, dynamics, mechanics of materials lecture and laboratory, kinematics and dynamics of machinery, machine design, freshman seminar for engineers, and ME laboratory. He received his B.S.M.E. in 1977, M.S.M.E. in 1979 and Ph.D. in Engineering in 1984 from Tennessee Technological University. Dr. McDonald was a NASA-ASEE Summer Faculty Fellow for four summers at the Marshall Space Flight Center in Huntsville, Alabama. He is a member of ASEE, ASME, NSPE, and is a registered Professional Engineer in Tennessee.