Study on Gas Drainage Pipeline Visualization Water and Slag Discharging System

Xue-Xi CHEN\textsuperscript{a}, Wei WANG\textsuperscript{b,*}, Geng-Yu YANG, Dong-Ming LI
North China Institute of Science and Technology Yanjiao Beijing-East 101601
\textsuperscript{a}xuexichen1210@163.com, \textsuperscript{b}jiawei0429@126.com
*Corresponding author

Keywords: Gas Drainage Pipeline, Water and Slag Discharging, PLC, Visualization.

Abstract. The water and slag of mine gas drainage pipeline seriously affect the efficiency of gas drainage, the existing water discharging equipment can not effectively solve this problem. According to this situation, the gas drainage pipeline visual water and slag discharging system was developed. PLC as the core of system accomplish the process of water and slag discharging by controlling solenoid valve on the new type automatic water and slag discharging device work together, PLC is controlled by the touch screen, the operating parameters of automatic water and slag discharging device are uploaded to the upper computer, that means "visualization" of the system. Performance tests by laboratory and field applications show that the system is safe and reliable, the discharge volume is large, the water and slag of mine gas drainage pipeline could be effectively discharged.

Introduction

For up gas drainage drilling, more slag will be discharged at the beginning of drainage [1], when coal seam permeability is better, this phenomenon is more prominent. In addition, the coal seam and strata contain a lot of water, due to the temperature difference effect, the gaseous water in the drainage pipeline will condense into liquid water [2]. Therefore, in gas extraction process, large amounts of water and slag mixed with methane gas move together, so the gas drainage pump will do a lot of wasted effort, which would make the efficiency of the gas drainage pump greatly reduce. Once the water and slag run into the union system, it needs to be discharged in time, otherwise it will clog drainage branch, or even main, not only affect the extraction results, and even lead to complete blockage failure of drainage pipe [3], so in the process of gas extraction, water blocking problem is very prominent.

Key equipment to solve the problem of water blocking is water discharging device, at present, there are two types widely used: artificial water discharging device and negative pressure automatic water discharging device. Artificial water discharging device wastes manpower, the labor intensity is high, and can’t achieve the purpose of continuous drainage. Most of the existing automatic water discharging device use the buoy and the guide rod type structure [4], which needs the higher requirement of installation environment, slagging effect is poor, needs frequent maintenance and has high failure rate. From the perspective of the coal mine automation [5], to develop a visual water and slag discharging system which is suitable for gas drainage pipeline has a very important significance.
The Architecture of Visual Water and Slag Discharging System

Visual water and slag discharging system is based on negative pressure environment, with PLC (programmable logic controller) as the core, solenoid valves on the water and slag discharging device box complete the switch action according to the preset procedures, realize the process of water and slag discharging. PLC connects with the human machine interface (HMI), which can monitor the water and slag discharging device's running status of real-time, meanwhile achieving the direct control of the device. The run data of water and slag discharging transmits to the upper computer through a communication cable, which can display each valve’s signal conditions and signal data recorded through the surface monitoring system, to achieve "visualization" of water and slag discharging process. The specific architecture of visual water and slag discharging system is shown in Figure 1.

![Diagram of Visual Water and Slag Discharging System](image)

Figure 1. Visual Water and Slag Discharging System.

As is shown in Figure 1, the system is divided into three layers: the management layer, control layer and field layer. The management layer is upper computer, located in coal mine surface. The control layer contains PLC control cabinet and the HMI, that can be located near the scene of the substation or other locations underground the coal mine. Field layer is the negative pressure automatic water and slag discharging device, located at the scene of gas drainage.

The Working Principle of Visual Water and Slag Discharging System

The Design of Negative Pressure Automatic Water and Slag Discharging Device

Traditional negative pressure automatic water discharging device mostly uses buoy and guide rod structure, which requires the devices must be horizontal, otherwise the guide rod is unable to open the valve, can’t form a drainage conditions [6]. Furthermore, after entering the slag between buoys and guides rod can lead to buoy can’t float, and the exclusion of the blockage is not convenient. The volume of traditional water discharging device is very small, drain slowly, the drain outlet can be easily clogged by slag, does not apply to the case of large pipeline displacement [7]. So the traditional negative pressure automatic water discharging device in the practical application of coal mining has general effect.

According to the defects of traditional device, new device of visual water and slag discharging system is taken with completely different design approach. The box of new device
is divided into two floors, and the box, import and export all have larger size, it not only applies to gas drainage branch pipelines, the same applies to mine pipelines. The spacer layer between the upper and lower box is funnel-shaped, easy to slag. In the middle of the spacer layer has a pressure switch, the pressure can just hold the weight of the highest level of the box and the pressure size can be adjusted. There are three openings on the top of the box, inlet interface, negative pressure interface and atmospheric pressure interface respectively. By the side of the lower box has two ports, the negative pressure interface and air interface respectively. The bottom of the box is also funnel-shaped and the middle of it is the outlet interface. The specific structure connecting of the automatic water and slag discharging device is shown in Figure 2.

Figure 2. Structure Connecting of the Automatic Water and Slag Discharging Device.

The Work Principle of System

Six connectors of the drainage are mounted explosion-proof solenoid valve which can be used in the coal mine underground, equipped with a water level gauge in the upper box. System control of the device is divided into two controlling methods of manually and automatically control. Manual control means the operator as required controls the on-off of the solenoid valve individually through man-machine interface, manual control is mainly used in the maintenance and troubleshooting. And automatic control means PLC by collecting changing signal of water level, make the corresponding solenoid valves start, stop and do other control operations. The running process of system is automatic control, the working process of water and slag discharging can be divided into the following three states:

1) Water cumulating of upper box: At this point, the inlet valve and the upper negative pressure valve open so that the upper box could connect with the gas pipeline. The upper box is in negative pressure environment, and at the same time the water is cumulating. The negative pressure valve of the lower box closes, and the atmos-valve opens, so that the lower box connects with atmosphere. The pressure of lower box comparing with upper box is strong, this differential pressure will be against the press switch to keep the upper box won't leak.

2) Water discharging of upper box: the water level gauge in upper box can detect the change of water level, when the water level rises to the highest, water level gauge will send signals to PLC. At the same time, PLC sends instructions to the valves, at first, the inlet valve and the
upper negative pressure valve close, the upper atmos-valve opens. After that, automatic water and slag discharging device stop inflow, upper box is in atmospheric pressure. Then the lower atmos-valve closes, the lower negative pressure valve opens, the outlet valve is still closed, lower box connects with the gas pipeline. At the same time, the pressure of upper box comparing with lower box is strong, the pressure of the upper box and differential pressure effect at the same time to open the pressure switch on the spacer layer, so the water runs into the lower box.

3) Water discharging of lower box: when the water level declines to the lowest, water level gauge will send signals to PLC, at the same time, PLC sends instructions to the valves. The lower negative pressure valve closes, the lower atmos-valve opens. The lower box is in atmospheric pressure. Then the upper atmos-valve closes, the upper negative pressure valve and the inlet valve open, then the upper box is in negative pressure environment. The differential pressure of the two boxes will close the switch on the spacer layer. Then open the outlet valve and the lower box begin to drain, so the upper box returns to the state of cumulating water.

The most serious problem of the automatic water discharging device is that the slag in the accumulative water precipitating for a long time blocked the outlet, making the automatic drainage device can’t work. So the automatic water and slag discharging device of the visual water and slag discharging system uses the design of box-type which has upper and lower levels, water and slag were mainly cumulated through upper box. When the water in the upper box is full, it will adjust the internal pressure of the two boxes through the negative pressure valve and the atmos-valve, making the upper box be in atmospheric pressure and the lower box in negative pressure, so the accumulative water and precipitated slag could be extracted easily. Then close the spacer layer to discharge the slurry of the lower box. Because the slurry stays a short time in the lower box and the drain pipeline caliber is large, so the slag can’t form obstruction because of deposition.

The Design of System Control Layer

PLC was first used to replace relays used in the automobile manufacturing industry, with the development of computer technology, PLC has been widely used in automatic control in the process of modern factory production, while being promoted to the automatic control of coal mine. Control of the system is mainly reflected on the control of PLC to the automatic water and slag discharging device, that is the output control of 6 valves and collection of water level signal of water level in the box. Water and slag discharging device needs the input and output signal work effectively in accordance with the appropriate steps. PLC is directly controlled by the HMI, HMI contains operators’ intervention to control the system, and the report of control center to the operator about the running state and results.

Hardware Design of Control Layer

The system control layer mainly includes PLC, control cabinets and HMI. PLC signal of the system has two kinds: digital input signal and digital output signal. The digital input signal is mainly high and low level signal of the water level gauge, and digital output signal is from six normally closed solenoid valves’ switch. HMI connects with the PLC through the communication interface. PLC, HMI, relay and other supporting auxiliary electrical components install in the control cabinet unity. The specific signal connections of the PLC modules are shown in Figure 3.
The control section of the system selects the kind of Siemens S7-200 CPU224XP type PLC as the core to achieve detection of automatic water and slag discharging device’s working condition and the water level signal, and the control of gas drainage pipeline slagging drainage process [8] HMI select TK6070iK type Weinview touch screen, which connects to the PLC via RS485 communication interface, and has a good interaction with S7-200 series PLC. Control cabinet is mine explosion-proof PLC control cabinet, it is flameproof and intrinsically safe structure, using flameproof enclosure, digital inputs and outputs are connected through an intermediate relay to achieve isolation protection to suppress signal interference. For the convenience of manipulation, touch screen mounted on the front of the cabinet box.

The Design of Software in the System Control Layer

PLC program is written by Siemens S7-200 series PLC’s dedicated programming software SETP7-Micro / WIN4.0, uses the ladder language to program. Touch-screen interface display and communication settings use Weinview touch screen’s special EasyBuilder8000 configuration software to design. A perfect control system not only requires powerful hardware to support, but also need a reasonable software design to achieve functions of the system. Software design is reasonable or not, right or not will affect to read and deal with the meter data, process control and efficiency of the operators.

The Design of Upper Computer Remote Monitoring Program

Upper computer means upper monitoring system, generally leads to computer system, changing signals is displayed on the screen. The upper computer remote monitoring program mainly records the water level changes of automatic water and slag discharging device and PLC instruction. The automatic water and slag discharging device has highest and lowest these two levels signal, we can determine whether there is something wrong in the automatic water and slag discharging device through data monitoring to these two signals, PLC instruction monitoring is used to monitor if the drainage control system is intact. The operators could calculate the displacement for analysing through the cycle count program. In the system of visual water and slag discharging system, PLC accesses to the underground monitoring sub-stations through lines, so each of valve signal conditions and signal data record of the
automatic water and slag discharging device can be displayed from the coal mine monitoring and control system.

Compared with the current popular programming language, Visual C++ can make more excellent operator interface flexibly, and can exhibit better display effect to the data analysis [9]. So the system’s upper computer remote monitoring program selects Visual C++ to write communication program for the collected data to storage, monitor and late analyze. Visual C++ achieves PC and PLC’s serial communication via MSComm control [10], extracts operation data of the PLC and analyzes. The data acquisition flowchart of the upper computer to the PLC is shown in Figure 4.

![Data Acquisition Flowchart](image)

**Figure 4. The Data Acquisition Flowchart.**

**Conclusion**

Gas drainage pipeline visualization water and slag discharging system use PLC as the core, and designed new negative automatic water and slag discharging device, the system has outstanding performance in the laboratory water and slag discharging performance test, and promptly drain it, has never been clogging, and can effectively remove the accumulated slag.
Especially in the underground practice, it can fully meet the drain needs of gas drainage pipeline. The automatic water and slag discharging device’s operating parameters is transmitted to upper computer remote monitoring program via PLC, achieving "visualization" in the working process. Through installing the input and output expansion modules, PLC can dominate more than one automatic water and slag discharging device, so it can be a good solution to the problem of gas drainage pipe’s accumulated by water and slag, so it is of great importance for improving the gas extraction efficiency and coal mine’s modernization.

Acknowledgement

This research was financially supported by the Fundamental Research Funds for the Central Universities (3142015020; 3142014114).

References


