SunText Review of Material Science
ISSN: 2766-5100
Open Access
Research Article
Volume 3:1

The Numerical Simulation of Force with Parameters of Angular Speed & Constant Angular Acceleration in Three and Five Freedoms of Robotic Arm II

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Received date: 25 January 2022; **Accepted date:** 27 January 2022; **Published date:** 30 January 2022

Citation: Run Xu, Kim Y (2022). The Numerical Simulation of Force with Parameters of Angular Speed & Constant Angular Acceleration in Three and Five Freedoms of Robotic Arm II. SunText Rev Mat Sci 3(1): 118.

DOI: https://doi.org/10.51737/2766-5100.2022.018

Abstract

There is big distance to attain 7KN between the conditions. The effective factor turn to the force is F1>F3>F2 in three freedoms with the angular speed of 10º~30º/s and of acceleration of 10º/s2. The force may increase from 4.8N to 1.5KN and 7KN with F3, F1 and F2 in five freedoms. Among them F3 is the least one and F1 is the biggest one. The effect factor turn is F2 >F1 >F3. So the F2 is important one and F1 is second while F3 is least with the angular speed of 10º~30º/s and acceleration of 10º/s2. In robot design and application the force and angle with angular speed is important so this study will model numerical simulation and discuss detail data to investigate their force. The force may increase as arm 1 angle increases whilst it may increase if angular speed increases in three freedoms. Meantime it will decrease if angular acceleration increases. It is found that with the angular speed increasing all three force may increase whilst the angular acceleration will cause its increase too in five freedoms. From these value it is observed that F2 is prior one to ensure the strength and fatigue life then F2 is second one to estimate its strength whilst F3 may be neglected. The force may increase as arm 1 angle increases whilst it may increase if angular speed increases in three freedoms. Meantime it will decrease if angular acceleration increases.

Keywords: Numerical simulation; Force and angle; Angular speed; Angular acceleration; Robotic arm; Angular Acceleration; Five freedoms

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 [4-7]. 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. Meantime there are two other ones call 4&5which is included in five freedoms as a rotational and crawling function. 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

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

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 andV_3 is 1、2 and 3 velocities respectively.

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

From Figure 2 it is known that position coordinate below

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

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.

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

V_A, V_B and V_D,is B、C and D velocities respectively. So D point velocity is

$$v_D = \sqrt{\dot{X}_D^2 + \dot{Y}_D^2} = \sqrt{\begin{aligned} & l_1^2\theta_1^2 + l_2^2(\dot{\theta}_1+\dot{\theta}_2)^2 + l_3^2(\dot{\theta}_1+\dot{\theta}_2+\dot{\theta}_3)^2 + \dot{\theta}_1 l_4^2 \sin^2\theta_1^2 + l_4^2(\dot{\theta}_1+\dot{\theta}_2)^2 \sin^2(\theta_1+\theta_2) \\ & + l_4^2(\dot{\theta}_1+\dot{\theta}_2+\dot{\theta}_3)^2 l_4 \sin^2(\theta_1+\theta_2+\theta_3) + 2l_1l_3\dot{\theta}_1(\dot{\theta}_1+\dot{\theta}_2+\dot{\theta}_3)\cos(\theta_1+\theta_3) + \\ & 2l_2l_3(\dot{\theta}_1+\dot{\theta}_2)(\dot{\theta}_1+\dot{\theta}_2+\dot{\theta}_3)\cos\theta_3 + 2l_1l_4\dot{\theta}_1\sin\theta_1 + 2l_2l_4(\dot{\theta}_1+\dot{\theta}_2)\sin(\theta_1+\theta_2) \\ & + 2l_3l_4(\dot{\theta}_1+\dot{\theta}_2+\dot{\theta}_3)\sin(\theta_1+\theta_2+\theta_3) \end{aligned}} \quad (5)$$

C point velocity is

$$v_C = \sqrt{\dot{X}_C^2 + \dot{Y}_C^2} = \sqrt{l_1^2\theta_1^2 + l_2^2(\dot{\theta}_1+\dot{\theta}_2)^2 - 2l_1l_2\dot{\theta}_1(\dot{\theta}_1+\dot{\theta}_2)\cos\theta_2} \quad (6)$$

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

Substituting two equations above to equation below

$$E_K = \frac{1}{2}\vec{l}_1(\vec{l}_1+\vec{l}_4+\vec{l}_5)(m_1+m_2+m_3)\theta_1^2 + \frac{1}{2}\vec{l}_2(\vec{l}_2+\vec{l}_4+\vec{l}_5)\ m_2(\theta_1+\theta_2)^2 + \frac{1}{2}\vec{l}_2(\vec{l}_2+\vec{l}_4+\vec{l}_5)\ m_2(\dot{\theta}_1+\dot{\theta}_2)^2$$
$$+\frac{1}{2}\vec{l}_3(\vec{l}_3+\vec{l}_4+\vec{l}_5)\ m_3(\theta_1+\theta_2+\theta_3)^2 + 2\vec{l}_4^{\,2} m_3\dot{\theta}_1\sin^2\theta_2 + \vec{l}_4^{\,2} m_3\dot{\theta}_1(\dot{\theta}_1+\dot{\theta}_2)^2\sin^2(\theta_1+\theta_2) + \vec{l}_4^{\,2} m_3(\dot{\theta}_1+\dot{\theta}_2$$
$$+\dot{\theta}_3)^2\sin^2(\theta_1+\theta_2+\theta_3) + 2\vec{l}_1\vec{l}_2 m_2\dot{\theta}_1(\dot{\theta}_1+\dot{\theta}_2)\cos\theta_2 + \vec{l}_1\vec{l}_2 m_3\dot{\theta}_1(\dot{\theta}_1+\dot{\theta}_2+\dot{\theta}_3)\cos(\theta_1+\theta_2) + \vec{l}_2\vec{l}_3 m_3(\dot{\theta}_1$$
$$+\dot{\theta}_2)(\dot{\theta}_1+\dot{\theta}_2+\dot{\theta}_3)\cos\theta_3 + \frac{1}{2}(\vec{l}_4+\vec{l}_5)(m_1+m_2+m_3)\theta_1^2 + \frac{1}{2}(\vec{l}_4+\vec{l}_5)\ m_2(\theta_1+\theta_2)^2 + \frac{1}{2}(\vec{l}_4+\vec{l}_5)\ m_2(\dot{\theta}_1+$$
$$\dot{\theta}_2)^2 + 2\vec{l}_1\vec{l}_4 m_3\dot{\theta}_1\sin(\theta_1+\theta_2) + 2\vec{l}_1\vec{l}_4 m_3(\dot{\theta}_1+\dot{\theta}_2)\sin(\theta_1+\theta_2) + 2\vec{l}_3\vec{l}_4 m_3(\dot{\theta}_1+\dot{\theta}_2+\dot{\theta}_3)\sin(\theta_1+\theta_2+\theta_3) \quad (8)$$

Here

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

$$\frac{\partial E_K}{\partial\dot{\theta}_2} = \vec{l}_2 m_2(\dot{\theta}_1+\dot{\theta}_2) + \vec{l}_4 m_3(\dot{\theta}_1+\dot{\theta}_2)^2\sin^2(\theta_1+\theta_2) + 2\vec{l}_4 m_3\dot{\theta}_1(\dot{\theta}_1+\dot{\theta}_2)\sin$$
$${}^2(\theta_1+\theta_2) + 2\vec{l}_4 m_3(\dot{\theta}_1+\dot{\theta}_2+\dot{\theta}_3)\sin^2(\theta_1+\theta_2) + 2\vec{l}_1\vec{l}_2 m_2\dot{\theta}_1\cos\theta_2 + \vec{l}_1\vec{l}_2 m_2$$
$$(\dot{\theta}_1+\dot{\theta}_2)\cos\theta_2 + \vec{l}_2\vec{l}_3 m_3(\dot{\theta}_1+\dot{\theta}_2+\dot{\theta}_2) + \cos(\theta_1+\theta_2) + \vec{l}_2\vec{l}_3 m_3(\dot{\theta}_1+\dot{\theta}_2+\dot{\theta}_3)$$
$$\cos\theta_3 + \vec{l}_2\vec{l}_3 m_3(\dot{\theta}_1+\dot{\theta}_2)\cos\theta_3 + 2\vec{l}_1\vec{l}_4 m_3\sin(\theta_1+\theta_2) + 2\vec{l}_1\vec{l}_4 m_3\sin(\theta_1+\theta_2$$
$$+\theta_3) \quad (10)$$

$$\frac{\partial E_K}{\partial\dot{\theta}_3} = \vec{l}_1\vec{l}_2 m_3\dot{\theta}_1\cos(\theta_1+\theta_2+\theta_3) + 2\vec{l}_4 m_3(\dot{\theta}_1+\dot{\theta}_2+\dot{\theta}_3)\sin^2(\theta_1+\theta_2+$$
$$\theta_3) + \vec{l}_1\vec{l}_2 m_3(\dot{\theta}_1+\dot{\theta}_2+\dot{\theta}_3)\cos(\theta_1+\theta_2) + \vec{l}_1\vec{l}_2 m_3\dot{\theta}_1\cos(\theta_1+\theta_2) + \vec{l}_2\vec{l}_3 m$$
$${}_3(\dot{\theta}_1+\dot{\theta}_2)\cos\theta_3 + \vec{l}_1\vec{l}_2 m_3\dot{\theta}_1\cos(\theta_1+\theta_2) + \vec{l}_2\vec{l}_3 m_3(\dot{\theta}_1+\dot{\theta}_3)\cos\theta_3 + 2\vec{l}_1\vec{l}_4$$
$$m_3\cos(\theta_1+\theta_2+\theta_3) \quad (11)$$

And

$$\frac{d}{dt}\left(\frac{\partial E_K}{\partial \dot{\theta}_1}\right)=\vec{l}_2 m_2(\ddot{\theta}_1+\ddot{\theta}_2)+4(\ddot{\theta}_1+\ddot{\theta}_2)\dot{\theta}_2\vec{l}_1\vec{l}_2 m_2\sin\theta_2 cos\theta_2+4(\ddot{\theta}_1$$
$$+\ddot{\theta}_2)\vec{l}_4 m_3\sin^2(\theta_1+\theta_2)+4(\dot{\theta}_1+\dot{\theta}_2)^3\vec{l}_4 m_3\cos(\theta_1+\theta_2)+2(\dot{\theta}_1+\dot{\theta}_2)\vec{l}_4$$
$$m_3\sin^2(\theta_1+\theta_2)+4(\dot{\theta}_1+\dot{\theta}_2+\dot{\theta}_3)\vec{l}_4 m_3 sin(\theta_1+\theta_2+\theta_3)-2\dot{\theta}^2\vec{l}_1\vec{l}_2 m_2$$
$$\sin\theta_2-2(\dot{\theta}_1+\dot{\theta}_2)\dot{\theta}_2\vec{l}_1\vec{l}_2 m_2\sin\theta_1+2\ddot{\theta}\vec{l}_1\vec{l}_2 m_2\cos\theta_2-2\dot{\theta}^2\vec{l}_1\vec{l}_2 m_2$$
$$\sin\theta_2+\ddot{\theta}\vec{l}_1\vec{l}_2 m_3\cos(\theta_1+\theta_2)-\dot{\theta}_1\vec{l}_1\vec{l}_2 m_3(\dot{\theta}_1+\dot{\theta}_2)\sin(\theta_1+\theta_2)+\vec{l}_2$$
$$m_3(\ddot{\theta}_1+\ddot{\theta}_2+\ddot{\theta}_3)\cos(\theta_1+\theta_2)+\vec{l}_2 m_3(\dot{\theta}_1+\dot{\theta}_2+\dot{\theta}_3)(\dot{\theta}_1+\dot{\theta}_2)\cos(\theta_1+\theta_2$$
$$)+\vec{l}_2 m_3(\ddot{\theta}_1+\ddot{\theta}_2)\cos\theta_3+\vec{l}_2 m_3(\dot{\theta}_1+\dot{\theta}_2)\dot{\theta}_3\cos\theta_3+\vec{l}_1\vec{l}_2 m_3(\ddot{\theta}_1+\ddot{\theta}_2+\ddot{\theta}_3$$
$$)\cos\theta_3+\vec{l}_2\vec{l}_3 m_3(\ddot{\theta}_1+\dddot{\theta}_2+\ddot{\theta}_3)\cos\theta_3+\vec{l}_2\vec{l}_3 m_3(\dot{\theta}_1+\dot{\theta}_2+\dot{\theta}_3)\dot{\theta}_3+4(\ddot{\theta}_1+$$
$$\ddot{\theta}_2)\vec{l}_1\vec{l}_4 m_3\cos(\theta_1+\theta_2)+2(\dot{\theta}_1+\dot{\theta}_2)^3\vec{l}_1\vec{l}_4 m_3\cos(\theta_1+\theta_2)-2(\dot{\theta}_1+\dot{\theta}_2+\dot{\theta}_3$$
$$)\vec{l}_1\vec{l}_4 m_3\sin(\theta_1+\theta_2+\theta_3) \tag{12}$$

$$\frac{d}{dt}\left(\frac{\partial E_K}{\partial \dot{\theta}_2}\right)=\vec{l}_2 m_2(\ddot{\theta}_2+\ddot{\theta}_1)+2\vec{l}_4 m_3(\dot{\theta}_1+\dot{\theta}_2)(\ddot{\theta}_2+\ddot{\theta}_1)\sin^2(\theta_1+\theta_2)-4\vec{l}_4 m_3(\dot{\theta}_1$$
$$+\dot{\theta}_2)^2(\ddot{\theta}_2+\ddot{\theta}_1)\sin(\theta_1+\theta_2)\cos(\theta_1+\theta_2)+2\vec{l}_4 m_3(\ddot{\theta}_1+\ddot{\theta}_2+\ddot{\theta}_3)(\dot{\theta}_1+\dot{\theta}_2)\sin^2(\theta_1$$
$$+\theta_2)+2\vec{l}_4 m_3(\ddot{\theta}_1+\ddot{\theta}_2)\sin^2(\theta_1+\theta_2)-4\vec{l}_4 m_3\dot{\theta}_1(\dot{\theta}_1+\dot{\theta}_2)^2\sin(\theta_1+\theta_2)\cos(\theta_1+$$
$$\theta_2)+2\vec{l}_1\vec{l}_2 m_3\ddot{\theta}_1\cos\theta_2+2\vec{l}_1\vec{l}_2 m_2\dot{\theta}_1\dot{\theta}_2\cos\theta_2+\vec{l}_1\vec{l}_2 m_3(\ddot{\theta}_1+\ddot{\theta}_2)\cos(\theta_1+\theta_2)$$
$$-\vec{l}_1\vec{l}_2 m_3(\dot{\theta}_1+\dot{\theta}_2+\dot{\theta}_3)(\dot{\theta}_1+\dot{\theta}_2)\sin(\theta_1+\theta_2)+\vec{l}_1\vec{l}_2 m_3(\ddot{\theta}_1+\ddot{\theta}_2+\ddot{\theta}_3)\cos\theta_1-\vec{l}_1\vec{l}_2$$
$$m_3(\dot{\theta}_1+\dot{\theta}_2+\dot{\theta}_3)\dot{\theta}_1\sin\theta_1+\vec{l}_2\vec{l}_3 m_3(\ddot{\theta}_1+\ddot{\theta}_2+\ddot{\theta}_3)\cos\theta_3+2\vec{l}_1\vec{l}_4 m_3(\dot{\theta}_1+\dot{\theta}_2)\cos(\theta_1$$
$$+\theta_2)+2\vec{l}_1\vec{l}_4 m_3(\dot{\theta}_1+\dot{\theta}_2+\dot{\theta}_3)\cos(\theta_1+\theta_2)+2\vec{l}_1\vec{l}_4 m_3(\dot{\theta}_1+\dot{\theta}_2+\dot{\theta}_3)\cos(\theta_1+\theta_2+\theta_3) \tag{13}$$

$$\frac{d}{dt}\left(\frac{\partial E_K}{\partial \dot{\theta}_3}\right)=\vec{l}_1\vec{l}_2 m_3\ddot{\theta}_1(\dot{\theta}_1+\dot{\theta}_2+\dot{\theta}_3)+2\vec{l}_4 m_3(\ddot{\theta}_1+\ddot{\theta}_2+\ddot{\theta}_3)\sin^2(\theta_1+\theta_2+\theta_3)+$$
$$4\vec{l}_4 m_3(\dot{\theta}_1+\dot{\theta}_2+\dot{\theta}_3)^2\sin(\theta_1+\theta_2+\theta_3)\cos(\theta_1+\theta_2+\theta_3)-\vec{l}_1\vec{l}_2 m_3(\ddot{\theta}_1+\ddot{\theta}_2+\ddot{\theta}_3)($$
$$\dot{\theta}_1+\dot{\theta}_2)\sin(\theta_1+\theta_2)+\vec{l}_1\vec{l}_2 m_3\ddot{\theta}_1\cos(\theta_1+\theta_2)+\vec{l}_1\vec{l}_2 m_3\ddot{\theta}_1\cos(\theta_1+\theta_2)+\vec{l}_3\vec{l}_2 m_3$$
$$(\ddot{\theta}_1+\ddot{\theta}_3)\cos\theta_3-\vec{l}_2\vec{l}_3 m_3(\dot{\theta}_1+\dot{\theta}_3)\dot{\theta}_3\sin\theta_3-\vec{l}_1\vec{l}_4 m_3\cos(\dot{\theta}_1+\dot{\theta}_2+\dot{\theta}_3) \tag{14}$$

$$\frac{\partial E_K}{\partial \theta_1}=\vec{l}_1(\vec{l}_1+\vec{l}_4+\vec{l}_5)(m_1+m_2+m_3)\theta_1+\vec{l}_2(\vec{l}_3+\vec{l}_4+\vec{l}_5)\ m_2(\theta_1+\theta_2)+\vec{l}_3(\vec{l}_3+\vec{l}_4+\vec{l}_5)\ m_3(\theta_1+\theta_2+\theta_3)$$
$$+2\vec{l}_4 m_3\dot{\theta}_1(\dot{\theta}_1+\dot{\theta}_2)^2\sin(\theta_1+\theta_2)-2\vec{l}_4 m_3\dot{\theta}_1(\dot{\theta}_1+\dot{\theta}_2+\dot{\theta}_3)^2\sin(\theta_1+\theta_2+\theta_3)-\vec{l}_1\vec{l}_2 m_2\dot{\theta}_1(\dot{\theta}_1+\dot{\theta}_2+\dot{\theta}_3)\sin$$
$$(\theta_1+\theta_2)+(\vec{l}_4+\vec{l}_5)(m_2+m_2+m_3)\theta_1+(\vec{l}_4+\vec{l}_5)m_2(\theta_1+\theta_2)+2\vec{l}_1\vec{l}_4 m_3(\dot{\theta}_1+\dot{\theta}_2)\cos(\theta_1+\theta_2)+2\vec{l}_1\vec{l}_4 m_3$$
$$(\dot{\theta}_1+\dot{\theta}_2+\dot{\theta}_3)\cos(\theta_1+\theta_2) \tag{15}$$

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

$$(\theta_1+\theta_2)+2\vec{l}_4\, m_3\,\dot{\theta}_1(\dot{\theta}_1+\dot{\theta}_2+\dot{\theta}_3)^2\sin(\theta_1+\theta_2+\theta_3)-2\vec{l}_1\vec{l}_2\, m_3\,\dot{\theta}_1(\dot{\theta}_1+\dot{\theta}_2)\sin\theta_2-2\vec{l}_1\vec{l}_2\, m_3\,\dot{\theta}_1(\dot{\theta}_1+\dot{\theta}_2)\sin\theta_2-(\vec{l}_4$$

$$+\vec{l}_5)m_3\,\dot{\theta}_1(\theta_1+\theta_2)+2\vec{l}_1\vec{l}_4\, m_3\,\dot{\theta}_1(\dot{\theta}_1+\dot{\theta}_2+\dot{\theta}_3)\cos(\theta_1+\theta_2)-(\vec{l}_4+\vec{l}_5)m_3\,\dot{\theta}_1(\theta_1+\theta_2)+2\vec{l}_1\vec{l}_4\, m_3\,\dot{\theta}_1\cos(\theta_1+\theta_2)+$$

$$2\vec{l}_3\vec{l}_4\, m_3(\dot{\theta}_1+\dot{\theta}_1+\dot{\theta}_2)\cos(\theta_1+\theta_2+\theta_3) \qquad (16)$$

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

$$(\dot{\theta}_1+\dot{\theta}_2+\dot{\theta}_3)\ \sin\theta_3-2\vec{l}_3\vec{l}_4\, m_3(\dot{\theta}_1+\dot{\theta}_2+\dot{\theta}_3)\cos(\theta_1+\theta_2+\theta_3) \qquad (17)$$

Potential energy of System

$$E_P=(\vec{l}_1+\vec{l}_4)\ m_1 g\cos\theta_1+(\vec{l}_2+\vec{l}_4)\ m_2 g\cos(\theta_1+\theta_2)+(\vec{l}_3+\vec{l}_4)\ m_3 g\cos(\theta_1+\theta_2+\theta_3) \quad (18)$$

$$\frac{\partial E_P}{\partial \theta_1}=\vec{l}_1\vec{l}_4\, m_1 g\,\dot{\theta}_1\sin\theta_1 \qquad (19)$$

$$\frac{\partial E_P}{\partial \theta_2}=\vec{l}_2\vec{l}_4\, m_2 g\,\dot{\theta}_2\sin(\theta_1+\theta_2)$$

$$\frac{\partial E_P}{\partial \theta_3}=\vec{l}_3\vec{l}_4\, m_3 g\,\dot{\theta}_3\sin(\theta_1+\theta_2+\theta_3)$$

Substituting Lagrange equation below (10) for above equations

Lagrange equation is

$$\frac{d}{dt}\left(\frac{\partial E_K}{\partial \dot{q}_i}\right)-\frac{\partial E_K}{\partial q_i}+\frac{\partial E_P}{\partial q_i}=F_i \quad ,\ (i=1,2,,,...,n) \qquad (20)$$

Here E_k is kinetic of system;

E_p is potential energy of system;

q_i is generalized coordinate, it is a group of independent parameters that can define mechanical system movement;

F_i is generalized force, when is a angular displacement it a torque, when q_i is linear displacement it a force;

n is system generalized coordinate.

System generalized force

Supposed that Fk(k=1,2,..,m) and Mj(j=1,2,..,n) is force and torque acting on system. Its power is

$$P=\sum_{k=1}^{m}(F_k v_k\cos\alpha_k)+\sum_{j=1}^{n}(\pm M_j\omega_j) \qquad (21)$$

Here ωj: angular velocity acting on component with Mj;

vk: the velocity in force Fk point of action; (the syntropy +, reverse direction -)

ak: angle between Fk and vk

When generalized coordinates is φ angular displacement generalized force=equivalent torque

$$\delta W_2=\sum_{k=1}^{m}(F_k\delta v_k\cos\alpha_k)+\sum_{j=1}^{n}(\pm M_j\delta\omega_j) \qquad (22)$$

Here a_k is zero; F_k =200N; V_k =0.2~0.3m/s; W_j = ; 20~30°/s M_j =20~30Nm. $\delta\varphi_j$ is virtual angular displacement; δs_k is virtual displacement.

Supposing that

$$\delta s_K = \frac{\partial s_K}{\partial q_1}\delta q_1 + \frac{\partial s_K}{\partial q_2}\delta q_2 \quad (23)$$

$$\delta \varphi_K = \frac{\partial \varphi_j}{\partial q_1}\delta q_1 + \frac{\partial \varphi_j}{\partial q_2}\delta q_2 \quad (24)$$

Replace equation below with above two equations

$$\begin{cases} F_1 = \sum_{k=1}^{m}\left[F_k \frac{\partial s_K}{\partial q_1}\cos\alpha_k\right] + \sum_{j=1}^{n}\left[M_J \frac{\partial \varphi_J}{\partial q_1}\right] \\ F_2 = \sum_{k=1}^{m}\left[F_k \frac{\partial s_K}{\partial q_2}\cos\alpha_k\right] + \sum_{j=1}^{n}\left[M_J \frac{\partial \varphi_J}{\partial q_2}\right] \end{cases} \quad (25)$$

This is generalized force equation.

Table 1: *Parameters of robot arms.*

items	Value	Item	Value
l1 /m	0.55	$\dot{\theta}_1$ /°/s	10~30
l2 /m	0.5	$\dot{\theta}_2$ /°/s	10~30
l3 /m	0.3	$\dot{\theta}_3$/°/s	10~30
m1/N	7.7	$\ddot{\theta}_1$ /°/s^2	10
m2/N	6.6	$\ddot{\theta}_2$ /°/s^2	10
m3/N	4.0	$\ddot{\theta}_3$ /°/s^2	10

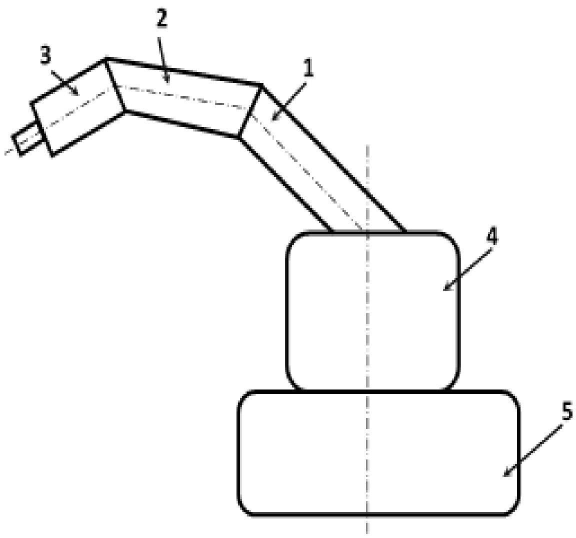


Figure 1: *Construction schematic of mechanical arm in series in robot 3-hand part; 2-wrist part; 1-arm part; 4-waist part; 5-two crawling wheel.*

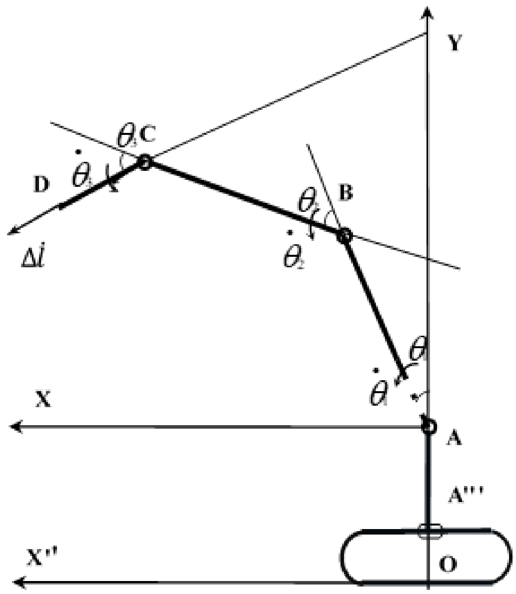
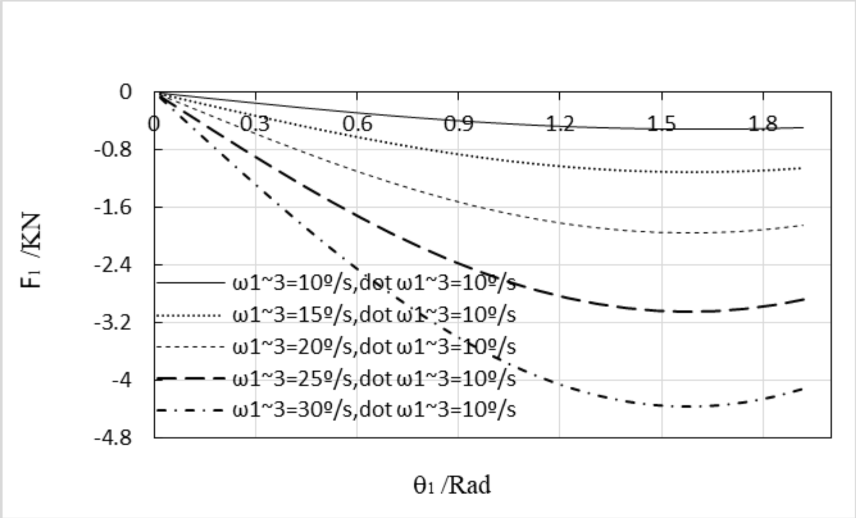
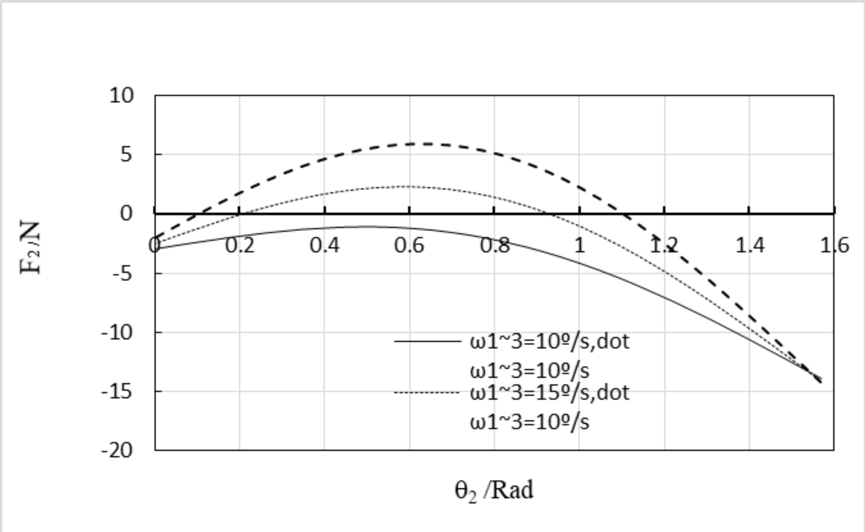


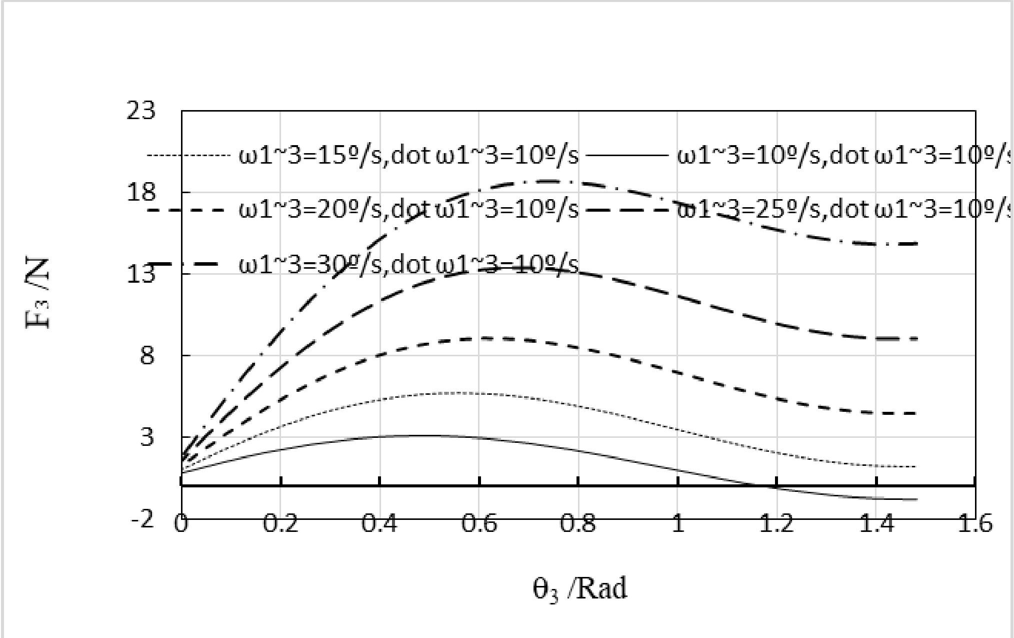
Figure 2: *principle schematic of mechanical arm in series in robot.*



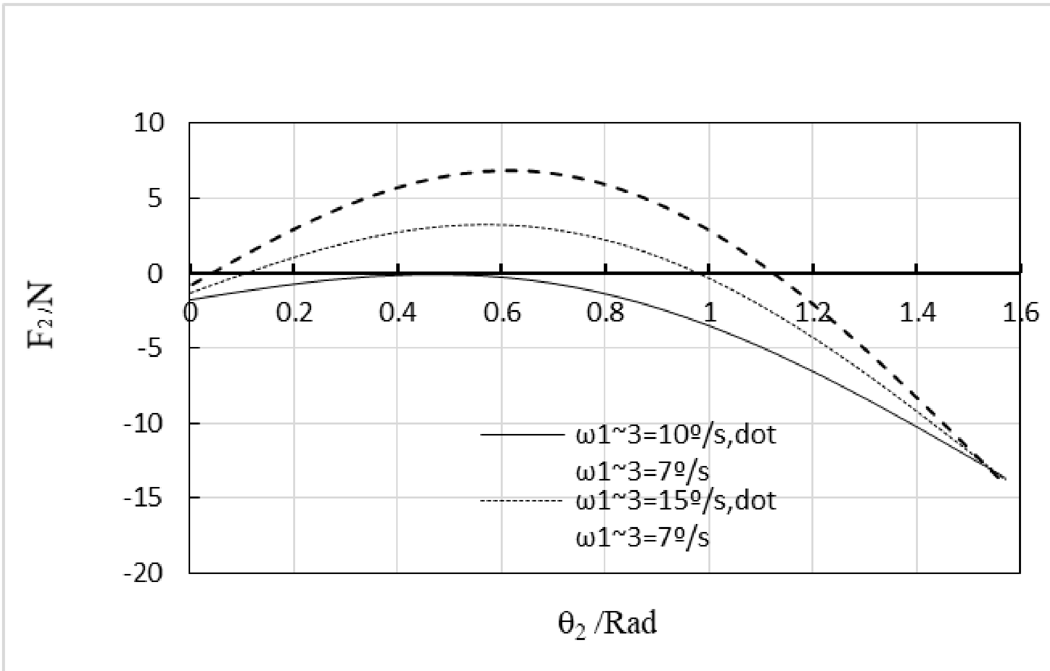
(a) F1.



(b) F2.

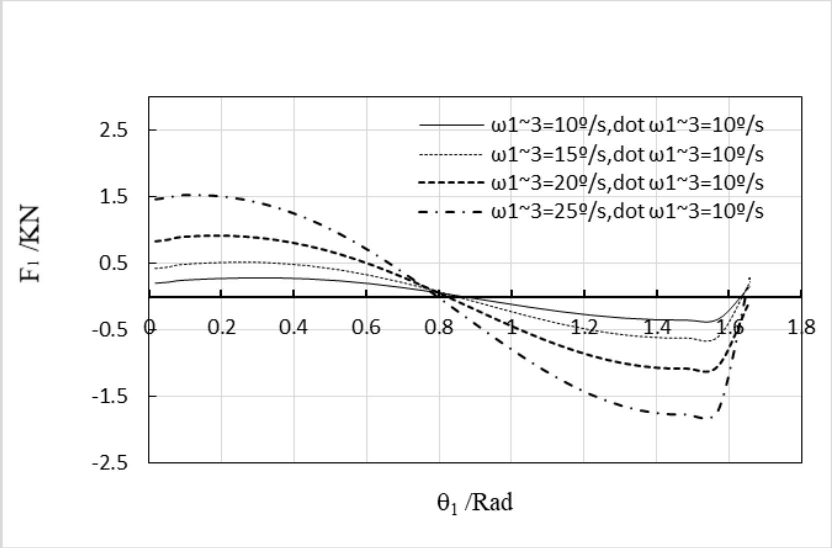


(C) F2.

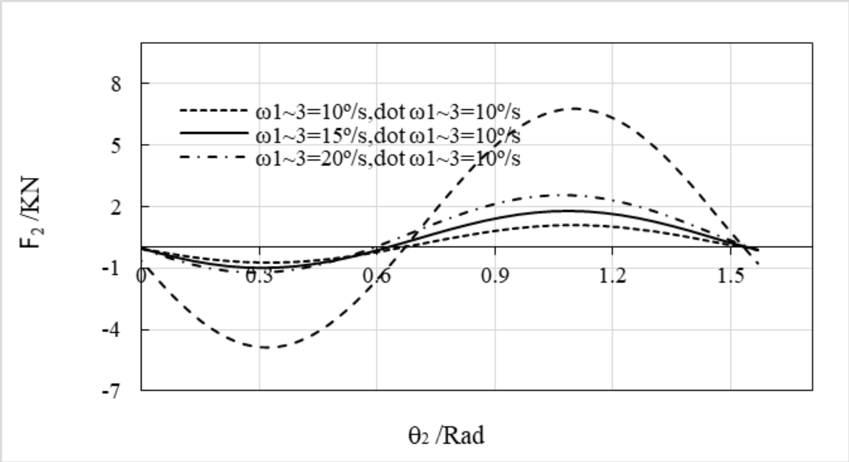


(d) F2.

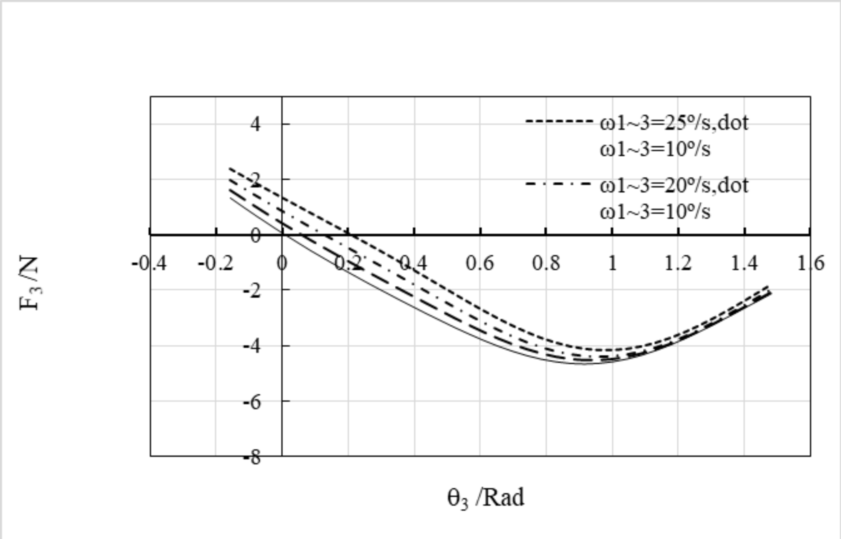
Figure 3: *The curve of force and angle with various angular speed and acceleration in three freedoms of robot arm under angular acceleration of 10º/s².*



(a) F1.



(b) F2.



(c) F3.

Figure 4: *The curve of force and angle with various angular speed and acceleration in five freedoms of robot arm under angular acceleration of 10º/s²*.

Discussions

As seen in Table 1 the parameter in robot arm is listed. [6~7] Here θ1, θ2, θ3 is the arm 1, 2, 3 angle respectively. l1, l2, l3 is arm length. m1, m 2, m3 is arm mass. Number is arm label. According to these parameters the below curves are gained as below in Figure 3& 4. As seen in Figure 3(a~c) the force of arm1 will increase with the angular speed increasing that expresses the proportional relation between them fitting to Newton theory well under acceleration of $10^{o}/s^{2}$. That says that angular speed raises the acceleration meantime the later raise the force too. The force in Figure 3 has 4.6KN, 5.5N and 20N with F1, F2 &F3 respectively. They all distributes into sinusoidal continuous wave that forms semiwave with 90º. The force may increase from 4.8N to 1.5KN and 7KN with F3, F1 and F2 in five freedoms system as seen in Figure 4. Among them F3 is the least one and F1 is the biggest one. The effect factor turn is F2 >F1 >F3. So the F2 is important one and F1 is second one while F3 is the least one. From these value it is observed that F2 is prior one to ensure the strength and fatigue life then F2 is second one to estimate its strength whilst F3 may be neglected (Table 1).

As seen in Figure 3 the force may increase as arm 1 angle increases whilst it may increase if angular speed increases in three freedoms. Meantime it will decrease if angular acceleration increases in Figure 3(d). The maximum is 4.4KN in Figure 3(a) if angular speed is 30º/s and acceleration is 10º/s2 so this point will be checked to ensure the robotic arm strength. There is big distance to attain 4KN between the conditions. The effective factor turn to the force is F1>F3>F2 in three freedoms. From Figure 3 (b) and (d) it is seen that the F2 may be bigger in $7^{o}/s^{2}$ than that is 6N in $10^{o}/s^{2}$ in three freedoms robotic arm (Figure 3).

In the modeling of five freedoms in movement of robotic arm the kinetic equation is established according to Lagrange formula based on three freedoms robotic arm. It compensates the blank in four freedoms and one impulsion on robot. It is found that the first and second solution is complicated and long the whole equations is concise than the traditional equation. This is a blank in five freedoms which can shorten the whole numerical computation a lot. Referring to the important occasion the kinetic equation will only be computed on three freedoms according to this study (Figure 4).

It is suggested that the big arm happens when angular speed and acceleration is big. So that the reasonable parameters are chosen to design and estimate their forces is important. Not to choose big angular speed and acceleration is key in order to increase the capability and force that may increase the whole cost as well. Overview the computation is shorter than the five freedoms traditional one. The solution is easy to use in software like Excel and Origin. The result is satisfactory and precise to be adopted to numerical simulation so the five freedoms method based on three freedoms is feasible.

Conclusions

- There is big distance to attain 7KN between the conditions. The effective factor turn to the force is F1>F3>F2 in three freedoms with the angular speed of 10º~30º/s and of acceleration of $10^{o}/s^{2}$.
- The force may increase from 4.8N to 1.5KN and 7KN with F3, F1 and F2 in five freedoms. Among them F3 is the least one and F1 is the biggest one. The effect factor turn is F2 >F1 >F3. So the F2 is important one and F1 is second while F3 is least with the angular speed of 10º~30º/s and acceleration of $10^{o}/s^{2}$.

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