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Effect of Excitation Vibration at Different Frequencies on Pick Cutting

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ABSTRACT

The pick vibration model was established and analyzed, and discussed the influence of vibration at different frequencies on the cutting load. Then a discrete element model of the interface coal seam is established in EDEM to analyze the change of cut load at different vibration frequencies. The conclusion shows that it is more suitable to apply high frequency vibration when the coal seam content is high, and it is more suitable to apply low frequency vibration when the rock layer content is more.

KEYWORDS

Pick; Vibration performance; Rotation cutting; Discrete element models.

1. INTRODUCTION

Drum cutter as a widely used cutting tool at home and abroad, its structure is simple, production and processing process is convenient, and in the underground installation and disassembly are more convenient. At present, the domestic coarer is more used for double drum type mining, and the picks distributed on the drum directly affect the mining efficiency, so it is of great significance to study the picks on the drum coarer. Scholars at home and abroad have made many relevant research programs. Among them, Li Lie and Jiang Hongxiang[1] used high pressure water jet to assist the rock breaking teeth, and explored the cutting performance of different positions; Liu Jinxia et al.[2] made a relevant study on the influence of different cutting speed of cutting teeth on cutting performance; Che Jianwei[3] analyzed and studied the theory of the relationship between shearer cutting force, its motion parameters and roller gear geometry parameters, and analyzed the influence of shearer cutting radius, traction speed and drum speed cutting force. Based on the particle mechanics method, Zhai Siyu[4] further analyzed the change rules of coal rock particle crack, force chain and stress, and further studied the mechanical properties of coal rock material. Domestic other scholars for the parameters of shearer influence for many research, zhang yu et al. Using EDEM software for cutting parameters of different cutting experiment, according to the design of the design of the different motion model, application of discrete element analysis of different models and numerical simulation test, reached the conclusion[5~8].

2. ANALYSIS OF THE VIBRATION CHARACTERISTICS OF SINGLE PICK

During the cut works, there must be a gap between the intercept and the pick, and the position of the gap is nonlinear. Therefore, consider the influence of the gap is nonlinear during the pick, and the vibration of the pick is regarded as the dynamic model as shown in Figure 1.

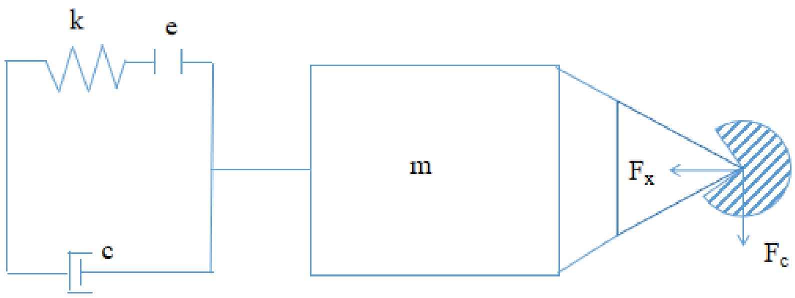

Figure 1. Dynamic model of pick

In the Figure 1, the cut load is *Fc*, N; m is the mass of the intercept itself, kg; *c* represents the damping coefficient of the whole system, N•s/m; *e* is the gap between the intercept and the gear, usually *e*=0.2~0.7 mm; *k* is the stiffness of the whole system, N/m; *x* is the displacement of the intercept in the same direction as the cut load when working, m. At this time, the dynamics of the intercept resistance can be listed as:

$$\ddot{x}+2\xi\omega\dot{x}+\omega^2 x=F_c \tag{1}$$

Where the value range of *x* is:

$$x=\begin{cases} x-\frac{1}{2}e & x>\frac{1}{2}e \\ 0 & -\frac{1}{2}e<x<\frac{1}{2}e \\ x+\frac{1}{2}e & x<-\frac{1}{2}e \end{cases} \tag{2}$$

In where, $\omega=\sqrt{\frac{k}{m}}$, $2\xi\omega=\frac{c}{m}$, get $\xi=\frac{c}{2\sqrt{mk}}$

ω—Natural frequency of the whole system, Hz; ξ—relative damping factor;

After data review, the damping coefficient of steel is generally 0.001~0.008, so according to the formula(1) to discuss the situation at different frequencies, according to the second order differential equation can be solved: if the general solution of the characteristic equation should have two different solutions, namely

$$x^2 + \frac{c}{m}x + \omega^2 = 0 \tag{3}$$

Because the calculated x should be a real number, the system frequency should be satisfied:

$$\omega \le \frac{c}{2m} \tag{4}$$

When applying the external vibration frequency, the vibration signal is applied to the pick.
When the applied frequency satisfies $\omega < c / 2m$, the corresponding displacement is

$$x = C_1 e^{\frac{-\frac{c}{m}+\sqrt{\frac{c^2}{m^2}-4\omega^2}}{2}h} + C_2 e^{\frac{-\frac{c}{m}-\sqrt{\frac{c^2}{m^2}-4\omega^2}}{2}h} + F_c \tag{5}$$

When the applied external vibration frequency satisfies $\omega \ge c / 2m$, the corresponding displacement is

$$x = (C_1 h + C_2)e^{-h\omega} + F_c \tag{6}$$

In MATLAB, the relationship between the displacement amount x and the cut thickness h and the frequency ω in the vibration signal is simulated, and the trend diagram of the cut thickness h and the vibration frequency ω are the corresponding independent variables, as shown in Figure 2.

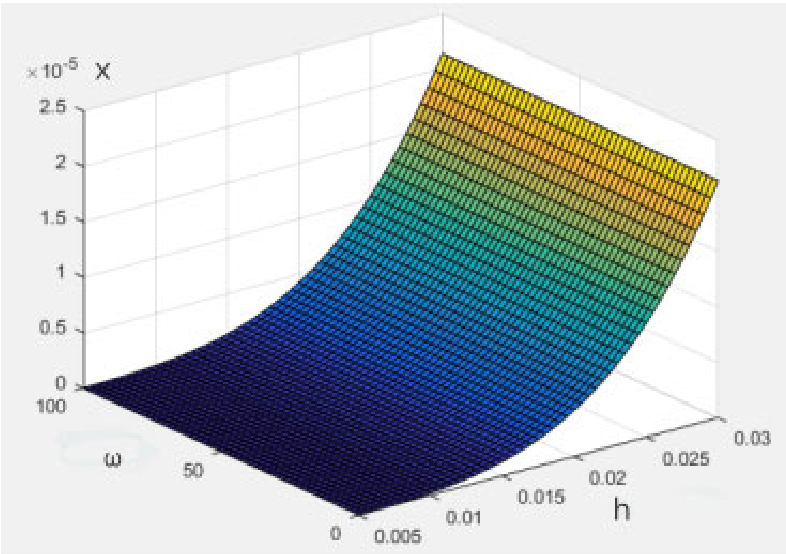

Figure 2. Trend diagram of intercept tooth displacement change

According to Figure 2, the displacement in the direction of the cut load and the total displacement does not change, indicating that the frequency change will affect the instantaneous cut load. The specific quantitative analysis needs to discuss the instantaneous load change at different frequencies.

With reference to the cut load at the instantaneous speed of the intercept, the vibration expression of the instantaneous load *F(t)* set at time *t* is:

$$F(t) = F_d \sin \omega t \tag{7}$$

Where, F_d—the maximum cutting force required for coal rock crushing, N;

t—The time of cutting the excitation vibration is half a cycle;

Therefore, when considering the influence of frequency on the instantaneous cut load, it is necessary to consider the vibration influence of the frequency size. Different frequencies correspond to different cycles, which will affect the instantaneous cut load size of the intercept to some extent.

3. SIMULATION ANALYSIS AFTER APPLYING THE DISTURBANCE

According to the theoretical analysis of the vibration characteristics of the second chapter, the excitation vibration of different frequencies will affect the instantaneous load of the intercept tooth, and the overall load change needs to be analyzed under actual circumstances. For the application of the excitation vibration, if the excitation vibration is applied in the test, the excitation vibration application is set on the intercept tooth model to replace the actual vibration application mode.

The model of the interface coal seam was established for simulation test, as shown in Figure 3, and the specific particle parameters are shown in Table 1.

For the vibration application mode of the single tooth model, consider the excitation vibration of different frequencies on the tackle model, so as to simulate the influence of the vibration on the tackle condition. The low frequency is set to 2 Hz, the high frequency is set to 200 Hz, and all the amplitude is set to 2 mm.

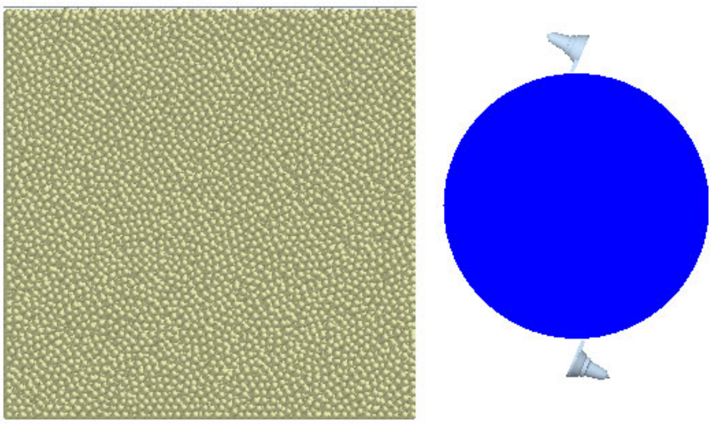

Figure 3. Model when cutting interface coal seam

In order to achieve the same axis comparison analysis of simulation data curve, the simulated data in the Analyst module after double data form a analysis diagram, through simulation under the surface of the total stress comparison diagram as shown in Figure 4, torque comparison diagram as shown in Figure 5, through the comparison curve value, the intercept applied low frequency vibration analysis and comparison.

Table 1. The specific particle parameters

The interacting particles	recovery coefficient	coefficient of static friction	coefficient of kinetic friction	Normal stiffness (N/m^2)	The tangential stiffness (N/m^2)	Normal maximum stress(Pa)	The tangential maximum stress(Pa)
Coal-Coal	0.10	0.65	0.10	1.2165×10^8	9.732×10^7	8.3183×10^6	2.3573×10^6
Coal-Gray coal rock	0.37	0.55	0.16	1.9537×10^8	1.5629×10^8	1.7615×10^7	7.4213×10^6
Gray coal rock-Gray coal rock	0.41	0.50	0.11	7.4136×10^8	5.9309×10^8	2.7563×10^7	1.2793×10^7

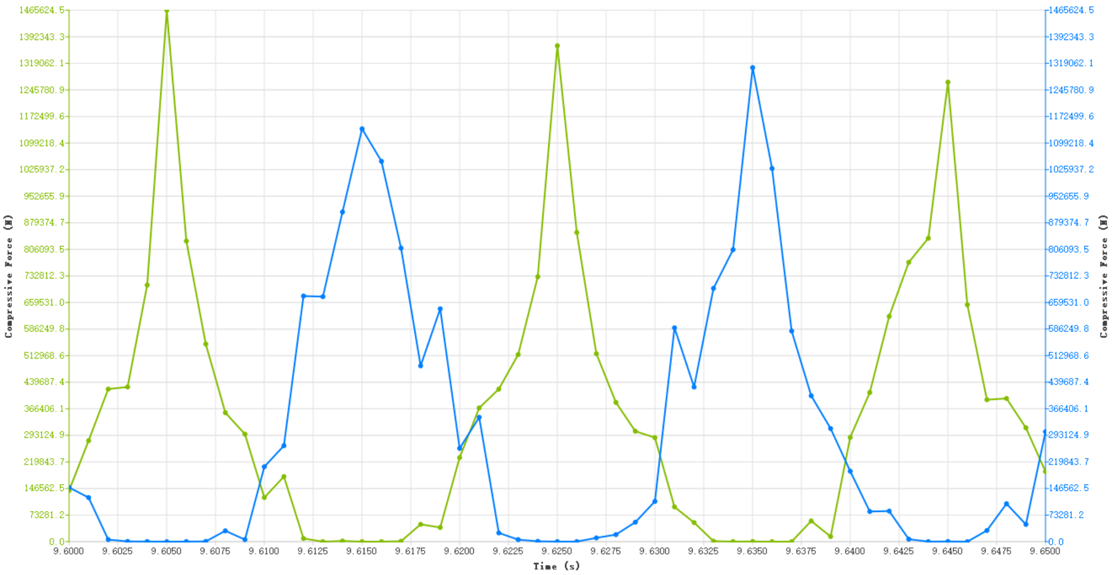

Figure 4. Comparison of total stress of tackle surface contact under low frequency vibration

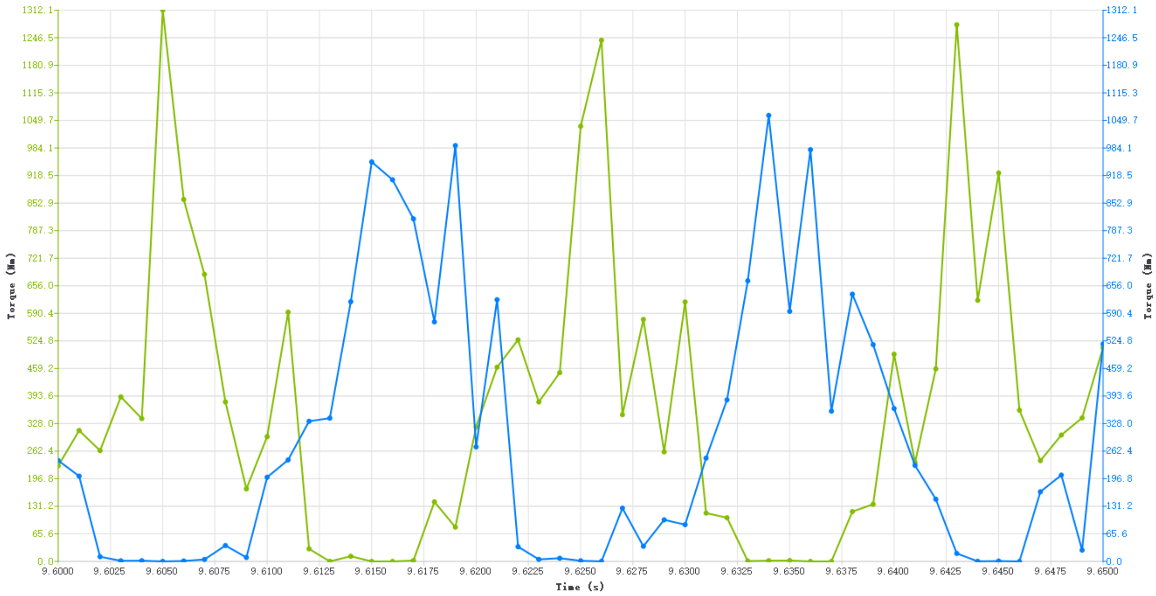

Figure 5. Comparison of intercept torque under low frequency vibration

From Figure 4 to Figure 5, the yellow-green curve is the curve after applying low-frequency vibration on the intercept tooth, and the blue curve is the curve without applying excitation vibration. Comparing Figure 4, the load on the tackle surface is increased after applying low frequency vibration, but the mean value of the overall cut load is reduced, and the size of the load before the peak is smaller than that of no excitation vibration, indicating that the load in the coal seam is lower than that of no excitation vibration, and the load difference in the rock layer is not large. Compared with the torque size of the intercept tooth, it can be concluded that the torque increases after the excitation vibration application, indicating that the average cutting force of the intercept pick is increased. In conclusion, the cutting load increases slightly, the cutting force is increased, the influence of the coal seam, and the movement in the cutting direction is more obvious, namely the displacement in the cutting direction is forward, so the excitation is applied to the low frequency vibration.

After discussing the influence of low frequency vibration on the intercept, the simulation of high frequency vibration is carried out. The comparison map of the high-frequency disturbance is shown in Figure 6, and the comparison map of the high-off torque under the high-frequency disturbance is shown in Figure 7.

In Figure 6 and Figure 7, the yellow-green curve is the curve after applying high frequency vibration on the intercept, and the blue curve is the curve without excitation vibration. From the comparison of Figure Figure 6, The cut stress after applying high frequency vibration is relatively stable, The difference between the mean is also small and the case without excitation vibration, And the load size before the peak is much smaller than that of no excitation vibration, It means that the load in the coal seam is lower than the excitation vibration, While the peak is greater than the case of unapplied excitation vibration, That the load in the rock formation becomes larger, It means that it is more suitable to apply high-frequency vibration when breaking coal, It is not suitable for the occurrence of high-frequency vibration during rock breaking; It is also concluded by comparing the magnitude of the torque that the average cut force increases after applying the high-frequency vibration, The displacement of the intercept tooth in the cut direction after applying high frequency vibration is forward.

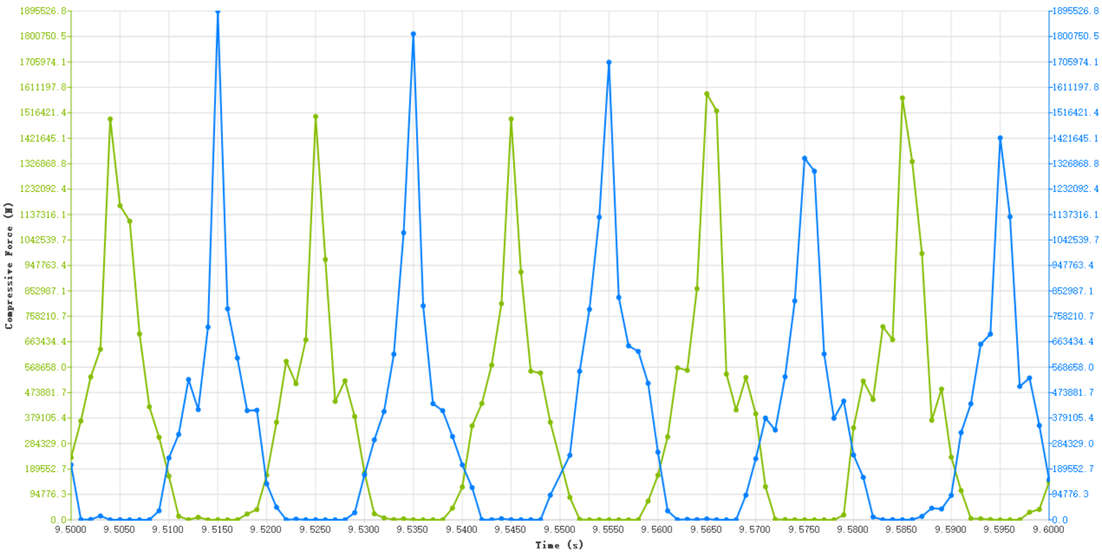

Figure 6. Comparison of total stress of tackle surface contact under high frequency vibration

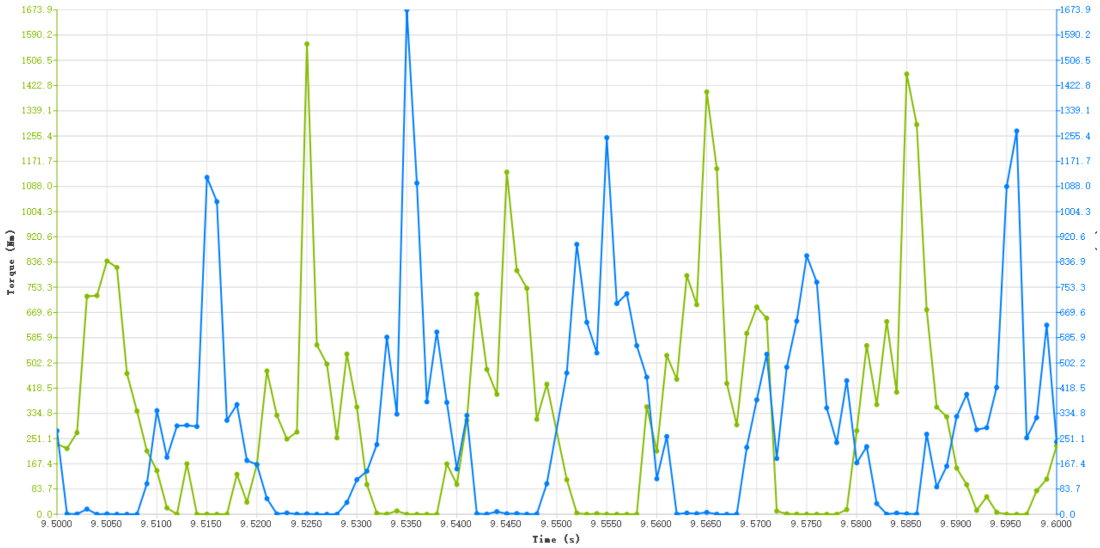

Figure 7. Comparison of intercept torque under high frequency vibration

4. CONCLUSIONS

By comparing the difference between low frequency vibration and high frequency vibration, the applied cutting under high frequency vibration cutting stress is more stable, cutting stress contrast low frequency slightly increased, the overall cutting torque shows the cutting force increases, illustrates the high frequency vibration cutting when cutting more force, but the cutting displacement in the cutting direction is larger than the low frequency vibration. Therefore, the corresponding working conditions are necessary to consider the influence of different frequencies on the intercept. If the homogeneous coal seam or coal seam is relatively large, the influence of high frequency vibration is more favorable; if the interface coal layer occurs, or the interface layer is thick and the rock content is higher, it is more suitable to apply low frequency vibration.

CONFLICTS OF INTEREST

The authors declare that they have no conflict of interest.

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