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Design of Control System for Mobile Phone Back Cover Appearance Inspection Machine

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Abstract

In response to the automation requirements for appearance defect detection in the production process of mobile phone back covers, this paper designs an integrated motion control system that integrates cleaning, visual inspection and intelligent sorting. The system supports the feeding of four products at a time. The mobile platform and the gantry synchronous handling shaft work in coordination to successively complete multi-station visual mapping of the front, back, side and hole positions, achieving automated detection of key features such as surface dirt, long straight edges, short straight edges, arc corners, logo marks and hole size. The control system adopts Lingchen motion control cards and uses EtherCAT bus communication to integrate motion control, visual recognition and material sorting logic. Based on the inspection results, the products are precisely distributed to OK, NG and Stain material trays, achieving fully unmanned operation throughout the process. This system can significantly enhance the detection accuracy and production efficiency of mobile phone back covers, meeting the high-precision online detection requirements of high-end consumer electronic components.

Keywords

Appearance inspection of mobile phone back covers ; Motion control card ; Defect detection.

1. Introduction

In the early days, factory workshops mainly relied on human eyes to detect the appearance defects of mobile phones. However, manual visual inspection has many drawbacks, such as a high rate of missed inspections, high labor costs, the influence of subjective consciousness on inspection results, difficulty in ensuring product quality, and the difficulty in preserving and recording inspection data. With the continuous advancement of automated detection technology, it has become an inevitable trend to use machine detection to replace manual visual inspection. The fully automatic appearance defect detection machine designed can significantly improve the detection rate and production efficiency, and better replace traditional detection methods. Zhou Yashen [1] et al. designed an online detection system for the core shape and size of lithium-ion capacitors based on machine vision. They built a hardware platform by applying high-definition CMOS industrial cameras, PLCS, photoelectric sensors, etc., to enhance the efficiency of online detection. Zhao Wei [2] et al. designed a control system for intelligent inspection vehicles used in nuclear power plants based on motion control cards, which has the advantages of small size, low efficiency, high performance and good real-time performance. Zhang Jiancheng [3] designed a PC-based detection and control system for the appearance defects of mobile phone middle frames. This system uses a motion control board card as the motion controller and combines normal following control technology and time-sharing exposure control technology to achieve precise control of the machine vision inspection system.

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This paper takes the gantry handling of raw materials, front inspection, back inspection, side inspection, transfer gantry handling and hole position inspection as the objects, and designs a multi-axis control system for the appearance inspection of mobile phone back covers, achieving the appearance cleaning and defect detection of mobile phone back covers. After a series of detailed and all-round inspections, it is expected that at least over 90% of the defects and dirt can be eliminated and classified and placed.

2. The Process Flow for Inspecting the Appearance of Mobile Phone Back Covers

The movement process of the mobile phone appearance inspection machine mainly involves the feeding gantry synchronous transportation shaft transporting the products in sequence to the front inspection station, back inspection station, side inspection station, and hole position inspection station for taking photos and inspecting the appearance of the products [4,5].

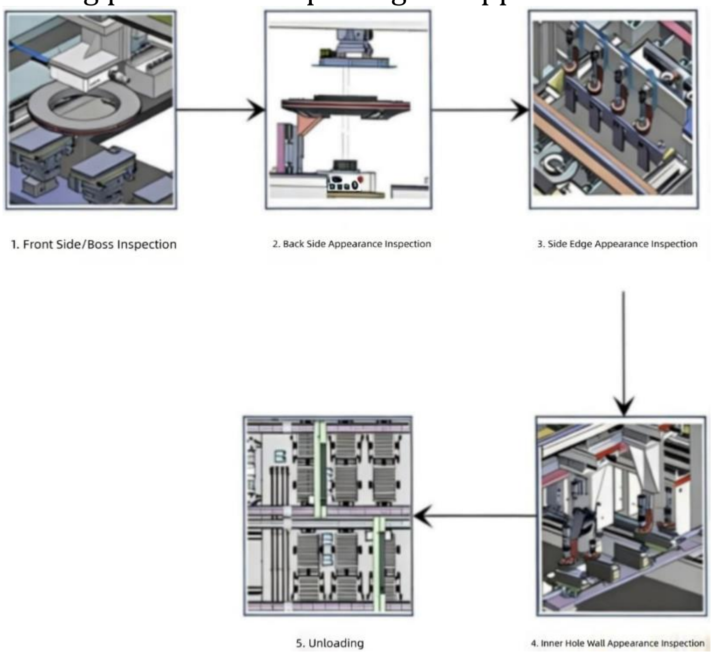

Fig. 1 Flowchart of the motion control process for the mobile phone back cover appearance inspection machine

(1) Front inspection station: XYU rotating carriers are used. During material loading, the position and offset Angle of the products are corrected through camera guidance positioning to eliminate the error of previous incoming materials. The carrier platform is equipped with four evenly spaced acupoints, which are moved along the X-axis. a group of 2.5D cameras above are linked along the Y-axis to inspect the four products in sequence. Each product is captured by static front photography three times to complete the defect collection. The mechanism is shown in Figure 2(a).

(2) Reverse inspection station: Four workpieces are moved along the X-axis. A set of 2.5D cameras below can take pictures along the Y-axis and move up and down along the Z-axis to collect images in sequence. Special treated NBR traceless suction cups are used to suppress rubber overflow. The reverse side of each piece is statically tapped three times to complete defect collection. The mechanism is shown in Figure 2(b).

(3) Side inspection station: Four products are moved along the X-axis. Four sets of 2D cameras above are equipped with electric slides, which can be adjusted along the Z-axis for synchronous inspection. The carrier platform rotates along the Y-axis to make the product vertical and rotates 360° along the X-axis to complete the detection of each side and the arc Angle. It is equipped with a traceless suction cup. The mechanism is shown in Figure 2(c).

(4) Hole position inspection station: Four evenly spaced carriers move along the X-axis. The two groups of inspection sources above (each group consisting of three cameras) are each responsible for the inspection of two products. The cameras can be suspended for XY linkage photography. After the outer carrier is detected, the distance can be adjusted towards the middle. A light source avoidance opening is set at the bottom of the carrier hole, and a traceless suction cup is provided to achieve precise detection of the three hole positions [6,7]. The mechanism is shown in Figure 2(d).

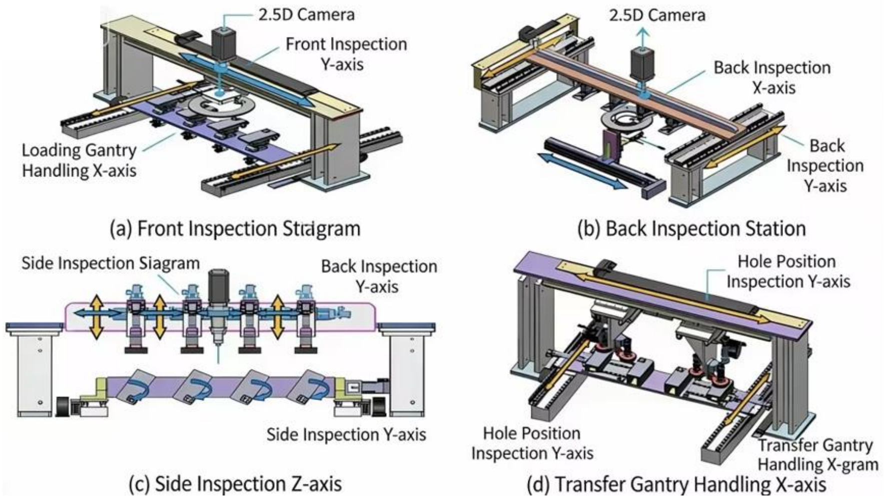

Fig. 2 Workstation structure diagram

3. Hardware Design of The Control System

This control system has a total of 28 motion axes and adopts the motion control card PCIe-M60-B2F from Lingchen Technology, which can support up to 32 axes at most. It is equipped with the IO input expansion module LCT-Mini-IN32 and the IO output expansion module LCT-Mini-OUT32. It adopts the EtherCAT bus to connect the servo drive and the expansion module, ensuring the high efficiency of the control system. The industrial control computer is connected to the display screen. On the display screen, production information, operation mode, communication status, equipment status, etc. can be seen [8,9]. The topology diagram of the EtherCAT motion control card is shown in Figure 3.

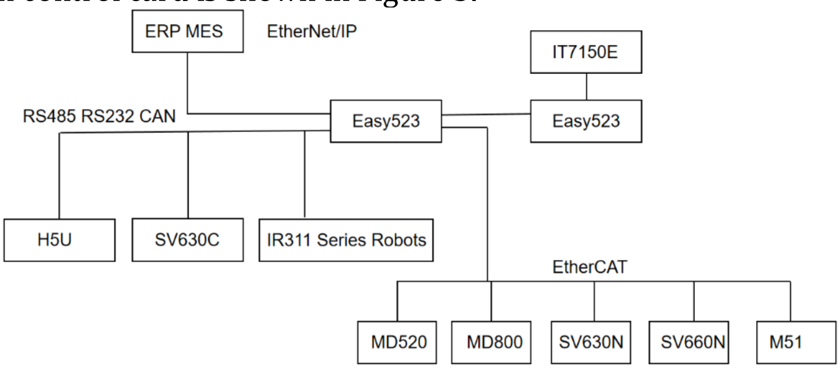

Fig. 3 Topology diagram of the control system

4. Electrical Schematic Diagram of The Control System for The Mobile Phone Back Cover Appearance Inspection Machine

4.1. Main Power Supply Circuit s

The total power of this control system is less than 13.8kW, and single-phase 220V power supply can meet the requirements. The circuit is divided into two parts: strong current (main circuit) and weak current (control loop). The main circuit adopts three-wire power supply of PE, N and L, which are successively connected to the 40A 2P main power switch, power indicator light and 40A 2P main leakage circuit breaker to achieve power on/off, status display and overload and short-circuit protection. The energy meter at the back end is used to monitor power and current. A filter is connected after the electricity meter to remove interference, and each power-consuming module is equipped with an independent circuit breaker to achieve separate protection. As shown in Figure 4.

The switching power supply is independently powered in three ways, respectively supplying the safety door lock, the servo driver brake and the auxiliary components to avoid mutual interference. The 0-V reference terminals of the 24-V DC power supplies are connected to a common reference point, provided that the power supplies permit common grounding. The lighting system adopts 220V fluorescent lamps. Multiple lamps can be connected in series. A front intermediate relay is used to expand IO signals for on-off control. As shown in Figure 5.

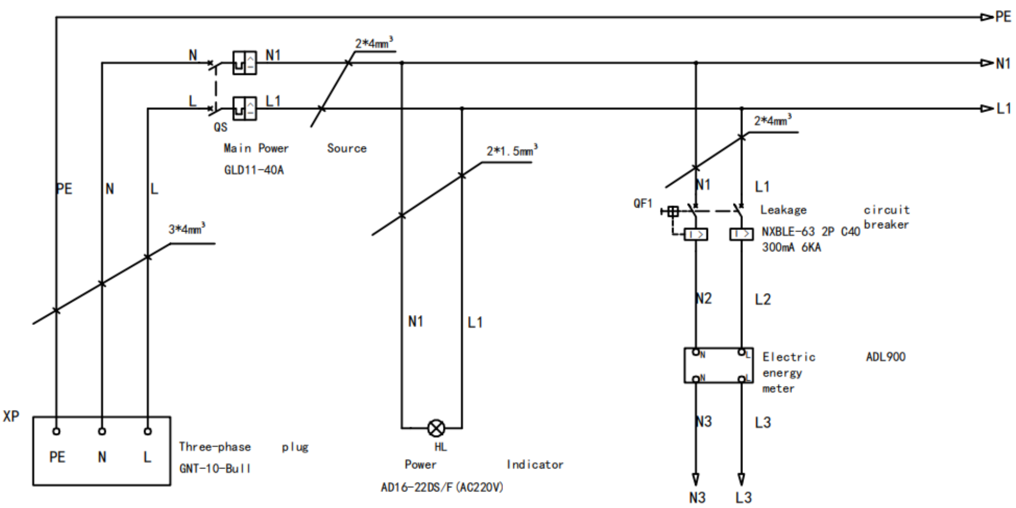

Fig. 4 Main Power Supply Circuit 1

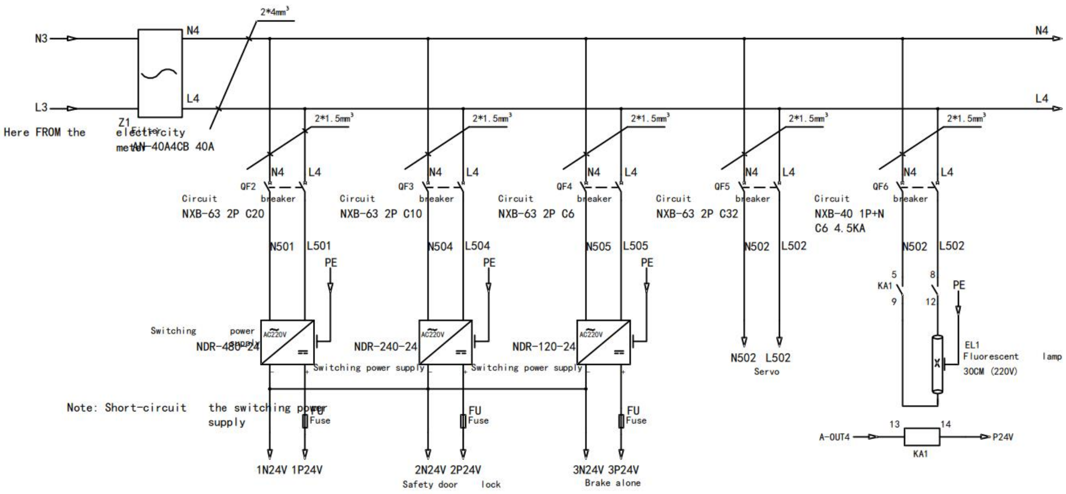

Fig. 5 Main Power Supply Circuit 2

4.2. Drive Circuit

This drive system adopts Inovance SV660NS1R6I-FS and SV680NS1R6I servo drivers to construct a dual-axis closed-loop control topology. As shown in Figure 6, both the Y-axis of the front detection and the X-axis of the reverse detection 1 are equipped with MS1H1 series 200W servo motors, which are connected to the single-phase AC220V main circuit via L502 and N502. The RXLG 100W/50Ω braking resistor is connected in parallel with the circuit to achieve the

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dissipation of regenerative energy and rapid braking. The encoder feedback interface CN2 forms a position closed loop. The I/O terminals complete the vehicle drive and the linkage control of the detection shaft, and at the same time, the trough-type photoelectric is connected to achieve positive and negative limit protection. The driver integrates a safe torque turn-off (STO) function, which can cut off the motor power in emergency conditions, effectively preventing uncontrolled starts and ensuring the safety of equipment and personnel. The overall topology meets the core requirements of multi-axis coordination, high-speed positioning and safe operation of precision inspection equipment.

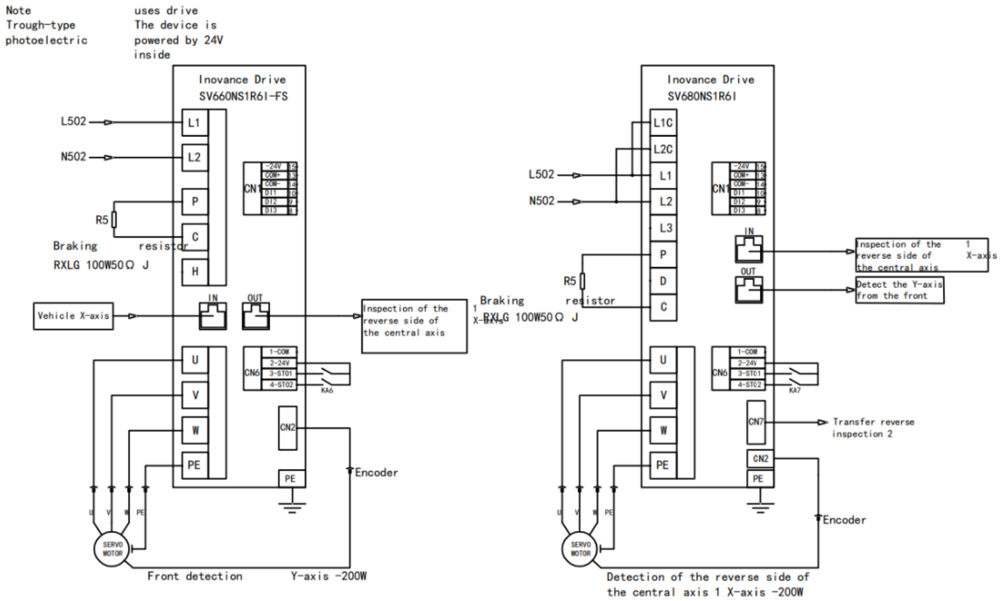

Fig. 6 Electrical schematic diagram of the servo motor and driver

5. Software design

This chapter discusses the software part of the motion control system in the design of the mobile phone back cover appearance inspection machine control system. The sequence of automatic operation actions of the entire machine is as follows: the feeding gantry handling station, the front inspection station, the back inspection station, the side inspection station, the transfer gantry handling station, and the hole position inspection station, totaling 6 stations, among which there are 4 inspection stations. The main difference between the gantry handling station and the inspection station is that the gantry handling station requires high-precision synchronous handling, while the inspection station mainly detects defects on the back cover of mobile phones by rotating the product or moving the camera, and the program is designed according to the actions of different stations.

5.1. IO Table

The upper computer uses Modbus TCP to communicate with the motion control card, and the calculation and analysis between the input and output signal points are carried out to achieve the coordinated movement of each motion module within the intelligent device. First, establish the IO table and define the signals for each IO input and output point by yourself before you can start writing the program. IO signals transmit data through the interface between the industrial control computer and external devices. The industrial control computer controls the status of the interface through the motion control card, converts the data to be transmitted into IO signals, and sends them to external devices. In the IO table, the IO signals for start, reset, pause, emergency stop, manual and automatic, safety relay, fluorescent lamp, and button light are all required for each machine. To facilitate programming, their signal points remain fixed.

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Table 1 Input points of 32-bit IO Expansion Module 1

No.	Input Point	Content	Serial Number	Input Point	Content
1	A-IN1	Start	17	A-IN17	Loading gantry negative pressure gauge 1
2	A-IN2	Reset	18	A-IN18	Loading gantry negative pressure gauge 2
3	A-IN3	Pause	19	A-IN19	Loading gantry negative pressure gauge 3
4	A-IN4	Emergency Stop	20	A-IN20	Loading gantry negative pressure gauge 4
5	A-IN5	Manual/Auto Signal	21	A-IN21	Front inspection station fixture negative pressure gauge 1
6	A-IN6	Safety Relay Status	22	A-IN22	Front inspection station fixture negative pressure gauge 2
7	A-IN7	Spare	23	A-IN23	Front inspection station fixture negative pressure gauge 3
8	A-IN8	Spare	24	A-IN24	Front inspection station fixture negative pressure gauge 4
9	A-IN9	Loading gantry lifting cylinder 1 initial position	25	A-IN25	Front inspection station fixture 1 positioning cylinder X1 initial position
10	A-IN10	Loading gantry lifting cylinder 1 action position	26	A-IN26	Front inspection station fixture 1 positioning cylinder X1 action position
11	A-IN11	Loading gantry lifting cylinder 2 initial position	27	A-IN27	Front inspection station fixture 2 positioning cylinder X1 initial position
12	A-IN12	Loading gantry lifting cylinder 2 action position	28	A-IN28	Front inspection station fixture 2 positioning cylinder X1 action position
13	A-IN13	Loading gantry lifting cylinder 3 initial position	29	A-IN29	Front inspection station fixture 3 positioning cylinder X1 initial position
14	A-IN14	Loading gantry lifting cylinder 3 action position	30	A-IN30	Front inspection station fixture 3 positioning cylinder X1 action position
15	A-IN15	Loading gantry lifting cylinder 4 initial position	31	A-IN31	Front inspection station fixture 4 positioning cylinder X1 initial position
16	A-IN16	Loading gantry lifting cylinder 4 action position	32	A-IN32	Front inspection station fixture 4 positioning cylinder X1 action position

Table 2 Output Points of 32-bit IO Expansion Module 1

No.	Output Point	Content	No.	Output Point	Content
1	A-OUT1	Tri-color light green + Start light	17	A-OUT17	Loading gantry vacuum break 1

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2	A-OUT2	Tri-color light yellow + Reset light	18	A-OUT18	Loading gantry vacuum 2
3	A-OUT3	Tri-color light red + Stop light	19	A-OUT19	Loading gantry vacuum break 2
4	A-OUT4	Fluorescent lamp KA1	20	A-OUT20	Loading gantry vacuum 3
5	A-OUT5	Buzzer	21	A-OUT21	Loading gantry vacuum break 3
6	A-OUT6	Start safety relay signal	22	A-OUT22	Loading gantry vacuum 4
7	A-OUT7	Spare	23	A-OUT23	Loading gantry vacuum break 4
8	A-OUT8	Loading gantry lifting cylinder 1 initial position	24	A-OUT24	Front inspection station fixture vacuum 1
9	A-OUT9	Loading gantry lifting cylinder 1 action position	25	A-OUT25	Front inspection station fixture vacuum break 1
10	A-OUT10	Loading gantry lifting cylinder 2 initial position	26	A-OUT26	Front inspection station fixture vacuum 2
11	A-OUT11	Loading gantry lifting cylinder 2 action position	27	A-OUT27	Front inspection station fixture vacuum break 2
12	A-OUT12	Loading gantry lifting cylinder 3 initial position	28	A-OUT28	Front inspection station fixture vacuum 3
13	A-OUT13	Loading gantry lifting cylinder 3 action position	29	A-OUT29	Front inspection station fixture vacuum break 3
14	A-OUT14	Loading gantry lifting cylinder 4 initial position	30	A-OUT30	Front inspection station fixture vacuum 4
15	A-OUT15	Loading gantry lifting cylinder 4 action position	31	A-OUT31	Front inspection station fixture vacuum break 4
16	A-OUT16	Loading gantry vacuum 1	32	A-OUT32	Front inspection station fixture 1 positioning cylinder X1

5.2. Frontal detection program design

Do When the action process of the loading gantry material handling station is completed, it interacts with the front inspection station. According to the front inspection areas, there are: the straight edge of the platform, the arc edge of the platform, the large surface, the LOGO, and the platform. Then, the program for the front inspection station part is written. The interaction flowchart between the feeding gantry station and the front inspection station is shown in Figure 7.

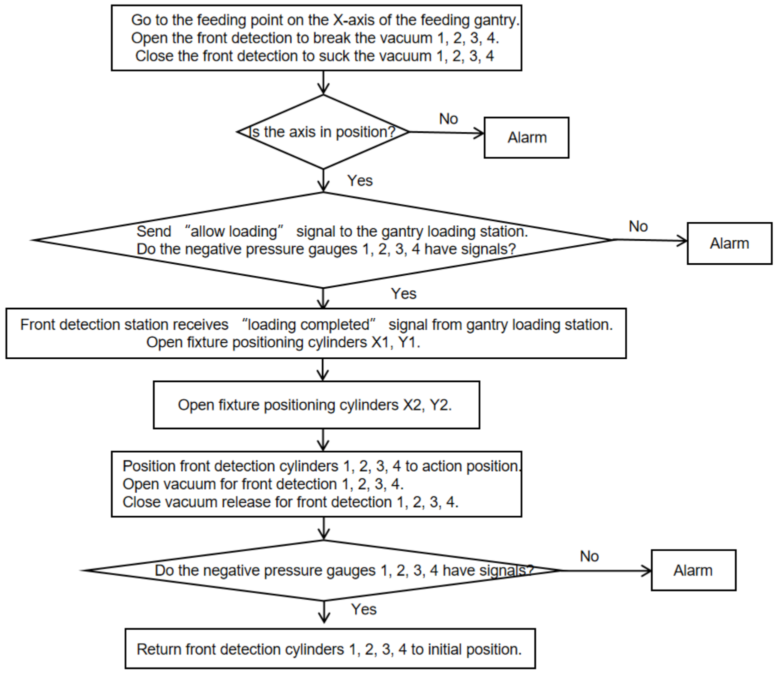

Fig. 7 shows the interaction flowchart between the feeding gantry station and the front inspection station

When the feeding gantry moves to the feeding position of the front detection station, each point will be saved during the debugging process. Among them, vacuum suction is used to hold the material. After it is held, the negative pressure gauge will send a signal. Breaking the vacuum is used for blowing air to prevent the suction nozzle from sticking to the material. When the vacuum suction or vacuum breaking is turned on or off, the negative pressure gauge must have a signal; otherwise, an abnormal alarm will occur and the machine will enter the ideo state. At the front inspection station, there are a total of 5 photo spots: the straight edge of the platform, the curved edge of the platform, the large surface, the LOGO, and the platform. A total of 4 pieces of material need to be tested. k1 represents the material number and k2 represents the number of photos taken. When k2>5, it indicates that the photo of the current material has been completed. When k>4, it means that all four pieces of material have been photographed.

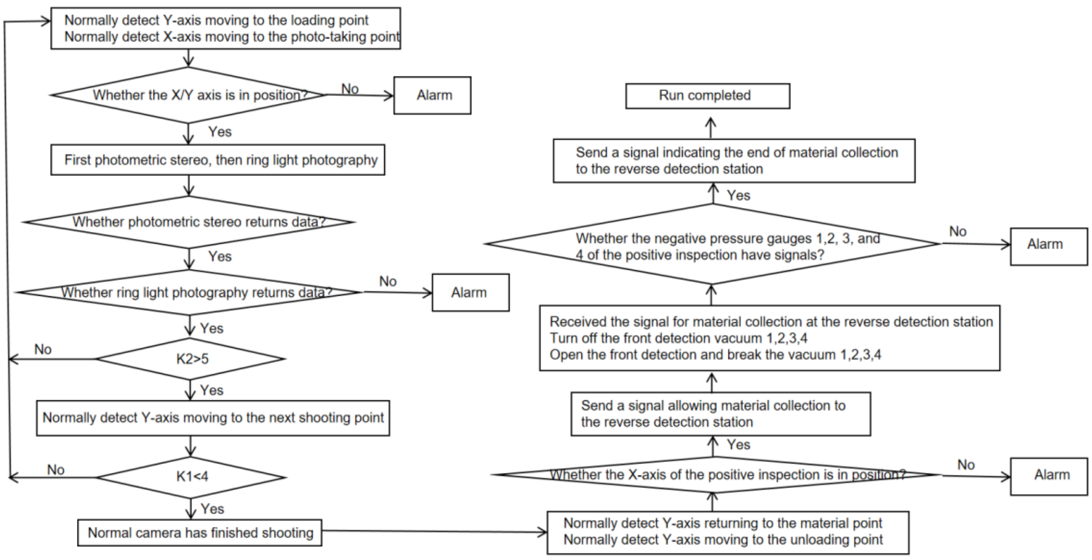

Fig. 8 shows the inspection flowchart

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6. PC Interface Design

The human-machine interaction interface of the system's upper computer PC end adopts a modular architecture design. The core includes two major functional modules: the main monitoring interface and the axis control interface, meeting the full-process requirements of equipment operation monitoring and motion debugging.

The main monitoring interface serves as the core visual window for equipment operation, integrating the real-time monitoring function of the entire equipment status. It can visually display key data such as the equipment operation mode, working status, online detection results, production batch information, and system operation parameters, achieving full-process visual control of the production process. This enables operators to grasp the equipment's working conditions in real time and respond promptly to abnormal conditions. The interface layout is shown in Figure 9.

The axis control debugging interface is specially designed for equipment debugging and point calibration. It supports independent control of a single axis in JOG movement mode and can achieve axis enabling control, zero return operation, and parameter setting of movement speed and single-step movement step length. After the shaft has completed the zero calibration, the preset point parameters can be directly called to achieve precise positioning, significantly improving the debugging efficiency and positioning accuracy. The layout of the shaft control and monitoring interface is shown in Figure 10.

Fig. 9 Main interface

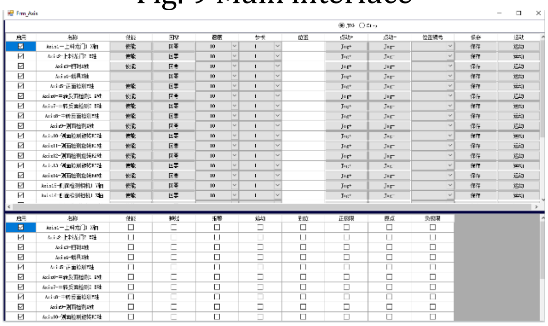
Fig. 10 Axis monitoring interface

7. Conclusion

The control system of the mobile phone back cover appearance inspection machine designed in this study takes the Lingchen motion control card as the core, relies on the EtherCAT bus to achieve 28-axis precise coordination, integrates cleaning, multi-station visual inspection and intelligent sorting functions, and can complete the full-dimensional defect detection of the front and back sides, sides and holes of the mobile phone back cover. The system, through a modular hardware architecture and standardized IO program design, realizes the automation of the detection process and intelligent product diversion, effectively reducing the rate of manual missed detections, improving detection accuracy and production efficiency, meeting the high-precision online detection requirements of high-end consumer electronic components, and

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providing a reliable technical solution and application reference for the automatic detection equipment of mobile phone back covers.

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