$$\ddot{\theta}(I + ma^2 \sin^2\theta + kma\sin\theta(R - a\cos\theta)(-\dot{x}_c \sin\phi + \dot{y}_c\cos\phi - (R - a\cos\theta)\dot{\theta}))$$
$$= \underbrace{I_3 - I\dot{\phi}^2 \sin\theta\cos\theta}_{=0} - I_3\dot{\phi}\sin\theta\dot{\phi} + (g + a\dot{\theta}^2\cos\theta)(-ma\sin\theta - km(R - a\cos\theta)$$
$$(-\dot{x}_c\sin\phi + \dot{y}_c\cos\phi - (R - a\cos\theta)\dot{\theta}))$$

$$\ddot{\phi}I\sin\theta = -\underbrace{(2I - I_3)}_{=I}\dot{\phi}\dot{\theta}\cos\theta + I_3\dot{\theta}\dot{\psi}$$
$$- km(g + a\cos\theta\dot{\theta}^2 + a\sin\theta\ddot{\theta})(a - R\cos\theta)(\dot{x}_c\cos\phi + \dot{y}_c\sin\phi + (a\dot{\phi} + \dot{\phi}R)\sin\theta)$$

$$\ddot{\psi}I_3 = -I_3(\ddot{\phi}\cos\theta - \dot{\phi}\dot{\theta}\sin\theta)$$
$$- km(g + a\cos\theta\dot{\theta}^2 + a\sin\theta\ddot{\theta})(R\sin\theta)(\dot{x}_c\cos\phi + \dot{y}_c\sin\phi + (a\dot{\phi} + \dot{\psi}R)\sin\theta)$$

$$m\ddot{x}_c = -km(g + a\cos\theta\dot{\theta}^2 + a\sin\theta\ddot{\theta})(\dot{x}_c + (a\dot{\phi} + \dot{\psi}R)\sin\theta\cos\theta + (a\cos\theta - R)\sin\phi\dot{\theta})$$

$$m\ddot{y}_c = -km(g + a\cos\theta\dot{\theta}^2 + a\sin\theta\ddot{\theta})(\dot{y}_c + (a\dot{\phi} + \dot{\psi}R)\sin\theta\cos\phi + (r - a\cos\theta)\cos\phi\dot{\theta})$$