Research on Key Technology of Environmental and Efficient Coal Storage and Loading

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Abstract. In this paper, the existing problems of coal storage and loading technology are put forward, such as serious environmental pollution, low efficiency and low degree of intelligence. Aiming at these problems, the large capacity closed coal storage technology, intelligent collaborative control technology of storage and transportation equipment, intelligent unmanned rapid quantitative loading technology, intelligent unmanned vehicle dispatching technology, and remote operation and maintenance technology and predictive maintenance technology of storage and loading electromechanical equipment are systematically studied, and the corresponding solutions are proposed. It is of great significance to promote the development of environmental and efficient coal storage and loading technology.

Keywords. Coal, Intellectualization, Storage, Control

1. Introduction
Coal provides important energy source supporting our economic development. From the perspective of geographical distribution, coal production is mainly concentrated in the western region, while the consumer markets are mostly located in the central and eastern regions [1]. The distribution characteristics of coal resources determine long-distance transportation and multiple transfers in coal logistics. At present, 60% of coal transportation in China relies on railway. In addition, to win the battle to defend the blue sky, realize the 'highway to railway transfer', reduce long-distance transportation of heavy trucks, reduce energy consumption and pollution emissions, a substantial increase in railway transportation of coal has become an inevitable trend. To this end, it is necessary to build a large number of coal freight stations, which is an important measure to transit from automobile transportation to railway transportation of coal [2]. Construction of coal freight station can meet the transportation needs of coal collection, storage, blending, transportation, and transshipment, which plays an important role in developing regional economy, reducing transportation costs, and reducing resource waste and consumption [3]. At present, our coal storage and loading system has some shortcomings such as serious environmental pollution, low efficiency, and low intelligence. Based on research of coal storage and loading system process, this project has developed tens of millions of tons of environmental, efficient and intelligent coal storage and loading technologies and equipment with the Internet of Things and intelligent control as the core. The purpose is to improve the capacity and technical level of our coal storage and loading system, and meet the needs of domestic coal storage and loading system for safety, efficiency, and environmental protection. Coal receiving, coal storage,
loading, etc. are the key links in the coal material storage and loading process. The technical level of these links and the degree of intelligent coordination between each link determine the coal material transportation efficiency of large coal freight stations. Focusing on key technologies in the coal material storage and loading system, this project studies closed coal storage technology, intelligent collaborative control technology of storage and transportation equipment, intelligent unmanned rapid quantitative loading technology, intelligent unmanned vehicle dispatching technology, remote operation and maintenance technology and predictive maintenance technology of storage and loading electromechanical equipment.

2. Closed environmental storage technology

The closed coal storage system includes closed coal storage yards and coal storage bunkers. The closed coal storage yards mainly include circular coal storage yards and strip coal storage yards. The closed coal storage bunkers mainly include trough bunkers, cylinder bunkers and square bunkers. The coal storage means has a close relationship with the surrounding road transportation conditions [4]. As freight station is mostly built along the railway line, closed strip coal storage yard is the optimal choice. By studying flow characteristics of materials in the storage process and unloading process, this project analyzes flow law of materials and proposes anti-blocking technology for the storage and transportation of large-flow coal materials to guarantee large-flow and continuous transportation of coal materials. By studying dust generation mechanism and dust dissipation law of coal materials in the transportation and reloading process, the project proposes a comprehensive dust suppression technology based on induced airflow analysis to reduce dust production during the storage and unloading process, thereby meeting the environmental construction needs of coal freight stations.

2.1 Anti-blocking technology based on material fluidity analysis

In the process of coal unloading, unsmooth material fall can easily lead to arching and flow obstruction, which reduces the coal unloading efficiency. To reduce bunker blockage and improve material transportation efficiency, adding a vibrating feeder at the bunker bottom has become a more widely used technical method. The feeder vibration level directly affects the unloading flow process of the entire pile, and vice versa, the pile flow characteristics will also affect working state of the vibrating feeder. Based on the analysis and research on flow characteristics and flow mechanism of bulk materials as well as anti-blocking characteristics during the vibratory feeding process, material anti-blocking technology is proposed to improve feeding performance of the feeder, thereby improving working efficiency of the entire system.

2.2 Comprehensive dust suppression technology based on dust generation mechanism of induced airflow

During the transportation process, coal bulk material presents as bulk solid, whose physical properties are between solid and liquid. Seen from a single particle, it is solid, but the aggregate formed by multiple particles shows fluidity, which can maintain its shape within a certain range. Based on the above characteristics of coal bulk materials, the discrete element method (DEM) is used to analyze its fluidity. The dust generation mechanism and dust dissipation law of coal materials during transportation and reloading are studied, and induced airflow-based dust generation mechanism analysis and comprehensive dust suppression technology are proposed to reduce the amount of dust produced when materials fall, thus meeting the environmental construction needs of coal freight stations.

3. Intelligent control technology of equipments in storage and loading system

The storage and loading system mainly includes key subsystems such as receiving coal, storing coal, and loading coal, as shown in Figure 1. The automatic control process of each system should be refined and analyzed based on its own characteristics to establish a model, so that coordinated operation of various equipment is possible. Coordination in the station involves numerous types of
equipment and has high requirements for response speed. This project achieves the abstraction and access of a large number of heterogeneous equipment through the establishment of equipment models. This project establishes an equipment coordination system and uses different task scheduling strategies for allocation of equipment resources, computing resources, and storage resources to achieve parallel execution of multi-tasks and improve execution efficiency of the system. Based on the established equipment coordination system structure, subsystems including the storage system, the conveying system and the loading system are analyzed to establish control model, thus realizing intelligent coordinated control of large-scale equipment. The research of intelligent loading system plays an important role in the reduction of coal production cost and the improvement of loading quality [5]. In this paper, the loading system is taken as the representative of the subsystem and its control scheme is discussed in detail.

This project adopts multi-sensor information fusion technology, intelligent control algorithm, expert database system, etc., to establish a stable, reliable, and compatible intelligent control system based on mastery of the loading process information, so that intelligent unmanned loading process of the whole process from material loading and constant-weight batching to compartment unloading is possible. The intelligent loading system mainly includes three levels: perception execution layer, collaborative control layer and application auxiliary layer, as shown in Figure 2. The perception execution layer mainly includes high-precision weighing sensor system, material detection system, vehicle tracking and identification system, hydraulic control system. The cooperative control layer is mainly to realize cooperation between various subsystems in the system. The application auxiliary layer is responsible for processing and analyzing the excessive data information from sensors in the perception execution layer, planning the unloading and loading process, and providing support for actuator action control according to the dynamic information changes of the cabin. On the basis of intelligent loading of a single loading station, the cloud technology is used to gather equipment information of each loading station to form a set of intelligent service platform for coal mine loading system [6].

![Figure 1. Key subsystems of the storage and loading system](image-url)
4. Intelligent unmanned vehicle dispatching technology
According to production characteristics, multiple information collection points are set up at the locations along the way of unloading vehicles, and advanced information, electronic, and digital technologies are used to establish effective centralized control connections between various scattered stations, thereby developing a set of intelligent unmanned vehicle dispatching system. The system has functions such as vehicle dispatch management, vehicle running route planning, and vehicle unloading link setting. In accordance with the designed scheduling algorithm, the system controls the automatic start and stop of various equipment through rapid analysis and calculation, and directs the passage, weighing and departure of vehicles to minimize the length of operation, thereby improving the enterprise production and operation efficiency and reducing operating costs.

5. Remote operation and maintenance technology and predictive maintenance technology of storage and loading electromechanical equipment
"Internet +" is introduced into the management of station equipment. With electromechanical equipment of the station as the core, smart sensors are used to collect status information of equipments. The collected information is transmitted via the Internet to the server operation and maintenance software for data analysis and processing, thereby realizing status monitoring and management of the entire operation cycle of the electromechanical equipment. The system can perform real-time status monitoring of the equipment in each storage and loading link, fault diagnosis on the equipment based on the monitored information, and predictive maintenance and management of the equipment based on the historical operating data of the equipment, thus effectively improving equipment operation reliability of the station. The system software service is deployed on the cloud. Any authorized Internet device can access the system. It is possible to query the basic parameters, operating data, alarm records, etc. of the station equipment anytime and anywhere through mobile phones, computers, etc. Remote operation and maintenance architecture is shown in Figure 3. To a certain extent, it reduces on-site operation and maintenance costs and improves equipment management efficiency of the station.
6. Conclusion

This paper analyzes storage and loading system of coal freight station. The current system has shortcomings such as serious environmental pollution, low efficiency, and low intelligence. In response to the above problems, closed coal storage technology, intelligent collaborative control technology of storage and transportation equipment, intelligent unmanned vehicle dispatching technology, and remote operation and maintenance technology and predictive maintenance technology of storage and loading electromechanical equipment are systematically studied with Internet of Things and intelligent control as the core, and the corresponding solutions are proposed, which is of great significance for improving the capabilities and technical level of domestic coal storage and loading system, and meeting the safety, efficiency, and environmental needs of domestic coal storage and loading system.

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