International Conference
1ST International Conference on Innovations, Recent Trends and Challenges in Mechatronics, Mechanical Engineering and New High-Tech Products Development
MECAHITECH'09

Bucharest, 8-9 October 2009

Improving Infrastructure Capabilities In National Research Center For Microstructure Testing By Microlab Project

Constantin D. Comeaga, Nicolae Alexandrescu, Gabriel C. Alionte
University Politehnica of Bucharest, Faculty of Mechanical Engineering and Mechatronics
313 Splaiul Independentei st., Bucharest, Romania
comeaga@hotmail.com

ABSTRACT

The cooperation between the specialists from Research an Development Center for Mechatronics from University POLITEHNICA of Bucharest and well-known European and Romanian universities and research institutes has shown a growing interest for testing structures with under-millimeter dimensions up to micrometer dimensions. The project MICROLAB chooses to create the optimal conditions for making also in Romania such advanced tests.

The project leaded to the acquisition of very new and modern equipments, unique in Romania in this moment and even very few at European level. It is worth to be mentioned the following equipments:

1. scanning micro-vibrometer MSA-500, producer: Polytec GmbH Germany; the system allows the dimensional analysis, the cinematic analysis of in-plane displacements for the study of plane micro-devices, the determination of plane vibrations and normal vibrations to the structure plane. The MSA-500 is placed on a pneumatic vibration isolation system, with semi-active control.

2. dynamic analysis system of the miniature structures, compound by: vibration analyzer with 3 concurrent laser beams 3D, system for spatial positioning of the vibration analyzer with 3 concurrent laser beams, excitation system and acquisition equipment. The 3D laser vibrometer is CLV-3D type, produced by Polytec GmbH Germany. For a very precise positioning of the measuring point onto the structure, the project team was developed a robot with high stiffness for the setting of vibrometer's optical head.

3. robot for the vibro-acoustic with scanning testing of the structures; the robot has 6 degrees of liberty, comprising a three translation structure, with aprox. 200 mm drive for each axis and a final orientation unit with 3 degrees of degrees of freedom; the robot can displace an acoustic transducer or a vibration non-contact transducer; the robot is placed in a special acoustic isolating room, realized also within the project.

4. dynamic testing system compound by specialized modal analysis software Me'Scope Pro 7754-3 type, Operational Deflection Shape software for the modal analysis without excitation, Operational Modal Analysis (OMA) software; TV 51110 excitation system comprising a vibration excitator and a power amplifier.

The impact of this far-reaching investment is multiple, from which we can point out:

- from educational point of view: increasing the training level of the students; since 2007 the students were proposed different project subjects for graduation, 4 students being selected by the project responsible; their results were special, thus observing on the project website; for the academic year 2009-2010 there were proposed new subjects which use

these equipments, existing a lot of requests on behalf of the students;

- from scientific point of view: the project will assure the logistic support for the development of researches in mini and micro-structures field; there were already made comparative studies regarding the dimensional evaluation methods of the microstructures, one paper being sent to an international conference; the results of the research activity developed at the diploma projects were presented in scientific papers.

INTRODUCTION

The Microlab project has begun in 2007 with a financing from the National Agency of Scientific Research through "Capacities" program, module IV. The overall objective of the project was to develop the National Research Center for Mechatronics of the Politehnica University of Bucharest, for microstructural analysis. National Center for Mechatronics has been developed since 2003 within the research structure of Politehnica University of Bucharest - Center for Research and Development for Mechatronics (UPB - CCDM) of the Faculty of Mechanical Engineering and Mechatronics with the funding of the Government of Romania and with the support of the World Bank. National Center for Mechatronics was designed as an experimental research modern pole, able to ensure the necessary participation of the partner universities (Politehnica University of Bucharest, Transilvania University of Brasov, Technical University of Cluj-Napoca) to the European R&D Network. The project supports the upgrading of the infrastructure of Research Laboratory for Computer Aided Testing Systems Mechatronics from the National Center of Mechatronics (BCUM project type), in the direction and adaptation of existing test systems to test, ultra miniature mechatronic systems, including Microsystems.

One of the research infrastructure development directions for the BCUM project was the dynamic analysis of the electro-mechanical systems, some experimental setups being developed for modal analysis and electro-mechanical impedance measurements. Subsequently the specialists from the U.P.B. – C.C.D.M. created a Laboratory for Acoustical Testing using a financing by means of project INFRAS and CEEX module IV. This laboratory is intended for measuring according with the standards into force the acoustical power and measuring acoustical intensity for computing the acoustical power but also for obtaining an emission map of the sound source. In the same time were established partnerships with few renowned companies specialized in acoustics and vibration. The laboratory hold equipment for dynamical analysis of the mechatronic systems up to the 2000-2003 years optimized for testing structures of tens millimeters size (miniatural accelerometers, miniatural force transducer, multi-channel analyzer, software for signal processing and modal analysis).

The technical cooperation between the specialists from U.P.B. – C.C.D.M. and well-known European universities has shown a growing interest for the field of testing structures with under-millimeter dimensions up to micrometer dimensions. The cooperation between specialists from U.P.B. – C.C.D.M. and National Institute for Research and Development in Microtechnologies developed in the last years was mainly for building microstructures. Both cooperation with foreign and Romanian specialists emphasize the demand for experimental testing of microstructures. The current project MICROLAB chooses to create the optimal conditions for making also in Romania such advanced tests.

The project was intended to extend the testing capability toward the microstructures area, by buying a laser vibrometer without contact, which can measure the vibration on 3 directions, buying also a scanning vibrometer incorporated into a microscope, also a

vibrating table, software for the Operational Modal Analysis (OMA), micro-accelerometers, increasing the vibro-acoustic isolation degree of the testing room. The project does not intend only buying some very performant equipment (all the programs and equipments mention before are the result of the application of some very recent patents, after 2002, to the well-known international companies), but also a research activity in order to integrate all these into an innovator system.

Two objectives were proposed at the starting phase of the project:

developing the research ability by acquiring high-level equipments

developing the logistic basis necessary for optimally using the equipments in the environmental conditions imposed by the producers.

The project also includes "the dissemination" of the equipments and techniques, by organizing at the end of the project a workshop and a training session for experts. Having a significant research component, totally co-financed, the project wants to present the results of this research by the participation to at least one congress or international conference, ISI rated.

Objective of the project

The general (common) objective is represented by the improvement of the research infrastructure of the Computer Assisted Testing Laboratory from the National Mecatronics Center, toward the creation of research capacities of the dynamics of microsystems, in this way ensuring at a national level the access of the experts in mechatronics to an experimental research base, very performant and capable to assure all the necessary capabilities for participating at international research programs. The Laboratory has an experienced management structure, including for creation and development of a testing laboratory, the project responsible having a certain training courses in the research management field, within a program from the World Bank for Romania. In the same time, the project responsible has also trainings and experience in creating a testing laboratory according to SR EN ISO 17025; he participated to 4 training modules within the Romanian Accredited Association.

THE SPECIFIC OBJECTIVES ARE AS FOLLOWS:

- updating and extending the research-development infrastructure from the National Mecatronics Center, a project BCUM type, to which are part 3 universities (Politehnica University of Bucharest, Transilvania University Brasov, Technical University Cluj-Napoca). The field is the dynamic testing of the mechatronics microsystems.
- rising the capacity to offer testing services for research and development, which are inner part of the development philosophy of the National Mecatronic Center.
- strengthening the inter-university research network of mechatronics, extending the interest toward the complex integrated micro and nanosystems.

Expected results

The direct results of the project will be:

- to assimilate some very modern equipments;
- to create a dynamic testing system based on innovating techniques and improvement of the experimental conditions.

In the same time but equally important, the project has proposed as results:

- the dissemination of the testing techniques based on the mentioned equipments

among the Romanian researchers and their training for the new assimilated techniques;

- the publication of at least one paper to an international conference, ISI quoted, in which are presented the results of the researches for the creation of the dynamic testing system fore-mentioned, with direct impact regarding the increase of the international visibility of the Laboratory and also of the National Mechatronics Center;
- the publication of a book regarding the modern dynamic testing methods, with examples for the Microsystems field.

The potential beneficiaries of the project are:

- researchers from the host university of the Laboratory and also from the partner universities of the National Mechatronics Center, which will be given a superior research infrastructure to the present one;
- researchers from the Microsystems field from universities and research centers in Romania and foreign countries, who are interested in testing the micro and nano-systems made by them;
- post-graduates from the host-universities;
- other experts from the structures testing field.

Expected major results

- modernization of 3 laboratories (Acoustic Testing Laboratory, Laboratory of the Computer Assisted Mechatronics Systems, Laboratory for High-precision Measurements) by: improving the logistics (testing rooms) and endowing with necessary equipment;
- promotion of dynamic testing modern methods field; growth of the training level for the students of Mechatronics major.

RESULTS OF THE PROJECT

1. Equipment and logistics

The project leaded to the acquisition of very new and modern equipments, unique in Romania in this moment and even very few at European level. It is worth to be mentioned the following equipments:

1. scanning micro-vibrometer MSA-500, producer: Polytec GmbH Germany (Figure 1,2 and 3); the system allows the dimensional analysis, the cinematic analysis of in-plane displacements for the study of plane micro-devices, the determination of plane vibrations and normal vibrations to the structure plane. The system comprise a differential laser vibrometer with testing frequency up to 2MHz, with guiding of the laser radiation through optical fiber both for reference spot and measuring spot, which is joining a microscope type system, having integrated a controlled deflection system of the laser spot. The vibrometer can be used independently too, excelling by the optical calculation of the difference between optical signals, which is allowing to make measurements at very high frequencies. Differential measurement option is allowing the elimination of the influence of noise vibrations of the substratum when measuring the microstructure vibrations and is also allowing the measuring of the mechanical transfer function between different points of the structure. Thus can be applied well-known techniques from the modal analysis field of big structures (ODS – Operational

Deflection Shape) and microstructures too. The command system of the whole MSA-500 assembly comprises a signal source with numerical synthesis, which can be used to excite the studied structure. The deflection system on two directions of the measuring laser spot can be controlled from the software application, thus eliminating the necessity to displace mechanically the structure (even the most performing positioning systems do not assure the necessary stiffness to measure the very low vibrations levels specific to microstructures, especially for the higher order vibrations modes). The deflection system can be programmed to direct the spot into the points of a network defined by user, the measured data being automatically stored. The measured data can be exported in UFF format, the export option to the modal analysis program ME'Scope being bought too. The MSA-500 is placed on a pneumatic vibration isolation system, with semi-active control.

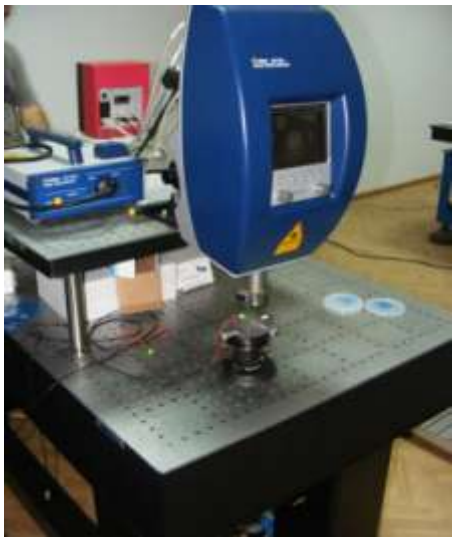

Figure 1: Differential laser vibrometer and optical head of the MSA-500 system

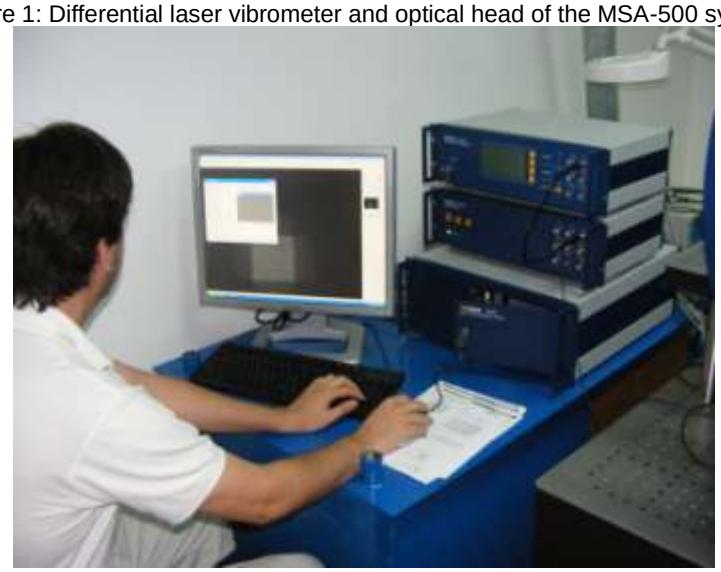

Figure 2: Command, data acquisition and post-processing unit, junction box and decoder of MSA-500

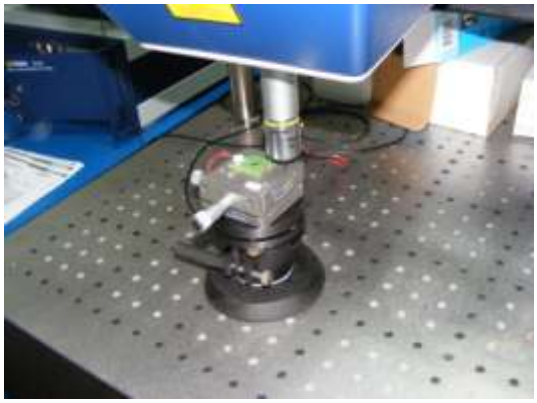

Figure 3: Dynamic testing of a MEMS type positioning system with electrostatic actuator using the MSA-500 system

2. dynamic analysis system of the miniature structures (Figure 4), compound by: vibration analyzer with 3 concurrent laser beams 3D, system for spatial positioning of the vibration analyzer with 3 concurrent laser beams, excitation system and acquisition equipment. The 3D laser vibrometer is CLV-3D type, produced by Polytec GmbH Germany, being the only laser vibrometer on the market able to simultaneously measure the orthogonal vibrations of the structure. For a very precise positioning of the measuring point onto the structure, by the initial proposal of the project it was proposed the setting of vibrometer's optical head on a robot with high stiffness. Such a robot did not exist in the Polytec company offer at the time of the project deposition, and it has appeared only in 2008. The project team has independently developed such a robot in 2008, using ISEL positioning axis, at the present time this robot being functional. For the acquisition of analogical signals from the processing and decoding unit of the vibrometer and the conversion into a numerical signal through an external acquisition board, it is used a LabVIEW application developed by the team project (already in the endowment of U.P.B.-C.C.D.M.). The robot can be controlled through another LabVIEW application. For testing without contact of big dimensions structures, a big dimension robot was done (useful volume 1200x1200x1000 mm3), the dynamic behavior being under improvement.

Figure 4: The structure of the dynamic analysis system of the miniature structures through 3D laser vibrometry: robotized positioning system and laser vibrometer with 3 concurrent laser beams 3D based on Doppler Effect

3. robot for the vibro-acoustic with scanning testing of the structures (Figures 5 and 6); this robot continues a previous research in order to automates vibro-acoustic measurements without contact; the robot has 6 degrees of liberty, comprising a three translation structure, with aprox. 200 mm drive for each axis and a final orientation unit with 3 degrees of degrees of freedom; the robot can displace an acoustic transducer or a vibration non-contact transducer; the whole robotized structure is controlled through applications made in LabVIEW by the project team; the robot is placed in a special acoustic isolating room, realized also within the project.

Figure 5: Robot for vibro-acoustic scanning - three translation structure

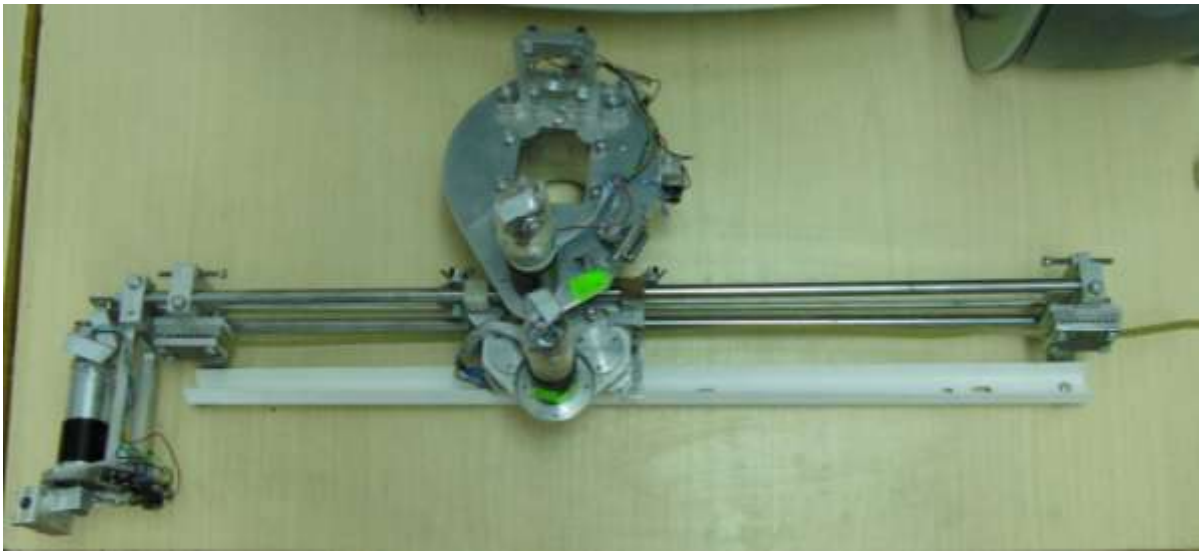

Figure 6: Robot for vibro-acoustic scanning – orientation system

4. dynamic testing system compound by specialized modal analysis software Me'Scope Pro 7754-3 type; (the software is allowing the application of ODS methods (Operational Shape Deflection), SIMO and MIMO (determination of the vibration modes and own frequencies to unique or multiple excitation)); Pulse hardware license (Bruel&Kjaer), upgrade from 12 to 17 channels; Modal Test Consultant software for modal analysis with sinus type excitation or impulse type excitation (this program allows the automation of the modal testing process of structures, the program has different facilities for: graphical design of the structure, control of the calibration, control of the test signals, synchronization of the acquisition to generation of the test signal, filtering the acquired signals and their post-processing in order to export the structure together with all the information about testing – freedom degrees, spectrum, frequency response functions – UFF format and Me'Scope Pro compatible); Operational Deflection Shape software for the modal analysis without excitation, with recording the time response functions of the system naturally excited (this program has similar facilities with Modal Test Consultant but all its functions are oriented toward the determination of the response functions between the measuring points unlike the Modal Test Consultant case – between a measuring point and a response point; this program allows too the export of the data in the post-processing program of the Me'Scope Pro modal parameters);Operational Modal Analysis (OMA) software (OMA method was put into practice of systems dynamic analysis in the last years, based on a statistical analysis of the response signals of a structure under aleatory excitation; the method fill out the ODS, SIMO and MIMO methods for the case of the system who cannot be excited with sinus type signal or impulse type signal and also for systems with time variable parameters, allowing the study of non-linear systems); TV 51110 excitation system comprising a vibration excitator and a power amplifier; this system is small and does not require a forced cooling source and will be integrated into another system who will allow testing the microstructures in conditions of outside vibrations, micro-accelerometers. Pulse, Modal Test Consultant, Operational Deflection Shape, Operational Modal Analysis programs have unlimited upgrade for all the product life time. All the equipment and the software were bought from Bruel&Kjaer company.

The testing systems are placed into a renovated room within the project and divided as a designing space (Figure 7) and a testing one (Figure 8).

Figure 7: Computer Assisted Testing Laboratory of the Mechatronics Systems – the designing room

Figure 8: Computer Assisted Testing Laboratory of the Mechatronics Systems – the testing room

2. Impact

The project will have a big impact on an important field, both at European and national level, as an engine for a competitive economic development - the micro and nanosystems area.

On a long term, the project has an economic impact, by offering the researchers from the public institutions (but also from private ones) some very performant equipments for testing the micro-mechatronics systems with very small dimensions. The impact of the project will be more than local, because of the integration of the equipments into a national character structure, having partners from 3 Romanian universities, so the impact will be national.

There will be a significant impact by growing the training level of the students from Mechatronics Diploma Studies, I-IV years of study and the ones from Advanced Mechatronics Master, which would have to grow also their employment opportunities.

The impact of this far-reaching investment is multiple, from which we can point out:

- from teaching point of view: increasing the training level of the students; since 2007 the students were proposed different project subjects for graduation, which appreciate the endowment made, 4 students being selected by the project responsible; we consider that their results were special, thus observing on the project website; for the academic year 2009-2010 there were proposed new subjects which use these equipments, existing a lot of requests on behalf of the students; in the same time, during the academic year 2008-2009 there were conceived presentations of students regarding the bought equipments and also the assembling and testing stages of the robotized structures; starting with 2009 will begin

the Advanced Mechatronics Master, where the project manager is also responsible for one teaching course from acoustic and vibrations field, being presented the methods, the equipments and achieve applications;

- from scientific point of view: the project will assure the logistic support for the development of researches in mini and micro-structures field; there were already made comparative studies regarding the dimensional evaluation methods of the microstructures, in collaboration with the experts from the National Institute of Microtechnology, one paper being sent to an international conference and other tests being in progress for structures made before by the experts from U.P.B – C.C.D.M. and mentioned institute [1]; some results of the research activity developed by the authors were already published [2], [3]; also the results of the research activity developed by the students at the diploma projects during the academic year 2008-2009 were presented in scientific papers [4], [5], [6];
- from technical point of view: the project has created an advanced research base in the structural analysis field, being offered conditions for manufacturers of precision equipments, sensors, etc in order to make researches in the product development stage; there are also conditions for the manufacturers from microtechnology field in order to make experimental studies;
- from the social point of view: there were created the necessary conditions for a modern training of the students from Mechatronics section, both from I-IV years of study and from Advanced Mechatronics Master, which will significantly increase their employment opportunities in the studied field.

REFERENCES

[1] G. Ionascu, E. Manea, C. D. ComeagA, N. Alexandrescu, I. Cernica, L. Bogatu. "Silicon cantilever beam micromachining and structure geometry characterization", The 32nd INTERNATIONAL SEMICONDUCTOR CONFERENCE (CAS 2009), October 12-14, 2009, Sinaia, Romania, accepted for poster presentation.

[2] C.D. Comeaga, C.G. Alionte. "Robotized system for modal testing of structures with 3-D laser vibrometer", International Symposium AVMS'2009-Timişoara, May 28, 2009, Proceedings of the X-th Symposium Acoustics and Vibration of Mechanical Structures AVMS-2009, pp. 70-75.

[3] C.D. Comeaga, C.G. Alionte. "Testing methods for the dynamics of microstructures", International Symposium AVMS'2009-Timişoara, May 28, 2009, Proceedings of the X-th Symposium Acoustics and Vibration of Mechanical Structures AVMS-2009, pp. 70-75.

[4] C. D. Comeaga, N. Alexandrescu, C. D. Chitu. "Automated system for modal testing of structures using laser vibrometry" – under publication in "Mecatronica" journal;

[5] C. D. Comeaga, N. Alexandrescu, C. Udrea, C. Necula, A. Paraschiv. "Robot for the vibro-acoustic with scanning testing of the structures" - under publication in "Mecatronica" journal;

[6] N. Alexandrescu, C. D. Comeaga, M. Matei. "Experimental study of a MEMS electrostatic actuator" - under publication in "Mecatronica" journal.