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Research Article

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Chassis Design of Mountain Transport Vehicle Based on Adaptive Leveling System

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Abstract In the development process design and manufacturing process of transport vehicle, the design of chassis has a great impact on the overall performance of the vehicle. The chassis design of the transport vehicle is of great significance to improve the driving safety, comfort and control stability of the vehicle. This paper systematically introduces the basic composition and working principle of the chassis of the mountain transport vehicle, and uses the module method to establish an analysis model of the chassis of the vehicle, analyze the chassis function of the transport vehicle, and give the design scheme of the chassis of the transport vehicle. The chassis power system, steering system, adaptive leveling structure and gear transmission structure are designed. A special structure of adaptive leveling system is adopted to simulate the realization of chassis functions, that is, it can adapt to the road conditions to a certain extent. The motor selection of the power system and the parameter determination of the gear are calculated. Finally, Solidworks is used to model each part of the chassis and complete the assembly of the complete vehicle chassis.

Keywords Mountain truck, chassis, adaptive leveling system, transmission system

Introduction

China's hilly and mountainous areas and other rugged terrain account for about 43% of the total land area of the country, and the plain area is only 12%. The hilly and mountainous areas are mainly planted with fruit, tea and other cash crops, and the traditional manual handling is difficult to meet the transportation needs, and the agricultural mechanization promotion task is heavy [1]. Most of the mountain transport vehicles adopt crawler or track as the transport chassis. In this paper, the structure of modular wheel set is adopted. Although the traditional crawler transporter has high stability and safety, it has slow running speed, poor remote mobility, poor mobility, etc., especially when passing through bridges or poor road pavements, its huge weight and crawler structure will damage the road surface, or even directly damage the road surface after driving in rainy days. As the road surface is muddy, the crawler compaction will make the road surface more slippery and damage the soil loss.

The chassis leveling system is mainly used for the chassis of agricultural machinery such as hilly and mountainous areas and orchards. Based on the inclination of the chassis, the adjustment amount is calculated, and the hydraulic cylinder, suspension or wheel track are used to adjust the vehicle body in an all-round way to adapt to the working environment [2]. HOEHN et al. studied a leveling system for planting machinery, which can adjust the height between the planting machinery and the land in real time, helping to maintain a stable soil cutting depth [3].

In order to meet the mechanized demands of diversified grape cultivation in Italy, University of Catania in Italy has researched and improved a traction straddling tool car used to meet the requirements of high-legged grape cultivation. The vehicle is towed by an ordinary tractor with 2 wheels equipped with hydraulic piston for driving. The working height can be adjusted. The hydraulic piston equipped with the traction rod can realize flexible steering. The reverse frame facilitates the installation of special tools to realize operations such as grass cutting, topping, spraying and soil tipping [4].

The forest monorail conveyer developed by Korea in 1994 has the advantages of strong gradeability, convenient loading and unloading and no damage to forest land. It is widely used in many forest parks around the world and is introduced to China for forest tourism and forest transportation. DongilChang et al. of Zhongnan National

University investigated the design parameters and cultivation conditions of small-sized orchard agricultural transporters in Europe. In addition to the research on types, row spacing and spacing of fruit trees planted in European orchards. Dongilchang et al. Considered the soil compaction, distribution and soil infiltration changes caused by driving in the orchard agricultural machinery orchard to determine the main size of the development of small orchard transport vehicles [5].

The railway transport vehicles researched and developed in China can be divided into two types according to different slopes. Traction and self-propelled. Trailer is mainly electric motor, internal combustion engine or hybrid power, while self-propelled car is mainly internal combustion engine. Crawler type mountain transport vehicle has the advantages of flexible route, small floor area, no damage to greening, etc; It has the advantage of no impact on the natural environment. South China Agricultural University has developed a chain-type wheeled cargo ropeway and a self-propelled double-track truck according to the unique geographical environment and agricultural characteristics of China. In addition, Hunan Agricultural University has developed a remotely controlled monorail trolley to meet the demand of automatic fruit transportation in mountainous areas in China [6].

In this paper, the chassis of mountain transport vehicle is analyzed, and an adaptive chassis leveling structure is adopted, including internal gear structure, lifting device and external connection with wheels. The structure is characterized by that the transport vehicle can make a certain degree of self-leveling according to different road conditions during driving, so that the transport vehicle itself can cope with a certain complexity, and improve the smoothness and handling stability of the transport vehicle. In addition, it can actively operate and control the ground clearance, so as to realize the functions required by mountain transport vehicles such as crossing steps and trenches[7-9].

Analysis of Chassis Design of Multi-Function Mountain Transport Vehicle

A. Function of adaptive leveling system

Self-adaptive leveling is a special structure connecting the main drive shaft and the tire. Its main function is to realize the self-adaptive road condition of the tire. According to the pothole and steep road condition, the chassis structure of self-adaptive leveling can avoid the large inclination of the body and improve the vehicle's longitudinal stability. The ability to cross obstacles and improve ground clearance can also be achieved according to the active operation of the driver.

B. Design elements

Based on the functions required by the chassis of mountain transport vehicle, the basic elements of chassis design are analyzed, including chassis frame, modular wheel set, adaptive leveling system and power system.

[1]. Modular wheel set

It is not only the basis for the normal operation of the transport vehicle, but also the carrier that can meet the functions required by the design requirements. The different matching modes of wheel set and the expected functions that can be achieved are the design elements.

[2]. Steering system

The steering system is a series of devices used to change or maintain the driving or reversing direction of the vehicle. Its function is to control the driving direction of the vehicle according to the driver's wishes.

[3]. Self-adaptive leveling system

The adaptive leveling system is a structure that can deal with complex road conditions more conveniently and safely, and can realize the adaptability of the vehicle itself to the road surface to improve the smoothness and handling stability.

[4]. Dynamical system

The power system is to ensure that the vehicle has the required traction, speed and coordinated change between traction and speed under various driving conditions, so that the vehicle can travel safely and stably and adapt to road conditions.

Chassis System Design

The chassis structure includes frame, motor, wheel set, transmission system, adaptive leveling structure and bogie. In this paper, the traditional single wheel is replaced with double wheel, and a special chassis structure of wheel set is designed. This structure adds a kind of adaptive leveling cross frame on the basis of the traditional wheel type, making the transport vehicle have the characteristics of small volume, light movement, strong mobility, etc., and the double-wheel structure reduces the pressure of the transport vehicle on the ground and prevents damage to the road surface.

The traditional transport vehicle cannot ensure good smoothness and handling stability when driving on complex road, and the vehicle body will tilt and roll over when driving on complex road. The adaptive leveling proposed in this paper mitigates this phenomenon when driving on a complex road, such as potholes, bumps, etc. The adaptive special structure will actively adapt to the road conditions, and spontaneous leveling mitigates the body bumps and tilt degree, which can ensure good smoothness and stability.

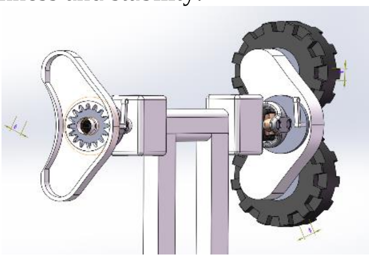

Figure 1: Self-adaptive leveling structure

A. Motor power calculation and model selection

The basic parameters of the transport vehicle shall be determined according to the maximum speed and when calculating the motor power, as shown in Table 1 below.

Table 1: Basic parameters of transport vehicle

Parameter	Numerical value
Weight of complete vehicle (kg)	1600
Maximum total mass (kg)	2000
Windward area (m ²)	4
Drag coefficient	0.6
Rear wheel diameter (m)	0.8
Rolling resistance coefficient *f*	0.15
transmission efficiency	98%
Maximum speed (km/h)	50
Front wheel diameter (m)	0.6

$$P_N = \frac{(F_f + F_W + F_i + F_j)\cdot G\cdot u_a}{3600\times 0.98} \quad (1)$$

$$F_f = Gf \quad (2)$$

$$F_W = \frac{C_D\cdot A\cdot u_a^2}{21.15} \quad (3)$$

$$F_i = Gsin\alpha \quad (4)$$

When climbing, acceleration resistance is not considered, Fi=0. Taking the climbing slope of the complete vehicle as 25% when the speed is 20km/h, the calculated PN=61.62 (kw)

Calculate the maximum power of the motor according to its rated power PN.

The calculation formula is as follows:

$$P_{max} = P_N \times \lambda \quad (5)$$

Where Pmax is the maximum power of the motor; λ is the overload coefficient of the motor, generally 2~3. Based on the above two calculations, if the rated power of the motor is 62kw, Pmax=124-186kw can be obtained, so the peak value of the motor is 186kw.

In the total power distribution of the motor, the front two motors share 50% of the total power, and the rear large motor bears 50% of the total power. Then the peak power Pmax of the front motor=40kw, and the rated power PN=15kw; Rear side large motor peak power Pmax=80kw, rated power PN=30kw.

Table 2: Basic parameters of Y-type motor

Model	Rated power kW	Rated current A	Speed r/min	Efficiency %	Power factor cos φ
Synchronous 3000r/min level 2					
Y160M1-2	11	**21.8**	2930	87.2	0.88
Y160M2-2	15	29.4	2930	88.2	0.88
Y160L-2	18.5	35.5	2930	89.0	0.89
Y180M-2	22	42.2	2940	89.0	0.89
Y200L1-2	30	56.9	2950	90.0	0.89
Y200L2-2	37	69.8	2950	90.5	0.89
Y225M-2	45	84	2970	91.5	0.89
Y250M-2	55	103	2970	91.5	0.89

Various models and parameters of Y series motor are listed in Table 2. Based on the rated power of the two motors obtained, the front motor is selected as Y160M2-2, and its main parameters are: the stage is level 2; Rated power is 15kw; Rated speed: 2930r/min; Efficiency 88.2%.
The rear side large motor is selected as Y200L1-2, and its main parameters are: stage 2; Rated power is 30kw; The rated speed is 2950; Efficiency 89%.
Analysis as main output shaft because front motor is connected with adaptive leveling structure.

$$P_N = \frac{T_N \times n_N}{9550} \quad (6)$$

Substitute the rated power and rated speed of the front motor to obtain the rated torque TN=48.89Nm.

B. Design of drive shaft

Calculation formula for diameter of driving shaft:

$$d_1 = C\sqrt[3]{\frac{P}{n_1}} \quad (7)$$

Where n is the shaft speed; P is power; C is the factor associated with the shaft material of 118. It can be listed according to the parameters listed in Table 2:

$$d_1 = 118 \times \sqrt[3]{\frac{15}{3000}} = 42mm$$

It can be concluded that the drive shaft diameter is 42 mm.
The driven shaft speed is calculated as:

$$n_2 = \frac{n_1}{i} \quad (8)$$

$$i = \frac{z_2}{z_1} \quad (9)$$

The rotating speed of the driven shaft is 4800 r/min,
The diameter of the driven shaft is calculated as:

$$d_2 = C\sqrt[3]{\frac{P}{n_2}} \quad (10)$$

From the data listed in Table 2: the diameter of the driven shaft is 37mm.

$$d_2 = 118 \times \sqrt[3]{\frac{15}{4800}} = 37mm$$

Self-adaptive Leveling Structure Design

A. Transmission system design

The main drive wheel receives the power from the main shaft to drive the driven wheels on both sides to rotate and then transmits it to the secondary driven wheel, and the secondary driven wheel drives the tire to rotate to realize movement. As shown in Figure 2.

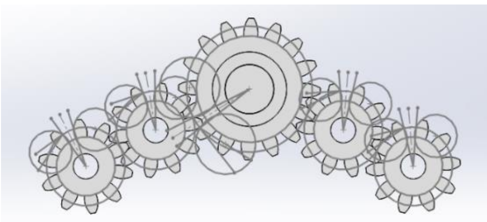

Figure 2: Gear drive structure

Take the modulus of driving wheel and driven wheel m as 1.25; Pressure angle α is 20 °; The crest height coefficient h_a^* is 1.0; Top clearance coefficient c^* is 0.25.

[1]. Calculation of basic parameters of driving wheel

Reference circle diameter: d= m z =20cm, Number of teeth: z=d/m=16, Diameter of gear tip circle: d_a=d+2h_a=22.5cm, Diameter of tooth root circle: d_f=d-2h_f=16.875cm.

[2]. Calculation of basic parameters of driven wheel

Reference circle diameter: d =12.5cm, Number of teeth: z=d/m=10, Diameter of gear tip circle: d_a=d+2h_a=15cm, Diameter of tooth root circle: d_f=d-2h_f=9.375cm.

The data of each component is calculated from the above formula, as shown in Table 3.

Table 3: Gear Size

	Modulus M	Number of teeth Z	Reference circle diameter D	Diameter of gear tip circle	Root circle diameter	pressure angle
Driving wheel 1	1.25	16	20cm	22.5cm	16.875 cm	20°
Driving wheel 2	1.25	10	12.5cm	15 cm	9.375 cm	20°

B. Lifting device

The main shaft drive gear is a nested gear with two teeth sharing one lantern ring. The self-leveling device has a lift-up device, which is mainly used to enable the self-leveling structure to achieve the active lift-up that is considered to be controlled. Lift the A wheels on both sides of the pulley block of the front wheel module to realize the step crossing function.

The main shaft gear is moved by the paddles to mesh with the gear ring on the lifting device, and the lifting device is driven to be lifted by the engagement so as to raise the A wheel and improve the chassis performance. As shown in Figure 3.

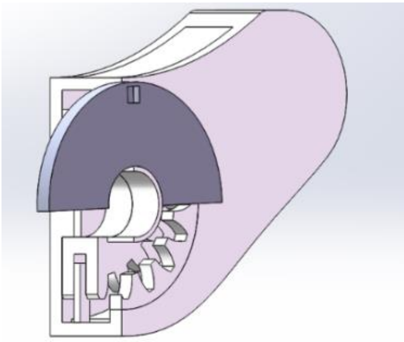

Figure 3: Lifting device

C. Wheel design

Different road conditions require different tire materials. For bumpy mountain roads, it is necessary to select tire materials with good abrasion resistance and tear resistance, and consider the impact of climate conditions on tire materials to ensure the driving stability and safety of vehicles. Therefore, it is necessary to select natural rubber and synthetic rubber tires with good high temperature resistance. The diameter of front wheel tire is 0.6m, and the diameter of rear wheel tire is 0.8m.

D. Steering system design

As the front wheel is a multi-shaft modular wheel set, the wear of wheel set, suspension imbalance and other situations affecting the service life of the transport vehicle will occur during the steering. In this paper, a simple connecting rocker steering structure is adopted, which can connect the wheels on both sides in balance, so that the wheels on both sides can realize the synchronous steering function under the operation of the driver. The operation is simple and has good stability, and the universal joint is added in the main shaft transmission part to realize the normal steering function of the vehicle [10]. As shown in Figure 4.

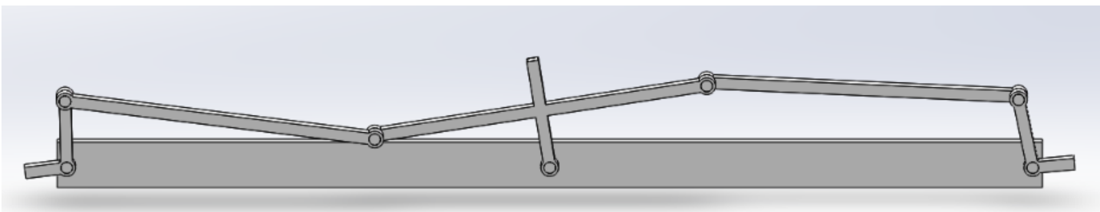

Figure 4: Bogie

Model Establishment and Assembly

A. Modeling of front and rear tires

Feature mapping of stretch boss, circumferential array was used in modeling the front and rear tires.

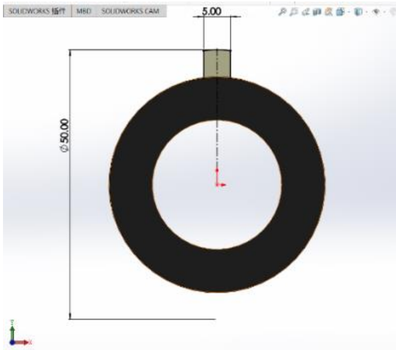

Figure 5: Drawing process of front wheel tire

B. Modeling of adaptive leveling system

The self-adaptive leveling structure needs to be equipped with a gear drive mechanism, so its center needs to be removed, and a certain shell is reserved. It uses tensile cutting, tensile thin-wall, fillet and other features. Using the stretched thin wall feature, draw the contour line on the upper arch surface to transform the entity reference and select thin wall. As shown in Figure 6

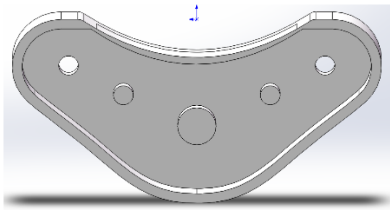

Figure 6: Drawing of adaptive leveling system

C. Drawing of gear transmission system

The gears need to be plotted so that they are meshed with gears of the same modulus and pressure angle to drive. This involves the drawing of an involute tooth profile, which is finally completed using a circumferential array. As shown in Figure 7

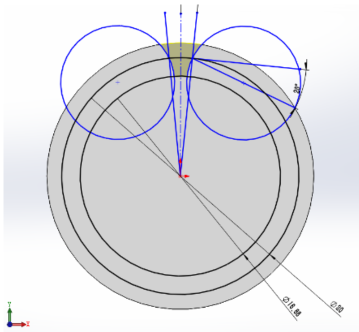

Figure 7: Drawing of gear

D. Assembly of complete vehicle chassis

The structure of the whole chassis needs to be realized through a series of assembly processes. The cooperation of some special parts and the meshing transmission of gears, the assembly of universal joints, etc. are realized through the frame to achieve the overall connection and assembly, so as to ensure the stability of the overall structure. As shown in Figure 8

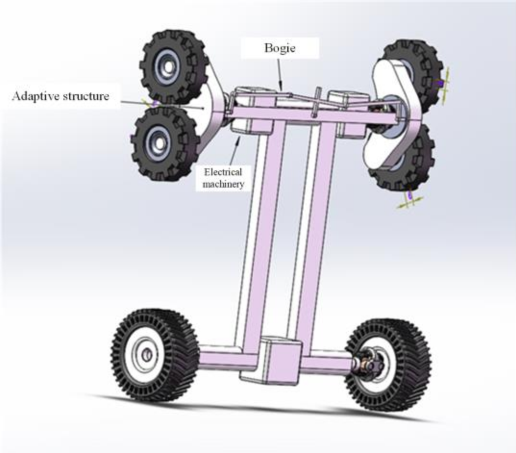

Figure 8: Drawing of adaptive leveling system

Conclusion

In this paper, the basic design of the parts of the chassis of the transport vehicle is carried out, and the motor with the optimal power is selected according to the maximum gradient, which is more suitable for the working environment of the mountain transport vehicle. An adaptive leveling structure is designed, which can adjust the height of both sides of the wheel according to the road conditions, so as to maintain the control stability and smoothness of the vehicle, and at the same time, actively improve the height of the front two sides of A wheel, and ensure good trafficability.

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