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Structural optimization and modal analysis of belt conveyor driving drum

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Abstract: In modern industrial production, belt conveyor is essential, its advantage is that it can save a lot of manpower and material resources. Belt conveyor accessories are more, the structure is complex, the complexity of the drum and the technical difficulty is higher. As we all know, the roller plays a great role in the belt conveyor, and its performance also determines the overall performance of the belt conveyor. There are many kinds of rollers on the market today. Because it carries a large number of different angles of force and friction, the loss is relatively large. In this paper, the drum structure is introduced first, and the expansion joint structure is selected as the research object. Then, the friction transmission principle between the drum and the belt is analyzed, and the variation of the envelope Angle and tension is calculated. Finally, the simulation results show that the acceleration of the improved drum is 0.1ms2 less than that before the improvement, indicating that the proposed research is helpful to the optimization of the belt conveyor drum.

1. Introduction

Belt conveyor, referred to as conveyor belt, is a kind of cargo conveying equipment, mainly driven by friction, for continuous cargo conveying [1]. Many highly automated lines in modern factories use belt conveyors as connectors for different equipment, so they are also a very common cargo conveying equipment in industry [2]. Belt conveyor accessories are more, mainly frame, belt, transmission device and drum. Among them, the roller is one of the most important accessories, and its normal operation is directly related to the whole conveyor [3]. The roller is the foundation and support for the belt conveyor. If the running performance of the roller is good, it can be used as the driving part and the medium of the conveyor belt to ensure the good operation of the whole belt conveyor [4].

The roller has a very important position for the whole belt conveyor. However, due to its long-term bearing forces in different directions, the working environment of the drum is different, and some of the working environment is very bad, and the operator does not know how to maintain it, so the life of the drum is relatively low. Therefore, the research content of this paper mainly includes how to improve the structure of the drum, extend the service life and improve the work efficiency. As the core component of belt conveyor, the strength and stiffness of the roller influence each other. Changes in drum size and material will affect the normal operation of other components, and the production cost and material cost are also worth noting. Therefore, in the case of ensuring the performance of the belt conveyor, the structure optimization of the drum has a very great significance for the benefit of the belt conveyor after being put on the market.

2. Related Words

Jassinbekov, O et al used finite element analysis to simulate the variation of a hydraulic drive rolling shell in their study, and the variable friction pressure depends on the adhesion between the belt and the roller with a coefficient of variation. It is found that the selection of appropriate parameters can improve the safety performance of the pipeline. However, this study fails to consider the problem of drum power, which will cause the problem of excessive power [5]. Hao, Y et al. found that the tensioning device is very important for belt conveyors. Although the improved belt device has certain advantages, it fails to consider the noise problem, which will lead to greater noise [6]. Liu, J et al. used CEMA for dynamic analysis and designed a system optimization method based on the price reduction model based on the neural network predictive controller. The simulation results showed that although the error was small, the startup speed seemed not to be ideal [7]. Feng, Y. et al., taking the intermediate belt conveyor in coal mine as the research object, applied MATLAB to analyze the change of conveyor belt tension under different start-up acceleration, and the study provided reference for the modal analysis in the algebraic conveyor transmission in this paper [8]. Wang, M et al. designed a fault detection system combining LOT and LGBM to reduce the fault of belt conveyor equipment, upload the collected information to the client of the Internet of Things platform, and then make statistics and display data on the client. The application shows that the fault diagnosis system can effectively avoid accidents, and the subsequent research can improve the flexibility of the system [9].

3. Method

3.1 Drum structure

There are many kinds of rollers, which are divided into transmission rollers and reversing rollers according to the stress mode [10]. The structure of the two rollers is different, and they also have different roles. The drive drum is usually installed at the head or tail of the fuselage to provide torque and to carry the tension of the conveyor belt. The reversing drum is mainly installed in the reversing part of the tail of the conveyor belt, and its function is to change the direction of the conveyor belt.

According to different use conditions, the roller surface can be coated or smooth. Whether the drum surface is coated with rubber needs to be selected according to the operating environment. How the environmental humidity is large, when the small water droplets formed on the surface of the drum, it is easy to cause slipping phenomenon, which is to use the rubber surface drum. The rubber face roller has a variety of lines, the purpose is to increase the friction between the drum and the conveyor belt [11]. Different lines can be selected according to the job site to prevent slipping and affecting work efficiency. Where the environment is dry, smooth rollers can be selected.

According to the different connection modes of the shaft and the spoke plate, it is divided into different structures. The connection methods mainly include welding, expanding sleeve connection, key connection and interference fitting connection [12]. Among them, the welded connection is mainly used for light rollers, the expansion sleeve connection is mainly used for medium and heavy rollers, the key connection is mainly used for light rollers and reversing rollers, and the interference fit connection is mostly used for light rollers and driving rollers. The expansion joint is mainly used for medium and heavy rollers, so the expansion joint structure is selected as the research object in this paper.

3.2 Frictional transmission principle between drum and belt

Figure 1 shows the stress principle between the belt and the drum. For example, Sl is the tension of the belt at the separation point 1 of the drum, and S_y is the tension of the belt at the meeting point 4 of the belt on the drum. $S_{y\max}$ is the ultimate tension and α is the wrapping Angle of the belt on the roller [13]. Between wraparound angles 1-4, S is the tension at any point of the belt, and β is the wraparound Angle corresponding to arc 1-4. When the belt length changes from point A to point B, then β has A small variable $d\beta$; when the belt length changes from point A to point B with a length increment of dl, the tension at point B is S+dS; when the wrapping Angle $d\beta$ has a relatively small increment, the tension increment is dS.

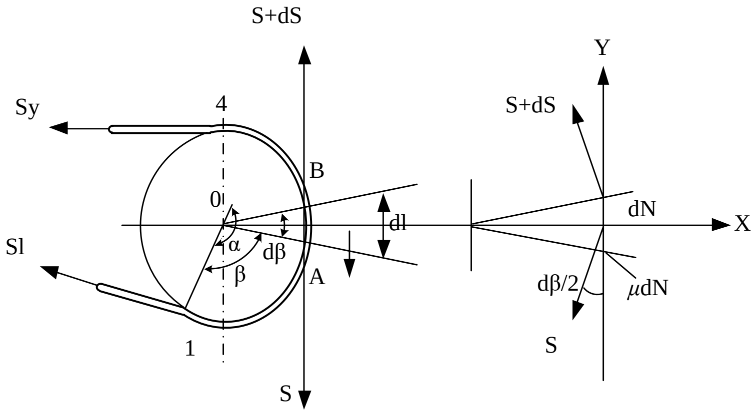

Figure 1: Stress principle of belt and roller

Choose one to take the belt with the incremental length on the arc from point A to point B as the object. If the roller rotates in A clockwise direction at this time, this part of the belt has tension at point A, and the direction of the force is the direction of the tangent line SA of point A. And the part of the belt B point also has tension, the direction of the action is the tangent B point $SdS+B$ direction, point A to point B formed Angle $d\beta$ Angle. The drum also has the opposite force dN on the belt and the friction generated by the two μdN, μ is the friction coefficient between the drum and the belt

Since the length increment of the belt is very short when the length changes from point A to point B, if the thickness of the belt can be ignored, the four forces mentioned above are regarded as the copoint force system, the midpoint of the respective action, and this point is regarded as the origin of the coordinates, and the rectangular coordinates are established. When the tension of the belt reaches its maximum, the friction force also reaches its maximum. In the absence of slippage, the equation of the force on the belt of this unit length can be obtained:

$$dN = S\sin\frac{d\beta}{2} + (S+dS)?\sin\frac{d\beta}{2} \tag{1}$$

$$S\cos\frac{d\beta}{2} + \mu dN = (S+dS)?\cos\frac{d\beta}{2} \tag{2}$$

Since $d\beta$ is small, $\sin\frac{d\beta}{2} \approx \frac{d\beta}{2}$, $\cos\frac{d\beta}{2} \approx 1$, after simplifying the above equation:

$$dN = S\frac{d\beta}{2} + (S + dS)\cdot\frac{d\beta}{2} \tag{3}$$

$dS = \mu dN$, omit $dS \cdot d\beta$, and solve the above equation:

$$\frac{dS}{2} = \mu d\beta \tag{4}$$

When the Angle of the envelope changes, the tension also changes. The function $S = f(\beta)$ can be used to derive the relationship between the tension between the points of encounter and the points of separation. According to the above, when the tension increases from S_1 to $S_{y\max}$, the envelope Angle increases from 0 to α, in this condition, take the definite integral at both ends of the first order ordinary differential equation:

$$\int_{Sl}^{S_{y\max}} \frac{dS}{S} = \int_0^{\alpha} \mu d\beta \tag{5}$$

Solved:

$$\ln\frac{S_{y\max}}{Sl} = \mu\alpha \tag{6}$$

The tension for any point on the arc AB can be expressed as:

$$S_{y\max} = S_{l\max}\cdot e^{\mu\alpha} \tag{7}$$

Where e is the base of the natural logarithm, e= 2.718.

The most common fault in the process of belt conveyor operation is that the belt slips on the drum. In order to prevent this phenomenon, the tension S_y of the belt at the contact point with the drum must meet $S_{ymax} > S_y > S_l$, that is, $S_y < S_l\, e^{\mu\alpha}$.

In view of the above situation, the tension of the belt on the drum envelope arc changes b→c→a, as shown in Figure 2. It can be seen that the belt tension changes in the arc of segment B→C according to the law reflected in the above formula. The tension of the belt reaches S_y at C; The tension of the belt remains constant in the C→A arc.

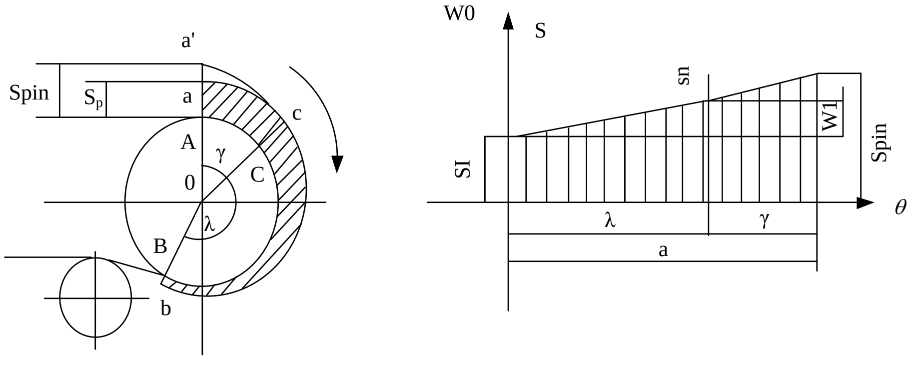

Figure 2: Variation of belt tension on roller

4. Results and Discussion

4.1 Experimental design

In order to better optimize the performance of belt conveyor drum, the following improvements are proposed:

(1) Optimization design of wheel hub structure. Change the connection mode of wheel hub and spoke plate in the past, and transform it into a whole. This design is simple and can save time and labor. It can not only improve the working efficiency of the belt conveyor, but also extend the service life of the drum.

(2) Shaft structure optimization design. The material of the belt conveyor roller shaft is usually 40Cr, and the shaft is not rotated in the design of the roller, so the two ends of the shaft can be partially polished. This is conducive to the operation of the drum and can save energy and reduce consumption.

(3) Cylinder structure optimization design. The diameter and length of the barrel, the wear of the brake and the tension of the belt determine the thickness of the barrel, and for the sake of insurance, the selection of the barrel is generally thicker. When welding the cylinder, in order to ensure the quality of the cylinder, the measures of welding at the same time are generally selected, and the measures of preheating the workpiece can also be selected. However, after the welding is completed, the residual stress needs to be eliminated by local heating and slow cooling.

(4) Optimization design of shaft seat. According to the restraint mode of the shaft and the optimization and reduction of the weight of the drum, the shaft seat is partially optimized to meet the working intensity, so that it can ensure the smooth running without abnormal sound.

4.2 Experimental scheme

The belt conveyor before and after the improvement of the drum is tested, and the experimental items such as power, belt speed, starting acceleration, running condition, tensioning device and static resistance coefficient of the drum are compared.

4.3 Experimental Results

Table 1: Performance comparison before and after improvement

Serial number	Experimental project	Result requirement	Modified front drum	Modified drum
1	Power	1.5 kw, 30 kw	7.5 kw	5.5 kw
2	Tape speed	No-load speed deviation +10%-5%	Band speed deviation +10% when unloaded	Band speed deviation +8% when unloaded
3	Starting acceleration	Starting acceleration shall not be greater than 0.3m/s2	0.2 m/s2	0.1 m/s2
4	Noise	When the belt conveyor is loaded, the noise shall not exceed 90db. Otherwise, corresponding measures should be taken.	75db	53db
5	Tensioning device	Work should be flexible and reliable	Working flexibly is less reliable	Work flexibly and reliably
6	Static resistance coefficient of roller	0.02 or less	< 0.03	< 0.02

Table 1 shows the performance comparison before and after the improvement of the belt conveyor. In terms of power, the improved drum reached a conclusion of 5.5kW. Obviously, the tensioning device changed from not too flexible and reliable to flexible and reliable before the improvement of 7.5kW, with obvious improvement.

4.4 Result Discussion

Through the experiment of the belt conveyor before and after the improvement of the drum, the experimental results are compared, and it is found that the improved drum is better than the improved drum in terms of power, belt speed, starting acceleration, and noise. Therefore, some modifications of the drum shown in 4.1 can effectively ensure the performance of the drum, and the starting acceleration is 0.1m/s2. At the same time, it can save energy and reduce consumption, and improve operation efficiency.

5. Conclusion

Through understanding the structure of belt conveyor and the friction transmission principle between roller and belt, this paper further studies the roller and puts forward the optimization design. According to the content of 4.1 in this paper, the belt conveyor drum is reformed. By comparing the parameters of the optimized roller, the experimental results are obtained, which prove that the optimization of the roller is feasible and has important significance for improving the belt conveyor roller.

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