Design of electronic control system for Z-pin four-axis numerical control implant reinforcement equipment

H H Chen, F J Meng, D S Zhang, L Q Miao, H B Guo, J Du and M Sang
ChangChun Equipment Technology Research Institute, Changchun 130012, China
Email: 173965139@qq.com

Abstract. Using the high-stability controller Delta AS324MT and the advanced high-precision servo system through the CANOPEN bus communication mode, the z-pin implantation is controlled with high precision and high efficiency, and the second encoder is applied to the qualifying mode to completely implement the closed-loop control of the qualifying length. Solve the technical problems such as the inaccuracy of the length and position, control the position precision and the precision of the implantation through the four-axis numerical control implantation method, and achieve the action control of the cutting by the joint pneumatic loop control. The actual test results show that this method improves the accuracy and efficiency of Z-pin implantation, greatly saves the labor cost, and reduces the harm of manual implantation to the human body.

1. Introduction

The technique of Z-pin implanting three-dimensional reinforcement is to implant a composite slender bar with a diameter of about 0.5 mm into an uncured laminated member, the Z-PIN implanted laminates are mechanically and chemically bonded to form a three-dimensional reinforced structure, which improves the bonding strength between layers. At present, the well-known technique is that the stress state of Z-pin varies in different stages. At the initial stage of implantation, Z-pin begins to enter the prepreg layer, most of which is in the foam carrier, due to the limited support of the foam carrier and the great implant resistance of the layer, Z-pin inclination and bending are easy to occur at this time. Z-pin implant depth does not match the set parameters. The precise positioning method of high-precision four-axis multi-root Z-pin implant length has not been explained in detail in other literatures. The scheme can achieve the following technical parameters: Z-pin diameter: 0.4-0.6 mm; implantation density: 3 x 3.5 x 5.10 x 10mm; outer diameter of the tray: 200 mm; thickness of the Foam Board to be implanted: 30 MM; implantation precision: 0.2 mm.
2. Hardware system design

Using the touch screen W127b high-resolution product made by Delta Company, the multi-screen switch is presented on the touch screen to realize the process parameter setting, real-time monitoring, and manual automatic switch and so on. PLC uses Delta Small and medium-sized controller AS324MT, this controller can realize differential signal output, signal stability, four servo drivers, x axis servo system, Y axis servo system, Z axis servo system and a axis servo system, are controlled by multi-channel pulse to control the actuator servo motor accurately. The core of the whole system is the control unit PLC, which controls the position of the x axis servo system and the Y axis servo system on the X and y planes respectively, and the depth of the Z axis servo system on the direction of the implanted drive axis, the A axis realizes the control of the length of the outgoing line, and on this basis, the position is precisely controlled by the closed loop with the second encoder. At the same time PLC through the external expansion of digital module to achieve control pneumatic solenoid valve [4], solenoid valves are used in double electronic control form, can reliably achieve cutting action. The basic operations are divided into single-step operations and continuous operations.

The specific work flow is as follows: first through the X-AXIS, y-axis two-axis linkage to make the
implant head to a predetermined position, and then through the a-axis line-out to achieve the required length, and then through the z-axis implantation action, followed by the start of the air mill, Z-pin compression, slice forward, slice backward to complete a cycle of cutting action. Then through the control of the air way to achieve a slice forward and backward once to complete a cutting action, pneumatic control block diagram as shown in figure 4 below.

![Flow Diagram](image)

**Figure 4.** flow diagram.

3. Software system design

The main interface is shown in figure 5. The SERVO axis in the upper left shows the current position of the X, Y and Z axes, the axis shows the line length, and the upper right shows the alarm warning. It mainly includes status display interface, position offset setting, process parameter setting, speed setting, manual setting, etc. Left foot shows a single step operation, that is, a z-pin insert cutting action, the lower right is automatically completed snake z-pin implantation action, in any position can
be suspended and continue to run the operation. A reset indicates that the program is back to its original state.

![System monitoring interface](image)

**Figure 5.** main interface.

Click the manual button on the Menu Bar and the following screen appears in manual mode. Of course manual mode can also automatically walk incremental distances. These include manual operations on the A, X, Y, and Z axes, which are often used in system debugging. The utility model is also provided with an air mill cylinder, a cutting cylinder and an action control for clamping the cylinder. The manual interface the interface is as follows.
Click on the menu bar speed setting button, then the following interface is the manual mode of the speed setting. Click the process parameter setting button in the Menu Bar, the following interface appears for the parameter setting mode. You can reset the displayed parameters. In the parameter setting interface, the number of internal cycles and the number of external cycles, i.e. the length and width of each cycle can be set, and the length, the number of cutting roots, the distance, the length of pressing in and the speed setting of each servo shaft can be set. The parameter setting interface is shown in the following figure.

![System monitoring interface]

Figure 6. manual interface.
4. Motor selection

1) type selection of z-axis drive motor

According to the force analysis, the servo motor is selected by the output Torque of the motor. Polymethacrylimide rigid foam (PMI) was selected as foam carrier, and the tensile extrusion Z-pin of carbon fiber reinforced epoxy was used as raw material. The drive roller radius is 9 mm, the total transmission efficiency is 90%, and the root number of Z-pin is 10. According to the formula, the motor output Torque \( m \) satisfies:

\[
 m \geq 0.3N \cdot M
\]

Take Factor of safety 2, so the motor output torque should not be less than 0.6 N M, choose Delta Motor ASD-A2-0421-M.

2) selection of x axis foam carrier drive motor

The friction force between the platform and the guide rail is the main resistance to be overcome when the platform moves horizontally on the guide rail driven by the motor directly, and the friction loss of the rotating shaft is neglected, it is considered that the tension of the synchronous belt is equal and equal to the resistance of the moving platform, so the driving torque of the motor should be: *

\[
 M / R \geq mg
\]

In the formula: 85% for the total transfer efficiency; \( r \) 15mm for the radius of the synchronous belt pulley; 0.2 for the Friction Coefficient between the platform and the Guide Rail; \( m \) for the platform and the load 10kg; \( g \) for the gravitational acceleration, 9.8 MS2. The substitution formula is:

\[
 m \geq 0.45 \text{ NM}
\]

Take Factor of safety 2, so the motor output Torque is not less than 0.8 n M, select Delta Motor Asd-a2-0721-m. The other two servo shaft type selection calculation method is the same as above.
5. Conclusions

The electronic control system of Z-pin four-axis numerical control implant can be designed to solve the technical problems such as the inaccurate positioning of length and position, the utility model greatly saves the Labor cost and reduces the injury to the human body caused by the manual implantation. The experiment shows that the design of the system is reasonable and feasible. The equipment can be widely used in aerospace composite material processing and other industrial fields. The equipment and products designed are shown in figures 8 and 9.

![Figure 8. device image.](image1)

![Figure 9. product image.](image2)

References

[1] Zhou zufu. 2015 Composite Materials Science Wuhan: Wuhan University of Technology.

[2] Chen xiangbao. 2014 Handbook of Polymer Matrix composites BEIJING: Chemical Industry Press

[3] Vasiliev V V, Barynin V A, Razin A F. 2016 Composite Structure 94(3) 1117~27

[4] Shu weiguo. 2018 Proceedings of the seventeenth annual conference of FRP / COMPOSITES C. Guangzhou 12 286 ~ 8

[5] Edited by Institute of Aeronautics of China. Design Manual for Composite Structures M. BEIJING: Aviation Industry Press, 2001

[6] Zhen Huasheng. 2007 J. Aerospace Materials Technology 4 14-6

[7] Du shanyi. 2017 Journal of composite materials 241 1-12

[8] Bansemir H, Haider O. 2008 Cyogenics 138(1) 51-9

[9] Gao keqiang etc. 2010 J. New Materials Industry 12 4-7

[10] Liu liqun etc. 2015 J. Energy Technology 316 331-7