Mechanical characteristics of drum shearer with large mining height under oblique cutting

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Abstract. In order to study the dynamic characteristics of the shearer with large mining height of 8.8 m under Oblique cutting, the spatial mechanical model of the Shearer under oblique cutting was established, the angle between the drum and the working face, the load of the drum and the dynamic characteristics of the fuselage are analyzed by discrete element method and dynamics. The results show that the maximum feed rate of the front drum is 1940mm, the maximum feed rate of the back drum is 1570mm, and the angle between the front drum and the coal wall reaches a maximum of 8° at 64s, and the cutting resistance of the front drum reaches a maximum at 80s, and finally fluctuates up and down at 3.5×10^5N, the cutting resistance of the back drum increases with the cutting depth, and finally fluctuates up and down at 3.0×10^5N. The load of the front drum is 1.2 times of that of the back drum. In the process of Oblique cutting, the support force on the lower surface of the front sliding shoe increases by 3.5×10^5N, the support force on the lower surface of the rear sliding shoe decreases by 2.5×10^5N, the support force on the upper surface of the front guiding sliding shoe increases by 1.1×10^5N, and the support force on the upper surface of the rear guiding sliding shoe decreases by 2.3×10^5N, the whole machine has the tendency of forward turning and side turning to the coal wall. The average radial force between the front rocker arm and the fuselage pin is about 1.8×10^6N, the average radial force between the front cylinder and the fuselage pin is about 2.2×10^6N, and the average radial force between the rear rocker arm and the fuselage pin is about 8.0×10^5N, the average radial force between the rear cylinder and the PIN shaft is about 1.3×10^6N, which shows that the radial force at the front of the fuselage, the rocker arm and the height of the pin shaft is obviously larger than that at the rear of the fuselage. The research results are important for the design and development of large mining height shearer.

1 Introduction

As the main energy source in our country, coal accounts for more than 67% of the primary energy structure; from the coal reserves, the thick coal seam accounts for about 44% of the

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proven coal reserves and 45% of the annual output of raw coal, the thickness of coal seams in most mining areas in China has reached the standard of thick coal seams. To some extent, the mining technology of thick coal seams represents the development level of National Coal Industry[1,2]; Since 2009, CHN Energy Shendong Coal Group has started the research of large mining height in working face, and from 2017 to 2019, it has successively built and put into use 8.0 m and 8.8 m large mining height working faces, and realized the full mining height of 8m thick coal seam at one time[3,4].

At present, the mining of large mining height is still at the primary stage, and there are problems such as insufficient theoretical support and lack of engineering experience. Some experts have done relevant research on large mining height shearer, most of them focus on mining technology, surrounding rock pressure and support, etc[5,6,7]. Among them, Lei Meirong[8] made a finite element analysis of the walking wheel and the guide slide shoe of the large mining height shearer to ensure the safety of the haulage mechanism in the mining process, Yang Tao[9] made a kinematics and dynamics simulation of the cutting part of the large mining height shearer, the mechanical analysis of the key parts of the cutting part is made to determine the reliability of the cutting part; However, the research on the shearer's oblique cutting condition is still insufficient, the problems such as the fracture of the rocker arm, the damage of the slipper and its connecting fixing device caused by the oblique cutting condition are not fully understood, and the theoretical research is lacking, especially under the oblique cutting condition, the shearer's stress changes greatly, the axial force of the barrel is large, and with the cutting of the drum, the fuselage vibration is serious[10], Based on the limited search conditions, no relevant research on the mechanical characteristics of the shearer with a large mining height of more than 8m under the condition of oblique cutting has been found, and in the existing research, using the proportion algorithm and the volume algorithm to calculate the drum load during the oblique cutting feed has error[11], even only qualitative analysis, and the analysis on the cutting resistance of the shearer with a large mining height under the condition of oblique cutting feed is less., therefore, it is necessary to study the dynamic characteristics of the shearer body in the process of oblique cutting.

In view of the above problems, this paper studies the dynamic characteristics of the shearer under the condition of oblique cutting, determines the structural performance parameters in combination with the existing large mining height shearer, establishes the spatial mechanical model under the different working face inclination angle in the process of oblique cutting, obtains the change rule of the angle between the drum and the working face and the drum load by using the dynamic and discrete element analysis, and analyzes it through the dynamic software The time-domain curves of the forces on the joints between the sliding shoes and the fuselage are obtained and analyzed.

1.1 Model construction of large mining height shearer

At present, there are few large-height shearer in our country. This paper uses for reference the 7LS8 double-drum Shearer reformed by Shanghai Tiandi Science & Technology Co., Ltd and the large-height shearer produced by Xi'an Coal mining Machinery Co., Ltd, according to the 8.8m mining height setting and the large mining height already used in Shangwan Coal Mine, the overall structure parameters of the drum shearer with large mining height described in this paper are finally determined.

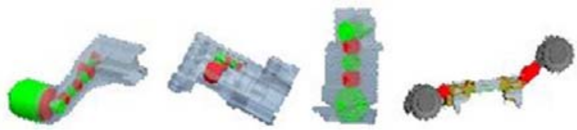

Fig. 1. Model of various parts of shearer

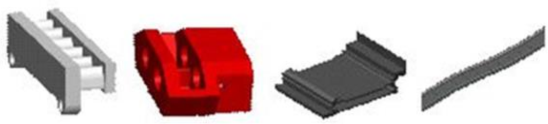

Fig. 2. Model of each part of scraper conveyor

On the basis of defining the position relationship and motion relationship among all parts of the whole machine, select appropriate motion pairs to assemble all parts. First, assemble all parts (cutting unit, traction unit and traveling punit). All parts of the shearer are built in strict accordance with the drawing model. As shown in the figure 1.

The layout of scraper conveyor determines the movement track of the whole shearer, and the guide slipper and smooth boots of shearer have great contact force with scraper conveyor. The middle part of scraper conveyor (Middle trough, Pin row and Pin row rail) is modeled, as shown in the figure 2.

1.2 Space mechanics model of shearer under oblique cutting

1.2.1 Oblique cutting characteristic

The main sumping modes of shearer are oblique cutting and tangent cutting[13], According to these two kinds of sumping methods, the sumping technology of shearer can be divided into three types: end oblique cutting, middle oblique cutting and tangent cutting.

The working tunnel environment of shearer is complex and changeable, especially under the condition of oblique cutting, the axial additional load is large, the structural parts of shearer are easy to be damaged, which is easy to cause accidents such as blocking of slide shoes, damage of connecting fixing device and bending of connecting rib plate of guide slipper, Mechanical analysis of shearer is the theoretical basis of structural optimization, life prediction and strength check, and the spatial mechanical model is more intuitive, clear and easy to accept than the traditional plane mechanical model[14].

There is an important relationship between the stress of the shearer under the oblique cutting condition and the inclination of the working face and the mining method. Considering that the inclination is too ideal in the actual condition, the paper does not describe the oblique cutting condition with the inclination of zero and the pitch angle of zero, and establishes the spatial mechanical model of the shearer under the oblique cutting condition with the inclination and the pitch angle.

The working condition of shearer oblique cutting is as shown in Figure 10, where (a) and (b) represent the schematic diagram of zero shearer downhill mining and overhand mining, (c) and (d) represent the schematic diagram of zero shearer downhill mining and overhand mining

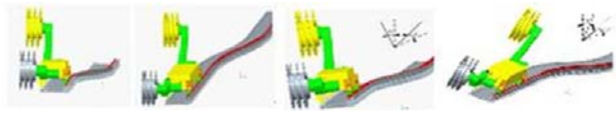

Fig.3 Schematic diagram of shearer oblique cutting feed

When the shearer moves along the curved middle trough to cut coal, the shearer is subject to cutting resistance, coal wall thrust (drum axial force), traction resistance, sliding shoe reaction force, crushing resistance (if the shearer is equipped with crushing device, there will be such force, otherwise there will be no force), For different mining methods and working face obliquity, the mechanical model of shearer's oblique cutting is different, but it can be described by the same mathematical model. Therefore, in order to avoid the burden, the spatial mechanical model of shearer's oblique cutting condition is given under the condition that the working face inclination is not zero and the pitch angle is not zero. As shown in Figure 4.

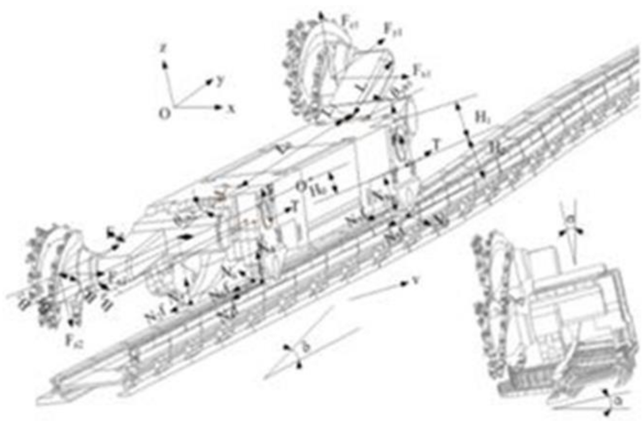

Fig.4 Shearer working space mechanical model

According to Figure.4, the mathematical model of oblique cutting under this condition is determined as shown in Formula 1.

$$
\begin{aligned}
&(F_{x1}+F_{x2})\cos\theta + N_5 - N_6 + G\cos\delta\sin\sigma = 0 \\
&2T - (F_{y1}+F_{y2}) + (F_{x1}+F_{x2})\sin\theta - G\sin\alpha - (|N_1|+|N_2|+|N_3|+|N_4|+|N_5|+|N_6|)f = 0 \\
&N_1 + N_2 + N_3 + N_4 + (F_{z1}-F_{z2}) - G\cos\delta\sin\sigma + 2F = 0 \\
&(N_1+N_2)B_1 + N_6H_0 - N_5H_0 - (N_3+N_4)B_0 + F_{z1}(B_1+B_2) - F_{z2}(B_1+B_2) \\
&+ F_{x1}(L\sin\theta_{yb1} + H_1 - H_0) - F_{x2}(L\sin\theta_{yb2} + H_0 - H_1) - 2B_0F = 0 \\
&2TH_0 - (|N_3|+|N_4|+|N_5|+|N_6|)fH_0 - (|N_1|+|N_2|)f(H_0+H_2) + (N_1+N_3)\frac{L_0}{2} - (N_2+N_4)\frac{L_0}{2} \\
&+ F_{z1}\left(L\cos\theta_{yb1} + L_1 + \frac{L_0}{2}\right) + F_{y1}(L\sin\theta_{yb1} + H_1 - H_0) + F_{z2}\left(L\cos\theta_{yb2} + L_1 + \frac{L_0}{2}\right) \\
&- F_{y2}(L\sin\theta_{yb2} + H_0 - H_1) = 0 \\
&2TB_0 - (|N_3|+|N_4|)fB_0 - |N_5|f(B_3+B_0) - |N_6|f(B_0-B_3) + (|N_1|+|N_2|)fB_1 - (N_5+N_6)\frac{L_0}{2} + \\
&(F_{y1}+F_{y2})(B_1+B_2) - F_{x1}\left(L\sin\theta_{yb1} + L_1 + \frac{L_0}{2}\right) + F_{x2}\left(L\sin\theta_{yb2} + L_1 + \frac{L_0}{2}\right) = 0
\end{aligned}
\tag{1}
$$

In style, T is the component of the single traction mechanism of the shearer along the y-axis direction, N; F is the component of the single traction mechanism of the shearer along the z-axis direction, N; G is the dead weight of the shearer, N; N_1、N_2 are respectively the z-axis support reaction force of front and rear smooth boots, N_3、 N_4 are respectively the z-axis support reaction force of front and rear guide slipper, N_5、N_6 are respectively the x-axis support reaction force of front and rear guide slipper; B_i is the position dimension of each force point along the x-axis direction, m; L_i is the position dimension of each force point along the y-axis direction, m; H_i is the position dimension of each force point along the z-axis direction, m; F_{x1}、 F_{x2} are the axial forces of the front and rear rollers, N; F_{z1}、 F_{z2} are cutting resistance of front and rear drum, N; F_{y1}、F_{y2} are the propulsion resistance of the front and rear rollers, N; θ is the angle of the fuselage caused by the difference of the transverse deviation of the middle trough of the front and rear sliding shoes, °; $\theta_{yb1}\theta_{yb2}$ are the swing angles of the front and rear rocker arms of the shearer, °; δ is the inclination of working face, °; σ is the pitch angle of the shearer, °.

1.3 Kinematics analysis of shearer under oblique cutting

The movement track of Shearer in the process of oblique cutting is related to the arrangement of scraper conveyor. According to experience, the horizontal angle between adjacent middle grooves of scraper conveyor is generally no more than 3°, In this paper, the horizontal angle between the middle trough is designed as 2 °, and the length of single middle groove is 1750mm. The oblique cutting and feeding process is realized by 9 middle grooves, the included angle between each two sections from section 1 to section 5 is 2 °, the included angle between each two sections from section 5 to section 9 is -2°, and the amount of the shearer pushing to the coal wall side after passing the S-bend of the scraper conveyor is 1550mm.

In order to get the accurate position of drum relative to coal wall and the angle between drum and working face, the oblique cutting process of shearer is analyzed by using kinematics and discrete element method (EDEM) , first of all, kinematics analysis of Shearer Oblique cutting tool path changes and so on.

1.3.1 Kinematics simulation of shearer fuselage

1.3.1.1 Simulation preprocessing

This paper studies the mechanical characteristics of the shearer in the process of oblique cutting and feeding. It mainly considers the forces exerted by the coal wall and scraper conveyor on the shearer, and does not consider the internal effects of the body temporarily. In order to highlight the external effects on the mechanical characteristics of the shearer and reduce the amount of simulation calculation, the cutting part, the traction part and the walking part of the shearer are simplified, that is, the motor and the driving part are not imported, to ensure the quality of the shell, that is, the position of the center of mass is the same before simplification. In the simplification of the cutting part, it is considered that there are many parts of the drum, and the force of the drum will be transferred to the front end of the rocker arm, so the drum is simplified as a particle at the front end of the rocker arm according to its position of the center of mass; The force of scraper conveyor on Shearer mainly comes from the friction between guide slipper and pin row, smooth boot and middle trough, so the contact surface of pin row and middle trough and smooth boot is used instead of scraper conveyor. After consulting the relevant literature and adjusting the contact parameters for many times, the elastic coefficient 165000, viscosity coefficient 120 and friction coefficient 0.15 are finally set. The specific model is shown in Figure 5.

According to the distance between the guide slipper and the length of the middle groove, it is determined that the displacement of the oblique cutting feed is 26160mm, the walking speed of the oblique cutting feed is 200mm/s, and the simulation time is 130s; the simulation step is 1s, the simulation steps is 130, and each step takes 10 sampling points. At the same time, the image of feed process is cut every 10s, and the specific motion process is shown in Fig 6.

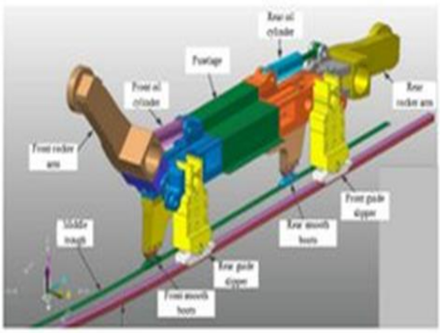

Fig. 5 The simulation model of coal shearer

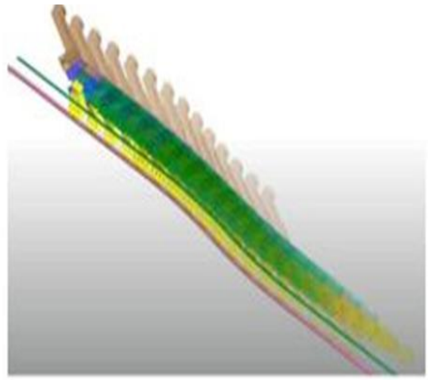

Fig. 6 Schematic diagram of shearer move

1.3.1.2 Simulation results and analysis

From Fig.7 to 10, it can be seen that in the 0-80s, the front drum gradually cuts into the coal wall, and at 80s, the feed amount reaches the maximum value of 1940mm. The rear drum is in the no-load state outside the coal wall, and at 80s-130s, the front drum moves 370mm to the side of the goaf, the rear drum starts to cut into the coal wall, and the feed amount increases until the straight-line cutting state. In this paper, the components of the shearer are idealized as rigid bodies, and the shape variables of the fuselage and components are not considered in the working process. Therefore, the angle between the front and rear drum and the working face is always equal. The angle between the drum and the working face increases first and then decreases.

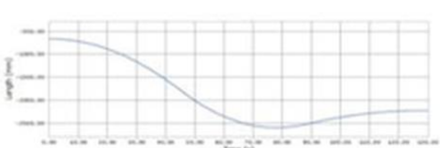

Fig. 7. Z-axis position of front drum mass center

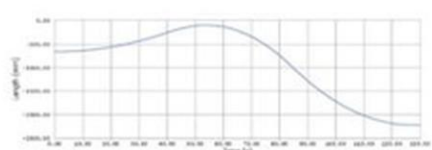

Fig. 8. Z-axis position of front drum mass center

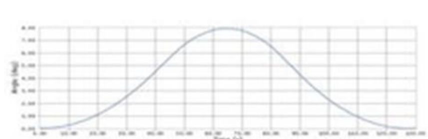

Fig. 9. The angle between the front roller and the working face

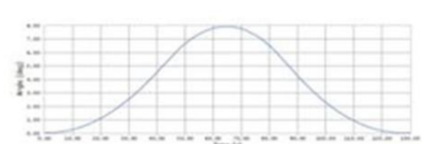

Fig. 10. The angle between the rear cylinder and the working face

When the front guide slipper of the shearer enters the straight section of the pin rail, there is still an angle of 6 ° between the body direction and the working face, and the rocker arm does not return to normal. As the rear guide slipper gradually enters the straight section of the pin rail, the direction of the whole machine is gradually parallel to the working face. As the front guide slipper enter the inclined section, the rear guide slipper is still in a straight section, and the rear drum is offset to one side of the goaf until the rear guide slipper enters the inclined section, the rear drum mining gradually cuts into the coal wall, The accuracy of simulation results can be determined by analysis and comparison, which can provide available data for subsequent simulation.

For the position of the drum mass centers and the angle between them and the working face, a set of data is extracted every 10s to get the drum position information, as shown in Tab.1:

Table 1. Drum relative position information

time	front roller		rear roller	
	Z axis position d_1(mm)	angle with working face θ_1(°)	Z axis position d_2(mm)	angle with working face θ_2(°)
0	-659	0	-659	0
10	-720	0.295	-634	0.295
20	-822	1.124	-560	1.124
30	-1160	2.549	-432	2.549
40	-1550	4.543	-252	4.543
50	-2007	6.663	-107	6.663
60	-2354	7.815	-127	7.815
70	-2550	7.783	-334	7.783
80	-2595	6.532	-733	6.532
90	-2497	4.283	-1274	4.283
100	-2373	2.313	-1711	2.313
110	-2286	0.955	-2011	0.955
120	-2237	0.196	-2180	0.196
130	-2226	0	-2226	0

1.3.2 Simulation analysis of drum load

In the process of oblique cutting, the load of the drum changes constantly, which has a decisive influence on the mechanical vibration of the machine body, at present, there is no precedent for the study of the cutting load of the 8.8m high shearer. Therefore, it is necessary to conduct a pioneering study on the load characteristics of the drum during the cutting process of the large high shearer.

The thickness of 1^{-2} seam of Shangwan Coal Mine in CHN Energy Shendong Coal Group is 5.35m~9.6m, and the average coal seam thickness is above 8m. Determination of coal seam depth and coal rock hardness based on geological conditions of Shangwan Coal Mine, the buried depth of coal seam is 200m, Coal rock hardness Proctor coefficient is set as $f5$.

The coal wall model of 8.8m*4m*20m is established according to the geological conditions of coal mine, and the cohesive bond is added between the particles to form the whole coal wall. According to table 4.1, the motion process is divided into different stages, and the motion parameters are set up in one stage, and the angle between the roller and the working face is changed in the next stage, so that the cutting process of the roller is consistent with the oblique cutting

The load time-domain curve of the front and rear drum of the shearer is obtained through the discrete element simulation, as shown in the figure.

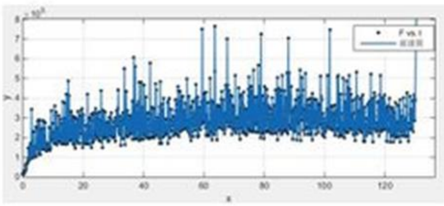

Fig. 11. Load curve of front roller

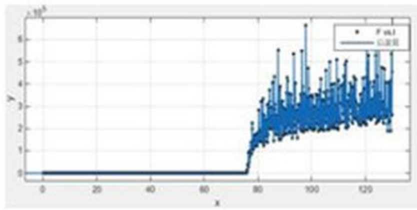

Fig. 12. Load curve of rear roller

From figures, it can be seen that in the 0-80s, the front drum cuts into the coal wall, and the drum load increases rapidly. With the increase of the feed amount, the increase of the feed speed and the drum load slows down. At this time, the rear drum does not cut into the coal wall, and the load is 0; when the movement is about 80s, the feed amount of the front drum reaches the maximum, and the load of the drum reaches the maximum value of 3.8×10^5N. The rear drum starts to cut into the coal wall. At this time, the angle between the drum and the working face is the largest, and the feed speed is the fastest, so the load of the rear drum increases sharply; After 80s, the feed amount of the front drum decreases until the straight cutting, the load of the drum decreases until it is stable, which is 3.5×10^5N. The feed amount of the rear drum increases but the feed speed is slow, and the load of the drum increases slowly until it is stable.

The reason is clear, at the beginning of oblique cutting, the number of picks participating in cutting on the drum is less, the cutting depth and width of the picks are not large, the energy used for cutting is less, and the drum load is relatively small, with the advance of the oblique cutting process, the number of picks involved in cutting increases, and the cylinder load also increases, When the oblique cutting enters the full cutting depth of the drum, the oblique cutting feed is close to the end and the drum reaches the maximum, with the moving drum of the shearer entering the linear cutting state, the load tends to be stable. Through the comparison between the kinematic simulation results and the discrete element simulation results of the shearer, it can be seen that the change trend of the drum load is closely related to the feed volume, feed angle and feed speed of the drum in the process of oblique cutting.

1.4 Mechanical simulation of coal mining machine under oblique cutting

The drum load under the oblique cutting of the shearer is acted as an external excitation at the drum center of mass. The load of shearer drum in cutting coal and rock is decomposed into cutting resistance in x-axis direction, traction resistance in y-axis direction and lateral force in z-axis direction. According to the literature, y =(0.5~0.7)x, z = (0.1~ 0.2)x. In this paper, y= 0.7x, z=0.2x.

The load data of the drum obtained from the discrete element analysis is applied to the center of mass of the drum by the spline interpolation function. The dynamic friction coefficient is set to 0.15 in the contact between the shearer and the scraper conveyor, and the simulation step and sampling point are consistent with the kinematic simulation setting.

1.4.1 Stress on the lower surface of smooth boot

As shown in Figure 13, the support force of the front smooth boot before the oblique cutting is 4×10^5N. As the front drum cuts into the coal wall, the support force increases rapidly to 6×10^5N, and increases gently to 6.5×10^5N with the increase of the feed amount, when the rear drum starts to cut into the coal wall, the support force of the front smooth shoe increases with the increase of the feed amount, and finally it is stable at 7.5×10^5N. The change rule of the walking friction force of the front smooth boot is consistent with that of the supporting force, with the maximum value of 1.7×10^5N. The friction force of the front smooth boot in the vertical direction of the coal wall is positive within 0-57s, that is, it points to the direction of the goaf, because there is a swing towards the coal wall in the front section of the shearer during this period, The variation law of the walking friction force of the front smooth shoe is consistent with that of the supporting force, and the maximum value is 1.7×10^5N. The friction force of the front smooth boot in the vertical direction of the coal wall is positive within 0~57s, that is, it points to the direction of the goaf. The reason is that the front section of the shearer swings in the direction of the coal wall during this period, and it is negative within 57s ~ 130s, that is, it points to the direction of the coal wall. because the front section of the shearer swings in the direction of the goaf during this period. The maximum value in the whole process is 3.5×10^4N, and the fluctuation is large.

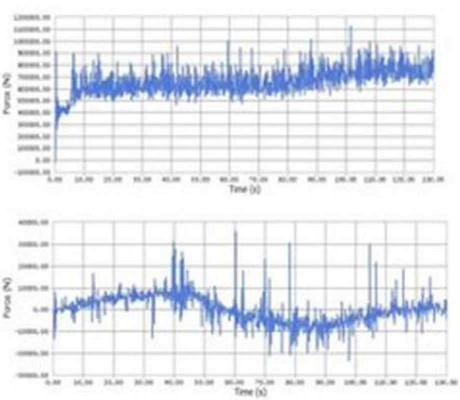

Fig. 13. The time domain curve of the force of the front smooth boots

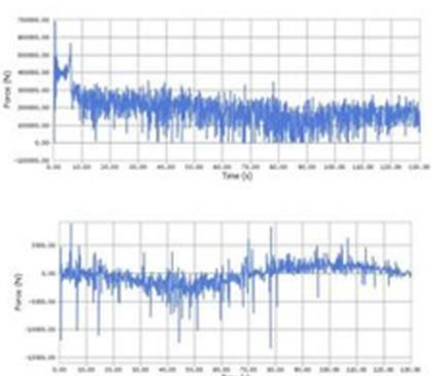

Fig. 14. The time domain curve of the force of the post smooth boots

As shown in Figure 14, the support force of the rear smooth boot before the oblique cutting is 4×10^5N. As the front drum cuts into the coal wall, the support force of the rear smooth shoe rapidly decreases to 2.5×10^5N, and decreases to 2×10^5N with the increase of the feed amount, when the rear drum starts to cut into the coal wall, the support force of the rear smoothing shoe continues to decrease to 1.5×10^5N with the increase of the feed amount, and it appears to be 0 many times in the whole movement process. The change rule of friction force of back smooth boot along the direction of coal wall is consistent with that of support force, the change rule of friction force in the vertical coal wall direction of the rear smoothing boot is similar to that of the front smoothing shoe in time, but the change range is small, and the maximum value in the whole process is only 1.3×10^4N.

1.4.2 Force on each surface of front guide slipper

As shown in Figure 15, the support force on the upper surface of the front guide slipper before the oblique cutting is 2.3×10^5N, which increases rapidly to 3×10^5N as the front drum cuts into the coal wall, and increases gently to 4×10^5N as the feed amount increases, when the rear drum starts to cut into the coal wall, with the increase of the feed amount, the change trend of the support force on the upper surface of the front guide shoe changes from increasing to decreasing, and finally to 3.4×10^5N, the variation law of friction force on the upper surface of front guide slipper along the direction of coal wall is consistent with that of support force, The friction force on the upper surface of the front guide slipper in the direction perpendicular to the coal wall keeps two-way vibration near 0.

However, the support force and friction force of the lower surface of the front guide shoe are always 0, which means that the lower surface of the front guide slipper does not contact with the pin rail.

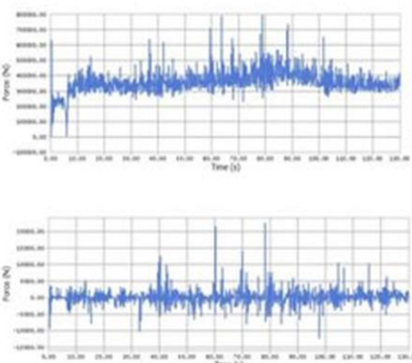

Fig. 15. The force time domain curve above the front guide slipper

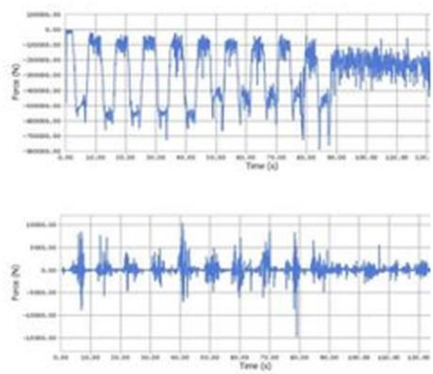

Fig. 16. Time domain curve of front force of front guide slipper coal wall

The force on the side near the coal wall of the front guide slipper is shown in Fig.16. In the 0 ~ 90s, its supporting force changes periodically, over time, the minimum support force increases gradually in each cycle, while the maximum changes slightly, but the impact increases, within each cycle, the support force rapidly increases from minimum to maximum, keeps going left for 3 seconds and quickly decreases to minimum. After 90 seconds, the front guide slipper leaves the "s" bend of the scraper conveyor and enters the straight section, with the support increasing from 2×10^5N to 2.7×10^5N. The law of variation of walking friction is consistent with that of supporting force, the vertical friction force is 0, but there is periodic small vibration in the range of 0 ~ 90s. According to the movement characteristics of the shearer's oblique cutting feed, the reason for the periodic change of the force on the 0 ~ 90 is that when the front guide slipper passes through the middle connection of the two adjacent pin rows, the movement direction and the force direction change suddenly, the support force and friction force are the largest, and the force is the smallest after passing through the connection.

The force on one side of the goaf of the front guide sipper is shown in Fig.17, and there is a periodicity similar to that on the side of the coal wall in the support force and friction force on its surface. The maximum value of the support force is 7.4×10^5N. With the change of time, the minimum value of the support force in each cycle is 0, and the maximum value decreases gradually, but the impact is enhanced. After 90s, the support force and friction force on the surface are all 0, which means that one side of the goaf surface of the front guide shoe does not contact with the pin rail after 90s.

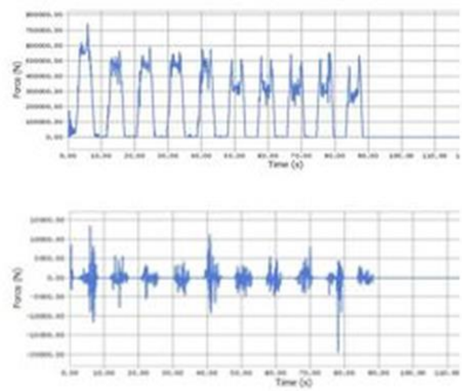

Fig. 17. Time domain curve on one side of front guide slipper goaf

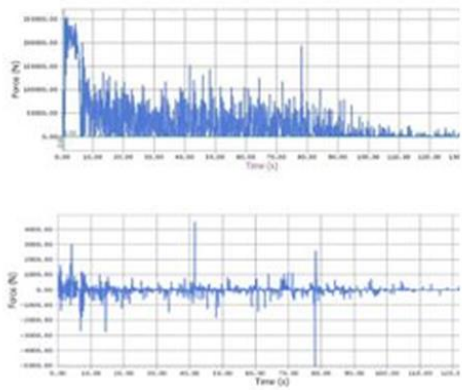

Fig. 18. The time domain curve of the force on the rear guide slipper

1.4.3 Force on each surface of rear guide slipper

As shown in Fig.18, the force on the upper surface of the rear guide slipper is about 2.5×10^5N before the oblique cutting feed. As the front drum cuts into the coal wall, it rapidly reduces to 1×10^5N, and then it becomes smaller with the increase of the feed amount of the front drum, at 80s, the feed amount of the front drum reaches the maximum. When the rear drum cuts into the coal wall, with the increase of the feed amount, the support force decreases gradually, and there are many times when the support force is 0 in the whole oblique cutting feed process. The variation law of the friction force on the upper surface of the rear guide slipper along the direction of the coal wall is consistent with that of the support force. The friction force on the upper surface of the back guide slipper shoe keeps two-way floating near 0.

The force on the lower surface of the rear guide slipper is shown in Fig.19. The support force before the oblique cutting feed is about 0, 0-80s. The support force increases with the increase of the feed amount of the front drum. After 80s, the feed amount of the front drum reaches the maximum, and the rear drum starts to cut into the coal wall. With the increase of the feed amount of the rear drum, the maximum value of the support force on the lower surface of the rear guide slipper continues to increase by 6.3×10^5N. The whole In the process of oblique cutting, the support force on the lower surface of the back guide shoe is 0 for many times, which leads to a large impact of the load. The variation law of friction force on the lower surface of rear guide slipper along the direction of coal wall is consistent with that of support force。The friction force of the lower surface of the back guide slipper in the direction perpendicular to the coal wall is small and the two-way vibration is kept near 0.

The force on one side of the coal wall of the rear guide slipper is shown in Fig.20, and its variation law is similar to that on the surface of the goaf of the front guide slipper. The difference is that its periodicity occurs after 40s, and the maximum supporting force is 6.2×10^5N, which indicates that the rear guide slippers do not enter the "S" section of the scraper conveyor before 40s. It can also be found from the image that when the front guide slipper enters the "S" bending section, it will affect the force on the rear guide slipper. The change law of walking friction is consistent with that of supporting force, The vertical friction is 0, but there is periodic vibration in the range of 40-130s.

The force on one side of the goaf of the rear guide slipper is shown in Fig.21, and its amplitude variation law is similar to that on the surface of the coal wall of the front guide slipper, the periodic variation law is similar to that on the coal wall of the rear guide slipper, and the maximum supporting force is 8.6×10^5N. The reason for this change is the same as the previous analysis.

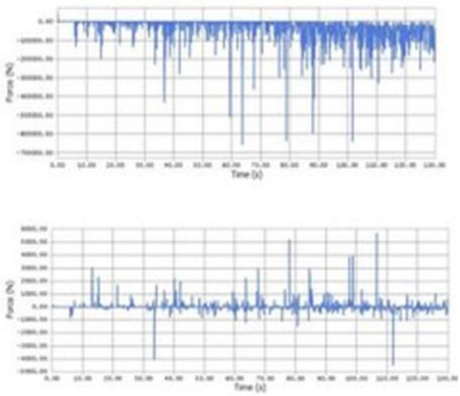

Fig. 19. The time domain curve of the force under the rear guide slipper

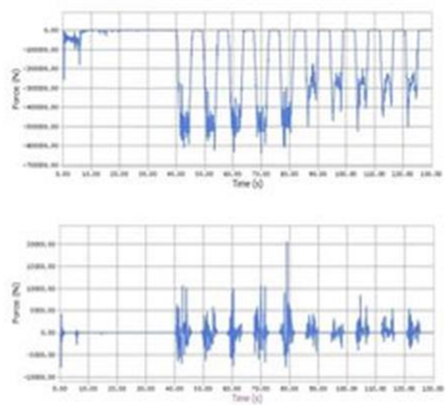

Fig. 20. Time domain curve of side stress of coal wall of rear guide slipper

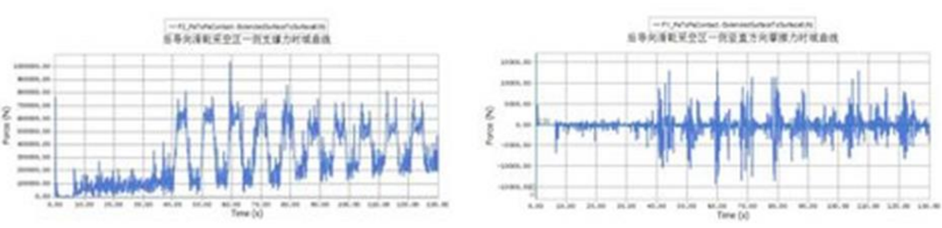

Fig. 21. Time domain curve on one side of a rear guide slipper goaf

1.4.4 Stress at each pin axis of the fuselage

The radial force of front rocker arm and fuselage pin shaft, and the radial force of front oil cylinder and fuselage pin shaft are shown in Fig. 22and 23. The average value of the former is about 1.8×10^6N, the average value of the latter is about 2.2×10^6N, and the size of the latter is 1.2 times of the former, with the same change rule. It can be seen from the curve that the change rule is consistent with the force change of the front drum, and the difference is that the force suddenly increases in 6s.

The radial force of rear rocker arm and fuselage pin shaft, and the radial force of rear oil cylinder and fuselage pin shaft are shown in Fig.24 and 25. The average value of the former is about 1.3×10^6N, the average value of the latter is about 8×10^5N, and the size of the latter is 0.6 times of the former, with the same change rule. It can be seen from the curve that the change rule is consistent with the force change of the rear drum.

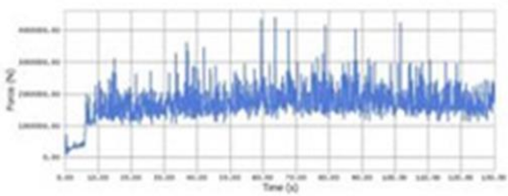

Fig. 22. radial force curve of front rocker arm and fuselage pin

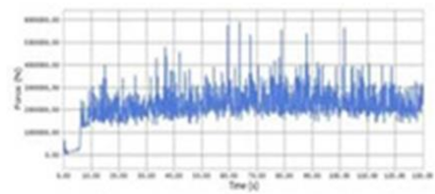

Fig. 23. radial force curve of front oil cylinder and fuselage pin

According to the stress curve of the contact surface of the shearer, it can be seen from the analysis of the movement process of the oblique cutting: before oblique cutting of high mining height shearer, the support force of the lower surface of the front and rear smooth boots is 4×10^5N, and the support force of the upper surface of the front and rear guide slippers is 2.3×10^5N, at this time, the whole shearer is running smoothly and the center is close to the coal wall; In the process of oblique cutting, The support forces on the lower surface of the front smooth boot and the upper surface of the front guide slipper were increased, which were stable at 7.5×10^5N and 3.4×10^5N respectively, The support forces on the lower surface of the rear sliding shoe and the upper surface of the rear guiding sliding shoe decreased and they were stable at 1.5×10^5N and 0N respectively, however, the increase of the support force on the lower surface of the rear guide slipper indicates that the front section of the whole machine tends to decline when the shearer is oblique cutting, resulting in the tendency of the back section to gradually rise; the upper surface support force of the front and rear guide slippers and the front smooth boots are all positive, while the lower surface support force of the front guide shoes is always 0, indicating that the front end of the fuselage is relatively stable in the vertical direction, however, the support force on the lower surface of the rear guide slipper is generally greater than that on the upper surface, especially after the rear drum cuts into the coal wall, it shows that the rear section of the shearer has a tendency to dump to the coal wall side. To sum up, the shearer machine has a trend of forward rollover and coal wall side rollover.

In the process of Oblique cutting, the support force on the two sides of the front and rear guide slipper is relatively stable in the straight section of the scraper conveyor, but when entering the "s" section, there is a great impact when passing through the joint position between the two pin rows, The maximum supporting force on one side of the coal wall of the front guide slipper is 8×10^5N, the maximum supporting force on one side of the goaf of the front guide slipper is 7.4×10^5N, the maximum supporting force on one side of the coal wall of the rear guide slipper is 6.2×10^5N, and the maximum supporting force on one side of the goaf of the rear guide slipper is 8.6×10^5N, it can be seen that in the process of oblique cutting, the supporting force on one side of the front guide shoe coal wall is slightly greater than that on the side of the goaf, and the supporting force on the other side of the rear guide shoe coal wall is less than that on the side of the goaf. Therefore, in the design of guide shoes and pin rows, the impact force on them should be fully considered, and the impact load generated here should be fully considered on the dynamics of the whole machine.

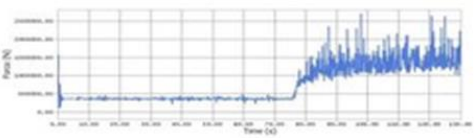

Fig. 24. radial force curve of rear rocker arm and fuselage pin

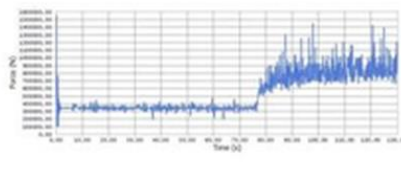

Fig. 25. radial force curve of rear oil cylinder and fuselage pin

For the radial force on the pin shafts of the fuselage, the change rule is the same as that of the roller. The radial force between the front rocker arm and the pin shaft of the fuselage on the front traction part is smaller than that between the front cylinder and the pin shaft of the fuselage, and the radial force between the rear rocker arm and the pin shaft of the rear traction part is larger than that between the rear cylinder and the pin shaft of the fuselage. The strength of the structure at each hinged ear shall be considered according to the stress characteristics of each pin shaft to avoid damage.

2 Conclusion

(1) Using kinematics simulation to analyze the movement discovery of oblique cutting of shearer with large mining height, the maximum feed volume of the front drum is 1940mm, and it is finally stable at 1570mm, when the rear drum starts to cut into the coal wall at 80s, the feed volume gradually increases to 1570mm and then becomes stable. The feed amount of the front drum is larger than that of the rear drum, at 64 seconds, the angle between the front and rear drum with the coal wall is the maximum, which is 8 °; Using the position information obtained from kinematics to analyze the cutting resistance of drum under the condition of oblique cutting by discrete element method, The cutting resistance of the front drum reaches the maximum value of 3.8×10^5N in 80s, and then stabilizes at 3.5×10^5N with the decrease of the feed amount. The cutting resistance of the rear drum gradually increases with the cutting depth, and finally stabilizes at 3×10^5N; It can be seen that the greater the feed amount, the greater the drum load, and the front drum load is 1.2 times of the rear drum load.

(2) Dynamic simulation of the whole machine under the condition of oblique cutting by applying external load to the drum, During the whole oblique cutting process, the support force of the lower surface of the front smooth boot increases by 3.5×10^5N, the support force of the lower surface of the rear smooth boot decreases by 2.5×10^5N, the support force of the upper surface of the front guide slipper increases by 1.1×10^5N, and the support force of the upper surface of the rear guide slipper decreases by 2.3×10^5N, at this point, the whole machine has the tendency of forward turning and side turning to the coal wall; The average radial force between the front rocker arm and the fuselage pin shaft is about 1.8×10^6N, the

average radial force between the front oil cylinder and the fuselage pin shaft is about 2.2×10^6N, the average radial force between the rear rocker arm and the fuselage pin shaft is about 8×10^5N, and the average radial force between the rear oil cylinder and the fuselage pin shaft is about 1.3×10^6N, The results show that the radial force at the front part of the fuselage, the rocker arm and the height of the cylinder pin is obviously larger than that at the rear part of the fuselage.

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