Design and Simulation Optimization of Obstacle Avoidance System for Planetary Exploration Mobile Robots

Guangxin Yang\textsuperscript{1,2}, Yuwang Liu\textsuperscript{2,*} and Lirong Guan\textsuperscript{1}

\textsuperscript{1}School of Shenyang Ligong University, Shenyang, China
\textsuperscript{2}Shenyang Institute of Automation, Chinese Academy of Sciences, Shenyang, China

*Corresponding author e-mail: liuyuwang@sia.cn

Abstract. This paper proposes a new type of planetary detection multi-modal motion robot based on pure mechanical structure. The detection robot does not contain traditional sensors, computers and power supply systems, and uses pure mechanical components such as gears, friction wheels, rack and pinion mechanisms, and cam mechanisms to perform functions such as energy generation, transmission, and obstacle avoidance. In this paper, the obstacle avoidance system of the mobile robot is designed and optimized for the core components.

1. Introduction

The planetary exploration robot is a mobile device that patrols the surface of the detected planet. Its scientific name is the patrol detector \cite{1}. They can adapt to a variety of complex environments on the surface of the planet, carry scientific research equipment to detect motion on the surface of the detected planet, and transmit the detected data back to the control organization for analysis. It is a space mobile robot that can move freely on the surface of the detected planet to complete scientific exploration tasks \cite{2}. In this paper, a new type of obstacle avoidance system based on pure mechanical structure for planetary detection multi-modal motion robot is designed and optimized by simulation.

2. Multimodal motion path planning

As shown in Figure 1, it is a multi-modal motion autonomous detection path planning diagram for a non-electrically driven planetary exploration robot. At the forefront of the mobile detection robot, an external detection baffle is provided to prevent the probe from damaging the damage caused by the impact. At the same time, the detecting baffle is also a trigger for detecting multi-modal motion of the vehicle. When the detecting vehicle encounters an obstacle during the forward process, the detecting baffle first contacts the obstacle, retreats and activates the obstacle avoidance system, avoiding Obstacle turning system and path reset system. At the same time, the steering wheel begins to retreat, and the reversing motion of the detecting vehicle begins to form a curve retreating trajectory, so that
the traveling direction of the detecting vehicle forms a certain angle with the position of the obstacle. While the probe car is turning back and forth, the reset system slowly returns the corner of the steering wheel to zero, and also slowly disables the backing system. However, the failure is an instantaneous reaction. Before the failure, the reversing motion of the probe car is normally performed. When the retreat system fails, the forward system is excited, so that the probe car re-runs the next detection cycle.

Figure 1. Probe car route plan

3. Design of obstacle avoidance system structure scheme

In order to simplify the structure, increase the reliability and durability, this paper proposes to adjust the steering wheel steering in a purely mechanical way through the bevel gear, friction wheel and belt drive. The specific scheme is designed as follows.

Figure 2. Back system structure diagram

As shown in Fig. 2, the engine generates torque transmission to the shaft 1, and the torque is transmitted to the shaft 2 through the bevel gear set 1. The friction wheel set 2 is engaged by the friction wheel set 1, and when the probe car is normally advanced, the friction transmission wheel 1 The position of the origin is not meshed with the friction wheel set 2, and the friction wheel set 2 has
no transmission. When the detecting vehicle encounters an obstacle, the friction transmission wheel 1 realizes the movement to the friction wheel set 2 by coupling with the detector. When the friction transmission wheel 1 meshes with the friction wheel set 2, the detecting vehicle realizes the braking. And the movement back. In order to enable the probe to retract sufficient distance and angle, the effective length of the friction drive wheel is appropriately increased. Driven by the resetting device, the friction transmission wheel 1 slowly slides out of the friction wheel set 2 to move to the origin. When the friction transmission wheel is completely disengaged from the friction wheel set 2, the probe car stops reversing, and FIG. 3 is a CAD diagram of the mechanism.

![Figure 3](image)

**Figure 3.** Back system structure and CAD sketch

4. **Simulation analysis of obstacle avoidance system**

   The material selected in this paper is TC4 titanium alloy. The material properties used in finite element static analysis are density, Young's modulus, Poisson's ratio and yield strength. The working environment temperature is 485 degrees. Under the limit temperature of 485 °C, the density is 4440 kg/m³ for the TC4, the Young's modulus is 70 GPa, the Poisson's ratio is 0.37, and the yield strength is 583 MPa.

4.1. **Establishment of simulation analysis model**

   After drawing the geometric model with SolidWorks, import the Abaqus simulation analysis software to create a geometric model. To simplify the analysis and calculation, the shaft and the belt drive are omitted. Fixed displacement boundary conditions: Add constraints to the detection robot chassis, making the chassis rigid and unable to displace, as shown in Figure 4.

![Figure 4](image)

**Figure 4.** Fixed boundary displacement condition

   Applying a load: By inserting a speed $V$ to the friction wheel, insert it into the gap of the other two friction wheels, as shown in Figure 5.
Dividing the mesh, the model uses a tetrahedral mesh to divide the overall structure. For complex structures, there is a possibility of stress concentration and deformation at the corners of the encrypted mesh, and the distant parts are sparse meshes, as shown in Figure 6.

4.2. Simulation result analysis

In the obstacle avoidance retreat system, the gap between the two friction wheels of the friction wheel set 2 is 10 mm, in order to ensure that the friction transmission wheel 1 can provide sufficient transmission force after entering the friction transmission wheel set 2, the system analyzes the friction transmission wheel 1 diameter, the stress and strain of the friction wheel set 2 when the simulated diameters are 10 mm, 10.1 mm, 10.2 mm, and 10.3 mm, respectively.

4.2.1 Analysis of results when the friction transmission wheel diameter is 10mm. As shown in FIG. 7, when the diameter of the friction transmission wheel 1 is 10 mm, no stress and plastic deformation are generated on the friction wheel set 2, indicating that the friction transmission wheel 1 having a diameter of 10 mm is not in contact with the friction transmission wheel set 2, and does not arise. To provide the role of transmission force.
4.2.2 Analysis of results when the friction transmission wheel diameter is 10.1mm. As shown in FIG. 8, when the friction transmission wheel diameter is 10.1 mm, after the friction transmission wheel 1 enters the friction wheel set 2, the maximum stress of the friction wheel set 2 is 346.7 MPa, and the TC4 titanium alloy is in a 485 degree environment. The yield stress is 583 MPa, so the material does not yield or plastically deform, but elastic deformation occurs, and the maximum elastic deformation is 0.031 mm.

4.2.3 Analysis of results when the friction transmission wheel diameter is 10.2mm. As shown in FIG. 9, when the friction transmission wheel diameter is 10.2 mm, after the friction transmission wheel 1 enters the friction wheel set 2, the maximum stress of the friction wheel set 2 is 522.4 MPa, and the TC4 titanium alloy is in a 485 degree environment. The yield stress is 583 MPa, so the material does not yield or plastically deform, but elastic deformation occurs, and the maximum elastic deformation is 0.078 mm.
4.2.4 Analysis of results when the friction transmission wheel diameter is 10.3mm. As shown in Fig. 10, when the friction transmission wheel diameter is 10.3 mm, after the friction transmission wheel 1 enters the friction wheel set 2, the maximum stress of the friction wheel set 2 is 583 MPa, and the yield stress of the TC4 titanium alloy in the 485 degree environment. At 583 MPa, yielding has occurred, and plastic deformation occurs. The strain is less than 0.01 mm, but elastic deformation still occurs, and the elastic strain is 0.127 mm.
(b) Plastic deformation cloud picture

c) Elastic deformation cloud picture

Figure 10. Diameter 10.3mm friction wheel simulation result cloud picture

5. Conclusion
   According to the above simulation analysis, when the diameter of the friction transmission wheel 1 is between 10.1 mm and 10.2 mm, the power can be effectively transmitted to the obstacle avoidance system and the stress of the friction wheel set is within an acceptable range without failure. Then, the diameter of the friction transmission wheel 1 is selected to be 10.1 mm.

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