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Development of Digital Engraving Machine Control System

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Abstract

With the introduction of a series of concepts such as Industry 4.0 and Made in China 2025, unmanned and intelligent production has become the key to the development of industrial production. Machine vision was combined with engraving machine and the accuracy of engraving machine was improved. The machine vision input mode was adopted to get rid of the constraint of traditional input mode, and the image processing technology in machine vision was used to process the input processing information, so that the engraving system can preprocess the engraving independently without relying on any software.

Keywords

Engraving machine; PLC; G code execution.

1. Introduction

In recent years, with the continuous improvement of the numerical control system function, International well-known machine tool expo in the display of numerical control industry development results, and put forward the previous speed and precision has been unable to meet the market requirements of numerical control system. Multi - function is becoming the trend of numerical control system, and its inevitability is emphasized. General CNC system is the index control system manufacturers can according to the needs of different users or industries, on the basis of the general CNC system, in a modular way to quickly add and delete the functional modules of the CNC system, to develop to meet the needs of the CNC system. Compared with developed countries, China's numerical control system technology is not mature enough, is still in the development stage. In recent years, many domestic manufacturers, institutes and universities have made great contributions to the development of numerical control system. Delta introduced "CNC," a numerical control system solution that uses the CNC controller NC300 as the control core of the system, using A2 or M series servo system to complete the system feed movement, choose S series spindle drive and high speed permanent magnet spindle motor to be responsible for spindle processing, at the same time with machine vision of the man-machine interface.More complete design of a numerical control system solution. However, the system solution does not support the conversion of image into CNC code, and the conversion of vector file into CNC code, which has certain limitations on CNC processing. The KT600 general numerical control system based on optical fiber servo bus is developed by Shanghai Kaian CNC Co., Ltd. and SoftServo Company. The software control system based on Linux + T-Linux and Windows2000 / XP is designed, which can control the movement of up to 16 axes. Servoworks numerical control software is used to complete the functions required by the system. Users can develop corresponding functions according to their own needs. Although the system has improved the openness of the system to a certain extent, the software system needs professional staff to maintain it, which is not convenient for the later function increase and modification.

Firstly, according to the functional requirements of the numerical control system, the modular design scheme of the system is proposed. In this paper, the program design of CNC system is

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realized, and the controller parameters are configured in PLC_CONFIG software. And complete the development of CNC system human-machine operation interface, including the main monitoring interface, machine vision monitoring interface, G code conversion and download interface. The final results show that the CNC system can meet the basic requirements of manufacturing.

2. Whole Analysis of Engraving Machine Control System

2.1. Engraving Machine Working Principle

CNC engraving machine is a product of the integration of engraving technology and CNC technology. It controls the operation of the engraving machine through the CNC system to implement the corresponding processing program, so as to realize automatic and efficient engraving processing. Its working principle is as follows: firstly, the engraving software digitizes the graphics to be processed, generates the processing track data and downloads it to the control system.Then the CNC system analyzes and processes the machining track data, carries out the corresponding interpolation operation and speed control, generates the control command and sends it to each axis of motion, so that the X, Y, Z axis of the engraving machine and the spindle coordinate movement, so as to complete the automatic engraving processing. The X and Y axes produce synthetic motion, and the Z axis controls the depth of the cutting head. Figure 1 is the working principle diagram of engraving machine.

Among them, the engraving software generates G code: the so-called grayscale map refers to the bitmap where each grayscale value determines the color of a pixel. The range of grayscale value is directly related to the number of storage bits occupied by pixels. For example, an eight-bit grayscale image can have 256 kinds of grayscale values at most. 0~255 gray values are transformed into binary arrays or matrices by layering. The black represents 1, and the white represents 0. In the process of engraving, the starting and falling knives of the cutter head are controlled, and then the points of 1 are connected into continuous short straight line segments. Continuously layered carving, so as to complete the process of processing.

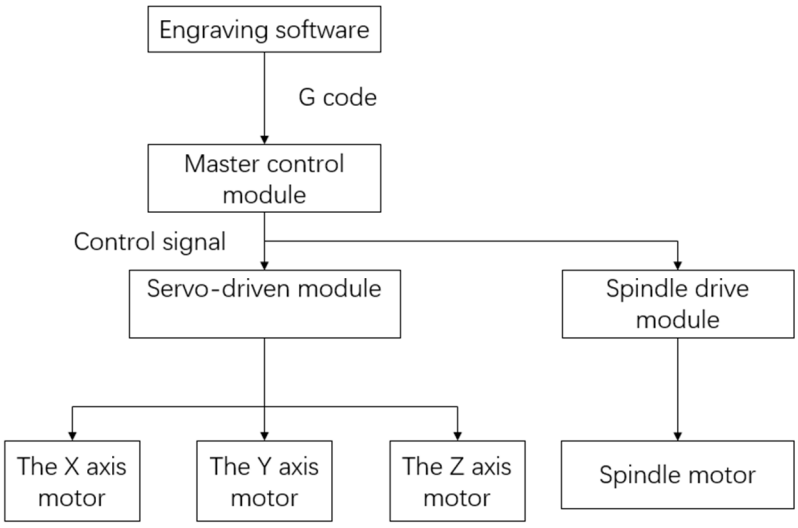

Figure 1. Engraving machine schematic diagram

The wiring diagram of the electrical control cabinet is shown in Figure 2: the external 220V power supply is supplied to CPS100 power module, X axis server, Y axis server, Z axis server and frequency converter respectively. The CPS100 power module converts 220V into 24V

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required by each terminal signal line. The controller MAC1630's 23 digital input channels and 16 digital output channels use 4 channels and 11 channels respectively. Q00~Q05 respectively control the pulse and direction signals of X axis, Y axis and Z axis servo drivers, and Q06~Q08 respectively control the enabling signals of X axis, Y axis and Z axis servers. The U, V, W and PE of the servo are used as the power electrical input of the servo motor. Q09 is the Z-axis locking signal, Q14 is the control signal of the frequency converter, and the above is the output of the controller. I00~I02 are the forward limit signals of the secondary axis, Y axis and Z axis respectively, and I03 is the emergency stop signal, which serves as the input of the controller.

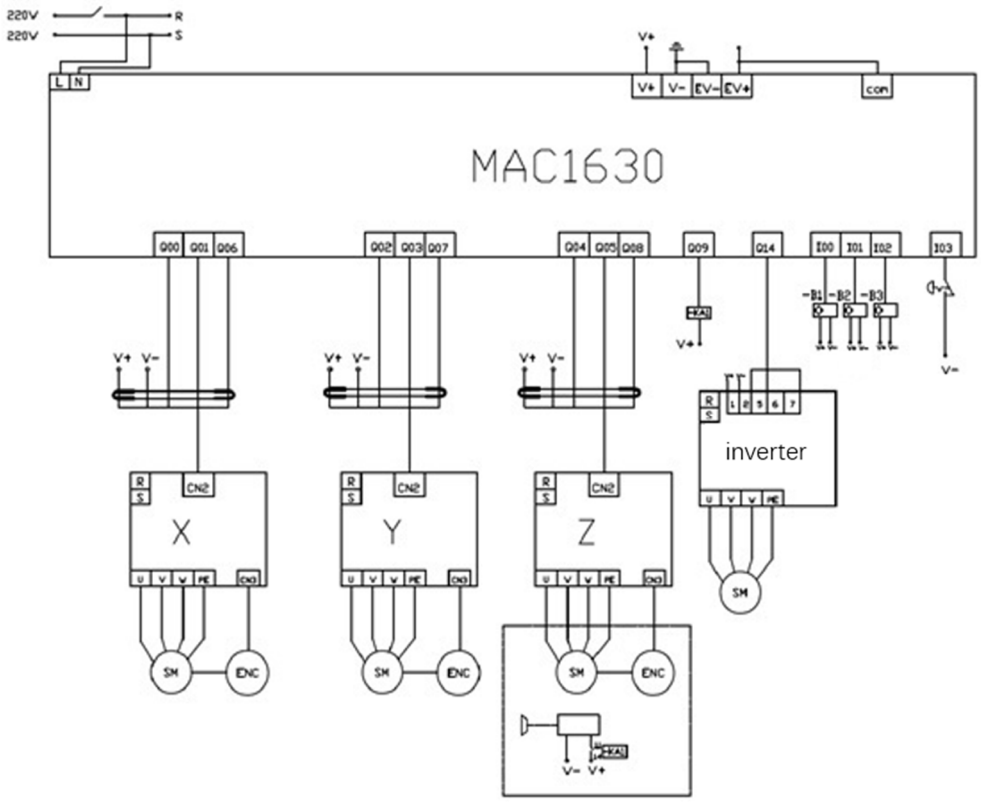

Figure 2. Electrical connection diagram of control cabinet

2.2. Key Technologies

In recent years, machine vision and CNC engraving machine has had a certain development, in the machine vision based engraving machine system used in the industrial robot technology. Now the main task of the industrial robot is based on the specified the location of the robot movement in the working space trajectory, action, posture, and the operating sequence and the time of booking instruction movement.When the robot working environment change, awareness and ability to adapt to the environment changes is poorer, therefore lags behind the development in the field of industrial robot. Therefore, in recent years, the rise of machine vision control technology, does not need to teach the trajectory and movement of industrial robots or offline programming, the introduction of machine vision technology can greatly improve the efficiency of industrial production and the degree of automation. In recent years, with the continuous development of computer technology, image processing technology, machine vision technology is produced, and in the need to achieve automation, intelligent in each field plays a decisive role, has made a great contribution to the progress of society. Machine vision technology is mainly used in the field of industrial automation, food, agriculture, medicine, aerospace and so on. With the continuous improvement of production efficiency and production automation requirements of enterprises, information processing and information

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exchange speed and efficiency, machine vision technology plays a particularly important role in the development of industry.

This project adopts machine vision input mode to get rid of the shackles of the traditional input mode. The image processing technology in machine vision is used to process the input processing information, so that the engraving system can carry out the pretreatment of engraving independently without relying on any software.

Vectorization of image data is the key and the difficulty to realize the automatic generation of processing code. This project adopts different vectorization methods for images with different contents. For images containing regional color or gray level, line vectorization method is adopted to determine the cutting path according to the color or gray level pixel value and its relative position. For images containing only edges, such as text. The edge tracking algorithm is used to track and calculate the edge point by point, record the true boundary, exclude the false boundary, and finally realize the vectorization by using the method of line fitting.

3. Principle of Machine Vision

Machine vision is a modern detection technology that uses an industrial camera, CCD, instead of human eyes. The industrial camera CCD processes the image of the object to be detected, converts the image information into digital signals, and extracts the required features from them, so as to realize the detection of the state of the object to be detected. With the development of digital processing technology and artificial intelligence, people have higher requirements for product quality and efficiency. It is also very important to find ways to improve product quality and speed up detection.

(1) Mechanical mechanism module The module mainly includes sample carrying platform, positioning mechanism, testing platform frame and rotating mechanism. The mechanical part is the basic part of the detection system to realize data acquisition, which determines the operating efficiency and detection accuracy of the system. The sample bearing platform and the positioning mechanism are mainly used to detect the sample and play a fixed role. The function of the rotating mechanism is to rotate the sample in situ and assist the imaging module to complete the image acquisition of the surface. The testing platform frame lays the foundation for the whole experimental platform, and forms a stable working environment.

(2) Computer hardware module This module is composed of computer related software, which is mainly responsible for image acquisition and post-processing of defect images. Using Matlab programming, clearly identify pits, cracks and other defects. To improve the accuracy and accuracy of defect detection of silicon nitride ceramic bearings.

(3) Motion control module The module is mainly composed of deceleration motor, contact switch, etc. The rotating platform and sample positioning device are controlled by a deceleration motor. After the picture collection starts, the rotation speed of the rotating mechanism is measured by a switch control, which is used to control the image collection speed. The function of the reducer motor is to provide power for the rotating mechanism.

(4) Defect imaging module Defect imaging module is mainly composed of CCD camera, lens, controllable LED light source and filter. Among them, CCD camera and lens are combined to convert surface defect image signal into digital signal. The function of controllable LED light source is to provide a stable lighting environment for the imaging system and reduce the influence of ambient light source. The function of a filter is to reduce the impact of reflected light by specifying a range of wavelengths of light.

Machine vision system is composed of CCD camera, lighting system, rotating platform, image processing module, control module and separation module. The overall system configuration is shown in Figure 3.

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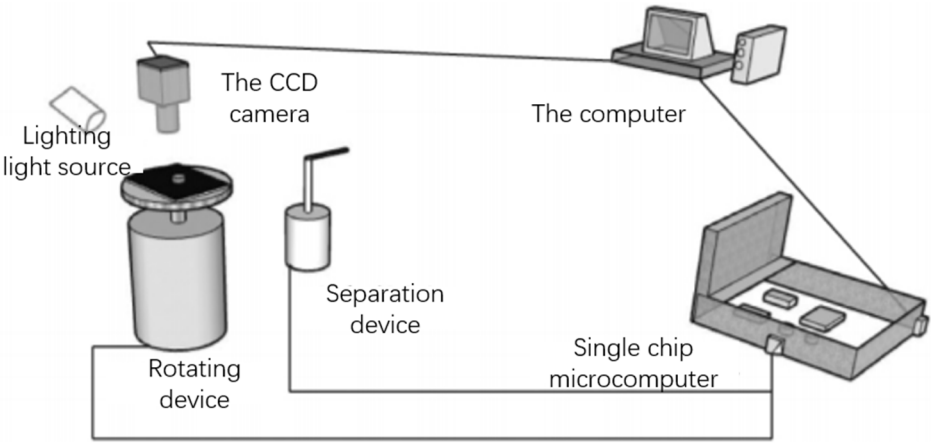

Figure 3. Gear Dimension Detection System Based on Machine Vision

Using the Nyquist criterion, the image resolution required is

Resolution = (field of view/minimum accuracy) ×2

According to the relationship between field of view and object distance in Figure 4, the following formula is used to calculate the required focal length so as to select the lens

Focal length = (pixel size object distance) × field of vision

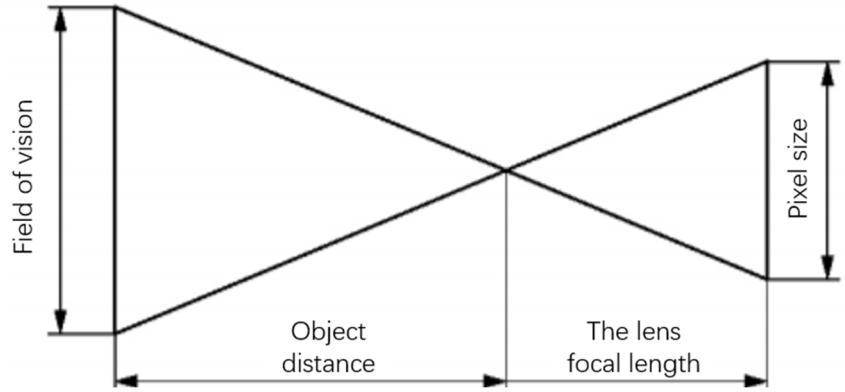

Figure 4. Optical principle

4. The Software Design of Engraving Machine Control System Based on PLC

The engraving machine control system uses PLC_CONFIG configuration software to program LAD ladder diagram to control the operation of the engraving machine, and the specific function is realized in the underlying controller. During the execution, the parameters of axis, shaft group and G code are first configured and enabled. After the program runs, the mechanical coordinates are converted to axial coordinates through coordinate transformation to complete the corresponding actions of the axis. The engraving machine's continuous running track is realized through the G code function processing process. Function realization of G code mainly includes G code pre-processing and execution module. The pre-processing module of G code first completes the selection of instruction unit, programming mode and coordinate plane, as well as the configuration of position, speed and acceleration. The G code execution module executes the G code according to the acquired interpolation instructions and data, and carries out the corresponding interpolation processing, processing of the running state of the shaft group and operation control, etc. The G code execution flow chart is shown in Figure 5.

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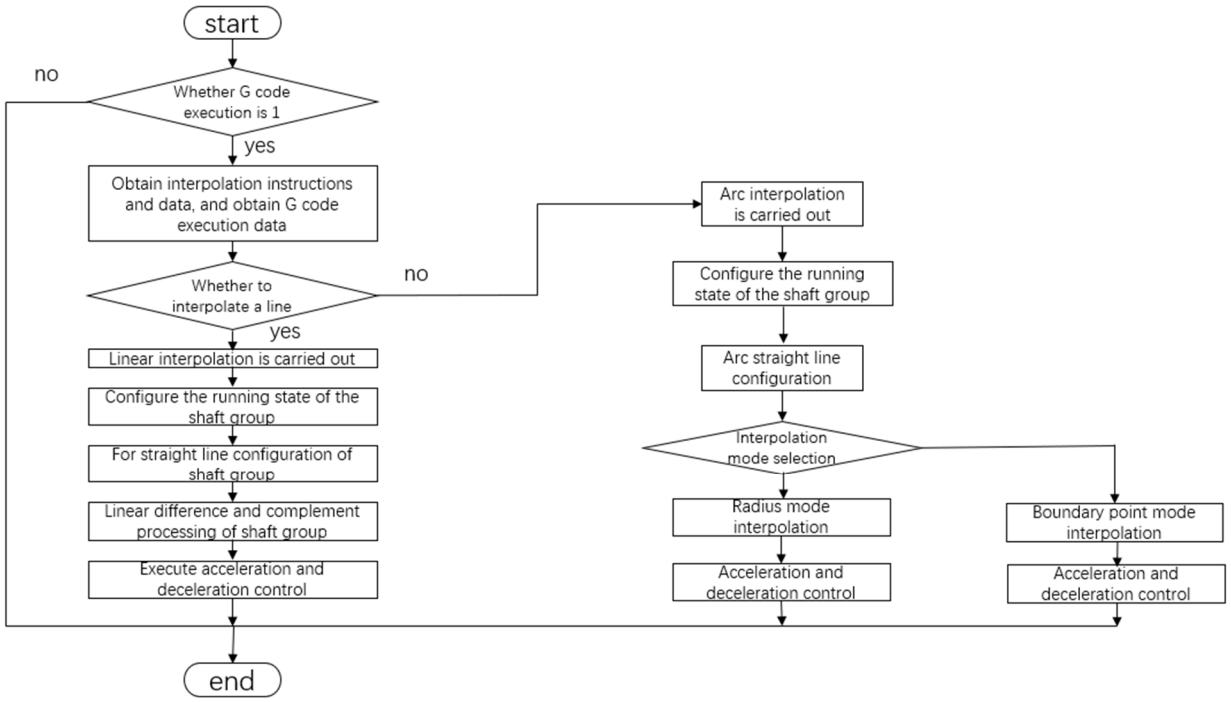

Figure 5. G code execution flowchart

4.1. Control System Control Program

The design of the monitoring software of the upper mobile terminal of the control system of the engraving machine corresponds to the working requirements of the engraving machine. The PLC configuration software PLC_config is used to program the LAD ladder diagram. The realization of the basic functions of the engraving machine mainly includes servo enablement, return to the origin, point operation, state monitoring and so on. The execution flow chart of the control program is shown in Figure 6.

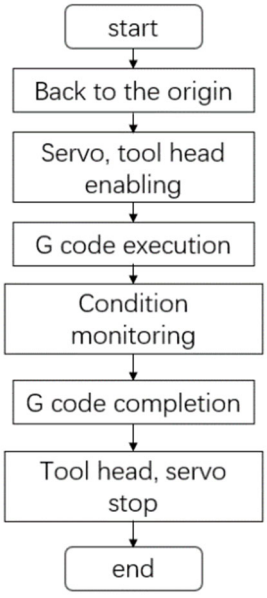

Figure 6. Control program execution flow chart

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Back to origin parameter	
Back-to-origin action mode	Mode 8: Only use the origin signal
Origin input signal type	External input
Return to origin starting direction	Positive
Origin search direction	Positive
Stop action when the positive limit input signal is ON	Reverse and stop immediately
Stop action when negative limit input signal is ON	Reverse and stop immediately
Back to origin speed	10000.000000
Approaching origin speed	5.000000
Acceleration back to origin	5.000000
Return to origin deceleration	5.000000
Acceleration of returning to origin	0.000000
Origin position offset	-20.000000
Origin detection shielding distance	10000.000000
Input signal near the origin	I02
Type of input signal near the origin	NO
Origin input signal	I02
Origin input signal type	NO
Positive direction limit input signal	I10
Positive direction limit input signal type	NO

Figure 7. Return to the origin parameter configuration

4.2. Overall Development of Control System

Before starting the engraving, the operation of returning to the origin is first carried out to confirm the position of the mechanical origin. Then according to the actual requirements of the carving pattern and the different processing materials, the position of X, Y and Z axis is adjusted through the point operation to determine the processing origin. The origin of the workpiece coordinate system is the machining origin, which is different from the mechanical origin. This is artificially set. The origin in the direction of Z axis is generally located on the surface of the workpiece. Then the servo enable, drive X, Y, Z axis servo motor operation; The tool head enables the operation of the spindle motor. After the above actions are completed, the execution of G code will begin. During the operation of G code, i.e., in the process of pattern engraving, the coordinate positions of X, Y and Z axes will be monitored in real time. When the G code is completed, to ensure the safety of the operation, stop the operation of the tool head first, and then carry out the servo stop. The above completes the basic operation process of engraving machine.

(1) Back to the origin: the function of the origin is mainly to carry out coordinate calibration and confirm the mechanical origin position of the engraving machine. The action of the engraving machine returning to the origin is carried out by calling the single-axis returning to the origin instruction MC_HOME. During the operation, the three axes X, Y and Z are started to look for the origin together. In the motion controller, only mode 8 of the origin signal is used to complete the action of returning to the origin, and its parameter configuration is shown in Figure7.

In the figure, the starting direction of the return to the origin is the direction in which the shaft starts to move when the return to the origin movement begins. Since the origin signal is a forward limit number, the direction is set to be forward, and the motor is rotating forward. The searching direction of the origin is consistent with the starting direction of the return origin, otherwise, the detection of the origin signal is invalid. The offset of the origin position is the rotation Angle of the motor after the origin input signal is detected. This position is the origin. Due to the mechanical error and measurement error, the offset of the origin position of different axes will be different.

The origin input signal is the forward limit switch signal of each axis, and the forward limit switch signal of the Z axis is connected to the digital input port I02 of the controller.

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The return to the origin mode and parameters are configured on the motion control parameter configuration interface and downloaded into the controller. The setting takes effect after the controller is repowered on. Its PLC program is shown in Figure 8.

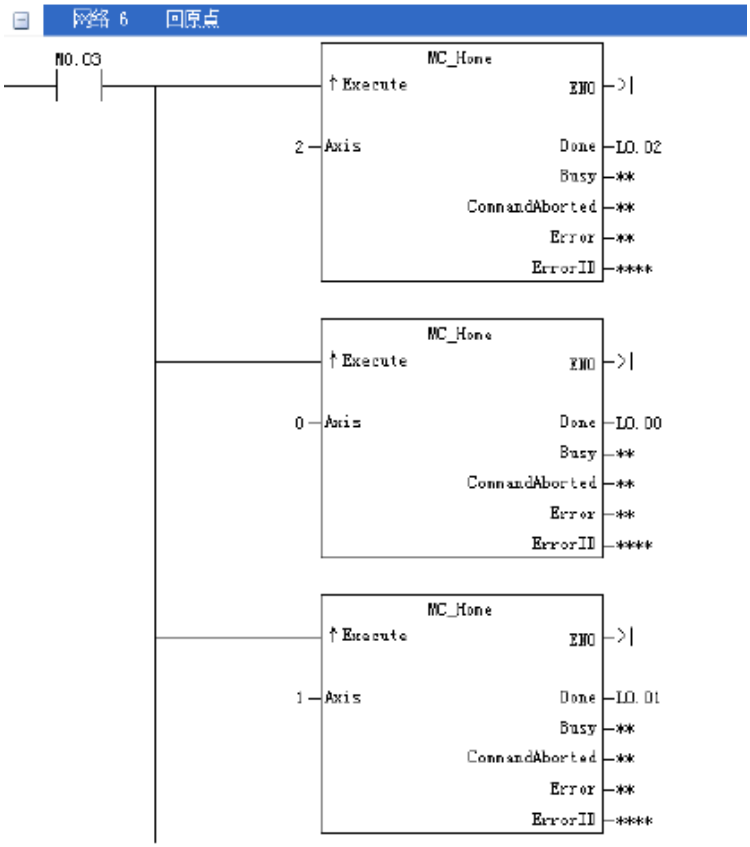

Figure 8. Back to the origin PLC program

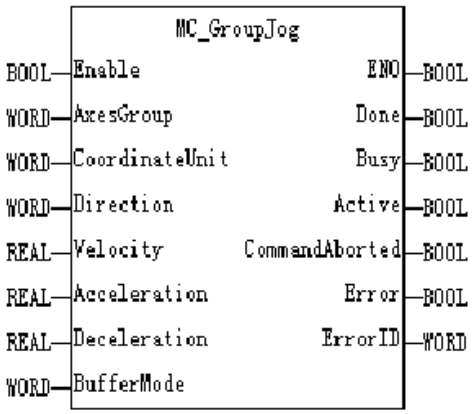

Figure 9. Shaft group point running function block

(2) Pointing operation: the instruction MC_GROUPJOG function block instruction is shown in Figure9, and the specified shaft group can be controlled by Pointing operation. Enable is "1" when the shaft set at the current speed as the starting speed, reach the target speed after constant speed movement; When Enable is "0", the shaft group starts at the current speed and slows to a stop. The direction of movement is determined by the parameters of Coordin ATUnits: where 0 is the X-axis direction,2 is the Y-axis direction, and 4 is the z-axis direction. Direction determines whether a motion is in the positive or negative Direction. 0 is positive and 1 is

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negative. The Velocity is the target speed, the Acceleration is Acceleration, and the Deceleration is Deceleration.

(3) State monitoring: the MC_GroupReadActualPosition function block instruction is shown in Figure 10 to read the current real-time position of the shaft group. The motion model of the engraving machine is the "Cartels coordinate system", which consists of X, Y and Z axes. The real-time position of the shaft group can be monitored by the variables VD100, VD102 and VD104.

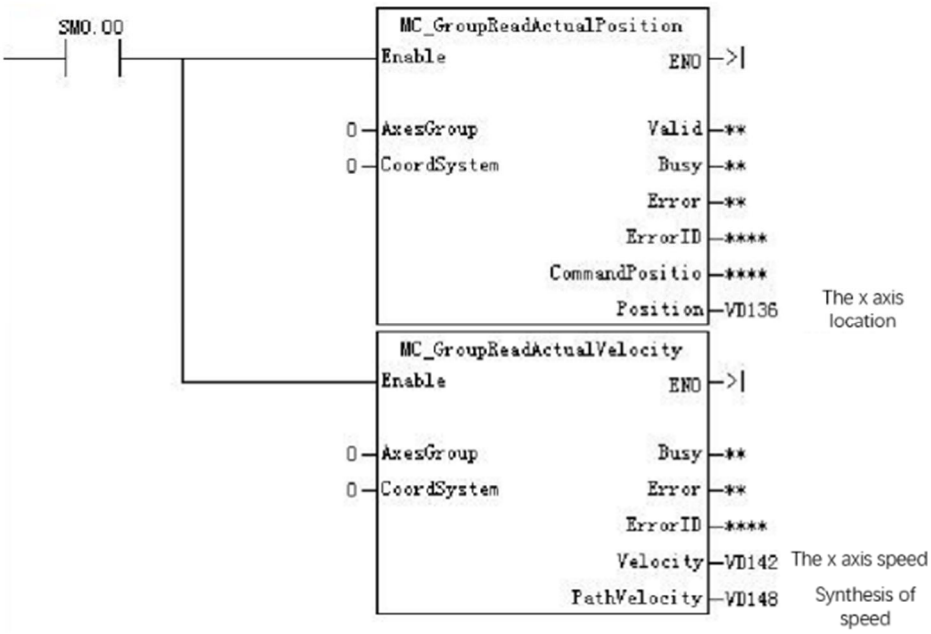

Figure 10. The current position of the read axis group

4.3. Parameter Configuration

Engraving machine before running, the first need to configure its shaft and shaft set parameters. In PLC_Config programming software through the motion control parameter configuration, configuration shaft and shaft set parameters. The PLC controller adopts the idea of object-oriented, and encapsulates the attribute information related to the shaft and shaft group into the shaft structure PAXIS_REF and shaft group structure PGROUP_REF respectively for management, including motion parameters, running state, protection parameters and so on. The emcrm Wr() extended RAM write function is used to read the axis and shaft set parameters in motion control configuration parameters from the NC area. If the parameters fail to be obtained from the NC area, the default value of the program will be restored.

When configured and enabled, select the shaft to be bound first, and then enable the shaft. After selecting the single shaft, enable the shaft directly. After selecting the shaft group, select the shaft first, and enable the last shaft, so that the shaft binding together to achieve synchronous output. When the state machine of the shaft group is in motion, the NC core will carry out coordinate system transformation, trajectory planning, interpolation and other operations. In the process of straight line interpolation of engraving machine, the position of each axis is equal to the component of space line in each axis. Interpolation is completed by converting the mechanical coordinate system to the axial coordinate system using the convert_mcs_to_acs() function. In the cartesian coordinate system model of engraving machine, the mechanical coordinate points can be directly converted to the axis coordinate points, and then the axis coordinate values can be obtained.

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5. Human Unit Interface Development

The design of configuration interface of general numerical control system is mainly to control the machining process and state monitoring. Firstly, equipment selection and parameter configuration are carried out to establish the communication between field equipment and interface. Then, bind the variables related to the operation of the device. By modifying the corresponding values of different variables, the different running states of the system can be realized. Finally, the configuration interface of the CNC system is designed. Users complete different control functions of the CNC system through the relevant controls in the interface.

5.1. Host Computer Page Design

As shown in Figure 11, the main interface of the upper computer software mainly realizes the real-time state monitoring and inching control of the engraving machine. Figure12 shows the tool machining starting point correction interface, whose interface functions mainly include the input text box of starting point coordinates before processing and the display label of corrected coordinates. As shown in Figure 13, the interface of PLC control panel is mainly used to control PLC controller and G code deviation correction.

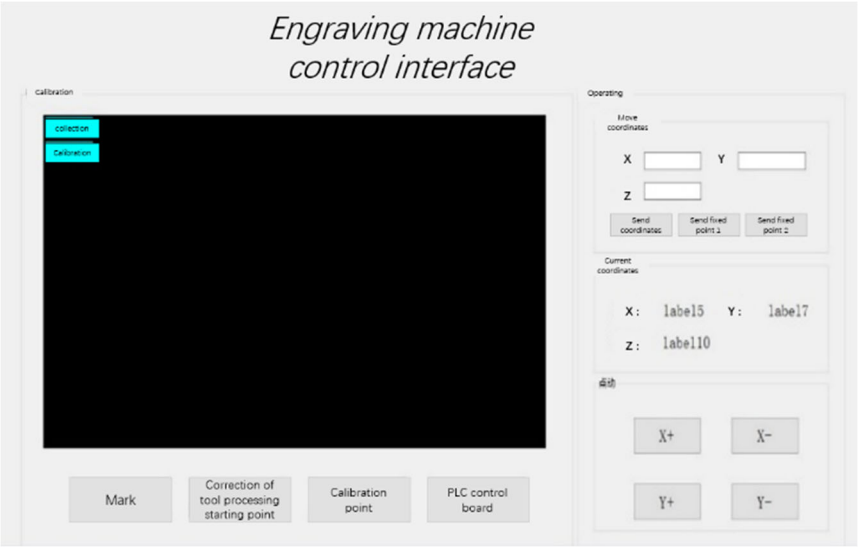

Figure 11. The main interface

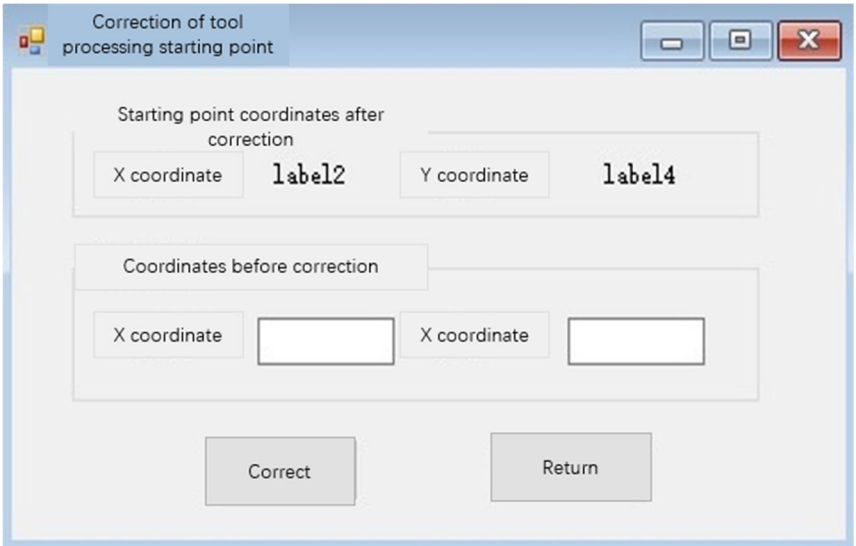

Figure 12. Tool machining starting point correction

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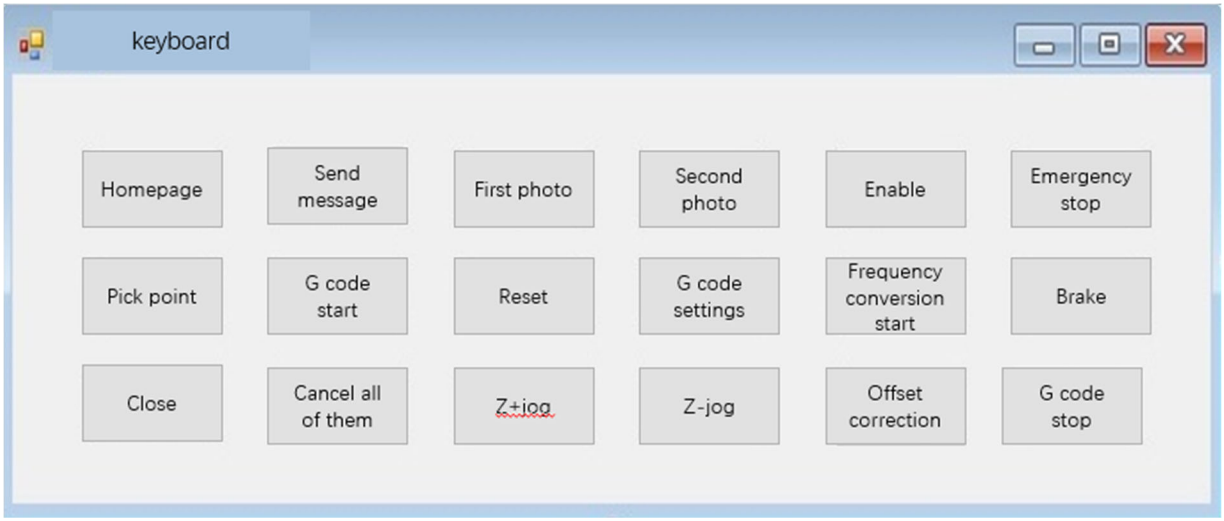

Figure 13. PLC control panel

5.2. G Code Generation Design

As shown in Figure 14. Firstly, we put import the grayscale image into the software, and adjust the size of the carving pattern and other parameters. Then we set the engraving mode and engraving attributes. In the end, we select the Engraving Tool and set the Engraving Tool parameters, and set the G code generation attributes and G code generation parameters in combination with the engraving tool head parameters and shaft set motion control parameters. Figure 15 shows the G code file generated by the software. G** is the G code interpolation command, followed by the interpolation coordinate parameters, etc.

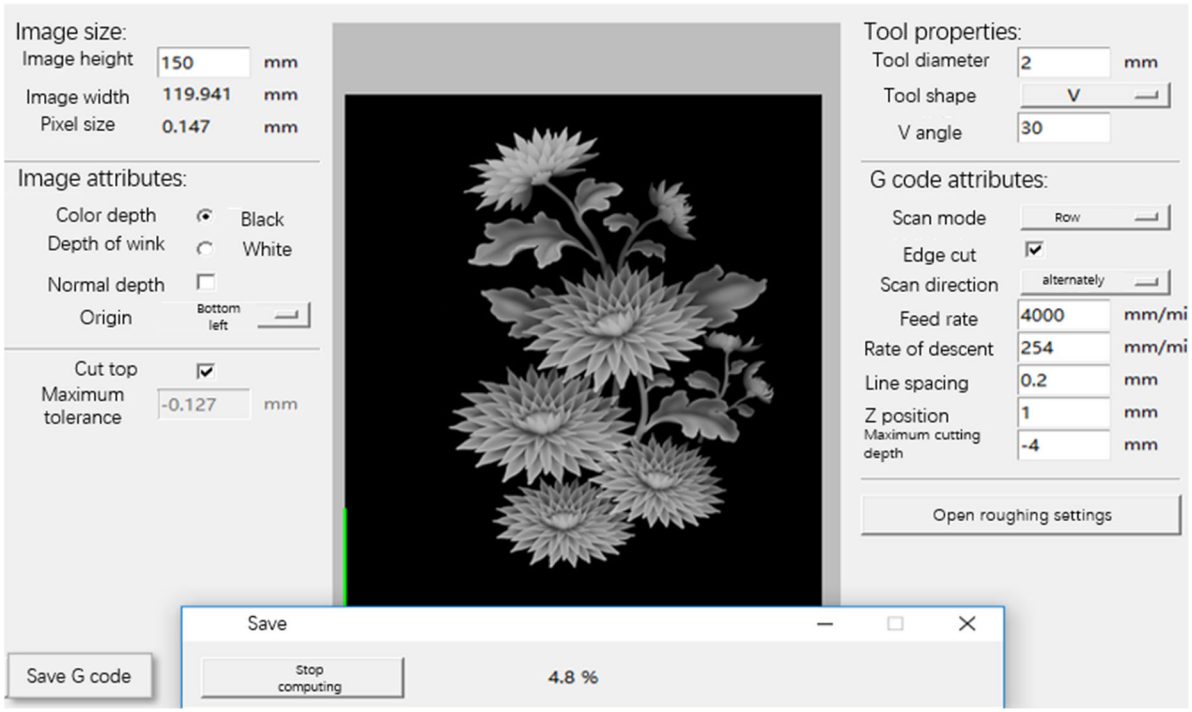

Figure 14. G code generation software

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```
G92 X0 Y0 Z0
G21
G00 Z1.0000
G01 F4000.0000
G01 F254.0000
G00 X119.9413 Y150.0000
G01 F4000.0000
G01 Z-4.0000
G01 X0.0000
G01 Y149.8534
G01 X119.9413
G01 Y149.7067
G01 X0.0000
G01 Y149.5601
G01 X119.9413
G01 Y149.4135
G01 X0.0000
G01 Y149.2669
G01 X119.9413
G01 Y149.1202
G01 X0.0000
G01 Y148.9736
G01 X119.9413
G01 Y148.8270
G01 X0.0000
G01 Y148.6804
G01 X119.9413
G01 Y148.5337
G01 X0.0000
G01 Y148.3871
G01 X119.9413
G01 Y148.2405
G01 X0.0000
G01 Y148.0938
```

Figure 15. Generated G code file

6. Conclusion

According to the functional requirements of numerical control system, we put forward the modular design framework of the general numerical control system, and put forward the hardware design scheme of the general numerical control system. In this paper, the electrical schematic diagram of the system is designed with the idea of modularization, and the controller program of the general numerical control system is developed. In addition, this paper also studies the grayscale image, CAD file automatic generation of G code technology, and with the engraving machine as the actuator, complete the test and verification of the general CNC system.but there are still some deficiencies, but also need to further improve the function. For example: CNC system in the processing of different materials, can be further divided; The precision of machine vision also needs to be improved.

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