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Electro-Mechanical Design Engineering: A Progress Report, and Future Directions for Mechatronics Education[1]

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Abstract

The Electro-Mechanical Design Engineering program has been in place as a five-year combined interdisciplinary program in mechanical and electronics engineering at the University of British Columbia since 1994. The students take *almost* all mechanical and most of the core electronics engineering courses during the first four years. They spend at least two four-month-long summer terms in industry as cooperative education students, where they receive training in practical design, drafting, manufacturing and instrumentation. The fifth year is dedicated to the complete design and manufacturing of a computer controlled machine in industry. Teams of two students design the complete mechanical system with actuators, sensors and computer control units under the joint supervision of a faculty member and a qualified engineer designated by the sponsoring company. Upon the completion and testing of the full electro-mechanical machine and four graduate courses, the students receive a *Bachelor and Master of Engineering in Electro-Mechanical Engineering*. The Electro-Mechanical students receive academic and

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industrial training in mechanical, electronics and software engineering, and are in high demand in industry and academia upon graduation. The present status and future of this program, including the proposed expansion of the program to the M.A.Sc. Degree (currently under faculty review), is discussed.

Key words: Mechatronics, Engineering Education, Machine Design, Co-operative Education.

1. Introduction

Present mechanical systems include electrical or hydraulic actuators controlled by high-powered electrical and low powered electronic units. The overall system is generally interfaced to an industrial computer, utilizing a real time operating system accommodating control, monitoring and human-machine interface software. The performance of the machine may be monitored or improved by mounting sensors on the system, processing the measured signals in real time within the computer, and sending commands to actuators to improve the machine performance. In short, a Mechatronics System Design engineer must posses the knowledge in mechanical design and structures, electrical motors and power amplifiers, analog and digital electronics, automatic controls, computer architecture, and real time software engineering areas. Current engineering curriculums split the mentioned areas into at least two or three independent disciplines; namely, mechanical, electrical and computer engineering. When the three main disciplines are taught independently, the design of a full electro-mechanical system requires two or three engineers who received separate training in classical mechanical, electrical and/or computer engineering. However, an engineer, who received essential training in all three disciplines with a focus on electro-mechanical design engineering, can handle the complete engineering task alone in a more efficient, creative and unified manner. Although such an education can be called Mechatronics Engineering, the authors prefer to use Electro-Mechanical Design Engineering where the focus is computer-controlled machine design. Mechatronics typically covers wider range of disciplines including physics and optics.

1.1 Program Origins

The first author has been conducting research in design of Computer Numerical Controlled (CNC) systems for machine tools since 1986. At that time, he initiated a course in Computer-Aided Manufacturing (MECH491) [1]. This course covered basic digital interfacing, in particular, real time linear and circular trajectory generation algorithms, as well as digital control law programming in assembler using Motorola MC68000 educational boards interfaced to three axis miniature milling machine driven by dc servomotors. Most of the components of the complete system were designed and tested, and the students were asked to complete missing real time functions and minor interfaces. The course was taught in this form with intensive computer interfacing and real time components until 1993. With the support of the mechanical engineering department, a separate mandatory course (EECE 485, *Digital Instrumentation for Mechanical Systems*) in digital logic design, introductory level real time software engineering and digital interfacing was developed in cooperation with the Department of Electrical Engineering. This course has been taught by Electrical Engineering as a service course for our department. The predecessor of the course was given under APSC 380 by Prof. P. Lawrence, who published a text and pioneered the movement at UBC [2]. The first author continues to teach MECH 491, but with more emphasis on designing real time trajectory generation, sensors and digital control systems for computer controlled machines [3].

Mechanical engineering students who completed a suite of electives including MECH 491, MECH 462(Finite Element Analysis)), and MECH 457 (Final Year Design Project) were given a Computer Aided Automation (CAA) designation on their degree.

The first author proposed a formal five-year Electro-Mechanical Design Engineering education at the University of British Columbia in 1992. After a year of deliberation and fine-tuning of the curriculum in cooperation with the Department of Electrical Engineering, the Faculty of Applied Science and the University Senate approved the program in early 1994. Electro-Mechanical Design option is *generally* different than the Mechatronics initiatives seen in North American universities. Some universities teach basic components of mechatronics systems in one or two mechanical engineering courses [4,5,6,7]. Usually, an interested faculty or a team of faculty members teach basic digital interfacing, assembler programming and application of digital control techniques to several laboratory set-ups, similar to the EECE 485/MECH 491 courses described above.

Stanford University has a very active "smart product design" program which consist of two to three graduate courses in software engineering and computer interfacing, accompanied by a smart or mechatronics product design [8]. The smart product design program is geared more toward graduate education. Although such programs do not provide detailed foundation of electronics and computer engineering, they require less logistics in implementing the introductory level mechatronics education in engineering faculties.

2 Current Program Description

Electro-Mechanical Design Engineering is an interdisciplinary, joint program with Mechanical and Electrical Engineering Departments at UBC. The students take almost entire core courses in mechanical engineering, and about 60% of electronics engineering during the first four years. The students spend two summer terms in industry during the second and third year, and spend one full year in designing an industrial-size, computer-controlled machine or product in the fifth year. At the end of year five, the students receive both bachelor and master of engineering.

Because of resource limitations, usually only ten students are accepted to EMEC program per year. UBC has two teaching terms (September-December; January - April) and a non-teaching summer term (May-August). Students from the second year mechanical engineering class are invited to apply to EMEC program. The students must have at least 76% grade point average. Two faculty members (the authors) interview each eligible applicant for a period of fifteen minutes. The students are encouraged to bring their creative designs, drafting samples, hobbies, electronic and software products to the interview. Each student receives various questions about their recreational activities, work experience, habits, artistic or musical skills. The social questions are used to see whether the student has an ability to communicate and work in a peaceful and professional manner in an industrial setting. The interviewers then start asking the students to describe how machines that the students are interested in (robot arm, car engine, printer) are built and controlled; that is, how the mechanical, electronic, the computer and software components are linked. The student is asked to list the necessary courses and relate them to different activity in robot design and control. The questions are geared toward understanding whether the student has done some initial investigation about the EMEC option, and has some aptitude, interest and practical ability for electro-mechanical design. Usually, out of approximately thirty eligible applicants, we accept ten students who demonstrate high academic standing, strong motivation, and an evident talent in mechanical system design. The selected students must maintain 76% or higher grade point average in years two to four, and failure is not allowed. Students who do not maintain the set academic standards, can still graduate by dropping to a Bachelor of Engineering version of the program (CAA designation).

The selected students join a tightly mentored "EMEC Option." Not only must they maintain high academic standards; they are encouraged to develop strong friendship and bonds among each other so that they can strengthen their team spirit. After finishing the second year standard mechanical engineering courses, the students are placed in industry during the four-month summer term as cooperative engineering students. A special effort is made by the CO-OP office to find drafting, design, assembly and manufacturing oriented summer jobs for the students.

The third year of the curriculum has a mixture of Mechanical and Electrical Engineering courses, which are listed in Table 1. These Mechanical Engineering courses constitute the core of regular program less one third-year-level fluids and one third-year-level thermodynamics course. The electrical focus on courses in digital logic, micro-computers, circuit theory, software engineering and electrical machinery. The credit load is about 15% higher than the regular program. Again, the students are sent to industry as summer COOP students at the end of year 3.

Table 1: Current Third year EMEC curriculum.

Year 3 Courses	*Credits*	*Course Name*	*Term*
CPSC 252	4	Prog. Des. & Data Structures for Engineers	1
EECE 256	3	Digital Logic Design	1
MATH 257	3	Partial Differential Equations	1
MECH 365	2	Machine Dynamics and Vibration	1
MECH 351	10	Engineering Product Design	1 and 2
MECH 375	3	Heat Transfer I	1
MECH 301	2	Mechanical Lab. I	2
EECE 254	3	Electronic Circuits I	2
EECE 259	3	Introduction to Microcomputers	2
EECE 283	2	Electro-Mechanical Lab. I	2
EECE 314	3	System Software Engineering	2
EECE 373	4	Electrical Machines	2
MECH302	2	Mechanical Lab. II	2
MECH 360	4	Mechanics of Materials	2
MECH 392	2	Manufacturing Processes	2

The fourth year curriculum does not include any electives or capstone design project. Instead, more interdisciplinary courses are injected to the curriculum as shown in Table 2. All other fourth year core Mechanical Engineering courses are completed. The six electrical courses include core material which train the students in analog circuit and digital electronics design and interfacing, as well as computer architecture and real time software organization for machinery control. The students also take a course in Finite Element Methods and a course taught by the first author on design of Computer Numerical Controlled Machines (MECH 491). In this course, the students learn how to model a mechanical or hydraulic drive, size electrical or hydraulic actuators, amplifiers and sensors. They learn frequency and time domain analysis of computer control systems, as well real time trajectory generation techniques. The students work on an industrial size milling machine, a high-speed XY table, and a hydraulic press. The real time control and trajectory generation algorithms designed by each student are tested on the machines using an open real time operating system and design tool kit developed in the first author's research laboratory [9].

Table 2: Fourth year EMEC curriculum.

Year 4 Courses	*Credits*	*Course Name*	*Term*
APSC 450	2	Professional Engineering Practice	1
EECE 315	3	Introduction to Operating Systems	1
EECE 356	4	Electronic Circuits II	1
EECE 379	3	Micro/Mini Comp. Systems Design	1
MECH 466	4	Automatic Control	1
MECH 462	3	Finite Element Analysis	1
EECE 494	3	Real Time Digital System Design	1
MECH 352	4	Design of Mechanical Components	2
MMAT 380	3	Structures and Properties of Materials	2
MECH 430	3	Engineering Data Analysis	2
MECH 431	3	Industrial Systems	2
MECH 465	4	Mechanical Vibrations	2
MECH 491	4	Computer Aided Manufacturing	2

After fourth year, the students begin their final year during the summer. They complete four graduate courses, and two twelve-month projects involving advanced machine design and electronic systems design during year five, see Table 3. The projects are solicited from industry, and are jointly supervised. The students are divided into teams of two students. Potential industrial collaborators are invited to an annual social gathering, which is organized and run by the EMEC students. Senior EMEC students present their background and interests to the industrial audience, followed by casual group discussions during the “tea party”. The interested industrial partner invites teams to its work-site, and proposes an Electro-Mechanical Design project to the EMEC coordinators and the students. If the student team and the company agree on the project and salary, and the faculty coordinator finds the project academically acceptable as a Master of Engineering project (i.e. course master project), the graduate level project design courses (MECH 551, MECH 552) start on May 1st of the fifth year.

Table 3: Fifth year EMEC curriculum.

Year 5 Courses	*Credits*	*Course Name*	*Term*
MECH 551	8	Advanced Machine Design Project	All three
MECH 552	6	Electro - Mechanical Design Project	All three
COMP	6	Complementary Studies	All three
TECH. ELEC	12	Graduate courses	All three

The calendar description of MECH 551 and MECH 552 are given as follows

MECH 551:

"A team of students complete a year long advanced machine design project. The project may be brought from a company whose design engineer can be a member of the supervision team. Initial sketches, computer aided engineering analysis, full assembly CAD drawings, manufacturing planning and cost analysis of the design will be delivered in a technical report." [1]

MECH 552:

"One year long electronic design project is targeted to automation industry. Student(s) will have to design a single-board computer and real time software dedicated to control or monitor a machine or process. A prototype board will be designed with PCB CAD software, manufactured and tested on the targeted machine or process. Projects from industry are welcomed." [1]

The EMEC coordinators leave significant freedom to the project team and the qualified company engineer who supervises the design in the company. The intellectual property ownership is kept by the company, which pays salaries to the students and funds the equipment purchase and manufacturing costs. The faculty supervisor ensures that the students do not deviate from the agreed master project, and the fundamental principles of engineering (i.e. solid mechanics, vibrations, thermo-fluids, controls and circuit analysis) are encouraged to be used as much as possible by the students. The faculty supervisor assists the project. The students must complete the design and manufacturing of the machine within twelve months. They have to submit an extensive Master of Engineering report to both the university and the company, followed by actual demonstration, oral presentation and defense. After completing all the courses and the project, the students receive both Bachelor and Master of Engineering degrees simultaneously.

In summary, the curriculum of the program provides in depth education of students in mechanical engineering, mechanical and electronics system design, digital instrumentation and real time machinery control via computers. The curriculum covers almost the entire courses in mechanical engineering, and about sixty percent of the electronic engineering disciplines. The students spend twenty months in industry, where they design and build industrial size electro-mechanical systems. The program has been running successfully with zero budget (over the regular mechanical engineering program), since 1994.

3 Program Results and Future Directions

The EMEC program can be examined from two aspects: process, and product. The process includes the curriculum material presented, the quality of students attracted, the relative costs of training the students, the experience of the students and faculty and the benefits to the university community. The product includes the success and qualifications of the students at the time of, and after, graduation. In this section, the process is examined, and strategies for improvement based on the experience of faculty, students, and employers are proposed. However, the outcome of the process is the product. This is examined in section 4, through a review of the sample work produced by 5th year EMEC students in the past 3 years,

3.1 Program Reviews

The EMEC program is a recognized innovative interdisciplinary graduate/undergraduate program. It is the winner of the 1998 Peter Larkin Award for outstanding contributions and improvements to the student experience and learning environment at UBC. It has met with an extremely positive response from local industrial employers who compete for EMEC undergraduate co-op and graduate M.Eng. Project students, as well as EMEC graduates. The program is exceeding popular with students who are attracted to the Mechanical Engineering program by EMEC. Students within the program take a strong role in the promotion and improvement of the program, including organizing the industry "tea-party", and developing the program web pages. Recent EMEC alumni have even sponsored industry projects for following 5th year students. They are very enthusiastic about the training they receive.

External reviewers of the program [10] find EMEC to be a very positive and innovative option in bridging the mechanical and electronics engineering education (i.e. Mechatronics). However, the sustainability of the program heavily depends on the close cooperation of Electrical Engineering Department. The course load has also been found quite intensive. There was also concern that excellent students were funneled into a more limited-in-scope M.Eng. Degree, rather than having the opportunity to move into a broader M.A.Sc (thesis masters program) which might lead to Ph.D. studies.

Thus the issues of concern about the program can be grouped into two categories: (1) curriculum issues – i.e., the workload, the academic career path and interdisciplinary dependencies, (2) access to resources to expand the program. These issues are addressed in the following subsections.

3.2 New Curriculum Proposal

In advance of the external reviews, based on feedback from students, colleagues, and industry participants, the authors have developed a revised EMEC curriculum. In the revision the authors have focused on the following goals:

- A more even distribution of the credit load for the EMEC program over the 5 years of study, with some reduction of the heavy credit load
- Synchronization of the EMEC curriculum schedule with Electrical and Computer Engineering (EECE) program to avoid scheduling conflicts and encourage participation of the EECE in a similar multidisciplinary program with Mechanical Engineering.
- Putting in place an academic path to a M.A.Sc. (thesis based masters) as well as the current M.Eng. (project based masters). This allows excellent students to bring their electro-mechanical engineering skills to research within the broad scope of Mechanical Engineering, e.g. thermodynamics, fluid mechanics, heat-transfer, solid-mechanics, vibrations dynamics, production engineering, etc., etc.

The proposed curriculum, given in Table 4, incorporates the following changes:

Table 4: Proposal for Revised EMEC curriculum.

Level	*Courses*	*Credits*	*Course Name*	*Term*
Year 2	EECE 256	3	Digital Logic Design	1
	CPSC 252	4	Programming. Design and Data Structures for Engineers	1
	MATH 253	3	Multivariable Calculus	1
	MECH 201	3	Mechanical Engineering Laboratories I	1
	MECH 250	1	Introduction to Engineering Software	1
	MECH 260	3	Introduction to Mechanics of Materials	1
	MECH 270	3	Thermodynamics	1
	APSC 201	3	Technical Communication	2
	EECE 259	3	Introduction to Microcomputers	2
	EECE 263	3	Basic Circuit Analysis	2
	MATH 256	3	Differential Equations	2
	MECH 202	3	Mechanical Engineering Laboratories II	2
	MECH 265	3	Rigid Body Dynamics	2
	MECH 280	3	Introduction to Fluid Mechanics	2
	MECH 203	1	Machine Shop Practice	-
Year 3	APSC 278	3	Engineering Materials	1
	APSC 279	1	Engineering Materials Lab.	1
	EECE 315	4	Introduction to Operating Systems	1
	EECE 373	4	Electrical Machines and Power Transmission	1
	MECH 360	3	Mechanics of Materials	1
	MECH 375	3	Heat Transfer I	1
	MECH 303[3]	2	Mechanical Engineering Laboratories III	1&2
	MECH 351	8	Engineering Product Design	1&2
	EECE 254	3	Electronic Circuits I	2
	ELEC283	2	Electro-Mechanical Lab 1	2
	EECE 314	3	System Software Engineering	2
	MECH 365	2	Machine Dynamics and Vibration	2
	MECH 392	2	Manufacturing Processes	2
	MMAT 380	3	Structures and Properties of Materials	2
Year 4	APSC 450	2	Professional Engineering Practice	1
	EECE 356	4	Electronic Circuits II	1
	EECE 379	3	Design of Digital and Microcomputer Systems	1
	MECH 466	4	Automatic Control	1
	COMP Studies	9	Complementary Studies	1 & 2
	EECE 494	3	Real Time Digital System Design	2
	MECH 352	3	Design of Mechanical Components	2
	MECH 430	3	Engineering Data Analysis	2
	MECH 431	3	Engineering Economics	2
	MECH 465	4	Mechanical Vibrations	2
Year 5 **OPTION I[4] : M.Eng. with Advanced Industrial Design Project Courses and Course Work**				
	MECH 551	6	Advanced Machine Design Project	Summer
	MECH 552	6	Electro – Mechanical Design Project	Fall/Winter
	TECH. ELEC[5]	18	Graduate courses (Max. 6 credits of undergraduate courses)	Fall/Winter
Year 5 **OPTION II[4]: M.A.Sc. with Design, Thesis and Course work**				
	MECH 551	6	Electro-Mechanical Design Project	Summer
	TECH. ELEC[5]	10	Graduate courses (All 500 level)	Fall/Winter
	MECH 598	2	Graduate Seminars	Fall/Winter
	M.A.Sc. Thesis	12	Research thesis	

[3] New course for EMEC, selected MECH labs. from MEC301 and MECH302 and taken concurrently with these courses, i.e. over both terms.

[4] **5th year options:** The students can select either OPTION I or OPTION II for their fifth year curriculum with approval of the faculty supervisors. For option II, a M.A.Sc. faculty supervisor must be identified.

[5] **Electro-Mechanical Electives:** MECH 462, MECH 491, ELEC 465, ELEC 466, ELEC 374, ELEC478, ELEC487, ELEC570, ELEC574, ELEC594, 500 level MECH courses.

1. Extension of the beginning of the EMEC program down to the beginning of the Second year of the Mechanical Engineering Program.

EMEC students take the majority of core electronics/computer engineering courses, plus almost entire core Mechanical courses. As they are presently overloaded in year 3 and 4; it would be desirable to spread the load to three years. Also, it is practically, quite difficult to schedule 2^{nd}, 3^{rd}, and 4^{th} year EECE courses within a 2 year span. Some 2^{nd}, 3^{rd} and 4^{th} year EECE courses are scheduled in conflict with each other. By having EMEC students take these courses in phase with EECE students, the scheduling will be less difficult, and the workload will be more manageable for the students. It also paves the way for an EECE Mechatronics option if Mechanical and Electrical Engineering 2^{nd}, 3^{rd} and 4^{th} year courses do not conflict. (The first year engineering program at UBC is a “pooled” program – students apply to and are split off into disciplines at the end of the first year).

Extension of the program to include second year allows some further tailoring of the second year program beyond inclusion of EECE credits, allowing a reduction of the credit overload. For example, a second-year-level three-credit design course (taken in first term of second year, prior to the taking of fundamental courses in mechanics of materials and rigid body dynamics) is replaced by a course in Electrical Engineering Design (EECE 256 Digital Logic Design). A strong mechanical engineering component of design curricula is maintained through the 8 credits of Engineering Product Design (MECH 351). A new third year laboratory course (MECH 303) is proposed which selects laboratories from the core set in MECH 301/302 and emphasizes laboratories involving instrumentation.

2. Expansion of the 5^{th} year level of the program to include a M.A.Sc. Option.

As shown, the students can select to do a M.A.Sc. degree, under the advisement of the program coordinators, and with the appointment of an appropriate M.A.Sc. Faculty advisor. Considering the academic background of the students, and level of training, this opens up the opportunity for students to obtain national and university graduate scholarships, and provides a pool of excellent graduate student candidates to all faculty in the department. The students are still required to complete an industrial project as part of their graduate work, separate from the M.A.Sc. thesis requirements. This requirement is necessary to maintain the design component and practical level of the student's education, without sacrificing the academic side.

The inclusion of this option requires some retooling of the program at the 5^{th} year level. Redefining MECH 551 and 552 as follows decouples the graduate level design courses (MECH 551/552).

"**MECH 551 - Electro-Mechanical System Design I:** - The design, analysis, manufacturability, instrumentation and computer control of a selected dynamic machinery assembly will be studied. Projects are completed by teams of two students." [1]

"MECH 552 - Electro-Mechanical System Design Project II - The full assembly, instrumentation, computer and electronic interfacing, and testing of a dynamic machine." [1]

Eighteen credits of technical electives are required. However, in practice, and due to the coupled B.A.Sc./Masters nature of the program, most students will take 6 credits of these electives during their less heavily loaded 4^{th} year. Students, especially those continuing to a M.Eng. designation, will be strongly advised to take the highly practical

MECH 491 (Computer Aided Manufacturing) and MECH 462 (Finite Element Analysis) courses (formerly core courses for EMEC). Students heading for a M.A.Sc. degree may be advised (in consultation with the designated faculty advisor, and program coordinators) to take electives directed toward their proposed graduate-level field of study.

3.3 Program Resources and Potential for Expansion

The EMEC has received a one-time grant from the university for equipment purchases to support students in their M.Eng. program (Data acquisition system, oscilloscope, computer equipped with CAD software, CCD camera, frame-grabber, transducers, etc.). Resource and space allocations are always at a premium, and therefore any proposed expansion of the program must be, at minimum, revenue neutral to receive approval from the departments and faculties involved (Mechanical Engineering, Electrical and Computer Engineering, Applied Science and Graduate Studies).

On the other hand, at the Graduate level, EMEC projects are well funded by the sponsoring companies, at a level of $CDN100-200K. The students are paid at senior co-op student rates, and the companies provide equipment, engineering supervision, and a high level of technical support. Thus, one alternative for expansion is to look to industry for some funding of the academic side of the program, with matching funding from government sources. Examples of options that are currently being explored are placement fees, and, at the graduate level, government R&D grants. The second option will be greatly enhanced by the inclusion of the M.A.Sc. option in the program.

As well, the initiation of a sister program in Mechatronics from the Department of Electrical and Computer Engineering is under discussion. While there are many logistical difficulties in starting such a program (but not as many as when EMEC was started), there are many potential benefits to the program, and certainly, demand for the product.

4. EMEC "Products": Sample Machines Designed by EMEC Students

Due to propriety nature of some of the designs, only few commercialized products are presented here without in depth details. However, they exemplify the general EMEC project philosophy which involves mechanical, electrical and computer system design.

A small company required a machine that hardens the inner walls of cast iron pipes used in delivering wet concrete. The pipes have 130mm diameter, 9.6mm wall thickness, and 2 to 5m lengths, which are joined with elbows and mounted on wet-concrete delivery trucks. Due to abrasive nature of wet concrete mixture, the inner surface of the pipes must be hardened to reduce wear. On the other hand, the external wall must be kept ductile in order to prevent cracks when the pipes are subjected to impacts on the truck. The EMEC project was to design a complete heat treatment machine, which can handle pipes with a maximum length of 5m. The company had a small shop with six machinists and welders, and a secretary. Their business was only to assemble the pipes purchased from overseas. However, the overseas manufacturers started to increase the price, and failed to deliver the pipes on time. The company had no previous experience in designing any machine. They recruited one young temporary engineer to help the EMEC student team who accepted the challenge. The two EMEC students and the temporary engineer (who had no previous design experience) designed the complete machine on ACAD. The part and assembly drawings were made, standard parts such as motors, heat lance, sensors and a PC with a motion control card were sized and acquired.

The students built the machine shown in Figure 1. The machine has 7m long slanted guide that carries the cast iron pipe. A special pipe clamping and rotation mechanism was built. An off-the-shelf heat lance was purchased, and integrated to the machine. The outer temperature of the pipe is measured using infrared sensors. Based on the heat transfer formulation and calibration, the pipe is rotated at constant velocity and the lance is moved forward inside the pipe. The linear velocity of the lance head is controlled in a closed loop manner using the monitored temperature. The lance carriage system contains six water jets just behind the lance head. The water jets are used to quench the inner walls of the pipe for hardening. A simple counterbalanced steel wire and roller mechanism is used to move the lance along the pipe axis. The wire rope is connected to AC servomotor sized to have sufficient torque to move the inertia and to overcome friction losses. The system is controlled by a PC equipped with an ISA bus based motion control card. Labview (TM) real time data collection and programming environment was used for the software development.

The complete mechanical design, fabrication, high power electrical wiring, instrumentation, software development and even painting of the frames were completed by the two EMEC student and the junior engineer, who formed a true engineering team. Although the electrical wiring and plumbing were designed and assembled by the students, certified technologists inspected the system. The sketches and assembly drawings of the machine were completed between May to August 1997; the machine was built by April 1998; and several pipes were hardened during the examination of the students on April 30, 1998. The students graduated in May 1998, and the machine has been working in production without any reported problem [11].

A two axis wood strander was designed and built for a wood machine tool builder in Vancouver. The strander carries a large disk with wood peeling knifes. As the wood is linearly fed towards the rotating cutting disk, the wood is milled away to produce flakes used in pulp industry. The knife mechanism and complete CNC system were designed and built by two EMEC students, see Figure 2 [12]. The company commercially produces the machine. Not all projects are necessary related to heavy industry. Projects in biomechanics, fuel-cell technology, and radioactive target material handling have also been undertaken. For example, one team designed and built a clinical activity monitor for measuring patient outcomes after knee and hip surgery [13], Figure 3. The devices have been reproduced and were used in over 30 clinical trials with pre-operative and post-operative patients at the Vancouver Hospital prior to the completion of the student project. A patent has been filed for this device. More design examples can be found in the EMEC web site: (http://www.mech.ubc.ca/Programs/ElectroMech/).

4. Conclusions

A five-year combined Bachelor-Master of Engineering degree program has been presented. The curriculum of the program provides in depth education of students in mechanical engineering, mechanical and electronics system design, digital instrumentation and real time machinery control via computers. The curriculum covers almost all courses in mechanical engineering, and about sixty percent of the electronic engineering courses. The students spend twenty months in industry, where they design and build industrial electro-mechanical systems. The program has been running successfully with a zero budget, received an innovative graduate program award from UBC, and is highly accepted by the local industry. The strategies for the continuing success of the program include expanding to a M.A.Sc. option, working with the Electrical and Computer Engineering department towards a similar Mechatronics program for EECE students, and accessing funding through joint government/industry initiatives.

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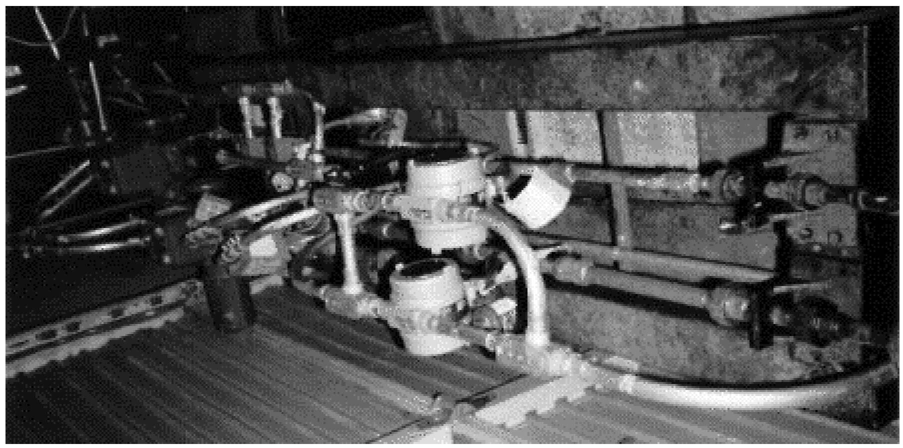
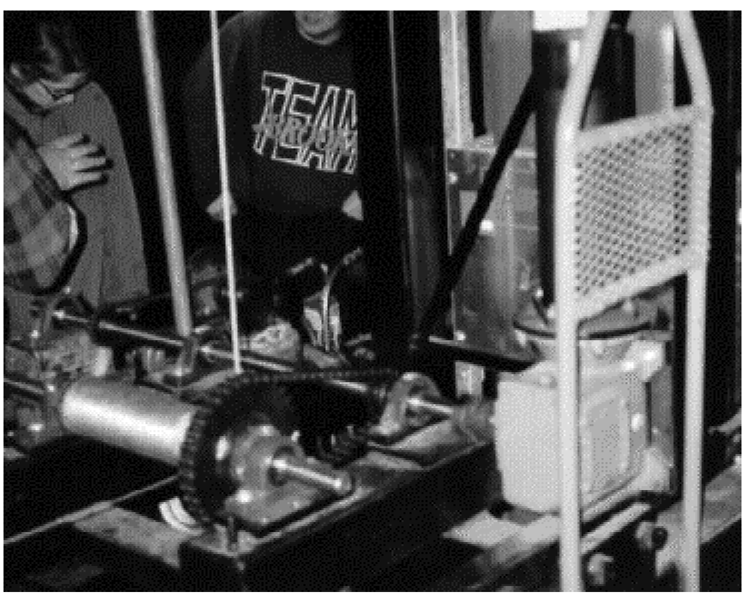
(a) General view of the pipe handling structure and control room.



(b) A sample view of the plumbing circuit.



(c) A sample view of lance motion delivery via pulleys and steel wire.

(d) Lance unit during flame hardening of the pipe.

Figure 1: A computer Controlled Pipe Hardening Machine designed by EMEC students [11].

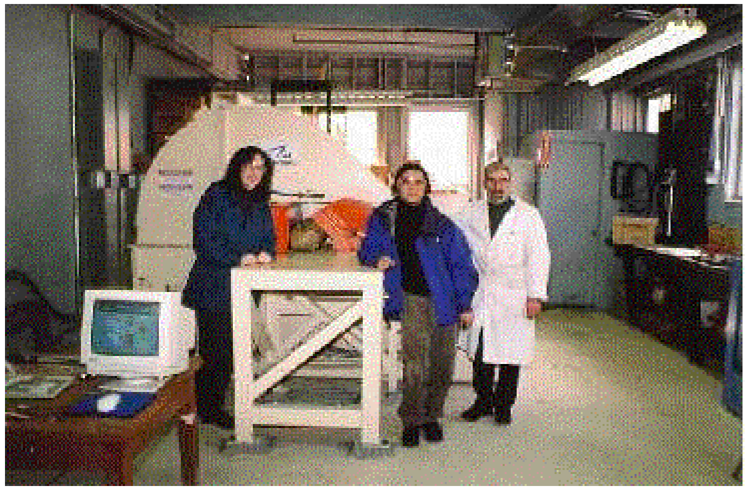


Figure 2: A CNC Wood Strander designed by an EMEC team [12].

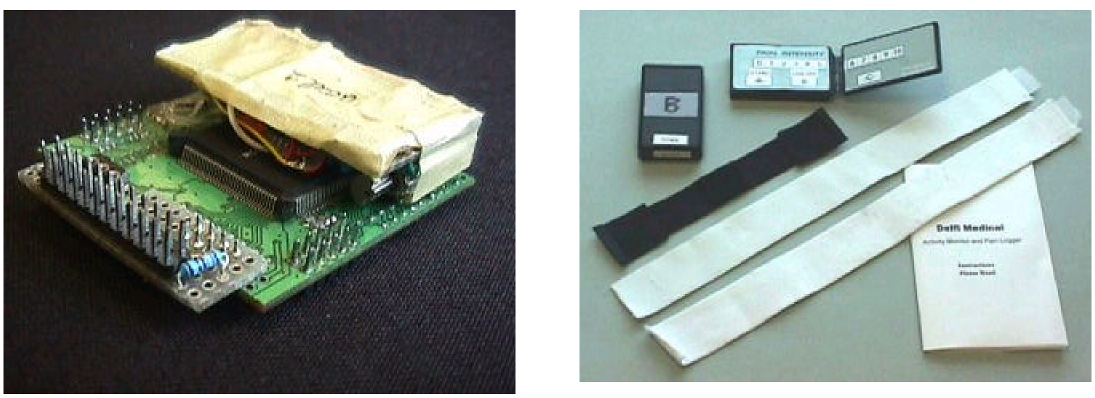


Figure 3: Device for measuring patient outcomes after knee and hip surgery designed by EMEC Students [13].