Journal of Achievements in Materials and Manufacturing Engineering
VOLUME 24
ISSUE 1
September
2007

Research projects and university education in mechatronics and robotics

J. Świder*
Institute of Engineering Processes Automation and Integrated Manufacturing Systems, Silesian University of Technology, ul. Konarskiego 18a, 44-100 Gliwice, Poland
* Corresponding author: E-mail address: jerzy.swider@polsl.pl

Received 23.03.2007; published in revised form 01.09.2007

Education and research trends

ABSTRACT

Purpose: of this paper: The paper is focused on presenting the outcome of the task set before its author by Professor Leszek A. Dobrzanski seven years ago, when he was a Dean of the Faculty of Mechanical Engineering of the Silesian University of Technology in Gliwice, Poland, concerning the development and implementation of the Faculty concept of research projects and education in automatic control, mechatronics and robotics.
Design/methodology/approach: The assumptions of the task and short description of the outcome of the activities undertaken for the creation of a laboratory infrastructure are provided, together with research scop formulation and commercial results of cooperation with industrial companies.
Findings: Following several years of activities coordinated by the author, particularly good conditions of educating engineers in mechatronics have been provided, including a unique laboratory infrastructure that is used both for research schemes, commercial projects in mechatronics and robotics conducted for industrial companies.
Practical implications: Practical implications include a unique laboratory infrastructure and well developed and implemented projects in the field of mechatronics.
Originality/value: This is a brand new paper.
Keywords: Development of new curricula for BSc and MSc studies in the field of materials science; Manufacturing and mechanical engineering; Challenges of the widening labour market

1. Introduction

Mechatronics is a concept entailing a wide range of modern knowledge, technologies and methodologies involved in the design, manufacture and operation of advanced technical systems.

The synergic combination of mechanics, machine dynamics, electro-technology, electronics, sensors engineering, artificial intelligence, analogue and digital control, virtual prototyping [7], makes it possible to achieve a new quality of modern technical systems on the one hand, and, on the other one- compels a fresh approach to the process of educating engineers who should be trained to design and operate such systems in technologically advanced environments. Starting with 2000, activities initiated by Professor Leszek Dobrzański, at that time a Dean of the Faculty of Mechanical Engineering of the Silesian University of Technology in Gliwice, Poland, have been undertaken to create favourable conditions for research schemes and university education in mechatronics. For the last few years an exceptional laboratory infrastructure emerged at the Institute of Engineering Processes Automation and Integrated Manufacturing Systems, including two laboratories and five workrooms, fully equipped for research schemes and training students in mechatronics and robotics, with specific focus on industrial automatic control, electro-pneumatics, strength hydraulics, proportional techniques, automatic tuning of continuous processes, programmed control, robotics and robotization of process technologies, sensors engineering, industrial networks, computer aided engineering tasks, virtual reality and integration of tuning and automatic control of manufacturing with organization and management [3, 4, 5, 6]. The workrooms and their equipment are presented in Fig. 1-7.

The laboratory infrastructure was financed by the Ministry of Science and Tertiary Education, the Faculty's own resources and - to a large extent - by proceeds from cooperation with market leaders, companies operating on the Polish market and actively involved in mechatronics. Its state-of-the-art environment

Fig. 1. Workroom: pneumatics, electro-pneumatics and programmed control-work stands

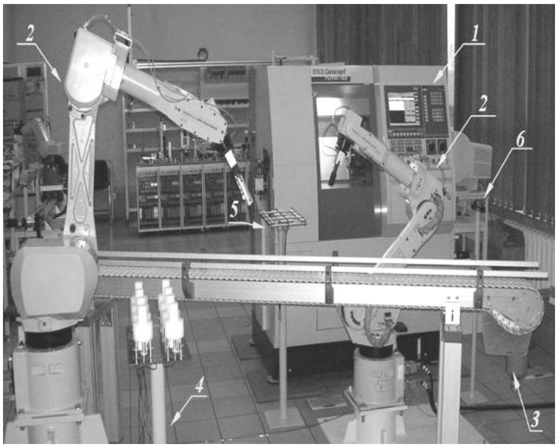

Fig. 2. Workroom: robotics, process technologies robotization-robotized flexible work centre with active safety system 1- CNC rolling machine, 2 – FANUC AM-100iB robot, 3 – belt conveyor, 4,5 – stores, 6 – reorientation work stand

Fig. 3. Modular, mechatronic manufacturing system

Fig. 4. Workroom: tests on sensors and industrial networks

Fig. 5. Robotics Laboratory – robotized work centre

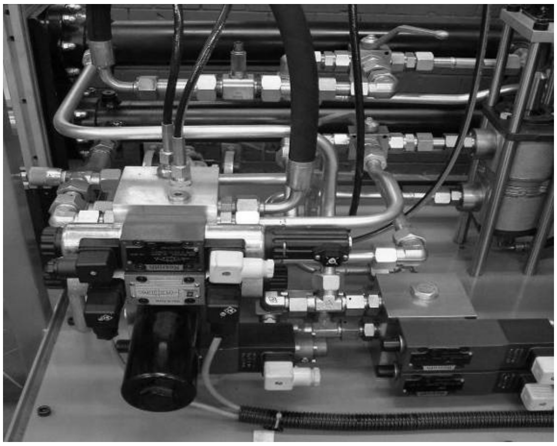

Fig. 6. Mechatronic work stand for testing hydraulic systems

facilitates research projects undertaken as part of PhD and DSc works, as well and day-to-day basic and specialised training of Faculty students [5].

2. Concept of education in mechatronic

The education in mechatronics provided at the Institute of Engineering Processes Automation and Integrated Manufacturing Systems is currently based on two fundamental fields of study: Automatic Control and Robotics, and Mechanics and Machine Building. Also, elements of mechatronics are offered within the other two fields of study: Management and Production Engineering, Technical and Computer Science Education. The variety of instruction and its range depend on the level of study courses, in compliance with the Charter of Bologna (Level I- BSc. courses; Level II MSc. courses, Level III Ph.D. courses). In addition, the teaching process is supplemented by individual projects run by the Student Scientific Society for Mechatronics and Robotics and industrial placements and internships offered by our cooperation partners from industry[5, 7]. A comprehensive nature of the concept of education in mechatronice is illustrated in Fig 7.

2.1. Basic training

The first stage of training in mechatronics is administered during Level I courses, aimed at providing rudiments of university technical knowledge. The training includes fundamental knowledge about mechanics, machine dynamics, subjects from the field of electro-technology, automatic control, control, computer science, following the assumption that the teaching process should be focused on the acquisition of basic theoretical knowledge and practical engineering training, essential in students future professional career. Accordingly, the subjects included in the basic training , apart from specialization blocks, are technical and basic engineering disciplines (mathematics, materials science, etc). The instruction has the form of classes, laboratories and project works. The knowledge acquired by our Faculty is interdisciplinary, and it supplemented by practical engineering skills essential for working in modern machine manufacturing companies, or automotive plants, and for fulfilling the requirements set by advanced technologies, new automated equipment and process machines. The range of the subjects in the specialization blocks makes it possible to combine different fields of science to secure an interdisciplinary offer, in accordance with a mechatronic perception of engineering problems and tasks. Semester projects and BSc. theses are focused on the needs of industrial companies and include practical solutions to the problems posed for consideration. The engineering profile is selected on the last semester of Level I courses.

2.2. Extended training

Level II courses are run on the bases of completed Level I studies and previously acquired knowledge and engineering skills. MSc courses are focused on developing independent, conceptual and creative engineering works. The knowledge about mechanics, control, computer science, and automatics is broadened by specialist and specific tasks involving the skills of programming, signals analysis, signals transmission, artificial intelligence, virtual modelling of manufacturing equipment and systems, robot control, sensors engineering, fieldbus industrial networks. The scope of subjects and tasks concern highly specialized technical problems presented in a systematic frame. The theoretical knowledge is extended by practical aspects of engineering demonstrated in the course of advanced laboratory classes, the scope of which often goes far beyond typical engineering issues. The subjects selected by students in accordance with their specialization are technical and reflect given fields of study. A special form of training is provided by semester projects and later, by MSc. theses, devoted to interdisciplinary issues involved in designing, operating, controlling and programming mechatronic equipment, robots, manufacturing systems. The projects entail the creation of interdisciplinary mechatronic teams appointed to perform complex tasks involved in the design and construction of mechatronic equipment, automatic control systems control, in accordance with students individual interests. The projects are supervised by Faculty staff members.

2.3. PhD courses

In compliance with the Charter of Bologna, Level III courses are individual PhD. studies offered to the most scientifically active students, who have proved their aptitude on Level II and have demonstrated research skills specializing in one of the thematic fields undertaken within the framework of Students Scientific Societies (Fig.2.1). The PhD specialization depends on students' individual preferences and is selected in consultation with their tutors, who later assume the role of PhD dissertation supervisors. The main fields of PhD training converge with the research activities of the staff of the Institute of Engineering Processes Automation and Integrated Manufacturing Systems, in accordance with the disciplines of: Machine Design and Machine Engineering, Automatic Control and Robotics, Mechanics and Computer Science, and concern broad issues of design and construction of systems in view of mechanics and system control (control algorithms, IT integration of manufacturing and transporting systems, dispersed systems, industrial networks, industrial sensors, sequential control and numerical control on the grounds of signals and networks combination, off and on-line programming methodology, supervisory control systems for mechatronic systems and their visualization). Placements or internships in industrial companies that are our cooperation partners constitute an important part of training, as they offer opportunities of verifying the assumptions and solutions accepted for PhD dissertations and facilitate their practical implementations.

2.4. Students Scientific Society for Mechatronics and Robotics

Students Scientific Society for Mechatronics and Robotics plays an important role in the process of training in mechatronics, as the students who are active members have special predispositions for independent research and for initiating new projects. The activities undertaken by the students usually stem from their passion for process technologies control, IT integration of process technologies, design of advanced mechatronic systems, programming of process machines and machine control systems, mobile and stationary robotics. Following their specific interests, they choose the BSc specializations and theses subjects. The solutions presented in the works performed by the students often result from highly-individual research, and sometimes from specific practical needs of our industrial partners cooperating with the Institute. The research results are periodically presented on scientific sessions and published in a special bulletin.

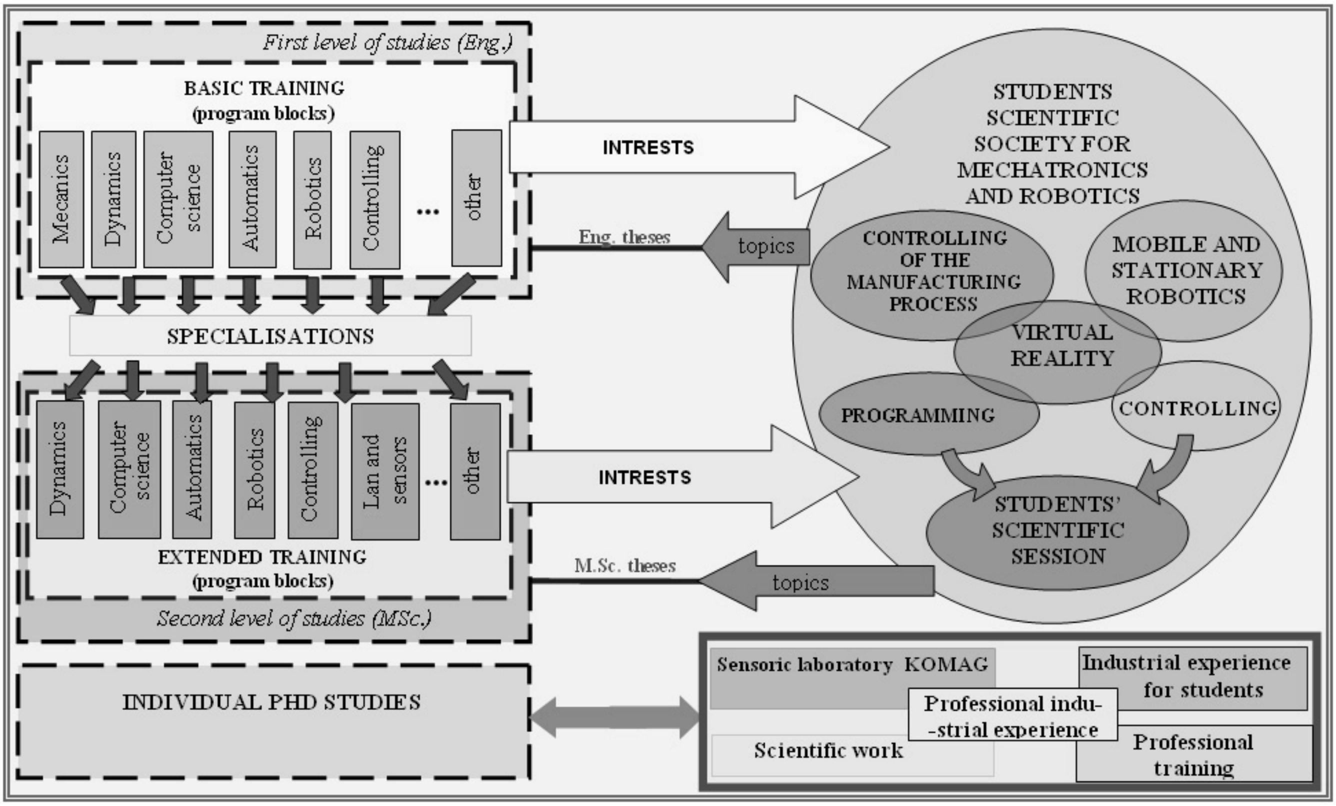

Fig. 7. Comprehensive concept of education in mechatronics

3. Concept of research

The laboratory infrastructure encompasses hardware and software, knowledge, practical engineering experience and real problems encountered in industrial enterprises, research partially financed and ordered by the Ministry of Science- all these factors have inspired many research schemes conducted in the Institute's laboratories by the staff, including: professors, assistant professors and PhD workers. The most advanced projects cover the disciplines of: robotics, support of the optimization of data transmission in AS-interface networks by means of artificial intelligence methods, implementation of fuzzy algorithms in automatic control systems, Mitsubushi standards in CC-Link networks and Q controllers, tests on the impact of the set-up of positioning and velocity errors of autonomous servo-drive controllers on the accuracy of drive positioning, manufacturing systems and applications of piezoelectric actuators into active damping of the vibrations of mechanical systems. Other research and development projects are run upon orders commissioned by industrial enterprises.

3.1. Robotics

The research into robotics is conducted in two workrooms. Workroom: Process Technologies Robotization is furnished with industrial manipulative robots IRb and FANUC with control

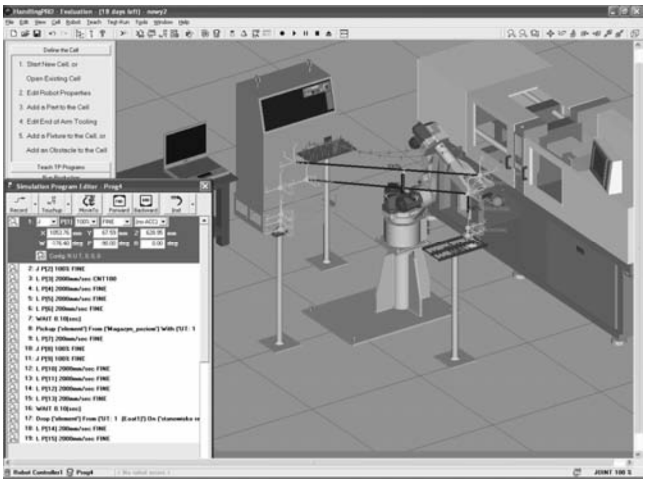

Fig. 8. Off-line programming of the robot aided by Roboguide system

systems NC: PTP (IRb) and CNC: CP (FANUC). The robots are equipped with special technological software enabling the accomplishment of a wide range of manipulative tasks involved in stores and process machines operation. In addition, one of the robots has a vision system detecting manipulated objects. Workroom: Process Technologies Automatic Control and

Robotization is furnished with two FANUC AM-100iB robots with R-J3iB CNC class control. The configuration of the robots also includes a machine tool in a flexible IT integrated work centre (by means of signals from PLC logical controllers and Profibus DP network, which provides the bases for dispersed supervisory control DNC). This work stand is used for research into IT integration of manufacturing systems and off-line programming of robots in consideration of collision-free criteria. The Workroom is also equipped with off-line programming systems: Roboguide(FANUC) and Robcad (eMPower, UGS) (Fig. 8).

Detailed areas of research

The investigation and determination of the algorithms of collision-free control of manipulative robots includes works in the following areas:

- Search for optimal methods of IT integration of manufacturing systems on the bases of binary signals transmission and fieldbus networks (eg. PROFIBUS, A-SI),
- Development of collision-free methods of manipulative robots control in 3D space by exploring new techniques enabling fast definition of:
    - 3D models of the robots surroundings (*Robot's World Model*),
    - Collision-free paths focused on the process of dynamic modeling of robots trajectory in their operational space by means of B-spline curves and Bernstein- Bézier's polynominals,
- Construction of computationally efficient planners of collision-free robots paths, in particular consideration of the robots cooperating in the same operational space,
- Creation of interfaces for data transmission between collision-free robot trajectory planners and off-line systems,
- Adaptation of kinematical and dynamic models of manipulative robots manipulators to off-line industrial robots programming systems to facilitate the optimization of the motion of the robot,
- Off-line programming of industrial robots for tasks to be completed on assembly lines in the automotive industry,
- Creations of time efficient supervision control algorithms in robotized systems characterized by dispersed structure, in consideration of PCs and PLCs.

The activities connected with the area of robotics also include the cooperation with industrial enterprises, especially in exchanging know-how and specialist industrial internships offered to our students.

3.2. Mitsubishi systems testing

The Workroom of Sensors and Industrial Networks is equipped with modular PLC systems made by Mitsubishi. The assembly board of the work stand includes A series controllers (model A2 and A4), Q controllers, CC-Link and MELSECNET network implementations, and MES- data activation module. The Mitsubishi controllers have basic input and output modules and MELSECNET modules. System A4 includes MELSECNET and Ethernet inputs modules and relay outputs modules. Besides, the basic controller board is interconnected with the extension board containing MELSECNET/MINI-S3 module of master type, with twisted pair and fiber optic connectors, and triac output model. A2 system is equipped with MELSECNET, inputs module and relay outputs module- see Fig. 9.

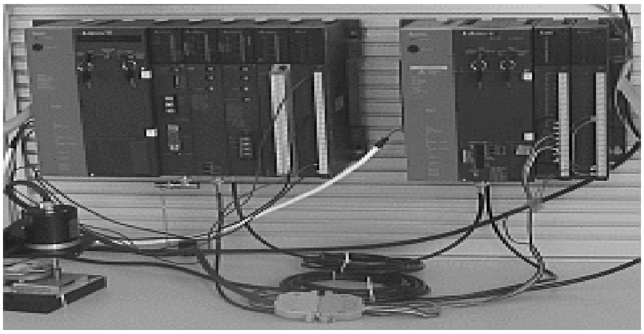

Fig. 9. Modular Mitsubishi A4 and A2 systems

Modular Q systems represent the next generation of Mitsubishi's PLCs. The Workroom has two systems including the inputs module and relay outputs module, Ethernet module and CC-Link network module. The basic board of one of the Q systems has MES data activation module. The general layout of the system is shown in Fig 10.The laboratory stand also has CC-Link network with remote inputs and outputs modules. This is a highly-efficient network of large throughput, based on the master-slave model. It can automatically ignore faulty nodes and reactivate them after servicing. It is also possible to adjoin new equipment without halting the network. The essential feature of the network is its open architecture- originally designed by Mitsubishi, it is now available to a wide range of manufacturers. The supervision over maintaining the required standards and coordination of partnership programs is now CC-Link Partner Association's responsibility. Our Institute has been entered on the list of CLPA partners within the framework of CC-Link research and development schemes and currently attempts are made at integrating various components of industrial automatics by means of CC-Link standard, basing on the equipment that will be made available by this organization. MES data activation module provides grounds for Mitsubishi's new product targeted at manufacturing management teams and systems. The main function of such systems is to ignore the bottlenecks in the information flow and to eliminate computers that function as gateways between PLC s and the database.

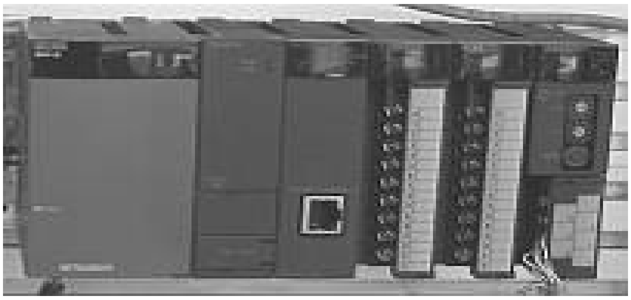

Fig. 10. Modular Q system

Specialized MES module has an option of direct data transmission from the process to the database, and, as it is mounted on the same basic board as the CPU, the speed of operations is considerably improved. The module can also buffer the data during communication breaks in the network- the data are recorded on the memory card and their transfer to the database shall be executed as soon as communication is restored. Currently works have been undertaken on the creation of a local system that will execute the adopted program (simulation of a manufacturing cycle). The collected data transferred to the database shall be used for analyses of production management. The study on the implementation and utilization of the possibilities offered by MES module are conducted by the Institute's research staff and MSc. theses students. Our plans for the nearest future include the expansion of research possibilities of Mitsubishi's system work stand by acquiring additional equipment that will enable the construction of redundant systems, including, first and foremost, Q series systems. As far as A series systems are concerned, attempts have been made to provide pseudo-redundancy by means of standard communication networks and I/O modules. In the next step, we also plan to obtain the equipment required for the construction of Q-Motion – a system of drives control based on specialized motion processor which constitutes an element of the available range of Q system modules.

3.3. Test on servo-drives positioning errors

One of the areas of R&D projects run at the Institute's laboratories is the analysis of the impact of the set up of autonomous positioning and velocity controllers on the accuracy of the whole drive positioning. According to the results of the research, "auto-tuning" functions used by many producers of drives do not guarantee very accurate positioning of numerical drives, based on clearance-free crossed and rolled gears. Tests on the accuracy of servo-drives positioning, depending on the load applied to the servo-driver shaft, utilise the model of high-piling store, equipped with the integrated electro-pneumatic manipulator, one axle of which is mounted on clearance-free gear manufactured Norgren-Herion (Fig. 11). The torques of the axle comes directly from the servo-drive shaft manufactured by B&R. The servo-drive has an autonomous control system based on ACOPOS 1016 amplifier. Mutual cooperation between COPOS controller and the supervisory PLC control system is executed by means of internal CAN network, enabling the PLC to send information on displacements to ACOPOS controller (Fig. 12) and waiting for feedback information on reaching given positioning [6, 7].

Due to the autonomy of B&R ACOPOS controller, all parameters associated with the servo-drive operation are calculated in the servo-controller. The computations of currents and voltage supplying the servo-engine are based on the controller internal algorithms; however, to secure the accomplishment of the tasks of accurate positioning , the parameters associated with amplification coefficients for each internal control unit of the servo-drive must also be inserted. The analysis of the results is aided by B&R Automation Studio programming module. Fig. .13 illustrates the access to the set-up structure of the servo-drive together with generated exemplary functions of shaft positioning and velocity. The final outcome of the research scheme was the design of the procedures of precise tuning of the servo-amplifier and the corresponding set-ups that guarantee satisfactory accuracy on the revolutions level of 0.001.

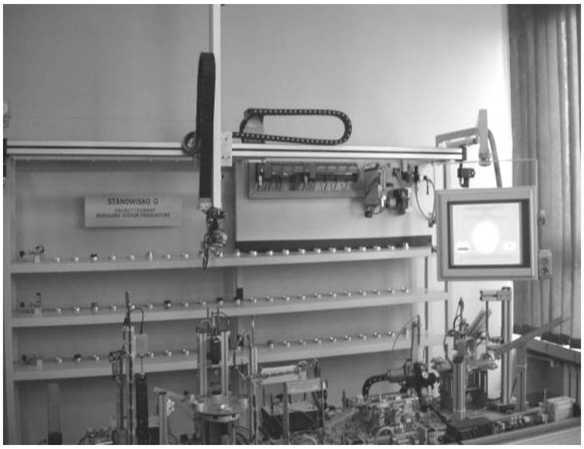

Fig. 11. View on research work stand based on the high-storing model

Fig. 12. Autonomous controller of servo-drive B&R ACOPOS 1016

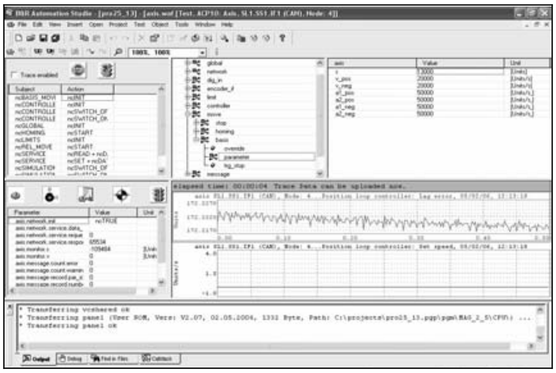

Fig. 13. Set-up window of the servo-drive parameters and diagnostic window for testing the functions of changes in engine shaft positioning and velocity

3.4. Optimization of data transmission in AS-interface networks aided by artificial intelligence methods

The process of technological line design or modernization aided by the structure of an industrial network requires the observance of the standards concerning industrial networks construction, which are often ignored for economic reasons. Companies offering integration services often make essential errors, the results of which are manifested after a while, often as emergency failures (Fig.14). The most common effect of improper implementation of industrial networks are transmission errors. Lost information packets often exceed the error level assumed by manufactures, generating messages about failures that halt the process. Such situation is unacceptable for factories and process plants that base their production on automated production lines [3, 5].

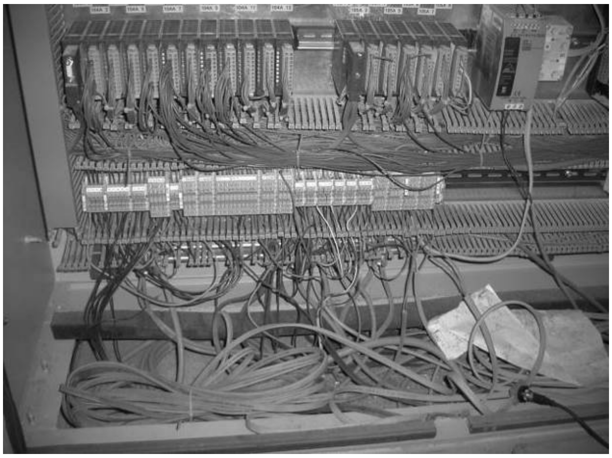

Fig. 14. Example of erroneous implementation of AS-interface industrial network

Accordingly, thanks to the technical potential available at the Workroom of Sensors and Industrial Networks, simulations were conducted under laboratory controlled conditions, aimed at indicating the degree of impact of various factors on transmission parameters. The data collected in the simulation process were subjected to detailed examination, and, in the next step, compiled in databases. In view of artificial intelligence methods, CBR - Case Based Reasoning techniques were used. CBR techniques and the data collected from real process technology facilities made it possible to devise a special tool 0- Sufinet software (Support for Industrial Network Forming), which facilitates the process of planning new AS-interface installations, and , in the case of the existing networks, indicates potential sources of disturbance and guides the engineer to identify most probable cause of the failure. An important economic outcome of the research project is significant reduction of the time required to restore correct functioning of AS-interface network and its undisturbed operation in the automatic mode. The structure of the experts system aide by CBR is based on continuous expansion of the knowledge base. The knowledge is obtained from knowledge engineers (maintenance and operational staff employed at production lines) and from specialists (experts at companies providing technologies). Wide cooperation between the Institute and industrial enterprises facilitated making contacts with knowledge engineers and experts in AS-interface networks. The cooperation results in continuous improvement of the data transfer optimization support systems.

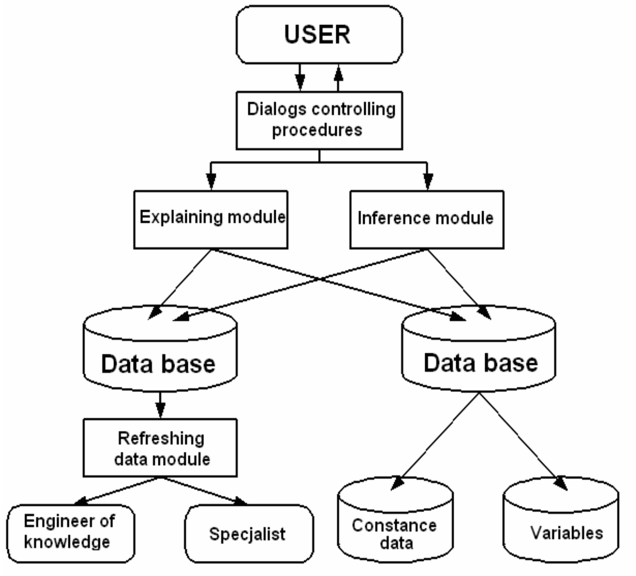

Fig. 15. General structure of the experts system

3.5. System of manufacturing and application of piezoelectric actuators for dumping the vibrations of mechanical systems

Recent years have brought about the advancement of new composite structures that are often called ”smart structures”. These include light elements such as bars, plates and plates containing, apart from classic load-bearing parts, sensors, finishing elements and control or even supply elements spread on their surface or mounted inside. Such solutions enable the measurement of strains on the surface of the elements, and, successively, after transforming the signal, the excitation (on the opposite side) of the required strains. Some specific applications of smart structures include active damping of vibrations [1, 2]. A great advantage of vibrations sensors, such as piezoelectric plates, is the possibility of global measurements and avoidance of specific locations.

Project objectives

The last few decades hale witnessed a great interest in piezoelectric plates and films [1] used as structural elements of intelligent/ smart structures.(Fig. 16), i.e. the structural system and its distributed and integrally connected measurement and operational elements. The piezoelectric elements have already been used as operational elements- inductors in open and closed smart systems (adaptation, active). The advantages of piezoelectric inductors and measurement elements include broad band of transferred signals, high efficiency of the conversion of mechanical energy to electric energy (and conversely), ease of shaping the elements for design purposes and simplicity of the system. Accordingly, together with Dresden University of Technology our Institute is running a project focused on the application of piezoelectric materials with spatially variable electrical properties into active systems of vibrations damping. The project shall also entail the derivation of piezoelectric actuators equations and the formulation of mechanical and electrical boundary conditions.

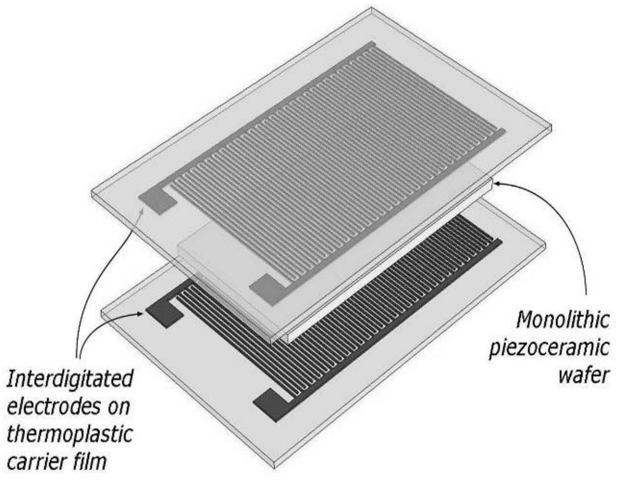

Fig. 16. Schematic illustration of feasible versions of the piezoceramic module compatible to thermoplastic composites with PEEK and PA films respectively

The main emphasis shall be put on the control of the vibration of plates by means of piezoelectric films and, in particular, on the impact of active control on the amplitude and frequency characteristics. Active reduction of transverse vibrations shall be accomplished by means of control considering dynamic and kinetic excitations. The analysis and experimental verification of the structure with distributed vibrations dampers in the form of piezoelectric elements shall be made. The results of the experiment involving active damping of flexible vibrations shall be presented, evidencing the efficiency of the applied control method. The piezoelectric elements shall serve as converters of mechanical and electric energy. In the case of mechanical energy transformation into the electric one, the piezoelectric shall perform the function of a sensor informing the system about the amplitude and frequency of the mechanical system vibrations. After the signal is transformed by the sensor, the generated output signal is directed to the piezoelectric that serve as a transformer of electric energy into mechanical energy and, in consequence, vibrations shall be generated in the counter- phase to the system vibrations. Thus, the principal objective is to construct a system analyzing the signals provided by the vibration sensors- the piezoelectrics – based on professional analogue and digital charts coupled with the computer, taking the readings of the amplitude and frequency of the vibrations of the mechanical systems in the forms of bars, plates and load bearing systems and the devise of the software analyzing the vibrations and, by means of the tuning system, generating a control signal to the damping elements (piezoelectric and operational ones). In addition, industrial logical controllers shall be used with analogue input and output charts and original control systems, based on the programmed microprocessor that shall ensure the accomplishment of the formulated control tasks. The next issue for the research is the analysis of the dynamic characteristics of dynamical systems with vibration damping. Computer simulation on the damping of plate vibrations shall be made, depending on the selected geometrical parameters connected with the piezoelectric material layers.

3.6. Implementation of fuzzy algorithms in automatic control

The Institute is involved in developing classic theories of control and automation and its varieties that make use of artificial intelligence techniques. Due to extensive cooperation with market-leading companies in the filed of automatic control, methods of its application are developed to solve diverse practical problems arising at the design of new systems and improvement of the existing ones. The research schemes include control and tuning of systems with unknown mathematical models, or systems in which it is impossible to update accurate measurements data that are essential to conventional tuning processes. Activities are undertaken to obtain orders from industrial enterprises concerning the construction of complete equipment and machines enabling the implementation of the mechatronic solutions worked out at the Institute. One of the most important expansion areas in modern automatics is the possibility of processes and machine control by means of artificial intelligence methods. The expansion of the range of artificial intelligence applications is connected with the rapid advancement of the infrastructure capabilities of PLCs, computers and software. The implementation of intelligent control systems already entails the majority of the most important branches of industry. Artificial intelligence methods enable the improvement of the quality of control, shorten the time of controllers design and start-up, and, in many cases, provide the only solutions securing the automation of a given process technology [7]. A comprehensively applied artificial intelligence method is fuzzy logic. Currently we are running research works into the possibilities of combining classic tuning methods and fuzzy logic in the control of machines operation and process technologies, including, projects focused on the efficiency of feeders in the textile industry. Some problems in automatic control that cannot be solved by conventional control algorithms involve the absence of the possibility of direct receipt of the feedback signal that would enable the calculation of the error and automatic tuning, significant uncertainty of the measured quantities, absence of permission to modify the machine and shut it down from the manufacturing process for the time of its technical improvement. In view of such problems, the Institute tries to obtain finance for the construction of physical and virtual models of the objects under manufacturing control to explore the possibilities of their automation. Currently works in progress include the development of hybrid tuning systems consisting of fuzzy and conventional controllers. Optimization tests on such systems are conducted by examining their quality features on the bases of the models. Detailed analyses of processes make it possible to devise methods of automatic tuning combining the expert knowledge (the operator's skills) expressed in the machine language by means of fuzzy controllers and utilizing the benefits of conventional control algorithms. The visualization of an exemplary physical model of a feeder used in the textile industry is shown in Fig. 17.

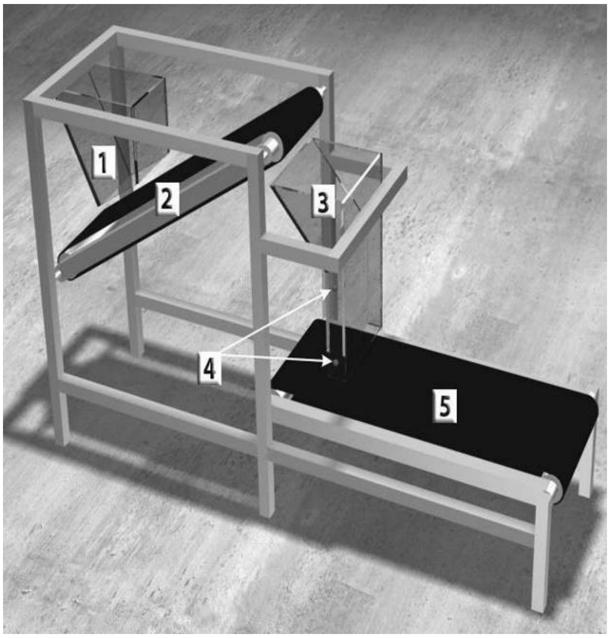

Fig. 17. Physical model of the feeder: charging hopper, (1), belt conveyor (2), intermediary funnel (3), optical barriers (4), receiving belt conveyor (5)

The developed tuning algorithms are implemented in professional PLC systems manufactured by GE-Fanu, series: VersaMAX or by Siemens S7 300 [3, 5, 7] and industrial programming SCADA (eg. InTouch by Wanderware) available at the Institute's laboratories.)

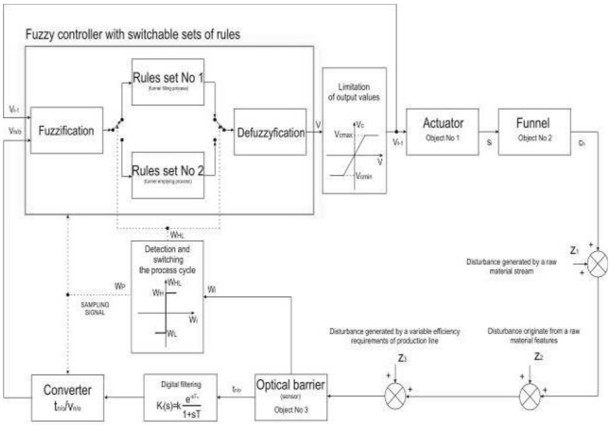

Fig. 18. Block diagram of the tubing system for the textile industry feeder

In the feeder model shown in Fig. 17 the system of controller inputs is responsible for the activation of signals from the objects (optic barriers of the intermediary funnel and the weight system responsible for control quality estimation) , which are initially processed by the central PLC unit and sent to the visualization application, where complex control algorithms are started, requiring considerable computational capacity inaccessible for PLC processors. The central unit of the processor receives the computational results from InTouch software and generates appropriate signals for the output module controlling the operational ,module (belt conveyors engines).

3.7. Orders from industrial enterprises

In recent years there has been a boom in the Polish economy. Local industries, recognizing the necessity of securing the competitive advantage, welcomes cooperation in conceptual and implementation schemes in the area of automatic control and robotics of manufacturing processes, compelling the design, construction, implementation and start-up of mechatronic systems to replace traditional mechanized systems operated by manual workers. Such tasks, in view of available research and infrastructure potential are undertaken by the staff of our Institute, resulting in new practical experiences, enhancing the attractiveness of our future research and development offer and having a direct impact on the training of our Faculty students in mechatronics.

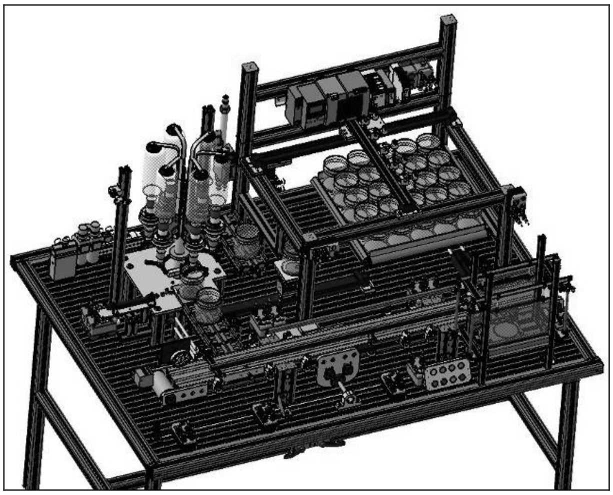

Fig. 19. Virtual model of a mechatronic system ordered by an industrial partner

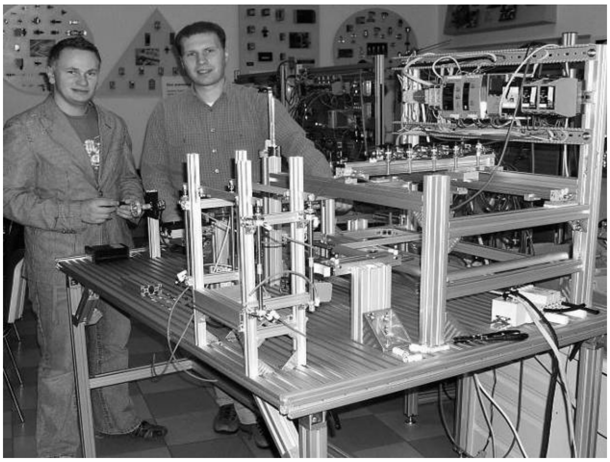

Fig. 20. Institute staff members in the course of completing the showed in Fig. 19

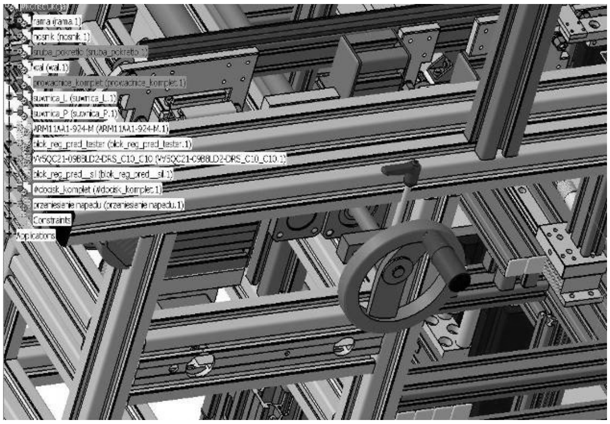

Fig. 21. Virtual model of a mechatronic module ordered by an industrial partner

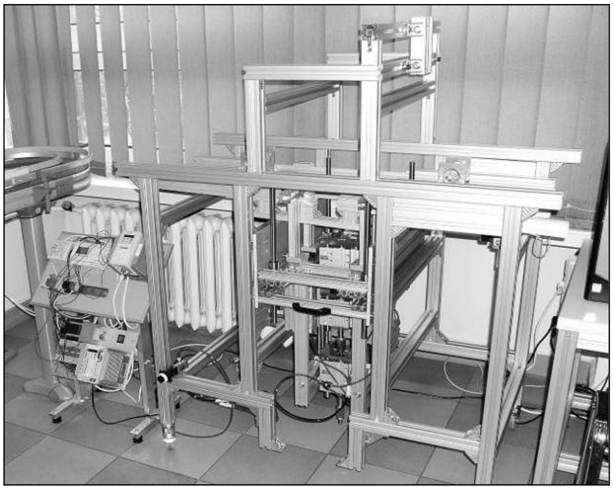

Fig. 22. The stand showed in Fig. 21 during its realization

4. Conclusions

The last seven years of gaining experience in educating and conducting research projects in the field of mechatronics and robotics at the Faculty of Mechanical Engineering have proved the achievability of the assumed concept. Whereas the specializations in mechatronics are getting more and more popular among the best students of the Faculty, the graduates find attractive jobs and high recognition in the eyes of prospective employers. The job market, potentially oriented at the graduates of the Silesian University of Technology, offers employment to well educated engineers, and the cooperation growing year by year between the industry and the Institute of Engineering Processes Automation and Integrated Manufacturing Systems contributes to continuous expansion of our laboratory infrastructure, attractive diploma theses subjects, industrial placements and internships at renowned companies, as well as advanced specific research and development projects undertaken by the Faculty and Institute staff members. Presently, a concept of starting-up Level I and II courses in the exclusive study field of mechatronics is being considered at the Faculty of Mechanical Engineering.

References

[1] M. Gude, W. Hufenbach, N.J. Modler, Design and manufacture of advanced piezoceramic actuators for the application in novel morphing structures made of fibre reinforced thermoplastics. Proceedings of the 12th International Scientific Conference on the Contemporary Achievements in Mechanics, Manufacturing and Materials Science CAM3S'2006, Gliwice-Zakopane, 2006,(Cd-ROM).

[2] M.J. Newman, Distributed Active Vibration Controllers, Recent Advances in Active Controlof Sound and Vibration: Lancaster-Basel:Technomic Publishing (1991) 579-592.

[3] J. Świder, G. Wszołek, The methodical collection of laboratory and project tasks of technological process control. Pneumatic and electropneumatic systems with logical PLC control. Silesian University Publishing Company, Gliwice 2003.

[4] J. Świder, G. Wszołek, A. Baier, G. Ciupka, O. Winter, Testing device for electrical car networks. Journal of Materials Processing Technology 164-165 (2005) 1452-1458.

[5] J. Świder, G. Wszołek, P. Michalski, Laboratory support for the didactic process of engineering processes automation at the Faculty of Mechanical Engineering. Journal of Achievements in Materials and Manufacturing Engineering, 15 (2006) 199-206.

[6] J. Świder, G. Wszołek, D. Reclik, Didactic model of the high storage system. Journal of Achievements in Materials and Manufacturing Engineering 16 (2006) 199-206.

[7] W. De Silva, Clarence, Mechatronics: an integrated approach. CRC Press LLC, USA, 2005.