Design of Automatic Control System for NDT Device

Liu Bin, Zhou Min

Department of Automation, Taiyuan Institute of Technology, Taiyuan, Shanxi, CHINA

Abstract

The article designed a kind of new nondestructive testing device control system to increase the test efficiency and improve the reliability of computed tomography. This system could not only precisely locate and control the turntable and lifting platform by adopting digital control, servo control and other advanced control methods, but also develop a high-precision servo turntable by using a three-layers closed-loop controller. This system, whose workpiece rotate-platform is particularly suitable for small-space detection, has an increasingly improved automatic detection efficiency of 20 work-pieces at a time and a wider detection scope of maximum height of up to 50cm. By the means of pre-setting parameters, high-precision servo turntable can rotate to any regulated angle, offering a satisfactory platform for computed tomography. The system, as a new type of automatic non-destructive testing platform, adapts to the digital transformation of traditional X-ray detection device as well.

1. Introduction

Non-destructive testing technology is one of the most important bases of modern industry, especially machinery industry for its wide use in material analysis and internal injury testing in the industrial field. In order to achieve high-speed, high precision, high-resolution, high reliability of detection and improve labor protection, it is a trend now to design a kind of scanning table (mechanical turntable) with the characteristics of more freedom of automatic rotation, accurate positioning and reliability. Since image quality depends to some extent on the scanning speed, the scanning mode and positioning accuracy, the design of scanning table and control system has become extremely crucial.

In view of the wide application of nondestructive testing in various metal flaw detection, this paper mainly talks about an inspection table exclusively designed for automatic and all-angled detection of multi work-pieces simultaneously in narrow and small space, using programmable logic controller as main control device, adopting variable frequency control, AC servo control and other advanced means of control and achieving data acquisition, sharing and remote control through the host computer control procedures directed by VC++ language. This system, as a new type of automatic non-destructive testing platform, is
characteristic of high practicality, accurate positioning, swift detection, high-degree automation, and good reliability, and adapts to the digital transformation of traditional X-ray detection device as well.

2. Design of Automatic Control System For Nondestructive Testing Device

A. The Structure and Function of the Scanning Table

As shown in Figure 1, the scanning table of this non-destructive testing system is composed of a computer monitoring system, automatic control units and motor-driven components. This control system carries first lifting freedom and second rotating freedom. At the precise control of automatic control units, the scanning table could complete the required shifting, rotating, lifting and other movements, providing technical support for measurements.

![Figure 1: Schematic diagram of detect system](image)

B. The Working Theory of the System

As shown in Figure 2, due to limited detecting space and different sizes of metal work-pieces, scanning table of this system is specially designed to a round turntable of 2-meter diameter with 20 detection places evenly positioning on it. Through rotating control, the work-pieces can be to the accuracy of ±1mm placed in the detection position between X-ray source and imaging detection system for the demonstration and recognition of work-pieces. For detecting work-pieces of different height, work-pieces can be moved up and down with the largest mobile distance of 50cm. The upper part of the lifting platform is a high-precision servo turntable, which could be rotated to any angle to the accuracy of 0.1°. According to the parameters set by the host computer, precision turntable can rotate arbitrarily at pre-installing angles so as to achieve three-dimensional reorganization of cross-section images.

![Figure 2: Schematic diagram of scan platform](image)

3. Hardware Design of Automatic Control System for Nondestructive Testing Device

The hardware of this automatic control system includes PC + PLC main control unit and plc inverter and servo control parts, dealing with the principle design of PLC, inverter, servo controller, motor, etc.
C. Design of Main Control Unit

In order to achieve remote control, the master computer of this system is put in a better environment and all the work of data acquisition and man-machine conversation is realized by an ordinary PC machine; the slave computer uses programmable controller, with high reliability even in harsh environment and strong logic control capacity, as automatic control. This system adopts high price-performance Siemens S7-200 (226) with 24 digital inputs and 16 digital output ports, which be able to meet the requirements of control system to I/O points and expand EM231 (A/D conversion module) and EM232 (D/A converter module) for ray source control and frequency control. Finally, through RS232 programmable logic controller, the master computer could finish information exchange by means of free communication port.

D. Control Design of Turntable and Lifting Platform

AC asynchronous motor closed-loop position control system, composed of programmable logic controller and frequency controller, is used to take control of turntable and lifting platform. In view of the interlocking (the two motors should not move simultaneously) of the turntable and the lifting platform together with reasonability consideration of cost and control approach, as shown in Figure 3, one frequency controller works two motors simultaneously. To avoid errors from mechanical design and guarantee that the turntable and lifting platform could operate fast and smoothly within a high control accuracy, this system uses a 16-bit motor-coaxial absolute coder to feedback high-speed pulses as signals of motor operating position, uses D/A module 0-10V voltage output frequency controller to ensure motor’s operations such as smooth acceleration, deceleration and low-speed cessation, which guarantee that even in larger inertia this system could work stably to the designed accuracy, ±1mm. Testing efficiency is greatly improved for it would take 10s to Position a work port and 7.5s to move up and down a distance of 50cm.

E. Control Design of High-precision Turntable

In order to achieve high-precision control of turntable, this system chooses YASKAWA SGDM Servo Controller coordinative with YASKAWA SGMPH-01AAAL8B servo motor and selects super precision ABRT turntable driven directly by Slot-less brushless servo motor. As shown in Figure 4, Servo controller and servo motor constitute a three-closed-loop control system composed of current loop, velocity loop and position loop. Current loop is the internal loop of this system taking in information collected by velocity loop coder (using Fuzzy PI control mode) and position loop coder (using proportional control mode). Through Q0.0 Siemens S7-200PLC sends position command pulse to the servo controller for the achievement of a smooth start and stop, with the highest frequency up to 20kHz and a multi-line PTO model. The motor is originally equipped with a 16-bit absolute encoder. Whenever the drive has accepted \(2^{16} = 65536\) pulses, the motor would rotate a circle with its pulse equivalent to \(\frac{360}{65536} = 19.8^\circ\) and rotation accuracy to \(0.1^\circ\) (approximate 18 pulses required), which not only ensure operation speed but also improve operation stability.

Control system software includes the master computer’s human-computer interaction system and the slave computer’s communication and control system. The master computer sends control requirements through Man-machine interface to the entire automatic control device and at the same time collects data of control system. The slave computer would take in the master computer’s command and then through the command interpreter send them separately into ray source, frequency control, servo control, interlock control and other modules for the completion of specific mission.

F. Software Design of the Slave Computer

The slave computer software is mainly composed of communication module, command interpreter module, servo-control modules, frequency control module, interlock control module, ray control module. By using Siemens s7-200’s PC / PPI cable as Communication connection between the master computer and the slave computer, communication module uses free port communication mode to complete communication operations by sending commands (XMT), receiving instructions (RCV) and ceasing operations. Frequency control module uses high-speed count instruction (HSC), disruption instruction and logic instruction to take complete control of the turntable and the lifting platform. Servo control module, by means of PTO multi Pipeline high-speed pulse output function, adopts high-speed pulse output instruction (PLS) to carry out arbitrary angle control of the precision turntable. The main control operation procedure of the slave computer is shown in Figure 5.
**G. Software Design of the Master Computer**

The master computer software, written in VC++, has main functions as digital imaging, man-machine interaction, data acquisition display and so on. Communication software is programmed by serial communication in API function, subject to be changed by programmers.

**H. Monitoring Interface**

![Figure 6. Man-machine interface of monitor system](image-url)
Man-machine interface provides a satisfactory environment for convenient operation and adjustment. All the control commands and control parameters are transmitted through the man-machine interface and all the real-time feedback dates are displayed on monitoring interface. As shown in Figure 6 this monitoring interface written in VC++ language includes ray control module, work-piece positioning control module, servo motor control module and control state display module.

5. Conclusion

Automatic control system for non-destructive testing device is one of the most important research topics in today's development of non-destructive testing technology. The performance of automatic control system is directly related to the completion of image acquisition and the quality of work-piece detection. Therefore, the PLC controller is widely applied in this field for its excellent anti-jamming performance, simple hardware structure and connection, simple flexible design method of control procedure. This automatic control system has successfully finished its modulation examination at the factory: communication procedure and monitoring interface operate normally without any electromagnetic interference; the work-piece turntable rotates fast and smoothly with positioning accuracy up to ±1mm; lifting platform could finish work-piece detection from a few centimeters to 50 centimeters; the high-precision turntable could rotate from 0.1° to 360° according to the parameters set by the master computer, all of which provide a good foundation for tomography. The system is not only practical but also adjustable with high degree of automation and reliability. As a new type of automatic non-destructive testing platform, this system also adapts to the digital transformation of traditional X-ray detection device.

References