```
clc;clear;close all;
syms m_p L_p L_r J_p J_r
syms alpha(t) theta(t) t taw
syms D_p D_r g
Eq1=(m_p*L_r^2+0.25*m_p*L_p^2*(1-cos(alpha(t)))+J_r)*...
    diff(theta,2)-0.5*m_p*L_p*L_r*cos(alpha)*diff(alpha,2)+...
    0.5*m_p*L_p^2*sin(alpha)*cos(alpha)*diff(theta)*diff(alpha)+...
    0.5*m_p*L_p*L_r*sin(alpha)*alpha^2==taw-D_r*diff(theta)
```

Eq1(t) =

$$\left(-\frac{m_p\,(\cos(\alpha(t))-1)\,L_p^2}{4}+m_p\,L_r^2+J_r\right)\frac{\partial^2}{\partial t^2}\,\theta(t)-\frac{L_p\,L_r\,m_p\cos(\alpha(t))\,\frac{\partial^2}{\partial t^2}\,\alpha(t)}{2}+\frac{L_p\,L_r\,m_p\sin(\alpha(t))\,\alpha(t)^2}{2}$$

```
Eq2=0.5*m_p*L_p*L_r*cos(alpha)*diff(theta,2)+(J_p+0.25*m_p*L_p^2)*diff(alpha,2)...
    -0.25*m_p*L_p^2*cos(alpha)*sin(alpha)*diff(theta)^2+0.5*m_p*L_p*g*sin(alpha)==-D_p*diff(alp
```

Eq2(t) =

$$\left(\frac{m_p\,L_p^2}{4}+J_p\right)\frac{\partial^2}{\partial t^2}\,\alpha(t)+\frac{L_p\,g\,m_p\sin(\alpha(t))}{2}-\frac{L_p^2\,m_p\cos(\alpha(t))\sin(\alpha(t))\left(\frac{\partial}{\partial t}\,\theta(t)\right)^2}{4}+\frac{L_p\,L_r\,m_p\cos(\alpha(t))\,\frac{\partial}{\partial}}{2}$$

```
Eq3=isolate(Eq1,diff(theta,2))
```

Eq3 =

$$\frac{\partial^2}{\partial t^2}\,\theta(t)=-\frac{D_r\,\frac{\partial}{\partial t}\,\theta(t)-\mathrm{taw}-\frac{L_p\,L_r\,m_p\cos(\alpha(t))\,\frac{\partial^2}{\partial t^2}\,\alpha(t)}{2}+\frac{L_p\,L_r\,m_p\sin(\alpha(t))\,\alpha(t)^2}{2}+\frac{L_p^2\,m_p\cos(\alpha(t))\,\mathrm{si}}{}}{-\frac{m_p\,(\cos(\alpha(t))-1)\,L_p^2}{4}+m_p\,L_r^2+J_r}$$

```
Eq4=isolate(Eq2,diff(alpha,2))
```

Eq4 =

$$\frac{\partial^2}{\partial t^2}\,\alpha(t)=-\frac{\frac{L_r\,m_p\cos(\alpha(t))\,L_p\,\frac{\partial^2}{\partial t^2}\,\theta(t)}{2}-\frac{m_p\cos(\alpha(t))\sin(\alpha(t))\,L_p^2\left(\frac{\partial}{\partial t}\,\theta(t)\right)^2}{4}+D_p\,\frac{\partial}{\partial t}\,\alpha(t)+\frac{g\,m_p\sin(\alpha}{2}}{\frac{m_p\,L_p^2}{4}+J_p}$$

```
Eq5=subs(Eq3,diff(alpha,2),rhs(Eq4));
Eq5=isolate(Eq5,diff(theta,2));
Eq5=simplifyFraction(Eq5)
```

Eq5 =

$$\frac{\partial^2}{\partial t^2}\,\theta(t)=-\frac{2\left(8\,D_r\,J_p\,\frac{\partial}{\partial t}\,\theta(t)-8\,J_p\,\mathrm{taw}-2\,L_p^2\,m_p\,\mathrm{taw}+2\,D_r\,L_p^2\,m_p\,\frac{\partial}{\partial t}\,\theta(t)+L_p^3\,L_r\,m_p^2\sin(\alpha(t))\,\alpha(t)^{}\right.}{}$$

```
% simplify(rhs(Eq5),"Steps",10)
% expand(Eq5)
% a=factor(rhs(Eq5),diff(theta))
```

```
Eq6=subs(Eq4,diff(theta,2),rhs(Eq3));
Eq6=isolate(Eq6,diff(alpha,2));
Eq6=simplifyFraction(Eq6)
```

```
Eq6 =
```

$$\frac{\partial^2}{\partial t^2}\ \alpha(t) = -\frac{16\,D_p\,J_r\,\frac{\partial}{\partial t}\ \alpha(t) + 4\,D_p\,L_p{}^2\,m_p\,\frac{\partial}{\partial t}\ \alpha(t) + 16\,D_p\,L_r{}^2\,m_p\,\frac{\partial}{\partial t}\ \alpha(t) + 2\,L_p{}^3\,g\,m_p{}^2\,\sin(\alpha(t)) + 8\,L_p\,L_r}{}$$