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Research of Response Difference on Coal Cutting Load under Different Cutting Parameters

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Cutting performance is always an important direction in coal research, and it is related to different structural and working parameters. However, most references tend to judge the effectiveness of optimizations with a mean value method while not taking the randomness of load into consideration. Based on this, the paper provides a method to judge the effectiveness of optimizations based on stochastic load fluctuations. Before providing the method, the shearer drum is established, and cutting performance is studied under a different number of conical picks, mounting angles, and cutting positions. To make judgments of optimization effectiveness, we find that only when the "fluctuation by structure" is larger than "fluctuation by randomness" can we make sure that the optimization is valid. Results indicate that the optimization of cutting position variations on cutting performance is invalid. In addition, the order of impact on cutting performance from strong to weak is the number of conical picks, the mounting angles, and cutting positions. The present paper provides a new idea for judging of the effectiveness of structure optimizations from the perspective of load randomness, and it is conductive to enrich related research on coal cutting.
Keywords: single pick, drum cutting, cutting positions, mounting angles, effectiveness of modification

Highlights

- *Coal cutting under a single-pick and drum cutting model is studied with the finite element method.*
- *The influence of cutting models, cutting positions, and mounting angles on cutting force is explored.*
- *Results show that the cutting force under a single-pick cutting model is three to four times larger than that under drum cutting model.*
- *A method for evaluation on structure variation effect is put forward, and the factors influencing cutting load in order from strong to weak are cutting model, mounting angle, and cutting positions.*

0 INTRODUCTION

A shearer is important equipment for coal mining, and its performance determines the efficiency of such mining. Working under complex and harsh conditions, the conical picks mounted on the shearer drum are the cutters that participate in coal mining directly and some material failures, such as heavy wear, are prone to occurring on picks. Therefore, research on strength and wear resistance on the cutter is always in progress. In terms of the contents in previous research, a wide range of factors, such as the geometric and physical parameters of conical pick [1] and [2] and structure of coal [3] and [4], often occur in research and the final results show that the cutting load can be influenced by these factors. In terms of the simulation model applied in research, the single pick cutting model and drum cutting model are widely used; the former model occupies the major proportion in research. In fact, from the perspective of pick arrangement and mounting angle, the drum cutting model is much closer to working conditions in coal mining than the single pick cutting models, which has been verified in some previous research. Wang et al. [5] studied peak cutting force under the different half-cone angle of picks, the tensile strength and brittleness index of coal and rock. Hekimoglu and Ozdemir [6] mentioned that the arrangement of cutter tools on the drum, known as tool lacing, is one of the most critical factors that have a significant influence on cutting performance and the different pick arrangements should be designed according to cutting conditions. Liu et al. [7] researched rock fragmentation processes with single and double cutters' model in the numerical method. He concluded that the proper line spacing played an important part in cutting efficiency improvement. In a word, the line spacing and pick arrangement play a vital role in cutting performance while those parameters cannot be simulated with single pick cutting models. Therefore, the drum cutting model is the proper model that is suitable for research on cutting performance of shearer.

In the coal-cutting performance research, three kinds of approaches are available: theoretical, numerical, and experimental. Menezes et al. [8] and Li et al. [9] studied the relationship between cutting parameters and cutting performance in the explicit finite element method. Wang et al. [10] and Gao et al. [11] studied tool forces in different theoretical methods. However, the experimental model of shearer is characterized by complicated structures and large volumes. Both the requirement of higher cost and

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the problem of lower efficiency limit the flexibility of the experimental model, and then it cannot be applied in many research studies [12] and [13]. With the improvement of computer performance and numerical analysis software, the numerical model has dominated in coal cutting research with lower cost and higher efficiency [14]. In addition, the accuracy of results obtained from the simulation method has been verified in a previous study [15]. Pijush Samui [16] studied the cutting performance under different cutting tools, cutting angles, cutting depths, and velocities with the finite element method, and the results showed that these mentioned parameters affect the cutting efficiency significantly. LS_DYNA proved to be a powerful tool for the simulation of the rock-cutting process [17].

The influence of structure parameters such as mounting angles on cutting load has been studied in many references. However, most references tend to judge the effectiveness of optimizations with the mean value method while not taking the randomness of load into consideration. Based on this, the present paper tries to provide a method to deal with this problem. Before providing the method, the shearer drum is established in a numerical method, and many groups of the simulation are done under different structure parameters, such as mounting angles and cutting positions. Then, an analysis of the cutting load with the mean value method and some differences in the cutting load in different situations can be obtained. A new method to judge the effectiveness of these differences in cutting load is essential. In the new method, the stochastic fluctuation on cutting load is taken into consideration. Finally, only when the differences in cutting load before and after optimization are larger than the differences resulting from the stochastic fluctuation can we make sure of the effectiveness of optimization.

1 METHOD AND SIMULATION

1.1 Cutting Conditions

In the research of coal cutting performance, Che et al. [18] studied the regularity from the perspective of motion form. Bilgin et al. [19] and Liu et al. [20] studied coal cutting performance when the cutter worked in linear motion, and the model of linear motion can be seen in Fig. 1a. Che et al. [21] studied cutting performance with a rotation model, and the model can be simplified, as shown in Fig. 1b. In addition, the models applied in previous studies can also be divided into the single-cutter model [4] and [22], two-cutter model [7] and drum cutting model [14] according to the number of cutters. Single-cutter model is mainly applied to study the cutting performance under different structural parameters of the cutter.

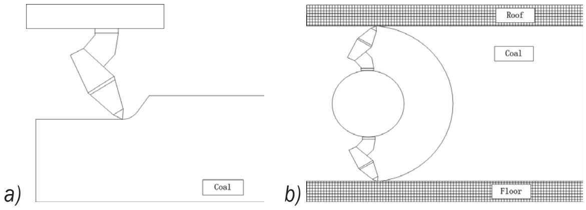

Fig. 1. *Common cutting model in references; a) linear cutting model, and b) rotation cutting model*

In general, coal cutting is the process that is accompanied by stress field variation. In reference to the research done by Liu et al. [7], Zhang et al. [23], and Horváth et al. [24], the stress field on coal under one cutter is distributed as shown in Fig. 2a; the stress distribution on coal under two cutters is also given out which is shown in Fig. 2b. From the graph in Fig. 2, stress distribution on coal is a roughly sphere that is centred on the contact point of conical pick. It can be seen that the stress fields are different under the different cutting models. It can also be inferred that the stress fields under drum cutting model will be different from that in a single-cutter model and two-cutter model. To study the stress fields on coal under drum cutting model, the shearer drum model needs to be established and cutting performance under different cutting parameters will be studied in this paper.

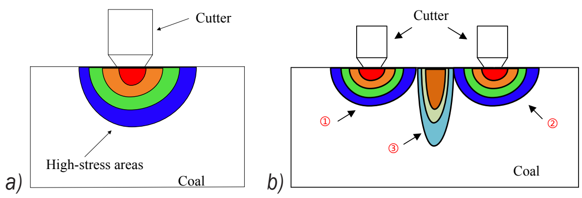

Fig. 2. *Stress field on coal: a) under one cutter's model [7], b) under two-cutter model [7] and [23]*

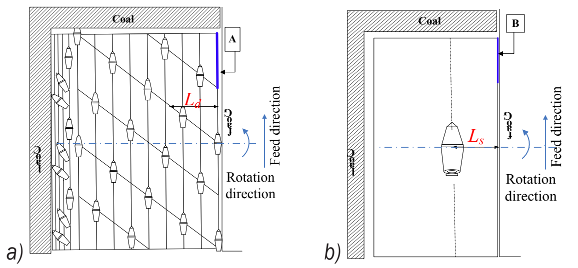

Fig. 3. *Simulation model: a) drum model, b) single pick model*

To study the effectiveness of the influence on cutting performance under different structural parameters, the cutting process, which is under different cutting models, the cutting positions, and the mounting angles, will be simulated in the paper. As for the selection of cutting positions and mounting angles, the principle can be seen as follows.

For the selection of cutting position, take the surface marked with 'A' as the reference surface and the datum is the free surface of coal seam. On the basis of the datum, four conical picks are selected, and they are equidistant with each other on the drum. L_d is used for the description of the positions of the selected conical pick. The cutting load on the selected conical picks, in which L_d is 0 mm, 200 mm, 400 mm, and 600 mm will be extracted and then used for analysis.

As for the selection of mounting angles, the angles widely used in references will be considered: they are 0°, 20°, and 40° in the simulation model. The cutting load, which is obtained from different mounting angles, will be analysed with the method newly provided in this paper.

1.2 Simulation Model

1.2.1 Definition of Material Parameters

Coal and rock are heterogeneous materials that contain many randomly distributed cracks and other defects. The accuracy of simulation results is closely related with appropriate material parameters. Regarding the present research, the main parameters of coal can be found in Table 1.

Table 1. *Parameters related to coal material*

Parameters	Mass density [g/cm³]	Young's modulus [MPa]	Poisson's ratio	Tensile limit [MPa]	Shear limit [MPa]	Shear strain at failure [mm]
Value	1.3	3100	0.3	1.2	9.0	0.01

1.2.2 Configuration of Finite Element Model

The coal cutting model consists of two parts: the shearer drum and coal. Based on Fig. 3a, the shearer drum model has been set up, as shown in Fig. 5. In drum model, the diameter of the drum is 2.2 m. There are fifty-six conical picks on the drum, and the amount of conical picks installed on the helical blade is 32, the rest are fixed on the end plate of the drum. Moreover, the conical picks on the end plate of the drum are designed with different mounting angles, and they are 0, 20°, and 40° respectively. Furthermore, the coal model is fixed by a full constraint, and the drum model can rotate on the Z-axis and move along the Y-axis. As for the movement parameters of the drum model, the linear velocity of conical picks (v_1) is 3.0 m/s, and haulage speed (v_2) is 0.2 m/s. As for the structural parameters of the coal model, the dimensions are 3610 mm × 930 mm × 2350 mm, and it is slightly larger than the dimension of the drum model. Moreover, the total amount of grid element is 7.5×10^{5}, and the dimensions of each grid element are 20 mm × 20 mm × 20 mm. In addition, a single-pick cutting model, which is used to explore the relations of cutting load between single pick cutting model and drum cutting model, is also built, as shown in Fig. 4.

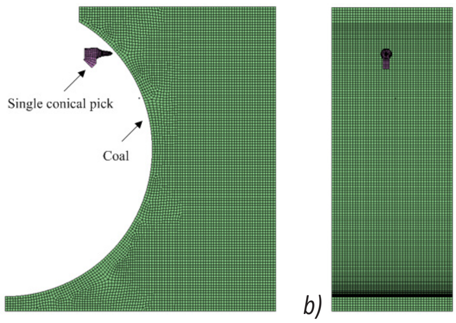

Fig. 4. *Single pick cutting model a) front view, b) side view*

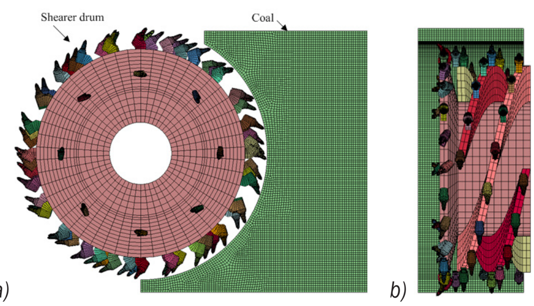

Fig. 5. *Drum cutting model a) front view, b) side view*

2 RESULTS AND ANALYSIS

2.1 Cutting Conditions under Different Cutting Model

2.1.1 Configuration of Finite Element Model

According to different functions, the conical picks installed on helical vane are responsible for removing coal from mining face. With a single-pick cutting model and drum cutting model, the process of coal cutting is simulated. Moreover, stress distribution on coal under different cutting models can be obtained.

Fig. 6 shows the stress field on coal under different cutting models.

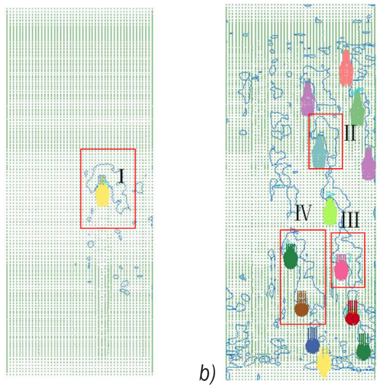

Fig. 6. *Range of stress distribution on coal under the different cutting model*

From Fig. 6, the range of stress field on coal is a roughly sphere centred on the contact points of conical picks and coal. In Fig. 6a, a single stress field occurs on coal under the single-pick cutting model. In Fig. 6b, under the drum-cutting model, stress field on coal is made up of different parts. For some parts in the figure, internal borders of different parts merge and vanish. Then, the stress field shows up with larger ranges, such as IV in Fig. 6b. Compare the range of stress field in the single-pick and drum cutting model, and the following regularity can be found. Under the drum cutting model, the range of stress field on coal is not a simple summation of those under a single-pick cutting model. In other words, the range of stress field on coal will expand under the drum cutting model.

When the cutting process is done with a shearer drum, many stress areas appear on the coal. The close distance makes the different areas easier to overlap with each other like that in Fig. 7; the stress area ③ is overlapped by area ① and ②. The stress in this area is greater than the original values. Although there is not any conical pick on the coal in ③, the coal still can be crushed once the stress in this area attains the crushing strength of coal.

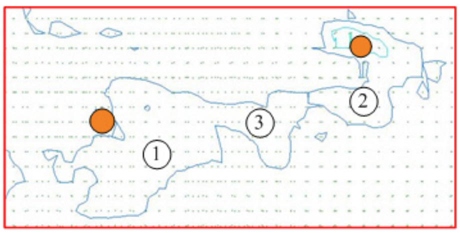

Fig. 7. *Enlargement diagram of IV*

2.1.2 Difference in Cutting Load under Different Cutting Model

For the conical picks on the helical vane of the drum, we want to explore the difference in cutting performance when they work under different cutting positions and cutting models. To achieve this, conical picks which are installed on different positions on the shearer drum are selected for research; they are the conical picks where L_D = 0 mm, 200 mm, 400 mm, and 600 mm. The cutting loads on the corresponding positions are marked with F_{D1}, F_{D2}, F_{D3}, F_{D4}, and they can be seen in Fig. 8. Now do the same in a single-pick cutting model. The single cutters, which are distributed where L_S = 0 mm, 200 mm, 400 mm, 600 mm, are established, and the cutting load on the corresponding positions are marked with F_{S1}, F_{S2}, F_{S3}, F_{S4} and they can be seen in Fig. 9. Figs. 8 and 9 show the cutting load on different positions under the single pick cutting model and drum cutting model respectively. Comparing Figs. 8 and 9, a difference exists on cutting load under different cutting positions. However, the influence of cutting positions on the cutting load is different in different cutting models. The cutting load is more vulnerable to be influenced by cutting positions in the single-cutting model. The reason is as follows.

Compared with the single-pick cutting model, the drum cutting model can be regarded as the combination of several single-pick cutting models, which means that the amount of cracking on coal seam under drum cutting model is several times the amount of cracking produced by the single-pick cutting model. The increased amount of cracking on the coal seam will make it much looser, and then the coal can be crushed under the smaller cutting force. In addition, the cracks spread all over the coal model under drum cutting model, and the conditions on the coal model are similar on different positions under drum cutting model. Therefore, little difference appears in cutting load under the drum cutting model. As for the relationship of cutting load obtained with the single-pick cutting model and drum cutting model, it can be seen in Table 2, from which we can conclude that cutting load in single-pick cutting model is 3 to 4 times larger than that in drum cutting model. In addition, from Table 2, in drum cutting model, the difference on cutting load in different conditions is less than 0.4 kN, and in single-pick cutting model, the difference is less than 3.0 kN. It can be verified again that the cutting load obtained from drum model is less influenced by cutting positions than that obtained from a single-cutter model.

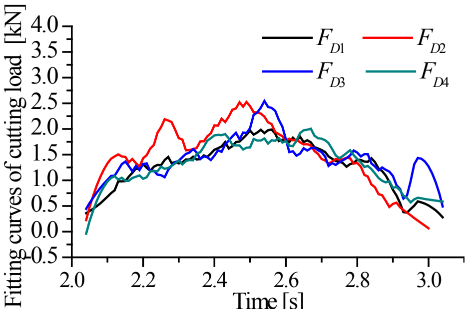

Fig. 8. *In drum cutting model, the cutting load on different cutting positions varied with time*

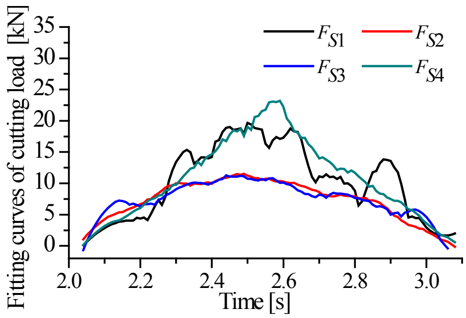

Fig. 9. *In single-pick cutting model, the cutting load on different cutting positions varied with time*

Table 2. *Cutting load on different cutting positions and models*

Model	L_D [mm]				
	0	200	400	600	$\Delta F_{amp}^{\max}$ [%]
Single pick	4.94	7.37	7.37	7.94	60.7
Drum	1.21	1.42	1.37	1.61	49.5
$\Delta F_{amp}^{\max}$ [%]	308	419	438	339	438

(In the table, $\Delta F_{amp}^{\max} = \dfrac{F_{\max} - F_{\min}}{F_{\min}}$)

In the study above, we explored the relationship between cutting load and cutting positions only using four conical picks. To further verify these conclusions, the objectives will be extended to all conical picks with different positions on the shearer drum, and the cutting load on those cutters with different positions on shearer drum is shown in Fig. 10.

Fig. 10 shows the cutting load on different picks when the drum rotates at the first and second revolutions. From the graph, the load on the cutting pick far from the end plate of the drum decreased greatly. From the graph, the cutting load in the adjoining conical picks is characterized by peak and valley alternations. According to the stress superposition effect, the stress superposition zone will occur in the position between these conical picks. Therefore, the stress on coal in the stress superposition zone is prone to be higher, and coal can be crushed with little additional force. For this reason, the cutting load on the stress superposition zone is much lower.

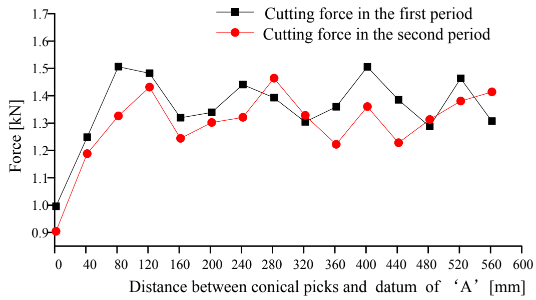

Fig.10. *Mean cutting load on different cutting positions*

2.2 Cutting Conditions under Different Mounting Angles

Conical picks on the end plate are characterized by different mounting angles. In this paper, the conical picks on the end plate are divided into eight groups. The mounting angles in each group are comprised of 0°, 20°, and 40°.

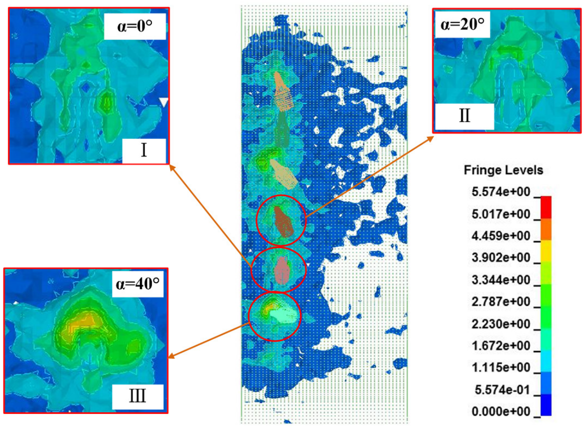

Fig. 11. *Stress distribution on coal when cutting by conical picks with different angles*

Fig. 11 shows the stress field on coal under the function of the conical pick with different mounting angles. From the figure, the maximum stress on the coal is 3.344 MPa under the function of conical picks with 0° and 20°. When the mounting angle is 40°, the maximum stress on the coal is 4.459 MPa, which is much larger than other situations. Therefore, when the mounting angle is 40°, the stress field on the coal (as shown in Fig. 11, section III) is characterized by larger ranges and higher values. Fig. 12 shows the cutting load on conical picks varied with time under different mounting angles. From the diagram, it can

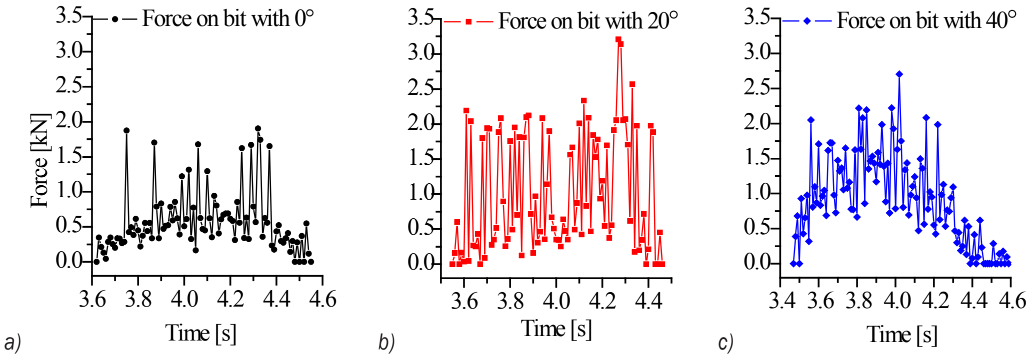

Fig. 12. *Cutting load on conical picks with different mounting angles; a) force on bit with 0°, b) force on bit with 20°, and c) force on bit with 40°*

be seen that the cutting load under different mounting angles is characterized by different fluctuations, and this can be judged from Fig. 13, which reflects the mean cutting load and the fluctuation of the cutting load under different mounting angles.

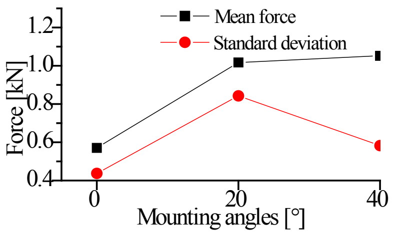

Fig. 13. *Force and deviation under different mounting angles*

Fig. 13 shows the statistical results of cutting load in different mounting angles. When the mounting angle is 20°, the mean cutting load is larger than those in other mounting angles. Moreover, both the mean and fluctuation of cutting load is the smallest when the conical pick is installed at 0°. Without doubt, we can make a comparison of the cutting load by means when they are installed with different mounting angles and then obtain the relationship between cutting load and mounting angles in general. As we know, the mean value method is to study the characteristics of load in a period. However, some larger load fluctuations and their frequency in the period cannot be obtained from the mean value method. Therefore, a threshold is essential, and the load fluctuation will be taken into consideration only when it is larger than the threshold. The threshold should be reasonable. If the threshold is much smaller, there will be many load fluctuations that meet the requirement, and then the threshold loses its effect. If the threshold is much larger, fewer load fluctuations will meet the requirement. In this paper, the mean cutting load will serve as the threshold. In other words, we analysed load fluctuations only when they are beyond the mean cutting load, and that can be expressed in the following:

$$C_{single} = \left[\frac{F_{\max} - F_{\min}}{F_{ave}} \right], \quad (1)$$

where $F_{\max}$ and $F_{\min}$ are the maximum, minimum cutting load in single crushing process; F_{ave} is the mean cutting load in the period $[\cdot]$ is rounding operation.

According to Eq. (1), the variation of cutting force in each crushing process can be obtained, and then the occurrence frequency of the same C_{single} will be made statistics. C_{single} and its occurrence frequency under different mounting angles can be seen in Table 3 and Fig. 14.

From Fig. 14, the positions of bubble on the vertical axis are values of C_{single}, which reflect the

Table 3. *Occurrence frequency of the coefficient C_{single} under different mounting angles*

Angle	C_{single}	1.1	1.2	1.3	1.4	1.5	1.6	1.7	1.8	1.9	2.0	2.1	2.2	2.3	2.4	2.5	2.6	2.7
α=20°	Frequency	3	0	2	2	0	1	3	2	1	0	0	6	2	4	1	1	0
Angle	C_{single}	1.1	1.2	1.3	1.4	1.5	1.6	1.7	1.8	1.9	2.0	2.1	2.2	2.3	2.4	2.5	2.6	2.7
α=0°	Frequency	5	6	11	8	13	10	8	8	5	0	1	1	1	1	0	0	0
Angle	C_{single}	1.1	1.2	1.3	1.4	1.5	1.6	1.7	1.8	1.9	2.0	2.1	2.2	2.3	2.4	2.5	2.6	2.7
α=40°	Frequency	6	4	2	6	0	1	0	0	1	0	0	0	0	0	0	0	0

ratio between load fluctuations and mean cutting load. The higher the bubble is on the vertical axis, the greater the ratio is. In this paper, only the situations when the load fluctuations exceed the mean cutting load are made into statistics. In other words, all load fluctuation coefficient C_{single} in this figure are greater than 1. From the graph, the order of the total bubble area should be: AREA (20°) > AREA (0°) > AREA (40°). The area of bubble is the reflection of the occurrence frequency of the same ratio between load fluctuation and mean value. The larger the total bubble area is, the more frequently the situations that the load fluctuations exceed mean cutting load appear. On basis of this, it can be found that the situations in which the load fluctuations exceed the mean load appear with highest frequency when the mounting angle is 20°. However, most of these fluctuations will not exceed two times the mean cutting load, and this can be concluded from the positions of the bubble on the vertical axis. For the conical picks with a mounting angle 0°, it might happen that the load fluctuation is 2.0 to 2.5 times above the mean cutting load; for the conical picks with a mounting angle of 40°, most of the load fluctuation is 1.5 times below the mean cutting load.

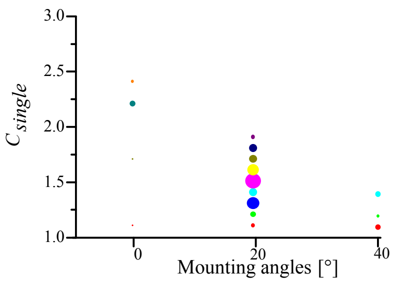

Fig. 14. *Value and occurrence frequency of C_{single} under different mounting angles*

2.3 An Evaluation for Effectiveness of Structure Modification

In this paper, the mean value is the main statistic to study the differences in cutting load under different conditions. Coal crushing is a process with randomness, which is reflected as follows: even under the same cutting conditions, the cutting load in different periods will also be diverse, and this diversity will be reflected on mean forces as shown in Fig. 15.

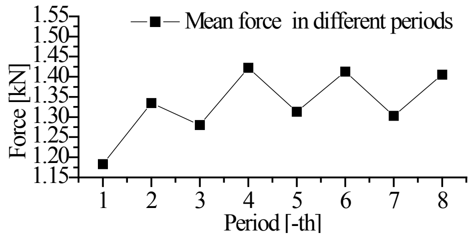

Fig. 15. *Variation of mean cutting load in different periods*

From Fig. 15, under the same condition, the mean cutting load is different in different periods, and the load fluctuates within a certain range. The reason lies in that coal crushing is the process with randomness. Furthermore, the statistical results of the cutting load on the other cutting positions can be seen in Table 4.

Table 4 shows the cutting load on different cutting positions of the shearer drum in different periods. Differences on cutting load in different periods can be found in the table, and the fluctuation of the cutting load in different periods accounts for about 10 % to 20 % of the mean cutting load in this process. In this case, now comes the question. In some designs for optimization, how can judgments on optimization effects be made? In this paper, a method for judgment on structural optimization effects is developed based on the stochastic fluctuation of the cutting load. In this method, to ensure the optimization effect on some improved structures, firstly, we need the results of the stochastic load fluctuation, which resulted from the stochastic process of coal crushing. It must be noted that the stochastic load fluctuation is calculated according to the structure that has not been optimized, and it is equivalent to the difference of cutting load in different periods. In addition, these stochastic fluctuations will be used as the reference group, and they are named “fluctuation by randomness”. Then, the differences in cutting load, which are obtained

Table 4. *Statistics of mean cutting load on different cutting positions in different periods*

L_D [mm]	Period [-th]								Statistics	
	T1	T2	T3	T4	T5	T6	T7	T8	$F_{max} - F_{min}$	$(F_{max} - F_{min}) / F_{ave}$ [%]
0	0.982	0.944	0.902	0.841	0.993	0.807	0.923	0.820	0.186	20.63
200	1.427	1.305	1.412	1.303	1.408	1.276	1.320	1.311	0.124	9.23
400	1.422	1.314	1.334	1.386	1.312	1.362	1.275	1.352	0.147	10.93
600	1.393	1.324	1.350	1.254	1.290	1.219	1.283	1.232	0.174	13.4

from the cutting load before and after modification, also need to be calculated and they are named "fluctuation by structure". Only when the fluctuation by structure is larger than fluctuation by randomness can we make sure that the structure optimization is effective in the cutting load. In addition, the following variables are defined for a brief description. The fluctuation by structure is measured by the variation of cutting force $\Delta F_{struct,x}$, which is equal to the results of mean cutting force $F_{struct,i}$ in the i^{th} period before structure modification minus the mean force $F'_{struct,i}$ in the same period after structure modification. The fluctuation by randomness can be obtained by the variation of cutting force $\Delta F_{time,x}$ which is equal to the mean force $F_{time,j}$ in the j^{th} period minus the mean force $F_{time,k}$ in the k^{th} period before modification. The optimization effect is measured by D. The method mentioned in this paper can be expressed with the following mathematical expression:

$$\Delta F_{struct,x} = F_{struct,i} - F'_{struct,i} \,, \tag{2}$$

$$\Delta F_{time,x} = F_{time,j} - F_{time,k} \,, \tag{3}$$

$$D = \Delta F_{struct,x}^{\min} / \Delta F_{time,x}^{\max}. \tag{4}$$

Taking the fluctuation of cutting load under drum cutting model as the reference group, analysis on the influence of the cutting position on the cutting load has been made, and the difference on cutting load in single-pick cutting and drum cutting model is also analysed in this part. In Fig. 16, the fluctuation by randomness is the fluctuation of cutting load under drum cutting. The fluctuation by structure in Fig. 16a is the difference of cutting load between single-pick cutting model and drum cutting model. The fluctuation by structure in Fig. 16b is the difference of cutting load under different cutting positions.

According to Fig. 16a, the differences in cutting load, which resulted from different structures, are larger than that from the stochastic fluctuation of the cutting load. Therefore, we conclude the following: excluding the impact of the stochastic fluctuation of the cutting load in different periods, the cutting loads obtained in single-pick cutting condition and drum-cutting condition will also perform with distinct differences. In other words, the difference of cutting load under a single-pick cutting model and drum cutting model is much larger than that caused by the stochastic fluctuation of coal crushing.

From Fig. 16b, the curves show the similar differences in cutting load resulted from randomness and structures modification. According to Eq. (4), D_b = 0.097, which also means that fluctuation by structure is smaller than fluctuation by randomness. In fact, the differences in cutting load exist under different cutting positions. However, these differences are even smaller than the fluctuation the resulted from the randomness of coal crushing. In other words, the difference resulting from the structure can be covered by the differences resulting from randomness. Therefore, the influence of cutting positions on cutting load is not insignificant according to this method.

In addition to the analysis of the influence of cutting positions and cutting models on cutting load, the impact of mounting angle is also studied with this method. In this part, taking the fluctuation of cutting load under the mounting angle of 20° as the reference group, the paper makes a comparison of the differences on the cutting load which resulted from randomness and mounting angles; the differences can be seen in Fig. 17.

According to Fig. 17, the difference in cutting load resulted from mounting angles is over 0.4. The difference in cutting load resulted from randomness of coal crushing is under 0.15. Therefore, the difference resulted from mounting angles is larger than that from the fluctuation by randomness. Therefore, we conclude that by taking the fluctuation of cutting load in different periods as the evaluation method,

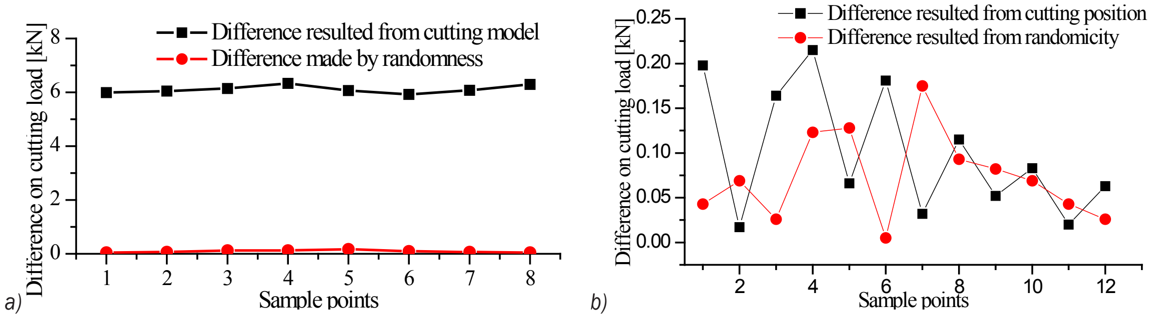

Fig. 16. *Comparison of load difference resulted from structure and randomness; a) under different cutting models, and b) under different cutting positions*

the cutting load obtained in different mounting angles performs with distinct differences. In addition, calculated from Fig. 17, $D_c = 2.67$. Compared with D_a in Fig. 16a and D_b in Fig. 16b, it can be found that $D_a > D_c > D_b$. Therefore, we conclude that according to the different impacts on cutting load, the order of the factors, which influence cutting load from strong to weak, should be cutting models, mounting angles, and cutting positions.

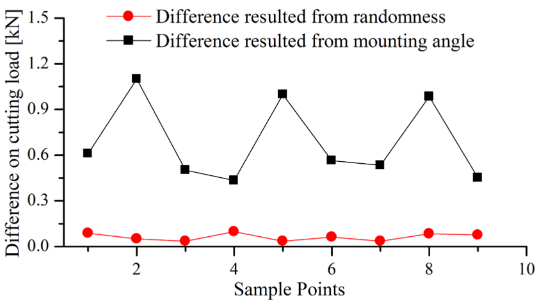

Fig. 17. *Comparison of load difference resulting from mounting angles and randomness*

3 CONCLUSIONS

1. When the cutting position is much closer to the free surface of coal seam, for the single-pick model, the cutting load can be cut down by 40 % when compared with the other positions; for the drum cutting model, the cutting load can only be cut down by 10 % when compared with the other positions on the shearer drum.
2. Under the same structural and working parameters, the cutting load on the conical pick in the single-pick cutting model is 3 to 4 times larger than that in drum cutting model; in addition, the fluctuation of cutting load obtained from a single pick cutting model is three times larger than that in the drum cutting model.
3. The curves of the cutting load are different when the conical picks are installed with different angles. C_{single}, the statistics of load variation in coal crushing, is introduced to describe the diversity of these curves. According to C_{single}, when the conical pick is mounted at 20°, most of the load fluctuation is two times larger than the mean cutting load. When the conical pick is installed at 0°, the mean cutting load and fluctuation will reach the minimum.
4. A method for judgment of the effectiveness of structure optimization, which is based on the stochastic fluctuation of the cutting load, is provided. Based on this method, the results show that cutting load is little influenced by cutting positions. In addition, the significance of structure parameters on the cutting performance from strong to weak is the number of conical picks, mounting angles, and cutting positions.

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5 NOMENCLATURES

L_d	distance between cutter and datum, [mm]
F_{ave}	mean cutting force, [kN]
$F_{\max}$	maximum of mean cutting force, [kN]
$F_{\min}$	minimum of mean cutting force, [kN]
$\Delta F_{amp}^{\max}$	differential ratio of cutting force, [-]
C_{single}	variation of force in single crush, [-]
$F_{struct,i}$	mean force in the i^{th} period before structure modification, [kN]
$F'_{struct,i}$	mean force in the i^{th} period before structure modification, [kN]
$\Delta F_{struct,x}$	force variation due to structure, [kN]
$\Delta F_{time,x}$	force variation due to randomness, [kN]
$\Delta F_{struct,x}^{\min}$	minimum force among $\Delta F_{struct,x}$, [kN]
$\Delta F_{time,x}^{\max}$	maximum force among $\Delta F_{time,x}$, [kN]
D	evaluation for modification effect, [-]

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