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Design and Analysis of a Continuous-Double-Cable Freight Ropeway

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Abstract. Aiming at the transport requirements and structural characteristics of double-bearing cable freight ropeway, a pulley type continuous-double-cable freight ropeway is proposed on the basis of the common double load-bearing cable freight ropeway. One wire rope forms two load-bearing cables through the automatic balance device of cable tension. The length of load-bearing cables can be adjusted according to the tension difference of cables during operation process of ropeway. In addition, the roller-type saddle for double-cable freight ropeway is designed to improve the adjustment ability of load-bearing cable. It ensures consistent sag between the load-bearing cables during transportation and avoids overturning of the running car. The calculation of ropeway structure is done according to the actual topography condition, and the loads of the main load-bearing components of the continuous double-cable freight ropeway, such as the automatic balance device of the cable tension, the roller-type saddle and the support leg ropeway, are obtained. The finite element analysis also is carried out on the basis of the loads of ropeway structure. The results show that the components of ropeway meet the structural strength requirement. The continuous-double-cable ropeway can maintain the tension equilibrium of the load-bearing cables, effectively reduce the difficulty of sag adjustment, and improve security in construction.

Keywords. Freight ropeway, load-bearing cable, automatic balance device, cable tension, finite element method

1. Introduction

The freight ropeway is widely used in transmission line construction to overcome the limitation of complex and harsh mountainous terrain condition [1-2].

The small carrying capacity ropeway (load not exceeding 2t generally) often adopts the structure type with single load-bearing cable. However, when the load is large, two parallel load-bearing cables are necessary to improve the security of the ropeway, so the double load-bearing cables freight ropeway occurs in construction of transmission line [3-4], as shown in figure 1.

The two load-bearing cables of ropeway need independent erection and anchoring. And the sag of two cables must be adjusted by manual operation to maintain equality. When the difference of cable sags varies greatly, the tension of cable with small sag may become very large and cause the breaking of cable.

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In this paper, a continuous-double-cable freight ropeway is proposed, which can realize the dynamic adjustment of the tension of load-bearing cable in real-time and better achieve the operation of the ropeway.

Figure 1. The conventional double cable freight ropeway.

2. The Design of Continuous-Double-Cable Freight Ropeway

2.1. The Design Scheme

In order to ensure the load balance of the load-bearing cable during transportation, it is necessary to adjust the length of deferent load-bearing cables in real-time. Therefore, this paper proposes a scheme of continuous-double-cable ropeway based on the structure of common double-cable ropeway.

The new ropeway includes load-bearing cable, traction cable, return cable, automatic balance device of cable tension, roller-type saddle and the support leg, car, return saddle, anchor. The design of ropeway is shown in figure 2 and figure 3.

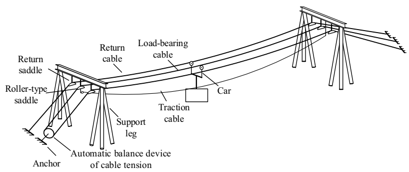

Figure 2. The diagram of continuous-double-cable freight ropeway.

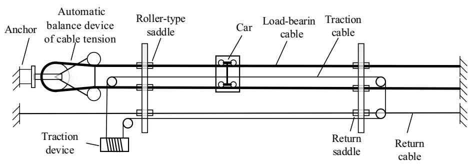

Figure 3. The diagram of continuous-double-cable freight ropeway (top view).

The single rope is used as load-bearing cable and wraps around the automatic balance device of cable tension. During operation process of ropeway, length of load-bearing cables is adjusted in real-time according to the tension difference of two sides of device.

The scheme can reduce the difficulty of construction and avoid the risk of single load-bearing cable fracture due to tension concentration in the transportation, and improve the security of the ropeway.

In this scheme, the automatic balance device of cable tension and roller-type saddle are innovative design, the other component has no chance. So the automatic balance device of cable tension and roller-type saddle are analyzed individually in detail.

2.2. Design of the Automatic Balance Device of Cable Tension

In the continuous-double-cable freight ropeway, the automatic balance device of cable tension is an innovative improvement compared with the ordinary ropeway.

The new device mainly includes the pulley bracket, the pulley of load-bearing cable, the spacing control pulley, the leg, the anchoring device and other parts, as shown in figure 4.

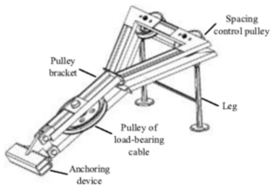

Figure 4. The automatic balance device of cable tension.

1) The anchoring device has two holes, which can be connected with the bracket by bolts. The anchoring device can be anchored to the ground.

2) The load-bearing cable is wrapped around the pulley of load-bearing cable, and the size of the pulley must match the load-bearing cable.

3) The two spacing control pulleys at the top of the leg can adjust the spacing to control the distance of the load-bearing cables.

4) The lowest part of the leg are disks, which increase the contact area with the ground. Meanwhile, the leg can rotate around the axis of the bracket, so as to chance the angle between the bracket and ground.

2.3. Design of Roller-Type Saddle

In order to implement the tension balance between load-bearing cables, the load-bearing cable saddle in common use is also improved, which is called the roller-type saddle, as shown in figure 5.

The roller-type saddle includes saddle bracket, roller plate and wheel.

1) The saddle bracket includes two arms, which are connected by a beam to ensure the distance between two load-bearing cables. One arm is L shaped, and a roller plate is installed in the middle to support the load-bearing cable, a wheel at lower end to support the traction cable. The other arm is straight with a wheel at lower end.

2) The roller plate has two support plates and a row of rollers. The rollers are evenly distributed along the curved edges of plate and can be rotated freely. The number of rollers can be determined according to the size of the plate. The plate is connected with the saddle bracket by an axle.

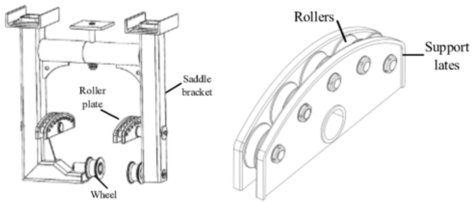

Figure 5. The diagram of roller-type saddle.

3. Selection and Analysis of Continuous-Double-Cable Freight Ropeway

3.1. Design Conditions

In general, the double load-bearing cable ropeway is mainly used to transfer the material (the single weight about 2t-5t). In this paper, the ropeway is set with single span in accordance with the common topographic conditions of the construction, and the load is 5t. The horizontal spacing distance and the height difference of the span are 400m and 107m respectively.

The calculation method of coupling effect of load-bearing cable and traction cable is used to calculate the structure load of the ropeway [5-7]. The results are shown in table 1.

Table 1. The results of working conditions.

Load-bearing cable	Maximum Tension(kN)	171.48
Traction Cable	Maximum Tension(kN)	40.78
First Support	Maximum Vertical Force(kN)	115.26
End Support	Maximum Vertical Force(kN)	154.61

3.2. Analysis of Ropeway Components

3.2.1. Working Cables

According to the calculation results of the design condition in table 1, the selection results of work cables are shown in table 2.

Table 2. The selection results of work cables.

Work cable	Specification	Tensile Strength /MPa	Safety Factor	Remarks
Load-bearing cable	Φ30	1770	2.89	wire rope of 6×36
Traction Cable	Φ22	1770	6.05	wire rope of 6×36

3.2.2. Automatic balance device of cable tension

The finite element analysis is carried out according to the size of the automatic balance device of cable tension. The material of device chooses Q235B, and elastic modulus is 2.1×10^5MPa. And the number of units of device is 96578, the element is C3D10. The stress distribution of pulley bracket is shown in figure 6.

Figure 6. The stress of pulley bracket.

It can be seen from figure 6 that the maximum stress of pulley bracket is 552.7MPa, which occurs around the hole of the wheel, the stress concentration area. The maximum stress in the rest area is not higher than that of 78Mpa, and the stress of the device can reach 3 times the safety factor. Therefore, the device meets the structural strength requirement.

3.2.3. Roller-type Saddle

The stress analysis of the roller-type saddle was carried out according to the working condition. First the model of roller-type saddle is built and the finite element analysis is carried out, as shown in the figure 7.

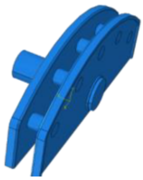

Figure 7. Finite element model of roller-type saddle.

The material of the saddle bracket is Q355, and the elastic modulus is 2.1×10^5MPa. The number of units is 46557, and the element type is C3D10. The maximum force of saddle is 100kN. The material of roller axle is 40Cr, the number of elements is 39219, and the element type is C3D8R. Based on the calculation, the stress distribution of the roller plate, roller axle and saddle axle are shown in figures 8~10.

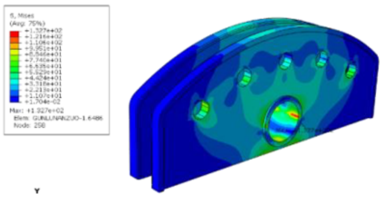

Figure 8. The stress of roller plate.

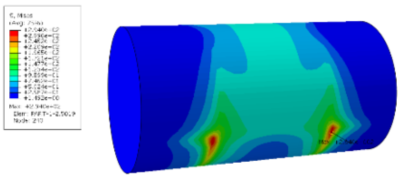

Figure 9. The stress of roller axle.

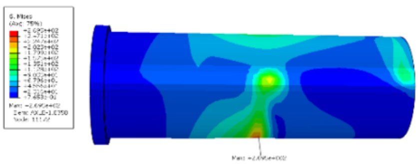

Figure 10. The stress of wheel axle.

It can be seen from figure 8 that the stress of the plate is relatively small, and the maximum stress is 132.7MPa. The maximum stress is mainly concentrated in the hole edge of the roller axle. The maximum stress in other regions is not greater than 100MPa. So the design of roller-type saddle meets the structural strength requirement. It can be seen from figure 10 that the maximum stress distribution of the roller axle is 294MPa, which occurs in the contact area of the roller axle and the roller plate. The stress in other regions is not greater than 170MPa and meet the structural strength requirement.

3.2.4. Support Leg

According to the design scheme, the support leg of ropeway adopts double I-steel beam and lattice structure. The length of the leg is 12m, the main material is 65×6, and the maximum force of single leg is 150kN. The material is Q355, the elastic modulus is 2.1×10^5MPa. The number of units is 2120, and the unit type is B31. By calculation, the stress distribution of the support leg is shown in the figure 11.

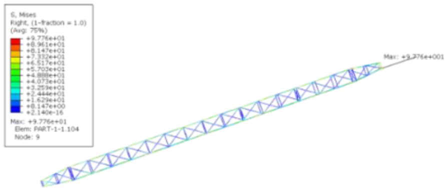

Figure 11. The stress of support leg.

It can be seen from the figure 11 that the maximum stress of the support leg is 97.76MPa, which occurs at the junction of the leg and the beam, meet the requirements of strength design.

In order to ensure the stability of the leg structure, the buckling analysis was performed to obtain the buckling load. And the first two order buckling modes and eigenvalues were obtained, as shown in the figure 12.

(a) 1st order mode (b) 2nd order mode

Figure 12. The first two order buckling modes of leg.

From the figure 12, the 1th order buckling eigenvalue of the leg is 12.045, and the buckling critical load is 1806.75kN, which is larger than the structural load of the support leg(150kN). So the stability of the leg meets the design requirements.

4. Conclusion

To solve the problems in construction of transmission line, a continuous-double-cable freight ropeway is put forward, which can keep the tension balance of load-bearing cables. And the design and analysis of automatic balance device of cable tension and roller-type saddle are given. The roller-type saddle can greatly reduce the sliding resistance of the load-bearing cable, and improve the balance adjustment effect of cable tension.

According to the calculation results of the actual topography condition, the main load-bearing structure of the continuous-double-cable freight ropeway, such as the automatic balance device of cable tension, roller-type saddle and the support leg are analyzed by the finite element method. The results show that the structure design meets the requirement of construction.

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