MECHANICAL PROPERTIES RESEARCH ON A NEW AUXILIARY PROPULSION DEVICE OF LARGE SLOPE ROADHEADER

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To solve the insufficient traction and poor stability problem of large slope excavating of the existing auxiliary propulsion device of roadheader, an auxiliary propulsion device using roadway coal wall as support is proposed in this paper. The propulsion device is composed of a fixed device, supporting device and sliding device and the typical working conditions in an operation cycle are analyzed. The mechanical equation of slope operation is established. Calculation model of side support force is obtained and the variation rules of side support force with midline shift and cylinder thrust are discussed. The rationality of middle cutting of roadheader is proved. At last, through the finite element analysis, the strength of the new auxiliary propulsion device is analyzed. The results show that the maximum stress of the auxiliary propulsion device is 165MPa and is located at the support seat, it could meet the structural design requirements. The results can provide effective additional thrust to assist the roadheader to advance and retreat in large slope roadway and at the same time ensure the effective cutting force and stability of the roadheader so as to solve the problem of large slope tunneling.

Keywords: Large slope; Roadheader; Auxiliary propulsion device; Mechanical properties

1. Introduction

With the decrease of easily recoverable coal reserves, the depth of the roadway to be exploited increases year by year. At the same time, the complexity of geological conditions and the rock hardness also increase. So, in order to reduce the distance of the mining roadway and speed up the roadway exploitation, more and more whole rock roadways with- large slope needs to be excavated. The maximum climbing capacity of the existing general roadheader in China is ±18° , but when the slope of the roadway exceeds 14° in the actual construction, the construction will become very difficult. At this stage, many mines in China are facing the problem of going up and down the hill with a large slope of rock roadway, and most of the uphill and downhill tunneling with a slope of 25° are constructed by the traditional drilling and blasting method due to capital, technology and other

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reasons. The drilling and blasting method has the problems of high labor intensity of workers, slow construction progress, and large potential safety hazards, which are prone to produce work accidents [1-3]. Affected by factors such as the rapid development of mechanization and automation of coal mine tunneling equipment and mining safety, blast production is gradually replaced by machine excavation, and the market will need a large number of large-slope roadheaders to meet the current production needs. Therefore, it is of great significance to develop a large slope hard rock boring machine to effectively alleviate the imbalance of mining ratio, reduce the amount of construction and improve the tunneling speed.

Big slope digging is divided into large slope uphill excavation and downhill tunneling. Downhill excavation has little impact on the cutting force and fuselage stability, and only needs to consider that it can be retreated normally to meet the requirements of downhill excavation on the auxiliary force of the roadheader. At present, the common practice in the mine is to install a winch at the rear of the roadheader as an auxiliary traction when the roadheader retreats, which can meet the needs of downhill excavation. However, this scheme can only solve the demand of downhill excavation and retreat, and cannot use a device to solve the problems encountered in uphill and downhill at the same time, and has certain limitations. Therefore, when excavating with a large slope, it is mainly necessary to consider the use of auxiliary propulsion device to solve the problems of uphill excavation propulsion and stability of the fuselage, and the function of auxiliary traction of downhill retreat should be taken into account. [4-8]

The main problems when digging uphill on large slopes can be summarized as: (1) The traction of the excavation was insufficient, especially in the whole rock excavation, which could not provide stable cutting propulsion to the roadheader on the sloped ground; (2) The stability of the fuselage is poor, and the specific pressure of grounding in large slope tunneling is small, which cannot provide sufficient adhesion, and the fuselage is easy to deflect or retreat when cutting; (3) When changing slope walking, it is easy to erect the track with shovel and rear support at the slope change, and the whole machine is overhead, and the walking is skidding, and the driving force cannot be effectively exerted.

Now, roadheader manufacturers have developed various forms of large slope roadheaders with auxiliary driving devices for large inclination tunneling, which solves some large-slope tunneling problems and improves the tunneling efficiency and safety to a certain extent, but there are problems of complex construction technology and slow footage speed. When the roadheader is pulling and leading the rear of the belt conveyor or working, the bottom plate of the roadheader does not have enough adhesion, and the driving force can't be effectively exerted, resulting in insufficient feeding force during cutting, and it is also easy to cause the roadheader to slip, swing the tail or nest machine. Especially when the slope reaches 25° under uphill excavation conditions, the adhesion of the roadheader to the bottom plater itself needs to overcome the component force generated by the direction of its own weight, and it also needs to ensure that it is greater than the downward thrust generated by cutting to ensure that the roadheader does not slide. Underground roadway adhesion coefficient is limited by the conditions of the roadway bottom plate, and the variation range is large, which can fluctuate from about 0.5 to 1. Adhesion is mainly related to the adhesion coefficient and vertical pressure, the vertical pressure on the ground is smaller than its own gravity under the condition of large slope, coupled with the influence of gravity downward component, the dynamic adhesion to the ground under the condition of large slope is much smaller than that of the flat roadway.[9-12] Therefore, it is easier to cause the roadheader to slide downward or swing left and right and resulting in work accidents when the roadheader goes up the hill with large gradient.

Therefore, this paper proposes a new type of auxiliary propulsion device for large slope roadheader, which can continuously provide bidirectional auxiliary traction force and fundamentally solve the problem of insufficient cutting feed force, and a set of devices can be applied to different working conditions of uphill and downhill, with a wide range of adaptability. At the same time, the typical working conditions of the opening and retracting auxiliary devices in the operation cycle process were analyzed, and the calculation method of the side support force was obtained by establishing a mechanical method. The variation characteristics of the lateral support force are explored, and the strength of the new structure is further analyzed and mastered. The successful development of the auxiliary propulsion device of the large slope roadheader will ensure the monthly footage of the large slope roadway, improve the work efficiency, ensure the normal connection of the mining area project, improve the working environment, reduce the labor intensity of workers, improve the construction safety, and speed up the construction progress of the rock roadway, which is of great significance to the stable and high yield of the coal mine with a large slope roadway.

2 Conventional auxiliary propulsion unit

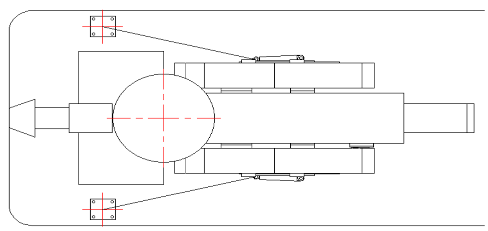


Fig. 1. Ground anchor cylinder assist device

In order to solve the problems faced by large gradient roadheader, the roadheader manufacturers or the use of mines through various forms of auxiliary propulsion devices to achieve stability and auxiliary propulsion of the roadheader.

One is to install the booster device on both sides of the track of the roadheader, as shown in Figure 1. Here, the booster device is usually equipped with two cylinders on both sides of the track, and the ground anchor needs to be laid at a certain distance in front of or behind the roadheader, and then the ground anchor is connected with the wire cable, and the oil cylinder is used to telescopic to complete the short-distance forward or backward of the roadheader. In addition, we can install a winch on the rear body of the roadheader to assist traction when the roadheader is backward. This traction method has the disadvantage of single traction direction, insufficient safety, and cannot achieve continuous traction. At the same time, it often needs to install the ground anchor device at intervals, the process is more cumbersome, costly and laborious, and this can only guarantee to provide auxiliary propulsion, and cannot guarantee the stability of cutting when digging uphill on a large slope [13-14].

The other is to install an external booster device at the rear of the roadheader, as shown in Figure 2. The roadway is supported up and down by using a separate jack cylinder to provide a stabilizing point, and then the telescopic cylinder which is installed at the stabilization point and the tail of the roadheader is used to realize the auxiliary forward and backward auxiliary propulsion of the roadheader. The existing problem is that the top heaven and ground oil cylinder has a destructive effect on the roof of the roadway, which is not conducive to the maintenance of the roof and has a certain impact on safety. [15-16].

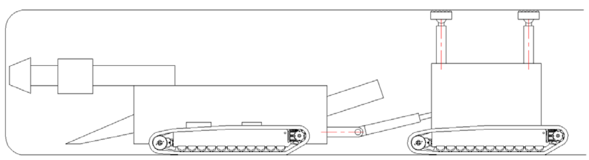


Fig. 2. Auxiliary propulsion device behind roadheader

The third is to install two small auxiliary crawler traction devices on both sides of the roadheader that use the coal wall to support the advancement, as shown in Figure 3. Because the crawler bottom area is larger, the roadheader which can walk in a straight line can achieve the auxiliary propulsion effect. But the underground roadway of the coal mine is uneven, and it is difficult for the roadheader to walk in a straight line, and the uneven coal wall will form a wedge effect when the side track walks, and it cannot move forward or backward [17].

The above analysis show that the existing booster devices have certain shortcomings, which cannot effectively control the stability of the roadheader. And it cannot provide stable and continuous propulsion force to improve the tunnelling efficiency, thus limiting its popularization and application on large slopes.

3 Design and force analysis of a new large-slope auxiliary propulsion device

Through the above analysis and comparison, it can be known that the roadheader and the roadway need to be connected as a whole to improve the continuous auxiliary propulsion of the large slope roadheader. In addition, due to safety problems, the roof can not be used to exert force, and it can only exert the vertical reaction force of the lane gang department to solve the stability problems such as fuselage deflection or retreat when the roadheader is cutting. Similarly, it is necessary to use the vertical reaction force of the roadway and the parallel friction force together to form a propulsion force to achieve the purpose of assisting the forward or backward propulsion of the roadheader. After repeated demonstration, comparative analysis and research of various schemes, a new type of high-slope roadheader with cutting stability and auxiliary propulsion device that can be used in practical was finally formed.

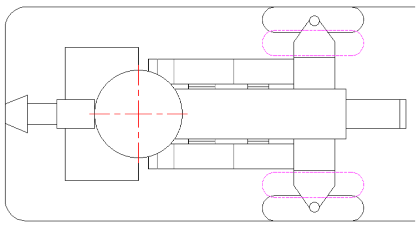
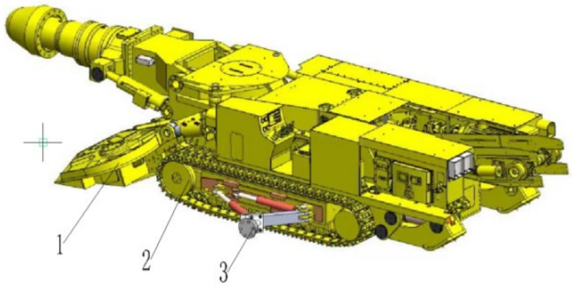


Fig. 3. Crawler-type auxiliary propulsion device

3.1 Structural components

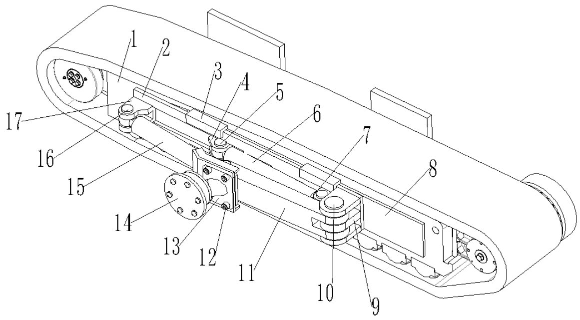
According to the overall arrangement requirements, the auxiliary propulsion device should have the function of fixing the fuselage and auxiliary propulsion. So the installation part of the device needs to be able to meet the high thrust strength requirements. At the same time, in order to meet the needs of single advancement of cutting, the cutting efficiency need to be improved and the propulsion stroke should reach more than 500mm. So, the whole set of equipment needs to occupy a certain installation area. And it is also conducive to directly change on the ordinary roadheader with a wide range of adaptation. And because the roadway support point is arranged in the lower part of the coal wall, the safety is good. The designed auxiliary propulsion unit in this paper is shown in Figure 4.

As is shown in Fig. 5, the auxiliary propulsion device is mainly composed of three modules: a fixing device, a support device and a sliding device. The fixing device is mainly used to restrict the direction of the sliding device. It is welded to the side of the track frame, which is mainly composed of the card holder, the front lug seat of the sliding cylinder, the pin shaft of the sliding cylinder, the fixed base plate and other parts. The fixing device fixes and welds the fixed base plate to the side plate of the track frame of the roadheader, and the card holder is also welded to the fixed base plate.



1 - Roadheader; 2 - Crawler travelling; 3 - Auxiliary propulsion unit;
Fig. 4. Roadheader including the auxiliary propulsion unit

The sliding device is mainly composed of a sliding plate, a sliding cylinder, and a rear ear of the sliding cylinder. The front ear of the sliding cylinder is welded on the fixed bottom plate, and the rear ear of the sliding cylinder is hinged on the slip plate by a pin shaft. The sliding cylinder is connected to the fixed base plate and the sliding plate; thus, the sliding cylinder telescoping drives the sliding plate to move on the fixed base plate. And the card base ensures the sliding plate to shift in the card base. The sliding of the fixed base plate drives the support cylinder and support frame installed on it to move back and forth.

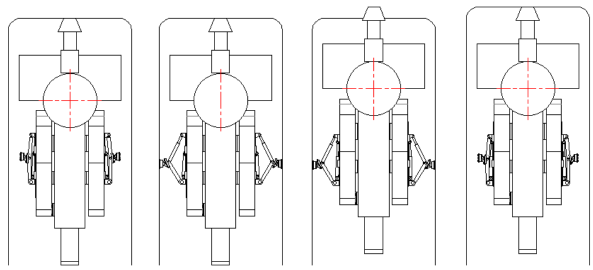


1-track; 2-slip plate; 3-card holder; 4-slip cylinder front trunnion; 5-sliding cylinder pin; 6-sliding cylinder; 7-slip cylinder rear ear; 8-fixed base plate; 9-supporting holder; 10-supporting pin; 11-supporting bracket; 12-screws; 13-fixed bearing; 14-universal supporting holder; 15-supporting cylinder; 16-supporting cylinder pin; 17-supporting cylinder holder
Fig. 5. Auxiliary propulsion assembly structure

The support device is mainly composed of a support holder, a support holder pin shaft, a support frame, a screw, a fixed bearing, a support frame pin shaft, a support cylinder, a support cylinder pin shaft, and a support cylinder holder. The support frame is fixed on the based plate by the support holder, and it is connected with the support cylinder by the support frame pin shaft. And the support cylinder is connected with the support cylinder holder through the pin shaft, and the support cylinder holder is fixed on the sliding plate. The fixed holder is fixed with the support frame by means of screws. The support cylinder telescoping drives the support frame to extend and retract, and drives the fixed holder on the support frame to extend and retract at the same time, which will realize the compression and separation of the universal support holder and the coal wall on the fixed seat.

The sliding surface of the sliding device in contact with the fixed device is lubricated with grease, and the sliding device can slide back and forth inside the fixed device under the action of the oil cylinder. Under the open state, the roadheader is fixed with the side of the coal wall to form a whole. The universal support holder is pressed against the coal wall by the thrust of the support cylinder, and the front and rear telescopic expansion of the sliding cylinder drives the fixed bottom plate to move forward and backward with the direction of crawler movement, so as to achieve the effect of providing auxiliary traction force for crawler travelling [18-20].

3.2 Typical working condition analysis



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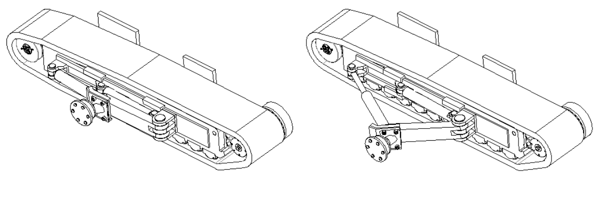

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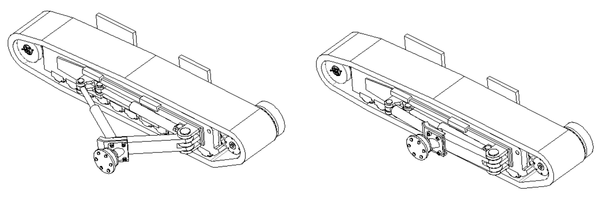


c d

a-Auxiliary propulsion unit slides to the front; b- Opening of the support; c-Hauling of the boring machine for drilling; d-Retraction of the support after operation

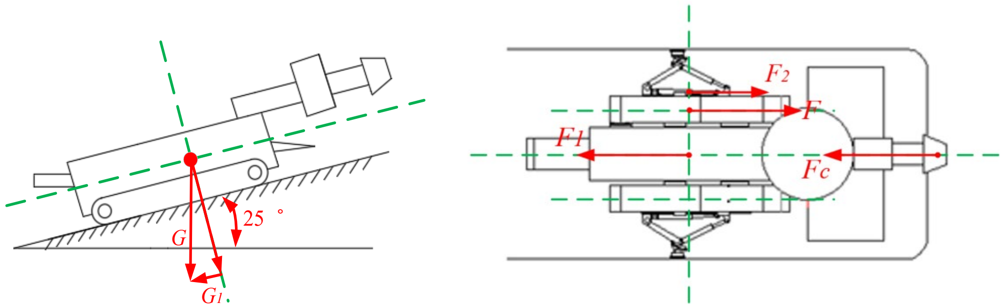
Fig. 6. Cycle process of auxiliary propulsion device of large slope roadheader

When the roadheader works in uphill digging, the auxiliary propulsion device will be slid to the front of the track, and the support will be opened to prop up both sides of the coal wall to ensure the stability of the machine when cutting and prevent the cutting from retreating. At this time, the roadheader move forward and the sliding cylinder is stretched forward to ensure sufficient auxiliary traction. When the sliding cylinder stops the skid movement after it finishes a stroke, the roadheader begins to cut in the up and down and left and right sweeps. After completing a cutting cycle, the support mechanism is taken back, at this time the support mechanism is already at the rear of the track. When the support mechanism is pushed to the front of the track with the sliding cylinder, a new digging cycle will start.

Because the propulsion force of downhill excavation is larger, it does not require auxiliary propulsion device at this time. When walking traction cannot meet the need for retreat, the auxiliary propulsion device will be slid to the rear of the track. And the support device will be opened, the sliding cylinder retracts backward to assist in propelling the roadheader. When a cylinder stroke finish, the support device is returned to the rear of the track and the next drilling is started. [21]

3.3 Mechanical analysis of the auxiliary propulsion unit

At present, the 25° slope can meet the 90% roadway tunneling needs, therefore, the mechanical calculation is carried out under the condition of 25° slope. At this time, the forces of the roadheader are shown in Figure 7.



(a) Side view force of slope operation (b) Top view force of slope operation

Fig. 7. Slope force analysis

From Fig. 7, the mechanical equilibrium equations of the roadheader in the direction of the slope can be obtained as:

$$2F+2F_2-G_1-F_1-F_c=0 \quad (1)$$

In the formula, F is one-side driving force; F_1 denotes the sum of internal and external friction resistance; F_2 represents one-side auxiliary thrust which is required for the whole machine; G_1 is the gravity component along the direction of the slope and F_c represents the propulsion resistance of the cutter head.

3.3.1 Determination of cut-off head propulsion resistance F_c

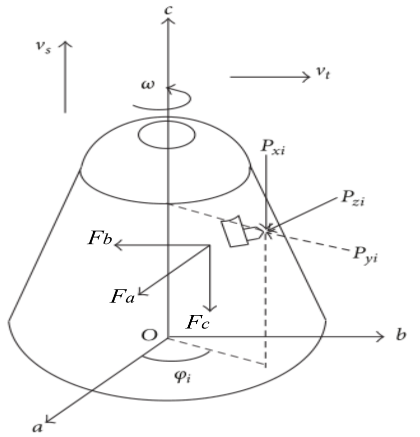


Fig. 8. Load diagram of cutting head

Taking the rotating center of the cutting head as the c-axis, the load schematic is built up as shown in Fig. 8. The ω shows the rotating direction of the cutting head; v_s is the drilling direction of the cutting head; v_t denotes the walking direction during the cutting. P_{zi}, P_{yi}, P_{xi} represent the cutting resistance, transverse resistance, and propulsion resistance on the *ith* cutting tooth, respectively, which can be obtained according to the calculation method of the instantaneous load of the cutting tooth when the roadheader sweeps and cuts the rock wall:

$$P_{zi} = P_k\left[k_t k_g k_y\left(0.25+0.018th\right)+0.1S_i\right] \tag{2}$$

$$P_{yi} = P_{zi}\left(0.15+0.00056P_k\right)\frac{2.5}{h^{0.4}} \tag{3}$$

$$P_{xi} = P_{zi}\left(\frac{C_1}{C_2+h}+C_3\right)\frac{h}{t} \tag{4}$$

where P_k is the rock contact strength; k_t and k_s represent the coefficients of the type of interceptor and the integrated influence coefficient of the geometry, respectively; k_y denotes the influence coefficient of the angle of intersection; t is the average spacing of the interceptor line; h shows the average thickness of the cut; S_i represents the projected area of the interceptor edge in the direction of traction after blunting; C_1 , C_2 , C_3 denote the influence coefficients of the cutting diagram, respectively.

On the basis of the calculation of the loads of a single cutting tooth, the theoretical value of the cutting head load is obtained by combining the loads of the cutting teeth that are involved in the cutting at any given moment.

The load on the cutting head is calculated according to the formulas:

$$F_a = \sum_{i=1}^{n}(P_{zi}\cos\varphi_i + P_{yi}\sin\varphi_i) \tag{5}$$

$$F_b = \sum_{i=1}^{n}(P_{zi}\sin\varphi_i - P_{yi}\cos\varphi_i) \tag{6}$$

$$F_c = \sum_{i=1}^{n} P_{xi} \tag{7}$$

where F_a, F_b, F_c denote the combined force of the cutting head along the three coordinate directions; *n* represents the number of cutting teeth involved in cutting; φ_i is the position angle of the *ith* cutting tooth at a certain moment. According to the above analysis, it can be known that when the roadheader is carrying out ramp operation, the force that hinders the advance of the roadheader along the ramp direction is the propulsion resistance F_c. The cut-off resistance F_b and F_a is perpendicular to the drilling direction of the roadheader, and it has no any effect when performing a force analysis along the ramp.

3.3.2 Determination of driving force *F for* single side of roadheader

The crawler walking mechanism of the roadheader realizes the mobilization and traction of the roadheader, and it not only bears the walking and steering resistance, but also undertakes the working resistance when the cutting head is cutting. The travelling driving force of one side of the track is:

$$F = \frac{P_W \cdot \eta_1 \cdot \eta_z}{2v} = \frac{M \cdot i \cdot \eta_1 \cdot \eta_2}{R_1} \tag{8}$$

where, P_w is the power of the hydraulic motor of the roadheader travelling mechanism; *M* denotes the output torque; η_1 represents the transmission efficiency of the travelling reducer; η_2 shows the transmission efficiency of the crawler; v is the travelling speed of the crawler; *i* denotes the transmission ratio; R_1 is the radius of the driving wheel.

3.3.3 Internal and external frictional resistance F_1

The friction resistance is unavoidable during the operation of the roadheader, and it is difficult to derive the accurate values by calculations and experiments. According to engineering experience, the sum of internal and external frictional resistance is 0.3 times the gravity,

$$F_1 = 0.3G \tag{9}$$

3.3.4 Determination of G_1

When the roadheader climbs at a gradient of 25°, according to the rule of mechanical triangle shown in Figure 7, the divergent force G_1 of gravity on the slope of 25° is equal to gravity G multiplied by the sine of the slope. The divergent force G_1 of the roadheader gravity in the direction of the gradient could be obtained as:

$$G_1=G\times\sin(25°)=0.42G \tag{10}$$

3.3.5 Lateral support force F_2

The simplified structure of the unilateral auxiliary propulsion device is shown in Fig. 9. Here, L_1 is the length of the support frame, L_2 denotes the distance of the cylinder fixing pin, L_3 represents the length between the support cylinder pins, and the angle θ varies with the width of the support roadway.

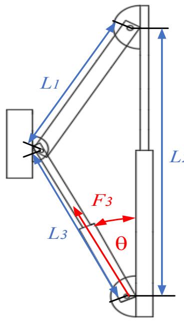


Fig. 9. Simplified diagram of auxiliary propulsion device

From Fig. 9, the lateral support force F_2 is gotten as:

$$F_2 = F_3 sin\theta \tag{11}$$

where, F_3 shows the support cylinder thrust; θ is the angle between the support cylinder and the side of the track.

Meanwhile, the lateral support force F_2 must be satisfied from equation (1):

$$F_2 = \frac{1}{2}(G_1 + F_1 + F_C - 2F) \tag{12}$$

4 Change Analysis of lateral support force under actual working condition

During the actual operation of the roadheader, it is not possible to guarantee that its middle line is always located on the center of the roadway. Therefore, it is necessary to master the change rule of side support force generated by auxiliary propulsion device when the center line of the roadheader is offset. When the roadheader deviates from the center line, the opening angle of the support cylinders of the auxiliary propulsion devices on both sides is different. Because the working pressure of the support cylinder is constant, the lateral support forces of the auxiliary propulsion devices on both sides are different at this time. Taking EBZ260 roadheader as an example, the main parameters are shown in Table 1. When the center line deviates to the left, the cylinder support angle and the left support force of the left auxiliary propulsion device change as shown in Figure 10.

As can be known from Figure 10, when the center line of the roadheader deviates to the left, the left support angle θ decreases gradually from the initial value of 40°, indicating that the cylinder is shrinking. At the same time, the lateral support force decreases in the form of parabola. When the center line offset exceeds 350mm, the lateral support force will decrease to below 150kN, and in this case, in order to maintain a stable lateral support force, it is necessary to increase the output pressure of the cylinder. If the cylinder pressure is beyond the rated range, the cutting depth needs to be adjusted to match the cutting force and auxiliary traction force, but the feed efficiency will be reduced. If the cylinder pressure exceeds the rated range, it is necessary to adjust the depth of the cut-off cutter to match the cut-off force and auxiliary traction force, but it will reduce the efficiency of the cutter. When the center line of the roadheader deviates to the right, the variables change in the same way as the left deviation described above.

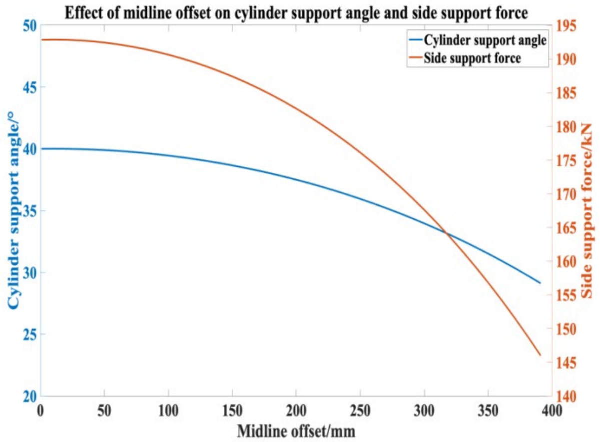


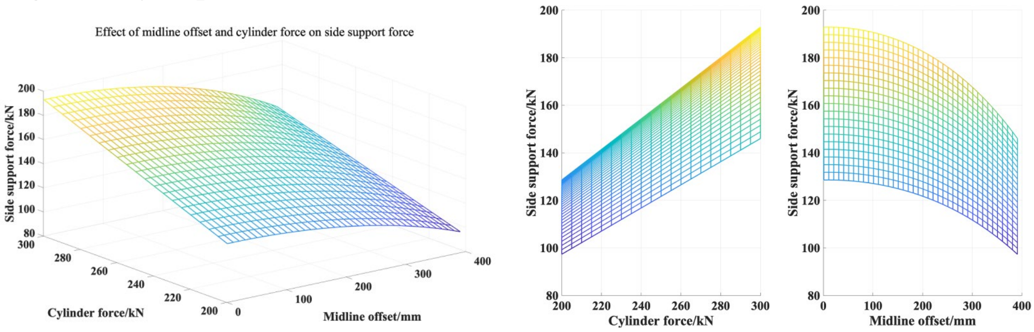
Fig. 10. Effect of midline offset on cylinder support angle and side support force

Table 1

Main parameters of EBZ260 roadheader and auxiliary propulsion unit

The whole machine works Weight/t	Overall width /mm	Width with auxiliary device/mm	Height /mm
85	3000	3600	2650
Maximum climbing angle/(°)	Cutting power /kW	Maximum line measuremet of auxiliary device/mm	Support change angle /(°)
25	260	700	30~40

In order to further grasp the variation law of lateral support force under the combined action of centerline offset and cylinder thrust, the cylinder pressure is further analyzed under the condition of constant cylinder pressure, and the results are shown in Figure 11. From Figure 11 XZ view, when the thrust force of the cylinder F_3 remains unchanged, the deviation from the center line will reduce the lateral support force of the auxiliary propulsion device on the coal wall. At the same time, the propulsion force and the cutting speed as well as depth of the roadheader reduce, and the cutting efficiency is relatively low. So keeping the roadheader in the centre line position is necessary when using the auxiliary propulsion device to cut in order to ensure the cutting efficiency. In addition, from Figure 11 YZ view, it can be known that the lateral support force will increase with the continuous increase of the thrust of the cylinder on the same side, and the maximum can reach 190kN. So the correct choice of cylinder pressure to ensure the rationality of the design is very important.



a) b c

a-Effect of midline offset and cylinder force on side support force; b- Relation of the side support and cylinder force; c- Relation of the side support and midline offset

Fig. 11. Effect of midline offset and cylinder force on side support force

5 Strength analysis of new auxiliary propulsion device

In order to further grasp the strength of the new auxiliary propulsion device proposed in this paper, the following will use finite element analysis software to discuss its stress distribution under hazardous conditions. The left side of the auxiliary propulsion device is still analyzed as an example. In order to reduce the calculation amount, the tracks are removed, the fixed base plate is thickened to increase the actual stiffness and the lower surface is fixed. At the same time, according to the typical working conditions of 2.2 and the change of lateral support force in part 3, the pressure in the vertical direction of 190kN and the frictional reaction force of 190kN generated by the external coal wall are applied to the universal support seat of the new device, as shown in Fig. 12.

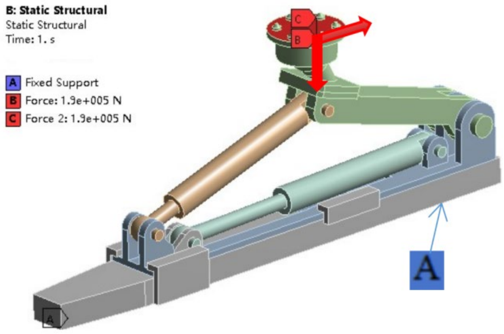


Fig. 12. Load and restriction

The finite element stress contour of the new auxiliary propulsion device is shown in Figure 13. It can be known that the maximum stress of the structure is equal to 165MPa, and it is located in the support holder. So the Q550 material can fully meet the use requirements. For the main stressed structural parts of the support frame and the sliding plate, the stress is small, the maximum stress is less than 100MPa, and the stress is more evenly distributed in the support frame, which fully demonstrates the rationality of the design method in this paper.

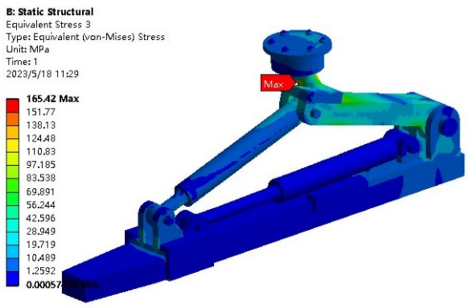


Fig. 13. Stress of new auxiliary propulsion device

From the strength analysis, it can be known that when the support holder adopts the two-force rod structure, it can give full play to the characteristics of the two-force rod only bearing pressure and tensile force. In addition, the support holder with the support cylinder forms a triangular stable structure, and thus a lighter structure can bear a larger external force. At last, the whole supporting device is stable, which can meet the actual requirements.

6 Conclusion

In view of the shortcomings of the existing auxiliary propulsion devices, this paper proposes a new type of auxiliary propulsion device, and the design and related analysis are carried out, and the conclusions are as follows:

(1) The auxiliary support cylinder of the roadheader is used to push the support frame to form two stable fixed points with the coal wall on both sides. The sliding

cylinder is used to push the track, which provides stable and reliable auxiliary traction for the roadheader to walk on a large slope, and at the same time it prevents the roadheader from swinging its tail when the roadheader cuts on a large slope. The combination of the sliding cylinder and the support cylinder is used to adapt to the large range of roadway and good stability, and solve the problem of insufficient traction of the roadheader with large slopes

(2) Through the typical working condition of large gradient of roadheader, the working principle of forward and backward of auxiliary propulsion device is illustrated. The mechanical model of the auxiliary propulsion device is established, and the calculation method of auxiliary thrust and auxiliary support force is obtained through mechanical analysis.

(3) With the increase of the offset, the lateral support force will decrease in the form of a parabola, from the maximum 190 kN to less than 150 kN. And the side support force will increase with the continuous increase of the thrust of the same side cylinder. At the same time, when the center line of the roadheader deviates to the left, the left side support angle θ will gradually decrease from the initial value of 40°, and the cylinder will shrink. It further shows the reasonableness of maintaining the center line position in auxiliary towing operation of large gradient roadheader.

(4) The maximum stress of the new device is located at the support holder, which is equal to 165MPa. At the same time, the maximum stress of the main stressed structural parts is less than 100MPa, which verifies the structural reasonableness of the auxiliary propulsion device designed in this paper.

The research results of this paper can provide new research and development ideas, and important methods for large gradient cutting.

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