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Study on Rapid Prediction of Coal Calorific Value by Hyperspectral Technique

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Abstract

Hyperspectral imaging technology combining image and spectral detection is used to image the spatial characteristics of coal samples of different qualities moving on the transmission belt, and spectral information of up to hundreds of narrow bands is collected.5G data transmission module is used to input into the big data server, and the calorific value of coal samples can be quickly detected by analyzing and processing with different specific algorithms. By comparing the test results of the national standard test method in the laboratory, the difference range is between 15 Cal/g to 79 Cal/g, which meets the error requirement of the national standard. The results show that the hyperspectral detection technology can achieve rapid, efficient and accurate prediction of coal calorific value, and has the characteristics of economy and safety. It can provide reliable and accurate basis for fuel management of power plants and combustion operation management and control of boilers.

Keywords

Hyperspectral; Calorific value; Coal; Rapid detection; Big data.

1. Introduction

The main force of the domestic power generation industry is still thermal power generation, accounting for more than 70% of the total.Coal is the main fuel for thermal power enterprises, and its cost accounts for 70%~80% of thermal power.Therefore, to promote the clean and efficient utilization of coal and digital management will become the best choice for thermal power enterprises to improve economic benefits, is the only way for the sustainable development of coal industry, and is the inevitable requirement for improving people's livelihood and building ecological civilization. The indexes of coal quality detection include calorific value, industrial analysis [1] (fixed carbon, volatile matter, ash, moisture), elemental analysis (C, H, O, N, S), harmful elements (Cd, Cr, Pb, Na, K, etc.) and other indexes (ash melting point, silicon to aluminum ratio, acid to base ratio, ignition temperature, burnout index). The calorific value of coal is an important index to evaluate the quality of coal [2], and the coal quality analysis technology adopts manual sampling and chemical inspection.Both at home and abroad by oxygen bomb calorimeter method determination of calorific value of coal [3], the methods though the results of the measurement precision and accuracy can reach the national standard, cycle is long, but the method analysis data feedback lag, human error is large, complex operation process, consumption of resources, reduce the combustion efficiency, increased power generation costs [4].It usually needs to go through sampling, subtracting, sample preparation and testing, etc., and the whole analysis process takes a long time [5]. For places with high requirements for real-time coal quality data, such as coal preparation plants and power plants, laboratory analysis cannot provide real-time coal quality data for production and operation, especially when the coal quality fluctuates greatly, it cannot grasp real-time coal

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quality data, adjust operation and take corresponding measures in time.Therefore, the application research of coal quality rapid analysis technology and system can realize high precision and rapid detection of coal quality, and provide necessary basis for power plant fuel management, boiler combustion operation management and regulation.Online coal quality testing technology is very important to improve the safety and economy of the production process.

Foreign research and development of neutron activation coal quality testing equipment, due to radioactive contamination, poor coal applicability, measurement error, large, expensive and less bulky equipment, industrial analysis index, element analysis is not comprehensive, strict in operation and management personnel, with radioactive danger, difficult to popularization and application for years, urgent need to develop new testing technology and equipment.Laser-induced breakdown spectroscopy [6,7] (LIBS) has the advantages of fast measurement speed, simultaneous multi-element analysis [8], safety without radiation, and low cost. However, the detection process is still unable to break away from the picking-production-inspection link, and the samples to be tested need to be treated with press cake [9], which increases the error factors brought by sample preparation.

Hyperspectral imaging is a new image acquisition technology, which has been widely used in remote sensing analysis, information security, food safety, industrial detection and other fields [10, 11]. Different from traditional red, green and blue RGB images, hyperspectral images collect data of objects in multiple bands, output three-dimensional data cube, and fully mine the spectral information of materials.In this paper, hyperspectral imaging spectrum technology is used to detect coal samples of 12 mm with different calorific value, analyze and predict coal quality, and realize fast, efficient and accurate online detection of coal quality.

2. Experimental Methods

2.1. Detection System

Based on the principle of hyperspectral imaging, scanspec-SWIR infrared hyperspectral imaging detection system was jointly developed by the company.The system is mainly composed of computer, hyperspectral camera, light source, optical components, sample transmission belt, 5G data transmission module and big data analysis server.The spectral range of hyperspectral camera is 900~1700 nm, which can achieve continuous spectral coverage of 50~200 narrow bands. The spectral resolution is 5 nm, the pixel resolution is 2048×2048, and the exposure time is 28 μs ~1 s.

2.2. 2.2 Data Acquisition and Analysis

The hyperspectral data acquisition and control system is shown in Figure 1. The measured coal sample enters the hyperspectral camera acquisition area from one end of the transmission belt. Relevant parameters of the data acquisition system are set through the control system, and the movement parameters of the transmission belt are regulated at the same time, so the coal sample can be detected online on the conveyor belt.The calorific value of coal is closely related to the functional group structure inside coal. In the process of coal transportation, the coal image information and spectral information are collected in the equipment through the hyperspectral camera, and sent to the background server for data analysis and processing through the 5G data transmission module in real time.

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Figure 1. Image of hyperspectral data acquisition equipment

3. Results and Discussion

Hyperspectral data of coal samples are stored in the big data server, and partial coal spectra are obtained after retrieval, as shown in Figure 2. The composition of coal is more complex, consisting of fixed carbon, volatile, ash, moisture, elements (C, H, O, N, S) and so on, and ash includes oxides of various mineral elements in coal.Therefore, the composite spectral curve shown in Figure 2 carries a large number of information of different parameters, which needs to be analyzed by the big data of the background server to obtain important performance parameters for coal quality analysis.

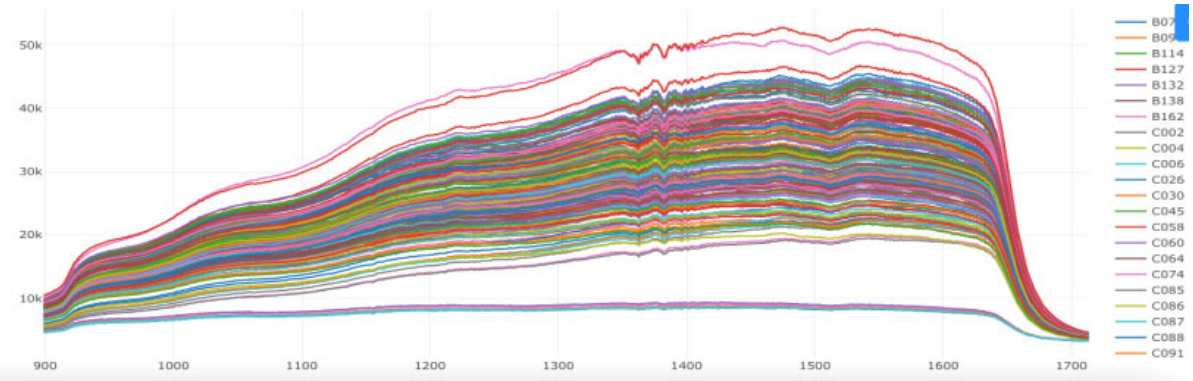

Figure 2. Spectrograms of selected samples in the database

Coal is rich in hydroxyl group, carbonyl group, amine group, methyl and methylene group, aromatic ring and hetero-atomic aromatic ring and carbon hetero-single bond, corresponding compound types may include alcohols, phenols, amines, esters, carboxylic acids, aliphatic hydrocarbons, ethers, aromatic hydrocarbons, hetero-atomic aromatic compounds, and mineral elements.The calorific value of coal is closely related to the content of many compounds and mineral elements.The calorific value of the spectral curve shown in Figure 2 ranges from 1857 Cal/g to 6201 Cal/g, with a wide range of calorific value, including spectral data of various coal qualities.

Figure 3 shows the images of coal with different calorific value. After big data analysis and processing, the calorific value of received base site is 1963 Cal/g, 2604 Cal/g, 3929 Cal/g, 4530 Cal/g, 5787 Cal/g and 6019 Cal/g respectively. Compared with traditional laboratory coal quality analysis,The maximum difference was 79 Cal/g, and the minimum difference was 15 Cal/g.The results show that the hyperspectral imaging detection system can realize the on-line detection of coal quality and obtain more accurate calorific value prediction results.

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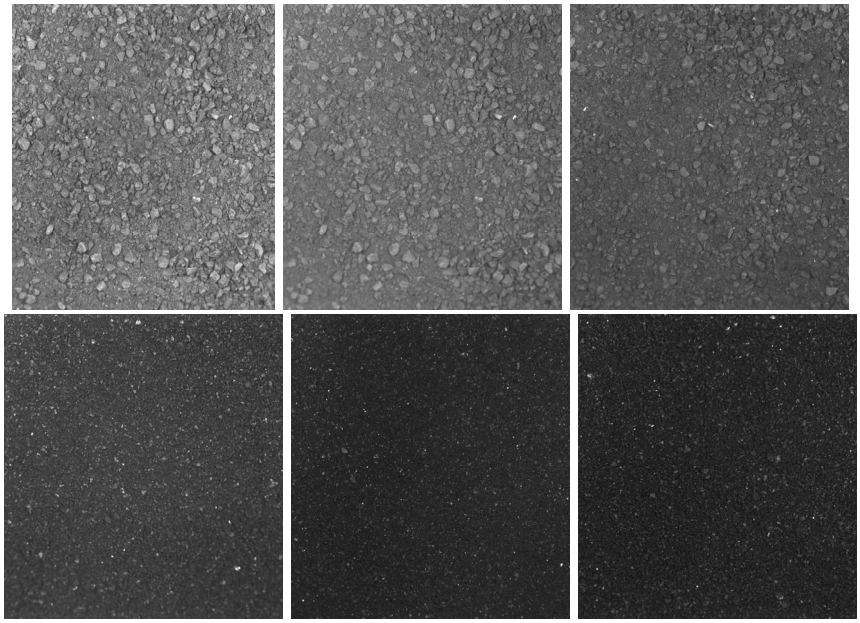

Figure 3. Coal samples with different calorific values

4. Conclusion

Hyperspectral imaging system capture the image and spectral information of coal sample on the transmission belt. And the morphology of coal surface and internal information internal information element content and calorific value can be collected by device at the same time. Through the high-speed 5G data transmission module, the data of coal is imported into the big data server. After comprehensive analysis and processing in the background, important parameters of coal quality are extracted, and the calorific value of coal samples in transmission can be predicted by relevant algorithms. The detection results are close to the current national standard laboratory test results, the difference is 15 Cal/g~79 Cal/g.Therefore, hyperspectral technology is suitable for the rapid detection of coal calorific value. Its operation method is simple, analysis and processing is fast and efficient, and calorific value prediction results are accurate.

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