Research and application of the conveyor self-advancing tail without repeated support

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Abstract. Aiming at the current situation of conveyor self-advancing tail process of the traditional heading face in the coal mine, such as “retreating machine-manually pulling--manually adjusting the deviation-ground anchoring”, in order to realize efficient and rapid excavation, a new type of conveyor self-advancing tail used in mining face suitable for crushing roof was developed. The design of the endless force, the stepping distance, the conveying capacity, the adapting belt speed and the idler type of the designed conveyor self-advancing tail were carried out. Based on the virtual prototype technology the intermediate frame of the tail and the dynamic frame were established and the model’s structural strength were checked. The correctness of the design of the whole machine was verified by the actual application of the tail in the coal mine. The successful development of conveyor self-advancing tail without repeated struts effectively solves the problem that the tail of the coal mining face can not be self-moving or needs to be support self-moving, which greatly improves the efficiency of the tail movement of the driving face. At the same time, it also provides the possibility to upgrade the automation of the face.

1. Introduction
The realization of efficient and rapid excavation of coal heading face is inseparable from the mechanization and automation upgrade of the excavation face equipment. There are usually three ways to transfer the tail of the belt conveyor in the domestic heading face: ① pulled by back off the driving equipment; ② self-moving by support; ③ winch traction.

The excavating equipment is pulled back and pulled by the chain to connect the tail of the belt conveyor with the excavating equipment, and the excavating equipment moves forward to pull the tail of the belt conveyor to a predetermined position. This method requires the equipment to move back and forth, the degree of damage to the bottom plate is large, and the belt conveyor and the tail are prone to shift during the pulling process. The belt conveyor needs to be twice adjusted, and the labor intensity is high and the efficiency is low. At the same time, the chain is easy to break, leading to safety accidents [1-4].

The support self-moving method of the conveyor self-advancing tail is to set up the self-moving mechanism at the tail of the belt conveyor to complete the self-moving of the bend pulley section. This method needs to support the roof repeatedly to realize the self-movement of the tail of the machine. This method has high requirements for the roof. After the roof is repeatedly supported, the roof is seriously broken. When the roof is broken, the support cannot effectively support the top, so that the tail of the machine cannot move automatically. At the same time, since the support bracket is set at the
of the machine, the tail of this type of self-transfer machine cannot be overlapped with the traditional belt transfer machine. In order to prevent the interference between the traditional belt conveyor machine and the support bracket, the tail of the support bracket type machine needs to be equipped with a turning belt transfer machine or a side unloading type transfer machine, which will greatly increase the purchase cost [5-7].

Winch traction is to lay anchor piles in front of the tail of the belt conveyor in advance, fix the winch on the tail of the belt conveyor, and use the winch to pull the anchor point to move the tail forward. In this way, the workload is large, the personnel input is large, the operation area is long, and the safety is poor. At the same time, there are also potential safety hazards caused by wire rope fracture.

2. Design of conveyor self-advancing tail without repeated support

In view of the existing problems of the tail, a set of self-shifting tail without repeated support was developed, which is suitable for the driving face with medium broken roof. It has its own power device, which can realize the overall lifting, pushing and adjusting deviation of the tail and realize the continuous transportation of materials without support.

2.1. Structure design of the whole machine

The new type of tail without repeated supporting shall have the following characteristics:

1. It can realize the continuous transfer of materials.
2. It shall be equipped with its own power system, and other equipment shall not be used to pull the tail of the machine.
3. The whole machine can move automatically without repeatedly supporting.
4. It has the functions of lifting, pushing, adjusting deviation, etc. to reduce the labor intensity of workers.
5. It has the function of belt deviation prevention.
6. Long lap stroke, reduce the tail moving frequency, and improve the working efficiency.

![Figure 1. General layout of the conveyor self-advancing tail without repeated support.](image)

According to the characteristics of self-moving tail without repeated support, the overall structure of the tail is shown in Figure 1. According to its own structural characteristics, this machine can be used in the medium broken roof driving face, where the roadway floor is not easy to be mudded when encountering water, roadway ramp $\leq 16^\circ$, slope Angle $\leq 5^\circ$, roadway width $\geq 4200$mm, roadway height $\geq 3200$mm.
2.2. Working principle

Figure 2 shows the general layout of the self-moving machine tail without repeated support in the roadway of the driving face. The driving equipment transfers the materials to the anchor protection transfer equipment and the belt transfer machine. The belt transfer machine laps with the support type tail through the lap car, and the tail realizes the continuous transfer of the materials through the connection with the tunnel conveyor belt.

![Figure 2. General layout of the driving face.](image)

①-Driving equipment ②-Anchor protection transfer equipment ③-Belt transfer machine ④-No repeated support self-transfer machine tail ⑤-Combined switch, dust removal fan and other auxiliary equipment

When the overlapping distance between the belt transfer machine and the tail of the machine without repeated support cannot meet a cutting cycle of the driving equipment, the tail of the machine without repeated support moves forward by its own power system. The tail of the machine realizes the cross lifting of the intermediate frame, the power frame and the moving track through the lifting mechanism: when the frame is lifted, the moving track contacts with the roadway floor; when the frame is landed, the moving track is lifted. The two ends of the pushing mechanism are respectively connected with the pushing track and the frame body, and the whole machine moves forward by means of cross stepping.

When the tail of the machine deviates from the roadway as a whole, the left and right deviation adjustment of the machine can be realized through the self-contained deviation adjustment mechanism of the machine body. The working principle of the deviation adjustment mechanism is similar to the frame and the moving track move.

2.3. Parameter calculation

2.3.1. Calculation of pushing step. The lap distance between the belt transfer machine and the tail $S_d$ is not less than the maximum footage that the production team of the mine can reach every day. The tail pulling time required by the maintenance team of the mine is set as $T_j$, the tail moving step distance is $L_b$, and the tail moving step time is $t_b$, then:

$$L_b \geq \frac{S_d t_b}{T_j} \quad (1)$$

2.3.2. Calculation of pushing force. In the process of tail moving, it is necessary to overcome the friction resistance between the traveling mechanism and the track recorded as $f_1$, the friction resistance between the belt loader and the tail recorded as $f_2$, and the gravity component of the tail along the roadway slope direction recorded as $G_1$, so as to obtain the required pushing force for tail moving recorded as $F_t$.

$$F_t \geq f_1 + f_2 + G_1 \quad (2)$$

$$f_1 = \mu_1 (G_2 + N_1) \quad (3)$$

$$f_2 = \mu_2 N_1 \quad (4)$$

Among them, $\mu_1$ is the rolling friction coefficient between the traveling mechanism and the moving track; $G$ is the self-weight of the middle frame, the power frame, the lifting mechanism, etc., $G_2$ is the gravity component perpendicular to the roadway direction; $N_1$ is the vertical pressure of the belt transfer machine, the dust removal fan, the combination switch, etc. arranged above the tail on the tail;
μ₂ is the rolling friction coefficient between the belt transfer machine, the dust removal fan, the combination switch, etc. and the tail. The force on the tail of the self-moving tail shown in Figure 3.

2.3.3. Calculation of adaptive belt speed and selection of idler [8-9]. According to the requirements of the miner, the main transportation material of the tail of the self-propelled machine without repeated support is bituminous coal, with an adaptive bandwidth of 1000mm, a transportation capacity of ≥1000t/h and a maximum inclination angle of ≤8°. According to the bandwidth, the carrying idler is preliminarily selected as three idler arrangements, and the length of idler is 380 mm.

\[ Q_n = 3600A_{max}VC_{st} \]  
\[ A_{max} = (l_m + \frac{b-l_m}{2} \cos \lambda) \frac{b-l_m}{2} \sin \lambda + \left[ \frac{l_m + (b-l_m) \cos \lambda}{2 \sin \rho} \right] \left( \frac{\pi \rho}{180} - \frac{\sin 2\rho}{2} \right) \]

According to Formulas (5) and (6), the belt speed \( V \) is 2.78m/s. Where, \( Q_n \) is the conveying capacity, t; \( A_{max} \) is the maximum loading section area, m²; \( C_{st} \) is the inclination coefficient, 0.97; the available width \( b \) of the conveying belt for transferring materials is 0.85m, the inclination angle \( \lambda \) of the idler is 35° and the operation stacking angle \( \rho \) is 20°.

\[ F_j = e \times a_0 \times \left( \frac{l_m}{V} + q_b \right) \times g \]  
\[ F_d = F_j \times F_s \times F_c \times F_a \]

Formulas (7) and (8) are static load \( F_j \) and dynamic load \( F_d \) respectively. The load coefficient \( e \) of idler is 0.8, the spacing \( a_0 \) of idler is 0.9 m, \( l_m \) is the conveying capacity, Kg/s; \( V \) is the belt speed, 2.78m/s; the unit conveyor belt weight \( q_b \) is 12.5 Kg; \( g \) is the gravity acceleration. According to the operation conditions, the operation coefficient \( F_c=1.2 \), impact coefficient \( F_i=1.06 \) and operation coefficient \( F_a=1.15 \) are taken. According to the belt speed \( V \), the static load of idler is \( F_j = 711.2 \) N, and the dynamic load is \( F_d = 1.04\text{kN} < 2.1\text{kN} \). As the material is unloaded directly from the belt conveyor to the tail of the self-propelled belt conveyor, the impact load is large, so the bearing idler must be cushion type. According to the calculation results, the suitable belt speed at the tail of the self-shifting machine without repeated support is \( V \leq 3.15 \) m/s; the bearing idler is a cushion idler with a diameter of \( \phi 108 \) mm and a length of \( l_m = 380 \) mm, while the return idler is a common idler with a diameter of \( \phi 108 \) mm and a length of 1150mm.

2.3.4. Structural check. Based on SolidWorks 3D solid modeling software, the middle frame and power frame models are established. In order to improve the accuracy and simulation speed of subsequent mesh generation, small fixed blocks, small ribs and other parts that have no impact on the
simulation are removed, and some chamfers and sharp corners are removed. The virtual prototype model of intermediate frame and power frame finally established were shown in Figures 4 and 5 [10].

![Virtual prototyping model of intermediate frame.](image1)

**Figure 4.** Virtual prototyping model of intermediate frame.

![Virtual prototype model of power frame.](image2)

**Figure 5.** Virtual prototype model of power frame.

Based on the SolidWorks Simulation module, the model was endowed with materials, fixed, loaded, meshed, and simulated [11]. Finally, the stress distribution of the intermediate frame and the power frame were shown in Figures 6 and 7. The maximum Von Mises stress values of the intermediate frame and the power frame are about 220MPa and 300MPa respectively, which meet the design requirements (Material is Q460, allowable stress is about 330MPa).

![Von Mises stress contour of intermediate frame.](image3)

**Figure 6.** Von Mises stress contour of intermediate frame.

![Von Mises stress contour of power frame.](image4)

**Figure 7.** Von Mises stress contour of power frame.
3. Application situation
Taking the application of belt roadway in 13-1 mining area of Huainan mining industry as an example, the roadway section and layout are shown in the Figure 8. The roadway slope is 7-12°, the changing slope Angle is about 3°, and the roadway roof and floor are all coal rocks. Before using this type of self-moving tail, all driving faces in this mine used the traditional tape tail, with an average monthly footage of 140-170m. After using this type of self-moving tail in the belt lane in 13-1 mining area, the pulling time of the tail was shortened from 1.5 hours to 25 minutes, and the number of tail workers was reduced from 2 to 1 person. The average monthly footage of the working face increased to 188m, which effectively reduced the number of people and improved the efficiency, with significant economic benefits.

At present, the new type of conveyor self-advancing tail without repeated support has been used in the underground rapid driving face of Huainan Mining Industry, Xinji Coal Mine, Huating Coal Industry and so on. The whole machine works normally and has high reliability. Figure 9 shows the application of the self-advancing tail in the underground coal mine.

Figure 8. The roadway section and layout.

Figure 9. The application of self-advancing tail in the underground coal mine.
4. Epilogue

Through practical use, the self-moving tail can reduce one tail worker and reduce the pulling time of the tail for one hour. The monthly wage of tail worker is 8000 yuan / month ($1,153.6), and the driving footage is increased by about 18m per month (converted to raw coal is about 840t/month). Using the new self-moving tail can save labor cost of 96,000 yuan/year ($13,843.2) for the miner, and increase the output value of raw coal by 3,024,000 yuan ($436,060.8) (the unit price of raw coal is calculated at 300 yuan /t). The purchase cost of the traditional tape tail is RMB 300,000 to 500,000 yuan ($43,260 to $72,100), while the purchase cost of the new self-moving tail is RMB 1.3 million yuan ($187,460). Considering the equipment purchase cost, personnel cost and raw coal output value, the new tail can increase the annual revenue for the mine by about 2.12 million yuan ($305,704) per year. At the same time, the use of this type of tail also reduces the number of underground workers to a certain extent, and reduces the risk of casualties.

The successful development of self-moving tail without repeated supporting effectively solves the problem that the tail cannot be self-shifted or needs to be self-shifted in the working face of coal mine, greatly improves the efficiency of pulling the tail of driving face, reduces the labor of workers, improves the driving speed, and also provides the possibility for automation and intelligent upgrading of underground driving face in coal mine.

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