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Design of Wheelset Clamp Type Insulation Coating Mechanism for Bare Wire

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Abstract. The insulation coating of bare wires is an important measure to ensure the safety and reliability of power transmission. The design of the coating mechanism for bare wire insulation coating robots is the key to intelligent coating. This article proposes a new type of wheel group clamping coating mechanism suitable for multiple types of bare wires. It has a conventional sag adaptive design, which can stably walk on the wire, achieve uniform coating, and meet the requirements of different coating thicknesses by adjusting the movement speed. Through mechanical analysis, software simulation, and experimental verification, it is shown that the vibration of the front and rear wheels during operation is not uniform, forming the pitching motion of the entire mechanism. The speed fluctuation remains at around 70mm/s, with a fluctuation rate of about 23%. After 0.2 seconds of coating startup, the operating speed of the nozzle and the output torque of the driving wheel tend to stabilize, proving that the mechanism has characteristics such as stable performance and smooth walking, It provides a new solution for the insulation coating of bare wires and has important application value.

Keywords. Overhead line, coating mechanism, insulation transformation, power robot, smart grid

1. Introduction

With the development of modernization and the widespread application of power equipment, the safety and reliability of power transmission and distribution are receiving increasing attention from people. Bare wires are a common transmission method in high-voltage distribution systems. [1] However, due to the lack of insulation on bare wires, there are high safety hazards. The height of overhead distribution line poles and towers is relatively low, and the problem of insufficient cross span distance often exists in actual operation. For example, exposed overhead lines pass through densely populated areas [2], forests, fish ponds and other areas, there are some ultra-high trees [3] that are difficult to cut down under the line, bird infestation of the line [4], illegal construction, illegal building, illegal fishing and other situations in the line protection area are prone to electric shock, short circuit, tripping and other accidents [5], Causing personal injury and property damage, seriously threatening the safe operation of the line. To solve the problem of insufficient crossing distance of overhead lines, the external surface insulation transformation of bare conductors can play a role in

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protecting line safety and enhancing line stability [6]. Therefore, the insulation coating of bare wires has become a problem that must be solved. Since 2018, the power grid company has explicitly coated insulation materials as a measure to reduce the safety risk of bare conductors [7].

The new type of wheel group clamping coating mechanism proposed in this article is the core mechanism of the bare wire insulation coating robot, and its design plays a crucial role in the coating effect and quality of the mechanism. The coating mechanism has a conventional sag adaptive design, which can maintain stable walking on healthy bare wires with sag, ensuring uniformity of coating. The speed of coating can be achieved by adjusting the movement speed of the mechanism to adapt to different coating thickness requirements. The replaceable wrapped coating nozzle design meets the requirements of multiple models of bare wires. Through mechanical analysis, software simulation, and experimental verification, it is shown that the mechanism has stable performance, smooth walking, compact structure, and easy operation.

2. The Scheme of Whole Machine

The insulated coating mechanism of wheel group clamping bare conductor is composed of a coating nozzle, a clamping component, a switching motor and a walking connection component. The main body of the mechanism is made of aluminum alloy material, the clamping component roller is made of steel material, and the motor is a DC brush motor. The walking action of the coating mechanism is driven by the robot walking, and the opening and closing action is driven by the opening and closing motor to open and close the clamping component. The movement of the coating nozzle follows the clamping component. The coating thickness is achieved by adjusting the coating speed, which is achieved by adjusting the walking speed of the mechanism.

It consists of upper and lower nozzles, upper and lower guide components, opening and closing linear modules, opening and closing motors, connecting plates, spring hinge supports, etc. The upper and lower nozzles are respectively fixed on the upper and lower guide components, with the upper guide component located at the movable end of the opening and closing linear module and the lower guide component located at the fixed end of the opening and closing linear module. When the robot is lifting and hanging wires, the opening and closing linear module is in an open state. After hanging wires, the opening and closing motor drives the upper guide component to move downwards through the opening and closing linear module. When the upper guide component touches the bare power distribution wire, the lower guide component moves upwards until the upper and lower nozzles are closed. After the nozzle is closed, the insulation coating operation can be carried out.

3. Dynamic analysis

For the nozzle structure, its rolling bearing will withstand gravity, and the supporting force and relative static friction force of the cable on the bearing will be ignored, ignoring the effect of friction along the cable direction on the bearing. The force analysis is shown in figure 1.

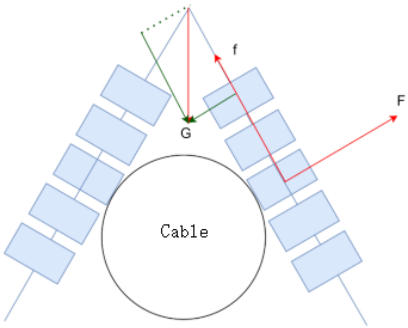

Figure 1. Force analysis of rolling shaft.

The angle between the two rows of bearings is 70 degrees, with a total of 10 bearings on each side for support.

The magnitude of the gravitational action on each bearing is:

$$G' = G/10$$

The force exerted by gravity G on a single bearing is decomposed into the direction of the support force and the magnitude of the axis direction:

$$G_1 = G' * \sin(0.5 * a)$$

$$G_2 = G' * \cos(0.5 * a)$$

So the force equation for the nozzle wheel to maintain balance in the horizontal direction is:

$$F = G_1$$

$$f = G_2$$

The friction force can be obtained through positive pressure and friction factor:

$$f = u_0 * F$$

After comprehensive analysis, it can be concluded that:

$$u_0 = \cot(0.5 * a)$$

The above formula is the critical value of the friction factor between the bearing and the cable. When the friction factor exceeds this value, the bearing can rotate freely, while when the friction factor is less than this value, the cable will experience dry friction with the bearing.

4. Simulation Analysis

When conducting dynamic analysis of the coating mechanism, the conditions were simplified and the motion state of the walking mechanism could not be accurately represented. Therefore, ADAMS software is used to simulate and analyze the motion process of the walking mechanism, providing a basis for the development and modification of the mechanism. The imported model is shown in the figure 2.

Figure 2. Coating mechanism model.

The following dynamic results were obtained after simulation:

Figure 3 reflects the Pitch value of the nozzle center of mass in the forward direction, and the fluctuation of this value reflects the non-uniform vibration of the front and rear wheels during operation, forming the pitch motion of the entire mechanism.

Figure 4 reflects the speed of the nozzle during the forward process, and its speed fluctuation reflects the speed stability of the entire mechanism. From the figure, it can be seen that its speed remains fluctuating around 70mm/s, with a fluctuation rate of about 23%.

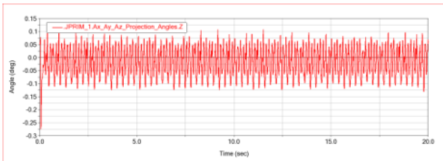

Figure 3. Center of Mass Deflection Angle.

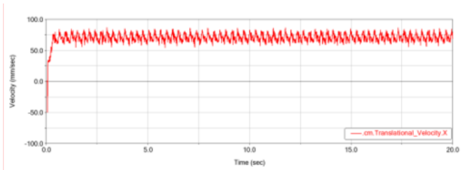

Figure 4. Centroid velocity curve.

Figure 5 shows the motion displacement and velocity curve of the nozzle center of mass. At the beginning of 0.2 seconds, the velocity increases several times, and the displacement change gradually increases. After exceeding 0.2 seconds, the operating speed of the mechanism fluctuates steadily, and its displacement also increases steadily without significant shaking.

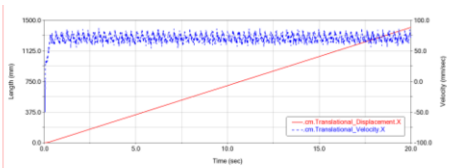

Figure 5. Centroid displacement velocity curve.

Figure 6 shows the variation curve of the output torque of the driving wheel, with a variation of 100Nmm, which reflects the output torque of the driving wheel when the mechanism moves on the cable.

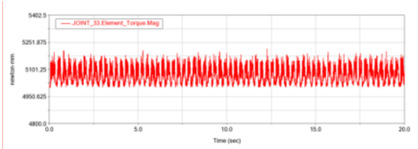

Figure 6. Change in output torque of the driving wheel.

5. Real Machine Test

Insulate and coat bare wires without slope, and measure the diameter of the coated wires at different positions. The testing process is shown in figure 7.

Figure 7. Coating experiment process.

The wire model is steel core aluminum stranded wire LGJ-70/10, with an outer diameter of 11.4mm. The first group is set with a walking speed of 4.9m/min, an extrusion speed of 0.6L/min, and a coating thickness of 2.5mm. The second group is set with a walking speed of 4.7m/min, an extrusion speed of 0.6L/min, and a coating thickness of 2.8mm. The third group is set with a walking speed of 4.0 m/min, an extrusion speed of 0.6L/min, and a coating thickness of 3.0mm. Record the thickness of three sets of experimental coatings as shown in table 1.

Table 1. Insulation layer thickness data after coating.

Coating length/cm	Thickness of the first set of insulation layer/mm	Thickness of the second set of insulation layer/mm	Thickness of the third group of insulation layer/mm
0	6.9	2.25	7.455
1	7.055	8.135	6.72
2	4.245	3.28	3.435
10	2.635	2.725	3.15
20	2.69	2.78	3.095
30	2.63	2.81	3.335
50	2.475	3.03	3.18
70	2.495	2.945	2.935
80	2.54	2.935	3.145
105	2.635	2.855	3.28
107	11.21	11.05	10.515
108	10.21	2.82	2.455

Based on the analysis of the above data, it can be concluded that the insulation coating thickness of a small section of wire before and after coating is completed will be too large. This is because the start and stop of coating require manual control, which may result in certain control errors; The middle section of the coating is automatically controlled by the parameters set by the control program, resulting in good uniformity of the coating and meeting the thickness setting requirements at the thinnest point.

6. Conclusions

A new type of wheel group clamping coating mechanism proposed in this article is suitable for insulation coating of multiple types of bare wires. This mechanism has a conventional sag adaptive design, which can stably walk on healthy bare wires with sag, achieving uniform coating. By adjusting the movement speed, different coating thicknesses can be achieved. Mechanical analysis, software simulation, and experimental verification show that the mechanism has stable performance and smooth walking, providing a new solution for the insulation coating of bare wires. Compared to insulating sheaths, coated insulation materials have advantages such as longer lifespan and lower material density, making them economical, fast, and reliable. The design and application of this institution provide an effective solution for the insulation transformation of bare wires, which has important application value.

Acknowledgments

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