A CURRICULUM IN MACHINE TOOLS TECHNOLOGIES FOR MECHANICAL ENGINEERING GRADUATES

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Abstract — *The machine tool industry is one of the most fundamental industries in Taiwan. It is particular important for central Taiwan as more than 75% machine tool makers are located in this area. While it is difficult for most institutions to design a curriculum to cover related topics in machine tools, this paper describes the implementation of a curriculum for this purpose with stress on mechanical engineering graduates. The curriculum includes a series of core courses, advanced courses, and supporting courses as well as laboratory courses and seminars. Due to the limited resources in faculties and facilities in the university, some courses are supported by senior engineers and managers from near-by machine tool industry. Some others, in particular laboratories and field trips, are supported by other research institutions and companies in this area through industry-academic alliance. The industry-academic alliance is a new trial supported by the Ministry of Education to promote interactions between the university and local industry. It is found that students are satisfied and feel comfortable for such arrangement as they learned much more than before through industry-supported technical courses and field trips. It is also observed that the strategy is successful to arrange industry-oriented application courses and seminars via industry-academic alliance.*

Index Terms — *curriculum, industry-academic alliance, machine tool, mechanical engineering graduates.*

BACKGROUND

The machine tool industry is one of the fundamental industries in Taiwan. It is particular important for central Taiwan as more than 75% machine tool makers are located in this area. While university graduates is the main source of high-level manpowers for the industry, it is difficult to educate graduates in the field of machine tools as it needs extensive training on design, analysis, manufacturing knowledge and practical experience. Normally, graduates in mechanical engineering are to be educated to understand general knowledge about mechanical engineering, while not supposed to be trained to become experts in specified industrial technology. Under this circumstance, it is difficult for most institutions to design a series of courses to cover technologies in machine tools. However, it usually takes a new graduate student in mechanical engineering more than one and half years to learn and understand fundamental technologies in this industry. Furthermore, most institution's faculties do not have enough experience in this field to teach these students, no to mention expensive laboratory work. This condition is common in most universities because most faculties stress their research work on high-tech related work but not the so called "conventional" industry. As a result, the gap between the machine tool industry and institutions can not be filled. This leads to the fact that it is very difficult tfor this industry to recruit machanical graduates in order to upgrade their technologies. The situation has been found in different industries and was noticed by the industry as well as by the government. It is then suggested to the Ministry of Education (MOE) to improve the condition. A task force on engineering education, with improving the interactions between the academic institions and industries as one of its missions, was then formed and funded by the MOE [1]. The program was then applied to different industries, including precision machinery and aerospace[2].

The 'Strategic Alliance on Precision Machine Tools', as part of the 'Curriculum Improvement Program on Precision Machinery', is formed by eight universities, five in central Taiwan and the other three in north Taiwan. As one of the member of the alliance, the Department of Mechanical Enginnering (ME) of National Chung-Hsing University (NCHU), as it is close to the heart of the machine tools industry, plays an important role and has been active in the program to develop curriculum and technologies in machine tools. This paper describes the curriculum and courses implemented in the program with stress on graduates in mechanical engineering. A special course, the 'Technologies of Precision Machine Tools', is then introduced and discussed as it is a typical industry-academica cooperated course. Progress of the curriculum is then followed to report current and future plannings of this curriculum.

CURRICULUM AND COURSE DESIGN

The focus of this curriculum is on machine tools and its up/downstream industrial technologies. Although there already exists many courses related to machine tools and precision engineering, there is no application-oriented course that links these courses with industrial applications, as mentioned in previous section. Moreover, most of these courses focus on theoretical discussions but very few on its

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practical applications. Therefore, the curriculum is aimed to provide students with a series of training in machine tools technologies, in particular applying mechanical engineering knowledge to current and future technologies in this industry.

A list of core and advanced courses, as well as supporting courses, is then outlined after extensive discussions as shown in Figure 1 [3].

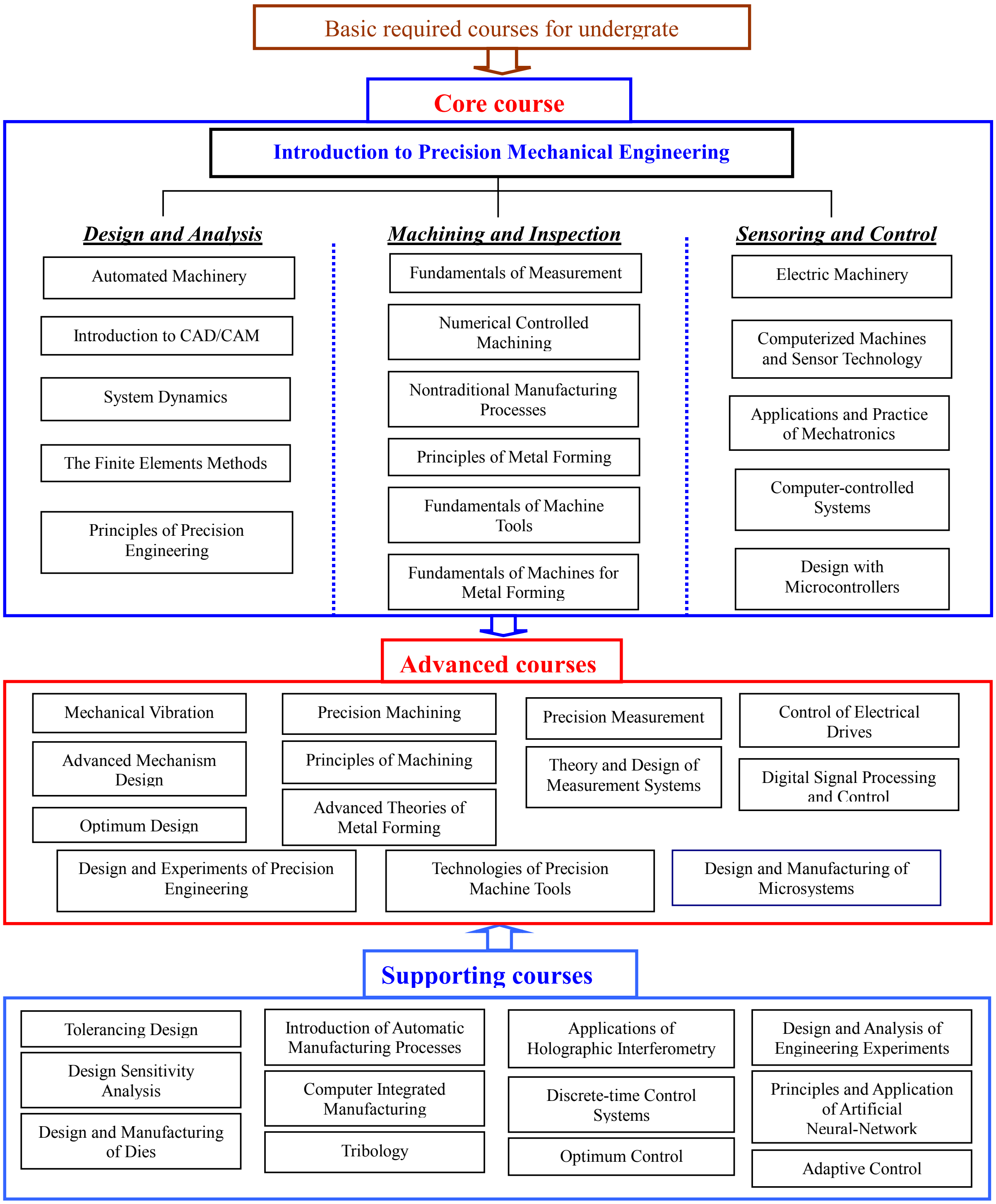

FIGURE 1
COURSE STRUCTURE OF THE PRECISION MACHINERY CURRICULUM. [3]

One of the requirements of these courses is that course lecturer needs to show how theories can be related to precision machine tools. As this curriculum is designed at the first run, current courses already offered in the department and related to machine tools and precision engineering are then reviewed and discussed if the course contents are suitable for the curriculum. If a course fits the requirement, then it is listed under the curriculum with minor modifications. New course that are not offered at the department is then planned and organized to be offered in the following academic years.

Courses in this curriculum are divided into three levels – the core courses, the advanced courses, and the supporting courses, with a series of courses at each level. Laboratory courses and seminars are also included in this curriculum. The purpose of core courses is to help students to establish the core knowledge and basic ability in precision machine tools. Core courses are offered mainly to undergraduates. As shown in Figure 1, an introductory core course for precision mechanical engineering is required for every student who attends the precision machine tool curriculum. The rest of core courses are further divided into three tracks – design and analysis, machining and inspection, and sensoring and control, as they are fundamentals of machine tools. Courses in each track focus on certain area of knowledge in order to provide students with enough theoretical background in a specified area of technology. Students in this program are required to take at least three core courses in the same category beside the introductory core course. Experiments or prototypes are required for some core courses that enable student to familiarize themselves with technology through hands-on practice while studying the theories. The graduate-level advanced courses are designed for students who already had a series of core courses and are willing to take a step further into this particular field of study. The supporting courses are precision machine tool related technologies that can provide students with more broad view on this area. In addition to the scheduled courses, a series of seminars focus on the development of precision machine tools technologies, opened to general public, is also offered. Non-student individuals can take the credit by registering as an auditor.

Laboratories at the department are also reorganized to form a 'Precision Machinery Laboratory' (PML) in coordination with these courses. The focus of the PML is to promote talent cultivation for precision machine tools and related technology, also to support experiments and hands-on practice for this curriculum. This laboratory is functionally divided into four units -- design and analysis, machining and manufacturing, inspection and control, and precision machinery industry-academic educational alliance. A supporting unit called 'teaching equipments' is integrated with these four units to complete the structure of this laboratory. The relationship between units and their integration is shown in the Figure 2.

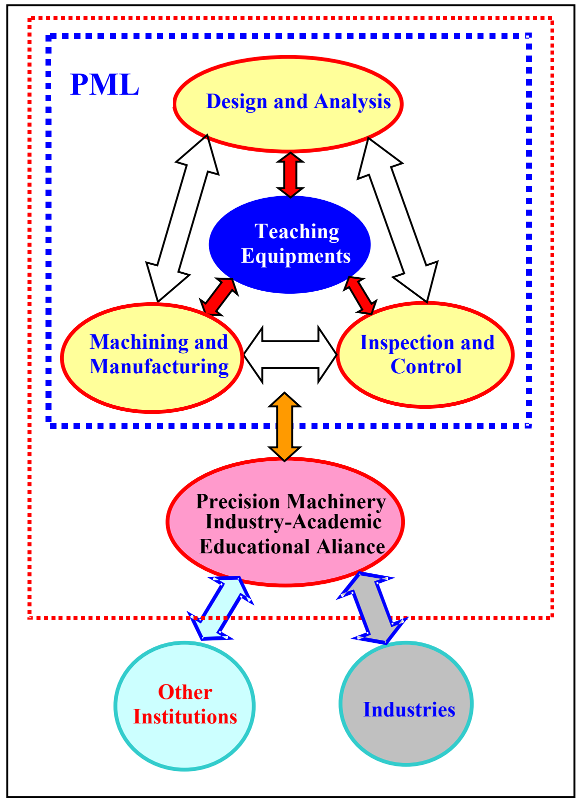

FIGURE 2
RELATIONSHIP OF THE PRECISION MACHINERY LAB. WITH INDUSTRIES AND OTHER INSTITUTIONS THROUGH THE 'PRECISION MACHINERY INDUSTRY-ACADEMIC EDUCATIONAL ALLIANCE'.

Equipments of the 'design and analysis' unit include more than twenty commonly used commercial and internal-developed CAD/CAM. This unit is to support different levels courses in this curriculum such as 'Introduction to CAD/CAM', 'Principles of Precision Engineering', 'Numerical Controlled Machining', 'Precision Measurement', 'Computerized Machines and Sensor Technology', 'Design and Experiments of Precision Engineering', and 'Design and Manufacturing of Dies'. The purpose of this unit is to teach students to utilize the computer-aided-engineering technology in design and analysis of precision machinery. Equipments of the 'machining and manufacturing' unit include most commonly used machine tools such as CNC machining centers, CNC turning centers, CNC wire EDM, CNC C-axis turning center. Also for a better demonstration, a desktop CNC lathe, and a high-speed spindle system are set up at this unit. The purpose of this unit is to let students to practice the process of precision machining, and to familiarize themselves with the systems of precision machinery. This unit also supports machining and inspection related courses in the curriculum. Equipments of the 'inspection and control' unit include commonly used measuring instruments such as machining dynamometer, spectrum analyzer, spindle dynamics analyzer, surface roughness instrument, laser interferometer, and acoustic emission sensoring system. The purpose of this unit is to teach students about the precision measurement and instrumentation.Again, this unit supports sensing and control related courses in the curriculum.

As previously mentioned, resources, including faculties and facilities, at the university are limited, outsourcing cannot be avoided in this circumstance. Furthermore, as has been observed, industrial collaboration can lead to a better acceptance of college graduates at the job market [4], the PML also take the responsibility to promote industry-academic cooperations. Through the MOE-sponsored 'Precision Machinery Industry-Academic Educational Alliance', we established the connection with industries and other institutions in curriculum promotion and equipment sharing. Communication and cooperation with industries and other academic organizations are through this unit. Through this channel, several projects was initiated and executed. Through the industry-academic cooperated projects, industries can solve or partially solve their problem, while faculties and students have opportunities to work on real industrial problems. Certain projects also provide chances for students to practice in the factories during the summer vacation.

THE TECHNOLOGIES OF PRECISION MACHINE TOOLS – A SAMPLE COURSE

As described in previous section, the industry-academic educational alliance provides a channel for interaction between the industry and the institution. While most industry-academic cooperation emphasizes on either funding research project', such as [5] and [6], the content of cooperation has recently shifted to be more education-oriented, in particular industry-supported design projects [7-10] or company-supported equipments and material [11-13]. Due to the limited resources in faculties and facilities in the university, some application-oriented courses in the curriculum are supported by senior engineers and managers from near-by machine tool industry. Some others, in particular laboratories and field trips, are supported by other research institutions and companies in this area through the industry-academic alliance. This arrangement differs from previous models of industry-academic cooperation project as university faculties and company managers designed topics of the course at the beginning. Senior engineers and managers then provide contents of the courses according to the syllabus. The 'Technologies of Precision Machine Tools' (TPMT), an advanced course, is a typical example of such an arrangement. We will discuss this course in this section.

Based on the category of machine tool technologies, this TPMT course is divided into three units – 'design of precision machine tools', 'precision machining', and 'inspection and testing of machine tools'. Each unit is designed by university faculty but organized by near-by machine tool research institutions and companies, including PMC (Precision Machinery Research and Development Center), the Taichung technology and service center of MIRL, ITRI (Mechanical Industrial Research Laboratory, Industrial Technology Research Institute), and the Taichung Service Center of MIRDC (Metal Industries Research and Development Center). Each unit consists of a series of three-hour lectures from fundamentals to applications. A field trip with real demonstrations is also arranged by the end of each unit. The contents and organizers of the TPMT course are listed in Table I. This course gives students a general understanding of design, analysis, and testing of the machine tools as well as how theories can be applied to industrial products.

TABLE I
CONTENTS OF THE 'TECHNOLOGIES OF PRECISION MACHINE TOOLS' COURSE

Unit	Lecture	Organized by
Design of precision machine tools	Introduction to design of high speed machine tools	ITRI
	Design of high speed spindles for machine tool	
	Design of feeding systems of machine tools	
	Design of control systems of machine tools	
	Design of ATC systems	
	Field trip: ITRI	
Precision machining	High speed machining and its machine tools	MIRDC and PMC
	New structure of machine tools	
	Technology and development of machine tool control and machining	
	The technology and development of micro-machining	
	Field trip: Fairfriend machine tool cooperation	
Inspection and testing of machine tools	The relationship between the evolution of machine tools and precision measurement	PMC
	The accuracy and inspection of machine tools	
	The performance and testing of machine tools (1)	
	The performance and testing of machine tools (2)	
	Field trip: PMC	

Figure 3 is an example of the course slide that shows the cross section of a high-speed motor-built-in spindle designed for a recently developed high-speed machine tool. Students are excited to reach such information on the technology as the spindle delivers much higher power than a dental drill does, though both rotate at very high speed. The design of such a spindle needs more extensive considerations and analysis, as its dynamic characteristics are different from a regular one. Machine tool structure for high-speed machining (HSM) is therefore differs from a common one in order to meet these higher specifications required for HSM.

Figure 4 shows another slide used at one of the lectures in the course to describe different precision machining processes. Some other machining processes in high precision are also demonstrated at the lecture. Students learned from this lecture that conventional machining processes could provide good accuracy and tolerancing, as compared to these so called 'high-tech' miniaturized fabrication processes. This is an importance issue as the job in machine tool industry is not very attractive to students because graduate students are often attracted by the 'high-tech' industry.

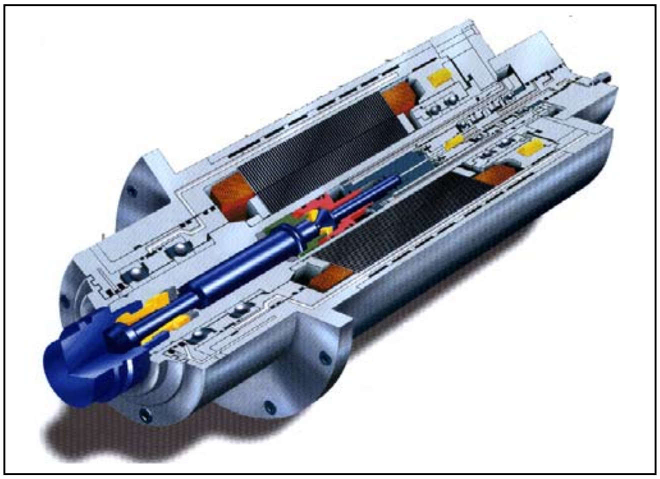

FIGURE 3
AN EXAMPLE OF COURSE SLIDES SHOWING A HIGH-SPEED SPINDLE.

FIGURE 4
YET ANOTHER EXAMPLE OF COURSE SLIDES SHOWING DIFFERENT MACHINING TECHNOLOGIES.

PROGRESS

This precision machine tool curriculum was designed in 2000 and implemented in 2001. In the past year, students are highly interested in the curriculum as they learn more practical knowledge with hands-on experience, in addition to theories. In particular, the interactions among students and industrial engineers do help students to get familiar with the machine tool industry that shorten the learning curve when they enter this job market. This curriculum is also encouraged by nearby industries, since they can recruit graduates with good background and also have their employees to take these courses as an on-job training.

Although the industry-academic educational alliance is a new trial, it is observed that interactions among the university and industries do improved through such an alliance. We are now in the second year of the four-year program continuing to promote the curriculum and to improve the environment such that the university and nearby industry are mutually complementary and beneficial. The environment to be improved includes equipment and facility sharing as well as course audit and credit system. Based on last-year's experience, we are in the process to arrange lectures for the TPMT course with better lecture material and evaluation process. It is expected that more students, with some from industry, will participate the curriculum and more nearby companies will join the program in the coming years.

CONCLUSION AND DISCUSSIONS

We describes the design and implementation of a curriculum on precision machine tools in the paper. The curriculum consists of the core courses, which are further divide into three tracks, the advanced courses and the supporting courses. A Precision Machinery Laboratory consisting of four units is formed to support experiments and hands-on practice for this curriculum. Three of the four units are technical units that provide equipments to facilitate the curriculum. The other unit, a industry-academic educational alliance, is a new trial to to promote interactions between the university and industries and other institutions.

It has been observed in the past two year that both students and industries do appreciate the curriculum as students lean much more industry-oriented engineering practice while industry can recruit students with better background they need. Some application-oriented industry-supported courses also show a success as the enrollment keeps high in these classes. A new trial of a course designed by faculties and industrial magagers while organized and lectured by senior engineers and managers from nearby industrial also showed a success. It is found that students are satisfied and feel comfortable for such arrangement as they learned much more than before through industry-supported technical lectures and field trips. It is also observed that the strategy is successful to arrange industry-oriented application courses and seminars via industry-academic alliance.

Although we observed these exciting outcomes from the curriculum, we also noticed that students are not trained for certain industry. As many technologies are similar with the same fundations, we still emphasize that fundamental courses must be completed when a student enrolled to this program. However, such an industry-oriented curriculum with some application-oriented course built on top of the fundamental courses does bring mutual benifits for both the university and the industry.

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