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STUDY ON DRUM LOAD OF SHEARER

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The shearer cutting drum plays an important role in improving the mining efficiency of the coal mine. Starting from the basic theoretical mechanics, this paper analyzes the force on the shearer cutting drum of a certain model, establishes the mathematical model of the force on the cutting drum, sets the shearer calculation parameters, and calculates the load of the cutting tooth on the shearer cutting drum. Through the analysis, it is concluded that the three-way instantaneous load of the drum cutting tooth is irregularly distributed, and the axial force has sudden changes in magnitude and direction. The research content of this paper has certain guiding significance for the layout design of shearer drum and cutting tooth.

Keywords: shearer, cutting drum, theoretical mechanics, mathematical model, cutting tooth

PREFACE

Shearer is an very important mechanical equipment in coal mining, and its performance has a decisive impact on the mining efficiency of coal mine [1]. With the continuous improvement of the social requirements for coal mining efficiency, the requirements for the performance of shearers are also getting higher and higher [2]. The cutting section is a working part directly involved in coal mining. The reliability and stability of its operation process will affect the overall performance of the shearer [3].

Drum shearer is the core equipment of high yield and high efficiency fully mechanized mining face, and the arrangement of drum and cutting tooth has always been one of the key points in the design of shearer drum. Traditional drum design often adopts the method of experience and imitation comparison. With the increasing installed power of shearers, simply relying on experience to increase the safety factor often makes the mechanical size of the designed shearer drum too large, the load distribution of the structure is difficult to be reasonably guaranteed [4].

With the increasing installed power of shearers in recent years, many high-power shearers have appeared at home and abroad. The common high-power shearers in the domestic market have reached about 1 800 kW. Shenhua Shendong Coal Industry Group has introduced a model of shearer with the upper limit of mining height of 7,1 m and the power of 3 000 kW. Therefore, it is necessary to establish a correct calculation method for the working load of drum cutting tooth and analyze the load characteristics of drum cutting tooth, It can provide theoretical basis for better guiding the design of shearer drum [5].

ESTABLISHING MATHEMATICAL MODEL OF DRUM LOAD

Figure 1 shows the three-dimensional model of a shearer drum. After simplification, we establish the stress diagram of the drum, as shown in Figure 2. The coordinate systems o, a, b, c respectively represent the vertical, horizontal and axial force directions of the drum, and the force model of the shearer drum is established. Instantaneous load of the drum refers to the superposition of the load of the cutting teeth participating in the cutting at the same time. The total number of cutting teeth is n_p. The position of cutting tooth A on the drum is the initial cutting position. The distance between any cutting tooth n_i (I=1, n_p) on the drum and

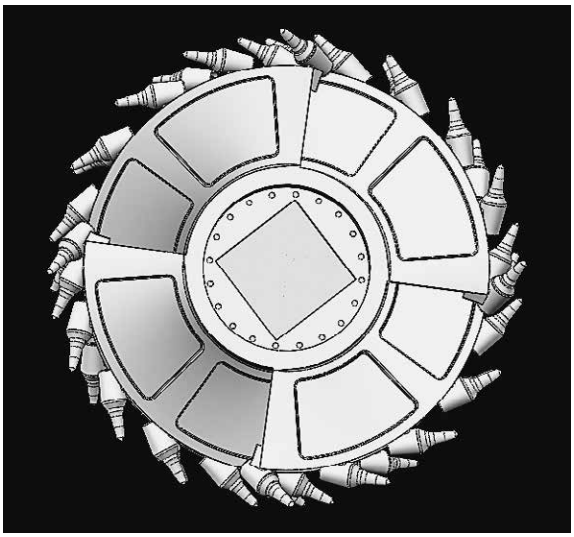

Figure 1 Three-dimensional model of drum

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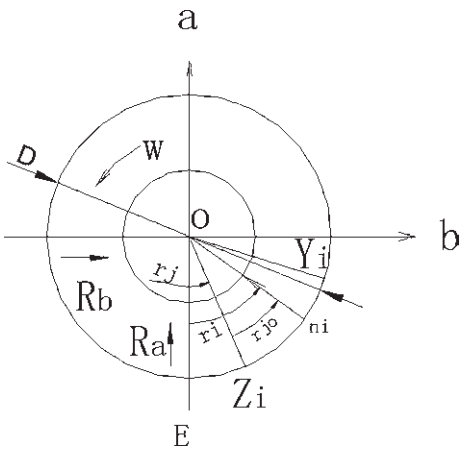

Figure 2 Stress diagram of drum

cutting tooth A in the circumferential direction is r_{jo} (rad). Load of drum (M_p, R_a, R_b, R_c).

$$a_i = -Y_i \cdot \cos r_i + Z_i \sin r_i$$
$$b_i = -Y_i \cdot \sin r_i - Z_i \cdot \cos r_i$$
$$c_i = X_i$$

In the formula:

a_i, b_i, c_i – Component force of the ith cutter in a, b and c directions

Z_i, Y_i, X_i – Tangential cutting resistance, radial resistance and lateral resistance of the ith cutting tooth

r_i – Distance from the ith cutting tooth to the initial position(rad), $r_i = r_j + r_{jo}$

r_j – Distance traveled by cutting tooth A during cylinder cutting (rad), $r_j = W_o t$

r_{jo} – Distance between the ith cutting tooth and cutting toot A in the circumferential direction of the cylinder (rad)

W_o – Drum rotation angular speed (rad/s)

Drum reaction force:

$$Raj = \sum_{i=1}^{nj} ai, \quad Rbj = \sum_{i=1}^{nj} bi, \quad Rcj = \sum_{i=1}^{nj} ci$$

Load torque of drum M_{pj}:

$$M_{pj} = \frac{1}{2} D \sum_{i=1}^{nj} Zi$$

In the formula:

R_{aj}, R_{bj}, R_{cj} – Vertical, horizontal and axial reaction forces of the drum when the cutting tooth A rotates over r_j distance / N

D – Diameter of drum / m

n_j – The number of cutting teeth that simultaneously participate in cutting when the cutting tooth A passes the r_i distance.

Divide the circumference of the drum into N equal parts, as follows:

Mean value force of three-way of drum (E):

$$E_a = \frac{1}{N} \cdot \sum_{1}^{N} R_{aj}$$

$$E_b = \frac{1}{N} \cdot \sum_{1}^{N} R_{bj}$$

$$E_c = \frac{1}{N} \cdot \sum_{1}^{N} R_{cj}$$

Variance of drum (σ):

$$\sigma_a = \sqrt{\frac{1}{N} \cdot \sum_{i=1}^{N} (R_{aj} - E_a)^2}$$

$$\sigma_b = \sqrt{\frac{1}{N} \cdot \sum_{i=1}^{N} (R_{bj} - E_b)^2}$$

$$\sigma_c = \sqrt{\frac{1}{N} \cdot \sum_{i=1}^{N} (R_{cj} - E_c)^2}$$

Drum load fluctuation coefficient (δ):

$$\delta_a = \frac{\sigma_a}{E_a}, \delta_b = \frac{\sigma_b}{E_b}, \delta_c = \frac{\sigma_c}{E_c}$$

The load of the drum is related to the cutting depth and the intercept distance of the cutting tooth and the number of cutting tooth participating in cutting at the same time.

DETERMINATION OF SHEARER PARAMETERS

The specific parameters of drum load of the shearer are as follows:
Mining height: 2,5 ~ 5 m
Cutting depth: 800 mm
Dip angle:≤ 15°
Coal hardness: f ≤ 4
Cutting motor: 2 × 750 kW
Diameter of drum: Φ 2 400
Rotating speed of drum: 33 r/min
Tractive force: 748/311 kN
Tractive speed: 0~12, 5~29, 3 m/min
Operating Weight: 70 t

The total number of drum teeth is 56, 32 blade teeth and 24 end plate teeth. The drum spiral blades are arranged with four heads, one line and two teeth, most of which are angular teeth, and a few are zero teeth. One line four teeth are used for the end disc teeth, one line eight teeth are used for the side section of the coal wall, and angle teeth: 5 °, 15 °, 25 °, 35 °, 45 ° teeth.

Setting of calculation parameters:
Mining height: 5 m
Cutting width of drum: 800 mm
Tractive speed: 10 m/min
Cutting tooth configuration factor: 1
Front shape coefficient of cutting tooth: 1
Cutting angle coefficient of cutting tooth: 1, 24
Cutting width of cutting tooth: 20 mm
Number of blades: 4
Blade outer edge rise angle: 17, 7°
Total number of cutting teeth: 56
Average cutting impedance of coal seam: 5 000 N/cm

Projection of blunt area of cutting tooth: 2 cm^2
Brittleness index of coal: 2
Cutting resistance coefficient: 0, 4
Caving angle of coal: 30°
Impact coefficient of caving angle: 0, 8

CALCULATION AND ANALYSIS OF DRUM LOAD

The drum load shall be calculated once every 10 ° of drum rotation, and the total number of calculation points is 36. When the cylinder rotates 10 °, the three-way force of the cutting tooth participating in the cutting along the circumference of the cylinder is 26 teeth in total, and the distribution from left to right teeth in the figure is No. 1 → No. 56 teeth. Figure 3 shows the numerical value of the three-dimensional force of the drum cutting tooth.

Observe the three-way force distribution diagram of the drum cutting tooth. It can be seen from the tangential force curve of the cutting tooth that it is basically distributed in a bow shape, with the maximum value of 11 kN in the middle and gradually decreasing towards both sides. Due to the influence of the installation angle of the cutting tooth, the tangential force value in the middle jumps, with a small jump range, which meets the design requirements. Combined with the three-way force curve, it can be found that the radial force and tangential force curves of the cutting tooth are basically similar, and the tangential force of the same cutting tooth is slightly less than the radial force by numerical comparison. The change of the axial force of the cutting tooth is very uneven. There is a change in both direction and force value, which is related to the installation angle of the cutting tooth and the cutting depth of the cutting tooth at that time. It can be seen that No. 1, No. 9, No. 18 and No. 27 teeth are 45 degree end disc teeth. The large installation angle leads to a sharp increase in the axial force. The closer the middle cutting tooth is, the deeper the cut in depth will be, and the three-way force of the cutting tooth will also increase. The most obvious change in the three curves is the axial force. Negative values indicate that the force direction points to the coal wall direction, and the axial force of the drum borne by the zero degree gear is zero.

Calculate the average value E of the three-way force on the drum, and the mean square deviation of the force on the drum σ, Drum load fluctuation coefficient δ, As shown in Table 1:

Table 1 **Calculation table of three dimensional force fluctuation parameters of drum**

E_a	E_b	E_c
130 105, 6	231 123	69 001, 3
σ_a	σ_b	σ_c
3 956, 5	4 056, 6	15 000, 1
δ_a	δ_b	δ_c
0, 03151	0, 01851	0, 21102

It can be seen that the fluctuation coefficient of vertical force, horizontal force and axial force of the drum δ In, the minimum fluctuation of horizontal force is 0,01851, and the maximum fluctuation of axial force is 0,21102. Through analysis, it is due to the irregular change of axial force of drum pick and the large fluctuation caused by the change of force direction.

CONCLUSION

This method can effectively calculate the load distribution of the three-way force on the cutting drum of a certain type of shearer. The analysis shows that the three-way force of the pick is irregularly distributed at a certain time, and the 45 degree teeth of the end plate can cause sudden changes in the axial force of the pick. The arrangement of the pick at the end plate needs to be optimized. The above calculation method and data analysis of drum pick load can be used as a theoretical reference for the design of high-power shearer cutting drum in the future, and has certain guiding significance.

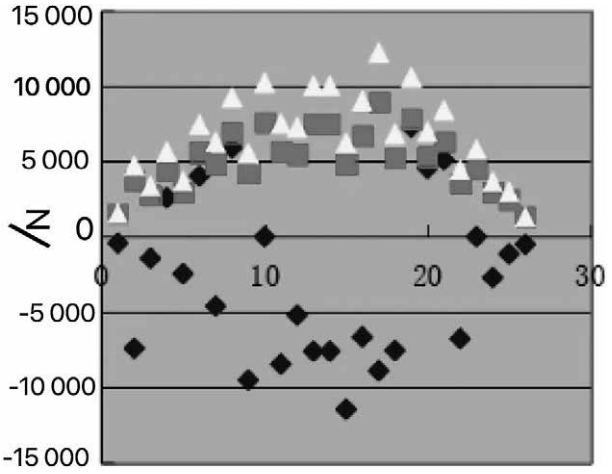

Figure 3 Three direction force distribution diagram of drum cutting tooth
▲ - Axial force, ■ - Radial force, ◆ - Tangential force

REFERENCE

[1] L.W.Du. Key technology of intelligent coal mining machine. Mining equipment (2021) 03, 206-207
[2] D.F.Ren. Application of frequency conversion technology in energy saving of coal mine electromechanical equipment. Integrated Circuit Applications 38 (2021) 06, 56-57
[3] W.L.Li. Application research on intelligent cutting control system of shearer. Energy and Energy Conservation (2021) 05, 188-189
[4] N.Yan, L.Wang, S.T.Gao. Study on the design method of basic parameters of shearer spiral drum. Coal Mining Machinery 33 (2012) 11, 8-10
[5] L.J.Zhao, X.L.Liu, Y.Y.Zhao. Influence of shearer drum parameters on coal loading effect. Coal Mining Machinery 33 (2012) 10, 30-31

Note: The responsible translator for English language is L.Y.Huang,Anshan,China