Design of Double Carrying Rope Material Ropeway System

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Abstract. According to the transport requirements and structural characteristics of double carrying rope material ropeway, a lever type double carrying rope material ropeway system is proposed. Through lever device and limit device, the tension between two carrying ropes can be adjusted automatically. Combined with the terrain, the stress status of the main components of the material ropeway is obtained through analysis and calculation, and the selection parameters of the components such as working rope, self-adjusting device and saddle are proposed and checked by finite element analysis. The results show that the components meet the structural strength requirements, and the automatic balance adjustment function of the designed material ropeway system can improve the stability of the material ropeway operation, reduce the difficulty of adjustment in the construction process, and improve the construction safety and efficiency.

1. Introduction
It is often faced with complex and harsh terrain conditions in mountainous areas during transmission line construction. The use of material ropeway can not only overcome the limitations of terrain conditions, but also has the advantages of small investment, low energy consumption and good environmental protection [1-2].

Material ropeway mainly includes working rope (carrying rope, pulling rope), saddle, trestle, running car, steering pulley, ropeway driving device and anchor underground [3-4]. Through the catenary method [5-6], for small tonnage material ropeway (the general load is not more than 2t), one single rope can generally meet the transportation demand. However, when the load is large, two ropes should be used to share the load, so the double carrying rope material ropeway is widely used in transmission line construction [7-8].

The carrying rope of current double carrying rope material ropeway needs to be erected and anchored independently. After the erection, the sag (length) of the two carrying ropes should be adjusted to be basically the same, so as to ensure the smooth running of the running car on the carrying rope (as shown in figure 1). When the rope length differs greatly, the tension of one of the carrying rope will be too large during transportation, which will easily cause the rope to break, thus causing safety accidents.

Figure 1. Conventional double carrying rope material ropeway
In this paper, a lever type double carrying rope material ropeway is proposed, and the lever type double carrying rope material ropeway design is carried out to realize the automatic balance adjustment of the rope tension of the material ropeway, reduce the adjustment difficulty during the construction process, and improve the stability of the material ropeway operation.

2. Design Condition of Double Carrying Rope Material Ropeway System

In general, double carrying rope material ropeway is mainly used for material transportation with load of 2t~5t. In this paper, the double carrying rope material ropeway with single span is designed according to the construction conditions of rough terrain (Span $L$ is 600m, height difference $H$ is 200m), and the load is 5t, as shown in figure 2.

![Diagram of material ropeway erection](image)

According to the calculation, the force of the components of 5t material ropeway under working condition is obtained, and the calculation results are shown in table 1.

| Component  | Parameter               | Value   |
|------------|-------------------------|---------|
| Carrying rope | Diameter (mm)          | 26      |
| Carrying rope | Maximum tension (kN) | 134.16  |
| Carrying rope | Safety factor          | 2.77    |
| Carrying rope | Diameter (mm)          | 22      |
| Pulling rope | Maximum tension (kN)   | 51.34   |
| Pulling rope | Safety factor          | 5.18    |
| Trestle 1    | Maximum load (kN)      | Legs 79.24 |
| Trestle 1    | Bearing beam           | 118.86  |
| Trestle 1    | Saddle                 | 79.86   |
| Trestle 1    | Legs                   | 182.62  |
| Trestle 2    | Maximum load (kN)      | Bears 273.93 |
| Trestle 2    | Bearing beam           | 273.93  |
| Trestle 2    | Saddle                 | 267.43  |
3. Design and Check Analysis of Double Carrying Rope Material Ropeway System

3.1. Design Scheme of Lever Type Double Carrying Rope Material Ropeway System

In order to keep the balance of the load in the transportation process, the length of the carrying rope of the double material ropeway needs to be adjusted in real time. Therefore, this paper proposes a design scheme of the lever type double carrying rope material ropeway system.

On the basis of the conventional double carrying rope material ropeway, a lever type self-adjusting device is proposed to adjust the tension balance between the carrying ropes. The specific system design is shown in figure 3.

![Figure 3. Diagram of lever type double carrying rope material ropeway system](image)

1- Anchor underground; 2- Lever type self-adjusting device; 3- Saddle of double carrying rope; 4- Trestle; 5- Running car of double carrying rope; 6- Carrying rope; 7- Pulling rope; 8- High-speed steering pulley; 9- Driving device; 10- Return saddle; 11- Return rope

Figure 3. Diagram of lever type double carrying rope material ropeway system

3.2. Design of Key Components of Material Ropeway System

The lever type self-adjusting device mainly includes anchorage device, limit device, lever device, connection device, support device and rope spacing control device, as shown in figure 4.

![Figure 4. Diagram of self-adjusting device for carrying rope](image)

1- Anchorage device; 2- Limit device; 3- Lever device; 4- Connection device; 5- Support device; 6- Rope spacing control device

Figure 4. Diagram of self-adjusting device for carrying rope

3.3. Analysis and Strength Check of Key Components Selection

According to the design scheme of lever type double carrying rope material ropeway system, the lever type self-adjusting device for carrying rope, saddle, trestle and other components are designed and checked. Since the calculation results of material ropeway components are affected by the selection
results of working rope, it is necessary to check and calculate the stress of components after determining the specifications of working rope.

3.3.1. Working rope. According to the calculation results of working condition in table 1, the selection results of working rope are shown in table 2.

| Item            | Specification | Tensile strength (MPa) | Safety factor |
|-----------------|---------------|------------------------|---------------|
| Carrying rope   | φ26           | 1670                   | 2.77          |
| Pulling rope    | φ22           | 1670                   | 5.18          |

3.3.2. Lever type self-adjusting device for carrying rope. According to the structural size of the lever type self-adjusting device for carrying rope, the finite element modeling analysis is carried out, as shown in figure 5.

The maximum stress of the lever type self-adjusting device is 268.32kN. Q355 is selected as the material of the wheel frame. The density of the material is \(7.9 \times 10^3\)t/mm\(^3\), and the elastic modulus is \(2.1 \times 10^5\)MPa. Through calculation, the stress distribution of wheel frame is shown in figure 6.

It can be seen from the figure that the overall stress of the wheel frame is relatively small, the maximum stress occurs around the bolt hole of the wheel frame, which belongs to the area of local stress concentration, and the maximum stress in other areas is not greater than 159MPa. The components meet the structural strength requirements.
3.3.3. **Saddle of double carrying rope.** According to the force of saddle, the stress analysis and check of saddle are carried out. According to the design size of the saddle, the finite element modeling analysis is carried out, as shown in figure 7.

![Figure 7. FEM model of saddle](image)

The maximum stress of the saddle is 267.43kN. Q355 is selected as the material of the saddle. The density of the material is 7.9×10^9 t/mm³, and the elastic modulus is 2.1×10^5 MPa. Through calculation, the stress distribution of saddle is shown in figure 8.

![Figure 8. Stress cloud of saddle](image)

It can be seen from the figure that the maximum stress of the saddle is mainly concentrated at the shaft hole connecting the saddle support frame and the casing pipe, which belongs to the local stress concentration area. The maximum stress in other areas is not greater than 253 MPa, and the components meet the structural strength requirements.

3.3.4. **Trestle.** According to the design scheme, the trestle is made of duplex I-beam and steel tube legs. The length of the leg structure is 2m, and the material specification of beam is 28a×3m. According to the size of the trestle, the finite element modeling analysis is carried out, as shown in figure 9.

![Figure 9. FEM model of trestle](image)
The maximum stress of the bearing beam is 273.93kN. Q355 is selected as the material of the saddle. The density of the material is \(7.9 \times 10^3\) t/m\(^3\), and the elastic modulus is \(2.1 \times 10^5\) MPa. Through calculation, the stress distribution of trestle is shown in figure 10.

![Stress cloud of trestle](image)

**Figure 10.** Stress cloud of trestle

It can be seen from Figure 10 that the maximum stress of the trestle occurs at the connection area between the leg and the bearing beam, which belongs to the local stress concentration area. The maximum stress in other areas is not greater than 320MPa, and the components meet the structural strength requirements.

4. Conclusion

In this paper, a design scheme of double carrying rope material ropeway with lever type tension automatic balance adjustment function is proposed combined with the problems existing in the process of erection and transportation construction of the material ropeway of transmission line. The components of 5t double carrying rope material ropeway are designed according to the terrain condition, and the design components are checked through finite element simulation analysis.

(1) Combined with the terrain, the force status of component of the material ropeway is analysed, and the design load of the component is proposed.

(2) According to the calculation results of working conditions, the main components are analysed and checked by finite element method. The results show that the structure design meets the strength requirements.

The double carrying rope material ropeway system proposed in this paper can adjust the tension balance between the carrying rope, which effectively reducing the difficulty of adjusting the sag and unbalanced tension between ropes, and improving the safety of construction.

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6. References

[1] Xinnian Zhou 2013 Engineering cableway and suspension bridge *China Communication Press*

[2] Zhusen Sun, Qian Miao and Ming Jiang 2011 Standardized Construction scheme for aerial ropeway of electric transmission line engineering *Electric Power Construction* **32**(3) pp 117-120

[3] Q/GDW 11189—2018 Special aerial material ropeway with transit materiel of over head transmission line engineering

[4] Q/GDW 1418—2014 Construction technology guide for aerial material ropeway transportation of electric transmission engineering

[5] Lifeng Zheng 2002 Theory study of cableway on the catenary algorithm *Fujian Agriculture and Forestry University*
[6] Jian Qin and Yongjun Xia 2013 The Matrix iteration method for analysis of suspension cable based on segmental category theory *Chinese Journal of Engineering Design* 20(5) pp 404-408

[7] Jian Qin, Liang Qiao, Ming Jiang and Yujing Hao 2019 Calculation method of material ropeway with multiple carrying ropes and analysis of tension unbalance effect *Journal of Safety Science and Technology* 15(9) pp 44-49

[8] Weidong Zhang, Jian Qin, Di Chen, Qiying Li and Liang Qiao 2020 Analysis and calculation method of multi-span and multi-load freight ropeway under working-cable coupling action *Chinese Journal of Engineering Design* 27(3) pp 293-300