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Review Article

The Numerical Simulation of Properties with Parameters in Three & Five Freedoms of Robotic Arm

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Abstract: 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 property. 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 F_1 is prior one to ensure the strength and fatigue life then F_2 is second one to estimate its strength whilst F_3 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 & acceleration; robotic arm; angular Acceleration; three & five freedoms.

1. INTRODUCTION

In recent the robotic arm has been applied to many occasion in factory which can help people to work in difficult, dirty and dangerous place so its application will be more prevailed in future which is estimated in this study. China has been the largest country which can own the largest domestic market in the world, but it has the third market occupant since it has not owned the enough advanced condition [1-5]. So that we must positively construct the clean and criteria house to meet the demand for robotic arm to ensure precise work.

In robotic design the force is an important factor to consider since the strength must meet demand no matter what it may work in factory [4, 5]. So that according to the function it may be designed to satisfy the no fracture and longer fatigue life for its long life and high load to work in automatic flow line to be substituted to human worker. The biggest one will destination in this paper and how to save manufacture cost is the second one. So it is needed that the mass and load may become first thing to prepare; secondly for the cost decrease the redundant load shall be prohibited.

In this paper the condition is changed like angular speed and acceleration to observe the three forces status to ensure security of strength and save cost status. The three freedoms and five ones are investigated in this paper detail with parameters like force and angle with angular speed and acceleration. We try to find the various condition of effective factor in order to search intrinsic properties relationship which is the destination in this paper.

In short the properties are searched through parameters in detail. We look forward to finding new change with force and speed & acceleration for further research.

2. 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.

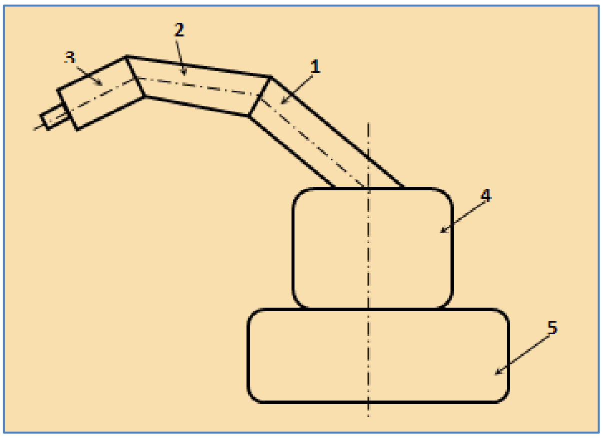


Fig-1: Construction schematic of mechanical arm in series in robot

3-hand part; 2-wrist part;1-arm part; 4-waist part; 5-two crawling wheel

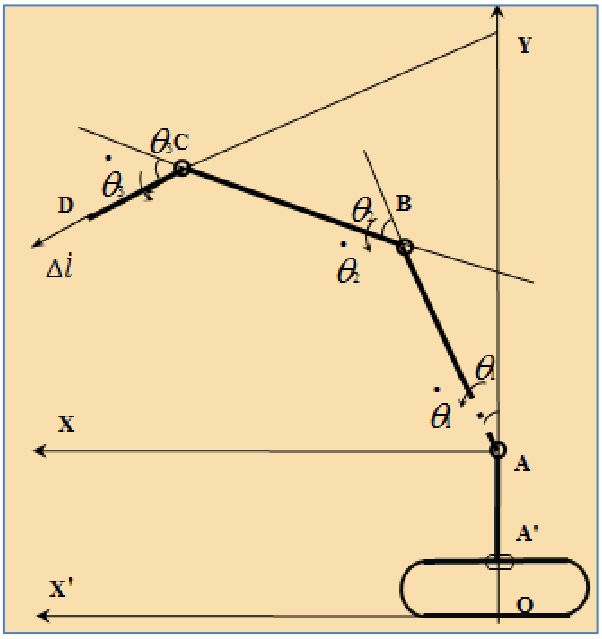


Fig-2: Principle schematic of mechanical arm in series in robot

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

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

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

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

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

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

Here

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

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

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

And

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

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

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

$$4\vec{l}_4 m_3(\dot{\theta}_1+\dot{\theta}_2+\dot{\theta}_3)^2\sin(\theta_1+\theta_2+\theta_3)\cos(\theta_1+\theta_2+\theta_3)-\vec{l}_1\vec{l}_2 m_3(\ddot{\theta}_1+\ddot{\theta}_2+\ddot{\theta}_3)($$

$$\dot{\theta}_1+\dot{\theta}_2)\sin(\theta_1+\theta_2)+\vec{l}_1\vec{l}_2 m_3\ddot{\theta}_1\cos(\theta_1+\theta_2)+\vec{l}_1\vec{l}_2 m_3\ddot{\theta}_1\cos(\theta_1+\theta_2)+\vec{l}_3\vec{l}_2 m_3$$

$$(\ddot{\theta}_1+\ddot{\theta}_3)\cos\theta_3-\vec{l}_2\vec{l}_3 m_3(\dot{\theta}_1+\dot{\theta}_3)\dot{\theta}_3\sin\theta_3-\vec{l}_1\vec{l}_4 m_3\cos(\dot{\theta}_1+\dot{\theta}_2+\dot{\theta}_3)$$

$$\frac{\partial E_K}{\partial \theta_1}=\vec{l}_1(\vec{l}_1+\vec{l}_4+\vec{l}_5)(m_1+m_2+m_3)\theta_1+\vec{l}_2(\vec{l}_3+\vec{l}_4+\vec{l}_5)\ m_2(\theta_1+\theta_2)+\vec{l}_3(\vec{l}_3+\vec{l}_4+\vec{l}_5)\ m_3(\theta_1+\theta_2+\theta_3)$$

$$+2\vec{l}_4 m_3\dot{\theta}_1(\dot{\theta}_1+\dot{\theta}_2)^2\sin(\theta_1+\theta_2)-2\vec{l}_4 m_3\dot{\theta}_1(\dot{\theta}_1+\dot{\theta}_2+\dot{\theta}_3)^2\sin(\theta_1+\theta_2+\theta_3)-\vec{l}_1\vec{l}_2 m_2\dot{\theta}_1(\dot{\theta}_1+\dot{\theta}_2+\dot{\theta}_3)\sin \quad (15)$$

$$(\theta_1+\theta_2)+(\vec{l}_4+\vec{l}_5)(m_2+m_2+m_3)\theta_1+(\vec{l}_4+\vec{l}_5)m_2(\theta_1+\theta_2)+2\vec{l}_1\vec{l}_4 m_3(\dot{\theta}_1+\dot{\theta}_2)\cos(\theta_1+\theta_2)+2\vec{l}_1\vec{l}_4 m_3$$

$$(\dot{\theta}_1+\dot{\theta}_2+\dot{\theta}_3)\cos(\theta_1+\theta_2)$$

$$\frac{\partial E_K}{\partial \theta_2}=\vec{l}_2(\vec{l}_2+\vec{l}_4+\vec{l}_5)\ m_2(\theta_1+\theta_2)+\vec{l}_3(\vec{l}_3+\vec{l}_4+\vec{l}_5)\ m_3(\theta_1+\theta_2+\theta_3)+4\vec{l}_4 m_3\dot{\theta}_1\sin\theta_2+2\vec{l}_4 m_3\dot{\theta}_1(\dot{\theta}_1+\dot{\theta}_2)^2\sin \quad (16)$$

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

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

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

$$\frac{\partial E_K}{\partial \theta_3}=\vec{l}_3(\vec{l}_3+\vec{l}_4+\vec{l}_5)(\theta_1+\theta_2+\theta_3)-2\vec{l}_4 m_3(\dot{\theta}_1+\dot{\theta}_2+\dot{\theta}_3)^2 sin(\theta_1+\theta_2+\theta_3)-\vec{l}_2\vec{l}_3 m_3(\dot{\theta}_1+\dot{\theta}_2) \quad (17)$$

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

potential energy of System

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

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

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

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

Substituting Lagrange equation below (10) for above equations

Lagrange equation is

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

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 q_i 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

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

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 Me.

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

Here a_K is zero; F_K =200N; v_K =0.2~0.3m/s; ω_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.

2. DISCUSSIONS

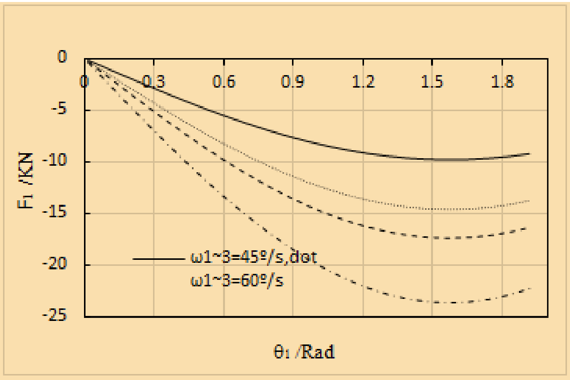
As seen in Table 1 the parameter in robot arm is listed. [6, 7] Here θ_1, θ_2, θ_3 is the arm 1, 2, 3 angle respectively. l_1, l_2, l_3 is arm length. m_1, m_2, m_3 is arm mass. Number is arm label. According to these parameters the below curves are gained as below in Figure 4. As seen in Figure 3(a~c) the force of arm1 will increase with the angular speed and acceleration increasing that expresses the proportional relation between them fitting to Newton theory well. That says that angular speed raises the acceleration meantime the later raise the force too. They all distributes into sinusoidal continuous wave that forms semiwave with 90º. The force may increase from 0.12KN to 18KN and 40KN with F3, F1 and F_2. Among them F3 is the least one and F1 is the biggest one. The effect factor turn is $F_2 > F_1 > F_3$. so the F2 is important one the value attains 4Tons and F_1 is second attained 1.8Tons while F_3 attains 12Kg. From these value it is observed that F2 is prior one to ensure the strength and fatigue life then F_2 is second one to estimate its strength whilst F_3 may be neglected.

Table-1: Parameters of robot arms

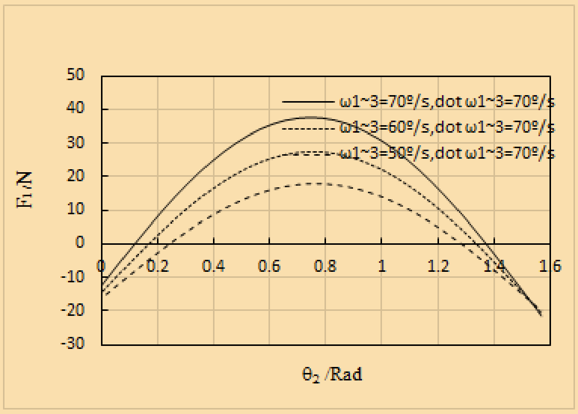
items	Value	Item	Value
l_1 /m	0.55	$\dot{\theta}_1$ /°/s	30~60
l_2 /m	0.5	$\dot{\theta}_2$ /°/s	30~60
l_3 /m	0.3	$\dot{\theta}_3$ /°/s	30~60
m_1/N	7.7	$\ddot{\theta}_1$ /°/s^2	30~60

m_2/N	6.6	$\ddot{\theta}_2$ /°/s²	30~60
m_3/N	4.0	$\ddot{\theta}_3$ /°/s²	30~60

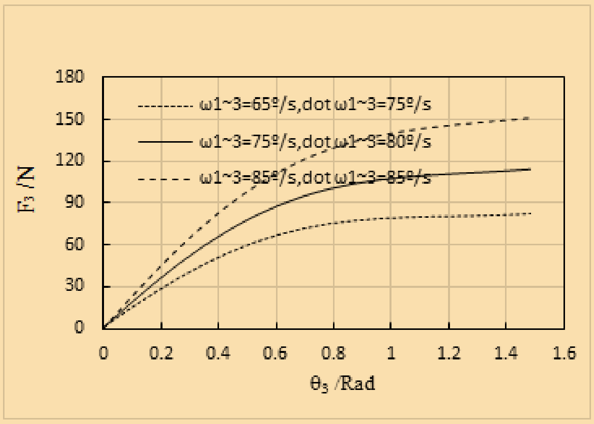
As seen in Figure 3 the force may increase as arm 1 angle increases whilst it may increase if angular speed increases in three freedoms. Meantime it will decrease if angular acceleration increases in Figure 3(d). The maximum is 24KN in Figure 3(a) if angular speed is 70º/s and acceleration is 70º/s^2 so this point will be checked to ensure the robotic arm strength. There is big distance to attain 5KN between the conditions. The effective factor turn to the force is F_1>F_3>F_2 in three freedoms.



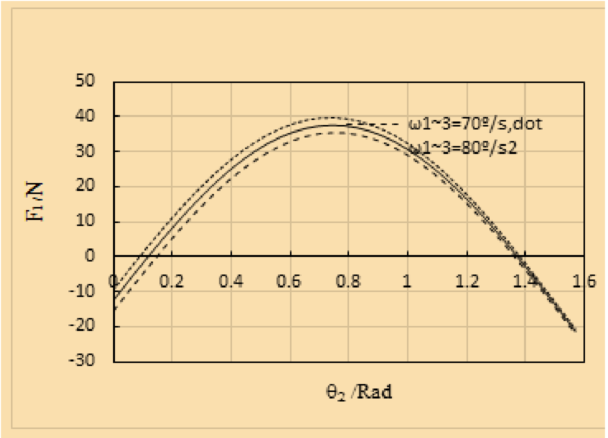
(a) F_1



(b) F_2



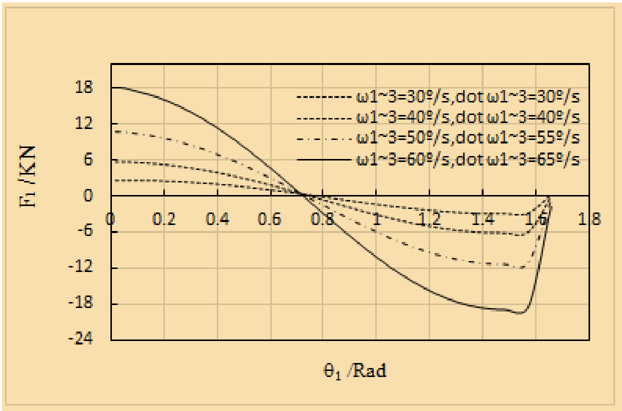
(c) F_3



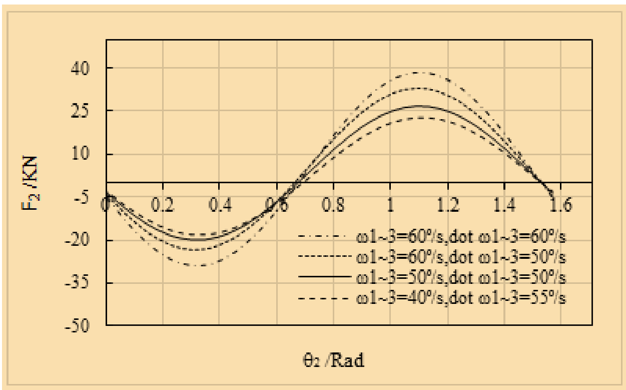
(d) F_2

Fig-3: The curve of force and angle with various angular speed and acceleration in three freedoms of robot arm

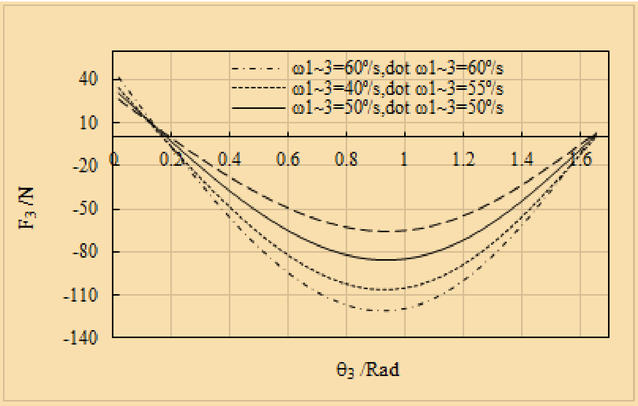
In the modeling of five freedoms in movement of robotic arm the kinetic equation is established according to Lagrange formula based on three freedoms robotic arm. It compensates the blank in four freedoms and one impulsion on robot. It is found that the first and second solution is complicated and long 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.



(a) F_1



(b) F_2



(c) F_3

Fig-4: The curve of force and angle with various angular speed and acceleration in five freedoms of robot arm.

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 properties is important. Not to choose big angular speed and acceleration is key in order to increase the capability and property 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.

3. CONCLUSIONS

1. There is big distance to attain 5KN between the conditions. The effective factor turn to the force is F_1>F_3>F_2 in three freedoms.

2. The force may increase from 0.12KN to 18KN and 40KN with F_3, F_1 and F_2 in five freedoms. Among them F3 is the least one and F_1 is the biggest one. The effect factor turn is F_2 >F_1 >F_3. so the F_2 is important one the value attains 4Tons and F_1 is second attained 1.8Tons while F_3 attains 12Kg.

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