Development of an Undergraduate Materials Laboratory in a Mechanical Engineering Department

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Abstract

In the Department of Mechanical Engineering at Northern Illinois University (NIU), in DeKalb, IL, undergraduate mechanical engineering students are required to take two courses focusing specifically on materials: MEE 330- Materials Science and MEE 331 - Manufacturing Processes. Previously, these courses consisted only of lectures. However, with the support of funding from the National Science Foundation's Instrumentation and Laboratory Improvement Grant Program and the State of Illinois, a laboratory section has been added to the materials science course. Our students will now gain direct, hands-on, laboratory experience about the relationship between the processing, structure, properties, and performance of engineering materials. This paper discusses the requirements of the laboratory, the equipment procured, the overall laboratory layout, and the experiments to be performed.

Introduction

A fundamental knowledge of materials science and engineering is critical to the success of industries that are important to the strength of the U.S. economy and U.S. defense[1]. American industry has noted, however, that many entry-level engineers are not being adequately prepared by universities to deal with the many new materials and processes being developed. One possible way to remedy this situation is to ensure that engineering students obtain an ample amount of direct, hands-on, laboratory experience with engineering materials.[2]

In the Department of Mechanical Engineering at Northern Illinois University (NIU), in DeKalb, IL, students are required to take the typical statics, dynamics, and strength-of-materials course sequence followed by a two-course sequence, MEE 330 - Materials Science and MEE 331 - Manufacturing Processes. Since the inception of the College of Engineering at NIU (1986), none of these courses has offered a laboratory. This shortcoming will soon be overcome, however, with the addition of a materials laboratory to be offered as a corequisite with the materials science course. The laboratory has been made possible by funding in the amount of $58,273 provided by the National Science Foundation (Grant #: DUE 9451043) and matching finding provided by the State of Illinois. Moreover, in August 1995, our college moved into a new engineering building (see Figure 1) and a substantial amount of money has been made available to help develop the new materials laboratory. With establishment of the laboratory, our materials science course will increase from three (3) to four (4) credit hours due to the addition of the laboratory corequisite.

One reason that I chose to begin my pedagogical career with NIU was that the College of Engineering had no materials engineering facilities at the time that I was hired. One of my personal career goals therefore became to establish a well-equipped laboratory where students could learn about engineering materials. I felt confident in my ability to achieve this goal due to my previous work experience in private industry, federal research laboratories, and academia. As a research engineer with ARMCO, Inc.'s Research and Technology Center, I was able to obtain a first-hand look at how an industrial research laboratory operates. My doctoral research conducted at The Materials Laboratory of Wright-Patterson Air Force Base and my Summer Faculty Research Participant fellowships at the Department of Energy's Argonne National Laboratory offered me a first-hand look at how a federal research laboratory functions. Finally, by touring the materials laboratories at Purdue University, Northwestern University, Wright State University, and The University of Dayton, I was able to determine what types of equipment should be included in a materials laboratory for undergraduate mechanical engineering students. During these tours, I also spoke with several professors to learn what types of experiments they routinely assign their students.

Some General Laboratory Issues

Over the past several years, which types of materials engineering research should receive the most funding has been a hot topic of discussion in the federal government. High on this list is materials synthesis and processing.[3] Granted that this area of research is of national concern, it is not the focus of the current project to develop a materials laboratory where students learn about research-intensive processes such as the synthesis of diamond coatings, etc. Instead, it is NIU's goal to establish a fundamental teaching laboratory in which students can gain hands-on experience with materials, possibly for the first time in their lives. In our laboratory, students will perform experiments which illustrate the relationship between the internal structure of a material and its hardness, tensile and compressive properties, magnetic properties, etc. Other major issues driving the development of the laboratory include:

. The need for our college to graduate mechanical engineers that can enter into our region's diverse industrial base and readily contribute to their employer's goals. NIU is located on the western edge of the high-growth, "high-tech," industrialized corridor extending west from Chicago along interstate highways 88 and 90, to Rockford, the second largest city in Illinois. This region, over 60 miles long, has been one of the fastest growing in population in the entire country over the past two decades. It is noted as a major research area boasting two prominent Department of Energy Laboratories, Argonne National Laboratory and Fermi National Accelerator Laboratory. The region's growth potential remains exceedingly strong and is built upon a firm and expanding manufacturing base. It is imperative that our graduates attain fundamental engineering expertise, especially in the area of engineering materials, in order that they can contribute immediately upon graduation to their employers' overall mission.

. The need for students to learn how to follow written procedural instructions. Those of us with experience in repairing automobiles or farm equipment or merely tinkering with gizmos in the garage probably can follow an instruction or repair manual fairly easily. However, for those who have never had to do these things, following written instructions can be challenging.[4] In order for students to learn how to follow written instructions in a laboratory each student will be required to purchase a laboratory manual presenting the theory involved with each assigned experiment and also giving detailed instructions on how to perform the experiments.

. The need for students to learn about safety in the laboratory. One of the most critical issues in an academic laboratory is safety. If a student were to be injured in a laboratory accident, be it the losing of an eye from the splashing of acid etch or the losing of a finger on a band saw, serious consequences could result. Such a catastrophe would have a negative effect on the College and could also result in a lawsuit being filed against the College. It is imperative, therefore, that an academic laboratory be well supervised and that the students be taught how to safely operate power equipment. By developing good safety practices early, students may someday be saved from experiencing a serious accident. Safety in the academic laboratory cannot be overemphasized.

. The need for students to learn about the environmental aspects of laboratories. Students should be trained how to properly dispose of chemicals and other potentially hazardous wastes. Too many engineers who eventually become supervisors have no knowledge regarding the proper disposal of hazardous wastes. A teaching materials laboratory is an excellent place for students to put into practice some of the principles they may have discussed in their engineering ethics class. Disregard for the environment is a very serious problem in our nation and should not be ignored.

. The need for students to learn about the care and maintenance of laboratory equipment, especially hand tools and laboratory supplies. Have you ever tried to fix your car only to discover that the person who last borrowed your tools did not return them? Even a basic work-ethic principle like always returning tools to their proper place of storage is something that should be instilled in engineering students. Some students have never had the opportunity to be instructed in matters like this.

. The need for students to gain confidence in their ability to solve problems. This may be one of the most important character traits that can be developed in a student as he/she advances toward graduation. The difference between an entry-level engineer with average problem-solving skills and one with better problem-solving skills is many times reflected merely by the amount of confidence that the person displays. One of the best ways to nurture this maturation process is to have students begin a laboratory course performing simple experiments, then continue through the semester performing experiments of increasing complexity. In this way, students learn that they *can solve* problems.

. The need for students to develop their written and oral presentation skills. A laboratory is the perfect forum to cultivate the students' ability to express themselves, both in written and oral form. However, to preclude the disdain for laboratory courses that can result from requiring students to submit very detailed and rigid laboratory reports, a different tact will be used. Instead of requiring each student to submit a separate report, groups of three, four, or five students (depending on the class size) will be formed and only one laboratory report per group will be required. This approach will encourage teamwork, a necessity in today's corporate world. Twice throughout the semester, each group will be required to present their work to the class during a short oral presentation. Computer software such as Microsoft Powerpoint, Mathsoft's Mathcad, and The MathWorks' MATLAB will be used to prepare the presentations. Using their laboratory manuals to lead them through each experiment, each student will also be required to keep a "day book" in which their progress on the experiments, including their results will be documented. It is emphasized that the entries into the day book are to be brief, but concise.[5] Using the laboratory manual and the day book, a laboratory report will be written summarizing the laboratory experiment performed. Each student's day book and each group's final technical report will be submitted for grading. The required format of the technical report, along with an example of a typical technical report taken from industry, will be available to the students as an appendix in their laboratory manual. (Note: It is envisioned that due to its writing-intensive nature, this new course will be incorporated into our college's Writing-Across-the-Curriculum Program.)

. The need to control theft and waste in the laboratory. Determining how to control theft and waste in an academic laboratory is difficult. Theft and laboratories go hand-in-hand. Moreover, it is very difficult to control theft in an academic setting unless you severely limit access to the laboratory, maintain continuous supervision, and use a very strict method of inventory control, such as requiring students to exchange their driver's licenses for tools they may wish to borrow, for example. At Northwestern University, waste is minimized by requiring the students to purchase their laboratory supplies from a university-run laboratory store. However, Northwestern University employs a full-time staff member to supervise their laboratory. At NIU, we currently do not have the funds needed to hire a full-time laboratory supervisor. Therefore, at this time, our plan is to limit the hours that the laboratory will be open to the students and keep our fingers crossed that theft will not become too much of a problem.

Equipment and Layout of the Laboratory

In choosing what equipment to purchase for the laboratory, the following question was raised. "What is the fundamental purpose of an engineering laboratory?" To answer this question it was considered that one of the most basic principles associated with engineering laboratories is the need to *measure* some quantity. Therefore, a well-equipped engineering laboratory should contain equipment capable of measuring quantities such as temperature, pressure, strain, noise, magnetism, etc. A materials laboratory should include equipment capable of applying forces so that the mechanical properties of materials can be measured. A materials laboratory should also include furnaces so that the relationship between the processing, structure, properties, and performance of engineering materials can be investigated. (This approach to teaching students about materials is the focus of the lecture portion of the course which uses the text by Van Vlack.[6])

The laboratory equipment was arranged with two principles in mind: safety and efficiency. An efficient laboratory is arranged so that the processes which take place within it flow from one work area to the next. Figures 2 and 3 illustrate the general layout of the laboratory. The laboratory includes a 2500-sq. ft. working area, two smaller 225-sq. ft. rooms, 110V, 220V, and 440V electric service, 11 0V-pedestal electric service at each of six (6) student workstation tables, a compressed air supply, a fume hood, and sinks with distilled and tap water. The six student workstation tables were designed using 2 ft. X 3 ft. panels of steel bridge deck grating positioned on either side of a 1.75-in. thick maple wood top. One-half inch thick sheets of neoprene rubber cover the sections of steel grating when a smooth working surface is preferred. This design allows the student workstations to function as versatile workbenches, or as load reaction tables when needed for mechanics-of-materials experiments involving large-span beams, etc.[7] Positioned on one section of the steel grating is an Amatrol mechanics-of-materials teaching kit (see Figure 4). These kits consist of a hydraulic actuator, a load frame, and an accessories case. Numerous types of materials behavior experiments can be performed using the kits, including tension, compression, bending, column buckling, and hardness tests. Located beside each student workstation table is a security cabinet used for storing the various pieces of equipment and instruments required for the laboratory experiments. The large 2500-sq. ft. area also houses an overhead crane and the following pieces of equipment:

MTS servohydraulic computer-controlled uniaxial testing machine
MTS screw-driven computer-controlled uniaxial testing machine
Tinius-Olsen uniaxial testing machine

Tinius-Olsen Charpy impact tester
Rockwell hardness tester
Huppert heat treat/annealing furnace
Sandpaper and rotating-wheel polishing stations
Water-cooled abrasive saw
Diamond saw
Heathway composite panel saw
Vibratory polishing station
Ultrasonic cleansing tank
Metallographic mounting presses
Vacuum ovens
Computers
Strain gage application kits
Student suggestion box
Bookshelf containing the following:
- Webster's New Student Collegiate Dictionary
- Roget's International Thesaurus
- The Making, Shaping and Treating of Steel, United States Steel, Tenth Edition, 1985
- Various Chemistry and Materials Science textbooks
- Engineered Materials Handbook, Vols. 1-4, ASM, 1990
- ASM Handbook, Vols. 1-18, ASM, Ninth Edition, 1989.
- Marks' Standard Handbook for Mechanical Engineers, Ninth Edition, McGraw-Hill, 1987

One of the 225-sq. ft. rooms adjacent to the larger work area contains a sink and all equipment requiring a relatively clean environment, i.e., a Reichert metallograph, various inverted metallographic microscopes, stereozoom microscopes, a Polaroid MP-4 macrophotographic camera, a Tukon microhardness tester, and a computer-controlled image analysis system including digitizing scanner. The other adjoining 225-sq. ft. room houses a sink and equipment required for rough processing, i.e., a band saw, a grit-blasting cabinet, bench grinders, hand tools, and workbenches.

<u>Laboratory Manual and Experiments</u>

The student laboratory manual will include the following:

- an overview of materials engineering and an introduction to the laboratory course,
- a brief discussion of laboratory safety and environmental issues,
- individual write-ups for each laboratory experiment (Each write-up will include a brief introduction to the experiment, the theory involved, and detailed step-by-step instructions on how to perform the experiment.), and
- appendices. (These will include a section on how to prepare and give an oral presentation, how to present experimental results through the use of a written technical report, and an example of a typical technical report taken from industry.)

The laboratory manual will be bound in such a way that new experiments can be added each semester. In this way, the manual can continue to be updated. Typical experiments to be assigned to the students include the following:

- Introduction to Hardness/Microhardness of Materials vs. Coldwork,
- Introduction to Mechanical Testing (tension, compression, flexure, and shear),
- Introduction to Metallography (metals, polymers, ceramics, composites),
- Introduction to Heat Treatment vs. Mechanical Properties,
- Introduction to Heat Treatment vs. Microstructure,
- Introduction to Impact Testing,
- Introduction to Fatigue Analysis,
- Introduction to Failure Analysis,
- Introduction to Temperature-Dependent Behavior of Materials, and
- Introduction to Time-Temperature-Dependent Behavior of Materials.

Summary

The objective of this paper has been to describe the development of a teaching materials laboratory in the Department of Mechanical Engineering at Northern Illinois University. The objective of the paper has not been to describe the specific experiments that will be assigned to the students. There are a multitude of materials engineering experiments that can be assigned to students in a typical materials engineering laboratory course. The reader is referred to the excellent compilation of such experiments in the work by Dr. Jacobs of Norfolk State University.*

At NIU, we have attempted to build an engineering materials teaching laboratory that is equipped with a wide variety of materials processing and testing equipment. The equipment is arranged so that the versatility and efficiency of the laboratory is maximized. An overriding goal of the development of the laboratory has been to build a laboratory that students would want to go to, rather than dread to go to. We feel strongly that laboratory instruction of the fundamentals of materials engineering is critical to the preparation of mechanical engineers that are in command of the fundamentals of mechanical engineering, are confident in their abilities, and can contribute to their employer's mission immediately upon hire. When the laboratory comes on-line in Fall 1996, we envision that our student enrollment and student retention rate will increase as word spreads that NIU's College of Engineering is committed to academic excellence through the practical application of engineering fundamentals.

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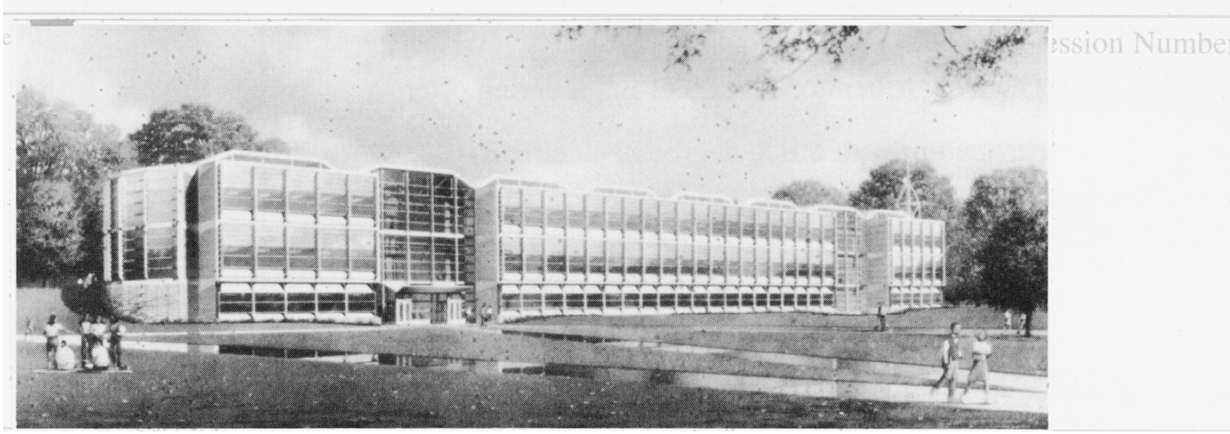

Figure 1. Northern Illinois University's College of Engineering. Opened August 1995.

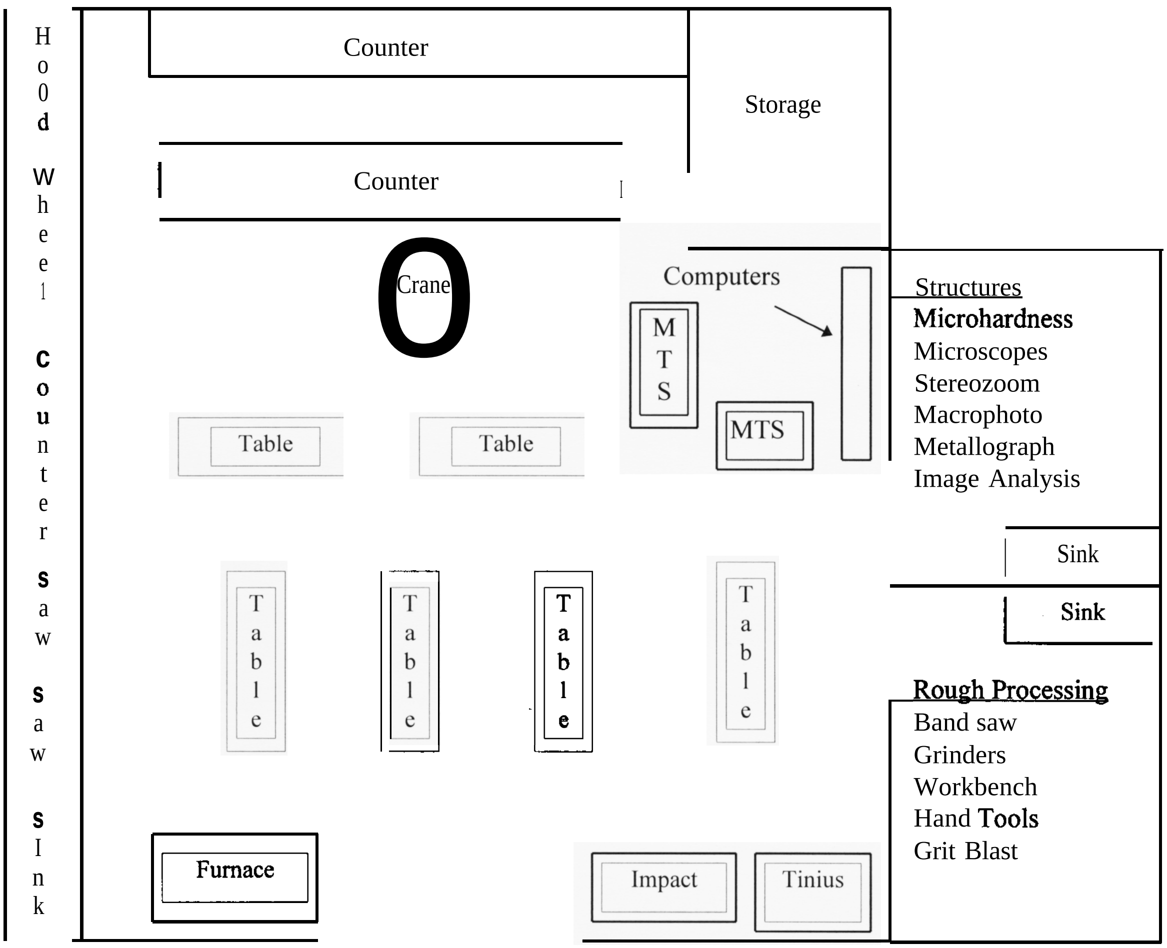

Figure 2. General layout of the materials laboratory. Main area is 50' X 50.' Two smaller rooms to the right are 15' X 15.' ["MTS" and "Tinius" are uniaxial testing machines. "Hood" is a chemical fume hood. "Wheel" is a two-wheel polishing station. "Saw" are two types of water-cooled abrasive saws. "Table" are student workstation tables complete with storage space and 11 OV electrical service.]

Figure 3. Materials Laboratory at NIU.

Figure 4. Amatrol mechanics-of-materials teaching kit.

Do not go beyond this point