Engineering Measurements in the Freshman Engineering Clinic at Rowan University

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Abstract

All freshmen engineering students at Rowan University are introduced to engineering experiments and calculations through a series of modules in measurements. The primary goal of this course is to expose freshmen engineering students to multidisciplinary projects that teach engineering principles using the theme of engineering measurements in both laboratory and real-world settings. This concept is an inversion of the traditional laboratory curriculum paradigm. The current situation is that freshman programs focus either on a design project or discipline-specific experiments that may not be cohesively integrated. In real-world settings engineers work in multidisciplinary teams on a variety of complex problems. The fundamental principles of measurement and their application are crucial to the solution of these problems.

Introduction

The College of Engineering at Rowan University was created through a $100 million gift from Henry and Betty Rowan in 1992. The College of Engineering's key features include collaborative teamwork in inter- and multi- disciplinary laboratory and coursework and the incorporation of state of the art technologies and innovative teaching methodologies. All engineering students from the four engineering disciplines namely Civil, Chemical, Electrical and Mechanical share a common engineering *clinic* class. This class is major hallmark of the Rowan engineering program as all engineering students throughout their eight semesters of study take it. The theme of the Freshman *clinic* class in the fall semester is engineering measurements followed by a competitive assessment laboratory in the spring semester. This paper focuses on the engineering measurement modules. The course is team-taught by faculty form each engineering discipline.

The overall objectives of this clinic are to expose students to engineering measurements incorporating engineering fundamentals while helping them acquire strong communication skills. These objectives are detailed below:

Engineering Measurements: *Students will* understand and apply the concepts of accuracy, precision, resolution and linearity; calibrate devices; have a knowledge of the basics of data acquisition; analyze a problem and select appropriate measurement devices *for actual engineering processes*.

Engineering Communication: *Students will* produce plots using Excel to illustrate engineering principles; use PowerPoint for presentations; use word processing for reports *of actual engineering problems*. *Students will* develop the ability to work in multidisciplinary teams, have effective meetings, and utilize a problem solving strategy *on real engineering problems*.

Engineering Fundamentals: *Students will* convert units, examine equations for dimensional homogeneity; use engineering equations; apply basic concepts (eg. hydrostatic pressure, Hooke's law, Ohm's law) *applied to actual engineering problems*.

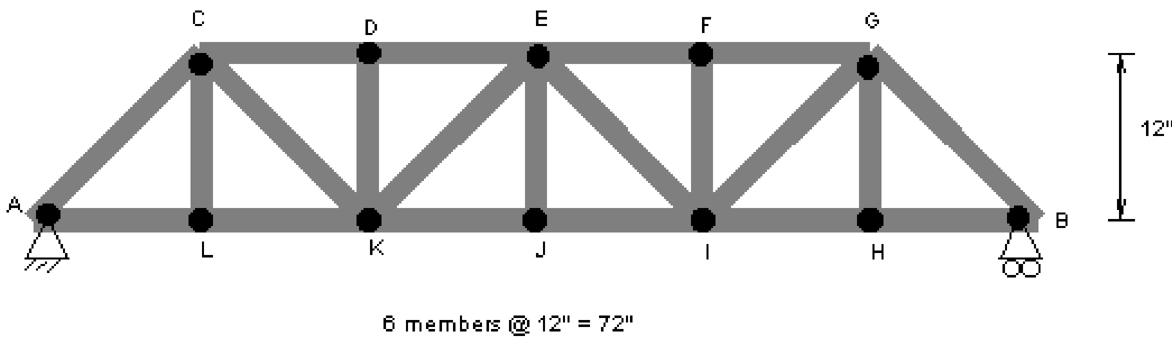
Four measurement modules are employed in this freshman engineering clinic: manufacturing, structural, process and electrical engineering. Spatial measurements and measurement fundamentals are introduced to freshman engineering students as they fabricate a MAG style flashlight from an aluminum rod. Several structural measurements are shown to the students using a bridge module. Students first survey a bridge site, conduct strain measurements on a model bridge and simulate the bridge. The university cogeneration plant is used to show the use of temperature, pressure, flow and concentration measurements. The students tour the cogeneration plant and record data of temperature, pressure, and flowrate of the water in the cogeneration unit. The students return to the computer laboratory and simulate two heat exchangers using their data and perform hand calculations for homework. This is followed by two weeks of experiments using temperature, pressure and flowrate devices seen in the cogeneration plant. The final module has the students construct a temperature alarm circuit and investigate the use of C++ programming in measurements. Thus the clinic focuses on measurements in the field and also in traditional laboratory settings. Field trips tend to excite students by breaking down the monotony of being indoors and also help them prepare for realistic engineering measurements.

Some novel laboratory experiments exposing students to fundamental engineering measurements are discussed below.

Structural Measurements

This three week module introduces students to basic structural measurements associated with the design and construction of a truss bridge through a series of field and laboratory experiments. Bridges serve as aesthetic icons, engineering achievements and defining structures for their communities. They tend to leave a lasting impression on the human mind. They are also reminders of historic battles and patriots honored. This module challenges students to determine the span of a bridge on campus assuming that it has been washed away by high floodwaters. Students are provided with a Sokkia™ digital theodolite, a leveling rod and a measuring tape. Bearing in mind that their knowledge of trigonometry is their only analytical tool for this problem, students in teams of four apply the principles of triangulation to measure angles and distances. This three hour outdoor class not only generates excitement but also helps reinforce their knowledge of trigonometry while being exposed to fundamentals of surveying.

The field surveying measurements are followed by stress and strain measurements. An instrumented aluminum truss bridge as shown in the figure below was constructed to introduce students to basic concepts of stress, strain and material properties. The bridge has a pair of plane trusses with a pin and roller support at its two ends. ¾ x 1/8 and ½ x 1/8 flatstock aluminum was used to construct the bridge. Steel nuts and bolts, washers and lock washers were used to connect the members. Omega bonded resistance strain gauges were mounted on certain members of the truss bridge to illustrate tension and compression in various members. These gages consist of a grid of very fine wire or foil bonded to a backing or carrier matrix. The electrical resistance of the grid varies linearly with strain. In use, the carrier matrix is bonded to the surface, force is applied, and the strain is found by measuring the change in resistance. The bonded resistance strain gage is low in cost, can be made with a short gage length, is only moderately affected by temperature changes, has small physical size and low mass, and has fairly high sensitivity to strain. A data acquisition system comprising of IoTech's DaqBoard/100A internal PC card, an external DBK 43A strain gauge card and DaqView and DaqViewXL



software is used for PC based data acquisition. Strain gauges mounted on various truss members were calibrated to determine the relationship between voltage and force in pounds in the members. Loads ranging from 25 to 75 pounds were place at the center of the bridge at the midpoint of the cross beam. Forces in various members due to the addition of the dead weight on the bridge could be read off directly from the computer screen. The negative or positive values indicated whether the member was in tension or compression. Students then performed calculations on Excel to determine the strain and stresses in each member of the truss.

Process Measurements

This module begins as "day in the life of an engineer." A problem is posed to students and they need to visit a cogeneration facility. At this site both traditional (gauges and thermometers) and data acquisition measurement systems are employed to monitor the steam and electricity generation process. The data acquisition system records 65 channels of information including vibrations, power, voltage, amperage, temperature, pressure, flowrates and process stream concentrations. The second and third laboratory sessions students take process measurements using similar equipment to that used in the cogeneration plant.

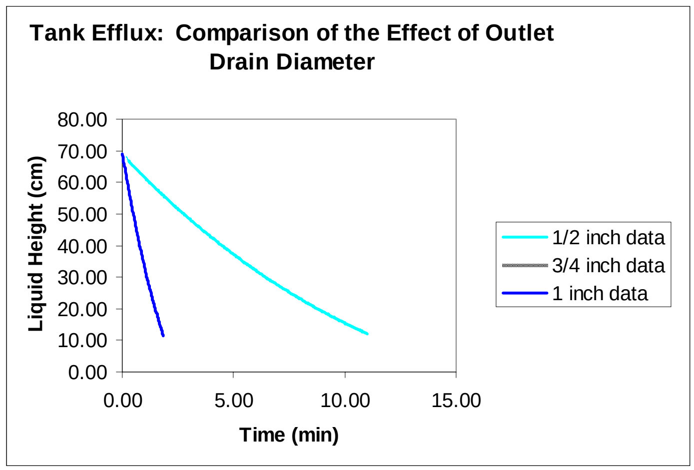
Freshman engineering students measure the temperature of water in an immersion heater and the power supplied to the immersion heater. A data acquisition system comprising of IoTech's DaqBoard/100A internal PC card, an external DBK 19 thermocouple card and DaqView and DaqViewXL software is used. To measure power supplied to the immersion heater a Digital Wattmeter (WD-768) from Vector-VID Instrument Division is used.

This experiment introduces freshman engineering students to the use of differential equations. An energy balance on this system, assuming the heat losses from the water are negligible is given by

$$mC_p^{liq}\frac{\mathrm{d}T}{\mathrm{d}t} = Q_{in} - 0$$

From this experiment students are able to compare the rated power, power delivered to the immersion heater and the power calculated from the solution to the differential equation.

Students calibrate and use an Omega Instruments PX242-005G5V pressure transducer which costs $138 for pressure measurements. Using the above data acquisition system and a DBK11A direct signal connection students measure the pressure of water within a 30 gallon tank. As students fill the tank they calibrate the pressure tansducer using a sight gauge mounted on the side of the tank. Next students perform three experiments using a 1/2, 3/4 and 1" outlet drain. In this experiment the slope of height as a function of time, obtained from a mass balance $\frac{\mathrm{d}m_{tank}}{\mathrm{d}t} = \frac{\mathrm{d}\left(\rho A_{tank} h\right)}{\mathrm{d}t} = -\dot{m}_{out}$, is not linear. The students transform their data to fit an approximate solution of the above equation assuming that there are no pressure losses in the system. A typical plot generated through this experiment is shown here. This assumption results in the solution of the above equation to be a function of the square root of the height of liquid in the tank. Students examine the error in pressure measurement devices by comparing readings from the sight gauge, diaphragm pressure gauge and pressure transducer.



Electrical Measurements

Electrical measurements are introduced to students through a simple temperature alarm circuit built on a breadboard. This laboratory helps students understand how electrical circuit building blocks are interconnected and their transfer characteristics. Students also take voltage measurements at various points in the circuit and relate these measurements to the transfer characteristics. The temperature alarm circuit starts with a TMP36 temperature module (fabricated by Analog Devices) that has a voltage-temperature characteristic given by

$$V\ (\text{volts}) = 0.01\ T\ (\text{temperature in Celsius}) + 0.5$$

Students are asked to take a voltage measurement at the output of the probe and then, solve for the temperature to ensure that it corresponds to room temperature. In addition to taking a measurement, students appreciate and comprehend the concept of a linear characteristic. This characteristic is to be converted to another linear function of the form

V (volts) = 0.1 T (temperature in Celsius)

A difference amplifier with a gain of 10 is used for this purpose. Students calculate the resistor values to achieve the gain of 10 and again take a voltage measurement at the output of the difference amplifier and relate it to the temperature. A comparator is then used to check the voltage at the output of the difference amplifier against a threshold. If the voltage is less than the threshold, it is concluded that the environment is cooler than desired and a light emitting diode (LED) lights up. Students vary the threshold to understand how the comparator works.

Conclusions

All of these modules show examples of multidisciplinary engineering. Each module employs computer integrated experiments using data acquisition systems for strain, temperature and pressure. Spreadsheets are employed for engineering calculations, plots and regressions. Presentations using PowerPoint are given by the students at the end of each module. In all of the modules students are introduced to unit conversions and engineering equations.

Biographical Information

KAUSER JAHAN is an Assistant Professor of Civil and Environmental Engineering at Rowan University, Glassboro, New Jersey. She completed her Ph.D. studies in the Department of Civil and Environmental Engineering at the University of Minnesota, Minneapolis in 1993. Her research interests include biodegradation of petroleum compounds and surfactant enhanced remediation of slightly soluble organic compounds.