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Mechanical Structure Design of Coal Mine Detection Robot

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Abstract. At present, great progress has been made in the research of rescue robots in our country, but it is still far from enough to meet the requirements of the actual mine disaster scene in the field of autonomous exploration. Therefore, it is necessary to carry out more long-term research. At present, every country in the world has developed a very high level of coal exploration robot, but further efforts are needed to reach the very mature stage. If the most crucial task is to replace human beings in rescue work, the original tentative function will often not be reached; we must make further efforts in the research of coal mine detection robots. In this paper, the characteristics of all kinds of robots are analyzed and compared, the moving mechanism of selected robots is determined, different obstacle movements are analyzed in different working environments of coal mine robots, and then the dynamic system of coal detecting robots Finally, using solid works software simulation analysis, and analysis to determine whether the design of the coal mine detection robot can meet the design requirements.

1. Introduction

In today's society, the development and consumption of coal and carbon energy are getting huger. According to the prediction report of China's sustainable development energy strategy, the proportion of coal will still reach about 50% by 2050. Therefore, it can be determined that for a long time now and now coal will remain the important source of energy for our people's daily life and the basic energy for basic industries.

However, as we all know, though coal mining has been going through a long history in our country and mining technology has become more and more mature, most coal mining remains a high-risk underground work. As a large coal-consuming country in our country, the frequency of coal mining accidents is the highest in the world. We can divide the rescue work into three parts. The first part is the preventive work before the disaster, which is mainly based on the usual supervision and management. The second part is the rescue during the disaster. This part can reflect the self-help capability and on-site work of the trapped people Personnel emergency response; the third part is the post-disaster rescue, to this part, often the most difficult moment of the disaster, when underground personnel cannot be self-help, ground rescue workers cannot go down to rescue. Therefore, disaster relief is a huge challenge we face.

The invention of a coal mine detection robot is an indispensable task in producing safe coal mines. Under the new situation of today's new society, efforts to create a resource-saving society and adhere to the strategy of sustainable development, the prospects for the use of robots is very broad, of great practical significance.

2. Robot movement analysis

2.1. Climb the stairs

Robots climb the stairs is a robot basic ability, as the robot climbs the stairs, the angle of the bottom of the robot's track and the ground gradually become larger and larger, until the robot's own center of gravity across step, the whole process is the robot climb the stairs. As we climb the steps, we can see that the position shown in Fig. 1 is the critical state of the robot crossing the steps. If the robot successfully crosses steps or other obstacles, the center of gravity of the robot must first cross the support point of the steps and only this robot can cross the stairs. In the process, we can analyze the maximum obstacle height the robot can cross.

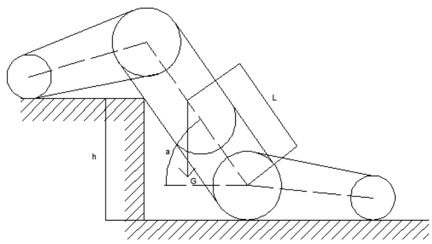


Figure 1. Robots climb the critical stage of the stairs

The following geometric relationships can be listed in Figure 1:

$$h = L\sin\alpha - R/\cos\alpha + R$$

Find the derivative can be drawn:

$$\frac{\partial h}{d\alpha} = L\cos\alpha - R\sin\alpha/\cos^2\alpha = 0$$

As a result, the maximum height H1 of the obstacle that can be levitated by the robot can be calculated. In addition, in order to allow the robot to climb higher obstacles, so the robot is also installed on a swing arm, the swing arm also installed a servo motor, the servo motor to provide drive power, driven by the servo motor, so that after When the swing arm is propped up to form 90 ° between the swing arm and the ground, an additional H is added to the height of the robot itself. Therefore, the height of the robot can be increased by one over the obstacle. The maximum height is: $H_{max} = H_1 + H$.

2.2. Climb the slope

Now analyze the robot climbing the slope of the state of motion, the robot is either in motion or at rest, as shown in Figure 2, the robot at this time by the driving force:

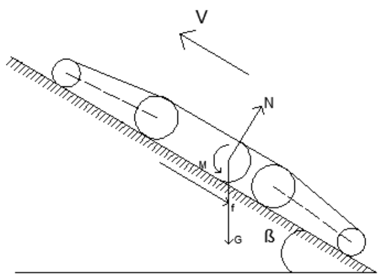


Figure 2. The force situation of robot climbing the slope

Suppose now that the maximum static friction coefficient of a robot when climbing a slope is μ, and the maximum static friction the robot receives: $F_{\max} = \mu G \cos\beta$. Only when $F > F_{\max}$ is satisfied, can the robot walk smoothly. When $F \le F_{\max}$ is satisfied, the robot slides down the slope due to gravity. From the above we can see the maximum static friction coefficient μ of the crawler robot climbing the slope, then the maximum gradient that the crawler can climb the slope is: $\alpha_{\max} = \tan^{-1}(\mu)$. The maximum acceleration that the robot must overcome to overcome the ground friction when the robot is moving on a slope is: $a_{\max} = (\mu\cos\beta - \sin\beta)g$.

After a series of calculations above, we can draw the corresponding conclusion: Coal mine detection robots can climb a slope of 30 degrees when climbing; the robot can cross the obstacles to a maximum height of 600 mm; robots can cross the maximum channel width is 400 mm.

2.3. Coal mining robots move on flat ground

We can assume that the robot's moving speed is the same on flat ground or it is the maximum and constant at a constant speed across the surface of the channel, as shown in Figure 3, so we can assume that v = 0.5m/s, m=50kg, R = 85mm.

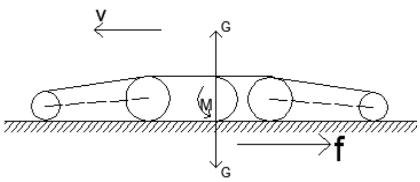


Figure 3. Analysis of robot driving on flat ground

The driving motor of the robot first passes through the gear box after outputting the power, so the driving motor needs to maintain the limit speed to ensure the maximum running speed of the robot. The maximum speed is:

$$n_{\max} = \frac{v_{\max}}{\pi D} = 56.2r/\min$$

2.4. A variety of gestures

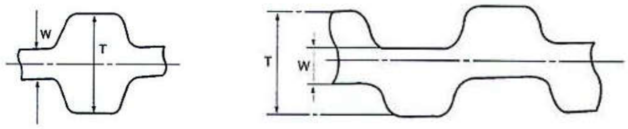
After analyzing the obstacle-crossing attitude of the above robots, we can know that the driving force generated by the permanent magnet DC motor inside the robot only acts on the main crawler when the robot crosses the step. When the robot crosses the step, the speed is not too fast, which means that the robot needs the output power is not much.

When the robot performs straight-line motion on the ground, the speed of the required motor output is larger because of its higher speed. On the contrary, when the robot performs a hill-climbing motion on a slope, the speed is slow but the required output torque is relatively large. Therefore, when designing a robot to select a motor, we should select both the maximum speed and the maximum torque required by the robot in different road conditions to ensure the rationalization of the robot design.

3. Design of Coal Mine Exploration Robot Track

3.1. Robot Caterpillar Parameter Design

Figure 4 (a) is a DA type double-sided tooth timing belt, because it is double-sided, so the teeth on both sides are symmetrical, Figure 4 (b) is a DB double-sided tooth timing belt, The teeth are not symmetrical but staggered distribution, the choice of this design is DB-type double-sided tooth timing belt.



(a) (b)

Figure 4. Trapezoidal tooth shape chart

3.2. Design of track

Track running smoothly and the center distance of the track has a great relationship, the center distance can neither be too large nor too small.

If the center is too small, then the pulley angle will be smaller, in a certain period of time, the track will turn the more the number of laps, which means that the life of the track will be reduced accordingly, the same if Center distance is too large, then the track length will be longer, then the crawler does not touch the ground side of the longer running time, which will reduce the stability of the track operation will make the robot more bumpy walking the entire body , Will reduce the life and work efficiency of other parts of the robot, because in the actual work, the robot is subject to various factors, the size of the robot body cannot be too large, so here we should let the robot center distance smaller, We choose center distance a = 380mm.

When calculating the length of the pitch line of the robot track, the size of the robot itself and the center distance of the initial determination should be taken into account. Known formula:

$$L_{d0} \approx 2a + \frac{\pi}{2}(d_{d1} + d_{d2}) + \frac{(d_{d1} + d_{d2})^2}{4a}$$

Substituting a , d_1 and d_2 , which has been derived above, into the above formula, we can find $L_{d0} = 1350.79mm$.

3.3. Robot pulley parameters

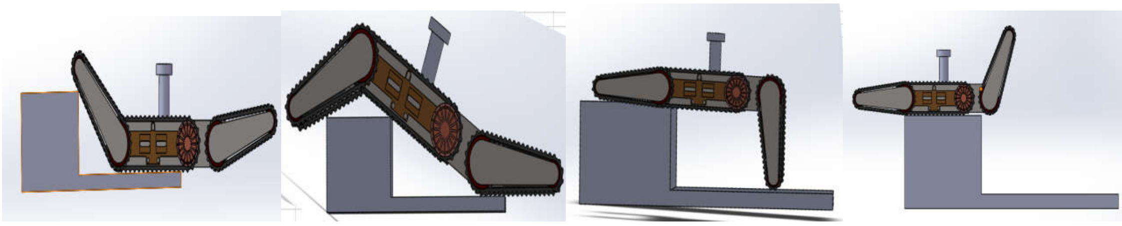
The number of teeth engaged by the small caterpillar wheel of a robot crawler can be calculated by the following formula:

$$z_m = ent\left[\frac{z_1}{2} - \frac{p_b z_1}{2\pi^2 a}(z_2 - z_1)\right] = 12$$

From this we can get $z_m > 6$. Timing belt can be up and running, the number of teeth on the small pulley is not arbitrarily set, the same ladder standard timing belt is the same, in the above we use the XH timing belt is the minimum number of teeth, and only meet the minimum requirements to make the belt work properly.

4. Movement Simulation Analysis of Coal Mine Detection Robot

4.1. Coal mining robots climb the stairs

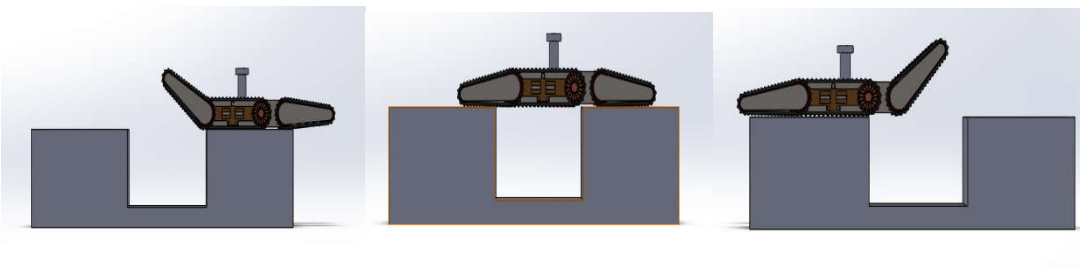


(a) **(b)** **(c)** **(d)**

Figure 5. Coal mine detection robots climb the stairs process

Figure 5 (a) shows the coal detection robot is climbing the steps; the robot's front arm can smoothly climb the stairs, so as to prepare for the next climb. Figure 5 (b) shows the critical position of the coal mine detection robot when climbing a step. The center of gravity of the robot and the edge of the step are exactly on a straight line. Figure 5 (c) shows the coal mine detection robot is about to climb to the step, then the robot's lower arm moves downward and the ground to form a 90-degree attitude, the main track and the forward arm move forward, so that the robot climb Stairs. Figure 5 (d) shows the coal mine detection robot successfully climbed the steps, after simulation in solid works software to prove that the design of the coal mining robot can climb smoothly up to a maximum height of 600mm steps.

4.2. Coal mine detection robots cross the channel



(a) **(b)** **(c)**

Figure 6. Coal mine detection robots across the channel process

Figure 6 (a) shows the coal mine detection robot crossing the channel, when the robot's front arm rises upward. Figure 6 (b) shows the coal mine detection robot swing arm has crossed the channel smoothly, the robot's body is across the channel. After the simulation analysis in the solid works software, the design of the coal detection robot can achieve the requirement of crossing the channel and can cross the maximum span 400mm channel.

4.3. Coal mine detection robot climbing slope

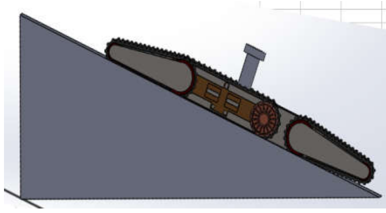


Figure 7. Coal mine detection robot climbing slope process

Figure 7 shows the state of the coal mine detection robot simulating the actual climbing slope in the solid works software. After the simulation analysis, it shows that the slope with the maximum gradient can be smoothly climbed.

5. Summary

In this paper, the working principle and the overall structure of the coalmine detection robot are studied in detail. The first is to select and design the walking mechanism of the coalmine detection robot. To meet the performance of the robot on the basis of the design of the power system, and then on the coal mining robot crawler part of the design and type of determination, after the completion of the initial design, after the solid works software simulation analysis, the final simulation Analysis shows that the design of the coal mine detection robot can fully meet the design requirements. Because this paper studies a robot with high precision, because of the limited research time and the insufficient ability of myself to make the work more perfect, there are still some shortcomings in this study: all kinds of working conditions of the research are carried out under ideal conditions, cannot fully meet the requirements of the actual situation; in the design, the design and selection process of the various parts of the robot are simplified correspondingly, for example, when the coal mining robot climbs the slope and ignores some of the friction, Therefore, some of the data in the text still need further research. With the development of technology and the accumulation of more and more experience, the combination of technology and practice will make coal detection robots more perfect.

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