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THE GRAPHICAL SIMULATION OF TRR SMALL-SIZED ROBOT

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Abstract: *the paper presents the graphical simulation of the TRR small-sized robot, using SimMecRob. Starting from the definition of the initial data, concerning the robot's geometry and from a set of configurations specific to the technological process, which must be reached at certain time moments, the set of the configurations are graphically represented as kinematic sketches, both individually and in a combined form. The time variations of the operational coordinates, velocities and accelerations are then plotted, for three variants of the technological process. Using a program written in MathCAD, the time variation of the Cartesian coordinates of the end-effecter's characteristic point is presented in the second part of the paper, representing the trajectory of the characteristic point, in the Cartesian space.*
Key words: *TRR robot, graphical simulation, MathCAD, SimMecRob, trajectory.*

1. INTRODUCTION

The mechanical structure of TRR small-sized robot, having three degrees of freedom, was analyzed from the point of view of geometric, kinematic and dynamic modeling in [1], [2], [3] and in [4] the numerical simulation was also performed, yielding the geometric, kinematic and dynamic parameters for a given task, as well as the dynamic functions, as provided by *SimMecRob* [5]. Using its graphical capabilities that allow the robot structure visualization both individually and in a combined form (using the command *Cfg-Des*) and by using the options *Calc-PG* and *Calc-DH*, the frame type attached to the mechanical structure can be specified.

2. GRAPHICAL RESULTS

The following figures (fig. 1-4) show the TRR small-sized robot into the four distinct configurations, as specified in [4], having PG-type frames attached. The simultaneous (combined) representation of the five configurations (including the zero configuration), is presented in fig. 5. The first part of SimMecRb simulation ends with the graphical representation of geometric, kinematic and dynamic parameters variation.

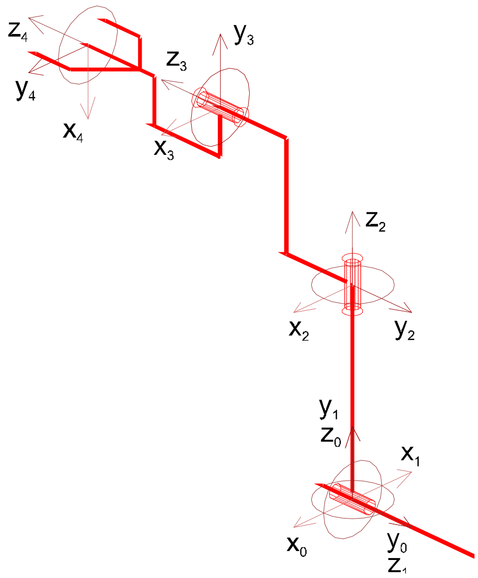

Fig. 1 TRR small-sized robot, 1st configuration

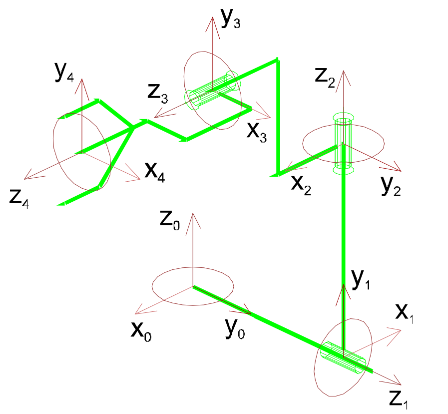

Fig. 2 TRR small-sized robot, 2nd configuration

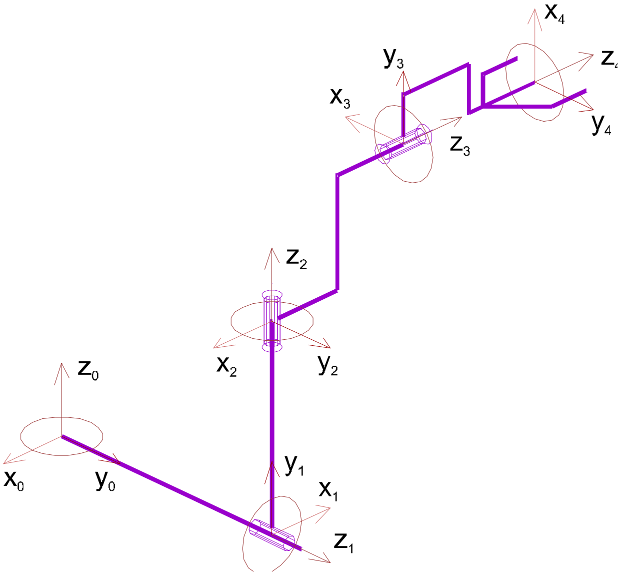

Fig. 3 TRR small-sized robot, 3rd configuration

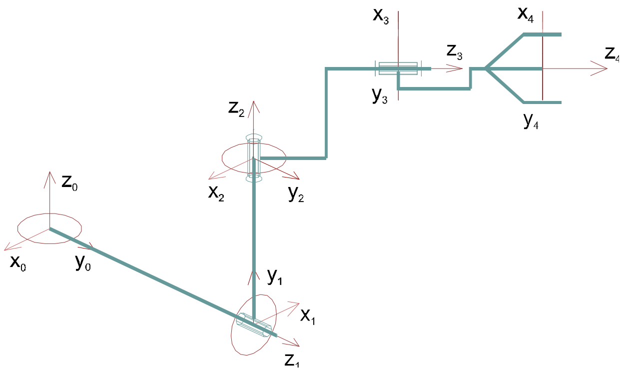

Fig. 4 TRR small-sized robot, 4th configuration

Figure 6 shows the position and orientation changes of the end-effecter with respect to time, figure 7 presents the variation of linear and angular velocities, and figure 8 identifies the time variation of the linear and angular accelerations of the gripper.

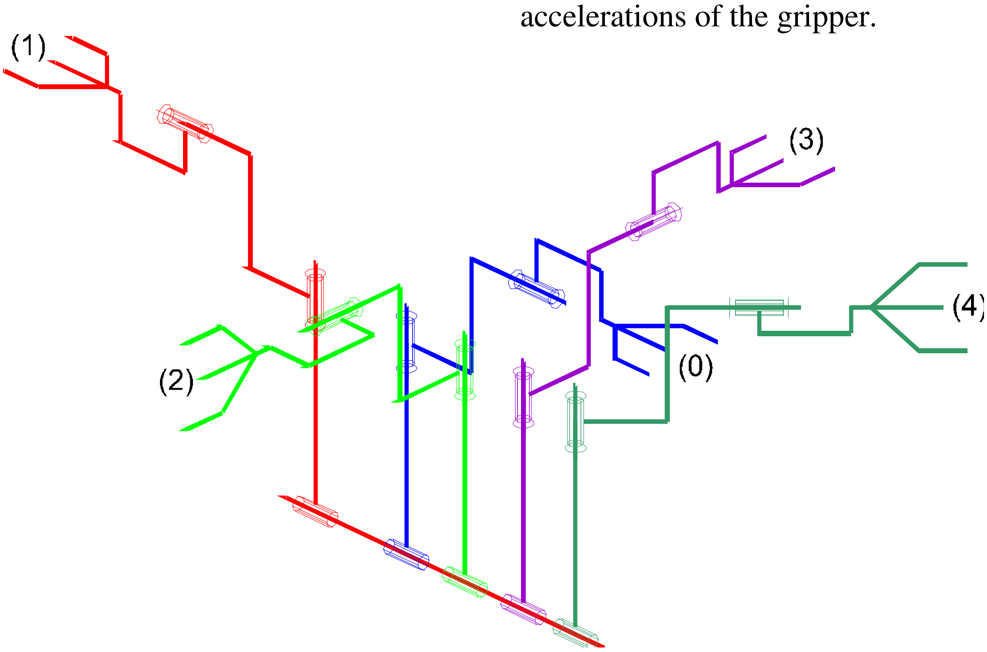

Fig. 5 TRR small-sized robot, configurations 0-4

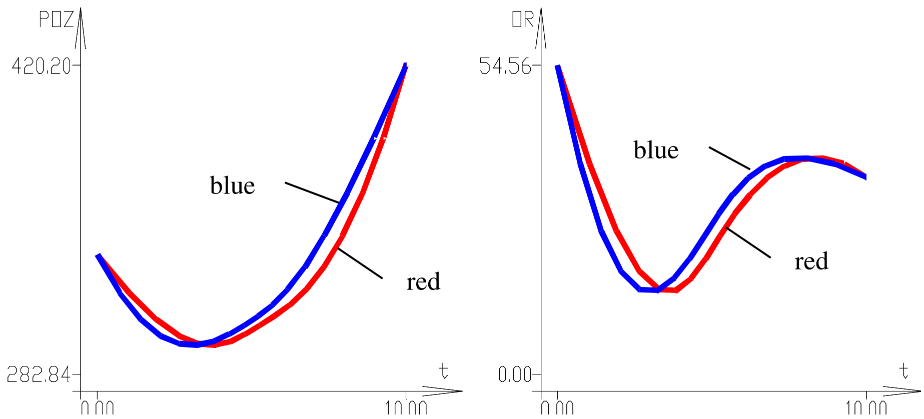

Fig. 6 Time variation of the end-effecter's position and orientation

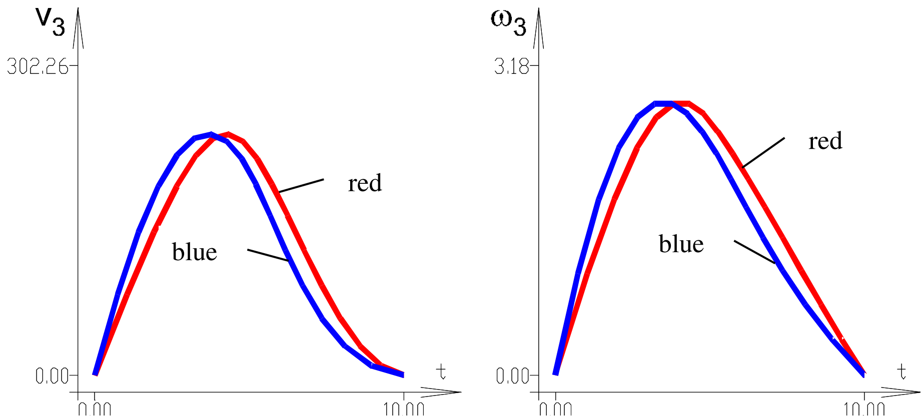

Fig. 7 Time variation of the end-effecter's linear and angular velocities

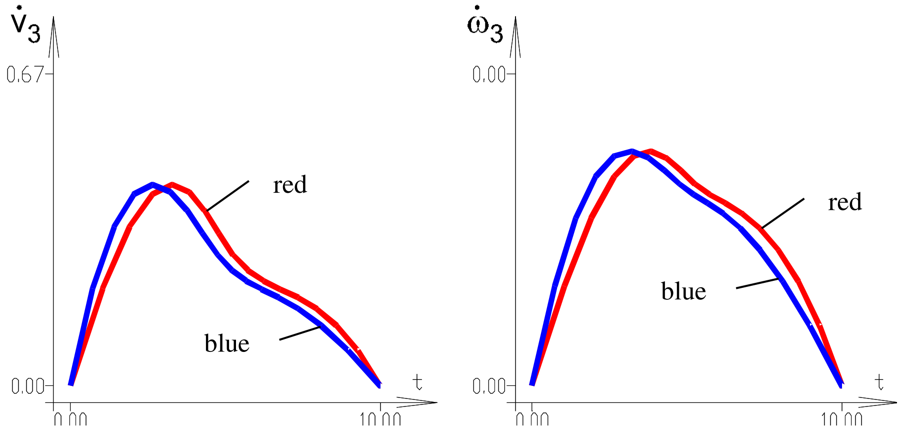

Fig. 8 Time variation of the end-effecter's linear and angular accelerations

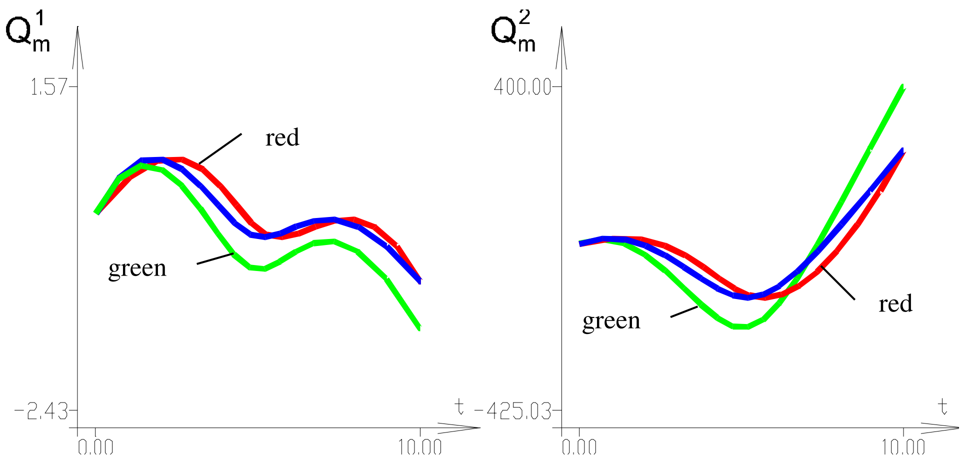

Fig. 9 Time variation of the generalized driving forces Q_m^1 and Q_m^2 (force F_1 and moment M_2)

Figures 9 and 10 represent the time variation of the generalized driving forces Q_m^1, Q_m^2 and Q_m^3. In order to do a comparison of the robot behavior into different task conditions, two different loading cases of the TRR small-sized robot were considered.

In the first case, keeping the same configurations and the same payload, the time corresponding to the middle configurations 1 and 3 was modified, according to the table 1. As a consequence, a delay of the local extrema of the functions describing the kinematic and dynamic parameters is noticed (fig. 6-10, the red curves).

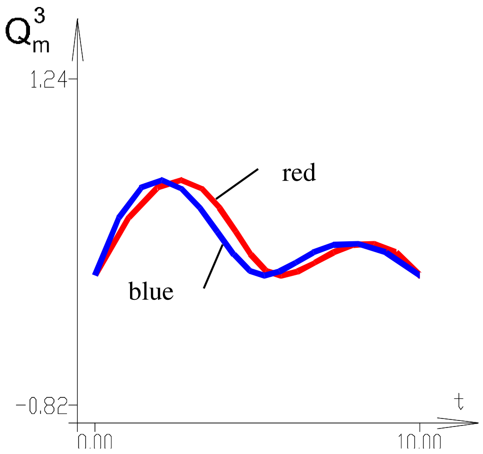

Fig. 10 Time variation of the generalized driving force Q_m^3 (moment M_3)

In the second case, while keeping the same configurations and time moments, the payload was modified, according to the table 2. An exact superposition of the plot of the kinematic parameters over those representing the initial loading case is noticed (the blue curves). The fact is explained, because the configuration time moments are unchanged, but the modification of the payload influences the generalized driving forces Q_m^1 and Q_m^2 (the green curves from fig. 9).

Table 1

The time of successive configurations, variant TRR-a

τ_p <s>, p=$\overline{0,4}$	0	3	5	8	10

Table 2

The payload, variant TRR-b

Reference frame	${}^4\bar{f}_4$			${}^4\bar{n}_4$		
	<N>			<N·m>		
DH	0,000	-2,000	0,000	0,000	0,000	0,000
PG	-2,000	0,000	0,000	0,000	0,000	0,000

3. THE PATH OF THE CHARACTERISTIC POINT OF THE GRIPPER

Based on the equations of the direct geometric model of TRR small-sized robot, determined in [2], having the set of configurations specified in [4], the visualization of the gripper's characteristic point is possible, with the help of a program written in MathCAD. Each variation interval of the generalized coordinates was split into 100 points, for each of them the operational coordinates were computed and by the union of these values the graph of the planar path is obtained, the *z*-coordinate being a constant.

The gripper's characteristic point position is described by the vector equation:

$$\bar{p}_4 = \begin{bmatrix} -(l_3 + l_4)sq_2 \\ l_0 + q_1 + (l_3 + l_4)cq_2 \\ l_1 + l_2 \end{bmatrix}. \qquad (1)$$

The MathCAD program is described in Program 1.

The graph of the path is presented in fig. 11, each path segment being depicted with different line properties.

4. CONCLUSIONS

The obtained graphs, along with the numerical data obtained and presented in [4] are useful in the study of the behavior of the TRR small-sized robot, ensuring the parameters of the technological process the robot is implemented in.

Program 1. MathCAD program for tracing the robot path for the given task

$l0 := 70$ $l1 := 130$ $l2 := 70$ $l3 := 100$ $l4 := 100$	- geometric elements
$i := 0..\ 100$	- discretization step
$q1_i := -0.7 \cdot i$ $q2_i := -1.8 \cdot i \cdot deg$ $px1_i := -(l3 + l4) \cdot \sin(q2_i)$ $py1_i := l0 + q1_i + (l3 + l4) \cdot \cos(q2_i)$	- first path segment
$q1_i := -70 + 1.15 \cdot i$ $q2_i := (-180 + 0.9 \cdot i) \cdot deg$ $px2_i := -(l3 + l4) \cdot \sin(q2_i)$ $py2_i := l0 + q1_i + (l3 + l4) \cdot \cos(q2_i)$	- second path segment
$q1_i := 45 + 0.45 \cdot i$ $q2_i := (-90 + 1.8 \cdot i) \cdot deg$ $px3_i := -(l3 + l4) \cdot \sin(q2_i)$ $py3_i := l0 + q1_i + (l3 + l4) \cdot \cos(q2_i)$	- third path segment
$q1_i := 90 + 0.4 \cdot i$ $q2_i := (90 + 0.45 \cdot i) \cdot deg$ $px4_i := -(l3 + l4) \cdot \sin(q2_i)$ $py4_i := l0 + q1_i + (l3 + l4) \cdot \cos(q2_i)$	- fourth path segment

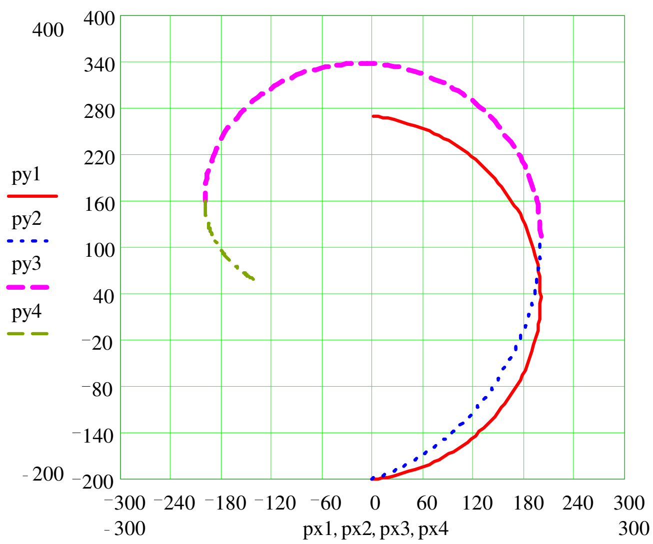

Fig. 11 The path representation of the TRR gripper's characteristic point for the given task

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Simularea grafică a minirobotului TRR

Rezumat: Lucrarea prezintă un model de simulare grafică a minirobotului de tip TRR, utilizând programul SimMecRob. Pornind de la definirea datelor iniţiale, referitoare la geometria robotului şi de la un set de configuraţii specifice procesului tehnologic, care trebuie atinse la anumite momente de timp, configurațiile specifice date prin valori numerice sunt reprezentate grafic sub formă de scheme cinematice, atât individual, cât și într-o formă combinată. Mai apoi sunt reprezentate grafic funcțiile de variație în raport cu timpul a coordonatelor, vitezelor și accelerațiilor operaționale,pentru trei variante ale procesului tehnologic. Folosind un program scris în MathCAD, este prezentată în partea a doua a lucrării legea de variație a coordonatelor carteziene ale punctului caracteristic al efectorului final, reprezentând traiectoria punctului caracteristic, în spațiul cartezian.

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