

## Barrier-crossing Design of the Inspection Robot in Substation with Wheel-Track

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**Abstract.** In order to meet the needs of mobile inspection robot drives fast on flat road, and walks normally in the complex environment (roadside stone, grass, etc.). We designed a new mobile platform of robot with the wheel-track. The mobile platform used wheels to drive normally on flat cement road. If the mobile platform encountered the curbstone (the curbstone height is generally 150-200mm), which used front and back swing arm to lift the mobile platform of robot, finally, the robot completed the barrier-crossing task with the motor driving force. If the robot encountered with gravel, grass, and other complicated environment that using wheel not to drive normally, which can use the front and back swing arm and track to walk.

### Introduction

Substation is the hub of power transmission network, the safety of the equipment running status is critical. The normal substation running and the reliable power supply are guaranteed by the effective inspection of the equipment. With the develop of the robotics, the manual inspection has been gradually replaced by robot inspection, reducing the labor force. Nowadays, the inspection robot include wheeled mobile, tracked mobile, leg-foot mobile, peristaltic mobile, etc. And the wheeled robot and tracked robot are used widely. The structure of wheel robot is simple, it had high running speed and efficiency, while it only applied to flat road surface, and completed obstacle in difficulty, and had a poor ability of walking on the soft and muddy road. The tracked mobile has strong terrain adaptability than wheeled robot, and it had strong obstacle ability and the environment adaptability in the complex environment, however, there is a big friction resistance between the track and the ground, especially in long distance or high speed motion or car is turning, which can consume a lot of energy and cause severe wear on track [1].

Theoretically, the leg-foot mobile is the most flexible motion mechanism, but it had a complicated mechanical structure and complex control, and there is no practical. Therefore, the design of a new structure inspection robot is a pressing problem in this field, which can drive fast on flat road and meet the needs of the complex substation terrain. In this paper, it describes the principle and the mechanical structure of the wheel-track robot. The platform is used for substation applications that should be equipped with cradle head, camera, robot arm and other equipment, so the volume size, practicality and agility and the appearance of mobile platform should have higher requirements. The main functional requirements includes a certain bearing capacity, flexible movement, flexibility and freely to turn forward, backward, left and right. If the robot encountered some obstacles(roadside stone, etc.), which can overcome the obstacle ability. The robot must have a low center of gravity and it should drive smooth and efficient in the process[1] [2].

## Mobile platform Design

In this paper, the wheel-track robot mobile platform contained four parts: wheeled walking mechanism, swing arm obstacle mechanism, track drive mechanism and the chassis frame. Walking mechanism was designed for front-wheel drive, the principle is that DC geared motor can drive wheel rotate and move the vehicle to back and forth through the transfer function of a small chain wheel, a chain, a large chain wheel and the output shaft. DC geared motor of driving large chain wheel rotate was mounted on the left and right sides in vehicle body, and the left and right large chain wheel are mounted on the front vehicle side. The principle of swing arm obstacle mechanism is that DC gear motor drove swing arm up and down through the transfer function of worm reduction box, output shaft and gear, the platform can across the high step and curbstone. The structure is shown in Figure 1.

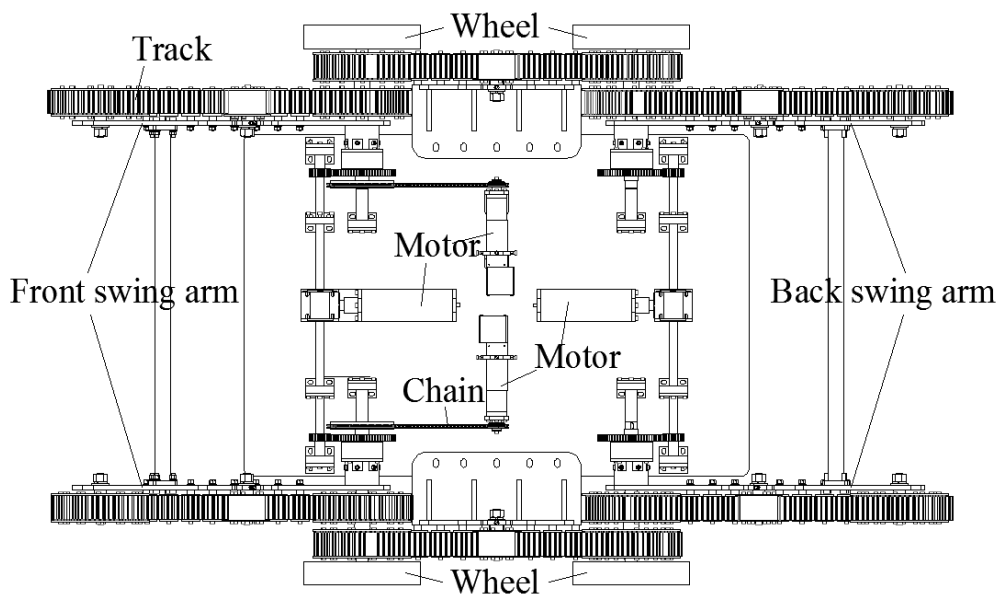


Fig.1. Wheel-track robot overall layout

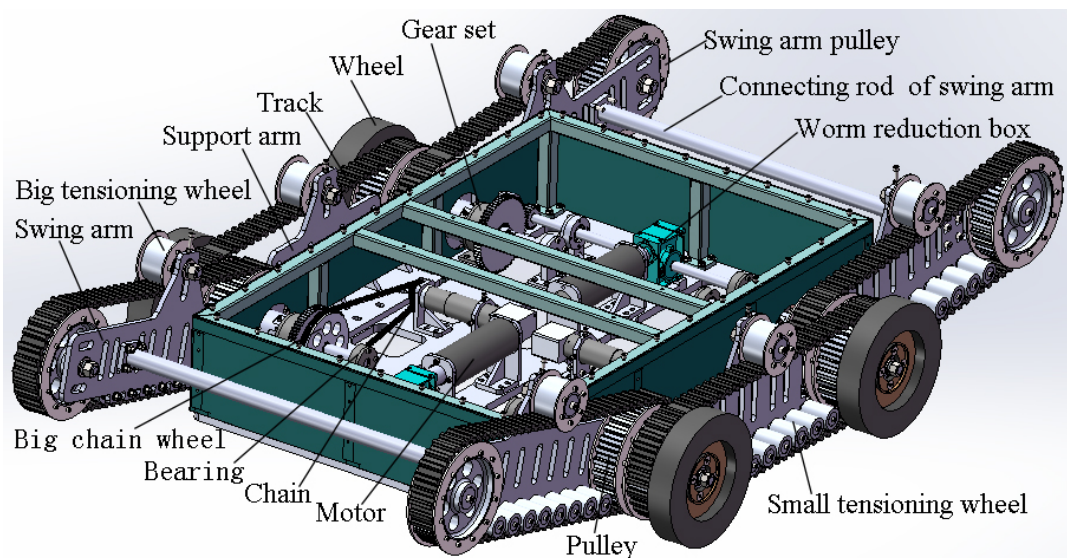


Fig.2. Wheel-track robot

The Figure 2 is the design of wheel-track robot mobile platform 3D map, the design of wheel-track robot mobile platform 3D map , the front and back swing arms are rotated by the front and back worm reduction box, the gear that transmitted torque and power respectively, and then rotate the swing arm up and down. With the swinging arm rotation, the robot mobile platform can

across curbs and other obstacles. The circular motion of left and right wheels are drove by the left and right DC gear motor, the small chain wheel, the chain and the big chain wheel, finally, it can achieve the move in front and back [3] [4].

**Wheeled walking Mechanism.** In Figure 3, the small chain wheel was mounted on the motor output shaft that drove the small chain wheel rotation by the key. The small chain wheel and the big chain wheel linked by the chain. Achieving The motor output torque transmission and the large chain wheel rotation through the chain. The large chain wheel was mounted on the output shaft, which can drive the shaft and the wheel rotation by the key, then it realized the robot move in front and back.



Fig.3. Wheeled walking mechanism

**Swing arm Obstacle Mechanism.** In Figure 4, output torque of the motor rotation transmitted to the worm reduction box through a coupling, the worm reduction box transmitted the torque to the output shaft through the key. The small gear on the output shaft circular rotation that drove the big gear set rotation together, The big gear set connected with the swing arm, and then the swing arm was rotated. Therefore, the robot realized the obstacle function by using the front and back swing arm support function.

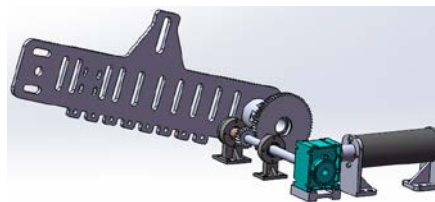


Fig. 4. Swing arm obstacle mechanism

In Figure 5, we selected 40 Cr as the material of the big gear set, at one end of it was received torque from small gear, and the other end sent the received torque to swing arm, which made the swing arm up and down. Its capacity of bearing is critical, which determined whether the robot can across obstacles smoothly. The analysis results shown that the maximum stress of big gear set is 497 MPa, and the yield strength is 785 MPa, so it can satisfy with the requirements of bearing capacity.

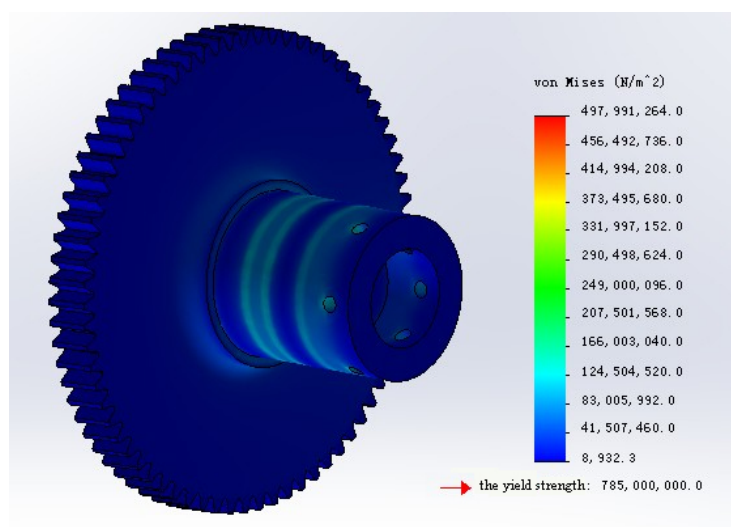


Fig.5. Stress analysis

**Track Drive Mechanism.** In Figure 6, the big chain wheel was mounted on the motor output shaft, and the motor drove the small chain wheel rotation, the big chain wheel was rotated through

the chain. The action toothed belt pulley was mounted on the output shaft, it rotated along with the big chain wheel, then driven toothed belt pulley was rotated by track. The top of track is closely fit with the tensioning wheel, the other side of the big tensioning wheel embedded in the swing arm slot hole. It can control the track tension degree by adjusting the bolt height. The track bottom was realized the tension by eight small tensioning wheel to avoid appearing track bend phenomenon, the other side of the small tensioning wheel embedded in the swing arm slot hole, the end shaft fixed by the nut.

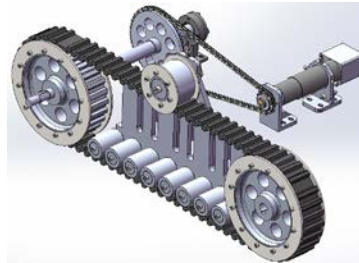


Fig.6. Track drive mechanism

**Chassis Frame.** In Figure 7, around the chassis that arranged some square tube support frame, the top of the square tube and in the distributed around are fixed by welding together, which can form the chassis frame eventually. Platform chassis is a carrier that installing the motor, worm reduction box bearing and other equipments. It must meet the load demand and control the chassis weight.



Fig.7. Chassis frame

In Figure 8 (a) and (b), these are chassis stress analysis diagram and displacement deformation map respectively, we select 2014-T4 aluminum as chassis materials, design total weight of robot is 130kg, we carried out simulation analysis on the platform chassis according to the robot bearing 200kg, the results showed that the chassis of suffering the maximum stress is 25MPa (yield strength is 290MPa), the maximum displacement of the deformation is 0.66mm. the results showed that the chassis satisfied the load requirements.

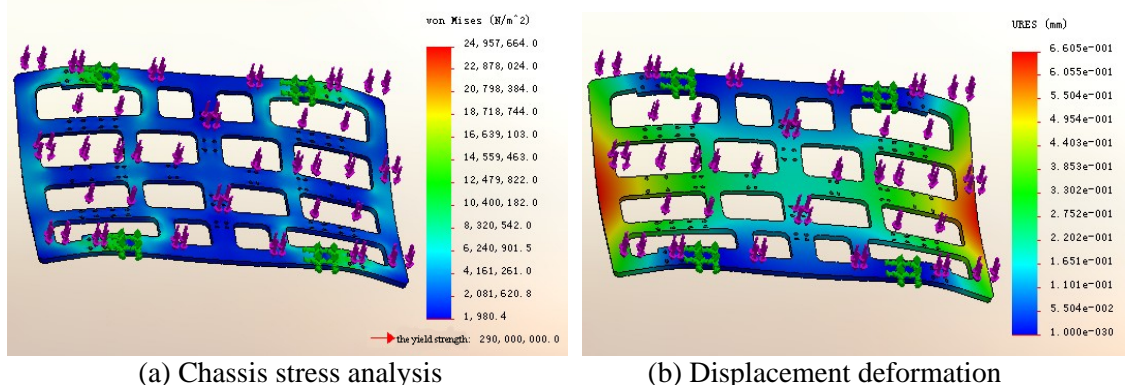


Fig. 8. Chassis stress analysis diagram and Displacement deformation map

## The results

**Normal Walking.** In Figure 9, the front and back swing arms are raised a certain height when wheel-track robot walks on flat road, which relied on wheel to walk.



Fig.9. Normal walking

**Barrier-crossing.** In Figure 10 (a), (b), (c), (d) and (e), if the robot encountered curb obstacles when it walks in the work, the front arm was lift a certain height, and the back arm was dropped down into the road surface, the motor drove the toothed belt pulley rotation through the chain wheel, chain and output shaft, the track was mounted on the toothed belt pulley that rotated along with it, thereby driving the robot moved forward until the robot contacted the curb surface. Finally, the robot completed obstacle task that relied on the front and back swing arms[3] [4].

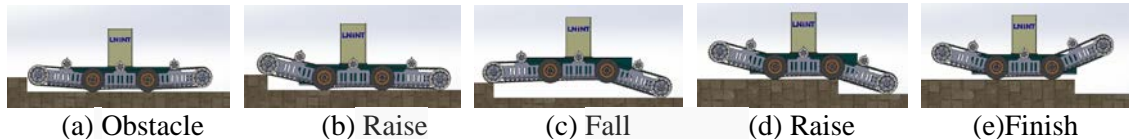


Fig.10. Barrier-crossing

**Walking under the complex environment.** In Figure 11, if the robot encountered curb obstacles when it walks in the work, the front arm was lift a certain height, and the back arm was dropped down into the road surface. The robot would not walk normally that relied on the wheel when the robot encountered the gravel, grass and other complex terrain. When the front and back swing arms of the robot were dropped down to hold up its body, it would drive in the complex environment that relied on the track[5].

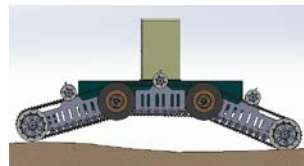


Fig. 11. Walking under the complex environment

## Conclusion

With the comprehensive analysis of the characteristics of the current substation inspection robot and the substation environment, we had designed a new wheel-track robot mobile platform. It solved the problem that wheeled robot had the poor obstacle function and tracked robot walked slowly and other difficulties through a combination of wheel and track. Further, the combination of wheel and track had a stronger environmental adaptability, which can reduced on spot construction in substations. In this paper, the relevant calculation about the robot is not enough (e.g.: motor selection calculation, obstacle performance computing, etc.). It focuses on design ideas, the robot will gradually become the main inspection robot in substation, which can play a leading role for the development of inspection robot.

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