PAPER • **OPEN ACCESS**

Design of a reciprocating freight ropeway in mountain orchard

To cite this article: Fan Guiju *et al* 2019 *IOP Conf. Ser.: Mater. Sci. Eng.* **563** 042056

View the article online for updates and enhancements.



IOP ebooks™

Bringing you innovative digital publishing with leading voices to create your essential collection of books in STEM research.

Start exploring the collection - download the first chapter of every title for free.

This content was downloaded from IP address 124.205.143.210 on 19/09/2019 at 10:32

IOP Conf. Series: Materials Science and Engineering **563** (2019) 042056 doi:10.1088/1757-899X/563/4/042056

Design of a reciprocating freight ropeway in mountain orchard

Fan Guiju[1, 2], Qin Fu[1], Feng Tiantao[1, 2, *], Zhang Hao[1] and Li Zhao[1]

[1]College of Mechanical and Electrical Engineering, Shandong Agricultural University, Tai'an 271018, China

[2]Shandong Provincial Key Laboratory of Horticultural Machinery and Equipment, Tai'an 271018, China

[*]E-mail: fttao79@163.com（Corresponding author）

Abstract. Aiming at the problem of high labor intensity in field transportation of fruit in mountain orchards, a single-span reciprocating ropeway transportation system was put forward according to the topographic characteristics of mountain areas and the income of fruit farmers. The ropeway transport system consists of an electric winch, two pillars on the left and right, a circulating traction wirerope, a track rope, wind cables, a sports car, and tensioning mechanisms. Through analysis and calculation, steel wire ropes with diameters of 12mm and 6mm are used as track rope and traction rope; electric winch machines with power of 1.5kW and reduction ratio of 15 are selected, and the friction reel diameter is 200mm. Finally a single-wheeled sports car is designed to ensure the normal transportation of the ropeway.

1. Introduction

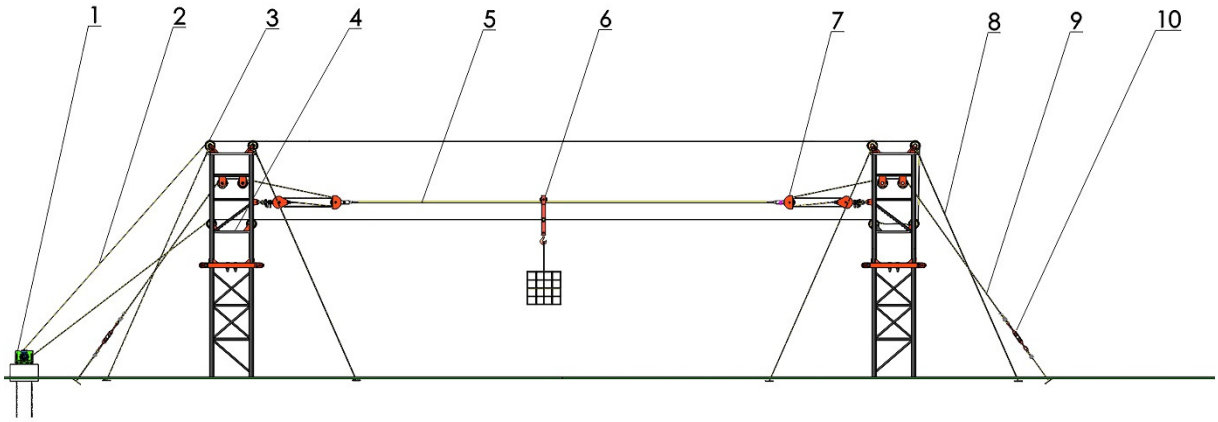
The mountain orchard is rugged and the road system is imperfect. The fruit field transportation mainly relies on manpower, high labor intensity and low production efficiency. Therefore, the research on the labor-saving transportation equipment of mountain orchards has become a hot spot. At present, mountain orchard transportation equipment mainly includes conventional wheeled transport vehicles, crawler transport vehicles, railcars and ropeway transport systems [1]. Among them, the cableway transportation is an overhead line transportation, which has less transformation to the orchard terrain and strong adaptability to mountainous terrain. It is a cost-effective mountain orchard transportation mode. The cableway transportation technology is mature, and it is widely used in the fields of skidding, passenger transportation, lifting, etc., but it is rarely used in fruit orchard transportation. Only a few orchards use ropeway to transport bananas and citrus [2]. The topographical conditions of mountain orchards are suitable for erecting ropeways, but the small scale of the orchard and the low standardization of orchard planting put forward higher requirements for the design of the ropeway [3]. In order to realize the field transportation of mountain orchard and comprehensively consider the economic conditions of fruit farmers and the convenience of ropeway operation, this paper proposes a design scheme of reciprocating ropeway transportation system for mountain orchard.

2. Overall design

The overall design of the mountain orchard reciprocating ropeway transport system is shown in Figure 1. The ropeway transport system consists of an electric winch, two pillars on the left and right, a circulating traction wirerope, a track rope, wind cables, a sports car, and tensioning mechanisms. The

Content from this work may be used under the terms of the Creative Commons Attribution 3.0 licence. Any further distribution of this work must maintain attribution to the author(s) and the title of the work, journal citation and DOI.
Published under licence by IOP Publishing Ltd

sports car is mounted on the track rope and clamped to the traction cable by a fixed rope grip. When the ropeway works, the friction reel drives the traction wire rope to move the sports car along the track rope, and realizes the reciprocating operation of the sports car through the positive and negative rotation of the motor. The cableway is used for field transportation in mountain orchards. The left and right towers are arranged without height difference, the string inclination angle α=0, the tower height h=3.5 meters, the design span l_0=100 meters, and the load cable deflection f=f_D=2 meters. The weight of the sports car and cargo are no more than 200kg, and the stable running speed is 1m/s.



1.electric winch 2.circulating traction wire rope 3.guide pulley 4. steel frame 5.track rope
6. cableway sports car 7. Tensioning block 8.cable wind rope 9. Tension rope 10.tighter
Figure 1. Overall design

3. Design of cableway rope

3.1 Track rope

In the aerial ropeway, the track rope is the main load-bearing component, so the choice of the load-bearing wire rope is of great significance to the safe operation of the ropeway. When selecting the carrying rope, it is necessary to meet the safety requirements, but also to take into account the price factor, and not blindly choose. At present, the 6×19+1 fiber hemp core wire is widely used for the track rope. For the selection of the track rope diameter, the commonly used method is the safety factor method, that is, the selected wire rope breaking force T_p satisfies the following formula.

$$T_p \geq T_{max} \bullet N_t \quad (1)$$

In the formula, Tmax is the maximum tension of the track rope, and the safety factor of the freight ropeway is generally N_T=2.5. It is known from the cable theory that when the concentrated load D is located in the span, the track rope has the maximum tension [4]. In order to reduce the calculation amount and ignore the self-weight of the track rope, the load on the load cable is as shown in Fig. 2 [5].

According to the force balance equation

$$(F+F_1)\sin\theta = F\sin\theta \quad (2)$$

$$(F+F_1)\cos\theta + F\cos\theta = P \quad (3)$$

P: Full load of sports car, P = 200kg = 2000N;

F: Track rope tension (N);

F_1: The friction of the carrying rope against the trolley when the car is stationary.

F_1 = 0 and F = 25.02 kN can be obtained.

According to the safety factor method, the wire rope with a diameter of 12 mm can be pre-selected, the minimum breaking tensile force Tp=73.8kN, and the weight of the track rope is W=50.5kg=505N.

The F obtained is only the tension that ignores the weight of the track rope, and is not the maximum tension of the track rope. The maximum tension of the track rope is

$$T_{max} = (W + P)\,\varphi_1 = 28.16\text{kN} \quad (4)$$

φ_1: Maximum tensile force coefficient, φ_1=11.24.

Check the selected wire rope using the safety factor method

$$N=Tp/Tmax=2.62>NT=2.5 \quad (5)$$

Therefore, the selected wire rope meets the requirements of the tension of the track rope, and the minimum diameter of the track wire rope is 12 mm under the premise of meeting the tension requirement. According to the above calculation results, the model number of the wire rope is 6×19FC-12—1670.

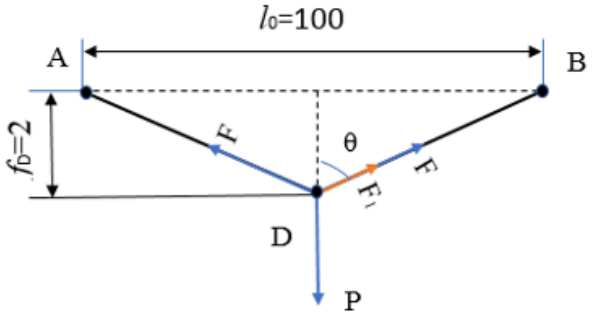


Figure 2. Force analysis of carried rope

The no-load deflection coefficient of the track rope is an important criterion to measure the tension of the suspension cable. This parameter is also essential when designing the cableway. It is recommended that the no-load deflection coefficient S0=0.3~0.5. There is a functional relationship between the deflection and the no-load deflection [4].

$$f_D=\gamma f_{0x}=\frac{1+2n}{[1+12(n+n^2)(k-k^2)]^{1/2}} \quad (6)$$

n: The ratio of the load to the weight of the wire rope, n=P/W=3.96;

F_0: The deflection of the no-load suspension cable in the span;

K: Distance coefficient ($x=kl_0$, $0\leq k\leq 1$).

From equation (6), f_0 = 1.74m can be obtained, that is, the no-load deflection coefficient is $S_0=\frac{f_0}{l_0}$=0.0174, which is smaller than the recommended no-load deflection coefficient, and the tension of the steel cable is large.

3.2 Traction cable

The traction cable is the moving part of the ropeway. It generally only acts as a traction and does not bear the load, but it will bear a large inertia impact when the sports car brakes [6]. For reciprocating ropeways, the diameter of the cable can be preselected according to half the diameter of the track rope. Therefore, the pre-selected traction wire rope is 6×19FC-6—1670, the breaking tensile force T_{P1}=18.5kN, and the reference weight q_1=1.26N/m. The traction cable has a load-free deflection coefficient S01=0.018, and the self-weight of traction cable W_1=126N. The tighting selvedge tension T_1 of the circulating traction cable can be determined according to the following equation [4].

$$T_1=T_0+T_{Q1}+T_{a1}+T_{R1}+T_{q1} \quad (7)$$

T_0: Installation tension of circulating traction cable, $T_0=\frac{W_1}{8S_{01}cos\alpha}=875$N;

T_{Q1}: The tension generated by the slope and load of the line, $T_{Q1}=P(\sin\gamma+f_{01}\cos\gamma)$=136.84N;

T_{a1}: Running inertia resistance, $T_{a1}=\frac{a}{g}(P+W_1)$=216.93N;

T_{R1}: Sports resistance, $T_{R1}=(T_{Q1}+W_1)\cdot f_{02}$=23.66N;

T_{q1}: The self-weight component of the traction cable, $T_{q1}=q_1 l_0\tan\alpha$=0.

In summary, T_1=1252.43N.

Circulating traction cable safety factor $N_1=\frac{T_{P1}}{T_1}=\frac{18500}{1252.43}$=14.77＞5.

It can be seen that the pre-selected steel wire rope meets the requirements, and the diameter of the steel cable is too large, and the pulling force required for the traction cable is small. In this case, wire

rope having a diameter of less than 6 mm can be re-calculated, and the inertial impact of the cableway brake is taken into consideration in the ropeway, and a 6 mm diameter wire rope is selected as the traction cable. That is, the traction cable is selected as 6×19FC-6—1670, q_1=1.26N/m; T_{P1}=12.8kN; T_1=1252.43N.

Loose selvedge tension of traction cable is T_2

$$T_2=T_0-T_{R2}+T_{q1}=851.34N \quad (8)$$

4. Design of Power system

The winch is the driving part of the ropeway, which can be divided into electric motor, gasoline engine and diesel engine according to the power. The reel is the working mechanism of the winch, which is divided into a friction reel and a winding reel, which can change the rotary motion of the engine into a linear motion of the wire rope on the reel, thereby pulling the sports car. In order to facilitate operation, save money, and realize reciprocating traction, the ropeway adopts an electric winch machine, and the reel is a friction reel. The friction reel relies on the friction force to drive the steel cable. After the wire rope is wound on the reel for several times, the two ends are respectively wound out from the reel. The whole circulation traction system is similar to the belt transmission, and the belt drive can be used to analyze the traction force of wire rope. Figure 3 is a schematic diagram of the force of the traction cable.

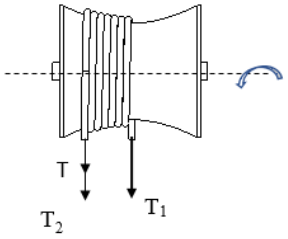


Figure 3. Friction reel

T is the traction force. It can be seen from the figure 3.

$$T=T_1-T_2 \quad (9)$$

The relationship between traction and motor power P is

$$P=\frac{Fv}{\eta} \quad (10)$$

v: Wire speed, v=1m/s;

η: The total transfer efficiency of the motor to the friction reel; take η=0.7.

The calculated motor rate is P=572.86W. The choice of 750W or 1.5kW motor can meet the requirements. In order to ensure the stable operation of the cable system under the increased deflection, the motor power is 1.5kW.

The friction reel is driven by friction. When the traction force is greater than the friction force, the cable will slip on the reel. The cable slip will affect the life of the wire rope, and the slip should be avoided as much as possible. Under the rated power, the condition that the cable does not slip is

$$e^{2\pi\mu n}\geq T1/T2 \quad (11)$$

n: The number of turns of the traction cable wire wound around the friction reel

μ: The coefficient of friction of the cable and the surface of the roll.μ=0.11.

The number of working laps that are guaranteed not to slip is

$$n=\frac{\ln T1-\ln T2}{2\pi\mu}=0.75 \quad (12)$$

It can be obtained that n≥0.56, that is, in order to make the wire rope not slip, the number of turns of the traction cable wire wound around the friction reel cannot be less than 0.56 turns. The more the number of winding turns, the larger the wrap angle, the greater the total friction generated by the wire rope and the roll contact surface, and the higher the transmission capacity.

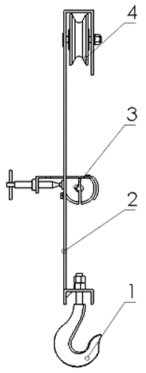
The wire rope is wound on the reel to generate bending stress. In order to reduce the influence of bending stress on the life of the cable, the diameter of the reel and the traction wire rope must be kept

at a certain ratio. Generally, the minimum diameter of the friction reel should be greater than or equal to the 30 times diameter of the cable, while being evenly worn, the hardness of the surface of the reel and the cable should be consistent [9-10]. The friction drum is selected to have a minimum diameter of 200 mm.

Select the motor with the pole number of 2, the speed is n=1440r/min, then the speed of the friction reel is $n_r = 60v/\pi D$, and the reduction ratio is $i = \frac{n}{n_r} = 15$.

5. Design of carrying trolley

The carrying trolley is a key component of the ropeway transportation, and is mainly composed of a walking wheel, a hanger, a cargo hook and a fixed grip. For freight or forestry ropeways with lighter weight and simple structure, domestic single or double-wheeled simple sports cars are used. The load of single-wheel sports cars is generally 5-8kN [8]. The design adopts a single-wheeled trolley, the walking wheel set is hinged on the hanger, the hanger is made of steel plate, the middle is connected with a grip, and the lower part is connected with a cargo hook. The gripping device comprises a fixed holding block and a movable holding block. The fixed holding block is fixed on the steel plate hanger, and the connecting plact is welded on the movable holding block. The connecting plate has a boss with a threaded hole at one end, and the screw rod passes through the connecting plate.By turning the screw rod, the screw motion of the screw rod can be converted into the horizontal movement of the movable block, that is, the screw rob can be used to control the grip to hold or loosen the traction wire. The figure 4 shows the design of the carrying trolley.



1.Cargo hook 2.Hanger 3.Fixed grip 4.Walking wheel
Figure 4. Carrying trolley

6. Conclusions

Aerial ropeways are widely used in the field of forestry transportation materials and are a mature technology, but they are used less in mountain orchard transportation. The main reason is that the size of the mountain orchard is small, the degree of standardization of fruit tree planting is low, and the cableway transportation cannot really play its role. With the advancement of urbanization and agricultural industrialization, the scale of orchard planting will gradually increase. The single-span cableway from the top of the mountain to the foot of the mountain or the multi-span loop cableway in the mountainous terrain will gradually increase. The reciprocating cableway designed and calculated in this paper is used for lateral harvesting of fruit in mountain orchard, which can reduce the labor intensity of fruit farmers in the field transportation and increase the transportation speed. When the ropeway is erected, it is only necessary to anchor the cableway bracket at both ends. The track rope and the traction cable pass through the orchard line. The construction amount is small and the damage to the orchard is small. The cableway is driven by the motor and transported back and forth by remote control to save manpower. It is also possible to carry a plant protection machine to spray the fruit trees to realize the comprehensive utilization of the ropeway system.

Acknowledgement
The authors would like to thank National Key R&D Program of China (2018YFD0700604), Shandong Province Natural Science Foundation (ZR2018MC017), Shandong Forestry Science and Technology Innovation Team Project (LYCX04-2018-22), Shandong Province agricultural equipment R&D innovation projects(2017YF003) and Shandong Agricultural University "Double-Class" Technology Innovation Team (SYL2017XTTD07) for the financial support.

References
[1] Nian Yalin, Shen Rongfeng, Zhang Xiaozhen, et al. (2014) Research progress on orchard transportation machinery. Agricultural Technology & Equipment, (22): 24-28.
[2] Wang Qinwu. (2001) The actuality and development of the passenger tram way building in China. China Ropeway, 1(2): 1-6.
[3] Hong Tiansheng, Su Jian, Zhu Yuqing, et al. (2011) Circular chain ropeway for cargo transportion in mountain citrus orchard. Transactions of the Chinese Society for Agricultural Machinery, 42(06): 108-11.
[4] Zhou Xinnian. (2013) Engineering ropeway and suspension bridge. China communication press, Beijin.
[5] Chen Yuxi. Jiao Guangwei. (2016) Application of wire rope loading cable and fiber loading rope. Metal Products, 42(05): 47-51.
[6] G.Piskoty, Ch.Affolter, M. Sauder, M.Na-mbiar, B.Weisse. (2017) Failure analysis of a rope-way accident focussing on the wire rope's fracture load under lateral pressure, Engineering Failure Analysis, 82:648-656.
[7] Lu Zhaoming. (2004) Design of Single-span&double-line Concentrated Load Reciprocating CargoRopeway. Nonferrous Metals Design, (04): 46-48.
[8] Pu Lianggui. Chen Dingguo. Wu Liyan. (2013) Machine design.High education press, Beijin.
[9] Shi Feng. (2016) The manufacture of the wire rope fatigue test bench and estimation for wire rope life. Harbin Engineering University.
[10] Li Zhe. (2012) Anslysis of the influence about the fray of Wire Rope due to Multilayer Winding Drum and Guide plate. Wuhan University of Technology.
[11] Chen Zilong, Jin Wenchuan. Yu rong, et al. (2016)Selection bolts Trolley Tighten rope clips fieight ropewayp. Machinery Design & Manufacture, (02): 56-58+63.