Introducing Emerging Technology into the Engineering Curriculum Through Capstone Projects

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Abstract

In the one semester, three engineering department, capstone design course taught in the Cullen College of Engineering at the University of Houston, multidisciplinary teams work on design projects provided by local industry and the faculty. A rich source of good design problems associated with emerging technology has been some of the University's research laboratories. This paper will describe some of these projects and how the entire class, as well as all engineering students, are introduced to the emerging technology associated with these projects.

Introduction

In episode 1410 of the "Engines of Our Ingenuity,"[1] John Lienhard states,

> "The Greek word tecnh (pronounced techne) describes art and skill in making things. Tecnh is the work of a sculptor or a stonemason, a composer, or a clock-maker. Ology is the study or the lore of something. Technology is the knowledge of making things. Some argue that we shouldn't call our species Homo sapiens or the-wise-people, but rather Homo technologicus or they-who-use-tecnh, for that is who we are.
>
> We freed our hands by walking on our hind legs before we took up tool-making. When we made our earliest stone tools 2.4 million years ago, our brains were still fairly small. Our capacity for thought began growing after we began making sophisticated implements. Thinking and tool-making are wed to one another."

Further, the American Heritage Dictionary's first definition of "technology"[2] is: "The application of science, especially to industrial or commercial objectives" which sounds much like their definition of "engineeing"[3]: "The application of scientific principles to practical ends as the design, construction, and operation of efficient and economical structures, equipment and systems."

Over the past 40 years undergraduate engineering curricula have "dropped" much of its traditional "technology" and replaced it with additional analysis based instruction and computation as the content has been reduced from about 150 hours to about 125 hours.

There are fewer and fewer “hands-on” opportunities for the students. Also the classic areas forming the foundations of the major engineering disciplines are beginning to branch out, for example, electrical engineering into micro electronics, computer engineering and information systems; mechanical engineering into nano-technology, smart materials, bio-medical engineering and micro-medical systems, etc. These areas are considerably more “high-tech” than electrical circuit bread-boarding, antenna design, engine testing, HVAC systems testing and classic controls which are some of the hands-on technologies utilized in undergraduate laboratories and design projects. Also, some of these “advanced” topics are not taught as part of the core undergraduate curriculum, nor even as part of special electives. The issue is then how to provide exposure to these emerging technologies to engineering students without introducing new courses. We have been attempting to solve this problem through our interdisciplinary capstone design course with the help of faculty working in these emerging areas.

The capstone design course at the University of Houston is taken by three of the five engineering departments: Mechanical Engineering, Industrial Engineering, and Electrical and Computer Engineering. The course was originally taught in the Department of Mechanical Engineering (ME) and has existed (until recently), more or less, in its present form since 1981. At that time it was taken by all mechanical engineering undergraduates. In the mid-80’s the Department of Industrial Engineering (IE) joined the course so that project teams were composed of both ME and IE students. The course was offered in both the fall and spring semesters and was being taken by up to 80 students a year. Five years ago the Department of Electrical and Computer Engineering (ECE) added the course as a degree requirement for all students entering in the fall 1998 and thereafter. Shortly thereafter some ECE students began taking the course as an elective. That number has grown over the past four years to about thirty in the fall, 2002. Fifty-five ECE students (for a course total of 86) were enrolled for the spring, 2003. There are currently (Spring 2004) 56 ECE students in a class of 87. It is anticipated that between 80 and 100 students from the three departments will eventually be enrolled in the course each fall and spring semester on a continuing basis. More complete descriptions of the new capstone course can be found in References 4 and 5.

One of the features of our capstone course is that most of the interaction with and among the teams occurs in cohorts composed of three or four teams. For example, for spring 2004, eight sets of 90-minute cohort meetings are scheduled at approximately two-week intervals. (Each set is actually six meetings as the 87 students in the class are divided into 22 teams, and the teams assigned to one of six cohorts.) Project planning and communication issues (as well as many other “professional” issues) are discussed with the current projects used as examples or case studies. The teams with projects involving similar technology are grouped in the same cohorts. Teams make informal presentations and present samples of their work at each cohort meeting. The teams are encouraged to work together as appropriate. There are four rounds of oral and written reports before the final report. These four reports are individual requirements, and the oral reports are presented to a rotating audience of different cohorts throughout the semester. Therefore by the end of the semester each student has heard at least two reports on each project. Therefore the “emerging technology” project of one team receives a significant exposure throughout the cohort and a limited exposure throughout the entire class. In addition, at the end of the semester, all teams prepare poster presentations and extended abstracts (as well as the usual final oral and written team reports) that are on display for three days in the Commons area for the Cullen College of Engineering for all engineering students and faculty to view.

The research laboratories that have had significant involvement with the capstone course over the last two years are listed below:

1. The Micro-Nano Engineering Laboratory[6]
Department of Electrical and Computer Engineering
Director: Jack Wolfe
Associate Director: Paul Ruchhoeft

The Micro-Nano Engineering Laboratory's (MNEL) mission is technology development for commercial applications of micro-and nanometer scale structures. The laboratory provides equipment and know-how to support a variety of projects spanning the range from novel integrated circuit structures to water purification filters. Students, both graduate and undergraduate, are provided with a common office space to facilitate crossdisciplinary learning.

Facilities include an ion beam proximity lithography tool, two RIE systems, a high-density plasma etching cluster tool with two process modules, a sputtering system with six sources, an SEM, a PECVD system, a microwave plasma etching system, and a small clean room. Many of the MNE Lab's projects use ion beam lithography. This is a process for defining integrated circuit structures where light ions, helium or hydrogen, expose resist. A broad, collimated ion beam irradiates a stencil mask, a thin silicon membrane containing a pattern of fine holes, and beamlets of transmitted ions transfer the mask pattern to a resist-coated workpiece. In the simplest implementation of this technique, ion beam proximity printing (IBP), the workpiece is positioned close to the mask and the image is transferredwithout changing in scale. A more sophisticated version is ion projection lithography (IPL) where the transmitted ion image is projected onto a wafer at a reduced size. Ion projection lithography is among the contenders for sub-75 nm IC manufacturing.

2. Optoelectronic Material and Devices Laboratory[7]
The Texas Center for Superconductivity and Advanced Materials
Director: Steven Pei

The Optoelectronics Materials and Devices laboratory focuses on developing novel mid-infrared (IR) sources and detectors with Ga(In) Sb/InAs/Al(In)Sb heterostructure materials. The primary thrust is to explore their potential in trace gas detection, remote chemical sensing, IR countermeasures, and IR imaging for commercial, space and defense applications. Laboratory capabilities include computer simulation of optical, electrical, and thermal properties of heterostructure devices, growth of compound semiconductors by Molecular Beam Epitaxy, characterization of electrical and optical properties of thin films, fabrication of advanced optioelectronic devices, testing of mid-IR photonic devices and high speed electronic devices and circuits, characterization of time dependent phenomena with pico- and femto-second pulsed laser.

Current projects include:

- Optically pumped type-II quantum well lasers for IR countermeasures
- Interband cascade and type-II superlattice diode lasers for chemical sensing applications
- Long wavelength IR photodetector based on type-II quantum wells
- Compliant universal substrates

3. Smart Materials and Structures Laboratory
Department of Mechanical Engineering
Faculty-in-Charge: Gangbing Song

The Smart Materials and Structures Laboratory (SMSL) supports research and teaching in the area of smart materials and structures. The main research activities include:

- Active vibration control using piezoceramic materials and shape memory alloys,
- Passive vibration control using shape memory alloys and magneto-rheological (MR) fluids,
- Health monitoring using smart materials, and
- Teaching tools using smart materials.

With funding from National Science Foundation, NASA, and University of Houston, the laboratory has state-of-the-art equipment, including six sets of dSPACE digital data acquisition and real-time control systems, three sets of optical fiber Bragg grating strain measurement systems, multiple oscilloscope and function generators, multiple low and high voltage power amplifiers for piezoelectric actuators, and multiple programmable current amplifiers. The laboratory also has many specific experimental setups to assist research and teaching. In addition to research, SMSL is highly integrated with the teaching mission of the University of Houston. SMSL sponsors and advise several senior capstone design projects each year, provides research experience for undergraduate (REU) projects, and has developed many experimental demonstrations for several undergraduate courses. SMSL has also been used actively as a tour site for outreach activities.

Fourteen projects of the sixty-five different projects (involving seventy-three teams) run in the last two years (four semesters, spring 2002 to fall 2003) in the capstone course which are considered to be in the areas associated with emerging technologies are listed and grouped under the three headings in Table 1. The number following the project refers to one of the three research laboratories listed above.

Table 1: Emerging Technology Projects: Spring 2002 to Fall 2003

Nano-Technology and Micro-Electronic Fabrication Systems

Positional Feedback System for Metrology Stage, fall 2003 (1)
Manufacturing Research Data Base, spring 2003 (1)
Preparation of NASA Nanocomposites, spring 2003 (project for NASA JSC)
Design of In-Vaccum Cold Chuck, spring 2003 (1)
Design and Construction of a High-Density Plasma Etching System, fall 2002 (1)
Control System for an x-y-θ Stage for Ion Beam Lithography, spring 2002 (2)
Effusion Cell Control System for Molecular Beam Epitaxy, spring 2002 (2)
Plasma Etching Control System, spring 2002 (1)

Controls: Smart Materials

Active Guide Wire for Angioplasty, fall 2003 (3)
Smart Crutch using an MR Fluid, fall 2003 (3)
Demonstration of Shape Memory Alloys, spring, 2003 (3)
Demonstration of Magneto-Rheological Fluids, spring, 2003 (3)

Biomedical Engineering: Haptic Systems

Remote Sensing Hand Using Internet for a Haptic Interface, fall 2003 (3)
A “Feeling” Robotic Hand, spring 2003 (3)

Seven of the fourteen projects (all in the first category) were sponsored by the two UH research laboratories concentrating on nano-technology. Four projects were proposed and advised by the Smart Materials Laboaratory in the Department of Mechanical Engineering. The two haptic system projects were undertaken at the suggestion of the Bioengineering Department at Texas Children's Hospital in Texas Medical Center in Houston, but advised by the Smart Materials Laboratory.

The Project Abstracts

Plasma Etching Control System, spring 2002

A LabView control interface for a plasma etcher was developed and tested and shown to be successful. This plasma etcher was used for patterning microcircuits on silicon chips in a vacuum chamber. The program controlled the vacuum system, the power supplies, and the pressure controller. The program also provided an interface for collecting and storing the operational data.

Effusion Cell Control System for Molecular Beam Epitaxy, spring 2002

A LabView control interface was designed, installed, and tested to control a Molecular Beam Epitaxy device. The program controlled the heater and the shutter and monitored a thermocouple. The LabView program also provided a user-friendly interface with the operator and monitored the data collection process.

Control System for an x-y-θ Stage for Ion Beam Lithography, spring 2002

A functional x-y-θ stage control system with a load-lock arm and substrate holder was successfully designed and fabricated to replace an existing manual system in an ion beam lithography system. A LabView control interface was also installed with the system. The new system allowed for the substrate to be moved relative to the mask so that several images could be formed without breaking into the vacuum system.

Design and Fabrication of a High-Density Plasma Etching System, fall 2002

Support equipment was designed and fabricated for a plasma etching system to produce small, straight holes in a polymer membrane to be used as part of a water filtration process to replace a chemical disinfection process. A controller, cooling system and RF power supplies were built. A membrane loading procedure was developed using a specially designed tool.

Design of In-Vaccum Cold Sink, spring 2003

A backside helium cooling system was designed to reduce stencil mask distortion due to overheating during x-ray lithography used for integrated circuit fabrication. Thermistors, placed on the membrane surface as carbon cement, were used to measure the temperature of the fragile membranes. The thermistors were calibrated with the aid of a digital hot-plate.

Preparation of NASA Nanocomposites, spring 2003

A mixing device was designed and fabricated to uniformly disperse nanotubes within an epoxy in order to increase the tensile strength of the epoxy. An existing mixer was replaced with a new device containing a variable speed motor capable of rotational speeds up to10,000 RPM with a 10 blade, aluminum impeller. A new vacuum mixing vessel was fabricated with special sealing around the shaft. Testing showed that the new mixing device did improve the quality of NASA's nanocomposites.

Manufacturing Research Data Base, spring 2003

A user-interface to an existing database was developed using MS Access database software and ColdFusion web-application software to establish a more efficient method for tracking the data associated with the manufacturing films and masks from silicon wafers. The final product was a thoroughly tested, web-based system in which the user has the ability to scan a bar code and retrieve or input data associated with a wafer's manufacturing process. A comprehensive user's guide was provided.

A "Feeling" Robotic Hand, spring 2003

This was a haptic feedback, demonstration project, and represented the first step in the design and implementation of a "Feeling" Robotic Hand that could be used, along with other sensors, to practice medicine at the distance. A pressure sensor (acting as a "probing finger") was calibrated and used to produce a proportional current to drive a force actuator, a voice coil, that applied a calibrated force to the "sensing finger".

Demonstration of a Magneto-Rheological Fluid, spring 2003

Three interactive experiments/displays illustrating the properties and applications of a Magneto-Rheological (MR) Fluid were designed, fabricated and tested. An MR fluid is a fluid whose viscosity changes in the presence of a magnetic field. The three experiments are: a MR fluid disk brake, a vibrating platform with MR fluid dampers, and a crane that raises and lowers an electromagnet in and out of an MR fluid. All three experiments possess interactive controls and were mounted in a ventilated, acrylic display case. A detailed description of this project is provided in the next section.

Demonstration of a Shape Memory Alloy, spring 2003

Two electrically controlled, interactive Shape Memory Alloy (SMA) actuator demonstrations were designed, fabricated and tested. A SMA is a metal that demonstrates the ability to return to some previously defined shape or size when subjected to the appropriate heating or cooling. The first demonstration is a weight lifting mechanism that uses seven strands of 0.015 inch diameter Nitinol wire to lift twenty pounds when the wires are electrically heated. The other demonstration is a flexible limb mechanism composed of a strip of flexible metal that has 0.015 inch Nitinol wire actuators attached to both faces of the limb. The coordinated, alternating electrical heating of each wire allows controlled movement of the flexible limb. The Nitinol has a transformation temperature of 90ºC, at which its crystal lattice structure changes from Martensite to Austenite that results in contraction of the wire. Both demonstrations are housed in a ventilated acrylic case currently on display in the lobby of the Department of Mechanical Engineering.

Implementation of a Positional Feedback System for Metrology Tool, fall 2003

The x-y stage of a metrology tool used to examine semiconductor wafers has been upgraded by implementing a positional feedback system using a proportional-derivative control scheme and coded with LabView software that interacts with a charge-coupled-device camera to determine the coordinates of the stage. Testing of the system revealed that the system's precision was about 20 microns which was not acceptable. Part of the problem was traced to way the camera acquires images and to the positioning errors associated with the DC motors.

Remote Sensing Hand Using the Internet for a Haptic Interface, fall 2003

The "Feeling Hand" project from the previous spring was repeated. Different techniques were utilized for both the "probing" and the "sensing" finger, and an internet link was added between the probing and sensing functions. A unique "probing finger" sensor was designed fabricated, calibrated, and tested successfully. The internet link was established using LabView. An attempt was made to develop a novel "sensing finger" using a (variable viscosity) MR fluid (see above) as the working fluid in a cylinder-orifice system but it was not successful.

Smart Crutch Using an Electro-Magneto Fluid, fall 2003

A Magneto-Rheological (MR) Fluid (see above) sponge damper controlled by an electromagnet was used in the design of an innovative crutch. A predetermined (and controllable by the user) electrical signal was generated with each crutch impact with the ground and then used to control the "damping" constant of the system (through the MR fluid) to reduce the impact shock of the crutch. The design was fabricated but met with only limited success because a damper system with a satisfactory orifice opening was not found. The iron particles present in the MR fluid tended to plug up the orifice.

Active Guide Wire for Angioplasty, fall 2003

A method was developed and implemented (in principle, not in patients) to overcome the lack of control in current procedures for directing the guide wire into position in the artery for an angioplasty procedure (displacement of plaque buildup in coronary arteries). Two Shape Memory Alloy (SMA, see above) actuators were micro-welded to opposite sides of the wire. By selectively heating and/or cooling the two opposed SMA actuators (by applying a pulse-width modulated current), the guide wire can be forced to turn to one side or the other as dictated while the progress its tip is followed on a real time fluoroscopic x-ray screen.

Two of these projects were motivated and specifically designed to increase undergraduate student interest and awareness of two modern controls actuators: “Demonstration of a Shape Memory Alloy” and “Demonstration of a Magneto-Rheological-Fluid”. A description of the MR fluid project is given below.

The Demonstration of a Magneto-Rheological-Fluid

An MR fluid is a liquid whose viscosity changes in proportion to an applied magnetic field. When the magnetic field is controlled by a computer, an MR fluid system can also become a very effective control device. The description to follow was taken from Reference 8

Introduction

The MR fluids have been around since the 1950’s and have been used in several vibration control devices.[9] The objective of the project was to raise the awareness and interest of University of Houston students and visitors to Smart Materials, especially MR-Fluids, by building an interactive display showcasing their properties and applications.

The original MR fluids, as designed by Jacob Rabinow, were nine parts iron particles and one part carrier liquid, which at the time was either silicone oil, petroleum oil, or kerosene depending on which one better suited the particular application. Additional additives improved the stability of the fluid and retarded the settlement of the particles. Even though the settlement of the iron particles remains an issue, it is mainly overcome by the dynamics of the applications. Since the relevant property of these fluids is their viscosity and the ability to control it, most of the applications are concerned with the shear forces applied to the fluid; therefore the relationship between magnetic field strength and shear yield stress is very important. This relationship varies with the composition of the fluid, but yield stresses in the order of 50 to 100 kPa and with initial fluid viscosities (without magnetic effects) of 0.1 to 1.0 Pa-s are commercially available. Figure 1 presents a yield stress vs. magnetic field intensity plot for a commercially available material.

Three interactive MR fluid experiments[8] were designed and fabricated: a magnetic-lift crane, a vibrating platform, and a disc brake. The experiments were designed to display the fluid’s properties as well as a few of its applications. All three experiments are fully interactive with the user via a control panel located on the front of the display case. Safety was a key concern in the design of the experiments. Another important feature was designing a visually pleasing set of experiments that required low maintenance.

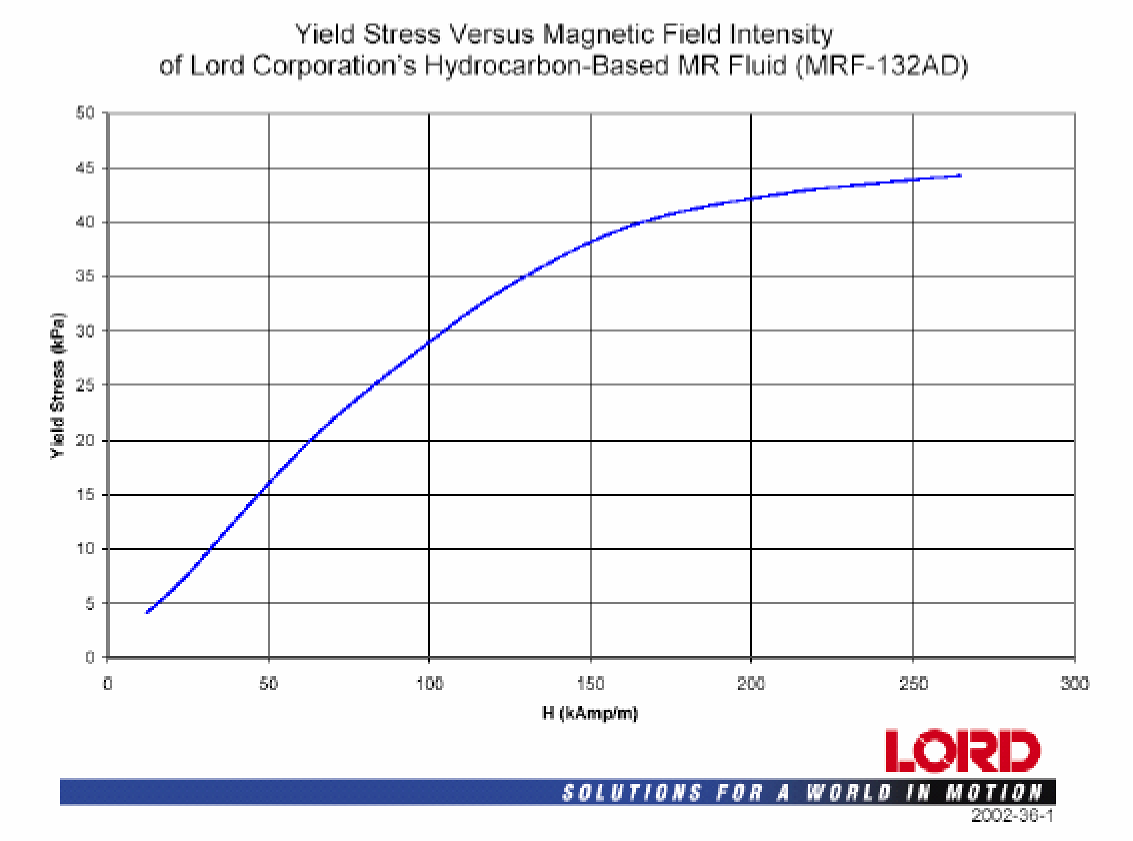

Figure 1: Yield Stress vs. Magnetic Field Intensity [10]

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The Magnetic-Lift Crane

The magnetic-lift crane illustrates how the MR fluid solidifies when a strong magnetic field is applied to it. A pulley platform was built to hold the wire that raises and lowers an electromagnet into a vat of MR fluid. As the magnet is immersed in the fluid, the user has the option of turning on the current to the magnet thus producing a magnetic field in a portion of the fluid. The MR fluid solidifies in the vicinity of the magnet and is picked up as the magnet is raised. Once the magnet is raised, the current can be turned off. Without the magnetic field, the solid reverts to a liquid state and falls freely back into the vat and splashes, allowing the user to see this transition from solid to liquid. The electromagnet is attached to a metallic rod that runs through a linear bearing to prevent side-to-side movement of the electromagnet so the fluid will not be splashed outside the container. Two square rods were added to the platform. One prevents the rotation of the electromagnet, while the other provides a place for position sensors to be mounted. The full set up of this experiment is shown in Figure 2. The crane's electromagnet has a 3-inch diameter core with 1000 turns of 26 AWG wire. The core has a ½-inch gap where most of the fluid picked up is held. The resistance of the electromagnet is 8.0 ohms. A

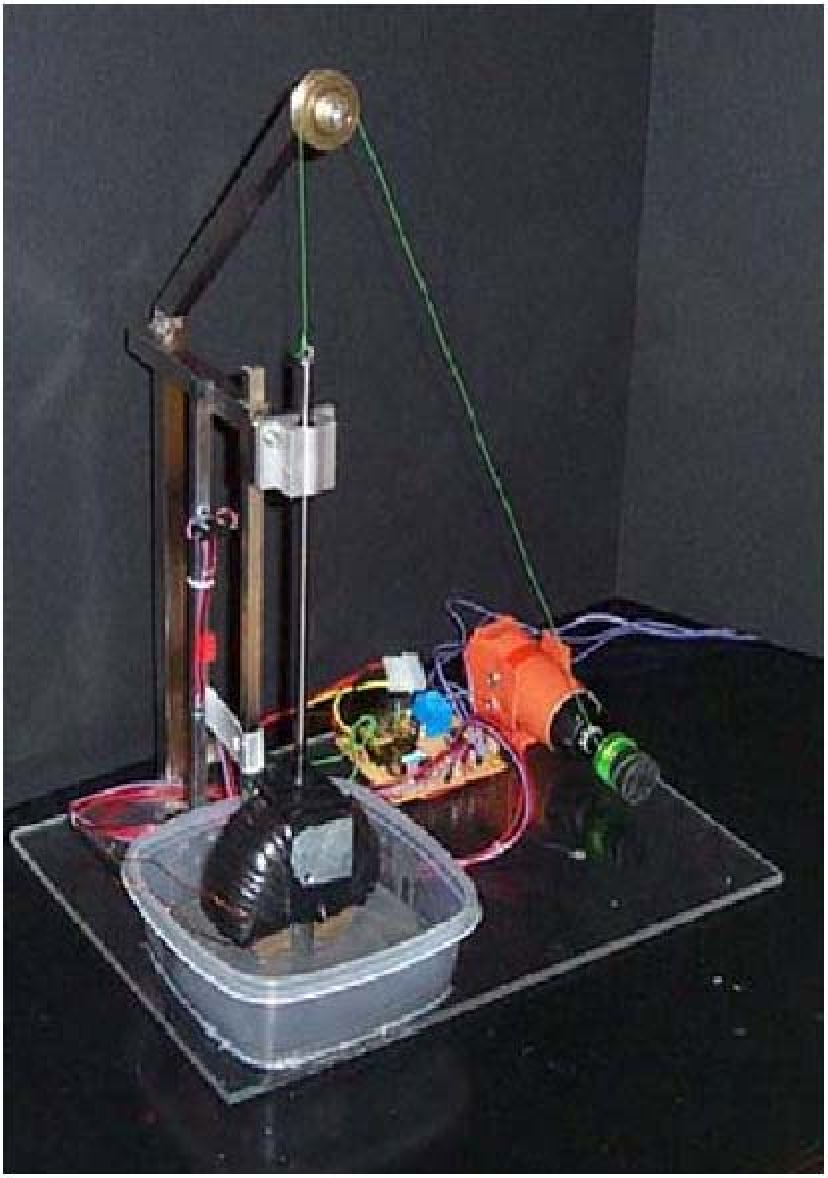

Figure 2: Magnetic-Life Crane

current of 1.0 A is required to generate the magnetic flux required for this experiment. A high torque motor was needed to lift the weight of the magnet as well as the solidified fluid. A Black & Decker™ 2.4 V electric screwdriver motor was used to provide the needed torque. A fishing line, which holds up to 25 lbs, was used to lift the electromagnet. The entire platform is constructed from 302 stainless steel. The crane, the vat, and motor are mounted to a piece of ¼-inch acrylic for easy installation and removal from the display case.

Vibrating Platform

The next experiment is a vibrating platform. The objective of this experiment is to show a direct application of the MR fluid to provide controlled vibration damping. The vibrating platform is shown in Figure 3. On top of the platform there is a DC motor that spins an unbalanced weight causing the platform to oscillate. Underneath the platform there is a metal plate that is attached to the platform itself and extends into a long, narrow container of MR fluid. Around the container holding the MR fluid is an electromagnet that when activated, increases the viscosity of the MR fluid which restricts the movement of the metal plate, therefore damping the vibration of the platform. This container is 5.0 inches high by 10.0 inches wide by 3/8 -inch thick. It is made out of Plexiglas to allow the user to see the fluid. The stand is made of copper fittings and ½ -inch copper tubing. The vibrating platform is attached with four horizontal springs to the stand (the yellow rectangle in Fig. 3). The internal dimensions of the stand are 12.0 by 10.0 inches. This is to provide enough room for the platform and for the springs to be slightly stretched. The platform itself is 6.0 by 4.0 inches and ¼-inch thick. The springs are 1½ -inches long and have a spring constant of 2.0 lb_f/inch. The (yellow) stand is detachable from the aluminum base plate. The legs of the stand are screwed into copper hubs that are permanently attached to the base so that the stand can be removed from the rest of the device for easy access to the container. Also, the container is held in place by a set of brackets that allow for the container to be removed from the base. Every part of the device is removable to allow for easy replacement of any defective part. The DC motor

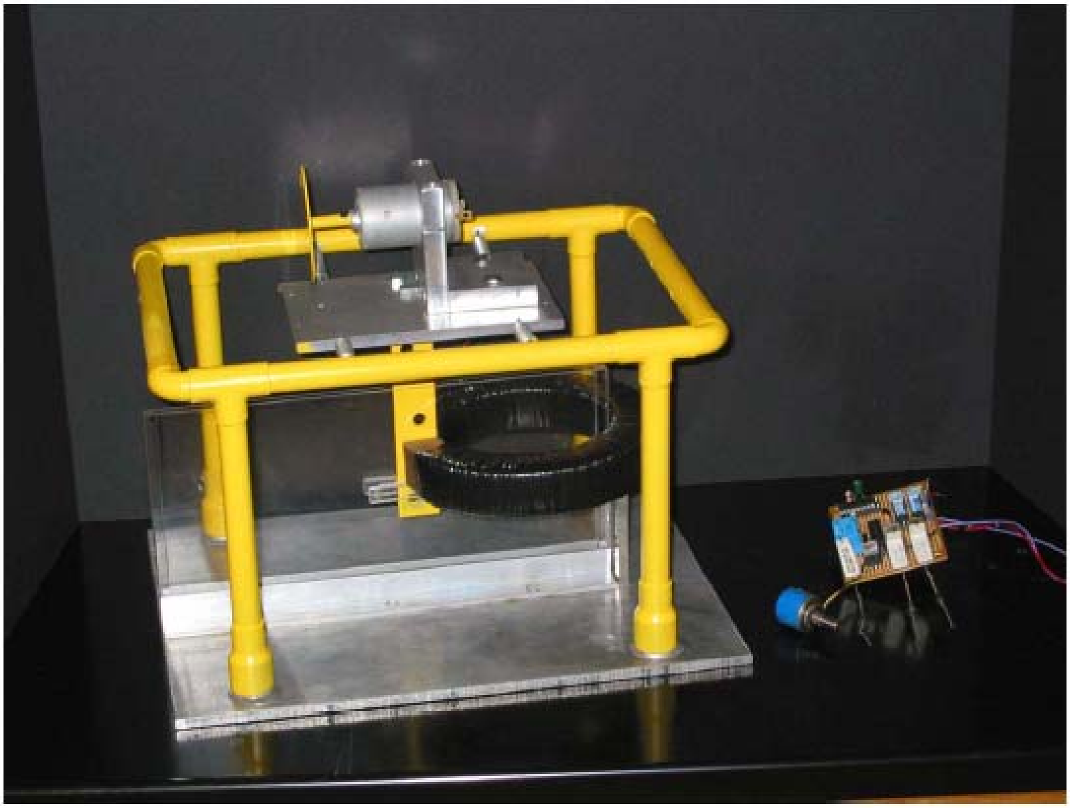

Figure 3: Vibrating Platform

has an initial input current of 2.4 A to overcome inertia and static friction. As soon as the motor starts spinning the microcontroller lowers the current to 1.0 A to keep the motor running at a low speed. The objective is to produce a rate of vibration that can be totally damped by the fluid. A detachable "L" bracket is used to hold the motor. The bracket allows the motor to be placed in different locations along the platform. The electromagnet used has a diameter of 6.0 inches with two coils connected in parallel each having approximately 1000 turns of 26 AWG wire and a total resistance of 8.0 ohms. The electromagnet is held in place by Plexiglas extensions that are glued to the container. The user has control over the starting and stopping of the motor but not over the amount of current that is provided to the motor; the current is regulated by a microcontroller. The user also has access to a 10-turn potentiometer that controls the current provided to the magnet which controls the viscosity of the fluid and hence the level of damping.

Disk Brake

The main body of the disk brake (Figure 4) is composed of three different materials. The outer shell, containing the fluid reservoir, is constructed from clear acrylic to allow the enclosed disk and fluid to be visible. The main bracket, base, and supports are constructed from aluminum. Aluminum was chosen because it is unaffected by the magnetic field. The third part is the disk and crank assembly, and it was fabricated with 1018 carbon steel. The steel disk allows for some of the magnetic field to be spread out over a larger area to increase the stopping power of the brake. Two journal bearings were chosen to support the crank and disk on the stands, and automotive camshaft seals were used to seal the bracket to the crank. The whole rotating assembly is lubricated with

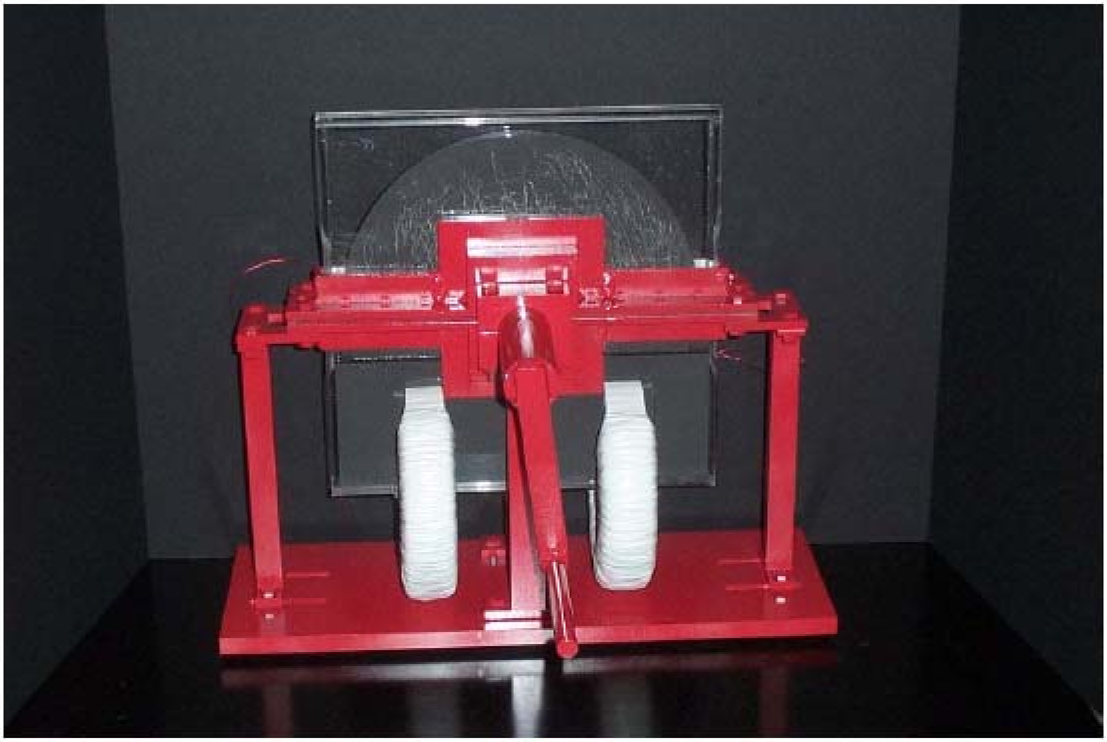

Figure 4: The MR Brake

automotive assembly lube. The fluid reservoir width is critical since making it too wide means that more current will be needed to ensure an adequate magnetic field is applied over the larger gap, and making it too small would mean a tighter tolerance on the disk to prevent rubbing on the fluid reservoir. A ¾ -in dimension was chosen for the gap. With a current of 3.0 A, a strong enough magnetic field is applied over the gap. The magnets (the two white coils near the center of Fig. 4) each use 26 AWG wire with three coils each having 500 turns. All six coils (three on each magnet) are connected in parallel to ensure that the magnets have the lowest resistance possible. Two thermistors are attached to the magnet cores to monitor their temperatures. If the temperature of a magnet rises above a predetermined level, the experiment will shut down automatically.

By turning the crank (in the center of Figure 4) the user obtains a direct indication of the fluid's "resistance" which, of course, increases as the strength of the magnetic field increases. The user has access to a knob that increase and the decreases the current provided to the electromagnet, regulating the strength of the magnetic field applied to the fluid. The knob is a 10-turn potentiometer that prevents the user from increasing the current too fast. The circuit therefore has no "spikes" or sudden changes in the current flow so the need for a differential controller is avoided.

Electronics and Controls

To control each experiment, the PIC16F84A microcontroller (from Microchip Technologies) operating at 4 MHz was selected. This controller has two I/O ports, an 8-bit free running counter with pre-scaler, four interrupt sources, and can sink or source 25mA per I/O pin. The cost is under $7.00, and the development environment can be downloaded for free from the manufacturer's website. The electromagnet cores were built of steel-1018 (low carbon steel), and the wire gauge used was 26 AWG except for the crane (23 AWG). The magnets were wound as superimposed independent coils that were later connected in parallel to minimize the magnet's resistance. All the circuits were mounted in individual prototyping boards to allow each experiment to function as a stand alone if necessary. The flow charts describing the logic of operation of the experiments and the assembly language code are available in Reference 8.

Safety Considerations

The experiments are powered from two 160 Watt computer power supplies. These pre-built devices are extremely stable and offer good surge protection. In addition, the two power supplies are connected to an extension cord with surge protection. The experiments have been carefully designed not to exceed the power supplies' power limits, and there are fuses in every critical part. As an additional feature, the display case is equipped with a supervisory circuit that turns off all the experiments if there is no system adjustments for two minutes. Most internal circuitry includes calibration potentiometers to allow fine-tuning and calibrating different parameters as components degrade over time. Relays were used to provide isolation between the high-current side of the circuit (i.e., motors and magnets) and the low current side (i.e., microcontrollers).

The Display Case for the MR Fluid Experiments

The three interactive experiments were mounted together in a display case. The display case is fully interactive and self-explanatory. The user would have no problems operating each experiment. Nevertheless, instructions for each experiment are posted with the case. In addition, a brief background of the history of MR fluids is exhibited behind the experiments. This display case will be of interest to by-passers and will help to raise their awareness about the MR fluids.

Conclusions

As engineering undergraduate curricula have been reduced in hours and become more analysis and engineering science based over the last 40 years, "technology" has been displaced from the curriculum. Current and "old" technology appears in textbooks and faculty discuss "applications" in class. However, there are few opportunities for undergraduates to "work" with products of the emerging technologies. The "leading edge" engineering research laboratories in the University have been shown to be good sources of interesting design projects involving systems associated with emerging technologies. Fourteen such projects which were undertaken over the past two years in the multidisciplinary capstone course in the Cullen College of Engineering at the University of Houston have been described in this paper. The paper has also described how the benefits of these projects have been extended not only to the other students in the class but also potentially to all engineering students.

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Biographical Information

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Richard Bannerot is a professor in the Department of Mechanical Engineering at the University of Houston. His research interests are in the thermal sciences and in engineering design education. For the past thirteen years he has taught the required "Introduction to Design" course at the sophomore level and has recently become involved in teaching the capstone design course. He is a registered professional engineer in the state of Texas.

ROSS KASTOR
Ross Kastor is a lecturer in the Department of Mechanical Engineering at the University of Houston. He has been teaching the capstone design course since 1991. He completed more than 40 years as a drilling engineer for Shell Oil Co., where he spent 16 years teaching drilling engineering in Shell's inside schools. He majored in machine design at The Ohio State University where he received the BSME and MSME degrees. He is a registered professional engineer in the States of Ohio and Texas.

PAUL RUCHHOEFT
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