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Optimization Design of the Wire Repair Tool for the Maintenance Robot with Charged Used in Substation

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Abstract. With the continuous development of the society, the development of the power grid is faced with the demand for high power supply reliability and high power quality, and there are fewer and fewer opportunities for power outage maintenance on important and critical lines. The damage of the wires in the overhead lines of the substation will affect the efficiency of the transmission. In this paper, the optimization design is carried out on the basis of the wire repair tool. The optimized tool adopts the structural design of the wire repair tool with insulating material to ensure the insulation performance. In this paper, the optimization design of the repair patch, clamping arms, transmission mechanism with worm gears and worm shaft, and wire gathering device is carried out. The structure, the motor drive system and control principle of the tool are also improved. The wire repair tool has been optimized for miniaturization, light weight, and intelligence

1. Introduction

The wire repair tool for the maintenance robot with charged used in Substation is mainly used in substations to repair the broken strands of overhead lines in substations of 220kV to reduce the danger level and ensure the power supply of the line. At this stage, the repair work of wires is mainly based on manual power cuts. The on-site personnel finds broken strands during the inspection process and makes markings. During power outage and overhaul, the repaired strands are repaired (lines which strength loss of the conductor at the same location has exceeded 5% of the total breaking force but less than 17%, and the cross-sectional area damage does not exceed 25% of the total cross-sectional area of the conductive part at the same time). At present, there are mainly three types of wire repair tools at home and abroad, which are respectively 10kV wire crimping pliers developed by State Grid ShangDong Electric Power Research Institute, as shown in Fig. 1; the overhead line conductor crimp repair tool developed by the Quebec Institute of Hydraulic Research in Canada; the first generation of wire repair tool used in substation developed by Shandong Luneng Intelligent Technology Co., Ltd, as shown in figure 2. Compared with the three tools, the wire crimping pliers and the first generation of wire repair tool used in substation have poor insulation properties and cannot guarantee the safety of the tools during operation. Overhead line wire crimping repair tools are only applicable to overhead lines. It cannot be used in substations with voltage levels of 220kV and below.

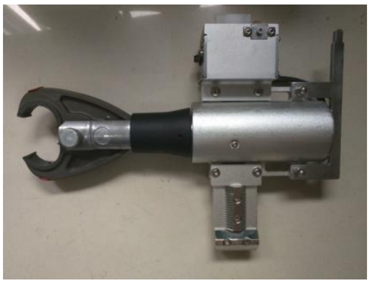

Fig.1 The wire crimping pliers

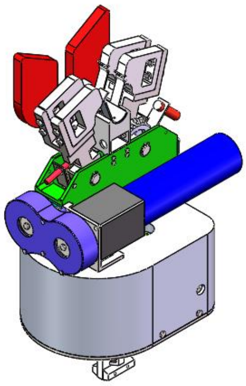

Fig.2 The first generation of wire repair tool used in substation

The second-generation of wire repair tool for the maintenance robot with charged used in Substation aims at solving the problems and insufficiency in the development process of the first-generation of wire repair tool used in substation, as shown in Figure 3.

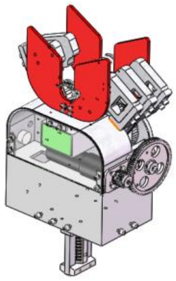

Fig.3 The new wire repair tool

2. Design Optimization

The second-generation wire repair tool is correspondingly improved on the basis of the first edition, and designed for miniaturization, light weight, and intelligence. In the structural design, the overall insulation of the POM material is used to reduce the overall weight on the basis of the overall insulation of the tools.

2.1. Mechanical Improvement

2.1.1. Repair Patch

The material of the repair patch was changed to 2A12 and 1060. Compared with the first version of 6061, the material of 2A12 and 1060 which has low stiffness coefficient can be easy to crimp and reduce energy loss under the premise of guaranteeing the crimp resilience, and the arc transition and length of the repair patch are also adjusted according to the test. The positioning of the two pins in the original design plan was changed to trapezoidal pin axis positioning at both ends in response to the problem of rotation during crimping in the first version through experimental design. The opening of

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both ends of the repair patch is in transition with the trapezoidal pin shaft. This improvement effectively solves the fixing problem of the repair patch and prevents the problem of the rotation of the repair patch during wire crimping. The repair patch is shown in fig. 4, and the assembly is shown in fig. 5.

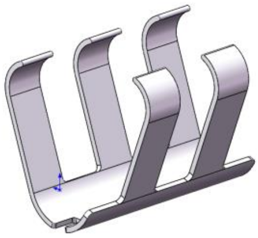


Fig.4 The repair patch

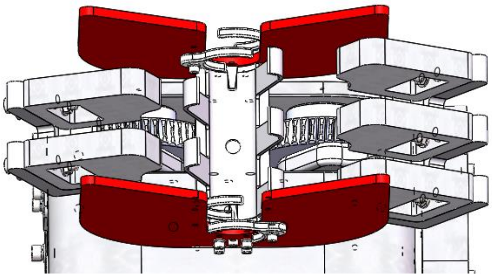
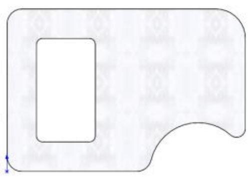


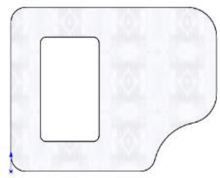
Fig.5 The wire repair tool with the repair patch

2.1.2. The Optimization Process of Gripping Finger

The effect of the wire after crimping is not tightly crimped in the first version of the prototype, and the presence of voids can cause excessive contact resistance and then cause heating. The reason why the wire crimping patch is not tightly crimped is that the arc at the portion where the finger grips the patch is not completely in contact with the outside diameter of the wire. Therefore, the optimized design of the gripping finger is shown in Fig. 6(a). The crimped portion is subjected to an extension process so that it fits as closely as possible to the outer diameter of the wire to ensure a larger crimped surface. However, there is a phenomenon that the crimped and repaired patch are externally crimped, and the crimping effect is greatly reduced after the crimped by the gripping finger after the extended treatment in the course of the test. The extension processing of the crimped portion does not satisfy the requirements, and the gripping head is further optimized as shown in Fig.6(b). The arc radius is optimized on the basis of the gripping head of the first version of the prototype and the repair patch is optimized so that the contact portion is in contact with the arc surface to reduce the crimping gap at the same time.



（a）



(b)

Fig.6 The optimization design of gripping finger

2.1.3. The Optimization Design of Clamping Arms

In the first version of the clamping arm, a clamping solution of 2+2 is adopted, and in the optimization design, a 3+2 design scheme is adopted. As shown in Fig.7 , the advantage is that the crimping range is larger and can be further improved to guarantee the quality of wire crimping.

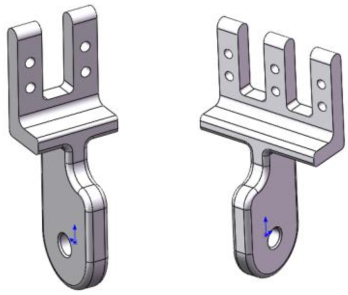


Fig.7 The clamping arms after optimization

2.1.4. The Optimization Design of Transmission Mechanism

The optimized transmission mechanism adopts a split and combined structure as shown in Fig. 8, that is, the worm gears and the worm shaft adopt a split structure. The worm gears and the worm shaft are separately processed and assembled, which greatly reduces the difficulty of machining the worm shaft, and improves the machining accuracy of the transmission and reduces the processing cost of the worm gears and worm shaft at the same time.

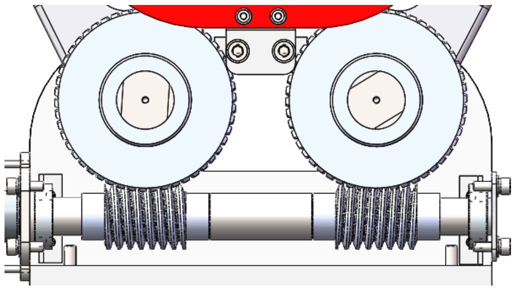


Fig.8 Transmission mechanism with split type

2.1.5. The Optimization Design of Wire Gathering Device

Two gathering parts are installed in the front of the wire gathering device to increase the effect of the gathered line compared with the first prototype, as shown in Fig. 9 (a), and the details as shown in figure 9 (b).

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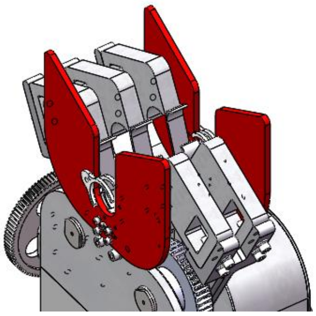
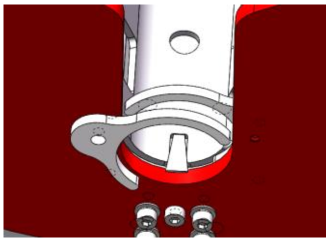


（a）



（b）

Fig.9 The optimization design of wire gathering device

2.2. The Optimization Design of Drive System

2.2.1. The Improvements of Drive Motor

The drive motor adopts the imported maxon DC motor as the power source. The maxon motor has the advantages of small size, high speed, high control accuracy, and stable output, which is beneficial to the miniaturized optimization design of the wire repair tool.

2.2.2. Communication System

The second-generation wire repair tool adopts remote control and performs wireless communication with the Beckhoff controller on the robot body. The wireless transceiver module has a buckle, which is clamped on the installation slide rail. The installation guide rail is fixed on the lower panel of the control box shell by bolts. The function of wireless transceiver module is remote wireless communication. The battery is matched with the gap of the battery holder, and the battery holder is fixed on the shell by bolts. The main function of the battery is to supply power to the control panel of the wire repair tool, the wireless transceiver module, the drive motor, and the information collection device. The flow scheme diagram of communication system of the second-generation wire repair tool is as follows:

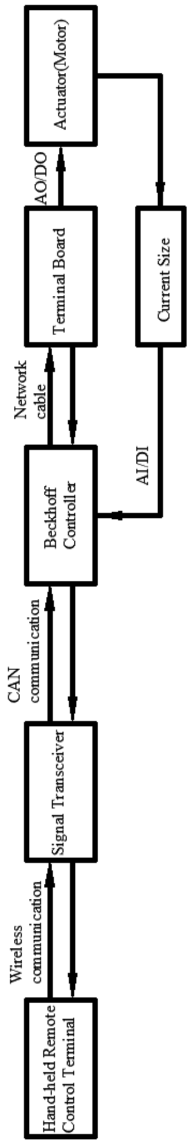


Fig.10 The flow scheme diagram of communication system of the second-generation wire repair tool

3. Conclusions

The wire repair tool for the maintenance robot with charged used in Substation is used to repair the broken strand conductor in the overhead line in the substation, reduce its hazard level, and guarantee temporary power supply. This paper optimizes and improves the structure and drive system of the first version of the wire repair tool. The second generation wire repair tool is designed to solve the deficiency of the first version wire repair tool in the prototype test and improve the wire crimping quality and efficiency.

Acknowledgements

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