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NANOMETRICS - ADVANCED NANOTECHNOLOGY IN METROLOGICAL AND INDUSTRIAL HIGH-TECH MEASURING PROCESSES

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Abstract: *The scientific work deals with a new advanced nano-technology developed in the metrological laboratories of the Institute,* ***entitled NANOMETRICS,*** *used in high-tech measuring processes integrated into intelligent and automated fabrication.*
This scientific paper illustrates examinations and laboratory experiments to nanometric micro-nanotechnologies integrated into NanoMetrology, such as, intelligent control nanometric micro-nanotechnologies:
- *of surface topography – micro-roughness and micro-contour;*
- *of metrological calibration;*
- *of micro-nano-linear and micro-nano-angular inspection;*
- *of micro-nano- heights for industrial marks;*
- *micro-nano-dimensional nanometric 3D.*

Key words: *micro-nanotechnologies, nanometrics, intelligent control, metrological calibrations*

1. INTRODUCTION

Intelligent advanced micro-nanotechnologies integrated into NanoMetrology have been designed and developed in the research laboratories and the metrology laboratories in the Institute, with the view to using them in measurement processes for measurement, inspection and integrated control of intelligent and automated fabrications.

By applying the concepts of integrative and advanced knowledge, great accomplishments have been made in converging directions of nano-sciences and nanotechnologies, advanced nano micro- nanotechnology applications in NanoMetrology immediate and intelligent fabrications.

2. EXAMPLES OF ADVANCED MICRO-NANOTEHNOLOGIES INTEGRATE INTO NANOMETROLOGY:

At the National Institute of Research - Development for Mechatronics and Measurement Technique in Bucharest - Romania has developed and integrated various intelligent technologies incorporated into Nanometrology, such as:

2.1 Intelligent control nanometric micro-nanotechnologies of surface topography – micro-roughness and micro-contour (fig. 1), by integrating nanometric mechatronic system type "Form Talysurf T•H" with special and dedicated software programs for ultra-precise determinations of the micro-geometry of surfaces – micro-roughness and micro-contour, (Coleman, 1989) approaching high metrological characteristics, as the axis resolutions of approx. 17 nm, the detector resolutions of approx. 8 nm, measuring range for the X axis of approx. 120 mm and for the Z axis of approx. 28 mm (for micro-contour) measuring range for the X axis of approx. and for the Z axis of approx. 1 mm (for micro-roughness).

Fig. 1. Nanometric equipment for the control of micro-rugosities and of the micro-contour of surface

The accuracy error of the nanometric mechatornic systems in the endowments of the laboratory was determined metrologically in the following value matrix:

Maximum error	Maximum uncertainty
50 nm	± 25 nm
1800nin	± 1000 nin
Medium radio	Maximum uncertainty
12,5 mm	± 25 nm
0,492 in	± 1000 nin

2.2 Advanced nanometric metrology calibration micro-nanotechnologies (Fig.2) for calibration / calibration of the full range of instrumentation and intelligent appliances and information [digital comparators, inductive / capacitive / Piezo electric / magnetic / photoelectric transducers etc.], on the measurement uncertainties [U95 = (20 + L / 1,000) nm] and with the measurement range [± 10 nm], etc.

Fig. 2. Nanometric mechatronic system for methodological callibratian

The nanometric accuracy error of the intelligent micro-metrology mechatronic calibration laboratory was determined in the following value matrix (table 1):

Crt no.	Position (mm)	Real displace-ment (nm)	Admitted displacement (nm)	Crt no.	Position (mm)	Admitted displacement [nm]	Real displa-cement [nm]
0	**1**	**2**	**3**	**0**	**1**	**2**	**3**
1	-10	200	-9	7	50	800	-180
2	0	300	-74	8	60	900	-355
3	10	400	-78	9	70	1000	-235
4	20	500	-98	10	80	1100	-233
5	30	600	-141	11	90	1200	-192
6	40	700	-129				

Tab. 1. Matrix of the error determined in laboratory

2.3 Intelligent nano-dimensional control nanometric micro-nanotechnologies for industrial micro-mechanical marks – micro-nano-liniar and micro-nano-angular inspection (fig. 3), developed and made in the Institute, micro-mechatronic systems, high-tech micro-purpose type with Galileo Vision System, which allow automatic inspection of parts, fast, easy and ultra-precisely, using two monitors and a special software measurement, similar to Windows OS (Taniguchi, 2000).

Fig. 3. Nanometric mechatronic system for 2D & 3D video-measuring

By these micro-mechatronic systems, the intelligent uncertainties were determined by measuring [U = max (0.19 + 5L / 1,000) nm, L in mm], measuring (x = 300 mm, y = 150 mm, z = 140 mm) and measurement resolution (50 nm and 100 nm) with a special software for automatic recognition of features, generating protocol measurement, capturing video image formats: "jpg" or "bmp", with graphics and reporting capabilities importing data (files for "DXF" or "iges") for programming and exporting them. (Bhushan, 2007)
The metrological verification of intelligent micro-mechatronic systems was conducted in the following matrix of values:

	point1	point2	point3	point4	point5
run 1	0.0000	25.4001	50.8002	76.2002	101.6004
run 2	0.0000	25.4002	50.8000	76.2002	101.6003
run 3	-0.0004	25.4011	50.7997	76.1999	101.6003
Maximun	0.0000	25.4011	50.8002	76.2002	101.6004
Minimum	-0.0004	25.4001	50.7997	76.1999	101.6003
Average	-0.0001	25.4004	50.8000	76.2001	101.6004
LEC	0.0000	25.4006	50.8001	76.2002	101.6005

In the laboratories of the Institute, the applications of these micro-mechatronic systems are used to determine micro-nano-dimensional nanometric micro-linear and micro-angular deviations for terminal sizes, calibres, gauges, etc.., and to determine micro-deviations from parallelism and perpendicularity of parts in the following industrial environments: mechatronics, aerospace, autotronics, electrical, electronics, metrology, etc..

2.4 Micro-nanodimensional intelligent control nanometric micro-nanotehnologies – heights, for industrial micro-marks (fig. 4), produced and developed in the Institute, by intelligent micro-systems type "Micro-HITE" (Gheorghe, 2007), that allow the determination of linear micro-nano-dimensional deviations of height and dedicated software allowing data transfer to central units of the manufacturing process or central metrology process, determining the measurement uncertainty [U = max (0,2 + 3L / 1,000) nm, L in mm], the measurement ranges (max.350 nm), resolutions (100 nm) and accuracy (± 25, ± 50 nm).
The calibration of the intelligent micro-systems was carried out in metrological reference conditions according to EN/ ISO/ CEI 17025:2005, stated in the following value matrix (table 2):

Crt. no.	Norm length (mm)	Micro-system indication
1	50. 000	50.000
2	125.000	125.000
3	150.000	150.000
4	200.000	199.9992
5	250.000	249.9993
6	300.000	299.9993
7	350.000	349.9995

Tab. 2. Matrix of metrologic calibration determined in laboratory

2.5 Control micro-dimensional nano-scale micro-nanotechnology - 3D (fig. 5) for industrial parts in automated manufacturing processes and metrological processes, were made and developed by an intelligent equipment type three coordinate measuring machine - LR and dedicated software for inspections meant to ensure ultra-standard geometries of industrial parts, inspections of special geometries (type camshaft, ball screw, etc.), geometry and micro-special-dimensional micro-parts nano-measuring (Cyichos, 2006), metrological characteristics uncertainty measuring [U = (90 + L/1000) nm, L in mm], measuring ranges (X = 1000 mm, Y = 700 mm Z = 560 mm) and resolution (10 nm 5 nm).

Fig. 4, 5. Nanometric mechatronic system for measuring, 3D mechatronic equipment

The volumetric error value of the intelligent equipment type 3D measuring machine, was determined in the following value matrix (table 3):

No. Crt.	X [mm]	Y [mm]	Z [mm]	Dev. [μm]	Graphic
1	0.0014	0.0027	14.9946	0.03	
2	5.7433	0.0015	13.8509	0.17	
3	0.0022	5.7431	13.8512	-0.11	
4	-5.7398	0.0022	13.8527	-0.08	
5	0.0005	-5.7424	13.8513	0.11	
6	9.8036	4.0596	10.5942	-0.02	
7	4.0623	9.8016	10.5956	-0.10	
8	-4.0588	9.8024	10.5966	-0.17	
9	-9.8017	4.0611	10.5966	-0.11	
10	-9.8026	-4.0588	10.5961	-0.20	
11	-4.0602	-9.8012	10.5965	0.07	
12	4.0620	-9.8011	10.5956	0.21	
13	9.8038	-4.0588	10.5940	0.05	
14	9.7996	9.7955	5.7318	0.01	
15	-9.7978	9.7983	5.7328	0.08	
16	-9.7985	-9.7967	5.7323	0.10	
17	9.7989	-9.7951	5.7317	0.02	
18	5.7416	13.8523	-0.0002	0.07	
19	-5.7371	13.8548	0.0001	0.13	
20	-13.8540	5.7394	-0.0014	0.14	
21	-13.8545	-5.7364	-0.0001	-0.05	
22	-5.7392	-13.8526	-0.0006	-0.03	
23	5.7399	-13.8516	-0.0008	-0.19	
24	13.8536	-5.7350	0.0003	-0.08	
25	13.8533	5.7369	-0.0008	-0.05	

Tab. 3. Matrix of the volumetric error determined in laboratory

3. CONCLUSIONS

In the development of the advanced micro-nanotechnologies field, the author and the specialized institute have addressed integrative concepts and new areas of scientific knowledge for implementation, testing and certification of nano-dimensional micro-micro- and micro-nano-angular, micro-heights, 3D, and interferometric monitoring and control.

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