Dynamics of Mechine

Final Project:

Wiper Mechanism

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Abstract

In the wiper mechanism, the external force on the linkage mechanism primarily comes from the friction generated by the wiper blade sliding on the windshield.

However, the friction characteristics of the wiper are very complex, as they must take into account different load conditions and environmental factors. Therefore, in this study, we simplify the friction force into an input torque applied on the blade link.

During operation, the wiper arm will inevitably deform due to the influence of friction. The relationship between this deformation and the applied force is described by a second-order differential equation, which is quite complex and difficult to solve using simple calculation methods. Thus, we make several simplifying assumptions about the deformation relationship, making it easier to compute using the six-linkage mechanism model.

After completing the kinetostatics analysis, we can obtain the sharking force and sharking moment caused by the entire linkage system. Further, based on the existing balance methods for linkage mechanisms, we perform a force balance analysis on the wiper's six-linkage mechanism, comparing the differences in Sharking Force and Sharking Moment before and after achieving balance.

Outline

1.Motivation

Wipers are one of the necessary safety devices on cars. When there are objects attached to the glass, such as water droplets, dust, and insects, the field of vision provided will be seriously affected, thus affecting the driver's clarity of vision and driving safety. Some factory also used this mechanism to clean up the surface of their product. It’s a simple and common mechanism.

The wiper's movement is controlled by a six-linkage mechanism, which comes in various designs to accommodate different wiper movement patterns. A common feature among these designs is the elongated distribution of the linkages, allowing the six-linkage mechanism to be installed in very narrow spaces. In cars, it is more common to see a parallel four-bar linkage paired with another oscillating four-bar linkage operating synchronously. The advantage of this mechanism is its simplicity in design.

As a common mechanism on transportation and manufacturing industry, it’s important to understand the status while the mechanism is operating. In addition, improve the mechanism.

2.Objective definition and modeling

Our goal is to balance the wiper mechanism, thus reduce the shaking force and shaking moment. By balancing the mechanism, we can lower the wear and tear of the wiper and the noise cause by the vibration.

Figure 1 is the wiper mechanism configuration selected for this study. Link 2 is our driving link and the angular velocity will be 50 rpm. There will be a friction force F_P acting on the end of link 4 and link 6.

All the parameters for the wiper are in table 1. Here m_i will be the mass of the link, L_i is the full length of the link, r_{g_4} and r_{g6} are the distance of the center of mass to the fixed pivot point of link 4 and link 6 respectively. I_{ggi} is the moment of inertia of the link.

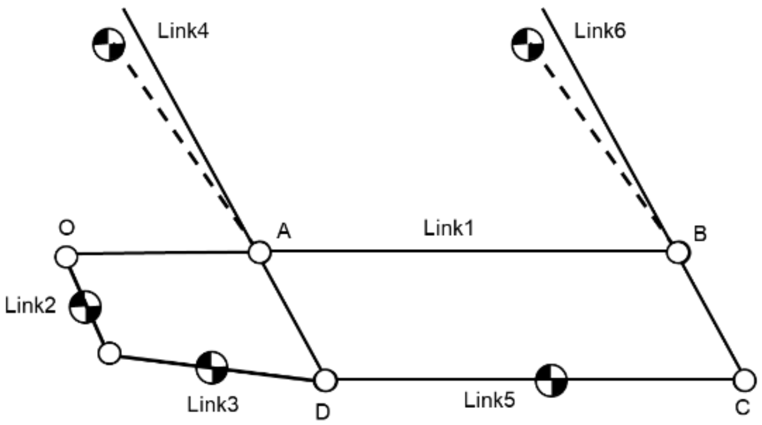


Figure 1. Wiper mechanism

m_2	m_3	m_4	m_5	m_6
1 kg	0.8 kg	0.5 kg	0.2 kg	0.5 kg

$\overline{OA}$	$\overline{AB}$	$\overline{AD}$	$\overline{BC}$	L_2	L_3	L_5	r_{g_4}	r_{g_6}
0.3 m	0.6 m	0.12 m	0.12 m	0.1 m	0.3 m	0.6 m	0.108 m	0.108 m

I_{gg2}	I_{gg3}	I_{gg4}	I_{gg5}	I_{gg6}
0.02 $kg \cdot m^2$	0.1 $kg \cdot m^2$	0.001 $kg \cdot m^2$	0.002 $kg \cdot m^2$	0.001 $kg \cdot m^2$

Table 1.

2.1Dynamic Analysis

Based on the relationship between the angle of the links, the angular position, velocity and acceleration of each link are analyzed in a kinematic analysis. The configuration selected for this study can be view as two four-bar-mechanism, which made the whole mechanism has two vector loops, as shown in Figure 2, so the following equations can be listed.

Loop 1:

$$S = \begin{cases} R_{OA} \cos\theta_1 + R_{AD} \cos\theta_4 = R_3 \cos\theta_3 + R_2 \cos\theta_2 \\ R_{OA} \sin\theta_1 + R_{AD} \sin\theta_4 = R_3 \sin\theta_3 + R_2 \sin\theta_2 \end{cases}$$

$$V = \begin{cases} -R_{AD}\dot{\theta}_4 \sin\theta_4 = -R_3\dot{\theta}_3 \sin\theta_3 - R_2\dot{\theta}_2 \sin\theta_2 \\ R_{AD}\dot{\theta}_4 \cos\theta_4 = R_3\dot{\theta}_3 \cos\theta_3 + R_2\dot{\theta}_2 \cos\theta_2 \end{cases}$$

$$A=\begin{cases} -R_4\ddot{\theta}_4 \sin\theta_4 - R_4\dot{\theta}_4^{\,2} \cos\theta_4 = -R_3\ddot{\theta}_3 \sin\theta_3 - R_3\dot{\theta}_3^{\,2} \cos\theta_3 - R_2\ddot{\theta}_2 \sin\theta_2 - R_2\dot{\theta}_2^{\,2} \cos\theta_2 \\ R_4\ddot{\theta}_4 \cos\theta_4 - R_4\dot{\theta}_4^{\,2} \sin\theta_4 = R_3\ddot{\theta}_3 \cos\theta_3 - R_3\dot{\theta}_3^{\,2} \sin\theta_3 + R_2\ddot{\theta}_2 \cos\theta_2 - R_2\dot{\theta}_2^{\,2} \sin\theta_2 \end{cases}$$

Loop 2:

$$S = \begin{cases} R_{AB}\cos\theta_1 + R_6\cos\theta_6 = R_4\cos\theta_4 + R_5\cos\theta_5 \\ R_{AB}\sin\theta_1 + R_6\sin\theta_6 = R_4\sin\theta_4 + R_5\sin\theta_5 \end{cases}$$

$$V = \begin{cases} -R_6\dot{\theta}_6\sin\theta_6 = -R_4\dot{\theta}_4\sin\theta_4 - R_5\dot{\theta}_5\sin\theta_5 \\ R_6\dot{\theta}_6\cos\theta_6 = R_4\dot{\theta}_4\cos\theta_4 + R_5\dot{\theta}_5\cos\theta_5 \end{cases}$$

$$A = \begin{cases} -R_6\ddot{\theta}_6\sin\theta_6 - R_6\dot{\theta}_6^{\,2}\cos\theta_6 = -R_4\ddot{\theta}_4\sin\theta_4 - R_4\dot{\theta}_4^{\,2}\cos\theta_4 - R_5\ddot{\theta}_5\sin\theta_5 - R_5\dot{\theta}_5^{\,2}\cos\theta_5 \\ R_6\ddot{\theta}_6\cos\theta_6 - R_6\dot{\theta}_6^{\,2}\sin\theta_6 = R_4\ddot{\theta}_4\cos\theta_4 - R_4\dot{\theta}_4^{\,2}\sin\theta_4 + R_5\ddot{\theta}_5\cos\theta_5 - R_5\dot{\theta}_5^{\,2}\sin\theta_5 \end{cases}$$

We can obtain the angular position of link 4 and link 6, according to the above vector loop equations.

2.2Kinetostatics analysis

Figure 2 is the Free-body diagram of all the moving links. We will have 17 unknowns and 17 equations for the system.

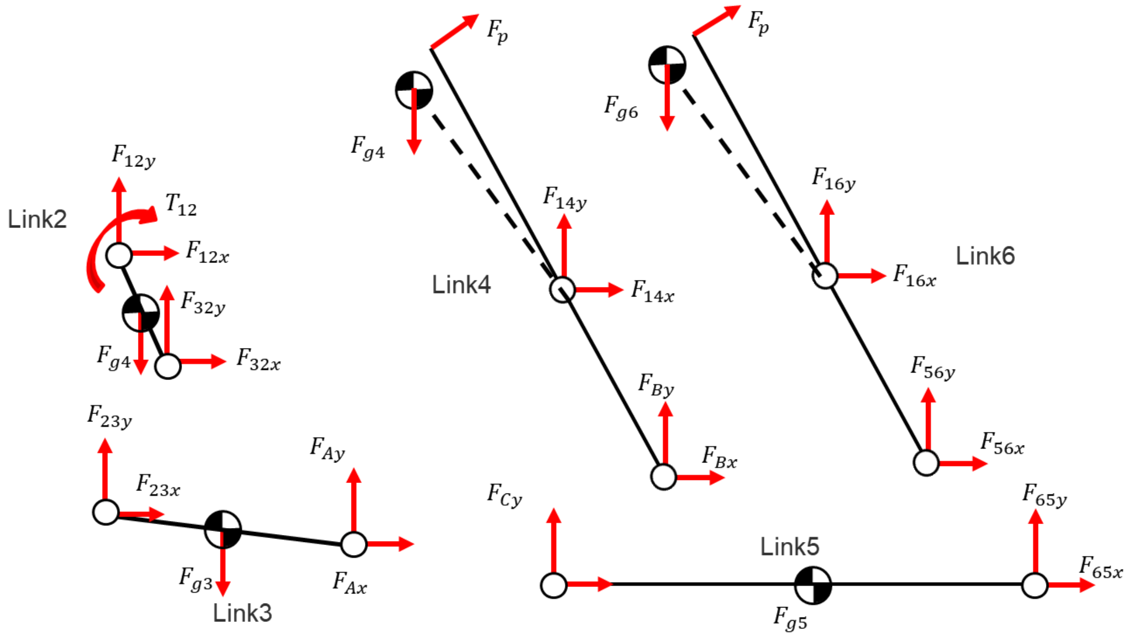


Figure 2. The Free-body diagram of each link.

Here's the following equations:

$$F_{12x}+F_{32x}=m_2a_{2x}$$
$$F_{12y}+F_{32y}= m_2g$$

$$F_{23x}+F_{Ax}= m_3a_{3x}$$
$$F_{23y}+F_{Ay}= m_3g + m_3a_{3y}$$

$$F_{14x}+F_{Bx}+F_{px}=m_4a_{4x}$$
$$F_{14y}+F_{By}+F_{py}=m_4g + m_4a_{4y}$$

$$F_{Cx}+F_{65x}= m_5a_{5x}$$
$$F_{Cy}+F_{65y}=m_5g + m_5a_{5y}$$

$$F_{16x}+F_{56x}+F_{px}=m_6a_{6x}$$
$$F_{16y}+F_{56y}+F_{py}= m_6g + m_6a_{6y}$$

$$T_{12} - \vec{R}_{g2} \times \vec{F}_{12} + \vec{R}_{l2} \times \vec{F}_{32} = I_{gg2}\alpha_2$$

$$-\vec{R}_{g3} \times \vec{F}_{23} + \vec{R}_{l3} \times \vec{F}_A = I_{gg3}\alpha_3$$

$$\vec{R}_{g4} \times \vec{F}_{14} + \vec{R}_{l4} \times \vec{F}_B = I_{gg4}\alpha_4$$

$$\vec{R}_{l5} \times \vec{F}_{65} - \vec{R}_{g5} \times \vec{F}_C = I_{gg5}\alpha_5$$

$$\vec{R}_{l6} \times \vec{F}_{56} + \vec{R}_{g6} \times \vec{F}_{16} = I_{gg6}\alpha_6$$

$$\mathrm{F}_{Ax} + \mathrm{F}_{Bx} + \mathrm{F}_{Cx} = 0$$

$$\mathrm{F}_{Ay} + \mathrm{F}_{By} + \mathrm{F}_{Cy} = 0$$

The reaction force on each link and the input torque can be obtained by solving these equations. As figures shown below.

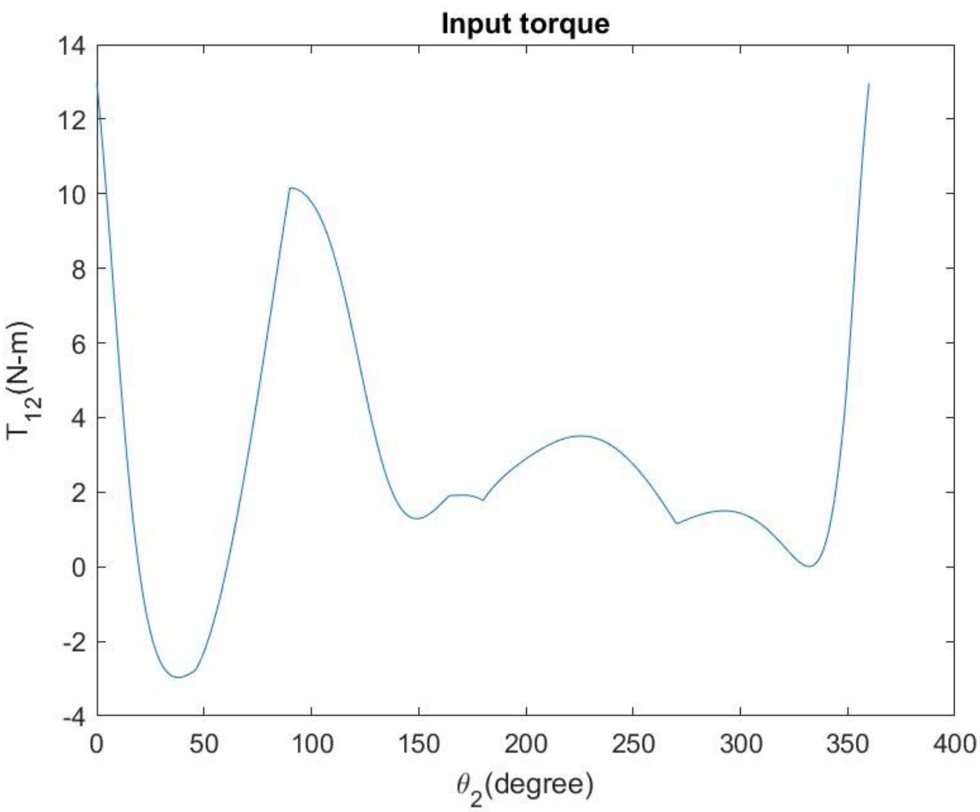


Figure 3.

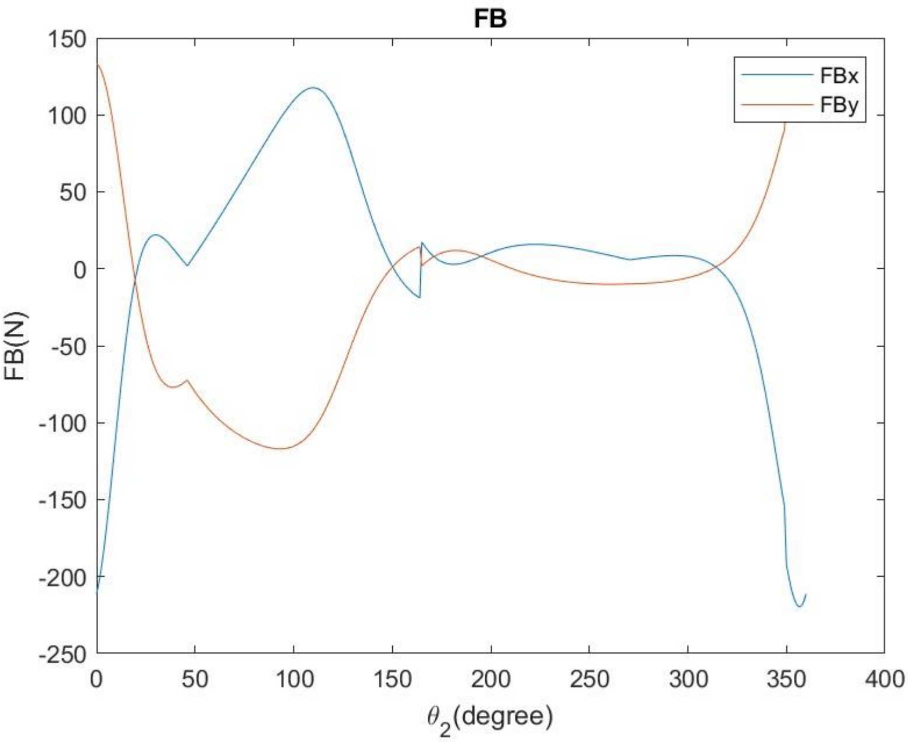


Figure 4.

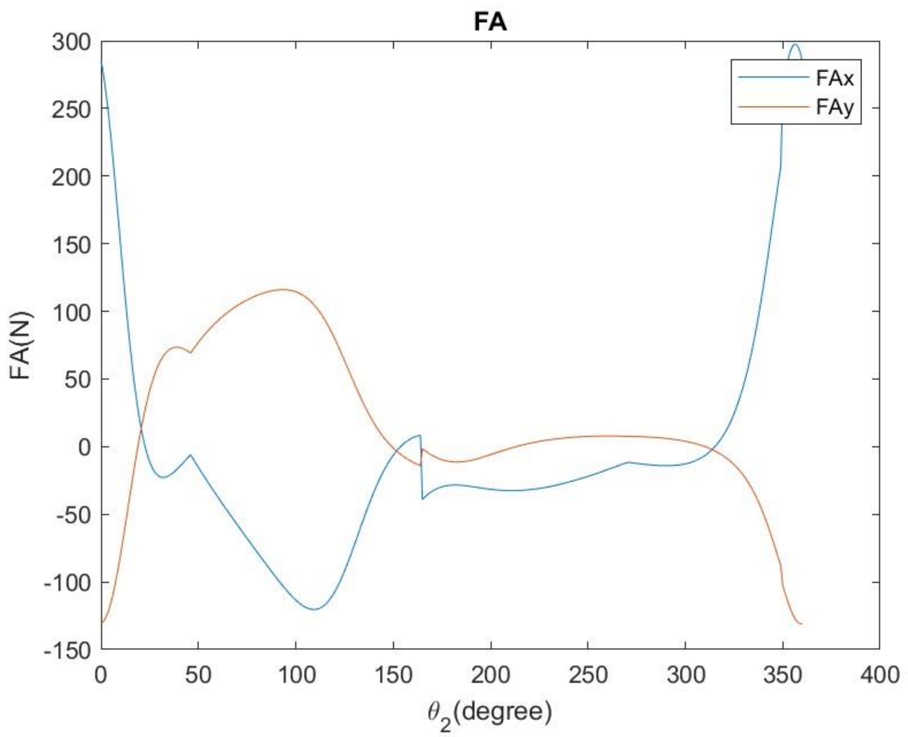


Figure 5.

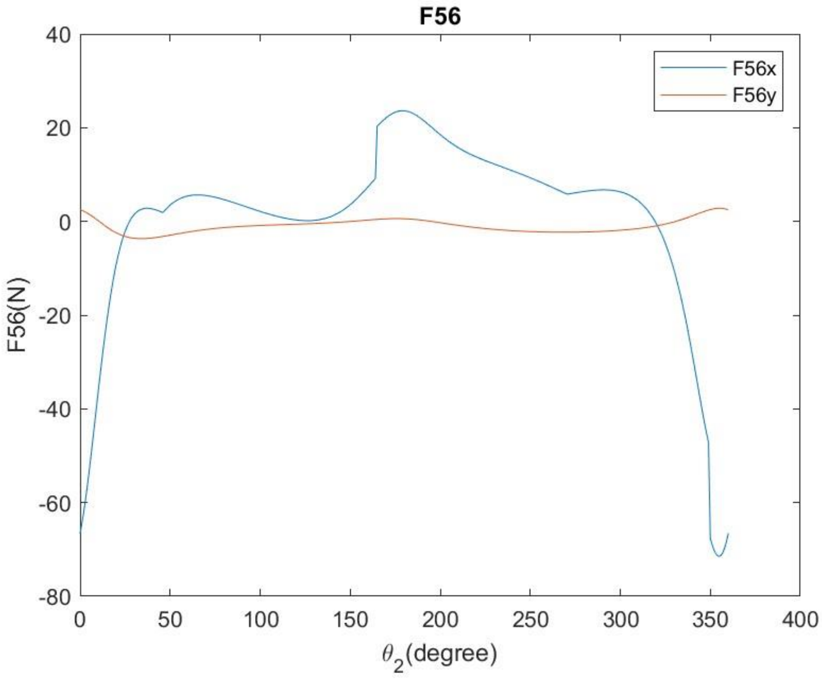


Figure 6.

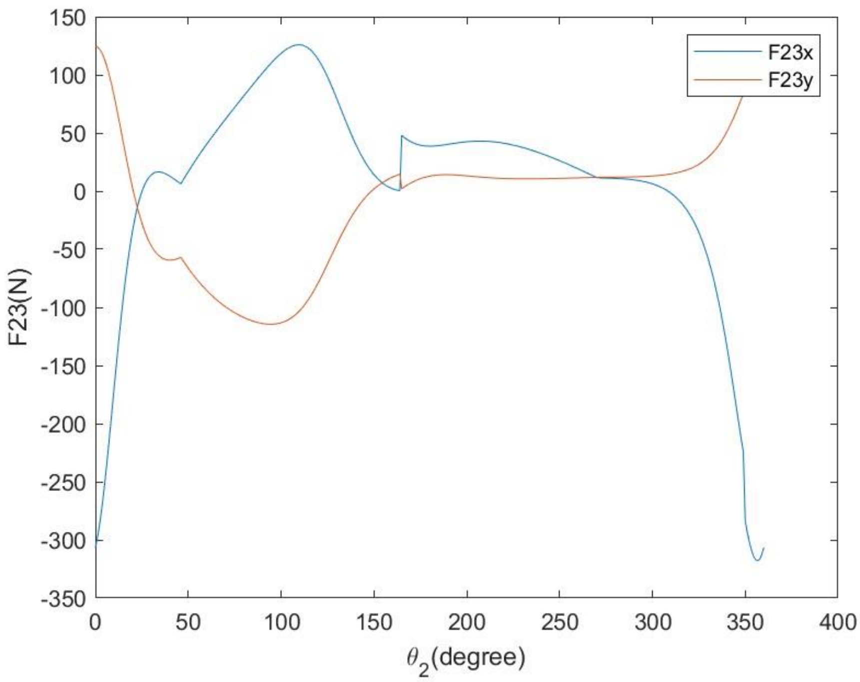


Figure 7.

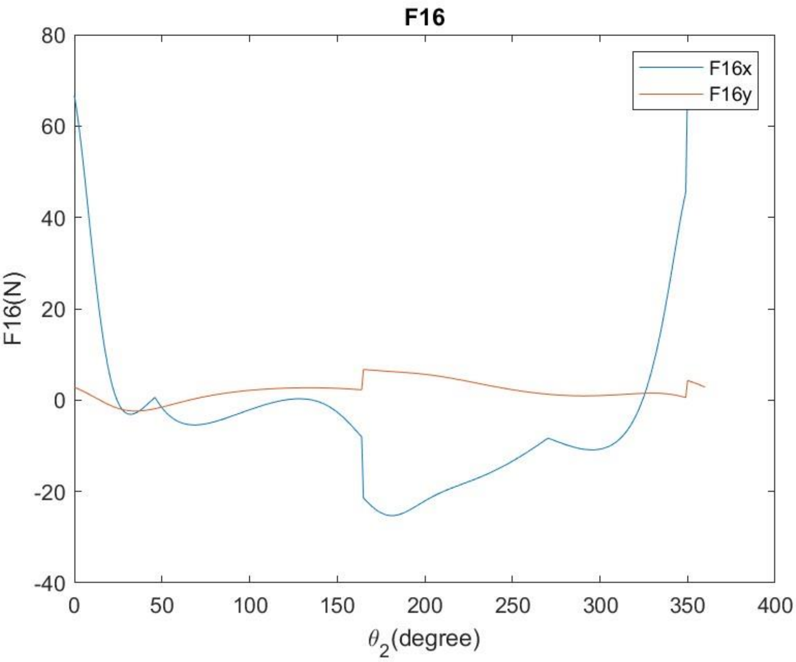


Figure 8.

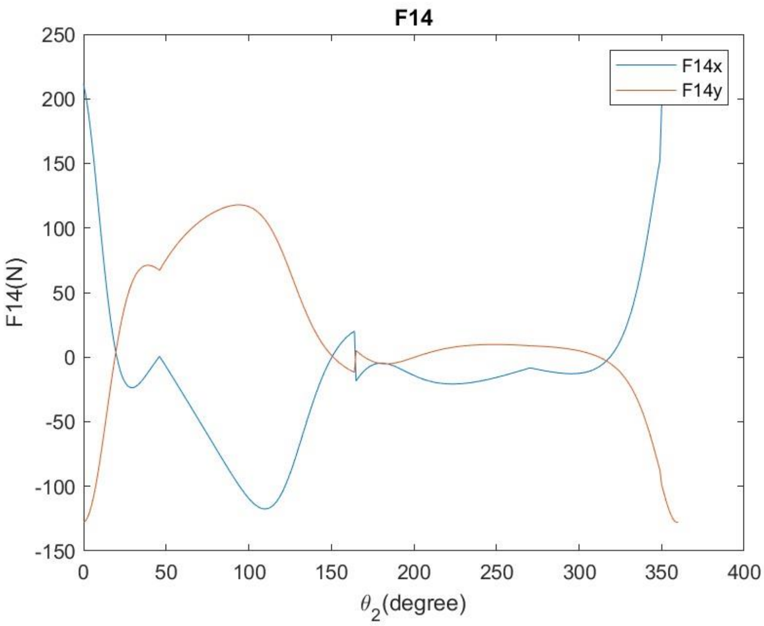


Figure 9.

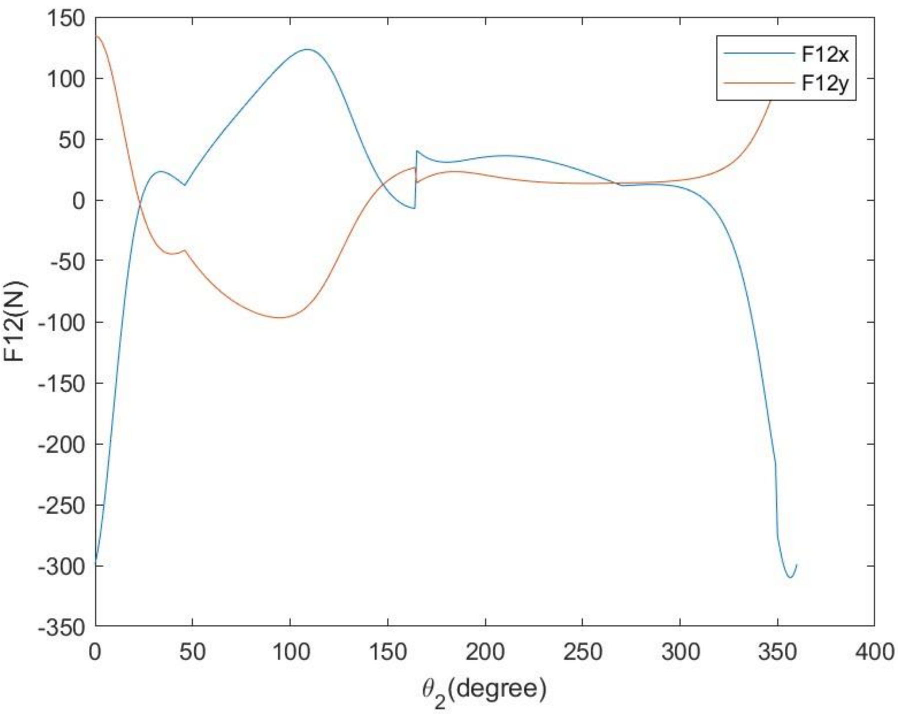


Figure 10.

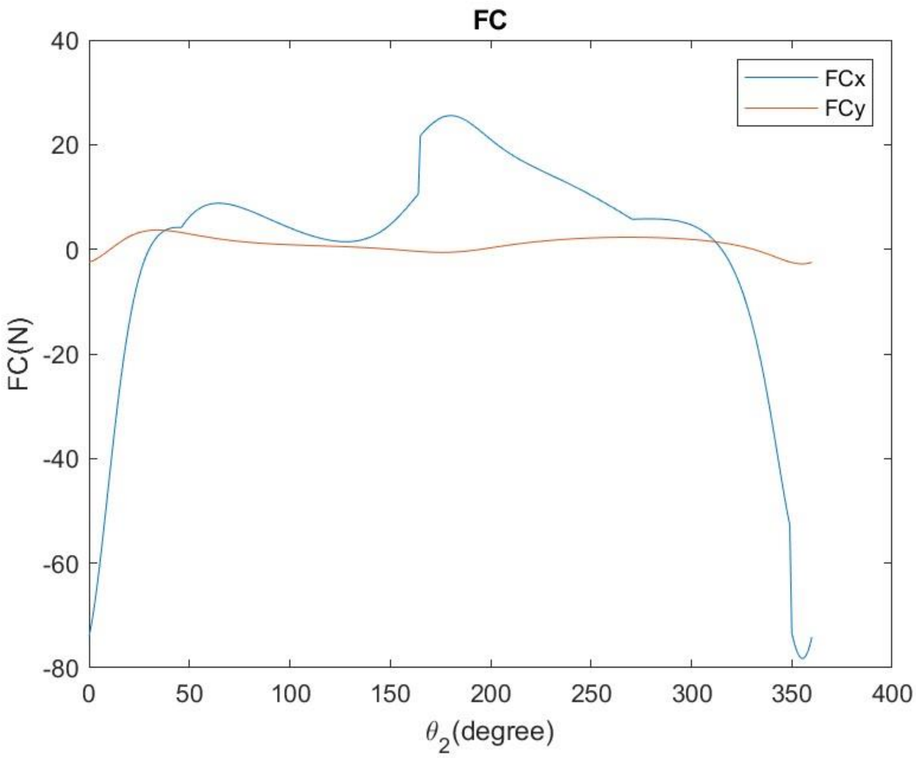


Figure 11.

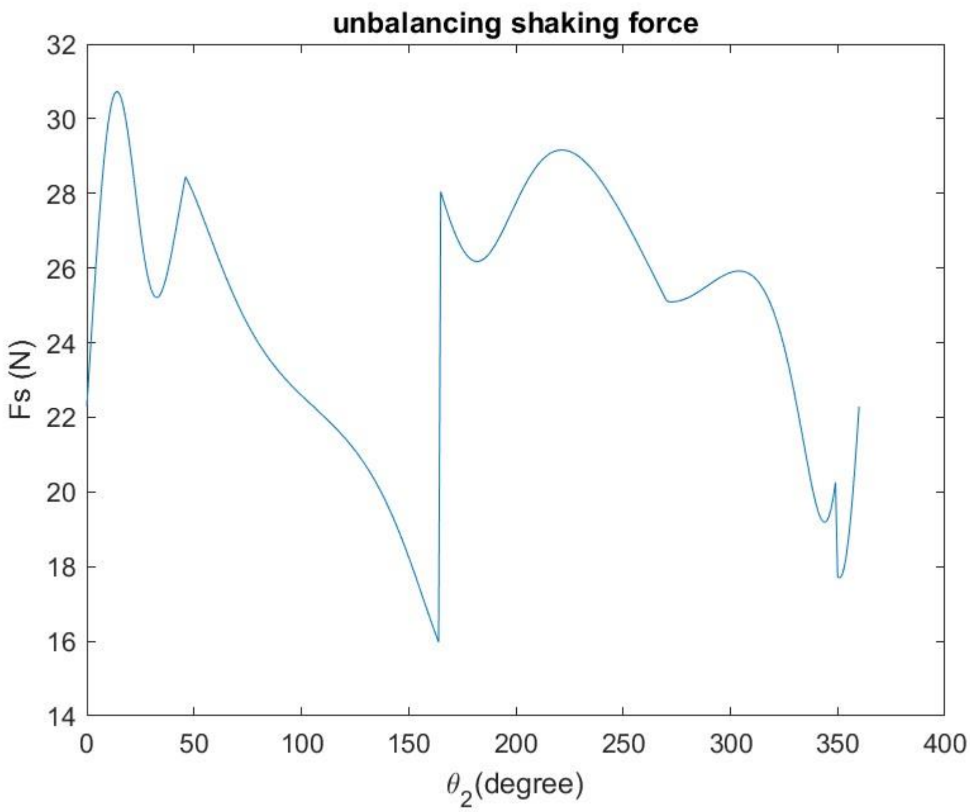
Furthermore, the shaking force and shaking moment can be calculate using the following equations.

$$\bar{F}_s = -(\bar{F}_{12} + \bar{F}_{14} + \bar{F}_{16})$$

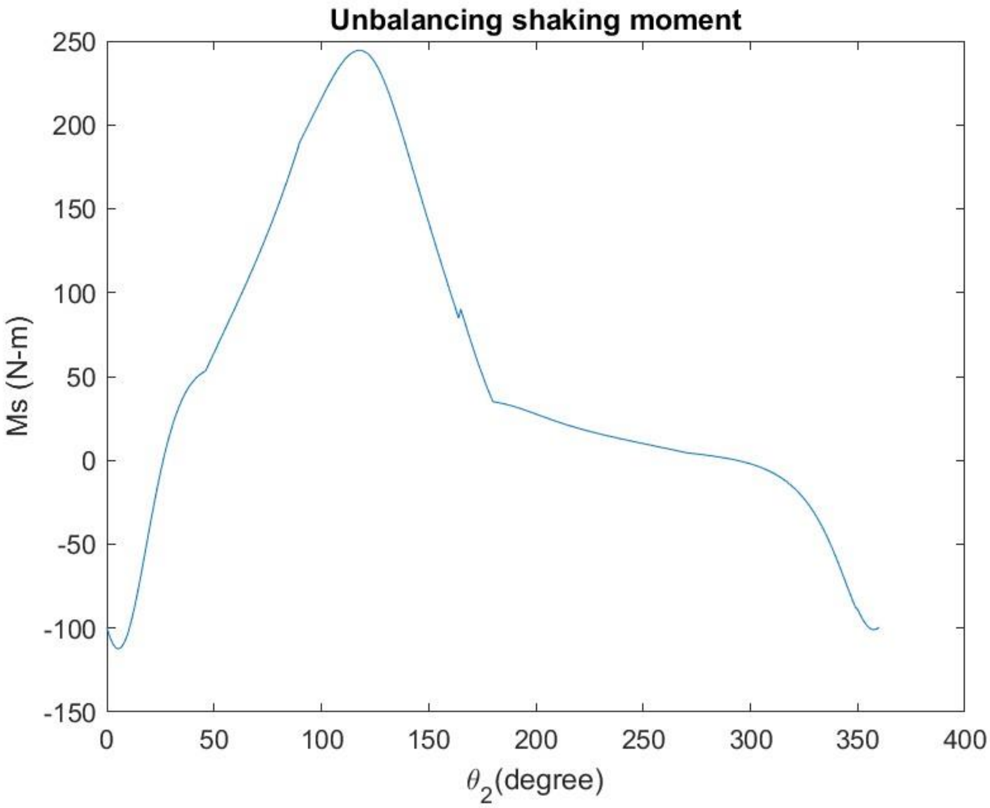
$$M_s = -\left[T_{12} + \bar{R}_1 \times \bar{F}_{14} + (\bar{R}_1 + \bar{R}_7) \times \bar{F}_{16}\right]$$

The below figures are the shaking force(a) and shaking moment(b).

(a)



(b)



Unbalancing shaking moment
250
200
150
100
50
0
-50
-100
-150
Ms (N-m)
0
50
100
150
200
250
300
350
400
θ_2(degree)

3.Dynamic balancing design

As figure 1 shown, the mechanism is form by two four-bar-mechanism. By using berkof's method, we can balance each loop one at a time, then use the two new configurations the following equations shown as for the mass center and add gear inertia counterweight on link 2, link 4 and link 6.

$$m_2 r_{g2} = 0.5 m_3 l_2$$
$$m_4 r_{g4} = 0.5 m_3 l_{AD} + 0.5 m_5 l_{AD}$$
$$m_6 r_{g6} = 0.5 m_5 l_{BC}$$
$${k_3}^2 = {r_{g3}}^2$$
$${k_5}^2 = {r_{g5}}^2$$
$$I_{c2} = m_2({k_2}^2 + {r_{g2}}^2 + l_2 r_{g2})$$
$$I_{c4} = m_4({k_4}^2 + {r_{g4}}^2 + l_{AD} r_{g4})$$
$$I_{c6} = m_6({k_6}^2 + {r_{g6}}^2 + l_{BC} r_{g6})$$

The new structure after balancing is shown as figure 12.

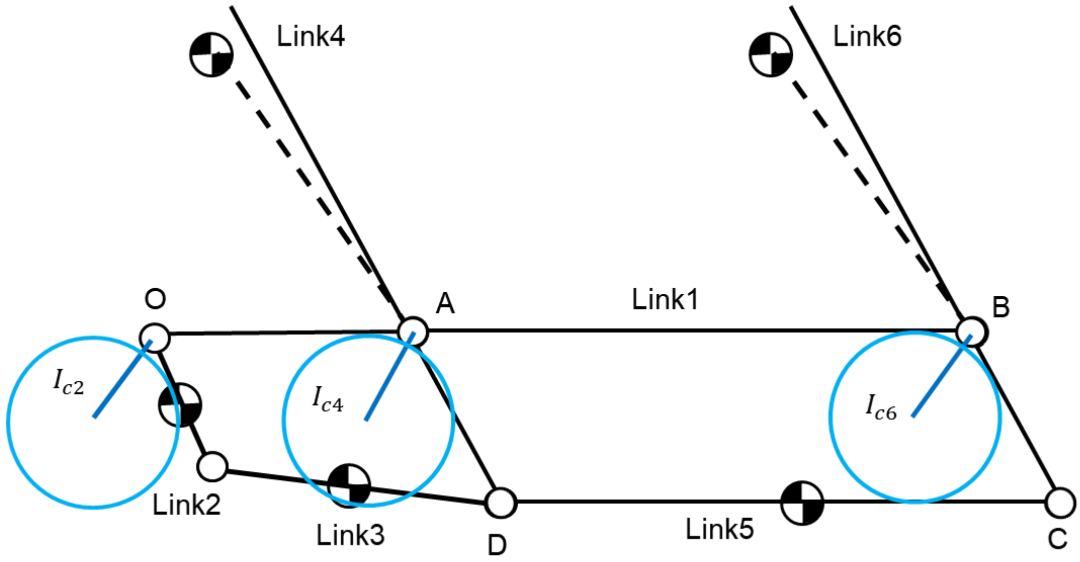
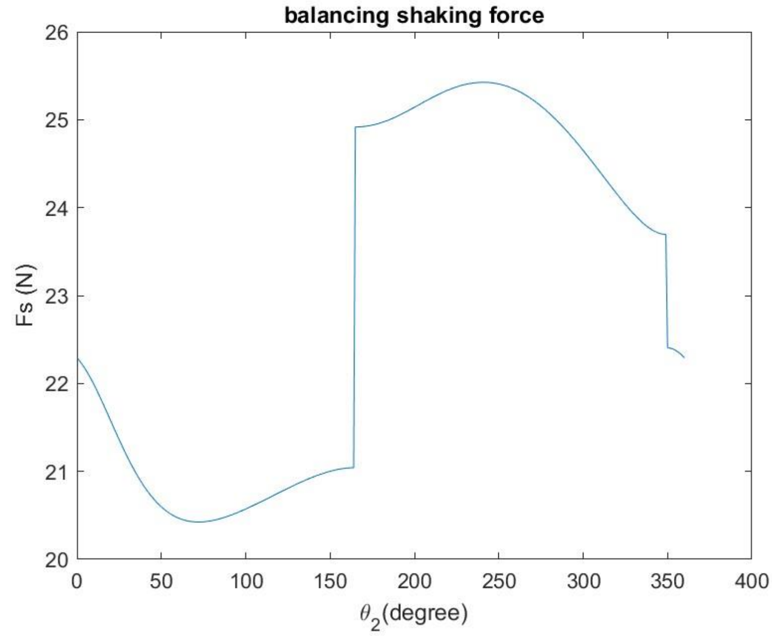


Figure 12.

The shaking force and shaking moment are shown as figure 13.

(a)



(b)

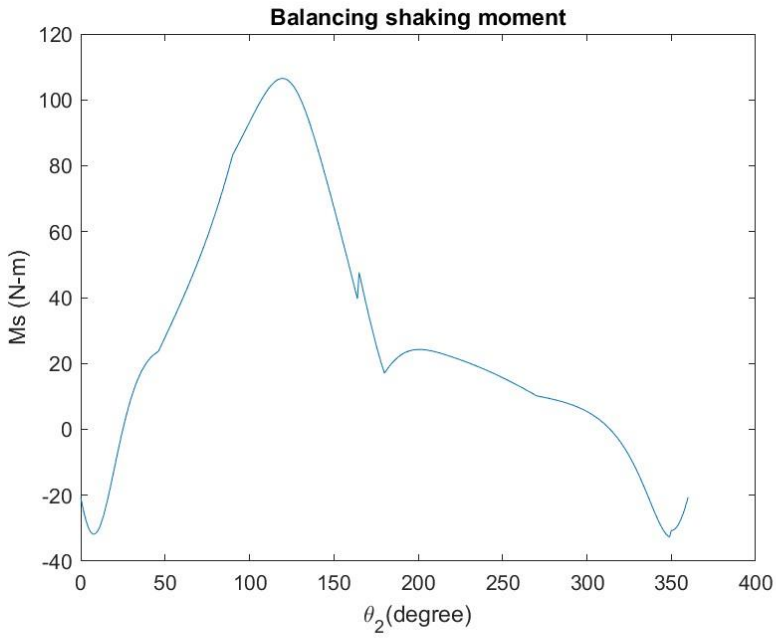
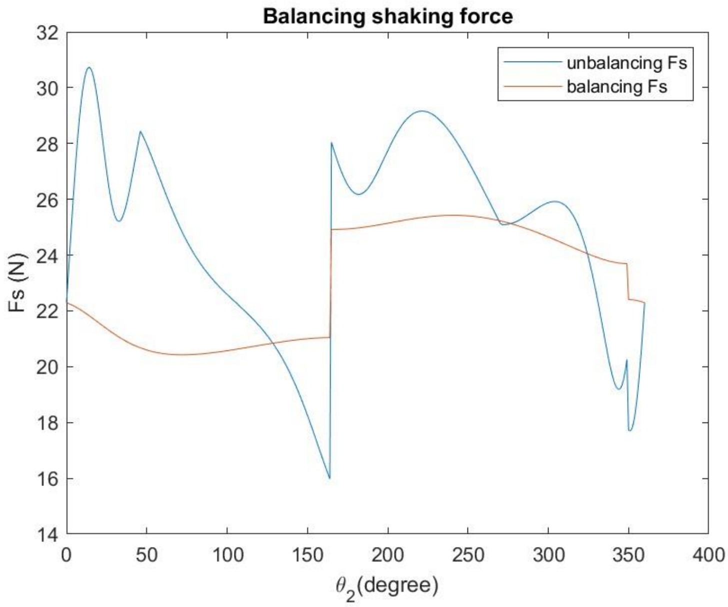


Figure 13.

Results and comparison

As figure 14 shown, the shaking force and shaking moment have decrease a decent amount. Which shows the modification we made does have balancing effect.

(a)



(b)

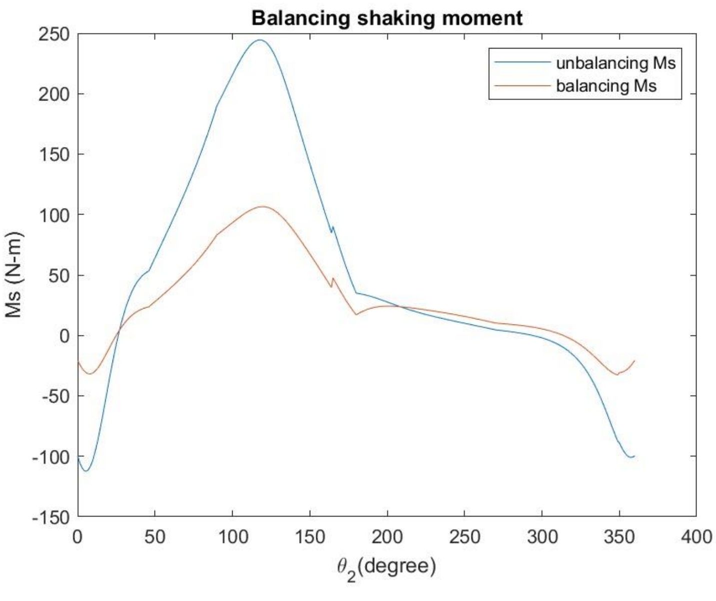


Figure 14.

Conclusion

Our study successfully analyzed the movement (kinematics) and dynamics of each link in the mechanism, and then balanced it. As the results shown, the shaking force and shaking moment have reduced. The results may not be the ideal balancing effect due to our choose of method. So in future work we will try using optimization method to get the optimum design for the wiper mechanism.

References

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