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The Design of Internal Curing Winding Machine for Tapered Composite Telegraph Pole

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Abstract. This paper designs a four-axis winding machine for the tapered pole based on the IPC and the embedded motion controller. Steam is introduced to the inside of the mandrel to heat and cure the composite. The synchronous movement control of the carriage, the beam, and the fiber pay-out eye is realized based on the electronic gear control. In this paper, the winding linetype and the control law, mandrel structure optimization, the mechanism and the composition of control system of the winding machine are described in detail respectively. Molding experiments indicate that the winding pattern of the winding machine is uniform and stable, the heat transfer efficiency of the optimized mandrel is high and the temperature distribution is uniform, so the synchronous uniform curing of the tapered telegraph pole is realized.

Keywords: composite, tapered telegraph pole, winding machine, control system

1 Introduction

Reinforced concrete telegraph towers and wooden poles both have defects, such as heavy weight, inconvenience for transport, vulnerability to pests, and perishability under the long-term erosion of the water [1][2]. With obvious advantages of high strength, corrosion resistance, light weight, good electrical insulation, etc., the composite material telegraph poles have a wide prospect in the electrical power transmission as the substitute of traditional poles [3].

The traditional two-axis winding machine has less degree of freedom, and the form of exercise is too simple, not suitable for asymmetrical tapered pole molding. Meanwhile, traditional external curing has low efficiency, and the product easily has the defects of voids and delamination, which lowers the strength of products. Internal heating curing realizes the in-situ molding of composite products, and it well controls the fiber content of the composite material and restrains the fiber relaxation, greatly improving the efficiency and the molding quality of the composite. Nevertheless, internal heating curing has the problem of the asynchronous curing of the composite

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due to the uneven mandrel surface temperature, so new internal heating curing multi-axis winding machine which is suitable for cone-shaped body molding is needed to realize the industrialized manufacture of the tapered composite pole.

This paper designs a four-axis winding machine for the tapered pole based on the IPC and the embedded motion controller. Steam is introduced to the inside of the mandrel to heat and cure the composite. The synchronous movement control of the carriage, the beam, and the fiber pay-out eye is realized based on the electronic gear control. In this paper, the winding linetype and the control law, mandrel structure optimization, the mechanism and the composition of control system of the winding machine are described in detail respectively.

Firstly, the winding linetype and the control law are analyzed according to the shape characteristics, and the formulas to calculate the winding angel are presented. Furthermore, the law of motion of the carriage and the spindle is analyzed, and the control project is decided. Secondly, in order to solve the asymmetrical temperature distribution of the tapered mandrel, the heat transfer and flow field model of the steam inside the mandrel are established according to the principle of the internal curing process, and the heat transfer process of the steam is simulated by using the finite element method. Based on that, the relationship between the temperature distribution and the mandrel structure is obtained, and the mandrel structure is optimized by adjust the number, the axial distribution, and the diameter of the holes, and the diameter of the core pipe. Finally, the mechanism and the composition of control system based on the Trio motion controller are introduced, and the control principle and control process of the winding machine are described in detail. Molding experiments indicate that the winding pattern of the winding machine is uniform and stable, the heat transfer efficiency of the optimized mandrel is high and the temperature distribution is uniform, so the synchronous uniform curing of the tapered telegraph pole is realized.

2 Winding Linetype and Control Law Analysis

The winding linetype and the control law are analyzed according to the shape characteristics, and the formulas to calculate the winding angel are presented in this section.

2.1 Winding Linetype Design

The winding lintype is designed based on the analysis to the structure characteristics of the tapered pole. Finally the formula to calculate the winding angel is presented.

2.2 Winding Control Law Analysis

The control scheme of the system introduced is to control the speed of the spindle in open loop way by using the Trio Motion Controller. The carriage moves with the spindle by the connection of electric gear. The speed ratio between the carriage and the spindle is *K*. The value of *K* changes with the position of the carriage. The motors of the beam and the fiber pay-out eye are connected to the spindle in the same way, and the speed ratio can be calculated according to the change of fiber band width [4][5].

The motion controller controls the carriage, the beam and the fiber pay-out eye with analog in closed loop way. And the P.I.D control is used to ensure the accuracy.

3 Internal Curing Principle and Mandrel Optimization

3.1 Internal Curing Principle

The mandrel structure of the winding machine introduced is shown as Fig. 1. There is a hollow core pipe inside the mandrel which allows the steam to introduce into the cavity inside the mandrel to heat and cure the composite.

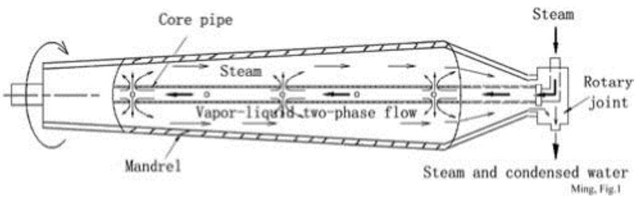

Fig. 1. The mandrel structure of the winding machine

The molding process of the thermosetting composite can be basically divided into three sections. First one is to introduce high temperature steam into the core pipe. When the temperature reaches to demand, keep it to a certain level for a certain time. Then, the cooling process starts.

3.2 Mandrel Structure Optimization

In order to improve the uniformity of the mandrel temperature, the heating process of the mandrel is simulated by using the finite element method. The simulation shows that the low-temperature position is the tail of the mandrel, and the reason is the insufficient flow. The following methods are presented to solve this problem.

1. Increase the number of the holes.
2. Increase the diameter of the holes.
3. Increase the diameter of the core pipe.

4 Design of the Tapered Pole Winding Machine

The winding machine is composed of spindle system and the carriage system. The spindle motor drives the mandrel to realize the variable speed rotation. Several servo equipments drive the carriage, the beam and the fiber pay-out eye to realize the advance and return movement along the axial direction of the mandrel.

The winding machine presented in this paper combines winding, curing, and demolding process. The system controls the servo equipment of each axis by the Trio Motion Controller according to the parameter received from users.

5 Conclusions

1. This paper designs a four-axis winding machine for the tapered pole based on the IPC and the embedded motion controller. Steam is introduced to the inside of the mandrel to heat and cure the composite.
2. The winding linetype and the control law are analyzed according to the shape characteristics, and the formulas to calculate the winding angel are presented. According to this, the law of motion of the carriage and the spindle is analyzed.
3. The mandrel structure is optimized by adjust the number, the axial distribution, and the diameter of the holes, and the diameter of the core pipe. Molding experiments show that the heat transfer efficiency of the optimized mandrel is high and the temperature distribution is uniform.
4. The control system based on the Trio Motion Controller of the winding machine is designed. Molding experiments show that the winding pattern uniform and the winding machine runs stable.

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