

Study on Control System of Steel Slag Desulfurization of Sintering Gas

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Control system of desulfurization of sintering gas falls into the desulfurization technology of sintering machine in the steel industry, applicable to desulfurization system of wet sintering gas. Under the system, the on-site data is sent to the central processing unit of the control cabinet for analysis via the sensor so as to effectively control the operating parameters of the equipment to match gas conditions with the working conditions of induced draft fan, oxidation compressor, lime milk pump, slurry circulating pump, gas heat exchanger and so on. Steel slag has strong alkalinity, which may be used as the raw material of desulfurizer to neutralize SO₂ in the exhaust gas. Its operating cost is far lower than that of limestone as desulfurizer. Meanwhile, it has solved the problem of the comprehensive utilization of steel slag in conformity with the national industrial policy and with economic and social efficiency. It features accuracy, timely control and stability.

1. Introduction

A large amount of SO₂ is contained in sintering gas. Thus, control of SO₂ emission is the focus of environmental protection in the steel industry. Due to a large amount of sintering gas and low solubility of SO₂, steel slag is used as the desulphurizer with follicular desulfurization method employed. The traditional desulfurization is achieved by controlling PH of desulfurization solution, resulting in inefficiency, waste of resources and increased costs.

Steel slag is a by-product of steel making, What can be used as desulfurizer in steel slag accounts for about 50%. Steel slag as desulfurizer instead of limestone reduces both limestone mining and CO₂ emission. Besides, its by-products are neutral and weak acid, which creates the conditions for material utilization.

The advantages of use of steel slag as desulfurizer go as follows: Alkaline substances in steel slag can neutralize SO₂ in the exhaust gas, especially applicable to SO₂ discharged by sintering machine. Steel slag abounds (Cui et al., 2009), which can meet a majority of domestic needs in the desulfurization industry. A certain amount of metal oxide compound is contained in steel slag, which is beneficial to oxidation of its by-products. The price of steel slag is much lower, which can greatly reduce the cost of desulfurization. Use of steel slag as desulfurizer complies with national environmental protection policy.

The difficulties of desulfurization mentioned above shall be addressed by an intelligent and easy-to-use control device, not only improving the efficiency but also making rational use of resources.

Control system of desulfurization of sintering gas is an intelligent centralized control system. Under the system, the on-site status and relevant data are sent to the screen of the control cabinet for analysis and control, rendering it possible for the operator to get access to the field data, integrate information resources and strengthen management.

With PLC as the control centre, the unit is connected to the touch screen by the bus, controlling PH of desulfurization solution, fluid level of desulfurization solution pool, ratio of desulfurizer and real-time monitor of equipment. From the viewpoint of recycle economy, steel slag is comprehensively utilized, which achieves the industrial waste recycling and properly resolves the comprehensive treatment and utilization of steel slag and SO₂, not only bringing good environmental benefits and creating considerable economic and social benefits(Guo et al., 2009).

2. Steel slag desulfurization agent

R&D of unit of steel slag desulfurizer preparation is environmentally friendly. It uses steel slag as the raw material, which has a strong alkaline and is used to neutralize SO₂ in the exhaust gas. Its operating cost is far lower than that of limestone as desulfurizer. Meanwhile, it has solved the problem of the comprehensive utilization of steel slag in conformity with the national industrial policy and with economic and social efficiency. Through unit of steel slag desulfurizer preparation, steel slag is ground into the particles sized 300-400 mesh. In addition, water, stabilizer and dispersant are added according to a certain proportion to form alkaline suspension. PLC intelligent control system is applied to control the operation. Being applicable, the unit can broadly meet the demand of the desulfurization industry, especially the desulfurization of sintering machine in the steel industry.

2.1 Steel Slag System Structure

The unit is divided into three parts: processing of steel slag, processing of water and additives, synthesis of desulfurizer. Here's the structure chart:

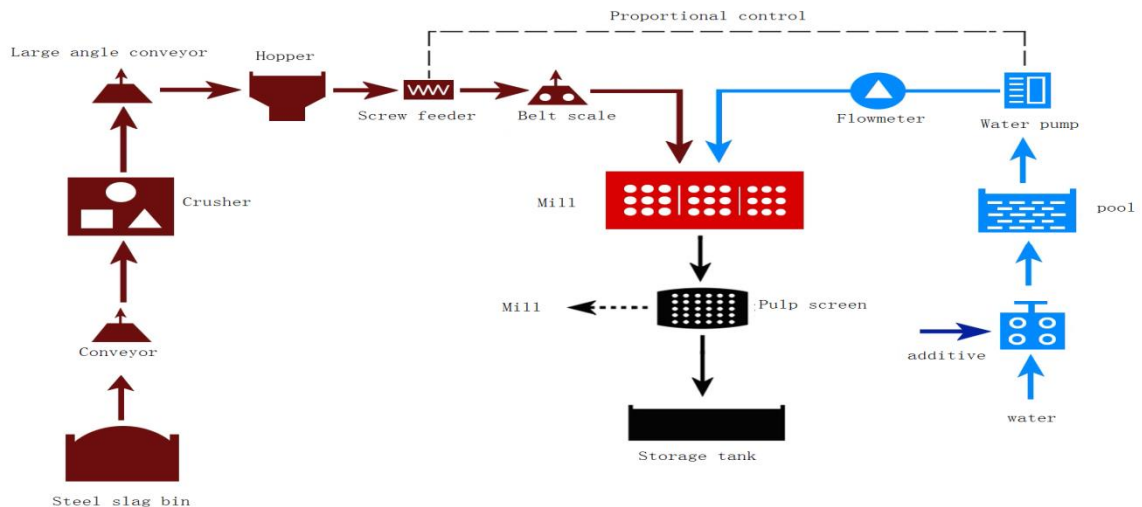


Figure 1: Flow chart of slag desulfurizer preparation

As shown in Figure 1, the process of slag desulfurizer preparation goes as follows: (1) that steel slag is sent to the crusher via the conveyor. (2) that steel slag is ground into particles and sent to the hopper via large inclination-angle conveyor. (3) that steel slag is sent to the belt scale via the screw feeder. (4) that the steel slag is sent to the mill according to the pre-set proportion. (5) that water, dispersant and stabilizer are mixed in accordance with a certain proportion and sent to the tank. (6) that water and additives are sent to the mill in accordance with the pre-set proportion via the pump. (7) that slag, water and additives are ground in the mill into the particles sized 100-200 mesh[4]. (8) that slag, water and additives are filtered by the vibration filter and sent to the slurry storage. (9) that the semi-finished desulfurizer is sent to the shear with the particles produced sized 300-400 mesh. (10) that the finished desulfurizer is sent to the pool via the pump.

The key to preparation of the unit as described in Figure 1 is to control the dosage of slag by employing the weighing method. Meanwhile, water and additives are added in a certain proportion. The flow of water and additives is controlled by the rotameter. Slag, water and additives are sent to the grinding mill with the particles produced sized 100-200 mesh, which meets the requirements of semi-finished products.

The following steps are included:

(1) Processing of steel slag

Slag under the system refer to that processed by ball milling, gravity separation and magnetic separation treatment, which contains alkaline substances and can be used as desulfurizer.

Slag processing is conducted through conveyor, crusher, inclined conveyor, screw feeder and belt scale.

Bulk slag, piled up in the warehouse, is sent to the crusher through the conveyor. Then the granulated slag is sent via the inclined conveyor to the hopper. Next it is sent to the belt scale by screw feeder according to the pre-set proportion and to the mill in the end.

Steel slag is ground into particles and sent to the mill in accordance with a certain proportion to prepare for the synthesis of desulfurizer.

(2) Processing of water and additives

Processing of water and additives is conducted via dispersant solenoid valve, tank, pump and rotameter. Water, dispersant and stabilizer are added into the mixer according to a certain proportion and sent to the pool after being mixed up. The mixture of water and additives is sent to the mill in accordance with the present proportion.

(3) Synthesis of desulfurization solution

Synthesis of desulfurization solution is conducted via mill, vibration filter, desulfuriser pump, desulfurization solution pump and shear.

The mixture of slag, water and additives is mixed up and ground in the mill with the particles produced sized 100-200 mesh. The semi-desulfurizer is sent to the storage tank through the vibration filter. The particles, the size of which does not meet the requirements, are sent back to the mill (Wen et al., 2008). The semi-desulfurizer is sent to the shear for the further grinding with the particles produced sized 300-400 mesh, which meets the requirements for finished products. The finished products are sent from the pump to the pool (He et al., 2009).

2.2 Steel Slag System control

The technology is employed to handle R&D and industrialization of unit of steel slag desulfurizer preparation. With PLC as the core control, the on-site status and information of conveyor, crusher, inclined conveyor, screw feeder, belt scale, dispersant solenoid valve, stabilizer solenoid valve, mixer, pump, rotameter, mill, vibration filter, desulfurizer pump, desulfurization solution pump and shear are sent to PLC for analysis via the bus.

R&D and industrialization of the unit are divided into three parts: processing of steel slag, processing of water and additives and synthesis of desulfurizer.

(1) Processing of steel slag

The system collects the status of conveyor, crusher, inclined conveyor and hopper. The status of on-site equipment is collected once per second, and then transferred to the input and output modules of PLC cabinet. PLC touch-screen displays on-site working conditions.

The control system includes control of conveyor's transporting slag, bulk slag's being ground in the crusher and inclined conveyor's transporting slag into the hopper. Slag processing adopts closed-loop adjustment and PID adjustment algorithm (Yu et al., 2009) which meets the operational requirements.

(2) Processing of water and additives

Data collection includes the amount of water, dispersant and stabilizer as well as the status of the mixer and the tank. The control system includes solenoid valve and mixer of water and additives. Processing of water and additives employs PID control algorithm (Guo et al., 2009) of closed-loop.

(3) Synthesis of desulfurizer

Synthesis control of desulfurizer is conducted via belt scale, pump, mill, vibration filter, desulfurizer pump, desulfurization solution pump and shear. Data collection includes slag weight measured by belt scale, flow of water and additives measured by rotameter as well as the status of the mill, vibration filter, desulfurizer pump, desulfurization solution pump and the shear.

The control system includes control of the amount of slag (Wang et al., 2009), the amount of water and additives, the operating of mill, vibration filter, desulfurizer pump and desulfurization solution pump as well as the shear. The system adopts PID control algorithm.

3. Control system of desulfurization

Based on Siemens PLC control, the control system controls fluid level of lime milk pool, PH of desulfurization solution and concentration of desulfurizer. The control system is connected to the Internet server through a remote communication interface to achieve remote data storage, maintenance and so on (Cui et al., 2008).

3.1 System Structure

The upper computer employs 2 industrial sets of machine, one for a host and the other for a backup. The lower computer is constituted by PLC, i.e. the field unit. They communicate through Ethernet to fulfil the monitoring tasks. The upper computer is responsible for data collection and sending related data to the database server for processing.

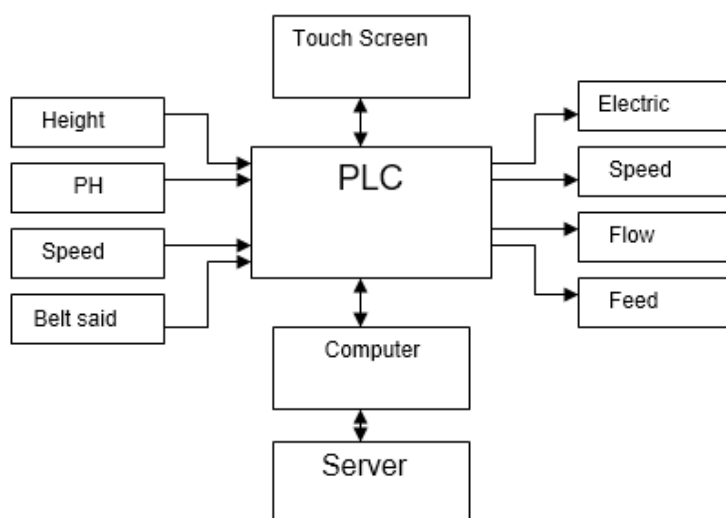


Figure 2: Functional block diagram of the system

With PLC as the core controller, the communication with man-machine interface module of PLC cabinet is achieved through RS485 bus (Wen et al., 2008). In addition, the system can be connected to the upper computer via Ethernet with the data stored in the server for queries. PLC can control PH of desulfurization solution on site and monitor the equipment real-time.

The main functions of the control system include measurement of fluid level and PH, control of pump speed, measurement and control of rotor flow and screw feeder.

3.2 System Control

System control includes:

(1) Data collecting system

Data collecting system includes fluid level, PH, rotor velocity, belt scale and so on.

The system collects sampling rate of the front-end equipment according to the selected data, periodically collects and processes switching value and analog quantity of field equipment and technology. The data collected is transferred via the network to the screen of the upper computer, as the basis of monitoring and operating the field device.

The basic functions of data collecting system include data collecting, processing, display, audible-visual alarm, recording and recalling, storage, retrieval and print of historical data, online calculation of performance and so on.

First of all, the status of external measuring points is periodically scanned via the sensor. And then the processed information will be written into the database as new data after rational judgment, engineering conversion and limits determination.

(2) Analog control system

Analog control system achieves closed-loop adjustment of analog, including adjustment of fluid level, PH and concentration.

a. Fluid level adjustment

Fluid level adjustment aims to level off the fluid level of desulfurization solution pool. When the system works properly, the fixed level of the surface is set. When it reaches a certain level, the alarm sounds and the feed into the desulfurization pool ceases. Closed-loop adjustment employs PID (Kill S, et.al, 1998), which is easy and can meet the engineering requirements.

b. PH adjustment

It aims at adjust PH of desulfurization circulating pool, where chemical reaction occurs to gas and desulfurization slurry, which is critical to ensure the efficiency. When PH is greater than the set value, it gives the feedback to PLC, which controls the speed of lime milk pump to adjust that of the desulfurizer. When conventional PID is employed, the satisfactory control cannot be achieved for the big lag of PH. Therefore, cascade PID algorithm is used in the desulfurization system (Orme, 1997)

c. Concentration adjustment of desulfurizer

Concentration adjustment of desulfurizer is achieved by controlling delivery of limestone by weighing and flow of water by flow rate of the rotor. Concentration is pre-set by the fixed ratio of limestone and water. The output achieved by PID algorithm of bias suppression is applied to the converter of screw feeder so as to live up to the expectations. As the principle is simple, conventional PID algorithm works. Other methods applied, such as appropriate extension of sampling period of PID adjustment, can stabilize the system within a certain range and enhance the effect.

d. Sequence control system

Sequence control system (SCS) allows operators in the control room to monitor and control motors and valves of the desulfurization system to achieve the chain and protection of the equipment. Highly intelligent control of devices can be done, and devices can be divided into functional and sub-functional groups according to function-related principles, and implementation can be done step by step in accordance with programming, thereby reducing the operator's manual intervention, labour intensity and risk of misuse.

Any device or function group can be abstracted as a function module. The function module of any device is manifested in its specific formal parameters, internal condition determination and output.

Function modules include parameter operator's input, automatic input, protective chain input, instruction shielding conditions, and instruction interlock and device status feedback. Internal condition determination of functions is determination programming written by programmers based on the technology requirements to ensure that all instructions can be executed as expected.

3.3 Software of the upper computer

To facilitate the management and operation, the function control of the system assembles at the monitoring centre. Timely status of the entire system can be achieved by valid configuration to present its local and general appearance in the upper computer. Real-time data is collected and put into the database and presented in the history curves and report (Lain and Aliod, 2000).

The configuration software developed by Zijin Bridge can satisfy the requirements. As the core component of Factory Suite, one man-machine interface, the software is component-based with the world's leading human-machine interface and object-oriented graphical development environment to configure users' applications in an efficient and fast way. Featuring a powerful network function, real-time data exchange with applications of the unit and other network computers can be done via DDE and NetDDE. Besides, it allows ODBC to get access to various types of database to facilitate the integrated management of the system data. In addition, it supports standard ActiveX control technology so that developers can easily embed ActiveX controls into Zijin Bridge configuration software script program (Lai et al., 2007).

The system is equipped with live, local and centralized control of equipment use, supply and distribution of materials, control volume settings and so on. Centralized management is conducted via Zijin Bridge configuration software, the operating diagram of which is shown in the Figure below.

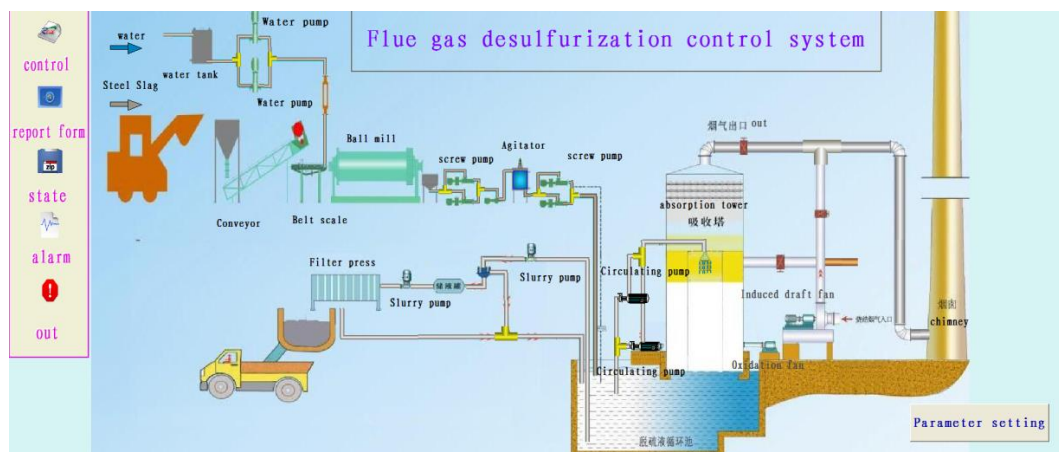


Figure 3: Monitoring main interface

It shows the overall system technology, operation of various parts of the desulfurization tower and real-time status of parameters.

When the system fails, the audible-visual alarm sounds. At the alarm bar is shown the fault. The location, name and time of the failure are recorded in the database for recalling and analysis.

4. Conclusion

Compared to the existing systems, unit of slag desulfurizer preparation has its unique advantages: steel slag as a desulfurizer significantly reduces the cost. It has a complete structure with easy maintenance and use. Designed on the basis of the concept of "unattended operation", the system incorporates PLC intelligent management and is equipped with audible-visual alarm. It is safe, reliable, advanced, economic and practical. In comparison with the existing technology, advantages of control system of the desulfurization unit go as follows: complete system, plain structure, easy operation and maintenance; efficiency is greatly improved and consumption of steel slag is minimized; real time, anti-interference, man-machine interface, audible-visual alarm. It can be widely applied in desulfurization control system, especially the desulfurization system of sintering machine

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