

Appendix A

Parameters of the Mass Matrix of the Dynamic Equation of Motion

Symbols of the parameters used are given in Table???. Some of the parameters are calculated as shown below.

$$d_i = l_i/2, J_{o_i} = \frac{1}{3}m_i l_i^2,$$

$$v_{ij} = \int_0^{l_i} [\rho_i \phi_{ij}(x_i)] dx_i,$$

$$w_{dij} = \int_0^{l_i} [\rho_i \phi_{ij}(x_i) x_i] dx_i,$$

$$\phi_{ije} = \phi_{ij} \Big|_{(x_i=l_i)}$$

$$\text{For link-1, } ML_1 = m_2 + m_{h2} + m_p \text{ and } JL_1 = J_{o2} + J_{h2} + J_p + m_p l_2^2,$$

$$ML_2 = m_p,$$

$$JL_2 = J_p,$$

The constant coefficients of the mass matrix are calculated as follows.

$$b_{111} = J_{h1} + J_{o1} + J_{h2} + m_{h2} l_1^2 + J_{o2} + m_2 l_1^2 + J_p + m_p (l_1^2 + l_2^2),$$

$$b_{112} = 2(m_2 d_2 + m_p l_2) l_1,$$

$$b_{113} = 2(m_2 d_2 + m_p l_2),$$

$$b_{114} = -2l_1,$$

$$b_{121} = J_{h2} + J_{o2} + J_p + m_p l_2^2,$$

$$b_{122} = (m_2 d_2 + m_p l_2) l_1,$$

$$b_{123} = m_2 d_2 + m_p l_2,$$

$$\begin{aligned}
b_{124} &= -l_1, \\
b_{131} &= w_{11} + (J_{h2} + J_{o2} + J_p + m_p l_2^2) \phi'_{11e} + (m_{h2} + m_2 + m_p) l_1 \phi_{11e}, \\
b_{132} &= (m_2 d_2 + m_p l_2) (\phi_{11e} + l_1 \phi'_{11e}), \\
b_{133} &= -(\phi_{11e} + l_1 \phi'_{11e}), \\
b_{134} &= -(m_2 d_2 + m_p l_2) (\phi_{11e} \phi'_{12e} - \phi_{12e} \phi'_{11e}), \\
b_{141} &= w_{d12} + (J_{h2} + J_{o2} + J_p + m_p l_2^2) \phi'_{12e} + (m_{h2} + m_2 + m_p) l_1 \phi_{12e}, \\
b_{142} &= (m_2 d_2 + m_p l_2) (\phi_{12e} + l_1 \phi'_{12e}), \\
b_{143} &= -(\phi_{12e} + l_1 \phi'_{12e}), \\
b_{144} &= -(m_2 d_2 + m_p l_2) (\phi_{12e} \phi'_{11e} - \phi_{11e} \phi'_{12e}), \\
b_{151} &= w_{d21} + J_p \phi'_{21e} + m_p l_2 \phi_{21e}, \\
b_{152} &= (v_{21} + m_p \phi_{21e}) l_1, \\
b_{153} &= v_{21} + m_p \phi_{21e}, \\
b_{161} &= w_{d22} + J_p \phi'_{22e} + m_p l_2 \phi_{22e}, \\
b_{162} &= (v_{22} + m_p \phi_{22e}) l_1, \\
b_{163} &= v_{22} + m_p \phi_{22e}, \\
b_{221} &= J_{h2} + J_{o2} + J_p + m_p l_2^2, \\
b_{231} &= (J_{h2} + J_{o2} + J_p + m_p l_2^2) \phi'_{11e}, \\
b_{232} &= (m_2 d_2 + m_p l_2) \phi_{11e}, \\
b_{233} &= -\phi_{11e}, \\
b_{234} &= -(m_2 d_2 + m_p l_2) \phi_{11e}, \\
b_{241} &= (J_{h2} + J_{o2} + J_p + m_p l_2^2) \phi'_{12e}, \\
b_{242} &= (m_2 d_2 + m_p l_2) \phi_{12e}, \\
b_{243} &= -\phi_{12e}, \\
b_{244} &= -(m_2 d_2 + m_p l_2) \phi_{12e}, \\
b_{251} &= w_{d21} + J_p \phi'_{21e} + m_p l_2 \phi_{21e}, \\
b_{261} &= w_{d22} + J_p \phi'_{22e} + m_p l_2 \phi_{22e}, \\
b_{331} &= m_1, \\
b_{332} &= 2(m_2 d_2 + m_p l_2) \phi_{11e} \phi'_{11e}, \\
b_{333} &= -2\phi_{11e} \phi'_{11e}, \\
b_{341} &= 0, \\
b_{342} &= (m_2 d_2 + m_p l_2) (\phi_{11e} \phi'_{12e} + \phi_{12e} \phi'_{11e}),
\end{aligned}$$

$$\begin{aligned}
b_{343} &= -(\phi_{11e}\phi'_{12e} + \phi_{12e}\phi'_{11e}), \\
b_{351} &= (w_{d21} + J_p\phi'_{21e} + m_p l_2 \phi_{21e})\phi'_{11e}, \\
b_{352} &= (v_{21} + m_p \phi_{21e})\phi_{11e}, \\
b_{353} &= -(v_{21} + m_p \phi_{21e})\phi'_{11e}, \\
b_{361} &= (w_{d22} + J_p\phi'_{22e} + m_p l_2 \phi_{22e})\phi'_{11e}, \\
b_{362} &= (v_{22} + m_p \phi_{22e})\phi_{11e}, \\
b_{363} &= -(v_{22} + m_p \phi_{22e})\phi'_{11e}, \\
b_{441} &= m_1, \\
b_{442} &= 2(m_2 d_2 + m_p l_2)\phi_{12e}\phi'_{12e}, \\
b_{443} &= -2\phi_{12e}\phi'_{12e}, \\
b_{451} &= (w_{d21} + J_p\phi'_{21e} + m_p l_2 \phi_{21e})\phi'_{12e}, \\
b_{452} &= (v_{21} + m_p \phi_{21e})\phi_{12e}, \\
b_{453} &= -(v_{21} + m_p \phi_{21e})\phi'_{12e}, \\
b_{461} &= (w_{d22} + J_p\phi'_{22e} + m_p l_2 \phi_{22e})\phi'_{12e}, \\
b_{462} &= (v_{22} + m_p \phi_{22e})\phi_{12e}, \\
b_{463} &= -(v_{22} + m_p \phi_{22e})\phi'_{12e}, \\
b_{551} &= m_2, \\
b_{561} &= 0, \\
b_{661} &= m_2, \\
t_{11} &= \phi_{11e} - l_1\phi'_{11e}, \\
t_{12} &= \phi_{12e} - l_1\phi'_{12e}, \\
t_{21} &= v_{21} + m_p \phi_{21e}, \\
t_{22} &= v_{22} + m_p \phi_{22e}, \\
t_{31} &= \phi'_{11e}, \\
t_{32} &= \phi'_{12e}, \\
t_1 &= t_{11}\delta_{11} + t_{12}\delta_{12}, \\
t_2 &= t_{21}\delta_{21} + t_{22}\delta_{22}, \\
t_3 &= t_{31}\delta_{11} + t_{32}\delta_{12},
\end{aligned}$$

The inertia matrix is formed as $B(1, 1) = b_{111} + b_{112}c_2 + (b_{113}t_1 + b_{114}t_2)s_2$,

$$B(1, 2) = b_{121} + b_{122}c_2 + (b_{123}t_1 + b_{124}t_2)s_2,$$

$$B(1, 3) = b_{131} + b_{132}c_2 + (b_{133}t_2 + b_{134}\delta_{12}) * s_2,$$

$$\begin{aligned}
B(1, 4) &= b_{141} + b_{142}c_2 + (b_{143}t_2 + b_{144}\delta_{11}) * s_2, \\
B(1, 5) &= b_{151} + b_{152}c_2 + b_{153}t_1s_2, \\
B(1, 6) &= b_{161} + b_{162}c_2 + b_{163}t_1s_2, \\
B(2, 1) &= B(1, 2), \\
B(2, 2) &= b_{221}, \\
B(2, 3) &= b_{231} + b_{232}c_2 + (b_{233}t_2 + b_{234}t_3)s_2, \\
B(2, 4) &= b_{241} + b_{242}c_2 + (b_{243}t_2 + b_{244}t_3)s_2, \\
B(2, 5) &= b_{251}, \\
B(2, 6) &= b_{261}, \\
B(3, 1) &= B(1, 3), \\
B(3, 2) &= B(2, 3), \\
B(3, 3) &= b_{331} + b_{332}c_2 + b_{333}t_2s_2, \\
B(3, 4) &= b_{341} + b_{342}c_2 + b_{343}t_2s_2, \\
B(3, 5) &= b_{351} + b_{352}c_2 + b_{353}t_3s_2, \\
B(3, 6) &= b_{361} + b_{362}c_2 + b_{363}t_3s_2, \\
B(4, 1) &= B(1, 4), \\
B(4, 2) &= B(2, 4), \\
B(4, 3) &= B(3, 4), \\
B(4, 4) &= b_{441} + b_{442}c_2 + b_{443}t_2s_2, \\
B(4, 5) &= b_{451} + b_{452}c_2 + b_{453}t_3s_2, \\
B(4, 6) &= b_{461} + b_{462}c_2 + b_{463}t_3s_2, \\
B(5, 1) &= B(1, 5), \\
B(5, 2) &= B(2, 5), \\
B(5, 3) &= B(3, 5), \\
B(5, 4) &= B(4, 5), \\
B(5, 5) &= b_{551}, \\
B(5, 6) &= b_{561}, \\
B(6, 1) &= B(1, 6), \\
B(6, 2) &= B(2, 6), \\
B(6, 3) &= B(3, 6), \\
B(6, 4) &= B(4, 6),
\end{aligned}$$

$$B(6, 5) = B(5, 6),$$

$$B(6, 6) = b_{661},$$

where $c_2 = \cos\theta_2$ and $s_2 = \sin\theta_2$

Components of \mathbf{h} matrix is evaluated as follows

$$h_{101} = -2(m_2 d_2 + m_p l_2) l_1,$$

$$h_{102} = 2(m_2 d_2 + m_p l_2)(\phi_{11e} - l_1 \phi'_{11e}),$$

$$h_{103} = 2(m_2 d_2 + m_p l_2)(\phi_{12e} - l_1 \phi'_{12e}),$$

$$h_{104} = -2(v_{21} + m_p \phi_{21e}) l_1,$$

$$h_{105} = -2(v_{22} + m_p \phi_{22e}) l_1,$$

$$h_{106} = -(m_2 d_2 + m_p l_2) l_1,$$

$$h_{107} = -(m_2 d_2 + m_p l_2) l_1 \phi'_{11e},$$

$$h_{108} = -2(m_2 d_2 + m_p l_2) l_1 \phi'_{12e},$$

$$h_{109} = -2 * (v_{21} + m_p * \phi_{21e}) * l_1,$$

$$h_{110} = -2 * (v_{22} + m_p * \phi_{22e}) * l_1,$$

$$h_{111} = -2 * (v_{21} + m_p * \phi_{21e}) * l_1 * \phi'_{11e},$$

$$h_{112} = -2 * (v_{22} + m_p * \phi_{22e}) * l_1 * \phi'_{11e},$$

$$h_{113} = -2 * (v_{21} + m_p * \phi_{21e}) * l_1 * \phi'_{12e},$$

$$h_{114} = -2 * (v_{22} + m_p * \phi_{22e}) * l_1 * \phi'_{12e},$$

$$h_{115} = 2 * (m_2 * d_2 + m_p * l_2),$$

$$h_{116} = m_2 * d_2 + m_p * l_2,$$

$$h_{117} = -(v_{21} + m_p * \phi_{21e}),$$

$$h_{118} = -(v_{22} + m_p * \phi_{22e}),$$

$$h_{119} = -2 * l_1,$$

$$h_{120} = -l_1,$$

$$h_{121} = -(\phi_{11e} + l_1 * \phi'_{11e}),$$

$$h_{122} = -(\phi_{12e} + l_1 * \phi'_{12e}),$$

$$h_{123} = -(m_2 * d_2 + m_p * l_2) * (\phi_{11e} * \dot{p}h_{i_{12}} - \phi_{12e} * \phi'_{11e}),$$

$$h_{124} = -(m_2 * d_2 + m_p * l_2) * (\phi_{12e} * \phi'_{11e} - \phi_{11e} * \phi'_{12e}),$$

$$h_{201} = (m_2 * d_2 + m_p * l_2) * l_1,$$

$$h_{202} = 2 * (m_2 * d_2 + m_p * l_2) * \phi_{11e},$$

$$h_{203} = 2 * (m_2 * d_2 + m_p * l_2) * \phi_{12e},$$

$$\begin{aligned}
h_{204} &= -(m_2 * d_2 + m_p * l_2), \\
h_{205} &= -(v_2 1 + m_p * \phi_{21e}), \\
h_{206} &= -(v_{22} + m_p * \phi_{22e}), \\
h_{207} &= l_1, \\
h_{208} &= \phi_{11e} + l_1 * \phi'_{11e}, \\
h_{209} &= \phi_{12e} + l_1 * \phi'_{12e}, \\
h_{210} &= (m_2 * d_2 + m_p * l_2) * (\phi_{11e} * \phi'_{12e} - \phi_{12e} * \phi'_{11e}), \\
h_{211} &= (m_2 * d_2 + m_p * l_2) * (\phi_{12e} * \phi'_{11e} - \phi_{11e} * \phi'_{12e}), \\
h_{212} &= \phi_{11e} * \phi'_{11e}, \\
h_{213} &= \phi_{11e} * \phi'_{12e} + \phi_{12e} * \phi'_{11e}, \\
h_{214} &= (v_{21} + m_p * \phi_{21e}) * \phi_{11e}, \\
h_{215} &= (v_{22} + m_p * \phi_{22e}) * \phi_{11e}, \\
h_{216} &= \phi_{12e} * \phi'_{12e}, \\
h_{217} &= (v_{21} + m_p * \phi_{21e}) * \phi_{12e}, \\
h_{218} &= (v_{22} + m_p * \phi_{22e}) * \phi_{12e}, \\
h_{301} &= -(m_2 * d_2 + m_p * l_2) * (\phi_{11e} - l_1 * \phi'_{11e}), \\
h_{302} &= -2 * (m_2 * d_2 + m_p * l_2) * \phi_{11e}, \\
h_{303} &= 2 * (m_2 * d_2 + m_p * l_2) * (\phi_{12e} * \phi'_{11e} - \phi_{11e} * \phi'_{12e}), \\
h_{304} &= -2 * (v_{21} + m_p * \phi_{21e}) * \phi_{11e}, \\
h_{305} &= -2 * (v_{22} + m_p * \phi_{22e}) * \phi_{11e}, \\
h_{306} &= -(m_2 * d_2 + m_p * l_2) * \phi_{11e}, \\
h_{307} &= -2 * (m_2 * d_2 + m_p * l_2) * \phi_{11e} * \phi'_{11e}, \\
h_{308} &= -2 * (m_2 * d_2 + m_p * l_2) * \phi_{11e} * \phi'_{12e}, \\
h_{309} &= -2 * (v_{21} + m_p * \phi_{21e}) * \phi_{11e}, \\
h_{310} &= -2 * (v_{22} + m_p * \phi_{22e}) * \phi_{11e}, \\
h_{311} &= -2 * (v_{21} + m_p * \phi_{21e}) * \phi_{11e} * \phi'_{11e}, \\
h_{312} &= -2 * (v_{22} + m_p * \phi_{22e}) * \phi_{11e} * \phi'_{11e}, \\
h_{313} &= -2 * (v_{21} + m_p * \phi_{21e}) * \phi_{11e} * \phi'_{12e}, \\
h_{314} &= -2 * (v_{22} + m_p * \phi_{22e}) * \phi_{11e} * \phi'_{12e}, \\
h_{315} &= -(\phi_{11e} + l_1 * \phi'_{11e}), \\
h_{316} &= -\phi_{11e},
\end{aligned}$$

$$\begin{aligned}
h_{317} &= -2 * \phi_{11e} * \phi'_{11e}, \\
h_{318} &= -(\phi_{11e} * \phi'_{12e} + \phi_{12e} * \phi'_{11e}), \\
h_{319} &= -(m_2 * d_2 + m_p * l_2) * \phi_{11e}, \\
h_{320} &= -(v_{21} + m_p * \phi_{21e}) * \phi_{11e}, \\
h_{321} &= -(v_{22} + m_p * \phi_{22e}) * \phi_{11e}, \\
h_{322} &= -(m_2 * d_2 + m_p * l_2) * (\phi_{11e} * \phi'_{12e} - \phi_{12e} * \phi'_{11e}), \\
h_{401} &= -(m_2 * d_2 + m_p * l_2) * (\phi_{12e} - l_1 * \phi'_{12e}), \\
h_{402} &= -2 * (m_2 * d_2 + m_p * l_2) * \phi_{12e}, \\
h_{403} &= 2 * (m_2 * d_2 + m_p * l_2) * (\phi_{11e} * \phi_{12e} - \phi_{12e} * \phi'_{11e}), \\
h_{404} &= -2 * (v_{21} + m_p * \phi_{21e}) * \phi_{12e}, \\
h_{405} &= -2 * (v_{22} + m_p * \phi_{22e}) * \phi_{12e}, \\
h_{406} &= -(m_2 * d_2 + m_p * l_2) * \phi_{12e}, \\
h_{407} &= -2 * (m_2 * d_2 + m_p * l_2) * \phi_{12e} * \phi'_{11e}, \\
h_{408} &= -2 * (m_2 * d_2 + m_p * l_2) * \phi_{12e} * \phi'_{12e}, \\
h_{409} &= -2 * (v_{21} + m_p * \phi_{21e}) * \phi_{12e}, \\
h_{410} &= -2 * (v_{22} + m_p * \phi_{22e}) * \phi_{12e}, \\
h_{411} &= -2 * (v_{21} + m_p * \phi_{21e}) * \phi_{12e} * \phi'_{11e}, \\
h_{412} &= -2 * (v_{22} + m_p * \phi_{22e}) * \phi_{12e} * \phi'_{12e}, \\
h_{413} &= -2 * (v_{21} + m_p * \phi_{21e}) * \phi_{12e} * \phi'_{11e}, \\
h_{414} &= -2 * (v_{22} + m_p * \phi_{22e}) * \phi_{12e} * \phi'_{12e}, \\
h_{415} &= -(\phi_{12e} + l_1 * \phi'_{12e}), \\
h_{416} &= -\phi_{12e}, \\
h_{417} &= -(\phi_{11e} * \phi'_{12e} + \phi_{12e} * \phi'_{11e}), \\
h_{418} &= -2 * \phi_{12e} * \phi'_{12e}, \\
h_{419} &= -(m_2 * d_2 + m_p * l_2) * \phi_{12e}, \\
h_{420} &= -(v_{21} + m_p * \phi_{21e}) * \phi_{12e}, \\
h_{421} &= -(v_{22} + m_p * \phi_{22e}) * \phi_{12e}, \\
h_{422} &= -(m_2 * d_2 + m_p * l_2) * (\phi_{12e} * \phi'_{11e} - \phi_{11e} * \phi'_{12e}), \\
h_{501} &= (v_{21} + m_p * \phi_{21e}) * l_1, \\
h_{502} &= 2 * (v_{21} + m_p * \phi_{21e}) * \phi_{11e}, \\
h_{503} &= 2 * (v_{21} + m_p * \phi_{21e}) * \phi_{12e},
\end{aligned}$$

$$h_{504} = v_{21} + m_p * \phi_{21e},$$

$$h_{505} = -(v_{21} + m_p * \phi_{21e}) * \phi_{11e},$$

$$h_{506} = -(v_{21} + m_p * \phi_{21e}) * \phi_{12e},$$

$$h_{601} = (v_{22} + m_p * \phi_{22e}) * l_1,$$

$$h_{602} = 2 * (v_{22} + m_p * \phi_{22e}) * \phi_{11e},$$

$$h_{603} = 2 * (v_{22} + m_p * \phi_{22e}) * \phi_{12e},$$

$$h_{604} = v_{22} + m_p * \phi_{22e},$$

$$h_{605} = -(v_{22} + m_p * \phi_{22e}) * \phi_{11e},$$

$$h_{606} = -(v_{22} + m_p * \phi_{22e}) * \phi_{12e},$$

$$\begin{aligned}
h(1) &= ((h_{101} * \dot{\theta}_2 + h_{102} * \dot{\delta}_{11} + h_{103} * \dot{\delta}_{12} + h_{104} * \dot{\delta}_{21} + h_{105} * \dot{\delta}_{22}) * \dot{\theta}_1 \\
&+ (h_{106} * \dot{\theta}_2 + h_{107} * \dot{\delta}_{11} + h_{108} * \dot{\delta}_{12} + h_{109} * \dot{\delta}_{21} + h_{110} * \dot{\delta}_{22}) * \dot{\theta}_2 + (h_{111} * \dot{\delta}_{21} + h_{112} * \dot{\delta}_{22}) * \dot{\delta}_{11} \\
&+ (h_{113} * \dot{\delta}_{21} + h_{114} * \dot{\delta}_{22}) * \dot{\delta}_{12}) * s_2 + ((h_{115} * \dot{\theta}_1 + h_{116} * \dot{\theta}_2 + h_{117} * \dot{\delta}_{21} + h_{118} * \dot{\delta}_{22}) * t1 \\
&+ (h_{119} * \dot{\theta}_1 + h_{120} * \dot{\theta}_2 + h_{121} * \dot{\delta}_{11} + h_{122} * \dot{\delta}_{12}) * t2 + h_{123} * \delta_{12} * \dot{\delta}_{11} + h_{124} * \delta_{11} * \dot{\delta}_{12}) * \dot{\theta}_2 * c_2 \\
h(2) &= (h_{201} * \dot{\theta}_1 + h_{202} * \dot{\delta}_{11} + h_{203} * \dot{\delta}_{12}) * \dot{\theta}_1 * s_2 + [(h_{204} * \dot{\theta}_1 + h_{205} * \dot{\delta}_{21} + h_{206} * \dot{\delta}_{22}) * t1 \\
&+ (h_{207} * \dot{\theta}_1 + h_{208} * \dot{\delta}_{11} + h_{209} * \dot{\delta}_{12}) * t2 + h_{210} * \delta_{12} * \dot{\delta}_{11} + h_{211} * \delta_{11} * \dot{\delta}_{12}) * \dot{\theta}_1 \\
&+ ((h_{212} * \dot{\delta}_{11} + h_{213} * \dot{\delta}_{12}) * t2 + (h_{214} * \dot{\delta}_{21} + h_{215} * \dot{\delta}_{22}) * t3) * \dot{\delta}_{11} \\
&+ (h_{216} * \dot{\delta}_{12} * t2 + (h_{217} * \dot{\delta}_{21} + h_{218} * \dot{\delta}_{22}) * t3) * \dot{\delta}_{12}] * c_2 \\
h(3) &= [(h_{301} * \dot{\theta}_1 + h_{302} * \dot{\theta}_2 + h_{303} * \dot{\delta}_{12} + h_{304} * \dot{\delta}_{21} + h_{305} * \dot{\delta}_{22}) * \dot{\theta}_1 \\
&+ (h_{306} * \dot{\theta}_2 + h_{307} * \dot{\delta}_{11} + h_{308} * \dot{\delta}_{12} + h_{309} * \dot{\delta}_{21} + h_{310} * \dot{\delta}_{22}) * \dot{\theta}_2 \\
&+ (h_{311} * \dot{\delta}_{21} + h_{312}) * \dot{\delta}_{22}) * \dot{\delta}_{11} + (h_{313} * \dot{\delta}_{21} + h_{314} * \dot{\delta}_{22}) * \dot{\delta}_{12}] * s_2 \\
&+ [(h_{315} * \dot{\theta}_1 + h_{316} * \dot{\theta}_2 + h_{317} * \dot{\delta}_{11} + h_{318} * \dot{\delta}_{12}) * t2 + (h_{319} * \dot{\theta}_2 + h_{320} * \dot{\delta}_{21} \\
&+ h_{321} * \dot{\delta}_{22}) * t3 + h_{322} * \delta_{12} * \dot{\theta}_1] * \dot{\theta}_2 * c_2 \\
h(4) &= [(h_{401} * \dot{\theta}_1 + h_{402} * \dot{\theta}_2 + h_{403} * \dot{\delta}_{11} + h_{404} * \dot{\delta}_{21} + h_{405} * \dot{\delta}_{22}) * \dot{\theta}_1 \\
&+ (h_{406} * \dot{\theta}_2 + h_{407} * \dot{\delta}_{11} + h_{408} * \dot{\delta}_{12} + h_{409} * \dot{\delta}_{21} + h_{410} * \dot{\delta}_{22}) * \dot{\theta}_2 \\
&+ (h_{411} * \dot{\delta}_{21} + h_{412} * \dot{\delta}_{22}) * \dot{\delta}_{11} + (h_{413} * \dot{\delta}_{21} + h_{414} * \dot{\delta}_{22}) * \dot{\delta}_{12}] * s_2 \\
&+ [(h_{415} * \dot{\theta}_1 + h_{416} * \dot{\theta}_2 + h_{417} * \dot{\delta}_{11} + h_{418} * \dot{\delta}_{12}) * t2 + (h_{419} * \dot{\theta}_2 + h_{420} * \dot{\delta}_{21} \\
&+ h_{421} * \dot{\delta}_{22}) * t3 + h_{422} * \delta_{11} * \dot{\theta}_1] * \dot{\theta}_2 * c_2 \\
h(5) &= (h_{501} * \dot{\theta}_1 + h_{502} * \dot{\delta}_{11} + h_{503} * \dot{\delta}_{12}) * \dot{\theta}_1 * s_2 \\
&+ (h_{504} * t1 * \dot{\theta}_1 + (h_{505} * \dot{\delta}_{11} + h_{506} * \dot{\delta}_{12}) * t3) * \dot{\theta}_2 * c_2 \\
h(6) &= (h_{601} * \dot{\theta}_1 + h_{602} * \dot{\delta}_{11} + h_{603} * \dot{\delta}_{12}) * \dot{\theta}_1 * s_2 \\
&+ (h_{604} * t1 * \dot{\theta}_1 + (h_{605} * \dot{\delta}_{11} + h_{606} * \dot{\delta}_{12}) * t3) * \dot{\theta}_2 * c_2
\end{aligned}$$

Vector of Coriolis and centrifugal force is given as $h=[h(1);h(2);h(3);h(4);h(5);h(6)]$

Stiffness matrix is given as

$$K = \text{diag}[0 \ 0 \ (w_{11}^2)m_1 \ (w_{12}^2)m_1 \ (w_{21}^2)m_2 \ (w_{22}^2)m_2],$$

Damping matrix is given as

$$D = 0.1 \text{diag}[0 \ 0 \ \sqrt{(w_{11}^2)m_1} \ \sqrt{(w_{12}^2)m_1} \ \sqrt{(w_{21}^2)m_2} \ \sqrt{(w_{22}^2)m_2}]$$