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The Dynamics of Torque and Force on Hammer with Six Freedoms by Lagrange Equation in Robotic Arm

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Abstract-: *the dynamic equation of three freedoms and friction impulsion vibration is established hammer in robotic arm by Larange equation. It is based on one of two freedoms. It is found that the first and second items is long and others is concise which is found in kinetic equation in this study. The M1 torque decreases when θ1 increases to 2200Nm with the speed of 0.1m/s. The highest torque M2 has about 6000Nm at the angle θ2 equals 0.6. The biggest one is at a=95m/s2 which has been 138Nm whose value is the biggest.*

Keywords: *- Dynamic Equation, hammering, Robotic Arm, Lagrange Equation, three freedoms*

1 Introduction

In modern industry the activity of robotic arm is high as an automatic device. It is an important branch for the Robot. Its feature has been completing anticipated working task by program. It is an automatic device for robot technological field to be gained the most practical applications that is in industry manufacture, medical healing, military, semi-conductive manufacture and space exploring. Its structure and property have an advantage of human and robot respectively especial in exhibiting human intelligence and adaption. Its precision and capability in all kinds of environment is excellent so that it has wide prospects in each field of economy. The punching destruction is often used in destruction applications. It shall be studied detail that dynamic equation is established to grasp each Parameters to wield its virtual use value. Because it has main two freedoms one is rotation and the other is punch it's this equation will be established according to these features. The each dynamic equation is plotted then substitute into Lagrange equation to search for the dynamic equation to be established. [1] Because it has five parts to move and hammering below equation is to be solved according to each parts movement. After establishing this equation it can be analyzed by related parameters to optimum and cost decreasing. The length and mass of components and position will be control parameters. [2] So in this paper these parameters will be further discussed to look for cost decreasing. It is hopeful to assist designer and related teacher in studying further at factory and university.

2 Modeling and establishing dynamic equation

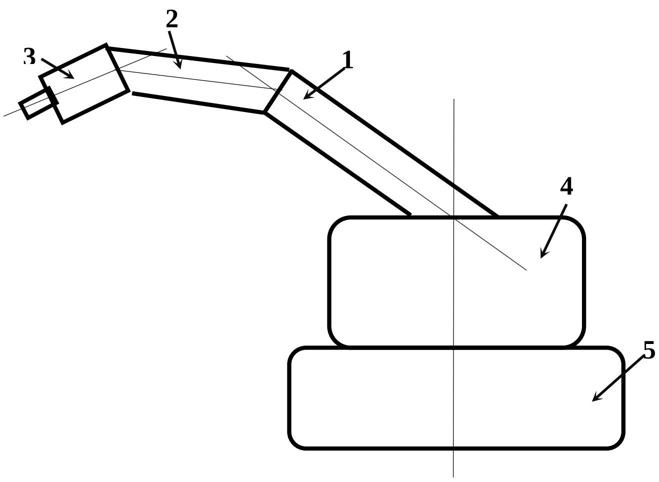

Figure 1 construction schematic of mechanical arm in series in robot

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

In Figure 1 there are five freedoms in mechanical arm that name as 1~3. Meantime there are two other ones call 4&5.

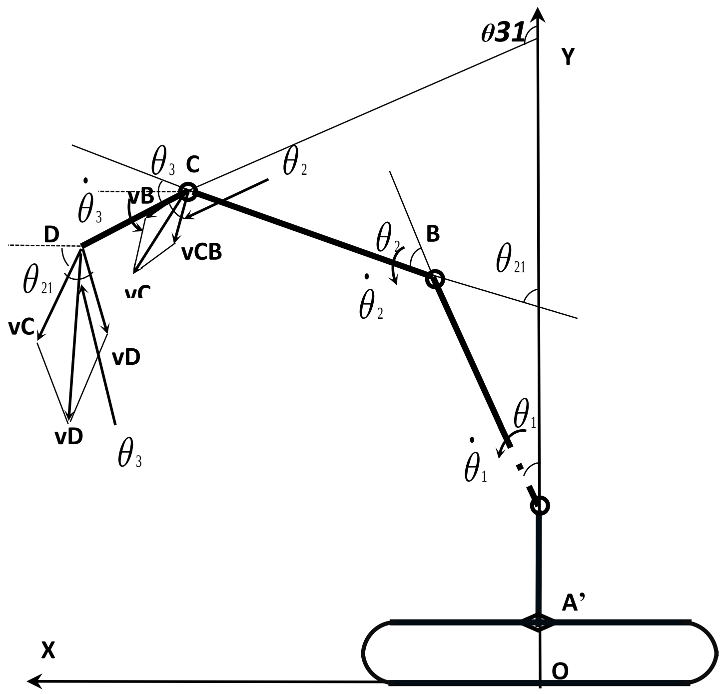

Figure 2 principle schematic of mechanical arm in series in robot

Here =360°-( ).

System kinetic energy is

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

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

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

C point velocity is

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

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

Substituting two equations above to equation below

$$\begin{aligned} E_K = {} & \frac{1}{2}\vec{l}_1(\vec{l}_1+\vec{l}_4+\vec{l}_5)(m_1+m_2+m_3)\theta_1^2 + \frac{1}{2}\vec{l}_2(\vec{l}_2+\vec{l}_4+\vec{l}_5)\ m_2(\theta_1+\theta_2)^2 + \frac{1}{2}\vec{l}_2(\vec{l}_2+\vec{l}_4+\vec{l}_5)\ m_2(\dot{\theta}_1+\dot{\theta}_2)^2 \\ & + \frac{1}{2}\vec{l}_3(\vec{l}_3+\vec{l}_4+\vec{l}_5)\ m_3(\theta_1+\theta_2+\theta_3)^2 + 2\vec{l}_4^2 m_3\dot{\theta}_1\sin^2\theta_2 + \vec{l}_4^2 m_3\dot{\theta}_1(\dot{\theta}_1+\dot{\theta}_2)^2\sin^2(\theta_1+\theta_2) + \vec{l}_4^2 m_3(\dot{\theta}_1+\dot{\theta}_2 \\ & + \dot{\theta}_3)^2\sin^2(\theta_1+\theta_2+\theta_3) + 2\vec{l}_1\vec{l}_2 m_2\dot{\theta}_1(\dot{\theta}_1+\dot{\theta}_2)\cos\theta_2 + \vec{l}_1\vec{l}_2 m_3\dot{\theta}_1(\dot{\theta}_1+\dot{\theta}_2+\dot{\theta}_3)\cos(\theta_1+\theta_2) + \vec{l}_2\vec{l}_3 m_3(\dot{\theta}_1 \\ & + \dot{\theta}_2)(\dot{\theta}_1+\dot{\theta}_2+\dot{\theta}_3)\cos\theta_3 + \frac{1}{2}(\vec{l}_4+\vec{l}_5)(m_1+m_2+m_3)\theta_1^2 + \frac{1}{2}(\vec{l}_4+\vec{l}_5)\ m_2(\theta_1+\theta_2)^2 + \frac{1}{2}(\vec{l}_4+\vec{l}_5)\ m_2(\dot{\theta}_1+ \\ & \dot{\theta}_2)^2 + 2\vec{l}_1\vec{l}_4 m_3\dot{\theta}_1\sin(\theta_1+\theta_2) + 2\vec{l}_1\vec{l}_4 m_3(\dot{\theta}_1+\dot{\theta}_2)\sin(\theta_1+\theta_2) + 2\vec{l}_3\vec{l}_4 m_3(\dot{\theta}_1+\dot{\theta}_2+\dot{\theta}_3)\sin(\theta_1+\theta_2+\theta_3) + \\ & J\omega_4^2 + \frac{1}{2}\mathrm{m}_3\mathrm{v}_3^2 \end{aligned} \qquad (8)$$

Here

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

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

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

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

$$+2\vec{l}_1\vec{l}_4\, m_3\sin(\theta_1+\theta_2) + 2\vec{l}_1\vec{l}_4\, m_3\sin(\theta_1+\theta_2) + 2\vec{l}_1\vec{l}_4\, m_3\cos(\theta_1+\theta_2+\theta_3)$$

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

$$^2(\theta_1+\theta_2) + 2\vec{l}_4\, m_3(\dot{\theta}_1+\dot{\theta}_2+\dot{\theta}_3)\sin^2(\theta_1+\theta_2) + 2\vec{l}_1\vec{l}_2\, m_2\,\dot{\theta}_1\cos\theta_2 + \vec{l}_1\vec{l}_2\, m_2$$

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

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

$$+\theta_3)$$

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

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

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

$$m_3\cos(\theta_1+\theta_2+\theta_3) + m_3 v_3\,\dot{v}_3$$

And

$$\frac{d}{dt}\left(\frac{\partial E_K}{\partial \dot{\theta}_1}\right) = \vec{l}_2\, m_2(\ddot{\theta}_1+\ddot{\theta}_2) + 4(\ddot{\theta}_1+\ddot{\theta}_2)\dot{\theta}_2\vec{l}_1\vec{l}_2\, m_2\sin\theta_2\cos\theta_2 + 4(\ddot{\theta}_1 \tag{12}$$

$$+\ddot{\theta}_2)\vec{l}_4\, m_3\sin^2(\theta_1+\theta_2) + 4(\dot{\theta}_1+\dot{\theta}_2)^3\,\vec{l}_4\, m_3\cos(\theta_1+\theta_2) + 2(\dot{\theta}_1+\dot{\theta}_2)\vec{l}_4$$

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

$$\sin\theta_2 - 2(\dot{\theta}_1+\dot{\theta}_2)\dot{\theta}_2\vec{l}_1\vec{l}_2\, m_2\sin\theta_1 + 2\ddot{\theta}\vec{l}_1\vec{l}_2\, m_2\cos\theta_2 - 2\dot{\theta}^2\,\vec{l}_1\vec{l}_2\, m_2$$

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

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

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

$$)\cos\theta_3 + \vec{l}_2\vec{l}_3\, m_3(\ddot{\theta}_1+\dddot{\theta}_2+\ddot{\theta}_3)\cos\theta_3 + \vec{l}_2\vec{l}_3\, m_3(\dot{\theta}_1+\dot{\theta}_2+\dot{\theta}_3)\dot{\theta}_3 + 4(\ddot{\theta}_1+$$

$$\ddot{\theta}_2)\vec{l}_1\vec{l}_4\, m_3\cos(\theta_1+\theta_2) + 2(\dot{\theta}_1+\dot{\theta}_2)^3\,\vec{l}_1\vec{l}_4\, m_3\cos(\theta_1+\theta_2) - 2(\dot{\theta}_1+\dot{\theta}_2+\dot{\theta}_3$$

$$)\vec{l}_1\vec{l}_4\, m_3\sin(\theta_1+\theta_2+\theta_3)$$

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

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

$$\frac{\partial E_K}{\partial \theta_1}=\vec{l}_1(\vec{l}_1+\vec{l}_4+\vec{l}_5)(m_1+m_2+m_3)\theta_1+\vec{l}_2(\vec{l}_3+\vec{l}_4+\vec{l}_5)\ m_2(\theta_1+\theta_2)+\vec{l}_3(\vec{l}_3+\vec{l}_4+\vec{l}_5)\ m_3(\theta_1+\theta_2+\theta_3)+2\vec{l}_4 m_5\dot{\theta}_1(\dot{\theta}_1+\dot{\theta}_2)^2\sin(\theta_1+\theta_2)-2\vec{l}_4 m_5\dot{\theta}_1(\dot{\theta}_1+\dot{\theta}_2+\dot{\theta}_3)^2\sin(\theta_1+\theta_2+\theta_3)-\vec{l}_1\vec{l}_2 m_2\dot{\theta}_1(\dot{\theta}_1+\dot{\theta}_2+\dot{\theta}_3)\sin(\theta_1+\theta_2)+(\vec{l}_4+\vec{l}_5)(m_2+m_2+m_3)\theta_1+(\vec{l}_4+\vec{l}_5)m_2(\theta_1+\theta_2)+2\vec{l}_1\vec{l}_4 m_3(\dot{\theta}_1+\dot{\theta}_2)\cos(\theta_1+\theta_2)+2\vec{l}_1\vec{l}_4 m_3(\dot{\theta}_1+\dot{\theta}_2+\dot{\theta}_3)\cos(\theta_1+\theta_2) \tag{15}$$

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

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

As seen in Table 1 the parameter in robot arm is listed. [1]

Table 1 Parameters of robot arms

items	Value
11 /m	0.55
12 /m	0.5
13 /m	0.3
m1/N	7.7
m2/N	6.6

m3/N	4.0
l4 /m	0.35
l5 /m	0.3
$\dot{\theta}_1$ /°/s	4
$\dot{\theta}_2$ /°/s	4
$\dot{\theta}_3$ /°/s	4
$\ddot{\theta}_1$ /°/s	3
$\ddot{\theta}_2$ /°/s	3
$\ddot{\theta}_3$ /°/s	3

3. Results and Discussion

In terms of dynamic equations it is calculated that the drawing between two parameters. Here v is the hammer velocity in part 3, it is supposed to be 0.02~0.5m/s. Force Fj and torque Mj could be computed in terms of angle θ and acceleration a. Mj is based on v. Fj is based on equation above. Detailed analysis and drawing between them is as below:

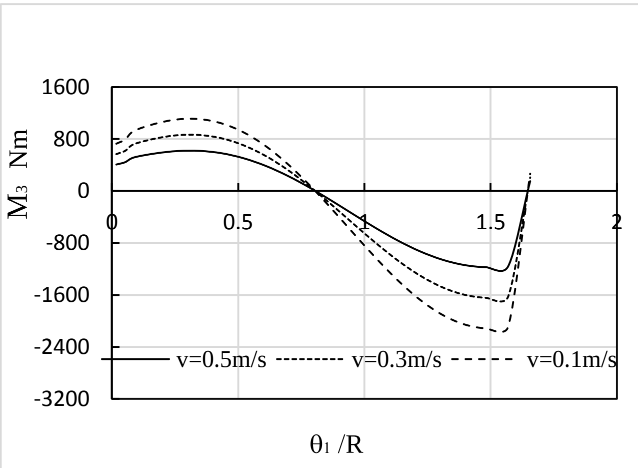

Figure 3 the relations of M& θ with the time in robot arm1

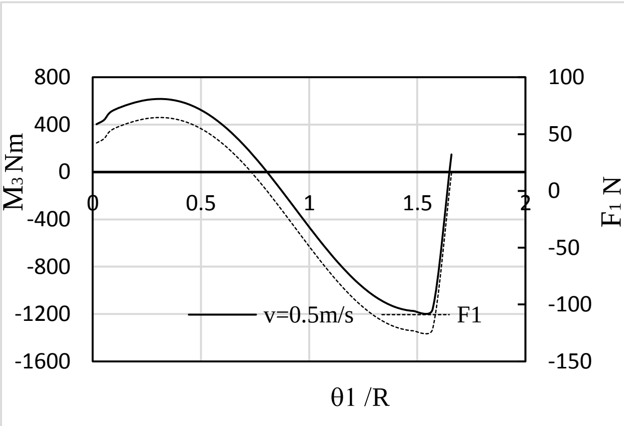

Figure 4 the relations of M& F1 and θ with the time in robot arm1

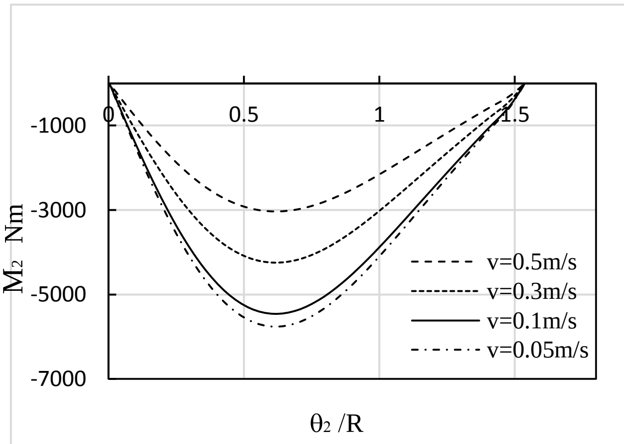

Figure 5 the relations of M and θ with the time in robot arm2

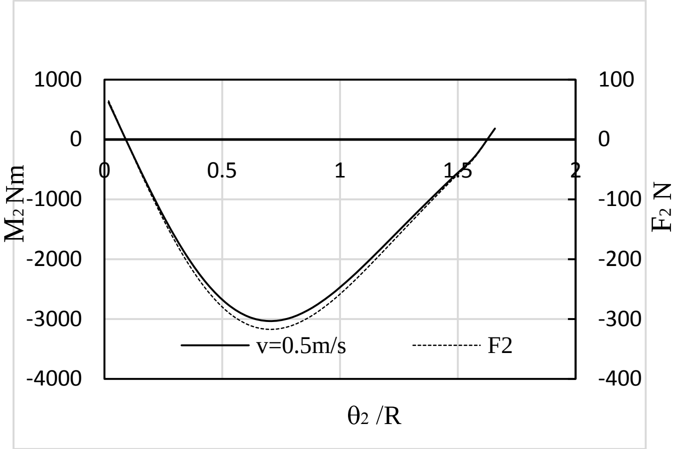

Figure 6 the relations of F1 and θ with the time in robot arm2

And as seen in Figure 4 the force decreases with the increasing angle θ1 to 120N. The M1 torque decreases when θ1 increases from 0 to 2200Nm with the speed of 0.1m/s. As Figure 3 with increasing speed to 0.5m/s the torque will reduce to -1200Nm with the same one. It is 1600Nm with 0.3m/s. The biggest M1 is at 0.2m/s which has the one about above. As seen in Figure 6 F2 reduces when angle changes from above value. The M2 decreases from 3000Nm with the same speed above as Figure 6 with the 0.5m/s. Meantime it is 4500Nm with 0.3m/s. The highest torque M2 has about 6000Nm at the angle θ2 equals 0.6.As Figure 8 the force decreases a little with increasing angle3 from 0 to 1.5N with 0.05m/s while the torque decreases from 0 to 30Nm with the angle. Meantime in Figure 7 torque decreases from 0 to 22Nm with the v of 0.2m/s. The torque raises in terms of speed decreases. The biggest one is at 0.05m/s which has been 25Nm.

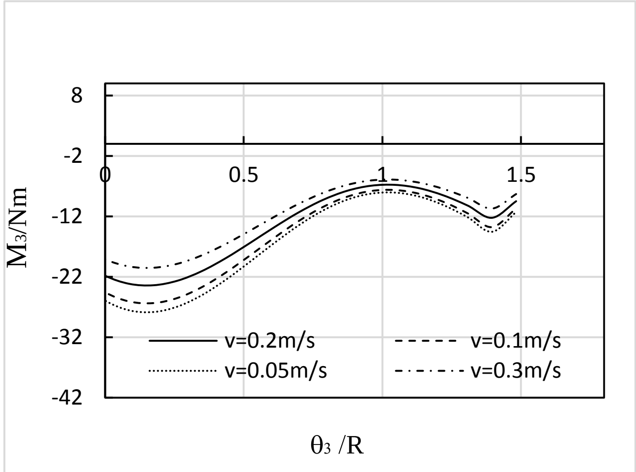

Figure 7 the relations of M and θ with the time in robot arm3

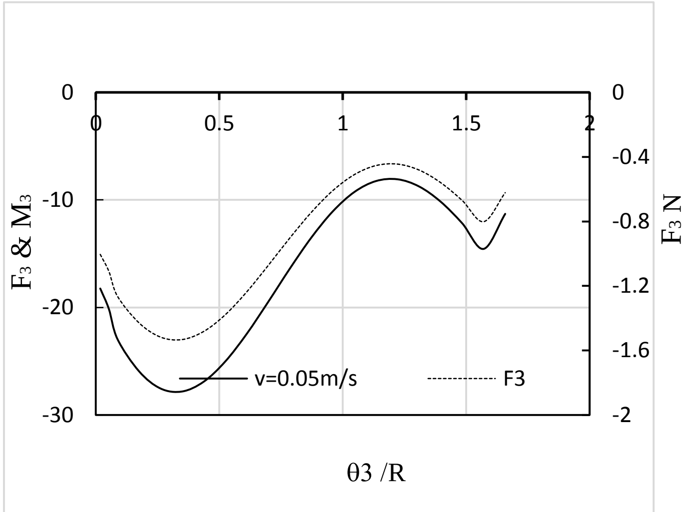

Figure 8 the relations of M &F1 and θ with the time in robot arm3

Potential energy of System

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

(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

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

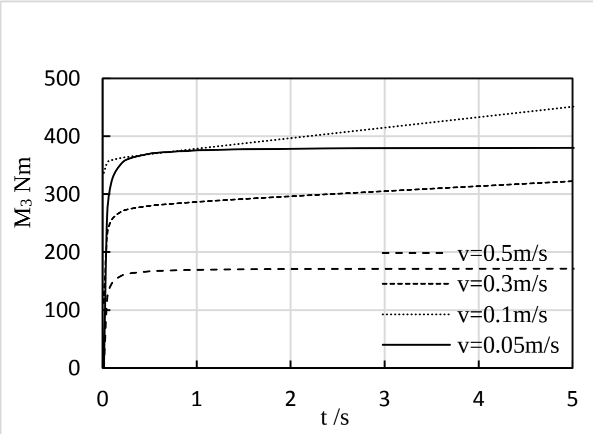

Figure 9 the relations of F_3 and M_3 & time at speed of 0.05~0.5m/s in hammer process.

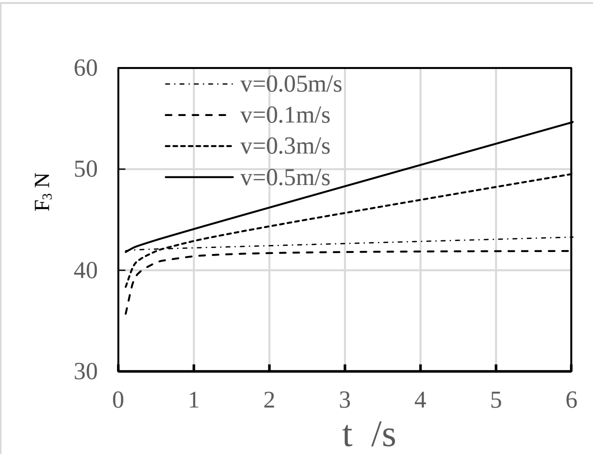

Figure 10 the relations of M_3 & time with the speed v of 0.05~0.5m/s in hammer process.

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 an 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 Me.

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

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

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

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

Replace equation below with above two equations

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

This is generalized force equation.

Figure 9 shows in the hammer process F3 attains 7N when acceleration is 90m/s2. The torque M3 attains 120Nm when is 90m/s2. With increasing a M3 and F3 will increase. On the other hand from Figure 10 with increasing a M3 can increase. Meanwhile when the v increases M3 will be decrease. The biggest one happens with 0.1m/s in hammer working. The 90m/s2 and 0.1m/s are the key parameters in robotic hammer which makes the force and torque the biggest. The biggest one is at a=95m/s2 which has been 138Nm whose value is the biggest.

He biggest one is at acceleration a=95m/s2 which has been 138Nm whose value is the biggest in the course of hammering... It will wield its highest capability to hammering under this condition.

The biggest one is at acceleration a=95m/s2 which has been 138Nm whose value is the biggest in the course of hammering... It wields its highest capability to hammering under this circumstance.

3 Conclusions

In the modeling of five freedoms in hammer of robotic arm the kinetic equation is established according to Lagrange equation based on two freedoms robotic arm. It compensates the blank in three freedoms and one impulsion on robotic arm. It is found that the first and second item is complicated and long besides others is concise. Referring to the important occasion the kinetic equation will only be computed on three freedoms according to this study. The M1 torque decreases when θ1 increases to 2200Nm with the speed of 0.1m/s. The highest torque M2 has about 6000Nm at the angle θ2 equals 0.6. The biggest one is at a=95m/s2 which has been 138Nm whose value is the biggest.

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