Design of Surface Quality Control and Detection System for Bearing Steel Balls

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ABSTRACT : *The mathematical model of steel ball surface deployment is obtained through the theory of bearing steel ball deployment, and the trajectory equation of steel ball surface deployment is deduced. The mechanism simulation based on Pro/Mechanism is used to verify the scanning trajectory curve of the probe, which can completely cover the surface of the steel ball. Considering the cost and performance of the system, the hardware and software design scheme of the system is completed based on single chip computer control. The waveform experiment of 8mm bearing steel ball detection shows that the system can complete the detection work efficiently, stably and accurately, which is of great significance for improving the bearing quality.*

KEYWORDS -*bearing steel ball, control system, detection, SCM*

I. INTRODUCTION

The reliability of bearings is one of the most important prerequisites for the normal operation of production equipment. The surface quality of bearing balls has a key impact on the service life and bearing capacity of bearings, especially under high pressure and high speed conditions. The surface quality problems of steel balls, such as scratches, cracks and pits, are prone to extension and expansion, leading to bearing failure and even accidents [1]. In order to ensure the reliability of the bearing work, the acceptance of the surface quality of the steel ball must pass the relevant testing or testing. However, there is no efficient testing equipment for the surface defects of the bearing steel ball in the market at present [2].

In order to improve the quality of bearings and realize the efficient, reliable and automatic detection of sub-surface defects on the surface of bearing steel balls, an automatic detection system for bearing steel balls based on single chip computer control is proposed and designed. According to the theory of ball surface deployment, the design and verification of the control system are completed, and the intelligent, efficient and accurate detection effect is realized.

II. MATHEMATICAL MODEL OF SURFACE DEPLOYMENT

2.1 Coordinate transformation

In this paper, the research on the detection trajectory of bearing steel balls is based on the meridian expansion principle. Because the expansion trajectory of steel balls is a complex three-dimensional helix, when determining the trajectory equation, it is necessary to select a reasonable coordinate system according to the expansion motion parameters [3], that is, to transform the original coordinate system in three-dimensional space.

Assuming that the original coordinate system of the steel ball is *O-xyz*, keeping the origin and *z* axis unchanged, the coordinate system *O-xyz*is obtained by rotating the X and Y coordinate axes around the origin in the counterclockwise direction, as shown in Fig.1.

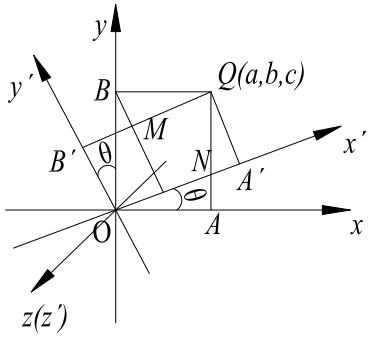

Fig.1 Coordinate system of steel ball surface expansion

Let there be a point Q in the space, whose coordinates in the original coordinate system are (*a, b,* c*)*, and in the rotating coordinate system are (*a', b', c'*). In the *O-xyz*plane, there are:

$$\begin{cases} |OA'| = |ON| + |NA'| = |OB|\sin\theta + |OA|\cos\theta \\ |OB'| = |NB| - |MB| = |OB|\cos\theta - |OA|\sin\theta \end{cases} \quad (1)$$

Eq.1 can be organized into matrix form:

$$\begin{Bmatrix} |OA'| \\ |OB'| \end{Bmatrix} = \begin{pmatrix} -\sin\theta & \cos\theta \\ \cos\theta & \sin\theta \end{pmatrix} \begin{Bmatrix} |OA| \\ |OB| \end{Bmatrix} \quad (2)$$

The coordinates may be changed to:

$$\begin{pmatrix} x' \\ y' \\ z' \end{pmatrix} = \begin{pmatrix} \cos\theta & \sin\theta & 0 \\ -\sin\theta & \cos\theta & 0 \\ 0 & 0 & 1 \end{pmatrix} \begin{pmatrix} x \\ y \\ z \end{pmatrix} \quad (3)$$

2.2.Kinematics simulation

In order to verify whether the system will fail to detect the surface, the kinematics simulation of the steel ball's unfolding trajectory is carried out by Pro/Mechanism software [4]. In this paper, the speed mode of the probe scanning motor is set to "cosine", and the parameters of gravity direction, mass attributes and damper are defined respectively in the simulation environment. After simulation, the displacement curve of the probe during scanning is obtained as shown in Fig.2. The simulation results show that the angular velocity of steel ball deployment is 27.5 rad/s and that of probe scanning is 1.1 rad/s. The calculation shows that when the diameter of sensor probe is 2 mm, the steel ball with diameter less than 8 mm can be detected. At this time, the probe scanning trajectory curve can completely cover the surface of the steel ball, so the steel ball will not miss detection.

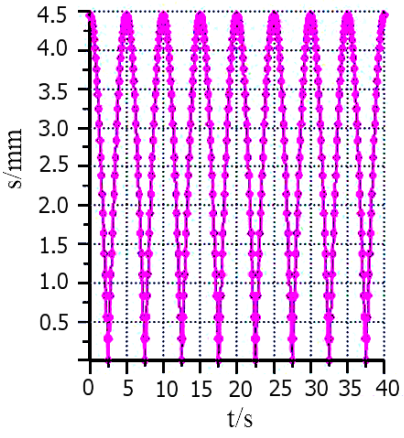

Fig.2 Kinematics simulation of probe

III. SYSTEM HARDWARE DESIGN

3.1. MCU module

With the popularization of automation, in recent years, single-chip computer has been more and more widely used in various automation control applications relying on its advantages of high operation speed, high stability, low voltage and low power consumption [5]. For example, MCS-51 single-chip computer is the mainstream product of embedded control system. Considering the ratio of cost and performance, the core controller of bearing steel ball surface detection system is STC series single chip STC89S52RC, which is based on 8051 core. It has fast processing speed and strong anti-interference ability.

Some pins and wiring diagrams of STC89S52RC are shown in Fig. 3. Among them, P1.0-P1.7 is an 8-bit standard bidirectional I/O port. Its load capacity is 3 LSTTL gates. RST is the reset end, which is valid at high level. The level width is above 24 clock cycle widths. XTAL1 and XTAL2 are the pins of the clock circuit. Their main functions are to connect with both ends of the external crystal oscillator and to form an oscillator on-chip. The input of the inverted amplifier of the swing circuit, VSS is grounded and VCC is connected to + 5V power supply.

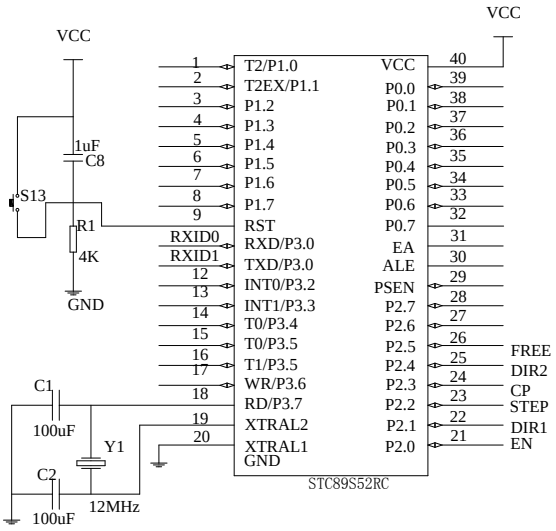

Fig.3 Connection diagram of single chip microcomputer pipe pin

3.2. Stepper motor

For the scanning motor, the three-phase stepping motor is selected in the detection system. Its model is 57HS3A50-3506, the working voltage is 5.2V, and the stepping angle is 1.2 degrees. The

motor driver has six input signals, stepping pulse signal STEP+, STEP-, direction level signal DIR+, DIR-, enabling signal EN+, EN-.

The hardware connection diagram of the stepper motor is shown in Fig.4. It can be seen from the diagram that the MCU sends the enabling signal through the pin P1.3 of the PI port, the pulse signal from P1.4 and the direction signal from P1.5. The working direction of stepping motor is mainly controlled by high and low conversion of P1.5 pin level when stepping pulse is sent out. The power-on state of stepper motor is controlled by enabling signal of P1.3 pin.

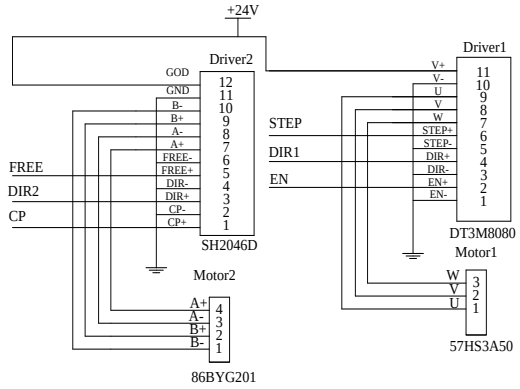

Fig.4Circuit connection diagram of stepping motor

3.3. Data acquisition system

In order to be easy to install and disassemble, the data acquisition module of this system is USB-4711A series, which can realize Plug and Play. It avoids the route damage that may be caused by the hot-swap of the computer installation board, and meets the high efficiency and real-time of data information acquisition. The data acquisition system can directly obtain the power supply for the acquisition card and other devices through the power supply of the USB port. It does not need the secondary access of external power supply. It has 16 channels of analog input, 2 channels of analog output, 16 channels of digital I/O and digital communication channels, and can output square waves of constant frequency [6].

The data acquisition system can complete the acquisition of the detection signal through the sensor probe, in which the two sensors on the sensor bracket are 180 degrees each other, and the defect data on the surface of the steel ball can be accurately obtained. Before data acquisition, it is necessary to establish sampling channels, i.e. setting sampling modes and sampling frequencies. It is necessary to determine the appropriate signal range according to multiple experiments, so as to get the test results more accurately.

IV. SYSTEM SOFTWARE DESIGN

4.1. Software control scheme

In order to realize the automation and intellectualization of the detection system, the optimal software control scheme should be formulated according to the working requirements of the stepping motor, as shown in Fig.5. In this paper, the software control scheme of the system meets two requirements: (1) accurately control the number of steps in the movement process of the detection mechanism; (2) ensure the minimum number of steps under the premise of completing the normal detection function. In the detection process, the stepper motor stores the total number of steps in the RAM unit. After completing the task specified by the system, it needs to check the operation according to whether the value of the RAM unit decreases to zero. If the value is zero, it indicates that the stepping motor can stop or lock when it completes the work process according to the program design; if the value is not zero, it indicates that the system has not completed the work task and needs to continue to work. The positive and negative inversion of stepper motor can be determined by the level of marker.

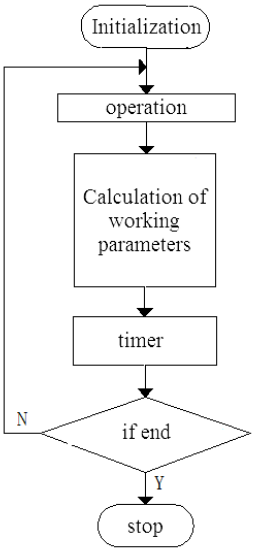

Fig.5Circuit connection diagram of stepping motor

4.2. Data processing

The bearing steel ball detection system can get the surface detection data through sensors, and complete the data processing by LabVIEW software. At the moment of completion of the detection, the system can analyze the signals

collected on the surface of the steel ball through the sensor detection circuit, get the test results, and set the operation after the steel ball detection through the program. If the surface test results are within the standard range, the steel balls will enter the qualified ball box through the single chip computer control system, and if the test results exceed the standard range, the steel balls will enter the unqualified ball box. The data processing scheme can realize real-time signal processing and backtracking analysis. The final data expression is mainly time domain analysis and display of processing data.

V. CONCLUSION

The quality of bearing steel ball is very important, which has a key impact on the bearing life. According to the requirement of bearing steel ball surface quality testing, a non-destructive automatic testing system based on single chip computer control is designed. According to the meridian deployment mechanism of bearing steel balls, the surface deployment trajectory equation is obtained, and the detection trajectory is simulated by Pro/Mechanism. Combining the trajectory equation and the driving principle of single chip computer, the hardware design and software control scheme of the system are established, and the waveform test of the steel ball detection signal is carried out. The results show that the detection efficiency and reliability of the system are very high, and the system has a good application prospect.

VI. Acknowledgements

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