Basic Experimental Analysis of Coal Washability

Lingyue Li*, Xianpeng Wang, Jie Li, Ziyao Wang, Xiaoping Tang, Xiaoping Ding

Huadian Electric Power Research Institute Co., Ltd., Beijing, 100031, China

*Corresponding author: 1263653199@qq.com

Abstract. This paper studies the selectivity of coal by analyzing indicators such as particle size, density composition, and selectivity, in order to determine the actual production performance of the Xiaoji Khan heavy medium shallow trough. The coal screening test is a fundamental method for determining the particle size composition and quality of coal at different particle sizes. The results of the screening test can provide insights into the block production rate of various coal seams and the quality characteristics of different particle sizes. It is an important basis for the rational utilization of coal resources and the development of coal product quality standards.

Keywords: basic experimental; coal; washability

1 Introduction

In China's energy production and consumption structure, coal plays a leading role, accounting for more than 67% and 56% of the primary energy production and consumption structure respectively. Coal will remain a dominant role in China's energy structure for a long time. Coal washing and processing is the preferred solution for clean and efficient utilization, which is of great significance for the full and rational utilization of coal resources and environmental protection. From 2010 to 2022, the coal washing rate in China has increased from 56% to 69.7%, and coal selection technology has also developed rapidly [1-3].

With the increase in coal production and consumption in China, environmental pressure is constantly increasing. Building high-quality, efficient, and large-scale modern coal preparation plants has become an important development goal for coal washing in China. A large number of modern large-scale coal preparation plants have been constructed and put into operation, laying a solid foundation for improving the quality of coal products. The intelligent transformation and upgrading of the existing system of the coal preparation plant can achieve systematic and intelligent linkage of key process links, control systems, and management systems, significantly improving the technical level of the coal preparation plant and enhancing the economic benefits of the enterprise [4-5].

The Xiaojihan Coal Mine Coal Preparation Plant is affiliated with Shaanxi Huadian Yuheng Coal Power Co., Ltd. It is a mine type power coal preparation plant with a production scale of 10.0Mt/a. In the context of digital key technology research

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and demonstration project construction at Xiaojihan Coal Preparation Plant, there are still problems such as high dependence on manual experience and the need for improvement in automation level in the production process. At present, large-scale intelligent construction of coal preparation plants is being carried out in China. In order to provide a theoretical basis for intelligent construction, a systematic experimental analysis of coal selectivity has been conducted [6-8].

2 Research Status of Intelligent Heavy Medium System in Coal Preparation Plant

In the control process of heavy medium sorting, most coal preparation plants in China use traditional manual methods to adjust the suspension density. Although some coal preparation plants have achieved automatic control, the PID controller parameters are still manually set and need to be repeatedly adjusted, resulting in poor dynamic performance of the system. In addition, due to the hysteresis of water replenishment and diversion, conventional PID regulation is difficult to achieve the desired control effect.

Many scholars have utilized popular algorithms such as machine learning and deep learning in recent years to improve the production efficiency of coal preparation plants in response to the challenges of process control in the heavy medium separation industry. Geng Yanbing used Model Predictive Control (MPC) algorithm to design an intelligent density control system controller, which can track the density of qualified media online and control the closed-loop of clean coal ash content. Wei Dai et al. proposed a model-based adaptive control method to address the strong time-varying and nonlinear nature of the reselection process, and conducted simulation verification. Cheng Zheng et al. applied the LSTM algorithm to a heavy medium suspension density control model to address the fluctuation of raw coal ash content and the hysteresis of suspension density, and verified the control accuracy of the model. Deng Jianjun et al. proposed using neural network learning and anti saturation integral control for feedforward control, and traditional PID control for feedback regulation. They also constructed a BP neural network learning controller based on data from Tangshan Coal Preparation Plant. Guo Xijin et al. believe that the conventional PID control method has a large overshoot, and propose using fuzzy control to reduce the adjustment fluctuation of heavy medium suspension density. Zhang et al. proposed a dual loop control algorithm, where the outer loop controller consists of a feedforward controller and a closed-loop MPC, while the inner loop controller uses MPC to adjust the replenishment amount of magnetic powder and water in the qualified medium bucket. Meyer, E. J established a state space mathematical model for heavy medium sorting by using dynamic matrices for data identification. Qiu Jiakai proposed to transport the suspension in the mixing tank to the concentrated tank through a reverse flow pump to increase the buffering capacity of the qualified medium tank, and to use neural networks and support vector machines to predict and control the liquid level and density.

At present, research on intelligent control systems for heavy media sorting mostly focuses on a certain operational link, lacking comprehensive algorithms and system optimization integration. Conducting basic experimental analysis on coal selectivity can provide theoretical support for the intelligent control model of coal preparation plants.

3 Experimental Study on the Separation of Selected Raw Coal

3.1 Screening Analysis of Selected Raw Coal

Coal screening test is a basic method for determining the particle size composition and quality of each particle level of coal. The screening test results can provide an understanding of the block production rate and quality characteristics of different particle sizes in each production coal seam, which is an important basis for the rational utilization of coal resources and the formulation of coal product quality standards.

Table 1. Shallow groove sorting feed screening test results.

Particle size /mm	productivity /%	ash content /%	Accumulated yield /%	Accumulated ash content /%
200-50	59.09	11.20	59.09	11.20
50-25	28.70	6.53	87.79	9.67
25-13	5.38	8.31	93.17	9.59
13~6	2.04	4.95	95.21	9.50
6-0.5	2.92	6.09	98.13	9.39
-0.5	1.87	10.62	100.00	9.42
total	100.00	9.42		

This screening test was conducted in accordance with the relevant provisions and procedures of the national standard GB/T477-2008 "Coal Screening Test Method". It was divided into six particle sizes: 200-50mm, 50-25mm, 25-13mm, 13-6mm, 6-0.5mm, and -0.5mm. The results of the screening test are shown in Table 1.

According to the results of the shallow groove sorting and feeding screening test, the ash content of the raw coal is 9.42%, which belongs to low ash coal; Due to pre screening, the cumulative yield of+25mm reached 87.79%, with the+50mm particle size accounting for 59.09%. In addition, there is no obvious change pattern between the ash content and particle size of the raw coal, and the ash content of particles smaller than 0.5mm is relatively high, indicating that there is a certain degree of mud formation in the gangue. Attention should be paid to the coal slurry water treatment process; From the perspective of gangue content, the+50mm hand selected gangue content accounts for 0.51%, indicating a lower gangue content, and there is no need to use pre selected gangue.

3.2 Analysis of Floating and Sinking of Selected Raw Coal

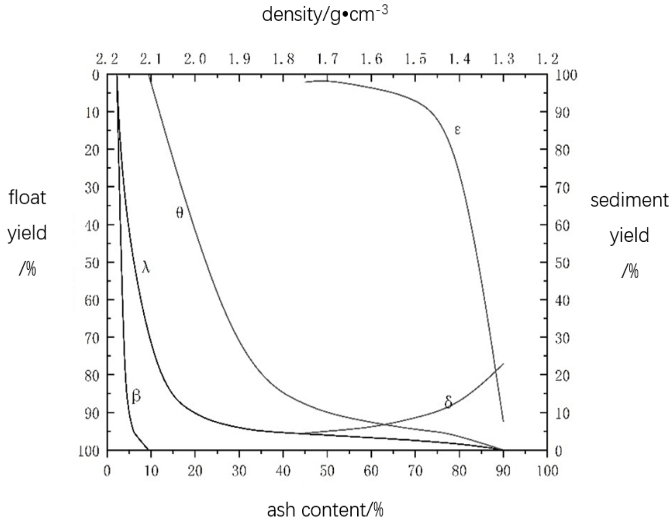

Fig. 1. Selectivity curve of sorting feed 200-0.5mm

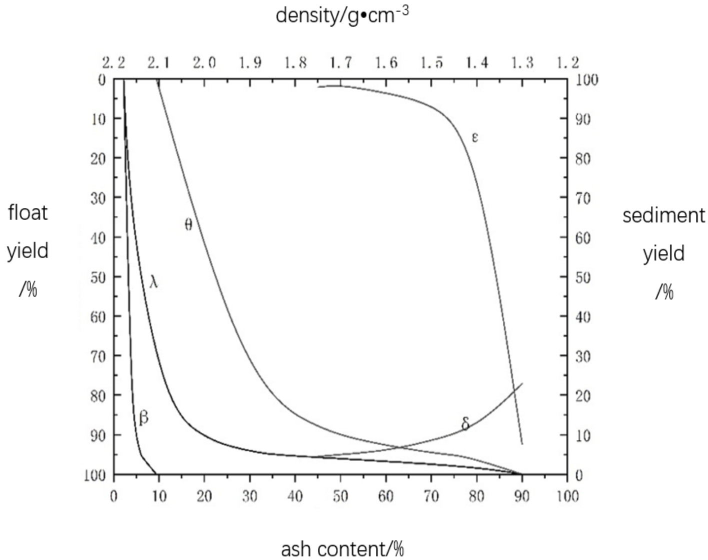

Fig. 2. Selectivity curve of sorting feed 200-50mm

According to the national standard GB/T478-2008 "Coal Floatation and Sinking Test Method", the test is conducted. According to technical requirements, the floatation and sinking test is divided into particle sizes of 200-50mm, 50-25mm, 25-13mm, 13-6mm, and 6-0.5mm. Obtain the following comprehensive table of float and sink tests and corresponding selectivity curves.

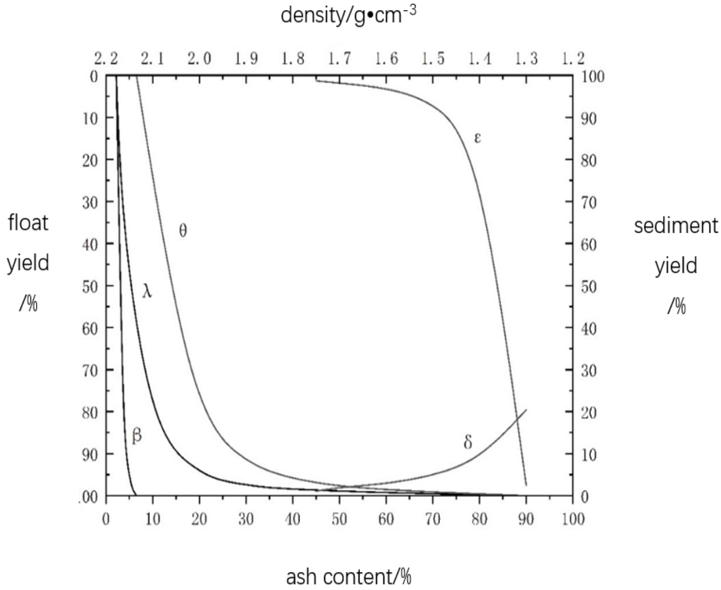

Fig. 3. Raw coal 50-25mm selectivity curve

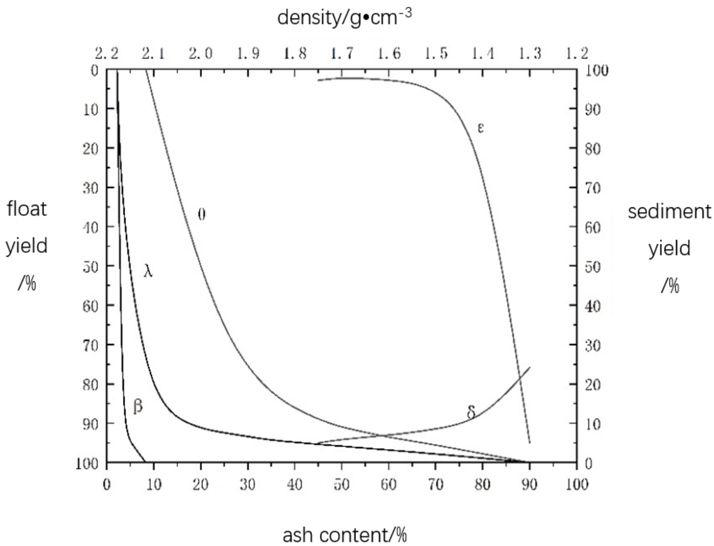

Fig. 4. Raw coal 25-13mm selectivity curve

The comprehensive table of screening, floating and settling tests for sorting feed shows that the yield of raw coal at different density levels is mostly distributed at both ends, with less content in the middle density level. The dominant density levels are -

1.3g · cm^{-3} and 1.3-1.4 g · cm^{-3}, accounting for 86.58%, indicating high yield of clean coal, easy sorting, and the possibility of producing low ash clean coal; From the changes in the dominant density levels of each particle size, it can be seen that as the particle size decreases, the content of low-density levels shows a decreasing trend, while the content of high-density levels shows an increasing trend, indicating that the coal quality is relatively hard and the gangue is fragile. At the same time, this supports the conclusion in the screening test analysis that gangue is prone to mudification.

The corresponding particle size selectivity curves are shown in Figures 2 to 6.

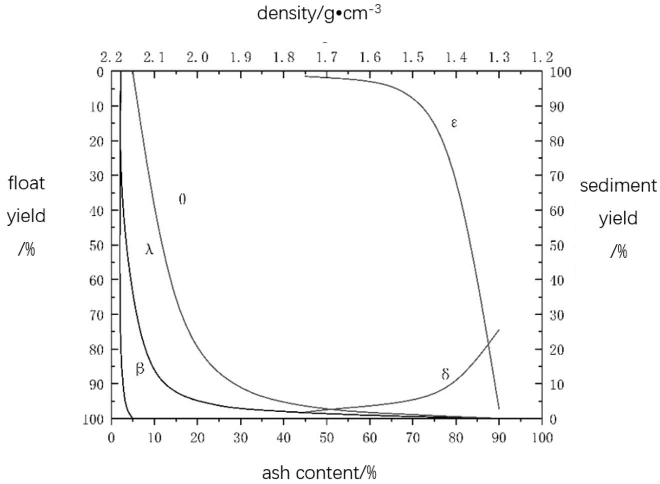

Fig. 5. 13-6mm selectivity curve of raw coal

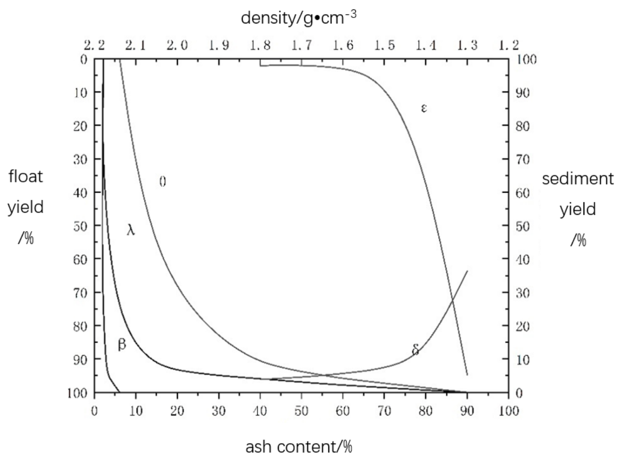

Fig. 6. Raw coal 6-0.5mm selectivity curve

3.3 Selective Analysis of Selected Raw Coal

Based on the principle of equal elemental ash content, the separation indicators of each particle size of raw coal can be obtained from the selectivity curves of each particle size under equal elemental ash content. When the refined coal ash is divided into 6.24%, the corresponding elemental ash content in Figure 1 is 41.00%. According to the principle of equal elemental ash content, the sorting density, adjacent density content, refined coal yield, refined coal ash content and other indicators are obtained on the selectivity curves of each particle size in Figures 2-6, as shown in Table 2.

Table 2. Index of Ash Content Method for Sorting Feed Elements

Particle size /mm	λ/%	δ/g.cm^{-3}	ε/%	γ/%	Ad/%
200-50	41.00	1.750	1.90	93.94	6.772
50-25	41.00	1.750	1.56	98.47	5.768
25-13	41.00	1.745	2.77	94.94	5.221
13~6	41.00	1.739	1.56	98.02	3.933
6-0.5	41.00	1.738	2.07	96.00	3.876

According to Table 2, the sorting density of each particle size is not significantly different, and the ash content of clean coal slightly decreases with the decrease of particle size. The yield of clean coal is not significantly different, indicating that graded selection is not necessary.

Theoretical indicators are the best indicators achieved under ideal conditions, based on the selectivity of raw coal and product quality requirements, without considering coal selection methods, equipment performance, efficiency, and operational level. The actual indicators used in production are often lower than theoretical indicators due to various factors. To find the true relationship between actual indicators and theoretical indicators, it is necessary to start from the upper and lower limits of the selected raw coal particle size, particle size composition, and float settle composition. Under specific coal selection methods, equipment, and operating conditions, process indicators that can reflect these factors should be selected, such as actual separation density δ p, possible deviation Ep value, or imperfection I value. Using the distribution curve as a tool, the float settle test data of the raw coal should be calculated and converted into the actual yield and actual ash content of each product. Based on the single machine inspection, the distribution curve can be obtained. By shifting the distribution curve, the yield and ash content of clean coal at different sorting densities can be predicted. The predicted yield and ash content of clean coal at different sorting densities can be combined to obtain the actual washability data. And based on this, the actual selectivity curve is plotted.

As shown in Figure 7, due to losses and pollution in the actual sorting process, the actual yield of clean coal under the same ash content is lower than the theoretical yield. The β s curve is above the β 1 curve, but the endpoints of the two lines coincide. And the λ curve must intersect. At the upper part of the curve, the λ s curve is above the λ 1 curve due to the inclusion of high-density materials in the low-density material, and at the lower part of the curve, the λ s curve is below the λ 1 curve due to the inclusion of low-density materials in the high-density material.

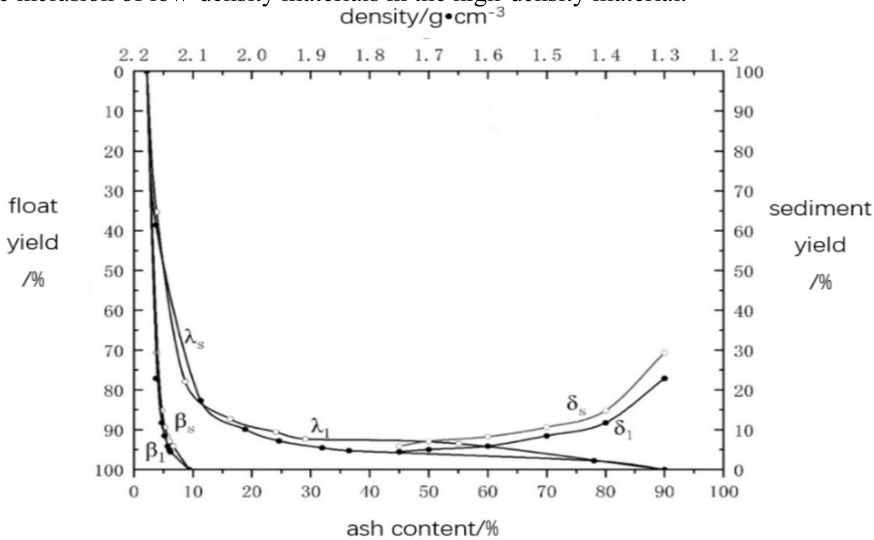

Fig. 7. Theoretical and Practical Selectivity Curve

4 Conclusion

Perform screening and settling tests on the sorted feed, clean coal, and gangue, and analyze their particle size, density composition, and selectivity indicators; By drawing the actual selectivity curve, the actual sorting indicators are obtained. From the degree to which the actual selectivity curve deviates from the theoretical selectivity curve, it can be seen that the actual production performance of Xiaojihan Heavy Medium Shallow Trough is better.

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