

## **MECHATRONICS, MULTIDISCIPLINARY FIELD OF TECHNOLOGY**

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### **1. Introduction**

The term "mechatronics" or "mechanotronics" for the first time appeared about 15 years ago. It has been used mainly in Japanese technological literature for the interdisciplinary field of technology combining fine mechanics with fine electronics. The word "mechatronics" has been interpreted as a compound of two words: MECHANics and elecTRONICS expressing the contemporary relations between micromechanics and microelectronics, Tryliński (1987), Petrik (1987).

Mechatronics has arisen due to the electronic technology progress, particularly in microelectronics. There is no doubt that its unprecedented development was also possible other, thanks to the progress in micromechanics and material engineering, Whitehouse (1991). It is the fine mechanics that creates (by means of design) the material shape of electronic components and devices.

The present new technologies being developed in microelectronics offer the possibility of utilizing the mechanical properties of semiconductors in novel systems of miniature devices like e.g. sensors, transducers, motors and other actuators. Improvements made due to these elements one can see in many fields of technology (automation, metrology, robotics, common use devices – video camera etc.), medicine (organ assisted devices – pacemakers, infusion pumps, arm and leg prostheses, catheter surgery arrangements etc.) and biology. Generally, that is the mechanical engineering which enables industrial production of electronic devices often using special (electro-, opto-, mechano- and chemical) technological processes. Particularly, the fusion of microelectronics and micromechanics technology may cause a misunderstanding in classification to a specific area, which may arise for example, in the case of 3D technology of semiconductor device.

## 2. Mechatronic systems and their components

In the beginning mechatronics was developed mainly for automates and enabled robotics to origin and expand. Therefore it sometimes was identified as a synonym of robotics. Now, the term "mechatronics" (rather than "mechanotronics") is assumed to be much more wide, including research, design and production, respectively, of the elements necessary for mechatronic solutions.

The elementary functional unit of a mechatronic solution is the mechatronic system. It is defined as a mechanical system, performance of which is enhanced by the control system by means of electrical devices, which could not be achieved by mechanical means (devices), Hing-Shaung Ju (1991).

In general, a mechatronic system consists of three essential elements: sensor, control unit and actuator; each one being of different nature and belonging to different disciplines of science or technology and therefore requiring the algorithms of design and analysis typical for different areas.

The sensors consist of pickups or transducers and signal conditioners. The transducer transforms often a mechanical or optic signal (rarely the chemical one) into the electrical signal. The output signals of the transducer are the weak ones (often very weak) and must be amplified by means of electronic devices to the level readable for the controller.

The actuators of mechanical (hydraulic) or electrical (DC or AC motors) nature may include also some assistant devices, like speed reducers or energy transformers.

The control unit is based on a microprocessor system.

It can be noticed that the research and development of mechatronics as well as the design of mechatronic systems and elements involve knowledge from many different fields, mainly from mechanical, electrical and material engineering likewise electronics, informatics and optics.

Although mechatronics is a really existing new field of technology, a short definition of it is very difficult to formulate. The statement that mechatronics is a combination of micromechanics, microelectronics, optics and informatics (software) is not a satisfactory one. Instead of definition it is much easier to give the issue of essential and characteristic features of the discipline, its elements and devices. Among the other it is possible to formulate ten following features (cf Pawlicki, 1992)

1. equisharing multidisciplinary branch of technology, i.e. no constituent discipline of mechatronics is dominant;
2. little sizes of mechatronic elements (of millimeters and often micrometers order) and in consequence, small masses;
3. an inhomogeneous structure of mechatronic elements (devices), which contain besides mechanical also electrical, optical, chemical and other sube-

lements, being their integral components (e.g. monolithic semiconductor devices, semiconductor hybrid systems, signal sensors and transmitters);

4. a variety of materials being used (metal, plastic, ceramics);
5. specific technologies used in manufacturing of the elements (injection, ultra-compression, ion implantation, vapor and anode coating, electroerosion and laser machining, electronic and laser welding etc.);
6. a little energy consumption displayed by mechatronic devices;
7. usefulness of mechatronic devices for converting and transduction signals of different nature;
8. nonconventional principles of design, in which stress-strain calculations of the construction may be neglected;
9. combining the functional properties of a mechatronic device with the features of its framework and casing;
10. a relatively high price of mechatronic product with regard to its volume or mass unit.

It is obvious that the features of mechatronics mentioned above are neither homogeneous nor equivalent ones. Some of them may be attributed separately to many other disciplines of technology, although together they characterize only mechatronics and its products.

### 3. Some fields of mechatronic technology and its applications

Mechatronics as a multitechnological discipline has been developed mainly for industrial applications but it is also very useful in science (e.g. nuclear physics) and many other nonindustrial areas of practical importance, like aeronautics, astronautics, medicine, agriculture or the army. Characteristic mechatronic solutions including systems and their constituent elements one can see as well in an industrial production as in scientific experiments, on boards of ships, aircrafts and space ships, respectively, or in a health service.

The areas of mechatronics in which a significant advance has been achieved and results of which are applied to both industrial and nonindustrial practice concern mainly

- mobile robots, including autonomous mobiles and teleoperations;

- production automation mainly, but not only, for the electronic and precise industry;
- mechatronic machines including a design process, expert systems, and a management of multitechnological development process;
- embedded real-time systems;
- constituent elements of mechatronic systems such as intelligent sensors and actuators with tools as well as subsystems like communication networks, user interfaces and solutions (software) enabling general and distributed control.

The area of mechatronic application concern also the medicine, revealing recently a spectacular progress. Some therapeutical arrangements including mechanisms and controls are

- surgery robots for surgery (e.g. orthopedic and brain operations);
- artificial organs such as heart (Brezade et al, 1992), lung or kidney and assisting devices such as respirator, infusion pump or heart pace-maker;
- powered orthosis for lower limb and total arm prosthesis (Roveta, 1991).

Let me see, particularly at sensors and miniature tools applied to medicine, in view of my personal interest.

Sensors and actuators are the elements of a mechatronic system, without which the realization of the whole structure is impossible. But they create also another independent factor of mechatronic meaning, forming the essential part of measuring devices and tools of special use.

The revolutionary progress that has been made in microelectronics, micromechanics, optics, material engineering and precision technology, Just (1987), enables the realization of miniature special use sensors and actuators. Small sizes of these devices make them nonintrusive (of reduced invasion in medical applications), often more accurate and reliable because of the better materials applied. Because of the small mass requirement concerning the mechatronic devices the price of better material may be the some as of the worse one.

Small sizes bring also another advantages about. Due to the small masses the inertia is reduced and hence the forces acting. In effect the tactile applications are possible without a risk of object or sensor damage. Besides, they also occupy less space and therefore reduce local disturbance processes.

Sensors, especially made of silicon, reveal subsystem features because of a preliminary data processing. It is possible by incorporation of some computer capabilities to the sensor. Such a solution enables a direct transmission of messages to an actuator, which can e.g. pace the heart (implantable pacemaker) on demand, according to the measured ekg potential. The same considerations concern the

dispensing of a drug into a tissue vein using an infusion pump. The aforementioned examples may be considered also as the mechatronic systems.

The miniature electrooptical and chemooptical sensors may transduce and transmit the signals from inside of the body outside for further processing. Image sensors due to the optic fiber are of the important meaning in endoscopic or catheter surgery. Coupled with microdevices like microactuators and microtools may be applied e.g. to gall-bladder or appendix amputations as well as to gynecological operations. Additionally, using the catheter method one can perform a coronary artery (of the heart) repairing, e.g. so-called intravessel ablation. Such an operation procedure does not demand for the patient to stay at the hospital for more than two days.

Due to miniaturization many of analytical examinations of the blood may be performed inside the body (blood vessel) without any blood samples collecting. Only miniature sensors and actuators make possible the realization of cardio and neurosurgery robots.

#### 4. University training in mechatronics

Training in mechatronics is an essential activity that results in development of modern technology and its applications (medicine, agriculture, common use devices making an everyday life easier and enjoyable). Many universities of technology offer courses in mechatronics of different attractive training programs. Generally, they are comparable. Some universities offer training on the base of mechanical engineering education, other (more often) apply electrical engineering as a base. At the Fine Mechanics Faculty of the Warsaw University of Technology we have chosen the way lying between the aforementioned ones. The characteristic feature of our training program is that it includes about 40% contribution of electrotechnics, electronics and computer science (mainly software) subjects, respectively, to about 3500 hours of the 5 years course.

The two first years of studying are intended for training in mathematics, physics, material engineering and foundations of mechanical and electrical engineering, electronics, computer science (software), metrology, automation, design of mechanical and micromechanical structures and technological processes of precision and electronic devices production.

Some of these subjects, in selected domains, are developed in further education during the next years of studying.

Starting from the third year course there is a possibility of preliminary professionally specialization (the real specialty training starts from the eight semester). The Fine Mechanics Faculty offers several specializations of fixed studies plans and

programs and almost twenty training projects for individual form of study under the tutorial control.

The program fixed specializations are

- design of precision devices;
- production of fine mechanical and electronic devices;
- technical metrology;
- industrial metrological systems;
- robotics;
- industrial automation;
- optical devices and systems;
- biomedical engineering.

Looking at the aforementioned specializations given in their traditional names, it may seem that there is no relation to mechatronics. In fact, the connection is very close, which may be confirmed looking at the names of subjects being lectured, particularly in the program contents<sup>1</sup>. Similarly, the above notice concerns informatics, which does not appear in the names of specializations, being one of the essential elements of mechatronics, widely represented in programs contents and training methods.

Besides the MS studying program there are also offered BS courses and postgraduate studies on the PhD level as well as post diploma courses in different specializations and of different durations.

## 5. Conclusions

Mechatronics has arrived not so long ago, but has already established its position among related technological disciplines. The scientific journal – *Mechatronics* (Great Britain) is published quarterly and periodically are organized international conferences and congresses like the 1st Japanese-French Congress of Mechatronics in Besancon (France), 1992 or being actually arranged, the International Conference on Machine Automation, Mechatronics, Spells Profitability, February 1994,

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<sup>1</sup> *Plans and teaching programs for Fine Mechanics Faculty of the Warsaw University of Technology*, ed. Holejko D., Pawlicki G., Faculty of Fine Mechanics, Warsaw 1993

Tampere (Finland). In many European universities of technology (Belgium, Holland, Switzerland and others) there are institutes and departments of mechatronics, which deal with research and training in the mechatronic field.

Mechatronics is a promising and profitable technology, that enables the realization of modern devices, machines and systems with improved flexibility, adaptivity, safety and reliability. Due to mechatronic systems it is possible to achieve the quality assurance and quality control both in manufacturing and in other nonindustrial applications, like transport, agriculture and particularly in medicine.

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