Automotive Mechatronic Systems : A Curriculum Outline

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ABSTRACT

In this paper, a review of mechatronics is presented with emphasis on the desired qualities of university graduates as viewed by industry. A detailed description of a sequence of two new courses on automotive mechatronic systems and a specialized laboratory are discussed. The new coursework has been added to the curriculum towards the degree of systems engineer at Oakland University and will be first offered in Fall '97. The development of the courses and the laboratory has been supported by Ford Motor Company.

Keywords : Systems Engineering, Mechatronics, Education, Automotive.

1. INTRODUCTION

With the introduction of the Transactions on Mechatronics early in 1996 as a joint publication of IEEE and ASME, renewed focus has been given to the need for research and academic development on a multidisciplinary engineering basis. Over the decades, academics and universities have diversified their curriculums to skill students well in their specialized fields. Current programs in electrical and mechanical engineering have many subfields of specializations. Characteristic of this are the current curricula for the study of mechanical and electrical engineering.

Such specialization is reflected in the work methodologies of many projects where the planning and design focusses strictly on defined areas of specialization, not over the system as a whole. As a result, graduates, starting in industry turn out to be trained with less than desirable level of team working skills often needed in interdisciplinary engineering projects. Industries views on the level of preparation of university graduates has been recently documented in Kheir et al [14].

Oakland University, with support of Ford Motor Company, has developed a sequence of two new courses in the field of Automotive Mechatronic systems. The courses will be first taught in Fall '97. In this paper a detailed description of the contents of the courses and the new lab components will be presented. Section 3 presents a discussion on the definition of mechatronics and Section 2 the needs for skilled engineers in this field, from different standpoints. To emphasize on the automotive mechatronics, Section 4 is devoted to these applications.

2. DEFINITION OF MECHATRONICS

The Transactions on Mechatronics has adopted the following definition for the field. "Mechatronics is the synergetic integration of mechanical engineering with electronic and intelligent computer control in the design and manufacturing of industrial products and processes" [1]. In the many definitions of mechatronics through-out literature, several keywords seem to be adequate in representing the characteristics of this field.

Together they describe mechatronics as an integrative discipline utilizing the technologies of mechanics, electronics and information technology to provide for enhanced products, processes and systems. The concept underlines the necessity for integration and intensive interaction between different branches of engineering, rather than being a new branch of engineering. Figure 1 shows the different disciplines coming together where Mechatronics is the "synergetic combination" of the different disciplines [12].

Design in the automotive industry, like many system engineering products or processes, requires manipulation and control of their dynamics to meet the required specifications. This involves the use of enabling technologies such as sensors, actuators, communications, software, optics, electronics, structural mechanics and control engineering.

A key factor in the mechatronics philosophy is the integration of microelectronics and information technology into mechanical systems, so as to obtain the best possible solution. This kind of a design therefore

has to be an outcome of a multi- or transdisciplinary activity, rather than an interdisciplinary one.

technologies [5]. Mechatronic design activity requires the operation and communication of engineering de-

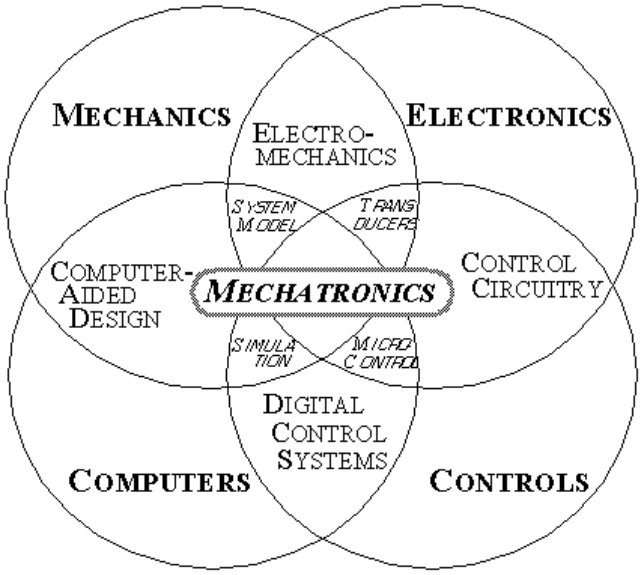

Figure 1 Mechatronics is the synergetic combination of precision mechanical engineering, electronic control and systems thinking in the design of products and processes [12].

3. ENGINEERING SKILLS IN MECHATRONICS

It is noted that the need for mechatronic engineering emerges directly from the revolution of production and design technology in industry. Since mechatronic products and systems are characteristically different from those of traditional machines and electronic products, their development demands special methods and strategies.

Buur [4] argues that there are four particular patterns which characterize the product development practice of the most successful Japanese corporations. They are i) react quickly to changes in competition, ii) shorten the product cycle, iii) emphasize the competitive product properties and iv) plan carefully for new markets. Reduction in product lead times is difficult to achieve by traditional compartmentalized sequential-product-development strategy, in which too much crucial information is lost at every transition from one department to another, resulting in loss of valuable time.

To be internationally competitive, the product design and development activity must be performed concurrently, to ensure that a multidisciplinary design team considers all aspects of the product design with sufficient attention to market needs and manufacturing

signers from different disciplines. It is interesting to note that some of these requirements are part of what is being known as *Systems Engineering thinking*.

Indeed, also in the Netherlands [2] it is noticeable that the industry has an increasing interest in mechatronic designers. In order to design products and production processes, characterized by fast response and high precision, one cannot be satisfied with a basically mechanical design to which later a control system (subsystem) has been added. Only an "integrated-design" based on the knowledge of construction possibilities, electronics and computer hardware, control engineering, and computer science can lead to advanced products [6].

Although the mechatronic designer does not have to be a specialist in all the concerned technical areas, he / she should have a reasonable degree of knowledge of the other disciplines in addition to the one which is his / her major study, in order to function with success in a mechatronics design team environment.

To a similar conclusion came the commission, convened by the Massachusetts Institute of Technology, which studied the productivity and performance of the USA industry [13]. The MIT's commission recommendations stress on the need for a new nucleus of engineers who have broader backgrounds but with spe-

cialist knowledge of a discipline and abilities to operate in a multidisciplinary project team. This proposition agrees with the concept of the mechatronic engineer presented earlier in the definition of mechatronics.

The commission also studied various sectors of higher education, including the engineering curriculum and made some recommendations. These include the following:

1. A new cadre of students and faculty characterized by the ability to operate effectively beyond the confines of a single discipline needs to be created.
2. Emphasis on real-world, hands-on experience should be made and the students in engineering schools should be exposed to real problems that go beyond the idealized abstractions that have dominated texts and homework since the 1950s.
3. The importance of teamwork should be emphasized by introducing a practical team project that could substitute the undergraduate thesis.

In the Automotive industry in particular, there is a serious need for engineers who are well trained in mechatronics methodologies who can function effectively in a team working environment, and have engineering abilities to help in the modeling, design, evaluation, analysis and trade-offs studies for automotive systems.

Accordingly, there is pressure on universities to produce such qualified graduates. For it is the task of the universities to train students to deal with both high level scientific technology in the various disciplines and, to think, communicate and design effectively at the same time. Graduates should not only be familiar with the problems they will encounter in industry, but also with the methodology to attack them. M. Acar marks that we're looking for geniuses when we state these advanced requirements. For this reason he is talking about the Renaissance man for the true Mechatronics engineer [3].

4. Mechatronic Systems in Automotive Applications

Several applications in Automotive industry may be illustrative for the involvement of mechatronic design approach [9]. It is no coincidence that the first issue of the Transactions on mechatronics has a survey on the role of electronic controls for future automotive mechatronics [10]. Their topics include integrated circuit technologies, power electronics, software, emission requirements, alternative fuels, safety and traffic congestion, diagnostics, and adaptive semi-active vehicle suspension system [11].

A well-planned Systems Engineering Process for research, development and engineering of multidisciplinary mechatronics products is a key factor for success and competitive edge in the automotive industry. Critical elements in the process include communication (from customer requirement, government regulation, engineering specifications, manufacturing, marketing), technical and technology know-how (knowledge of engineering, prototyping, testing and manufacturing), and resource management (life cycle cost, man power, product evaluation, reliability and durability).

In many instances, advanced computer simulation software has been used as a platform to convey, share and analyze these elements, resulting in cost and time reduction in the process. The trend in the automotive mechatronics therefore is going in the direction of integrated multidisciplinary engineering simulation that can emulate the design and analysis of prototype products before committing to actual fabrication.

5. Course Descriptions

Supported by Ford Motor Company, Oakland University was able to fulfill the need for specialized courses in Automotive Mechatronic Systems. This resulted in the development of an undergraduate course "Automotive Mechatronics I" and a graduate course "Automotive Mechatronics II". Still under consideration is a third higher level graduate course where advanced topics will be highlighted. The name of this course is suggested to be "Advanced Automotive Mechatronic Systems".

Automotive Mechatronics I.

This first course is a dual level (senior graduate / beginning graduate) course which broadly emphasizes modeling, identification and simulation techniques, CAD software, automotive sensors and instrumentation, actuators and power train devices, automotive and industrial electronics as well as control systems. The capstone of the course will be a case study where engineers will be teamed together to design, implement and evaluate strategies using simulation and investigate different alternatives and trade-offs. Written and oral reporting will be required.

An overview of mechatronics as an evolving field is presented; modeling, identification and simulation;

Figure 2 A Typical laboratory setup under the hood of a vehicle, to measure mechatronics characteristics.

introduction to computer-aided engineering software including MATLAB, SPICE, SABER, EMAS, EMSS; study of automotive sensors, instrumentation, actuators and powertrain devices; automotive and industrial electronics (analog and digital) presented; automotive and industrial control systems; focus on product design; mechatronics case studies.

Automotive Mechatronics II.

The second course structure and contents will highlight a number of advanced topics on sensors and controllers with emphasis on criteria for selection of sensors and their interfaces, electromagnetic compatibility and emerging technologies in automotive mechatronics.

It is envisioned that this course will be team taught with invited lectures from industry to present specialized topics. The course includes an extensive review of fundamentals of software and modeling, sensors, actuators, power train characteristics, automotive and industrial control systems; selected advanced topics include engine and exhaust gas sensors; issues of sensors interfaces; injection electronic circuits, engine controller, transmission controller, pneumatic servos and active suspension;

emphasis on electromagnetic compatibility includes issues related to systems design, compatibility requirements, filtering, shielding and grounding, testing; emerging technologies in automotive mechatronic systems are presented including power train, driver information devices, chassis, body control devices. Student projects will be the capstone component of this course.

6. LABORATORY EXPERIMENTS

For several years, Oakland University has been aware of the importance of mechatronics and of multidisciplinary training for students in engineering. Illustrative is the lab-course on the Electro Hydraulic Servo mechanism [7] and the many automotive related projects in collaboration with the surrounding automotive industry. Figure 2 shows an example laboratory setup for an automotive related project.

Illustrative for a mechatronics laboratory is also the integrated electro-mechanical controls laboratory at Christian Brothers University [8]. It facilitates equipment setups for students with backgrounds in chemistry, electronics and mechanics. The focus on digital and multi variable controls, robotics and local area networks highlights the multidisiplinary aspects of mechatronics.

Team work from preliminary design to hands-on development is intended to be the concept for the practical part of the new developed course work. Students will be exposed to professional hardware and software,

similar to the tools they will encounter in their future industrial working environment.

Concerning the Mechatronics Measurement and Computing Equipment, the lab-setup is furnished to highlight the multidisciplinary aspects of automotive engineering in the curriculum.

An open car body and subsystems with sensors, actuators, electrical and electronic components serves as the workbench in the mechatronics laboratory. The sensors and actuators, being the essential physical transducers in the system, are connected to a measurement and data aquisition station. The aquired data is read and processed with computer workstations that run signal processing and simulation software tools. Power supplies and signal amplifiers will be part of the setup to drive the actuators with the controls from the workstations.

Applications from true automotive manufacturing problems will be used for student projects in the laboratory assignments during the courses.

7. ACKNOWLEDGMENTS

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8. REFERENCES

[1] F. Harashima, M. Tomizuka and T. Fukuda, "*Mechatronics - What is it, Why, and How? an Editorial*". IEEE/ASME Trans. on Mechatronics, Vol.1. No.1. March 1996.

[2] J. van Amerongen and W. Jongking, "*Mechatronics in the Netherlands*". IEEE/ASME Trans. on Mechatronics, Vol.1.No.2. J une 1996.

[3] M. Acar and R.M. Parkin, "*Engineering Education for Mechatronics*". IEEE Trans. on Industrial Electronics. Vol.43. No.1, Februari 1996.

[4] J. Buur, "*Mechatronics Design in Japan*". Institute for Engineering Design, Technical Univesity Denmark, 1989.

[5] D. Bayliss, R. Akueson, J. Knight and R.M. Parkin, "*Implementing concurrent engineering, using intelligent systems*". In Proc. CEEDA '94, 2nd Conf. Concurrent Eng. & Electronic Design Automat., Bournmouth, Apr 7-8, 1994, pages 75-80.

[6] J. van Amerongen, A.W.P. Bakkers, P.C. Breedveld and T.J.A. d Vries, "*Tools for Mechatronic Design*". Int.Symposium Enabling Objects for Industry, Univ. Twente 1994, pages 16-21.

[7] M.K. Das and Ka C. Cheok, "*Electro-Hydraulic Servo-Mechanism - A Laboratory Project for Undergraduate / Graduate Control Courses*". Proc. of the American Control Conf. pages 1246-1249. San Francisco, June 1993.

[8] J.E. Beaini, L. Althaus, J.C. Olabe and E. Welch, "*Integrated Electromechanical Controls Laboratory, using programmable logic controllers*". Proc. of the American Control Conf. pages 2036-2039. San Francisco, June 1993.

[9] R.K. Jurgen (editor), "*Automotive Electronics*". Handbook, McGraw-Hill, 1994.

[10] M.B. Barron and W.F. Powers, "*The Role of Electronic Controls for Future Automotive Mechatronic Systems*". IEEE/ASME Trans. on Mechatronics, Vol.1. No.1. pages 80-88. March 1996.

[11] R. Isermann, "Modeling and Design Methodology for Mechatronic systems". IEEE/ASME Trans. on Mechatronics, Vol.1. No.1. pages 16-28. March 1996.

[12] J.A. Rietdijk, "*Ten propositions on Mechatronics*". In Mechatronics in Products and Manufaturing Conf., Lancaster University, UK, Sept.11-13, 1989.

[13] M.L. Dertouzos, R.K. Lester and R.M. Solow, "*Made in America - Regaining the productive edge*". New York, Harper Perennial, 1989.

[14] N.A. Kheir, K.J. Astrom, D. Auslander, Ka C. Cheok, G.F. Franklin, M. Masten and M. Rabins, "*Control Systems Engineering Education*". Automatica, The IFAC Journal, pages 147-166, 1996.