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Research and Development of Powertrain of Bionic Mobile Rechargeable Material Truck

Yang Liu, Zhesheng Hou and Zhengxiao Bai

School of Jilin Institute of Chemical Technology, Jilin, Jilin 132022, China

Abstract: In order to facilitate the transportation of corn stalks and material resources, this paper designed a remote-control transport vehicle for one-time transportation of corn cobs, corn stalks, corn leaves, corn cobs and corn stalks. Its function is to avoid obstacles, and remotely operate through Bluetooth or wireless mode, feedback the working status and task progress of the car in real time, and automatically identify the path and transport materials to the specified destination. Through CATIA modeling, the motion simulation is carried out by ADAMS, and the rationality of the design is confirmed by finite element analysis of the stressed structural parts.

Keywords: Unmanned Transport Vehicle; CATIA; ADAMS; Finite Element Analysis.

1. Introduction

As a widely grown crop, corn is favored by farmers and markets for its high yield and high value, becoming one of the agricultural gold industries. In China, corn, as one of the main grain crops, accounts for 20% of the total grain output[1]. Exploring the storage and transportation technology of corn straw is helpful to increase farmers' income and promote the development of rural economy. This is not only an important means to improve agricultural production efficiency, but also an important measure to promote China's agriculture to achieve sustainable development and circular economy. The effective use of straw resources plays a key role in exerting the role of agricultural resources and expanding the scope of agricultural economy, and provides an important support for the realization of agricultural circular development. The development of circular agriculture has become a new economic growth means and development trend. Under the background of the slow development of China's rural economy and the single source of farmers' income, the rational use of straw resources, the realization of the dual benefits of grain and straw, and the further development of straw industry are helpful to promote the development of agricultural industry and accelerate the pace of agriculture.

Corn stalk transport robot is an intelligent agricultural transport platform, using industrial AGV technology, can independently plan the path to achieve intelligent transportation, without manual intervention, with a high degree of flexibility, suitable for agricultural facilities inside and outside. Agricultural intelligent transport platforms are developed on the basis of industrial AGVs [2]. In addition, the agricultural intelligent transportation platform can realize independent planning of path driving, can achieve intelligent transportation inside and outside agricultural facilities without intervention, and can also carry relevant working parts to synchronously complete real-time monitoring, path planning, and accurate navigation. It has provided a great improvement in the level of agricultural mechanization, intelligence and automation. Agricultural mechanization has become an indispensable part of modern agriculture, and improving the level of agricultural intelligence and mechanization is an important way to promote the sustainable development of agricultural resources in China. To sum up, this paper designs a crawler conveyer that can remotely control and one-time corn cob, corn stalk, corn leaf, corn cob and corn stalk [3-4].

2. Design of Key Components of Crawler Transport Aircraft

2.1. Track Type Selection Design

The transportation capacity of the tracked unmanned transport vehicle depends on the comprehensive performance of the tracked chassis vehicle. At this stage, the relatively mature medium and large electric crawler chassis on the market have a weight and load range of 2T and 8T respectively, a speed range of 6-8 km/h, and a maximum climbing Angle of 30°, in addition to the lower speed, the other indicators are more in line with the design requirements. Therefore, combined with the mature chassis indicators and the requirements of this design for the crawler chassis to drive normally on grassland, hills, muddy land and other terrain, the main performance indicators of the crawler chassis developed in this paper are proposed, as shown in Table 1.

Table 1. Main performance specifications of the crawler transporter

Serial number	Name of index	Parameter	Serial number	Name of index	Parameter
1	Vehicle mass (kg)	2000	**5**	Obstacle/climbing speed (km/h)	0.5-8
2	Payload weight (kg)	8000	**6**	Body size (cm)	2000×3000×2000
3	Maximum flat speed (km/h)	12	**7**	Energy sources	Electric energy
4	Angle of climb (°)	20	**8**	Energy diversion control	Slow steering

2.2. Track Size Calculation

2.2.1. Track Width and Length Parameters

When the mass of a fully loaded vehicle is m, the ground length d1 and width b of the track directly affect the specific ground pressure of the vehicle. When the ground length d1 is determined, the larger the width b, the smaller the ground specific pressure, and the overall width of the vehicle will also increase, resulting in an increase in steering resistance and steering radius. Track width b can be obtained by empirical formula:

$$b = (0.9\sim1.1) \times 209 \times \sqrt[3]{m \times 10^{-3}} \quad (1)$$

Track ground length d1 and vehicle gauge width B have great influence on vehicle steering performance. The ratio between the two has the following relationship:

$$\varepsilon_b = {d_1}/{B} \quad (2)$$

In the formula, ε b is the scale coefficient with the value from 1.2 to 1.8.

Combined with the design index and vehicle layout, when B =1600 mm, it can be obtained from formula (1) and formula (2), track width b =376mm, ground length d1=1920mm.

The ground specific pressure PNy can be obtained by the formula d1 and b of the track ground length:

$$P_{Ny} = \frac{mg}{2bd_1} \quad (3)$$

Where: P_{Ny} is the ground specific pressure; g is the acceleration of gravity, which is 9.8 m/s^2.

It is calculated that P_{Ny} =13.861 KPa, which meets the ground ratio between the robot chassis track and the ground lower than 0.14 MPa requirements [5]. Therefore, the track selection conforms to the design index.

Based on the above calculation data, XF-150 track can be selected, track width b=380mm, pitch tp = 170mm, Grounding ratio length d1=1920 mm.

2.2.2. Driving Wheel Parameter

The body power system transmits power to the driving wheel through the variable speed system, and the driving wheel engages the crawler gear teeth to generate driving force to make the vehicle move. In order to ensure the smoothness of the vehicle movement, under various driving conditions, the engagement between the drive wheel and the track should be smooth and stable, and no impact, stripping or interference can occur. Select the number of driving wheel teeth Zm =17, then according to the standard JB/T 6682-2008, the formula for calculating the pitch circle diameter of the wheel pass driving wheel is as follows:

$$D_x = \frac{t_p z_m}{\pi} \quad (4)$$

Where D_x is the pitch circle diameter of the driving wheel; z_m is the number of driving wheel teeth; According to formula (4), D_x = (59×17)/3.14=320mm. When the driving wheel speed of the vehicle is constant, the larger the wheel body radius, the faster the vehicle will travel. According to the motor speed, the diameter of the driving wheel is determined to be 320 mm. Table 2 shows the basic parameters of the track chassis.

Table 2. Basic parameters of the track chassis

Name of parameter		Parameter values
Track	Ground contact Length/mm	1920
Track shoe	Pitch/mm	170
	Breadth/mm	380
Axle	Longitudinal beam Dimension/mm	180×80×4
	materials	Q345B
	Elasticity modulus/GPa	206
	Yield strength/MPa	345
	Trength of extension/MPa	417-510
Driving wheel	Diameter/mm	320
Thrust wheel	Diameter/mm	260

3. Track Chassis Design

3.1. Preliminary Modeling

According to the above calculation and consulting the design manual, the preliminary modeling is carried out in the CAD design software. The dynamic part of the conveyor's track chassis after modeling is shown in Figure 1. In order to realize the loading function and transportation function of the conveyor, a support structure must be designed for the conveyor. First of all, this support structure should occupy a small space, so as to facilitate smooth driving under large loads; Finally, the support structure should have good rigidity to provide reliable support for the transport vehicle when it is loaded. In order to achieve the above functions, 12 bearing wheels on one side are used to share the weight. The pressure on the platform is evenly distributed among the 24 load-bearing wheels, each pair of which is bolted to the load-bearing beam of the track chassis, thus keeping the support structure and the track chassis relatively fixed. Through the above calculation, the driving wheel, track piece, bearing wheel, support frame and so on are designed.

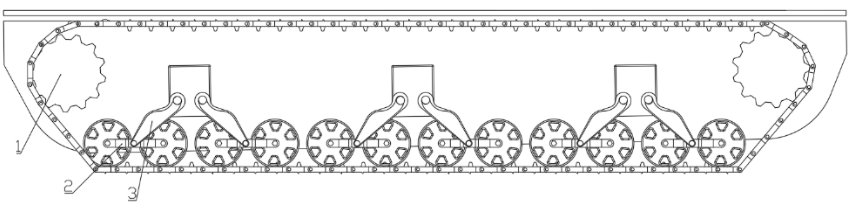


Fig 1. Power part of track chassis
1. Driving wheel; 2. Bearing wheel connecting rod; 3. Load rod

3.2. Crawler Chassis 3D Modeling

The crawler chassis is designed to adapt to the complex forest terrain, and its structure mainly includes dual brushless DC motors, speed reducers, drive wheels, support wheels, guide wheels and tracks. In order to improve obstacle crossing, climbing and steering ability, the chassis adopts an inverted trapezoidal structure, and the power unit is rear-mounted, with four motors independently controlling the front and rear drive wheels to enhance passability and reduce the steering radius.

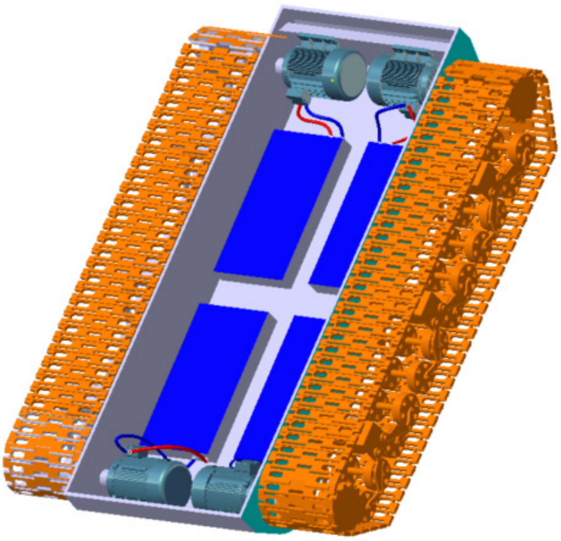


Fig 2. Conveyer chassis power section

During the movement, the driving wheel converts the energy of the motor into driving kinetic energy, the support wheel ensures the normal operation of the track, and the guide wheel and tension device maintain the correct winding of the track and absorb the impact. The design of the support wheel allows it to be adjusted according to the terrain, preventing uneven load on the chassis on complex terrain and enhancing stability. The control of the chassis is realized by remote control, and the differential drive mode is adopted. The DC motor drives the driving wheel directly through the reducer. The control system independently manages each motor to achieve forward, backward and steering functions by changing the speed of the motors on both sides. The 3D model is shown in Figure 2.

3.3. Driving Simulation Test based on ADAMS/view

ADAMS (Dynamic Analysis of Automated Mechanical Systems) is the authoritative virtual prototype simulation software developed by MSC with a market share of more than 50%. It allows users to build and test virtual prototypes to simulate the kinematic and dynamic properties of complex mechanical systems. ADAMS can be used to study the stress conditions of tracked vehicles under different driving conditions, thus shortening the design cycle and saving costs [3]. By importing the 3D model into ADAMS for dynamic simulation, parts with high dynamic load can be identified, design defects can be found, and optimization can be carried out. As shown in Figure 3, it is the crawler transporter model imported into ADAMS/view.

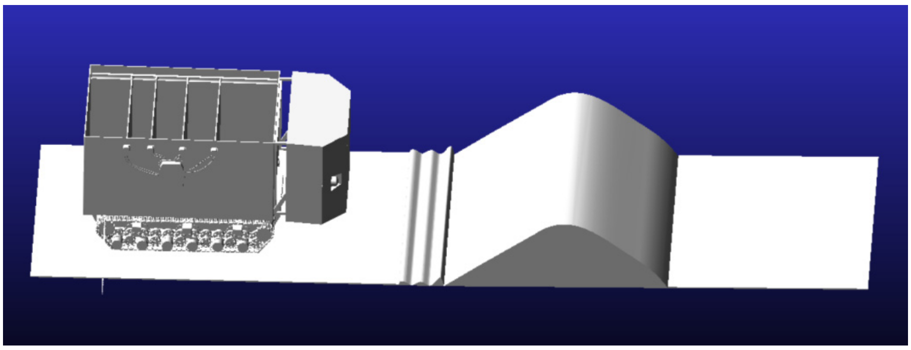


Fig 3. Crawler transporter into adams

After the model is imported into Adams, gravity and related quality attributes of each component are added first. In order to better simulate the driving condition of the transport vehicle on different roads, the mass of the main part of the vehicle is defined as 2000 kg. After that, fixed pairs, rotating pairs, contact constraints and coupling pairs are added to the model. Because the track is a flexible body, importing the track model into Adams will make the entire constraint process very tedious, and any constraint error will affect the simulation result. Therefore, this paper finally selects the macro command developed by adams for secondary development. The contact between each track piece and the bottom surface, the contact between the track piece and the driving wheel, and the contact between the track piece and the bearing wheel are restricted through the program.

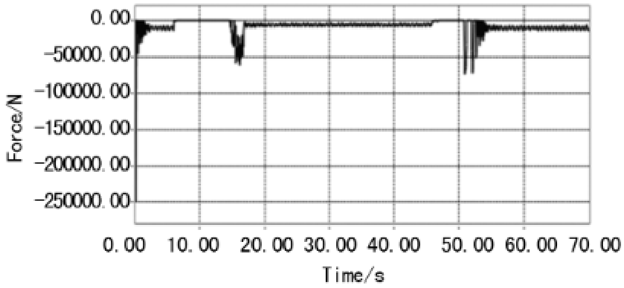
4. Mechanical Simulation Analysis

4.1. Introduction to Simulation Experiment

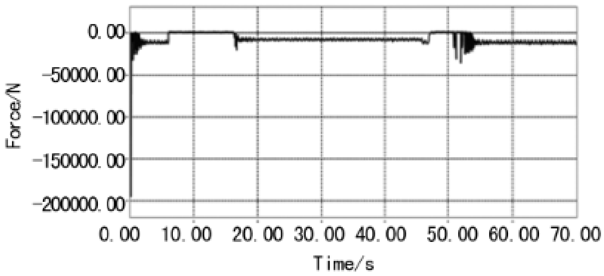
In order to further verify the obstacle crossing ability of the tracked vehicle on the field and gully ground, gully and highland step models were established according to the theoretical calculation results combined with the actual working environment in the field, and the obstacle crossing simulation was verified by Adams, and the required force was calculated.

4.2. Simulating Calculation

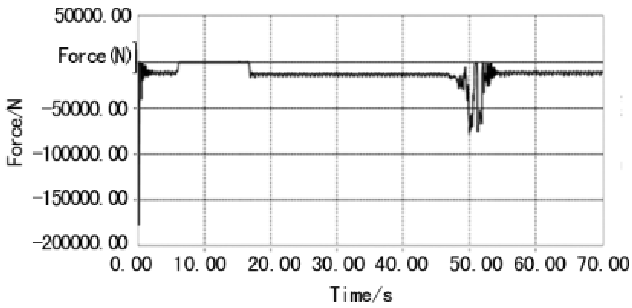
The track vehicle passes the corrugated road at a constant speed, and the drive wheel is set with a fixed speed, so that the vehicle passes the corrugated road at a speed of 20km/h. Based on the existing units provided in ADAMS, the entire system unit is set to MKS, and the solver chooses GSTIFF's 13 format and changes Error to 0.1 to meet the system requirements. The speed drive applied to the left and right driving wheels is 30.0d*time, indicating that the driving wheels turn 30 per second. The simulation time is 10 s and the number of steps is 1000.



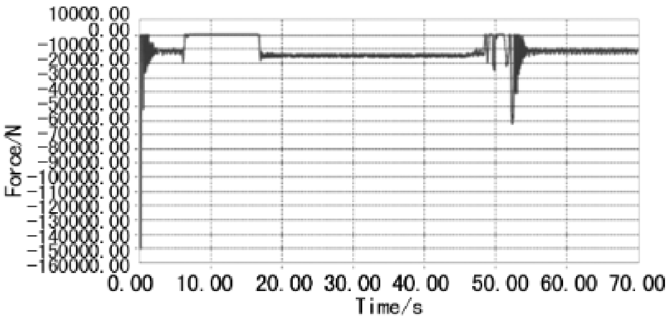
(a) left front drive wheel



(b) left rear drive wheel



(c) right front drive wheel



(d) right rear drive wheel

Fig 4. The simulation

As can be seen from figures (a) and (b), when the track platform has a load of 2000 kg, the driving wheel needs about 6.25×107N force when it wants to cross the mountain, during which fluctuations occur, indicating that when the left front drive wheel meets obstacles, the driving force provided by the motor will shock, and the left rear drive wheel needs about 5.0×107N force. The driving force required by the track platform is less than the maximum force provided by the motor, which meets the actual requirements.

As can be seen from figures (c) and (d), when the track platform has a load of 2000 kg, the driving wheel needs about 6.15×107N force and the rear auxiliary track needs about 6.0×107N force to cross the mountain. The driving force required by the track platform is less than the maximum force provided by the motor, which meets the actual requirements.

When the crawler transporter starts to walk, because the speed slowly accelerates from 0 km/h to 20 km/h, the contact force of the front drive wheel will fluctuate at the beginning. When the crawler walking mechanism runs at a constant speed, the contact force of the front driving wheel on both sides of the track is the largest, and then decreases successively, and the contact force of the last driving wheel is the smallest.

5. Conclusion

In this paper, CATIA and ADAMS are used to establish the virtual prototype model of crawler transporter, and the parts are merged through the Boolean operation function of ADAMS, which reduces the number of parts and improves the calculation efficiency. Develop a macro command program to add contact force and quality parameters to achieve batch add contact force. The dynamic analysis of multi-rigid body obstacle crossing of crawler transporter based on virtual prototype is completed. The analysis results show that the vertical displacement of vehicle body is consistent with the height of obstacle setting during obstacle crossing, and the whole obstacle crossing process is relatively stable and in line with the expected analysis.

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