Mechanical Design and Research of a Novel Power Lines Inspection Robot

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Abstract—**This paper proposes a novel mechanical structure for power transmission lines inspection robot. The proposed structure composed of two identical lifting arms which are connected through middle girders with two rotational joints. Symmetric mechanical structure is adopted as a whole. There are four mainly units, including motion units, open-close units, pressing units and rotating joints. Walking and obstacle-overcoming experiments on the simulative lines achieve the desired effects in the lab. It proves the validity of the mechanical structure design and the maneuverability of the robot.**

Keywords-high-power transmission line inspection; robot; mechanical structure; maneuverability

I. INTRODUCTION

Nowadays, there are mainly three methods of power line inspection, which are manual inspection, inspected by the use of helicopter and robot. Both of the first two have some drawbacks, such as high cost, inefficiencies and so on [1-2]. With the development of robotic technology, more and more researchers and groups at home and abroad are focusing on developing robots that can be used in the power line inspection [3].

As a result, many power line inspection robots have been developed. Expliner [4-5] is a designed by Kansai Electric Power Corporation, which can move over different kinds of spacer dampers. The prototype is 500mm*1060mm*715mm in size and weighs about 84 kg. LineScout [6-9], which has been used in the power lines inspection, was developed by Montambault and Pouliot. With the robust maneuverability, less than 2 min is required to cross the obstacles, like spacers, suspension clamp and so on. Besides that, a light manipulator fixed on the robot can be used to do some simple maintenance.

Wang, Li [10-12] proposed a dual-arm robot for power lines inspection. The platform is raised for 500kV extra high voltage OGWs (Overhead Ground Wires). The robot mechanism has high crossing capability, and the obstacle-crossing movements are safe. A novel tribrachiation robot for transmission line inspection is introduced by Xi'an Jiaotong University [13]. A dual-parallelogram structure is used to adjust the gesture while overcoming the obstacles.

Based on the research of robots mentioned above, a novel anthropomorphic robot called Linebot is proposed to perform inspection on the 500kV power lines, shown on fig.1. It has good maneuverability and is able to overcome the obstacles easily, such as suspended clamps, the vibration dampers, and so on. Linebot is composed of four units, including walking units, open-close units, pressing units and rotating joints. What's more, any of the units could be driven separately. As a result, different method can be preferred according to different obstacles.

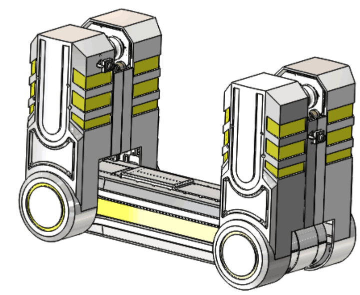

Figure 1. Prototype of Linebot.

II. MECHANICAL DESIGN OF LINEBOT

A general power lines is shown in Fig.2. The 220KV High voltage power transmission lines found on the State Grid Corporation of China are in a two-conductor bundle configuration.

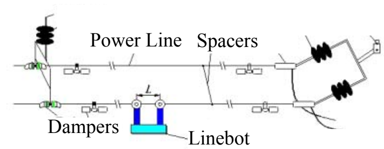

Figure 2. Obstacles on power line.

Along the bundle, spacer dampers are installed about 50 m to maintain the prescribed distance between conductors. There are many other obstacles along the lines. Along the power wires, the suspended clamps, the vibration dampers, isolators and so on are the common obstacles. And the robot should be able to cross them in short time.

Other different types of obstacles can also be found on the power lines, such as double insulator strings and pendent obstacles. The corona-ring suspension clamps are another type of common obstacles to be overcome. Beyond that, there are some slopes of different angels to be overcome.

III. MECHANICAL STRUCTURE OF LINEBOT

As shown in Fig.3, to overcome these obstacles above, Linebot was proposed which is composed of two

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symmetrical parts connected through middle girders with two rotational joints. There are 8 drive cells totally. Each part contains motion unit, open-close unit and pressing unit, and all of which can be controlled separately to achieve desired motions. In this way, it moves steadily and has great maneuverability.

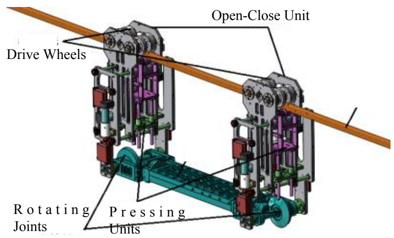

Figure 3. The mechanism of Linebot.

A. Motion Unit

Two motion units, which are the main unit of the robot, provide the movement function. Each of the units has enough force to drive the robot move forward or backward steadily.

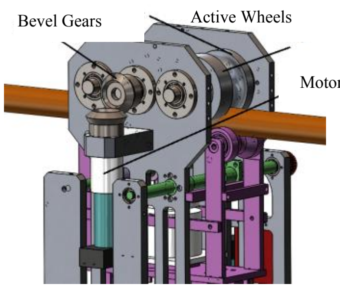

Figure 4. Active motion component.

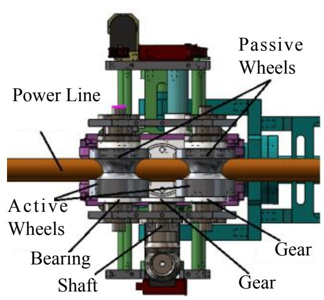

Figure 5. Passive motion component.

On Fig.4 and Fig.5, each motion unit contains two parts, the active and the passive component. A brushless DC motor coupled to a planetary flanged-output gearbox and a pair of bevel gears with built-in heavy-duty cross-roller bearing supports the active wheels. As a result, it can keep in compact size and lightweight.

B. Open-Close Unit

This simple but critical system shares the same principle as the motion unit (Fig.6). Two right-end and left-end lead screws are used to drive the wheels open or close. There are also two polished rods to support this movement. All of the four rods are connected with belt pulleys. What's more, less energy is cost because of the advantage of self-locking characteristic of the trapezoid lead screw. To ensure unwanted opening of the unit, an absolute potentiometer, coupled to the DC motor, is used to monitor the drive shaft.

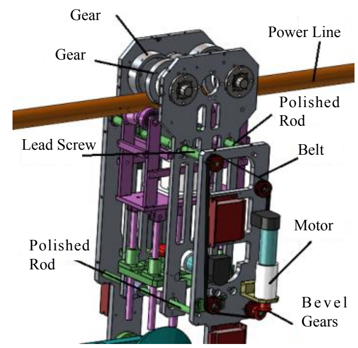

Figure 6. Open-close unit.

C. Pressing Unit

Pressing units are the heart of the motion component, supporting 50% of the total weight while overcoming the obstacle. As seen in Fig.7, a pair of spur gears is used to drive a trapezoid lead screw lift and hold the weight of the robot. Self-locking characteristic of the gears and screw eliminates the danger of sudden drop of the robot by supporting the wheels.

D. Rotating Joint

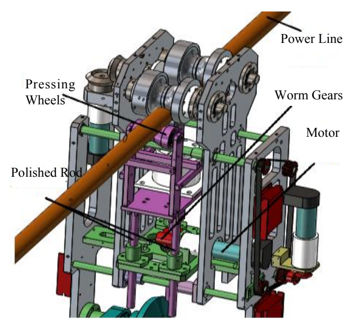

Figure 7. Pressing unit.

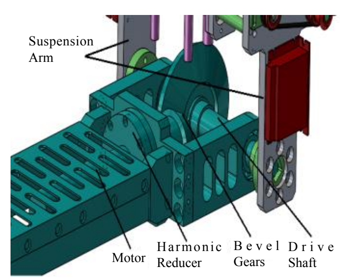

Figure 8. Rotating joint.

This degree of freedom is essential to cross obstacles. As it rotates, Linebot is lifted up or down and driven forward to cross the obstacle. Illustrated in Fig.8, three different kinds of reducer are used to output enough torque, which are planetary gearbox, a pair of bevel gears and a harmonic drive. Because the total reduction ratio is 960, it rotates slowly but steadily. What's more, the compact harmonic drive helps to reduce the weight of the joint.

IV. MOTION ANALYSIS OF LINEBOT

To evaluate the performance of Linebot, a schematic diagram (Fig.9) and a series of analysis were conducted.

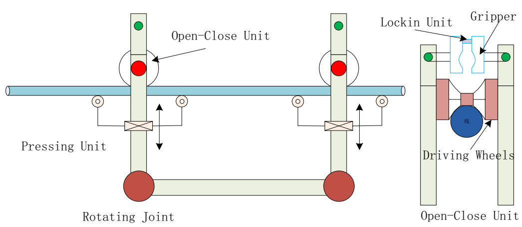

Figure 9. Schematic diagram of mechanism of the Linebot.

The part II was off from the line with the use of the pitch joint. Part I moved forward until part II negotiated the obstacle and then lifted up on the line then. In the same way, the part I will negotiate the obstacle.

- Linebot stopped moving when detected the obstacle, and pressed the wheels of part II. Then the open-close unit of part I was opened.
- With the help of two rotate joints, part I was put down and part II was driven forward until part I was on the other side of obstacle.
- Part I was lifted up and the open-close unit was closed when the wheels of part I was lifted higher than the cable. After that, pressing unit pressed drive wheels on part I.
- After pressing unit of part I was taken off and the open-close unit was opened, part I was put down until it was lower than the cable.
- The drive wheels in part I drive Linebot forward until part II crossed the obstacle. Next, part II was lifted up.

In this way, Linebot overcome obstacles like spacers, dampers and so on.

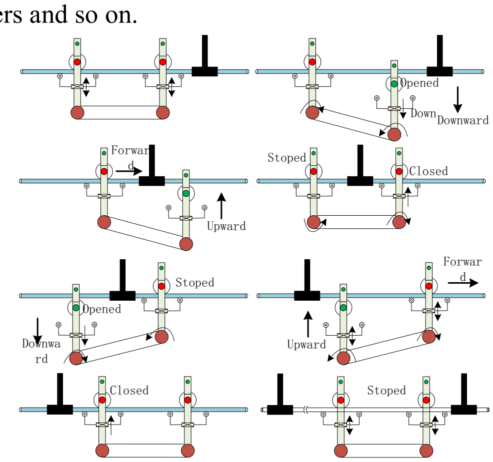

Figure 10. Process of crossing the obstacle.

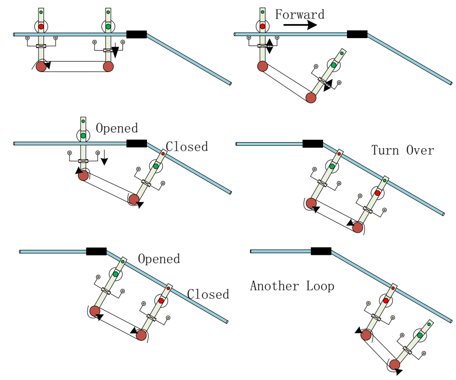

Figure 11. Process of crossing the obstacle.

V. CONTROL SYSTEM OF THE ROBOT

The control system of Linebot (Fig.12) is composed of ground control system and onboard control system. There are many sensors on Linebot, like angle sensors, cameras and so on. A portable control box with GUI interface, a pilot lever, wireless and video modules are the main components of the ground system. The pilot level can be used to control the Linebot more easily. The feedback of the information from the cameras and sensors could be shown on the screen of the GUI interface. There are also main control unit and motor drivers on the onboard control system.

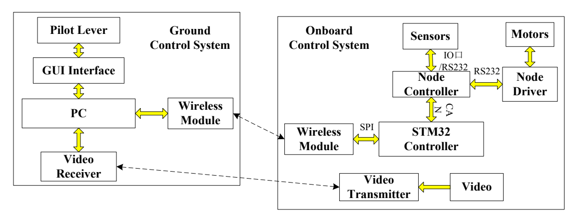

Figure 12. The control system of Linebot.

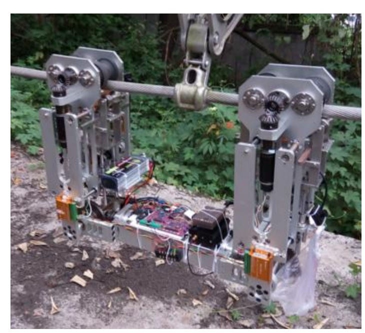

Figure 13. Experiment of obstacle overcoming.

The Linebot can be controlled with the use of pilot lever. Firstly, the control command is sent to the PC, and then transmitted to the controller on the onboard control system. After that, the command is decoded and sent to the node controller. When the motor drivers received the command, the motors were driven.

VI. EXPERIMENTS

To verify the feasibility of Linebot, a simulation environment was set up. It replicates a part of the 220kV power line in about 1 to 1 ratio and contains some obstacles like spacers and dampers. Some tests were done in this context, like moving on the cable, obstacle overcoming, shown in figures below.

It shows that the robot can move steadily on the cable and its average velocity is about 0.2m/s. About 4 minutes was needed to cross the obstacle, which is effective to fulfill the robot obstacle-navigation task. And the obstacle-navigation process runs smooth and has no lash.

VII. CONCLUSION

In this paper, a novel power line inspection robot was introduced. It is composed of two identical lifting arms which are connected through middle girders with two rotational joints. Motion of the robot is analyzed and evaluated to evaluate its maneuverability, after being manufactured. What's more, some experiments are performed on the experimental condition.

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