ACADEMIA ROMÂNĂ
SCOSAAR

HABILITATION THESIS

TITLE:

„ RESEARCH AND CONTRIBUTUIONS TO DESIGN, MANUFACTURE AND CONTROL OF MECHANIC, MECHATRONIC SYSTEMS AND OF ROBOTS”

ABSTRACT

Fundamental Domain: **Engineering Sciences**

Habilitation Domain: **Mechanical Engineering, Mechatronics and Robotics**

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Research Scientist II / Assoc. Prof. PhD. Eng.

BUCHAREST, January, 2017

Foreword

I had the chance to work (research scientist and professor) in the challenging field of mechanical engineering, mechanic and mechatronic systems and robots. This is why, the habilitation thesis is aimed to evidence main aspects (research, contribution, results, recognition) of my activity within the period 2000 – 2016, after being awarded the PhD title.

In my opinion this was a, relatively, tough period, with "ups and downs" in my private life that sometimes really impacted on my professional activity but, maybe what matters most, at this bottom line, is that I can see only the positive and good results.

I am grateful to all my professors, colleagues and researchers I worked with, and there are my special thanks to some of them, chronologically mentioned as follows:

- prof. dr. eng. Marian GHEORGHE („POLITEHNICA" University of Bucharest), adviser of my doctoral thesis, who always pushed me foreword, to get new knowledge in the field of mechanical engineering ant its complementary domain (Applied Statistics)
- prof. dr. ing. Adrian NICOLESCU and prof. dr. eng. Tiberiu Gabriel DOBRESCU („POLITEHNICA" University of Bucharest), who trusted me to teach new courses to the students specialized in Industrial Robots and Industrial Logistics
- dr. eng. Teodor NECŞOIU (general manager SC OPTOELECTRONICA-2001 SA), who got me hired at his company with activities in research, innovation, technological development);
- prof. dr. eng., research scientist I Luige VLĂDĂREANU (Institute of Solid mechanics, Romanian Academy), who offered me the opportunity to do research and get new knowledge in the complex field of mechatronic systems and robots.

Even they are mentioned last, their support is not least and I mention my family (son and husband, father and brother) and my dearest old, reliable friends.

Bucharest, January, 24, 2017

Mihaiela ILIESCU

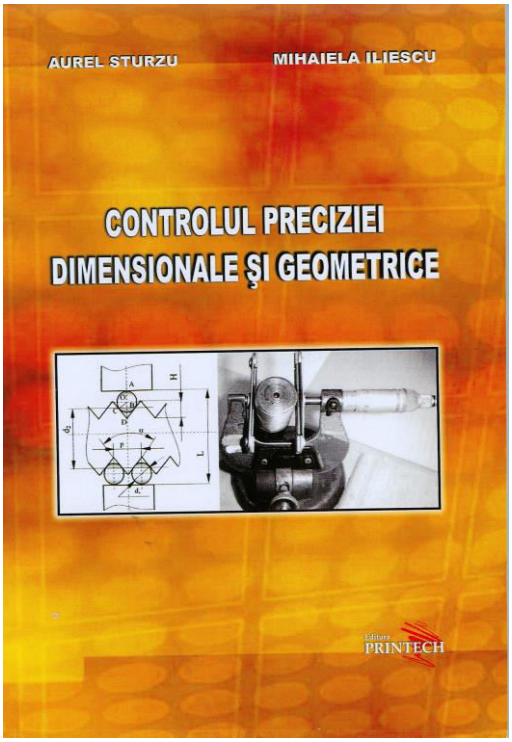
Content

ABSTRACT

The habilitation thesis named „RESEARCH AND CONTRIBUTUIONS TO DESIGN, MANUFACTURE AND CONTROL OF MECHANIC, MECHATRONIC SYSTEMS AND OF ROBOTS" points out the main results obtained in scientific research and didactic activities, within the period 2000 – 2016, after being awarded the PhD title. These results are relevant to the aimed doctoral field that is Mechanical Engineering, Mechatronics and Robotics.

The thesis is structured in seven parts, briefly presented next.

Part I. Control of Geometric and Dimensional Precision



This part is made of chapters 1 and 2, in fact chapters of the book written and published with Prof. PhD. Eng. A. Sturzu (as first author), named „Control of Dimensional and Geometric Precision) .

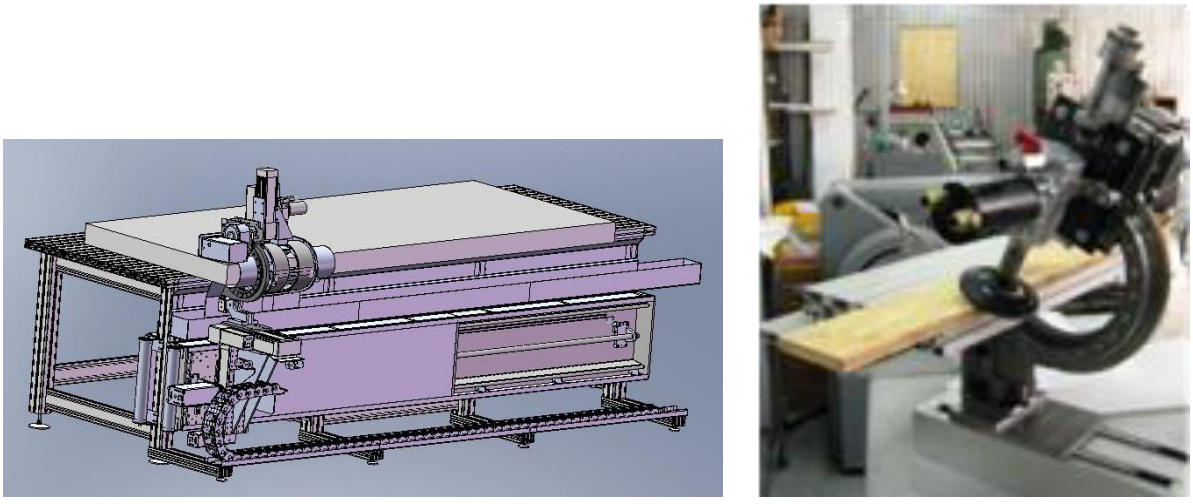
In this two chapters there are evidenced specific aspects related to control of dimensions (chapter 1) and of threads (chapter 2) with different instruments and equipments

There is also chapter D_1&2 (D stand for dissemination) that points out research and results disseminated by papers in conferences and journals, as well as in patent license.

So, one research is on design and manufacture of marble and granite CNC beveling machine – see figure 1 (**a.** – the model and **b.** – the customized product).

References:

- M. Iliescu, M. Lazăr, "Relevant Aspects when Developing a New Customized Product – Marble and Granite CNC Bevelling Machine", Proceedings in Manufacturing Systems, Vol. 5 (2010), No. 4, pg. 209-212, ISSN 2067-9238.



a. 3D model **b.** CNC beveling machine prototype

Fig. 1 CNC bevelling machine (design and manufacture only with Isel® components)

The second presented research is on the device for measuring machining forces, device that is inovative due to its elastic element design and the position of its resistive transducers (see figure 2). It has been awarded the patent license no. 121790/30.04.2008.

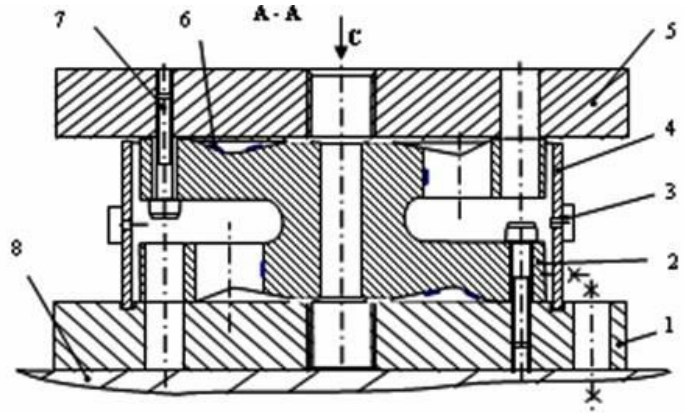
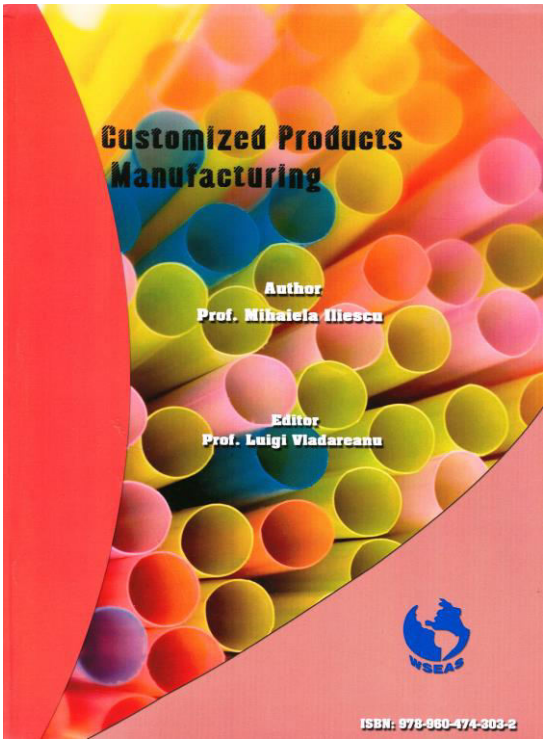


Fig. 2 Device for measuring machining forces

References:
● ILIESCU M., TURDEANU E., "Calibration Characteristics and Equations of a Dynamometer - Determined with IEMI Type ElectronicBridge", 15th International Conference on Manufacturing Systems, pag. 265-268, ISSN 1842-3183, Bucureşti, 2006.
● TURDEANU E, ''Contrubuţii la dezvoltarea captoarelor de măsurare a forţelor de prelucrare'', Doctoral thesis, "POLITEHNICA" University of Bucharest, 2004

Part II. Customized Products Manufacturing



This part is made of chapters 3 and 4, in fact chapters of the book written and published (2011).

In chapter 3 there are presented CNC equipments and some examples of customized machined parts. There are also evidenced principle, schemes and examples of laser micro-machining techniques, such as micro-welding and micro-drilling.

Chapter 4 evidences some plastics forming processes, like: Reaction Injection Molding (RIM) and Injection Molding,

There is also chapter D_3&4 (D stand for dissemination) that points out research and results disseminated by papers in conferences and journals.

So, one research is on the design of a RIM injection head for injection of polyurethane (PUR) and wooden fibers – see figure 3.

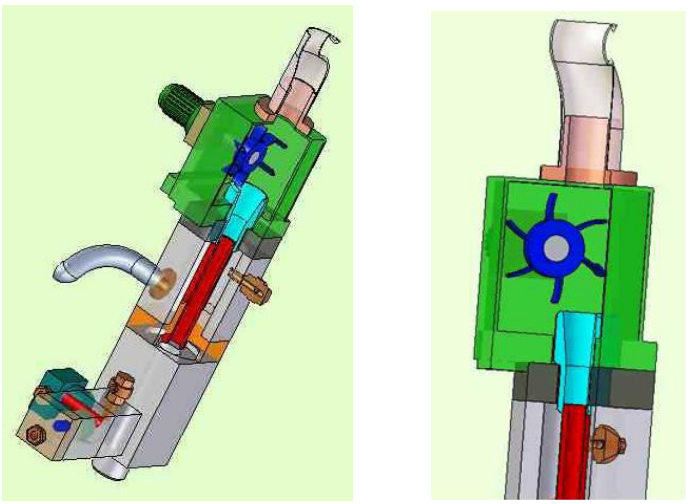


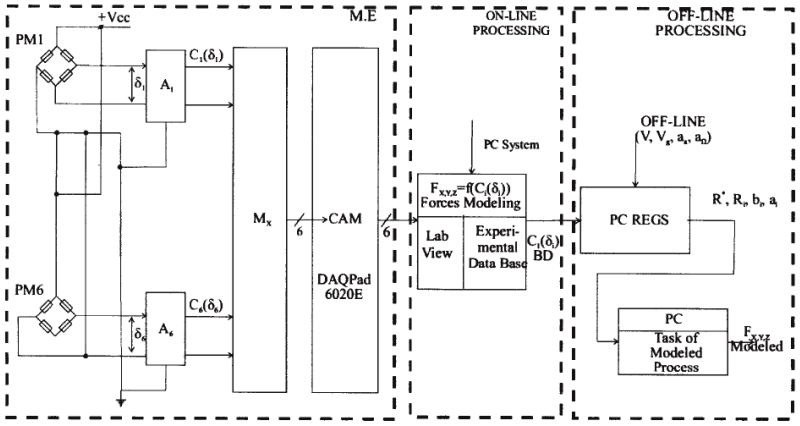
Fig. 3 RIM Injection Head

References:

● M. Iliescu, C. Opran, "Reaction Injection Moulding of Wood Reinforced Polyurethane Composites", Non-conventional Technologies Review, no. 2/2006, ISSN 1454-3087, Romania.

The second presented research is on modelling and controlling of machining forces when milling polymeric composites - cutting forces in cylindrical-face milling of 30 % glass fibers reinforced polymeric composites. There are pointed out experiments design, data measuring, acquisition and processing system for the experimental model regression analysis, as well as a real time control scheme designed to determine the measuring errors – see figure 4.

a. cylindrical-face milling process



b. architecture of data measuring, acquisition and processing system

Fig. 4 Research on machining forces when milling glass fibers reinforced polymeric composites

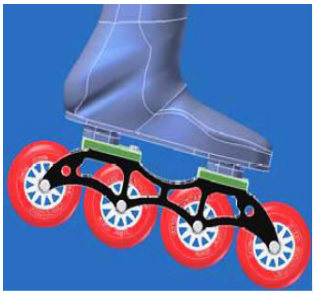
References:

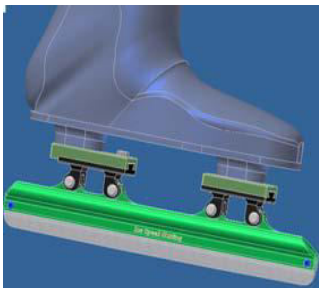
● M. ILIESCU, L. VLĂDĂREANU, P. SPÂNU, "Modeling and Controlling of Machining Forces when Milling Polymeric Composites", Plastic Materials 2/2010, pag. 231-235, ISSN 0025 / 5289

● ILIESCU M., SPÂNU P., MELNIC L., "Polymeric Composite Reinforced with Glass Fibers – Temperature Mathematical Model in Milling", Plastic Materials 2/2008, pag. 198-202, ISSN 0025 / 5289

The third mentioned research is focused on the development of a new skates system - modeling, simulation and prototyping. Main issue was to design an innovative system that enables mounting on the same boot, both rollers – for rollers skates, and blade – for ice skates, so that to get a fast, accurate and safe skate.

Once modelling the new customized product and simulations of various loading cases are over, any necessary changes could be done, so that to avoid failures or miss-matching of component elements of the skates systems. By 3D printing technique (on ZPrinter 310 Plus) there were obtained the desired skates prototypes – see figure 5.


roller skate


ice skate

a. skates models


roller skate


ice skate

b. skates prototypes

Fig. 5 The new skates system

Part III. Manufacturing Technologies for Mechanical Components of Industrial Robots

This part is made of chapters 5 and 6, in fact chapters of the books written and published (2013).

In chapter 5 there are presented basic principles in turning; tools and (modular) systems for fixing them, different CNC lathes and their characteristics.

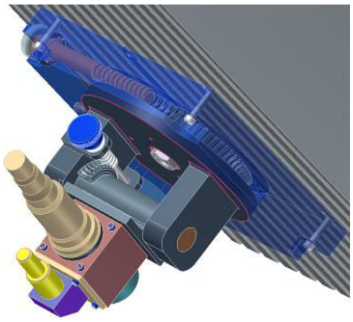
Chapter 6 evidences principles, advantages and disadvantages of some rapid prototyping techniques like: SLA,, SLS, 3DP, FDM and, finally, some applications.

There is also chapter D_5&6 (D stand for dissemination) that points out research and results disseminated by papers in conferences and journals.

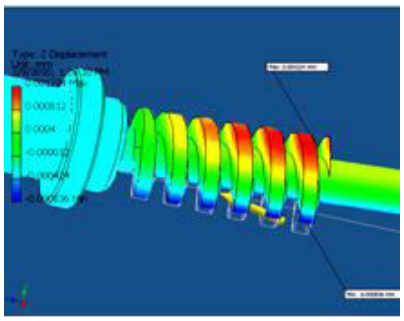
So, one research is on design and prototyping of a mecahnical system / device for CNC laser micro-machining. It was a real industrial need for it, more specifically of using an existing laser head of a TRUMF TruPulse unit and an Isel automation Euromod CNC machine, so that complex surfaces to be generated by various laser micro-machining procedures.

There were designed two types of gears for moving the components, finally due to high accuracy required, it was decided for worm – worm wheel gear for both, rotation of the plateau (around OX axis) and rotation of the laser head support (around OY axis).

Simulation of kinematics, strength and torsion of gear teeth and interference detection were done in order to discover any necessary changes to be done before prototyping by 3D printing. The developed mechanical system is to be noticed in figure 6 (**a.** model; **b.** simulation; **c.** prototype).



a. model



b. worm loading simulation - displacement distribution

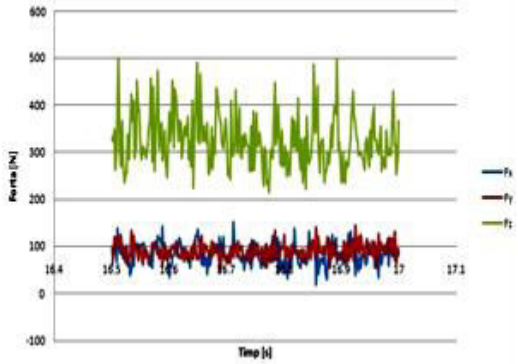
c. prototype

Fig. 6 Mecahnical system / device for CNC laser micro-machining

References:

- M. Iliescu, "Developing and 3D Prototyping of a Customized Device for CNC Laser Micro-Machining", Academic Journal of Manufacturing Engineering, issue. 2/2011, vol. 9, pag. 31-36, ISSN 1583-7904, România.
- Mihaiela Iliescu, Dragoş Dumitrescu, Gabriel Velea, (2010), Modeling and Simulation of a Positioning-Fastening-Adjusting Device for Laser μ-Machining CNC System, 4th International Conference on COMPUTATIONAL INTELLIGENCE, pag. 95-100, ISSN 1790-5117, Romania, April 20-22, 2010

The second presented research is on distributed control system for machining process optimization in drilling mineral composites reinforced by 3% glass fibers. The focus is on drilling experiments for determination of regression models of force and moment, as well as on the decentralized and distributed control system for monitoring force and moment values – see figure 7.

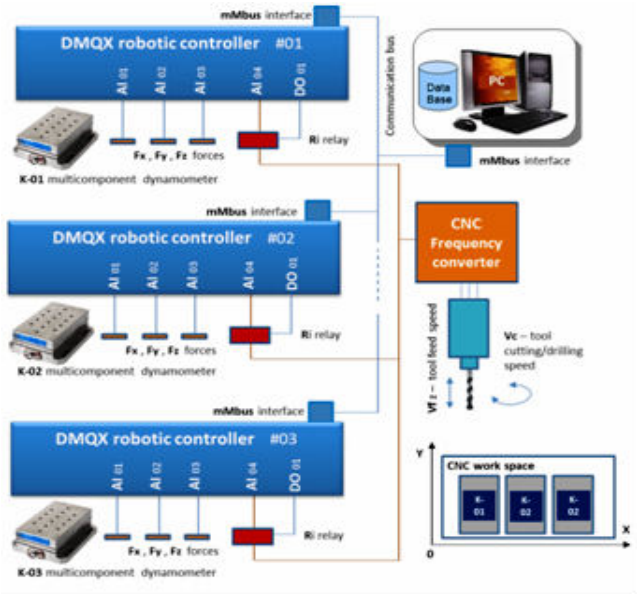


a. drilling force's components experimental values

$$F_z = 110.625 + 8.781D + 185.720f - 0.792v_c + 14.739Df - 0.063Dv_c - 1.337fv_c - 0.105Dfv_c \quad [N]$$

$$M_z = -0.219 + 0.098D - 0.198f + 0.023v_c + 0.150Df - 0.0007Dv_c - 0.0017fv_c - 0.0008Dfv_c \quad [Nm]$$

b. regression models determined



c. distributed control system of the machining process

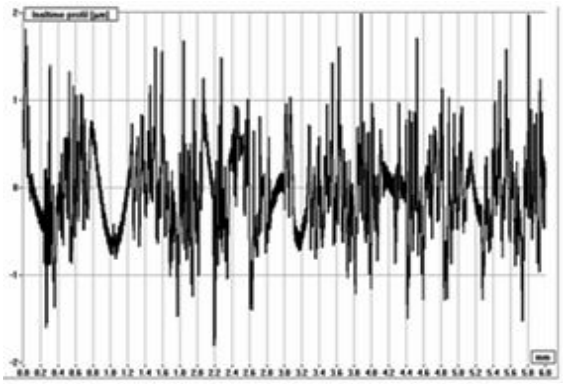
Fig. 7 Research on machining machining process optimization in drilling mineral composites reinforced by 3% glass fibers

References:

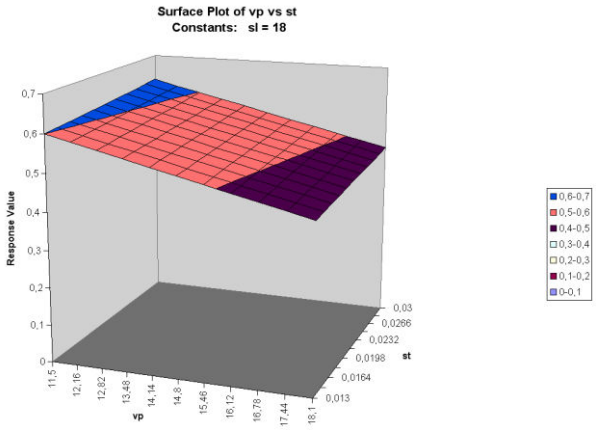
- M. Iliescu, C. Spirleanu, A. Patrascu, L.Vladareanu , "Distributed Control System for Machining Process Optimization in Drilling Mineral Composites Reinforced by 3% Glass Fibers", New Technologies and Products in Machine Manufacturing Technologies, TEHNOMUS Journal 2015, no. 22/2015, pg. 426-433, ISSN-1224-029X, Cod CNCSIS-115

The third mentioned research is focused on a flexible robotic cell for optimization of grinding process for 40C130 metallized coating. There are involved applied statistic methods, such as design of experiments and regression analysis joint with the virtual projection method, known as Vladareanu-Munteanu method, for design and develop a real-time control system.

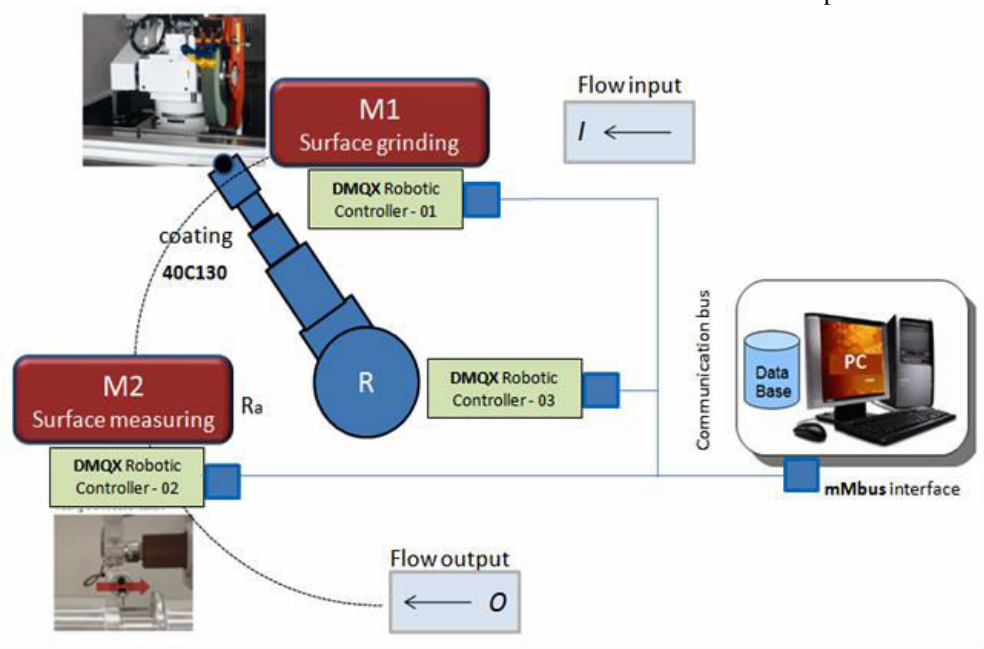
Thus, flexible robotic cell with distributed control is presented. As result, required surface roughness, R_a parameter, would be efficiently achieved with optimized grinding process parameters values – see figure 8.



a. grind surface roughness profile



b. surface plot



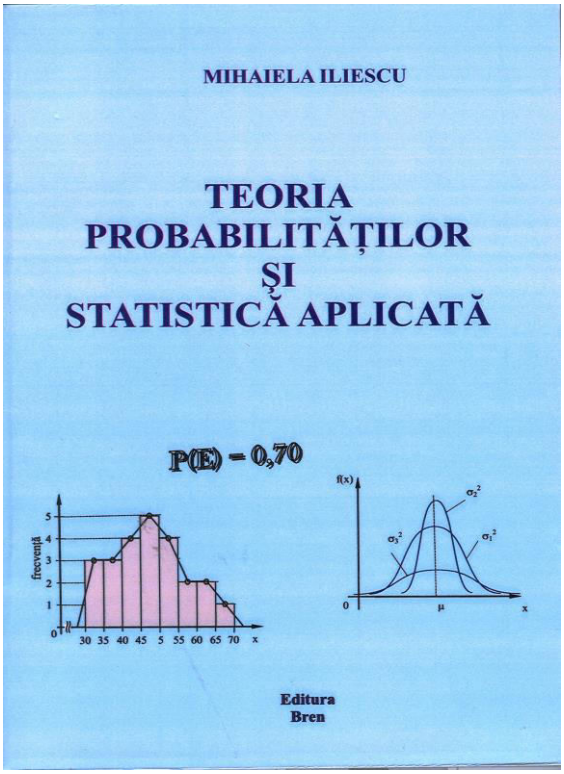
c. flexible robotic cell

Fig. 8 Research on a flexible robotic cell for optimization of grinding process 40C130 metallized coating.

References:

- Mihaiela Iliescu, Cristian Spîrleanu, Nicolae Bercan and Luige Vladareanu, "Flexible Robotic Cell for Optimization of Grinding Process for 40c130 Metallized Coating", Academic Journal of Manufacturing Engineering, AJME, Vol. 13, ISSUE 2/2015, pg. 30-35, ISSN: 15837904, Cod CNCSIS-127

Part IV. Probabilties Theory and Applied Statisitics



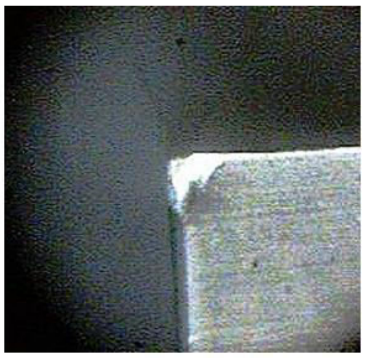
This part is made of chapters 7 and 9, in fact chapters of the book written and published (2013).

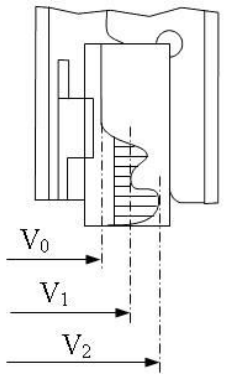
In chapter 7 there are presented main aspects of data exploring: variance, stnadard deviation, stem and leaf diagram; histograms, box plot.

Chapter 8 offers some guidance in multi-factors experiments design like: Plackett-Burman, Box-Behnken, Box-Wilson (CCD).

There is also chapter D_7&8 (D stand for dissemination) that points out research and results disseminated by papers in conferences and journals.

So, one research is on cutting tool durability, T [min], in turning 40C130 thermal spray coatings. There are evidenced steps carried on for determining its regression model as dependence of independent process variables (controllable inpouts) that are: cutting speed, v [m/min]; feed, s [mm/rev]; depth, t[mm] – see figure 9.





$$VB = |V_1 - V_0|$$
$$VB_{max} = |V_2 - V_0|$$

a measuring VB wear parameter

$$T = e^{A_0} v^{A_1} s^{A_2} t^{A_3} = 8{,}944 \cdot v^{-0{,}491} \cdot s^{-0{,}212} \cdot t^{-0{,}501}$$

b. exponential type regression model

$$T = 5{,}5775 - 0{,}9325 \cdot v - 0{,}4925 \cdot s - 0{,}7525 \cdot t + 0{,}0525 \cdot vs + \\ + 0{,}3075 \cdot vt - 0{,}4025 \cdot st + 0{,}0725 \cdot vst$$

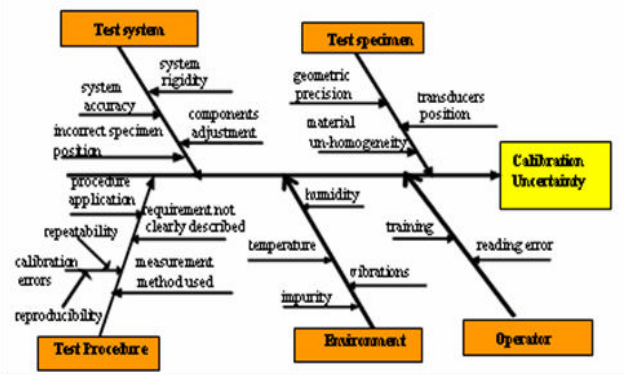
c. polynomial type regression model

Fig. 9 Cutting tool durability regression models

References:

- ILIESCU M., GHEORGHE M., ”*Statistic Models of Cutting Tool Durability Function in Turning 40C130 Thermal Spray Coatings* ”, University POLITEHNICA of Bucharest Scientific Bulletin, Series D, vol. 69, no. 3/2007, pag. 47-54, ISSN 1454-2358, România

The second presented research is on uncertainty evaluation in linear calibration of the force measuring mechanical system (dynamometric). So, the Ishikawa chart of uncertainty sources has been identified and, finally, uncertainty parameters values were calculated (based on sets of experimental data) for linear calibration in each loading cases, F_x, F_y and F_z - see figure 10.



a. Ishikawa chart

F_x loading						
s_y	s_{x_0}	x_0	s_{xx}	$\bar{x}$	$u(x_0)$	$U(x_0)$
9.1221	2.1313	106.122	25,000	100	1.5586	3.1172
F_y loading						
s_y	s_{x_0}	x_0	s_{xx}	$\bar{x}$	$u(x_0)$	$U(x_0)$
15	3.6145	101.1566	25,000	100	2.6397	5.2794
F_z loading						
s_y	s_{x_0}	x_0	s_{xx}	$\bar{x}$	$u(x_0)$	$U(x_0)$
31,6944	6.7722	104.3162	25,000	100	4.9490	9.8980

b. uncertainty parameters values

$$F_x = 0{,}2402 \cdot \varepsilon_x - 0{,}0052 \cdot \varepsilon_y - 0{,}0218 \cdot \varepsilon_z - 1{,}4849 \quad [\text{daN}];$$

$$F_y = -0{,}0092 \cdot \varepsilon_x + 0{,}2443 \cdot \varepsilon_y - 0{,}0181 \cdot \varepsilon_z - 4{,}3150 \quad [\text{daN}];$$

$$F_z = -0{,}0100 \cdot \varepsilon_x - 0{,}0237 \cdot \varepsilon_y + 0{,}2361 \cdot \varepsilon_z + 1{,}42352 \quad [\text{daN}]$$

c. calibration equations

Fig. 10 Uncertainty evaluation in linear calibration of force measuring system

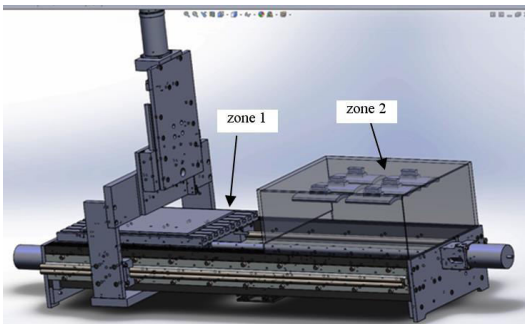
References:

- ILIESCU Mihaiela, ROHAN Rodica,, ”Management of Uncertainty Evaluation Process in Calibrating a Force Measuring Device”, Journal of Electrical and Electronics Engineering, Academy of Romanian Scientists, vol. 5, no. 1, May, 2012, pag. 95 -100, ISSN 1844-6035, University of Oradea, Romania
- Iliescu M, Turdeanu E., **“**Calibration Characteristics and Equations of a Dynamometer - Determined with IEMI Type ElectronicBridge”, 15th International Conference on Manufacturing Systems, , ISSN 1842-3183, Bucureşti, 2006.

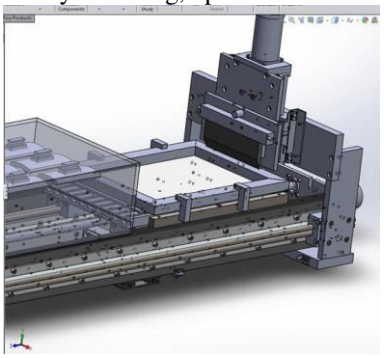
Part V. Mechatronic System for Printing Ultrathin Layers of Perovskite Solar Cells

This chapter points main steps in design, develop and manufacture of a mechatronic system for printing ultrathin layers of perovskite solar cells. The innovation of this mechatronic system consists in its modular structure enabling the application of three different printing technologies. Some preliminary tests and results are also evidenced.

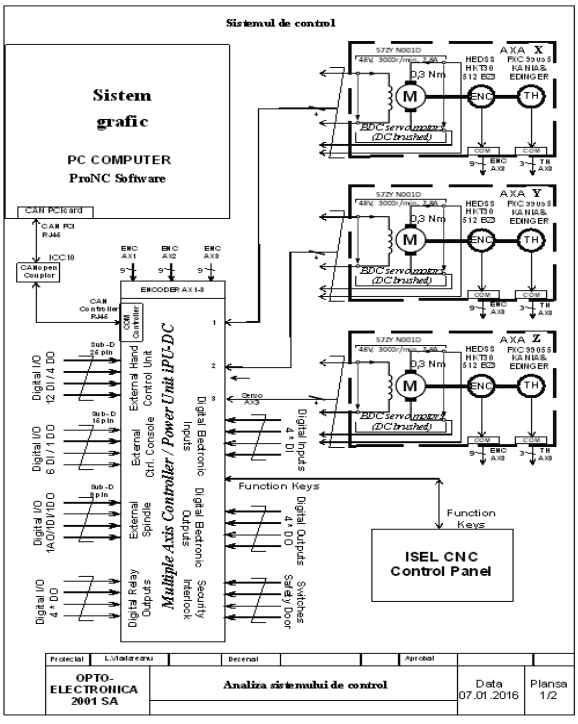
Figure 11 presents the model of 3-axes mechatronic system and its control system arhitecture.



- zone 1: for perovskite material / layer deposition;
- zone 2: for layer heating, up to 120 °C



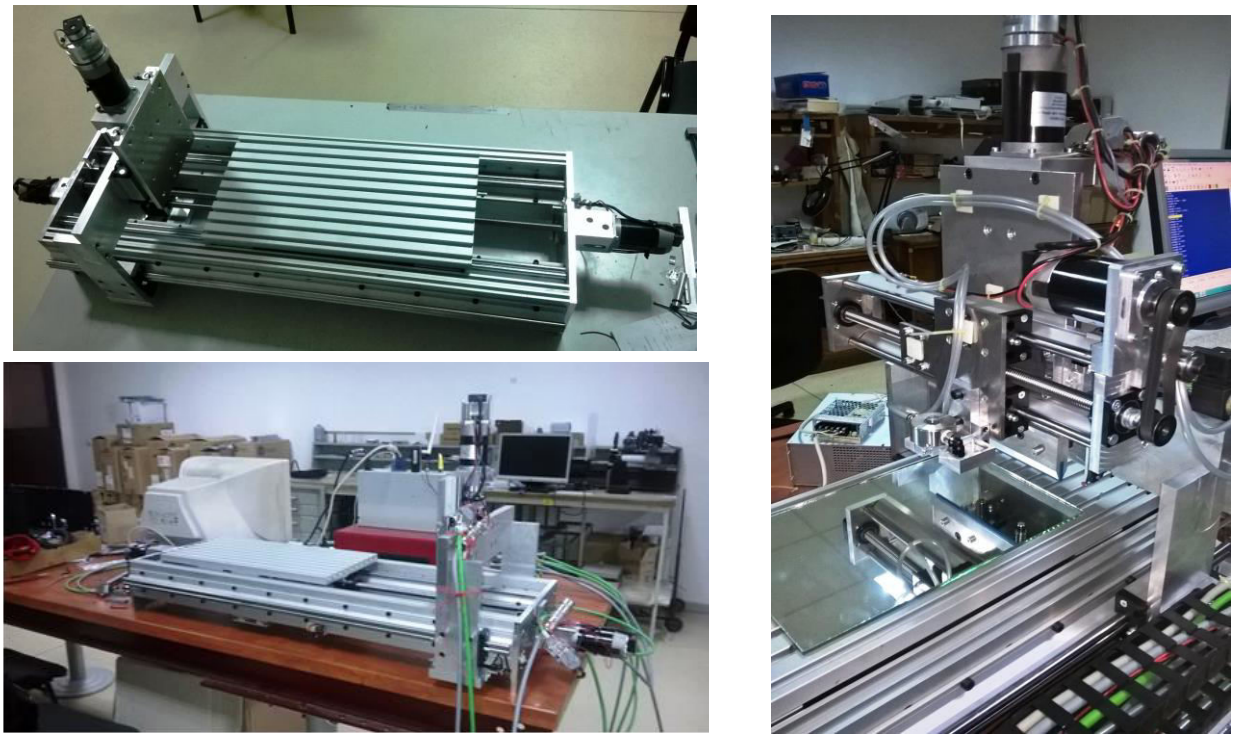
a. 3-axes mechatronic system model



b. architecture of control system

Fig. 11 3-axes CAD model of mechatronic system for printing ultrathin layers of perovskite solar cells

Due to additional restrictions / conditions determined by perovskite material's charatersitics, a 4th motion axis had to be designed, so that, relatively, optimum conditions to be created for spraying and deposition of ultrathin layers. In Figure 12 there are presented both mechatronic systems – the initial one with 3-axes, and the latest one, with 4-axes.



a. 3-axes mechatronic system **b.** 4-axes mechatronic system

Fig. 12 Multi-axes mechatronic system for printing ultrathin layers of perovskite solar cells

Acknowledgment:
This work has been funded by research project "Perovskites for Photovoltaic Efficient Conversion Technology", no. *8 SEE; EEA-JRP-RO-NO-2013-1,*
(http://www.infim.ro/projects/perovskites-photovoltaic-efficient-conversion-technology-0) .

References:

- Mihaiela ILIESCU, "Multi-Axes Mechatronic System for Printing Ultrathin Layers of Perovskite Solar Cells Prototype - design and manufacture", 10th International Conference on Software, Knowledge, Information Management & Applications (SKIMA 2016), China, 15 – 17, December 2016
- Cristina Besleaga, Laura Elena Abramiuc, Viorica Stancu, Andrei Gabriel Tomulescu, Marian Sima, Liliana Trinca, Neculai Plugaru, Lucian Pintilie† George Alexandru Nemnes, Mihaiela Iliescu, Halldor Gudfinnur Svavarsson, Andrei Manolescu, and Ioana Pintilie ,"Iodine Migration and Degradation of Perovskite Solar Cells Enhanced by Metallic Electrodes", The Journal of Physical Chemistry Letters website, . DOI 10.1021/acs.jpclett.6b02375

Part VI. Design of Functional Model for the Versatille, Intelligent, Portable Robotic Platform, VIPRO

This chapter points out results of activities carried out with the research team, managed by the project manager, in designing experimental model and in obtaining functional model of the VIPRO platform – see figure 13. Also, the access page to the VIPRO e-learning module is to be noticed in figure 14.

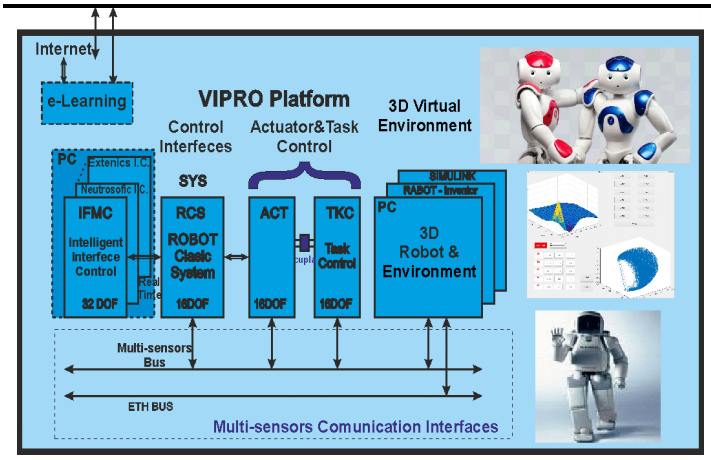


Fig. 13 Arhitecture of experimental and functional model for the VIPRO platform

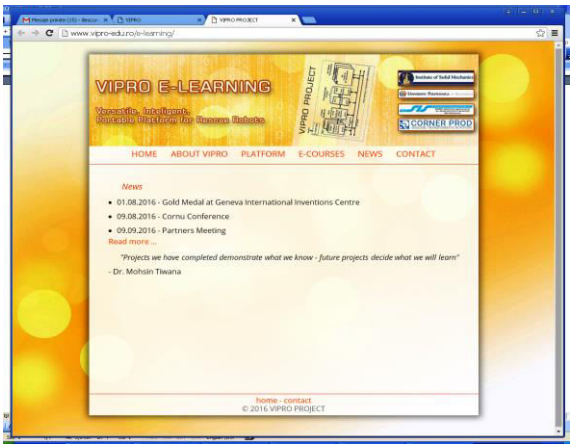


Fig.14 Acces page to e-Learning module (http://www.vipro-edu.ro/e-learning/)

Recognition of this research results is evidenced by the Gold Medal awarded at the 44th International Exhibition of inventions, Geneva, April, 2016

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Part VII. Final Conclusion

This part of the habilitation thesis evidences that mainly, all the activities (research, didactic) and, consequently, results I have done after being awarded the PhD degree (July, 2000), are relevant to the doctoral field of Mechanical engineering, mechatronics and robotics.

It is estimated that, further career development will be within the research team of the Mechatronics and robotics department, Intitute of Solid Mechanics, Romanian Academy. Also, further collaboration development with research institutes at Măgurele plaftorm and with various SMEs interested in research and inovation, would be of benefit.