Research on the Method of Transmission Line Deicing Robot Overcoming Obstacles with Inclined Angle

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Abstract. The current experimental researches on deicing robots are all based on simplified rigid straight lines. In the experiments of actual running lines, it is found that the robot is difficult to cross obstacles with oblique lines. The analysis method of simplifying the transmission line into a straight line has large errors. Analyzed the relationship between the line inclination angle and the robot structure when crossing the actual transmission line, and proposed a new robot structure and optimization plan for the obstacle crossing action; the designed robot integrates obstacle crossing and deicing function, simple structure and easy control; through simulation and The experiment realizes the function of crossing obstacles with inclined lines, which greatly enhances the adaptability and practicability of the deicing robot.

Keywords: Transmission Line; Deicing Robot; Inclination; Obstacle Crossing

1. Introduction
With the development of robotics, the use of deicing robots for deicing has become a reality.[1] The research and development technology of foreign deicing robots is relatively mature, but the deicing robots are relatively bulky and costly, while domestic robot research and development are in the laboratory stage.

Aiming at the icing situation of high-voltage transmission lines, this paper proposes an efficient, thorough and convenient deicing robot, which is mainly composed of a transmission mechanism, an obstacle crossing mechanism, a deicing mechanism, a walking mechanism and a camera mechanism, and it has an online “walking” function.[2] It can automatically cross the obstacles on a high-voltage wire to complete the deicing work between the towers, and can detect the damage of the line.

2. The Overall Structure Design of the Variable Diameter Pipeline Robot
Robot is a complex mechatronics system, involving mechanical structure, automatic control, communication technology and other fields, but the mechanical structure is the basis of the entire system, and it is also the biggest obstacle to the practical application of robots.[3] The high-voltage line of the deicing robot on the transmission line has a certain slope, can it smoothly cross the obstacles and completely and efficiently deicing? This paper designs a new and practical deicing robot for high-voltage power transmission lines.[4] The robot has the following functions: (1) It can crawl smoothly on the transmission line at the expected speed; (2) It has the function of climbing and crossing obstacles; (3) It has the function of preventing Skidding function; (4) The traveling speed is
coordinated with the deicing speed; (5) The ice coating on the transmission line can be removed efficiently and completely. Figure 1 shows the body structure of the deicing robot.

![Figure 1. The body structure of the robot](image)

3. Force Analysis and Finite Element Analysis of Robot Pipe
The deicing robot designed by this research group mainly adopts the control method of human-machine combination and local intelligence, which mainly includes the remote control system, the robot body control system and the execution layer. The composition structure of the entire control system is shown in Figure 2.

![Figure 2. Deicing robot electric control system](image)
The wireless transceiver module adopts the APC220 module. [5] The APC220 module is a highly integrated half-duplex micro-power wireless data transmission module, which is embedded in a high-speed single-chip microcomputer and a high-performance radio frequency chip. [6] It adopts efficient cyclic interleaving error detection and correction coding, and its anti-interference and sensitivity are greatly improved. It can correct up to 24 bits continuous burst error. [7] The system selects the Mega128 of the AVR series as the main control chip, which contains abundant hardware resources and can easily communicate with the wireless transceiver module APC220. The motor is driven by Freescale’s MC3386, which can drive two Motors. [8]

In the remote control mode, it receives the control commands issued by the remote control system, interprets them as the motion sequence of each motor, and sends them to the execution layer for execution; when autonomously crossing obstacles, it detects information based on the knowledge base and sensors, Carry out robot motion planning autonomously and generate motor motions. [9]

4. Finite Element Analysis of Pipeline Robot

4.1. Obstacle Crossing Principle

The basic premise for deicing robots to de-icing on transmission lines is that the robot can travel smoothly on the line. There are obstacles such as shock-proof hammers, clamps, and insulators on the transmission line. In addition to walking along the wires, the key is to overcome obstacles that can cross smoothly and reliably.

When the robot's forearm encounters an obstacle, the obstacle sensor sends a stop signal to stop the robot from moving, and the robot starts to automatically cross the obstacle. The forearm and the rear arm are retracted at the same time. The middle arm clamp is equipped with front and rear sensors that control the forearm and the rear arm respectively. When the front sensor approaches the wire, the forearm stops contracting, and when the rear sensor approaches the wire, the rear arm stops contracting. The wire clamp on the middle arm clamps the wire, and the wire clamp on the rear arm clamps the wire; through the front. The arm lifting and rotating motor raises the forearm to the highest position, the forearm electromagnet pin is retracted, the forearm lifting and rotating motor slows down and rotates the forearm clockwise by 180°, the forearm electromagnet pin pops out, and the position of the forearm is fixed; the forearm moves forward, over obstacles. After that, the forearm electromagnet latch is retracted, the forearm lifting and rotating motor slows down and the forearm rotates 180° clockwise, the forearm electromagnet latch pops out, and the forearm position is fixed; at this time, due to the gravity of the robot, the middle arm clamps the front of the clamp. The sensor is separated from the wire, the forearm is lowered to the wire. Until the front sensor on the middle arm clamp is close to the wire and stops falling; the middle arm clamp and the rear arm clamp release the wire, and the forearm and rear arm extend to the highest point at the same time; the robot walks forward until the rear arm meets. When the obstacle is reached, the robot stops moving. The hind arm uses the same obstacle-climbing principle as the forearm to cross obstacles.

4.2. The Relationship between the Line Inclination and the Size of the Main Robot Mechanism

Overhead line is a continuous and coupled space system structure composed of multi-span conductors, multiple towers, foundations and auxiliary connectors. In the actual transmission line, the geographical environment that the line corridor traverses is more complicated. For example, it passes through large areas of reservoirs, lakes, and high mountains. There are large distances between transmission poles and towers. The terrain of the foundation is different, and the transmission line uses Aluminum is a relatively flexible metal material. The transmission line between two adjacent towers presents an arc shape instead of a tight straight line. There is a certain angle between the short-distance transmission lines on both sides of the clamp and the horizontal plane. This angle is the inclination existing in the actual transmission line. This angle will vary depending on the foundation terrain, the distance between the towers, the type of transmission line and other related factors. There are differences depending on the difference, the inclination angle will make it difficult for the robot to
cross obstacles. In engineering practice, the general overhang angle is $5^\circ \sim 12^\circ$; when the line passes through the mountainous area, the overhang angle it can reach $20^\circ \sim 25^\circ$, and the overhang angle exceeding $25^\circ$ is very rare [10].

The inclination of the line and the position of obstacles constrain the size of the robot body. This research group uses the inclination of the wire and the position of the obstacles as constraints to design and calculate the size of the robot. The rigidity of the wire within a short distance on both sides of the clamp is treated, and the influence of wire deformation is not considered when analyzing the robot's obstacle crossing. The body material of the de-icing robot is aluminum alloy LY12. The structure of the robot and the circuit is simplified into a rigid system during operation. Both the clamp and the rear arm clamp have clamped the wire, and the two-point fixation makes the longitudinal axis of the robot parallel to the same side wire. The line inclination angle is considered here, and the relationship between the line inclination angle and the size of the mechanism when the robot crosses over insulators and cable clamp obstacles is analyzed and calculated.

Conditions that the robot needs to meet when crossing the shockproof hammer:

$$\begin{align*}
 x_2 + x + x_3 + L_3 + x_2 & \leq x_1 \\
 H_2 + H/2 + x_3 & \leq H_3 - H_4/2 \\
 L_4/2\cos\theta + x_2 + x + L + x_2 + L_3/2 & < s
\end{align*}$$  

(1)

Conditions that the robot must meet to cross the insulator:

$$\begin{align*}
 L_4/2 + x_2 + L + x + x_2 + L_4/2\cos\theta & < s \\
 x_1 - (L_4/2\cos\theta + x_2 + x) - x_2 - H_3 \cdot \tan\theta & \geq (d + L_2/2)/\cos\theta \\
 [x_1 - (L_4/2\cos\theta + x_2 + x) - (x_3 - D_2/2)] \cdot \tan 2\theta + H_3 & = x_4
\end{align*}$$  

(2)

The inclination angle of the actual transmission line must exist. In a relatively flat line, the arm extension $x_4$ is small. At this time, the displacement distance of the walking box mainly depends on the structural size of the obstacle; as the inclination angle increases, the increase in $x_4$ is obvious; Symmetrical inclination angle analysis on both sides of the obstacle, the inclination angle of the line must theoretically be less than $25^\circ$, then the robot's obstacle crossing ability fully meets the actual line conditions.

5. Conclusions

By analyzing the actual working conditions of the power transmission line, the relationship between the size of the robot mechanism and the actual line inclination angle is obtained, which makes the robot structure design analysis more accurate; a deicing robot with high maneuverability can be designed to overcome obstacles in the actual inclination line, with a simple structure. The control is simple; the correctness of the robot structure is verified through simulation and experiments, and it can cross obstacles with inclination lines. The robot has good adaptability and strong practicability. Analysis to the actual application.

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