Design of Six Axis Automatic Painting Machine for Automatic Up and Down

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Abstract. In this paper, we develop an automated spray paint machine which can load up and down the material automatically and complete the six sides painting spraying once. The painting machine principally consists of wood paint processing conveyor belts, board painting workbenches, frame racks, driven components and spindle components and so on. The painting machine uses the special chain conveyor lifts to achieve automatic loading and unloading of board; Then make full use of 90-degree horizontal rotations of those four station at the board painting workbench and 180-degree flips of every station to achieve a six-sided painting at a time; And use the combination between two PLCs and the inverter to achieve multi-axis motor control. What’s more, it can realize unmanned automatic machining process operation, have a high degree of automation, an advanced and brief craft process and an improved production efficiency, increase utilization of paint and save production costs.

Introduction

As for the traditional painting operation in the wood board production and processing process, the operator usually holds the paint gun by hands to spray directly towards the wood boards. Such method has the features of large labor intensity and physical power consumption but common painting effect, and the paint spray may damage the health of the operator.

In recent years, some automatic painting devices or facilities have been developed for automatic painting, such as advanced painting robots. But such equipment is usually imported equipment with high cost and difficult parts replacement, and the technicians need to have high programming skills, so it is hard for middle and small sized enterprises to purchase and apply such equipment.

At present, some cheap board painting equipment with simple structure is also developed in China, but such equipment usually has low automation, low painting efficiency and common painting effect, and needs great human assistance, so it has high operation requirements for the operators and can easily waste paint and time [1,4].

Therefore, the existing wood board painting equipment is researched in this paper in order to develop the six-axis automatic-loading/unloading numerical-control painting machine for painting six faces of the wood board at one time. Such painting machine, with high automation and simple technological process, can realize unmanned automatic processing operation, improve production efficiency and paint utilization ratio, save production cost, etc.

Main Structure Design of Painting Machine

The painting machine is composed of the processing and transmission belt for wood board painting, the working table for wood board painting, the frame type rack, the driving component, the spindle assembly and so on.
**Processing and Transmission Belt for Wood Board Painting**

In order to make the wood board automatically enter the painting area of the painting machine and automatically exit from the painting area after painting completion, we adopt the new processing and transmission belt for wood board painting, as shown in Figure 1. Meanwhile, we adopt the special chain board to hold the wood board to realize automatic loading/unloading function, as shown in Figure 2 and Figure 3.

![Figure 1. Processing and transmission belt for wood board painting.](image)

1 - Support Component, 2 - Chain Wheel, 3 - Chain, 4 - Motor, 5 - New Chain Board, 7 - Wood Board, 7 - Adjustable Bracket

As shown in Figure 2, chain 4 is installed with a special positive chain board 1 at an interval about the length of the wood board; the upper part of chain board 1 is made into L shape in order to fix the placement angle of wood board 3; along the width direction, wood board 3 is installed with four short axes placed on positive chain board 1; the two ends of the short axis at the front end of the wood board are made into stair-step to make the axes clamped on the support frame of the working table for wood board painting. Positive chain board 1 holds and transmits wood board 3 to the working table for wood board painting, and can smoothly move away from the working position along the positive direction.

![Figure 2. Structure for wood board entry to transmission belt.](image)

1 - Positive Chain Board, 2 - Short Axis, 3 - Wood Board, 4 - Chain

The structure for wood board exit from the transmission belt shown in Figure 3 is similar with the structure for wood board entry to the transmission belt shown in Figure 2. The difference lies in inverse chain board 1 shown in Figure 3, and the direction of the inverse chain board is exactly opposite to that of the positive chain board. The purpose of such setting is to make the projection of inverse chain board 1 able to bring short axis 2 of wood board 3 to exit from the working position after wood board 3 is completely painted.

![Figure 3. Structure for wood board exit from transmission belt.](image)

1 - Inverse Chain Board, 2 - Short Axis, 3 - Wood Board, 4 - Chain
Working Table for Wood Board Painting

In order to improve the working efficiency of the painting machine, four working positions are set in the working table for simultaneously implementing the three steps — loading, painting and unloading, as shown in Figure 4. Specifically, the wood board is sent to the working position from the left pending position; then, the working table is rotated by 90 degrees and the wood board is overturned by the motor to be painted at the processing position; then, the working table is rotated by 90 degrees again to the taking position for the transmission belt to take off the wood board. Meanwhile, □-shaped wood board support frame shown in Figure 5 is adopted to hold the wood board to be processed in order to paint the six faces of the wood board at one time, without contacting the wood board.

![Figure 4. Working table for wood board painting.](image)

1 - Base, 2 Support Frame, 3 - Support Wheel Frame, 4 - Synchronous Pulley, 5 – Wood Board Support Frame, 6 - Stepping Motor

Four wood board support frames shown in Figure 4 are placed at an interval of 90 degrees to correspond to four stepping motors 6 for the rapid painting operations at the four working positions. Four groups of support wheel frames 3 are distributed on support frame 2 at an interval of 90 degrees to reduce the mechanical fatigue brought by the cantilever structure. The synchronous pulley at the middle is used for transmitting the power of the main motor.

![Figure 5. Wood board support frame.](image)

1 - Support Frame, 2 - Support Port, 3 - Baffle Plate

As shown in Figure 5, two support ports are located at the front end of support frame 1, and are used as the wood board transmission access and used for supporting the wood board. When the headmost short axis of the wood board contacts baffle plate 3 during transmission, the wood board will be dropped from the positive chain board into support frame 1; baffle plate 3 is coordinated with the short axis at the stair-step to prevent the wood board from dropping off the working position during 180 degrees rotation; after wood board painting, the inverse chain board of the transmission belt takes off the wood board from support frame 1 outwards through support port 2.

Transverse and Longitudinal Driving Components

The working table of the painting machine is provided with five groups of rotational motions to control the painting working position change and the wood board rotation; it is also provided with three groups of straight reciprocating motions to control the paint gun displacement. As shown in Figure 6, the transverse and longitudinal driving components are used for controlling the paint gun...
displacement along X-axis and Y-axis, wherein the transverse driving component includes the spindle assembly shown in Figure 6(b), used for controlling the paint gun displacement along Z-axis and the angle rotation of the paint gun.

![Figure 6](image)

(a) Longitudinal Driving Component (b) Transverse Driving Component

Figure 6. Transverse and longitudinal driving components.

As shown in Figure 6(a), longitudinal motor and synchronous pulley 1 are linked by the synchronous belt to transmit the motor power to the output axis so as to drive the transverse driving component to make longitudinal motion. As shown in Figure 6(b), transverse motor and synchronous pulley 3 are linked by the synchronous belt fixed with spindle assembly 2 so as to drive spindle assembly 2 to make transverse motion; spindle assembly 2 can drive paint gun 4 to make the motion along the height direction and control the angle rotation of paint gun 4.

**Software Control Design**

Two Panasonic AFPX-C60T PLCs and frequency converter are adopted for the design to realize multi-axis motor control. The basic control diagram is as shown in Figure 7 and Figure 8. PLC input part includes touch screen control, X-axis, Y-axis and Z-axis origins control, X-axis, Y-axis and Z-axis origins proximity sensor signal inputs, and rotation angle sensor control signal input of the rotating table. Once the external signal is sent to PLC, PLC will control the servo motor of each axis to control the motion (each axis has corresponding limiting protection control) and wood board rotation. Meanwhile, PLC controls the frequency converter through the relay to control the speed regulation of the motor and accordingly control the rotating table motor and the transmission belt motor. Additionally, the motor speed is fed back in a form of closed loop through the sensor in order to more accurately control the whole painting machine.

![Figure 7](image)

Figure 7. Control component diagram 1.
Painting Locus

Due to the operating environment features of the painting machine, the plane painting operation is mainly implemented. By virtue of the structure design, the painting machine can plan the motion locus of such operation.

The retracing scanning type paint jetting mode is adopted to orderly paint the working surfaces, as shown in Figure 9.

The rectangular coordinates are adopted for the structure design of the machine, so it is relatively simple to plan the motion locus for the plane painting operation of the painting machine. Firstly, the paint gun is moved to the original working position; then, the paint gun makes motion with fixed step length on the painting machine according to the horizontal motion step length determined by the painting process requirements, thus automatically realizing the continuous rectangular operating surface.

Conclusion

The wood board painting production is taken as an example in this paper. In allusion to the process requirements for rapid painting operation of the panels, a new automatic painting machine suitable for the furniture industry is developed in this paper, as shown in Figure 10. The traditional painting machine has working position defect, so the operating mechanism of the traditional painting machine is improved in order to design an integral structure for the painting machine. Such design
mainly includes the structure design for the working table, the transmission belt and the machine body. Specifically, 3D modeling method is adopted for structure optimization, and PLC program diagram is also introduced in order to control the multi-axis motor of the painting machine through PLC programming and finally realize the mentioned design of the new painting machine. The machine designed thereby has simple mechanism and convenient maintenance, thus providing a theoretical design foundation for the industrial automation production practice of enterprises, strengthening the adaptivity of the painting machine to the present production mode of the middle and small sized enterprises, and improving the market response ability of the middle and small sized enterprises.

Figure 10. Automatic wood painting machine with automatic loading/unloading function.

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References