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The Numerical Simulation of Torque with Parameters of Speed & Angular Speed Acceleration in Five Freedoms of Robotic Arm III

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Abstract

There is big distance to attain 12KNm between the difference speeds of conditions v=0.5~2.5m/s at angle ω=45º/s. When the ω increases the torque will become big, meantime the speed v increases the torque is big too. The biggest one is 18KNm with above condition at acceleration $\dot{\omega}$= 20º/s^2. It means that the decreased acceleration will increase the torque. The least one is happened on ω=25º/s. there is little change between acceleration $\dot{\omega}$= 20º/s^2 and 25º/s^2. There is a trend the former is a little larger than the later. The effective turn is v>ω>ω.

Keywords: Numerical simulation; Torque; Angular speed; Acceleration; Five freedoms; Robotic arm

Introduction

The robotic arm as a new mechanism has been wielded in factory for semi conduction etc. transportation and integration circuit wielding. The auto and artificial intelligence robotic arm is developed from experimental lab to factory to launch producing. Therefore grasp the robotic arm kinematic and dynamic will become urgent and necessary in modern society. As a multiple system Lagrange equation may be solved its dynamics which is a method currently [1-3]. Due to its precision demand in process the position defining is very important especially to precise part making. Through defining a route it may be defined a displacement and then the velocity and acceleration may be defined through the equation besides the force and torque forces. For our checking strength and making size the dynamical forces may be used to it. Such as the motor size and arm shape and size will be checked out to design it. So in this study the dynamic forces may be calculated through Lagrange equation according to kinematic constant to check the feasibility on force to function [4-6]. In this study the destination is that investigating the torque and speed & angular speed & angular acceleration. To separate three independence parts the velocity and acceleration will be calculated through displacement and force may be computed meantime with Lagrange equation separately. So each resolved resolution may be checked through comparing with others and literature. This is the destination in this paper to arouse the further research.

In short, to increase the data base and look for the best conditions in motor choosing and robotic arm strength calculation efficiently the effect of robotic arm forces on angular speed and constant acceleration has been searched for a certain constant in this study. In this paper the three and five freedoms system is adopted to look for the differences between them to compute with numerical simulation.

Numerical Simulation

In Figure 1 there are three freedoms in mechanical arm that name as 1~3. Meantime there are two other ones call 4&5which is included in five freedoms as a rotational and crawling function. In Figure 1 the schematic shows the simplified principle of robot. The coordinate XAY is three freedoms and X′A′Y it five freedoms. In this study the five freedoms not three one is deduced since it is complicated (Figure 1,2).

The system kinetic energy is [1, 3]

$$E_k = \frac{1}{2}\sum_{i}^{n}(m_1 v_1^2 + m_2 v_2^2 + m_3 v_3^2) \qquad (1)$$

Here m_i : mass of i component ; J_{si} : rotary inertia of i component relative to center of mass; v_s : center of mass in i component; ω_i : angular velocity in i component; v_1, v_2 and v_3 is 1、2 and 3 velocities respectively.

$$v_D = \sqrt{\dot{X}_D^2 + \dot{Y}_D^2} \qquad (2)$$

From Figure 2 it is known that position coordinate below

$$\begin{cases} X_D = \vec{l}_1 \sin\vartheta_1 + \vec{l}_2 \sin(\theta_1+\theta_2) + \vec{l}_3 \sin(\theta_1+\theta_3+\theta_3) \\ Y_D = (\vec{l}_1+\vec{l}_4)\cos\theta_1 + (\vec{l}_2+\vec{l}_4)\cos(\theta_1+\theta_2) + (\vec{l}_3+\vec{l}_4)\cos(\theta_1+\theta_2+\theta_3) \end{cases} \qquad (3)$$

Derivating the equations we gain the $\dot{X}_c, \dot{Y}_c$ and $\dot{X}_3$ velocity in hand， $\dot{\theta}_1, \dot{\theta}_2$ and $\dot{\theta}_3$ one in joints. Suppose that the acceleration is $\ddot{\theta}_1$, $\ddot{\theta}_2$ and $\ddot{\theta}_3$ and the angular acceleration is $\ddot{\omega}_1, \ddot{\omega}_2$ and $\ddot{\omega}_3$ in joints.

$$\begin{cases} \dot{X}_D = \dot{\theta}_1 \vec{l}_1 \cos\theta_1 + (\dot{\theta}_1+\dot{\theta}_2)\vec{l}_2 \cos(\theta_1+\theta_2) + (\dot{\theta}_1+\dot{\theta}_2+\dot{\theta}_3)\vec{l}_3 \cos(\theta_1+\theta_2+\theta_3) \\ \dot{Y}_D = \dot{\theta}_1(\vec{l}_1+\vec{l}_4)\ \sin\theta_1 + (\dot{\theta}_1+\dot{\theta}_2)(\vec{l}_2+\vec{l}_4)\sin(\theta_1+\theta_2) + (\dot{\theta}_1+\dot{\theta}_2+\dot{\theta}_3)(\vec{l}_3+\vec{l}_4)\sin(\theta_1+\theta_2+\theta_3) \end{cases} \qquad (4)$$

v_B, v_C and v_D is B、C and D velocities respectively. So D point velocity is

$$v_D = \sqrt{\dot{X}_D^2 + \dot{Y}_D^2} = \sqrt{\begin{aligned} & l_1^2\theta_1^2 + l_2^2(\overset{*}{\theta}_1+\overset{*}{\theta}_2)^2 + l_3^2(\overset{*}{\theta}_1+\overset{*}{\theta}_2+\overset{*}{\theta}_3)^2 + \overset{*}{\theta}_1 l_4^2 \sin^2\theta_1^2 + l_4^2(\overset{*}{\theta}_1+\overset{*}{\theta}_2)^2 \sin^2(\theta_1+\theta_2) \\ & + l_4^2(\overset{*}{\theta}_1+\overset{*}{\theta}_2+\overset{*}{\theta}_3)^2 l_4 \sin^2(\theta_1+\theta_2+\theta_3) + 2l_1 l_3 \dot{\theta}_1(\overset{*}{\theta}_1+\overset{*}{\theta}_2+\overset{*}{\theta}_3)\cos(\theta_1+\theta_3) + \\ & 2l_2 l_3(\overset{*}{\theta}_1+\overset{*}{\theta}_2)(\overset{*}{\theta}_1+\overset{*}{\theta}_2+\overset{*}{\theta}_3)\cos\theta_3 + 2l_1 l_4 \dot{\theta}_1 \sin\theta_1 + 2l_2 l_4(\overset{*}{\theta}_1+\overset{*}{\theta}_2)\sin(\theta_1+\theta_2) \\ & + 2l_3 l_4(\overset{*}{\theta}_1+\overset{*}{\theta}_2+\overset{*}{\theta}_3)\sin(\theta_1+\theta_2+\theta_3) \end{aligned}} \qquad (5)$$

C point velocity is

$$v_C = \sqrt{\dot{X}_C^2 + \dot{Y}_C^2} = \sqrt{l_1^2\theta_1^2 + l_2^2(\overset{*}{\theta}_1+\overset{*}{\theta}_2)^2 - 2l_1 l_2 \dot{\theta}_1(\overset{*}{\theta}_1+\overset{*}{\theta}_2)\cos\theta_2} \qquad (6)$$

$$v_B = \vec{l}_1 \dot{\theta}_1 \qquad (7)$$

Substituting two equations above to equation （1）has below

$$\frac{\partial E_K}{\partial \theta_1}=\vec{l}_1(\vec{l}_1+\vec{l}_4+\vec{l}_5)(m_1+m_2+m_3)\theta_1+\vec{l}_2(\vec{l}_3+\vec{l}_4+\vec{l}_5)\ m_2(\theta_1+\theta_2)+\vec{l}_3(\vec{l}_3+\vec{l}_4+\vec{l}_5)\ m_3(\theta_1+\theta_2+\theta_3)$$
$$+2\vec{l}_4 m_3\dot{\theta}_1(\dot{\theta}_1+\dot{\theta}_2)^2\sin(\theta_1+\theta_2)-2\vec{l}_4 m_3\dot{\theta}_1(\dot{\theta}_1+\dot{\theta}_2+\dot{\theta}_3)^2\sin(\theta_1+\theta_2+\theta_3)-\vec{l}_1\vec{l}_2 m_2\dot{\theta}_1(\dot{\theta}_1+\dot{\theta}_2+\dot{\theta}_3)\sin$$
$$(\theta_1+\theta_2)+(\vec{l}_4+\vec{l}_5)(m_2+m_2+m_3)\theta_1+(\vec{l}_4+\vec{l}_5)m_2(\theta_1+\theta_2)+2\vec{l}_1\vec{l}_4 m_3(\dot{\theta}_1+\dot{\theta}_2)\cos(\theta_1+\theta_2)+2\vec{l}_1\vec{l}_4 m_3$$
$$(\dot{\theta}_1+\dot{\theta}_2+\dot{\theta}_3)\cos(\theta_1+\theta_2) \tag{8}$$

$$\frac{\partial E_K}{\partial \theta_2}=\vec{l}_2(\vec{l}_2+\vec{l}_4+\vec{l}_5)\ m_2(\theta_1+\theta_2)+\vec{l}_3(\vec{l}_3+\vec{l}_4+\vec{l}_5)\ m_3(\theta_1+\theta_2+\theta_3)+4\vec{l}_4 m_3\dot{\theta}_1\sin\theta_2+2\vec{l}_4 m_3\dot{\theta}_1(\dot{\theta}_1+\dot{\theta}_2)^2\sin$$
$$(\theta_1+\theta_2)+2\vec{l}_4 m_3\dot{\theta}_1(\dot{\theta}_1+\dot{\theta}_2+\dot{\theta}_3)^2\sin(\theta_1+\theta_2+\theta_3)-2\vec{l}_1\vec{l}_2 m_3\dot{\theta}_1(\dot{\theta}_1+\dot{\theta}_2)\sin\theta_2-2\vec{l}_1\vec{l}_2 m_3\dot{\theta}_1(\dot{\theta}_1+\dot{\theta}_2)\sin\theta_2-(\vec{l}_4$$
$$+\vec{l}_5)m_3\dot{\theta}_1(\theta_1+\theta_2)+2\vec{l}_1\vec{l}_4 m_3\dot{\theta}_1(\dot{\theta}_1+\dot{\theta}_2+\dot{\theta}_3)\cos(\theta_1+\theta_2)-(\vec{l}_4+\vec{l}_5)m_3\dot{\theta}_1(\theta_1+\theta_2)+2\vec{l}_1\vec{l}_4 m_3\dot{\theta}_1\cos(\theta_1+\theta_2)+$$
$$2\vec{l}_3\vec{l}_4 m_3(\dot{\theta}_1+\dot{\theta}_1+\dot{\theta}_2)\cos(\theta_1+\theta_2+\theta_3) \tag{9}$$

$$\frac{\partial E_K}{\partial \theta_3}=\vec{l}_3(\vec{l}_3+\vec{l}_4+\vec{l}_5)(\theta_1+\theta_2+\theta_3)-2\vec{l}_4 m_3(\dot{\theta}_1+\dot{\theta}_2+\dot{\theta}_3)^2 sin(\theta_1+\theta_2+\theta_3)-\vec{l}_2\vec{l}_3 m_3(\dot{\theta}_1+\dot{\theta}_2)$$
$$(\dot{\theta}_1+\dot{\theta}_2+\dot{\theta}_3)\ sin\theta_3-2\vec{l}_3\vec{l}_4 m_3(\dot{\theta}_1+\dot{\theta}_2+\dot{\theta}_3)\cos(\theta_1+\theta_2+\theta_3) \tag{10}$$

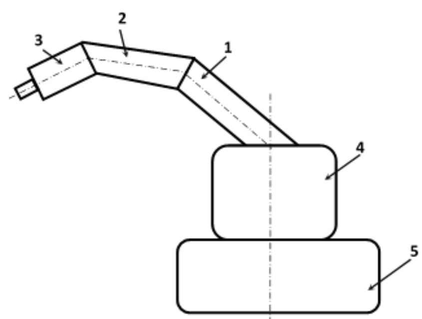


Figure 1: *Construction schematic of mechanical arm in series in robot, 3-hand part; 2-wrist part; 1-arm part; 4-waist part; 5-two crawling wheel.*

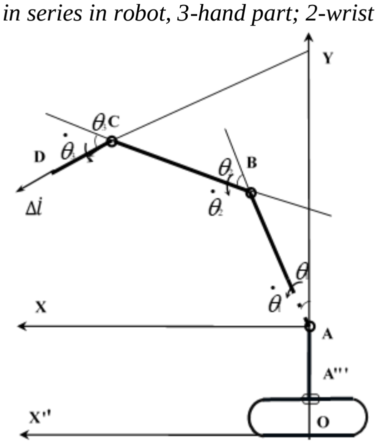
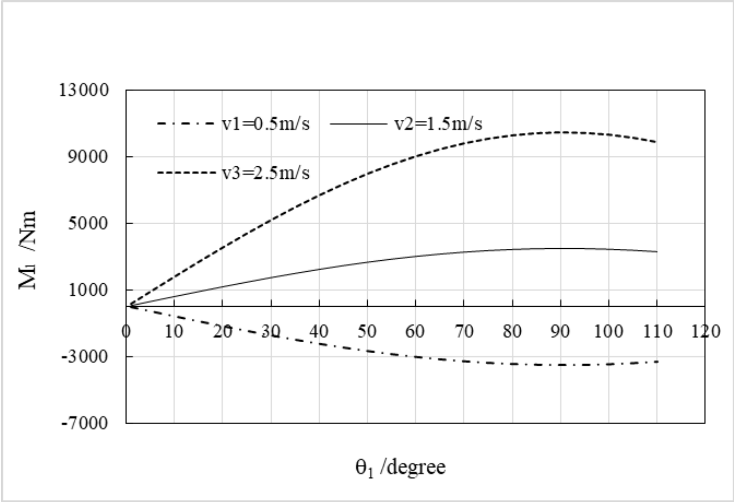
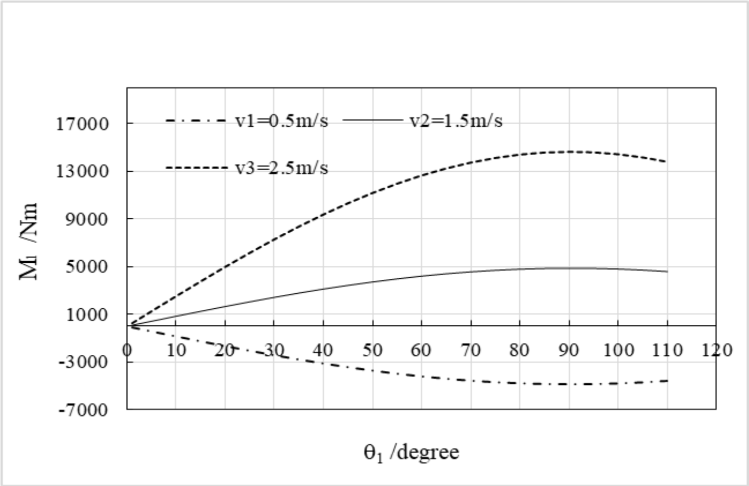


Figure 2: *Principle schematic of mechanical arm in series in robot.*

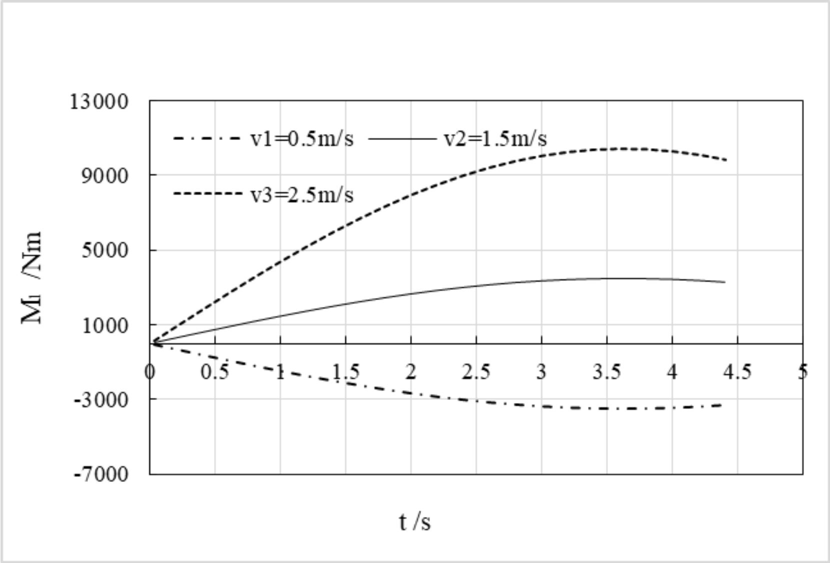


(a) ω=25°/s.

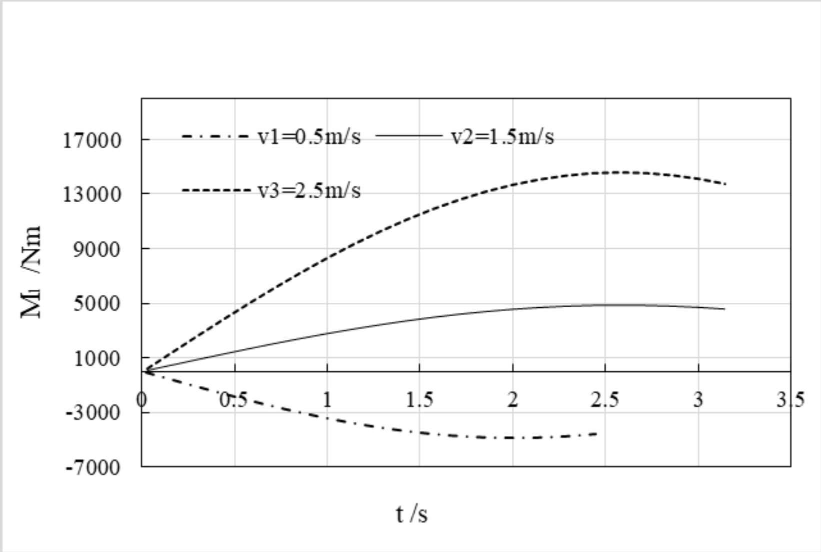


(b) ω=35°/s.

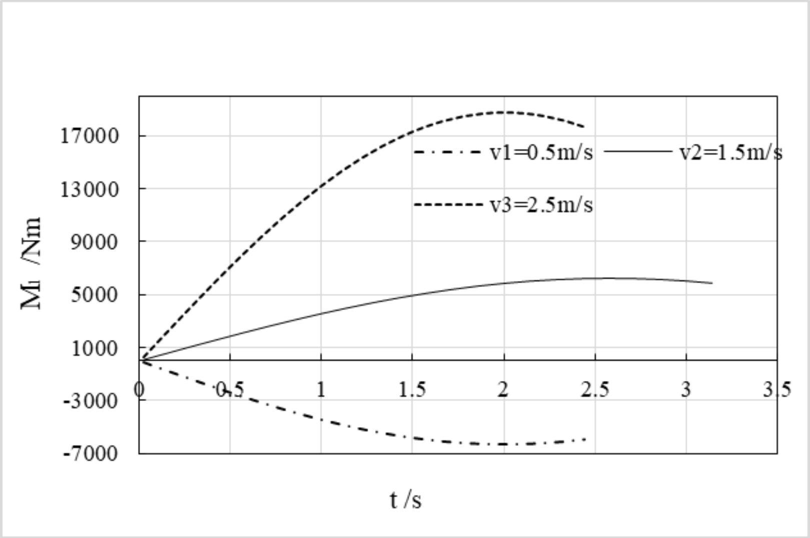
Figure 3: *The torque with time and speed v under angular speed ω and acceleration $\dot{\omega}$ of 25°/s².*



(c) ω=25°/s.



(d) ω=35º/s.



(e) ω=45º/s.

Figure 4: *The torque with time and speed v under angular speed ω and acceleration $\dot{\omega}$ of 20º/s².*

Discussions

It is suggested that the big arm torque from Figure 3 happens when terminal speed & rotary angle and angular acceleration is bigger and smaller respectively. So that the reasonable parameters are chosen to design and evaluate their properties is important. Not to choose big terminal speed and acceleration is key in order to increase the capability and property that may increase the whole cost as well. The biggest one arrives 10,000Nm at speed 2.5m/s and angel 90º under ω=25º/s meanwhile it is 14,000Nm at the same conditions as above under ω=35º/s and $\dot{\omega}$ =25º/s² (Figure 3,4).

It is suggested that the big arm torque from Figure 4 happens when terminal speed & rotary angle and angular acceleration is bigger and smaller respectively. So that the reasonable parameters are chosen to design and evaluate their properties is important. Not to choose big terminal speed and acceleration is key in order to increase the capability and property that may increase the whole cost as well. The biggest one arrives 19,000Nm at speed 2.5m/s and angel 90º under ω=45º/s meanwhile it is 1,000Nm at the same conditions as above under ω=25º/s and $\dot{\omega}$ =20º/s2. There is not big difference between above two angular acceleration with 25º/s and 20º/s. This expresses that the big difference causes big different torque in robotic arm 1. Overview the computation solution is tedious to use in software like Excel and Origin since it has many small equations. The result is satisfactory and precise to be adopted to numerical simulation so the five freedoms method based on three freedoms is feasible. In Figure 3~4 with increasing terminal speed the torque may be increased and with angular speed becoming big the torque may be increased. The biggest torque is 14KNm and 19KNm when angular speed is 35º/s and 45 º/s respectively. This one needs to be checked the strength correction when the speed is 2.5m/s. The ω1~3 is supposed to be same with ω and angular acceleration $\dot{\omega}$ of 25º/s2 in Figure 3~4 in addition. The effective turn is v>ω>$\dot{\omega}$.

Conclusions

There is big distance to attain 12KNm between the difference speeds of conditions v=0.5~2.5m/s at angle ω=45º/s. When the ω increases the torque will become big, meantime the speed v increases the torque is big too. The biggest one is 18KNm with above condition at acceleration $\dot{\omega}$= 20º/s^2. It means that the decreased acceleration will increase the torque. The least one with 1KNm is happened on ω=25º/s. there is little change between acceleration $\dot{\omega}$= 20º/s^2 and 25º/s^2. There is a trend the former is a little larger than the later.

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