Orientation Robotic Mechanism used in Industrial Operations

Paul Ciprian Patic, Gabriela Mantescu, Marin Mainea, Lucia Pascale

***Abstract*—**The robot is a complex automated system that has the role of manipulating the parts and tools, replacing the action of human. An industrial robot is a system that does not operate in isolation, it communicates with other robots and machine tools, conveyor belts, thus reaching the idea of a flexible manufacturing cell. One of the most important robot classes is manipulating robots for manufacturing operations, which include industrial robots. There are, undoubtedly, many definitions of the industrial robot, which is a universal machine, used to perform some intellectual activity, human jobs or to have the capacity to replace man in different actions. The goal of this paper is to make a study on the kinematics of the mechanisms involved in industrial robot composition, some data regarding the dynamics of industrial robotic systems and the structure of a robotic position system used in industrial operations in order to optimize and correct the performances.

***Keywords*—**Gripper, Industrial Robots, Mechatronics, Micro-positioning, Robotic mechanism, Sensors System.

I. Introduction

THE construction of flexible manufacturing cells and the industrial robot driving system requires the use of certain techniques of artificial intelligence used to construct superior hierarchical levels, advanced predictive control techniques in inferior hierarchical materialization.

Although the term used under the name of Industrial Robot is often accepted and used together with the term C.I.M. (Computer Integrated Manufacturing), but optimization and management of the manufacturing cell, is still a problem for engineers.

To achieve flexibility in use, together with the safety and autonomy of operation, a unified approach to the robotic manufacturing cell is required, combining automatic and artificial intelligence elements [1], [9].

Main applications of industrial robots are contour or dot welding, assembly operations, painting, molding of large parts, quality control, handling of radioactive substances or toxic substances.

Paul Ciprian Patic is with the Valahia University of Targoviste, Romania (corresponding author to provide e-mail: patic@valahia.ro).

Gabriela Mantescu is with the Institute of Multidisciplinary Research for Science and Technology from Valahia University of Targoviste, Romania (e-mail: gabriela.mantescu@gmail.com).

Marin Mainea is with the Valahia University of Targoviste, Romania (e-mail: marinmainea@yahoo.com.

Lucia Pascale is with the Valahia University of Targoviste, Romania (e-mail: lucia.p@gmail.com.

The industrial robot is defined as a three-dimensional, reprogrammable, multifunctional manipulator capable of moving materials, tools, parts or special devices after scheduled trajectories to perform multiple manufacturing operations [14].

II. The electrical drives

To complete the main application one need to explain the robotic system from two points of view: electric hardware and the software part.

A. The electrical control box

In Fig. 1, from below, one can see the electrical control box. Two controllers for the linear axes forming the XOZ system and the four feeders (two for the axle controllers and two for the two linear axis motors) are mounted at the top of this box. For space considerations, the electric grill controller is not mounted in the box. It is positioned on the work table, made of aluminum profiles [12].

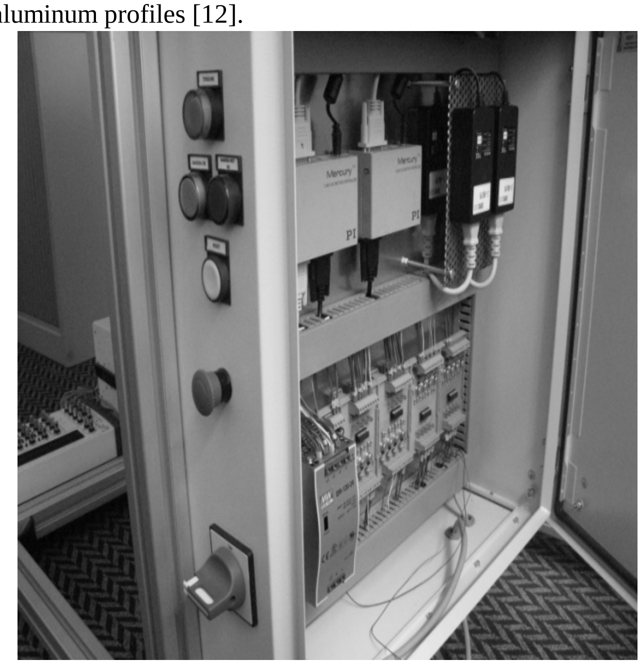

Fig. 1 Electrical control unit

In Fig. 2 one can see that the electrical control unit is positioned in an accessible panel, its position helping very much the human operator in handling and in exploitation the device [4], [13].

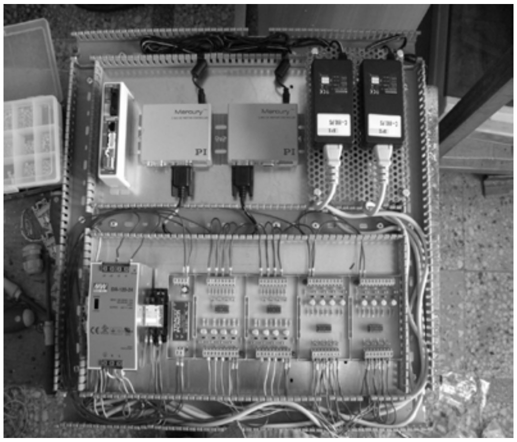

Fig. 2. The electrical control unit is positioned in an accessible panel.

B. The Optical safety barriers

In order to avoid accidental intrusion into the working area of the operator's hands or foreign objects, the system has been designed with optical safety barriers, such as the OMRON F3S-B182P-L / F3S-B182P-D. These barriers have the function of stopping the operation of the mechatronic system if, in the workspace, the operator inserts the hand or various objects that can distort the effects of the working cycle [7].

The characteristics of the optical barriers are as follows:

- Number of optical rays: 10 ÷ 70.
- Height of the protected area: 500 mm.
- Detection distance: 0.2 ÷ 6 m [12].

III. SPECIALIZED SOFTWARE. SOFTWARE TESTING

The micromechanical positioning is done by specialized software.

Testing the software consists of the following steps:

- current application to programmable software / controller;
- generating I / O signals to prepare the system configuration;
- introducing into memory the specific program by console programming or by software tools added to the system;
- after programming, any code error is checked by diagnostic functions; if possible, one can simulate an entire operation to check if everything is OK.
- running the system: before pressing the start button, need to check in detail if the input and output wiring is correctly executed in accordance with the I / O assignment. Once the correct wiring is confirmed, the application can be started [3], [5], [8].

A verification operation must be performed to check the operating system and an adjustment of the control system, if necessary. Complete testing runs until the mechatronic system is safe to operate.

The LS3 limiter senses the closed position of the griper. To start / stop the cycle there are 1 start button - PB1 and 1 stop button - PB2 [10], [15].

The components of this application have been assembled, positioned and adjusted and subjected to partial and complete operation tests. Finally, the design and modeling cycle has been achieved.

The mechatronic micro-position system physically performed together with the implemented protection system is shown in Fig. 3 [2].

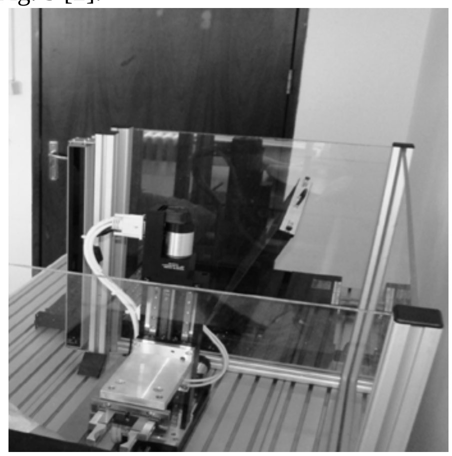

Fig. 3. The micro-position mechatronic system, located in the protected space, on the work table

IV. MICRO-GRIPPER SUBSYSTEM WITH TWO FINGERS

One used a CAD software to design the gripper system with two fingers.

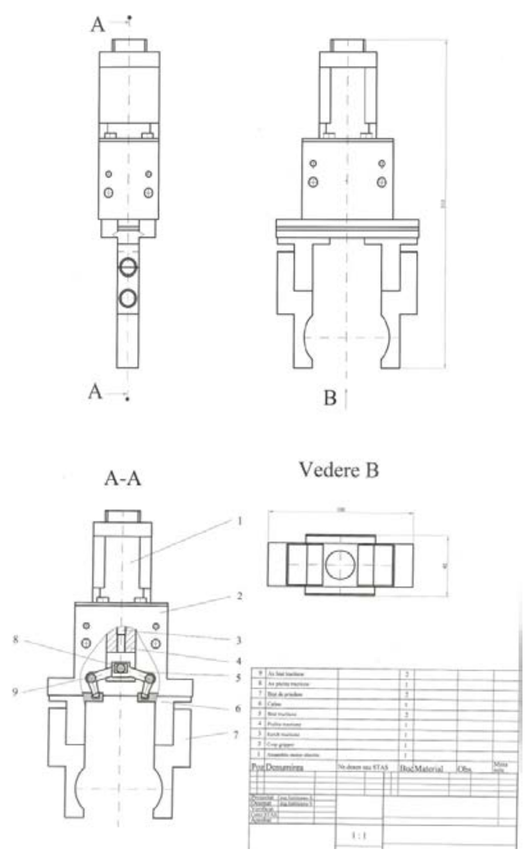

Fig. 4 Micro-griper design using AutoCAD software

And the section view is presented below [12].

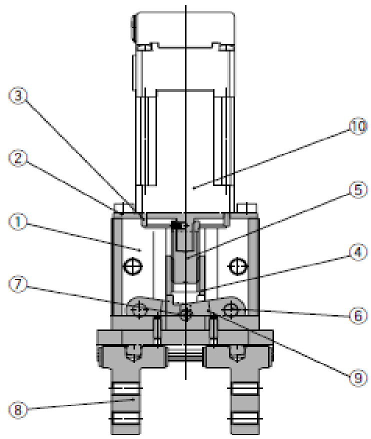

Fig. 5 Section through the Gripper prehensile mechanism

TABLE I. DESCRIBE THE GRIPPER MECHANISM

Nr.crt.	Describe	Material	Observations
1.	Body	Aluminum alloy	Anodized
2.	Tray engine	Aluminum alloy	Anodized
3.	Guide ring	Aluminum alloy	-
4.	Sliding nut	Stainless steel	Thermal treatment + special treatment
5.	Sliding bolt	Stainless steel	Thermal treatment + special treatment
6.	Guide roll	High carbon chrome steel	-
7.	Guide roll	High carbon chrome steel	-
8.	Fingers assembly	-	-
9.	Arm	Special Stainless steel	-
10.	Step by step motor	-	-

In Table I the information on the materials from which the parts of the prehensile mechanism are made is centralized.

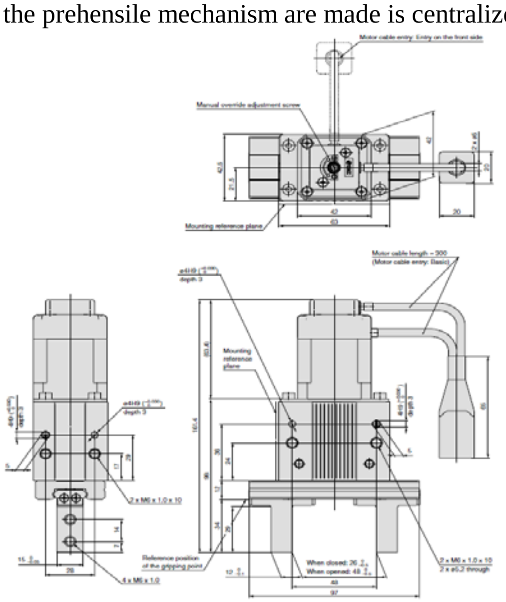

Fig. 6 Overall and functional dimensions of the LEHZ 32- K2-22 gripper subassembly

The overall gauge and functional dimensions of the LEHZ32-K2-22 gripper subassembly model are shown in Fig. 6.

In figure from below are the finger friction forces and the clamping force of the piece.

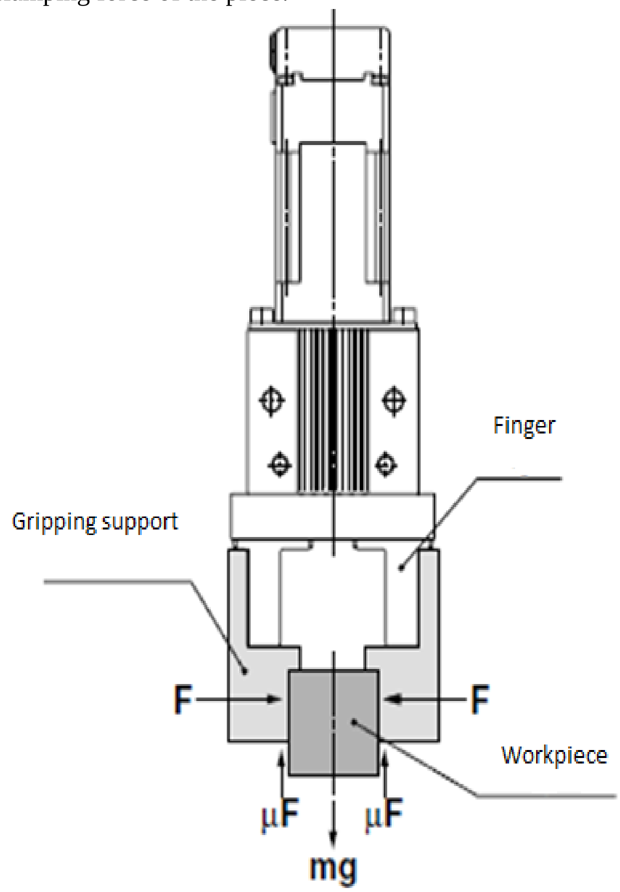

Fig. 7 Friction piece - gripper finger and piece clamping forces

The conditions for supporting the piece in the gripper (comprehension mechanism) are shown in table from below.

TABLE II.

When $\mu = 0,2$	When $\mu = 0,1$
When $\mu = 0.2$: $F = \frac{mg}{2 \times 0.2} \times 4 = 10 \times mg$ (10 x Workpiece weight); When $\mu = 0.1$: $F = \frac{mg}{2 \times 0.1} \times 4 = 20 \times mg$ (20 x Workpiece weight)	When $\mu = 0.2$: $F = \frac{mg}{2 \times 0.2} \times 4 = 10 \times mg$ (10 x Workpiece weight); When $\mu = 0.1$: $F = \frac{mg}{2 \times 0.1} \times 4 = 20 \times mg$ (20 x Workpiece weight)

The friction coefficient values according to material couplers are summarized in Table III.

TABLE III.

Friction coefficient μ	Material couplers
0,1	Metal (surface roughness R_z 3,2 or less)
0,2	Metal
>0,2	Rubber, wood tar etc.

V. THE KINEMATIC SCHEME OF THE GRIPER SUBASSEMBLY

The kinematic scheme of the gripper subassembly is shown in Fig. 8 [6]

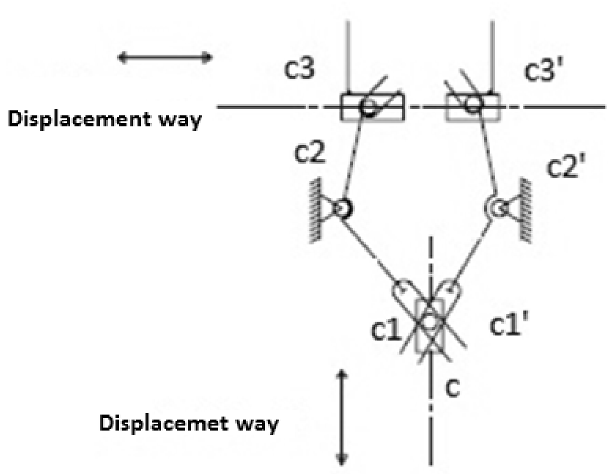

Fig. 8 The kinematic scheme of the gripper subassembly

Where:

- C – screw-nut couple;
- C1, C1' - roto-translation couple;
- C2, C2' – roto-translation couple;
- C3, C3' – translation couple.

The mechatronic system, designed as required, has as a requirement the movement and positioning of the gripper in a vertical plane (Fig. 9). Getting the movement in the vertical plane on the two axes, X and Z directions, is accomplished with two kinematic screw-nut couplings; the first coupling for displacement on OX horizontal, the second couple for vertical displacement on OZ axis [2].

The gripper will execute the motion for which it was projected, in a horizontal plane and perpendicular on the vertical plane in which it was positioned [11].

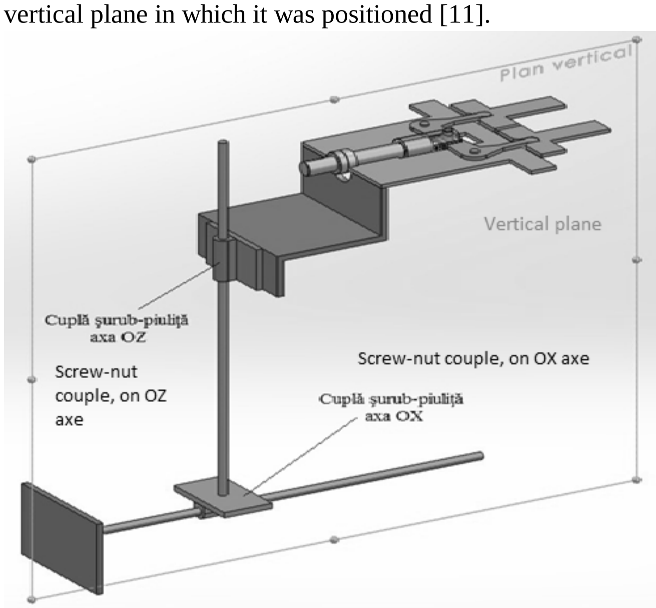

Fig. 9 The kinematics of the virtual model of the robotic system

Schematic representation of the entire positioning system is depicted in Fig. 9. The schema was modeled in SolidWorks and aims to determine and establish the mobility of the mechanisms that make up the mechatronic system.

The system is made of 3 subassemblies, which are operated independently. The first mechanism, the movement for the OX axis, is the support for the second mechanism, the one for the displacement on the OZ axis. This, in turn, is the basis for the third mechanism (gripper).

The first basic mechanism is built from a screw-nut coupling. The mechanism is driven by a virtual rotation motor, the resulting motion due to coupling the translation (Figure 10).

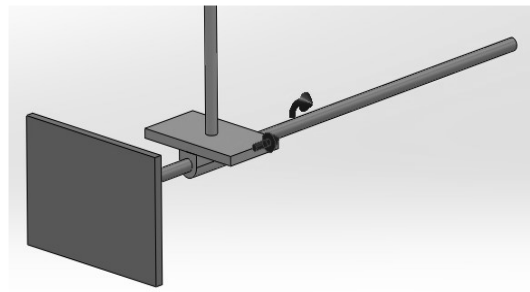

Fig. 10 Modeling of the first mechanism (displacement on the OX axis).

The second mechanism is the same as the first one, the screw-nut couple of the first mechanism becomes itself the base for the screw-nut couple being responsible with displacement on the OZ axis (Fig. 11).

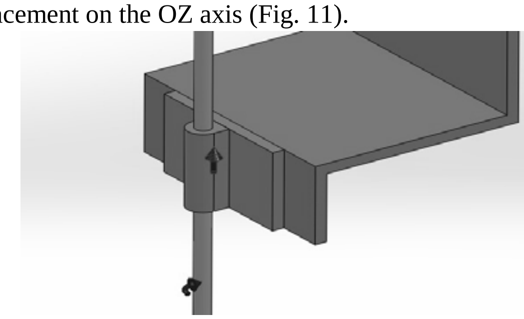

Fig. 11 Modeling of the second mechanism (displacement on the OZ axis).

The gripper is a mechanism on which the base is the screw-nut couple of the second mechanism. Its action is also made by a rotating motor, resulting the translation in the mirror of the two fingers (Fig. 12).

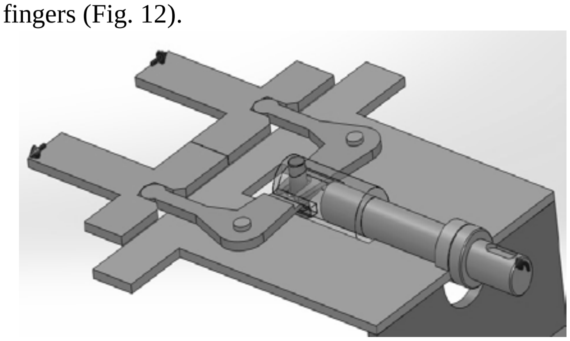

Fig. 12 Scheme of the second mechanism (displacement on the OZ axis).

Analyzing the mobility of the mechanisms in the first two movements, one find that for each mechanism, in part, one only have a screw-nut coupling, which is considered a class V coupling. This is to transform the rotational movement into translational movement, and inverse.

The mobility of the mechanism is determined by the Dobrovolski formula configured for the mechanisms of the III family of plane mechanisms:

$$M_{1,2} = 3n - 2C_5 - C_4 \qquad (1)$$

where:

n = 1 – mobile element number (couple);

C_5 = 1 – class V couples number (screw-nut coupling);

C_4 = 0 – class IV couples number.

$$M_{1,2} = 1 \qquad (2)$$

The third mechanism (gripper) is more laborious, the construction of this mechanism is modified by the conditions imposed by its purpose (Fig.13).

The chosen model must provide a finger-opening stroke:

$$C = 22 \text{ mm} \qquad (3)$$

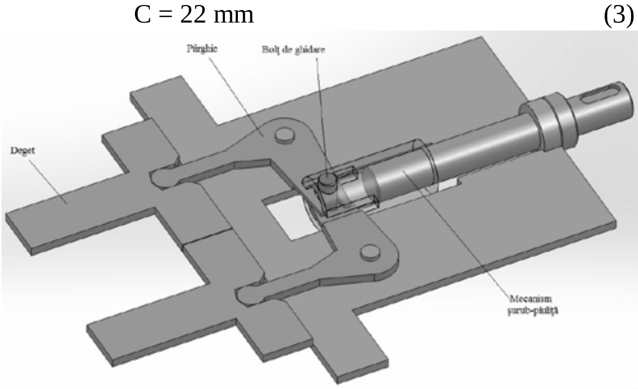

Fig. 13 The kinematic scheme of the gripper mechanism.

The result is that a single finger will have to move C / 2 = 11 mm. The finger displacement is achieved with the help of an step by step electric motor to ensure the accuracy of the movement. This means that the gripper has a mechanism that turns the rotation movement of the step by step motor in the finger translation motion. The mechanism must be able to move two fingers, symmetrically, in the mirror, relative to a planar plane, which is the plane in which the first two movements of the mechatronic system take place (As one presented in Fig. 9).

In the figure from below, it can be seen that for the 11 mm stroke of the finger, a primary form of the lever was built. This ensures that it is operated by the symmetry axis of the gripper and the desired displacement is obtained in the perpendicular direction along the symmetry axis [11], [16].

The finger movement for the 11mm stroke is achieved by building a lever. The lever is an element of the mechanism that conveys the movement from the screw-nut assembly to the finger. This, transforms the well-determined translational movement from one direction into a translational movement determined in another direction, perpendicularly, by a rotation motion (As one can see in Fig. 14).

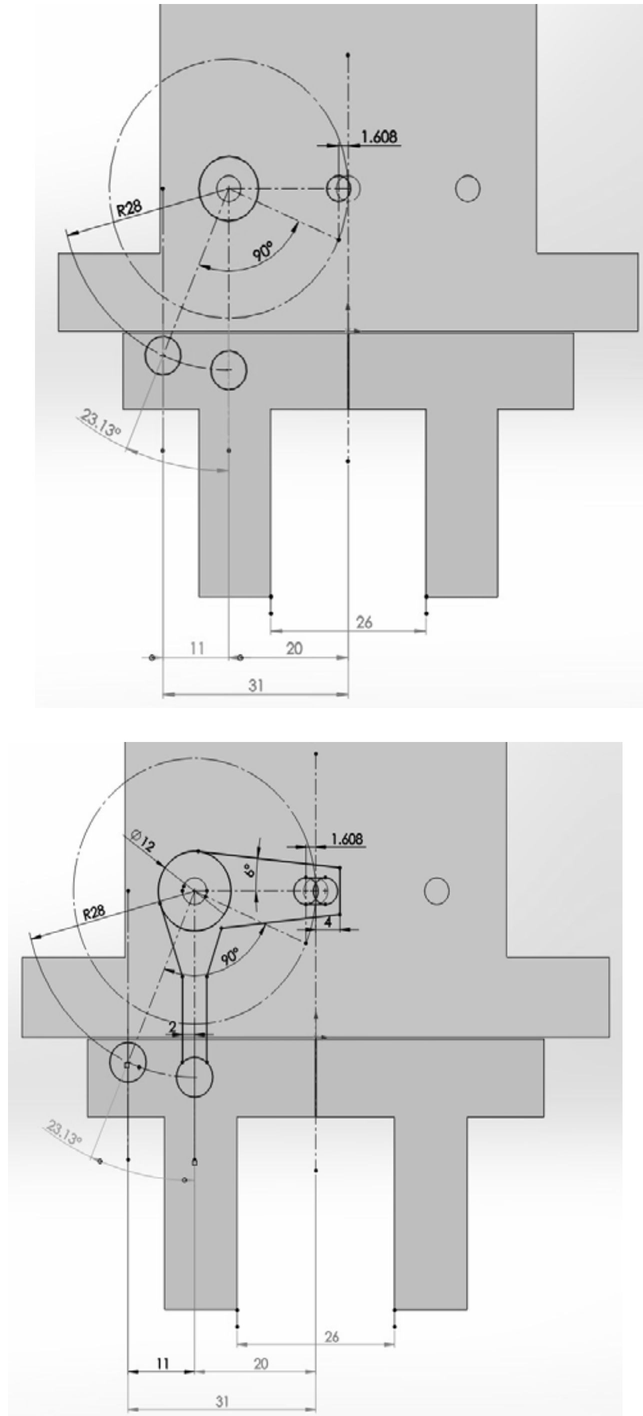

Fig. 14 The geometry obtaining 11 mm stroke for a finger

The geometry simulation for the two finger positions, for the minimum distance between them (2,600.5 mm) and the maximum distance (4,800.5 mm), was determined the final form of the lever. The type of the couplings between the mechanisms was established.

The coupling link between the lever and the finger is a Class IV coupling.

The finger has to make the translation movement on the guide on which it is mounted. The lever arm describes a rotation movement. The end of the lever arm is spherical and the finger contact surface is flat (Fig. 15).

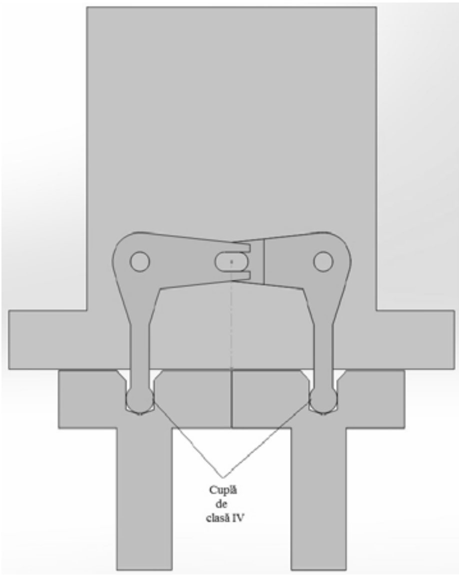

Fig. 15 The final form of the lever

In the symmetrical, mirroring operation of the two fingers, the two levers have the same action point. In the case of the finger, a coupling (class IV) is created that transforms the translation motion of the motion screw into the rotation of the lever. (Fig. 15) [12].

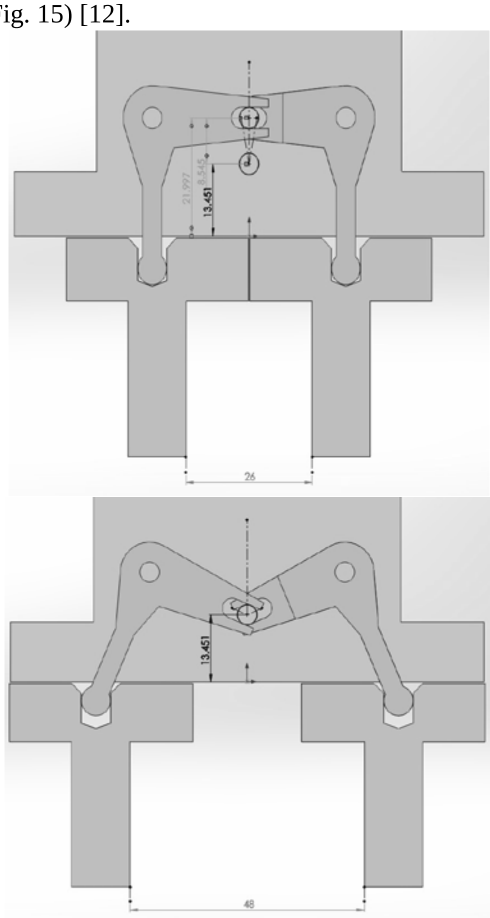

Fig. 15. Construction of the link coupling between the lever and the movement screw

At the construction and positioning of motion screw of gripper interior looks like in the following figure (Fig. 16) [11]:

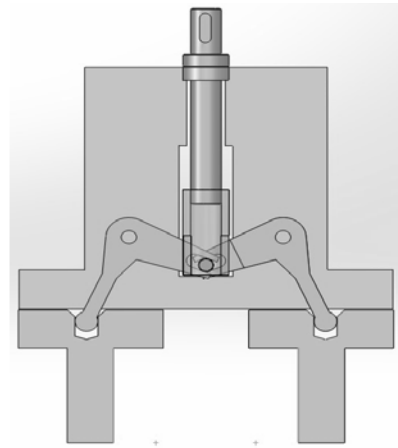

Fig. 16. The final shape of the gripper mechanism

VI. Calculating the Mobility of the Gripper Mechanism

It is considered the mobility of the mechanism for a single finger or both fingers. The degree of mobility is determined by the equation formula (3).

For one finger one have:

$$M_{gripper} = 3n - 2C_5 - C_4 \quad (3)$$

$$M_{gripper} = 1 \quad (4)$$

Where:

n = 3 – mobile element number;

C_5 = 3 – class V couples number;

C_4 = 2 – class IV couples number.

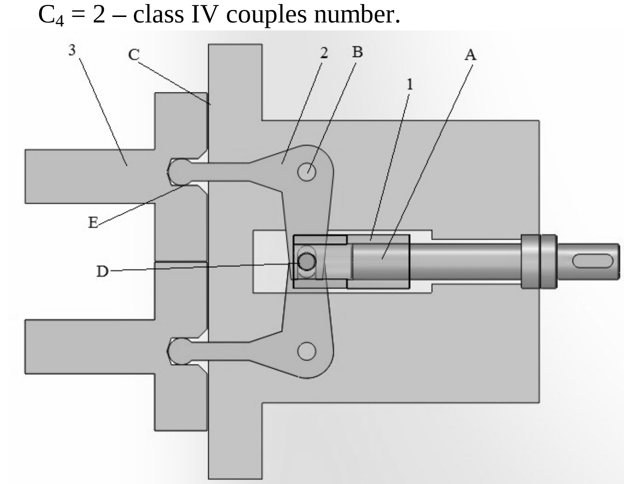

Fig. 17 Gripper mechanism elements and couplers

Where:

1,2,3 – mobile elements of the mechanism;

A,B,C – class V couples: A – translation; B – rotation; C – translation.

D,E – class IV couples.

In order to ensure the positioning and tightening of the manipulated object, the gripper blades are adapted for fitting profiled fingers.

The mobility of the designed and modeled model is given by the mobility of the three independent mechanisms that make up this system [11]:

$$M_{system} = M_1 + M_2 + M_{gripper} = 3 \quad (5)$$

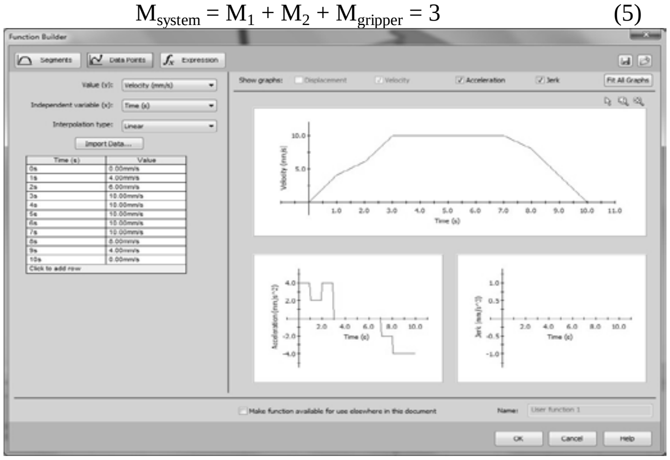

Fig. 18 Functionality feature of an engine for OY axis

Below, one presents two study cases, regarding the displacement and velocity on OY axis for the gripping system.

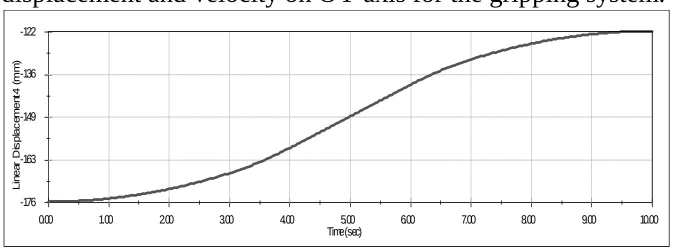

Fig. 19 Linear displacement of the OY axis for a time interval Δt = 10 s (the two axes engines are running simultaneously)

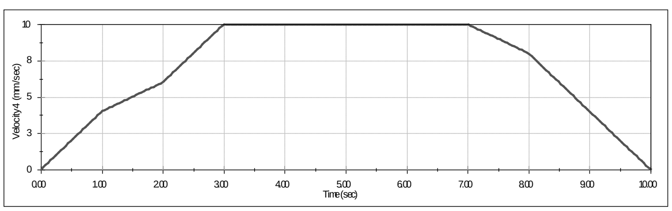

Fig. 20 Linear velocity of the OY axis for a time interval Δt = 10 s (the two axes engines start simultaneously)

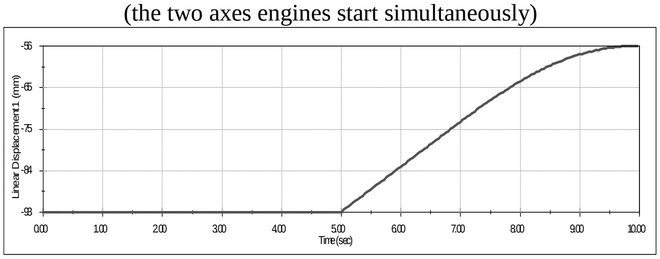

Fig. 21 Linear displacement of the OY axis for a time interval Δt = 10 s (the two axes do not start at the same time, the axis OY motor starts after t = 5 s delay)

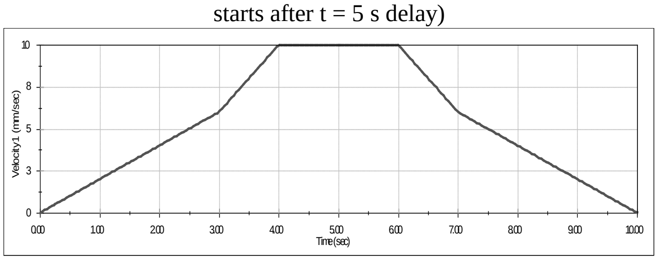

Fig. 22 Linear velocity of the OY axis for a time interval Δt = 10 s (the two axes do not start at the same time, the OY axis motor starts after t = 5 s delay)

VII. Conclusion

The industrial robot is defined as a three-dimensional, reprogrammable, multifunctional manipulator, capable of moving special materials, tools, parts or devices along programmed trajectories to perform multiple manufacturing operations.

The robotic system for micro-position was developed, designed and modeled in a modular structure in the Modeling and Simulation Laboratory of the Faculty of Electrical Engineering.

In these paper, one tries to study the kinematics of the mechanisms involved in robot composition, the theoretical foundations of the dynamics of industrial robotic systems and the structure of a mechatronic micro-powering system used in manipulation operations in order to optimize and correct the performances of the Industrial Robots. Also, one proposed to underline, following objectives: Analysis of the action and structure of an industrial robotic system for the purpose of implementation in the manufacturing processes; Presentation of an industrial robot; Functionally optimal optimization of a mechatronic micro-powering system used in handling operations; Programming for manipulation of different objects; Planning the dynamics of the robot in Cartesian coordinates, generating trajectories connecting two points of the workspace; Obtaining simultaneous joints of the micro-powder mechatronic system used in step-by-step manipulation operations.

The objectives proposed are analysis of the action and structure of an industrial robotic system for implementation in industrial manufacturing processes, presentation of an industrial robot with a gripper attached, the optimization of optimal functionally of a mechatronic micro-powering system used in handling operations, programming for manipulation of different objects, planning the dynamics of the robot in Cartesian coordinates, generating trajectories connecting two points of the workspace and the last but not the least obtaining of simultaneous driving joints of the micro-positioning mechatronic system used in manipulation operations helping by step-by-step DC engines.

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Paul Ciprian Patic is from Valahia University of Targoviste, Electrical Engineering Faculty, Automatics, Informatics and Electrical Engineering Department. The domain of interest are Mechatronics, Industrial Robotics and Educational Robotics, Manufacturing Flexible Systems. He is president of the Romanian Robotics Society, Targoviste Subsidiary, and, also, a member of International Federation of Robotics, or Romanian Automatics and Informatics Society. He wrote many papers presented in different national and international Conferences and published in journals and conferences proceedings.