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Dynamic Simulation and Velocity Adjustment of Mechanism

Hong-Ming Kang
Department of Electrical Engineering, National University of Tainan, Shu-Lin St., Tainan 700, Taiwan
E-mail: *khm_nut@yahoo.com.tw*

Abstract

In order to improve longevity, efficiency and working quality of machinery, taking the six-bar mechanism as example, the velocity fluctuation of six-bar mechanism and its adjustment method are studied. At first, an equivalent dynamic model of six-bar mechanism was established with the vector loop equations and kinematic and dynamic characteristics were analyzed based on the model. Then kinematic and dynamic simulation of six-bar mechanism was carried out with software Matlab. The simulation results reveal the real movement regularity of six-bar mechanism of shaper in the stable operation stage. By comparing the simulation results with theoretical calculation, the validity of this method was verified. Finally, the flywheel which can store and release energy was used to adjust the periodic velocity fluctuation. The simulation results with or without flywheel show that the flywheel is of considerable adjustment effect on periodic velocity fluctuation. The peak value of angular velocity and angular acceleration of equivalent component were decreased by 11.3% and 99.57% respectively, thus to improve movement stability. This method proposed in the paper has universal significance for the general mechanism analysis and design.

Keywords: Matlab; Six-bar mechanism; Simulation; Velocity fluctuation; Adjustment.

1. Introduction

Generally speaking, in order to get the precise mechanism movement and force analysis, it is necessary to determine the mechanism driving component real operation condition [1]. Due to the change of the driving force and resistance acting on the mechanical system will cause mechanical system speed fluctuation, thus resulting generate additional dynamic pressure in the mechanism kinematic pair, and cause the vibration of mechanical systems. In order to reduce vibration, it must be on the mechanical speed fluctuation and its regulating method research [2-5]. Firstly, the equivalent dynamics model of six-bar mechanism was established with closed vector loop equations and the equivalent moment of inertia [6] and equivalent moment were analyzed. Secondly, using Matlab [7] software to carry out the movement simulation, through the theoretical calculation and simulation result were compared to verify the correctness of the simulation analysis. Finally, the flywheel which can store and release energy was used to adjust the periodic velocity fluctuation. Thereby reduce the mechanical operation speed fluctuation degree [8].

2. The establishment and analysis of system dynamics equation

Mechanical system real movement law depends on the external forces acting on the mechanical system, the quality of the components, the rotation inertia, component size and position of mechanism and other factors. In the solving process, firstly the mechanical system motion equation was established according to the kinetic energy theorem. From the mechanical system itself, each component has a certain

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quality and moment of inertia. These factors combine to determine the movement law of the original link and all components of the mechanical system.

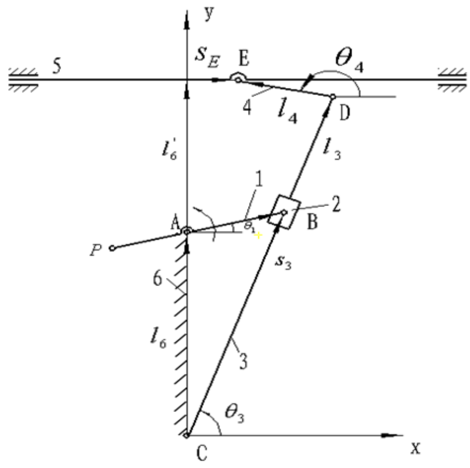

Fig.1 The kinematic sketch of six-bar mechanism

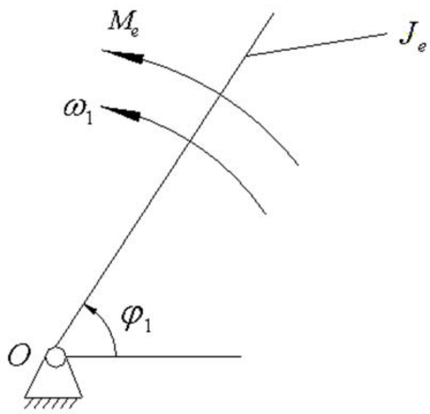

Fig.2 The equivalent dynamics model

In order to calculate and simulation convenient, with six-bar mechanism of shaper of a single freedom system as an example, the kinematic sketch is shown in Fig.1. Crank AB segment is the actuator. It was driven by a motor. The PA is balance block. When crank AB rotates, the slider 2 drives swinging lever 3 to swing back and forth, then the power transmits from swinging lever 3 through link 4 to drive plough head 5 to move back and forth. This is the major cutting process. Firstly, the equivalent dynamics model of six-bar mechanism of shaper was established and shown in Fig.2.

The general formula of equivalent moment of inertia J_e is as follows.

$$J_e = \sum_{i=1}^{n} [m_i (\frac{v_{si}}{\omega})^2 + J_{si} (\frac{\omega_i}{\omega})^2] \quad (1)$$

The general formula of equivalent moment M_e is as follows.

$$M_e = \sum_{i=1}^{n}[F_i \cos\alpha_i (\frac{v_{si}}{\omega}) \pm M_i (\frac{\omega_i}{\omega})] \tag{2}$$

Among them, n is the active component number in the mechanical system. M_i 、 F_i 、 m_i respectively for the role in the i component torque, power and the quality of components. J_{si} is the i component around the center of mass moment of inertia. v_{si} is the velocity of the center of mass of the i component. α_i is the angle of the force F_i direction and the velocity v_{si} direction of the component. ω_i is the the angular velocity of the i component. ω is the angular velocity of mechanical system transforming component.

Six-bar mechanism equivalent component angle φ average is divided equally into n tiny angle, then every small incremental for $\Delta\varphi = \varphi_{i+1} - \varphi_i (i = 0,1,2,\cdots n)$. Instantaneous angular velocity is indicated by the ω_{i+1}. J_{i+1} is the equivalent moment of inertia of this moment in the mechanical system. ω_i and J_i are expressed as the angular velocity and the equivalent moment of inertia of the mechanical system model before the moment respectively. The column equation is shown.

$$\omega_{i+1} = \frac{M_e(\varphi_i, \omega_i)\Delta\varphi}{J_i\omega_i} + \frac{3J_i - J_{i+1}}{2J_i}\omega_i \tag{3}$$

α_i is the instantaneous angular acceleration.

$$\alpha_i = \frac{\omega_i d\omega_i}{d\varphi_i} \tag{4}$$

Among them $d\omega_i = \Delta\omega_i = \omega_{i+1} - \omega_i$, $d\varphi_i = \Delta\varphi_i = \varphi_{i+1} - \varphi_i$.

Type (3), (4) the numerical solution (finite difference method) obtained, and the specific derivation as shown in the literature [1]. By the above analysis, we can conclude that the movement simulation of six-rod mechanism of shaper was carried out. It is necessary to calculate the size of the angular velocity, the angular acceleration, the equivalent moment of inertia and the equivalent force of the equivalent moment each turned a tiny corner.

3. Equation solution

3.1 Solution of the equivalent moment of inertia

According to the calculation of front solution, it is known that the equivalent moment of inertia is a function of the position in the mechanical system. The position of six-bar mechanism calculated, then the equivalent moment of inertia will solve. According to the formula (1), the expressions of the equivalent moment of inertia of six-bar mechanism of shaper can be expressed as follows.

$$J_e = J_{s1} + J_{p1} + J_{m2} + m_3\left(\frac{v_{s3}}{\omega_1}\right)^2 + m_4\left(\frac{v_{s4}}{\omega_1}\right)^2 + m_5\left(\frac{v_{s5}}{\omega_1}\right)^2 + J_{s3}\left(\frac{\omega_3}{\omega_1}\right)^2 + J_{s4}\left(\frac{\omega_4}{\omega_1}\right)^2 \tag{5}$$

Type (12), all unknown quantity of the equivalent moment of inertia J_e of six-bar mechanism of shaper has been solved by the above all solving. The input φ_0 to 0° as start, with 15° for the step, and gradually increased to 360°. The movement simulation of its corresponding φ_i value was carried out using Matlab software. The value of equivalent moment of inertia of corresponding to six-bar mechanism can be solved.

3.2 Solution of the equivalent moment

By such as shown in Fig.1, the work resistance of plough head 5 of six-bar mechanism of shaper is a function of the location. If the work done of the three-phase ac asynchronous motor by all evenly to six-bar mechanism of shaper in the mechanical system, the resistance moment of average production can be expressed as $M_m = P/\omega_m$.

M_n is rated torque of motor and angular velocity ω_n is rated angular velocity of motor. C point angular velocity ω_0 is synchronous velocity and the three-phase ac asynchronous motor torque is zero. The driving torque M_d of the line at any point was written in the following formula.

$$M_d = \frac{\omega_m - \omega}{(\omega_0 - \omega_n)/M_n} + M_m \tag{6}$$

On the type, $(\omega_0 - \omega_n)/M_n$ is the motor mechanical characteristic coefficient g. So, according to the angular velocity can solve the driving torque $M_d = \frac{\omega_m - \omega}{g} + M_m$.

If the motor torque directly to the crank, the equivalent moment as follows.

$$M_e = M_d - M_m = (\omega_m - \omega)/g \tag{7}$$

From the type (14) can be seen, the equivalent moment is a function of velocity. If you want to obtain the mechanical system equivalent moment, it must be solved by combining with movement law of shaper.

3.3 Movement simulation and analysis

Using the Matlab software simulation, the input φ_0 to 0° as start, with 15° for the step, and gradually increased to 360°. During every 15° call m programming file, and use type (3) and (4) for calculating the angular velocity and angular acceleration of equivalent component. Set the initial conditions for ω_0 = 5 rad/s, t_0 = 0, φ_0 = 0, the calculated results are saved to the array. Using Matlab software to carry out the movement simulation, angular velocity and angular acceleration curve is shown in Fig.3.

As can be seen from Fig.3, a given initial conditions has been determined. The spindle turned for a cycle and did not reach the periodic movement state. When i=31 and the spindle rotated 465°, angular velocity are consistent with i=7, $\varphi_7 = 105^{\circ}$. Since then six-bar mechanism of shaper will make periodic movement and running into a stable state. When the equivalent component angle rotation to $210^{\circ} \sim 355^{\circ}$, fluctuation range was significantly larger. But at this moment it is just a quick return of six-bar mechanism of shaper, this is most likely to produce a velocity fluctuation. Simulation curve is consistent with the reality. So that the simulation result is correct.

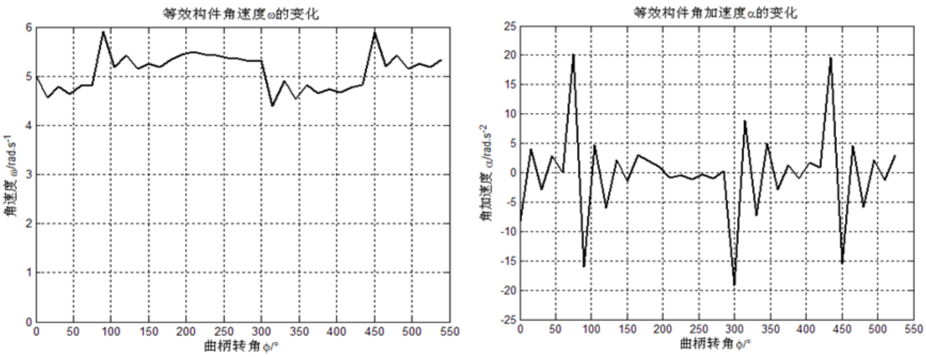

Fig.3 The real movement of shaper in the stable operation stage

3.4 Speed fluctuation and adjustment

For the periodic speed fluctuation, it is possible to use to increase the equivalent component quality or moment of inertia approach to reduce angular acceleration of the equivalent component. So as to realize the movement of mechanical systems tend to balance. The usual method is to install flywheel. The cyclical speed fluctuation was adjusted using flywheel energy storage and release characteristics. For six-bar mechanism of shaper, the variable part of the equivalent moment of inertia should be ignored. And that a flywheel mounted on the equivalent component, the rotational inertia of the flywheel is as follows.

$$J_F = \frac{\Delta W_{max}}{\omega_m^2 [\delta]} - J_e \tag{8}$$

If $J_e << J_F$, J_e can be ignored.

$$J_F = \frac{\Delta W_{\max}}{\omega_m^2[\delta]} \tag{9}$$

In the formula, $\Delta W_{\max}$ is the maximum profit and loss of system. $\Delta W_{\max} = E_{\max} - E_{\min}$.

Through calculation, we increase a flywheel of moment of inertia for 587.92849 in the rotary shaft of the equivalent component shaper. Using Matlab simulation, angular velocity and angular acceleration curve of the equivalent component obtained after the implementation as shown in Fig.4.

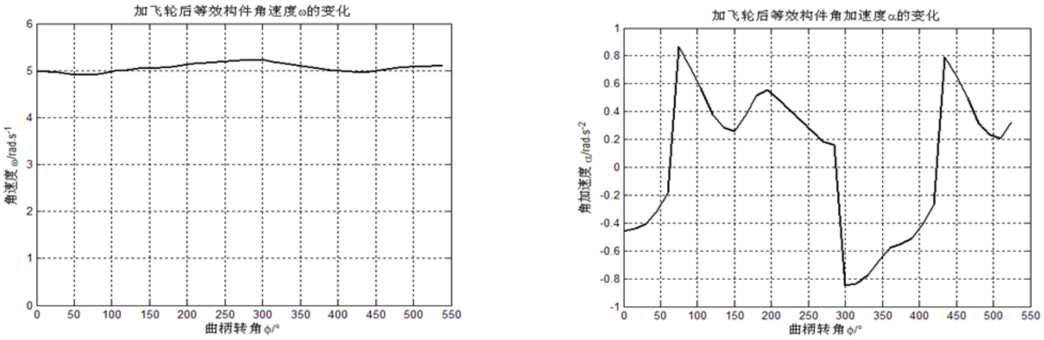

Fig.4 The real movement of shaper installing flywheel

As can be seen from Fig.4, the angular velocity and angular acceleration curve of equivalent component of installation flywheel was smooth significantly and volatility was reduced significantly. The peak value of angular velocity and angular acceleration of equivalent component were decreased by 11.3 % and 99.57% respectively, thus to improve movement stability. Thus installing flywheel is effective measures to improve the mechanism kinematics characteristics.

4. Conclusion and Prospect

According to the simulation results, the six-bar mechanism of shaper in operation process, driving component inevitably there is a certain degree of speed fluctuation, and the speed fluctuation have important effects on the kinematics and dynamic properties of six-bar mechanism. Install flywheel is one of the main means to reduce the speed fluctuation of the mechanical operation. To install flywheel mechanism simulation by Matlab, the results show install flywheel mechanism movement stability has significant improvement. This method can be used to the organization structure design of movement smooth as the main objective, or through the continuous simulation to seek optimal flywheel inertia in the case of known mechanism.

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