AC 2007-1935: PEDAGOGY FOR THE DEVELOPMENT OF AN INSTRUMENTATION LABORATORY

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Pedagogy for the development of an Instrumentation Laboratory

Abstract

In this paper, the authors discuss and stress the importance of engineering experimentation with particular reference to mechanical measurements. Precise and accurate instrumentation techniques and the correct interpretation of results thereof are extremely important for advances in engineering research and development. A new course in the area of engineering instrumentation was designed developed and successfully implemented at Miami University of Ohio. This presentation mainly focuses on course, curriculum and laboratory development with equal emphasis on mathematical analysis and experimental verification. The newly proposed instrumentation laboratory mainly concentrates on providing the students with the necessary background pertaining to *mechanical measurements.*. Theoretical aspects are discussed in detail, during lecture meetings and problem solving tutorial sessions. However, at present, students get very little hands-*on* experience. Further, the students, who have acquired the knowledge of mechanical machine elements and associated instrumentation techniques are required to *apply* their knowledge to the discipline of mechanical engineering. Bending Moment Diagrams and Shear Force Diagrams are created using L.V.D.T. (Linear Variable Differential Transducer). Furthermore it is planned to incorporate a portable *strain-meter* that can be utilized to verify experimental data with theoretical calculations. Eventually, when student groups work on their experimental project, they would be able to understand and appreciate the needs and necessities of mechanical measurement techniques. They will also be able to effectively utilize and apply the knowledge gathered and gained during the lecture classes, study period of several semesters, in a variety of courses. Whenever appropriate, comparisons are made and analogies are provided, so that the students will be able to identify the similarities that exist between mechanical, electrical and thermal models. While conducting and completing instrumentation experiments, the students are strongly encouraged to apply their knowledge of physics, chemistry, mathematics, electric circuit analysis, materials science, statics, strength of materials, dynamics, fluid mechanics, thermodynamics and heat transfer. It is hoped that the new instrumentation laboratory will provide the students with good practical hand-on knowledge in the area of mechanical measurements.

Introduction

The students that enter this instrumentation course will have already completed most of the pre-requisites such as Statics, Strength of Materials, Dynamics, Fluid Mechanics, Thermodynamics, etc. For example in Dynamics they will have studied of the dynamic response of physical systems. The focus may be to concentrate on motion of mechanical systems such as in translation or rotation or a combination of both translation and rotation. The students are capable of developing engineering models using laws of physics and rules of mathematics. Students also enter the course with some basic understanding of linear algebra such as matrix manipulation techniques and statistical analysis. Introduction to the experimental method is accomplished by allowing the students to observe, measure, record, tabulate, calculate and verify. Static and dynamic measurements on engineering systems such as beams have been successfully tried and the results have been documented. It is proposed to extend this type of experimentation to columns as well. At a later stage students will be introduced to pendulums and gyroscopes as well. It is hoped to introduce the students to a wide variety of mechanical and electrical transducers. The students have taken a required course in statistics and are expected to apply their knowledge of *principles of probability and statistics* to experimental measurements. ABET stresses the importance of written communication skills. Therefore, technical report writing will be an integral part of the laboratory experience.

Future Goals

The ultimate aim of this laboratory is to familiarize the students with different data acquisition techniques. After this course, students take courses in mechanical vibrations. Therefore, it is also proposed that experiments be designed and developed wherein the students can incorporate devices to measure and control the vibratory behavior of certain mechanical models and systems. As a modest start, students will be required to examine the mechanical vibration behavior, and control of single degree of freedom and continuous systems. Students enter this instrumentation course with a sound knowledge of the principles of fluid mechanics; the authors propose to design and develop experiments that will include pressure and velocity measurements. It is our desire to incorporate modern transducers and flow regulators as a part of laboratory experience for the students. This course has plans to include experiments that provide the students with a clear idea of how a design process works. We have plans to utilize statistical methods extensively. Experimental set-up will be designed wherein the students can determine stress, strain and deflection.

The authors also propose experiments that involve study of different materials, failure analysis from static as well as dynamic loadings. It may be a bit difficult, but the authors do recognize the fact that there is a need for the students to learn about analysis of mechanical components. For example there is need to design experiments that include pulleys, gears, belts, shafts, screws, welded parts, etc. It may seem ambitious, however, team design projects, along with written project reports and oral presentations may benefit student learning. The additional objective is to provide several experimental set-ups to teach the students the basic principles of dynamics, mechanical instrumentation and control in a learner-oriented format. The experiments in the laboratory are planned to be example-driven. The students will gather, generate and tabulate data for in-class laboratory experimentations and realistic homework problems. The laboratory is primarily used for the *ENT 404 Instrumentation course.* However it supplements as an instructional environment for a variety of other required mechanical engineering courses as well. Emphasis is placed on basic principles associated with instrumentation, signal and data acquisition, first principles of dynamic modeling, detection and identification methods and parameter estimation methods. It is proposed that these become a part of the laboratory experiment design in order to provide a critical approach to help students understand principles of mechanical instrumentation. It should be reiterated that the philosophy behind the development of the new mechanical instrumentation laboratory is to reinforce the theoretical knowledge gained by the students during lecture classes.

Previous Work

In a paper he presented at the 2004 ASME Heat Transfer/Fluids Engineering Summer Conference at Westin Charlotte & Convention Center**,** Charlotte, North Carolina **(**July 11-15, 2004) one of the authors (Dr. Mysore Narayanan) raised seven questions.

1. What should be counted as appropriate goals in an undergraduate engineering course that has a significant laboratory component?

2. Are the teaching practices utilized by the instructor in this course providing reasonably acceptable paths toward accomplishing the specified learning goals?

3. What do students actually accomplish in the course and the laboratory exercises and how does the instructor's teaching methodologies contribute to students' intellectual development and progress?

4. How does the instructor respond to students' learning difficulties?

5. Does the teacher revise the teaching strategies to address such problems?

6. What impact does this type of teaching have on students' life-long learning attitudes?

7. Are they able to "learn how to learn?"

Tom Angelo's "Dozen"

The authors recommend the use of Thomas Angelo's (1993) *Fourteen Principles for Improving Higher Learning* while creating an interactive syllabus for an Instrumentation course with a significant laboratory component.

1. Students' performance excel when they are encouraged to engage more actively in their academic work. (rather than passively attending lectures and taking notes.) This is accomplished by motivating students to explain to fellow learners creative ideas and practical implications as viewed in different contexts.

2. Students are asked to focus their attention by being made aware of the basic structure of what is to be learned. Here, the priorities of content are stressed while the subject matter is discussed.

3. Students are asked to write down specific learning goals and compare them with

their peers and also the instructor. Students are encouraged to set and maintain realistic goals that can be accomplished in a given time frame.

4. Students are asked to meaningfully connect new information to knowledge acquired previously in relevant courses. Students are required to provide multiple examples, analogies and metaphors.

5. Students are asked to successfully identify and unlearn erroneous previous knowledge if any.

6. Students are encouraged to organize subject matter and content in meaningful ways that are personally and academically appropriate. Accommodate different styles of learning.

7. Students should be able to generate concept *maps and mental models.* Students should receive specific feedback. Encourage them to incorporate constructive feedback in their portfolios and journals.

8. Students are provided in detail, and in advance, the rubrics that are used in assessment and evaluation. Model exams and study guides help to a large extent.

9. Student must be encouraged to invest adequate time in addition to high quality focused effort. Allow them to understand the real-world constraints while achieving mastery of the content.

10. Students find real-world applications in many contexts to transfer what they are learning. Encourage students to generate their own applications based on the concepts discussed.

11. Students should perceive and adopt high expectations of achievement. Compare students' expectations with instructors' expectations. Allow them to review what their peers have accomplished during previous years.

12. Students experience a balance of intellectual challenge and academic support. Realize that novices may need more support.

13. Students clearly perceive the value in what is to be learned. It is very important that the instructor communicates with the student that content is held to be very valuable. Make sure that the student understands that mastery of the content will ultimately lead to other important goals.

14. Students interact frequently with other learners and instructors. Engage the students in a dialogue and challenge the students with assignments that groups perform better than individuals.

Given below is a partial list of instrumentation systems that are planned for the new laboratory. The list is by no means complete. There are plans to add more as funds become available. This laboratory is necessary to support the very first *Mechanical Engineering Laboratory Instrumentation* course where students will be introduced to mechanical measurement systems and instrumentation. Proposed equipment to be used in laboratory experiments include:

A wide variety of potentiometers
LVDTs (Linear Variable Differential Transformers),
Different types of pressure gages
A variety of manometers
Piezoelectric crystals
Electronic pressure sensors
Assortment of electronic sensors and transducers
Variety of pressure transducers
Different types of thermometers
An assortment of thermocouples
Different type of thermistors
Strain gages
Portable strain meters
Load cells
Accelerometers
Electromechanical shakers
Deadweight testers
Digital multimeters
Digital oscilloscopes
Signal generators
Data acquisition cards
Diaphragms
Bourdon tubes
Pirani gage
Heat conduction gages
Omegascope for heat transfer experiments
Wheatstone Bridge set up
An experimental set up for verification of center of pressure
An experimental set up for the verification of Bernoulli's equation
An experimental set up for the verification of Torricelli's law.
Signal conditioning equipment

Etc.

It is important to emphasize that the above list is only partially complete. The preceding listing of instrumentation is not meant to be all inclusive but to provide a starting point for any newly proposed instrumentation laboratory. This paper mainly concentrates on providing the students with the necessary background pertaining to *mechanical measurements..* Pertinent theoretical aspects are discussed during lecture meetings and problem solving tutorial sessions. At present, various hardware laboratory projects are being designed utilizing the types of data gathering devises previously discussed. These will provide students with necessary *hands-on* experiences.

Conclusions

When student groups work on their experimental projects, they will understand and appreciate the needs and necessities of mechanical measurement techniques. They will also be able to effectively utilize and apply the knowledge gathered and gained during the lecture classes, study sessions, and in a variety of courses. Whenever appropriate, comparisons are made and analogies are provided, so that the students will be able to identify the similarities that exist between mechanical, electrical and thermal models. While conducting and completing instrumentation experiments, the students are strongly encouraged to apply their knowledge of physics, chemistry, mathematics, electric circuit analysis, materials science, statics, strength of materials, dynamics, fluid mechanics, thermodynamics and heat transfer. The authors expectations are that the instrumentation laboratory will provide the students with good practical hands-on knowledge in the area of mechanical measurements while strongly reinforcing theory and analytical methods.

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APPENDIX A

Laboratory Learning Objectives. An Example.

The newly established division of Instrumentation *Laboratory* is expected to fulfill several learning objectives. For example here is a list that has been proposed for one of the experimental set up. There are the ten learning objectives for this particular lab.

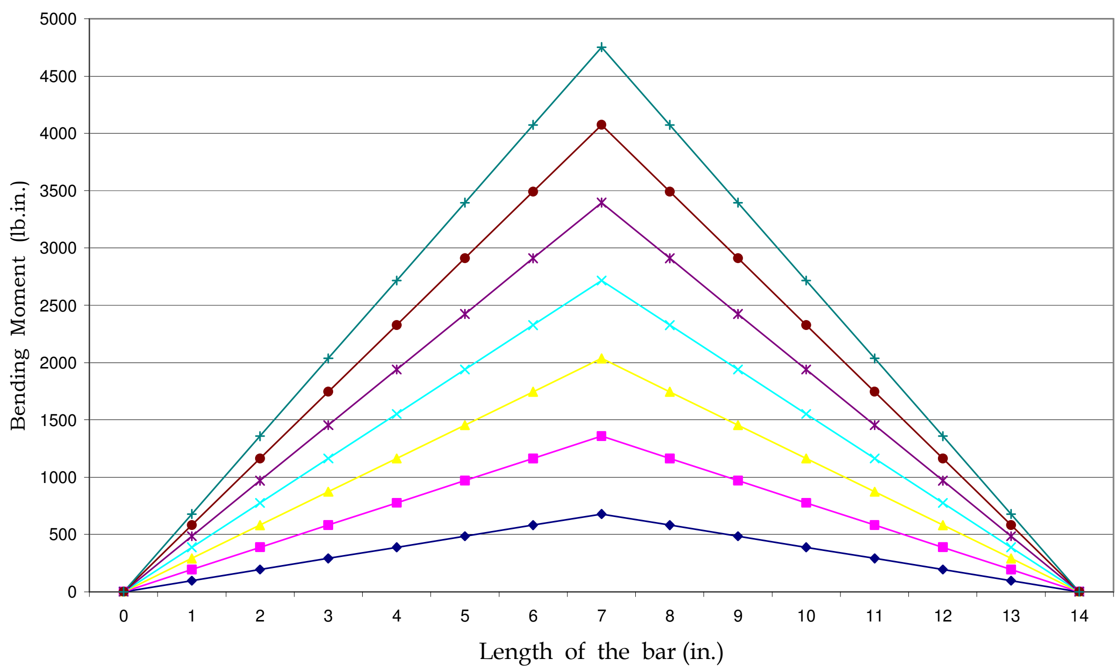
1. A complete and clear understanding of the way the *flexure formula* is applied to calculate maximum *bending stress.*
2. An understanding of the design methodologies involved.
3. The limitations under which the flexure *formula* can be applied.
4. Given load conditions, how to design a beam with safety considerations.
5. Knowledge of the effect of moment of inertia on bending stress.
6. Derive all necessary mathematical equations pertaining to the discussion.
7. Define: *flexural center,* section *modulus* and neutral *axis.*
8. An understanding of design *stress* and *stress concentration factors.*
9. Recommend different structural shapes as appropriate.
10. Provide Bending Moment and Shear Force Diagrams.

APPENDIX B

An Example from Student's Lab Report:

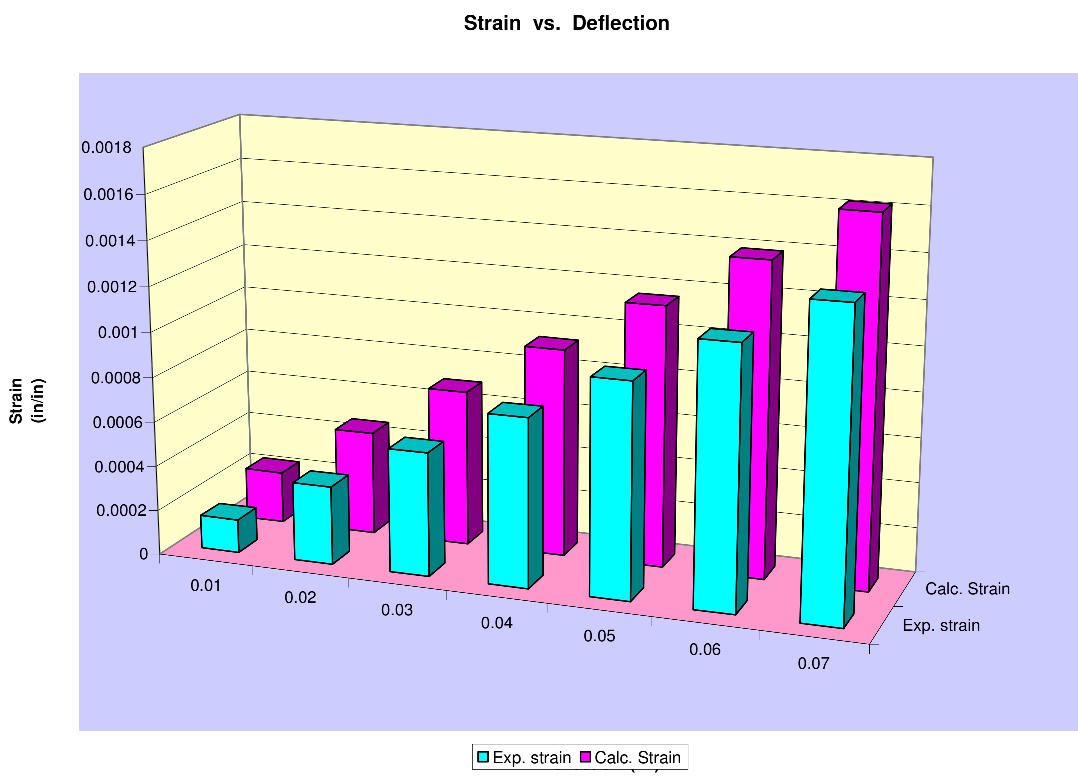
This experiment involves a set up for measuring deflection of a beam supported at either end. The students gather a significant amount of data by loading the beam at the center and measuring the deflection at the center. A strain gage mounted underneath the flat aluminum bar is utilized for this purpose. This strain gage forms one of the 'arms' of a Wheatstone Bridge. By balancing the bridge using 'Null' method or 'Deflection' method the students will be able to calibrate the 'instrumentation set up' to provide them with necessary data. This data helps the students to calculate the bending moment as well as the strain experienced.

Bending Moment Diagram



APPENDIX C

An Example from Student's Lab Report: (Previously presented at the 2003 ASEE National Conference, Nashville, TN.)



APPENDIX D

An Example from Student's Lab Report: Stresses the importance of Hyperbolic Functions. (Mathematical Analysis of a Catenary Curve : St. Louis Arch)

$\text{Sinh } x = \frac{1}{2} [e^{x} - e^{-x}]$

$\text{Cosh } x = \frac{1}{2} [e^{x} + e^{-x}]$

For the St. Louis Arch:

Given: f_C = Maximum Height of Centroid = 625.0925 feet

Given: L = Half of Centroid @ Arch Base = 299.2239 feet

Given: A = 68.7672

Given: C = 3.0022

Governing Equation

$$Y = A [\text{Cosh}(XC/L) - 1]$$