

$$R = \left(\begin{array}{c} x(t) - cy \sin(a(t)) + cx \cos(a(t)) \\ y(t) + cx \sin(a(t)) + cy \cos(a(t)) \\ 1 \end{array} \right) \quad (1)$$

$$dR = \left(\begin{array}{c} \frac{\partial}{\partial t} x(t) - cy \cos(a(t)) \frac{\partial}{\partial t} a(t) - cx \sin(a(t)) \frac{\partial}{\partial t} a(t) \\ \frac{\partial}{\partial t} y(t) + cx \cos(a(t)) \frac{\partial}{\partial t} a(t) - cy \sin(a(t)) \frac{\partial}{\partial t} a(t) \\ 0 \end{array} \right) \quad (2)$$

$$\begin{aligned} dR^T dR &= (cy (\frac{\partial}{\partial t} a(t)) \cos((a(t))) - (\frac{\partial}{\partial t} x(t)) + cx (\frac{\partial}{\partial t} a(t)) \sin((a(t)))) (cy \cos(a(t)) \frac{\partial}{\partial t} a(t) - \frac{\partial}{\partial t} x(t) + cx \sin(a(t)) \frac{\partial}{\partial t} a(t)) + ((\frac{\partial}{\partial t} y(t)) + \\ &cx (\frac{\partial}{\partial t} a(t)) \cos((a(t))) - cy (\frac{\partial}{\partial t} a(t)) \sin((a(t)))) (\frac{\partial}{\partial t} y(t) + cx \cos(a(t)) \frac{\partial}{\partial t} a(t) - cy \sin(a(t)) \frac{\partial}{\partial t} a(t)) \\ K &= \frac{m ((cy (\frac{\partial}{\partial t} a(t)) \cos((a(t))) - (\frac{\partial}{\partial t} x(t)) + cx (\frac{\partial}{\partial t} a(t)) \sin((a(t)))) (cy \cos(a(t)) \frac{\partial}{\partial t} a(t) - \frac{\partial}{\partial t} x(t) + cx \sin(a(t)) \frac{\partial}{\partial t} a(t)) + ((\frac{\partial}{\partial t} y(t)) + \\ &\frac{2}{cx (\frac{\partial}{\partial t} a(t)) \cos((a(t))) - cy (\frac{\partial}{\partial t} a(t)) \sin((a(t))) (\frac{\partial}{\partial t} y(t) + cx \cos(a(t)) \frac{\partial}{\partial t} a(t) - cy \sin(a(t)) \frac{\partial}{\partial t} a(t))} I (\frac{\partial}{\partial t} a(t)) \frac{\partial}{\partial t} a(t)}{2} + \end{aligned}$$

$$dR^T R dQ = \left(\begin{array}{c} -2 \text{ dat } (cx \text{ dxt } \cos(at) + cy \text{ dyt } \cos(at) + cx \text{ dyt } \sin(at) - cy \text{ dxt } \sin(at)) \\ 0 \\ 0 \end{array} \right) \quad (3)$$

$$dK dq = \left(\begin{array}{c} -m \frac{\partial}{\partial t} a(t) (cx \cos(a(t)) \frac{\partial}{\partial t} x(t) + cy \cos(a(t)) \frac{\partial}{\partial t} y(t) - cy \sin(a(t)) \frac{\partial}{\partial t} x(t) + cx \sin(a(t)) \frac{\partial}{\partial t} y(t)) \\ 0 \\ 0 \end{array} \right) \quad (4)$$

$$\begin{aligned} dK ddq &= \left(\begin{array}{c} I \frac{\partial}{\partial t} a(t) - \frac{cy m \cos(a(t)) \frac{\partial}{\partial t} x(t)}{2} + \frac{cx m \cos(a(t)) \frac{\partial}{\partial t} y(t)}{2} - \frac{cx m \sin(a(t)) \frac{\partial}{\partial t} x(t)}{2} - \frac{cy m \sin(a(t)) \frac{\partial}{\partial t} y(t)}{2} + cx^2 m \cos((a(t)) - a(t)) \frac{\partial}{\partial t} a(t) + cy^2 m \cos((a(t)) - a(t)) \frac{\partial}{\partial t} a(t) - \frac{cy m \cos((a(t))) \frac{\partial}{\partial t} x(t)}{2} + \frac{cx m \cos((a(t))) \frac{\partial}{\partial t} y(t)}{2} \\ - \frac{m (cy \cos((a(t))) \frac{\partial}{\partial t} a(t) - 2 \frac{\partial}{\partial t} x(t) + cx \sin((a(t))) \frac{\partial}{\partial t} a(t) + cy \cos(a(t)) \frac{\partial}{\partial t} a(t) + cx \sin(a(t)) \frac{\partial}{\partial t} a(t))}{2} \\ \frac{m (2 \frac{\partial}{\partial t} y(t) + cx \cos((a(t))) \frac{\partial}{\partial t} a(t) - cy \sin((a(t))) \frac{\partial}{\partial t} a(t) + cx \cos(a(t)) \frac{\partial}{\partial t} a(t) - cy \sin(a(t)) \frac{\partial}{\partial t} a(t))}{2} \end{array} \right) \quad (5) \end{aligned}$$

$$M = \left(\begin{array}{c} -I \text{ ddat} - \frac{m (2 cx (\text{ddyt} + cx \text{ ddat}) - 2 cy (\text{ddxt} - cy \text{ ddat}))}{2} \\ -m (\text{ddxt} - cy \text{ ddat}) \\ -m (\text{ddyt} + cx \text{ ddat}) \end{array} \right) \quad (6)$$

$$C = \left(\begin{array}{c} 0 \\ cx \text{ dat}^2 m \\ cy \text{ dat}^2 m \end{array} \right) \quad (7)$$

$$G = \left(\begin{array}{c} 0 \\ 0 \\ 0 \end{array} \right) \quad (8)$$