Development of Low Cost Experimental Measurement Solutions for Capstone Design

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Abstract

One challenge faced by students in realizing their final design goals for a capstone course is the validation of results obtained from numerical techniques, such as finite element analysis. This is particularly common in institutions where, due to resource constraints, students have limited access to testing equipment and lab facilities. This study describes the setup and implementation of a low cost bank of measurement test stations that can be easily acquired and implemented to assist students in validating numerical results. Test stations were developed to measure temperature, force, strain, or acceleration. The cost to create all four stations was less than $700. The intention of the stations is not to provide access to the most accurate testing capabilities, but rather to instill an understanding of the importance of developing experimental procedures for testing and validating numerical results using a structured approach.

Keywords

capstone design course, senior design, measurement stations, undergraduate education, data acquisition

Introduction

Capstone courses have long been regarded as an important learning experience for engineering students. Such courses provide students with opportunities to solve real-world engineering problems and help prepare them to practice engineering. Engineering departments, industry, and the Accreditation Board for Engineering and Technology (ABET) all find capstone design courses highly beneficial[1,2].

While capstone courses are valued, an emphasis on theory in the engineering curriculum may leave some students with little preliminary instruction on design methods[3]. Students are likely aware that results obtained from numerical techniques, such as finite element analysis simulations, have replaced much of the experimentation previously needed to develop designs. However, the importance of the validation of such results must still be emphasized.

Validation tells the degree to which a simulation accurately represents the real world[4]. One way to validate a model is to collect laboratory data at selected set points and then compare these data to the simulation results. However, some colleges and universities may find experimental testing equipment prohibitively expensive. This paper describes the development of inexpensive testing stations that may be used in capstone courses to validate results obtained from numerical techniques.

Station selection

To determine whether students recognized a need for the experimental test stations and also to determine the types of measurement stations that would be most beneficial to students, a survey questionnaire was prepared and administered to senior-level students enrolled in a capstone course. In addition, faculty members, who had experience with capstone design projects and measurement systems, were consulted. The survey questions that were administered to the student are shown in Figure 1.

Figure 1. Senior Design Measurement Stations Survey

1. Would it be useful to have access to measurement systems for basic quantities such as strain, acceleration, force, temperature, voltage, current, resistance? Yes ___ No___
2. If Yes, please indicate which measurement systems would be most useful to your team (4 being highest, 1 being lowest)
   Strain ___ Acceleration ___ Force ___ Temperature ___ Voltage ___
   Current ___ Resistance___

The results for question 1, indicated that 100% of the students surveyed were in favor of having access to these test stations. Figure 2 shows the response to question 2.

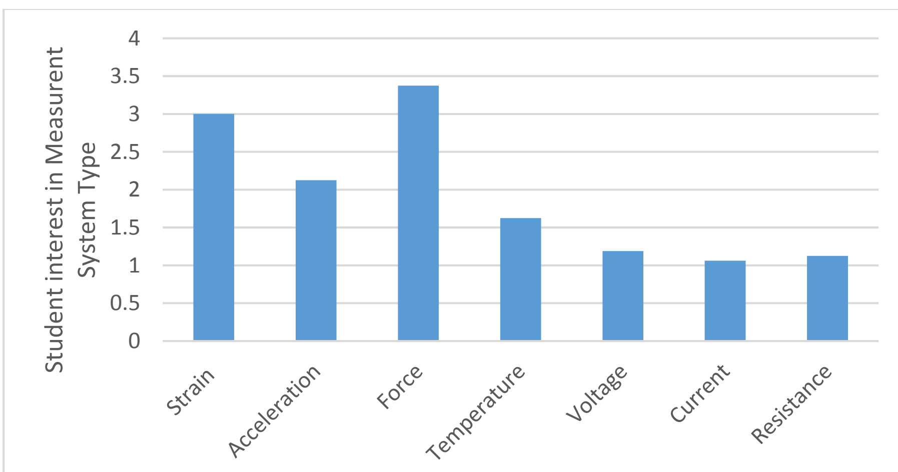

Figure 2. Student Interest in Measurement System Type (4 being highest and 1 lowest).

Group responses from students and input given by faculty were consistent, and it was decided that the development of measurement stations capable of measuring force, temperature, acceleration and strain would be most appropriate and beneficial to students.

Station development

As shown in Table 1, equipment totaling less the $700 was purchased to develop four test stations. The use of data acquisition cards from National Instruments® was chosen due to the low system cost and the ability to use sensors interchangeably with the appropriate configuration. A brief description of each station is provided below.

Table 1. Equipment Cost

Item #	Description(Supplier, Part No.)	Quantity	Unit Cost(USD)
1	National Instruments data acquisition card (NIDAQ USB-6000)	1	149.00
2	Power supply (Extech 30V 382200)	1	107.99
3	Weight set for load cell calibration (1000g)	1	125.60
4	Load cell (Omega LCL-020)	1	77.00
5	Load cell mounting kit (Omega LCM-CL1)	1	33.00
6	Thermocouples, K type (Omega CHAL-032-BW)	1	22.00
7	Strain gages (Omega SGD-3/120-LY11)	1	67.00
8	Accelerometer (SparkFun ADXL335)	1	14.95
9	Strain gage bridge completion module (Omega BCM-1)	1	85.00
		Total	**681.54**

Force Measurement Station. The force sensor consists of an Omega load cell. The sensor was installed using the mounting kit and allows for axial loading measurements. The 5 Volts for sensor excitation is supplied by the Extech® power supply. The National Instruments® data acquisition card and Labview® was used to measure the applied force.

Strain Measurement Station. The strain gages are attached to the component for which strain is to be measured using the supplied adhesive. The strain gage was then connected the bridge completion module operating on a quarter bridge circuit allowing measurement of axial or bending strain. The bridge module requires 10 Volts for excitation supplied by the Extech® power supply. Strain was measured using Labview® interface set to a quarter bridge configuration.

Acceleration Measurement Station. The SparkFun ADXL335 sensor allows for measurement of acceleration in the x, y, and z directions simultaneously. An excitation voltage between 1.8 -3.6 Volts was required by the sensor. The NIDAQ was configured to interpret and convert the sensor's output voltage to acceleration.

Temperature Measurement Station. The K type thermocouples are connected directly to the NIDAQ and the thermocouple sensor interface selected in Labview® and configured to output temperature. The sensor was calibrated in Labview® using the boiling and ice points as reference.

After physically setting up the measurement stations to collect strain, force, temperature and acceleration data, detailed manuals providing instructions to students on how to use each station were developed. Since Labview® software was used in conjunction with the National Instruments® data acquisition cards, students will be required to complete a Labview tutorial module prior to using the measurement station equipment. Preliminary findings have shown that capstone students, with the aid of the manuals, are able to use the stations to collect data.

Conclusion

This study shows that it is possible to develop inexpensive testing stations that may be used by capstone students to validate results obtained from numerical techniques. Additional work is underway to determine the impact of the stations on design quality and student achievement, as well as the impact of the stations on student attitudes about the capstone experience.

References

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