AC 2007-1284: A NOVEL LABWORK APPROACH FOR TEACHING A MECHATRONICS COURSE

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Professor Ioana Voiculescu received a Ph. D. degree in Mechanical Engineering from Politehnica University, Timisoara, Romania, in 1997 in the field of Precision Mechanics. She finished her second doctorate in 2005, also in Mechanical Engineering, but with the emphasis in MEMS. She has worked for five years at the U.S. Naval Research Laboratory, in Washington, DC in the area of MEMS gas sensors and gas preconcentrators. Currently, she is developing a MEMS laboratory in the Mechanical Engineering Department at City College of New York. She is an IEEE member, an ASME member and a reviewer for IEEE Sensors Journal in 2004, 2005 and 2006.

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Professor Benjamin Liaw received his Ph.D. degree from the University of Washington in 1983. After a year of post-doctoral research study at University of Washington, he joined the faculty of CCNY in 1984, where he is a Full Professor at Department of Mechanical Engineering. During 2000-2002 he was also appointed Acting Associate Dean for Undergraduate Studies, School of Engineering. His interests include (1) the design, analysis, manufacturing and testing of composites and smart materials, and (2) improving engineering education through innovative teaching and research techniques, with emphasis on attracting underrepresented minorities and women. Through years he has published more than 70 refereed papers with funding support from NSF, NASA, ARPA, AFOSR, ARO, U.S. Army TACOM-TARDEC and ARDEC-Picatinny Arsenal, AT&T, Digital Equipment Corporation, Alliant Techsystems, Frontier Performance Polymers, NYS GRI and PSC CUNY. In addition to being active in research, he had also served as the ECSEL Project Director at CCNY in 1993-2001. The main charge of the NSF-funded ECSEL Coalition is to improve undergraduate engineering education through design for manufacturing across the curriculum.

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Abstract

This paper presents a novel approach adopted to enhance the hands-on learning aspect of a Mechatronics course for undergraduate mechanical engineering students. In addition to traditional homework, which is usually solved analytically and/or numerically and conventional laboratory experiments, in which students follow certain pre-written, spoon-feeding procedures to complete assignment, our approach designed a set of "labwork" as an integral part of this course for students' learning through their own "design of experiments" to solve engineering problems. To solve these "labwork" assignments, students were required to work as a team in the laboratory outside class hours. Each team was assigned several engineering problems to be solved (e.g., to find the stress concentration factor of a rectangular plastic plate with a U-notch under uniaxial tension). Instead of conventional approach (e.g., finite element method), the team was asked to use the equipment and software available for them in the lab (e.g., three strain gages and a strain indicator); designed, set-up and conducted their own experiment (e.g., where to place the three strain gages at the most suitable locations so that the stress concentration can be assessed most accurately?); analyzed the data and compared their results with solutions obtained by other means (e.g., from textbooks/handbooks, finite element solutions, etc.); and finally submitted final written reports. During these learning processes, the students were able to solve the "labwork" assignments collaboratively among themselves and without much intervention from the instructor and lab technician. The students arranged with the lab technician the optimal time frame when they were free and could work in the lab. The technician was assisting the students during the "labwork" but his input was minimal. In a nutshell these "labwork" assignments require students to apply the theoretical knowledge they have learned during lecture sessions of the course and to use laboratory skills in equipment and software they have acquired during conventional laboratory sessions. As a result students will be challenged to solve engineering problems independently and as a team, and gain confidence in their ability to apply their knowledge for problem solving when encountering new and uncharted terrains. From the survey conducted for the "labwork" evaluation, the student feedback was positive.

1. Introduction

Mechatronics, a truly multi-disciplinary approach to engineering, integrates the classical fields of mechanical engineering, electrical engineering, computer engineering, and information technology to establish basic principles for a contemporary engineering design methodology[1]. Mechatronics, has become a key to many different products and processes. Modern systems have reached a level of sophistication which would have been hard to imagine using traditional methods. The integration of mechanics, electronics, control and computing exploits and exceeds the relative advantages of single disciplines, and when they are integrated, the synergy ensures that performances reach unprecedented levels[2]. The importance of Mechatronics Engineering will further increase due to consumer demands. Thus it has a vital role to play in the new millennium.

The global engineering market requires engineers who embrace a mechatronics perspective with advanced systems skills for participation on multi-disciplinary teams[3,4]. There has also been significant activity in the last decade to revise engineering curricula to include more concrete engineering practice rather than just engineering science[5]. In this respect a key strength of the ME 311, Fundamentals of Mechatronics course at City College of New York is the laboratory which encourages students to apply and absorb mechatronics concepts. The main goal of the laboratory is to help students gain useful knowledge and skills in the general area of sensors and actuators, ordinary differential equations used to model measurement systems, laboratory software and signal conditioning[6]. Such knowledge and skills are necessary for the success in students' future professional careers (including graduate studies) and for the continuation of their life-long learning. In order to achieve this goal, students complete several laboratory experiments. The experiments starts with a short tutorial explained by the instructor and the students working in teams conduct the experiments based on this tutorial while being closely monitored by the instructor or lab technician. In this way the students achieve confidence using their practical and experimental skills.

A novel concept regarding the laboratory experiments was introduced in order to develop abilities for the students to identify and formulate real-world engineering problems, carry out research, think creatively and work individually. In this respect, in addition to the experiments conducted in the classical manner the students receive "labwork". For this novel type of homework assignments the students work independently in the laboratory outside class hours. We developed the labwork idea based on an original homework concept developed by our colleague Professor Latif Jiji. Several years ago Professor Jiji introduced in his course the concept of take home laboratory experiments, where the students were asked to conduct independent laboratory experiments at home, eventually helped by their family[7]. In our case the students solve the homeworks in the laboratory. The students are still supervised by a technician but he is not giving the students all the details necessary in order to solve the "labwork". The students receive one week to solve the "labwork" and they need to arrange with the technician the time when they could be in the laboratory. The technician assists the students in the laboratory when they are working for the "labwork" but his input is minimal. In order to solve the labwork the students use the laboratory equipment and software and follow the experiment information detailed in the homework description. The students are able to independently solve the labwork without the instructor's help and communicate the results through written reports. The labwork includes engineering concepts the students learned during the theoretical part of the course and requires students to use their skills concerning laboratory software and equipment and engineering problem solving. As a result the students will be challenged to independently solve and analyze an engineering project and gain confidence in their ability to apply their knowledge to new and unencountered situations. The labwork experiments expose the students to practical and theoretical issues and will be described in this paper.

2. Labwork experiment descriptions

The labwork covers topics introduced in the Mechatronics course ME 311 and also in the Mechatronics laboratory experiments. The laboratory experiments feature the integration of sensors, actuators and real time data acquisition and control using industrial hardware and the software LabView and MatLab[8,9]. The laboratory experiments cover the information presented in the Mechatronics course and include; stress and strain measurements using strain gages connected in a Wheatstone bridge configuration, monitoring the speed of several bodies during free fall using optoelectronic sensors, study of mechanical vibration using four transducers ; piezoelectric accelerometer, capacitive transducer, velocity transducer and linear variable differential transformer (LVDT), and temperature measurements using thermocouples.

Each of these experiments is intended to have the following activities[10]:

-Understanding the problem, identification of objectives and variables to be controlled.
-Understanding the physical principles of the sensors and the process to be controlled.
-Selection of the appropriate control algorithm and nature of the interface.
-Connecting the system.
-Developing and implementation of the computer program in LabView and MatLab.

The labwork has the same scope and activities as the experiments, the students are allowed to work in groups and they are in the laboratory when no classes are scheduled there. The difference between the laboratory experiments and labwork consists in the fact that the students do not receive help from the instructor when they are working for labwork. In this way the students are required to think independent and gain confidence in their skills and knowledge. The labwork concept was created in order to introduce in practice the theoretical principles developed in the Mechatronics course. During the semester the students are assigned four labwork assignments, which are described in this paper.

2.1 Labwork about the stress and strain concentrators

The objective of this labwork is to demonstrate the existence of stress (strain) concentration in the vicinity of a geometric discontinuity created in a polymethyl-methacrylate (PMMA) bar. This labwork is intended to familiarize the students with the strain gain concept and the procedure to mount and bond Vishay strain gages[11].

For this labwork ten PMMA bars with different discontinuities were prepared as illustrated in Fig. 1. The discontinuities were simple circular or semicircular holes, notches and cracks, drilled through the depth of the bars, in the center or at the edges of the bars. In order to measure the stress value around a discontinuity the students were asked to mount 3 strain gages in the vicinity of the hole at varying distance from the edge of the hole, with one of the gages placed adjacent to the edge. In the Mechatronics laboratory a special kit for bonding the strain gages was prepared for this labwork. The kit contains additives, bonding pens and materials needed for the bonding of Vishay stain gages along with a description of the bonding procedure. Using the labwork description, the special kit and the bonding information the students were able to mount and bond the Vishay stain gages on the PMMA bars without any help from the instructor. They also decided the area where they glued the strain gages on the specimen. Fig. 2 presents a student working for this labwork. A P-3 Wheatstone-bridge strain indicator has been used to measure the strain. Based on the strains indicated by the three strain gages the students sketched the stress and strain diagram around the discontinuity for the specific PMMA bar and calculated the stress (strain) concentration factor.

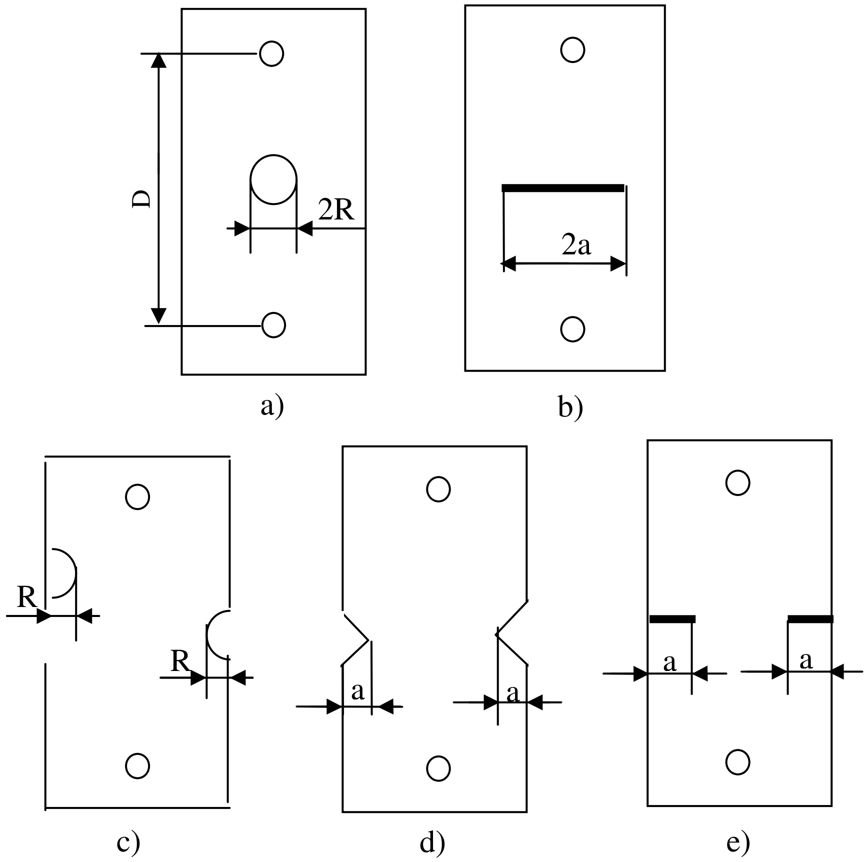

Fig. 1. Various PMMA plats with discontinuities.

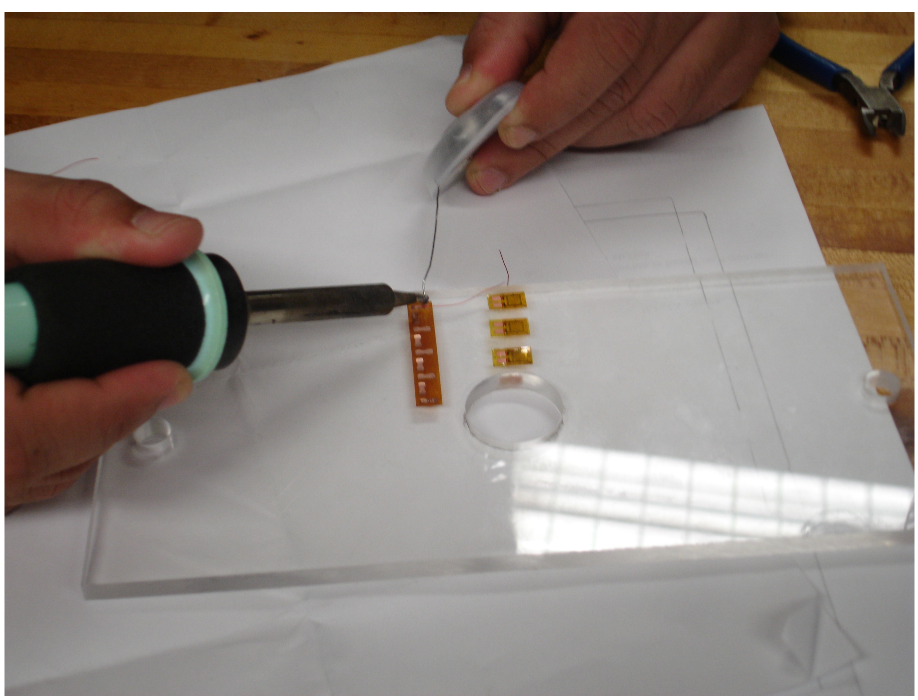

Fig. 2. Student soldering the wires to the gages during the labwork.

2.2 Labwork about recording the frequency of the tuning forks.

During this labwork the students get familiar with sound collection using a PC sound card and a microphone. The sound was produced by a set of tuning forks. The tuning fork vibrations created pressure variations. The pressure variations were digitized using a microphone. The resulting signal was transferred to the PC using a sound card. The students were asked to write Matlab programs in order to acquire and analyze frequency data. The set up for this labwork is illustrated in Fig. 3.

Eight different tuning forks were used for this labwork along with an acoustic box, which was used as a support for these tuning forks. The students were asked to vibrate each tuning fork separately hitting them with a rubber tuning fork hammer. A Matlab program was used to acquire data which consist in pressure variations caused by the vibrating tuning fork. The students were asked to write a fast Fourier transform program using Matlab software. After gathering data, the fast Fourier transform program was used to convert the digital data into the frequency of the tuning forks. The main objective of this labwork was the understanding of the fast Fourier transform. The students were asked to conclude about the relation between the resonant frequency and the tuning fork tine length.

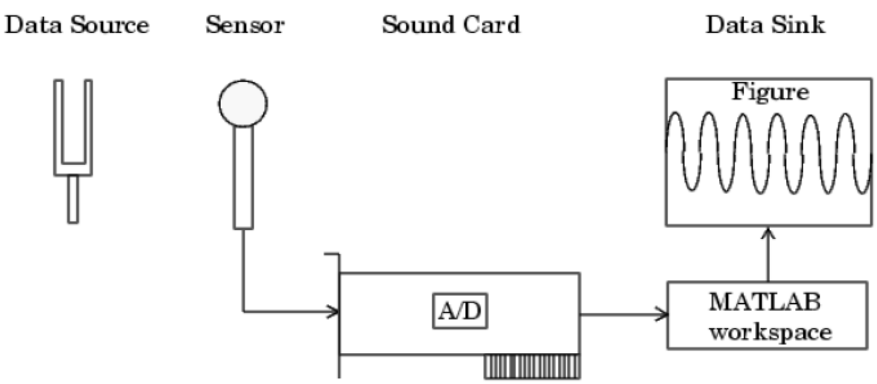

Fig. 3. Set up for the tuning fork labwork. The tuning fork vibrations are captures by a microphone. The resulting signal is transferred to the PC using a sound card. A Matlab program is used to collect data.

2.3 Labwork about recording the skin temperature

This labwork explores two methods of temperature data acquisition: a LabView based virtual instrument and a Matlab program. These two methods were used to obtain sampling of student's skin temperature. The students were asked to build a virtual instrument for measuring the skin temperaturte using LabView. This virtual instrument, illustrated in Fig. 4, was connected to an integrated temperature sensor in an NIDAQ signal accessory and was used to collect data of student's skin temperature as shown in Fig. 5.

The Matlab program was also used to collect data of skin temperature using the same temperature sensor, as illustrated in Fig. 6. The students were asked to collect skin temperature data using both methods. These values were then used to calculate and compare various statistical parameters; as the standard deviation of the temperature distribution, the temperature average (mean) and the temperature root means square (RMS).

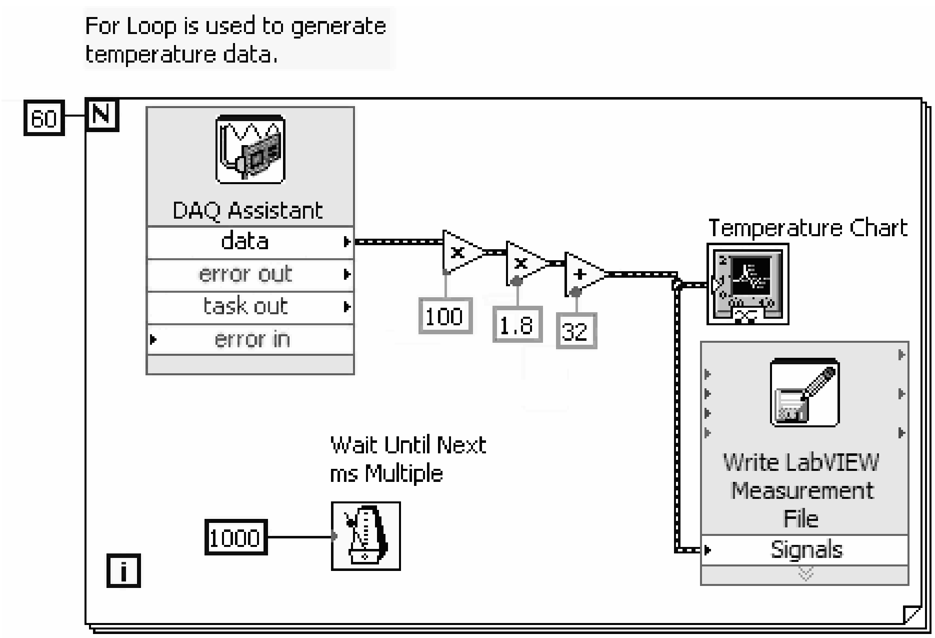

Fig. 4. Virtual instrument for measuring the student's skin temperature created with Labview.

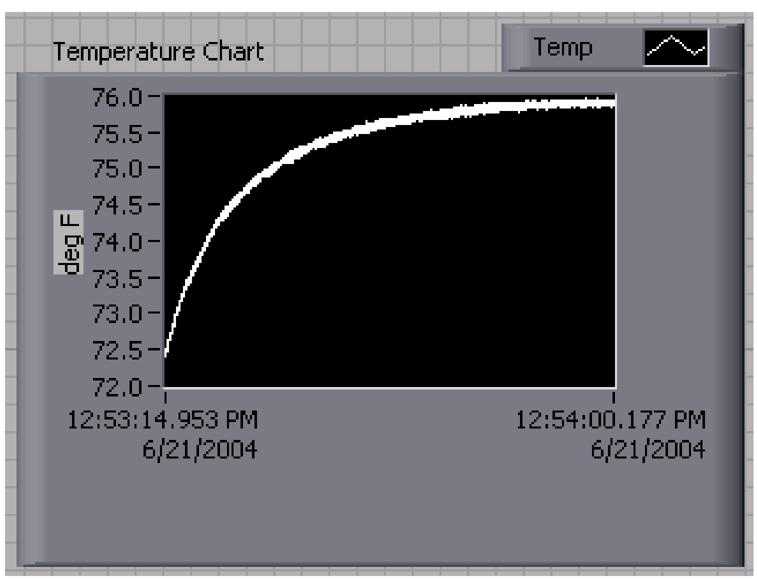

Fig. 5. Sample data collected with Labview virtual instrument

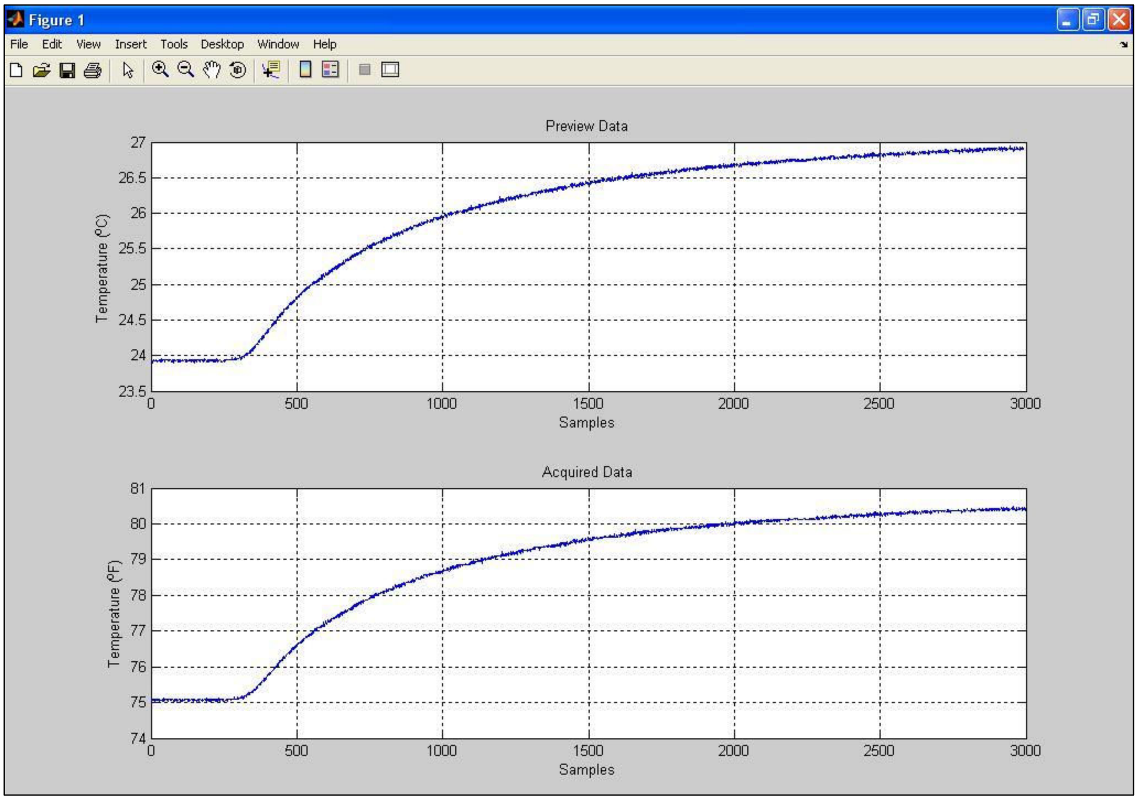

Fig. 6. Sample data collected using the Matlab program.

2.4 Labwork about the cantilever beam vibrations

The purpose of this labwork is to explore the effects of dimensions and material on the cantilever beam's frequency response characteristics. The response of the cantilever beam under harmonic excitation was simultaneously measured using a strain gage and a piezoelectric accelerometer, and compared with real time theoretical response. Cantilever beams with different lengths made from two different materials; steel and composite material were used. During the labwork the beam was secured at one end. An impulse force was applied to the free end of the cantilever beam using an impulse hammer, in order to determine the system's natural frequency and the damping coefficient. In addition the effect of beam material's type on the speed of the wave through the beam was examined.

A Vishay strain gage was mounted about 40 cm from the free end of the beam. This strain gage was calibrated and used to determine the strain variation corresponding to the beam vibrations. In this respect a micrometer was used to deflect the beam and produce variable strain. The strain gage calibration was performed using a P3 strain indicator recorder and a digital multimeter to measure the corresponding voltage.

A piezoelectric accelerometer measured the acceleration at the free end of the beam and was mounted about 2.5 cm from the free end. After the beam strain gage was calibrated an impact hammer was used to apply an impulse force at the free end of the beam. The cantilever beam with the strain gage and the accelerometer mounted on it is shown in Fig. 7

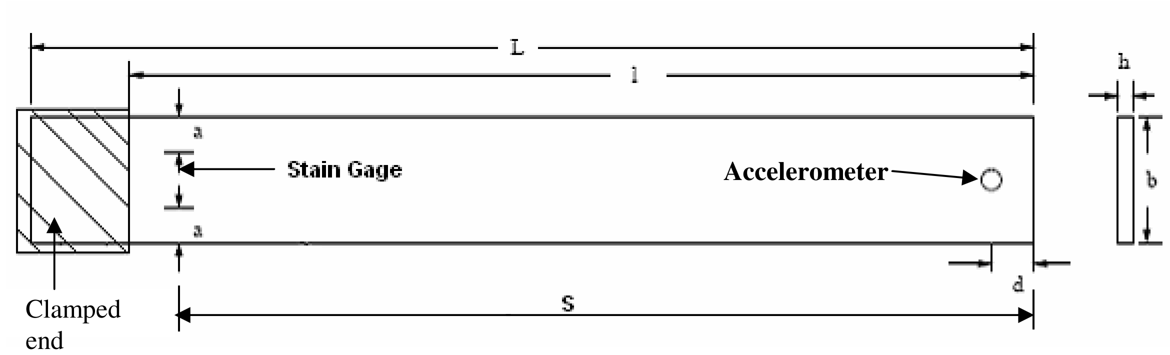

Fig. 7. Cantilever beam with the strain gage and the accelerometer marked.

Using a program written in Matlab the information from the strain gage, accelerometer and impact hammer were recorded. The recorded graphs are shown in Fig. 8. Based on these results the students were asked to plot the curves: acceleration (m/s^2) versus time, force (Pa) versus time and strain/stress versus time. They also were asked to calculate the damping coefficient. The theoretical damped frequency was also calculated and compared with the experimental value[12]. The speed of the vibration wave was calculated.

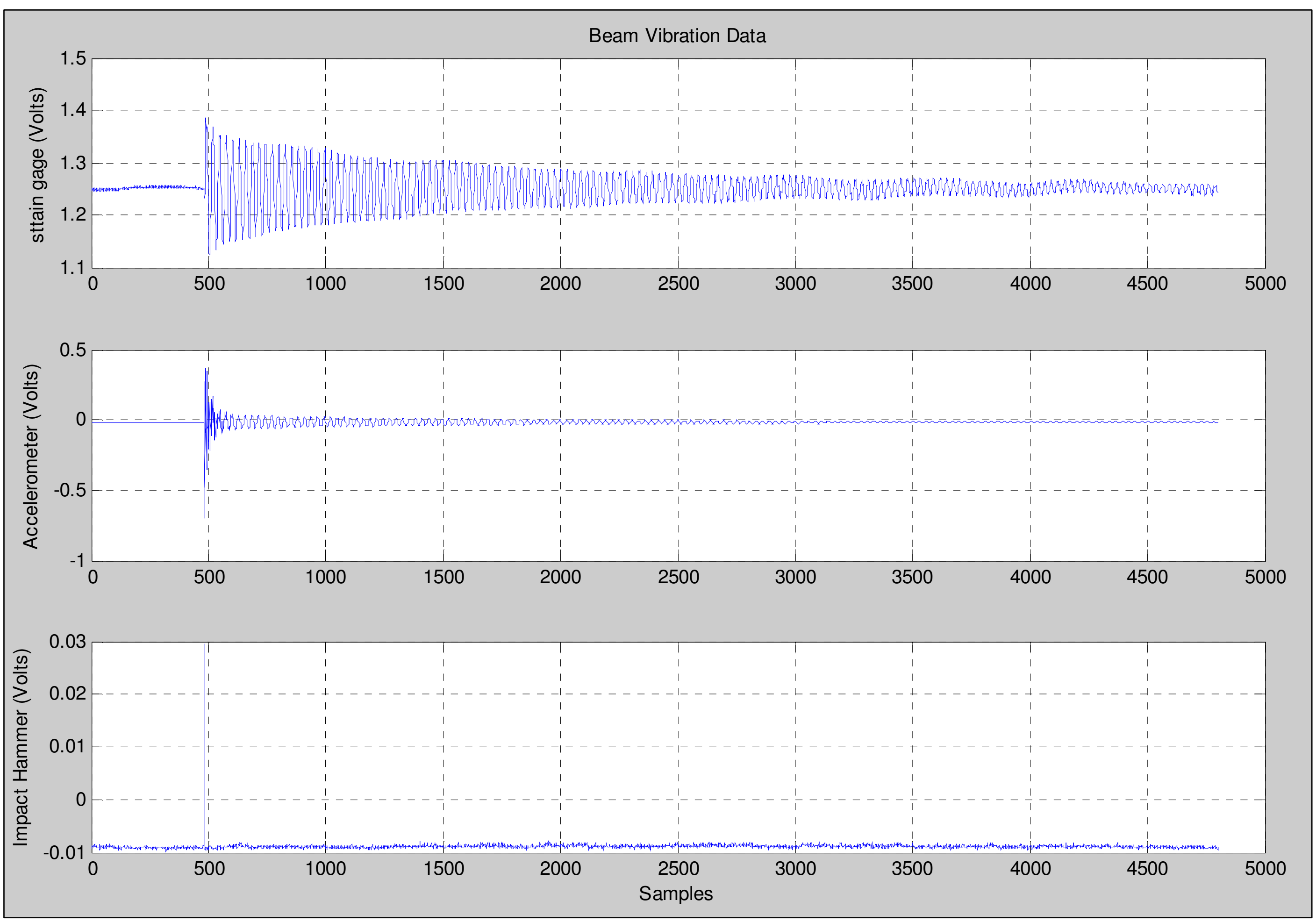

Fig. 8. Plotted data acquired using the Matlab program written especially for this labwork.

3. Student feedback.

To get an accurate assessment of student perception of the labwork concept, a survey was administrated to all the students enrolled in the Fundamentals of Mechatronics course. The survey was based on the following questions: 1) Did the labwork help you understand the subject better; 2) Was the labwork interesting and you had fun doing them; 3) Did the labwork take up too much of your time and 4) Will you recommend the labwork pedagogy to be adopted in other courses. The survey results are given below in graphical form, as illustrated in Figs. 9-12.

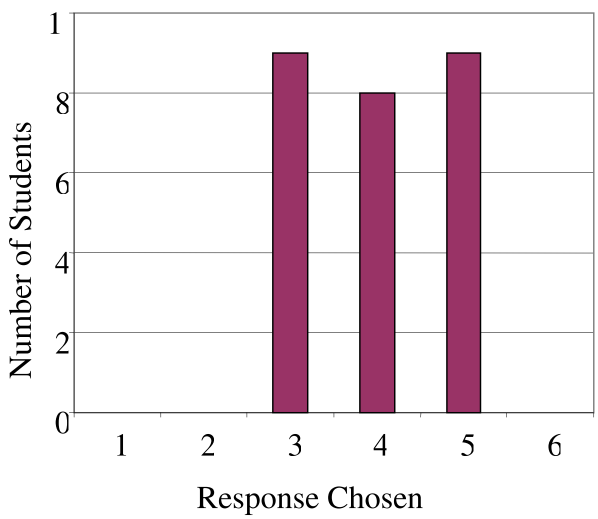

Fig. 9. Students response to question 1: The response meanings are: 1 and 2 not helpful, 3 and 4 some what helpful, 5 quite helpful.

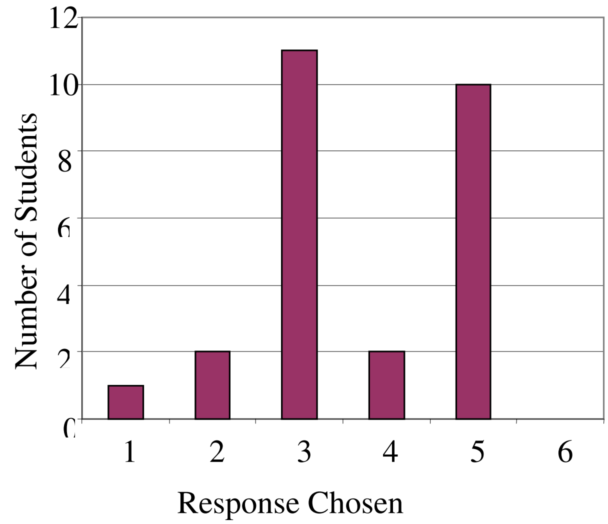

Fig.10. Students response to question 2: The response meanings are: 1 and 2 not helpful, 3 and 4 some what helpful, 5 quite helpful.

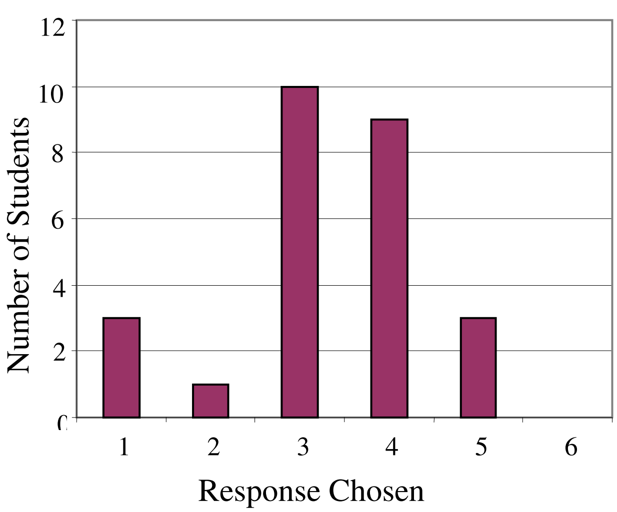

Fig. 11. Students response to question 3: The response meanings are: 1 and 2 not helpful, 3 and 4 some what helpful, 5 quite helpful.

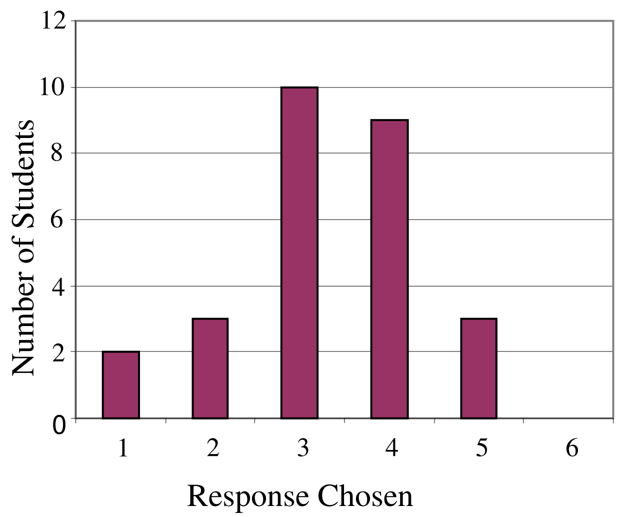

Fig. 12. Students response to question 4: The response meanings are: 1 and 2 not helpful, 3 and 4 some what helpful, 5 quite helpful.

According to the survey, the majority of the students enjoyed working on these labwork assignments and considered the labwork as being useful and interesting. The grades for these homework assignments conducted in the laboratory are better in comparison with classical homework assignments based only on the theory.

4. Conclusions

The labwork represents independent homeworks in the laboratory. The students conducted the experiments in the Mechatronics laboratory under the supervision of the laboratory technician but with minor help from him. The labworks are an invaluable supplement to the theory taught in the classroom and to the laboratory experiments conducted under the supervision of an instructor or technician. After completing these labworks the students enhance their skills and confidence to work independent.

During these labwork sessions the students have been exposed to the following aspects of mechatronic applications:
-working with strain gages and bonding the gages on the specimen at a specific location;
-working with Matlab program and writing programs for specific applications; as fast Fourier transform or collecting data;
-working with Labview program and building a virtual instrument;
-using sensors as accelerometer or temperature sensor;

The experiments used for these labworks are completely automated. In other words, with the click of a button the computer acquires all data, performs all required mathematical analysis and writes the results. This is possible due to the versatility of the Labview and Matlab software. Conducting the labwork the students are able to compare the theoretical and experimental results in real time. Thus these labwork assignments serve as illustrative examples of how the theory and the experiment complement each others. Based on the survey results summarized in Fig. 9-12, the labwork pedagogy, in general is favored positively by students.

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Biography

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