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Mechatronics in the Technical University Sofia – Result of the Cooperation between the Mechanical Engineering Faculties in Nis and Sofia

Todor NESHKOV

Faculty of Mechanical Engineering, Technical University Sofia, Sofia 1000, 8-Kliment Ochridski Blvd., Bulgaria
tnesh@tu-sofia.bg

***Abstract*— Analyses of the career development of students in the subject of Engineering have shown that specialized education in Mechatronics is necessary to be designed. Thus Mechatronics has become one of the newest university specialities in Engineering. This is induced by the present-day demand of the industry which show a major need of engineers who have interdisciplinary skills and the abilities to come up with new ideas and products for the rapidly changing market, and they have to have very good knowledge in modern information technologies. In this way educational programs in Mechatronics have been developed in many countries around the world including in the Technical University of Sofia.**

***Keywords*— mechatronics, career development, interdisciplinary, changing markets, information technologies**

I. INTRODUCTION

The term "Mechatronics" was firstly introduced by Tetsuro Mori (a senior engineer of the Japanese company Yasawa) in Japan in 1969 to describe the integration of mechanics and electronics. The speciality "Mechatronics" has been changed continuously during the following years by adding new courses according to the newest demands of Industry. Universities went after industry demands. The broad area of Mechatronics education provokes different approaches in preparing students for the dynamic market of highly integrated products. Some universities organize such education programs within a given department (Mechanical, Electrical, or Control) or with the cooperated efforts of several departments. Some curricula include subjects not from all four basic engineering areas or are concentrated around one spinal discipline (e. g. control engineering). If we follow the history of mechatronic studies, we may point out several approaches. In [1] Craig puts the stress on:

1. Balance between modeling/analysis skills and hardware implementation skills
2. Mechanical engineers to be proficient in control design
3. Understanding the physical and mathematical fundamentals
4. Lab exercises
5. Team work to develop and present a mechatronic system

Wikander (Mechatronics Lab, Department of Machine Design, Royal Institute of Technology, Stockholm, Sweden) et al. [2] claim that a new Mechatronic approach is needed where a shift from mechanical hardware to computer software is established in implementation of functionality. We may say that this the first emphasis on Information technologies over the process of design: "The older subsystem-based approach of designing the separate homogeneous subsystems and interfacing them afterwards does not provide the full integration of the design process of a given mechatronic system". His main concepts are:

- Shift from mechanical hardware to computer software
- Greater integration than the older subsystem-based approach of designing
- Interdisciplinary courses integrated in an existing program of mechanical engineering
- Design process, problem-based learning, team organization
- Roland Siegwart (Institut de Systémes Robotiques, Swiss Federal Institute of Technology, Lausanne, Switzerland) [3] gains all the skills through projects where theory meets practical illustration because this element adds more motivation to the studies. His concept:
- Smart Product Design
- Bonding the interdisciplinary knowledge
- Team projects for mobile robots participating in a contest in the end

The practical education is an emphasis also in the Ritsumeikan's Department of Robotics [4]. The exercises in the courses of advanced robotics there are held from the second until the last year in the university. As for the previous case system, integration is a basic purpose for the students to achieve. Despite the great difficulties they meet, they receive background knowledge and experience in order to proceed with their careers and research in robotics. The scientist who is considered to be in the basis of Mechatronics is Masayoshi Tomizuka (Department of Mechanical Engineering, University of California at Berkeley, Berkeley, CA, USA). In his work [5] he states: "Issues surrounding integration as well as working in team cannot be taught in lecture courses.

Students must experience them, and in this regard laboratory courses are essential in mechatronics education". In addition he emphasizes on:

- Integration
- Teamwork
- IT tools should be broadly incorporated into education

Brown et al. (Hull University) [6] express their preference toward the approach of project based practical engineering and to support it with theoretical learning. They place the basic questions concerning mechatronics education about the owner of this type of courses, the contents, and the way to "teach such a different philosophy with such a wide range of diverse subjects".

Mechatronic education at the University of South Carolina is being developed together with programs of Smart Structures and Adaptive Materials in the Mechanical Engineering in cooperation with the departments of Electrical Engineering and Computer Science [7]:

- Intertwined blend of mechanisms, sensors, actuators, electronics, and information technology. The ideal graduate should be able to hit the ground running in all these areas concurrently in order to achieve maximum performance with minimum training time.
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The course sequence in Mechatronics in the University of Arkansas at Little Rock described by Wright [8] is a supplementary one for the system-engineering program there. The multidisciplinary character of this type of undergraduate education is formed by the following sequence: Introduction to Engineering, C Programming, Elements of Mechanical Design, Circuits and Systems, Digital Systems, Control Theory, Instrumentation and Measurements, and Mechatronics (in the senior level) together with CAD/CAM laboratories and lectures. The design skills are the target of a free-form design project where students have to develop, analyze, simulate and produce a prototype, concerning also cost and budgets. A special competition (US FIRST design competition) in building a teleoperated mobile robot in 42 days is an additional task for the students of the university to enhance their training in cooperation with pre-college students.

An open-ended project is developed for the undergraduate Mechatronics course of Stanford University. Carryer [9] describes it: "The intent is to teach mechanical Engineering students enough about electronics and software so that they will be able to be effective interdisciplinary team members and leaders. The philosophy is that the best way to learn the capabilities **o**f the technology is to actually learn to apply them oneself".

The graduate Mechatronics course in the Woodruff School of Mechanical Engineering at Georgia Institute of Technology [10] is concentrated on the microprocessors and microcontrollers in mechanical systems. The course contains considerable part of hands-on design and work (usually in teams of couples of students) and ends with a final project also organized in teams. Computer programming and electrical engineering disciplines are mostly covered.

Van Brussel (a famous robotic researcher, supporter of interdisciplinary mechatronic education) [11] says*:* In the past, machine and product design has, almost exclusively, been the preoccupation of mechanical engineers. Solutions to control and programming problems were added by control and software engineers, after the machine had been designed by mechanical engineers. This sequential-engineering approach usually resulted in suboptimal designs. Recently, machine design has been profoundly influenced by the evolution of microelectronics, control engineering, and computer science. "

A new systematic approach to understanding of education in Mechatronics is suggested in [12]. The new paradigm assumes that the education environment is inevitably characterized by synergistic integration, including globalization, localization, and individualization at different levels and in different aspects of the industrials system. Taking into account the industry demand and expected for "Mechatronic" engineers knowledge we may propose the following curriculum model:

Basic Topics:

1. Basic Science module – approximately 20%
2. Mechanical and Measurement Engineering module – approximately 20%
3. Electrical and Electronic Engineering module – approximately 20%
4. Information Technology/Computer Science module - approx. 25%. 5. Control Engineering module – approx. 10%
5. Humanities/Management module – approx. 5%

Specific Topics:

- Modelling and design
- Motion control
- System integration
- Vibration and noise control
- Actuators and sensors
- Micro devices and optoelectronic systems
- Intelligent control
- Automotive systems
- Robotics
- Manufacturing, etc.

According to our research the industry demands for university education in "Mechatronics" is as follows:

Project-Oriented New Courses and Programs with:

- More practical work in class and in enterprises
- Emphasis on team working
- Competitive approach in pursuing project tasks.

Design of new laboratories equipped by industry and according to their needs.

On the other side industry may help of education by:

- More training
- Organize design workshops and factories.
- Organize competitions
- Scholarships and grants for promising students
- Offer better payment for young specialists
- Joint research projects with universities

II. Master Degree Program In Mechatronics At The Technical University Of Sofia

Many new Mechatronics courses have been developed all over the world during the last years [15],[16],[17],[18]. Those courses have been developed either mechanical engineering departments or electrical engineering departments and very rarely in computer science ones. In practice, now the majority of them are offered in mechanical engineering departments as is the case at the Technical University of Sofia. The education in Mechatronics has gradually emerged in Bulgaria during the last ten years and had been located in the Mechanical Engineering Faculty of the Technical University of Sofia [14]. It has been developed with the help of the DAAD Project "Mechatronics", Pact of Stability in which universities from the following countries participated: Germany, Hungary, Slovenia, Serbia, Macedonia, and Bulgaria (2000-2006).

At the TU-Sofia, we consider that what is of utmost importance is to achieve balance of the disciplines in the following fields of study and research: mechanical engineering, electrical and electronic engineering, control systems, and information systems. Also, we pursue to reach balance in the development of the following skills: theoretical knowledge (ability of modeling and analysing) and experimental validation of models and design. For this purpose, all the disciplines in our master program in Mechatronics are grouped in modules with recommended coefficient of weight of those modules in percentage as shown above.

Students who enroll in Master program in Mechatronics are usually those who graduate as bachelors in Mechatronics, Mechanical Engineering or Electrical Engineering. Students with bachelor degrees in Mechanical Engineering who enroll in Master program in Mechatronics are supposed to take a special extra course in "Fundamental in Electrical Engineering" (about 10 credits). Students with bachelor degrees in Electrical Engineering have to take an extra special course in "Fundamental in Mechanical Engineering" (about 10 credits). The Master program in Mechatronics at the Mechanical Engineering Faculty aims at providing students with interdisciplinary knowledge and skills, integrated design approach, manufacturing and maintenance of products and processes. More precisely the topics that are to be covered in this program include: system design (selection of sensors, actuators, electronic components and computer simulation), microprocessor technology (system architecture, digital systems, memory storage devices, input/output devices), interfacing techniques, digital communications, software development, and control systems.

The Selected Topics in Mathematics are aimed at the increased practical knowledge of set theory, images, mathematic statistics, experiment planning, graph theory, probability theory, etc.

Selected Topics on Mechanics is an extension of the "Mechanics I and II" from the undergraduate program. It contains topics from the analytical mechanics and vibrations theory, and discrete multimass systems connected with the design and analysis of transport and hoisting machines, building machines, robots and manipulators.

The Basics of Mechatronics course provides knowledge of the structure, functions, environment of the mechatronic systems, as well as their basic elements. An emphasis is placed on the methods for mechatronic systems design; concept preparation, planning, object design, etc. The theoretical bases for mechatronic systems modeling and different models of mechanical building elements, electric actuators and machines are reviewed.

Various technologies and technological processes are taught in the Micromechanics subject, which are used for the production of micromechanical structures. Technological equipment for their production and operations control means is reviewed. The design gmethods of micromechanical elements, the production technology development, and assembly methods are covered. The laboratory exercises provide an analysis of the available equipment design, optimal technological parameters settings of the equipment, and concrete production operations of the students for preparing micromechanical modules.

The theoretical issues of the optical and optoelectronic devices and specific solutions of some groups of such devices are covered in the subject Optic and Optoelectronic Devices. There are included the principle schemes of the basic types of optical, optoelectronic and laser systems that are used in industry and for research, the typical units of these systems, optical and fiber-optical sensors. The laboratory exercises give the students some skills in the operation in the use of optical and optoelectronic equipment, the ability to choose the right one for a given task in their future engineering careers, and to communicate with specialists in the given area.

The lecture material in Reliability of Machine Products deals with the problems and methods for planning, determining, normalizing, providing the reliability of products during their design, manufacturing and exploitation. Some issues here are basic reliability models, Markov models and processes application, processes that impede reliability and the influence of design and technology on them, methods for diagnostics of machines, systems and processes, etc. The laboratory exercises include some the investigation of the processes that impede reliability, calculation methods and the creation of algorithmic methods for reliability modeling and analysis, as well as diagnostic experiments with specialized equipment and software.

The discipline of Engineering Analysis and Simulation Modeling covers the types of models, their application in engineering analysis, practical problems in machine and appliance building through static and dynamic models, stochastic processes, experiment data analysis, regression analysis, dispersion analysis, correlation analysis, experiment planning, simulation methods. Students are provided with skills in working with the basic software products in this area.

The purpose of the subject Mechatronic Systems with Multi-joint Structures is to introduce the students with the kinematics and dynamics of these Mechatronic systems, the method of impedance control, Mechatronic systems with closed multi-joint structures, and new types of Mechatronic systems. The experimental work is carried

out with software programs for dynamic modeling and simulation and analysis of the results is made.

Intelligent Control and Technical Vision subject covers topics on the methods of modeling, identification, and simulation of incompletely defined structures, digital, adaptive and intelligent control, synthesis and optimization in control problems, increase of system autonomy through artificial intelligence and acquisition of sensor information, technical vision systems, object recognition, video information processing, communication and integration of these systems with the other components of the Mechatronic systems..

Sensor and Actuating Systems contains issues on acquisition, conversion and processing of information from sensors, integrated sensor schemes, integration of sensor, actuator and control systems. The laboratory exercises improve the understanding of the theoretical material.

The subject of Technical Legal Issues and Law presents basic knowledge about the application of normative acts in two directions: the normative order of the firms and economic units according to the issues of the civil and trades law; the obligatory and the voluntary regulations for manufacturing and selling safe ant qualitative machine products. The purpose of the Industrial Management discipline is to provide knowledge about the basic problems in managing the industrial organizations, management thinking and functions.

Intelligent Manufacturing Systems provides the students with knowledge about the application of artificial intelligence and the integration of manufacturing and computer systems. Main issues are: historical development and today's problems of artificial intelligence, data bases, and knowledge bases connected with machine building, expert systems, IMS in robotics, etc. An emphasis is placed on the application of IMS as a base for the "Factory of the Future".

Advanced Motion control is a course related to automation. Students are taught how to control the position or velocity of machines by the use some type of power devices such as linear actuators, electric motors, hydraulic pumps and others. Motion control is an important part of robotics, CNC machine tools, automated production and assembly lines and many others.

III. Conclusions

At the TU-Sofia we pay a special attention on practice and research work considering that this is a very important part of the education on Mechatronics. All our students are asked to design and elaborate a mechatronic device. Mechatronics with its complexities and rapid development is one of the most challenging courses in university education. With appropriate strategy, excellent result could be achieved, but not with the traditional way of education.

One of the most difficult tasks is to stimulate university bodies to overcome existing organizational barriers and to begin development of co – operative teams from specialist in different field, for education in Mechatronics. This could be achieved by participating in projects with close connection to the industry.

Number of universities and programs for education in Mechatronics is growing very fast. One of the best ways to have a competitive education is the integration. Universities have to offer double degree programs which will attract more students all over the world.

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