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Design of a Machine Vision-Based Detection System for Semiconductor Refrigeration Sheets

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Abstract:

Semiconductor refrigeration sheets are widely utilized across various fields, often in the form of combined semiconductor refrigeration units. The performance of these combined units hinges on the consistency of the electrochemical characteristics of the individual semiconductor refrigeration sheets. Consequently, it is crucial to test and sort these sheets before they leave the factory.Visual inspection involves using machines to measure and judge, replacing human eyes. Visual detection converts the target into image signals via machine vision products, such as image capturing devices like CMOS and CCD sensors, and transmits these signals to a specialized image processing system. This system transforms the pixel distribution, brightness, color, and other information into digital signals. The image processing system then performs various operations on these signals to extract the characteristics of the target. Based on the discrimination results, it controls the equipment's movement on site.This mechanism is valuable for production, assembly, or packaging, providing significant benefits in detecting defects and preventing defective products from reaching consumers. This paper presents the design of a semiconductor detection system based on machine vision to detect and sort semiconductor refrigeration sheets.

Keywords:

Semiconductor Refrigerator, Machine Vision, Testing, Sorting.

1. Research background

Semiconductor refrigeration sheet is a new type of refrigeration device made of thermoelectric semiconductor materials. Compared with the traditional compressor cooler, it has the following advantages:

1. Environmental protection: it is a green refrigeration device without refrigerant during operation;

2. The mechanical structure is simple: it is not as complicated as the traditional refrigerator. It can be made into any shape and size of refrigeration device through any combination of refrigeration couple;

3. Long service life: it can be used up to 100000 hours under normal working conditions;

4. The refrigeration capacity is easy to control: after the direct current is applied, a certain temperature difference is rapidly formed at the positive and negative ends of the semiconductor refrigeration sheet. By controlling the working voltage, the refrigeration capacity can be arbitrarily changed, and the minimum refrigeration power is below 1W. In the field of micro refrigeration, the semiconductor refrigeration sheet has the advantage that the traditional refrigerator cannot replace.

5. Flexible working mode: when the working voltage at both ends of the semiconductor refrigeration sheet is reversed, the semiconductor refrigeration sheet can quickly enter the heating working state from refrigeration.

Traditional compressor coolers rely heavily on refrigerants, and Freon is a typical refrigerant. In recent years, it has been found that Freon has a huge pollution to the environment. Freon emissions

in the atmosphere take hundreds of years to disappear. It has a huge damage to the ozone layer. The destroyed ozone layer has formed an ozone hole, so that the earth & apos;s surface is exposed to strong ultraviolet radiation, resulting in the increase of human skin cancer patients.Freon also has certain impact on the greenhouse effect that has seriously troubled human beings in recent years. The greenhouse effect has led to a series of impacts in recent years, such as global warming, sea level rise, the increase of diseases and pests, land desertification, etc.

Because of the huge influence of refrigerants used in traditional compressor coolers on the environment, and the advantages of semiconductor refrigeration sheets, a wave of research on semiconductor refrigeration technology has been aroused in the 1960s in the world. In recent years, great progress has been made in semiconductor refrigeration technology. The technical problems such as low coefficient of merit Z of semiconductor thermoelectric materials, backward welding and manufacturing technology of refrigeration couple, and low efficiency of heat dissipation at the hot end of semiconductor refrigeration sheet have been solved one by one.

With the overcoming of the technical problems of semiconductor refrigeration, as shown in Figure 1, the semiconductor refrigeration sheet has been widely used in various aspects. The infrared detector of the infrared guided air-to-air missile carried by Russia&apos ;s MIG series fighter just uses the semiconductor refrigeration sheet to cool its probe to reduce the working noise and improve the detection accuracy and sensitivity; the space detector rota landing The sensor on the top of the device is equipped with a semiconductor refrigeration sheet on the reverse side of the quartz crystal to heat or cool the quartz crystal according to the needs; the thermal protection plate of the infrared camera installed on the Hubble Space Telescope is cooled by the semiconductor refrigeration sheet; the car refrigerators produced by Shenzhen Meigu Electronic Technology Co., Ltd. by using the semiconductor refrigeration sheet every year have reached millions and are sold to the market. At the same time, the development of semiconductor refrigeration technology has also promoted the development of a number of medical equipment, bringing benefits to the majority of patients, such as cataract cryosurgery tablets, insulin incubator, etc.

Fig. 1 Application of semiconductor refrigeration sheet

With the wide application of semiconductor refrigeration sheet, new requirements are put forward for the test instrument of semiconductor refrigeration sheet. At present, the main testing instruments of semiconductor refrigeration chips in the market are Lindsey test system in Germany, z-meter test system in Russia and ulbac-riko test system in Japan. This kind of instrument has advanced test algorithm, high test accuracy but high price. The price of Lindsey test system in Germany has reached one million, the test process is tedious and the test time is long. At present, the domestic semiconductor refrigeration technology has reached a certain level, and a large-scale industry has been formed in the field of middle and low-end semiconductor refrigeration. The annual output of semiconductor refrigeration chips is more than tens of millions. Guangdong Fuxin electronic, a large-scale semiconductor refrigeration chip manufacturer in China, has sold semiconductor refrigeration chips, car refrigerators and red wine cabinets to Europe, Australia and the United States, with an annual output value of hundreds of millions of yuan. However, in addition to several large enterprises

such as Fuxin, most of the domestic semiconductor refrigeration sheet manufacturers and secondary manufacturers are small and medium-sized enterprises, unable to purchase these expensive imported test instruments. The lack of test instruments has brought great trouble to the factory inspection of domestic semiconductor refrigeration sheet manufacturers and the selection of semiconductor refrigeration sheets by secondary manufacturers. Therefore, it is of great significance and practical application value to develop a test system which can quickly test the characteristic parameters of semiconductor refrigeration chip, and the method is simple, the result is reliable, the accuracy meets the requirements of domestic industrial production, and the price is moderate.

2. Research status at home and abroad

In the 1960s, American scientist Harman successfully tested the Seebeck coefficient of semiconductor thermoelectric materials, which was named as the Harman method. In 1978, Soviet lukomsky reduced the error of the coefficient of merit Z to less than 10%. In 2000, B.J. Huang proposed to compensate the semiconductor refrigeration by means of heating plate. In 2008, w.john Bilski et al. Proposed to use PID fuzzy control algorithm to online correct the temperature difference between the cold and hot ends of the semiconductor refrigeration sheet to improve the test accuracy; in 2011, Campbell. L.A et al. Designed a set of water-cooled cycle semiconductor refrigeration sheet characteristic test device to improve the test accuracy.

The testing instruments of foreign relatively mature semiconductor refrigeration chips are Lindsey test system in Germany and z-meter test system in Russia as shown in Fig. 2 and Fig. 3. The testing algorithm of such instruments is advanced, the testing accuracy is high, but the price is expensive. The price of Lindsey test system in Germany has reached one million, and the testing process is tedious. At present, there are only some scientific research institutions and Colleges and universities purchase these imported testing instruments, while most of the domestic semiconductor refrigeration sheet manufacturers and secondary manufacturers are small and medium-sized enterprises, unable to purchase these expensive imported instruments.

Fig .2 test system of Lindsay semiconductor refrigeration sheet

Fig. 3 test system of Russian z-meter semiconductor refrigeration sheet

In 2004, David Han and others of Shanghai Jiaotong University proposed to place an electric heating module on the cold end. The heating capacity of the electric heating module was regarded as the cooling load of the semiconductor refrigeration chip, and the phase of the semiconductor refrigeration chip was tested by adjusting the working current of the electric heating module. In 2006, Gong Changmeng and others of Southeast University proposed a transient method to test the optimal value Z. they proposed a new calculation formula of the optimal value coefficient Z by studying the calculation formula of the parameters of the semiconductor refrigeration sheet, but their calculation formula is based on the assumption that the Joule heat generated by current I can be ignored, so the accuracy is not high. In 2014, Liu Liangbin and others from Hunan University of science and technology proposed an adiabatic compensation method to test the characteristic parameters of semiconductor refrigeration sheets. They proposed to use the heat generated by the heating module to compensate the heat absorbed by the cold end of the refrigeration sheet from the heat exchanger to keep the temperature of the air inlet and air outlet of the heat exchanger unchanged, which reduced the heat transfer from the heating module to the outside in the traditional test. Because of the inaccurate calculation of the cooling capacity, the control method further improves the test accuracy of the relevant characteristic parameters, but the simplicity of the method needs to be improved in the industrial production.

In 2013, Liu Zhenglai and Yang Junyou from Huazhong University of science and technology designed a hgte-ii thermoelectric parameter test system, as shown in Figure 4.

Fig. 4 hgte-ii thermoelectric parameter test system

3. Roject content

3.1 Research content and objectives

The purpose of this project is to design and manufacture a kind of semiconductor detection system based on machine vision, which is mainly used for the dimension detection of the refrigeration chip and the separation of performance parameters, to solve the problem of cumbersome process and high labor cost. The main performance indexes include:

(1) The equipment adopts pneumatic, electrical and mechanical transmission, PLC and pneumatic control, which can realize the functions of material delivery positioning, product code identification, visual detection, electrical detection, sorting, blanking and printing of good (secondary) product list;

(2) Use machine vision technology to carry out dynamic detection of products to determine whether the overall dimension is qualified;

(3) Check the key electrical parameters of the product through the electrical testing system to determine whether the performance is qualified;

(2) It is required to have high reliability, accurate test results, low noise, etc., and certain static and control accuracy;

(3) PLC control, photoelectric monitoring of the action of each part, automatic sorting of defective products in operation, emergency shutdown in case of any abnormality, so as to eliminate the fault in time;

(4) compact structure, safe and reliable, small floor area and simple operation.

3.2 Programme

(1) Overall scheme design

On the basis of full investigation and research, the feasibility analysis and demonstration are carried out to determine the scope of use of the testing equipment, assembly process method, the structure and overall layout of the primary selected components, etc. When drawing up the overall plan, the determined plan is advanced and has high economic benefits. This project is designed for the special test of a certain type of refrigeration sheet, that is, the tested refrigeration sheet has a large production batch and the specifications remain the same.

A) Main contents of investigation and research

Mainly understand the type, nature, size, shape, detection method, form and sorting requirements of the refrigeration sheet, understand the operation technology level of the operator for the detection of existing products of the same type, and understand the working environment of the newly designed detection equipment, including temperature, humidity, etc.

B) Access to relevant technical data

Mainly refer to the existing drawings, technical data and relevant use information of the same type of testing equipment; at the same time, refer to various domestic and foreign relevant scientific and technological documents to understand the current situation and development trend of the same type of machinery at home and abroad.

C) Preliminary design

Determine the use scope and productivity of the testing equipment, carry out the testing process analysis, determine the testing method and form and draw the process flow chart; preliminarily select the type of testing equipment, the structure of each component and draw a sketch; determine the overall dimension of the testing equipment and draw the overall dimension connection diagram; draw up the transmission system diagram of the whole machine and the working cycle diagram of the testing equipment; andAt the same time, complete the overall layout, determine the main technical parameters and draw the overall drawing of the equipment.

(2) Technical design

A) Design calculation

According to the overall scheme of the equipment, the motion design calculation, structural design and dynamic calculation are carried out for the components of the equipment. At the same time, the strength and rigidity of some parts should be checked, and the assembly drawing, special part drawing and general part supplementary processing drawing of each component should be drawn.

B) Preparation of technical documents

Design calculation specification: including the overall scheme design, motion calculation of parts, structural design, dynamic design, strength and rigidity check of relevant parts, etc. At the same time, the economic benefit of the whole machine is analyzed.

Operation instruction: including technical performance of the equipment, construction description of each component; installation, debugging, lubrication method of the assembly equipment, troubleshooting method of common faults; list of vulnerable parts, drawings, electrical equipment list; acceptance standards of the assembly equipment; preparation of a detailed list of various general parts and standard parts.

(3) Detection process design

Analyze and determine the detection method and form, detection procedure, detection route, number of stations and so on. As shown in Figure 5:

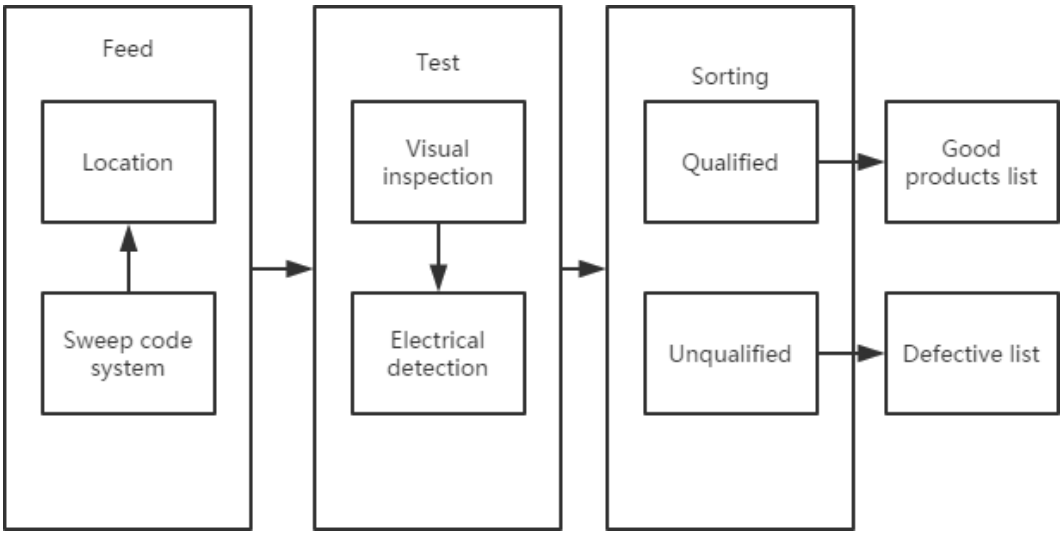

Fig. 5 detection process of refrigeration sheet

A) Test procedure

Detection procedure refers to the sequence of each detection action during the detection. The proposed equipment testing procedures are as follows. Loading and positioning of refrigeration sheet → code scanning record → detection and identification → sorting → blanking → printing of good (secondary) product list. As shown in Figure 6:

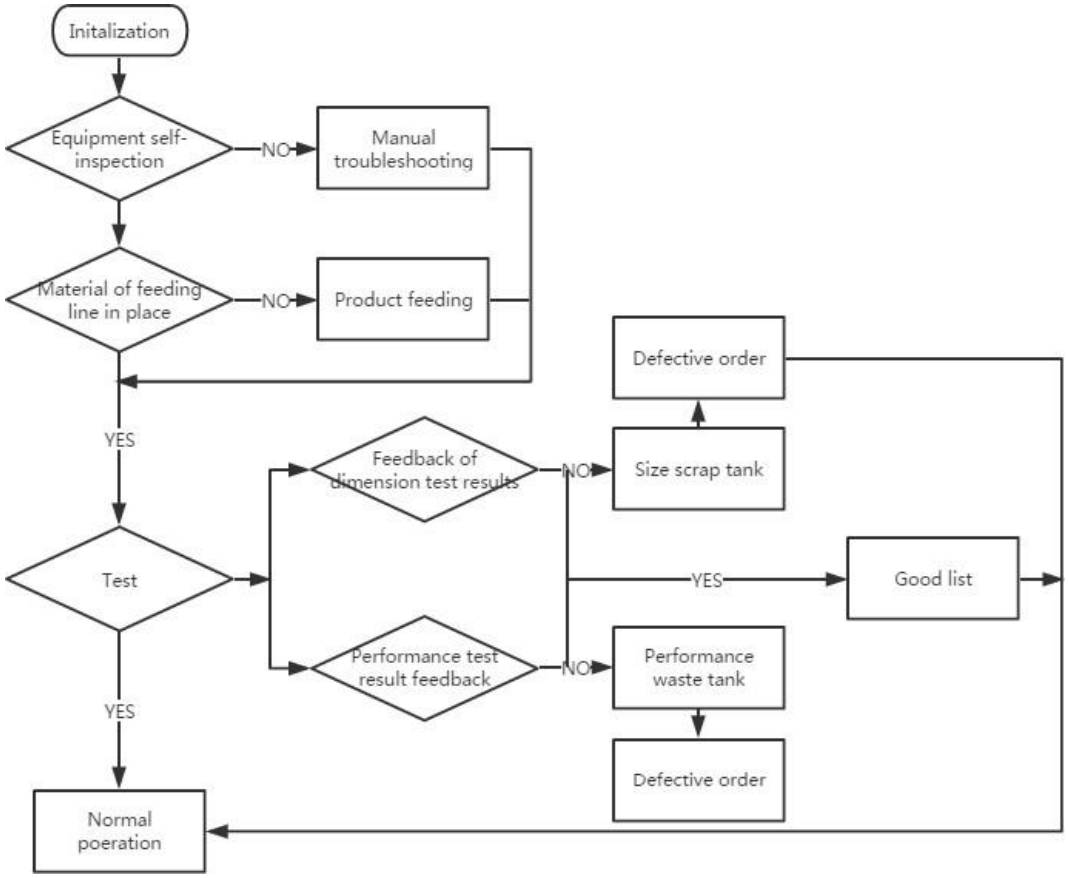

Fig. 6 test procedure of refrigeration sheet

The integrated testing system of semiconductor refrigerating wafer mainly consists of two parts: monitoring software and control software. The monitoring software is mainly composed of equipment

condition monitoring, parameter setting, equipment operation, alarm history record and prompt, data management, voltage internal resistance trend interface of semiconductor refrigeration chips, etc. The system startup equipment first enters the equipment condition monitoring interface. According to the number, location and operation status of the semiconductor refrigeration chip on the transport line, the marshalling mode and the number of robot grabbing blocks are set. The system is switched to automation, and the equipment enters the operation status by clicking on the operation button. When the equipment fails, sound and light alarm and interlocking shutdown will be issued. In the monitoring interface, alarm will be given in the form of warning lights and the fault will be inquired in the historical alarm interface.

The unqualified single semiconductor refrigeration chips will appear in the test of the single semiconductor refrigeration chips when the semiconductor refrigeration chips are grouped. As a result, the equipment can not continue to produce. If the equipment manually participates in replacing the unqualified single semiconductor refrigeration chips in the production, the production efficiency and safety of the staff can not be guaranteed. The system has set up spare parts trough and waste products trough. When the robot detects the unqualified monomer semiconductor refrigerating sheet in the process of marshalling, it first puts the unqualified monomer into the waste products trough, then grabs the spare parts semiconductor refrigerating sheet from the spare parts trough and detects it. If it is qualified, it directly carries out marshalling and puts it into the third position of the blanking line body. If it is unqualified, it puts it into the waste products trough and continues to move from the spare Semiconductor chillers are grabbed in the tank and replaced until the replacement is successful. After successful replacement of semiconductor refrigeration chips, the unfinished semiconductor refrigeration chips are continued to be grouped. The counting of the number of semiconductor refrigeration chips in the spare tank and the waste tank is counted by the photoelectric sensor installed at the bottom. When the waste tank is full and the spare tank is short of material, the equipment stops and sends out prompt information.

After the material of semiconductor refrigerating sheet reaches the working station of feeding line body, the material number of semiconductor refrigerating sheet is counted by photoelectric sensor. When the photoelectric sensor receives the induction signal to represent the material here, the number of semiconductor refrigerating sheet is collected by PLC through photoelectric sensor to interact with the robot, and the robot communicates with the robot according to PLC. The retrieved data information determines the grasping position of the single semiconductor refrigeration chip. Because the quantity of material in a given semiconductor refrigerating sheet is fixed, such as when the semiconductor refrigerating sheet is scattered and the material of the semiconductor refrigerating sheet is not in place, if the number of the remaining semiconductor refrigerating sheet is counted by the number of times grasped by the robot, the real-time monitoring of the quantity of the semiconductor refrigerating sheet can not be realized, it is likely to happen. The collision accident of robots causes great damage to the service life of robots. Therefore, it is necessary to monitor the number of single semiconductor chillers by sensors. When the material of semiconductor refrigerating sheet is displaced due to the deformation of battery, a fault alarm is issued and the interlocking shutdown robot is prevented. Stop the malfunction of the equipment when the robot moves.The sensor can monitor the number of semiconductor chillers in real time to determine the grasping position and placement position of the robot, such as the scattering of semiconductor chillers on the wire body, the artificial moving of the position of semiconductor chillers or the material of semiconductor chillers not reaching the position. In case of emergencies, sound and light alarms will be issued at the first time and the robot will be shut down in a chain according to the fault situation. In order to prevent the material position of semiconductor refrigerating sheet from changing due to bulging and deformation of semiconductor refrigerating sheet, a laser displacement sensor is installed on one side of the material of semiconductor refrigerating sheet. When the material of semiconductor

refrigerating sheet is displaced due to the deformation of battery, a fault alarm is issued and the interlocking shutdown robot is prevented. Stop the malfunction of the equipment when the robot moves.

B) detection process

The detection route refers to the supply route, the movement route of materials in the detection process, and the output route of sorting finished products. The proposed process of the equipment is linear, that is, the movement route of the tested material in the detection process is linear, and the movement direction is horizontal.

The feeding transmission belt is equipped with the supporting fixture for the refrigeration sheet, so the refrigeration sheet does not need to be accurately positioned when feeding; the semiconductor refrigeration sheet moves with the feeding transmission belt, and first scans and identifies the two-dimensional code on the refrigeration sheet through the two-dimensional code scanning device, and the information obtained through scanning is stored in the controller as the only identification code of the product for tracking the subsequent detection and use; then the product is transported to the CCD. Dynamic visual identification is carried out under the camera to judge the external dimension parameters; then the refrigeration sheet enters the electrical test module to test the relevant predetermined performance parameters (such as resistance, etc.), and the test results are fed back to the controller; the sorting module sorts the refrigeration sheet according to the test results sent by the controller; finally, the controller forms a good product list composed of product identification code. And defect list.

C) number of workers

Generally, it refers to the number or pieces of simultaneous detection on the detection station. This equipment is the number of detection stations staying and executing detection actions, i.e. 2 stations.

(4) working cycle

When testing materials with testing equipment, due to the large number of tested products, the number of actuators of the testing equipment is large and the action is complex. In order to complete the testing work well, each actuator should not only move according to a certain rule, but also require each action to coordinate and cooperate with each other. These requirements are completed by drawing up the working cycle diagram.

A) draw up the motion law of each actuator

According to the allowable movement speed and acceleration of the process time, testing material, testing time and testing executors required by the testing process of a brand of refrigeration sheet of the testing equipment, the working time, return time and dwell time of each executor are determined, and the law of speed change is determined at the same time.

B) draw up the cooperation relationship of detection actions of each actuator. For the mechanical transmission parts, the motion law of each actuator is transformed into the angle relationship with the main distribution motion of the testing equipment.

C) draw the working cycle diagram of testing equipment

When drawing the working cycle diagram of the testing equipment, based on the main actuator, the motion law of each actuator is expressed according to the testing procedure.

D) express the signal sending time and working state of each control element on the circulating diagram, and check and modify the circulating diagram.

(5) general layout

A) arrangement of main transmission mechanism

Determine the layout and movement form of the main transmission mechanism according to the detection process route, and then arrange the whole detection equipment based on its center line.

B) arrangement of actuators

Detection is to arrange the measurement and delivery mechanism of tested materials, the sorting and delivery mechanism of tested products, the detection actuator and the finished product output mechanism.

According to the inspection process flow chart, based on the main transmission system, each actuator

is arranged on the corresponding position. Then arrange the position of the motion driving parts of each actuator.

C) arrangement of operating parts and control system

When designing the working table of the testing equipment and the position of the operating parts, the size of each part of the human body shall be considered. It is preferred to determine the position of the operator, and the general operator is standing at the front of the detection equipment. Generally, the movement direction of the control shall be consistent with that of the controlled.

The height of the worktable of the testing equipment is proposed to be within 700-900mm.

The indicating instrument, signal lamp, alarm, safety valve and other devices on the detection equipment are all arranged in a position convenient for the operator to observe, maintain and be safe and reliable.

D) select the form of machine support

When selecting the form of the supporting parts of the machine, the shape and structure of the whole machine shall be taken into consideration, which is not only beautiful but also convenient for the operator to work, but also convenient for assembly and maintenance.

The "one" support is proposed for this testing equipment.

E) general layout drawing

On the general layout, the relative position and connection dimension of each component of the testing equipment and the main outline of the machine shall be clearly indicated.

Design of equipment control system

The core component of the control system of the testing equipment is Mitsubishi FX3U series PLC, and the Winton mt6070ih is selected as the human-computer interface of the system.

According to the control requirements of the testing equipment, it is necessary to realize the functions of manual debugging, reset to zero and automatic operation.

The manual debugging mode can realize the functions of left and right movement, fixed-point movement of the worktable, independent control of lifting by each manipulator and executive parts, forward and backward, suction and discharge of suction cup, clamping and loosening of positioning clamping cylinder, lifting and lowering of feeding cylinder, etc.

The automatic operation mode is divided into single cycle operation and continuous operation. Press the button in the automatic operation interface of the host to select. The automatic operation mode realizes each assembly process according to the workflow, and displays the assembled quantity in the output counting window.

In the process of detection, in case of failure, press the emergency stop key to stop, and after troubleshooting, press the reset key to return to the original point for re operation.

(7) parts processing and complete machine assembly

Carry out the purchase of general parts and standard parts and the design and processing of non-standard parts; complete the whole machine assembly and debugging of the mechanical body and control system; optimize and improve the local structure to achieve the expected functions.

4. Conclusion

This project abandons the cumbersome procedures of traditional sensor detection and instead designs a sorting system based on machine vision detection, tailored for industrial assembly line operations. The system uses an industrial camera to capture workpiece images and employs image recognition methods to identify the workpiece size, communicating with the controller to feedback the test results.

The machine vision application system consists of several key components. A light source and optical system illuminate the workpiece for clear imaging, while a CCD camera or other image capturing device converts the target into an image signal. This signal is then digitized and processed to extract features based on pixel distribution, brightness, and color. An intelligent judgment and

decision-making module analyzes these features and produces judgment results based on preset tolerance and conditions. The mechanical control execution module then carries out the necessary sorting actions based on these results.

The flexible design of the electrical test module adapts to performance tests for products of different specifications and sizes, allowing for detailed sorting based on performance differences. Specifically, defective products can be categorized according to their performance discrepancies, facilitating follow-up rework operations for those lacking specific performance parameters.

Overall, this system streamlines the detection and sorting process, making it more efficient and adaptable to various industrial needs.

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