An Innovative Integration of Data Acquisition and Manufacturing Practice as an Introduction to Mechanical Engineering

Vincent P. Manno, ASME Member
Professor
Department of Mechanical Engineering
Tufts University
Medford, MA 02155
vincent.manno@tufts.edu

Anil Saigal, ASME Member
Professor & Head
Department of Mechanical Engineering
Tufts University
Medford, MA 02155
anil.saigal@tufts.edu

Tufts has developed a sophomore BSME course entitled "Introduction to Mechanical Engineering" to provide a motivating and reinforcing experience for students new to the major. In the course, the class is split in two groups. For the first seven weeks of the semester, the first group learns about machining processes, drawings and dimensioning, and tolerances. In addition, they fabricate their own air motors. The second group learns about transducers and computer-based data acquisition. They develop individual sensor configurations and code to measure the rotational speed of the air motors. In the second half of the semester, the groups switch roles. On the last day of the semester, each student uses his/her own code and instrumentation system to measure the operating speed of the air motor that he/she fabricated. It is an immense source of pride, confidence and accomplishment for the students. Often for the first time in the curriculum, they build and test a complex device and have their first genuine engineering experience.

I. INTRODUCTION

Tufts is one of the few, if not the only, engineering school in the country that graduates more engineers than it initially matriculates. This is due in part to an innovative curriculum that Tufts offers to its first-years students. Besides taking the regular courses in mathematics, physics, chemistry, liberal arts including English composition, programming and drawing/CAD, the students also have to take two half-courses from various disciplines dealing with hands-on engineering. Some of the half courses offered during the past year by mechanical engineering faculty include prototyping home robots, life in moving fluids, design and performance of musical instruments, gourmet engineering, how things work, and sound and society. Besides these, courses from other departments include biotechnology engineering, skyscrapers, computer processing of images and a number of other courses. These courses are not only open to first-year engineering students but also to liberal arts students. This helps students get a feel for 'engineering' and what they can contribute to the society. As a result there is a net transfer of students from liberal arts to engineering.

After the first year, the task of keeping students excited about engineering, in general, and their declared major, in particular, falls to the degree programs. Two years ago, the Department of Mechanical Engineering at Tufts University made a major commitment to enhance and strengthen the sophomore year BSME curriculum. To this end and in large measure due to its EC2000 assessment process, the department introduced a new sophomore level course: ME 1 - Introduction to Mechanical Engineering.

II. INTEGRATION OF DATA ACQUISITION AND MANUFACTURING PRACTICE

ME 1- Introduction to Mechanical Engineering consists of two parts: Fabrication and Instrumentation. The fabrication portion of the course deals with basic fabrication (shop safety, machine shop operations, Computer Numerically Controlled (CNC) machining and manual prototyping, overview of modern rapid prototyping) used in mechanical engineering [1]. The goal of this part of the course is to prepare students for the project components of junior and senior concentration courses. The instrumentation portion of the course deals with the basics of sensors and transducers, signal conditioning, data acquisition using LabVIEW™ 6 (Student Edition) [2], basic data characterization techniques including statistical and frequency analysis and an introduction to signal processing topics such as data windowing, triggering and filtering. An integral part of the Instrumentation portion of the course is the utilization of special RoboLab™ virtual instruments developed in collaboration with the Lego Corp. [3]. This approach utilizes the Lego RCX "brick" interface and basic sensors (e.g. touch, light, rotational, temperature) as the building blocks of a basic sensor→signal→data sequence. The goal of this part of the course is to prepare students for the didactic and exploratory experiments that they will undertake in junior and senior year courses.

The course meets in a classroom format for 2 contact hours per week and there are also small section (10-12 students) weekly lab sessions for 2.5 contact hours in duration. Table 1 summarizes the topics covered during the "classroom" portions and Table 2 summarizes the weekly lab session topics. Both lab sequences use a continuous building and "just in time" approach with the ultimate outcomes of a working motor and a functional measurement system.

Another important feature of the course is the writing of two documents during the Instrumentation portion. The first document is a "proposal" in which the student takes on the role of an engineering consultant who is marketing his or her ability to develop a measurement system for the air motor. Each student shares their draft proposal with special "Writing Fellows", who are undergraduate students, trained by the university to mentor their peers in improving written expression. After meeting with the Writing Fellows and after completing their measurement project, each student submits a final written report. This is often the first student experience with writing from an "engineering" perspective.

Figures 1 and 2 show the air motor assembly and the individual components that each student fabricates. Figure 3 is a schematic outlining the typical measurement system approach. A light sensor is used to detect the "bright-dark" variation of the rotating flywheel, which has been painted half black, half white. Figure 4 is a representative student developed interface or "front panel". The front panel is connected to a fairly complex set of object-based, data flow coding block diagram using LabVIEW™ and a RoboLab-based data analysis virtual instrument or VI.

Table 1 – Combined Syllabus of Course
Group A does Fabrication followed by Instrumentation
Group B does Instrumentation followed by Fabrication

Class	Fabrication	Instrumentation
1	Introduction	LabVIEW introduction
2	Machining Processes	Virtual Instruments
3	CNC Machining	Virtual Instruments
4	EZ CAM	LabVIEW Structures
5	Orthographic Projections	Basic sensors
6	Screws and Springs	Transducers & signals
7	Dimensioning	Data I/O, RoboLab primer
8	Dimensioning	Arrays & Clusters
9	Tolerances	Arrays & Clusters
10	Tolerances	Charts, Graphs & Data Export
11	Working Drawings	Curve Fitting, Data Statistics
12	Working Drawings	Signal Processing
13	Exam	Exam

Table 2 – Combined Syllabus of Lab Sections
Group A does Fabrication followed by Instrumentation
Group B does Instrumentation followed by Fabrication

Lab Week	Fabrication	Instrumentation
1	Shop Familiarization	LabVIEW Manipulation
2	Part Fabrication	RCX Measurements
3	Part Fabrication	Sensor Data Acquisition
4	Part Fabrication	Pendulum Response w/ trigger
5	Part Fabrication	Charting and Data I/O
6	Motor Assembly	Project Development

The labs and course pedagogy are designed so that each student experience is a "success" – all motors and measurement systems "work". However, the students also learn that both mechanical devices and software work "better" if they have strong fundamental design and if they are executed more carefully. The duality of this message is deliberate. Even though they all start with the same plans, materials and measurement hardware and software, some motors work better and some measurement systems are more reliable. This not only provides encouragement to students early in their education but also teaches them a valuable engineering "truth".

III. CLOSING REMARKS

Many topics and experiences that characterize the course are often distributed individually throughout various upper level mechanical engineering courses at most universities. What makes the Tufts approach innovative is the integration of the individually executed, fabrication and performance monitoring using a common project early in the engineering curriculum. The course's placement in the second semester of the sophomore year serves as a class "team building" experience. Students in the BSME program begin to establish collaborative work patterns and relationships prior to the junior year in which many of the core courses occur. This provides a basis for success in the upper-class years. The student response has been enthusiastically favorable. It is an immense source of pride, confidence and accomplishment for the students who realize that they can build and test mechanical systems and products. It is often their first genuine engineering experience and it occurs as they are studying foundational engineering science and mathematics courses.

This course approach and curricular placement can be transferred and scaled to various university settings. However, experience and assessment have shown that there are lessons to be learned. First, the approach is labor and equipment intensive. Its successful execution for a combined class of approximately 50 students requires 2 faculty members teaching each "portion" as one of their course assignments, 3 teaching assistants and approximately 20 person hours per week of technical support staff. In addition, the lab sessions monopolize the use of 2 table top CNC lathes, 2 tabletop CNC turning centers and several manual machines (e.g. drill presses) and 6 computer data acquisition workstations with complete RoboLab hardware set-ups.

IV. ACKNOWLEDGMENTS

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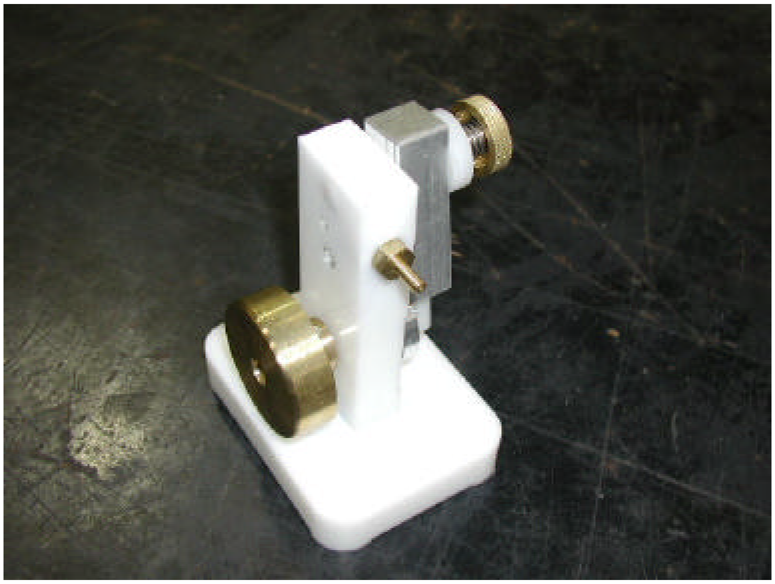

Figure 1 – Air Motor Assembly

Figure 2 – Individual Components of the Air Motor

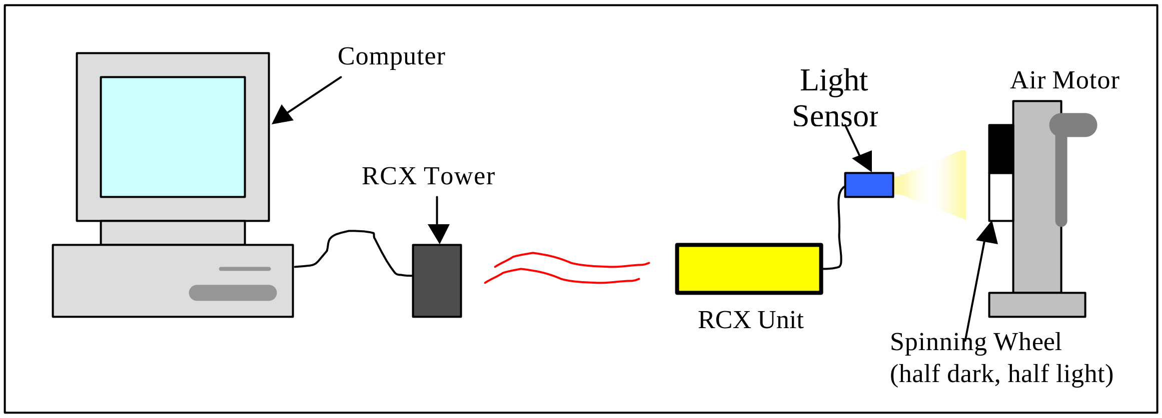

Figure 3 – Overview of the Measurement System

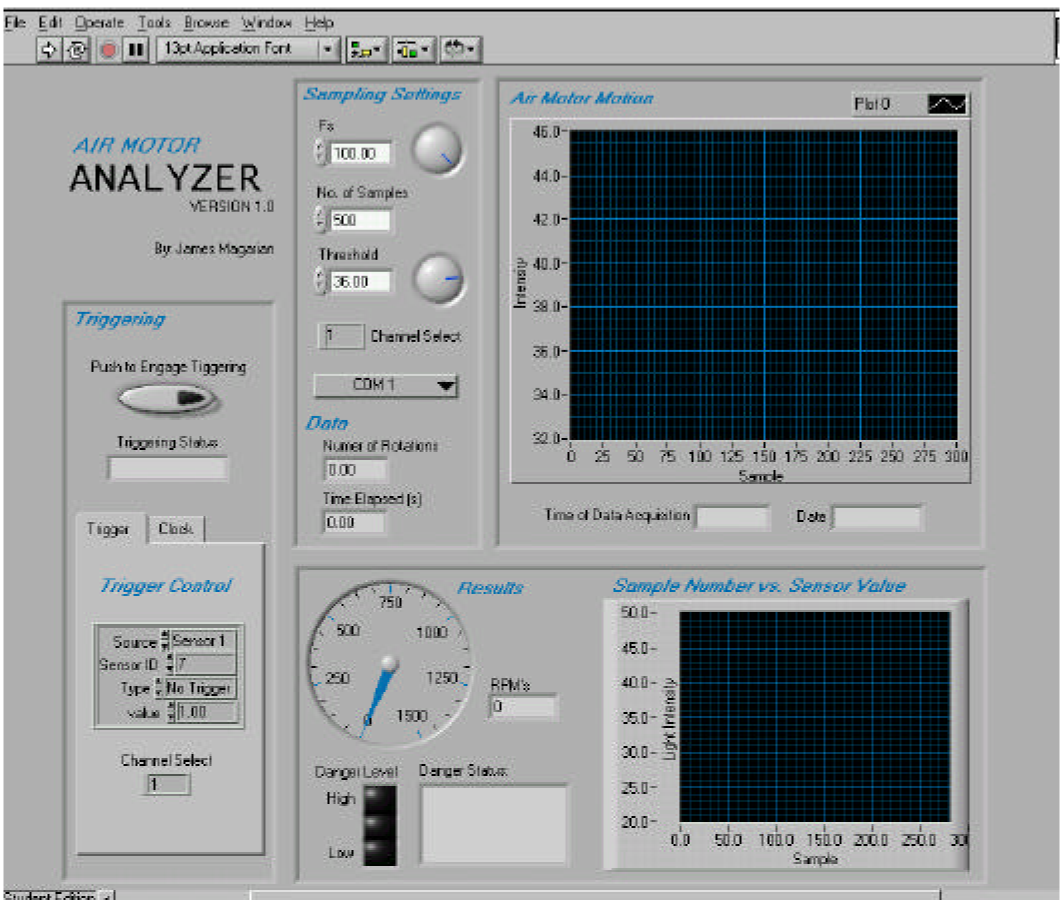

Figure 4 – Student Generated Virtual Instrument “Front Panel” Interface