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Design of Crucible Waste Recycling Control System based on PLC.

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Abstract

Aiming at the recycling of production waste attached to the surface of the crucible and the cleaning of the crucible during the production process in enterprises, a PLC-based automatic control system is designed. The hardware design, PLC program design, and upper computer configuration of the control system are elaborated in detail. By using this control system, the operator can directly operate and monitor the real-time status through the operation of the electrical control cabinet, which liberates labor and improves the efficiency of waste recycling.

Keywords

Crucible Waste; Automatic Control; PLC.

1. Introduction

With the acceleration of industrialization and the expansion of production scale, China has become the world's largest manufacturing country, with continuous improvement in industrialization level. Various industrial enterprises are distributed throughout the country, covering multiple fields, including steel, energy, chemical, electronics, and more. However, the discharge of industrial waste during this development process has caused serious pollution and damage to the environment. Problems such as air pollution, water pollution, and soil pollution are becoming increasingly prominent, causing negative impacts on people's health and the ecological environment[1]. Under the 2035 sustainable development strategy goal, environmental protection and the concept of a circular economy have become deeply rooted, aiming to reduce negative impacts on the environment[2]. At the same time, due to resource scarcity and rising energy prices, waste recycling has become an important way to save resources. By effectively recycling industrial waste, it is possible to reduce dependence on raw materials, lower production costs, improve production efficiency, and also help alleviate the situation of resource shortages.

2. The Purpose and Process of Waste Recycling and Cleaning Device

Crucible waste refers to the alkaline powder attached to the surface of crucibles in industrial production. It reacts with water to produce a large amount of hydrogen gas and alkaline gases, which pose significant harm to the environment and human health. The purpose of the crucible waste recycling and cleaning device is to automate the entire process of waste recycling and crucible cleaning to ensure safety[3].

The process is mainly divided into two steps: digestion and cleaning. In the digestion process, a mechanical arm grabs the crucible to be cleaned and places it into a digestion tank. Vacuum is applied, followed by argon gas replacement to remove oxygen from the digestion tank. Then, the recycled digestion solution is injected for recycling. After the digestion reaction reaches the set time, the digestion solution is drained, and the crucible is taken by the mechanical arm to the cleaning tank for cleaning. The process flowchart is shown in Figure 1.

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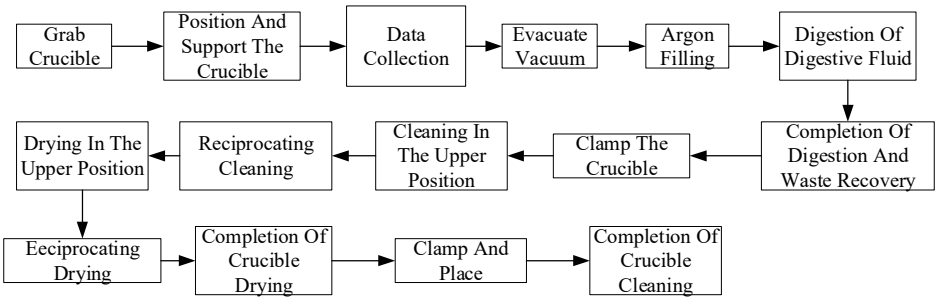

Figure 1. process diagram

3. Electrical Control System Design

The gas control system mainly consists of PLC, human-machine interface and monitoring system, vortex fan, solenoid valve, pneumatic valve, level gauge, photoelectric position sensor, lifting motor, oxygen sensor, hydrogen sensor, pressure sensor, injection and drainage pump, and liquid level limit sensor. Among them, the PLC selected is Siemens S7-200smart SR60 series CPU. Additionally, it is expanded with one digital input/output module EMDR32 and one analog input module EMAQ04.The human-machine interface and monitoring system adopt the Kunlun Tongtai touch screen TCP7062TD and MCGS configuration software. The vortex fan, lifting motor, injection and drainage pump, etc., are all controlled by AC contactors for switching control, with circuit breakers and thermal relays for short-circuit and overload protection. The control mode includes remote and local modes. The remote mode refers to the control of the start-stop status by the PLC controller, rendering the start-stop buttons on the site control box ineffective. The local mode refers to controlling the start-stop status using the start-stop buttons on the local control box, at which time the output signal of the PLC is ineffective. The oxygen sensor, hydrogen sensor, and pressure sensor adopt 4-20 mA current output to monitor the gas and pressure environment inside the digestion tank. The level gauge, fork liquid level sensor, and pump outlet pressure sensor transmit signals through 4-20 mA current to the PLC for data acquisition. The liquid level limit sensor transmits switch signals to the PLC for signal acquisition. The electrical control system structural diagram is shown in Figure 2, and the PLC cabinet is shown in Figure 3.

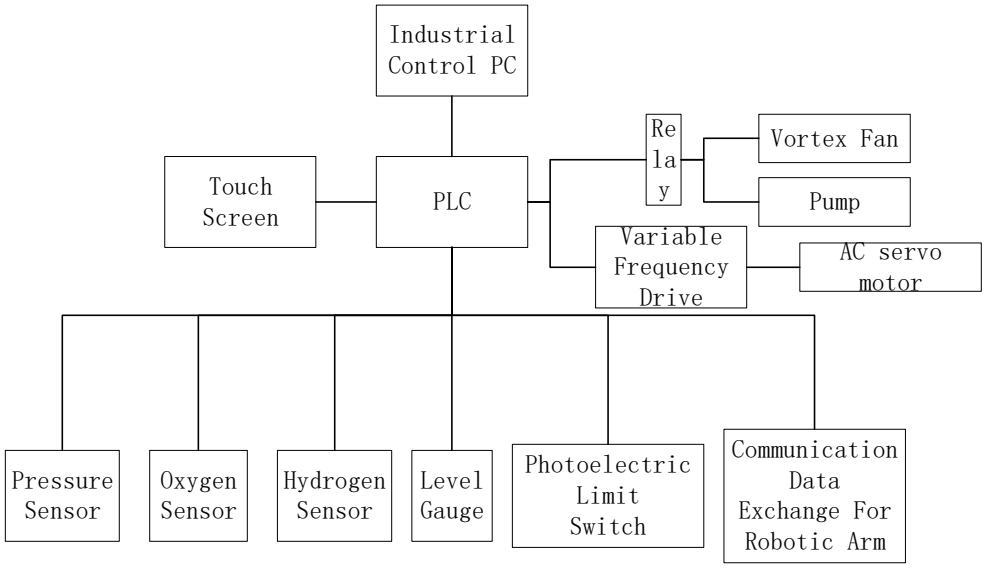

Figure 2. PLC control scheme diagram.

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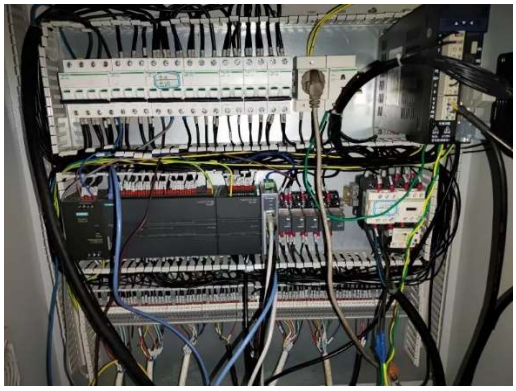

Figure 3. Electrical cabinet wiring diagram.

4. PLC Program Design

The PLC control program is divided into two categories: refining crucible and synthetic crucible. The specific cleaning process design is as follows.

4.1 Crucible Waste Recycling and Cleaning Control System Program Design

Designing automatic control for crucible waste recycling and cleaning, based on control requirements and the company's process needs, as shown in Figure 4. Once it is confirmed that there are no special conditions on-site, clicking the start button will trigger the system to first determine the status of valves and motors in remote control and check for any alarms. Additionally, it will verify if there are any alarms related to liquid levels, pumps, fans, etc. If all operational conditions are met, the automatic process for crucible waste recycling and cleaning will commence.

The process is divided into two stages: digestion and cleaning. The digestion process includes the following steps: Open the digestion tank cover, and the robotic arm grabs the crucible with waste material and places it into the digestion tank. The robotic arm then resets, and the tank cover is closed. Create a vacuum of -0.096MPa and replenish with argon gas up to 2Kp to displace the oxygen inside the tank cover, ensuring that the oxygen content is below 0.2%. Inject the digestion solution into the tank to begin the digestion process. After the set digestion time, the digestion solution is recovered, and the robotic arm opens the cover to grab the crucible and transfer it to the cleaning tank.

The cleaning process involves the following steps:

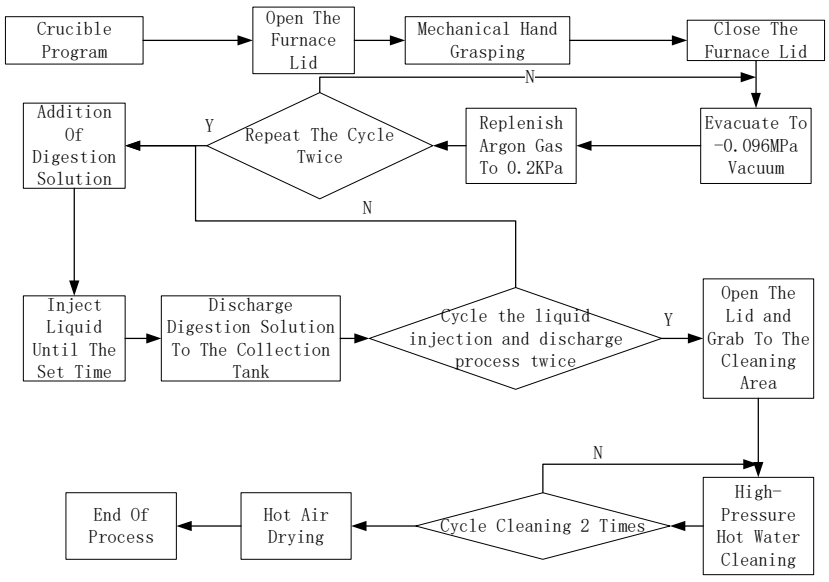

Figure 4. Control Flowchart for Crucible Recovery and Cleaning

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Using tap water and hot water, and then using a high-pressure water gun to clean the upper and lower positions in a back-and-forth cycle four times, thoroughly cleaning the interior and exterior of the crucible. Subsequently, rinsing with deionized water once before activating the hot air dryer for hot air drying in preparation for the next production cycle. When cleaning oil-refined crucibles, it is necessary to use high-temperature and high-pressure hot water to wash repeatedly until all oil residues are removed. This is to avoid affecting the next product production.

5. Human-Machine Interaction Interface Configuration

The Human-Machine Interaction Interface Configuration can be translated into English as "Human-Machine Interaction Monitoring Interface." It is a computer monitoring system that graphically displays the operational information and sends execution commands to the field. Users can centrally manage the field operations through the monitoring screen. The functionality of this upper-level monitoring system, in accordance with process requirements, is shown in Table 1.

Table 1. Monitor contentmonitor content

Function Categorization	Function Description
Status Monitoring	System manual/automatic control status, System alarm status, Digestion time, Valve and pump remote/local control status, Valve open/close position status, High/low limit level alarm status, Valve and pump fault status, Valve and pump running/stop status
Parameter Setting	Pressure setting, Time setting, Limit setting, Parameter adjustment, Delay setting, Cycle count setting
Start/Stop Button	Manual/Automatic control selection, Alarm buzzer mute button, Alarm buzzer mute button, Synthetic crucible cleaning automatic start/stop button, Pump/Valve fault reset button, Pump manual start/stop button, Valve manual open/close button

5.1 Status Monitoring

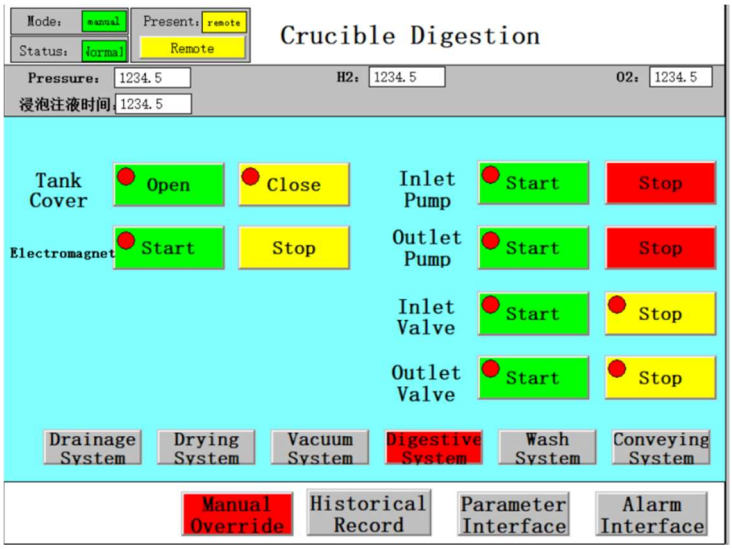

Figure 5. Manual Control Monitoring Interface

Users can determine various system statuses by observing the color of corresponding position indicator lights. A red background indicates "yes," while a green background indicates "no." Since it

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takes some time for valves to open/close, a green background with blinking indicates that the valve is in the process of closing but has not reached the closed position yet. Similarly, a red background with blinking indicates that the valve is in the process of opening but has not fully opened. Figure 5 serves as an example for illustration.

5.2 Setting Parameter Values

The parameter setting interface is shown in Figure 6. The parameter interface is primarily used to set key parameters for two types of crucible waste recovery and cleaning processes. These parameters have a significant impact on the recovery rate of crucible waste and directly affect the cleaning effectiveness. The relevant parameters are placed in Textbox controls. To modify the parameters, you can change the data in the Textbox control and then click the adjacent "OK" button to save the data to an XML file, completing the parameter setting process. When using the parameters, you can retrieve the corresponding parameter content by reading the relevant information from the XML file.

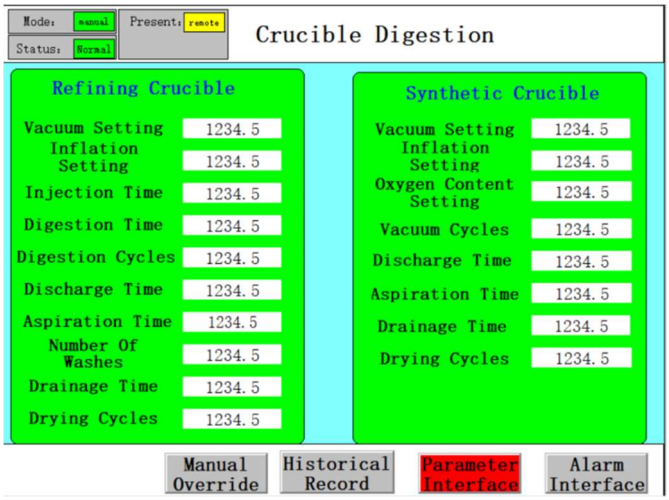

Figure 6. Parameter Setting Interface

5.3 Automatic Control Interface

The automatic control interface is shown in Figure 7. This interface is mainly used to monitor the entire crucible waste recovery and cleaning process and initiate the automatic procedure upon clicking "Start". In this interface, real-time monitoring of hydrogen and oxygen content, pressure values, and operational status is available. It contains a total of 5 Button controls, enabling the initiation, cessation, and reset of semi-automatic operations.

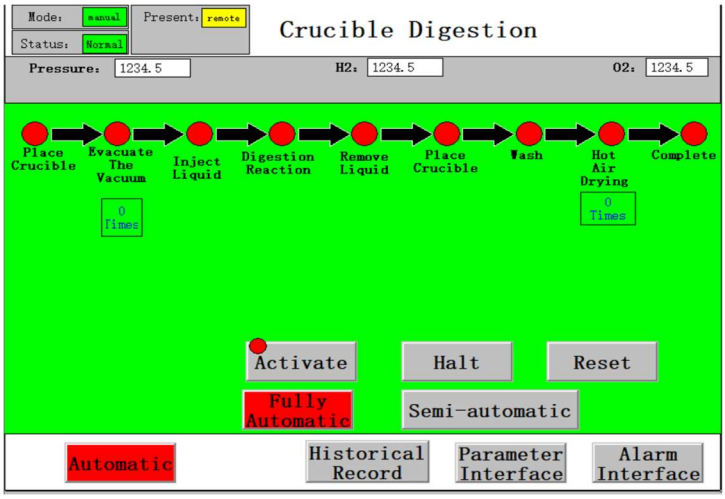

Figure 7. Automatic Control Interface

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6. Conclusion

Automatic control is the mainstream trend of production methods, which can greatly improve production efficiency, reduce errors, and save manpower, materials and financial resources compared to traditional manual control. This paper focuses on the process of supplying crucible waste recovery and treatment, and designs an automatic control system with PLC as the core. Through practical operation and verification, the system achieves key parameter monitoring, fault reminders, production process automation, and various parameter historical storage and query functions, greatly satisfying the production needs on-site.

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