A Structural Design of a Robot for Removing Bird's Nest on Power Transmission Line

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Abstract. This paper deals with the field of bird's nest cleaning equipment, in particular, a new type of bird's nest-removing robot for power transmission towers. Bird's nests are often built on the transmission and distribution network towers. The branches, grass stems, iron wire and other materials that are carried by birds to make the nest can easily cause the short connection of the charged body, causing tripping, or even burning out the equipment, causing a power failure of the catenary machine power equipment, causing a great impact on the normal power transmission and distribution network. In view of the bird's nest problem on the transmission tower, this paper proposes a bird's nest robot that can be operated on the transmission line, which can maneuver the robot for the removal of the nest during the construction work of the electrician. This operation method is safe, fast, and efficient, and solves the problem of difficulty in operation and danger of operation during maintenance of the power line.

Keywords: Power transmission line; Robot; Cleaning equipment; Safe.

1. Introduction

Bird's nests are often built on the transmission and distribution network towers. Branches, grass stems, and iron wires from birds are very likely to cause short-circuiting of charged bodies, causing tripping and even burning of equipment, causing power outages in contact with the network equipment and causing great impact on the normal transmission and distribution network. (A bird's nest on a power tower is shown in figure 1) At present, the way to clear the nest is manually removed by manual climbing. For low voltage towers, the bird's nest is removed by simple mechanical means using smashing, shearing, and burning. For the clearing of the nest on the middle and large towers, it is extremely difficult to coordinate the actual operation. After our investigation in the field, we found that the traditional method of removing the bird nest will no longer meet the needs of electrical development, and the whole power system is eagerly craving a new kind of high efficiency other than the nest system. The traditional mechanical clearance mode is not easy to operate, and the direct contact clearance mode is easy to cause potential safety hazards to personnel and equipment, especially the hook, hanging rope and towing type equipment. In the actual outdoor operation process, it is easy to wire up and hang the line, forming a serious potential safety hazard. For non-contact clearance, the current use of fire, nest burning not only easy to cause outdoor fire risk, is not conducive to the safety of electrical equipment, at the same time, the equipment in the daily maintenance and use of the process of attention is complex, prone to safety accidents.

Figure 1. Bird's nest on the transmission line

2. Structural Design

The robot technology for removing bird's nest mentioned in this paper is as follows:

A new kind of removal of the bird's nest robot on the power line of the electric system, including the body, the signal transmitter at the top, and the other side of the signal receiver. The signal transmitter is the same shape as the signal receiver, and to prevent the signal from interfering in the transmission, there is a signal shield between the transmitter and the receiver. The first crank slider mechanism and the second crank slider mechanism are fixedly mounted on the bottom of the cleaning vehicle body, and the two are the same size. A bird-removing device is fixedly mounted on the top of the middle portion, and a visual camera is fixedly mounted on the front side. A symmetrical pair of 4-dof mechanical arms is fixed and installed on the front side near the side of the visual camera. The physical parameters such as length, mass, and snatch force of the arm are identical. Each robot arm is equipped with a corresponding two-degree-of-freedom clamping robot, and the left and right mechanical hand-held mechanical heads having different functions, the left robot is a lifting mechanical head, and the right robot is a punching mechanical head. A non-slip rubber ring is provided on the robot to prevent it from falling off during operation of the mechanical head.

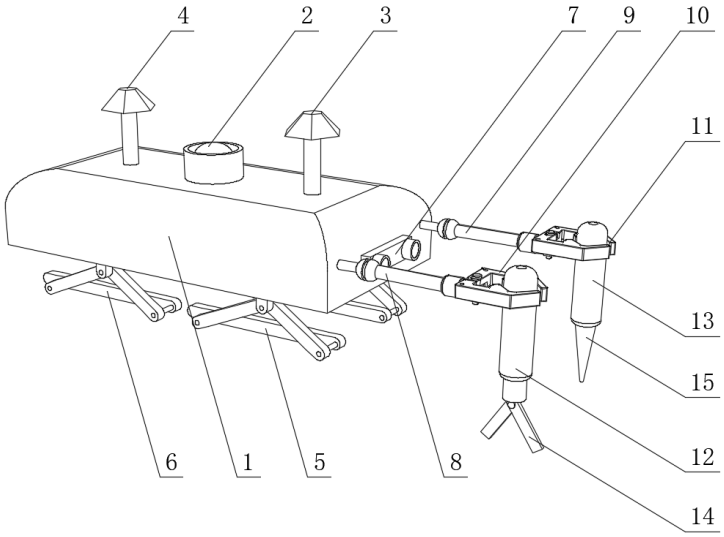

Figure 2. Robot structure diagram

Table 1. Robot structure table

Serial number	Structure name	Serial number	Structure name
1	Robot body	9	The second mechanical arm
2	Signal shielding	10	Mechanical claw
3	Signal receiver	11	Mechanical claw
4	Signal transmitter	12	Right workpiece arm
5	The first crank slider	13	Left workpiece arm
6	The second crank slider	14	Right workpiece head
7	Visual camera	15	Left workpiece head
8	The first mechanical arm		

The structure of the robot is shown in figure 2 and table 1.

The robot adopts aluminum alloy material, which greatly reduces the weight of the robot and improves the load capacity and maneuverability of the robot. The power supply system uses a dual-supply lithium-ion battery pack, which can continuously drive the equipment for more than 2 hours; the travel system uses a crank slider rubber. The running system uses the friction force of rubber wheel and wire with crank slide to provide the moving power of the running car, and the kinetic energy, is provided by the worm gear motor. The obstacle removal system, including cutting mechanism and foreign body clamping and positioning mechanism. On the premise of not damaging

the circuit, the foreign body blown on the wire can be easily cleared by cutting and removing method. The remote-control system is provided by LAN remote control.

3. Manipulator Dynamics Analysis

The robot uses a four-degree-of-freedom manipulator to establish a commonly used D-H coordinate system as shown in figure 3.

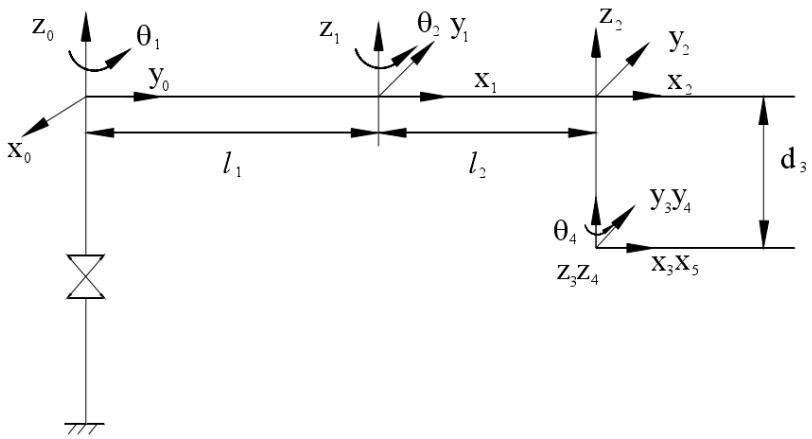

Figure 3. D-H coordinate system

As shown in the figure, the link coordinate system relative to the transformation matrix ${}_{i}^{i-1}\mathrm{T}$ can be obtained as follows.

$$ {}_{i}^{i-1}\mathrm{T} = \begin{pmatrix} cos\theta_i & -sin\theta_i cos\alpha_i & sin\theta_i sin\alpha_i & 0 \\ sin\theta_i & cos\theta_i cos\alpha_i & -cos\theta_i sin\alpha_i & 0 \\ 0 & sin\alpha_i & cos\alpha_i & d_i \\ 0 & 0 & 0 & 1 \end{pmatrix} $$

Where α_i represents the characteristic of the link i itself, and d_i and θ_i represent the relationship between the link i and the link $\mathrm{i}-1$. A four-degree-of-freedom robot consists of four rotating joints and four moving joints. For the rotating joint, the joint variable is only θ_i, and the remaining parameters are unchanged; for the moving joint, the moving variable is only α_i, and the remaining variables are unchanged. The corresponding parameters are as follows:

Table 2. Connecting rod parameter table

Number of links	Variable	α_i	d_i	$cos\alpha_i$	$sin\alpha_i$
1	θ_1	0	l_1	1	0
2	θ_2	0	l_2	1	0
3	θ_3	0	0	1	0
4	θ_4	0	0	1	0

Where the length of the connecting rod is:

$$ l_1 = 250mm, l_2 = 150mm $$

Therefore, the pose matrix of each joint is:

$$ {}_{1}^{0}\mathrm{T} = \begin{pmatrix} cos\theta_1 & -sin\theta_1 cos\alpha_1 & sin\theta_1 sin\alpha_1 & l_1 cos\theta_1 \\ sin\theta_1 & cos\theta_1 cos\alpha_1 & -cos\theta_1 sin\alpha_1 & l_1 sin\theta_1 \\ 0 & sin\alpha_1 & cos\alpha_1 & 0 \\ 0 & 0 & 0 & 1 \end{pmatrix} $$

$$
{}^{1}_{2}\mathrm{T} = \begin{pmatrix} cos\theta_2 & -sin\theta_2 cos\alpha_2 & sin\theta_2 sin\alpha_2 & l_2 cos\theta_2 \\ sin\theta_2 & cos\theta_2 cos\alpha_2 & -cos\theta_2 sin\alpha_2 & l_2 sin\theta_2 \\ 0 & sin\alpha_2 & cos\alpha_2 & 0 \\ 0 & 0 & 0 & 1 \end{pmatrix}
$$

$$
{}^{2}_{3}\mathrm{T} = \begin{pmatrix} cos\theta_3 & -sin\theta_3 cos\alpha_3 & sin\theta_3 sin\alpha_3 & 0 \\ sin\theta_3 & cos\theta_3 cos\alpha_3 & -cos\theta_3 sin\alpha_3 & 0 \\ 0 & sin\alpha_3 & cos\alpha_3 & -d_3 \\ 0 & 0 & 0 & 1 \end{pmatrix}
$$

$$
{}^{3}_{4}\mathrm{T} = \begin{pmatrix} cos\theta_4 & -sin\theta_4 cos\alpha_4 & sin\theta_4 sin\alpha_4 & 0 \\ sin\theta_4 & cos\theta_4 cos\alpha_4 & -cos\theta_4 sin\alpha_4 & 0 \\ 0 & sin\alpha_4 & cos\alpha_4 & 0 \\ 0 & 0 & 0 & 1 \end{pmatrix}
$$

4. Advantage Analysis

The robot hand on the cleaning vehicle body has good accuracy, and the grasping control system can regulate the strength and orientation, so as to avoid the potential electrical damage to the surrounding power equipment when the bird's nest is removed to the greatest extent, with high safety performance.

Through the non-direct contact of the remote-control system, the work risk of the demolition personnel is greatly reduced, and the whole process is operated by the wireless control mode of the local area network, which greatly protects the personal safety of the staff, and has wide application range and strong application.

This design can remove the bird's nest by robot and remote-control system. It has universal applicability to all kinds of transmission and distribution towers, poles and various circuit environments around the nest. It is easy to operate and has good demolition effect.

The cleaning operation is simple and easy to learn. The remote control of the operator can be specifically set to remove the required parameters through electronic devices such as mobile phones.

5. Development and Prospects

With the development of robot technology, more and more robots are replacing human beings to do jobs with harsh environment and complicated working procedures. Aerial transmission line inspection robots, de-icing robots, obstacle removal robots and other live working robots emerge one after another. The transmission line moving robot needs to cross obstacles such as spacer bars, clamps, and anti-vibration hammers to perform inspections and fault repairs on the transmission lines. Therefore, the mobile obstacle crossing mechanism, energy supply mode and live working ability of the robot become the key problems and technical difficulties in the research of this kind of robot. The transmission line operation robot needs to design a reasonable structure and perform specific work on the transmission line. Therefore, the robot's design mechanism, operation mode and live working ability have become the key issues and technical difficulties of this type of robot research. This project attempts to solve the design problem of overhead transmission line removal robots, form the design scheme of mobile mechanism and operation mechanism, and lay a technical foundation and platform foundation for the study of live working robots on overhead transmission lines. After continuous improvement, the robot can carry out more live working projects and play a greater role in grid maintenance.

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