Vibration characteristics research of the polygonal effect of scraper conveyor

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Abstract. This article mainly studies the chain of scraper conveyor and analyzes the dynamic characteristics of the chain in the condition of load and load free. Numerical simulation, including the speed of movement and the simulation of chain tension, is used to simulate the special points of scraper conveyor chain. By a series of simulation simulations, the experimental results show that the number and pitch of the sprocket are the main factors that influence the dynamic characteristics of the chain, making the chain produce polygonal effect. Above all, the simulation data shows that the movement is relatively stable and the fluctuation decreases with the increase of the number of sprocket. In the case of load, the tension of the chain tensioning force obviously increases, and the polygon effect of the chain is intensified. Therefore, we hope to provide some theories and basis for our production activities by studying the chain of scraper conveyor.

1. Introduction

With the continuous development of the national coal industry, the application of scraper conveyor in coal mining equipment is becoming more and more important. Because of the working principle and working environment of scraper conveyor, the chain demand of scraper conveyor is constantly improved. The influence of polygon effect on the dynamic characteristics of the chain is very large.

In this paper, we study the dynamic performance of the scraper conveyor chain. Through the chain of special point simulation and comparison analysis, we study the influence on polygon effect of velocity and tension, at the same time we also study the polygon effect on the influence of scraper conveyor chain to further optimize the chain transmission in real production equipment. This conclusion provides the basis and theoretical basis for the study of the chain of scraper conveyor in future and provides advice and guidance on how to select the scraper conveyor chain in coal production.

2. Chain speed fluctuation of scraper conveyor

As shown in Figure 1, the chain composed of multiple rigid links cause phenomenon that horizontal symmetry surface of the flat link is alternately intersecting and intersecting in the chain drive. Every contact the link is engaged with the sprocket with the tangential and phase cutting alternately, which will cause the vertical displacement fluctuation of the chain on the edge of the scraper conveyor, resulting in vibration and noise.
2.1. Chain speed fluctuation of scraper conveyor

When before and after the sprocket in any position, we calculate the speed of the tension side chain, which is at last on the front and rear sprocket meshes into and the first recess action chain link speed can get as shown in figure 1 (a), (b), (c), (d) of the two sprockets in the special position with the matching speed link.

The rear chain wheel type of the scraper conveyor is used before and after and the chain gear number is z. In figure 1 (e) the drive speed value constant of front and rear sprocket is assumed, and the direction is counter clock wise. The drive sprockets at any time before and after the tooth into the link and the recess action link by $\alpha$ and $\beta$ respectively, and the phase Angle of the alpha value range for $\alpha$ from 180° to - 180° and its $\beta$ value range is from - 180° to 180°.

By the vector theory of velocity, we can calculate the longitudinal instantaneous velocity and transverse instantaneous velocity of the chain in figure 1 (e).

\[
\begin{align*}
& v_{x1} = r \omega_1 \cos \alpha \\
& v_{y1} = r \omega_1 \sin \alpha
\end{align*}
\]  

Type: \( r \) -- sprocket pitch circle radius, \( r = p / 2 \sin (180 \degree / z) \).

When meshes into the chain link in the chain of graduation circle minimum phase position (\( \alpha = 0 \)), which is shown in figure 1b and figure 1c. The chain of longitudinal velocity component is the largest and the minimum horizontal velocity component, such as type 2:

\[
\begin{align*}
v_{x1} &= v_{x_{\text{max}}} = r\omega_1, \quad v_{y1} = v_{y_{\text{min}}} = 0
\end{align*}
\]  

When the link of the chain is in the maximum phase position of the sprocket circle (\( \alpha = \pm \pi / z \)). As shown in figure 1a and figure 1d, the longitudinal velocity component of the chain is the smallest, and the transverse velocity component is the largest namely

\[
\begin{align*}
v_{x1} &= v_{x_{\text{min}}} = r\omega_1 \cos \frac{180\degree}{z} , \quad v_{y1} = v_{y_{\text{max}}} = r\omega_1 \sin \frac{180\degree}{z}
\end{align*}
\]

![Figure 1. Polygon effect of sprocket](image)

According to the above analysis, it finds that the sprocket wheel drive system speed and chain speed inhomogeneity coefficient $K$ at any time of the engagement cycle, example for figure 4.
According to the above theory, it can be concluded that the speed all changes periodically in the process of the chain link mesh chain of transverse and longitudinal, and periodical change of transverse and longitudinal speed chain and sprocket meshing cycle is consistent, so in the process of mesh chain will have the phenomenon of periodic vibration and generate additional dynamic load.

2.2. Fluctuation of chain longitudinal acceleration of scraper conveyor chain

The longitudinal instantaneous acceleration of the chain can be obtained according to the vertical instantaneous velocity of the chain, as shown in equation 5:

\[
a = \frac{dv}{dt} = \frac{d}{dt}r_\omega \cos \alpha = -r_\omega \cos \beta \sin \alpha
\]

When the chain ring of the sprocket is in the maximum phase position of the sprocket circle, the Angle of the Angle is the largest and the vertical instantaneous acceleration is also largest. When \( a = \frac{180^\circ}{z} \), \( a = -\frac{180^\circ}{z} \).

We learn the longitudinal instantaneous acceleration of the chain in the circular radius of the chain wheel, as shown in type 6:

\[
a_{\text{max}} = \frac{\omega_1}{2}
\]

2.3. The speed fluctuation of the side chain of the scraper conveyor

Due to the sprocket polygon effect, the load side chain tooth trendy chain scraper conveyor speed cyclical fluctuations and at the same time the velocity of the load side chain tooth chain is not constant with periodical fluctuations.

The mean speed of the chain in the chain transmission system is constant. According to figure 1 (e), the instantaneous angular velocity of the chain wheel is obtained, as shown in equation 7:

\[
\omega_2 = \frac{v_\gamma}{r \cos \beta} = \frac{\omega_1}{r \cos \beta} = \frac{\omega_1 \cos \alpha}{\cos \beta}
\]

Because of the scraper conveyor chain drive system before and after the two sprockets of the same type, so the chain transmission system constant, constant velocity ratio \( I = 1 \), but the existence of the polygon effect, make the chain transmission system is the instantaneous transmission ratio, and the instantaneous transmission ratio changes all the time, the instantaneous transmission ratio, such as the type 8:

\[
i_s = \frac{\omega_1}{\omega_2} = \frac{\cos \beta}{\cos \alpha}
\]
It is known that the instantaneous transmission ratio of the scraper conveyor system is close to the relative position of the sprocket rotation in the meshing process.

The limit position of the link between the front and rear sprockets is shown in figure 1 (a), (b), (c) and (d) of the four states. When the link is placed on the front and back of the two sprockets, as shown in figure 1 (a) and (b), the instantaneous transmission ratio is instantaneous, as shown in equation 9:

\[ i_s = 1 \]  

When link on the two sprockets position as shown in figure 1 (c), namely the \( \alpha = 0, \beta = -180^\circ / z \), the instantaneous transmission ratio is:

\[ i_{s\text{min}} = \cos\left(\frac{180^\circ}{Z}\right) \]  

When link on the two sprockets position as shown in figure 1 (d), namely the \( \alpha = -180^\circ / z, \beta = \text{zero} \), the instantaneous transmission ratio, such as type 11:

\[ i_{s\text{max}} = \frac{1}{\cos\left(\frac{180^\circ}{Z}\right)} \]  

The speed fluctuation of the chain is the same as the speed fluctuation of the load side chain. The instantaneous transmission ratio of KZ can be used as shown in equation 12:

\[ K_z = \frac{i_{s\text{max}} - i_{s\text{min}}}{i_{s\text{m}}} = \frac{1}{\cos\left(\frac{180^\circ}{Z}\right)} - \cos\left(\frac{180^\circ}{Z}\right) = \frac{\cos\left(\frac{180^\circ}{Z}\right) - 1}{\cos^2\left(\frac{180^\circ}{Z}\right)} \]  

3. Simulation analysis of chain polygon effect of scraper conveyor

Meshing transmission of sprocket and chain are to rely on the sprocket tooth toggle link to realize the rotation. Due to the limited sprocket gear, the transmission process in the meshing point to chain a wave speed, which cause the vibration of the conveyer, we usually call this phenomenon the multilateral effect.

Here that the speed of the chain wheel is variable. And setting the rotation of the sprocket function isthe angular velocity and angular acceleration as the initial Angle, for the mesh point of tangent and conveyor line laid Angle, velocity and acceleration of the meshing point chain, respectively.
\[
\begin{align*}
\dot{v}_i &= R_s \omega \cos(\varphi) \\
\ddot{v}_i &= \ddot{v}_t = R_s \beta \cos(\varphi) - \varphi \cos(\varphi) \\
\varphi &= \varphi_0 + \theta(t) - \int \frac{\theta(t)}{Z} \left( \frac{2\pi}{Z} - \frac{\pi}{Z} \right) \\
R_s &= \frac{L_p}{2 \sin \frac{\pi}{Z}}
\end{align*}
\]

(13)

Firstly, we start to read the data after each point in a relatively stable when running the program to the moment to the time of \( T_0 \), so we can eliminate the influence of the initial conditions and finally the simulation results of figure 3 ~ 4 to show that the polygon effect. We will result in difference, each point velocity difference \( \Delta v_i = v_{i(t)} - v_{i(0)} \), difference of tension \( \Delta F_i = F_{i(t)} - F_{i(0)} \), the static tension \( F_{i(0)} \) for each point and stable operation.

**Figure 4a.** Caused by polygonal effect of the chain wheel drive (9 teeth)

**Figure 4b.** Speed variation caused by polygon effect (9 teeth)
Figure 4c. Chain wheel drive polygon effect causes the change of speed of special point chain (9 teeth)

Figure 4d. Chain wheel drive polygon effect causes the change of tension of special point chain (9 teeth)

The simulation results show that the main influence of polygon effect is the number of sprocket, because the more the rack has, the more the operation is stable. The velocity fluctuation is in the case of 7 teeth. In the case of 9 teeth, the fluctuation value is [-0.048m/s, 0.01m/s] respectively. And the fluctuations are more pronounced on the side.
Figure 5a. Tension variation caused by polygon effect (7 teeth)

Figure 5b. Speed variation caused by polygon effect (7 teeth)
Figure 5c. Driving polygon effect causes the change of tension of special point chain (7 teeth)

Figure 5d. Chain wheel drive polygon effect causes the change of speed of special point chain (7 teeth)

From the simulation results we can obtain that the length of the conveyor is sensitive to the polygonal effect, and the shorter the scraper conveyor, causing the more obvious the influence.

4. Conclusion
Based on the study of the chain of scraper conveyor, the causes of chain polygonal effect are analyzed and the factors affecting polygonal effect are analyzed. The relevant conclusions are as follows:

1) The main influencing factor of the chain polygonal effect is the number of teeth of the chain wheel. With the increase of the number of teeth, the speed fluctuation of the chain movement decreases, making the scraper conveyor movement more stable.
2) In the absence of load and load, a series of simulation of the scraper is carried out. The experiment shows that the load will obviously increase the tensioning force of the chain.

3) Through the comparative analysis of 7 teeth and 9 teeth, it can be seen that the chain length has a certain effect on the polygon effect, so by controlling the length of the chain, it can reduce the vibration of the scraper chain in the movement and increase the stability.

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