AC 2007-410: RECENT DEVELOPMENTS IN MECH LAB I AT THE UNIVERSITY OF SOUTH FLORIDA

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Introduction

Mechanical Engineering Laboratory I is the first of two laboratory courses for ME students. It was revamped in the fall of 2004 when the author started teaching Mech Lab I. The course revisions came out of an experience by the author when he was on a mission statement committee for a commercial lab. Initially, the mission statement committee thought that the purpose of the lab was to run tests. After much discussion, the committee realized that the purpose of the lab was to provide information. The information provided by the commercial lab could be used to make decisions about the quality of materials, to overcome a malfunction, or to improve the product. With this insight in mind, the Mech Lab I course became an avenue for teaching students how to provide information from the tests that they conduct.

The students attend two lectures a week and one lab session per week. The lectures immediately precede the laboratory periods. With this scheduling, the lecture topics carry over directly into the laboratory period. There are eight identical lab setups for each of the eight experiments, so each lab group performs the same experiment simultaneously.

Experiments

Four new experiments have been introduced. They are: Performance of an Electric Motor, Air Flow, Air Cylinder Forces, and Time Constant of a Thermocouple. The other labs are: Statistical Analysis, Strain Gage (Application and Use), Accelerometer (Vibration Measurements), and (8) Thermocouple (Construction and Use).

Students are given a handout that lists the experiments in the order they are performed, as well as a statement of essence of each lab. The entire handout of all the lab instructions and data sheets is 70 pages long. A detailed write-up of each experiment is available from the author.

Lab 1: Statistical Analysis: The students measure two dimensions of the nut or bolt with a digital calipers and measure the resistance of the resistors with a multimeter. They then have to determine how many tests should be run to have a certain accuracy and confidence level.

Lab 2: Electric Motor Performance: Each student team measures voltage, current, force, length of moment arm, and rpm, and records the data at both 5 and 12 volts. They then calculate the output torque, the output power, the input power, and the motor efficiency. The following performance curves are then plotted: torque vs. rpm, power (out) vs. rpm, power (in) vs. rpm, and efficiency vs. rpm. The operating points (torque and rpm) for both voltages are determined by plotting the fan load curve for a hypothetical fan on the torque vs. rpm plot. Changing the voltage is analogous to changing the accelerator setting in a gasoline engine. Finally, the students look at the performance of the power supply by plotting how the output voltage of the power supply varies with power. This is one of the few instances where the operating point of equipment is discussed and determined.

Lab 3: Strain Gage Application: This lab provides students with the opportunity to apply a strain gage. This "hands-on" experience is particularly important with current students, because they can no longer work on their cars and model building has been reduced to clicking together plastic parts. In other words, students now play video games and do not work on equipment. This experiment is run over two weeks, so that the students work in pairs to apply the strain gage. They measure the strain on a bending beam and compare the experimental value of strain to the calculated value.

Lab 4: Force in an Air Cylinder: In addition to measuring the forces produced by an air cylinder and comparing this with the calculated forces, the students must use error propagation to estimate the error in the forces. This uses the standard "chain rule technique". The chain rule can be applied to the equation for the force produced by an air cylinder, which is: $F = A \times P$. Applying the chain rule gives:

$$\Delta F = \frac{\partial F}{\partial P} \times \Delta P + \frac{\partial F}{\partial A} \times \Delta A$$

When the partial derivatives are substituted, this becomes:

$$\Delta F = A \times \Delta P + P \times \Delta A$$

All of these values are easy to evaluate, except ΔA. The students must measure the diameter of the air cylinder, calculate the standard deviation, and then calculate the largest area and smallest area as given by the diameter $\pm 6\sigma$. This demonstrates the use of error propagation in a very practical situation.

Lab 5: Vibration of a Beam and Accelerometer: The vibration of a beam is measured qualitatively using a piezoelectric accelerometer and a storage oscilloscope. The magnitudes of adjacent peaks are measured, and the period and frequency are also determined. The frequency and damping ration are then calculated. A damping material is applied to the beam and the calculations are repeated to emphasize that the damping coefficients must be determined with a dynamic test.

Lab 6: Air Flow: This lab is relatively simple, but it shows the students one way to measure airflow through an adjustable nozzle using a rotameter. The performance curves show how the airflow through the nozzle varies with the nozzle setting and the air pressure. The students determine the performance of an adjustable nozzle and the cubic feet per minute at a specified pressure of a commercial compressor is supplied. The students then calculate how many nozzles a compressor can supply.

Lab 7: Thermocouple Construction: The students construct a thermocouple and use an ice bath to measure the cooling rate of a cup of boiling water. They first check the calibration of the thermocouple, and then employ ice and boiling water. After the students measure the cooling rate of the water, they perform extensive calculations to estimate the film coefficient of the boiling water-air interface.

Lab 8: Time Constant of a Thermocouple: The students are introduced to data acquisition and determine the time delay of a thermocouple. When going from cold water into hot water, the new temperature is not reached instantaneously. The students also measure the time constant when going from hot water into air, and see that it takes a lot longer to reach the temperature of air because of the lower film coefficient. They determine the time constants and also estimate the film coefficient in both cases.

The experiments are relatively inexpensive. The cost is less than $200 per setup. The students perform a variety of measurements including: rpm, force, pressure, air flow, voltage, current, resistance, strain, deflection, frequency, temperature, time constant of a thermocouple, and linear dimensions with a micrometer. More importantly, the students not only take the measurements; they generate information that can be used to make decisions.

Computers

Since the spring semester of 2005, computers have been used at each lab station. This has turned out to be very helpful. Blackboard also is used extensively, and all of the laboratory write-ups and data sheets are available to the students, both through Blackboard and in hard copy. In the lab, the students can access the appropriate data sheet and input their data. Using EXCEL, during the lab period they then calculate their results, and plot the required graphs. It is very helpful to see the data immediately plotted in the lab, rather than at the next class one week later. Another advantage of having the lab computers is that if one student is having difficulty performing a task, another student can reach for the keyboard or mouse and help with or complete the task. This would never happen if the students were using their personal laptops. One of the goals of every lab course is to have the teams work together, and the lab computers have increased these student interactions.

Student Presentation

The students also make a 10-15 minute oral presentation about something hypothetical and interesting that they want to measure. For example, one team member has a friend who is a "fishing guide." The guide wants to make sure that her clients use the best fishing line. She wants the group to find equipment to perform the necessary tests. The student team will then search on the Web for suppliers of tensile testing equipment, select the equipment based on performance and cost, and present their findings to the fishing guide. Of course there are any number of possible scenarios. They do, however, make for realistic engineering presentations. The presentation of each team is recorded with a video camera that records on DVDs. This enables each team member to view the presentation DVD and write a summary of what the team did right, what the team could improve, what, individually, they did right, and what could be improved. Some of the past topics have been: Drag in a Wind Tunnel, Radiator Testing, Go-Cart Testing, Fishing Line Testing, TV Dish Receiver, Chassis Dynamometer, & Engine Dynamometer.

Summary

In summary, the students have many different "hands-on" experiences with up-to-date equipment. They develop performance characteristics of a motor, physically apply and use a strain gage, construct and use a basic thermocouple, and begin to understand non-steady measurements, to name a few of the results. The course receives excellent student evaluations, and the computers increase student interactions.