DESIGNING THE VIRTUAL MODEL OF A MECHATRONIC MICRO-POSITIONING AND MICRO-MEASURING SYSTEM FOR EXPERIMENTAL MODEL REALIZATION

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Abstract

This paper aims is to present the realization of a virtual model, as well as the experimental model for a mechatronic micro-positioning and micro-measuring system on two axes, OX, and OZ respectively. The paper also includes experimental results on measuring the gripping force developed between the fingers of an electrical micro-gripper, with two fingers, incorporated into the experimental model of a mechatronic micro-positioning system.

***Index Terms:** flexible mechatronic system, micro-positioning, micro-gripper*

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1. INTRODUCTION

Current micro-positioning equipment development is directly influenced by the evolution of measurement technologies, manufacturing technologies of components made of semiconductor materials, as well as electro-mechanical micro-systems fabrication technologies (MEMS). Series production of micro-positioning systems requires high demands on mechanical design, choice of materials, manufacturing and testing methods [1]. These high demands have direct influence on costs.

In positioning application development, it is not enough simply to optimize individual components within a usual micro-positioning system, but innovative design principles must be relied on [2].

Micro-positioning systems are powered by electric motors platform with travel routes from a few millimetres to hundreds of millimetres. As guidance systems commonly use roller bearings, generating frictional forces, their resolution and reproducibility is generally limited to 0.1 μm (usually not lower than 0.1 μm) [3].

For mechatronic applications it which it is necessary to obtain sub-micrometer resolutions, it is required to use frictionless positioning systems, such as linear electromagnetic motors, electro-dynamic actuators or piezo-electric actuators. In such applications, electro-dynamic motors and linear electro-magnetic actuators are less used because they generate a lot of heat and produce magnetic fields that can interfere with other processes [4].

Increasing the competitiveness and efficiency of manufacturing impose to current technological equipment configurations to meet increasingly stringent requirements on performance accuracies that are geared towards the micro- and nano-metric range, as well as increased automation.
In this regard, the National Institute for Research and Development in Mechatronics and Measurement Technique Bucharest has conceived, designed and developed a flexible mechatronic micro-positioning system with two axes that meet the requirements outlined above.

2. REALIZATION OF THE VIRTUAL MODEL OF A MECHATRONIC MICRO-POSITIONING AND MICRO-MEASURING SYSTEM

In order to realize the virtual model of the flexible micro-positioning mechatronic system, there has been established the technical theme of the work, with technical characteristics, the scheme of the experimental model of the mechatronic system (figure 1), and operation cyclorama (Table 1).

Thus, the technical features are: positioning accuracy: ± 0.00025 mm; sleds cycle: 0 ÷ 200 mm on x and on z, load transport on axis x: 100 ÷ 200 N, load transport on axis z is 25 ÷ 50 N , (electric or pneumatic) gripper, with the possibility of gripping and positioning parts up to 0.5 kg; power supply: 220 Vca/50 Hz (15V-CC motors, 24V-griper and controller); work mass: 1250x780x750 (mm).

Figure 1 schematically depicts the experimental model of the micro-mechatronic system, highlighting its components.

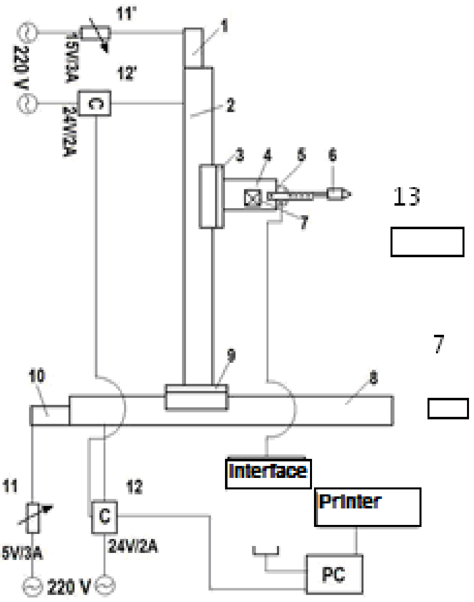

Fig. 1: Scheme of the experimental model of the mechatronic system

Mechatronic system components:

1 & 10 –CC motors
2 & 8 – linear axes
3 & 9 – linear axes sleds
4 – Electric gripper
5 – Profiled fingers
6 – Piece
7 – Temperature sensor
11 & 11'– power
12 & 12'– controllers
13 – Piece presence sensor.

Overview of the mechatronic micro-positioning system:

The mechatronic micro-positioning system mainly features the positioning system made of two linear axes that are electrically driven. The two axes of the designed micro-positioning system are connected to two controllers, the linear cycle for each positioning axis being 200 mm.

The electric gripper is mounted on the vertical sled, ensuring the grabbing of the piece in order to ensure micro-positioning. The gripper fingers will be costumed depending on the shape of the marks to be positioned.

Since positioning accuracy is of sub-micron size, specific environmental conditions are required and thus a temperature sensor is mounted in the structure of the system.

The temperature sensor is included in the control circuit, in order to warn or turn the system off when exceeding the ambient temperature which may compromise the accuracy. Linear axis driving is ensured by CC motors and transmission type screw-nut type ensures safety and positioning accuracy. In Table 1 is shown the operating cyclorama of the micro-positioning system.

Table1. Operating cyclorama of the micro-positioning system

No. crt.	Functioning cycle phases	Parameters
1	Connecting to network Computer initiation Axes powering, position sensor, optical barrier Software loading	
2	System initiation– Displacement in reference position 01	
3	A – gripper dies opening	
4	1 – horizontal displacement	x=120 mm; z=100mm
5	2 –vertical displacement (descend)	x=120mm; z=160mm
6	B – dies closing	Piece grabbing
7	3 – vertical displacement (ascend)	x=120mm; z=58mm
8	4 – horizontal displacement	x=190mm; z=58mm
9	C– dies opening	Piece deposition
10	5 – horizontal displacement (recessing)	x=120mm; z=58mm
11	6 – vertical displacement (retreat)	x=120mm; z=100mm
12	D – dies closing	
13	Return to the reference position 01	x=100mm; y=100mm

Also, for the realization of the virtual model, there has been established the product designation, i.e. positioning precision in measuring, characterizing surfaces in complex vector space, intelligent mechatronic system for determining global constants of measurements of optical systems with complex software algorithms, system calibration of inductive displacement sensors and penumo-electric sensors. The kinetic scheme of the experimental model of the mechatronic system is depicted in fig. 2.

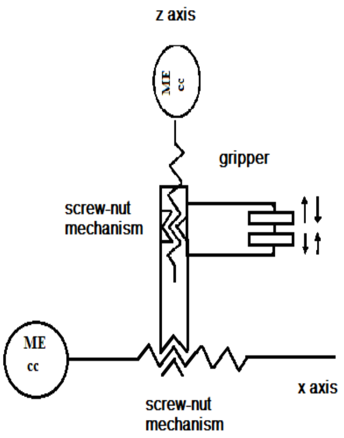

Fig. 2: Kinetic scheme of the experimental model of the mechatronic system

The main part of the flexible micro-mechatronic positioning system consists of the ensemble of the two electrical linear axes.

The design of the two electric linear axes was performed individually for each axis for horizontal or vertical mounting. Figure 3 presents a linear axis, highlighting its components.

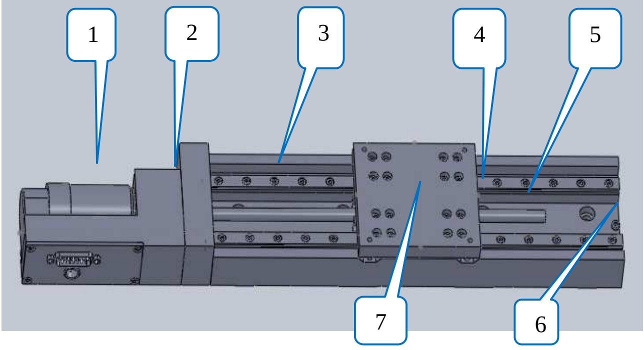

Fig. 3: Mechatronic ultra precise x/z axis

1- Ultra precise actuator for x/z axis; 2- Support for x/z axis actuator; 3- Guiding Support for x/z axis;
4- Precision nut element; 5- Precision screw element; 6- Ultra precise sensor; 7- Positioning support element

In figure 4 a) & b) are presented the assembly of the x-z axes, vertically and respectively horizontally, by offering an example of the driving of the forces and moments on the mechatronic axis [xz].

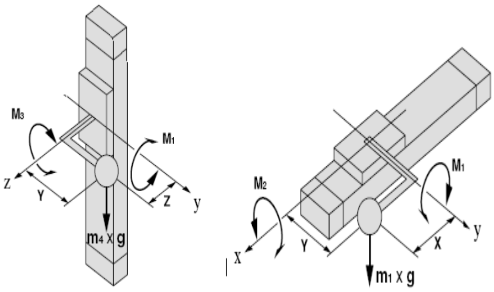

Fig4. Representation of the vertical assembly a) and the horizontal assembly b) for the mechatronic linear axis

The designed positioning system is made up of two linear axes mounted vertically so that they will build the XZ Cartesian system of the assembly.

In figure 5 is presented the virtual assembly of the linear positioning axes and the gripping system mounted on the linear axis Z, highlighting the linear axis X.

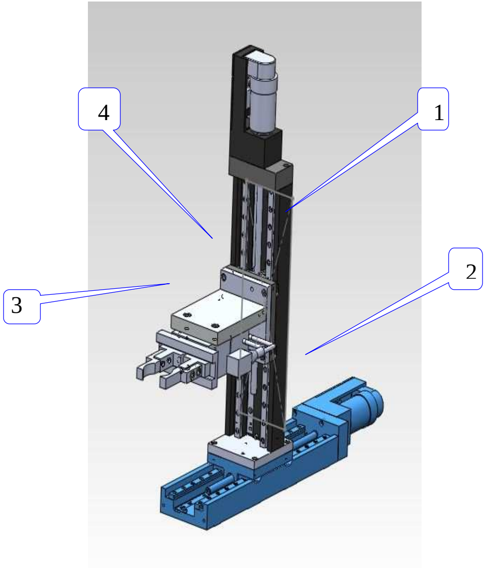

Fig.5: Assembly of the linear positioning axes, highlighting component elements:1- mechatronic OZ axis; 2- mechatronic OX axis; 3- micro- high-tech grabbing device; 4- linking element

In figure 6 are presented the linear positioning axes, the grabbing system, the piece repository and the optical barrier mounted on the worktable of the mechatronic micro-positioning system.

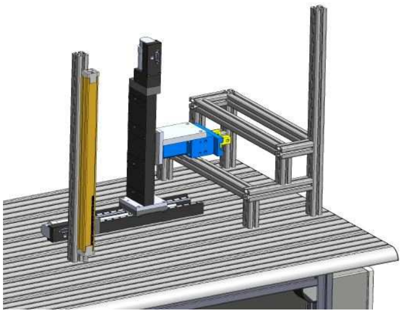

Fig6 Virtual model: linear x-z axes, electric gripper and optical barrier mounted on worktable made of aluminium

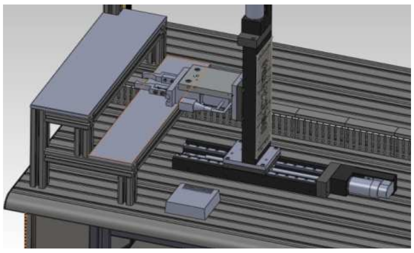

Fig7: Horizontal and vertical axes system, grabbing system and temperature sensor, mounted on the worktable

In figure 8 is presented the virtual model of the electric gripper, on which are placed dies and grabbing fingers of cylindrical pieces.

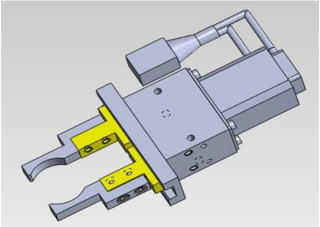

Fig8: Virtual model of the electric gripper, on which are placed dies and grabbing fingers of cylindrical pieces.

In figure 9 is presented the detail: virtual grabbing system, in open position.

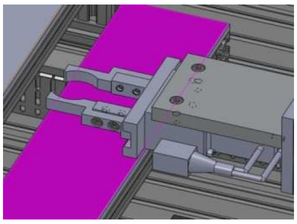

Fig. 9: Detail - virtual grabbing system, in open position

In Figure 10 is depicted the whole virtual model of the mechatronic system.

Fig. 10 Virtual model of the mechatronic micro-positioning system

The virtual model of the mechatronic system for micro positioning resulted in the realization of the experimental model.

3. REALIZATION OF THE EXPERIMENTAL MODEL OF THE MECHATRONIC SYSTEM FOR MICRO-POSITIONING

3.1. Overview of the mechatronic system for micro-positioning

The experimental model of the mechatronic system for micro-positioning was conceived, designed and built in modular fashion and is placed in the laboratory of INCDMTM Bucharest. The experimental model was based on activities such as: studies and assumptions on components and systems for the integration of micro-components: guidance systems, micro-actuators, micro-sensors, micro-transducers, micro-controllers and computer units, high performance and programmable functions that ensure operational self-regulation and intercommunication, conceptual models and design assumptions and micro-mecatronics mechatronic systems, examples of constructions used in the structure of technological / micro-technological and control and measurements; the design of the mechatronic system for ultra-precise positioning; the realization of the virtual model of the mechatronic micro-positioning system.

The experimental model of the mechatronic micro-positioning system for positioning and micro-positioning was designed to be integrated in the following applications: precision positioning in measuring, characterizing surfaces in complex vector space and temperature, determining global constants of measurements of optical systems with complex software algorithms, inductive displacement sensor and pneumo-electric sensor calibration.

The mechatronics system for micro-measurement and micro-positioning consists of the following subsystems: linear positioning vertical axis; gripper with two fingers; controller; beam sensor; temperature sensor; positioning sensor; process software; electric actuator subsystem; process software; support mass.

The main part of the mechatronic system is the micro-positioning system, consisting of two linear axes, electrically powered. The two linear axis of micro-positioning system are connected to the two controllers C-863.10 model; the linear stroke for each positioning axis is 200 mm.

Linear axis drive is provided by CC motors, and the transmission screw-nut type ensures safety and positioning accuracy. The linear electric axis transforms movement of rotation of CC motor 24 V, in the translational movement by screw-nut type mechanism, the displacement increment is 0,2 µm.

In figure 11 is shown a linear axis, highlighting its components.

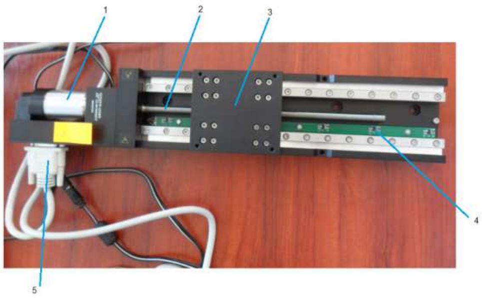

Fig. 11: Linear electric axis

The component elements of linear axis are:

1 CC motor
2 Screw drive
3 Platform of mechatronics axis – z/x
4 Positioning sensor
5 Connection cable to controller

In general, the linear axis of sub-micronic precision have linear racing limited to avoid aggregation of errors.

The system flexibility lies in the possibility of mounting two electric axes both horizontally and in the vertical plane; the displacement errors are corrected by the specific software.

3.2. Assembly of electric linear axes

By design, the mechatronic axes are designed for one single positioning direction, horizontally or vertically mounted.

In order to achieve the accuracy guiding specified and to avoid guides torsion, axes must be mounted on a flat surface.

The assembly of linear electric axes has been achieved by positioning each other so as to materialize the two axes of movement in a vertical, x-z (figure no. 12).

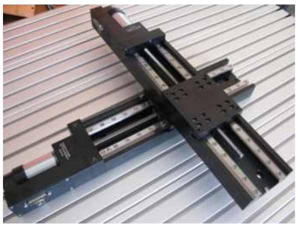

Fig. 12: Mounting and assembly of two linear mechatronic axes in horrizontally plane

The linear axis x is fixed with screws and nuts in channels “T“of the work table, as can be seen in the figure 13.

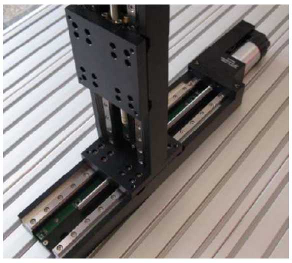

Fig.13: Mounting and assembly of mechatronics linear axes in vertical plane

Fixing the horizontal axis, with screws and nuts in channels “T“ of the work table.

In order to achieve the positioning system, the two linear axes are mounted in the vertical plane forming a Cartesian system XZ. The linear axis Z was set on the table of the X axis, in vertical position, through the screws (figure 14).

Fig.14: Assembly linear axes in vertical plane

Fixing the horizontal axis, with screws and nuts in channels “T“ of the work table.

In order to achieve the positioning system, the two linear axes are mounted in the vertical plane forming a Cartesian system XZ. The linear axis Z was set on the table of the X axis, in vertical position, through the screws (figure 15).

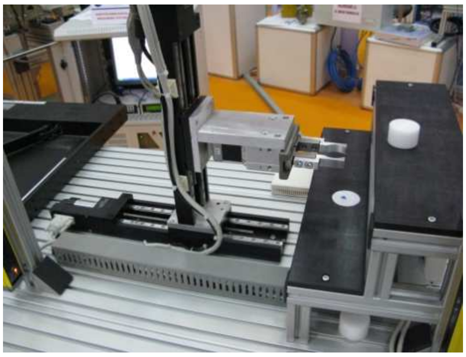

Fig. 15 The two linear axes, mounted in the vertical plane

Electric linear axes are precisely machined, with high precision guides, embedded in passive aluminium alloy support, having high stability with a minimal weight, allowing movement of 25 ÷ 200 mm.

Linear guides with re-circulating ball bearings, ensures high rigidity of the system; the platforms of linear axes can carry up to 20 kg and push / pull up to 50 N.

To protect the equipments, on the sled are mounted non contact sensors with Hall Effect, sensors that provide highly accurate automation opportunities.

The proper functioning of the linear axis is only possible in combination with a controller and appropriate software. The two linear axes of micro-positioning system are connected to two controllers (figure 16) C-863.10 model; the linear stroke for each positioning axis is 200 mm.

Fig. 16: Controllers of the two electric linear axes

The control was selected so as to be able to read and process the reference signals and limit sensors and incremental position encoding to ensure proper performance of the servo - control system.

For the safety of electric linear motion sleds are used groups of Hall effect sensor, which informs about the position of an object relative to a reference point.

Since positioning accuracy is of sub-micron size, we use a temperature sensor mounted near the system. Temperature sensor (Figure 17) is included in the control circuit, in order to warn or stop the system when ambient temperature exceeded that may compromise accuracy. Sensor, with no moving parts, greatly increases reliability compared to other types of electromechanical sensors and in addition can be adequately protected.

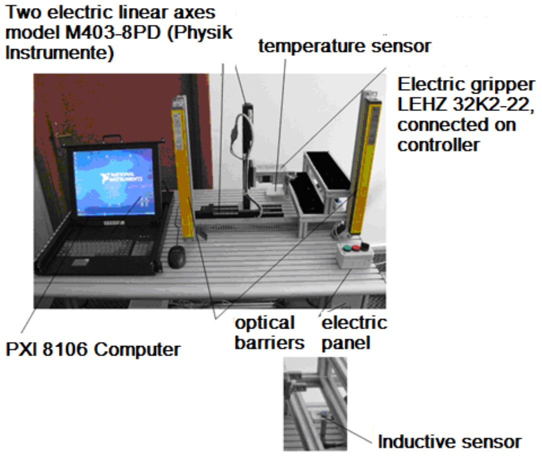

Fig. 17 The system's components, mounted on the worktable

The electric gripper LEHZ 32K2-22 was assembled on the table of vertical axis through connecting pieces (figure no.18).

Fig.18: LEHZ 32K2-22 Gripper, connected with a controller, ensure automatic loading –unloading of the parts

The electric grippers are mounted on the vertical sledge of micro-positioning system. It provides for catching the piece for micro-positioning, enabling support of a part with a mass up to 0,5 kg. The gripper fingers will be individualized by shape of the parts that will be positioned.

In figure 19, are represented comparatively, the virtual model and the experimental model of micro-positioning mechatronic system.

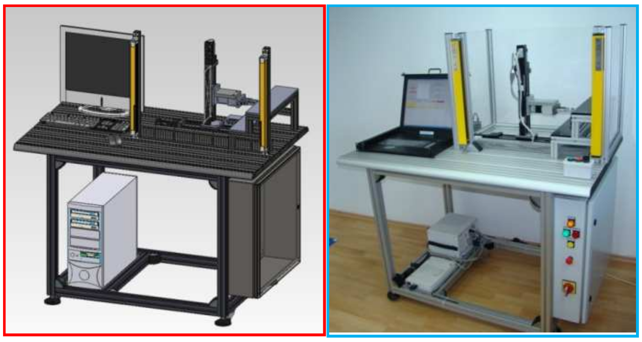

Fig. 19: Virtual model and experimental model of micro-positioning mechatronic system.

The innovative character of this mechatronic product is achieved by modularity and flexibility, is intended as for applied research and for technological applications.

4. MEASUREMENT OF VALUES FOR CLAMPING FORCE

The clamping forces developed by the fingers of electric micro-gripper, included in the gripping system of micro-positioning mechatronic system, were measured in static conditions, using a compact force transducer [5].

The compact force transducer, can measure static and dynamic compression forces up to 50kN. This force transducer is suitable for micromanipulation, pharmaceutical applications, press connection processes, etc.

This force transducer, was chosen to determine the values of the clamping force, because the material from which it is made (stainless steel) and the compact and robust design provide a high stability, in particular in a micro-measurement field, enabling reliable measurements.

The tests consisted of measuring the clamping force developed by the fingers of micro-gripper at the catching of part.

The part of handling is considered to be the force transducer, together with gauges used to vary the size of the piece.

In the closed position, between electric gripper jaws remain a distance of 29,5 mm. Maximum opening of the jaws of electric gripper is 49,25 mm. The force transducer used for the experiments has a height of 27,9 mm. In order to vary the size of parts to be handled, to achieve measurements, were used gauges ranging in size between 2 ÷ 6,6 mm.

For each value of thickness of the workpiece, were made three measurements of the clamping force. In table 2 are summarized the average values obtained for the clamping force, depending on the size of the workpiece.

Table 2 – The average values obtained for the clamping force, depending on the size of the workpiece.

No. crt.	Workpiece thickness [mm]	Average value for clamping force [N]
1	29,9	52,43333
2	30,0	51,94667
3	30,1	49,92333
4	30,9	51,30333
5	31,4	52,41667
6	31,9	41,50333
7	32,4	43,46667
8	33,9	47,08333
9	34,1	44,70000

In figure 21 are shown the trend of change the average clamping force depending on the dimensions of the workpiece.

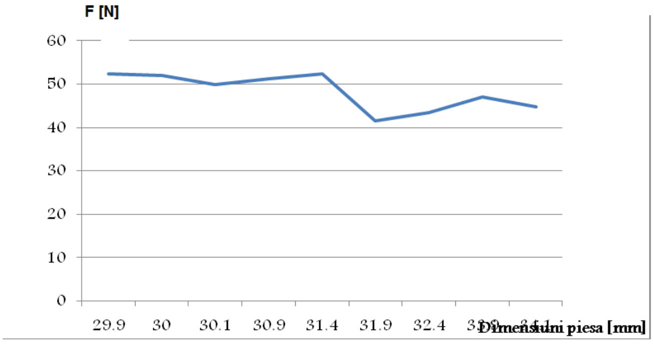

Fig. 21: The trend of change the average clamping force depending on the dimensions of the workpiece.

Although the first three tests seemed that the clamping force will decrease uniform, as you increase the size of the piece, at the end of nine tests it was found that the variation can not be considered uniform of the clamping force.

The linear evolution of a clamping force depending on the size of the part is shown in figure 22.

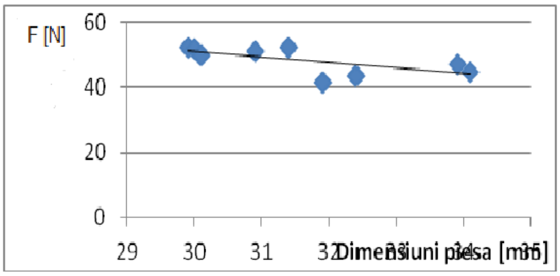

Fig. 22: The linear evolution of a clamping force depending on the size of the part

From the graph shows that the trend of clamping force is to decrease, as you increase the size of the workpiece, but this trend can not be considered an uniform decrease.

CONCLUSIONS

It was shown the realisation mode of virtual model and experimental model of a micro-positioning mechatronic system. Consisting of two linear axes electrically driven, with linear maximum stroke of 200 mm the system is a flexible mechatronic product, multifunctional, integrated in technological platforms.

The innovative character of this mechatronic product is achieved by modularity and flexibility, is intended as for applied research and for technological applications. Specific applications that can be integrated micro-positioning mechatronic system are: precise positioning of a various components, to measure and micro-processing; characterization of surfaces in complex vector space and temperature; integration in intelligent mechatronic systems to determine global measurements constants of optical systems with complex software algorithms; calibration system of inductive sensors for displacements and air powered sensors.

The micro-gripper used in the gripping system as electrically powered, realised in compact design, having reduced dimensions, but allowing relatively large variations of the stroke, obtaining at the same time values of the clamping force equivalent to air gripper widely used.

Although the first three tests seemed that the clamping force will uniform decrease, as you increase the size of the part, at the end of nine tests it was foundthat the variation of a clamping force can not be considered uniform. The clamping force Forța de strângere have average values in the range 41.50333 ÷ 52.43333 N, which is a difference of 10.93 N, for dimensions of a workpiece within the range 29.9 ÷ 34.1 mm (that is a variation of 4.2 mm).

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