New Concepts and Solutions of "Micro-Nano-Mechatronics and Micro-Nano-Integronics" Applied in Intelligent Measurement Technique and in the Future Development of the Automotive Industry"

Conf. PhD Eng. Vasile Bratu ; ***"Valahia" University of Târgovişte, Romania***
Professor PhD Eng. EurIng. Gheorghe Ion Gheorghe; ***National Institute for Research and Development in Mechatronics and Measurement Technique, Bucharest, Romania***
PhD Student Eng. Simona Istriţeanu; ***National Institute for Research and Development in Mechatronics and Measurement Technique, Bucharest, Romania***
Lecturer PhD Student Eng. Veronica Despa ; ***"Valahia" University of Târgovişte, Romania***
Lecturer PhD Eng. Adriana Cârstoiu; ***"Valahia" University of Târgovişte, Romania***

I. Introduction

- The new concepts and innovative solutions of «Micro-Nano-Mechatrons, **µnM** and Micro-Nano-Integronics, **µnI**», applied in intelligent measurement technique by integrating them into future intelligent automobile industry, are treated in a systematic and synergetic new vision of knowledge and scientific discoveries, creating new generations of advanced systems and products for industry, research and education and by integrating new mechatronic and integronic techniques and methods and also in structures of technological, scientific and industrial intelligent platforms.
- At the basis of all these new concepts and innovative solutions, new systematic and synergetic vision, new generations of high-tech systems and products, new processing techniques and methods of measurement and new intelligent platforms are integrative vectors Mechatronics / Micro-Nano-Mechatronics and Integronics / Micro-Nano-Integronics already presented by the authors in scientific papers: Science of "Micro-Nano-Mechatronics" integrated in research and "Innovative Vectors «Mechatronics and Integronics» in education, training and viability on labor market"

- Innovative vector "Micro-Nano-Mechatronics" is implemented in the design of high-tech solutions of intelligent mechatronic products and systems in a constructive-functional strategic vision in leading positions, control, self-diagnosis and decision, thus ensuring the quality of intelligent manufacturing.
- Innovative vector "Micro-Nano-Integronics" is implemented in the design of intelligent integronic products and systems highly-integrated solutions, in technical fusion architecture, technological and similar to human anatomy and human behavior, thus ensuring quality and computerized intelligent manufacturing, security of manufacturing processes and intelligent management of efficiency and effectiveness.
- Global innovative vectors of «Micro-Nano-Mechatronics and Micro-Nano-Integronics», organized in a integrative holistic database, turns for the design and realization of hybrid products and systems - mechatronic and integronic, namely micro-nano mechatronic and micro-nano-integronic, to the constituent parts and related new principles, such as:

- «adaptronic multidisciplinary» combination;
- integration of components, subassemblies and products in "technical and technological systems" - intelligent systems manufacturing;
- integration of intelligent computers and processors;
- integrated and intelligent control;
- simultaneous design and virtual simulation technique;
- intelligent diagnosis and self-diagnosis technique;
- signal and information processing technique;
- «human simulation» technique;
- «Micro-Nano-Mechatronics and Micro-Nano-Integronics» [4], [5], are based on the new generative, evolutionary and integrative concept - synergistically to:
- spatial, temporal and functional integration;
- intelligent adaptive behavior based on perception, self-learning, self-diagnosis and systemic reconfiguration;
- flexibility appropriate to hardware and software sites, advanced;
- predictive development of simple, complex integrator, structures;

- «Micro-NanoMechatronic and Micro-NanoIntegronic» Micro-NanoEngineering [4], [7], is applying in its new concept, basic techniques for fabrications of 3D nanostructures, nano-electromechanisms, nano-optic structures, nano-biotechnologies, is applying bacis techniques for fabrications / microfabrications and nanofabrications with high resolutions, is applying high techniqurs for MEMS / NEMS / BIOMEMS / BIONEMS, apply high techniques for biological and biotechnological opportunities, nanoteroperative, etc.., apply high techniques for biosensor for microfluidic microcomponents, etc., apply techniques to operate micro and nanoscopic, etc., applies techniques for high static and dynamic micromeasurings to assess micro and nanovibrations for material characterization, etc.., applies techniques for micro and nanotribology, etc., apply high techniques for spectroscopic analysis, nanocalibrations, etc. and other highly developed techniques.

II. Micro-Mechatronic and Micro-integronic process Systems, designed and implemented in the smart manufacturing of automotives (Renault - Dacia, Romania)

- **2.1. Intelligent Micro-Mechatronic Machine for Dimensional Control and Marking „Power Transfer Unit" for the Auto Subassemblies in Large Scale Series Production (fig. 1)**

Figure 1. Machine for dimensional control and marking "PTU"

- The intelligent machine is designated to measure the dimensions c=144,2 mm, dce=92,1mm, k=17,1mm and dcs=112mm and to mark automat of these heights with the other data of identification (type of piece, series, date etc.)
- Mecatronic intelligent measurement determines and verifies the real dimensions in view to fit the conic assembly (the selection of the space-rings dimensions that will be mounted in the bearings back for obtaining the correct conic group).
- The machine is equipped with two immaterial barriers against breaking in the work area.
- The intelligent machine is structured on three stations: two for control and one for automatic marking and validations:

-control station no.1: measures the "c" and "dce" dimensions for the principal axis fitting ;

-control station no.2: measures the "k" and "dcs" dimensions for the secondary axis fitting ;

-marking - validation station no.3: it marks automatically with three micro-percussion marking systems for the all-three pieces; it reads the inscriptions and validates the data consistency.

- The intelligent measuring is fitted with photo-electric incremental transducers by micronic precision and digitized on an Industrial process control computer.
- The machine is provided with an auto-correct system for measuring dimensions according to the temperature variations.
- It's also provided with two complex masters for calibrating the two control stations.
- The all work-process of the machine is driven and monitored by a programmable automaton with a specialized controller; there is a continuous communication (man-machine) with final decision and feed-back.
- ➲ The machine is revealed by:

- New MIX intelligent concepts [6], in shape, structure and operating comparative with the technical European levels regarding measuring, validation and certification:

→ sensoric intelligent and integrating, with micronic and sub-micronic measuring functions;

→ mechanic and micro-mechanic constructions with high precision, metrological stability and reliability;

→ complex matrix of intelligent actuators with movement / micro-movement functions and positioning / micro-positioning;

→ electronic and automation intelligent architecture with sensing condition, transforming informational signals, information flow transfers, measuring and validation information, results displayed and data acquisitions and decisional diagnose;

→ non-material structure integrated in technical infrastructure, with protection and security functions for the measuring process, according to protection specifications.

- The original technical infrastructure design, using specialized soft wares for simultaneously design (enginery competition): (AutoCAD, SolidWorks, Catia, etc.);
- New testing, validation and certification methods for products according to the same methods in Europe and in the world, applied to the acceptance by mixed teams Romanian and French, in conformity with European procedures.

➲ **Technical features:**

- Time: 85 sec (measurement + marking)
- accuracy of the measurements: ± 0,005 mm;
- electrical supply: 220 V.c.a./50 Hz;
- pressure supply: 5,5-6 bar;
- operating pressure: 5 ±0,2 bar;
- work temperature: : +10ºC ÷ +40ºC
- programmer automate: SIEMENS
- measuring and control process: intelligent automat;
- 100% control
- manual loading and downloading of the work piece;
- basing: on special taps for each pair of measurements

2.2. Mechatronic Intelligent Unit for Tightness Cheking (Negative Pressure / vacuum)Reverse Module TL8 – Machined (fig. 2)

- **The testing intelligent unit is a mono-block construction and verifies the air loss from the pieces who composed the Reverse module (Power transfer unit)"**

Figure 2

- **The unit is made by three tightness checking machines air-air for three pieces: "body reverse module", "coupling reverse module" and "cover reverse module". These three pieces will be assembled in a block forming the "Reverse Module" also called "Power Transfer Unit".**

- The unit has an automatic working cycle;
- The intelligent measuring program is set for each type of pieces ;
- The measuring is made sequentially: "cover-coupling-body"
- The pieces are set inside the machine, on the corresponding tightning plate;
- The pressure subassemblies press the pieces on the tightning plates;
- The tapered and clamping subassemblies pressurize the bores of the pieces;
- The ATEQ-cell introduces air in the obtained cavity of the piece (-0,5 bar);the admissible air loss must be under 0,25 cm3 /s;
- If the piece is good it's automatically marked;
- The machine is part of the production line for the Power Transfer Unit for the 4x4 auto.

- The method consists in order to obtain the followings:
- a closed cavity by sealing the faces and the bores with the different mechanic, electric or pneumatic systems;
- air / vacuum insertion in the cavity;
- stabilization at working pressure and automatic verification of air leaks by pores, fissures or cracks.
- The unit consists of three control stations:
- control station for cover reverse module (fig. 3);
- control station for coupling reverse module (fig. 4);
- control station for body reverse module (fig. 5)
- These three stations are fitted on the same body.
- ➲ **Technical features:**
- electrical supply: 220 V.c.a./50 Hz;
- pressure supply: 6 bar;
- work pressure 5 bar;
- tightness test pressure: -0,5 bar;
- admissible air loss: 0,25 cm3 /s;
- accuracy: ± 0,02 cm3 /s;
- work time/tour: ~ 40 sec/piece

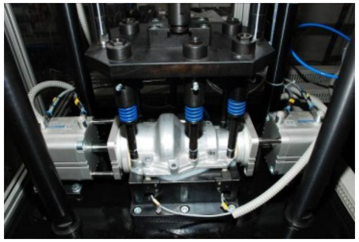

Figure 3 control station for “cover” PTU

Figure 4 control station for “coupling” PTU

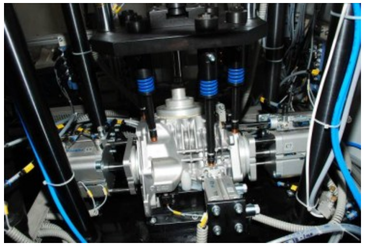

Figure 5 control station for “body” PTU

III Micro-robotic Systems for nano-processing and micro-positioning

- **3.1. Robotic, micro and nano-robotic MEMS & NEMS**
  Robotic, micro and nano-robotic MEMS & NEMS [1], [2], ensure the future and the evolution of development technologies, micro and nanotechnologies, as follows: systems and technologies for micro-nanopositionings and micronanomeasuring, principles and new concepts in "hybrid precise system" for systems and technologies to scale micro and nano; advanced hardware for micro-nanoprocessings, internal architectures with controllers that provide highly intelligent processing of the digital signal, advanced mechatronic applications for Industry, Biology and Medicine.

- **3.1.1.Cartesian nanomanipulator with nanometer resolution, presented in figure 6.**
- **Technical and functional characterization:**

- increment displacement: 0.4 nm
- range: 10 ÷ 100 mm
- working speed: 2000 m / s.
- displacement: continuous or in steps;
- acceleration time to maximum speed: 0.3 ms
- response time: 10 ms
- nanopositionings and nanomovements: ideal;
- Controller: multi-channel with high accuracy.

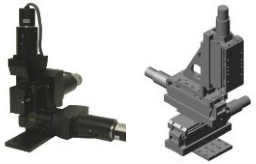

Figure 6

- Cartesian nanomanipulator with nanometer resolution, comprises the modular/standard units, such as linear motion transfer module of linear small range movement with high stability and ultra-linear transfer module on the wide range linear motion (Fig. 7).

Figure 7

- 3.1.2. Microrobotic system with 6 axes for high accuracy alignment of complex micro-nanopositioning (Fig. 8)
- Technical and functional characterization:

- parallel kinematic structure: 6 guidelines;
- resolution actuators: 0.033 nm
- repeatability in space: 0.3 nm
- kinetic system: compact serial and good dynamic, scanning and alignment, precise;
- view points: the main control Cartesian coordinates,
- controller: Digital LabView program,
- routines: alignment integrated

Figure 8

- Positioning micro-robot "6-axis hexapod with parallel kinetics" (Fig. 9)
- Technical and functional characterization:

-controller: high speed;
-orientation: plan and space;
-resolution ultra-high,
-repeatability: ± 1 mm;
-transducer resolution: 0.001mm;
-scanning: multi-axis linear and rotation;
-pivot points: virtual;
-algorithm: sophisticated for controller;

Figure 9

- 3.1.4. Nano-manipulator Micro-NanoSystem (fig. 10)
- Technical and functional characterization:

-work domain: 3÷15 mm, 10÷25 mm;
-vertical rotation: 90 ˚,
-horizontal rotation: 360 ˚,
-assembly: on microscope;
-software: programmable control;
-increment 1 nm, 4 nm
-resolution: 0.4 nm 4nm;
-thermal variation: <2 nm/h, at 20 ˚C
-unidirectional repeatability: <0.4 mm; 4nm;
-bidirectional repeatability: <0.5 mm, 5nm;
-hysterezis: <0.5 mm; 5 mm
-speed domain: 0.5 nm/sec ÷ 500 μm/sec, 5 nm/sec ÷ 5 μm/sec
-reaction time <0.3 msec, response time: 10 μm;
-acceleration: 0.5 m/sec2 ÷ 5 m/sec2 / 0.5 μm÷5 μm;
-force push / pull: 15/50 N; lateral force: 100N;
-voltage: 12 V Power consumption: 1 W,

Figure 10

- 3.1.5. Other examples of "hexapod robot" for micro-nanomovements and micro-nanopositioning in space, realized in innovative constructive solutions (Fig. 11):

Figure 11

- 3.2. Intelligent robotic mechatronic systems
- 3.2.1. Intelligent mechatronic robotic system for investigation of electronic components (Fig. 12)

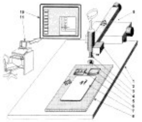

Figure 12

- 3.2.2. Intelligent mechatronic robotic center for microprocessings in mechatronic industry (Fig. 13)

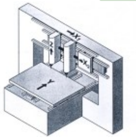

Figure 13

3.2.3. Mechatronic robotic measurement microequipment in coordinates with parallel mechanism (Fig. 14)

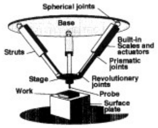

Figure 14

- **3.3. Applications of integronic micro-nano-robotics in Mechatronics / Medical Integrons and Integronic Robotics**
- **3.3.1. Applications in Medical Mechatronics**
- MicroNanoRobotica [2] developed more in Medical Mechatronics than in any other field, field where micro-nanodevices are needed, capable of a certain autonomy and penetration in the area affected by injection, drip, inhalation or skin or muscle massage.
- In the in-situ process, the nanorobots are introduced into the human body to detect tissue or cell of interest and movement in the identified area, following positioning and fixation on the area or close to it.
- In the figures below (Fig. 15, Fig. 16, fig. 17) are shown nanorobots working.

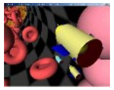
Figure 15

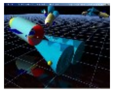
Figure 16

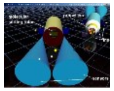
Figure 17

- **3.3.2.Applications in integronic robotics**
- Integronic robotics development, led to the development of microrobots or robotic microsystems or can "develop movements" or "respond" higher to human accessibility, such as making spiral movements (human inaccessible), reacting to the radioactivity of air, react to radiation ultraviolet, reacting to the electromagnetic field, reacting to changes in temperature with the thousandth of a degree, responding to ultrasound, inaccessible to man.
- Today's integronic robotics are:

(a) models of human movements and activities in all professional event structures, selecting the types of movements and activities most effective and most useful activity coefficient,

(b) movements shaping for certain types of creatures (eg, snake, turtle, dragonfly, etc.). in all structures of biological event, selecting the types of movements useful to human activity,

(c) shapes and equips integronic micro-nanorobotics with "bodies that fulfill the functions of the analyzer visual, auditory" etc.

(d) shapes and equips robotic micro-nanosystems, with "artificial thinking devices ";

- Among the applications already in testing and completion, there are:
- (a) biotronic micro-nanorobot for inside evaluation of the blood vessels,
- (b) nanomicrobiotronic micro-nanorobot for microsurgery in the vital organs, of the human body;
- (c) microbiotronic micro-nanorobot for taking samples of vital organs (diseased) from human body;
- (d) nanomicrobiotronic micro-nanorobot to stimulate human myocardium,
- (e) etc.
- Moreover, the realization and development of nano-micro-logical informatics implies, in particular, 3D simulation, using finite element method, repeated review until meeting expectations, the integration of different programs (CAEMMEMS, SIMODE, SOLID, Limes, LIDES, etc..), repeated testing (COSMOS-2D and 3D), re-simulation (SPICE, etc..) dynamic re-simulation (FEM, ANSYS, NASTRAN, COSMOS, ABAQUS, etc.). etc.
- Among the potential applications of micro-nano-robotics, can identify the following:

- In medical technology, where it is required the manipulation of medical instruments, remote control, inside blood vessels, for carrying out surgical applications, surgical micro-robots, we must possess the intelligent instrument for appropriate surgery, a micro-nano-processor, a matrix of micro-nano-sensors and micro-nano-actuators, a light micro-nano-source and an integrated image processing micro-nano-unit, the realization of these micro-nano-surgical micro-nano-robots depends on several factors such as friction during micro-displacement, difficulty guidance on the move, bio-compatibility with the bodies that move and will perform micro-nano-surgery, etc;
- **3.3.3 Research on the hexapod micro-robot**
- (**a) Micro-robotic system description**
- The micro-robotic hexapod system (Fig. 18) consists of a mechanical moving platform supported by six linear actuators, electronic controls and connection cables. Movement in all 6 degrees of freedom is performed by linear actuators driven by DC motor.

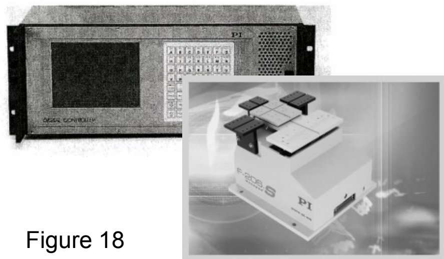

Figure 18

- The mechanical part is controlled by the PC, by the DC motor controller.
- With the integrated updated micro-programmes / software, the controller can be configured to control additional axes.
- **(i1) The Mechanics of the hexapod robotic system**
- **The design of the mechanical part**
- The robotic system is based on a parallel kinetic and parallel metrology design with actuators acting stationary, vertically.
- In Figure 19 is presented the kinetic structure with parallel linear actuators and connecting levers, of constant length.

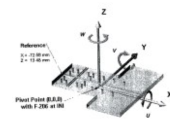

Figure 19

- **(i2) The translations of the hexapod robotic system**
- The translations (XYZ movements) are measured relatively to the position of the platform after a INI command. All translations (XYZ movements) are performed on a straight line.
- **(i3) The rotations of the hexapod robotic system**
- For rotations, the rotation pivot point is taken into account. They can be set with the linear coordinates R, S, T defined from the point (0,0,0) located along the centerline of the mechanism at a gap from the upper surface of the platform shown in fig.20.
- The R,S and T coordinates are moving with the platform (the pivot point of the platform translates XYZ movements). Any rotation (or movement of U, V and W) is made around the pivot point. The pivot point value can be changed only if the platform is parallel to the XY plane (U = V = W = 0)
- The final position after a rotation with motion components is calculated taking into account the position of the UVW components in the following order: U, then V, then W. This is done without seeing if these values were given explicitly in this command or as result of previous orders. Moreover, the move to the final determined position is uniform, with all simultaneous movement execution.

- The assessment of U, V and W position specifications is illustrated in Figure 21.

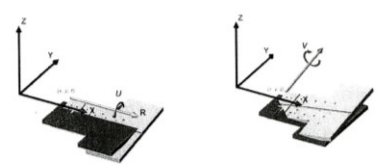

Figure 21

- **(i4) Hexapod robotic system workspace**
- Workspace XYZ depends on rotation coordinates values U, V and W as shown in Figure 22 and Figure 23 respectively.

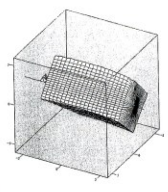

Figure 22

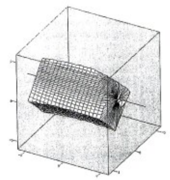

Figure 23

- (j) The location of pivot point at the start-up, after initializing (fig. 24)

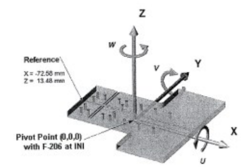

Figure 24

- (k) Setting the upper platform pivot point (fig. 25)

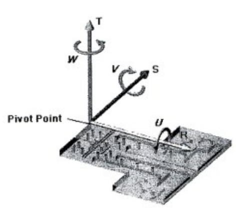

Figure 25

IV Conclusions

- **The conclusions** of the scientific paper highlight the following aspects:
- The conceiving and defining new micro-nano-mechatronic and micro-nano-integronic fields;
- The design of new constructive solutions integrated in mechatronic products and systems at a macro-, nano- and micro- scale;
- The promoting of new systemic and synergistic visions of scientific knowledge and discoveries in the fields of mechatronics and integronics;
- The creation of new generations of high-tech mecahtronic and integronic systems and products.