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Experimental Determinations on Kinematics of a Translational Joint of an Industrial Robot

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The paper presents a 6-DOF industrial robot and the driving system of its base translational joint. By imposing certain positions of the translational joint and determining the durations in which these positions are reached, average speed is computed. The paper shows how the clearances influence the average speed, depending on the displacement value.

Keywords: *robot kinematics, position control, average speed*

1. Introduction

Nowadays, robots are often used in industrial applications [2], [3]. High speed, accuracy and repeatability are performances requested in most of the cases [9], [10], [13].

The clearances between the mechanical transmissions links influence the motion kinematical parameters, thus the position-orientation matrix of the robot's characteristic point being different than is expected.

The paper presents experimental determinations on the base translational joint of a 6-DOF industrial robot used in educational purpose.

2. The 6-DOF Industrial Robot

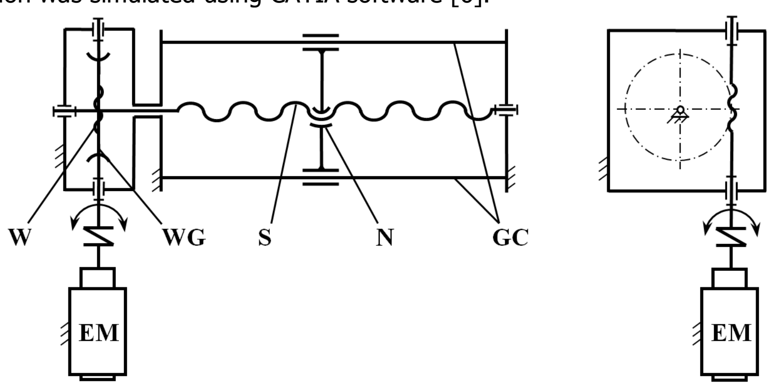
The 6-DOF industrial robot is presented in fig. 1 [7], [8], [11], [12]. The guiding device mechanism has a serial topology, meaning that the links form an open chain. Denoting by "T" the translational joints and by "R" the revolute joints, the structure is, starting from the base to the end-effector, TRTTRR.

The robot presents 3 different types of driving systems: electric (for the base translation, column rotation, arm vertical translation and 2 rotations of the prehension device), hydraulic (the arm horizontal translation) and electromagnetic (to the prehension device). A variant of prehension device, driven by shape memory alloys (SMA) elements [1], [4], was also accomplished.

Figure 1. The 6-DOF industrial robot [7], [8], [11], [12]

3. The Base Translational Joint

The robot's base translational motion is obtained as follows: the electric motor (EM) transmits the rotational motion to the *worm – worm gear* transmission (W – WG), which forwards it to the *screw – nut* transmission (S – N), as shown in fig. 2. The nut is solidarized to the robot's body, which leans on the guiding columns (GC). These mechanical transmissions were geometrically modeled [5] and the operation was simulated using CATIA software [6].



a) Top view b) Side view

Figure 2. Kinematical scheme of the base mechanical transmissions [8]

In order to stop the translational joint in certain positions, tactile sensors of limit switches type were mounted on the horizontal guiding columns (fig. 3). Thus, in the moment when the limit switch button is pressed, the motion stops.

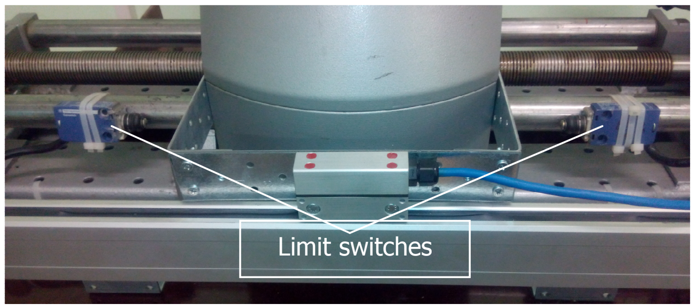


Figure 3. Limit switches mounted on the horizontal guiding columns [8]

4. Experimental Determinations

The following steps were performed:

- 10 distances to be accomplished by the translational joint were established, from 5 [mm] to 50 [mm], with a successive increasing of 5 [mm];
- the time periods of joint motion necessary to cover every distance were determined, from the moment of starting the driving, until the joint stops;
- using the expression (1), the translational joint average speed was computed.

$$v_{med} = \frac{\Delta x}{\Delta t}. \qquad (1)$$

The results are presented in table 1.

Table 1.

Crt. no.	Position x [mm]	Time t [s]	Average speed v_{med} [mm/s]
1.	5	4,4	1,14
2.	10	6,7	1,49
3.	15	9,6	1,56
4.	20	12,3	1,63
5.	25	15,0	1,67
6.	30	17,8	1,69
7.	35	20,5	1,71
8.	40	23,3	1,72
9.	45	26,2	1,72
10.	50	29,1	1,72

The joint displacement, depending on time, is presented in fig. 4 and the joint average speed, depending on the distance accomplished, is shown in fig. 5.

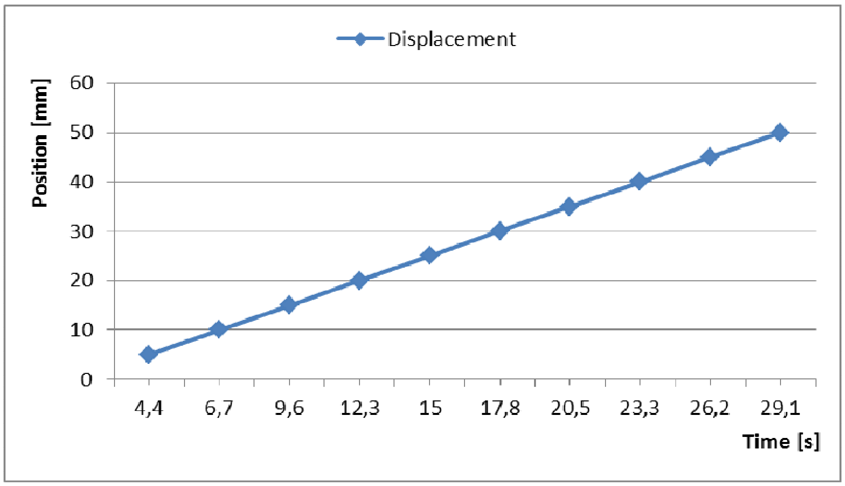


Figure 4. Translational joint displacement depending on time

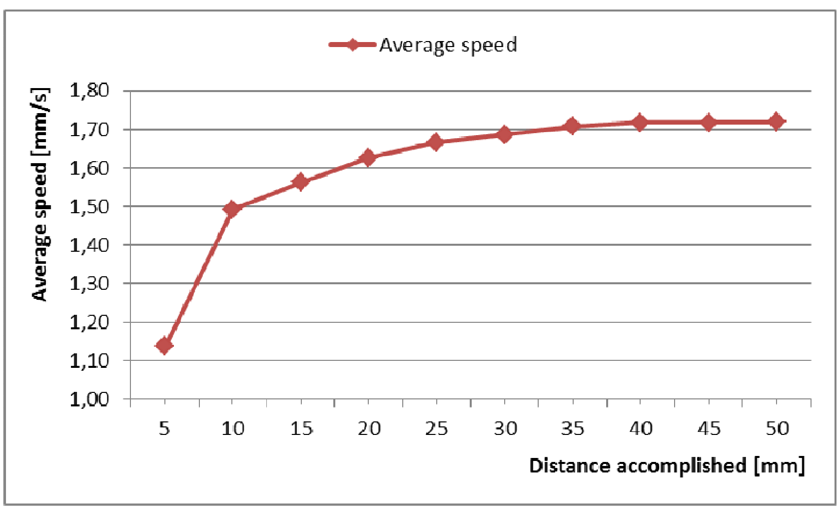


Figure 5. Translational joint average speed, depending on distance accomplished

5. Conclusions

As seen in chapter 4, the joint average speed is not constant.

It could be affirmed that 2 factors determine this variation of average speed value:

- the clearances between the links of *worm – worm gear* and *screw – nut* mechanical transmissions;
- the acceleration from the beginning and the deceleration from the end of the motion.

As seen table 1 and in fig. 5, starting from the current number 8 and from the distance accomplished of 40 [mm] respectively, the average speed value is constant, so the influence of these 2 factors could be neglected.

The system can be improved if the exact moment of motion beginning is determined by using a tactile sensor for starting the time counter.

As future research, the influence of clearances between the links of mechanical transmissions in the case of reversing the motion sense can be studied.

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