Track Design of Track-Wheel Transport Vehicle and Strength Analysis of Important Components

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Abstract. Through the comparative analysis of different types of transport vehicles, the paper puts forward the concept of Track-Wheel transport vehicles and expounds the crawler travel mechanism of the wheel-shift interchange transport vehicles. It is concluded that the Track-Wheel transport vehicle has the advantage of operating in harsh environments such as mud and sand. The article designs the track mechanism and focuses on the strength checks of the important components of the track walking mechanism, namely the track, the load wheel and the load wheel axle. And it is concluded that under the maximum load, the track, the load wheel and the load wheel axle can meet the bearing requirements.

1. Introduction
With the development of the economy and society, more and more land has been developed, and the large amount of transportation produced by various places has greatly accelerated the speed of economic development. However, with the in-depth development of land and complex terrain, traditional trucks have been unable to cope with complex road conditions with high efficiency. Moreover, in harsh environments, the risks of transportation are extremely great, and the lack of transportation capacity has become a bottleneck restricting land development and economic development. In order to change this situation and break the problem of restricting land development, this paper designs a Track-Wheel transport vehicle. [1] [2] The transport vehicle has two kinds of walking mechanisms, wheeled and track type. In normal environment, the wheeled walking mode is adopted; in extremely harsh environments, the track walking mechanism can be used to assist the transport vehicle to safely and efficiently pass through the bad terrain.

2. Track overall design
2.1. Design and selection of track-wheel walking scheme
In order to make up for the shortcomings of the wheeled walking mechanism in terms of passability, the project intends to enhance the vehicle terrain adaptability through the method of wheeled and composite walking. The combination of the wheel and the track can increase the contact area between the vehicle and the ground, and enhance the adhesion of the vehicle on the soft road surface or the sandy soil surface, that is, the maximum soil thrust FX. The vehicle traction force and the hook
traction coefficient are effectively improved, and the transit performance of the transport vehicle is enhanced.

At present, there are three types of wheel interchange technology suitable for transport vehicles: rubber track set, wheel track automatic conversion, wheel and track hybrid drive. The advantages and disadvantages of each technical solution are as follows:

2.1.1. Rubber track set. The rubber track is placed outside the second and third axle tires of the transport vehicle, and the second and third axle tires form an overall track travel, as shown in Fig.1. Advantages: the track set solution has a small weight increase, a simple structure and convenient implementation.

Disadvantages: passivity improvement is not obvious; driving on rubber muddy roads, there are problems with track and tire slippage; special tools need to be replaced.

2.1.2. Wheel track automatic conversion. According to the road conditions, automatic conversion [3] of wheels and tracks can be realized to meet the passability requirements of multi-road conditions. Advantages: strong ability to pass through complex areas; short conversion time; no need to disassemble and replace; the overall layout is basically unchanged.

Disadvantages: Wheel and track drive mechanism and control are complex; automatic conversion of wheels and tracks is greatly affected by sediment; technical maturity is not high and reliability is poor.

2.1.3. Wheel and track hybrid drive. According to the road conditions, the transport vehicle can realize the conversion of the two driving modes of wheel and wheel, to meet the passability requirements of multi-road conditions.
Advantages: strong ability to pass through complex areas; short conversion time, no need to disassemble and change.

Disadvantages: Increase the crawler drive assembly, increase the weight; control flow, structural design is complex.

The transportation vehicle needs to face various complicated terrains during transportation. In order to ensure the terrain adaptability of the vehicle, reduce the switching time of the wheels and reduce the work intensity of the personnel, this paper intends to select the hybrid driving scheme of the wheel and the track, as shown in Fig.3.

2.2. Transport vehicle track overall structure layout

2.2.1. Track overall integration. Each crawler travel mechanism is connected to the frame by two longitudinal arms, and the oil and gas spring is connected as an elastic member to the trailing arm at one end and to the vehicle body at the other end. The track portion is free to rotate about the lower arm hinge to accommodate road undulation changes and vehicle pitch. The crawler traveling mechanism can realize vertical retraction by the contraction of the oil and gas spring, and the vehicle walks normally in a wheeled manner when the crawler traveling mechanism is stowed, thereby realizing low-energy and high-mobility running of the vehicle on the structured road surface. When the crawler is put down and in contact with the ground, the vehicle travels with the wheeled composite traveling mechanism, which increases the contact area with the ground, reduces the grounding ratio and the amount of wheel sag, and achieves reliable driving during the vehicle landing process. When the crawler walking mechanism is not working, it is retracted into the interior of the vehicle body to prevent the sand from entering the sports joint, and further protects the crawler walking mechanism.

![Figure 3. Wheel and track hybrid drive](image)

2.2.2. Track system self-cleaning technology. Since the hydraulic system has self-tightness, the crawler traveling mechanism does not need to be integrally sealed to reduce the sealing difficulty of the amphibious transport vehicle system. The bottom of the car body is designed with high-pressure water jet and jet cleaning device. When the transport vehicle passes through the environment such as sewage, silt, etc., the cleaning device starts to work, and the cleaning of the moving parts of the traveling mechanism is realized. Avoid the debris such as sand and sand entering the moving joints and transmission chain of the crawler running mechanism, causing mechanical failure or mechanical structure damage. When the crawler walking mechanism is not working, it is retracted into the interior of the vehicle body to prevent the sand from entering the sports joint, and further protects the crawler walking mechanism.
3. Track structure design and important component check

The crawler travel mechanism is shown in Fig. 5. The crawler travel mechanism consists of six pairs of load wheels, tensioners, drive wheels, hydraulic motors and tracks wrapped around the edges of the wheels. The hydraulic motor powers the drive wheels. The track is made of rubber.

In order to reduce the load caused by the installation of the track, the crawler mechanism is lightly designed. While ensuring a sufficient grounding area while minimizing the length of the track, the track travel mechanism is designed to be flat and long, the track drive wheel has a small diameter of 480 mm, and the track is made of rubber. The CAE analysis optimizes the track size and weight. Under the condition of ensuring the strength of the track, the load of the crawler traveling mechanism is obtained through mechanical analysis, and the number and size of the load wheel are determined by the strength check, so that the number and size of the load wheel are within a reasonable range. The driving wheel and the tensioning wheel are made of non-metal material, and the structural members are made of low-density and high-light metal such as titanium alloy. The quality is optimized under the premise of ensuring the strength of each functional component, so that the quality of the crawler walking mechanism is minimized. Similarly, in order to reduce the weight of the power and transmission parts, the driving method of the crawler track mechanism is hydraulically driven, which simplifies the transmission mechanism and reduces the weight.

![Figure 4. Track system self-cleaning technology](image)

### Table 1. Technical parameters of track mechanism

| Num | Technical index | Numerical value |
|-----|----------------|----------------|
| 1   | height         | 480mm          |
| 2   | length         | 1600mm         |
| 3   | width          | 320mm          |
| 4   | Unilateral load| 3500kg         |
| 5   | speed          | About 5km/h    |
| 6   | Drive mode     | Hydraulic motor drive |
| 7   | Installation method | Independent installation |
| 8   | Weight         | About 300kg    |
3.1. Rubber track assembly lightweight design and assessment
Rubber track maximum traction and safety multiple calculation

\[ F_{DP} = 0.55mg\lambda \]  \hspace{1cm} (1)

\[ P = n \times F_S \]  \hspace{1cm} (2)

\[ N_i = P/F_{DP} \]  \hspace{1cm} (3)

Where \( m \) is part of the vehicle mass that the track system bears; \( \lambda \) is track adhesion to the ground; \( P \) is total tensile strength of steel wire; \( n \) is number of steel wires; \( F_S \) is force of a single wire.

Table 2. Parameters of rubber track

| Parameters                              | Numerical value |
|-----------------------------------------|-----------------|
| The quality of the rubber track assembly | \( m \) 7000    |
| Wire diameter \( D \)                    | 1.6             |
| Number of steel wires \( n \)            | 56              |
| Single wire strength \( F_i \)           | 2930            |
| Total tensile strength of steel wire \( P \) | 164080         |
| Tractional force \( F \)                 | 38500           |
| Track safety factor \( N_i \)            | 4.26            |

The main bearing part of the rubber track is metal core, [4] which is made of high-strength steel 40Cr. The yield strength of 40Cr material is \( 785 \text{Mpa} \). The three-dimensional diagram of metal core is shown in Figure 6.

![Figure 6. 3D illustration of a core](image1)

![Figure 7. Discretized grid style](image2)

The loading form of the mechanical simulation analysis is shown in Fig. 7. The load applied by the core is loaded on the running surface of the road wheel, and the direction perpendicular to the core surface points to the road surface. The core is only partially connected to the grounding surface through the tread. The single-side crawler bears \( 70000 \text{N} \) load, and each core carries \( 70000 / 4 = 17500 \text{N} \). The finite element analysis results are shown in Fig. 8 and Fig. 9.
Figure 8. Von Mises analysis results

Figure 9. Displacement analysis results

It can be seen from Fig. 8 that the maximum von Mises stress of the core is 301.7 MPa, which is less than the yield strength of the material, which is 785 MPa. As can be seen from Fig. 9, the maximum displacement of the core is 0.17 mm, and the deformation is very small. Therefore, the strength of the core is sufficient, the structure is stable, and the overall design is reasonable.

3.2. Road wheel axle and road wheel strength assessment

3.2.1. Road wheel. The road wheel is an important part of the track walking mechanism. It is the main load-bearing part of the car body and transfers the weight of the whole vehicle to the track. The design of the load wheel should take into account the cooperation between the load wheel, the drive wheel, and the tension wheel. Generally speaking, the number of road wheels is proportional to the weight of the whole vehicle. For the transport vehicle designed in this paper, the relatively small multi-pair roller structure will be used and evenly distributed. At the same time, we must also consider the grounding ratio of the vehicle and the efficiency of the walking. Finally, we decided to use 6 pairs of load wheels and long track structure.

3.2.2. Road wheel axle strength assessment. When calculating the load of the road wheel axle, [5] it is regarded as the pin shaft whose shearing force is applied at both ends, as is shown in Fig.10.

The external force $F$ is the force of the single-side crawler total load on each of the load-bearing wheels. There are 6 pairs of load-bearing wheels on each side of the transporter. When driving on a flat road, the gravity is evenly distributed on each of the load-bearing wheels. However, considering special circumstances: When the vehicle is tilted, the single-sided crawler bears the full weight, and
the crawler is only concentrated on the six load wheels on one side. At this time, each load wheel is subjected to a force of 1/6 of the total weight.

Total gravity \( G = 2 \times mg = 137200\text{N} \); so \( F = G / 6 = 22866.67\text{N} \). Axle diameter of truck road wheel \( D = 0.03\text{m} \). Shear surface stress is \( \tau \).

\[
\tau = \frac{F}{2 \times \left( \frac{\pi D^2}{4} \right)} = 16.17\text{Mpa} \tag{4}
\]

Road axle uses 45 carbon steel, and \([\tau] = 80\text{Mpa} \). \( \tau < [\tau] \), so the axle meets the requirements.

Road wheel strength assessment. Within the allowable range, the contact between the road wheel and the track can be approximated as a cylinder-plane contact, which is:

\[
\sigma_j = 0.418 \times \left( \frac{FE}{LR} \right) = 193.54\text{Mpa} \tag{5}
\]

Where \( R \) is radius of road wheel, \( R = 0.08\text{m} \); \( L \) is road wheel contact length with track, \( L = 0.07\text{m} \); \( E \) is Elastic Modulus, which is \( 2.1 \times 10^{11}\text{pa} \). Road wheel uses 45 carbon steel, and \([\sigma_j] = 475\text{Mpa} \). \( \sigma_j < [\sigma_j] \), so the axle meets the requirements.

4. Conclusion

The article described and designed the track walking mechanism of the track-wheel vehicle, and checked the strength of the track, road wheel, and road wheel axle. The results show that under the most unfavorable working conditions, that is, when the vehicle is tilting, the track is unilaterally stressed, and the track, road wheel, and road axle can also meet the load conditions.

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