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NOISE CONTROL ENGINEERING EDUCATION AT PURDUE UNIVERSITY

R J Bernhard, J S Bolton, P Davies, J D Jones & L Mongeau

Ray W Herrick Laboratories, School of Mechanical Engineering, Purdue University, West Lafayette, IN 47907-1077, USA

INTRODUCTION

The noise control engineering educational program at Purdue University is included within the curriculum of the School of Mechanical Engineering. It consists of both undergraduate and graduate level courses, and graduate education opportunities which include a research component. In this paper the current program will be described with emphasis on elements the authors believe are particularly important to the success of graduate noise control engineers. The future directions of the program will also be discussed.

THE UNDERGRADUATE PROGRAM OFFERING

Historically, the noise control engineering educational program at Purdue evolved within the School of Mechanical Engineering. While there are complementary programs within the University for acoustics, audiology and electro-acoustics education, the education programs concerned with noise control developed around the noise control engineering research program initiated in the early 1970's at the Ray W. Herrick Laboratories, which is part of the School of Mechanical Engineering. Thus, the educational program evolved with a focus on mechanical engineering topics.

Undergraduate mechanical engineering programs in the United States are constrained by the Accreditation Board for Engineering and Technology, Inc. (ABET) to require a certain set of core courses. The requirements leave little room for defining a specialty in noise control engineering. However, the students of these programs are well grounded in fundamentals such as mechanics, measurement theory, electrical circuit theory, design, and mathematics. From this basis it is relatively straightforward to develop the skills required of a noise control engineer. To allow an introduction to the specialty area of noise and vibration control engineering, two classes are offered within the School of Mechanical Engineering as final year technical elective courses. Course descriptions and textbook information for these courses are shown in Table 1. Students may also take so-called dual-level graduate classes, which are open to both undergraduate and graduate students as electives. Course descriptions and textbooks for dual-level classes are shown in Table 2.

It is traditional in the United States to monitor a student's studies in undergraduate programs rigorously. Students are required to turn in homework and take examinations during the term. This type of educational delivery has the advantage that all students are

Table 1: Undergraduate Elective Courses

Course	*Title*	*Course description*
ME413	Noise control (Text: Foreman[1])	Fundamentals: acoustic waves, reflection, scattering, absorption, tones, noise. Psychoacoustics: voice, ear, theories of hearing, loudness, deafness. Environmental acoustics: sound in buildings, acoustic tiles, sound insulation, sound absorption. Measurement: microphones, accelerometers, sound level meters, data taking and reduction. Noise control: use of absorbing and damping materials; vibration isolation and enclosures. Machinery noise: gear, bearing, fan, compressor, heating and ventilation system noise, automobile and aircraft noise. Community reaction. Legal aspects.
ME464	Vibration measurement and control (Text: Rao[2])	An introduction to vibration diagnostic and control methods. Modeling and analysis methods for low-order (one and two degree of freedom) systems with some discussion of analysis of higher order systems. Fourier transforms and transfer function techniques. Introduction to vibration measurement transducers, experimental modal testing, and diagnostic analysis. Demonstrations and laboratory experiments. Vibration control design strategies, including balancing and isolation.

monitored and encouraged to study consistently throughout the semester (which raises the intensity level of the learning process). It has the disadvantage of making some students dependent on their instructors to the point where they may lack confidence in their ability to learn material on their own or solve complex, multi-disciplinary problems. To counteract this tendency, both elective courses include a project experience. Typically the projects are small, realistic design problems where the students apply the principles they learned in class. A list of the projects used in the Spring 1996 semester of ME 413 is shown in Table 3. Projects are typically done in teams of 3 to 6 students. The students are encouraged to use team-building skills and design techniques learned in the core Mechanical Engineering courses.

Table 2: Dual Level Courses

Course	*Title*	*Course description*
ME513	Engineering Acoustics (Text: Kinsler et al. [3])	The simple oscillator. Wave motion in strings, bars, and membranes. Free, forced, and transient vibration. Applications to vibration isolation. Fourier series and integrals. Subjective response to sound. The acoustic wave equation. Acoustical intensity and energy density. One-dimensional acoustic problems: duct acoustics. Simple sources: monopole, dipole, quadrupole. Room acoustics.
ME563	Mechanical Vibrations (Text: Thompson[4])	Review of systems with one degree of freedom. Lagrange's equations of motion for multiple degree of freedom systems. Introduction to matrix methods. Transfer functions for harmonic response, impulse response, and step response. Convolution integrals for response to arbitrary inputs. Principal frequencies and modes. Applications to critical speeds, measuring instruments, isolation, torsional systems. Introduction

Table 2: Dual Level Courses (Cont.)

		to nonlinear problems.
ME564	Vibrations of discretized systems (Text: Meirovitch[7])	Theory of small oscillations of discrete or discretized systems of high dimensionality. Formulation of equations of motion using Lagrange's equations and the influence coefficients. Finite element reduction of continuous systems. Natural frequencies and modes: numerical methods. Free vibrations and forced vibrations characteristics; modal expansion; approximation techniques; damping. Assembly of large systems from subsystem concepts, impedance techniques.
ME579	Fourier methods in digital signal processing (Course notes and reference material)	Fundamentals of signal processing associated with Fourier analyzer systems are presented. Emphasis is on amplitude accuracy and frequency resolution properties necessary for reliable experimental methodologies in system identification, spectrum estimation, and correlation analysis. Deterministic as well as random, data analysis are presented. Students are required to develop algorithms that significantly expand the utility of Fourier analyzer systems.
ME580	Nonlinear engineering systems (Text: Jordan and Smith[9])	Methods of analysis of nonlinear ordinary differential equations arising in engineering systems. Review of linear systems. Stability concepts. Phase plane methods. Perturbations and averaging methods of analysis. Self-excited and parametrically-excited systems. Relaxation oscillations. Systems with more than one degree of freedom.
ME597B	Structural acoustics (Text: Fahy[4])	The study of sound and structural interaction. Wave number transform analysis methods. Sound radiation from vibrating structures. Sound transmission through structures. Acoustical excitation of structures. Sound in enclosures with flexible walls.
ME597M	Aeroacoustics (Text: Pierce[6] with notes)	Review of the fundamentals of linear acoustic theory in the general context of fluid mechanics and thermodynamics. Thermoacoustic phenomena in laminar boundary layers. Turbulent boundary layers and their interaction with compliant structures. General principles of aerodynamic sound generation . Applications to turbomachinery, propulsive thrust devices, road vehicles, aircraft, and other fluid machinery.

Students graduating from the undergraduate program with a specialty in noise and vibration control engineering are good entry level employees in industrial noise labs and as specialists for design functions within a company. Without further education their career paths usually migrate either to design functions or to routine testing.

Table 3: Class Projects for ME413, Spring, 1996

Project 1	Insertion loss of a rotating butterfly valve muffler
Project 2	Noise control of a bathroom ventilating fan
Project 3	Noise control enclosure design for a large screw compressor
Project 4	Reduction of road vehicle sunroof buffeting
Project 5	Sound transmission through automotive rubber seals

The university does offer a program of study with more flexibility within the Department of Interdisciplinary Engineering (IDE). One of the options in IDE is Acoustical Engineering. While a few students take this option, more students are attracted to Mechanical Engineering because of the greater breadth of potential job opportunities.

GRADUATE EDUCATION

Graduate education beyond the Bachelor of Science degree is offered in a number of options. The student may pursue a Master of Science under two options: the thesis option and the non-thesis option.

The non-thesis option consists of coursework only. Ten semester-long classes are required at Purdue. Some students may do part of their courses under independent study options where the student studies under the individual instruction or guidance of a professor. These experiences may be project-oriented or course-oriented. Both dual-level and graduate courses are allowable on a Masters plan of study but undergraduate courses are not allowed. Course descriptions for the graduate courses are shown in Table 4. Generally this option takes the student 12 to 16 months.

The thesis option masters degree requires seven semester-long courses and a thesis. The coursework must be selected from dual-level or graduate courses. A plan of study with a specialty in noise control includes 4 or 5 courses from the lists in Tables 2 and 4. In order to be considered to be of acceptable academic quality, the thesis must be a "contribution to knowledge". Thus, generally the work must be of publishable quality. This option generally will take the student 18 to 24 months to complete. The graduates of this

Table 4: Graduate Level Courses

Course	*Title*	*Course description*
ME613	Advanced engineering acoustics (Text: Kinsler[3] et al., Pierce[5] and course notes)	An extension of ME 513. Sound transmission between two media. Acoustic resonators and application to muffler theory. Structural radiation and sound. Acoustical measurements and signal processing: sound intensity, surface intensity, coherence and cepstral techniques. Numerical acoustics: finite element analysis, boundary element analysis, and statistical energy analysis. Advanced topics.
ME664	Vibrations of continuous systems (Text: Soedel[9])	Theory of small oscillations of continuous systems. Love's equations for thin shells, reduction to special cases of shallow shells, plates, beams, etc. Initial stresses; influence of shear; thermal excitation. Initial value problems; forced vibrations; structural damping. The dynamic Green's function; impedance concepts; variational approaches. Experimental procedures, scaling, composite, and stiffened shells.
ME681	Finite and Boundary Element Methods (Text: Reddy[10])	The solution of problems in mechanical engineering using the generalized numerical techniques; the finite element method and the boundary element method. Topics include reformulation of partial differential equations into appropriate form for each method. The development and implementation of code and solution of problems. Applications include; acoustics, fluid dynamics, heat transfer, design, mechanics, and biomechanics.

program are very attractive to employers. Most are very skilled in the area of their thesis topic and are able to conduct high quality research and development work for their employers. These graduates are also very capable of managing laboratories and projects.

At Purdue University, the Ph.D. program follows successful completion of a Masters degree. The Ph.D. program requires significant additional coursework, usually seven or more classes beyond the Masters degree, and a dissertation. The plan of study must include advanced mathematics and must be a coherent course of study to support the expressed research objective. The dissertation must be judged by the examining committee to be a "significant contribution to knowledge". It is expected that the dissertation will result in archival publications in peer reviewed journals. The Ph.D. course of study generally takes 3 to 4 years beyond the Masters degree. Graduates fill positions in universities, research laboratories, and industry. They are as likely to become technical leaders on broad technical issues beyond noise control engineering (the company's problem of the day) as they are to become leading specialists in noise control and related disciplines.

It is important to note that at Purdue there is not a great deal of institutional or government financial support for graduate studies. The students are either self-supporting, often as teaching assistants, or are supported by funds from research contracts. This presents significant challenges to the faculty to find financial support through sources that are compatible with the educational purposes of the University. If these challenges are well met the student experience can be outstanding. The keys are to find research for which the typical timing and resources of the university are ideal and to avoid situations were specific product experience is required. In the proper experience, the student not only learns noise control engineering but also learns research methodology, decision making, and technology transfer skills.

FUTURE DIRECTIONS

The most important new factors facing higher education in the United States are the opportunities which have arisen for educational delivery. Satellite and fiber optics links are already in heavy use at Purdue. Purdue is connected by a state-wide fiber optics link to manufacturers throughout the state of Indiana and its branch campuses. The link is used for live, interactive audio-video instruction at remote sites. The courses offered on this network are also videotaped and provided to companies outside the state and to the National Technological University for distribution by satellite. ME 513, ME 563, ME 597, and ME 613 have been offered through this type of distance education.

Multimedia delivery of educational material is becoming more commonplace, particularly on personal computers. This format offers some interesting opportunities for presentation of material that should enhance the learning experience of the student. As the current technological limitations of the Internet are overcome, educational delivery by the Internet may become another commonplace, cost-effective form of educational delivery.

The new alternatives for educational delivery raise the potential for competition to the university as the traditional source of education. It can be argued that there is significant need for alternative education formats different from university courses. However, the role of the university has always been to provide the type of formal education where the student gains the background and maturity upon which to build a career. Personal contact with advisers and other students is a very important element of the university experience. Thesis based graduate education is an outstanding experience and would be hard to duplicate outside the university. Unless universities fail completely to respond to the challenges of new educational delivery systems and the needs of employers, the role of providing formal education will stay at the universities.

Although university faculty have sometimes been involved, specialized training, such as short courses, has traditionally been provided by alternative sources. This sector of educational delivery will grow as the need for re-education of engineers grows and better educational delivery systems evolve. The universities will play a significant role as distance education delivery improves but, as is now the case, will not be a sole source provider.

Another changing factor which affects the future direction of education is the changing role of the engineer. In recent history many engineers, and in particular the specialist such as the noise control engineer, have played a supporting role to the design engineer. Some of this was a result of the difficulty of using the computer and other instruments as engineering analysis tools. Some has been the result of the general organizational structure and corporate culture of companies, particularly those that built large complex systems such as military systems, where engineering functions have tended to be segregated. The new role of the engineer, as dictated by concurrent engineering and design team concepts, means more engineers are now involved in noise control engineering and require appropriate training. Thus, more students and industrial employees will require noise control engineering education. Conversely, the noise control engineer must function as a member of the design team and must be well grounded in the fundamentals of engineering. The current educational process appears to be well designed to fill these needs.

CONCLUSIONS

The educational delivery systems for noise control engineering at Purdue have been developed to meet the needs of a variety of students. The need for the traditional undergraduate noise control engineering education is growing as engineering generalists recognize that they need a knowledge of noise control engineering to function as design engineers. The non-thesis masters, which serves as an educational option for advanced generalists and engineers looking to increase their capabilities, continues to grow in popularity as more industrial sites become capable of receiving distance education and as companies encourage engineers to actively pursue continuing education. The masters thesis option and Ph.D. are used by those desiring to be research specialists, academics, and technical managers in industry. While educational delivery systems will change and demand for noise control engineers will grow, these functions will remain the primary role of the university.

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