The Design and Application of Automatic Control System for Inorganic Membrane Filter

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Abstract

For the existing inorganic membrane filter, this paper set up an automatic control system using PLC and touching screen, unified regenerate counter blowing control, online discharging control, pneumatic conveying control, process monitoring display and alarm etc., to reach the remote and on-site control. Hardware composing and software function of control system has been built. Performance parameters, match with actual capacity, of dust removal system are set by application. The application indicates that: when the pressure drop set to 25000 pa, regeneration counter blowing program starts, counter blowing interval set to 15 s, counter blowing time set to 0.15 s, pulse cleaning pressure set to 6860000 pa, the whole system moves stably and reliably, and it has high efficiency of dust removal.

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Keywords: inorganic membrane; automatic control system; regeneration counter blowing; online discharging; pneumatic conveying; PLC (programmable logical controller)

1. Introduction

Inorganic membrane filter remove dust from gas streams. It is widely used for the practical application, if controlled effectively, labour will be saved greatly\cite{1,2}. PLC, with a high cost performance, is reliable and stable\cite{3,4}. This paper chooses Siemens PLC\cite{5} to reach the automatic control for inorganic membrane filter. The designed system runs in a chemical plant, the result indicates that: the whole system is reliable and stable and easy to operate.

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2 System design
2.1 System components

The dust removal system is controlled and monitored by PLC. Then the paper design 5 function modules and paint the pictures of system flow and system function configuration. The electrical control principle diagram for designed system is shown in Fig. 1.

![Electrical control principle diagram](image1)

![The flowchart of inorganic membrane dust removal system](image2)

Fig. 1. Electrical control principle diagram                      Fig. 2. The flowchart of inorganic membrane dust removal system

2.2 System flowchart

The system works as the following steps: Inorganic membrane filter 1 running. When the running time (pressure drop) reach T1 (ΔP1), pulse blow valve V1 open, regeneration counter blowing starts until the running time (pressure drop) reach T2 (ΔP2), pulse blow valve V1 shut. When the material level (weight level) reach the preset higher level H1 (W1), valve V9 open to fluidized. Subsequently open valve V3, valve V6, valve V2, valve V5 in turn, with gravity, the dust come into tank 3. When reaching the preset lower level H2 (W2), valve V2 and valve V3, valve V6 shut in turn. After several times, the material level (weight level) in tank 3 reach the preset higher level h1 (w1), valve V4, valve V7, valve V8 open, dust come into dust storage tank 4, when reaching the preset lower level h2 (w2), valve V4, valve V7, valve V8 shut; system cycles, as shown in Fig. 2.

2.2.1 Regeneration counter blowing control

After a period of time, since the dust accumulate on the surface and internal structure, pressure drop sharply increase. Regeneration counter blowing is needed [6]. Counter blowing pressure should overcome four pressure: 1, the pressure drop of the membrane elements 2; 2, the pressure drop of the dust cake; 3, the operation pressure; 4, the pressure to overcome dust cake bond strength.

There are two modes of regeneration counter blowing control: manual activation, manual cleaning dust; automatic activation, automatic cleaning dust. The regeneration counter blowing was triggered by two available modes: first, time mode. This means the running time of the dust removal equipment is the only trigger. Second, pressure drop mode. This means that a cycle will not start until the pressure drop attains a specific value. The interval time is depend on the pressure drop in the same way as the time mode. I.e. during working, pressure drop fluctuates within the scope of certain (ΔP1, ΔP2). If this value attains the preset value, valve V1 open, then pulse blow gas flowed into inorganic membrane filter,
regeneration counter blowing starts. Once it starts, corresponding 12 pulse blow valves run 0.15 s every 15 s. The membrane elements are cleaned in groups subsequently. This performance achieves continuous on-line operation. When the pressure drop attains another preset value, valve V1 shut. As shown in Fig. 2. In the whole regeneration counter blowing process, valve V9, valve V2, valve V3, valve V5, valve V6 should be closed, so it doesn't affect the on-line discharging process. The pulse blow valves should be opened very fast, opening time <0.1 sec.

Fig. 3. Regeneration counter blowing control flowchart. Fig. 4. On-line discharging control flowchart

2.2.2 on-line discharging control

There are two modes of online discharging control: manual activation, manual discharging, automatic activation, automatic discharging. The height (weight) signal of the dust from the sensor of material level (gravity). According to either of them, the system automatic starts discharging. When the material level reach the preset material (weight) level H1 (W1), V9 open to fluidize 30s, then close. Subsequently open valve V3, valve V6, valve V2, valve V5 in turn, with gravity, the dust come into the tank 3. The value of material level(gravity) sensor decrease gradually, when reaching the preset value H2 (W2), valve V2, valve V3, valve V5, valve V6 shut in turn, discharging process is done. As shown in Fig. 4. During the discharging process[7], the inorganic membrane filter 1 is connected with the tank 3 using one communicating pipe to remain pressure constant. Between each pipeline, two valves are used to prevent leakage and save cost.

2.2.3 Pneumatic conveying control

After several times of discharging, the material (weight) level in tank 3 attains the preset higher level h1 (w1), valve V4, valve V7, valve V8 open, dust come into dust storage tank 4, when reaching the preset lower level h2(w2), valve V4, valve V7, valve V8 shut in turn. During the pneumatic conveying process, to ensure the pneumatic conveying does not affect the removal process, valve V2 and valve V3, valve V5, valve V6 should be closed. Using level gage and gravity sensor simultaneously can reduce the possibility of overflow[8,9], rise the stability of system. As shown in Fig. 5.

2.2.4 Process monitoring display

Process monitoring display using the man-machine operation interface of touch screen, realize dust removal system running state display and remote control command input.

2.2.5 Alarm

To ensure the system operation safety and reliably, it is essential to monitor the working condition of the dust removal system. We should pay attention to: too low temperature of raw gas, vessel and blowback vessel etc., blowback vessel pressure, membrane elements pressure drop etc. The limit alarm values are to be set on the operator terminal of the PLC.
3 Hardware system design

According to the above analysis, we can sum up the functions of the system: to detect the digital signal (temperature and pressure drop) and analog signal (counter blowing valve); regeneration counter blowing control; on-line discharging control; pneumatic conveying control; process monitoring display and alarm. With online, remote, field control function; this system can display dynamically on the touch screen and it can realize the setting and remote control.

3.1 The components of control system

To ensure the essential function and reliability of the system, input/output blocks and CPU are applied to the dual redundant hardware. I.e. when PLC1 is in malfunction case, PLC2 is in hot spare, which can switch to the work state in time, as shown in Fig. 6. This system selects Siemens S7-300 series microcontrollers as the core control system, bring power itself. MT500 as human-computer interface, system structure shown as Fig. 7. The hardware mainly includes power supply, signal input unit, main control unit, signal output unit.

3.2 I/O configuration

To analyse the requirements of inorganic membrane dust removal system control, the determination of PLC I/O counts are given. As shown in table 1.

<table>
<thead>
<tr>
<th>Switch inputs</th>
<th>Switch outputs</th>
<th>Analogue inputs</th>
<th>Analogue outputs</th>
</tr>
</thead>
<tbody>
<tr>
<td>I/O counts</td>
<td>78</td>
<td>36</td>
<td>10</td>
</tr>
</tbody>
</table>

4. Software system design
Program design uses SIMATIC STEP 7 V5.4 Siemens programming software and ladder diagram and structural form programming. Touching screen software are programmed by the EV5000 configuration editing software. According to the work process, the system software is designed, which includes the main program and subprogram. The software flowchart of main program as shown in Fig. 8. The software flowchart of subprogram as shown in Fig. 3., Fig. 4., Fig. 5.

![Software flowchart](image)

**Fig. 8. The flowchart of main program**

**5. Conclusion**

The designed system was debugging and operating in a chemical plant. When the pressure drop set to 25000 pa, we can get a high dust removal efficiency. For the leakage of instrument, the pressure drop cannot be easily detected, regeneration counter blowing program is triggered by time set to 3900s, counter blowing interval set to 15 s, counter blowing time set to 0.15 s, pulse cleaning pressure set to 6860000 pa, there is no increase of pressure drop. System runs stably. It is a reasonable and scalable design, what is more, it can be widely applied in dust removal factories.

**References**


