Research on a New Type of Lattice Roller Frame

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Abstract. In view of the structural defects of the current belt conveyor roller frame, such as heavy weight and high labor intensity of disassembly and assembly, a new lattice roller frame was designed by changing the structure and profile. On the premise of meeting the work conditions, the weight of the roller frame was reduced by more than 45%, which not only reduced the labor intensity of disassembly and assembly, but also reduced the tonnage and cost of consumables of the belt conveyor, and it has a broad market prospect.

Keywords: Lattice; Roller Frame; Belt Conveyor; Structure Optimization.

1. Introduction
Belt conveyors are the most commonly used conveying equipment in the bulk material conveying industry due to their strong environmental adaptability, low operating cost and long conveying distance. As one of the key components of the belt conveyor body which is the main component of the entire conveying equipment, the structure design of the roller frame must not only consider the basic functional requirements, but also consider the convenience of installation and transportation, cost, appearance and so on. Specially, the entire belt conveyor in the roadway needs to be relocated and re-installed on the next fully mechanized face when the production task of one fully mechanized mining face is completed. If the weight of the belt conveyor is too heavy, miners need to work for a long time due to the difficulty of installation. Therefore, under the prerequisite of meeting the functional requirements, it is necessary to tap the potential of the roller frame structure and design a new type of that to meet the actual needs.

2. The Structure of the Roller Frame
The groove angle of the roller frame can be divided into 35°, 45°, 60° and 75° according to the conveying inclination angle and material characteristics. The larger the groove angle, the larger the corresponding conveying inclination. Most of the belt conveyor rollers have a groove angle of 35°, and three roller groups are installed on it. The traditional roller frame, which mainly consists of the beam, the middle support, the side support, and the base, is formed by stamping and welding of section steel, and the machining process is not only complicated but also energy consuming. The new roller frame mainly adopts the truss structure and is welded by different forms of round steel. The roller mounting seat is manufactured by stamping steel plate. Therefore, the overall structure is lightweight and easy to handle and install. The comparison of traditional and new structure is shown in Figure 1.
3. Theoretical Analysis
Satisfying functional requirements and mechanical conditions are the basis of structural design. First, it is necessary to conduct rigid body mechanics analysis on each part of roller frame. Take the belt conveyor bandwidth $B=1400$mm, belt speed $V=4.0$m/s, transportation volume $Q=3800$t/h, and roller spacing $a_o=1.5$m. And the belt strength $S_t=4000$N/mm is the basic known accounting parameter, then each roller rack bears about 500kg weight. Because the roller rack is of groove structure, the final load-bearing capacity of the material in the middle roller and the side roller is different. Assuming that the bearing capacity ratio of the middle and side rollers is 7:3, the force diagram is shown in Figure 2, $F_1=375$N, $F_2=1750$N, among which the three rods AE, EG, and GB are made of Q235A steel with a diameter of 16mm, AC, CD, DB three rods are also made of Q235A steel with a diameter of 16mm, EC and GD are made of two rectangular Q235A steel plates with a side length of 32mm×8mm, and the plate thickness $\delta=6$mm.

![Figure 2. The simplified force diagram of roller frame.](image)

![Figure 3. Simplified force diagram of the hinged form of the roller frame.](image)

![Figure 4. The simplified force diagram of side hinge support.](image)
The hinge model is applied to this calculation, the force diagram is shown in Figure 3 and Figure 4. \( I_{AC} = 3217 \text{mm}^4, I_{AE} = 2 \times 3217 = 6434 \text{mm}^4, I_{EC} = 2 \times 1365 = 2730 \text{mm}^4 \). For the convenience of calculation, assuming \( I_{EC} = 1, I_{AE} = 2.361, I_{AC} = 1.181 \). After force analysis, it can be deduced that the EC and GD rods are zero rods.

\[
F = F_1 \times \sin 55^\circ + F_2 = 2057N
\]

\[
F_{AE} = \frac{F}{\sin 23^\circ} = 5265N
\]

\[
F_{AC} = F_{EG} = \frac{F}{\tan 23^\circ} = 4846N
\]

\[
\sigma_{AC} = \frac{4846}{201} = 24\text{MPa}
\]

\[
\sigma_{AE} = \frac{5265}{113 \times 2} = 23.3\text{MPa}
\]

Based on the rigid connection model, the simplified force diagram of roller frame is shown in Figure 5. It can be concluded from the figure that the rods EC and GD are zero rods, and the AB rods are two-force rods. If the constraint between point A and point B is released, and the hinged support at point A is changed to a movable sliding support, the force diagram can be further simplified to the model shown in Figure 6.

![Figure 5. The force diagram of the rigid connection form of the roller frame.](image)

![Figure 6. The simplified force diagram of the rigid connection form of the roller frame.](image)

The torque balance equation at point A is:

\[
F_{BY} \times 7.22L = F \times 2.47L + F \times 4.75L
\]

And

\[
F_{BY} = F = 2057N
\]

Then

\[
F_{BX} = \frac{F_{BY}}{\tan 23^\circ} = 4846N
\]

\[
M_G = 56585N \cdot \text{mm}
\]

\[
\sigma_{AE} = \frac{5265}{201 \times 2} + \frac{56585}{402 \times 2} = 83.4\text{MPa}
\]

\[
\sigma_{EG} = \frac{4846}{201 \times 2} + \frac{56585}{402 \times 2} = 82.4\text{MPa}
\]
Deflection calculation: Since the beam is a variable cross-section beam, the average moment of inertia of the beam is taken as \( I_\theta = 3385000 \text{mm}^4 \), and the maximum deflection is

\[
\frac{24.7FL(7.22L)^2}{24EI} \left(3 - 4 \times (2.47L)^2\right) = 0.55 \text{m} \leq \frac{\text{span}}{1200} = 1.45 \text{mm}
\]

The result meets the requirements.

4. The Finite Element Analysis of Roller Frame

The force analysis results of roller frame in the last section can be verified by finite element analysis. And the advantages of new roller frame can be easily found by comparing the stress value of finite element analysis of new and traditional roller frame. The force applied on each roller frame is 500kg, which can be the boundary condition of the finite element analysis. The stress and displacement contours of traditional roller frame are as Figure 7 and Figure 8. The stress and displacement contours of new roller frame are as Figure 9 and Figure 10.

The finite element analysis results are basically consistent with the theoretical analysis results. The comparison of stress and displacement results between new and traditional roller frame are shown in Table 1.

| Table 1. The comparison between new and traditional roller frame. |
|---------------------------------------------------------------|
| **Traditional roller frame** | **New roller frame** |
| Weight (kg) | 43.5 | 22.5 |
| Maximum Weight (MPa) | 50 | 45 |
| Maximum displacement (mm) | 0.96 | 0.58 |

**Figure 7.** The stress nephogram of traditional roller frame.

**Figure 8.** The displacement nephogram of traditional roller frame.
5. Loading Test
Based on the theoretical and simulation analysis, it can be seen that the new lattice roller frame had good performance and obvious advantages. In order to further verify the reliability of the structure, Ningxia Tiandi Northwest Coal Mining Machinery Co., Ltd. carried out a sample trial production and static load test on the new structure of roller frame with a bandwidth of B=1400mm, and the experimental site is shown in Figure 11. The vertical displacement data of the roller frame was obtained during test, and it is shown in Table 2.

Table 2. The relationship between the roller vertical displacement and the loaded weight.

| Loaded weight (kg) | Vertical displacement (mm) | Loaded weight (kg) | Vertical displacement (mm) |
|--------------------|----------------------------|--------------------|----------------------------|
| 200                | 0.4                        | 700                | 0.7                        |
| 300                | 0.5                        | 800                | 0.8                        |
| 400                | 0.5                        | 900                | 0.8                        |
| 500                | 0.6                        | 1000               | 1.0                        |
| 600                | 0.6                        | 1500               | 1.3                        |

Figure 9. The stress nephogram of new roller frame.

Figure 10. The displacement nephogram of new roller frame.

Figure 11. The static load test on new roller frame.
6. Conclusion
The results of related theoretical calculations and experiments shown that under the premise of the same working conditions, the weight of the new roller frame was reduced by more than 45% compared with the traditional one, which not only reduced the labor intensity of personnel disassembly and assembly, but also reduced the tonnage and cost of consumables for belt conveyors, and actively fulfilled my country's mission of achieving carbon neutrality and carbon peaking. At present, partial industrial tests have been carried out in the Jinfeng Coal Mine and Zaoquan Coal Mine of Shenhua Ningxia Coal Group. The pictures of industrial application are shown in Figure 12. The equipment is operating in good condition and has broad market prospects.

![Figure 12. Industrial application example of new roller frame.](image)

Acknowledgments
Thanks to Tiandi Science & Technology Co.,Ltd. for their strong support of this research. The research is based on the project of artificial intelligence non-contact belt conveyor coal quantity and belt surface health detection system. The project number is 2020-2-TD-ZD002.

References
[1] Zhang Z W and Song W G 2015 Engineering Design and Application of Belt Conveyor.
[2] Zhang C 2003 New Belt Conveyor Design Manual
[3] Zhao Y W and Li Y H 2004 Present situation and development trend of belt conveyor Coal Mine Machinery
[4] Zhang J, Jin W, Xie X, et al. 2020 Design of Long Distance and Large Dip Material Belt Conveyor Journal of Agricultural Mechanization Research