Research and development of the control system of space multi-dimensional profiling and planing based on PLC

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Abstract. Aiming at the complex processing problem of a rectangular composite plate with warpage in space to remove both sides of the frame and ensure the maximum of the inner core plate of the composite plate after removing both sides of the frame, a space multi-dimensional profiling and planing control system based on PLC is developed. According to the process requirements, the overall design of the space profiling and planing system is carried out, focusing on solving the problem of planing the space warping of the composite board frame. In the aspect of system hardware, the scheme selection, mechanical structure design, pneumatic control scheme design and electrical control scheme design are carried out; In the aspect of system software, based on the TIAPortal software platform, the PLC profiling program is compiled, and the human-computer interaction of the touch screen is designed. The profiling and planing process of composite plate is realized on the prototype, which improves the production efficiency while realizing automation.

Keywords: Profiling; Composite plate; PLC.

1. Introduction

As shown in “Fig.1”, in order to hot-roll a special powder material into a plate, the special metal powder is paved in a special low-carbon steel frame, and the steel frame is covered with metal steel sheets on the upper and lower sides, and then the metal steel frame and the steel sheets coated on the upper and lower sides of the steel frame are hot-rolled to obtain a rectangular composite plate containing special material plate (referred to as core plate) and covered by low-carbon steel materials.

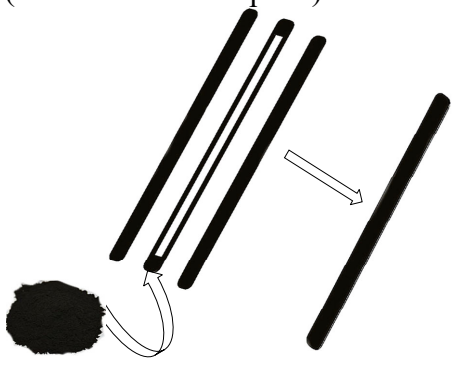


Figure 1. Schematic diagram of composite plate composition.

The composite plate will have obvious warpage during the hot rolling process and after cooling. The expansion and contraction of the steel plate plane caused by warpage will cause the width of the plate to change. At the same time, irregular wavy space warpage will occur in the spatial direction, as shown in “Fig .2”.

Figure 2. Hot rolled composite plate.

According to the processing requirements, it is necessary to take out the core plate in the composite plate as much as possible. In the early period, the frame of the composite plate was removed by the pickling steel sleeve, which dissolved the outer steel sleeve of the outer composite plate to obtain the inner core plate material. This method requires a large amount of nitric acid solution, which is costly and polluting. The current processing method is manual processing. The frame is cut off with a plate shearer and the surface steel sheet is torn off manually. Manual processing is not only labor-intensive, but also the most important thing is that the plate shear can only cut in a straight line, and the utilization rate of the core plate is the lowest. Because the core plate material itself is very expensive, manual processing costs a lot. Therefore, this paper designs a set of automatic space profiling and planing system for the frame of the composite board, which can realize the automatic planing to remove the frame on both sides of the composite board and maximize the utilization rate of the core board.

2. Overall structure and working principle of the control system for spatial multi-dimensional profiling

2.1 Mechanical structure of the control system for profiling and planing of composite plates

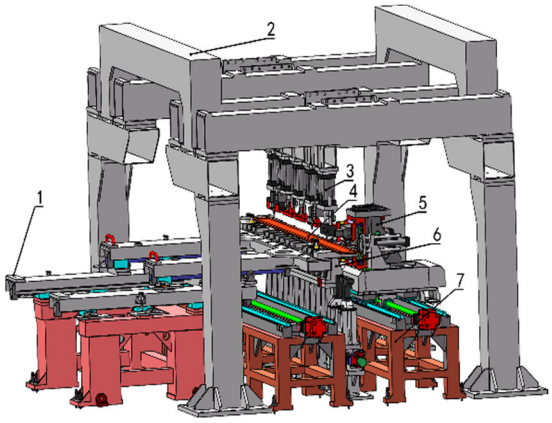
The typical parameters of composite plate shape are shown in “Table I” below.

Table 1. Shape parameters of composite plate

Material plate parameters	Value (mm)
number	705#
length	2350
width	167
thickness	3.6
Maximum warpage in Z direction (thickness)	60
Maximum warpage in Y direction (width)	61
Width of border to be removed on both sides	30

According to the shape characteristics of the composite plate, the composite plate belongs to the thin and long thin plate which is difficult to be processed. The plate is narrow and thin, and the plate body is warped. Reasonable structural design and control system become the key to realize automatic processing, improve processing efficiency and ensure processing accuracy [1].

The mechanical structure of the profiling control system is shown in “Fig.3”. The whole control system is mainly composed of six parts, namely, feeding table, frame, clamping mechanism, profiling tool holder, machining table and linear slide.



1 - feeding table; 2 – frame; 3 - clamping mechanism; 4 - composite plate;
5 - profiling tool rest 6 - machining table 7 - linear slide seat

Figure 3. Mechanical structure diagram

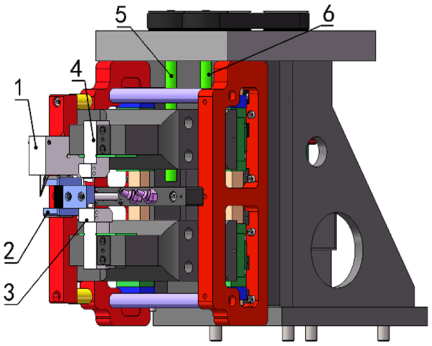
2.2 Working principle of profiling control system

After power-on, the functional sequence of the system includes:

(1) clamping and positioning. After the composite plate is sent to the processing table through the feeding table, the positioning sensor feeds back the position information of the composite plate to the PLC. The controller controls the solenoid valve to extend the clamping cylinder, and presses the parts of the composite plate except the frame on the horizontal working table. During clamping, the pressure is not applied to the frame on both sides of the composite plate, After pressing, the frame part of the composite plate still has a certain degree of warping and side bending.

(2) After the completion of loading and clamping of the composite plate, the laser sensor is used to collect the warpage in the vertical direction of the frame and the electronic ruler sensor is used to collect the bending data in the width direction of the frame, providing a data basis for the subsequent automatic curve planing process.

(3) Through the analysis of the process object, the profile planing adopts PLC electric control profile planing, which is different from the traditional reciprocating linear planing. The electronically controlled profiling tool holder is shown in “Fig.4”. The profiling tool holder has four servo linkage transmission shafts, including a long-distance straight-line sliding X-axis slide rail, a short-distance Y-axis, two Z-axis mounted with the planing tool moving up and down in the vertical direction. The upper and lower planing tools of the Z-axis clamp the composite plate in two planing tools. After fitting calculation, with the cooperation of the four transmission shafts, the planer moves with the frame warping and side bending interpolation, so that the movement tracks of the upper and lower planers adapt to the warped frame of the composite plate, and a right-angle groove is planed by multiple layered cutting, so that the core plate and the frame are separated, so as to achieve the purpose of profiling.



1 - Laser sensor; 2 - Electronic ruler sensor; 3 - Z2 axis planer;
4 - Z1 axis planer; 5 - Z1 axis; 6 - Z2 axis

Figure 4. Schematic diagram of profiling tool holder

The profiling planer has a total of left and right sets of planing tool holders, which are used for profiling and planing the left and right frames of the composite plate.

(4) After the removal of the frame, the controller controls the pneumatic transfer gripper to transport the composite plate out of the processing platform and into the subsequent processing process.

The specific work flow of the profiling control system is shown in “Fig.5”.

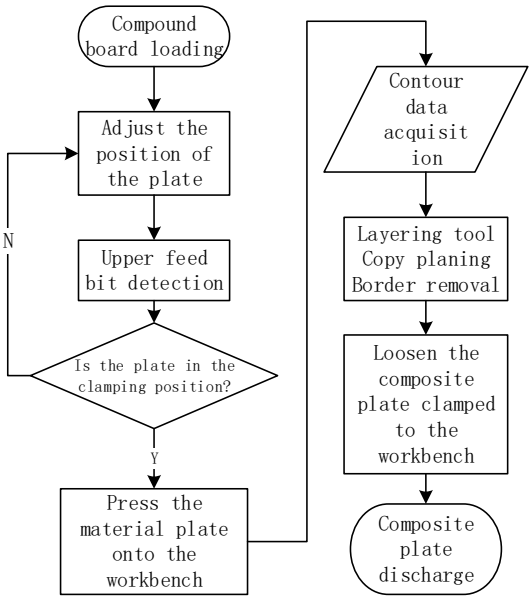
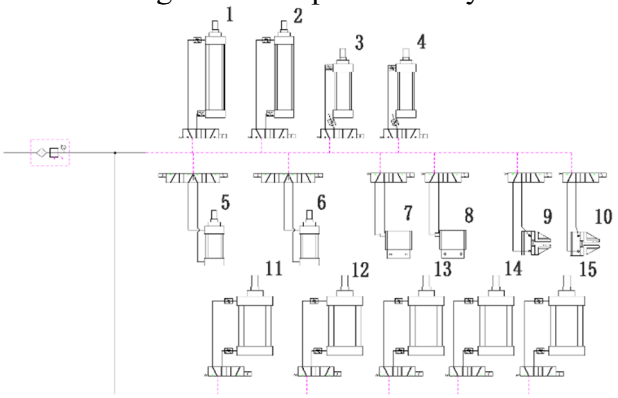


Figure 5. Working flow chart of profiling and planing system

3. Design of pneumatic control system

According to the control process flow of profiling and planing, the pneumatic structure is used in the feeding, data collection and feeding processes from the clamping of the composite plate on the workbench to the removal of the frame of the composite plate into the subsequent processing process flow, and the pneumatic operation task is completed under the action of the PLC controller. The pneumatic system is composed of air pump, air source, solenoid valve, cylinder, speed control valve, magnetic switch, etc. The schematic diagram of the pneumatic system is “Fig.6”.



1 - Clamping collet cylinder; 2 - Clamping collet cylinder;

3 - Transfer cylinder; 4 - Transfer cylinder; 5 - Data acquisition mechanism cylinder; 6 - Data acquisition mechanism cylinder; 7 - Clamping pneumatic collet; 8 - Clamping pneumatic collet; 9 - Transfer pneumatic collet ;

10 - Transfer pneumatic collet; 11 - Workbench compression cylinder;

12 - Workbench compression cylinder; 13 - Workbench compression cylinder; 14 - Workbench compression cylinder; 15 - Workbench compression cylinder.

Figure 6. Pneumatic schematic diagram

4. Electrical control system design

4.1 Hardware composition design

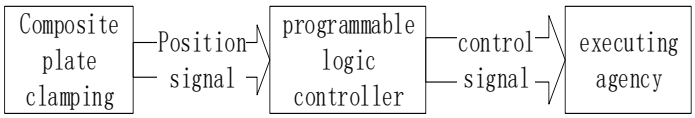


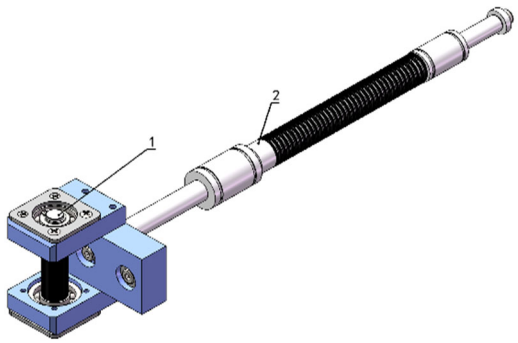
Figure 7. Control system structure

4.2 Profiling data acquisition

The data acquisition mechanism is equipped with a laser sensor and a linear displacement sensor. The laser sensor and the linear displacement sensor collect the composite plate shape data. The laser sensor uses the current analog quantity and analog quantity signal AI module for data transmission. The linear displacement sensor uses the voltage analog quantity through the signal transmitter and analog quantity signal AI module for data transmission. In this paper, the frame warpage and side bending are collected by the sensor every 10mm, and the discrete point data reflecting the shape warpage of the composite plate is obtained, and the data is transferred to the PLC for storage and processing.

The light emitted by the laser sensor is irradiated on the surface of the composite plate frame, and the X-axis movement drives the sensor to move and irradiate the composite plate, so that the light spot moves along the incident optical axis. If the light spot moves x 'on the photosensitive surface of the detector, the triangular measurement method is used to non-contact collect the shape data of the upper and lower sides of the warped composite plate according to the triangle similarity principle and the ratio relationship of each side, Measure the warpage data of the upper and lower sides of the frame relative to the processing table [2].

The linear displacement sensor is used to measure the side bending data of the composite plate with a width of 30mm relative to the standard frame by touching both sides of the composite plate against the surface of the sensor measuring guide wheel. The X-axis movement drives the sensor to move horizontally to measure the composite plate. The measurement method is shown in the “Fig.8”.



1 - Measuring guide wheel, 2 - Displacement sensor

Figure 8. Measuring principle diagram of displacement sensor

1) PLC model selection

The data processing module includes CPU module, signal module, communication module, and programming software, among which the controller PLC is the automation core of the whole profiling control system.

The profiling control system needs high stability and fast computing ability. It controls 8 servo motors at the same time and selects Siemens S7-1500 high-performance PLC. This PLC has fast processing speed, strong networking ability, high diagnosis ability and high security. It is equipped

with a 32-point word quantity input module, a 16-point digital quantity output module and a 4-point analog quantity input module. The redundant points of the module are reserved for standby.

4.3 Software composition design

1) human-computer interaction

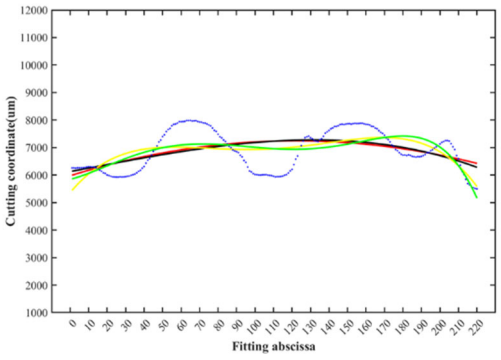
The planing profiling control system uses the Siemens compact series touch screen to realize the dialogue and interaction between the operator and the control system, while reducing the number of actual keys and saving the DI module interface [3]. The touch screen in the profiling system is used for the switching of the profiling system switch status, the display of profile data, and the setting of planing parameters.

The touch screen adopts the Siemens smart panel, which has the functions of alarm, formula management and user management. The protection level is IP65, which is suitable for meeting the human-machine needs of the profiling planer control system. The high protection level is also suitable for use in industrial sites.

2) Planing fitting algorithm

The least-squares algorithm is used for curve fitting, and the discrete points of the composite plate shape data collected by the data acquisition sensor are processed to obtain a smooth polynomial curve. According to the curve, the interpolated discrete points are obtained as the motion coordinates of the servo motor, and then the PLC controls the four-axis linkage servo tool holder, and the profiling is realized by interpolation.

The second to fifth order fitting comparison is made for the warpage change data of the composite plate frame. Combining the engineering practice and data fitting results, the third order fitting is used for fitting, and the corresponding data fitting is shown in the “Fig.9”.



Red line - second order fitting curve;Black line - third order fitting curve;Yellow line - fourth order fitting curve;Green line - fifth order fitting curve.

Figure 9. Least square fitting

The program uses logic and sequence control ideas, and is written using the TIAPortal software platform.

4.4 Real machine debugging verification

Each work unit of the equipment shall be debugged according to the process flow of the profiling control system. Through multiple inspections and repeated debugging, each function included in each work unit of the machine tool can be stably operated. On this basis, the profiling and milling control system is jointly debugged to ensure the overall coordinated control performance of the system.

The processing site of profile planed composite plate is shown in the following “Fig.10”.

Figure 10. Physical image of profiling

5. Conclusion

To sum up, the control system scheme of composite plate profiling and planing proposed in this paper integrates algorithm and communication, with reasonable structure design and high system integration. It replaces manual operation and realizes automatic removal of composite plate frame. The processing process is safe and pollution-free, green and environmentally friendly, and the processing yield is high. It successfully meets the design requirements and has engineering application value.

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References

[1] Lin Xuejie. Research on the calculation of force and energy parameters in the process of circular saw cutting metal [D]. Central South University.

[2] Li Dongdong, Wang Yongqiang, Xu Zengpu, et al. Study on the measurement error of laser triangulation method when the object surface is inclined [J]. Sensor and Microsystem, 2015, 34 (02): 28-29.

[3] Liao Fangming, Wu Hongwu. Design of intelligent screen change control system for extruder based on head pressure curve [J]. Plastic Industry, 2012, 40 (11): 47-49.