Simulation and Modeling of a Column Industrial Robot Used in some Different Mounting Processes

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Abstract: - These column industrial robots are used largely in manipulation and mounting operations of a different spares with small and medium dimensions, with regulate forms, which is processed in flexible cells ready in star or circular way of the components. The column Industrial Robots type represents a large used category, starting with the period of the beginning of automatic flexible manufacture. Starting from column industrial robot architecture one tries to find a simulation procedure for the designing of robots using two methods for resolve this problem. One of them is the polynomial interpolation of three degree method and the other used method is the connection of linear functions in parables. This work presents some determinations regarding the simulation of positions, speeds and accelerations which exists into a translation or rotation couple from a kind of robot.

Key-Words: - Industrial Robot, Automatic Processes, Column Industrial Robot, Design, Translation, Rotation.

1 Introduction

Because of actual trend of reorganization of a flexible system in the processing in line of the work station components or a robotized posts and because the organization of the cells in star mode are some disadvantages in exploitation, nowadays it happens a small revolution, meaning that all old components were replaced by actual Industrial Robots with articulated arms or portal type [2].

Actually, those Industrial Robots are present in automatic island type included in a flexible cell processing using plastic deformation, injecting plastic mass in a matrix or stencil and using the process of cold or warm plastic deformation which included tools machines where is integrated some constructive variants using mounting industrial robots [4], [5], [12].

Because of the low costs comparing with other types of Industrial Robots, they are buying, in present, by the firms which want an automatically flexible process stand-alone type (without general integration). For that it can obtain some materialize isolate nucleus of flexible cells processing, with some very attractive costs.

2 Clasifications of the Column Industrial Robots Type

For a systematically approaching of these constructive variants of Industrial Robots it requires a splitting of a general architecture like they are known. A classification of the column Industrial Robots may be made based on a hierarchy of the criteria shown below:

a. After the type of the coordinated system in which it realized the positioning of the Industrial Robot's arm;

b. After the type of Industrial Robot's column structure.

The C1 and C3 groups include the Industrial Robots with column architectures having positioning movements of the arm in cylindrical coordinates.

The distinction between those two kinds of groups it is made after:

a. C1 – simple column type structure;

b. C2 – supplemental stiffening structure on the whole Industrial Robot construction.

Generally, the constructive variants by the both groups of Industrial Robots it can remarks the using of the electrical system to obtain different movements to define those 3 liberty degrees for one arm and for those 2 or 3 liberty degrees of the orientation system it can use electrical or pneumatically engines.

In figure 1 it shows the column Industrial Robot constructive scheme, which is included inside of groups from above.

In C2 and C4 groups are included industrial Robots with column generate architecture having a positioning movement of arm in Cartesian coordinates. The distinction between the two groups it is made like below:

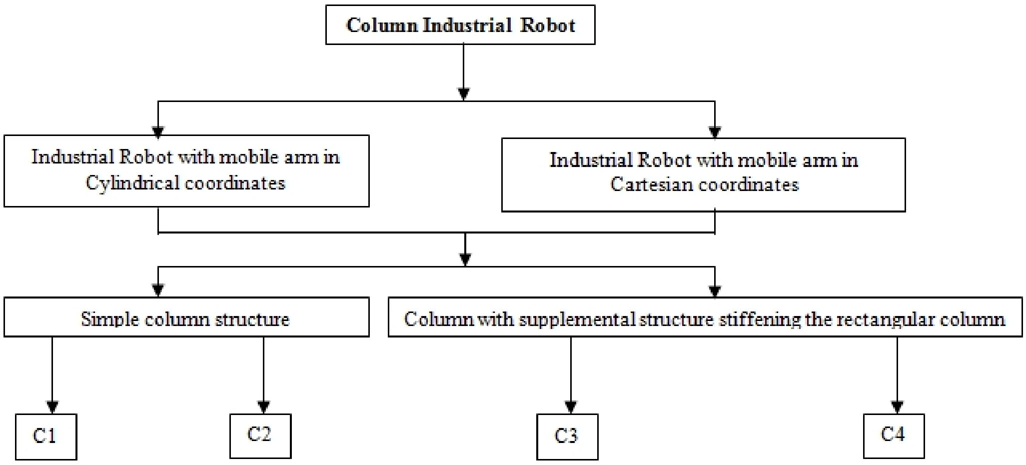

Fig. 1. The classification of the column Industrial Robots

2.1 C1 and C3 Groups

To realize rotation movement of a whole column of the Industrial Robot, all the structures are provisioned with a base electro-mechanical rotation module. These can include a harmonic reduction gear with an elastic element, mounted on the rotated platform, on which is fixed the column of the Robot. In the second case, having in view the construction of whole mechanism (the transmission made with harmonic reduction gear and leads cogging) it will excluded all the pranks and the mechanical transmissions. For that, there is not necessary a supplementary constructive measurements to take over, to assume the future existing errors. Even is very rare, it must be mentioned and a third variant to realize the base rotation module. It includes the movement of the gears with an internal denture and, for that, it is compulsory to take over all the pranks from the gears using two pre-tensioned legs [4], [5], [12].

To realize the vertical translation of the column of the whole Industrial Robot, it will use the solution presented in Figure 2 and Figure 3.

The structure of the kinematical chain is included, in the case of Industrial Robots from C1 group, a continuous current servomotor working with a disc rotor which is mounted on the superior plan of the column, coupling directly to a screw-nut mechanism. For the Robots from C3 category the leading motor it is mounted on the rotation base module of the Industrial Robot. The transmission is made using leads cogging. For both variants, the leading screw is radial and axial fixed even on turntable and, also, on the superior plan of the Robot. The nut made a vertical translation, the movement it is made together with mobile assembly in the same direction.

For the kinematical chain which permit the third degree of freedom movement (horizontal translation) the leading could be done, theoretically, with an electric motor coupled with screw-nut mechanism, or with a hydraulic or linear pneumatically engine.

2.1 C2 and C4 Groups

To realize the ground movement it uses a continuous current servomotor with permanent magnets, without brushes and pinion-trammel-hook mechanism. The motor is placed on the mobile platform, near the column, the trammel-hook is fixed on the longitudinal arm of the Robot and the rotating shaft is fixed on the move away plateau (translation movement) [15].

Some used variants, for that the longitudinal course is a little bit shorter (under 2 meters), using, in the place of pinion-trammel-hook mechanism, the screw-nut system with bowls; in this case the motor is coupled through a leads cogging transmission, which permits the bring the motor synchronized with the screw, to obtain a smaller dimensions for all infrastructure.

For vertical translation it can use a screw-nut mechanism with bowls or rolls; the screw is fixed on the column and the nut makes a translation movement, together with vertical mobile element. The motor is fixed at the base of the Industrial Robot, near the column, the transmission of the movement were made, at the leading screw, by the leads cogging [16].

For the horizontal translation of the arm it can use similar systems with those using at the Industrial Robots from C1 and C3 groups.
For the oriented degrees, depends of applications, it can calls to the notion solutions, which are descried above. We can find, also, Industrial Robots having a pneumatically leads for all degrees of freedom and in the same way, electrical motors, by leading and transmitting all kind of (this motors are installed at the end of all arms).
Using Industrial Robots which is specialized for some specific applications, the functional characteristics varies in large limits, generally, they are characterized by high performing, using, for that, some specific constructively components, obtained very precise translation movements [4], [5] and [12].

3 The Simulation and Modeling's movements for a Column Robot

In figure 2 it is shown the constructive scheme of the Industrial Robot which must be designed and in which are included the axes of translations (for TTT robot) and rotations (for RTT robot).

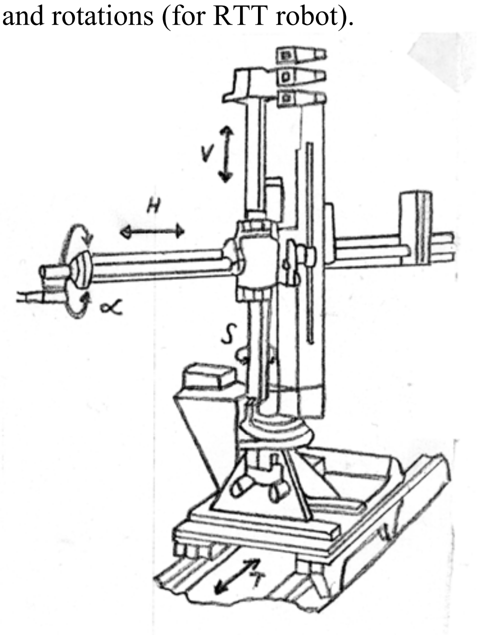

Fig. 2. The constructive scheme of the Industrial Robot

The performances and the characteristics of the column Industrial Robot from figure 2 and 3 (TTT and RTT) it is shown below:

1. the number of liberty degrees: 6;
2. base translation/rotation: 760mm or 300º;
3. the speed of base translation/rotation: 1 m/s or 90º/s;
4. the vertical translation: 760mm;
5. the speed of vertical translation: 1m/s;
6. the horizontal translation: 760mm;
7. the speed of horizontal translation: 1m/s;
8. the first degree of orientation rotation: 300º;
9. the speed at the first degree of orientation rotation: 45º/s;
10. the second degree of orientation rotation: 180º;
11. the speed at the second degree of orientation rotation: 45º/s;
12. the third degree of orientation rotation: 270º;
13. the speed at the third degree of orientation rotation: 45º/s;
14. the load capacity: 40Kg;
15. the precision of positioning: ±0,05mm;
16. electrical acting;
17. the command control:
   - 17.1. flexible program;
   - 17.2. positioning program, teach program;
   - 17.3. eight application programs.
18. the space occupied: 2 m^2;
19. the mass of the robot: 1.200 Kg;
20. The average time between failures: 700 hours.

An industrial robot is a complex, technical system consisting of several subsystems operating within the robot's physical make-up. Each of these subsystems performs its own carefully defined functions and contributes to the overall function of the industrial robot. Three of the more important of these subsystems include kinematics, the control system, and the drive system [14], [15] and [16].

Kinematics
Kinematics refers to the spatial arrangement, according to the sequence and structure, of the axes of movement in relation to each other. There are four basic types of movement that an industrial robot may have: Cartesian, Cylindrical, Polar, and Jointed-arm.
Cartesian Co-Ordinate Robot
The Cartesian co-ordinate robot is one that consists of a column and an arm. It is sometimes called an x-y-z robot, indicating the axes of motion. The x-axis is lateral motion, the y-axis is longitudinal motion, and the z-axis is vertical motion. Thus, the arm can move up and down on the z-axis; the arm can slide along its base on the x-axis; and then it can telescope to move to and from the work area on the

y-axis. The Cartesian co-ordinate robot was developed mainly for arc welding, but it is also suited for many other assembly operations.

Cylindrical Co-Ordinate Robot

The cylindrical co-ordinate robot is a variation of the Cartesian robot. This robot consists of a base and a column, but the column is able to rotate. It also carries an extending arm that can move up and down on the column to provide more freedom of movement. The cylindrical co-ordinate robot is designed for handling machine tools and assembly.

Polar Co-Ordinate Robot

The polar co-ordinate or spherical co-ordinate robot consists of a rotary base, an elevation pivot, and a telescoping extend-and-retract boom axis. These robots operate according to spherical co-ordinates and offer greater flexibility. They are used particularly in spot welding.

Jointed-Arm Robot

The jointed-arm robot resembles a human arm. It usually stands on a base on which it can rotate, while it can articulate at the "shoulder" joint, which is just above the base. The robot can also rotate about its "elbow" and "wrist" joints. With the swiveling and bending at the wrist, six degrees of freedom can be obtained. The jointed-arm robot is the most popular form for a robot and is capable in welding and painting work.

Control Systems

The control systems of an industrial robot determine its flexibility and efficiency, within the limits set beforehand by the design of the mechanical structure.

Purpose of the Control System

The control system provides a logical sequence for the robot to follow. The system provides the theoretical position values required for each step and continuously measures the actual position during movement. As the robot operates, the control system evaluates the theoretical/actual difference, together with other measured values and stored data (theoretical speeds), and produces actuating variables to drive the robot.

Types of Control Systems

There are two basic types of control systems: the point-to-point control system and the continuous path control system. With point-to-point control, the robot records the point where it picks up a part and the point where it releases that part. The robot then determines the best path to take between the two points. The point-to-point system is used when greater repeatability is required, or when the path between endpoints does not matter. Point-to-point control systems work well in loading and unloading applications.

Continuous Path Control System

A continuous path control system is one in which the robot is programmed to follow an irregular path exactly. Inside the control system, the path to be travelled is represented by a large number of points in close proximity; these points are stored in the robot's memory. In the working cycle, the robot follows the points to reproduce the desired path. The system is used for jobs when the robot is required to follow a specific path, such as in welding or painting.

Drive

The drive of the robot converts the power supplied to the grippers into kinetic energy used for moving the robot. The basic types of drive systems include electrical, pneumatic, and hydraulic.

Electrical Drive Systems

Electromechanical drive systems are used in about 50 percent of today's robots. These systems are servo motors, stepping motors, and pulse motors. These motors convert electrical energy into mechanical energy to power the robot.

Pneumatic Drive Systems

Pneumatic drive systems are found in approximately 30 percent of today's robots. These systems use compressed air to power the robots. Since machine shops typically have compressed air lines in their working areas, the pneumatically driven robot is very popular. Unfortunately, this system does not make for easy control of either speed or position--essential ingredients for any successful robot.

Hydraulic Drive Systems

The designers use this system because hydraulic cylinders and motors are compact and allow high levels of force and power, together with accurate control. A hydraulic actuator converts forces from high pressure hydraulic fluid into mechanical shaft rotation or linear motion. Hydraulic fluid power is more cost effective for short-stroke, straight-line positioning requiring high forces, controlled acceleration, and repetitive motion. No other drive system packs as much power into such a small package; no other drive is as safe or as resistant to harsh environments.

Continuing our study, for the proper representation of variations of positions, velocities and accelerations for these study couplers robots one uses two methods, utilize very often, to solve these problem of movements of a robot. The first method used was the polynomial interpolation of degree 3. The other method is the connection of linear functions in parables.

One can say that both methods transform the task space in coordinates joint.

Polynomials can be used to approximate more complicated curves. A relevant application is the evaluation of the natural logarithm and trigonometric functions. This results in significantly faster computations. Polynomial interpolation also forms the basis for algorithms in numerical quadrate and numerical ordinary differential equations.
Polynomial interpolation is also essential to perform sub-quadratic multiplication and squaring, where an interpolation through points on a polynomial which defines the product yields the product itself.
The interpolation polynomial of three degree is like below:

$$P(x) = a_3x^3 + a_2x^2 + a_1x + a_0$$

The statement that P interpolates the data points mean that:

$$P(x_i) = y_i, \text{ where } i\in\{0, 1, 2, 3\}.$$

The second method is the connecting linear functions in parables. This method is generally used when the robot trajectory passes through several points, but can be used, also, to move from point to point. To join two different points are used rectilinear trajectories and to respect the conditions of speed and acceleration (through by crossing points) straight paths are connected in parables.
The trajectory of motion of the robot are studied from two points of the workspace.

This method reveals three time intervals:
- the task duration;
- the periods duration in which the function is parabolic type;
- the periods duration in which the function is always linear.

The condition of the connection between the two portions of the function is enforced with equal speed in common point [18].
Specify of the movement trajectory is an essential element to ensure of some proper performance. This means, in fact, establish of a bi-univocal links between each point on the curve movement and well-defined time moments, so basically know in every point of the speed and acceleration's movements. Choosing the path of movement depends on a number of factors that can cite: the type of robotic application, the restrictions from the area of operation, the mechanical properties of the robot [23].

Linear functions of the form f(x) = a x + b and the properties of their graphs are explored interactively using an applet.
The exploration is carried out by changing the parameters a and b defining the linear function.
Defining the Linear Functions: Any function of the form f (x) = m x + b, where m is not equal to 0 is called a linear function. The domain of this function is the set of all real numbers. The range of f is the set of all real numbers. The graph of f is a line with slope m and y intercept b.
A function f (x) = b, where b is a constant real number is called a constant function. Its graph is a horizontal line at y = b.
The domain of all linear functions is the set of all real numbers.
The optimum position of a column industrial robot is a very important problem, which can not be solved without a complete analysis of the robot working, from the kinematics and kineto-static point of view. The position of an industrial robot must be settled in accordance with the solutions of an optimization problem. The objective function, which should be minimized, expressed the energy consumed for a duty cycle, the maximum power, the maximum driving force or moment from the driving system or the inverse efficiency of the robot. In the minimization process are taken into consideration some constrains as: the application must be into the work field of the robot, the relative speeds and accelerations between the contiguous elements of the active kinematics pairs must be maintained in the permissible limits [9].
The optimum position of the robot frame in respect to the given application is determined so that:
- the robot productive rate must be maximum (the time of a duty cycle must be minimum);
- the energy consumption for a duty cycle must be minimum;
- the maximum power consumed during a duty cycle must be minimum;
- the maximum driving force or moment from the driving system, measured during a duty cycle, must be minimum [9].

The movement of an object handled by a column industrial robot between two imposed positions P_1 and P_2 can be carried out in an infinite number of ways; when a solution less problem arises, it is necessary for an optimum solution from a point of view to be chosen. These refer to the movement of the work piece relative to the base of the robot, as well as to the position of the base of the robot relative to the application defined by the two points P_1 and P_2 [9].

The path of an end-effector of a robot consists in a number of given points that are connected by segments; each one of the latter is a curve that approaches more or less a straight line. Each one of these path segments is described by the movements of the link ensemble where each link follows a law of motion which shape is fixed. So, end-effector describes a path that comes from "fixed shapes" of servomotors laws of motion. To obtain enough accuracy for a path, it is necessary that each of joints moves with an appropriate law of motion. Each servomotor must move following a law of motion that can bring the end-effector on the planned path in each moment, this is possible only if the law of motion can be changed continuously [13].

Below one represent, in parallel, first the polynomial interpolation of degree 3 method and secondly, the other method - connecting linear functions in parables. So one can observe, graphically, the both methods explained above.
First of all, one choose to determines a simulation of a robot with 3 degrees of translation (TTT), which is moves from P_1 (0, 0, 0) to P_2 (150, 200, 300) (not required the shape of the trajectory).
After the graphic representation one obtains that both actions, the accelerations and breakings, are different from one couple to another, because the lengths of paths, which is moving, are different. The movement is performed simultaneously on all three directions [18].

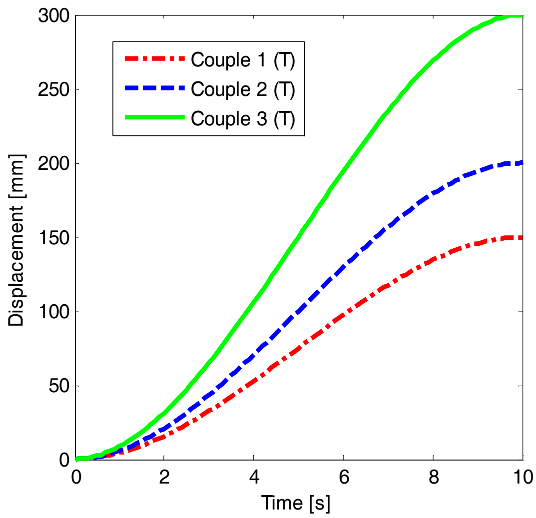

Fig. 3. The displacement of TTT Robot (first method)

In figure 3 one represents the displacement versus time. The displacement from couple 1 is smaller then those from couple 3 [16].

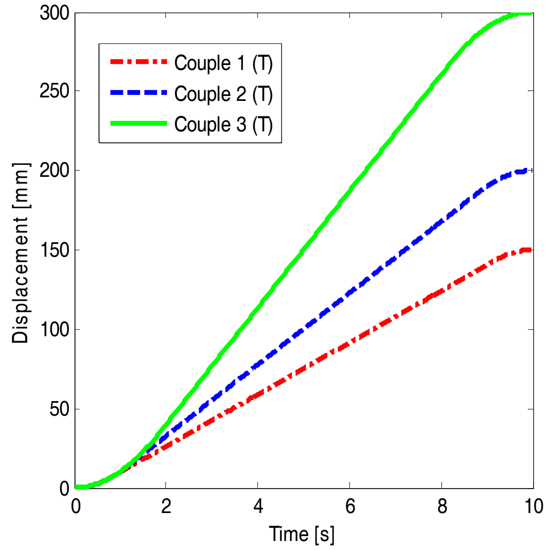

Fig. 4. The displacement of TTT Robot (second method)

In figure 4 one represents the displacement versus time. The displacement from couple 1 is smaller then those from couple 3.
The differences from the first method it can observe in the beginning, until two seconds from the start and after eight seconds, at the end of functioning of the robot.

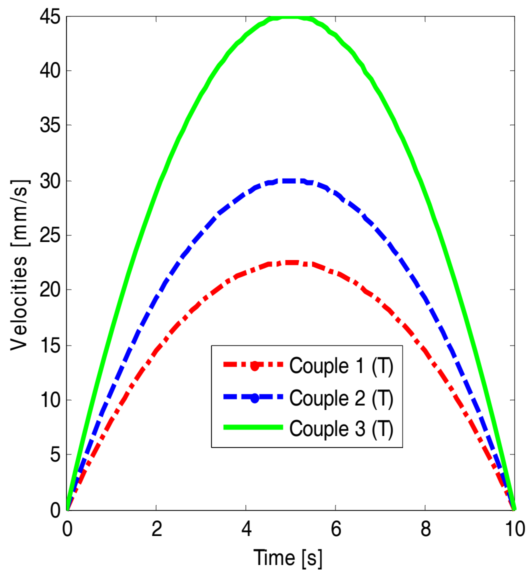

Fig. 5. The velocity of TTT Robot (first method)

In figure 5 and 6 one determines the velocities versus time. Like above, the speed from couple 1 is smaller then couple 2 and 3.
The graphical differences are more evident like above, when one used the displacements.

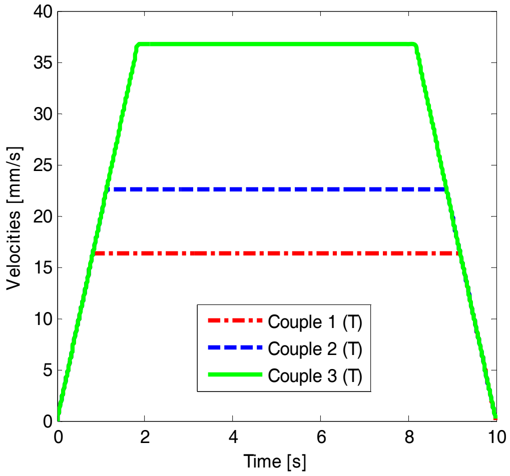

Fig. 6. The velocity of TTT Robot (second method)

One can observe that the speeds represented in the second method have a large constant level stagnation, between the two and eight seconds.

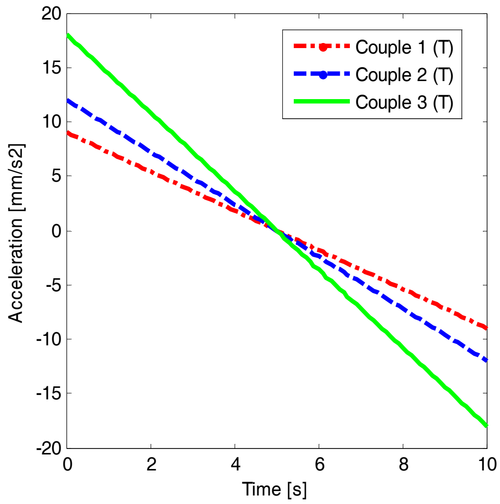

Fig. 7. The acceleration of TTT Robot (first method)

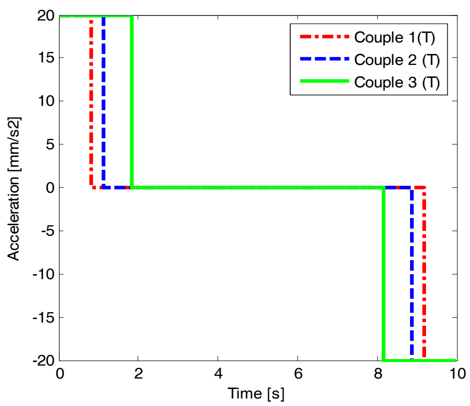

Fig. 8. The acceleration of TTT Robot (second method)

In figure 7 and 8 one has the accelerations versus time. The acceleration has a decreasing trend in both methods, noting that, in the second method, one obtains a constant plateau during zero level.

Passing to the second case study, one choose to determine a simulation of a robot with 3 degrees of translation (RTT), which is moves from P_1 (0, 0, 0) to P_2 (120, 200, 300) (not required the shape of the trajectory) [18].

In the bottom of figure 9 it presented the constructive and kinematical scheme of the Robot [2], [4], [5] and [12].

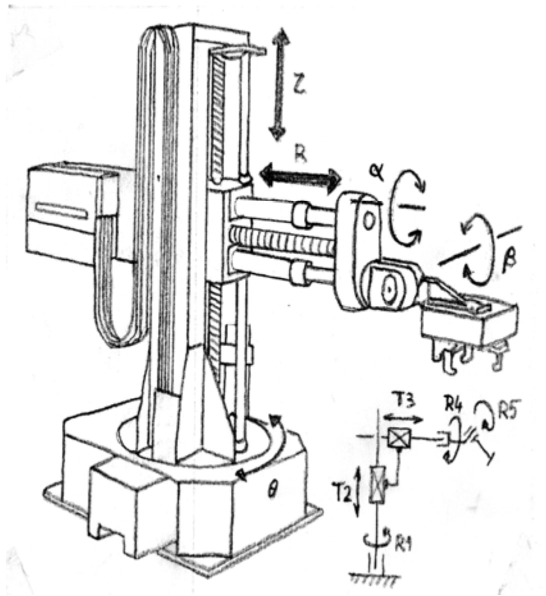

Fig. 9. The kinematical scheme of the Robot

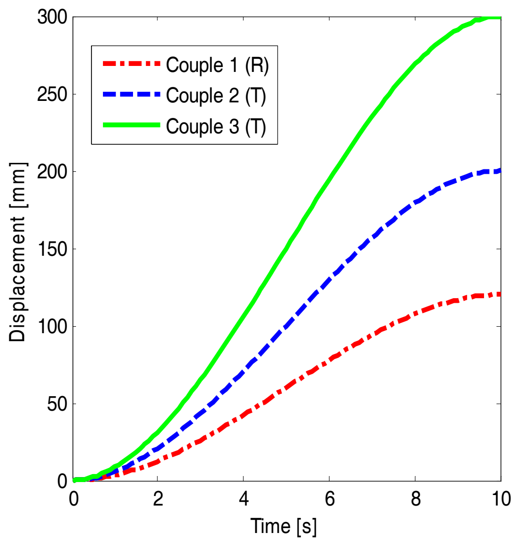

Fig. 10. The displacement of RTT Robot (first method)

In figure 10 one represents the displacement versus time. The displacement from couple 1 is smaller then those from couple 3. One can observe that the figure 3 and 10 are similar, but only the first degree of freedom (basis rotation of RTT Robot) is a little bit different, comparing with TTT Robot [15], [16].

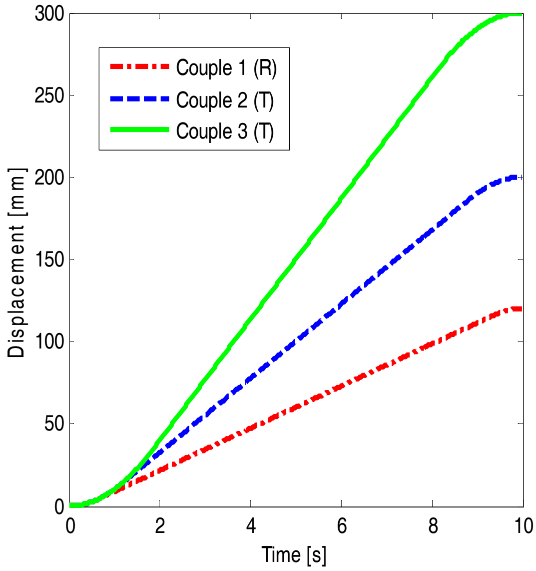

Fig. 11. The displacement of RTT Robot (second method)

In figure 11 one represents the displacement versus time, also. The displacement from couple 1 is smaller then those from couple 3, like above, but one can observe some differences at the start and to the end of the whole displacement.

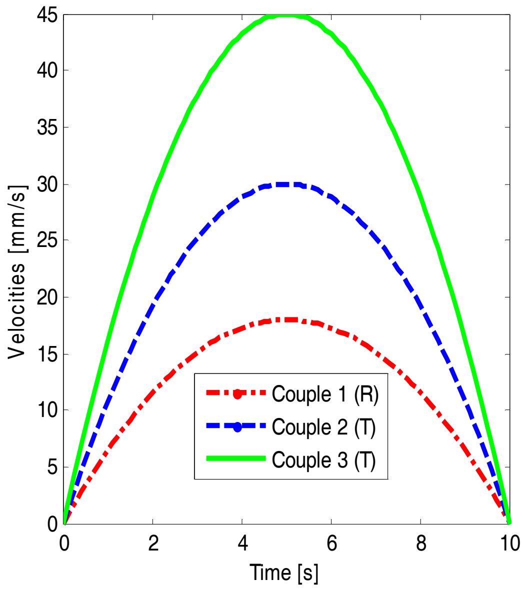

Fig. 12. The velocity of RTT Robot (first method)

In figure 12 and 13 one has the velocities versus time. The speed from couple 1 is smaller then couple 2 and 3.
The graphical differences between those two methods are more evident like above, when one used the displacements.

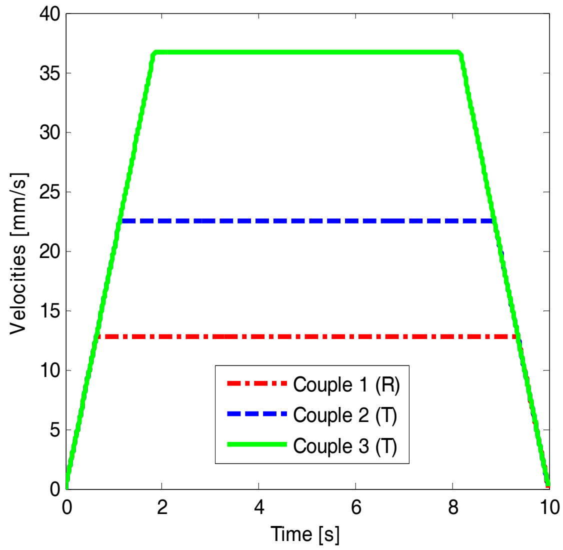

Fig. 13. The velocity of RTT Robot (second method)

One can observe that the speeds represented in the second method have a large constant level stagnation, between the two and eight seconds.

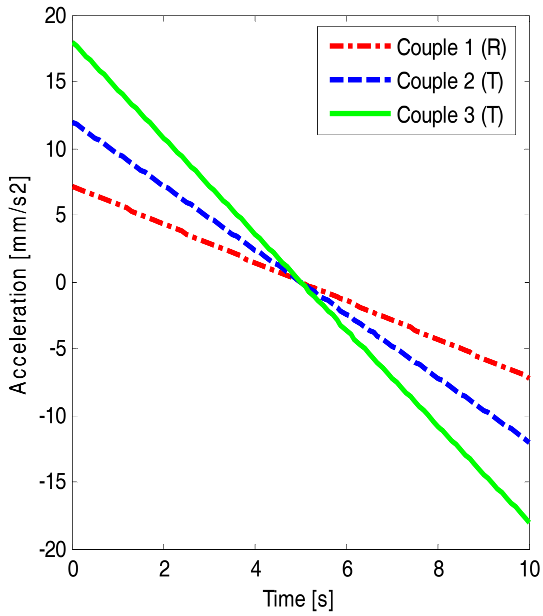

Fig. 14. The acceleration of RTT Robot (first method)

In figure 14 and 15 one has the accelerations versus time. The acceleration has a decreasing trend, noting that, in the second method, one obtains a constant plateau during zero level.

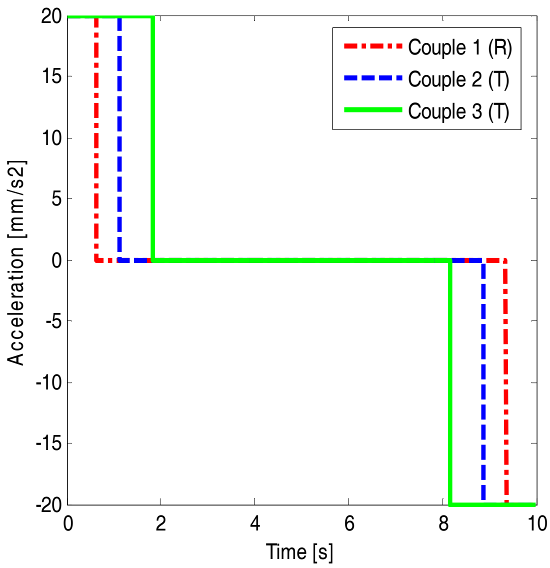

Fig. 15. The acceleration of RTT Robot (second method)

Also, like above, using the TTT robot type, after the graphic representation one obtains that both actions, the accelerations and breakings, are different from one couple to another, because the lengths of paths, which is moving, are different. The movement is performed simultaneously on all three directions.

4 Conclusion

Starting from column industrial robot architecture we try to find a modeling and simulation procedure for the designing of some Industrial Robots.

This paper presents a modern and quick method to design of some modules of an Industrial Robot type. It established a mathematical procedure to project of the Robot.

After the graphic representation one obtains that both actions, the accelerations and breakings, are different from one couple to another, because the lengths of paths, which is moving, are different. The movement is performed simultaneously on all three directions.

In conclusion, one recorded the maximum values at the couples that make big displacements, so the engines who lead the couples are very loaded.

For future research will try to develop other methods studying robots with different degree of freedom and maybe one try to implement a mathematical study for an industrial robot with six degree of movements.

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