DESIGN AND RESEARCH OF CONVEYOR BELT DEVIATION CORRECTION DEVICE FOR POWERFUL BELT CONVEYOR

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In order to solve the important problems such as smooth running and no deviation of belt conveyor, based on the analysis and calculation of dynamics and kinematics of belt conveyor, the design of belt deviation detector and deviation correction device for strong belt conveyor is completed. Firstly, the size selection of all parts of the whole system, the strength and stiffness of the structural part are checked and calculated, and the main parts such as box, shaft parts and idler are selected and calculated. Then, the calculation of belt offset, deviation correction force and friction force, the determination of the pull rod and anti-impact part of the detector, the determination of the strong automatic deviation correction scheme of the idler, the calculation of the interaction force between the conveyor belt and the idler, the running speed of the belt and the running speed of the belt to the center line of the conveyor are emphasized, and finally the overall design of the automatic deviation adjustment system is determined. The structure of the strong automatic deviation correction device for idler is also designed, and finally the whole deviation adjustment system is checked and demonstrated. In this study, a new belt deviation strength correction device is designed, which overcomes the disadvantages of the previous deviation adjustment device and has great economic and social benefits for improving the safety and reliability of the equipment.

Keywords: belt conveyor; deviation; rectifying device; automatic deflection adjusting system

1 Introduction

The belt conveyor is a kind of machinery that uses the friction between the belt and the frame to generate driving force, and can deliver the materials to the destination without interruption [1]. It is mainly composed of belt, tensioning device, transmission device, idler, steering device, etc. It can transport materials from the starting point to the end point on a production line to form a complete operation process [2,3]. It is widely used not only in retail production lines, but also in wholesale production lines. Conveyor belt can not only transport materials, but

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also contact the production processes of various production enterprises to form a large-scale and rhythmic production and transportation line [4]. However, due to various factors, the center line of the belt conveyor always deviates from the predetermined track, resulting in deviation. According to the belt usage specification, if the offset of the belt along the belt direction exceeds 5% of the belt width, it will be defined as belt deviation [5-6].When the upper belt deviates, the material will fall on the lower belt. When the materials are transported back to the tail, a large amount of materials are scattered at the tail [7]. The material passing through the sweeper is sandwiched between the tail roller and the belt, which leads to the deviation of the belt in the tail roller and affects the normal operation of the conveyor. When the upper belt deviates seriously, the empty belt turned up will fold or even tear. If the deviation is more severe, the upper conveyor belt may fall off the upper idler and onto the floor, which will cause serious problems in the operation of the conveyor [8].

Therefore, when the swing of the conveyor belt along the width of the conveyor belt exceeds the normal range (usually 5% of the belt width), the conveyor belt deviates, and serious production accidents will occur if it is not adjusted [9]. The deviation of the bottom belt on the middle frame or the belt on the roller will aggravate the wear of the edge of the conveyor belt and shorten the service life of the belt. Therefore, it has great economic and social benefits to solve the problems existing in the design and operation, correctly judge the causes of belt deviation and eliminate them in time to ensure the safe and stable operation of the equipment [10].According to the research and investigation on the market demand and equipment requirements of the conveyor belt correction device of the powerful belt conveyor, the production environment of the conveyor in some small and medium-sized factories is usually very bad [11], with large dust and many safety risks. Manual adjustment often has poor correction effect due to its high labor intensity and high requirement on operator's experience [12]. Therefore, it is of great practical significance to study a conveyor belt rectifying device with large rectifying range, good bearing capacity, long service life and simple structure [13].

2 Material and Methods

2.1 Design of deviation detector for strong conveyor belt

2.1.1 Overall design of belt deviation detector

In order to overcome the disadvantages of traditional deviation monitoring equipment, a vertical roller type deviation corrector is designed. When the conveyor belt deviates or the floating amount is too large, it will not work in the normal track, and if it deviates from the track, the lateral displacement of the conveyor belt will touch the vertical roller, which will make the vertical roller rotate and produce a deflection angle, and then predict the deviation of the conveyor belt. Moreover, this vertical roller can also provide accurate deviation fault information-deviation address, waiting for maintenance instructions. The display deflects the belt and deflection information, amplifies, transforms and transmits the received signal to the display console, and feeds it back to the server to complete the reflection function and automatic correction. When the adhesive tape derails, if it comes into contact with the vertical roller, the adhesive tape will push and rotate the vertical roller, which is equivalent to a travel switch. When it touches the vertical roller, the switch will automatically open, so as to obtain a signal, detect the offset angle, and transmit it to the monitor for processing. Through PLC communication, the monitor will display the continuous deviation band, waiting for maintenance. The overall design of the derailment monitor is shown in Fig. 1.

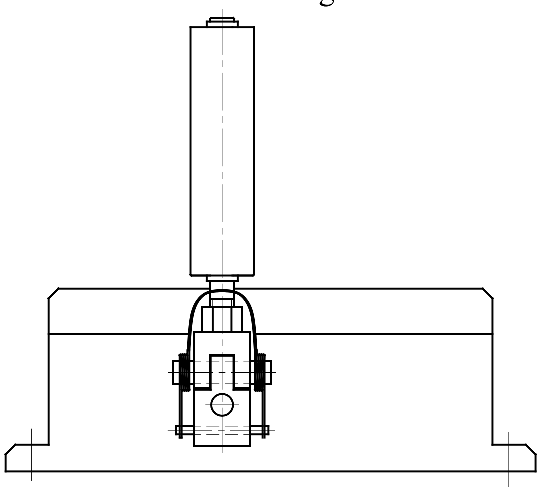

Fig. 1 Schematic diagram of deviation monitoring switch

2.1.2 Working principle of belt deviation detector

The deviation monitor has a normal deviation interval for setting the conveyor belt movement. When the conveyor belt floats left and right, if it touches the vertical roller, the conveyor belt will push the vertical roller to rotate, and the potentiometer in the switch box will start to work, continuously recording the movement track of the conveyor belt, so as to obtain the changing voltage in the signal acquisition circuit. Maintenance personnel can observe the continuous deviation of the conveyor belt through the connected display, so as to detect and eliminate it early. See Figure 2 for the action position of the deviation monitor.

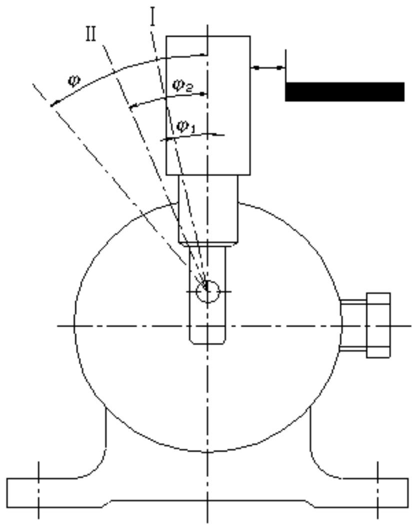

Fig. 2 Schematic diagram of movement position of deviation monitor

When the belt shifts to I, the servo motor does not rotate, and the belt is within the normal deviation range. Gradually, the conveyor belt will push the vertical roller to rotate to position I, and then the servo motor will start working to correct the conveyor belt to return to the predetermined track. At this time, if the power of the servo motor is too small to prevent the conveyor belt from continuing to shift, the belt will continue to shift to position II. When the vertical roller is pushed to position ii by the conveyor belt, it proves that the conveyor belt has experienced serious floating. The servo motor receives a larger feedback signal, the motor speed increases, the vertical roller correction force increases, and the automatic deviation correction is completed. In order to prevent the switch from being damaged due to excessive belt deviation, the position angle of swing lever (generally less than 90°) is set. When the conveyor belt stops floating left and right and returns to the normal deviation range, the switch will automatically reset under the action of the reset spring. The adjusting roller is automatically reset under the drive of servo motor.

2.1.3 Design of the pull rod and anti-impact part of the detector

When the vertical roller deviation correction device touches the vertical roller in lateral displacement, it can rotate through the vertical roller to a great extent, so that the detector can detect the deviation angle, and thus the gear connected with the lower long shaft of the pull rod can rotate. When the gear is engaged with the gear, the waveform of the lateral displacement of the conveyor belt is converted into digitally controlled voltage, which is collected and processed to determine the deviation of the belt. The long shaft connected with the pull rod is equipped with a torsion spring, which makes the pull rod rotate and reset, thus reducing the friction between the adhesive tape and the pull rod. A steering knuckle and a reset spring are arranged under the pull rod of the detector. When the vertical roller is impacted by a large piece of material, it deflects along the running direction of the belt, and the deflection angle can reach 90 degrees at most. After the impact, the vertical roller is reset under the action of the reset spring. See Fig. 3 for the connection structure with the pull rod potentiometer.

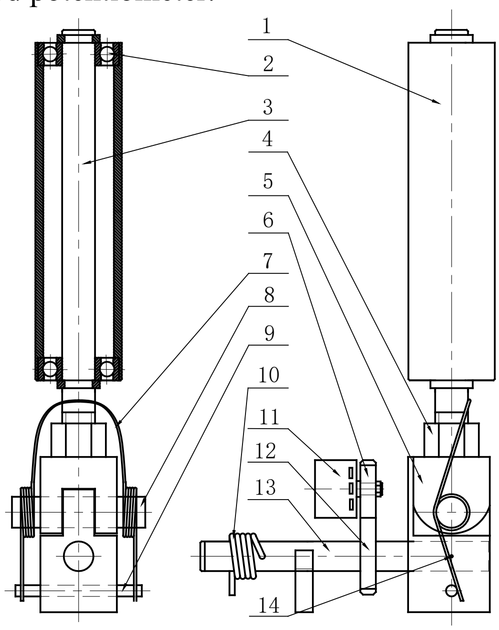

Fig. 3 Connection structure diagram of pull rod and potentiometer

1- roller; 2- bearing; 3- Pull rod shaft; 4- Fasten bolts; 5- Steering knuckle; 6- driven gear;7- shock absorption return spring; 8- Fixed axle pin; 9- Positioning pin; 10- return spring; 11- Locator;12- big gear; 13- optical axis; 14- locating pin

2.2 Design of deviation correction device for strong conveyor belt

2.2.1 Scheme design of automatic rectification device at roller

Offset adjustment system has three functions: manual mechanical adjustment, manual control adjustment and automatic control adjustment. The deviation information is detected by the deviation monitor and then transmitted to the microcomputer system. The deviation and position are displayed in the microchip system. The rotation of the motor is controlled by the single chip microcomputer, and the motors M1 and M2 are started. When the deviation does not exceed the limit range, the deviation detector stops sending deviation signals, and the tape runs normally. Refer to Fig. 4 for schematic diagram of drum deflection adjustment.

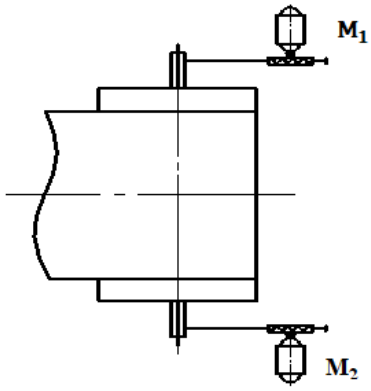

Fig. 4 Schematic diagram of drum deflection adjustment

2.2.2 Scheme design of strong automatic deviation rectifying device for idler

A rotating conical roller with excellent performance and a new offset roller are adopted. Two sides of the offset roller are tapered rollers, and a two-way thrust bearing set is added. When the conveyor belt deviates from a certain side, the outer diameter of the roller on one side is smaller than that of the roller on the other side, which has resistance to transportation, so it is pulled by the conveyor belt to rotate in the traveling direction of the conveyor belt. The installation of bearings greatly reduces friction and rotation resistance, and further improves the sensitivity of the roller. The working principle is shown in Fig 5.

When the conveyor belt deviates from the normal track, the swing monitor detects the abnormal conveying of the conveyor belt, and the pull rod drives the belt. High and low levels are used to control the input of sliding rheostat to analog-to-digital converter to turn on or off. After the waveform is converted into high and low level digital signals, it is input into the single chip microcomputer system, and then processed and output by the single chip microcomputer. If there is some deviation in the actual effect, the single-chip microcomputer system will issue the instruction again, and the second harmonic of AC will transmit the rotation command to the solid-state relay. When receiving the command, the parking or running will be controlled by the motor. Fine-tuning the screw makes the conveyor belt offset in the opposite direction. At the same time, the angle offset side roller adjusts the appropriate angle under the action of the adjustable support frame, so as to realize the forced deviation correction, and make the conveyor belt move on the right track and run normally. After correcting the deviation, driven by the motor, the lead screw remains self-locking and in its current position, maintaining the conveyor belt floating within 5% of its width. If the automatic strong deviation correction is invalid, a signal will be sent to stop the machine. The deviation will be manually processed, and the interface will display the deviation value δ. If it is detected that the floating amount is too large, the position of the problem will be detected in time, and the maintenance workers can know the running state of the conveyor belt in time according to the detection trend, and eliminate the fault in time.

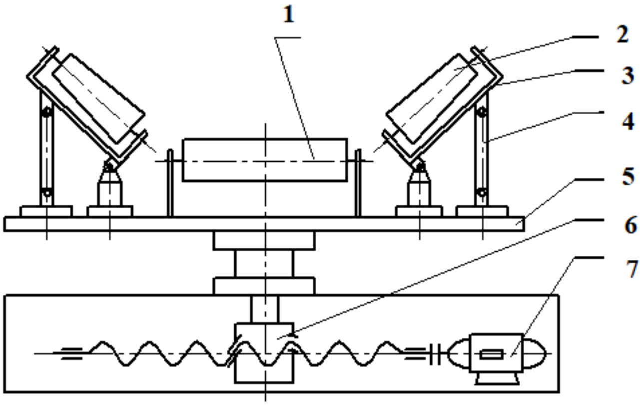

Fig. 5 Schematic diagram of rotary automatic deflection adjustment

1- main roller; 2- Angular offset side roll; 3- Side roll support frame; 4- Adjustable support frame; 5- Main support beam;6- Integral nut; 7- Motor

2.2.3 Structure design of strong automatic deviation rectifying device for idler

(1) Strength calculation of conveyor belt

See Fig 6 for the layout and size of belt conveyor.

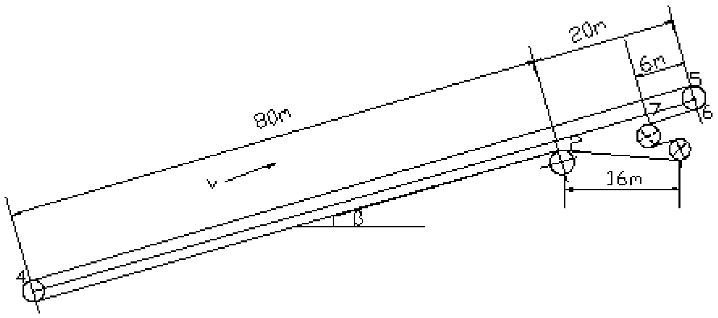

Fig. 6 Schematic diagram of layout and size of belt conveyor

(1) Calculate the calculated safety factor of conveyor belt:

$$m=\frac{S_n}{S_{max}} \tag{1}$$

m——safety factor;

S_n—— rated breaking force of conveyor belt, n;

S_{max}—— the tension of the maximum tension point on the conveyor belt, n.

Among $S_n=BG_x$ (2)

S_n—— rated breaking force of conveyor belt, n;

G_x—— longitudinal tensile strength, N/mm;
B—— Maximum width of conveyor belt, mm.
When G_x=1000N/mm, B=1000mmtime

$$S_n=1000\text{mm}\times1000\text{N/mm}=1000\text{KN}$$

When S_{max}=94.13KNMaximum time:

$$m=\frac{1000\text{KN}}{94.13\text{KN}}=10.624$$

(2) Calculate the allowable safety factor of conveyor belt:

$$[m] = m_{\circ}\frac{k_a c_w}{\eta_{\circ}} \tag{3}$$

$m_{\circ}$—— basic safety factor;
k_a—— Dynamic load coefficient;
c_w—— Conversion coefficient of additional bending elongation;
$\eta_{\circ}$—— conveyor belt joint efficiency.
See Table 1 for some basic parameters of conveyor belt.

Here, the rigid rope core belt is adopted, and its basic safety factor$m_{\circ}$=3.0, bending elongation coefficientc_w=1.8, General dynamic load coefficientk_aTake between 1.2 and 1.5, herek_a=1.2, when$\eta_{\circ}$=0.95When, it is obtained by formula (1.3):

$$[m]=3.0\times\frac{1.2\times1.8}{0.85}=7.624.$$

Because m >[m], the selected conveyor belt meets the strength requirements. According to the above calculation results, it can be seen that the selection of ST1000 conveyor belt can meet the requirements.

Combined with the technical specifications of steel rope conveyor belt, the diameter of steel rope in the core belt of ST1000 steel rope is selected here as follows d=4mm.

(2) Design of center roller

When the bandwidth is 1000mm, the diameter of the selected center roller is ϕ 108mm. When the bandwidth is 1000mm, the length of the central roller is 305 mm. Important official end diameter is ϕ 25mm, the shaft diameter is selected as ϕ 30mm. See Fig 7 for design parameters of central roller shaft.

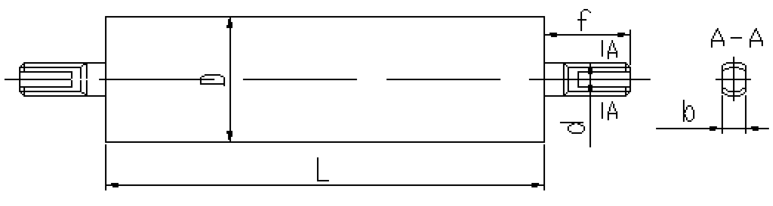

Fig. 7 Design parameter diagram of central roller shaft

(3) Checking of bearings

According to the working conditions, it is decided to install two angular contact ball bearings at both ends of the shaft in reverse. It is known that the radial force on the bearings is F_r=900N, Axial force is F_a=400N, Tangential force is F_t=2200N, Diameter of gear indexing circle d=314mm, Gear speed n=1440r/min, There is a moderate impact load in the process of operation, and the life expectancy of the bearing. $L_h^{'}$=15000h. The two primary bearing models are 7207C, and the basic rated dynamic load of angular contact bearing 7207C can be known from the sample of rolling bearing. C=30.5kN, Basic static load rating C_0=20KN.See Fig. 8(a), (b) and (c) for the check of bearings.

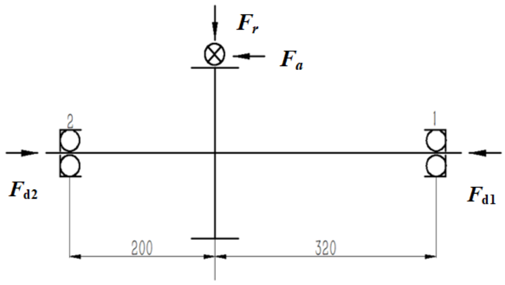

Fig. 8(a)

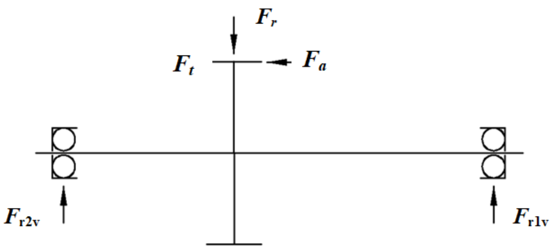

Fig. 8(b)

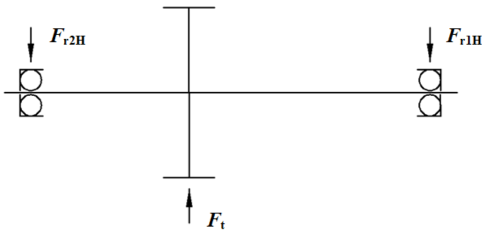

Fig. 8(c)

Fig. 8(a), (b) and (c) Exploded views of spatial force system on shafting components

(4) Selection of keys and checking of connection strength

The key is to realize the circumferential fixation between the shaft and the parts on the shaft through the key to transmit motion and torque. Here, the ordinary is adopted, and the working face of the key is the side, and the force is transmitted by the side, which is used for the shaft with high speed or bearing impact and variable load. It has the advantages of convenient installation and accurate positioning.

(1) Key selection

Select appropriate specifications and sizes by combining the overall structure. The final result is the ordinary (type B), which has the advantage of good keyway fixation compared with other types. Its specifications are: GB/T1095-2003 key B8×7×20 and GB/T1095-2003 key B12×8×20.

(2) Check the strength of keys.

Because of the small size, small shaft diameter and heavy load of the key at the sprocket joint, the strength of the stressed should be checked. See Fig 9 for the strength check diagram of the key.

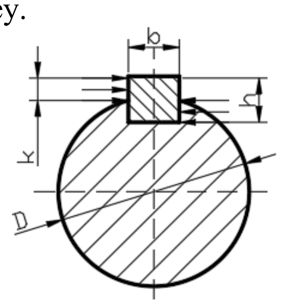

Fig. 9 Strength check diagram of key

Compressive stress of key:

$$\sigma_p = \frac{2T}{DkL} \le \sigma_{pp} \tag{4}$$

T -key connection transmits torque,N·M;

D —— diameter of shaft, mm;

L —— working length of key, mm;

k —— contact height between key and idler, mm;

σ_{pp} —— Maximum allowable extrusion stress of key connection, MPa.

will T=90.45, D=28mm, L=20mm, k=14mm, Substitute (1.4) to calculate the extrusion stress of bond B8×7×20:

$$\sigma_{p1} = \frac{2000 \times 90.45}{28 \times 3.5 \times 20} = 92.29\text{MPa} \tag{5}$$

Similarly, the extrusion stress of bond B12×8×20 can be obtained:

$$\sigma_{p2} = \frac{2000 \times 188.27}{40 \times 4 \times 20} = 117.67\text{MPa} \tag{6}$$

From the selected materials of shaft and sprocket and the slight impact load, it can be known that the maximum allowable extrusion stress of key connection is 100MPa~120MPa. Through the above calculation and comparison, we can see that σ_{p1}=92.29MPa , σ_{p2}=117.67MPa . Within the allowable range of the maximum allowable extrusion stress of key connection, that is, the key design meets the strength extrusion conditions, and the key design is reasonable.

(5) Design of tapered side roll

(1) Design of end face diameter of tapered side stick

When the bandwidth is 1000mm, the diameters of both ends of the tapered side roll are respectively ϕ150mm, ϕ100mm, the length of tapered side stick is 400mm, and the length of tapered side drag stick frame is 450mm. According to the design requirements, take the width of tapered side drag rod frame. B_1, B_2 50mm and 100mm respectively. Because the diameters of the two ends of the tapered side roller are respectively ϕ 150mm, ϕ 100mm, considering the working requirements of the tapered side roller, the height of the tapered side roller frame is 125mm. See Fig. 10 for details.

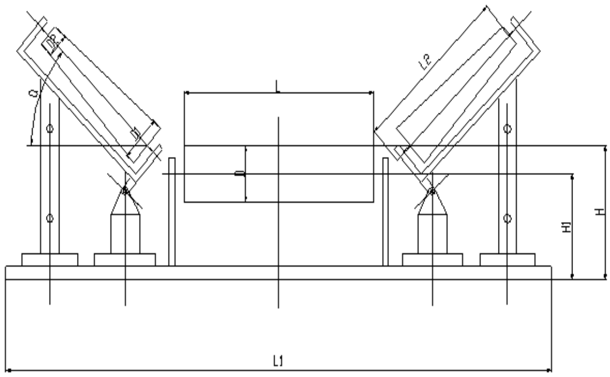

Fig. 10 Series parameter diagram of tapered reversible self-aligning drag roller

Thickness of tapered side drag rod frame according to design requirements$B$=15mm, and the connecting bolt of tapered side drag rod frame is hexagon head bolt M14(GB/T 5782-2000). See Fig. 11 for design parameters of side idler support.

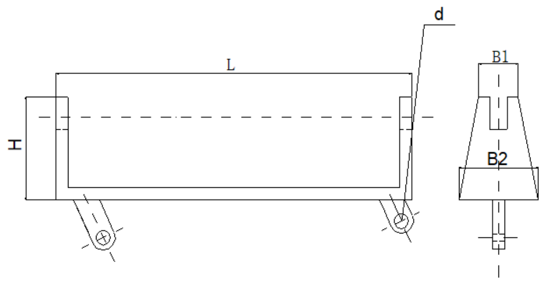

Fig. 11 Design Parameters of Side Trolley Support

(6) Design of support frame

(1) Overall size design of support frame

As the bandwidth is 1000mm, look up Table 5 to get the length of the support frame. L=1350mm. According to the bandwidth and the size of the drag roller, take the width of the support frame. B=200mm. According to its working requirements, take its support thickness. B_1 is 30mm. According to the size of each drag roller and the overall size of the support frame, the inclination angle is obtained. α Is 25, so determine the position parameters of each drag roller support. L_7, L_8, L_9, 170mm, 290mm and 350mm respectively.

(2) Design of connecting and supporting dimensions of tapered side roller frame

According to the size of the tapered side drag rod frame, take the connection support width of the tapered side drag rod frame. B_2 is 30mm. As the bandwidth is 1000mm, look up Table 5 and take the connecting support (height) height of the tapered side drag bar frame according to the size of the tapered side drag bar frame. H_1= 165 mm, tapered side drag rod frame connecting support (short) height. H_2 =25mm. According to the size of the tapered side drag rod frame, take the connecting and supporting length of the tapered side drag rod frame.L_1、L_2、L_3 100mm, 50mm and 20mm respectively.

(3) Size design of central roller bracket

As the bandwidth is 1000mm, take the height of the center roller bracket. H_3, H_4 180mm and 140mm, respectively, taking the width of the central roller bracket. B_3 15mm, and take the length L of the central roller bracket. L_4, L_5, L_6 100mm, 50mm and 20mm respectively.

(4) Dimension design of the joint of the support frame

According to the design and working requirements of the overall size of the support frame, take the size of the joint. R, B_4. They are 30mm and 45mm respectively. See Fig. 12 for specific design parameters of tapered side idler frame.

In addition, according to the shaft design, the flange coupling (GB/T 5843-2003) is selected, and the model is GY7. According to the diameter of the central shaft and the working requirements, the key is the common (GB/T1095-2003), and the basic size of the key is selected L_8. B are 65mm and 22mm respectively.

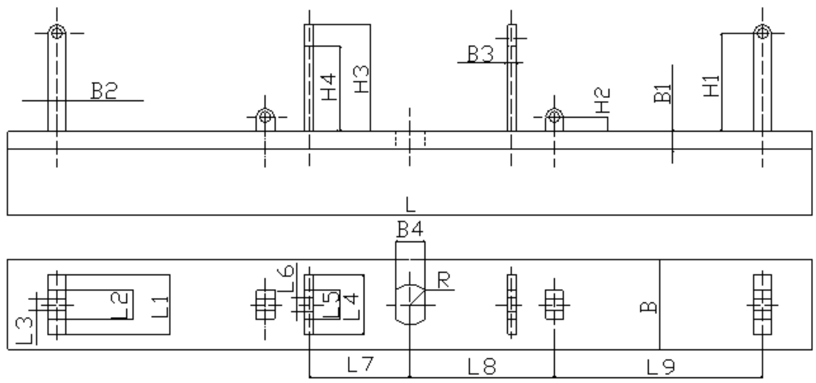

Fig. 12 Design parameter diagram of support frame

(7) Overall size design of lower box body

According to the overall nut size design and working environment and performance requirements, take down the height of the box H315mm.According to the design of lead screw size and the size of the selected motor and its working environment and performance requirements, the length of the box is removed L1500 mm. According to the design of the overall nut size and screw size, as well as the working environment and performance requirements, the width of the box body is removed B590 mm. According to the working environment and performance requirements of the lower box, the thickness of the box is removed C30 mm.

3 Results and Discussion

First of all, by analyzing the stress state of the belt during operation, the root cause of the belt deviation is summarized and analyzed, and a large number of production data are statistically analyzed. By calculating the offset, rectifying force and friction force of the belt in the system, determining the tie rod and anti-impact part of the detector, determining the strong automatic rectifying scheme of the roller, calculating the interaction force between the conveyor belt and the roller, calculating the running speed of the belt and the speed of driving the belt to the center line of the conveyor, finally determining the overall design of the overall system of automatic rectifying. Then, the structure of the roller strength automatic correction device is designed. Finally, the whole deviation adjustment system is checked and demonstrated, and a new belt deviation strength correction device is designed. It has overcome the disadvantages of the previous deviation adjusting device and has great economic and social benefits to improve the safety and reliability of the equipment.

4 Conclusion

This paper mainly aims at the problems that belt conveyors are prone to overspeed or even stall and run off during the downward transportation process, and designs the conveyor belt run off detector, automatic deviation adjustment system, deviation correction device and damping roller. The system provides the optimal research scheme from the parameter analysis and testing, structure and circuit optimization design. Based on the theoretical analysis of the reasons for the belt deviation, a new belt deviation strength correction device is designed by integrating the existing belt deviation correction technology to overcome the disadvantages of the existing belt deviation adjustment device, which has significant economic and social benefits to improve the safety and reliability of the equipment. The research of this project is clearly positioned for application research. In the process of research, attention is paid to summarizing the phased research results, improving the shortcomings in use, and finally achieving the optimization goal of the whole project.

Acknowledgement

This work was financially supported by Science and Technology Development Program of Wei Fang City, Shandong Province (2022GX040, 2022GX041).

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